Art, Science & Technology
Part II: Epistemes

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Introduction

In *Part I: Causality by Design*, I defined Art, Science & Technology and the causal relationship between them. I demonstrated that these terms are pointers to a gestalt world of meaning. Each has many facets. What is focal and subsidiary in our awareness varies with one's purpose and perspective.

For my purpose, Art – broadly defined - is a form of codified knowledge conveying *meaning* from one human mind to another allowing communication without immediate personal address. With it humanity creates a *pseudo*-environment, a *kosmos* [1], of invariants and affordances of its own making. Passed generation to generation, not just orally, but also fixed in an extra-somatic matrix it becomes a virtual second genetic code. It communalizes humanity on a plane inaccessible to any other species on the planet.

Technology – broadly defined - is tooled knowledge, *i.e.*, knowledge fixed in Matter/Energy as *function*. It enframes and enables Nature creating a human ecology that, today, encompasses the entire planet, an inhabited space station and probes surveying the solar system for more living room.

The subject of Art & Technology is the Natural Person. Works of aesthetic and technological intelligence are the product of human purpose, of Design, of formal and final causes. It is, however, in the Natural Person that personal & tacit knowledge resides as bundles of neuronal memories and reflexes of nerve and muscle. Codified and tooled knowledge have no meaning or function and remain sterile artifacts without intermediation by a Natural Person. Ultimately therefore, all knowledge is personal & tacit.

Science, on the other hand, is both codified and tooled knowledge. It began as an abstract mental exercise of reducing things through logic – mathematical and otherwise - in the ancient and medieval worlds. It became, however, with the Scientific Revolution of the 17th century, committed to the design of instruments to force Nature to reveal Her Secrets. Thus the subject of Science is Nature and Reductionism is its traditional methodology. Material and efficient causes are sufficient. W*hen-then* causality rules

[1] *Kosmos* to the ancient Greeks meant 'the right ordering of the multiple parts of the world (Hillman 1981).

with Time's Arrow moving out of the Past into the Present then into the Future by way of prediction. Nonetheless, modern Science too is the product of Design – of tacitly integrating subsidiary (controlled or invariant conditions) and focal awareness of effect or affordance into gestalt knowing. Reductionism, however, is insufficient in understanding living things, *i.e.*, biology, including its products such as Art, Science & Technology. Put another way, we require "a constructivist companion to the reductionist thesis" (Kauffman 2000, 268).

In this second of a triptych of articles I will trace the coevolution and coconstruction (Kauffman 2000) of Art, Science & Technology using mathematical 'epistemes' (Foucault 1973). In the third and final panel – *Return to the Garden* – I will examine whether or not *kosmos* has been achieved? Is our brave new world beautiful? These questions will be explored in *Dr Faustus' Tour of New Atlantis and the Garden of Eden.*

Epistemes

The fabric of intellectual history is partially woven from the threads of coincidence. One such thread involves scholars who, distant in Space yet near in Time, raise the same seminal question or propose a similar answer without intermediation. Robert Merton (1973) called this 'multiple discovery'. Arguably such is the case with 'episteme'.

In 1962 the American Thomas Kuhn introduced the term 'paradigm' to the philosophy of science; in 1969 the French philosopher Michel Foucault coined the term 'episteme' (English translation 1973); and, in 1972 U.K. researchers Emery & Trist resurrected and extended I. Chin's (1948) psychological concept of 'temporal gestalten' to 'overlapping temporal gestalten' in organizational change theory and social forecasting. The concept is arguably 'ideologically commensurable' across knowledge domains and disciplines of thought (Chartrand July 2006). My usage integrates all three under the rubric 'episteme'.

For Kuhn a paradigm is the subsidiary conceptual framework of 'normal science' (Kuhn 1962, 1970, 1996). Original use of the term was restricted to the natural & engineering sciences. Its meaning has, however, been extended to "… a generally accepted world view" (OED, *paradigm*, noun, 4). It is the backdrop that gets torn down and replaced in a scientific revolution. New scenery is erected allowing introduction of a new storyline and cast of characters, *e.g.*, the shift from Newtonian to Relativistic Physics. A paradigm is the subsidiary frame to the focal foreground called 'scientific discovery'. Such revolutions, however, are accompanied by 'Kuhnian loss' (Fuller 2000), *i.e.*, some ideas and avenues of research are lost.

Episteme is "Foucault's term for the body of ideas which shape the perception of knowledge at a particular period" (OED, *episteme*). It is the dominant theme characterizing 'knowing' in a given historical era. Idhe traces the concept back to Foucault's teacher, Merleau-Ponty and his expression "being is synonymous with being situated" (1991, 39). This becomes, in Foucault's words, a "perceptual 'something' is always in the middle of something else, it always forms part of a field" (quoted in Idhe, 1991, 40).

An episteme is the situation, the field, the context, the subsidiary environmental invariants of the noösphere. It is against and in the context of this field that focal attention takes place. Once upon a time such a concept would constitute an ideology (Chartrand July 2006). The word 'ideology' has many meanings today (Gerring 1997) but was coined simply enough by Condillac, a contemporary of Adam Smith (1776), to mean 'the science of ideas' (OED, *ideology*, 1a). Separation of Church and State was critical to both American and French Republican Revolutions. Creation of a secular 'science of ideas' to counter the awe and mystery of religious and metaphysical thought and ritual was part of a revolutionary agenda designed to overthrow an Ancient Regime of subordination by birth.

A change of episteme, as with Kuhn's paradigm, is also accompanied by a loss "in terms of items which drop out and disappear and in which others appear for the first time" (Idhe 1991, 16). However,

> [n]either Foucault nor Kuhn is able to answer why such shifts occur. Foucault's suggestion that erosion occurs from the outside parallels Kuhn's sense of internal accumulated anomalies. But in both cases it becomes clear that the arguments which establish the new paradigm as ascendent become possible and plausible only after such a shift, a different way of seeing, has occurred. (Idhe 1991, 38-9)

For Emery & Trist (1972) the Present is an overlapping temporal gestalten woven from the many strands constituting the social process, *e.g.,* Art, Science & Technology. Each strand has its own distinct history and nature. Each stretches ontologically back into its Past captured by the word *re-ligio* – to link back. In this sense Time's Arrow runs both backwards and forwards in the noösphere. There is 'path dependency' and 'precedent' at play. [2] Put another way, the Past is always Present. Such a view, of course, contradicts the concept of 'modernity' as the homogenous co-temporality of all sectors of society.

The Present inevitably becomes the Past and today's weave is different from yesterday's as will be tomorrow's. Hence each historical and contemporary era can be characterized by its own distinct pattern of overlapping temporal gestalten. Furthermore one may, according to Emery & Trist, anticipate the future pattern of the weave.

Using systems theory Emery & Trist tentatively answer how shifts in paradigms and epistemes occur. The mechanism is the 'emergent process' which exhibits distinct phases during its development (Emery & Trist 1972, 24-37). For example, from the 17th until the 19th century the experimental sciences existed outside the university [3] acting like an 'emergent process'. First through concealment and latter by parasitism, the natural sciences gradually entered the university, absorbed more and more of its

[2] Path dependency and precedent are arguably reflections of the psychological Law of Primacy: that which comes first colours our perception of all subsequent events.

[3] It was only in 1809 that the first 'research university' was established - the University of Berlin. Before, as pointed out by Robert Merton:

> The generic hypothesis under discussion holds that at a time in Western society when science had not become elaborately institutionalized, it obtained substantial legitimacy as an unintended consequence of the religious ethic and praxis of ascetic Protestantism. (Merton 1984, 1093)

resources (financial and human) until finally it became what it is today – arguably the dominant knowledge domain on campus.

In this regard, Michael Polanyi asserts that the university is now the 'natural' home of the natural sciences (Polanyi 1960-61, 406). This he considers appropriate because the natural sciences concern the objective unchanging laws of nature while other domains are subject to the artificial laws and exigencies of the human condition. He argues that the source of new knowledge in other domains is therefore outside the university in the 'real' world. Such a view represents a radical shift from the medieval episteme of the university as home of the Liberal Arts.

While a change of epistemes causes some loss of knowledge it usually represents a quantum leap in overall understanding. Losses tend to be greatest in the Natural & Engineering Sciences (NES) less in the Humanities & Social Sciences (HSS) [4] and, excepting censorship, least of all in the Arts where the new does not necessarily displace the old but rather adds to patrimony. On the other hand, transition generally provides a sense – true or false - of progress.

Arguably the foundational episteme of Western Civilization is mathematics. We do almost everything 'by the numbers'. We have done so since the ancient Greeks and, over Time, we have become much better at it. In this regard, Foucault noted that in the medieval episteme there is:

> a nondistinction between what is seen and what is read, between observation and relation, which results in the constitution of a single, unbroken surface in which observation and language intersect to infinity." (quoted in Idhe 1991, 38)

If one replaces the word 'language' in the above quotation with the word 'number' one has, in my opinion, the dominant episteme of contemporary Western and increasingly Global Civilization. Of course, if one treats mathematics as a form of human language then replacement is purely cosmetic.

I will now use five mathematical epistemes – four historic and one emergent - to trace the coevolution and coconstruction of Art, Science and Technology. First, however, it is necessary to define coevolution and coconstruction. These are two of four key concepts I identify in the philosophical work of noted molecular biologist/chemist, Stuart Kauffman (2000). The other two are 'autonomous agent' and 'adjacent possible'. I will treat the last later.

Kauffman's central concept is the autonomous agent (Kauffman 2000, 49-79). This is a Kantian-like entity with natural purpose acting on its own behalf in an environment and able to reproduce itself through "thermodynamic work cycles" (Kauffman 2000, 49). In the biosphere there is a hierarchy of autonomous agents. Kauffman points to the evolutionary transition from single-cell organisms without nuclei,

[4] Furthermore, epistemes, like philosophies:

> "rarely die, even if refuted or undercut. More likely, they either go underground - reluctantly yielding even the smallest terrain - or, more frequently, resuscitate themselves in a new guise. I even suspect that the enduring, institutional aspects of philosophy are not that different from what happens in other forms of human industry." (Idhe 1991, 13)

prokaryotes, to eukaryotes, *i.e*., single-cell organisms with a nucleus *plus* mitochondria in animals or plastids in plants using chlorophyll.

Life, of course, has burgeoned far beyond single-celled creatures. Kauffman notes there are some 265 different cell types in the human body (Kauffman 2000, 182). Each is an autonomous agent. Each, however, collectively combines to form a higher order agent – an organ - that, in turn, forms a functioning part of a yet higher order agent – the individual human being. The mechanism driving increasing diversity and complexity is coevolution defined as the mutual evolutionary influence of two species (molecular, organic or social) that become dependent on each other. Each exerts selective pressures on the other, thereby affecting each others' evolution. This often involves morphological coconstruction, *e.g.*, the shape of an orchid flower matching the bill of the hummingbird. Coevolution and coconstruction apply in both symbiotic and predator/prey relationships.

I will now probe the changing mathematical epistemes through which Art, Science & Technology have coevolved and coconstructed each other. These are: Harmony, Perspective, Motion, Probability and the Adjacent Possible.

Harmony

When Western Civilization was young Art, Science & Technology were one. In the sixth century B.C.E., a quasi-mystical figure named Pythagoras, none of whose writings have survived, sat in the southern Italian sun at the Greek colony of Kroton plucked a string and thought. What he thought was that there was a cognate relationship between mathematics (number) and Matter/Energy. And with this thought began the Western tradition of Art, Science & Technology.

With respect to Art, Pythagoras set the standard for music, poetry and therefore drama. He also arguably founded the first experimental Science – music. Both Aristotle and Plato accepted his 'numeric' findings implicitly as fact. The Pythagorean Theorem and his other 'practical' discoveries were applied as Technology especially in architecture and construction. Arguably he established Harmony as the first episteme of Western Civilization. By Harmony I mean the:

> [c]ombination or adaptation of parts, elements, or related things, so as to form a consistent and orderly whole; agreement, accord, congruity" (OED, *harmony,* 1)

For the ancient Greeks balance, harmony, proportion and resonance were everything. This sense is captured by the ancient Greek word *kosmos* – the right placing of the multiple parts of the world (Hillman 1981, 28). [5] Harmony is inherent in the music of the spheres, *i.e*., astronomy, and in the design of cities:

> The polis is the place of art... The magus, the poet who, like Orpheus and Arion is also a supreme sage, can make stones of music. One version of the myth has it that the walls of Thebes were built by songs, the poet's voice and harmonious learning summoning brute matter into stately civic

[5] As pointed out by Hillman the only English word to retain this original aesthetic sense is 'cosmetic'. The Romans converted 'kosmos' to 'cosmos' with the sense of the physical universe or Star Trek's 'out there where no one has gone before'.

> forum. The implicit metaphors are far reaching: the "numbers" of music and of poetry are cognate with the proportionate use and division of matter and space; the poem and the built city are exemplars both of the outward, living shapes of reason. (Steiner, 1976)

In temples and public buildings, the ancient Greeks used the proportions of the human body. According to Marcus Vitruvius in the 1st century B.C.E., the Doric column represents the proportions of a warrior; the Ionian, those of a matron; and, the Corinthian, those of a maiden (Vitruvius 1960, 103-104). It was Protagoras the Sophist (485-410 B.C.E.), who began his work 'Truth' with the statement: "Man is the measure of all things - of things that are, that they are, of things that are not that they are not" (Internet Encyclopedia of Philosophy 2002). It is from this sentiment that Renaissance humanism arose. Man, not God, was the measure of things and Man was mutable, God was not.

The glory that was Greece, however, was the focal product of a subsidiary system of slavery and class subordination. Thus the distinction between the Mechanical and Liberal Arts was based on class: nobles practiced the Liberal (or free) Arts; slaves and servants practiced the Mechanical Arts. [6] This partially explains why in spite of inventing the steam engine and mechanical devices of great complexity the ancient Greeks and Romans failed to innovate them.

The Mechanical Arts included, among many others, architecture, painting and sculpting (the decorative arts) and drama but not medicine and music. Even writing was considered a Mechanical Art by the Greeks but not by the Romans (Fuller 2000, 44-47). To Plato, Art or *techne* represented a threat that should be restricted to hymns to "the gods and praise of famous men... For if you go beyond this… not law and the reason … which by common consent have ever been deemed best, but pleasure and pain will be the rulers in our State" (Plato 1952, 433-434).

Quite simply, *techne* was inferior and not worthy of philosophical consideration with the notable exception of Plato's early dialogue *Ion* in which its inferiority is considered (Dorter 1973). For Aristotle, on the other hand, *techne* simply resulted in an inevitably failed imitation of Nature. As we will see, the Renaissance masters successfully passed this test of imitation.

Beyond the human realm, however, lay the universal Pythagorean forms of the circle, square, triangle and their variants, *e.g.*, the parabola. In Euclid's *Elements* of about 300 B.C.E., two-dimensional space was reduced to the mathematics of such universal forms. Archimedes (c. 290–280 - 212/211 B.C.E.) moved the cognitive relationship between number and nature into the three-dimensional world of volume. Measuring different forms was resolved through 'exhaustion' whereby one considered the area measured as expanding to account for successively more and more of the required space. In astronomy this method was extended to the celestial motion of the stars and planets. In effect, motion to the ancient Greeks was geometric exhaustion applied, step by step, through time. Ancient Greek mathematics was thus essentially concerned with spatial relationships finding its fullest expression in Euclidian and

[6] Ominously, however, Aldrich argues that the classicist attitude of studied indifference towards technology continues today but with the mechanical device cast in the role of slave (Aldrich 1969, 383).

Archimedean geometry and ultimately in the astronomy of Ptolemy in the second century C.E.

If Greece gave us Science then the Romans gave us Technology. They took from and translated the Greek but with subtle differences in meaning and gross differences in application. For example, they took the Greek *logos* (logic) and translated it as *ration* (reason) (OED, *reason*, etymology) meaning to calculate as in calculatory rationalism. They also changed 'causality' from the Greek sense of the mutuality of causes to their singularity. Similarly, *kosmos* (beauty) transformed into the cosmos (the physical universe).

With the fall of Rome, all knowledge in the West became the preserve of the Christian Church. The secular system collapsed. In secluded, distantly separated monasteries surviving written works of the Ancient World were lovingly copied and preserved. They provided the epistemological gold standard for secular knowledge in the so-called 'Dark Ages' while the Bible shed all the light thought necessary on God's purpose.

With respect to the plastic arts some knowledge was preserved and replicated in the palaces of the Princes of the Church (Filoramo 1990). Art and texts, albeit hidden from an illiterate laity [7], continued to circulate in Church abbeys, monasteries, palaces and libraries. The geometry of perspective, however, was lost in the West and abandoned in the Byzantine Empire in favour of the 'space-less' or unworldly religious icon. [8] This reflected the ascendancy of Christianity. As one of three monotheist religions subscribing to the Mosaic Code (the others being Judaism and Islam), it explicitly prohibits worship of graven images. Among all three 'peoples of the book', so named in Islamic tradition, censorship of the image traces back to Moses and the Golden Calf. In the book (the meaning of 'Bible'), the Word is sacred but the image is at best profane; at worst, evil incarnate.

The resulting atmosphere of secrecy and suppression is chillingly captured by Umberto Eco's novel, *The Name of the Rose* (Eco 1980). Brother Jorge's fear of the power of comedy (contained in a supposedly lost treatise by Aristotle) to endanger the authority of the Church feeds a medieval tale of murder and the destruction of a great library - the collected enlightenment of an age - by the fires of censorship.

And, after the Fall, the works of the ancient Greek mathematicians were, for the most part, lost to the West. Only gradually were they recovered from Byzantine and Arab sources. In the interim, medieval guilds held a monopoly of tooled knowledge, or the 'mysteries' (Houghton 1941, 35) and operated without mathematical theory applying 'rules of thumb' and 'magic numbers'. Even after recovery of Greek and Roman classics guild masters and apprentices worked in the vernacular and did not have access to 'theoretical' works in Greek and Latin. The breakdown of the guilds and introduction of craft experimentation near the end of the medieval period, however, led to new forms and

[7] The 'Double Faith' hypothesis also applies to Hindu metaphysics where the animal faces of the gods are known to be P.R. devices making them accessible to the masses.

[8] The power of such non-realistic works of Art on the public was evidenced in the Iconoclast Controversies that convulsed the Eastern Empire (Diehl 1957).

types of mathematics and instruments – scientific and musical - all calibrated to provide a mathematical reading of physical reality (Zilsel 1945). This was, of course, an emergent phenomenon that came to maturity with the instrumental, experimental Scientific Revolution of the 17th century.

Nonetheless, Harmony continued to rule but now it was the Harmony of God, not of Man. The medieval episteme was one of "[s]ymmetry, resemblance, and the great Medieval notion of analogy" (Idhe 1991, 37). The sense of this medieval episteme is perhaps best captured in the alchemistic expression: *As Above, So Below*.

One constant, however, was the 'No Name Artist'. Very few works in the visual or plastic arts were attributed to their creators. In the Ancient World they were usually slaves and servants; in the Medieval World such works were considered the product of divine inspiration not attributable to an individual. Things changed.

Perspective

In the early 15th century the mathematical laws of perspective were discovered (or rediscovered) by architect Filippo Brunelleschi (1377-1446). Once Renaissance imitators, using perspective, successfully approximated the original – natural and ancient - the Arts, specifically the visual arts, received a significantly higher social status and the visual artist attained to celebrity. Thus in 1563 in Florence, under the personal influence of Vasari :

> the painters, sculptors and architects cut their previous connections with the craftsmen's guilds and formed an Academy of Art *(Accademia del Disegno)*, the first of its kind that served as a model for later similar institutions in Italy and other countries. (Kristeller 1951, 514)

Recognition reflected, however, not just their results but also their method: geometric perspective. The artist/engineer/ humanist/scientist was a geometer, a mathematician, an image captured in Dürer's 1514 engraving of *Melancolia* holding a protractor in his right hand with his chin supported by his left in a pose reminiscent of Rodin's much later statue *The Thinker* (1880). That which allowed music to become a Liberal Art – its Pythagorean mathematical connexion – was now demonstrated in the Visual Arts which gained its own Academy.

Beyond what I call 'the Design Revolution' (Chartrand July 2006), three emergent processes began that have since ripened into our Present. The first involves the Natural Person – the Individual. The second involves 'objectivity'. The third concerns the printing press.

<u>First</u>, erosion of absolute Church/State authority began in the 15th century when the artist/engineer/humanist/scientist began to claim godlike powers of creation, *i.e.*, creating something out of nothing - *ex nihilo* (Nahm 1947, 1950). [9] This marked the eruption of the individual out of feudal subordination. Most Renaissance giants were of humble birth yet achieved noble ends – new knowledge, new creations. The 'Cult of the Genius' was born (Woodmansee 1984, 446, 47ff, Zilsel 1918). Man again became the

[9] I argue elsewhere that this resulted on the demand side from increased competition between Church and State for talent (particularly in Italy) and on the supply-side a drastic reduction in educated labour caused by the Black Death a generation before the Renaissance. (Chartrand July 2006)

measure of all things. And, in Law today, rewarding 'genius' remains the justification for intellectual property like copyright and patents (Chartrand March 2007).

In the 16th century the Protestant Reformation recognized an individual's direct link to a personal God rather than depending on intercession by Church, Pope, saint, priest or philosopher. Instead they were to consult God's Other Book – Nature (Merton 1984). With the scientific revolution of the 17th century, Nature began to reveal Her Secrets at the hands of the individual, isolated scientist using the experimental method, not Scripture nor the works of the Ancients. With the republican revolution of the late 18th century, the ideological and legal foundation of the Natural Person was laid and an Ancient Regime of subordination by birth overthrown. [10] All due to a group of painters!

Second, Heidegger argues that the essence of the contemporary world is objectivity resulting from the triumph of 'representation' in Art during the Renaissance and in Science with Descartes in the 17th century. In effect, it is our ability to model or imitate nature, especially using mathematics including geometry that brings certainty of knowledge and perspective. Through representation everything in and of the world is brought before us from the perspective of object. We call them 'models', 'simulations', *et al*. The result is that we live in "The Age of the World Picture" (Heidegger 1938). This iconic conclusion is visible in the contemporary Natural & Engineering Sciences where confirmation through picture or graph makes 'seeing believing'. Scientist do not watch a cascade of numbers as in the film *The Matrix* (Wachowski & Wachowski 1999) but rather they 'read' their graphic representation as 'lived' in a virtual reality. In Polanyi's terms we *indwell* in our representations. They become more real than that which our native senses tell us.

The role of visual representation in Science should not be underestimated. Consider the "artificial revelation" (Price 1984, 9) provided by the telescope (macroscope) and microscope taking us beyond the ken of our mesoscopic native senses. Scientific 'observation' and 'visual thinking' [11] were born out of Renaissance perspective:

> Observation, from the seventeenth century onward was a perceptible knowledge furnished with a series of systematically negative conditions. Hearsay is excluded, that goes without saying but so are taste and smell, because their lack of certainty and their variability render impossible any analysis into distinct elements that could be universally acceptable. The sense of touch is very narrowly limited to the designation of a few fairly evident distinctions (such as that between smooth and rough); which leaves sight with an almost exclusive privilege, being the sense by which we perceive extent and establish proof, and in consequence, the means to an analysis *partes extra partes* acceptable to everyone. (Foucault quoted in Idhe 1991, 41)

[10] Foucault claims this Natural Person – 'Man' in his words - "is probably no more than a kind of rift in the order of things, or, in any case, a configuration whose outlines are determined by the new position he has so recently taken up in the field of knowledge." (quoted in Idhe 1991, 33)

[11] "This visualism is … an essential part of scientific (perceptual) praxis. Even more strongly, … such visualism within science occurs in gestalt and often intuitional ways with respect to insight. What may be called 'visual thinking' plays a much larger role than is recognized in most philosophy of science." (Idhe 1991, 109)

In my terms, tooled knowledge extends the human reach and grasp far beyond its natural limits. To see and touch such unseen, unreachable spaces our tools must go where no human can. They report back in numbers (digital) converted into graphic (analogue) representations – a form of codified knowledge – to be 'read' by the human eye. [12] Observation today involves a cyborg-like relationship between a Natural Person and a machine, *i.e.*, Instrumental Realism (Idhe 1991).

Third, the printing press was the first but not the last engine of mass production. With Gutenberg's 'moveable type' press of 1456 C.E., once a work was 'fixed' in type, copies became cheaper and cheaper as the costs of a work and typesetting were spread over a larger and larger print run – the principle of mass production. Initially it was old knowledge – works of the ancients and Church Fathers - that were of commercial interest. Nonetheless new knowledge found a cheap and efficient Technology for communication by visual artists as well as the initially few 'modern' authors. It was, however, a blessing for 'dissidents' who wrote in the 'vernacular', not Latin or Greek. In fact, copyright was originally imposed to censor such populist troublemakers – secular and religious (Chartrand Sept. 2006).

Motion

This new 'perspective' was a new way of seeing the world and the world changed. The 'New World' was discovered by the end of the 15th century and subsequently, by order of the Pope, was duly divided by the Treaty of Tordesillas in 1494 between Spain and Portugal. Northern European nations were not happy and in Martin Luther they arguably found a voice. Thus early in the 16th century the Renaissance gave way to the baroque [13] world of Protestant/Catholic religious wars. [14] God, not Man, became again the measure of all things.

Throughout the Troubles, however, four emergent processes from the early Renaissance waxed – the author, ballistics, navigation and experimentation. First, with the printing press and a growing reading public the modern author was born arguably with John Milton's 1644 *Areopagitica* and its call for press freedom and author's rights. Then Aesthetics was founded as a separate branch of philosophy in the mid-18th century by Alexander Gottlieb Baumgarten. It is important to note that "the original meaning of the term aesthetics as coined by Baumgarten… is the theory of sensuous knowledge, as a counterpart to logic as a theory of intellectual knowledge" (Kristeller 1952, 34). In effect, Baumgarten philosophically separated Art from subordination to politics and religion roughly a hundred years after the Scientific Revolution liberated experimental philosophy from the same masters. And then, near the end of the 18th century, Kant argued that an author's work is not an object but rather an extension of personality and subject to protection as such. And it is in 'Kantian' terms that literary and artistic works were subsequently protected by the Berne (Copyright) Convention of 1886 (Chartrand March 2007).

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[12] As previously noted in Part I, at the experimental level, both touch and smell are in the process of being codified to then be played back to a human 'reader'.

[13] As in grotesque (OED, *baroque*, a. and n., B).

[14] These wars waged on and off for centuries finally ending, hopefully, with the 2007 political settlement in Northern Ireland – an extreme example of an overlapping temporal gestalten.

Second, beyond the astronomical mathematics of Copernicus, Kepler and Galileo, it was canon fire that provided the major impetus for development of a true mathematics of motion. In fact, military-industrial ballistic missile contracts financed many of Galileo's experiments (Hill 1988). These are generally recognized as the beginning of the first Scientific Revolution. Mechanics began to drive mathematics.

Third, the need for improved navigation provided another major impetus to the mathematics of motion. Gresham College [15] was established in 1598 "to make public instruction available to craftsmen and mariners in various subjects, including astronomy and geometry, and to serve also as a center for navigational studies" (Ross 1975). The Royal Observatory was established in Greenwich in 1675 specifically to find a way to calculate longitude. [16] The spirit of playful fascination with new instruments and devices in the 17th and 18th centuries, especially those intended to measure longitude, is captured in Umberto Eco's novel: *The Island of the Day Before* (Eco 1994).

In the 1670s, 'the geometry of infinitesimals', *i.e.*, geometric exhaustion, achieved a breakthrough with the simultaneous invention of 'the calculus', independently by Newton (1643-1727) and Leibniz (1646-1716). Calculus provided a true mathematics of motion expressed in algebraic rather than geometric terms. This breakthrough together with Newton's three laws of motion served as the foundation stone of modern natural science. By the middle of the 18th century in France 'scientific' engineering emerged requiring formal training in calculus. American engineers, however, "were still debating in the 1920s whether students needed to learn calculus" (Kranakis 1989, 18).

Fourth, the unprecedented evolutionary ascent of our species to global dominion, achieved in some twenty-five generations, arguably resulted from the institutionalization of a new way of knowing - the experimental method, or, as it was originally called, 'experimental philosophy' (Johnson 1940, 417). Developed by craftsmen of the late or High Middle Ages of the western European civilization (Zilsel 1945), it was first fully articulated by a late Renaissance genius, Sir Francis Bacon in his *Of the Proficience and Advancement of Learning Divine and Humane* published in 1605.

According to Bacon, dominion was to be achieved by reducing Nature's complexity through instrumentally controlled experimental conditions forcing her to reveal Her Secrets. She did. The question was first put using instruments developed in the craft workshops of the European Age of Discovery. It was here that Bacon saw the prototype for his 'House of Solomon', the house of wisdom and of knowledge. He called on scholars, practioners of the Liberal Arts, to come down from their ivory towers and test Nature in the workshops of the Mechanical Arts where, in his time, the necessary instruments were available. He also called for a History of the Trades to provide scholars with an understanding of the findings being made in the rapidly advancing Mechanical Arts, *e.g.,* ballistics, metallurgy, navigation, ship construction, etc. [17]

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[15] The College was the initial London venue for the Royal Society.

[16] It was not, however, until 1761 that John Harrison, "a working-class joiner" created his H4 'watch' which proved sufficiently accurate and sturdy, under the stresses of 18th century sea travel, to permit reliable calculation of longitude. (BBC News Online, August 3, 2003)

[17] According to what I call 'the Houghton Hypothesis', the subsequent turning away from the Baconian vision was the result of certain founding members of the Royal Society known as the *virtuosi*, especially John Eveyln who "… abandoned the history of trades, which Bacon [urged]…, because of 'the many

Newton's Laws of Motion established the 'billiard ball' science of inanimate Matter/Energy that has no will or volition of its own, *i.e.*, no purpose. This clockwork universe was an ideological device required for political and religious legitimization of the new experimental philosophy. Legitimacy took the form of a charter to *The Royal Society* in 1660 (Jacob 1978; Jacob & Jacob 1980). The Charter in fact represented the success of a theological compromise engineered by chemist Robert Boyle, arguably father of the Royal Society. With the connivance of Newton (Guerlac & Jacob 1969) this compromise became warmly embraced by the Anglican Church as a theological tool against both the Puritans and the Church of Rome. [18]

In *Some Considerations touching the Usefulness of experimental natural philosophy*, written at the height of Cromwell's Commonwealth in the 1650s, Boyle provided the metaphysical rationale by placing the laws of the physical world, *i.e*., the geosphere, in stasis above and beyond human or divine intervention. This is known as the 'Latitudinalist compromise' (Jacob 1978).

The argument was published in 1686 in Boyle's *A Free Enquiry into the Vulgarly Received Notion of Nature.* The act of Creation had, once and forever, established the Laws of Nature. Having set the machine in motion God withdrew and Nature became the legitimate subject of experimental philosophy. [19] There were, however, three exceptions. Theologically, the human soul and angels continued to be subject to the Divine. This limitation is reflected in Descartes' separation of mind and body (or the ghost in the machine). It is also apparent in the first study of humanity as a natural entity by Buffon, the father of anthropology, in 1749. He sought to be "protected from theological and philosophical objections because he carefully sequestered man's 'moral' characteristics - the 'metaphysical' attributes of reason, free will, and so forth - from his natural history of the species" (Grene & Depew 2004, 323). The third was thus biology which had to wait for Kant, forty years later, to be at least partially liberated from religious restriction.

About the charter of the Royal Society it is important to observe four things. First, before its grant any tampering with Nature could be construed as witchcraft or alchemy with secular and religious consequences for their practioners. Outside England, many experimental philosophers including Galileo experienced this to their great sorrow and suffering.

Second, the English king, unlike other European monarchs, was also head of the Church of England. Thus the charter was effectively an English bill of rights for experimental philosophy with respect to *both* politics and religion.

Third, it was granted nearly thirty years before the English Bill of Rights of 1689 established a free press and democracy in England. Whether the first contributed to the second remains, to me at least, an open question.

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subjections, which I cannot support, of conversing with mechanical capricious persons'" (Houghton Apr. 1942, 199).

[18] Boyle's interpretation allowed for the King to serve as God's representative on earth ruling over human souls without accepting Republican/Puritan/Secular radical materialism on the one hand and the Church of Rome on the other.

[19] Ironically, Isaac Newton did not personally accept the new philosophy and continued to believe in alchemy, miracles and divine intervention in the material world (Harrison 1995).

Fourth, it effectively legitimized tooled knowledge – Technology - which lifted the veil by the numbers and gave humanity dominion over Nature. Thus when Michel Faraday invented the first electromagnetic motor in 1821, did he send his colleagues a learned article? No. Did he send schematics? No. Rather he sent a working electric motor to each of them (Baird 2004, 1). The necessary knowledge was tooled into the product. Reverse engineering allows some to be extracted but much can not be readily codified. The Machine now became the measure of all things physical, not Man or God.

Probability

The mathematics of motion became embodied in the steam powered mechanics of the first Industrial Revolution of the early 19th century. With it the human species escaped near total dependence on natural power sources especially human muscle. This led to a rapid and extensive division and specialization of labour and of knowledge. It was, nonetheless, a world of clockwork precision. One could literally watch the gears of progress turn

Behind the scene of massive mechanical engineering in transportation (land and water) and manufacturing, a second less visible Industrial Revolution in chemistry and electricity was underway. In both the *when-then* causality of mechanics was tempered by a probabilistic reality. In any chemical reaction the desired result is only part of the final outcome, *i.e.*, efficiency is not 100%. Similarly only some of an initial stream of electrons makes it to the desired location. Nonetheless, by mid-century chemistry and electricity achieved levels of effectiveness in controlling Nature sufficient to allow invention and innovation of the photograph and gasoline (to feed the internal combustion engine) as well as the sound recording, telegraph and telephone.

In the Arts the photograph displaced painting and drawing as the *partes extra partes* means to document Nature. By the end of the 19th century Cubism, Expressionism, Impressionism, Surrealism, *et al* began to challenge Realism as the aesthetic standard. At the same time, the steel-faced engraving plate "made it possible for just about everyone . . . to have a three-shilling print" transforming the popular market for visual artists (Hughes, October, 1984, p. 27). Sound recording did the same for music. These new technologies permitted the industrialization of Art through commercial exploitation of revenue streams implicit in copyright (Chartrand March 2007). This, in turn, resulted in the emergence of a 'popular' culture which has globally eclipsed traditional high and folk art. Nonetheless, in response to the 'de-humanizing' effects of industrialization, and at about the time of the first telephone call in 1876, the Art for Art's Sake Movement withdrew from mainstream industrial society (Henderson 1984, 46) and the myth of the Starving Artist was born.

In the late 19th century and early 20th, knowledge about the geosphere of physics itself shifted. There was, in effect, a second Scientific Revolution. The foundation of reality was no longer indivisible billiard balls but rather probabilistic quantum states. The law of large numbers and probability rather than calculus thus became the mathematical foundation of the new Relativistic as opposed to the old Newtonian physics. It was this tectonic shift in mathematical epistemes that compelled Edgar Zilsel

[20] to part with the Vienna Circle and Logical/Empirical Positivism (Raven & Krohn 2000, xxxix) as well as Bertrand Russell and his Logical Atomism.

As for Biology, it remained a descriptive science of taxonomies and forms established by Linnaeus a century before until Darwin published in the mid-19th century and Mendel's work re-discovered near centuries end. Natural selection was then recognized as the mechanism of evolution (natural purpose) and Biology began to build statistics based on the law of large numbers and probability as its mathematical foundation.

In the contemporary episteme of probability it is the ever increasing sensitivity of scientific instruments that generate the numbers to be calculated and then represented to us as 'Instrumental Realism'. This is especially true in the emerging science of genomics where life is changing from a mystery into 'testable' probabilistic equations of molecular biology and organic chemistry measured and manipulated by increasingly sophisticated instruments.

Adjacent Possible

From time to time new mathematical forms have bobbed above the surface of the current dominant episteme of probability. One (or more) will likely become the Future dominant. These include fractals (As Above, So Below), catastrophe and improbability theory (Taleb 2007), object-based programming like Alchemy (Kauffman 2000), qubits [21] (*e.g.*, four-fold rather than binary computing), *etc.* One, however, subsumes all as emergent processes: Kauffman's Adjacent Possible.

Given an ever changing environment, autonomous agents constantly adapt, adjust and evolve or go extinct, sometimes in avalanches of change. They do so by experimenting with mutations called preadaptations or exaptations which:

> … in an appropriate environment [are] a causal consequence of a part of an organism that had not been of selective significance [but] might come to be of selective significance and hence be selected. Thereupon, that newly important causal consequence would be a new function available to the organism." (Kauffman 2000, 130)

But from where do preadaptations and exaptations come? According to Kauffman, using chemical reaction charts as his model, they come from the 'adjacent

[20] Zilsel's doctoral dissertation was on the Law of Large Number. On his views Raven & Kron write:

> the so-called law of large numbers… states what at first glance seems to be a rather truistic statement of probability theory, namely that "with a large number of repeated throws of a chance game... the relative frequency almost equals the mathematical probability." Nature, however, could be rather different. She could produce frequencies quite different from the expected result. It is therefore not at all trivial to ask why the law of large numbers is applicable at all. Zilsel construed this problem as being part of a wider one: how can rational mathematical constructions apply to a vague and irrational nature? This is what Zilsel termed 'the application problem'. (Raven & Krohn 2000, xxxix)

[21] Elsewhere I have described how the 'qubit' can be used taxonomically as an ideological commensurate across biology, economics, epistemology, etymology, law, philosophy, physics and psychology (Chartrand July 2006).

possible' consisting "of all those molecular species that are not members of the actual, but are one reaction step away from the actual" (Kauffman 2000, 142). Extended to the noösphere, it is those thoughts and ideas which are candidates for application at the next level of ideological evolution. Economic and biological systems expand or explore the adjacent possible as quickly as possible subject to timely selection of the fit and unfit, *e.g.,* going out of business. If selection takes too long, then fitness may decline or simply melt away.

A characteristic of the adjacent possible is that its size increases exponentially faster than an increase in the diversity, complexity and number of autonomous agents. For example, a doubling in diversity may result in a fourfold or greater increase in the adjacent possible. This explains the proliferation and diversification of life. One can conclude that there is: "a tendency for self-constructing biospheres to enlarge their workspace, the dimensionality of their adjacent possible, perhaps as fast, on average, as is possible" (Kauffman 2000, 244). This means an exponential increase in the ways and means by which autonomous agents make a living. Transition from an agricultural- to a manufacturing-based economy demonstrated such an exponential increase in job opportunities, not just in numbers but also in the kinds of jobs. The shift to a knowledge-based economy will have a greater effect. I will have more to say about the adjacent possible in Art, Science & Technology *Part III: Return to the Garden*.

Conclusion to Part II

In Part II I have traced the coevolution and coconstruction of Art, Science & Technology from the beginning of Western Civilization using changing mathematical epistemes. Beginning with Harmony in the Ancient and Medieval Worlds the episteme shifted to Perspective in the Renaissance then to Motion with the Scientific Revolution and finally to Probability with the second Scientific Revolution. From this review I draw two conclusions.

First, epistemes behave like the steps of Maslow's 'Need Hierarchy'. They are built one upon another through Time. Old epistemes do not die but rather become the substrate on which the new is built. In each case, however, there is a necessary change in instrumentation (tooled knowledge) to provide the numbers necessary for the new episteme to become established.

Second, epistemes other than mathematics are at play. Arguably the most important is the Natural Person. Another is religion. In the Ancient World, 'Man' was the measure of all things. In the medieval period God became the measure then with the Renaissance first 'Man' displaced God then God displaced Man during the Reformation and Counter-Reformation. With the Scientific Revolution of the 17th century, however, a new player entered the field – the Machine.

This revolution was as much about Theology as Science. It required a great Anglican compromise that has arguably held almost until today. The geosphere of inanimate Matter/Energy is subject to the Laws of Nature which do not change due to divine or human intervention. These Laws can be learned (and then applied for human purpose) by experimentally and instrumentally forcing Nature to reveal Her Secrets. Using the resulting knowledge humanity in twenty-five generations has enframed and enabled the entire planet to serve its species-specific purposes.

The biosphere and noösphere of human thought, on the other hand, remain until now much more obscure involving more than Newton's *when-then* causality. With the discovery of the DNA helix, however, the compromise has arguably been shattered. Humanity can now imprint living Nature with human purpose. This includes, of course, humanity itself. To reach the Tree of Life, however, requires us to return to the Garden of Eden. It will be there that a new compromise between Science and Faith will be achieved. This is the subject of the last part of this series of articles on Art, Science & Technology *Part III: Return to the Garden*.

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