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Scientific 'Genius' – Shaper or Reflection of Society?

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"I have not the shadow of a doubt that any man or woman can achieve what I have, if he or she would make the same effort and cultivate the same hope and faith."
-- Mohandas Karamchand Gandhi

Moments of ingenuity and lifetimes of 'geniuses' have been studied and theories applied to political leaders, artists, poets, musicians, and scientists. Since *science*[1] is usually considered by our 21st century technologically-sophisticated and economically-driven Western society as one of the highest forms of mental activity, it is perhaps relevant and instructive to look historically at the achievements of several persons who played very significant roles in the development of our scientific tradition and the broadly-held paradigms that resulted from those traditions.[i] However, when one examines the academic and literary study of persons of extraordinary talent, whom society popularizes with the noun 'genius' and whose level of innovation, insight, and creativity are described with the adjective 'genius,' one often sees scholars of intellectual tradition in debates as to whether the society creates these persons through the march of human events or whether these persons, through their paradigm-shifting discoveries or creative works, mold society according to their new perspectives.

Do the so-called 'great men' shape society or are they merely reflections of the natural course of events?[2] Are they truly unique gifts to humanity, endowed with rare god-given talents, or are they

[1] The 20th-century German philosopher Martin Heidegger defines science as the 'theory of the real' (Heidegger 157). For the purposes of this paper, let us define *science* as the body of knowledge obtained by methods of observation. It is derived from the Latin word *scientia*, which simply means knowledge, and the German word *wisenschaft*, which means systematic, organized knowledge. Thus, science, to the extent that it is equivalent to *wisenschaft*, consists not of isolated bits of knowledge, but only of that knowledge which has been systematically assembled and put together in some sort of organized manner (Fischer 5-7). In particular, the science with which we are concerned is a body of knowledge that derives its facts from observations, connects these facts with theories and then tests or modifies these theories as they succeed or fail in predicting or explaining new observations. In this sense, science has a relatively recent history, perhaps four centuries (Platt).

[2] Use of the term 'great men' is anachronistic by modern standards. It has been used throughout the past two centuries to recognize the important contributions attributed to historically significant leaders, artists, and intellectuals, whom were generally identified as male Europeans. Clearly, women, such as the French intellectual Madame de Chatelet (1706-1749), Italian physicist Laura Bassi (d. 1778), Franco-Polish chemist Marie Currie (1867-1934), American astronomer Maria Mitchell (1818-1889), and Russian mathematician Sonya Kovalevsky (1850-1891) have contributed to society in ways equal to or greater than the so-called 'great men.' Likewise, the contributions of Chinese, Indian, and Muslim scholars on the intellectual development of Renaissance Europe and the 19th-20th century contributions of persons of African descent, such as mathematical astronomer and surveyor Benjamin Bannekar (c. 1731), holder of over 100 patents Granville T. Woods (c. 1856), mechanical engineer Elijah McCoy (c. 1860), heart surgeon Daniel Hale Williams (c. 1893), carbon filament patent-holder Lewis Howard Latimer, (1848-1928), and blood plasma innovator Dr. Charles Drew (d. 1950) on North American science and technology cannot be, nor should be, ignored. However, since the term 'great men' has been used as part of the intellectual canon, and it is psychologically 'loaded' with certain meaning that excludes, rather than includes, it is useful in the context of this discussion of 'genius.'

exquisite products of a society's values, social interactions, economics, and worldview? One is often forced into placing these persons of genius into one or the other classification of either socially nurtured talent, which reflect a cultural era, or specimens of supernatural qualities, which derive from nature. But need that be the case? There is a school of thought, voiced by Ralph Waldo Emerson and George Plekhanov that comfortably rationalizes the dichotomy of nature versus nurture and the debates between the proponents of cultural reflection versus those advocating independent societal impact. When one examines the significance of acts of ingenuity and the legacy of so-called 'geniuses,' one recognizes genius as both resulting from the society and providing important foundations for the advancement of society. While this *representative* framework debunks the myth of the solitary genius, in the spirit of Blaise Pascal, it recognizes and celebrates the heroic aspects of great minds as role models for future great minds.

While many persons of significant ability have contributed to the Western scientific tradition, an examination of the commonalities, differences, and mythologies surrounding a few key icons of the major historic scientific and technological eras offer vivid examples of representation and influence. Let us examine the modern icon of the 'Atomic Age,' Albert Einstein. It is also helpful to contrast two Renaissance symbols – Galileo and Leonardo da Vinci – and question why one meets the modern definition of 'genius' and the other does not. Finally, ancient contrasts between the intellectual Plato (through his alter ego Socrates) and the first recorded multi-talented engineer -- Imhotep, architect of the first pyramid -- allow for the exploration of differences between thinkers and doers. In each case, the lives and works of these men provide useful instruction in the pain associated with paradigm shifts, the manner in which they became iconic indicators of their respective eras, and how legend and promotion served to embellish and solidify their images in time.[3]

Characterizing 'Genius'

Genius is defined as exceptional or transcendent intellectual power or one who possesses such.[4] It is derived from the Latin *genius*, which was a deity of generation and birth; a guardian spirit.[5] The Arabic *jinniy* likewise was a spirit in Moslem legend, capable of exercising supernatural influence over men.[6]

In modern usage, the word 'genius' has been over-extended and sloppily applied. Americans think of great scientists, such as Albert Einstein and great inventors, such as Thomas Edison, but we also apply the term genius to superstar athletes, pop musicians, media moguls, crafty politicians, Wall Street manipulators, and billionaire technologists. Popular magazines publish annual lists of the 'best and brightest' geniuses. They are often thought of in terms of their output, inventions, or economic wealth. Business success and the ability to outwit the competition are sometimes equated with 'genius.' For example, David Granger, the publisher of **Esquire**, sees modern geniuses as rebels and radicals who are going against the grain, producing miracles in defiance of convention and generally representative of the

[3] The focus on these five men who have contributed to Western tradition is not meant to diminish the significant contributions of women, nor those of other great civilizations and ethnic groups. For completeness, it is important to note that advanced urban civilizations unfolded independently in multiple centers across the ancient world. A pattern of Neolithic settlements coalescing into centralized kingdoms based on intensified, hydraulically-enabled, agriculture occurs at least six times in different sites: Mesopotamia (modern Iraq) after 3500 BCE, Egypt after 3400 BCE, Indus River Valley after 2500 BCE, along the Hwang Ho (Yellow River) after 1800 BCE, Mesoamerica after 500 BCE, and South America after 300 BCE (McClellan 32). However, an examination of these men helps to demonstrate how Western society defines 'genius' and uses the term for its own purposes.

[4] American Heritage Dictionary
[5] American Heritage Dictionary
[6] American Heritage Dictionary

tenor of our times" (Granger 26). Technical and management trade journals give strategies for 'thinking like a genius' and seek to analyze the creativity of Leonardo and Mozart, the ability to view problems through different paradigms like Einstein, and the trial-and-error methodology of Edison. Would-be geniuses are encouraged to look at problems differently, think in opposites and metaphors, make thoughts visible, produce many works with novel combinations of materials and approaches, force relationships, and be willing to take big risks (Michalko 125-129).

Over the past 300 years, Western society has come to think of geniuses as those individuals who exhibit an extreme focus on a set of problems or mysteries, whose focus results in a justification of their exceptionality. Honore de Balzac portrayed genius in a class above others, "To most biographers the head of a man of genius rises above the herd as some noble plant in the fields attracts the eye of a botanist in its splendor" (Balzac 4). Francis Galton believed that, "Most great men are vigorous animals, with exuberant powers, and an extreme devotion to a cause" (Galton 164). Balzac characterized genius in his character Louis Lambert as having an intense focus and inner contemplation. In Balzac's view, Louis had, "…a sort of appetite which nothing could satisfy, …a passion for knowledge,… [one who] transferred all his activities to thinking, as others throw all their life into action." Lambert had "the gift of summoning to his aid at certain times the most extraordinary powers, and of concentrating all his forces on a given point," according to Balzac. Persons of extraordinary talent, deemed geniuses, have creative insight and inspiration, are often multi-talented, and produce exceptional accomplishments. In the mold of Aristotle, Balzac's Lambert devoured books of every kind, fed indiscriminately on religious works, history, philosophy, and physics. Geniuses are also thought of as, at a minimum, eccentric, and in the extreme, mad. Balzac portrays Lambert as having difficulty dealing with the ordinary,

> "…almost in rags and absorbed in reading…he found it very hard to submit to college rules, to walk in the ranks, to live within the four walls of a room where eighty boys were sitting in silence on wooden forms each in front of his desk. Taught at last by cruel experience, he was obliged to 'look after his things,' to use the school phrase. He was forced to take care of his locker, his desk, his clothes, his shoes; to protect his ink, his books, his copy-paper, and his pens from pilferers; in short, to give his mind to the thousand details of our trivial life —while they were overlooked by a boy of the highest promise, who, under the hand of an almost divine imagination, gave himself up with rapture to the flow of his ideas" (Balzac 26-27)

Cesare Lombroso cites Aristotle's observation that, "many persons become poets, prophets, and sybils, and like Marcus the Syracusan, are pretty good poets while they are maniacal; but when cured can no longer write verse" (Lombroso 2). Likewise Lombroso cites Pascal's observation that, "extreme intelligence was very near to extreme madness," and Diderot's, "…how near are genius and madness" (Lombroso 3). Modern popular literature and films also depict a schizophrenic John Walsh, in *A Beautiful Mind*, and an insane mathematics professor and his increasingly unstable daughter in the play *Proof*.

When one surveys the polarized arguments of what makes a so-called 'great man,' one notices a substantial shift in Western thinking from 'genius' as a momentary flash of inspired innovation, which was popular in the Renaissance, to one where a unique person occupied a pedestal defined and maintained by society. Ray McDermott notes that, "By 1750, the genius was a position, a socially recognized identity, in European society." A more insidious implication of the institutionalization of ingenuity in the persona of a 'genius,' was how it served to exclude equally talented practitioners and highlight the achievements of a sole genius, whether deserved or not. McDermott goes on to observe that, "Once the throne was built, it had to be filled. If there were no geniuses available, the throne had to be filled nonetheless; if there were a plethora of geniuses available, one person had to be put on the throne nonethemore" (McDermott 2).

Even if one acknowledges the praiseworthy accomplishments of geniuses, 18th century intellectuals wondered about the source of genius. In 1711, Joseph Addsion attributed the "prodigies of mankind" to the "strength of natural parts, and without any assistance of art or learning, have produced works that were the delight of their own times and the wonder of prosperity" (Addison 282). Others espousing the innate uniqueness or a natural source of genius included Thomas Carlyle and Francis Galton. Galton, who was the cousin of Charles Darwin, argued in 1865 for the hereditary basis for talent and character (Galton 157-158). Carlyle spoke of a man's works resulting from "utmost conscious exertion and forethought" that grows from "the unknown deeps in him." "Whatsoever is truly great in him springs-up from the inarticulate deeps" (Carlyle 108-112). Balzac referred to "an Academician [as] a great man in embryo." The naturalists' philosophy of innate intelligence lasted well into the 20th century with Stanford's Lewis Terman, who took Alfred Binet's intelligence tests to the extreme of encouraging a eugenics movement (Terman 318).

Alternatively, a more socially derived attribution of genius was argued by Adam Smith (1723-1790), who commented that, "Genius…is not, upon many occasions, so much the cause as the effect of the division of labour. The difference between the most dissimilar characters, between a philosopher and a common street porter, for example, seems to arise not so much from nature as from habit, custom, and education" (Smith 14). However, the social theorists, as well, took their criticism of the role of the individual 'genius' too far. For example, Leslie White argued that, not only is the great man understood as an effect or manifestation, rather than as a prime mover, he believed that, "It is not the abundance of 'geniuses' that produces the 'high tides of human affairs'…an idiot or a goose can accomplish it [great periods of cultural development] just as well. It is not high or low levels of ability that is significant in such contexts; it is being strategically situated in a moving constellation of events" (White 232).

Framework for a More Balanced View of 'Genius'

Need we force the concept of 'genius' into one or the other polarized classifications of either socially nurtured talent, which reflect a cultural era, or specimens of supernatural qualities, which derive from nature? At least three leading philosophers of the period 1650-1900 argued against the designation of 'genius' as some rare, innate, solitary, intellectual oddity. From the early 20th century Marxist philosophy of George Plekhanov (1857-1918), to the earlier observations of Ralph Waldo Emerson (1803-1882), and the yet earlier humble protestations of Blaise Pascal (1623-1652), acknowledge the extraordinarily talented leaders, artists, inventors, and discoverers, and recognize their talent as both resulting from society and impacting the course of Western society's development.

Blaise Pascal's work on the geometry of conic sections, calculus, probability theory, the vacuum, and an early form of a counting machine earned him notable and well-deserved accolades throughout Europe in the 1650s (McDermott 6). As a deeply religious man, Pascal had difficulty accepting praise, since it conflicted with his sense of humility. He held a 'double conception' of institutional genius in the service of God. As such, Pascal was thankful of the gift of great intellect, but felt it was less worthy than charity. He recognized genius, but argued that society should not make it too sacred or too unique, because it comes from fortuitous circumstances and is positioned as significant by human institutions (Pascal 74-75). "You have nothing naturally that is superior to them. If the public conception elevates you above the run of mankind, let the other humble you and keep you in a perfect equality with all mankind; for that is your natural state" (Pascal 75).

Ralph Waldo Emerson sought the democratization of genius. According to McDermott, "*Representative* is the appropriate political term for Emerson's genius. Emerson's genius, as representative, seeks new connections, not to stand above others, but to go deeper into what joins them." "Writing for a new American democracy that promised individuals the conditions for growth that would allow further growth for all," notes McDermott, "Emerson's genius is a fully attractive character that celebrates less the individual bearer of genius and more the people who delegate a representative of their wisdom" (McDermott 15). According to Emerson, "He is not only representative, but participant" (Emerson 17). As an example, Emerson cited Napoleon as, not only the product of his powerful will, but also a culmination of the will of the people of Revolutionary France (Emerson 213-221).

George Plekhanov saw genius as a function of socio-economic relationships. According to McDermott, the heroic genius of Plekhanov is "the great beginner who reports inevitably to the most pressing local constraints and possibilities" (McDermott 17). True to his Marxist philosophy, Plekhanov remarked,

> "A great man is great not because his personal qualities give individual features to great historical events, but because he possesses qualities which make him most capable of serving the great social needs of his time, needs which arose as a result of general and particular causes" (Plekhanov 176).

To Plekhanov, the individual actions of great men, being products of historical trends, can change the specific character of the trend, but not the trend itself. They are participants in the trend and reflections of it. Or, as McDermott interprets Plekhanov, "The genius should run ahead of society, but, comes from the society. The genius is raised by the times, running ahead of the times, and reinserting advances into the evolution of the times (McDermott 17).

The balanced philosophical frameworks of Plekhanov and Emerson, plus the cautionary humbleness of Pascal, can be demonstrated by examining the works, lives, societies, and myths surrounding a few of the scientific world's 'great men.'

Notable Works of 'Geniuses'

Regardless of which theory one subscribes to, the achievements of great ingenuity are remarkable and the results from an intense focus of energy and intellect. Emerson observes that, "…they seem to fascinate and draw to them some genius who occupies himself with one thing, all his life long. The possibility of interpretation lies in the identity of the observer with the observed" (Emerson 16). Emerson continues by acknowledging the respect due these persons, "Mankind have in all ages attached themselves to a few persons who either by the quality of that idea they embodied or by the largeness of their reception were entitled to the position of leaders and law-givers" (Emerson 24). In large measure, according to Plekhanov, "…these individuals possess more or less talent for making technical improvements, discoveries and inventions" (Plekhanov 165).

> "A great man is a beginner precisely because he sees further than others and desires things more strongly than others. He solves the scientific problems brought up by the preceding process of intellectual development of society; he points to new social needs created by the preceding development of social relationships; he takes the initiative in satisfying these needs. He is a hero. But he is a hero not in the sense that he can stop or change the natural course of things, but in the sense that his activities are the conscious and free expression of this inevitable and unconscious course. Herein lies all his significance; herein lies his whole power. But this significance is colossal, and the power is terrible" (Plekhanov 176).

Let us examine the colossal impact of a few 'great men,' or 'great minds,' of science over a very broad range of history. By doing so, one sees the development of socially-driven engineering in Imhotep's ancient Egypt lead to the foundations of Greek natural philosophy and intellect, to the Renaissance's legacy of valuing the science of Galileo over the engineering of Leonardo, and finally, in our modern era, observing how the works of Einstein and his contemporaries became institutionalized as government-sponsored "Big Science" and popularized as part of our culture. In each of these cases, the 'geniuses' and their ingenuity are products of their respective societies and important contributors to the growth and development of our scientific tradition. While these works deserve to be celebrated, one should also notice that they were the culmination of previous, sometimes equally innovative, works. The difference seems to be one of retrospective admiration, and recognition of the importance of publicity and mass popularization.

One of the most significant events of the 20th century was the overthrow of the Classical worldview, that was anchored by the framework of Newton and Descartes. This harmonious world of absolute space and time and indivisible atoms was shattered by an 'Einsteinian Revolution,' which ushered in an age of no absolutes in favor of uncertainty and probabilities, the duality of particles and waves, the transformation of matter and energy, and for the first time, the threat of total annihilation. While Albert Einstein (1879-1955) was by no means a singular contributor to this 'Atomic Age,' he combined existing concepts in novel ways to produce a major paradigm shift in both scientific and social thinking.

Einstein was the son of an unsuccessful businessman, and, atypical of the genius stereotype, he exhibited no precocious talents and dropped out of high school. He attended the Federal Polytechnic School in Zurich. After college he was refused a position as a schoolteacher because of his Jewish ancestry, so Einstein took a minor position in the Swiss patent office. He was then able to have enough time to earn a doctorate from the University of Zurich in 1905 (McClellan 345).

In 1905, Einstein published a series of extraordinary papers that would shake the foundations of modern physics. His *Special Theory of Relativity* concerned uniform motions in space and time and by 1915, he published on the *General Theory of Relativity*, which dealt with gravity and accelerated motion (McClellan 346). Einstein argued that space was warped due to the gravitational forces of heavy bodies. He was also a major contributor to the field of quantum mechanics and particle physics, having published a 1905 paper on the photoelectric effect. In these papers, Einstein argued that light comes in discrete bundles instead of waves. This led to an understanding of the inherent uncertainty and probabilistic limits of nature, rather than the earlier deterministic mechanical model of the atom (McClellan 346-347). As Bernard Cohen cites, "It is a measure of Einstein's greatness that at the time when he was inaugurating the revolution in relativity, he was also making fundamental contributions to quantum theory" (Cohen 422).

Three hundred years earlier, Galileo Galilei (1564-1642) was born in Pisa and raised in Florence. His father served the Medicis at court as a musician. Galileo attended medical school at the University of Pisa and secretly studied mathematics. Through patronage connections, he taught mathematics at the University of Pisa and the University of Padua. These low status, low paying jobs also aggravated him, since he had no love for teaching students and felt that it detracted him from his research. This disgruntled, undistinguished professor at a second-rate university stumbled onto the telescope in 1609, which would be the vehicle for his fame (McClellan 223-224).

Though Hans Lipperhey of Holland invented the telescope in 1608, Galileo improved upon the design of what was, in essence, a spyglass, increasing its magnification to 30x and turned it toward the heavens. The new celestial world he discovered included the mountains of the moon, sunspots, four of Jupiter's moons, and a myriad of new stars. His findings were based on careful protracted observations that led to the acceptance of the telescope as a legitimate tool in astronomy (McClellan 224). "As a result, Galileo's marvelous discoveries soon became incontrovertible, and they brought forth the question of the true system of the world," notes McClellan and Dorn. In addition, as Cohen remarks, " He was one of the first major scientists who made experiments an integral part of science, along with mathematical analysis. In fact, his combination of experimental technique and mathematical analysis has quite properly earned him a place as a founder of the scientific method of inquiry" (Cohen 142).

Leonardo da Vinci (1452-1519) is perhaps the most famous figure of the Renaissance, due to the popular knowledge of his paintings, more than the knowledge of his achievements in science and engineering. Born as the illegitimate son to notary in Vinci, Leonardo apprenticed to the artist and goldsmith, Verrocchio, in Florence. He also freelanced as an artist, sculptor, civil engineer, and military engineer during his life in Milan, Venice, Rome, and Pisa. In a letter to Duke Lodovico Sforza, seeking employment, Leonardo bragged of the wide range of his engineering capabilities including: construction or bridges, tunnels, canals, trellis work and ladders, drainage of moats, production of cannon, armored wagons, mortars, dart throwers, machines for throwing fire, and "infinite apparatus for offense and defense." During times of peace, he offered Sforza skills at building public and private edifices, conduits for water, sculpture in marble, bronze, and terra cotta, and in painting, "…that which is possible to do, I can do as well as any other, whoever he may be" (DeCamp 397-398).

It is clear through an examination of Leonardo's notebooks that he was bursting with ideas. The range of mechanical problems he considered included a steam gun, multi-barreled cannon, multi-leveled city, oil press, mechanical musical instruments, textile machinery, diving suit, submarine, turret windmill, a brake with curved shoes, parachute, printing press, surveying instruments, spiral gears, lathe, crane, dredge, and a mitered canal lock (DeCamp 401). However, most of these ideas were merely drawings, not devices that he actually built. Alternatively, Leonardo's work shows how painters who were influenced by the scientific observational methods of the High Renaissance gave art greater realism, action, and emotion. In the process, the painter was elevated from mechanistic workshop artisan to creative genius.

Prior to Leonardo's revolutionary approach to realism in the High Renaissance, painters captured or created scenes as framed, symmetrical, non-fluid portraits that were devoid of realism. For example, the exact year that Andrea del Castagno painted the *Last Supper*[7] is unknown, however, we know he painted it in Florence sometime between 1440 and his death, due to the plague, in 1457 (Murray 107). Leonardo was born in 1452 and, because of his innovation as a scientist and inventor, he brought an extensive understanding of anatomy, botany, optics, perspective, the behavior of nature, and the study of proportion to his art. Leonardo applied his keen observational skills and knowledge of optics and perspective to create a three-dimensional scene. He used his knowledge of human anatomy to portray detailed characters and emotional nuances. His knowledge of mechanics, dynamics, and fluids were applied to scenes in a manner that created a feeling of action.

All three innovative techniques can be found in Leonardo's *Last Supper*. [8] Leonardo worked on his masterpiece in 1497, some 40 years after Castagno's death. When comparing the two portrayals, one sees not only a difference in styles over the intervening 40 years, but the tremendous impact of anatomical observation, three-dimensional perspective, and, in the case of Leonardo, a distinct artistic ability to depict action and tension. Leonardo's *Last Supper* is one of the most famous works of Western art, referred to by Peter and Linda Murray as, "…the first painting of the High Renaissance" (Murray 238).

[7] See plate 85, Andrea del Castagno, *Last Supper*, which now hangs in the Uffizi museum (Murray 108)

[8] See Leonardo da Vinci, *Last Supper* (Frere 20-21)

Much of the modern scientific method owes its approach to the logical framework of hypothesis testing laid out by Socrates (469-399 BC) and the refinements to his philosophies by his disciple, Plato (427-347 BC), and Plato's student, Aristotle (384-322 BC).[9] Though Socrates opened the door to examination of the inner self, he also set in motion a metaphysics and critical cross-examination of ideas that define a valid approach to seeking knowledge and a scale by which the scientific community still determines truth.

Socrates believed, and his student Plato expressed, that there is an absolute truth that can be revealed through logical philosophy, rather than the human senses. He believed that there was another world of ideas and truth around us that we could not directly touch with our human senses. Using an allegorical style, Plato argued that reality was to be found in 'ideas' or perfect 'forms,' not in the world of 'appearances'[10] (Adams 11). Plato, relaying the point of view of Socrates in his **Dialogues**, affirmed the belief that real knowledge was unobtainable through the lens of the physical senses.[ii] To Plato absolute truth was unattainable because he believed that what we see around us is merely an image.[11] However, Plato separated form and content in a way that allowed the power of reason, logic, and allegory to get one closer to the truth. In the **Republic's** *Allegory of the Cave*, in which the cave represents the realm of belief or faith and the light represents the realm of truth and knowledge, Plato's philosophy of natural order holds that the ability to attain true knowledge is accomplished through a difficult path of acquisition (Adams 11).

The path that Plato recommends is a journey within the mind. Therefore, getting closer to the truth in the real world requires dealing with probabilities, natural variations, and perfect blocks of logical propositions. Platonic logical truth and unambiguous conclusions are found by following clear rules of deduction. The ascension out of the cave, from belief to knowledge, is a painful journey, but once positive movement is made, it can be seen to be a move in the right direction toward reality. When one is out of

[9] It is important to note that much of what we know about Socrates' approach to philosophy comes from a series of conversations from other writers, notably Plato. Since Plato was a playwright, a student of Socrates, and an ardent admirer of Socrates, the historical accuracy of Socrates' words cannot be verified. For our purposes, we will assume that when Plato attributes certain beliefs and philosophies to Socrates, it may be safe to assume that Plato shares those views and perhaps has embellished them with his own philosophies.

[10] These ideal forms were not limited to physical objects. For example, in *Symposium*, ideals went beyond physical forms and geometric proofs, but included emotional and spiritual concepts, such as love and beauty. Socrates tells how Diotima corrected his understanding of love and elevated his consciousness to a higher form of love. She explained that eros was neither beautiful nor ugly and that Socrates was in love with beauty (*Symposium* 204ab). . The ideal form of love must be looked at from the perspective of the beloved, not the lover (*Symposium* 204c). As such, according to Diotima's explanation to Socrates, the ultimate objective of all eros is beauty itself and a desire to give birth in beauty (*Symposium* 208c-209e, 210e).

[11] Likewise, the late astronomer and Cornel professor, Carl Sagan (1934-1996), pointed out that our modern scientific method of inquiry is also based upon our senses. Since we inhabit physical space and time, phenomena outside this realm, things of the microscopic world of the interior of atoms or the macroscopic world of the universe, are beyond our physical senses. Although, one may use electron microscopes to probe the atom or radio telescopes to study the universe, we cannot escape the fact that these are merely devices that transform signals into forms that our senses can recognize (Sagan, **Cosmic Connection** 15-16). Likewise, K.C. Cole notes that, "…truth can be highly counterintuitive and sense is hardly common" (Cole 6). She explains that there is great difficulty in getting true information from what we call the 'real world,' since we only glimpse that world through patterns or signals that are created, at least in part, outside ourselves (Cole 39). Cole notes that scientists can only measure those things that are known or suspected to actually be there (Cole 48). We also miss a great deal because we perceive only things on our own scale and the sheer complexity of nature, where every part influences every other part, creating a tight weave of causes and consequences that are much too knotted to untangle (Cole 58, 77). In addition, signals make sense only in context. In a different context, the same message can have no meaning at all. Cole explains that if you send someone a message in code, but they have no way to decode it, your message has no more information than total nonsense (Cole 86). Therefore, if one understands human limitations, one will be forced to understand the limitations of science and why science alone cannot capture the breathtaking enormity of the world outside human senses. Socrates and Plato were correct -- Humans cannot know all things. Absolute knowledge depends on absolute definitions, which are inaccessible to humans (Stone 39).

the cave and one's eyes adjust to the light, there is yet another truth -- namely that the light is actually produced by the sun. Truth, in this sense, is relative to the seeker's level of knowledge. We experience this today when science makes a discovery, it seems to only peel off layers of a never-ending "ever juicier mystery," as Frank Oppenheimer called it (Cole 49). Regardless, to Plato, truth emerged through the power of reason and we observe truth as making common sense

Plato taught his pupils that a convincing proof required the following elements. First, it is essential to *define* the terms used. Secondly, it is essential to state clearly what we all agree to take for granted, e.g., that a+c = b+c if a=b. Third, it is critical to make clear, and to justify, what procedures one may invoke to define our terms or to dissect figures in order to exhibit relations between their parts. (Hogben 63).

Socrates, and by extension Plato, started with an assumption that he knew nothing for sure. However, he used a yes/no logic via cross-examination of hypotheses that sought to disprove falsehoods and, by a process of elimination, allow one to move closer to the truth. [iii] This Socratic interrogation, where the respondent is restricted to yes/no answers, operates somewhat in the manner suggested by Cole, "You see something and then try everything you can think of to make it go away; you turn it upside down and inside out, and push on it from every possible angle. If it's still there, maybe you've got something" (Cole 96).

While the Greek penchant for pure intellectual thought, without any specific useful end required, laid the groundwork for the future scientific method, the much older *technology*, or if one prefers *engineering*, is more clearly a function of societal values and directed energy.[12] As such, it provides a glimpse of how ancient society enshrined 'genius' as deity-inspired feats of monumental development, rather than one of human intellect alone.

The development of engineering and architecture over 5,000 years ago in ancient Egypt vividly demonstrates the extent to which technology can have practical social and religious bases.[13] Unlike the Greeks, who later benefited from the advances of Egyptian and Mesopotamian scholars and who developed an abstract theory of knowledge, the Egyptians used knowledge for the practical accomplishment of goals tied to their religious worldview. [iv] One also finds that the most accomplished practitioners of engineering and science were accorded high status as priests and established a role model for later cult heroes. One such person was Imhotep. Other than kings, he is the earliest historical personage supported by tangible proof of his existence.[14]

Tradition revered Imhotep as a great architect, physician, royal scribe, and sage. Imhotep achieved such great importance that in later years he was revered as the 'patron saint' of scribes (Hornung

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[12] *Technology* is how society does things, not how it thinks of them. Suffice it to say for our use that *technology* is science plus purpose. While *science* is the study of the nature around us and subsequent development of scientific 'laws,' technology is the practical application of those laws, in sometimes non-rigorous ways, toward the achievement of some material purpose (Dorf 1).

[13] An examination of Egyptian engineering and science, principally during the Old Kingdom (c. 2670-2150 BCE) and Middle Kingdom (c. 2040-1650 BCE), shows that religion drove the development of, and was reflected by, their monumental architecture. These architectural wonders served as a societal organizing principle and demonstrated the power of the state, which was believed to be run by either an incarnate god on earth or the son of a heavenly god. In addition, the supporting sciences, such as mathematics, astronomy, geography, and medicine all had practical purposes in support of the Egyptian religious worldview.

[14] We know of Imhotep through the discovery in 1926 of his name and titles on the base of a statue of King Djoser who reigned at the beginning of Dynasty III (c. 2654-2635 BCE). His name recurs on temples, in books, and through the Greek translations of writings that refer to him. One Greek translation notes, "The entire Greek language will relate thy tale and every Greek will worship Imouthes [Imhotep], son of Ptah" (Morenz 250). Also, the St. Petersburg Pushkin Museum has a votive statuette of Imhotep among it collection (Strouhal 245). In addition, we know of amulets from Dynasty XXVI that commemorate Imhotep's deification (Redford 16).

16). As his name implies – 'He who cometh in peace'[15] -- Imhotep was the author of the earliest work of wisdom literature, what one might think of as works on ethics, or 'instructions in wisdom' and 'directives for life' (Morenz 111). The advice given by the senior officials who wrote the surviving five complete and seven partial texts was meant to ensure personal success in concert with the needs of the state and the norms of ancient Egyptian society. These treatises cover truth-telling, fair dealing, rules for a well-ordered life, justice, wisdom, obedience, restraint, and humanity. They generally took the form of verses addressed by a father to his son or a king to an heir. These books were used as teaching texts in the schools for scribes and, at least in the cases of Imhotep and Prince Hordjedef, the authors of these ancient works were held in such high esteem that they were deified (Strouhal 31).

Among his titles were those of High Priest of Heliopolis, Chief of the Observers, and Grand Vizier. As a vizier (*tjaty*), to whom the king would delegate his own priestly functions to officials, Imhotep would have been responsible for management of the state-run economy, administrative functions of the state, and the judicial system. Dating back to the Dynasty II, the Vizierate alone was responsible to the king for proper order in the land (Hornung 21).

Imhotep was also the royal chamberlain and court physician to Djoser and in later years he was worshiped as a god of healing (Nunn 10). Sir William Osler[16] refers to Imhotep as, "…the first figure of a physician to stand out clearly from the mists of antiquity" (Jackson 13). He was worshiped as a medical demi-god from 2850 to 525 BCE and as a full deity from 525 BCE to 550 CE (Jackson 14). As such, the Egyptians placed him as one of only three mortals with the healing powers of the gods Amun, Thoth, Min, Horus, Isis, and Serapsis[17] (Strouhal 251). His image graced the Temple of Imhotep, perhaps one of the first hospitals[18] (Jackson 13). The Greeks came to identify him with their own Asclepius (Hornung 16). Asclepius was mentioned as a wise physician in Homer's **Iliad** and later, like Imhotep, was promoted to godhood (De Camp 23).

Imhotep is the most ancient engineer whom we know by name and inventor of the pyramid, [19] which among the Seven Wonders of the Ancient World, only the pyramids survive to this day[20] (De

[15] See Jackson, p. 13.

[16] **Evolution of Modern Medicine**, London, 1921, p. 10.

[17] The other mortals worshiped for their healing power were Amenhotep, the son of Hapu who was an architect and senior official in the court of Amenophis III, and Antinous, the Emperor Hadrian's lover (Strouhal 251).

[18] In the Ptolemaic period, according to Donald Redford of the Pennsylvania State University, "Temples often had sanatoriums on their premises where the afflicted in mind and body could come to spend the night and, in dreaming, be approached and helped by the resident deity of the temple" (Redford 79). Likewise, sufferers would come to Imhotep's temple for prayer, peace, and healing.

[19] Djoser's Third Dynasty successors built other step pyramids. At Meidum, a pyramid with eight steps was built. At some later stage, perhaps in the reign of the Fourth Dynasty king Sneferu, the steps themselves were filled in with stone packing and then faced with white limestone, producing the first true pyramid shape (Saggs 52). Following Sneferu, Khufu (c. 2589-2566 BCE) institutionalized the practice of architecture and the skilled crafts associated with engineering to such a level, unparalleled even by modern standards, which the Great Pyramid at Giza could be built. Consider the immensity of the Great Pyramid that sits on the west bank of the Nile just above Cairo. It is the largest stone structure ever built. "The cathedrals of Florence, Milan, St. Peter's at Rome, St. Paul's in London, and Westminster Abbey could all be placed at once on an area the size of its base," according to L. Sprague De Camp (De Camp 24). Except for the Great Wall of China, it was the largest single human construction of antiquity (De Camp 25). It required 94 million cubic feet of masonry (2.6 million cubic meters), made up of 2.3 million blocks averaging 2.5 tons each. Its total weight is 6 million tons. It stands 485 feet high in 210 layers of stone, with 763 feet on each side, and covers 13.5 acres (McClellan 42-43). The outer façade is polished stone and its interior has chambers, buttresses, and passageways. "The architects and engineers who built the Great Pyramid and the others like it commanded some elementary and not-so-elementary practical mathematics, …design and material requirements demanded such expertise, as did the very exact north-south and east-west alignment", notes McClellan and Dorn. The Great Pyramid was laid out true to the axes within 2.5 to 5.5 minutes of an angle, the sides of the base come to within seven inches of forming a perfect square, and, in spite of its enormous 53,077 square meters, is almost perfectly level with a maximum error of only 21 millimeters (Strouhal 170-171). The last Egyptian pyramids were built around 1600 BCE. Perhaps, Ahmose I constructed the last one. By this time, about

Camp 19). In addition, as head architect, Imhotep had to survey the site, calculate and decide on the type and quality of materials to be used, the quantities required, arrange for it to be hewn in the appropriate quarry, arrange for transportation of the materials to the building site, estimate the size and qualifications of the labor force, and manage junior scribes who would make arrangements for housing, feeding, and equipping the workers (Strouhal 170). The architect would also employ astronomers to lay down the north-south axis, which in the case of the Step Pyramid, was only off by three degrees (Strouhal 170).

As the greatest architect of the ancient world, Imhotep authored a book on the traditional schemes for temple construction.[21] It was found in a temple library and was said to be the model for the Ptolemaic temple at Edfu. This temple was, "one of the best preserved monuments in antiquity," according to Morenz. The temple at Dendra, also of the Ptolemaic period, was based on this ancient tradition as well (Morenz 85). These temples refer to an adherence to Imhotep's plans in wording that is similar to Holy Scripture – 'without taking [anything] away from it or adding to it …' (Morenz 85).

'Geniuses' Produced from Society

Every society determines reality, truth, beauty, and values in accordance with its own worldview and its evolutionary point in time. Likewise, cultural development has been facilitated by evolving, sometimes revolutionary, paradigms. The worldviews held by individuals or by groups are very influential in determining behavior, as well as in determining motivations, attitudes and actions.

According to Pascal, "Institutional greatness depends on the will of men, who have believed with reason that they ought to honor certain positions and attach certain signs to them" (Pascal 76). He also recognized that the greatness of a 'genius' that results in an ingenious discovery is the direct result of predecessors whose collective works establish the foundation for a new discovery, notes McDermott.. In essence, Pascal promoted a social theory of authorship. He suggested that,

> "Certain authors, speaking of their works, say: 'My book,' 'My commentary,' ' My history,' etc. They would do better to say: 'Our book,' 'Our commentary,' 'Our history,' etc., because there is in them usually more of other people's than their own" (McDermott 7).

Likewise, Emerson observed that the greatest genius is the most indebted,

> "Every ship that comes to America got its chart from Columbus. Every novel is a debtor to Homer. Every carpenter who shaves with a foreplane borrows the genius of a forgotten inventor. Engineer, broker, jurist, physician, moralist, theologian, and every man, inasmuch as he

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seventy pyramids dotted the Egyptian landscape. None were as grand and as well built at the Great Pyramid and, therefore, many have eroded away (De Camp 28-29).

[20] The Seven Wonders known by the Greeks around 100 BCE were: The Pyramids of Egypt, the Hanging gardens of Babylon, the Statues of Zeus by Pheidas at Olympia, the Temple of Artemis at Ephesus, the Tomb of King Karia at Halikarnassos, the Colossus of Rhodes, and the Pharos (lighthouse) of Alexandria (De Camp 19).

[21] Imhotep's use of stone was an important innovation in tomb building that would later culminate at Giza. The use of stone as a medium, plus the geometrical symbolism of the pyramid tomb as a place of ascent to heaven marked a change in the Egyptian religious symbolism. The realization of the symbolic purpose, according to the renowned Egyptologist Jan Assmann of the University of Heidelberg, was intimately connected with its elevation and its orientation to the cardinal points. The accuracy of the Old Kingdom pyramids with the south, east, north, and west reproduced the course of the sun and the constellations. Assmann interprets this iconographic symbolism as, "The sacred space of the pyramids was understood as an enclave in which the earth and its directions mirror the topography of the heavens" (Assmann 59).

> has any science, is a definer and map-maker of the latitudes and longitudes of our condition" (Emerson 18).

Imhotep's architectural and engineering skills were natural outgrowths of the Egyptian obsession with religion. Religion and rituals also played a fundamental role in the life of Egypt. Given its precarious dependence on water from cyclical Nile River flooding and the critical nature of the rebirth of crops, it is not surprising that Egyptian religion dominated so many aspects of society.[22] The Egyptologist Siegfried Morenz of the University of Leipzig argues that the all-pervading religion was the basis of Egyptian civilization.[23] As such, Imhotep is best known as the architect and director of the work on Djoser's mortuary complex, which included the Step Pyramid of Saqqara. As mentioned previously, the Step Pyramid was the first pyramid, but it was more than that; it was a tomb, a temple, a festival court, and an entire residence for Djoser made out of imperishable stone. This allowed Djoser's memory and reverence to remain alive into the Ptolemaic Period (Hornung 13-17). Hieratic graffiti on the passage walls of the northern and southern buildings record the admiration felt by Egyptians who visited the monument more than a thousand years after it was built (Edwards 51).

As noted earlier, the roots of Western scientific inquiry can be traced back to the classical philosophies of the Greeks. As such, Plato's intellectual exercises were an outgrowth of the Greek wealth and their spirit of open questioning. Much of the scientific method owes its approach to the mimetic assumptions of Socrates and Plato, and to the substantial refinements to Plato's metaphysics by Aristotle. As such, Aristotle's metaphysics defined a valid approach to seeking knowledge and his poetics defined metrics by which the scientific community still determines truth.

The Ionian Greeks had an earthy tradition that stressed the enjoyment of life, commercial property, aesthetic refinement, and acceptance of newcomers. This allowed free thought and inquiry to flourish. Pre-Socratic Ionian Greek natural philosophers established nature as a valid subject of inquiry.

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[22] In the Archaic Period (3100-2670 BCE), the falcon Horus, god of the sky, ruled the world in the form of each reigning king and the sun god Re (Ra) illuminated it in the form of a changing and renewed sun (Hornung 4). The war chief of the Falcon clan, who first united the valley of the Nile, became thought of as a god, because he controlled the river's gift of fertility, enforced submission, and exacted tribute from every dweller on the river's banks (Derry 7). In fact, the worship of the deified king through repeated acts of cult was thought to be essential for the prosperity of Old Kingdom society (Morenz 85). "The magical powers at the king's command, by virtue of his divine nature, were omnipotent," notes Erik Hornung of the University of Basel. H.W.F. Saggs of the University of Wales puts it more explicitly, "From the point of view of an ancient Egyptian, the king was, quite literally, a fertility giver and controller of the Nile and all life of the land; from whom the Egyptians' point of view he was, without question, a god upon whom the life of the land depended" (Saggs 26). As the society grew in numbers and geographic size, as water and land had to be distributed, as squabbles had to be settled, and as Egyptian civilization became more acquisitive and complex, the kings began to regulate society through deified edicts. Because of the ease of navigation from one end of the country to the other by means of the gentle Nile, it was relatively easy to produce a unified system of government (Saggs 26). Also, religious centers acted as focal points for the surrounding regions and concentrated wealth and power through gifts to the temples or through tax.

[23] For example, Egyptian pictorial art performed a function in the magic or cult that had religious ends. In the early years, art did not have to display any aesthetic appeal, since it was destined for a dark burial chamber, rather than for human viewers. The art only had to be there, its very existence provided god (the dead king) with a body that could be given vitality by the performance of rites and which could dispense salvation and receive gifts (Morenz 6). Words themselves and the objects they described were identical, therefore there was magic in the power of words, incantations, and spells (Morenz 9). When it comes to history, the only acceptable subject was the sacrosanct ruler, who was appointed by god, whom or in relation to whom all essential things happened (Morenz 11). The large number of mythological and ritual funerary inscriptions from the later pyramids, the so-called Pyramids Texts, are the earliest examples of Egyptian literature, but their function was wholly religious (Morenz 7). According to Morenz, "The Egyptians' peculiarly intense preoccupation with the service of the dead, which involved donations to secure a proper funeral and provision for the hereafter, had a very considerable impact on property relationships and thus also on economic life, administration, and law" (Morenz 12). The core concept of harmonious justice, called maat, was defined by religion, bestowed by the creator-god (e.g., Atum), defended and guaranteed by the sacrosanct king, and administered by viziers who bore the title of 'priests of maat' (Morenz 12-13). In this way, ancient Egyptian art, language, literature, law, and government were based on religion, which Morenz calls the 'womb of culture.' He also suggests that the close ties between religion and the Egyptians' basic outlook on life, their way of thinking, their goals, social order, and philosophies, created a fundamental harmony that explains the longevity of the ancient culture (Morenz 13).

From its earliest manifestations, the Greek mind had turned to natural philosophy, which was indistinguishable from Greek science. Led by Thales of Miletus, the Greeks saw the formation of the earth by natural processes, no longer through an act of the gods. "The Ionians conceived of nature as a completely self motivating entity," according to science historian, Thomas Goldstein. The workings of the universe occurred as mere extensions of the primordial chaos, automatic functions of its basic elements. Matter possessed its own evolutionary quality. 'Order' and 'law' were mere concepts superimposed by the human mind on the autonomous processes of nature[24] (Goldestein 52). Ionian Greek philosophy and its classical definitions of truth and beauty, exemplified by the Socratic logic of Plato, and the later Hellenic-era metaphysics of Aristotle, laid the foundation for rational scientific inquiry.

It is clear that the development and evolution of advanced mathematics by the priestly classes and the practical applications by the scribes of Mesopotamia and Egypt existed long before the Greeks and has had a considerable influence on a number of societies, including our own.[25] As Hogben notes, "There is no doubt that the raw materials of Greek mathematics were imports." He also cites the influence of the Phoenicians of the Levant on the Greek colony of Miletus, on the father of Greek geometry -- Thales of Miletus (640-546 BC) -- and their influence on the travels of Pythagoras in Egypt and Mesopotamia[26] (Hogben 60-61). One might also surmise that Alexander's conquests of Persia and India provided ample opportunity for his teacher, Aristotle, to 'borrow' the works of Babylonian, Persian, and Indian scholars to further expand and refine Greek philosophy into a rigorous scientific method.

So, the Greeks did not monopolize abstract thinking; but they certainly refined it.[27] Through his words and actions, Plato, through his alter ego Socrates, demonstrated key concepts critical to the future process and ethics of scientific collaboration. Among them include a belief that there is an absolute truth that can be revealed through logical philosophy. He also used binary yes/no logic via cross-examination

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[24] It was Pythagoras who is credited with the introduction of the vision of an intrinsic natural order and Plato adopted this vision (Goldstein 52).

[25] Though the roots of modern inquiry rests on a framework solidified by the Greeks, it is important to recognize that Thales of Miletus, Anaximander, Pythagoras, Socrates, and Plato developed many of their ideas using earlier ancient works as their base (Goldstein 48-64). Among their influences were Phoenician, Egyptian, and Mesopotamian scholars. As the archaeologist Sir Leonard Woolley noted, "We have outgrown the phase when all the arts were traced to Greece and Greece was thought to have sprung, like Pallas, full-grown from the brain of the Olympian Zeus; we have learnt how the flower of genius drew its sap from Lydians and Hittites, from Phoenicia and Crete, from Babylon and Egypt. But at the roots go farther back: behind all lies Sumer" (Woolley 194). Mathematician Lancelot Hogben argues that, "The veneration of the Greeks by their successors is indeed due to the fact that they were the first to insist explicitly on the need for proof." Though Greek mathematics were imports, "…they had to pass the customs of Greek incredulity," among a society partial to dispute resolution and competition among rival teachers (Hogben 60-61).

[26] The French Assyriologist Jean Bottero of the Ecole Pratique des Hautes Etudes argues in favor of abstract Mesopotamian thought as the foundation for Greek pre-Socratic philosophy.

> "From a knowledge based on pure observation *a posteriori*, starting from individual cases that were fortuitous and unforeseeable, divination became thus *a-priori* knowledge…before the end of the third millennium at least. That knowledge was deductive, systematic, capable of foreseeing, and had a necessary, universal and, in its own way, abstract object, and even had its own manuals. That is what we call a science, in the proper and formal sense of the word" (Bottero 136).

Bottero argues that, "… the Greeks did not develop their conceptions of science, which we inherited, out of nothing; in this important point, as well as in others, they owe a debt to the ancient Mesopotamians." What may have passed on to the Greeks, according to Bottero, was this "scientific point of view, scientific treatment, and the scientific spirit" (Bottero 125).

[27] According to C. M. Bowra, the Greeks raised mathematics beyond the practical applications of the Egyptians. The Greeks triumphed in pure mathematical thinking without reference to practical considerations. Beginning with geometry, Pythagoras and his disciples saw in numbers certain permanent principles that were the keys to most problems. They promoted the thought and practice that most phenomena could be understood if one could discover the mathematical laws that governed them. The mathematical school of thought was then followed by the philosophical school, which sought reality behind phenomena through words, rather than numbers. (Bowra 165-167).

of hypotheses that sought to disprove falsehoods, and, by a process of elimination, allow one to move closer to the truth. In addition, in a manner that would be important to future holistic approaches to knowledge, Socrates held a conviction that the process of logical inquiry can explain nature in a way that is not necessarily inconsistent with religion.

By the late Medieval or early Renaissance period. Leonardo was able to develop and apply his genius due to the largesse of his wealthy patrons, who also gave him time to observe and think. Plekhanov argues that Leonardo was a product of the Renaissance, "Leonardo da Vinci and Michelangelo did not create this trend; they were merely its best representatives" (Plekhanov 171).

Being the illegitimate son of the middle-class Ser Piero Da Vinci, Leonardo, as was typical of the bourgeois society of his day, was effectively ostracized from his father's world. According to biographer, Michael White, "He was prevented from attending university and could not hope to enter any of the professions, such as medicine or law, because it was strictly against the rules of the professional guilds to accept anyone with his background. Although he achieved wonders in a vast range of studies, Leonardo was never able to come fully to terms with the fact that he had been deprived of a formal university education" (White 15-16). Since Leonardo was not formally educated, he became a product of the guild system and he managed to take advantage of the patronage and contacts that came his way. In addition to the Duke of Milan, Leonardo was associated with the political operative Niccolo Machiavelli, the sinister Cesare Borgia, and the Medicis, plus he had a rivalry with Michelangelo (DeCamp 398-399). Like many of his predecessors, Leonardo spent a period in the mechanistic world of the large workshops[28] (Van Os 244). Unlike the average guild artisan, Leonardo's patron was the Duke of Milan, Ludovicio Moro. The newly enlightened, urban, nouveau riche became important patrons of artists and artisans. The Church also became a powerful patron of the arts.[29] Notably, Leonardo's *Last Supper* was painted for the monastery of Santa Maria delle Grazie (Murray 238).

Unlike ordinary artisan painters, Leonardo was obsessed by creation of a work with spiritual power and spent more time contemplating it than painting (Frere 9-10). Leonardo told the Duke of Milan, "…those possessed of elevated minds work the most when they seem to be doing the least… when they have found the perfect form for their ideas, they can give them a visible shape through the labour of their hand" (Frere 12).

With patrons that allowed this kind of creative freedom and tolerated the extensive time associated with a visionary process, Leonardo moved beyond mere craft to high art (White 309-310). It is only in this enlightened work environment, which may not have existed for Castagno forty years earlier, that superior observation skills and a scientific understanding of nature allowed the artisan to emerge as a creative genius.

Likewise, after his publication of *Starry Messenger* (*Sidereus nuncios*), Galileo parleyed his new fame into a move from the University of Padua to a much more prestigious and well-paid position as Chief Mathematician and Philosopher at the Medici court in Florence (McClellan 225). Later, he also became a member of the *Academia dei Lincei* (*Academy of the Lynx-Eyed*), patronized by the Roman aristocrat Federico Cesi. According to McClellan and Dorn, Galileo fashioned himself into a scientific courtier, in competition with the established professors at the university.

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[28] Both Leonardo and Castagno were products of the collaborative guild system, with Leonardo becoming a master in the Guild of Painters in 1472 (Murray 230).

[29] The Church amassed unparalleled wealth due to the legacies left by victims of the plague and by profiting from the supposed healing powers of the relics of the Christian martyrs (Van Os 245).

The Renaissance courts of Italy, private solons, and informal associations of amateurs provided a new social support system for scientists. They also provided a flexibility of research and a seat of change not found in the static university system. They legitimized and defined the role of science and scientists in the 17th century. The patronage system provided financial support, but the patrons also gained influence and enhanced reputations from the scientists they supported (McClellan 226-227).

Three hundred years later, Albert Einstein's accomplishments arose from an age of intense investigation of nuclear physics. While he is often portrayed as the solitary genius or singularly-focused discoverer of nature's greatest secrets, Einstein's work stood on a solid foundation laid by his predecessors and contemporaries. According to Cohen, "Einstein himself argued that his intellectual creation should be considered as a part of an evolutionary rather than a revolutionary development in physics" (Cohen 435). For example, in 1887, the American physicist Albert Michelson (1852-1931) failed to detect the motion of the earth relative to the then-supposed stationary ether. The null result of which would eventually be predicted by Einstein's relativity theory. In Germany in 1895, Wilhelm Roentgen (1845-1923) discovered X-rays, a new type of radiation that extended the range of electromagnetic radiation beyond convention theories. J.J. Thomson (1856-1940) demonstrated the particulate nature of cathode rays in 1897. Antoine-Henri Bacquerel (1852-1908) accidentally discovered that uranium ore clouded unexposed photographic plates in 1898. Marie Curie (1867-1934) discovered that heavy elements emitted different types of radiation, including electrons, gamma rays, and alpha rays. In addition, Max Planck (1858-1947) suggested that light or radiation travels in discrete energy packets or quanta and did not exist according to the energy continuum of classical physics. In the early 20th century, Ernest Rutherford (1871-1937) and Nils Bohr (1885-1962) proposed a model of the atom, which was mostly empty space, that had electrons orbiting a solid nucleus, in the manner that the planets orbit the sun (McClellan 344-347).

This was the world in which the young Einstein inherited. Einstein himself credited Michael Faraday (1791-1867), of whom he kept a portrait of on the wall of his study, with setting the stage for the grand revision of physics that made Einstein's work possible (Boorstin 679-684). After Faraday, the world would no longer be one of Newtonian forces, but one of pervasive fields of force. According to McClellan and Dorn, "Einstein was perfectly positioned to effect a revolution in contemporary physics: he was well educated technically in the central dogmas of the field, yet he was young enough and professionally marginal enough as an outsider not to be locked into established beliefs" (McClellan 345). So, Einstein did not invent the concepts of mass, energy, light, and acceleration, rather, he combined these concepts in a novel way. He looked at the same world as the other physicists, but he saw something quite different (Michkalko 128).

'Geniuses' Shaping the Development of Society

When one looks at the works of scientific ingenuity, one must recognize the important role these new discoveries had in shaping the development of society. As Carlyle observed, "The Great Man here too, as always, is a Force of Nature…he lasts for ever with us" (Carlyle 112-113). Likewise, Emerson notes that "The river makes its own shores, and each legitimate idea makes its own channels and welcome -- harvests for food, institutions for expression, weapons to fight with and disciples to explain it" (Emerson 13).

As the scientific community entered the 20th Century and faced discoveries that confounded Newtonian physics, the Nietzschean concept of relevance came into play. Friedrich Nietzsche (1844-1900) reminded us that truth is, "…an infinitely complex dome of ideas on a movable foundation as if it were on running water." Nietzsche continued, "Truths are illusions of which one has forgotten that they are illusions; …a sum of human relations which became poetically and rhetorically intensified, metamorphosed, adorned, and after long usage seems to a nation fixed, canonic, and binding" (Adams 636-637). This was the state of Newtonian science as well. It no longer explained new discoveries because scientists became too comfortable with their mutually agreed frame of reference, or what Kuhn called normal science.

As an example, consider the breakthrough thinking that was required in the early 20th Century. One of the most important implications of Einstein's General Theory of Relativity is the concept of reference frames. As Nietzsche describes, reference frames can be considered simply as a certain point of view. So, in order to understand the relationship between what one sees and what is going on, one needs to add, or subtract, the influence of one's own reference frame.[30] Therefore, logic is a useful tool but it has its limits. Reference frames help us understand that there is a duality in nature. "The opposite of truth is not heresy," as Oppenheimer reminded us. It may be a different kind of truth.[31]

Given the position of Einstein as a public intellectual and acknowledged 'genius' of modern physics, Einstein was able to impact the world through advocacy of a critical public policy, which led to the development by the U.S. of the atomic bomb. Einstein's historic letter to President Franklin Roosevelt in 1939 warned of the possibility that Germany, already at war in Europe, might develop an atomic bomb.[32] Roosevelt authorized a small exploratory project that grew into the largest research and development initiative in history – the Manhattan Project, which involved 43,000 people working in 37 installations, at a cost of over $2.2 billion dollars[33] (McClellan 360-361). The era of 'technology as applied science' and government-sponsored 'Big Science' was underway.

To scientists, Galileo was the foremost leader in advancing experimental science. He impacted the world of science by enabling the understanding of telescopic astronomy, the principles of motion, the mode of relating mathematics to experience, and the science of experimentation. He uncovered laws associated with vector velocities, trajectories of projectiles, inertia, free fall, the gravity of an object on inclined plane, and transformed individual visual experiences into intellectual conclusions (Cohen 135-141). Sir Isaac Newton hailed Galileo as the primary founder of his own rational dynamics and it would take another 50 years after Galileo for Newton's revolution to achieve the potential inherited from Galileo (Cohen 144-145). However, to the non-scientist, Galileo's impact on the societal understanding of humanity's place in the universe is paramount.

Galileo was involved in a dispute in 1613 at the dinner table of the Medicis over the religious implications of Copernicanism and the role of science in support of religion. In his *Letter to the Grand*

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[30] Consider how a shadow in Plato's cave is a two-dimensional slice of a three-dimensional object. The three-dimensional object casting the shadow remains invariant as the shadow moves and changes form based on the light falling on the object and the background on which it falls. However, everything we see and measure is under the influence of a reference frame. This shift in perspective allows relationships to become clear. It allows us to see relationships between common objects that obey Newtonian physics and extrapolate those relationships to the orbits of the planets. Conversely, failure to take into account one's reference frame can lead to what Plato called 'shadows' (Cole 192-195). As Plato warned us, when we take our reference frame for granted, we mistake it for reality.

[31] Each added view adds insight, as long as the viewer understands the kind of frame that influences the perspective. Physicists Neils Bohr and Christopher Morley cautioned us with the truism, "The opposite of a shallow truth is false; the opposite of a deep truth is also true" (Cole 202). Logician Keith Devlin argues for a softer mathematics that incorporates metaphors as well as formal reasoning. To really understand what it means to think rationally, mathematical logic will likely need to join forces with psychology, sociology, biology, and even poetry. (Cole 157-164).

[32] This was based, in part, on the 1938 demonstration by Germany's Otto Hahn that certain heavy elements could be split into more simple components, followed by a Nazi émigré to Sweden, Lise Meitner's theoretical explanation of the immense energy that would be released from a nuclear fission chain reaction (McClellan 361).

[33] Enrico Fermi created the first controlled nuclear chain reaction at the University of Chicago in December 1942. Under the direction of J. Robert Oppenheimer, the world's first atomic bomb was exploded at the Trinity site near Los Alamos labs in new Mexico. On August 6, 1945 the U.S. *Enola Gay* dropped a uranium-235 bomb on Hiroshima, Japan killing 70,000 people. On August 9, of the same year, a plutonium-239 bomb was dropped on Nagasaki. Japan surrendered five days later (McClellan 361).

Duchess Christina Concerning the Use of Biblical Quotations in Matters of Science (1615), Galileo took the position that faith and reason cannot be in contradiction since the Bible is the word of God and nature is the work of God. Galileo could not ignore the facts of observation, but sought to rationalize them with God's plan. However, in instances where there appears to be a contradiction, science supercedes theology in questions concerning nature. As he put it, "the Bible was written to be understood by the common people and can readily be reinterpreted, but nature possesses a reality that cannot be altered." For Galileo, as McClellan and Dorn explain, if scientists demonstrate some truth of nature that seems to contradict statements found in the Bible, theologians must then articulate reinterpretations of the literal sense of Holy Writ (McClellan 228). "Galileo's postulate that science and human study of nature should take priority over traditional theology represents a radical step, much removed from the medieval role of science as handmaiden to theology" (McClellan 228).

Centuries later, Albert Einstein would write an introduction to Stillman Drake's translation of Galileo's **Dialogue** (1953). In it he lauded Galileo's 'leitmotif' or passionate fight against authoritarian dogma and his acceptance of 'experience and careful reflection' as the only 'criteria for truth' (Cohen 439). Galileo was not fully rehabilitated by the Church until the 19900s (McClellan 242).

Oddly, Leonardo was perhaps the world's first documented creative genius, however, "He had hardly any influence at all on the science and engineering of his time," notes L. Sprague DeCamp (DeCamp 396). "But, of all these gadgets, only a few – the canal lock, and perhaps the screw-cutting machine and the turret windmill – were actually reduced to practice. Sometimes the idea was not workable," says DeCamp. For example, Leonardo's flying machines relied on human muscle, the mass of which was shown by Borelli in 1680 to be no where near the proportion to weight needed to fly like birds. His battle cars were too heavy for the human-powered cranks to operate them. (DeCamp 402). While Leonardo's ideas drew upon extensions of his observation of the natural world, he did not have the formal intellectual training in physical sciences or mathematics to allow his sketches to become real.

While his career as an engineer is debatable, his impact on art is unmistakable. Leonardo da Vinci's career shows how painters influenced by the scientific methods of the High Renaissance gave art greater realism, action, and emotion. In the process, the painter was elevated from a cog in the mechanistic wheel of workshop production to one of creative genius, free to portray realistic scenes as the mind's eye saw it. As previously noted, examinations of two famous depictions of *The Last Supper* provide a basis for comparison of art with and without the influence of critical scientific observation.[v]

What did Leonardo actually accomplish? According to DeCamp, "He painted several immortal pictures, such as *The Last Supper* and *Mona Lisa* (*La Gioconda*). He dug some canals, cast some cannon, staged charades for kings and dukes, and made countless sketches [in over 30 volumes of notes]" (DeCamp 402-403).

Just as in modern times, scientific truth evolves based upon new knowledge and an internal competition among ideas within the scientific community. As such the Socratic and Platonic philosophies ultimately gave way to the refinements of Aristotle. Aristotle, the son of a physician and Plato's pupil of twenty years, took his master's basic philosophy, added more structure and advocated verification of intuitive natural laws with objective observation[34] (Loomis vii-xiii). Loomis noted that he reasoned like

[34] Unlike Plato, Aristotle did not believe in a world of ephemeral appearances of changeless ideas. Louise Loomis, editor of a 1940's translation of Aristotle's Metaphysics, notes that Aristotle argued that, "…the world really is, has been, and will continue to be, regardless of human eyes and imaginings" (Loomis xvii-xviii). Hazard Adams notes that Aristotle believed that reality was the process by which form manifests itself through the concrete and by which the concrete takes on meaning, working in accordance with ordered principles. Aristotle believed that change was a fundamental process of nature, a creative force with a conscious direction toward perfection (Adams 49). However, like Plato, Aristotle thought it necessary to, first of all, understand and explain the workings of the human mind and to show what kinds of reasoning were valid and could be relied upon to provide knowledge with surety. In his *Organon*, Aristotle made clear the processes of logical, reasoned thinking and for proving the correctness of its conclusions. He made plain the steps by which a science or body of knowledge may be firmly built up from its starting point

Plato, from ideal abstract principles, whenever the subject of the reasoning lay outside his field of observation. Both a great thinker and a great scientist, Aristotle set the tone for future scientists by his method of inquiry and an avowed determination to yield to observation as the final arbiter. As a result, an atmosphere of sober empiricism distinguished the Hellenic Greeks from the Ionians, with Aristotle being credited as a great dividing line in Greek philosophical history. Aristotle's pupils and their successors carried on his teachings at the *Lyceum* for over 800 years, until, like Plato's *Academy*, it was closed by order of a Christian emperor in Constantinople (Loomis X). [vi]

When one looks at the impact of ancient engineering, one recognized that the Egyptian pyramids were symbolic as well as literal exercises in state building (McClellan 45). Archaeologist Michael Hoffman of the University of Virginia observes, "The impact of contrived and monumental architecture – the ways it manipulated space and scale – certainly were linked to the social function of the royal mortuary cult itself. As Egypt consolidated from local chieftainships into regional kingdoms, into the world's first national state, it developed the royal tomb as its flag: a symbol of political integration, under god" (Hoffman 336).

Not only were the pyramids symbolic, they served a practical purpose. Pyramid building, certainly in the Old and Middle Kingdoms, served as a dominant activity around which Egyptian society was organized. Egyptologist Mark Lehner of Harvard asks the question 'how the pyramids built Egypt' might be more interesting than 'how the pyramids were built' (Shaw 45). Likewise, Assmann refers to Egypt as a case of *ethnogenesis*. As Assmann explains, "The old Kingdom is not only the period in which pyramids are built, but also the time that was defined and indeed 'created' by the pyramids – as planning time, building time, cult time, and eternal time" (Assmann 53). It was a time when collective construction of gigantic structures caused laborers from all over the country to speak the same language in order to plan, agree, and live together[35] (Assmann 53). In this sense, Egypt as a culture and as a nation was created.[36]

The massive public expenditure entailed in the development of the pyramids was not solely for the glorification of a king, but rather for the welfare of the state, according to Hornung. Since the Egyptians believed that the king's creative powers held together the very order of the world and had to be

in certain fundamental axioms or obvious statements, perceived intuitively to be true. Every science, as Aristotle pointed out, must begin with a few general truths. They cannot be logically proved, but our minds by simple intuition accept them as obviously true. Without such assumptions as foundations, we could never start to build anything (Loomis, xi-xxxviii).

[35] Lehner drew on strands of evidence from various disciplines to determine that, unlike the popular notion reinforced by the Judeo-Christian tradition and by Hollywood movies, such as The Ten Commandments, a vast slave class did not build the pyramids. He studied geological history, the living arrangements, bread-making, animal husbandry and remains to determine that the workers who built the pyramids were part of a rotating labor force in a modular, 1,600-2,000 person, team-based organization. The workers' graffiti revealed team names, such as 'Friends of Khufu,' and 'Drunkards of Menkaure.' He also discovered that these workers lived in a barracks-style setting near the site of the pyramid being built, and were fed prime beef. These were not common laborers, but skilled workers. (Shaw 99). Along with these skilled workers from all over the country, the manual labor of quarrying and hauling massive stone blocks was done by unskilled labor and slaves. A surplus of idle agricultural workers available seasonally for three months a year during the Nile floods provided the labor pool. "Contrary to a once-common belief," says McClellan and Dorn, "forced slave labor did not build the pyramids, but labor was conscripted (like military conscription today) and organized in work gangs." Lehner explains that obligatory labor in the ancient world ranged from slavery to the highest levels of society, somewhat like a feudal system, where everyone owed service (bak) to a lord. Even the highest officials owed bak. So, like cathedral building in Medieval Europe or barn raising among America's Amish, the combination of a strong sense of community obligation and the lack of a sense of individual political and economic freedom explain the advanced social organization of this period (Shaw 49-99).

[36] The sequence of early pyramids were giant public works projects designed to mobilize the population during the agricultural off-season and to reinforce the idea and reality of the state of ancient Egypt (McClellan 44-45). "Monumental building was therefore a kind of institutional muscle-flexing by the early Egyptian state, somewhat akin to the arms industry today," notes McClellan and Dorn. Lehner observes, "The colossal marshaling of resources required to build the three pyramids at Giza – which dwarf all other pyramids before or since – must have shaped the civilization itself" (Shaw 46).

preserved even beyond death, the construction of a pyramid was a communal religious effort on the part of Old Kingdom Egyptians. These people were not 'free' in the modern sense of the word, but rather were in various ways bound to and dependent upon the king and other divine powers (Hornung 24). According to Hornung, "The clear structure, the firm order, and the tight organization of the state, which made it possible for all its energies to be concentrated on a single cultic task, found symbolic expression in the form of the pyramid"[vii] (Hornung 24).

Promotion of the New Paradigm and the Legend of the 'Genius' who Inspired It

When it repudiates a past paradigm, a scientific community simultaneously renounces as a fit subject of inquiry, the past paradigm's experiments and subsequent textbooks.[37] Scientific education makes use of no equivalent of the art museum or the library of classics, according to Thomas Kuhn. The result is sometimes a drastic distortion in the scientists' perception of their discipline's past. More than the practitioners of other creative fields, the scientist comes to see his or her discipline as evolving in a straight line to the present paradigm. In essence, the new paradigm is seen as progress and thus no alternative is available to the scientist while remaining in the field. The new paradigm is free to mature until the endless circle of challenge and debate inevitably signals its death.

The process of recognizing the need for a paradigm shift and making the shift can be summarized by Emerson's admonition, "Every hero becomes a bore at last" (Emerson 31). Scientific truth evolves based upon new knowledge and an internal competition among ideas within the scientific community.

Scientists and engineers, being fully human, also experience the effects of paradigms.[viii] They and their findings are influenced by the mainstream of social thought framed by current technology and prevalent belief systems. As Heidegger reminds us, "[Even though] every phenomenon emerging within an area of science is refined to such a point that it fits into the normative objective coherence of the theory…that normative coherence itself is thereby changed from time to time" (Heidegger 169). Even Aristotle was willing to reject or change his theories when a closer examination of nature proved them wrong. He was quite aware that his work was only the beginning, to be corrected and developed by those who came after him, citing, "Inventions are either the elaboration by later workers of the results of previous labor handed down by others, or original discoveries, small in their beginnings but far more important than what will later be developed from them" (Loomis xxv).

Within the community of scientists, since the validity of scientific truth, or probable truth, is based on statistical arguments. The community relies on truth by consensus, better known as 'peer review.' This peer review is based on a shared paradigm or worldview on how to evaluate evidence and come to agreement, or at least temporary agreement, until it is overruled by new insights and information. Cole describes scientific truth as "…less a collection of facts than a running argument" (Cole 127). At some point in the scientific process, the theory no longer fits reality. When this happens, "No great man can foist on society relations which no longer conform to the state of these [productive] forces, or which do not yet conform to them," notes Plekhanov.

> " The more or less slow changes in 'economic conditions' periodically confront society with the necessity of more or less rapidly changing its institutions. This change never takes place 'by itself;' it always needs the intervention of men, who are thus confronted with great social problems. And it is those men who do more than others to facilitate the solution of these problems who are called great men" (Plekhanov 176-177).

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[37] Kuhn described a *paradigm* as a way of seeing the world and practicing science in it. The characteristics of a new paradigm include new scientific achievements sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity and, at the same time, sufficiently open-ended to leave all sorts of problems for the new group of practitioners to solve.

Kuhn explains that revolutions close with a total victory for one of two opposing camps, with the winner rewriting scientific knowledge. The new structure of the work itself is sufficient and it becomes the new set of apriori assumptions for future scientific work. Will the victorious group ever say that the result of its victory has been something less than progress? That would be admitting that they are wrong and the old paradigm holders are right. To the victors the outcome of a revolution must be defined as progress and they are uniquely positioned to make certain that future members of their community see past history in the same way because the new paradigm holders are the ones that get their work published (Kuhn 166).

The role of promotion and persuasion in the creation of the mythological 'genius' is echoed by Pascal, "The same gradations are found among geniuses as in conditions, and the power of kings over their subjects is only, it seems to me, an image of the power of minds over those minds that are inferior to them, over whom they exercise the power of persuasion" (Pascal, Letter to Queen Christina of Sweden, June 1652).

Let us take a look at the role of 'public relations' and 'spin' from the ancient times. Though archaeologists can verify Imhotep's existence, and his obvious magnificent works of stone, the sheer range of expertise attributed to Imhotep may have grown as his legend became cult. The worship of Imhotep from the New Kingdom (c. 1550-1070 BCE) into the Greco-Roman period resulted in him being given divine lineage, as the son of Khereduankh, his real mother, and the god Ptah (Redford 70). Not unlike the legends of medieval saints of the Catholic Church, a truly great man may have been given attributes beyond reasonable human capabilities. Because, if the legends are true, Imhotep stands as a truly unique historical multi-genius, exceeding both Aristotle, who wrote on a wide array of subjects from mathematics, to zoology, to ethics, and Leonardo da Vinci, who was both a great artist, scientist, and inventor.

Few people in the history of the world have set the standard for excellence in multiple disciplines. Hippocrates and Galen discerned the causes of disease as biological, rather than spiritual, but they did not simultaneously run the economy of an empire. Newton, Galileo, and Copernicus introduced the world to revolutionary laws of physics and astronomy, but they did not simultaneously practice medicine. Even in modern times Albert Einstein set the standard for physicists and Thomas Edison for inventors, but neither wrote wisdom literature or philosophy. Modern Nobel Laureates are renowned for their excellence in a single domain, including great works of literature, but they are not simultaneously architects of monumental stone works meant to last forever. If one is to believe the legend, none of these great personages of history mastered the scope of disciplines and the depth of expertise as Imhotep, the first 'Renaissance Man.'

One explanation for the extent of Imhotep's skill set might be the general practice in the Old Kingdom of bestowing honorific titles on members of the royal court. Some titles that began as a mark of function became marks of rank within the hierarchy. Saggs cites Klaus Baer's findings of some individuals having as many as 200 titles, a sign that the ancients were obsessed with considerations of rank in relation to the king (Saggs 27). When it came to rank, the most important officer of the state was the Vizier. The earliest viziers were royal princes, a relic from when the king kept all authority within his circle of kinsmen. By Dynasty V, viziers no longer had to be princes by birth, but they had to be men of considerable ability, since his task was to oversee the whole administration and be second to the king in status, and in some cases, of greater importance in practice (Saggs 28). So, Imhotep as a vizier would have been considered at the very height of power, prestige, influence, and control of Djoser's kingdom.

Another explanation may lie in the motivation of the Ptolemies. Ptolemy V Epihanes, the Greek pharaoh, in an effort to cope with a famine and the revolt of King Ergamenes of Meroe, sought to associate himself with the founder of the Memphite Dynasty – Djoser – to attain legitimacy in the eyes of the Egyptians (Grimal 64-65). This motivation to discover, cultivate, embellish if necessary, and propagate Third Dynasty heroes by the Ptolemies may also have contributed to the growth of the Imhotep legend. As Nicolas Grimal of the Sorbonne reminds us,

> "Imhotep the courtier is now better known than Djoser the king, and it was Imhotep, rather than Djoser, who later became the object of a popular cult. In fact, the cult of Imhotep was spread from Alexandria to Meroe (via a temple of Imhotep at Philae), and even survived pharaonic civilization itself by finding a place in Arab tradition, especially at Saqqara, where his tomb is supposed to be located. Djoser on the other hand, was not deified, and he only achieved immortality through his pyramid" (Grimal 65-66).

Yet another explanation lies in the profitability of cults. "The driving force behind these enormous cults was that they paid," according to Redford. "They were expensive to run, but they attracted worshipers and pilgrims in the thousands, in some cases from outside Egypt, as can be seen from hieroglyphic dedications on bronze votive statues." This is a pattern of religious exploitation that European Christians should be well familiar with, since the sale of relics and benefices was so common in the medieval period that Giovanni Boccaccio and Geoffrey Chaucer lampooned it in the **Decameron** and the **Canterbury Tales**, respectively.[38]

Whatever the reasons behind his popularity -- whether it is as crass as the profit motive, a public relations move by the Ptolemies, a veneration of great leaders of the skilled architectural and engineering trades, or whether he is the impetus for wisdom in the manner that Benjamin Franklin became in 18th century America -- it is clear that the collective cultural mind of the Egyptians was so impressed by the innovative and inspiring work of Imhotep, that 5,000 years later, we still speak of him. He is an iconic symbol of the values of ancient Egypt: skill in service of the king (god), wisdom, literacy, healing, and the ability to transcend time through immortal acts of monumental creation and through legendary good works.

Consider also how Plato, as a playwright and a student of Socrates may have embellished his **Dialogues** with his own philosophies. Indeed, it may also be safe to assume that Plato' use of Socrates as a literary vehicle in the **Dialogues** adds a certain kind of authority to Plato's own beliefs. Galileo used a similar device, conversations between imaginary characters – Salviati, Sagredo, and Simplicio -- that represented different sides of the argument, in **Dialogue Concerning the Two Chief World Systems** (Galileo xxv, 6-7).

What better way to solidify one's powerful philosophies about truth and methods of obtaining truth than by making the most ardent proponent of truth a martyr? Plato made Socrates a martyr to faith, logic, and truth.[39] He says that it is not he, but the Oracle at Delphi who says Socrates is the wisest man.

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[38] The Church sanctioned and profited from the supposed healing powers of the relics of Christian martyrs (White 2: 26). One finds in literature caricatures, such as Chaucer's Pardoner, who is openly larcenous, and yet operates with the full authority of a Papal Bull. This seller of relics is an "entirely viscous man" who has no interest in the message of Christianity, other than how it is used to profit him (Chaucer 348). Through the sale of benefices, Boccaccio describes the clergy in Rome as, "… having carried on more trade and had more brokers than there were engaged in the textile or other business in Paris" (Boccaccio 30).

[39] When Socrates is put on trial for corrupting the youth of Athens, he defends himself by arguing that the false charges are brought by those who accused him of being a natural philosopher, e.g., he "inquires into things below the earth and in the sky," a sophist, e.g., he "makes the weaker argument stronger," and teaches others to follow his example. Socrates defends himself by stating that, though he "takes no interest in these things, " he also "sees no conflict between those who inquire about the heavens and a belief in the gods." He also denies that he is a professional teacher, because he does not take money. Most importantly, Socrates denies that he is wise, rather he attributes his wisdom to divine inspiration and cites a divine source as the certification of his wisdom.

Under divine direction, Socrates' has a duty to lead a philosophic life focused on truth and justice. Socrates also argues that divine law supersedes the laws of Athens and admonishes Athens for being unjust. Given his divine mission to be Athens' 'gadfly,' he dos not fear of death. Socrates will not change his divine mission, "even if [he] has to die 100 deaths' (Plato, *Apology 30b*). Through this device and Socrates' ultimate penalty of death by hemlock poisoning, Socrates' philosophies became ordained and so did those of Plato. As Aristotle carried the basic tenets of Plato forward, massively increased the body of written works on numerous subjects, Plato's' genius (or that of Socrates as Plato's alter ego) became enshrined in the Classical world view and the curriculum of medieval universities and monasteries.

As we have seen through an examination of Greek philosophy, the sheer process of Socratic/Platonic speculation, argument, intuition, plus a dash of Aristotelian empirical reasoning allowed the Greeks to move, within the space of three generations, from the early mythical notions to a point that is surprisingly close to modern scientific concepts (Goldstein 52). Having channeled the power of Greek philosophical thought into a logical system of scientific classification, Aristotle came to exercise an enormous influence over European science for the next two thousand years (Loomis, xi-xxxviii). When Europe awakened from the feudal Dark Ages and the Medieval suffocation of theocracy[ix] to an enlightened approach to knowledge[40] that included the works of Francis Bacon, Sir Isaac Newton, and Nicolaus Copernicus, it embraced the process of observation, generalization, explanation, and prediction that was fully rooted in an earthy materialism, indicative of the age. Thanks to Greek philosophy, Europe came to understand that the physical realm of nature is real, orderly, and, in part, understandable, or as Max Planck stated, "That is real which can be measured" (Heidegger 169). Likewise, the 20th-century German philosopher Martin Heidegger defines science as the 'theory of the real' (Heidegger 157). This view of knowledge became pervasive, changing assumptions not only in science but also in the entire social fabric of Europe.

Conversely, though Leonardo was a fame-seeker and, what Decamp called, an "incorrigible dabbler and dilettante," he failed to make a significant impact on the science of his times. Because he tried to master all the sciences, he often dropped his work and forgot his obligations. He suffered from an inability to complete the projects he started. "Leonardo's abortive projects included two colossal equestrian statues, the construction of a canal to Pisa, urban renewal at Florence, completion of the Milan Cathedral, and drainage of the Pomtine Marshes," according to DeCamp (DeCamp 400-401).

Most importantly, Leonardo's genius was unrecognized because he never published his ideas. Leonardo went as far as any man of his time. Sometimes he anticipated the discoveries of later scientists like Galileo or Stevin. He was so driven by his urge to discover and create that he made little time for human relationships. Though he could be charming, he usually presented an aloof façade. His

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[40] Two aspects of these scientists' work stand as foundations of modern science. They include the empirical approach based upon objective, rational observation, and the use of mathematics to describe nature. The two criteria for the dynamic entity of scientific truth, either one of which is generally sufficient to cause persons to accept a principle, are first, that it can be checked by observation in a manner in which its consequences lead to its support rather than to contradictions; and second, it can be derived from intelligible principles (Fischer, 49). These principles laid the groundwork for modern scientific methods of inquiry and were forcefully argued by Rene' Descartes, the philosopher, and Francis Bacon, the theologian (Capra 15-120). This new approach also included the process of generalization, explanation, and prediction, or what can be thought of in modern terms as the *hypothesis*, *theory*, and *law*. An *hypothesis* is a tentative assumption made in order to test its scientific consequences, but which as yet has received little verification or confirmation. A *theory* is a plausible, scientifically acceptable statement of a general principle and is used to explain phenomena. A *law* is a statement of an orderliness or interrelationship of phenomena that, as far as is known, is invariable under the stated conditions (Fischer 47). It should be stressed that the term law is used differently in reference to scientific knowledge than to other areas of everyday life. A scientific law is descriptive rather than prescriptive. It is a statement used to describe regularities found in nature, and is not a statement of what should happen. It is not correct to consider that natural objects obey the laws of nature; rather, the laws of nature describe the observed behavior of natural objects. Another guiding principle of science is its supranationality -- its inherent right to transcend national boundaries and allow scientists throughout the world to verify experimental results, challenge, theories, and allow technology to leverage new scientific discoveries.

secretiveness may have led him to write his notes backwards, right to left (DeCamp 400-403). In either case, he failed to grasp the importance of an invention that would have enabled him to achieve his goal – the printing press. He knew about the printing press and even sketched mechanical improvements to it, but he did not realize how even a small printed book would multiply his voice (DeCamp 401-403).

Other than a treatise on painting extracted from his notebooks and printed in 1651, no one began to publish the rest of his material until the 1880s. According to DeCamp, "By that time the mechanical arts had advanced so far beyond Leonardo's time that his designs were only historical curiosities" (DeCamp 403). This is why Leonardo can be thought of as the last of the ancient engineers, rather than the first of the modern ones. His lack of publicity, combined with his guild-based practical training, rather than university intellectual approaches, are also among the reasons why, unfortunately, Leonardo would not be considered a 'genius' by modern standards.

Consider as a contrast, Galileo. First of all, in addition to his artful leverage of the support of powerful patrons, Galileo published his works for the world to read. After his first discoveries with the telescope, he rushed into print a 40-page pamphlet called *Starry Messenger* and dedicated it to Cosimo II de Medici, the grand duke of Tuscany (McClellan 224). Cesi's Academia dei Lincei published several of his works, including *Letter on Sunspots* (1613) and the *Assayer* (1623) (McClellan 227). In his most controversial publication, the one that the Inquisition used to force him to recant Copernicanism – *Dialogue on the Two Chief World Systems* – Galileo wrote the work in Italian for the largest popular audience he could reach (McClellan 230). Even though he was convicted by the Inquisition of 'vehement suspicion of heresy'[41] and was sentenced to house arrest for the remainder of his life, the fame of the aging Galileo and his status as a Medici luminary allowed him to publish *Discourses on Two New Sciences* (1638), which provided a mathematical analysis of a loaded beam or cantilever and offered a theory of falling bodies (McClellan 233-234). Though numerous commentaries, plays, poems, lectures, and manuscripts of Galileo's disappeared over the years, and most of his letters to his daughter, Virginia, were destroyed by the mother abbess of the convent in which she lived, over two thousand letters exist from his correspondence with contemporaries (Sobel 10-11).

Second, Galileo was a contentious person who was often looking for a fight. He had a sort temper, mastered language, a gift for mockery in debate, and loved wine (McClellan 224). Galileo's flamboyant style of promulgating his ideas, in bawdy humorous writings, sometimes loudly at dinner parties and staged debates, brought astronomy and a new worldview into the mainstream public arena (Sobel 7). When he moved from the university to the Medici court, he became embroiled in disputes and controversies, many against academic adversaries who supported the Aristotelian classical worldview and, a more dangerous group, the theologians. His support of Copernicanism and his conflicts over theologians' literal interpretation of the Bible, created great animosity among theologians, and landed him in front of the Inquisition in 1616 and again in 1633 (McClellan 227-229). Without a controversy, it might be impossible for a 'genius' to become known.

Third, within what could only be considered as rational preservation of one's life, he stood on principle in the face of powerful foes and became a hero to the scientific community, even into modern times. Galileo made the argument for rationality and the rule of observation, even if it meant trumping the dogma of the Church.[42]

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[41] Actual conviction of heresy would warrant immediate burning at the stake (McClellan 233).

[42] Consider Galileo's proposition as summarized in excerpts from a letter to Benedetto Castelli, of the University of Pisa, in 1613.

> "Two truths can never contradict each other. Holy Scripture could never lie or err…its decrees are of absolute and inviolable truth. Although scripture can indeed not err, nevertheless some of its interpreters and expositors may sometimes err in various ways. For in that way there would appear to be [in the Bible] not only various contradictions, but even grave heresies and blasphemies, since [literally] it would be necessary to give to God feet and hands and eyes, and no

When one considers the role the publicity and image in the concept of 'genius,' its is also instructive to remember that modern depictions of Einstein range from the humorous 'absent-minded professor,' to the wiry white-haired bicycle rider, to the unkempt obsessed old man in a never-ending search of a unified field theory. These quaint caricatures of Einstein, the professor, miss the point that Einstein was considered a genius in his field by the promotion of his contemporaries and subsequent reflections by modern physicists and science writers on the historical significance of his contributions. He stood on the foundation laid by other physicists, corresponded and collaborated with them, recommended physicist Max Planck for the Nobel Prize in 1918, and, in return, was validated and promoted by them.

Indeed, Cohen cites reasons why Max Planck's early commitment to and lectures on relativity were major reasons for the rapid spread of interest among physicists in the topic (Cohen 406). Max Planck found it easy to proclaim the revolutionary character of Einstein's achievement:

> "This new way of thinking about time makes extraordinary demands on the physicist's ability to abstract, and on his imaginative faculty. It well surpasses in daring everything that has been achieved in speculative scientific research, even in the theory of knowledge. This revolution in the physical Weltanschauung, brought about by the relativity principle, is to be compared in scope and depth only with that caused by the introduction of the Copernican system of the world" (Cohen 444).

Likewise, Max Born, upon his first reading of Einstein's papers in 1907 remarked that, "Einstein's reasoning was a revelation to me. [His] theory was new and revolutionary. [It] had the audacity of challenging Isaac Newton's established philosophy" (Cohen 410).

Conclusions

As we have discussed, scientific 'genius' characterizes a moment of exceptional ability by talented people who are not unique, but who both epitomize their eras and leave a significant legacy upon

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less corporeal and human feelings, like wrath, regret, and hatred, or sometimes even forgetfulness of the things gone by and ignorance of the future.

Nature being inexorable and immutable and caring nothing whether her hidden reasons and modes of operating are or are not revealed to the capacities of men, she never transgresses the bounds of the laws imposed on her. Hence it appears that physical effects placed before our eyes by sensible experience, or concluded by necessary demonstrations, should not in any circumstances be called in doubt by passages of Scripture that verbally have a different semblance, since not everything in Scripture is linked to such severe obligations, as is every physical effect.

Scripture being therefore in many places not only accessible to, but necessarily requiring, expositions differing from the apparent meaning of the words, it seems to me that in physical disputes it should be reserved to the last place, [such questions] proceeding equally from the divine word of the Holy Scripture and from Nature, the former as dictated by the Holy Ghost and the latter as the observant executrix of God's orders.

I should think it would be prudent if no one were permitted to oblige Scripture and compel it in a certain way to sustain as true some physical conclusions of which sense and demonstrative and necessary reasons may show the contrary.

But I do not think it is necessary to believe that the same God who has given us our senses, reason, and intelligence wished us to abandon their use, giving us by some other means the information that we could gain through them – and especially in matters of which only minimal part, and in partial conclusions, there is [in the Bible] so small a part that not even the planets are named.

So you see how disorderly, if I am not mistaken, they would proceed in physical disputes not directly pertaining to faith, by taking at face value passages in Scripture often poorly understood by them. He who sustains the true position will be able to use a thousand experiences and a thousand necessary demonstrations and his side, while the other side will have nothing but sophisms, paralogisms, and fallacies.

He who has truth on his side has a great, indeed the greatest, advantage over the adversary, and since it is impossible that two truths be in contrary, we need not fear assaults made by anyone who pleases – provided that we also are given the right to speak and to be heard by understanding persons not excessively moved by their own passions and interests" (Galileo 224-227).

which our scientific tradition is built. “We know now that individuals often exercise considerable influence upon the fate of society, but this influence is determined by the internal structure of that society and by its relation to other societies,” Plekhanov reminds us (Plekhanov 164). He goes on to provide a caveat that supports the importance of individual contributions, “Nevertheless, there is no doubt that history would have had different features had the individual causes which had influenced it been replaced by other causes of the same order” (Plekhanov 175). Since ‘great minds’ are both the products of society and key shapers of society, perhaps it is time to put the concept of ‘genius’ in perspective.

Genius is a socially contrived construct, that in the modern American capitalistic society is too often used to separate a vast number of intelligent people who have moments of genius from a few ennobled icons who are thought to be somehow significantly more intelligent and creative than the bulk of the best that science has to offer. Einstein’s life and discoveries shows us the value in building upon previous works, collaborating, synthesizing new paradigms, and being recognized by one’s peers and government institutions. The importance of a formalized intellectual basis of new theories and the publication of these ideas demonstrates a penchant for such laurels being placed on the scientist, such as Galileo, or the philosopher, as with Plato, rather than the engineers, architects, inventors, and doers, as we have seen with Leonardo and with Imhotep. In all the cases examined in this paper, even the ancient ones, such as the popularization, or dare one say, the deification of Imhotep by the Ptolemies, the codification of Plato and Aristotle’s philosophies into university education, and Galileo and Einstein’s use of publications and correspondence (and Leonardo’s lack of use thereof), one can see that the designation as a ‘genius’ has more to do with telling an interesting story, often after the fact, than in the actual hard work and creative innovation of the people involved.

The important social question for modern ‘would-be geniuses’ is this – if you are the one that is placed on the pedestal, deserved or not, what is your subsequent responsibility to the society that placed you there as a role model for future generations and as the representative of an entire era of your peers? Do scientists and engineers have a responsibility to society, and if so, what is that responsibility?[x] Whether we agree with Albert Einstein’s decision to encourage President Roosevelt to counter the Nazi threat of atomic weapons with the U.S. Manhattan Project, at least he recognized his responsibility to make a statement on public policy in an area in which he was qualified to do so. To paraphrase the Bible, to whom much is given, much is required.

This debate around the role of scientists and engineers as ethical social agents has been around for ages. Nearly fifty years ago, Jacob Bronowski reinforced the basic argument that scientists have a responsibility to humanity. Bronowski stated that, “The dilemma of today [1956] is not that human values could not control a mechanical science.” It was the opposite: "The scientific spirit is more human than the machinery of governments.” He saw scientists as belonging to a community that fosters free critical thinking and tolerance – just the characteristics needed by our troubled society. Bronowski argued that science is a human activity and is practiced by “very human” scientists. The late Dr. Bronowski eloquently and logically argued his points. He showed us that, unlike the stereotype of the solitary genius, scientists are as fully human as artists and, as such, they display a full range of creativity. Being human, however, means that scientists can no more shirk their responsibility to improve our lot than politicians. His argument, that scientists have a crucial responsibility (for which they are uniquely trained) to make the public fully aware of the implications of their work, should serve to bring the ‘overly tunnel-visioned’ researcher back into the realm of political activist and citizen. Although he believed that the facts produced by science are neutral, science as a human activity is not neutral. With this established, he advocated a role for scientists as educators of the public on the positives and negatives of new discoveries. Bronowski shunned the idea of scientists as governors and plead for an adoption of the scientific ethic by world leaders (Bronowski 71).

According to Bronowski, no longer do scientists have a right to hide behind the veil of scientific neutrality. They must participate in decision making as full partners with the public.[43] Also, because of society's ennoblement of a few innovators, those persons not only have the potential to impact society, but also a social obligation to do so in a positive manner.[44] Emerson observed that, "Great men exist that there may be greater men' (Emerson 38). As such, scientists of great ingenuity and endowed by the public with the title of 'genius,' deserved or not, bear a responsibility to help shape society in a positive manner, commensurate to, or in excess of, the benefits they have received from society.

It seems that there has been at least adequate verbal support among the scientific community to encourage an active role by scientists in the decision-making processes of new technology implementation. Certainly it is no longer adequate for scientists to lock themselves in their laboratories and blindly search for 'neutral' facts. Bronowski, Harrison, and Yellin had a common thread running through their viewpoints -- science may or may not be neutral, depending upon which semantics one wants to adopt, but scientists are not, and should not be neutral.

From this perspective, engineers and scientists must be part of the decision-making process. Engineers as a group and as individuals have special responsibilities as citizens, which go beyond those of non-engineer citizens. "All citizens have an obligation to devote some of their time and energies to public policy matters. Minimal requirements for everyone are to stay informed about issues that can be voted on, while stronger obligations arise for those who by professional background are well grounded in specific issues as well as for those who have the time to train themselves as public advocates," as put forth by Philosopher Mike Martin and Engineer Roland Schizinger (Martin 29l). In addition, Paul Goodman notes, "As a moral philosopher, a technician should be able to criticize the programs given him (her) to implement" (Martin 1).

So, we see that technologists should accept more responsibility for the implications of technologies on humanity. Their loyalty needs to be to humanity, not just to their employers or their

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[43] Twenty years ago, Mount Holyoke College Professor Anna J. Harrison presented an interesting case for the expert scientific consultant and against the expert scientific witness in technology decision-making. The, then, president of the American Association for the Advancement of Science, Harrison contended that the integrity of scientists was called into question when an individual accepts the role of witness for a contending party. When this happens the role of that individual necessarily becomes that of marshalling scientific knowledge to support the position of a contending party. She viewed scientific experts as, by definition, biased and therefore advocated a restriction of their role to that of consultant. This consultant role was consistent with Harrison's belief that, since technology necessarily involved a negative impact regardless of its positive impact, should be governed by an enlightened public. She stated:

> "My experience has been that, in endeavouring to communicate relevant scientific knowledge to individuals who have limited backgrounds in science, these individuals can comprehend the information very quickly if they understand the nature of scientific knowledge" (Harrison 123).

From this perspective, Harrison saw the role of scientists as educators of the public and as consultants to special interest groups. In a fashion similar to Bronowski's argument, Professor Harrison once again stressed the importance of scientists coming out of their labs to participate in the decision-making processes of technical innovation by helping the public decide on socially appropriate courses of action.

[44] In 1984, Joel Yellin, then Senior Research Scientist at the Massachusetts Institute of Technology, proposed a system of expert advisors who would help create a deeper emphasis on the principle of public participation in technological decisions. Yellin saw the growing use of experts in government agencies and the delegation of public responsibility to these agency experts as being a serious threat to representative government. In an argument similar to his contemporary, Anna Harrison, Yellin conceded that administrators of agencies such as the Environmental Protection Agency (EPA) have far broader responsibilities than initially envisioned by politicians. They are called upon to assure worker health and safety, to protect and improve air and water quality, and to guarantee the safety of complex engineering systems. They also must predict the long-term consequences of major industrial and government decisions which, increasingly involve technological innovation that results in social changes which surpass the capacity of the general public to absorb these changes, not to mention understand all aspects of the technology. Yellin conceded the necessity for technical experts but warned of the dangers of the professional technocrat (Yellin 126). His solution placed the scientist on a representative advisory board formed by the public with competence and the public interest as its chief operating rules. With Yellin, we saw yet another argument for responsible scientists participating in technical decisions rather than merely allowing the stated neutrality of science to cause an abandonment of this responsibility to professional bureaucrats.

governments. We have seen that their professions support this concept (at least verbally). The scientific values of truth, objectivity, dissent, independence, respect, and supranationality, coupled with the engineering ethic of serving the benefit of humanity, could solve many of our most pressing problems. The predicament in which society now finds itself requires a stop to buck-passing rhetoric in favor of a re-examination of the social responsibility of engineers and scientists and a wholesale renewal of their ethical canons. We live in a society that rapidly diffuses technology, each with intended and aggregative unintended consequences on the well being of society, to an increasing number of anachronistic rights claimants who each exercises the maximalist uses of technology. As such, designers and developers of technology can no longer seek moral solace from only seeking to minimize harm. They must proactively seek to maximize the most benefits for the largest number of people, while delivering the most benefit to those most negatively impacted, or likely to be negatively impacted, by the unintentional consequences of complex technology. They need to operate out of a new ethical paradigm; one that is a bottom-up, empirically based, neo-consequentialist set of personal morals and professional requirements. This renewed ethical imperative would lead to scientific research and product designs for the most positive consequences, rather than settling on the current approach of minimizing the maximum regret.

Technologists must do so as an act of allegiance to their professions' commitments to social justice as the primary goal, and hold other allegiances to employers, trade associations, profit motives, and self-advancement secondary. Failure to do so will continue to place the profession in a reactive mode to ever-increasing negative aggregative consequences, competing claims of "rights holders," mistrust by the public, degradation of the profession, and ultimately governmental regulation.

The argument of the supposed neutrality of scientists and engineers is no longer an acceptable shield behind which technologists can hide. Given that technologists must get directly involved in technology policy issues, it is timely and proper that a renewal of professional ethics is also in order. The standard bearers for the profession, those ennobled 'geniuses' and the subsequent keepers of their legacies are in the most important positions to argue for change, help judge sense from nonsense, and therefore shape the future society.

"It does not require a clever brain to destroy life. In fact any fool can do that.
But it takes brains – and extraordinarily brilliant brains to create conditions for human happiness and to make life worth living."

\- Kwame Nkrumah

Speech at the Academy of Sciences, Accra, Ghana
November 30, 1963

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End Notes

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[i] **Further Discussion on the Philosophy of Science and Technology**

Heidegger notes that, '…science, as a theory of the real, …stakes everything on grasping the real purely. It does not encroach upon the real in order to change it. Pure science, we proclaim, is disinterested" (Heidegger 1: 167). However, science is based upon a search for the truth in a society that bends the truth to suit its needs. Jacob Bronowski stated it this way:

> "The society of scientists is simple because it has a directing purpose: to explore the truth. Nevertheless, it has to solve the problem of everyday society, which is to find a compromise between man and men. It must encourage the simple scientist to be independent, and the body of scientists to be tolerant. From the basic conditions, which form the prime values, there follows step by step a range of values: dissent, freedom of thought and speech, justice, honor, human dignity, and self respect" (Bronowski 68).

In an absolute sense, truth and neutrality in science are limited to the facts of nature that are there for observation via our senses. In a less absolute sense, truth in science is limited to that which is directly observed and sensed by the observer. Even here any expression of absolute truthfulness is limited by the time and space relationships between the observer and that which is being observed, and also by the restrictions inherent in the use of language to express the observation. Anything beyond this is, in effect, a belief rather than absolute, true knowledge. In brief, it is impossible to separate fact in nature from one's own interpretation of it (Fischer 5-7).

As we have seen, science has many facets. In essence it seeks to be pure neutral knowledge extracted painfully from nature through systematic means for dissemination to all humanity. However, as exemplified by the Pragmatic theorists, much of the relevance of science to mankind and to society arises by way of technology. The origin of the word *technology* gives valuable insight into its meaning. It is derived from the Greek words, *techne* and *logos*. The former means art or craft and the latter signifies discourse or organized words. The practice of technology frequently is that of an art or craft, as distinguished from science, which is precise and is based upon established theoretical considerations. Even though we do not normally think of technology as consisting of written or spoken words, as implied by logos, it does involve the systematic organization of processes, techniques and goals. As Heidegger observed, "…the only important quality has become their readiness for use…their only meaning lies in their being available to serve some end that will itself also be directed toward getting everything under control" (Heidegger xxix). Heidegger refers to the undifferentiated supply or 'standing-reserve' of the available matter that is objectified by man via technology as a means to an end (Heidegger xxix).

There are intimate relationships between science and technology; yet science is not technology and technology is not science. Technology is applied, but not necessarily based upon science. In fact, as California State University's Robert Fischer notes, "To define technology as applied science is to miss much of the significance of the relationship that exists between science and technology" (Fischer 5-7). He defines technology as the totality of the means employed by peoples to provide material objects for human sustenance and comfort.

One connotation of the working definition of technology is that it is a human activity. It is people who use the products of technology. Furthermore, it is people whose livelihood and comfort is the goal of technology, whether this goal is actually accomplished by technology or not. According to Fischer, technology is directed in specific instances toward specific material objects, that is, toward the production of physical objects. This is not to exclude the importance of non-material concepts to human sustenance and comfort, but it is meant to drive home the central theme that technology is driven by physical needs. By definition, technology is not neutral because it is directed toward satisfying a physical need, as determined by a human value system.

Technology is power and one who controls technology controls the power inherent in its application. Technology is defined, to some degree, by our relationship with the environment. It involves our attempt to control and shape the world and to make use of whatever resources are available in that environment (Fischer 76). The basic Western motive for 'bringing about technology' is the desire to obtain more or better material things. "There are of course more immediate and less profound motivations for individuals in either science or technology, such as the desire to get a paycheck and retain one's job," as Fischer notes.

Other points of comparison involve grander motives such as the ancient beliefs of using technology to devote monuments to gods, heroes or esthetics. The concept of technology as "more and better material things" is a Western concept born out of the flowering of knowledge and materialism that was indicative of the European Renaissance.

Even Aristotle, in his Metaphysics, distinguished between theoretical knowledge, whose goal is truth, and practical knowledge, which seeks action (Loomis 11). As such, technology is how we do things, not how we think of them. Suffice it to say for our use that technology is science plus purpose. While science is the study of the nature around us and subsequent development of scientific 'laws,' technology is the practical application of those laws, in sometimes non-rigorous ways, toward the achievement of some material purpose (Dorf 1). However, technology relies very heavily upon basic scientific knowledge in addition to existing technologies. There is also a strong influence in the reverse direction. Modern science relies to a large extent upon current technology as well as prior scientific knowledge. Science and technology reinforce each other by complex interactions. Each one, science or technology, can build upon itself or upon a linkage from one to the other. Fischer notes that, "Technology is dependent on science for knowledge of the properties of materials and energy and for predicting the behavior of natural forces. "Science is equally dependent upon technology for its tools and instruments, for preparation of materials, for the storage and dissemination of information, and for the stimulation of further research" (Fischer, 78).

Indeed, science is not technology and technology is not science, but they are firmly interrelated. One could not exist in modern society without the other.

[ii] **Scientific Interpretations of Truth**

To what extent can one actually know nature? Aristotle believed that the truth was in the material and he searched for the universals that lead one to truth. Mathematics also offers powerful ways to get closer to the truth. Carl Sagan eloquently expressed our potential and limitations as he compared our physical realm to the world of a grain of salt. Since there are more atoms in salt than connections in our brains, we can never expect to know everything with certainty in the microscopic world of a grain of salt. Just as unknowable are phenomena on the cosmic scale of the universe (Sagan, **Broca's Brain** 15-16). However, if we use the empirical approach and seek out regularities and principles, we can understand both the grain of salt and the universe through extrapolation. K.C. Cole suggests that, "The fact that patterns repeat allows us to formulate laws of nature – really, recipes encoded in equations that describe relationships that repeat over and over again" (Cole 72). She concludes that math helps scientists articulate, manipulate, and discover reality (Cole 7). We may never understand everything, but one can get some pretty good indications that allow rational conclusions to be drawn.

Therefore, science is usually considered by Western society as one of the highest forms of mental activity -- one with truth as its goal. Heidegger notes that, '…science, as a theory of the real, …stakes everything on grasping the real purely. It does not encroach upon the real in order to change it. Pure science, we proclaim, is disinterested" (Heidegger 167). However, science is based upon a search for the truth in a society that bends the truth to suit its needs. Jacob Bronowski stated it this way:

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[iii] **The Socratic Method of Argument 'Toward the Truth'**

Socrates believed that the truth of reality is in our souls (Meno 86b). He also believed that knowledge is gained through recollection of universal truth (ideals), rather than through 'learning' (Meno 81d). In Meno, he demonstrates the recollection of 'untrained' knowledge of geometric shapes by questioning a slave, who has not been taught geometry (Meno 82c-e). Through Socrates' questions, he first leads the slave to a point where he admits that he does not know the answer and knows he doesn't know the answer (Meno 84bc). According to Socrates, one must reach a state of knowing that one does not know, in order to be open to learning or 'recollecting' (Meno 84c). In this exercise, the slave is seen as actually deducing the answers from common sense responses to Socrates' questions. Socrates states that if you repeatedly ask the same questions in various ways, it will ultimately lead to as accurate knowledge as can be had by humans (Meno 85d).

Plato's rigor regarding the definition of terms is shown best by an example from Meno, in which the dialogue examines the definition of virtue. Though there are many virtues, Plato, through Socrates, seeks to show that there must be a core ideal form (eidos), which leads to a common definition (Meno 72cd). Socrates questions Meno, and shows that since the essence of several example virtues is the same, there must be a 'same' thing in common among the examples (Meno 73c). Socrates strictly enforces a rule of logic that one cannot include the term to be defined in the definition. He forces Meno to distinguish between 'a virtue' and 'virtue' (Meno 73e). Throughout the dialogue, Socrates and Meno tried similar analogies with colors and shapes (Meno 74bd). They also examined characteristics of virtue in relation to the ability to secure good things in life (and bad) and judge them in relation to 'how' they are acquired, e.g., justly or unjustly. (Meno 78b-e). Throughout the dialogue, Socrates restricts Meno from defining virtue's characteristics or parts as virtue itself, thereby laying down a core principle of Socratic logic (Meno 79bc).

The problem of not clearly defining terms can lead to a circular argument. This is best demonstrated in Euthyphro, where Socrates carries on a dialogue to determine the definition of holiness. They start by trying to determine if everything that is holy is also just. If so, he asks if the reverse true, e.g., everything that is just is holy or is holy a part of just (Euthyphro 11e-12a)? The argument continues, citing that if what is holy is a division of just, then we must find out what kind of division it is (Euthyphro 12d). Socrates makes similar analogies with shame and fear (Euthyphro 12b-12c). As the dialogue continues, adjustments to the definition of holy are made; including one where holy is ministry to the gods (Euthyphro 12e-14b), such that those that look after the gods are pious and holy (Euthyphro 12e), whereas, those things that look after men are just (Euthyphro 12e). The problem with this logic is that it violates the concept of the gods as 'ideal' forms, and implies that to 'look after' means that humans are trying to 'improve' the gods. They further refine the definition to mean it as "slaves looking after their masters" (Euthyphro 13de). They try again, this time refining the argument and definition of holy as an art of prayer and sacrifice (Euthyphro 14c-15c). This leads to definitions of 'sacrifice' as making a donation to the gods, 'prayer'as requesting something from them, and therefore, 'holiness' would become a skill in trading between gods and men (Euthyphro 14c-e). Socrates and Euthyphro recognized that they engaged in a circular argument that has an unresolved ending (Euthyphro 15bc).

Meno, again, provides a good example of Socrates' approach to hypothesis testing. If virtue is knowledge, it is good, beneficial, and can be taught (Meno 89cd). However, Socrates asks who are the teachers of virtue and challenges Antynus as to whether one can have knowledge of good teachers without experiencing them (Meno 92c). The yes/no logic leads Antynus to determine if good men pass on their knowledge of goodness. Socrates gives several examples of good men who had their sons educated, but not taught virtue (Meno 93b-94d).

Socrates leads the questioning to the conclusion that, if neither the sophists nor worthy men are teachers of the virtue, nor can there be pupils, therefore it cannot be taught nor is it knowledge (Meno 96bc).

[iv] **Egypt's Advanced Technological Society**

Like Mesopotamia, ancient Egypt showed evidence of having a very advanced engineering capability, by its accomplishments if not by its technological means. Settled city life facilitated new forms of technologies, such as metalworking, pottery, stone carving, and new forms of social organization. Bronze metals (copper alloyed with tin) offered distinct advantages over stone as tools and weapons, so control over Sinai copper mines was of great importance to Egypt. Metalworking involved a complicated set of technologies, including mining ore, smelting, hammering or casting the metal into useful tools. Bronze metallurgy required furnaces with bellows to raise temperatures to 1,100 degrees Celsius (McClellan 41). Ultimately, the city-states were conquered and consolidated into a nation-state, and later into an empire. Increased crop yields, surpluses, and wealth led to a desire to trade with neighbors, even distant ones, for luxury items and raw materials, including Nubian gold. By the close of the Bronze Age, the tomb of Tutankhamen showed the exquisite achievements of the Egyptians in fine arts, in the service of the religious mortuary cults. Here we find works in gold, silver, semi-precious metals, ivory, and curved furniture unrivalled by European technique until the Renaissance (Derry11).

It is also important to recognize that the omnipresence of religion as the basis for art, literature, law, government, and philosophy, was also the driver of Egyptian science, engineering, and skilled trades. However, the goals of science and engineering were practical ones. According to McClellan and Dorn,

"Writing and reckoning were first and foremost practical technologies with practical origins meeting practical needs. Knowledge in the first civilizations was subordinated to utilitarian ends and provided useful services in record keeping, political administration, economic transactions, calendrical exactititude, architectural and engineering projects, agricultural management, medicine and healing, religion, and astrological prediction" (McClellan 46-47).

Almost half of all known pharaonic doctors practiced during the Old Kingdom, during which, specialization was well advanced (Nunn 11). The medical profession was associated with the priesthood, since religion was the basis of Egyptian medicine (Morenz 7-8). "Death was seen as caused by a message from the deity, except in those cases where violence was obviously involved," notes Morenz. Medical diagnoses, practices, and prescriptions were closely associated with magical incantations.

The Egyptian conservatism ensured that favorable remedies would be retained and used as the basis for further advances. Their early development and use of papyrus provided the means for codifying and distributing successful remedies (Nunn 23). By the Middle Kingdom (c. 2040-1650 BCE), many important medical papyri had been written. In fact, six of the forty two books of human knowledge possessed by the ancient Egyptians were medical texts. They included: The structure of the body, diseases, the instruments of doctors, remedies, the diseases of the eyes, and diseases of women (Nunn 24).

Like the formulaic mathematical procedures, medicine was practiced using prescriptions and incantations that seemingly were unrelated to the underlying causes of problems. For example, a gynecological papyrus from year 38 of Amenemhat III's reign was found at el-Lahun and contains thirty four prescriptions on three long pages. The prescriptions are structured around the questioning of a patient, then proclamation of the symptoms, followed by a stock remedy (Parkinson 78-79). These 'diagnoses' and prescriptions looked somewhat like trial-and-error 'home remedies' that centuries of American farm families adopted, without much understanding of the underlying causes of maladies.

Egyptian astronomy evolved out of the need to establish the exact periods of time deemed indispensable for the performance of certain rites. Morenz provides an example from the Osirian cult, where the service was divided up on an hourly basis. "In the mortuary service, astronomical observations played a significant part, in view of the mythical links deemed to exist between the dead and celestial bodies and the need to compile a simple chronology on behalf of the occupant of the tomb" (Morenz 8). The invention of the calendar provided an ecclesiastical year or a calendar of festivals, which listed dates for observances and sacrifices. Astronomy not only developed in this way, but also was kept alive by the continuous observations necessary to fulfill the requirements of the cult (Morenz 8).

Even the science of cartography, in its earliest representations, was concerned with the geography of the afterworld. It was designed to serve as an aid to the dead on their journey and can be found on the bottoms of Middle Kingdom coffins. Not until the Ramesside period, five hundred years later, were maps compiled for economic or other practical purposes, such as the plan of the gold mines at Wadi Hammamat (Morenz 9).

Mathematics was supported by the state's temple authorities and it was a critical tool for organizing and maintaining Egypt's agricultural economy. The administrative nature of mathematics also explained the Egyptians' tradition of recording verbal and quantitative information in the form of lists. According to R.V. Parkinson, "They [were] not analytic or theoretical treatises, but lists of practical examples for solving problems encountered in administrative and building works (Parkinson 77-780). For example, to determine the daily share of some ten-gallon annual ration given to workers, the Egyptians would solve the problem formulaically in the following manner:

You shall make this fat (worth) 10 gallons into ro; this makes 3200. You shall make the year into days; this makes 365. You shall divide 3200 by 365; this makes 8 + 2/3 + 1/10 + 1/2190 (= 8.767), making in ro: 1/64 of a gallon (= 5 ro) + 3 ro + 2/3 + 1/10 + 1/2190. This is the daily share (Parkinson 78).

The Egyptians of 3,500 BCE to about 1,700 BCE used a symbolic hieroglyphic number system. The symbols were combined to form intermediate numbers and formed a base-10 system that was not positional (Kline 19). Egyptian numbers operated like later Roman numerals, with separate signs for the decimal numbers and no place value. The Egyptian system was essentially additive, but they used a method of duplication, an approach of multiplication by doubling and redoubling numbers, that worked with a Roman-style number system (Kline 19). They also arrived at a superior calculation of pi, 256/81 or 3.16, compared to the rough value of 3 found in Babylonian mathematics, and developed tables that facilitated working with fractions (McClellan 49-51). In general, the Egyptian system was cumbersome and less efficient than its contemporary Mesopotamian system in handling advanced calculating requirements (McClellan 49).

It is clear that the development and evolution of advanced mathematics by the priestly classes and the practical applications by the scribes of Egypt existed long before the Greeks and has had a considerable influence on a number of societies, including our own. As Lancelot Hogben notes, "There is no doubt that the raw materials of Greek mathematics were imports." He also cites the influence of the Phoenicians of the Levant on the Greek colony of Miletus, on the father of Greek geometry, Thales of Miletus (640-546 BCE), and their influence on the travels of Pythagoras in Egypt and Mesopotamia (Hogben 60-61). One might also surmise that Alexander's conquests of Egypt, Persia, and India provided ample opportunity for his teacher, Aristotle, to 'borrow' the works of Egyptian, Babylonian, Persian, and Indian scholars to further expand and refine Greek philosophy into a rigorous scientific method.

It is from this technically advanced pharaonic empire that the famous pyramids and monumental temples were organized, funded, and developed. As one considers the achievements of Egypt, it is important to remember, as Derry and Williams note, "…a civilization which had reached such perfections before Moses lay in his cradle, and which, though its thirty dynasties continued until the time of Alexander the Great, passed its zenith more than 3,000 years ago" (Derry 11).

[v] **Further Comments on Leonardo's Artistic Capabilities in Comparison with Castagno's**

Attention to perspective is quite evident in Leonardo's work, but not so in Castagno's. Stylistically, Castagno makes heavy use of parallel and perpendicular lines, squares, and rectangles to outline the room where the Last Supper takes place. The room has very little depth, but it is filled with dark marble and ornate symmetrical columns, reminiscent of Hellenistic Greek or early Roman architecture. The perspective of the viewer to the scene is perpendicular. The entire scene is framed as a painting, which one views as a detached observer. Alternatively, Leonardo portrays a room with great depth. The changes in size of distant ceiling tiles and the convergence of lines in corners give one a three-dimensional feeling. That feeling is further extended by three open windows at the end of the room, which show light and the rolling hills of the countryside in perspective to the perceived distance from the observer.

Leonardo's knowledge of optics can be seen by his realistic use of light. In Castagno's painting, the light seems to enter the room from the right, but it is a subdued or diffused light that clearly shows the faces of each of the Apostles. The table at which Jesus and the Apostles sit is stark, bright white, and seems to be illuminated directly from the front. Castagno gives the viewer a confused feeling as to where the sun is in the sky.

Leonardo's realism goes beyond mere objects. Leonardo had an uncanny ability to observe a scene and portray the setting in a natural manner. For example, where Castagno's room is ornate, Leonardo's is quite simple, giving one the feeling that the room was borrowed for a short time. This simplicity seems a more realistic scene for thirteen religious and political heretics on the run from the authorities. Castagno uses a two-dimensional supper table to create an artificial barrier between the Apostles and the viewer. In contrast, Leonardo's table is shown as three-dimensional, and food is placed in a manner that one feels that an actual dinner is occurring. Rather than the table being a barrier to the viewer, as seen in Castagno's work, Leonardo's table has subdued colors and its location and angle in the painting gives the viewer a feeling that one is standing just on the other side of it. Leonardo transports the viewer into the scene.

As previously discussed, the depiction of characters evolved over the 40 years between Leonardo and Castagno. Leonardo was a keen observer of nature and people. His notebooks are filled with detailed studies of human hands, heads, faces, and muscles in various states of movement. According to Jean-Claude Frere, "He developed studies of facial expressions with exaggerated features and telling details that were supposed to reveal the figure's psychology and nature" (Frere 22-27). Christ is seated in the center in both works, with the Apostles seated symmetrically in relation to him. However, there is a stark difference in the action and feelings brought forth by Leonardo, in comparison to Castagno. Christ is barely visible and is certainly not the centerpiece in Castagno's work. Christ and the Apostle's are distinct, with individually sad expressions crowned by halos. The men are equally sized and spaced in relation to each other. Castagno depicts contemplative isolation among the group. In contrast, Leonardo's characters seem more human. They have no halos. Their arms are outstretched. The supper has been interrupted and food is in disarray. Outrage shows on their faces. Because Leonardo's Christ and the Apostles are seated at a three-dimensional table that is somewhat at an angle in the room, the size of each Apostle seems to differ, and the spacing between them depicts interaction. In fact, Leonardo's Apostles interact with each other in small groups, as if they have just received shocking news. Of course, Leonardo's Judas seems the most shocked, as he leans back from Christ and is the only Apostle whose face is somewhat shadowed.

[vi] **Further Comments on the Medieval European Worldview**

The classic Roman civilization built upon Greek science to develop their mighty empire with its renowned technical prowess. The Romans, being driven by conquest, glory, commerce, and an increasing need to find new resources never really flowered as scientists. Free thought was not the hallmark of Rome. The Roman way of doing things was impressed upon its citizens and conquered states as a matter of standard procedure. The Romans did, however, undertake massive engineering feats such as extended roads, aqueducts and highly structured cities (DeCamp 172-280). Here technology flourished but no new ideas of philosophical importance stand out. Great translators of other works, the Romans were exploiters of resources and fantastic implementers of technology. As Rome crumbled under the weight of countless invasions, the cosmic vision of the Greeks and the technological achievements of the Romans shriveled. With Europe over-run by the Germanic tribes, scientific inquiry was stunted for a millennium. Europe slept in a stupor of ignorance for one thousand years. "To those who lived through the catastrophe, it seemed that the utter breakdown of civilization had come, the ruin of everything humanity had ever tried to create over thousands of years, a verdict from a wrathful heaven," according to Goldstein (Goldstein 55). Europe reacted with a radical readjustment of mind, turning their backs on the world of the senses, which now seemed unworthy of intellectual scrutiny. The end of Roman civilization meant a steadfast attachment by Europeans to the dogma of Christianity. To Europeans it offered the only hope left.

When the hope given by the Church was no longer needed, new morals and money provided the impetus for Europeans to cast the Church aside in favor of a new age -- the Renaissance. Suddenly, being earthy and gauche was in. Once again Europe entered an age of free inquiry, but this time a novel twist accompanied the new age. The new twist was represented by a view of life advocated by a new breed of wealthy philosopher/scientist.

The European Scientific Revolution of the 16th and 17th Centuries began with Nicolaus Copernicas who overthrew the geocentric view of Ptolemy and The Bible that had been accepted for over a thousand years. After Copernicus, the earth was no longer the center of the universe but merely one of the many planets that circled a minor star in an insignificant galaxy. Radical in its impact, this view of the world robbed humans of their proud position in the center of God's creation. Without dogmatic theological constraints, other scientists such as Johannes Kepler who is credited with the laws of planetary motion, Galileo Galilei the re-discoverer of many of the principles of gravitation and the invention of the telescope, and sir Isaac Newton who combined much of his previous work into the laws of motion each contributed to the Renaissance's spirit of inquiry.

[vii] **Paradigm Shift -- Mud Burial Mounds Do Not Give Permanency Befitting a God**

The early dynasties of Egypt, having stone to work with, left a memorial that, fifty centuries after the Great Pyramid of Giza was raised over the mummified body of Cheops, is still the most magnificent tomb in the world (Derry 10). Among the temples at Thebes, there stands the Great Hall of Karnak, still the world's largest colonnaded room (329 x 170 feet) that covers as much space as the cathedral of Notre Dame (Derry 11).

According to Hornung, in the course of a single generation, the pharaonic architecture experienced a transition from its modest beginnings of brick, wood, and woven mats into the mighty stone edifice in which the king was to reside in death. Saggs notes that the earliest burial customs of Lower Egypt included burying the dead in settlements, sometimes under the floor of a house. Since the Egyptians believed that a dead person had the same need for a house as a living person, a mastaba, or box-like structure of mud brick, was erected over a subterranean tomb. The early mastabas had the burial pit divided into compartments for the body and the dead person's treasured possessions. Inside the larger structure above ground, there were compartments for food, drink, a wooden boat for travel in the afterlife, and other necessities. (Saggs 50-51). But the people from Upper Egypt had a custom of burying the dead with a mound of sand above the grave. Remember also, that deep in the Egyptian psyche is not only the myth of the mound rising from the waters, but the fact that the land of Egypt was built up from the alluvial deposits from the Upper Nile (Davidson 28). So, in myth and in fact, Egypt arose from the waters. In addition, the mythology of ancient Egypt includes the story of creation arising from Atum sitting on the primeval hill. The mound of sand over a grave came to be equated with this primeval hill, and was thought to have life-giving power. As such, it came to be considered an indispensable part of the tomb (Saggs 51).

It was Djoser (c. 2654-2635 BCE) who in Dynasty III established his kingdom at Memphis, the symbolic balance of Upper and Lower Egypt, and thus combined the burial customs of the north and south in the form of the first pyramid. Djoser was the royal sponsor of this technological and artistic wonder and his chief architect, Imhotep, brought into being the Step Pyramid of Saqqara, west of Memphis. Imhotep transformed the old mound of sand, incased in a stepped arrangement of bricks, into a massive structure that covered and enclosed the complete tomb. The Step Pyramid was a stone replica of the 'primeval mound' that emerged at the moment of creation from the chaotic waters to serve as the basis for the ordered cosmos, according to Egyptian cosmology. Thus, its visual effect was the replication of a religious event (Saggs 50-51).

Djoser and Imhotep experimented with several tomb designs, beginning the tomb as a mastaba. At Saqqara, they built a stone mastaba of unusual size and shape. It was square instead of oblong like its predecessors, and it was over 200 feet on a side and 26 feet high. They later enlarged this mastaba twice by adding stone to the sides. Before the second of these enlargements was completed, the king decided to make it into a layer of four square mastabas of decreasing size piled one atop the other (De Camp 22-23). Then Djoser, or Imhotep acting on his behalf, changed his mind again. The novel feature that Imhotep added was the layering of six successive stages of lesser lengths, and those layers were in permanent stone, rather than mud brick. These six successively smaller layers of stone blocks gave it a 'stepped' look, which rose to over 204 feet (Saggs 51). The massive stone mound encompassed a rectangular area 596 yards long and 306 yards wide. It had an elaborate network of shafts, tunnels, ramps, corridors, and chambers in its substructure. It also had a central chamber for the king's body and other chambers to accommodate members of the royal family (Saggs 50-51). The king's chamber was built entirely from pink granite from Aswan and was located at the bottom of the shaft (Edwards 37). The entire compound was surrounded by an enclosure wall of glistening white limestone that was about 33 feet in height and over a mile in circumference (Saggs 51). Within the wall was a festival court, where Djoser could celebrate an unending series of sed festivals of renewal, and chapels for his mortuary cult. A life-size statue, which was walled up in a chamber on the north side of the pyramid, depicted Djoser in his festival regalia. Even ceiling beams and half open doors were made of imperishable stone. As Hornung observes, "…the statue's visage gives some hint of the controlled sense of purpose that enable the nearly superhuman accomplishments of the age…[and] Djoser's funerary enclosure served as a new and highly visible symbol for Memphis, which, as implied by its name 'Balance of the two lands,' was situated at the juncture of Upper and Lower Egypt" (Hornung 14-16).

[viii] **The Process of Scientific Paradigm Shifts**

Not unlike the evolution of metaphysics and critical aesthetics among philosophers, the process that cause scientists to accept new evidence and change schools of thought was thoroughly examined in 1962 by MIT professor Thomas Kuhn, a science historian and philosopher (Kuhn 1-181). Kuhn noted that paradigm development goes through several predictable structural stages from 'normal science' to new paradigm acceptance. Normal science looks somewhat like aesthetic theories based on 17th Century 'Neoclassicism,' in which nature has structure and follows rules. As Alexander Pope (1688-1744) suggested, there is an unchanging 'methodized' nature of structure, genre, harmony, and symmetry, which was the standard for developing and judging artistic forms (Adams 273-274). Normal science as defined by Kuhn means the body of research firmly based upon one or more past scientific achievements that some particular scientific community acknowledges for a time as supplying the foundation for its further practice (Kuhn 163). The findings of such achievements are the bases for all underlying scientific assumptions and free the scientific community from constantly re-examining its first principles. It is somewhat like John Dryden's (1631-1700)

17th-century acceptance of rules of time, place, and action to the aesthetics of poetry and rests on Immanuel Kant's (1724-1804) 18th-century treatment of apriori assumptions to his systems-like theory of aesthetics in a 'phenomenal' world of sensory data (Adams 213-240, 374-386). Likewise, by accepting Newtonian physics as a framework of inviolate rules, this freedom allowed members of the scientific community to concentrate exclusively upon the subtlest and most esoteric of the phenomena that concerned it. Inevitably this increased the effectiveness and efficiency with which the group as a whole solved new problems.

However, there are always competing schools of thought, each of which constantly questions the very foundations of the others. It is these competing schools that provide science with a self-correcting mechanism that ensures that the foundations of normal science will not go unchallenged (Kuhn 163). The overthrow of scientific paradigms look somewhat like 19th-century Expressive Theories of aesthetics, involving creativity and imagination, where, as William Wordsworth (1770-1850) suggested to his contemporaries, intuition and feeling become the basis of imagination that gives one the power to grasp nature (Adams 436-446). In a similar fashion, scientific revolutions are inaugurated by a growing, often intuitive, sense, restricted to a narrow subdivision of creative minorities within the scientific community, that an existing paradigm has ceased to function adequately in the explanation of an aspect of nature for which that paradigm itself had previously led the way. This sense of crisis drives a re-evaluation of the existing view and need not be generated by the work of the community that experiences the crisis. For instance, new instruments such as the electron microscope or new laws like Maxwell's wave theories may develop in one specialty and their assimilation may create a crisis in another (Kuhn 163-166). So as the crisis, that common awareness that something has gone wrong, shakes the very foundations of established thought, it generates a scientific revolution.

Just as in politics, scientific revolutions seem revolutionary only to those whose paradigms are affected by them. To outsiders scientific revolutions may seem to be normal parts of the developmental process, almost invisible. Astronomers, for example, could accept X-rays as a mere addition to knowledge since their paradigms were unaffected by the existence of the new radiation. But for the Kelvins, Crookes and Roentgens, whose research dealt with radiation theory and cathode ray tubes, the emergence of X-rays necessarily, violated one paradigm as it created another. From their perspective, these rays could only have been discovered by something going wrong with normal science. Those scientists whose paradigms are threatened typically react with resistance. Only when the number of instances that refute the old paradigm grows beyond supportable structures of the establishment, does a new paradigm arise. The decision to reject a paradigm is always simultaneously a decision to accept another with the judgment leading to that decision involving the comparison of both paradigms with nature and with each other.

Kuhn continues by challenging those who claim that when paradigms change, the world itself changes. Rather, led by a new paradigm, scientists actually adopt new instruments and look in new places. Even more importantly, scientists see new and different things when looking with familiar instruments in places they have looked before. It is almost as if the professional community had been suddenly transported out of Plato's cave into the sunlight where familiar objects are seen in a different light and are joined by unfamiliar ones as well. Of course, there is no geographical transplantation. Outside the laboratory, life continues as before. But, paradigm shifts cause scientists to see the world differently and they, in effect, are responding to a different world. It then becomes only a matter of time before their paradigms become popularized in a community of technologists and the social fabric begins to be re-woven as a result.

It is best stated by Emerson, "Genius is the naturalist or geographer of the supersensible regions, and draws their map; and, by acquainting us with new fields of activity, cools our affection for the old. These are at once accepted as the reality, of which the world we have conversed with is the show" (Emerson 21).

[ix] **Further Comments on Medieval Mysticism and its Impact on the Development of Science**

"Medieval mysticism meant accepting the rule of invisible forces…within the Good Lord's mysterious blueprint …rooted in the beyond, over the tangible, everyday experience," according to science historian Thomas Goldstein (Goldstein 138). While judging religion and the state of scientific knowledge in the hindsight of history is somewhat unfair, it allows one to question whether religious dogma and reliance on faith instead of rational mental faculties slowed the development of the European scientific method and impeded medical progress when its adherents most needed it. Since ancient times, the educated elite knew the power of Aristotle's reasoning, Hippocrates', Herophilus', and Galen's observation and experimentation, and it knew that the Muslim scholars of the 9th -to 14th-century Spain excelled in medicine and chemistry (White 2: 26-51). In spite of this knowledge, medieval society rejected this early scientific approach in favor of faith. In 1270, Thomas Aquinas, writing in his *Summa Contra Gentiles*, cautioned the faithful not to lift the veil from those ultimate mysteries that are destined to be concealed from the human mind.

Referring to Aquinas, Thomas Goldstein notes:

> "The greatest rational thinker of the Middle Ages, in other words, privy to the most complete scientific knowledge of his time, was warning his own generation and the generations to come not to overestimate the power of rational thought, but to acknowledge the superior scope of mystic intuition and sheer faith as paths toward understanding" (Goldstein 249-250).

For hundreds of years, the medieval Church set up a series of obstacles to scientific inquiry including: attributing disease to demons; sanctioning and profiting from the supposed healing powers of the relics of the Christian martyrs; using the *Apostle's Creed* and its belief in the resurrection of the body to outlaw dissection in medical schools; promoting ideas that abasement adds to the glory of God, that cleanliness was a sign of pride, and that filthiness was a sign of humility. As late as the 18th Century, church leaders were preaching against the 'dangerous and sinful practice' of inoculation (White 2: 27-69). For example, during the 1721 breakout of smallpox in Boston, even though Zabdiel Boylston's inoculation technique was proven to produce a lower mortality rate than inflicted by the natural disease, it was widely opposed by the medical establishment as unsafe, and by the church as an interference with God's will (Tucker 17-18).

Throughout European history, schools of thought contrary to Church teachings were seen as blasphemous, and appropriate punishment was doled out. Prodded by St. Bernard, conservative theologians from Paris, Orleans, and Lyon hounded the masters of Chartres and summoned them to appear before a tribunal to face charges of heresy for teaching a scientific view of the intrinsic creative powers of nature -- a view that threatened the 700-year-old doctrine of nature as the passive object of God's creation (Goldstein 69-70). This was the mentality that burned at the stake Giordano Bruno in 1600 for uttering and publishing the heresy that there were other worlds and other beings inhabiting them (Sagan, **Cosmic Connection** 185). Staunch religious dogma was the reason for the Catholic hierarchy's imprisonment of the aged Galileo Galilei for proclaiming that the Earth moves (Drake 330-351). Johannes Kepler, after whom the laws of planetary motion are named, was excommunicated by the Lutheran Church for his uncompromising individualism on matters of doctrine and because of his writing of *The Somnium*, in which he imagined a journey to the moon. In addition, Kepler's mother was dragged away in a laundry chest in the middle of the night to be burned as a witch for giving birth to such a heretic and selling herbs (Sagan**, Cosmic Connection** 50-71).

[x] **Further Discussion of the Role of Technologists in Ethical Decision-Making**

That we live in a society being increasingly influenced by scientific activities and developments is a matter beyond intelligent debate. Few would argue to the contrary. That this same technological thrust now threatens our existence is also taken as a matter of fact. The public is increasingly concerned that the benefits of scientific knowledge are being outweighed by our inability to control the negative consequences. In the post September 11, 2001 world, we live with the terror of threats -- seen and unseen, actual and predictive – that allow certain political leaders to reduce some of our individual rights and enable business leaders to shelve their social responsibility in order to make a fast buck.

In a society where one's livelihood via either corporate employment, government grants, or academic research publication requirements is literally what feeds scientists and their families, what institutional support (separate from personal sacrifice based on morality) is needed so scientists will be more apt to make ethical decisions and be rewarded rather than punished for whistle-blowing? Whistle blowers, such as David Parnas, are admirable in that he saw the inherent danger in the objective of the SDI (Strategic Defense Initiative) research and built a case among his peers for why "the emperor had no clothes." However, the public is justifiably shocked to learn of the inner working of large research institutes. In the Parnas case, he seemed constantly challenged by peers who went along with the doomed SDI research, as part of the funding game, even though they knew the system could not work. Rationalizations, such as the government is going to spend the money anyway, we can use the funding to advance the state of computer science, and we can redefine the problem, seemed to be the norm (Parnas 46-52). When institutions and the scientists are bound to make decisions based on personal economics, what can institutions or professional societies do to eliminate this conflict of interest between business objectives and scientific integrity?

In an era when scientific research can be used for both good or evil, as shown by biological research for cures that could also be helpful to bio-terrorists, has the assumption of the neutrality of facts outlived it's usefulness? As science (knowledge) and technology (applications) are increasingly intertwined, must we consider banning certain research, not just restricting the publication of the research? And, who decides?

Arguments can be made for continuing the Australian research in mouse pox and genome sequencing of viruses based on convincing agricultural and medical benefits that are possible derivatives of the research (Pollack). Equally strong arguments can be made as to how publication of this research enables terrorists or rogue states to more quickly develop weapons of mass destruction (Pollack). Does this situation help society understand that a certain threshold must exist beyond which it is unsafe to venture in the name of pure research? If we restrict knowledge, what makes us think that others won't eventually make similar discoveries? Is full disclosure safer than restrictions? How does one stop Frankenstein? Does the approach to nuclear weapons limitations provide any guidance to those in biotech?

Likewise, government initiatives to use data mining techniques to profile terrorists, corporate monitoring of employees' computer use, and Internet commerce sites routinely capturing and selling personal preference information are merely a few of the similarities between America in 2003 and George Orwell's Oceana of 1984. We live in a culture that is quickly moving toward a paperless and faceless society. However, the faceless or non-human contact of our Information Age only enhances our vulnerability.

Our economy requires identification numbers, credit records, medical, dental, educational, criminal, and family records to be stored, matched, updated, and archived by computers. Dependency upon databanks is not an indictment of those sources, per se. However, the ultimate threat to privacy and distortions of reality revolve around the use of our files by agencies to judge our creditworthiness, our insurability, our employability, educatability, and our desirability as neighbors or tenants. This creates an enormous potential risk to the privacy and accuracy of our personal records in databanks, nationwide. Even more disturbing, Accenture and HNC Software are building a profiling system designed to analyze airline passenger living arrangements, travel patterns, real estate history, demographics, financial, and other personal information to prepare a threat index that can be compared to a terrorist profile (Rosen 2-3). However, through maliciousness or accident we may become a perceived threat or at least an undesirable.

Over forty years ago, George Orwell, wrote a scathing attack on the tendency of modern societies to erode privacy in his prophetic novel, Nineteen Eighty-Four. His totalitarian world of Oceania drew a striking resemblance to his world of 1948 and our world of 2003. In Oceania, individual ignorance was strength. Today in America, citizens leave the decisions up to the politicians and experts who "have better data." The prevailing aristocracy of Oceana is not one of "old money" or family ties, rather, as in America today, it is one made up of global corporations, technocrats, trade associations, money managers, and media conglomerates. In his interview with the billionaire chairman of Oracle, Larry Ellison, New York Times reporter Jeffrey Rosen noted, "As Ellison spoke, it occurred to me that he was proposing to reconstruct America's national security strategy along the lines of Oracle's business model," one of consolidating hundreds of separate databases into a single database on the Internet (Rosen 7). Oceania's "The Party" complacently used surveillance techniques like the omnipresent telescreens that watch every waking, sleeping, and even excreting action. In the post-9/11 America, video surveillance is commonplace (Lessig 8). ID badges can track one's movements in buildings (Rosen 4). ADT's GPS system can track humans the way Lojack tracks cars (Saphir, New York Times, Letter to the Editor, 3/16/2000). Every web site that is visited and every email that is sent or received can be monitored (Guernsey 1-3). To 'The Party,' reality is not external. "Not in the individual mind, which can make mistakes, and in any case soon perishes; only in the mind of 'The Party,' which is collective and immortal," as the interrogator O'Brien insists.

We live in a world where our 2003 is not as overtly totalitarian as Orwell's 1984, but every electronic signature, fingerprint, or transaction record we leave is a non-transitory record that is more easily monitored, more cheaply searched, transparent to the person being searched, and can lead to the erosion of personal privacy (Lessig 7-12). Orwell's Unperson was an accurate foreshadowing of our dilemma.

As we dash into the electronic society, with written records and receipts fading into the "inaccuracy of individual memories," as Orwell's Party would state it, the reality of our transactions, our lives, and the lives of others become flexible. From the bureaucracy's perspective, our reality exists at its discretion. As such, society will increasingly hold in disdain those engineers who provide a host of excuses from, "If I don't, someone else will," to "Guns don't kill people, people kill people," to "I'm not responsible for how politicians use my research," to "I'll leave it to the theologians." Such answers are reprehensible cop-outs in an attempt to justify either blood money or an archaic claim on unfettered academic freedom.

Our technology is causing social changes at a tremendous rate. The destructiveness of modern weaponry has outpaced our social ability to cooperate. As Pool observes,

"For better or worse, technology has changed. Our days of innocence, when machines were solely a product of larger-than-life inventors and hard-working engineers, are gone. Increasingly, technology will be a joint effort, with its design shaped not only by engineers and executives, but also psychologists, politicians, political scientists, management theorists, risk specialists, regulators, courts, and the general public. It will not be a neat system. It is probably not the best system. But, given the power and complexity of modern technology, it is likely to be our only choice" (Pool 305).

Scientists and engineers have a history of cooperation on their side. They can be the vanguard of a total international movement to save humanity. If they do not, our lease on the future may be unrenewable. The great scholar Alfred North Whitehead delivered a series of lectures in 1925 in which he warned us of the danger of non-cooperation.

> "During the past three generations, the exclusive direction of attention has been a disaster of the first magnitude. The watchwords of the nineteenth century have been struggle for existence, competition, class warfare, commercial antagonism between nations, and military warfare. The struggle for existence has been construed into a gospel of hate. However, successful organisms are those that modify their environment so as to assist each other. A species of microbes that kills the forest also exterminates itself.
>
> In the history of the world the prize has not gone to those species which specialized in methods of violence, or even in defensive armour. In fact, nature began with producing animals encased in hard shells for defense against the ills of life. It also experimented with size. But smaller animals, without external armour, warm-blooded, sensitive, and alert, have cleared these monsters off the face of the earth. Also, the lions and tigers are not the successful species. There is something in the ready use of force which defeats its own object. Its main defect is that it bars cooperation.
>
> Every organism requires an environment of friendship. The Gospel of Force is incompatible with a social life" (Whitehead 259).

Humans would fare much better if we follow the lessons of nature. Cooperation and a moral use of our non-neutral technology are the key ingredients to the success of the human organism. Enlightened scientists and engineers might teach us this lesson. It is reasonable to contend that the scientific ethic is the doctrine that should be embraced as an idealized goal and that engineers and other technologists can be the agents of success. As we embrace the idealized ethics of science and engineering, one needs to walk down this path with a clear understanding of limits, biases, and a neo-consequentalist view of the social implications of technical innovation. One hopes that renewed emphases on ethical decision-making and product designs might be accompanied by professional codes of ethics with 'teeth.' For the most sensitive and risky technologies, professional engineering and scientific societies might need to evolve to function much more like their parallels in law, medicine, and pharmacy, where those professions are governed by and licensed under the conditions set forth by the professional societies.

Regardless of the organizational path, scientists and engineers who insist upon declaring themselves neutral are, in effect, unethical. As that 1960s mantra succinctly stated, "If you are not part of the solution, you are part of the problem."

The raging debate centers around what can be done to alleviate these threats and who should bear the responsibility for implementing solutions. After all, when the threat of biological genocide due to a genetically engineered mutant virus having escaped a pharmaceutical laboratory confronts humanity, who is to blame? When our entire civilization hangs on a fifteen-minute thermonuclear missile flight-time thread, are scientists or politicians the culprits? Those whose education or tastes have confined them to the humanities protest that scientists alone are to blame. Scientists say, with equal contempt, that humanists, politicians, and the 'commercializers' cannot wash their hands of blame because they have not done anything to help direct a society whose ills grow worse from, not only error, but also inaction (Bronowski, 5).

As scientist and philosopher Jacob Bronowski points out, there is no comfort in such bickering. Neither solves the problem. Bronowski states,

> "There is no more threatening and no more degrading doctrine than the fancy that somehow we may shelve the responsibility for making decisions of our society by passing it to a few scientists armored with a special magic" (Bronowski 6).
>
> For indeed, "…it should make us shiver whenever we hear a man of sensibility dismiss science as someone else's concern. The world today is made, it is powered by science; and for any man to abdicate an interest in science is to walk with open eyes toward slavery " (Bronowski 6).

In more recent times, Stanford professor Robert McGinn described several ethical problems facing modern 21st Century engineering practitioners. These problems include execution problems, such as unfair distribution of benefits and costs, the fear of whistle blowing, and lack of consideration of long-term effects. He also described communication problems, such as fraud and misrepresentation (McGinn, *Ethics* 18-26). Scientists and engineers have also erred by having misplaced loyalties. They have become servants to organizations rather than to the public. The basic canons of professional ethics have been subverted to gain employment and to preserve national power structures. Ian Barbour sees the danger, not in technology as such, but in uncritical preoccupation with technological goals and methods (Barbour 65). Some of the less enlightened engineers have fostered a gee-whiz attitude of applying technology either for technology's sake or for the short-term profits of employers.

The ethical issues go beyond prevention of government and business abuses, one must demand a higher standard of those who are carelessly irresponsible technologists, who participate in nuclear proliferation, treat chemical plant safety as an add-on, risk the lives of Space Shuttle crews by knowingly launching against the better judgement of experts, and develop such technologies as computerized ‘spyware.’ In a complex modern technological society, one whose interconnected systems threaten to spin out of control, we must collectively ask technologists, “Are you living up to the proper engineering codes of ethics or have you delegated your responsibility to business interests and government ideologues”? Rosen’s interview of Oracle executives indicated a profound lack of ownership of ‘policy issues,’ such as the balance between privacy and security. As Tim Hoechst, a senior vice president of Oracle, is quoted as stating, “At Oracle, we leave that to our customers to decide. We become a little stymied when we start talking about the ‘should wes’ and ‘whys’ and the ‘hows,’ because it’s not our expertise” (Rosen 5-6).

As an example of the types of traditional codes of ethics, occasionally (and sometimes routinely) ignored by technologists, consider the following from twenty years ago:

- The National Society of Professional Engineers declares itself "to hold paramount the safety, health and welfare of the public" in the performance of their professional duties. (Martin 294).
- The Engineers' Council for Professional Development[x] declares that engineers must "uphold and advance the integrity, honor, and dignity of the profession by using their knowledge and skill for the enhancement of human welfare" (Martin 300).
- The Institute of Electrical and Electronics Engineers declares that its members must "protect the safety, health and welfare of the public and speak out against abuses in these areas affecting the public interest (Martin 302).

To the engineering profession we ask, "Are you following your own professed ethics when you build a dump nuclear waste?" Such shortsightedness can cause permanent damage to the environment, to children's lives, and our survival as a people.

In the past the actions of individuals or single industries or even single nations mattered little to the outcome of the world. Modern technology is quantitatively more pervasive in society and leads to quantum changes in the qualitative influences of technology. "The rifle wiped out the buffalo, but nuclear weapons can wipe out mankind," as Mesthene states (Mesthene 25). We have a whole new generation of weapons, microbes, and chemicals that can influence the future of the planet. With this established, scientists and engineers must go back to their professed ethics. They must stop developing the technology of destruction.