SCIENCE AND THEOLOGY IN THE SCIENTIFIC REVOLUTION

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March 12, 2013

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The "Scientific Revolution" is the period in European history when the conceptual, methodological and institutional foundations of modern science were first established.[1] According to John Henry, precipitating factors or "scene-setting" periods occurred in the sixteenth century, the main focus of the revolution occurred in the seventeenth century, consolidation of the new modern scientific method in the eighteenth century.[2] This paper will examine the scene-setting role of Copernicus in the sixteenth century, the revolutionary Galileo Affair in the seventeenth century and finally, the work of Newton in contributing to the new scientific method in the eighteenth century. At the centre of this movement is the quest for the unity of truth, essentially the re-interpretation of scripture. This is the framework within which the Scientific Revolution developed and took place.

A startling array of factors became the amalgam within which the theological and scientific revolutions were incubated, developed and coalesced into a new basis for the praxis of science and subsequently a new view of God and His handiwork. These causal factors arise from the Renaissance, and according to Henry, encompass:

- The increasing failure of the Roman Catholic Church to provide the necessary stability for the organization of spiritual and material life;
- The consequent rise of city states, regional and national principalities, and the break up of local feudal jurisdictions;
- Economic changes led to the rise of urban life; the development of commercial enterprise based on private capital and the origins of the banking system
- The Renaissance was also a period of European expansion and voyages of discovery made possible in part by the invention of the magnetic compass.[3]

Voyages of discovery contributed to an increasing sense of personal and social identity. This rise of personal identity would be reflected in the appearance of portraiture, both self-portraits and portraits of others.

A group of intellects in the Italian city states began to study humanity and focused upon the achievements and potentialities of mankind. Their concern was to revive the wisdom of the Ancients.[4] These intellects are called the "humanists" and were concerned with the dignity of man. The humanists emphasized the importance of active life and lived for the public good.[5] Their discovery of writings by philosophers other than Aristotle (Plato, The Neoplatonists, Stoics and Epicureans) provided an alternative to Aristotelianism. Mathematical and magical writings were recovered and these disciplines were taken more seriously.

Hence, the Renaissance was a period in which the Aristotelian authority gave way to new forms of natural philosophy and to "new conceptions of how knowledge is best discovered and established with some degree of certainty".[6] This new sense of personal identity was promulgated by a greater emphasis upon "discovering the truth for oneself as a result of one's own experiences and efforts".[7] This new attitude towards the perception of reality lies at the heart of the Scientific Revolution and causes great debates to this day. The Scientific Revolution wrought a new view of truth.

Luther's break from Rome in 1519 reflects this new attitude. Protestants were encouraged to read the Bible for themselves. The Gutenberg Press made copies of the Bible more readily accessible and the rise of the merchant class meant more people could read the Bible for themselves. The reformers insisted upon a plain and literal reading of the Bible. Protestant naturalists brought this new way of reading the Bible to a new way of reading "God's other book", the Book of Nature.[8] This led to a new way of looking at the natural world in a plain and literal way. Natural philosophy was no longer governed by allegory and symbolism from the authoritative source, scripture. Rather, there was now an emphasis upon experience and observation as a means of discovery; this is one of the characteristic features of the Scientific Revolution.[9]

The humanist emphasis on "the public good" was reflected in the Scientific Revolution in that the mathematical sciences and the magical arts were always intended to be practical. The humanist emphasis on useful knowledge began to blur boundaries between mathematics and magic on one hand and natural philosophy on the other.[10]

The origins of the Scientific Revolution are established through these reformist ideas of the humanists; increased use of mathematics to understand the workings of the natural world, new emphasis upon observation and experience for discovering the truth and the newly extended assumption that natural knowledge should be useful.[11]

This investigation will begin with Copernicus as an astronomer. In 1514 the Lateran Council, convoked by Leo X, asked for the opinion of Copernicus regarding the reform of the ecclesiastical calendar. This work of Copernicus is viewed as a preliminary step towards the scientific revolution.[12] Copernicus worked out his system of astrology and the heliocentric system in full mathematical detail in *De Revolutionibus* with a combination of mathematics, physics and observation. His insistence upon the physical truth of this theory based on mathematical grounds was his major contribution to the scientific revolution.[13] In fact, the publication of *De Revolutionibus* is considered to be the beginning of the scientific revolution. Copernicus had established a new norm for the seeking of truth; "this must be true because the mathematics demands it".[14] Thus the foundation and arena for dissent in the scientific revolution is set; Copernicus has thrust into prominence a different view of the status of truth. He has introduced the concept of truth by appeal to evidence in science as opposed to the church's stance of truth by appeal to evidence in religion.[15] Herein lies the problem of relating religious and scientific claims to truth; the natural philosophers were struggling to explain God's natural world through their observations and experience while the church remained adamant that everything was to be explained through scripture.

The work of Copernicus also prompted the need for precise measurements. The close agreement between the mathematical astronomy and the new heliocentric cosmology could only mean that mathematical measurements would point to the physical truth. Precise measurements became increasingly important for the success of mathematicians.

The development of special measuring devices resulted. Calculating instruments meant that the practical usefulness of mathematics could be extended beyond the ranks of gifted mathematicians. These instruments also highlighted the importance of precise observation and measurement of the physical world in the proper understanding of that world.[16]

In the sixteenth and seventeenth centuries, a diverse range of mathematical instruments came into use to facilitate problem-solving in all branches of mathematical disciplines. The more advanced instruments were usually designed to provide crucial information for users incapable of performing the mathematics required to garner that information.[17] The proliferation of these new mathematical instruments, designed for uneducated users, meant that mathematicians themselves were becoming aware of more and more areas of everyday life where mathematics proved essential to an understanding of natural phenomenon.[18]

Although the microscope was not used extensively during this time, it was of great importance for the Scientific Revolution. It was in the very nature of this instrument to imply a particular natural philosophy and a particular methodology. The microscope is an example of an instrument designed to demonstrate the claims of a new philosophy, and their use confirmed that the correct approach to nature was through an experiential or experimental method.[19] This new experimental method became a characteristic feature of the Scientific Revolution. This new experimental method allows scientists today to lay claim to their immense cognitive authority.[20] See Appendix 'A' for a listing of discoveries, instrumentation and methodologies developed during this period.

The first session of the Council of Trent was convened in December of 1545 in response to Luther's break from Rome in 1519. Natural philosophy was not the concern of this gathering. Decisions arrived at relating to scripture and tradition originally in response to Luther's challenges were later used to respond to these new ideas pertaining to truth introduced by Copernicus. In fact, the heliocentric system offered by Copernicus was condemned due to the decision that this heliocentric model of the universe was contrary to the scriptures.

The Council of Trent similarly rejected Luther's doctrine of private interpretation. The Roman Catholic Church had bared their "authoritative teeth" to these theological and scientific reformers. In order to maintain their authority, the "Congregation of the Index" was established which consisted of a list of books which Catholics were forbidden to read without special permission. The Roman Catholic Church fathers were adamant that the interpretive authority of the church was to be protected at all costs. And we shall see that such rigidity of thought did come at great cost to this institution.

The force of religious belief and this stance of the Roman Catholic Church are important to bear in mind as we move our discussions into "The Galileo Affair". Up until the theological upstart, Luther, and his scientific counter-part, Copernicus, the Roman Catholic Church had maintained the monopoly on interpretation of scripture and how this was to be applied in natural philosophy. The status of truth was scripturally based and anyone who through differently would be labeled as heretic. From our post-modern perspective, this attitude appears absurd. However, this is the theological / scientific framework within which theologians and natural philosophers belonging to the Roman Catholic Church found themselves.

On the other hand, Protestant scientists were granted that freedom of thought and creativity brought about by Luther's doctrine of independent interpretation. Natural philosophers were thereby allowed to see God as the author of both nature and scripture, making the Bible a partial textbook for natural science. Protestant scientists were allowed to make this theological and intellectual leap. Roman Catholic scientists were not and so engaged in all kinds of scriptural hyperbole in order to substantiate their scientific claims from a scriptural perspective.

The Galileo Affair has been termed "the paradigm case of troubled interaction between science and religion".[21] The stage was set for the struggle for intellectual freedom versus the powerful church committed to self preservation. Galileo confronted the Roman Catholic Church over the biblical assessment of heliocentrism. This became a significant part of a large-scale turning point in western culture, giving way to the modern scientific mind set. Thus, we shall see that the Galileo Affair was in important event in the history of theology too, not just science.[22]

By the second half of the sixteenth century, theology and the new astronomy (Copernicanism) resided together with very little interaction.[23] Copernicanism was being accepted slowly and gradually. It was not yet threatening to theologians as it still had few followers. In fact, no mention of this is made at that Council of Trent. Still, there were concerns on both the Protestant and Catholic sides about clashes between Copernicanism and scripture, namely the Augustinian stance that the unity of truth requires consistency between the truths of natural science and the word of God in scripture.[24]

During the half century after Trent, the decisions of the Council were gradually integrated into the Catholic mind-set.[25] At this time, Robert Cardinal Bellarmine (1542 – 1621) was the leading Catholic theologian of the day. He had represented the Roman Catholic Church vigorously through the Counter-Reformation and had taken on a very defensive stance. Pope Paul V asked

Bellarmine to meet with Galileo in 1616 about Copernicanism. Therefore, Bellarmine is the most direct link between the Council of Trent and the Galileo Affair.[26]

The theological environment as created by Bellarmine immediately prior to the Galileo Affair encompassed the following issues;

- Who is to determine the correct meaning of scriptural text?[27]
- Does Copernicanism require a change from the simple sense of scriptural passages, which is how they were universally understood by the Ancient Fathers of the Church, to a new figurative sense as the true literal meaning intended by the Holy Spirit?[28]
- Finally, any re-interpretation would threaten the Principle of Interpretive Authority of the institutional church as stated in the Fourth Council of Trent.[29] (This edict had resulted in a growing tendency to take the Bible literally after Trent.)

This is the theological bias with which Bellarmine met Galileo in 1616. The truth contained in scripture and the authority of the Roman Catholic Church were to be protected against such attacks, a fully defensive Counter-Reformation stance.

Galileo was a loyal member of the Counter-Reformation Catholic Church. His commitment to the heliocentric view of the world placed him in an awkward position. Analysis of Galileo's *Letter to Castelli* reveals that his commitment to Copernicanism is not compromised, nor is his requirement for certitude in science and the even higher certitude of scripture.[30] The Bible has certitude because it is the word of God. Hence, the basic issue was not the interpretation of scripture, but rather its re-interpretation. The newly-born natural sciences and subsequent introduction of the re-interpretation of certain scriptural passages threatened the Principle of Interpretive Authority of the Roman Catholic Church. The whole notion of science was very much in transition at this time. It was clear that the church would not grant to Galileo that which it had not granted Luther; the personal ability and right to interpret scripture.[31] In fact, the Roman Catholic Church continues to grapple with this issue. As recently as 1979, Pope John Paul II writes:

> The greatness of Galileo is recognized by all, as is that of Einstein; but while today we honour the latter before the College of Cardinals in the apostolic palace, the former had suffer much – we cannot deny it – from men and organizations within the Church…I hope that theologians, scientists, and historians imbued with a spirit of sincere collaboration, will more deeply examine Galileo's case, and by recognizing the wrongs, from whatever side they may have come, will dispel the mistrust that this affair still raises in many minds, against a fruitful harmony between science and faith, between the Church and world… Galileo formulated important norms of an epistemological character that are indispensable for reconciling Holy Scripture and science. In his letter to the Dowager Grand Duchess of Tuscany, Christine of Lorraine, he reaffirms the truth of Scripture:

> “Holy Scripture can never lie, provided its true meaning is understood, which – I do not think it can be denied – is often hidden and very different from what a simple interpretation of the words seem to indicate” (national edition of the works of Galileo, vol. V, p. 315). Galileo introduces a principle of interpretation of the sacred books that goes beyond the literal meaning but is in accord with the intention and type of exposition proper to each of them. It is necessary, as he affirms, that “the wise men who explain it should bring out their true meaning.”[32]

The timing of the central events around the Church’s condemnation of Copernicanism in 1616 is extraordinary. We have already noted that for the first seventy years after the publication of Copernicus’s book in 1543, the new astronomy and the older understanding of the Bible co-existed quietly.[33] Then, from 1611-1616 the objections raised again Copernicanism grew scripturally and theologically. At this time, Galileo was making some of his most important discoveries, especially with the newly developed telescope which tended to confirm Copernicanism.[34] In 1609 Galileo had learned of the invention of a device by Hans Lipperhey which made distant objects appear closer. Within a few months he had constructed a telescope of about 30 power. In early January of 1610, Galileo turned his instrument to the heavens and discovered a mountainous moon, separate stars and four satellites of Jupiter.

A Protestant by the name of Johannes Kepler may also have contributed to the condemnation of heliocentrism. We will never know for sure as Galileo never referred to Kepler’s outspoken defense of Copernicanism in his *Astronomia nova* published in 1609. In many ways, modern astronomy begins with this book, which announced Kepler’s first two laws of planetary motion (the planetary paths are elliptical; the radius line from the sun to the planet sweeps out equal areas in equal times).[35] While it is assumed that Galileo would have read Kepler’s work, and perhaps even agreed with it, it would have been suicidal for Galileo to refer to the work of the Protestant Kepler at the height of the Counter Reformation.[36]

In December of 1613, the Grand Duchess Christina raised the issue of Copernicanism with a Benedictine priest, Benedetto Castelli. This fellow was also a good friend of Galileo. Galileo responded to this conversation, from which he was absent, in his *Letter to Castelli*.[37] This letter was an explanation of Copernicanism. In 1615, a Dominican priest by the name of Niccolo Lorini, submitted a complaint to the Holy Office denouncing this letter as heretical, but the complaint was dismissed. This is the first official involvement of the church in the case. At this time also, Galileo had prepared an elaborate *Letter to the Grand Duchess Christina* which expanded on his earlier letter to Castelli. This letter was to become a landmark in the literature on biblical exegesis.

Concurrently in 1615, a Carmelite Father by the name of Foscarini, published a book with defended Copernicanism, reconciling those findings with scriptural passages. This paper does not allow for analysis of Foscarini's *Lettera*. Suffice it to say it caused a great upheaval in the spring of 1615 and it is speculated that this contributed to Galileo's decision not to publish his *Letter to the Grand Duchess Christina*. What we do know is that Fosarini's *Lettera* gave the churchmen the occasion to protect their interests by making a move against Copernicanism without directly confronting Galileo. Hence, by the summer of 1615, Galileo's defence of Copernicanism in his *Letter to the Grand Duchess Christina* was already too late to change the course of events which had been set in motion.[38]

The Holy Office moved quickly in response and Copernicanism was condemned by a Decree of the Congregation of the Index on March 5th, 1616. The Pope asked Bellarmine to meet with Galileo with the following recommended censures;

1. The sun is the center of the world and is completely immobile by local motion.
   Censure: All agreed that this proposition is foolish and absurd in philosophy and is formally heretical, because it explicitly contradicts sentences found in many places in Sacred Scripture according to the proper meaning of the words and according to the common interpretation and understanding of the Holy Fathers and of learned theologians.

2. The earth is not the center of the world and is not immobile, but moves as a whole and also with a diurnal motion.
   Censure: All agreed that this proposition receives the same censure in philosophy; and in respect to theological truth, it is at least erroneous in faith.[39]

Each proposition received a theological censure and the first was declared "formally heretical". The second proposition was deemed "at least erroneous in faith". This verdict was published publicly in March of 1616 by a Decree from the Congregation of the Index. Three books were placed on the Index of Forbidden Books; Foscarini's *Lettera*, Copernicus's *De Revolutionibus* and Diego de Zuniga's *Commentary on Job*. These censures effectively separated the person of Galileo from Copernicanism. Rather it was Galileo's loyalty and obedience that was to be tested.[40]

Galileo continued to search for definitive proof of heliocentrism and sought to do this by explaining the tides. This document was submitted to Pope Paul V who immediately ordered Cardinal Bellarmine to meet with Galileo on the issue of Copernicanism with specific intentions; Firstly Bellarmine was to inform Galileo of the condemnation of heliocentrism by the Holy Office and ask Galileo to drop his commitment to that position. If agreed to that was the end of the meeting.

Second, if Galileo refused, then he was to be placed under an injunction to obey. If accepted, the meeting was over. Finally, if Galileo opposed the injunction, he was to be imprisoned.[41]

As a result of this private session with Galileo, two documents were written which contain serious inconsistencies. The first document from Cardinal Bellarmine, a letter, stated that Copernicanism "cannot be defended or held". Galileo understood this to mean that this translated as "defended as true" and "held to be true" which would still allow arguments, pro and con. The issue of interpretation is central once again. The second document, a memorandum written by an unnamed scribe in attendance at the meeting, contained much stronger wording and stated "nor henceforth to hold, <u>teach</u>, or defend it <u>in any way, either verbally or in writing.</u>"[42] Essentially, this meant that no more discussion of the topic of heliocentrism was to occur. This ambiguity was significant for Galileo, as the second part of his trial in 1633 related to exactly this point; <u>not to teach.</u> Cardinal Bellarmine had died in 1621 and so was not available to conclusively settle this issue. The word of God, the Bible, is first and foremost at this stage of the Galileo affair. Heliocentrism was contrary to scripture and was, therefore, wrong and heretical.

Galileo did not touch Copernicanism for the next eight years. In 1623 he undertook a conversation with the new pope, Urban VIII who appeared comfortable with Galileo taking up the topic of Copernicanism again in a hypothetical sense. This pope thought that such matters could never be demonstratively settled as "there are no restrictions on the power of God to create whatever kind of world He might choose to create."[43]

Emboldened by these positive conversations, Galileo proceeded to write his postponed book on the structure of the world. Eight years later, in February of 1632, his *Dialogue Concerning the Two Chief World Systems, Ptolemaic and Copernican* was published.

An immediate fire storm of protest erupted, sales of the book were stopped and copies confiscated by the summer of 1632. In September, Pope Urban VIII appointed a Special Commission to look into the matter and the 1616 memorandum was found. Galileo's book had obviously violated the decree 'not to hold, teach or defend it (Copernicanism) in any way, either verbally or in writing'. The final phase of the Galileo Affair, the second trial, began in the spring of 1633 and ended in June.

Now the proceedings focused not on scripture and its interpretation or the science of heliocentrism, but rather on Galileo himself. Was he loyal or disobedient?[44] The trial summary drawn up for the pope and cardinals to judge, appears to have contained subtle inaccuracies designed to reflect negatively on Galileo. As a result, Galileo was charged with two counts of heresy, both of which explicitly mention the Bible. Galileo spent the final nine years of is life under house arrest in his home outside of Florence.

A pattern emerges from Galileo's two-phased trial; the first stage presented the problems of the relationships between science and religion and of biblical exegesis versus scientific truth. These controversies are central. The decision that Copernicanism is contrary to scripture followed. This was publicly announced and everyone was expected to accept and obey this ruling. When Galileo violated this decision, the trial was based on Galileo's obedience or lack thereof rather than the original conceptual issue. Hence, the cultural atmosphere at the end of the trial was very different from that of the beginning. Debates over the truth of scripture had transitioned to authority disputes over loyalty and disobedience. This raises the possibility that institutionalized religion is governed by a logic of authority.[45]

Prior to the Galileo Affair, Galileo and the Jesuits enjoyed an amicable relationship. Jesuit scientists were first-class in their contributions, and their observations came into conflict with the church doctrine as determined by the Council of Trent. In addition, the General of the Society of Jesus had ordered that the Jesuits were to defend Aristotle in all things and to not disagree with him in any way. Once again, the personal conviction of the scientist was butting heads with the authority of the church. One of the topics involved was hydrostatics.

The Jesuits were both a strong driving force behind the Counter-Reformation and, after the Council of Trent, primary defenders of Catholic orthodoxy.[46] The Jesuits were to maintain a "solid and uniform doctrine" in their teaching and writing in theology and philosophy. This was defined as the teaching of St. Thomas Aquinas in theology and Aristotle in philosophy. There was in place a strong censoring system applying to books written by members of the Society and those taught at Jesuit colleges. After the decree of 1616 condemning Copernicanism, the Society's focus on a "strong and uniform doctrine" had a major impact on Jesuit scientific writing. Jesuit scientists had to choose between their religious commitments and the new anti-Aristotelian science. The results were tragic for both the Jesuits and the Church. Jesuit scientists chose their religious world and Jesuit science died.[47] Once again, the authority of the church and expectation of obedience ruled. Jesuit science was one of the casualties of the condemnation of Copernicanism.

Ironically, the advances of science to this point, were in great part due to universities founded by the Roman Catholic Church in order to prepare these scholars to serve the church. Where the Christian tradition and science parted ways was in the determination of the source of data about reality. The Christian tradition is convinced that God is revealed a great deal through scripture, reason, tradition and experience. Science limits its investigations to observations about the material world and puts forth hypotheses about material causation in the world. These two worlds collide when scripture requires <u>re-interpretation</u> caused by scientific observation. The Council of Trent did not allow for this and, consequently, within the Roman Catholic Church, biblical interpretation became more and more literal. Although this western Christian tradition provided philosophers, theologians and scientists with the construct within which their studies could take place, be recorded and be built upon, a "scientific rigor mortis" set in for the Roman Catholic scientist. These scientists simply weren't allowed to threaten or question the Roman Catholic Church's authority in all things scriptural. Galileo had been labeled "heretic" and scientific advances by Roman Catholic scientists was thwarted. As a result, Protestants maintained a disproportionate representation in the European-wide movement known as the Scientific Revolution.[48]

The core of what became known as the scientific method in modern physical sciences is stated in Galileo's book *Il Saggiatore* and is to be the concept of a systematic, mathematical interpretation of experiments and causal facts.[49] Galileo had produced a new language for understanding the universe, the language of mathematics.

The excitement of inquiry, investigation and creativity unleashed by the Protestant Reformation had gathered momentum. Luther's reformation and subsequent Protestantism started in 1519, demanded an unceasing process of interrogation and examination. Protestant scientists, no longer tethered to the authority of the Roman Catholic Church, required no mediator to assist them in explaining and understanding their observations and discovers. Scientists were inspired by this potentiality and considered their natural philosophy as a way of revealing God's mystery and as a way of understanding the majesty of God. Once again the issue of re-interpretation of scripture is in the forefront. What has changed from Galileo's time of heresy, is that now Protestant scientists can investigate their universe compliant with their God. No mediator is required or present and the inquisition into the natural world is free to move forward.

This is the world into which Newton arrived. The year 1642 began and ended symbolically for astronomy; Galileo died in January and Isaac Newton was born in December. Newton produced the greatest scientific achievement of the 17th century; the mathematical system of the universe. Newton was dutifully raised in the Protestant tradition. He rejected a host of traditions, one of which was the Doctrine of the Trinity. He was a Unitarian. He did not believe in the Trinity and considered this to be a 4th century corruption of Christianity.

In his *General Scholium*, Newton appeals for a humble and inductive approach to both natural philosophy and religion. He was committed to a dual reformation of these domains which he considered "thoroughly bound together"[50] It is known that Newton had been developing a profoundly theological understanding of nature and its phenomena long before 1704, when he first published his *Opticks*. This included not only a belief that God created the world and continues to sustain it, but a conviction that natural philosophy, when practiced correctly, would lead inductively to a belief in God and design.[51] In addition to his scientific endeavours, Newton studied theology, prophecy and church history both during the decade before he began to write the *Principia* and during the years he composed it.[52] Newton firmly believed that his natural philosophical method would lead to the conclusion that the universe was the product of God's creation. He was attempting to construct a natural philosophy which was inextricably associated with God.[53]

Galileo had determined and solidified theories of dynamics; the laws of gravity and the laws of motion. Working from Galileo's theories, Newton proved that the force that acted on planets and moons was the same force that caused a stone to fall to the ground; gravity. Newton's major contribution to science, and the centerpiece of his work, is the concept of universal gravitation; that every particle of matter attracts every other particle with a force proportional to the product of the two masses and inversely proportional to the square of the distance between them.[54] This applies to the tiniest of dust particles as well as the largest of stars.

His findings were set forth in 1687 in the *Philosophia Naturalis Principia Mathematica* or *Principia*. This work established a model of the structure and functions of the universe based on universal gravitation which remains in use today.

The *Principia* consists of three main parts or books. The first book is a consideration of the motion of particles or bodies in free space either in known orbits, or under the action of known forces or under their mutual attraction. He expounds on the three laws of motion from which he derives the principle of universal gravitation.

Book II investigates motion in a resisting medium and of hydrodynamics with special application to waves, tides and acoustics. Newton completed the work around tides, and mathematically explained them which Galileo had been so wont to do. Book III deals specifically with the motions and mutual attractions of celestial bodies.

Newton's work represents the finale in a long chain of theory and discovery which evolved throughout the scientific revolution. Copernicus had proposed the heliocentric conception of the universe. Giordano Bruno claimed that the universe was far different than the ancients and the church perceived and that it stretched out infinitely. Then Kepler reduced planetary motions to intelligible mathematical rules. Galileo developed the system of earthly mechanics that he hinted at and attempted to apply to the heavens. Newton's work was the culmination of the chain of science. Newton's famous enunciation to Robert Hooke in 1676 encapsulates this; "If I have seen further, it is because I have stood on the shoulders of giants."[55]

The *Principia* linked the last two pieces of the puzzle; Galileo's physics and Kepler's astronomy and emerged with his grand design of gravitational force. He had conceived a demonstrable model for the workings of the universe solely relying on mechanics and completely separate of any spiritual influence. Hence, the *Principia* marks the most profound break from the Middle Ages, the grip of the Roman Catholic church and Aristotelianism. Newton's theories were backed by solid mathematical tools. His mechanical explanation of the universe contained no mysticism or spirituality. The truth of the universe was proven by mathematics. Newton had granted astronomy the right to be known as a science.[56]

Next to the *Principia*, the *Opticks* stands as Newton's greatest work. It summarized his discoveries and theories concerning light and colour, the spectrum of sunlight, the degrees of refraction associated with different colours, the colour circle, the invention of the reflecting telescope, the first workable theory of the rainbow and experiments on what would later be called interference effects in conjunction with Newton's rings.[57] The Newtonian universe introduced the concept of a sub-atomic universe, birthing the world of quantum mechanics.

Copernicus introduced the fundamentally novel idea of heliocentrism. The Roman Catholic Church attempted to suppress this novelty due to its subversive nature, but according to the International Encyclopedia of Unified Science, novelty cannot be suppressed for long.[58] The external condition of heliocentrism transformed this mere anomaly into a source of acute crisis.[59] This anomaly of heliocentrism, bravely defended by Copernicus, Galileo and Kepler, and finally proven by Newton, lead the scientific community to a new set of commitments and a new basis for the practices of science. The scientific transformation was revolutionary.[60] Scientific imagination was transformed. The Aristotelian universe was effectively replaced by a new truth and, although the world did not change with this paradigm shift, the scientists afterwards certainly worked in a different world. The theological world of the Roman Catholic Church was rocked and threatened by the work of Luther. Consequently, the world within which Roman Catholic theologians and Protestant theologians studied had been irrevocably changed. Both of these areas of endeavour now, science and theology, practiced in different worlds. The members of each group would see different things when they looked from the same point in the same direction.

During the Scientific Revolution, the “natural philosophy” of the day changed beyond all recognition and approached closer to our modern concept of science.[61] Aristotelianism had been replaced by the new mechanical philosophy, key to understanding all aspects of the physical world; from the propogation of light to the generation of animals, from pneumatics to respiration, from chemistry to astronomy. The mechanical philosophy marks a definite break with the past and sets the seal upon the Scientific Revolution. This mechanical philosophy was inseparable from developments in the understanding of mechanics, kinetics and dynamics. Mechanical philosophy was as influential in the life sciences as it was in the more physical sciences. Educated medical practitioners embraced this new mechanistic physiology. The need for a new comprehensive system to replace the comprehensiveness of the Aristotelian system is reflected in this mechanical philosophy.

The most important aspect of this need for comprehensiveness can still be seen in modern biomedical sciences. Our own world view is heavily influenced by the mechanistic notion of the “bete machine”, with all its implications for biology and medicine. In this sense, the mechanical physiology of Descartes and others can be seen as the origin of modern biomedical sciences.[62]

This paper has discussed the complex interplay of many forces, technical, religious, theological, political, economical, metaphysical, methodological and the use of rhetoric as this new approach to ‘doing’ science evolved. The Scientific Revolution was culminated by the work of Newton resulting in a complete sea-change in the understanding of the natural world and in assumptions about how to reach and confirm the truth of such an understanding.[63]

Copernicus, Galileo and Newton maintained a belief in God and sought to interpret the new worlds which were being discovered through a re-interpretation of scripture. Their science was not a stand-alone area of research, but research to be undertaken within the world which God had created. Their humility is paramount in maintaining the respect which God's creation deserves. For without God's second book, the book of nature, our scientific landscape would be far different than that which is enjoyed and worked in today. Without the freedom and creativity of thought granted to us by God, and recognized by the men discussed in this paper, the landscape of our civilization would be vastly altered. The results of their scientific imagination and work touch our lives in a myriad of ways. The amalgamation of this creativity focused upon God's book of nature has resulted in advances in all kinds of scientific endeavours. Some of these endeavours have maintained the humanist emphasis for the public good. Other advances have a far more sinister and greedy emphasis, which too affect the public but not necessarily for good. For this reason, science and those who practice it, need to maintain a respect for God's creation and respect for our own creativity, to whit, to maintain a posture of humility. Such a posture will help ensure that an emphasis on the public good is to be maintained and that science is not performed for its own sake.

The Scientific Revolution showed man to be merely a smaller part of a divine plan. Man no longer found himself at the centre of the universe, he was now simply a small part of the much greater whole.[64] Consider the meteorite which slammed into central Russia on February 15, 2013. Its sonic blasts shattered countless windows and injured more than 750 people. Our post modern scientists didn't even know this was going to happen, let alone be able to alter its course. How humbling indeed!

APPENDIX A
INSTRUMENTATION AND METHODOLOGIES DEVELOPED IN THE SCIENTIFIC REVOLUTION

1. Andreas Vesalius (1514-1564) was an author of one of the most influential books on human anatomy, *De humani corporis fabrica*, published in 1543.
2. French surgeon Ambroise Pare (c. 1510-1590) is considered as one of the fathers of surgery; he was a leader in surgical techniques and battlefield medicine, especially the treatment of wounds.
3. William Harvey, the anatomist (1578 – 1657) described the circulatory system partly based on the works by the Italian surgeon and anatomist Matteo Realdo Colombo (c. 1516 – 1559).
4. Herman Boerhaave (1668 – 1738) is sometimes referred to as a "father of physiology" due to his exemplary teaching in Leiden and textbook *Institutiones medicae* (1708).
5. The science of modern dentistry developed between 1650 and 1800. The 17th century French physician Pierre Fauchard (1678-1761) has been named *"the father of modern dentistry"* and is said to have started dentistry science as we know it today.
6. Pierre Vernier (1580 – 1637) was inventory and eponym of the vernier scale used in measuring devices.
7. Evangelista Torricelli (1607 – 1647) was best known for his invention of the barometer.
8. Franciscus Vieta (1540 – 1603) gave the first notation of modern algebra.
9. John Napier (1550 – 1617) invented logarithms.
10. Edmund Gunter (1581 – 1626) created the logarithmic scales (lines or rules) upon which slide rules are based.
11. William Oughtred (1575 – 1660) first used two such scales sliding by one another to perform direct multiplication and division; and thus is credited as the inventor of the slide rule in 1622.
12. Blaise Pascal (1623 – 1662) invented the mechanical calculator in 1642. The introduction of his Pascaline in 1645 launched the development of mechanical calculators first in Europe and then all over the world. He wrote a treatise on the subject of projective geometry at the age of sixteen and later corresponded with Pierre de Fermat (1601-1665) on probability theory, strongly influencing the development of modern economics and social science.
13. Gottfried Leibniz (1646 – 1716) building on Pascal's work, became one of the most prolific inventors in the field of mechanical calculators. He also refined the binary number system, foundation of virtually all modern computer architectures.
14. John Hadley (1682-1744) was mathematician inventor of the octant, the precursor of the sextant. He built the first parabolic Newtonian telescope.
15. Denis Papin (1647 – 1712) was best known for his pioneering invention of the steam digester, the forerunner of the steam engine.
16. Abraham Darby (1678-1717) developed a method of producing high-grade iron in a blast furnace fuelled by coke rather than charcoal. This was a major step forward in the production of iron as a raw material for the Industrial Revolution.
17. Thomas Newcomen (1664-1729) perfected a practical steam engine for pumping water, the Newcomen steam engine. Consequently, he is regarded as a forefather of the Industrial Revolution.
18. Otto von Guericke (1602-1686) was the first human on record to knowingly generate electricity using a machine in 1672.
19. In 1729, Stephen Gray (1666-1736) demonstrated that electricity could be "transmitted" through metal filaments.
20. Benjamin Franklin (1706-1790) demonstrated that lightening was electricity.
21. The "Leyden jar" was invented in 1745 and was the first electrical storage device.
22. Thomas Savery (c. 1650 – 1715) patented an early steam engine in 1698.
23. Georg Agricola (1494 – 1555) is known as "the father of mineralogy" as a result of the publication of his book De re metallica.

24. Robert Boyle (1627-1691) is credited with the discovery of Boyle's Law.
25. Antoine Lavoisier (1743 – 1794) is called "The father of modern chemistry". He developed his law of Conservation of mass in 1789.
26. Henry Cavendish (1731 – 1810) discovered hydrogen in 1776.
27. Joseph Priestley (1733 – 1804) discovered oxygen in 1774.
28. The three founding fathers of botany are German physician Leonhard Fuchs (1501 – 1566); Otto Brunfels (1489 – 1534) and Hieronymus Bock (1498 – 1554).
29. Carl von Linne (1707-1778) catalogued all the living creatures into a single system that defined their morphological relations to one another: The Linnean classification system. He is often called "the Father of Taxonomy".[65]

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