University of Alberta

A Fractal Evolutionary Model of History Incorporating Variation

by

Curtis George Bauer ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment

of the requirements for the degree of Master of Arts

in

History

Department of History and Classics

Edmonton, Alberta

Spring, 2005

0-494-07977-0

Your file Votre référence
ISBN:
Our file Notre reference
ISBN:

ABSTRACT

The objective of this thesis is to provide a new evolutionary model to describe the history of science. Models from the nineteenth century onwards have either contained elements of *positivism*, the assumption of growth towards some ideal, or *negativism*, the assumption of decline towards some non-ideal. Although not incorrect, these models are incomplete due to their focus on selection to the neglect of variation. Based on Kuhn's paradigm and Foucault's episteme, the *fractum* is developed here containing equal phases of variation and selection. This structure allows for a shifting normalcy within a population of ideas, combines internalism with externalism, defines the revolution as discontinuous *and* continuous within micro and macrocosms, and uses an entropic energy approach to give directionality. Unlike predecessors, the fractal model describes movements away from equilibrium and when tested against history, is found to accurately describe the events of the Copernican Revolution.

TABLE OF CONTENTS

LIST OF FIGURES

Prologue

An updated theory is required for the history of science. Contemporary historians of science typically shun the use of theory, and quite possibly for good reason. Theory to date has been confining. It has focused almost solely on how knowledge has been conditioned or how it *should be* conditioned. Why should one use such theory when it is only capable of describing half of history? Hardly ever mentioned are historical periods of 'blooming' where the boundaries widen, causality breaks down, and new structures appear that had not been seen previously.

The most recent and influential theoretical models in the history of science appeared nearly a half century ago. Thomas Kuhn's *The Structure of Scientific Revolutions* (1962) and Michel Foucault's *Les Mots et les choses* (1966) introduced the concepts of the *paradigm* and the *episteme* as intellectual blocks bounded in structure and time. Along with the so-called *paradigmatic* or *epistemic shift* came the concept of revolution as a discontinuous break with the past. The implication that continuity, and hence progress was a myth, was troubling to many. The debate over incommensurability consumed much time and energy – inconclusively so – and since then Kuhn and Foucault have become *passé*. However, rather than discard their useful and bold concepts, perhaps one should set this troublesome 'problem' of incommensurability aside and start over.

In *Structure* Kuhn suggested that the succession of paradigms could be best understood as an *evolution*. Foucault, although against teleological interpretations of history, used evolutionary terminology freely throughout his works. Is there merit in applying the concept of evolution to the paradigm and episteme? There are undeniable parallels between biological evolution and intellectual evolution. In both, structures play subtly with their environments, generating variations that are subjected to selection, in the process changing their environments forever. 'Evolution' is also used and alluded to consciously and unconsciously within society and academia to describe a special kind of change. Perhaps evolutionary theory still has the potential to allow for a new formulation of history.

Yet why has there not been a simple formulation thus far? Of course the very meaning of *evolution* itself is not fully understood and is still evolving. Past theories focused on causality and the chain of events, and came to see evolution as a selection process only. No where was it recognized that variation is of equal importance. Perhaps by revisiting the paradigm and the episteme, this time in terms of variation instead of selection, their explanatory potential can be enhanced. The intent here is not to critique preceding works as naïve. Selection theories are not 'wrong'. Rather the intent is to add to them the other half of the story.

One final word. Every thesis has its time and place, including this one. The theses referenced herein form the basis – the unconscious archaeological plane – from which my own idea arises. This thesis, if it becomes useful, should become modified as time goes on. Consider Marx's "*je ne suis pas Marxiste*". History shows that evolutionary theory has evolved, and we can reasonably conclude that it will continue to do so. The model presented here is only an approximation upon a larger and immensely more complicated structure and is only intended to assist the expert historian.

Introduction

The object of this thesis is to provide a new evolutionary model for the history of science that gives variation an importance equal to that of selection. In particular, the model presented here is intended to describe the growth and decline of science better than any before it. The method used to approach this problem is to first examine the history of models, then to critique these models, and then to formulate a new model and test it against history.

In Chapter One a concise history of models describing scientific growth or decline is provided spanning roughly from the nineteenth to twentieth centuries. As with all theses, this one has been formulated with a good dose of deduction and uses a 'dialectic' to separate models into categories of growth or decline. Although this dialectic is not able to describe all models in their entirety, elements within each betray certain affiliations. Growth models, henceforth termed *positivistic*, began to appear in the early nineteenth century and are still appearing today. Decline models, henceforth termed *negativistic,* began to appear in the late nineteenth century and are also still appearing today.

In Chapter Two, positivistic and negativistic models are subjected to a critique from the point of view of an evolutionary modeller. The intent here is to establish what has prevented an evolutionary formulation of history. The main critique is that positivistic and negativistic models are describing identical processes – that of selection towards an end-point, or equilibrium. The first describes selection to a 'good' or desirable end-point, whereas the second describes selection to a 'bad' or undesirable end-point. This focus on selection has been to the detriment of variation, and quite likely rendered models incapable of describing movements away from equilibrium.

In Chapter Three *a fractal evolutionary model of history incorporating variation* is presented. The *fractum* is a concept similar to the paradigm and episteme, but slightly different in that it contains within it variation at all times and allows thinkers within to hold different ideas to a greater or lesser degree on common themes. Also the addition of a variation 'phase' to a selection 'phase' essentially allows the historian to combine internalism and externalism within the same model. Furthermore, the fractum contains a shifting normalcy, meaning that there can be ideals or 'norms' as long as they are recognized as transient. The 'revolution' is redefined as a period of maximum variation instead of requiring causality in the form of 'anomalies'. As its name implies, the fractum also uses a fractal structure of micro and macrocosms in which smaller fracta within larger ones can alternately 'rise and fall'. Finally the fractum exhibits entropic energy flow, which provides it with *directionality* (i.e. a movement from one side of the dialectic to the other) and also demands that the presence of any fractum in an environment alters that environment irreversibly.

In Chapter Four this fractal model is put to the test. Kuhn's paradigm and Foucualt's episteme are reinterpreted as fracta that display both variation and then convergence in structure while occurring simultaneously with other fracta. A brief reinterpretation of the Copernican Revolution then follows, showing how Copernicus's model arose at a time of maximum variation within Ptolemaic cosmology and how interpretations bifurcated along a geocentric / heliocentric dialectic, only to converge on an end structure different than the one at which it started.

By making these changes to the paradigm or episteme, this thesis will show that it is possible to move beyond our positivistic and negativistic conceptions of the history of scientific knowledge simply by using a model incorporating *variation as inherent* in scientific evolution.

Chapter One *History*

Theories of growth or decline in science are briefly examined here from the nineteenth century to the present searching for evidence of a 'dialectic'. On the one side of the dialectic a belief in progress can be seen, something that will be henceforth termed *positivism*, and on the other side a belief in decline or anti-progress can be seen, something that will henceforth be termed *negativism*.[1] The reader must bear in mind that this categorization into two dimensions of what is essentially a multi-dimensional structure is difficult and does not describe these models in their entirety.[2] However, in general, all models examined here betray affiliations towards either positivism or negativism.

Positivism from the nineteenth century to the mid-twentieth century

In common philosophical terms, *positivism* is defined as the view that scientific experiment or theory is the premier, and perhaps only method by which certainty can be attained.[3] In this thesis, a different definition is used. Positivistic models, scientific or otherwise, are recognizable by their belief in a convergence on some end-point which is generally 'good' or positive (i.e. an ideal state of truth). The end-point is in essence an equilibrium point, and since reaching it is desirable, positivistic models tend to provide advice as to how to approach this point. Hence positivistic models tend to identify 'factors' in history that would allow progress to continue into the future. Positivistic models are also characterized by a sort of 'arrogance' towards the past – an assumption

---

[1] The dialectic referred to here is in the spirit of Hegel where antithesis follows thesis.

[2] Given more time and resources one could examine multiple dimensions where the structure changes in multiple directions simultaneously (i.e. on a spherical set of axes).

[3] Positivism can be traced back to Francis Bacon (1561-1626), but is generally thought to have had its

that past views were naïve and only present or future views will be correct. Positivism can be represented graphically by a trend line culminating on something 'good' as seen in **Figure 1-1.** It should be noted that this characterization of growth can also include 'revolutionary' models.[4] Instead of a smooth trend, revolutionary models would be somewhat jagged, but the end result would still be the same.

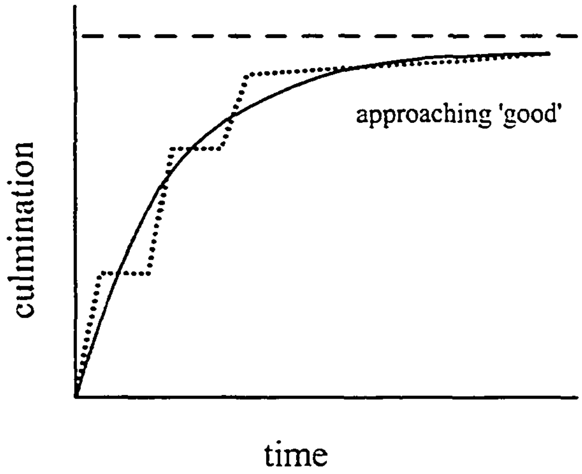

Figure 1-1. The positivist's basic conception of growth. Growth is seen as something 'good' and approaching an ideal asymptote. The solid line represents a traditional view of growth while the dotted line represents a 'revolutionary' or staged view (both trends are essentially equivalent).

When did this sort of positivism first appear? It is difficult to identify the start point of any concept, but growth models definitely began to appear in Western Europe

---

'modern' philosophical founding with August Comte (1798-1857).

[4] For example, Robert Richards characterised periods in time where 'static', 'growth' and 'revolutionary' models of science prevailed among positivists. See Richards, R.J., "Theories of Scientific Change" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York, New York University Press, 1997, pp.203-227 (this is a paper is from a chapter out of Richards, R.J., Darwin and the Emergence of Evolutionary Theories of Mind and Behavior Chicago: University of Chicago Press, 1987). The static model assumed that science was approaching a point where all would be known. The growth model assumed that growth would continue indefinitely. The revolutionary model assumed that science would grow to a certain point, and then a shift in thinking would be necessary for progress to continue. Interestingly, the static, growth and revolutionary models are all very similar – the only difference being

during the late Renaissance in noticeable contrast to traditional attempts to recapture ancient knowledge (*prisca sapentia*). Perhaps the first growth model to appear was Giambattista Vico's (1668-1744) history of nations, in which each progressed through stages increasingly 'human'.[5] Shortly after, Immanuel Kant (1724-1804), Johann Herder (1744-1803) and G.W.F. Hegel (1770-1831) also identified philosophical growth in the 'human spirit' through compounding ages.[6] As the Renaissance passed to the Enlightenment, growth models began to reflect new 'scientific' viewpoints. For example, the economic and moral theories of Adam Smith and Thomas Malthus were essentially growth models in which society was guided by an 'invisible hand' to its most efficient point.[7] This concept of efficiency became essential to political models of the nineteenth century, such as Karl Marx's 'Historical Materialism', which was perhaps the most refined example of a staged growth model of history, having society pass through tribal, ancient, feudal, capitalist and eventually communist stages on its way to a more efficient, and therefore superior, form of economy.[8]

As a relatively new area of study, introspectives on the growth of science lagged somewhat behind cultural or political models. However by the early nineteenth century,

---

that the path to ideal truth is either smooth or jagged.

[5] Vico, G., The New Science of Giambattista Vico Ithaca: Cornell University Press, 1948 [1744, 3rd edition]. Vico envisioned 'religious', 'heroic', and 'civil' stages through which all societies would pass. For example, Vico claimed the North American Indians would have followed this natural path had they not been 'interrupted' by Europeans (p.372).

[6] See Kant, I., Kritik der reinen Vernunft (Critique of Pure Reason) New York: Palgrave Macmillan, 2003 [1781]; See Herder, J.G., Ideen zur Philosophie der Geschichte der Menschheit (Outline of a Philosophy of the History of Man) München: C. Hanser, 2002 [1800]; See Hegel, G.W.F., Phänomenologie des Geistes (Phenomenology of Spirit) Indianapolis: Hackett Pub. Co., 2001 [1807]. For a summary of these thinkers and their conceptions of growth see Berlin, I., Three Critics of the Enlightenment Princeton: Princeton University Press, 2000.

[7] See Smith, A., An Inquiry into the Nature and Causes of the Wealth of Nations New York: The Modern library, 1985 [1776]; See Malthus, T. R., On Population New York: Random House, 1960 [1798].

[8] Marx, K., *Kapital* (Capital) Oxford: Oxford University Press, 1995 [1867]. For a summary of Marx's theory see also Bender, F. L., Karl Marx: The Essential Writings London: Westview Press, 1972, p.160. Marx's endpoint , or desired equilibrium point, was the worker's paradise and the withering away of the

staged growth models became readily noticeable in histories of science. Perhaps the earliest example is August Comte's *Cours de philosophie positive* (1830-42) in which knowledge was seen as progressing from primitive to sophisticated stages, each increasing in scientific rationalization and mathematization.[9] Comte was paralleled in Britain by William Whewell who also described science as progressing through increasingly sophisticated epochs in his *History of the Inductive Sciences* (1857).[10] Both Comte and Whewell saw science as approaching final truth, in the process coming to replace religion as repository of knowledge. The ethics and morality developed by these authors were advice as to how science and society could be advanced thusly.

The idea of science as efficiency appeared in the mid-nineteenth century. Herbert Spencer developed a model of growth in the 1850s which tied together physical, organic and social entities (i.e. any 'sensible existence') into one grand progression.[11] Science as a 'form of thought' was also part of this progression, and was prophesized to become superior based on its efficiency compared to other forms of knowledge production. Similarly, the empiricist Ernst Mach reiterated the view of science as a progression of simpler, all-encompassing laws, which essentially conferred evolutionary advantage via efficiency.[12]

With the appearance of Charles Darwin's *Origin of Species* (1859), models such

---

state. Important to note is that Marx was positivistic in a traditional sense when it came to science.

[9] Comte, A., Cours de philosophie positive (The Positive Philosophy) New York: AMS Press, 1974 [1830-42]. Comte thought that areas of knowledge production that had not yet been mathematized, such as sociology, were simply sciences in a primitive stage. Comte is often referred to as the founder of sociology and influenced later sociologists such as Emile Durkheim.

[10] Whewell, W., History of the Inductive Sciences, from the Earliest to the Present Time New York: D. Appleton, 1858.

[11] Spencer, H., First principles (Edition 3d impression) London: Williams & Norgate, 1910 [1862]. See also Spencer, H., Structure, Function and Evolution London: Michael Joseph, 1971, pp.60-70 and Richards, Darwin, p.286.

[12] Mach, E., Mechanik in ihrer Entwickelung (The Science of Mechanics; a Critical and Historical Account of its Development) LaSalle, Ill.: Open Court Pub., 1960 [1893].

as Spencer's or Mach's came to known as 'evolutionary'. Yet positivistic evolution was not Darwinian in the sense that Darwin's mechanism of variation and selection was never used. For the most part evolution was taken by positivists to mean that life was progressing through stages towards perfection based on utility or efficiency.[13] Darwin's *Origin* appeared at a time already abounding with so-called evolutionary theories of change, and was only one of many that positivists looked to for confirmation.[14] Indeed, Spencer developed his 'evolutionary' model prior to Darwin's and scarcely altered it in light of this new theory. Positivistic models were closer in affiliation with Lamarckism, claiming that structural change (i.e. morphing) was more or less the immediate result of biological, economic or social pressures.[15]

Hence the general trend in evolutionary positivism in the twentieth century was modelling based on Lamarckism. For example, Henri Bergson claimed that at the level of the individual and society the intellect was growing and evolving like an organism, driven by the *élan vital* – a sort of creative intuition that allowed science to progress by

---

[13] One notable exception was Chauncey Wright's conceptual evolution and progress by accidental and random variation. See Wright, C., Philosophical Discussions New York. B. Franklin. 1971 [1877]. See also Blake, R. M., Theories of Scientific Method : the Renaissance through the Nineteenth century New York: Gordon and Breach. 1989, p.266.

[14] See Darwin, C., On the Origin of Species by Means of Natural Selection Peterborough, Ont.: Broadview Press, 2003 [1859]. Darwin's model was still in dispute in the late nineteenth and early twentieth centuries (see Bowler, P.J., Evolution: The History of an Idea Berkeley: University of California Press, 1983). Darwinism did not rest on solid scientific ground until the mid-twentieth century. Up until genetic theory appeared, it had been unable to explain how novel variations would not be simply washed away with population growth according to theories of 'pangenesis' (see Darwin, C., R., The Variation of Animals and Plants under Domestication New York: AMS Press, 1972 [1868]).

[15] Jean Baptiste Lamarck (1744-1829) was a French botanist who developed a 'somatic' theory of transmutation of species (in part) by an organism's ability to adapt to its environment during its lifetime and then pass these adaptations on to its offspring. In contrast Darwin used a 'genetic' model in which an organism is born with certain characteristics which either provides a reproductive benefit or liability. That positivistic modelers had more in common with Lamarck than Darwin is not to say that they are 'wrong'. Rather this simply points out that Darwin's influence on the 'evolutionary' modelers of this period was more *post-facto* than direct, and that Dawin's model was itself a variation on common themes of evolution. For a description of Lamarck's theory refer to Lamarck, J. B., Philosophie zoologique, ou, Exposition des considérations relative à l'histoire naturelle des animaux (Zoological philosophy : an exposition with regard to the natural history of animals) Paris: Chez Dentu [et] L'Auteur, 1809.

adaptation.[16] Bergson's British contemporary Alfred Whitehead also championed an organic view of growth, pointing out that the scientific method changed and adapted itself as societal views changed.[17] Bergson and Whitehead, although moving away from traditional evolutionary teleology, still envisioned a morphing of science 'led' by an entity, or life force, external to science itself.

Up to the early twentieth century positivists had been using history to establish the progression of science through history towards some sort of ideal state. Consistent with this aim, was the appearance of a new structure concerned with identifying the 'factors' that had led to the success of science. For example Robert Merton, inspired by Max Weber's sociological treatise *The Protestant Ethic and the Spirit of Capitalism* (1905) which attributed the rise of capitalism to religious ethos, found the Scientific Revolution to be the result of the 'puritan ethos' which contained a collection of *sentiments*, or unobservable mental states that could arise within culture if conditions were right.[18] Merton was joined by others like Edgar Zilsel, who claimed that the Scientific Revolution was attributable primarily to economic utility (1944).[19]

Merton's approach was very popular, and in part inspired the search for the exact

---

[16] Bergson, H., Creative Evolution Westport: Greenview Press, 1977 [1907], p.8. Although Bergson disagreed publicly with Spencer, he used very similar energy analogies in his own model.

[17] Whitehead, A. N., Science and the Modern World New York: Free Press, 1967 [1925]. Interesting to note was that Whitehead was one of the first to state that scientific judgements are dependent on the values of the society in which they develop (externalism).

[18] Merton, R.K., "Science, Technology, and Society in 17th century England" Osiris (4), 1938. The claim that science arose out of the puritan ethos came to be known as the 'Merton Thesis'. See also Shapin, S., "Understanding the Merton Thesis" Isis (79), 1988, pp.594-605. Merton picked up the idea of sentiments from the sociologist Vilfredo Pareto (1848-1923) and then went on to identify the 'ideal norms' of science – universalism, communism, disinterestedness and scepticism. To Merton the goal of the social order in science was to achieve these ideal norms and remain as autonomous as possible from external cultural interference (see Merton, R.K., "Science and Technology in a Democratic Order" Journal of Legal and Political Sociology 1, 1942: pp.115-126).

[19] Zilsel, E., "The Sociological Roots of Science" American Journal of Sociology (47), 1942, pp.245-279. The theses of Weber (Religious Ethos → Economy), Merton (Religious Ethos →Science) and Zilsel (Economy → Science) can be seen as forming three sides of a triangle (Lesley Cormack, personal

birth date of science. A debate began amongst positivists, largely autonomous from other intellectual debates, as to *when* science had formed and whether or not it was a continuous or decisive break with the past.[20] Those who believed in continuity included Pierre Duhem (fl. 1902-1916), who claimed that 'scientific' activity took place in the Middle Ages and earlier.[21] Those who believed in a decisive break included Herbert Butterfield, who considered the Scientific Revolution to be *the* single greatest event history. Following in the tradition was Rupert Hall, who claimed the Scientific Revolution was a unique intellectual transformation, and Alexandre Koyré, who described the Scientific Revolution as 'mutation' in the human intellect.[22] From the outside looking in, this debate between sudden or steady growth seems merely an issue of scale, but it absorbed much intellectual energy.[23]

Discussion around sudden or steady growth, combined with an 'internal' sociological approach dominated the history of science throughout the mid twentieth century.[24] However, in the later half of the twentieth century a new staged model of growth appeared, this time in a more generic form as described in Thomas Kuhn's book *The Structure of Scientific Revolutions* (1962).[25] Kuhn described scientific *paradigms* –

---

communication).

[20] Lindberg, D.C., "Conceptions of the Scientific Revolution from Bacon to Butterfield: A Preliminary Sketch" Reappraisals of the Scientific Revolution, Edited by David C. Lindberg and Robert S. Westman, Cambridge: Cambridge University Press, 1990, p.14.

[21] Duhem, P., M., M., La Théorie Physique: son Objet, sa Structure (The Aim and Structure of Physical Theory) New York: Atheneum, 1962 [1906].

[22] See Butterfield, H., The Origins of Modern Science, 1300-1800 London: Bell, 1949; See Hall, A.R., The Scientific Revolution 1500-1800 London: Longmans, 1954. See Koyré, A., From Closed World to Infinite Universe Baltimore: John Hopkins University Press, 1957 (Koyré actually used the term 'mutation' in his Études Galiléennes Paris: Hermann, 1939).

[23] It is interesting to note that the continuity / discontinuity debate in the history of science also preceded a similar debate within evolutionary theory sparked by Eldredge and Gould's 1972 paper on punctuated equilibria.

[24] See Cohen, H. F., The Scientific Revolution: a Historiographical Inquiry Chicago: University of Chicago Press, 1994.

[25] Kuhn, T.S., The Structure of Scientific Revolutions Chicago: University of Chicago Press, 1962. Kuhn's

loosely defined as groups of commonly held scientific principles and laws – which, at certain moments in history arose from 'pre-paradigmatic' states to bring scientific perspectives to bear where there had previously been none. The paradigm brought with it a certain worldview, or gestalt, which conditioned its member's thoughts and allowed the assimilation of various phenomena (Kuhn called this 'normal' science). However, when stubborn phenomena resisted assimilation into the paradigm, a *revolution* could occur, and a new paradigm could arise to replace the old.[26]

The revolution was discontinuous with the past, but positivists could still interpret the revolution as leading to a permanent stage of normalcy.[27] There could still be an approach to truth – merely one with more bumps on the way. However, to others the notion of the discontinuous revolution implied that science did not accumulate, but merely jumped from one worldview to the next. Although perhaps not Kuhn's intent, his model exposed the paradoxical nature of staged growth in science – that of penultimate progress.

---

ideas were also presented in other papers (see for example Kuhn, T.S., "The Function of Dogma in Scientific Research" Scientific Knowledge, Edited by Janet Kourany, Wadsworth, 1987, p.261).

[26] During the revolution competing worldviews were incommensurable, and debates could not be resolved on scientific merit alone. Kuhn's idea of incommensurability was borrowed from Gestalt psychologists (such as Kohler and Koffka), who claimed that the mind can form incommensurable interpretations of the same group of entities, two well known examples being the Necker cube and 'Duck-Rabbit' images. Kuhn's concept of the paradigm was also inspired by Ludwig Fleck's (fl.1930s) speculations that scientific facts themselves had a life cycle (see Fleck, L., The Genesis and Development of a Scientific Fact Chicago: University of Chicago Press, [1935] 1979). Fleck claimed that facts were created by scientific communities in a 'thought collectives' (also known as a *Denkstil*, *Zeitgeist*, or *Weltanschauung*). The 'thought collective' conditioned the thoughts of its members, and grew and died like a biological entity.

[27] Kuhn was directly influenced by traditional positivists like Koyré who felt that science appeared out of 'revolution' and was now converging on truth (as described in Horgan, J. The End of Science New York: Broadway Books, 1996, p.46).

Negativism from the early to mid-twentieth century

To reiterate, negativism is a term invented here to describe the opposite, or antithesis, to positivism. Being opposite to positivism, negativistic models, scientific or otherwise, are recognizable by their assumption in a decline to some point of false truth or a 'non-ideal' state. The point of false truth is to be avoided, and negativistic models are characterized by their offering remedies to prevent decline.[28] Negativistic models are also characterized by nostalgia towards the past – an assumption that old views were correct and present views were somehow misled. Negativistic models are also highly external – that is knowledge is conditioned by imperatives given by culture, not by 'nature'. Negativism can be graphically represented by an asymptotic decline towards something 'bad' as seen in **Figure 1-2.**

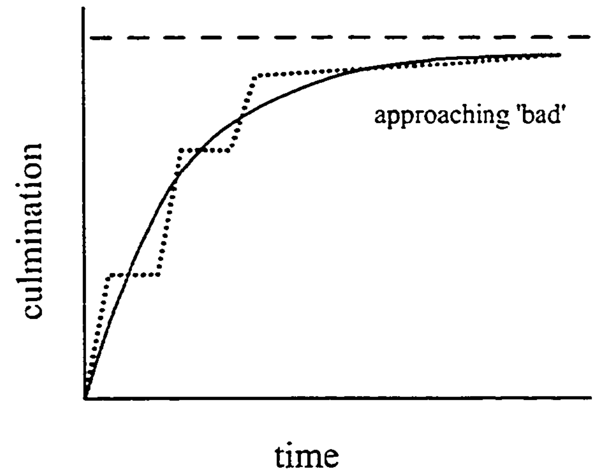

Figure 1-2. The negativist's basic conception of decline. Decline is seen as something 'bad' and approaching a non-ideal asymptote. Again, the solid line represents a traditional view of decline while the dotted line represents a 'revolutionary' or staged view (both are essentially equivalent).

[28] Like positivists, negativists also believed in truth. However, the difference emphasized here is that

Negativism did not suddenly appear with Kuhn's model – Kuhn's model merely served to indicate its presence. Yet when did negativism first appear? Again it is difficult to identify an exact starting point, but negativism was definitely present in the late nineteenth and early twentieth-centuries and was closely associated with the rise of relativism in Western culture at this time. For example, philosopher Friedrich Nietzsche claimed that forces external to the modern individual were forcing him to become less and less human.[29] It was only his 'will to power' that would allow him to remedy this decline and rise above the impending disaster, becoming in effect a 'superman'. Likewise Sigmund Freud's fledgling psychology (fl. 1900) claimed that mental problems of increasing severity in adulthood could be traced to one's childhood experiences.[30] The remedy to this decline was to confront these childhood experiences and purge the memory. In studies of culture, Franz Boas and Margaret Mead claimed from their examinations of Pacific islanders (c.1928), that cultural roles were the result of social conditioning.[31] Modern culture was becoming progressively more repressed as it got away from its primitive origins, and that only by returning to a cultural 'freedom' as experienced by the islanders could it be saved.

Unsurprisingly, negativistic views of science also began to appear in the early twentieth century. Influenced by Nietzsche, Oswald Spengler predicted in his *Decline of the West* (1918) that modern scientific Western culture was becoming too powerful and arrogant and was inexorably headed for decline.[32] The remedy was a backlash against

---

negativists believed decline was occurring or would occur *before* truth could return.

[29] Nietzsche, F. W., Der Wille zur Macht (The Will to Power) New York: Random House, 1968 [1901].

[30] See for example Freud, S., Drei Abhandlungen zur Sexualtheorie (Three Essays on the Theory of Sexuality), translated and edited by James Strachey, New York: Basic Books, 2000 [1905].

[31] Mead, M., Coming of age in Samoa; a psychological study of primitive youth for Western civilization New York: Blue Ribbon Books, 1928.

[32] Spengler, O., Untergang des Abendlandes (The Decline of the West) New York: The Modern Library,

modern ways, which would pave the way to a 'return' of a more humanistic society (note the nostalgia inherent in this claim).

Shortly after, negativism also appeared along with the first signs of 'externalism', or the idea that scientific knowledge was partly or completely conditioned by the culture in which it exists. For example, the capitalist / communist discourse of the 1930s displayed simultaneously externalism and negativism.[33] Soviet physicist Boris Hessen argued (1930) that Newtonian science was corrupted by its formulation and control by the bourgeois, and would continue to be corrupted if used solely by capitalists.[34] The remedy to this decline was the re-interpreting of science by the proletariat. Similarly, Marxist J.D. Bernal claimed that science was being harnessed by capitalism for things such as mass production warfare, and if allowed to continue in its present state would result in a de-humanizing of society. The remedy was for society to fund a group of 'proletariat scientists' who researched and formulated knowledge and technology that would only benefit humankind.

Marxists such as Hessen and Bernal felt science could be rehabilitated. Others felt it should be dispensed with altogether. Frankfurt School Marxists such as Theodore Adorno and Max Horkheimer came to see the Scientific Revolution not as the start of a triumphant rise, but instead the start of a tragic fall for humanity.[35] Science was

---

1962 [1918].

[33] Note however that most externalist theories at this time were still positivistic in their appraisal of 'pure' science.

[34] From the paper by Hessen, B., "The Socio-Economic Roots of Newton's Principia" Science at the Cross Roads, Edited by N.I. Bukharin London: Frank Cass, 1971 [1930], pp.149-212. See also Graham, L.R., "The Socio-political Roots of Boris Hessen: Soviet Marxism and the History of Science" Social Studies of Science (15), 1985, pp.705-722 for an explanation of the ulterior motive of Hessen. Graham claimed that Hessen made the 'bourgeois' characterization of Newtonian physics so that Einsteinian relativity could become politically acceptable to the Soviet authorities – the strategy being that if Newton's formulas are being used by 'proletariat' scientists, then the same could be done for relativity theory. Hessen eventually died in prison in 1938 during one of Stalin's purges of the Soviet scientific community.

[35] Horkheimer, M., Adorno, T., "The Culture Industry: Enlightenment as Mass Deception", The Dialectic

considered an exploitation of intellectual 'labour', and its offspring technology was a manifestation of the capitalistic will to dominate and control nature.[36] The remedy was to dispense with scientific enterprise altogether.

Perhaps less stark, but still negativistic in content, was the view of science emerging in France in the 1950s. Here Georges Canguilhem began to use the concept of 'discourse' to describe the struggle for the control of meaning, knowledge and power through certain ages.[37] This concept could be applied to any form of knowledge, and science was no exception. For example, Canguilhem claimed that Descartes' 'animal as machine' philosophy was typical of a late Renaissance discourse that demanded separation between human and non-human beings.[38] Although not expressly claimed, such a view implied that scientific knowledge was largely arbitrary, and therefore increasingly misleading unless one understood how it had been formed. Canguilhem's most famous student, Michel Foucault, expanded further and more actively on such themes. Foucault's model – although amended later in content – was most clearly spelled out in his book *Les Mots et les choses* (1966).[39] Here he described how Western perceptions of life, wealth and language (*the human sciences*) 'mutated' through several distinct *epistemes*.[40] Each episteme was characterized by a unconscious adherence to

---

of Enlightenment New York: Herder and Herder, 1944.

[36] One could argue that the idea of technology as inherently bad and unnatural arose out of an environment of destruction wrought by World War Two. It is interesting to note that negativistic models with strong elements of nostalgia also formed in popular culture at this time, such as Tolkein's *The Lord of the Rings* (a decline model approaching a 'bad' equilibrium unless remedied) or Orwell's *1984* (a decline model with society already at a 'bad' equilibrium).

[37] Canguilhem, G., A Vital Rationalist: Selected Writings from Georges Canguilhem Edited by Francois Delaporte, New York: Zone Books, 1994. Canguilhem's model was a variant of Gaston Bachelard's 'epistemological break'.

[38] Canguilhem, pp.219-236.

[39] Foucault, M., Les Mots et les choses: Une archéologie des science Paris: Gallimard, 1966 (published into English as The Order of Things in 1970). Ironically, Foucault's claim that the human sciences could never become 'true' sciences exposed that he was a 'positivist' in the more widely used sense of the word.

[40] In *Les Mots*, Foucault's Western European epistemes were the Renaissance (pre 1650s), the Classical

certain assumptions.[41] The epistemic model can be seen as negativistic for several reasons. For one, it implied that progress was a myth. Second, it implied that knowledge in the human sciences was actually getting *further* away from the truth due to the compounding of philosophical problems. To his credit, Foucault attempted to avoid causality in not giving reasons for epistemic breaks.[42] However, he implied that philosophical impasse was the 'cause' of epistemic shifts, similar to how Kuhn implied that anomalies were what 'caused' paradigm shifts. For example Foucault predicted ever greater problems for the Modern episteme because of the inability of man to understand himself as an object of knowledge.[43] The remedy to decline would be a new episteme where the discourses of man are studied instead of man himself.

Positivism from the mid-twentieth century to present

The appearance of Kuhn and Foucault's mirror image models of positivism and negativism is interesting enough in and of itself. However, their appearance within a few years of each other is remarkable. This suggests a new 'age' had begun for both

(~1650 to 1800), the Modern (~1800 to 1950) and the Contemporary (~ 1950 to the present). Numerous authors have described how Foucault's works resembled *Annales* histories (see Major-Poetzl, P., Michel Foucault's Archaeology of Western Culture Chapel Hill: The University of North Carolina Press, 1983, p.16; see Rabinow, P., The Foucault Reader New York: Pantheon, 1984, p.16; see Burke, P., Varieties of Cultural History Ithaca: Cornell University Press, 1997, p.162; see Hacking, I., "Michel Foucault's Immature Science" Nôus, Vol.13, No.1, p.45). *Annales* histories, such as those of Fernand Braudel, began by focusing on material histories of 'the masses' over long, medium and short *durées* (see Braudel, F., La Méditerranée et le monde méditerranéen à l'époque de Philippe II Paris: Colin, 1949). Around the time of Foucault, *Annales* histories also began incorporating elements of the intellectual *durée* as well.

[41] For example, Renaissance knowledge was conditioned by unconscious deference to God's reflections on heaven and earth, Classical knowledge by identities and the need to categorize, and Modern knowledge by a search for identity in past origin.

[42] See White, H., "Foucault Decoded: Notes from Underground" History and Theory, Vol.12, No.1, 1973, p.29. Foucault avoided causality because he sought to provide a counter-history to the typical positivist chain of events. Like Spengler and Heidegger before him, he was driven by a desire to expose the 'myth' of progress in the human sciences.

[43] See Foucault, M., The Order of Things: An Archeology of the Human Sciences New York: Vintage Books, 1970, p.387. Foucault claimed that the concept of man "...is an invention of recent date [a]nd one perhaps nearing its end." If this concept were eliminated "...one can certainly wager that man would be

positivistic and negativistic modellers.

Kuhn and Foucault's models were similar in that each age had its own gestalt which was totally different from those preceding.[44] Gestalt's inherent incommensurability, or discontinuity, was challenging to positivists in that it suggested that final truth might never be reached. For example, scientific knowledge might simply jump from paradigm to the next – the Einstein of today might be the Ptolemy of tomorrow. Furthermore, if taken to represent a challenge to progress, the arbitrary, unconscious state of knowledge at any one time can actually be seen as leading humanity further from the truth. This challenge revealed positivists post-1966 focused on 'saving' continuity in knowledge.[45] These positivists hoped to discredit the revolution and demonstrate that knowledge was still able to converge on final truth.

For example, one model brought forth to 'save' continuity was Karl Popper's 'falsification' criterion for science.[46] Developed much earlier, but brought to prominence in the 1960s, 'falsification' claimed that scientific theorems were unique in that they could be proved wrong, or falsified, whereas religious or ideological theorems could not.[47] Scientific knowledge would approach 'truth' as it successfully resisted repeated falsification attempts and achieved greater universality. Popper's model appealed to positivists in that it demarcated science from other forms of knowledge production while

---

erased, like a face drawn in the sand at the edge of the sea."

[44] Indeed, both Foucault and Kuhn were influenced by the views of Alexandre Koyré that the Scientific Revolution had been a 'mutation' in the human intellect. As for direct influence, Foucault did admit to being familiar with Kuhn's book *Structure* near the end of writing *Les Mots*, but claimed that his main influence remained Canguilhem (who had, interestingly, also been influenced by Koyré). See Taureck, B., Michel Foucault, Hamburg: Rowohlt, 1997, p.76.

[45] This wording implies that these positivists formulated the main components of their models prior to the challenge of discontinuity.

[46] Popper, K.R., The Logic of Scientific Discovery London: Hutchinson, 1959.

[47] Popper may have been influenced by the Quine-Duhem thesis (1952) which claimed that any theory could be toppled if only one of its components was found to be not true. See Quine, W.V., From a Logical Point of View Cambridge MA: Harvard University Press, 1953.

providing a mechanism by which science could commensurably converge on truth.

Imre Lakatos developed a similar model based on a progression of 'research programmes'.[48] Echoing Comte, Lakatos demarcated science from other forms of knowledge production based on its 'maturity' (i.e. autonomy) from 'outside' sources. Once autonomous, the research programme would undergo a sequential modification at its periphery while a 'hard core' of first principles remained unchanged.[49] Like Popper's model, Lakatos's model was able to demarcate science as well as make it a cumulative measure in which successive theories would be able to explain old phenomena as well as new.

Though appealing, some disagreed with the staunchly 'internalist' positioning of these demarcation theories and their inability to correlate well with the history of science. For example, Paul Feyerabend claimed that progress in science was often made by going against established norms. In his book *Against Method: Outline of an Anarchist Theory of Knowledge* (1975), he called for allowing other 'systems of thought' (i.e. non-scientific systems) a role in constructing knowledge.[50] Feyerabend claimed that using a plurality of mutually inconsistent theories, something he called 'proliferation', would

---

[48] See Lakatos, I., Mathematics, science and epistemology Cambridge: Cambridge University Press, 1978, p.107. Note that although using a model similar to Popper's, Lakatos often had harsh words for his counterpart.

[49] See Lakatos, pp.117, 225. To Lakatos, progress was marked by the appearance of novel predictions while degeneration was marked by the absorption of facts. Lakatos considered analogues to the 'Darwinian' struggle of ideas models to be elitist, and lumped Ludwig Wittgenstein, Thomas Kuhn and Stephen Toulmin together as such. He saved especially harsh criticism for Toulmin, and claimed (perhaps rightly) that Toulmin's evolutionary metaphors remained mere metaphors.

[50] Feyerabend, P.K., Against Method London: Verso, 1988 [1975]. Feyerabend most famously claimed that science was capable of expanding to explain all just like myth making. Indeed, this view was also supported by other contemporary exposes of the influence of hermetic magic on many of the 'heroes' of the Scientific Revolution (see Yates, F.A., "The Hermetic Tradition in Renaissance Science" Art Science and History in the Renaissance, Edited by Charles S. Singleton, Baltimore: John Hopkins Press, 1967). Feyerabend's impact is described in Lenoir, T., "Inscription Practices and Materialities of Communication" Inscribing Science: Scientific Texts and the Materiality of Communication Stanford: Stanford University Press, 1998.

allow for new insights to challenge existing theories.[51] Although often cited as relativistic, Feyerabend's critique focused on method – not the actual content of scientific knowledge produced. In essence, Feyerabend only slightly expanded upon Popper's and Lakatos's models combining falsification (i.e. 'proliferation' would challenge theories to resist falsification) with 'research programmes' (i.e. theories would be modified at their periphery while keeping their 'hard-core' intact). The only difference was that progress could be 'saved' by adopting more anarchistic methods of challenging science.

When compared to history these models were not quite convincing in their entirety, but they served to placate the positivist's desire for continuity. Yet the problem of growth was still unresolved. On the whole, positivists recognized that science had its limitations. For example, Derek Price observed that there was an exponential increase in scientific activity throughout the twentieth century, and that it would eventually reach a 'saturation' point with respect to the rest of society.[52] Gerald Holton theorized that there was a limited amount of 'interesting' discoveries per field and that as the number of discoveries available dwindled, the number of scientists in that field would far outweigh the remaining discoveries to be made.[53] However, such 'saturation' limits were seen as problems that could be avoided with the right institutional policies.[54] If policies encouraged or facilitated scientists to 'leapfrog' on to a new field, then growth could be

---

[51] As described in Feyerabend, P.,K., Knowledge, Science and Relativism, Philosophical Papers Volume 3, edited by John Preston, Cambridge: Cambridge University Press, 1999, pp.108-111. The 'proliferation' model tended to support Kuhn's own observation of the proliferation of novel or creative new theories in the face of stubborn anomalies. However, Feyerabend did not endorse Kuhn's model.

[52] See Price, D.J., Little Science, Big Science…and Beyond New York: Columbia University Press, 1986, p. 21. Price observed that during and after World War Two, 'little' (amateur) science was replaced by 'big' (professional) science requiring massive financial resources.

[53] Holton, G., Thematic Origins of Scientific Thought Cambridge MA: Harvard University Press, 1973, p.415.

[54] Price advocated supporting 'invisible colleges' or clusters of scientists that were uninfluenced by larger society. Price's approach inspired some in the 1980s and 1990s to 'scientifically' study science, an approach also seen in numerical and statistical examinations of citation indices.

continued.[55] The new scientific field would gather talent and energy until saturation would again occur. As seen in **Figure 1-3**, 'leapfrogging' was seen as a desired trajectory for science.

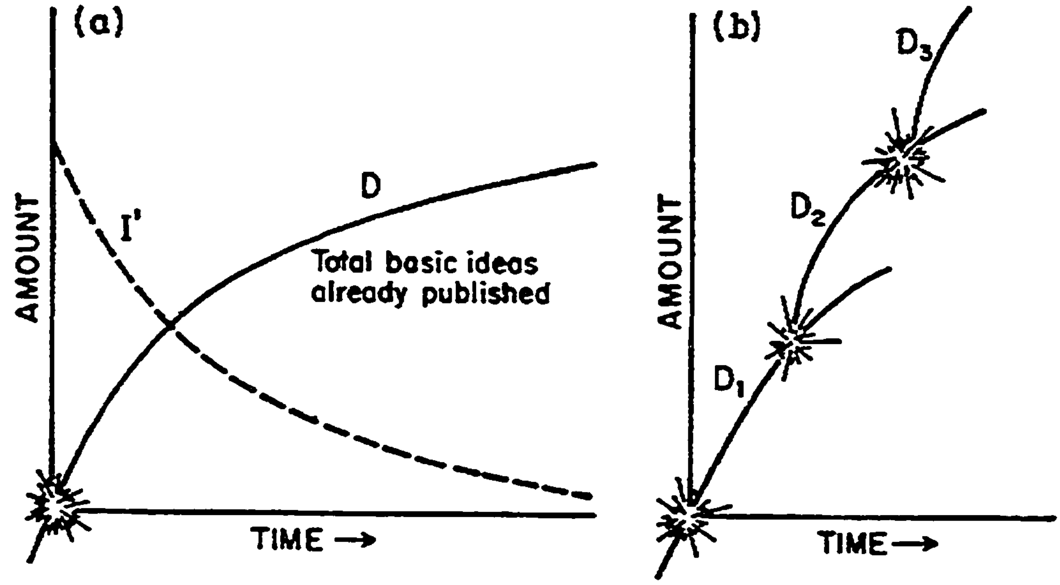

Figure 1-3. Scientific progress to late positivists.[56] (a) The cumulative number of discoveries made with time is represented by D while I' indicates the number of interesting discoveries remaining. (b) Knowledge accumulates by 'leapfrogging' from discoveries D_1 to D_2 to D_3 and so on with time. Note the similarity of (b) with Figure 1-1.

Such 'leapfrogging' models closely resembled the staged models of a century earlier and served to placate the positivist's faith in growth. Yet there was still an underlying feeling of unease, or a lack of closure to the problem of growth. Again the evolutionary analogy was invoked by positivists to defend continuity. Kuhn often described progress in science to be analogous to the evolution of species.[57] Popper's

---

[55] Holton, pp.408-421.
[56] Holton, p.424.
[57] See Kuhn, T., "The Road Since Structure" Science and the Quest for Reality, Edited by Alfred I. Tauber.

falsification criterion also later took on 'evolutionary' overtones, implying that the survival of scientific theories was akin to 'survival of the fittest'.[58] Feyerabend also invoked the evolutionary analogy to describe scientific progress.[59] Even positivistic scientists joined in. Ernst Mayr, a renowned evolutionary biologist, used an evolutionary analogy to demonstrate how biological science was continuous.[60]

For the most part these analogies remained only analogies. But other philosophers took this problem more seriously in the later half of the twentieth century. For example, Stephen Toulmin attempted to develop an evolutionary model in which the scientific discipline could be seen as a species tracked through time from one generation to the next.[61] He focused on tracing the survival of concepts through a competition model occurring at levels both 'internal' and 'external' to science as seen in **Figure 1-4.**[62] By tracing survival causality, Toulmin hoped to demonstrate the continuity and growth of scientific knowledge.[63]

New York: New York University Press, 1997, pp.231-248.

[58] Popper, The Logic, p.278. However, since falsification was used earlier by Popper to claim that evolutionary theory was 'unscientific' (it could not be subjected to falsification) his later attempts to use such analogies seemed somewhat disingenuous.

[59] Feyerabend, Knowledge, Science and Relativism, pp.106-111. Feyerabend was probably influenced by Wittgenstein's characterization of knowledge as a 'form of life' and by Mach's characterization of evolution as efficiency.

[60] Mayr, E., The Growth of Biological Thought Cambridge MA: The Belknap Press, 1982. Mayr claimed that biological science, unlike physics, was never dominated at any one time by a single conscious or unconscious paradigm or episteme. He claimed that biological science progressed by accumulation, or branching out, rather than by incommensurable revolution. Yet Kuhn also recognized that a new paradigm does not necessarily have to come into conflict with others (see Kuhn, "The Nature and Necessity of Scientific Revolutions", p.26).

[61] Toulmin, Human Understanding Oxford: Clarendon Press, 1972, p.141. Toulmin, like Feyerabend, also showed the influence of Wittgenstein's characterization of intellectual constructs as 'forms of life'.

[62] Toulmin, pp.352-353. Toulmin considered science to form internally, but then be subject to external influence. He also considered scientific concepts to be 'micro-institutions' and scientific institutions to be 'macro-concepts', alluding to the interplay of ideas on small and large scales.

[63] Toulmin, p.99. Toulmin, like Feyerabend, argued that scientific method could not be seen as an ideal rationality since one's rationality could be demonstrated at times by the willingness to change method. But Toulmin also considered relativism to be equally misguided. He considered Kuhn's model to be 'relativist'

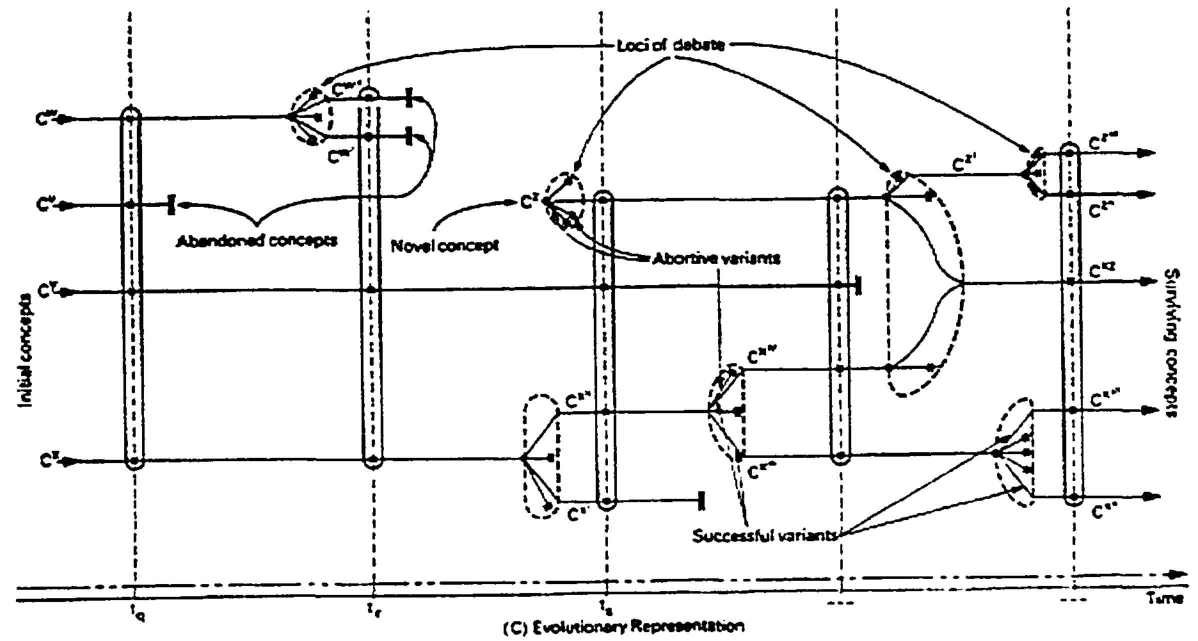

Figure 1-4. Toulmin's model of the evolution of science.[64] Concepts are tracked through a causal chain of survival, with the winners having superior conceptual inclusiveness than the losers.

Again echoing positivists of a century earlier, efficiency was brought out as the driver (and result) of scientific evolution. For example, philosopher Larry Laudan claimed that 'research traditions', structures similar to paradigms, competed against each other on the basis of demonstrating *reliability*.[65] Borrowing from Lakatos's model, Laudan claimed that research traditions evolved by the appearance of subordinate and even core theories that demonstrated greater reliability, or efficiency than their

and disagreed with the discontinuities inherent in revolutions.

[64] From Toulmin, pp.352-353.

[65] Laudan, L., "Explaining the Success of Science: Beyond Epistemic Realism and Relativism" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York: New York University Press, 1997, pp.137-161. See also Laudan, L., Progress and its Problems: Towards a Theory of Scientific Growth Berkeley: University of California Press, 1977. Closely akin to Popper's falsification, Laudan considered reliability to be a measure of efficiency – one theory can be judged superior to others based on how reliably it solves empirical problems. However, he differed from Popper in that some demonstrations of reliability were more significant than others and in doing so endorsed historical scrutiny of typically ahistorical models.

competitors.[66] Echoing a similar theme but from a more internalist point of view, was Phillip Kitcher, who viewed scientific evolution as hinging on the most optimal or efficient level of competition and cooperation between members of the scientific community.[67] He found that efficiency demanded those members who held ideas of greater conceptual inclusiveness in the community would advance themselves farther than those who did not. Similarly, David Hull thought of ideas in science as operating like 'viruses', implanting and reproducing themselves from host to host. Scientists infected with viruses of greater 'conceptual inclusive fitness' had greater chances of 'winning' because they increased the credit of their supporters within the scientific community.[68] Less efficient viruses would of course be eliminated from the 'gene pool'.

With models like Hull's blurring the lines between scientific and biological entities, it is no surprise to see models of science fully committed to evolutionary survival appearing at this time. For example, Michael Ruse claimed that scientific thinking was itself the culmination of successful traits gained by 'normal' human beings in the course

---

[66] Laudan was attempting to save continuity and attacked Kuhn and his concept of the 'revolution' by claiming that revolutionary science was no different from normal science (see Laudan, Progress and its Problems, p.134). Similar to Lakatos, Laudan believed that when one research tradition triumphed over another, it simply increased in, or accumulated explanatory power (see Laudan, Progress and its Problems, p.96). However, Laudan and Lakatos were unable to solve the logical problem of 'morphological consistency' when describing how research traditions change. Change, even at small scales, requires some amount of discontinuity.

[67] See Kitcher, P., The Advancement of Science Oxford: Oxford University Press, 1993, p.59. Kitcher considered revolutions to simply be the machinations of 'veterans and apprentices'. New ideas triumph over others because each generation has its own way of doing things (this is basically a recapitulation of an earlier observation by Max Planck). Hence the revolution was largely a phenomenon that, although altering the culture of scientists, did not alter its progress. Kitcher's model is like game theory focused on optimal cooperation and coordination between scientists. Unfortunately, like all logical models (and indeed all models in general), this one is susceptible to assumptions based on current perceptions of human nature.

[68] See Hull, D.L., "Studying the Study of Science Scientifically" Perspectives on Science Volume 6, Number 3, 1998, pp.209-231. See also Hull, D., L., Science and Selection: Essays on Biological Evolution and the Philosophy of Science Cambridge: Cambridge University Press, 2001, pp.97-98. Hull thought of the evolution of science in terms of replicators and interactors. A replicator passed on its structure to the next generation, while an interactor interacted with the environment. Hence the replicator, protected from the environment, allowed for continuity (and accumulation) in knowledge. Hull considered only the internal culture of science in the transmission of ideas. He attacked the concept of incommensurability in

of hominid evolution.[69] As science evolved, those who held 'true' ideas reproduced themselves faster than those who held 'false' ideas.[70] Clearly therefore, the history of science should be one of enhanced survival capability of *homo sapiens*. But would negativists agree?

Negativism from the mid-twentieth century to present

As with positivism, negativism carried on unabated into the mid-twentieth century. In the 1970s Herbert Marcuse continued to theorize along the same lines as Adorno and Horkheimer, claiming that science was a manifestation of the will to dominate nature, and would contribute to an increasingly artificial society unless controlled.[71] Martin Heidegger also continued to see science as becoming more artificial and therefore 'bad' unless it could be controlled by philosophy – a branch of knowledge which existed on a higher epistemological plane.[72] Echoing Bernal in the 1980s, Steve Fuller argued that big science was becoming increasingly elitist and therefore 'bad' and its knowledge increasingly irrelevant to everyday citizens.[73] Technology was also

---

an attempt to discredit Kuhn's 'discontinuous' model.

[69] See Ruse, M., Taking Darwin Seriously New York: Prometheus Books, 1998 [1986]. See also Ruse, M., Evolutionary Naturalism London: Routledge, 1995. Ruse argued that "...the principles of science...are reflections of the innate dispositions...which are burned into the thinking process of every mature normal human being." (Ruse, Evolutionary Naturalism, p.163). This basically implies that science has now become an 'instinct'. Ruse also considered ethics to have formed in evolutionary biology.

[70] Curiously, Ruse endorsed a positivistic model of science, yet was social constructivist when it came to explaining the 'Darwinian Revolution'. He considered Darwin's theory to be a by-product of Victorian notions of progress and cultural domination (see Ruse, Taking Darwin Seriously, p.141).

[71] Marcuse, H., Counterrevolution and revolt London: Allen Lane, 1972.

[72] See Heidegger, M., "The Age of the World Picture" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York: New York. University Press, 1997, pp. 70-88. Heidegger claimed that modern science was getting further away from truth because the 'world-picture' of modernity demanded little-more than the examination of this picture (science) and put very little emphasis as to how this picture had been formed (philosophy).

[73] Fuller, S., Thomas Kuhn: a Philosophical History for Our Times Chicago: The University of Chicago Press, 2000. Fuller adheres to a social constructivist argument claiming that *Structure* was a product of Harvard academia's response to the Cold War and that Kuhn was duped into becoming an apologist for big science. Fuller also claimed that SSK (Sociology of Scientific Knowledge) and STS (Science and

subjected to negativistic analysis, with Neil Postman arguing that it was becoming an increasingly oppressive force in society and therefore 'bad' unless one understood and limited one's exposure.[74]

But a slightly modified form of negativism also appeared at this time – one claiming to question the validity of scientific knowledge itself. Of course Foucault was at the forefront of this trend, suggesting that 'scientific' studies of sexuality framed and made necessary the discussion on sexuality, and effectively conditioned sexual behaviours.[75] The remedy to this arbitrary conditioning was to understand how it came about in history, with the intent being that this would lead to liberation.[76] Others inspired by Foucault's revisions began to subject the heroes, or 'dead white males' of the Scientific Revolution to a re-examination.[77] During this so-called 'cultural turn' in the study of history, science became viewed as a collection of discourses in which cultural forces struggled to create and control meaning.[78] Championing this philosophy in the 1970s was the 'Strong Programme'. Led by Barry Barnes and David Bloor, the Strong Programme claimed to study the sociology of scientific knowledge (SSK) as a social construction with little or no reference to an external 'reality'. The most notable work

---

Technology Studies) were drawn into a pointless debate about incommensurability, when they should have focused on the transgressions of 'big' science. Such a harsh critique, I submit, adds little to our understanding of the evolution of science, except insofar as providing an excellent example of negativism.

[74] Postman, N., Technopoly: the Surrender of Culture to Technology New York: Knopf, 1992.

[75] Foucault, M., Histoire de la sexualité: La volonte de savoir Paris: Gallimard, 1976 (L'usage des plaisirs, 1984; Le souci de soi, 1984). Published in English as The History of Sexuality.

[76] As Foucault's ideas matured, he became a social activist and his histories became even more geared towards providing a moral message. Foucault was ultimately interested in social equilibrium. He wanted to redress the power imbalance between the repressive force of the state and the individual desiring liberation. See Macey, D., The Lives of Michel Foucault London: Hutchinson, 1993.

[77] Traweek, S., "Faultlines" Doing Science and Culture, Edited by Roddey Reid and Sharon Traweek, New York: Routledge, 2000, pp.21-48.

[78] Cultural analyses of history at this time became heavily reliant on Derridian post-structural views of language as a discursive site, in which opposing factions struggled to create meaning by attaching words to chains of signifiers. See Eagleton, T., Literary Theory: An Introduction Oxford: Basil Blackwell, 1983, pp.127-150.

arising from the Strong Programme was Steven Shapin's and Simon Schaffer's book *Leviathan and the Air Pump* (1985), which examined the discourse between Thomas Hobbes and Robert Boyle over the interpretation of the phenomenon of the air-pump.[79] Shapin and Shaffer observed that Boyle could not rely on evidence alone, and only properly trained witnesses (i.e. gentlemen) were qualified to interpret and use science while the less qualified 'others' (i.e. philosophers, commoners and women) were excluded. Hence the scientific community came to be composed of groups of similarly conditioned people that 'see things in similar ways'.[80] The implication was that scientific knowledge was overwhelmingly a product of the social milieu from which it had formed.

Similar social constructivist re-examinations of the Scientific Revolution became numerous in the following decades. Mario Biagioli claimed patronage systems were instrumental in forming both the object of knowledge and its content – even for supposed heroes of science such as Galileo.[81] Paula Findlen revealed in her book *Possessing Nature* (1994) that natural philosophers of the Scientific Revolution constructed identities and emblems for themselves and altered their perceptions of nature in order to compete for patronage.[82] Peter Dear used discursive analysis in tracking the concept of

---

[79] Shapin, S., Schaffer, S., Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life Princeton: Princeton University Press, 1985.

[80] As quoted in Fuller, S., Science Minneapolis: University of Minnesota Press, 1997, p.21. Shapin reiterated this claim in the 1990s, claiming that networks of trust were more critical to the functioning of science then so called 'crucial' experiments (see Shapin, S., A Social History of Truth Chicago: University of Chicago Press, 1994).

[81] See Biagioli, M., "Galileo's System of Patronage" History of Science (28), 1990, pp.1-62. See also Biagioli, M., "Galileo the Emblem-Maker" Isis (81), 1990, pp.230-258. Biagioli claimed that Galileo, far from being a disembodied and pure pursuer of truth, found his very identity – his *raison d'être* – in patronage. For example, Galileo's naming of the planets of Jupiter as the 'Medician Stars' indicated that science might not have been his expressed aim. Indeed, his sponsors were not even interested in Copernicanism. Rather, they were interested in novel discoveries since 'ownership' over these helped to solidify their identities in existing social hierarchies.

[82] Findlen, P., Possessing Nature: Museums, Collecting and Scientific Culture in Early Modern Italy Berkeley: University of California Press, 1994. The 'bodies' of the natural world were used to signify a natural philosopher's identity. Emblems containing images of animals such as foxes or owls which were

'experiment' throughout the Scientific Revolution, and found that a social struggle over its meaning was required for it to be accepted as a legitimate.[83] William Eamon tracked the discursive struggles within certain cultural groups of the Scientific Revolution, and found that natural magic had played a bigger role than previously thought.[84] Even the content of science in regions peripheral to Europe was subject to revision, such as in Gyan Prakash's exposé of the Indian fabrication of an ancient Vedic 'science' that was meant to compete with the legend of the European Scientific Revolution.[85]

These observations in themselves could not be defined as negativist (i.e. there is no explicit claim that science is getting worse, or approaching false truth). However, social constructivist theory implied to some extent that scientific knowledge was arbitrary. Indeed, the so-called 'symmetry postulate' of social constructivism claimed that scientific truth and falsity were created in exactly the same way.[86] Proof of this symmetry was given in the form of scientific 'failures' such as phrenology (i.e. the

---

meant to represent wisdom. By offering up their collections for sponsorship, the natural philosopher would share in a mutual benefit with his patron for status in the hierarchy, retaining identity and status for the possession of knowledge and the signification of meaning.

[83] Dear, P., Discipline and Experience: The Mathematical Way in the Scientific Revolution Chicago: University of Chicago Press, 1995. Prior to the Scientific Revolution, Jesuits considered mathematics to be a lowly art because it conflicted with Aristotelian notions of *experimentum*, or communal experience of observation. However, during the Scientific Revolution, the meaning of *experimentum* was changed into our present notion of a 'solitary intervention in nature' – and mathematics was granted enhanced status and the ability to represent reality.

[84] Eamon, W., Science and the Secrets of Nature Princeton: Princeton University Press, 1994. Interestingly, Eamon showed the influence of Foucault in describing unconscious epistemic and discursive mentalities of those living at the time of the Scientific Revolution (p.11). Eamon revealed that an enormous number of 'magical' texts containing self-help 'recipes' of white and black magic spells were printed during the Scientific Revolution and were popularly distributed across Europe, mostly at book fairs and carnivals. Eamon claimed that natural magic was suppressed by the Church because it threatened to usurp its control over 'supernatural' knowledge, and by science as it struggled for control over 'natural' knowledge. Parallels can be seen here in the attack on the 'carnival' mentality by the new rational middle class (as described in Stallybrass, W., White, A., The Politics and Poetics of Transgression Ithaca: Cornell University Press, 1986).

[85] Prakash, G., Another Reason: Science and the Imagination of Modern India Princeton: Princeton University Press, 1999.

[86] Golinski, J., Making Natural Knowledge: Constructivism and the History of Science Cambridge: Cambridge University Press, 1998, p.15.

examination of intelligence based on cranial measurements).[87] It is therefore no surprise to find negativistic models of this time infusing social constructivist techniques. For example, feminist authors such as Carolyn Merchant described the Scientific Revolution as a 'rupture' in culture, where the motherly image of nature was transformed into the view that nature was a weak, disordered female body in need of masculine authority.[88] This rupture in the past was what explained the current culture of 'man versus nature' in science. Similarly, Evelyn Fox Keller claimed that a 'man versus nature' dichotomy began with Francis Bacon and his view that nature must be 'tortured' in order to reveal her truth.[89] Londa Schiebinger claimed that early scientific study of the body amounted to a discourse where the superficial differences between upper class European males and women and 'lower' races were used to justify excluding these groups from the *polis* – something which explained the male / female disparity in science to the present day.[90] The remedy to this decline was to return to a pre-Scientific Revolution societal view of nature.[91]

---

[87] Shapin, S., "History of Science and its Sociological Reconstructions" History of Science (20), 1982, pp.157-211.

[88] Merchant, C., The Death of Nature: Women, Ecology and the Scientific Revolution San Francisco: Harper, 1980. Merchant's book was instrumental in inspiring many environmental movements of the 1980s and 90s. Interestingly, environmental theories are often negativistic in forecasting an approach towards 'disaster' unless remedies are taken to avert decline. They are also focused on equilibrium in the search for a final 'balance' between man and nature, and nostalgic in seeking ideal times in the past when all was pure.

[89] Keller, E.F., "Feminism and Science" Feminism and Science Edited by Evelyn Fox Keller and Helen E. Longino, Oxford: Oxford University Press, 1996, pp.28-40.

[90] See Schiebinger, L., Nature's Body. Gender in the Making of Modern Science Boston: Beacon Press, 1993. Schiebinger found direct correlation between the meaning of the Linnaean class of *Mammalia* and the female body. See also Schiebinger, L., "Why Mammals are Called Mammals: Gender Politics in Eighteenth century Natural History" Feminism and Science edited by Evelyn Fox Keller and Helen E. Longino, Oxford: Oxford University Press, 1996, pp.137-153.

[91] Feminist revisions were also paralleled at this time by revisions in Orientalism. Eurocentric studies as to why the Orient did not have a Scientific Revolution gave way to examinations of the East/West colonial discourse (see for example Needham, J., The Grand Titration: Science and Society in East and West London: Allen & Unwin, 1969). Edward Said, heavily influenced by Foucault, pointed out that viewing the East as merely the West 'in waiting' reflected a colonial discourse in which all cultures were seen as lesser than the Western ideal (see Said, E., Orientalism New York: Pantheon Books, 1978).

These negativist social constructivist arguments were compelling. Yet they revealed a lack of closure vis-à-vis the thorny problem of 'reality'. A parallel school of 'Science and Technology Studies' (STS) emerged in the later half of the twentieth century attempting to tackle this problem. Prominent in this school was Bruno Latour and Steve Woolgar, who in the 1970s began to subject science and scientists to ethnographic and anthropological studies.[92] Throughout the 1980s and 1990s Latour developed theories under the banner of STS suggesting that scientific facts formed out of a 'collective' of human and non-human actors instead of out of a traditional 'reality'.[93] Scientific experimentation, or intervention in nature, was merely a process of phenomena creation to which factual or non-factual status was assigned and then reified to larger culture giving the appearance of universality.[94] Hence STS claimed to have solved the problem of reality by redefining what reality was.

Whether or not this redefining of reality is plausible is not important here. What

---

[92] See Latour, B., Woolgar, S., Laboratory Life: The Social Construction of Scientific Facts Beverly Hills: Sage, 1979. Although Latour would consider himself to be very different than social constructivists, he shares many of the same basic views, such as how social consensus is as (or more) important than 'reality' in determining the validity of scientific knowledge.

[93] Latour, B., Pandora's Hope: Essays on the Reality of Science Studies Cambridge MA, 1999, pp.21, 193. The collective is the whole domain of science – society, nature, mind and God. Latour defined its functioning as 'an exchange of human and nonhuman properties inside a corporate body'. Hence the examining of the collective would reveal the 'myth' of progress in science. Indeed, the title of his book refers to the putting back into Pandora's Box our modern (i.e. 'bad') notions of progress in science. STS also developed actor- network theory, a complicated and difficult to use model by which actors (human or non-human entities with human attributes) interacted with the collective via mediators. For example, the success or failure of science depended on the compatibility of its actors and their networks, not on some external 'reality' (see for example Callon, M., "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Bireuc Bay" Power, Action and Belief, edited by J. Law, 1986, pp.196-233).

[94] Latour, B., The Pasteurization of France Cambridge, Mass.: Harvard University Press, 1988. Latour pointed to the germ theories of Pasteur as an example of how scientific observations become 'facts' and how these 'facts' can fluctuate. Other proponents of STS pointed out this arbitrariness of 'facts' throughout history. For example, the seventeenth century the *Philosophical Transactions of the Royal Society* assigned factual status to phenomena such as 'monstrous heads', 'triple-suns', 'rains of blood' or 'diamonds that glow in the dark when rubbed' (see Daston, L., "The Language of Strange Facts in Early Modern Science" Inscribing Science: Scientific Texts and the Materiality of Communication, Edited by Timothy Lenoir, Stanford: Stanford University Press, 1998, pp.20-38).

is important was that STS incorporated within it a negativistic interpretation of history. Latour argued that a rupture had come about with 'modernity', caused by the intelligentsia's modification of Kant's notion of the *a priori* to mean an external reality out of fear of having it dictated to them by mob rule (see **Figure 1-5**).[95] From reality came the equally 'bad' notion of artificiality, and ever since then these opposing poles had been getting farther and farther apart. The remedy to this decline was to discard our modern notions of reality.

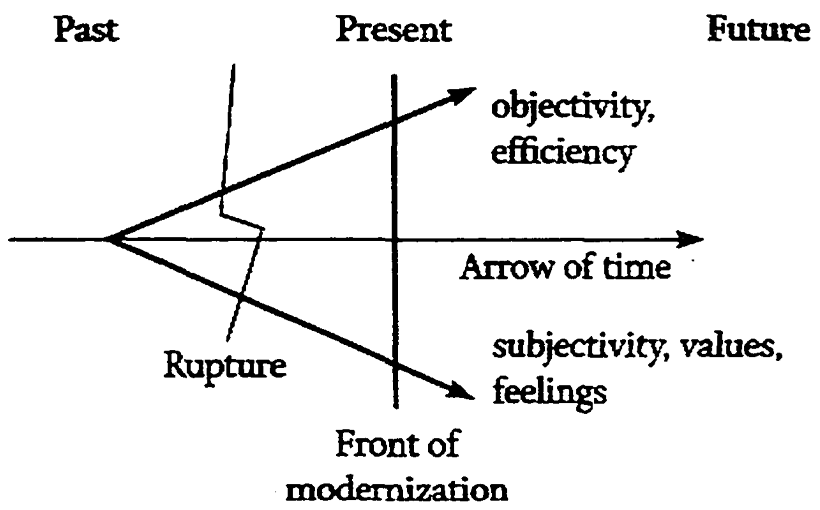

Figure 1-5. The evolution of knowledge according to Latour.[96] The intellectual structure had ruptured at some point in the past and as a result taken an 'incorrect' trajectory. With the arrows getting farther apart at the 'Front of modernization' it is implied that true knowledge (understanding) will continue to decline unless the rupture is remedied.

Also negativist in composition is Latour's compounding collective.[97] As seen in

[95] Latour, Pandora's Hope, p.10. Negativism can also be seen in Latour's nostalgia for a time 'pre-Kant' when this problem did not exist.
[96] From Latour Pandora's Hope, p.199.
[97] Latour shows the influence of post-modernism and post-structuralism throughout his works, often using terms like 'signs', 'translations', 'gaze', 'hybrids', 'dispositifs', 'discourse', 'folding', etc.

Figure 1-6, Latour describes eleven compounding layers of interaction between humans and non humans from the base level (i.e. 'social complexity') to the highest level (i.e. political ecology). Presumably more layers would be added as the collective moved into the future. Hence the collective was becoming more and more complicated requiring 'longer chains of action' to enrol nonhuman actors into the collective.[98] The end result would be the complete 'entanglement' of human and non-human actors. The remedy to this bewildering complexity was to unpack the 'black boxes' of knowledge in order to understand (and control?) the entanglement.

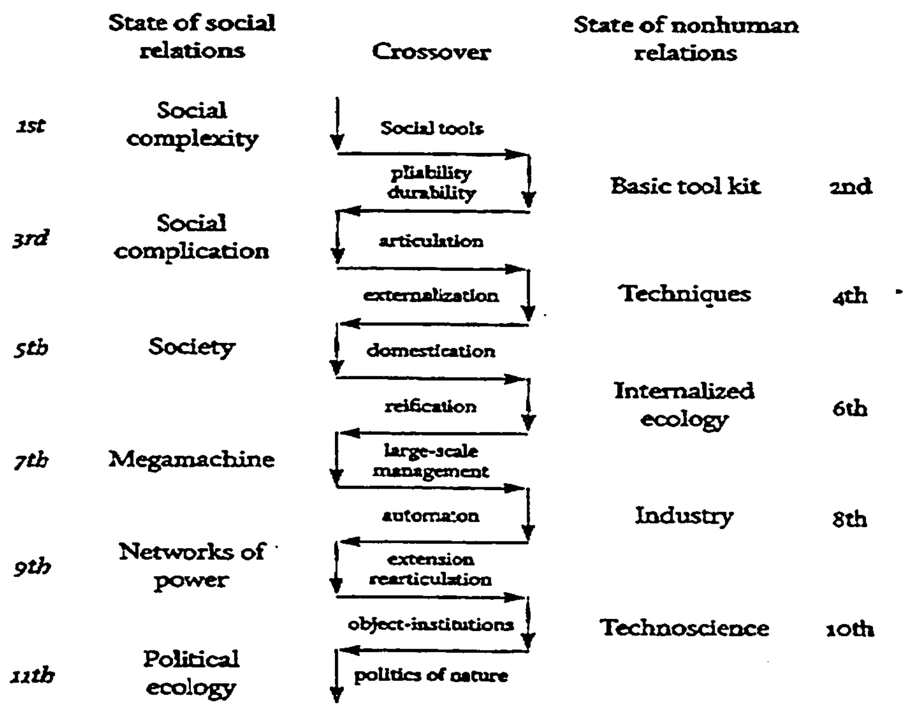

Figure 1-6. Latour's compounding collectives.[99] The longer chain of action from 1^{st} to 11^{th} levels renders modern society more complicated, and therefore harder to understand unless all the levels are 'unpacked'.

[98] Latour, Pandora's Hope, pp.195-196.
[99] From Latour Pandora's Hope, p.213.

Conclusion

This brief examination of history shows that most modellers of the history of science from the nineteenth century onwards have either had an affiliation with positivism, as a belief in growth towards some ideal state, or with negativism, as a belief in decline towards some non-ideal state. While these opposing 'schools' vary somewhat in detail, it should be obvious by this point that positivism and negativism are essentially mirror images of each other. This leads one to speculate as to what they have in common, and what within their gestalts has prevented a successful evolutionary formulation of history. This will be the focus of the next chapter.

Chapter Two *Critique*

As described in the previous chapter, positivistic and negativistic models of history are mirror images of each other. Positivism forecasts a 'good' end-point and offers advice as to how to continue growth, while negativism forecasts a 'bad' end-point and offers remedies to prevent decline. However in doing so, both have focused on selection to the detriment of variation. Also in focusing on selection, positivistic and negativistic modellers have come to see evolution as continuous, and have ignored the possibility that it may be as equally discontinuous.

To start, from the point of view of the modern evolutionary modeller, any model of history should contain equal parts variation and selection. However positivistic and negativistic models are notable for their focus only on selection. This is exemplified by their use of 'equilibrium' points towards which their histories approach. For example, positivists typically see their equilibrium point as some ideal state of truth, while negativists see equilibrium as some non-ideal state of false truth. But why does an approach to equilibrium represent selection alone? To the evolutionary modeller, movements towards equilibrium require a series of selection events. In a sense, variation in structure is being eliminated, or selected-out as less fit (i.e. as error) as equilibrium is approached. For example, Popper's falsification is a perfect example of selection towards equilibrium. Less-fit theories are selected-out in favour of fit theories as final truth is approached.

Once again parallels can be seen between models of scientific growth and other cultural theories in general. The focus on equilibrium has been very prevalent across the entire spectrum of Western thought throughout the nineteenth and twentieth-centuries.[100] To social theorists, society was often viewed as an organism in search of homeostasis.[101] Movements away from stasis were considered errors in need of remedy. To economic theorists, economies were often seen as cycling through 'boom' and 'bust' stages about a base level of growth.[102] Movements too far to either side of this 'dynamic' equilibrium were seen as 'bad' and in need of remedy. To political theorists, history often was forecasted to converge on some state of equilibrium, like, for example, 'the American dream', 'the worker's paradise', or the '1000-year Reich'. Of course, movements away from these points were seen by adherents as error.[103]

Not surprisingly, many philosophical models of the nineteenth and twentieth-centuries also relied on equilibrium in identifying *a priori* states upon which humanity would, or should collapse. In doing so, movements away from these equilibria were

---

[100] Prigogine, I., Stengers, I., Order out of Chaos New York: Bantam Books, 1984. Prigogine and Stengers claimed that in particular the equilibrium mindset was revealed with the conservation of energy law developed in the 1840s, in which non-equilibrium states came to be seen as 'exceptions' or 'errors'. The appearance of entropy theory shortly afterwards based on the unidirectional flow of energy from hot to cold, was 'absorbed' into the equilibrium mindset when these processes were seen as resulting in net thermal equilibrium at the end of time. (Incidentally, the first law of thermodynamics in which energy can not be created or destroyed, is still not reconciled with the second law of thermodynamics in which energy processes are irreversible). Prigogine went on to develop a 'non-equilibrium' thermodynamics for which he won a Nobel Prize, which can be seen as belonging loosely to the corpus of 'chaos' theories.

[101] This view was exemplified by the theories of Vilfredo Pareto. See Bailey, K.D., Social Entropy Theory New York: State University of New York Press, 1990, pp.61, 70-72.

[102] The best examples of the focus on equilibrium in economics were the attempts by Keynesian economists to damp out the boom and bust stages of economic cycles (see Mager, N.H., The Kondratieff Waves New York: Praeger, 1987). Cycles had two inevitable phases: a growth phase, represented by terms such as 'bubble', 'mania', or 'inflation', and a decline phase represented by terms such as 'crisis', 'crash', or 'correction' (see Kindleberger, C.P., Manias, Panics and Crashes: A History of Financial Crises New York: John Wiley and Sons Inc., 1996 (3rd ed), p.44). Further dynamic models such as the 'random walk' were developed pinned to equilibrium states demanded by their rational actors (see Peters, E.E., Chaos and Order in the Capital Markets New York: John Wiley and Sons, 1991, pp.26-39). Rational actor game theories are still very prevalent today, exemplified by the recent awarding of the Nobel Prize to John Nash as popularized in the recent movie *A Beautiful Mind* (2001).

[103] Again when such end-points were not achieved, political theories shifted to cyclic oscillation about equilibrium, exemplified by theories of 'rise and fall' related to economic or military 'factors'. See Kennedy, P., M., The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000 New York: Random House, 1987; see also Goldstein, J.S., Long Cycles: Prosperity and War in the Modern Age New Haven: Yale University Press, 1988.

considered error. For example, consider John Ralston Saul's recent book *On Equilibrium* in which advice is contained within as to how liberal democracy 'should be' so that stasis can be reached within society.[104] Naturally any variation generated by society not in line with the desired equilibrium would be characterized as error.

Where not considered error, variation was often ignored altogether by theorists in search of *a priori* equilibira. For example, consider Francis Fukuyama's *The End of History* in which the collapse of communism signalled liberal democracy as the ideal point, or *a priori* state of human needs and desires, upon which political history will end or reach equilibrium. Fukuyama clearly did not consider how or why these two competing variants arose in the first place, or the possibility of further variation arising out of liberal democracy in the future.[105]

As part of this milieu, it is no surprise to see our positivistic modellers of history of the nineteenth and twentieth-centuries overwhelmingly focused on ideal states and selection while viewing variation as error or ignoring it altogether. For example, Comte considered non-scientific variations in knowledge production as deviations from the true path which should be eliminated or selected-out. He predicted that "[t]he day is coming when all minds to which this habit [variability] of thought ... will find themselves shut out forever from any part in philosophy, on the ground that their only influence on thought must be evil, and alike anarchic and retrograde."[106] Comte clearly saw an

---

[104] Saul, J. R., On Equilibrium Toronto: Viking, 2001. Saul takes on the role of a secular priest in this treatise. Indeed, one must wonder if religious models, some being positivistic (for example, those forecasting the eventual conversion of the entire world), and some being negativistic (for example, those predicting conditions getting worse before the remedy appears), have provided the inspiration for the focus on equilibrium in secular philosophy.

[105] Fukuyama, F., The End of History and the Last Man New York: Free Press, 1992.

[106] Comte as quoted in Lenzer, G., Auguste Comte and positivism; the essential writings New York, Harper & Row, 1975, p.439. On another level Comte could not recognize how the human life-cycle itself might be purposeful. For example, he lamented that "[t]he slowness of our social development is no doubt partly

environment of truth forcing selection upon structures within, and did not consider the appearance of future variants. Similarly, Spencer's doctrine of 'energy equilibrium' required evolutionary convergence. Inefficient methods of knowledge production would be eliminated in favour of science as the most efficient.[107] Convinced of this, Spencer gave moral prescriptions designed to control or dampen variations on this path to truth. To Spencer, and indeed to all Utilitarians, variations that were deemed detrimental to 'social progress' would and should be eliminated as error.[108]

Although positivistic models in the twentieth century became more sophisticated, selection continued to be the *modus operandi* while variation continued to be neglected. Variation remained conspicuously missing even from so-called 'evolutionary' analyses of knowledge. For example, Bergson's *élan vital* – or creative force that drove knowledge to ever higher levels – was not a generator of variation, but rather as a pathfinder of thought that was superior to, or controlling of the scientific method.[109] Similarly, Merton's 'sentiments' were not seen as giving rise to new variations in thought of which

---

owing to the ... brevity of human life." (p.282) Yet from an evolutionary perspective, the brevity of the human life may be crucial for the growth of variation in perspective and subsequent social change. Consider the changes wrought by 'Young Turks' throughout the course of history.

[107] Richards, Darwin, p.291. Almost in homage to the first law of thermodynamics, Spencer defined evolution as "...the integration of matter and concomitant dissipation of motion; while dissolution is the absorption of motion and the concomitant disintegration of matter." To Spencer, any 'sensible' object, including ideas, would evolve by such a scheme (see Spencer, Structure, pp.59, 76-92).

[108] Spencer's focus on selection can also be seen in his catch-phrase *survival of the fittest*, which confirmed to others their own belief in Tennysonian selection as the prime operating principle of evolution. However, Spencer later in life confessed difficulty with selection as the only factor shaping evolution. In the 1890s he clashed with 'Ultra-Darwinists' over the role of selection, which he considered inadequate by itself to account for the complexity of life (see Richards, Darwin, p.293). Spencer was also reportedly 'staggered' when he discovered that according to the second law of thermodynamics, equilibrium essentially meant systems-death (see Bailey, p.58). It is interesting to note here that other models of this time were also struggling with the role of variation. Marx, although an admirer of Darwin's theory, concentrated almost exclusively on economic selection (as did Weber and Durkheim). However, later Marxists, like Gramsci, gave a more active role to individuals, allowing for some variation in response when subjected to economic selection. Here positivist models are themselves an excellent example of how ideas themselves evolve by the generation of variation on central themes.

[109] Bergson, although critical of Spencer for doing likewise, used first-law of thermodynamics energy analogies to describe evolution. For example, he claimed that evolution was analogous to a shell bursting

science was one, but rather as giving rise to one 'ideal' form of knowledge production. This can be seen in Merton's sociological models of scientific recognition and reward, where the action / reaction of the scientists to social pressures forced convergence (i.e. selection) upon the 'ideal norms' of science.[110] Furthermore, Merton's 'multiple discoveries' were not seen as variations similar in structure arising from different 'locations', but rather as redundancies that helped protect science from 'error'.[111]

Kuhn's model came closer to recognizing the presence of variation than any other had previously. In his study of the Copernican revolution he noted that prior to Copernicus there was a proliferation in different geocentric models – something that can be seen as growth in variation or a divergence in theoretical structures.[112] Kuhn again alluded to the proliferation of theories prior to a revolution in *Structure* and described the importance of 'individual variability' in paradigms as a promoter of revolution.[113] Yet Kuhn remained focused on selection. He considered the 'cause' of variation to be the anomaly – an entity external to the system itself. Also to Kuhn, this proliferation of variation was, except for the one true model, a miscellany of false truths or errors. Selection was also the guiding force behind both normal and revolutionary science in Kuhn's model. During normal science, theories within paradigms were conditioned or selected by one's worldview, while during revolutions one paradigm was eventually defeated or selected-out in favour of the other.

Being a mirror image of positivism, negativism also focused on selection while

---

into smaller fragments (see Bergson, p.109).

[110] Merton did not consider the norms to be on an evolutionary path.

[111] Merton, R.K., The Sociology of Science: Theoretical and Empirical Investigations Chicago: The University of Chicago Press, 1973, pp. 359-380. Merton argued that these cases of multiple discoveries in science were in fact routine.

[112] See Kuhn, T. S., The Copernican Revolution: Planetary Astronomy in the Development of Western Thought Cambridge: Harvard University Press, 1957.

viewing variations as 'error' or neglecting them altogether. Where positivists saw science's direction and content being shaped or selected by physical truth, negativists saw science's direction and content shaped or selected by philosophical or social truth. For example to Spengler, the variation known as 'Western culture' was seen as an error that would inevitably be eliminated in favour of some other culture more in tune with supposed *a priori* philosophical principles. Similarly Adorno and Horkheimer claimed in essence that Western scientific and mass culture was an error that would (and should) be eliminated and replaced with another culture more in-line with supposed *a priori* (and nostalgic) philosophical principles.[114] The same critique can be levelled at Heidegger and likeminded externalists who felt that science could be returned to the right path within a proper philosophical environment of selection. With respect to the proper social composition of science, Bernal felt that the unfavourable 'variation' of capitalistic science should be eliminated and replaced with proletariat science. None of the above realized that variations on scientific culture could (or should?) co-exist simultaneously. They were more concerned with the replacement or selection of unfavourable competitors and a return to the one true path.[115]

The concept of 'discourse' also brought with it a new sophistication to negativism. Yet this too was concerned with the conditioning effects of power on knowledge, and never with how new variations in thought could arise in the first place. For example, Canguilhem's Cartesian discourse described how knowledge was

---

[113] Kuhn, Structure, pp. 66-76; Also as quoted in Fuller, Thomas Kuhn, p.90.
[114] Similarly, their disgust with 'low' or mass culture in favor of 'high' culture failed to recognize the variation inherent in culture.
[115] This was concomitant with the prevailing twentieth century view of behaviour being conditioned solely by environment (a selection model). For example, Pavlov's experiment appeared to demonstrate that animal and human behaviour was a product of, or is selected by environmental inputs. But Pavlov ended his experiment prematurely. The dogs would more than likely have displayed other variations in behaviour

conditioned (selected) by the unconscious intellectual milieu in which it existed, but never how or why the new ideas of Descartes had arisen in the first place. Foucault was similarly focused on selection. Foucault's episteme, like Kuhn's paradigm, forced unconscious mass conformity upon its actors within periods of history that displayed variability when examined in detail.[116] After being critiqued for this, Foucault revised the episteme in his *Archaeology of Knowledge* so that they were not completely totalitarian.[117] But unable to recognize the 'exceptions' as variations within, he quietly dropped the notion of the episteme in his later works, preferring instead to focus on the more malleable concept of 'discourse'. Again Foucault's 'discourse' was concerned with the selection of thought as immersed in an environment of struggle for the control of meaning.

As described previously, the challenge of discontinuity revealed positivistic models with philosophical attachments to continuity. Yet these models still remained focused on selection to the exclusion of variation. Being primarily ahistorical, philosophers of science post 1966 adhered to selection models that were concerned with method – or epistemology – which makes science either 'good' or 'bad'.[118] Of course in

---

in response to the bell that would have continued to evolve (i.e. drooling *and* jumping up and down, etc.).

[116] Critics pointed out that not all members in a particular episteme thought or acted alike. For example, many historical figures of the Renaissance thought like those of the Classical episteme and vice-versa. See Merquior, J. G., Foucault London: Fontana, 1985, p.60 and Rosseau, G.S., "Whose Enlightenment? Not Man's: The case of Michel Foucault" Eighteenth century Studies, Volume 6, Issue 2 (Winter 1972-1973), 238-256. Kuhn's paradigm was also criticized for being too confining. For example, Hull criticized Kuhn for his 'monolithic paradigm' and grouped him in derogatively with 'social constructivists' (see Hull, Science and Selection, pp.43, 185-186).

[117] Foucault, M., *L'archeologie du savoir* Paris: Gallimard, 1969.

[118] Popper argued against teleological histories (see Popper, K.R., The Poverty of Historicism London: Routledge & K.Paul, 1957), but instead of finding alternative roles for history he dispensed with it altogether (i.e. it only had heuristic application). Hence evolutionary theory, essentially a historical theory, has often been criticized by philosophers. It has been criticized as tautological (i.e. the survivor's survival is caused by the traits possessed by the survivor). It has also been dismissed as deterministic (i.e. outcomes are pre-determined based on the traits possessed only by the survivors). However these arguments are typical of a focus on selection and only cast doubt on evolutionary causality, not evolutionary theory itself.

identifying how science should be (instead of how it really is?) variations of science that did not fit the philosophical mould were seen as error. The appearance of epistemological variations in the past or their continued appearance into the future was never considered. For example, Popper's falsification model was entirely focused on selection – scientific variants that resisted falsification would carry-on while others that were falsified or selected-out would perish. Hence Popper did not foresee any future increase in variation; rather he predicted only convergence. Similarly, Lakatos felt that progressive scientific laws could explain more with less, and hence there was no need of expansion and variation in core theory or in method. Feyerabend's model did allow room for variation in non-scientific theories, but being basically a combination of Popper's falsification and Lakatos' core / periphery, the 'proliferation' theories could be discarded once they had pointed the correct theory in the right direction by revealing phenomena that had been previously been ignored.

Toulmin deserves credit in criticizing so-called 'evolutionary' analyses of history for their failure to use a Darwinian mechanism of variation and selection. He criticized models such as Bergson's for being Lamarckian and having ideas 'morph' based on the intervention of active and mysterious life forces. Yet Toulmin remained attached to selection in tracking chains of survival causality to the exclusion of variation. Most tellingly, Toulmin came to see variation as impossible in science. To Toulmin, scientists did not think in random ways, and therefore an evolutionary model containing random variation could not be applied to scientific progress. Toulmin claimed that unlike biological evolution "...conceptual variation and intellectual selection [were] coupled" in

---

Due to ongoing variation in population, there is never one single path to survival and indeed the mere presence of variation in population suggests that the future may be unpredictable.

science.[119] In other words, the scientist was able to condition or select-out incorrect ideas before bringing them forth. Toulmin was also joined by Ruse in this claim, who felt that in biology the variants generated are totally random whereas "... variants of science are intentional."[120]

Selection continued to be the focus of philosophers interested in evolutionary models even in the latter half of the twentieth century. Hull admitted that he was interested in establishing an 'invisible hand' model that tended towards equilibrium.[121] According to Hull, differential distribution (i.e. variation) was merely an artefact of selection.[122] Hull's philosophical counterpart Philip Kitcher did promise variation a role in the growth of science, stating that it enabled a "...lineage to survive events in which monomorphic populations would have gone extinct".[123] However, Kitcher's logical model still reverted to seeing variations as errors, since scientists were 'logically deficient' if they did not return the correct output given identical input.[124]

Meanwhile negativistic modellers also remained attached to selection post 1966. Those who considered science and technology to be 'bad', such as Neil Postman, advocated a convergence on a societal structure that eliminated or limited these evils.

---

[119] Toulmin, pp.200-205, 338. By 'coupling' variation with selection, Toulmin reverted to Lamarckian morphing in his model despite criticizing others for doing likewise.
[120] Ruse, Evolutionary Naturalism, p.137. This 'problem' of the random variation will be revealed in the next chapter to be logically misconstrued.
[121] Hull, Science and Selection, pp.126-127, 140. Hull also admitted that such invisible hand models did not accord well with the history of science and that 'conceptual pluralism' was necessary, but remained far more interested in 'conceptual pruning'. Hence the title of his book as *Science and Selection*.
[122] Hull, Science and Selection, pp.109-111. 'Differential distribution' is Hull's own term for variation, which is created by subjecting replicators to greater or lesser selection than others. However, Hull tacitly admitted that variation can occur without selection by stating that drift was 'differential replication' in the absence of interaction.
[123] See Kitcher, pp.69-72.
[124] See Kitcher, pp.303-389. Such cooperation / competition models of science bear a close resemblance to predator / prey models in ecology. Like sociology, economics and political theory, the fledgling field of ecology was in the nineteenth and twentieth centuries, almost solely based on equilibrium with attention focusing on refining ahistorical cooperation / competition models using mathematics (see Kingsland, S. E.,

Never were scientific or technological behaviours seen as additional, or new variations on behaviour within larger culture. Quite tellingly, some negativist philosophers of science took their own discipline to task for containing variation. For example, Steve Fuller lamented the plurality of science studies, which he derogatorily called 'the philosophies of X'.[125] Instead of identifying the divergence in theories as an increase in variation typical of evolutionary growth he preferred instead to see it as something 'bad'. Other negativists continued their affiliation with selection in seeking historical causality. For example, Foucault continued to write histories that located the 'cause' of present attitudes on arbitrary shifts in the past.[126] He considered the simultaneous appearance of dialectical structures not to be variations, but rather as one having been a reaction to the 'other'. Likewise negativists interested in finding the 'cause' of present erroneous scientific attitudes of 'man versus nature' failed to recognize that such dichotomies might instead represent divergence in thought, or a growth in variation, appearing around the time of the Scientific Revolution. For example, Latour's histories focused on finding the 'cause' of the 'incorrect' trajectory of realism / relativism instead of seeing this as an evolutionary appearance of two structures out of one (i.e. bifurcation). Latour's cumulative and compounding collective was also seen as a phenomenon in need of greater reduction, instead of being recognized possibly as an entity growing in structural variation.

Even when positivists 'flipped' to negativism, they could still be seen as focusing on selection and ignoring variation. When scientific disciplines appeared to be diverging

---

Modeling Nature Chicago: The University of Chicago Press, 1985).
[125] Fuller, Thomas Kuhn, p. 13.
[126] For example, Foucault claimed in the 1970s that views of sexuality had taken an arbitrary evolutionary path to their present form , and therefore implied they were not to be trusted. See Foucault, Histoire de la

or increasing in complexity in the 1960s, many positivists considered this to be an increase in 'artificiality'. For example, Pitrim Sorokin (Merton's colleague) considered the proliferation of scientific disciplines to be 'bad'. He claimed that in its present state (in the 1960s) science had a "...multitude of different theories...fighting one another" and that "such...contradictions...fosters more and more uncertainty."[127] By the 1960s Koyré also felt that modern science had somehow 'lost its way' and was becoming more and more 'detached from reality'.[128] Even scientists joined in, such as biologist Gunther Stent who in his *The Coming of the Golden Age: A View to the End of Progress* (1969) predicted that the increasing dispersion of effort would result in the end of cumulative progress in science.[129] No where was it recognized that an increase in disciplines could be representative of evolutionary growth and variation.[130]

Surprisingly, in searching for selection causality both positivistic *and* negativistic modellers often showed affiliations with socio-biology.[131] For example, positivists Hull

---

sexualité.

[127] Sorokin as quoted in Merton, The Sociology of Science, p. 168.

[128] As mentioned in Prigogine, Stengers, Order, pp.32-36. Prigogine also noted that many philosophers and historians of science were becoming 'anti-science' (such as Heidegger) or 'pessimistic' (such as Arthur Koestler).

[129] Stent, G.S., The Coming of the Golden Age; a View of the End of Progress Garden City, N.Y: Natural History Press, 1969. Stent predicted that increasingly enormous efforts would be necessary to obtain even minor scientific advances (similar to Kuhn's 'final' normal science).

[130] Interestingly, some theorists of history have also lamented the divergence of structure in their own field. For example, the tendency of historians of science to focus their efforts on micro-histories has been criticized (see Cunningham, A., Williams, P., "De-centering the 'big picture': The Origins of Modern Science and the modern origins of science" British Journal for the History of Science (26), 1993, pp.407-432). However, this may indicate instead a field enjoying growth and variation as it evolves. See Novick, P., That Noble Dream Cambridge: Cambridge University Press, 1988, for an excellent example of how the historical profession has gone through multiple stages of variation and selection with time.

[131] The term 'socio-biology' is not meant here to give allegiance to any particular ideology, rather it is meant to describe how thinkers of all types have attributed human behaviours to biological causality. In common understanding, socio-biology is considered to have begun with Konrad Lorentz, who presented data claiming that aggressive male behaviour was the natural outcome of competitive evolution (see Lorenz, K., On Aggression London: Methuen & Co. Ltd., 1966). In the 1970s socio-biologists showed that there were links between cultural behaviours and evolutionary advantage (like the incest taboo) suggesting that 'nature' was the 'cause' of behaviour. This revealed opponents who felt that such claims justified cultural domination of one group over another, arguing instead that 'nurture' was the mode of behaviour.

and Ruse were inspired by Richard Dawkins's claim that the gene was the controller of all human behaviour, and Edward Wilson's claim that behaviours were conditioned by evolution.[132] More subtly, but no less significantly, negativistic modellers also often used socio-biological 'causes' for behaviours in their models.[133] Foucault's works made allusions to a 'bio-power' that shaped behaviour and suggested a motivator for discourse rooted deep in a primal *a priori*.[134] Some feminist analyses suggested there was a 'masculine' tendency to control nature that was also rooted deep in the body.[135] Likewise STS also showed an attachment to a base level collective of 'Machiavellian primates' where humans and non-humans interacted in a primitive struggle for existence.[136] This present critique is not to say that such socio-biological analyses are 'wrong'. Indeed

---

[132] See Dawkins, R., The Selfish Gene Oxford: Oxford University Press, 1976. See also Wilson, E.O., On Human Nature Cambridge MA: Harvard University Press, 1978. Hull was especially influenced by Dawkins's characterization of the 'meme' as a virus that implanted itself from mind to mind.

[133] Freud can be considered one of the first negativists to have used socio-biology in his analyses. Whether his claimed biological 'instincts' were true or not, Freud focused almost entirely on causes and remedies to 'bad' adult behaviour found in childhood experiences with biology and sexuality. It is no surprise that later variations on Freud continued in this tradition. For example, Carl Jung claimed many causes of behaviour could be located in primal evolutionary biology (see Jung, C.G., Contributions to Analytical Psychology New York: Harcourt, Brace and Co., 1928). Psychological historians also used biological analogies in formulating their models, such as Erik Erikson's view of history as a 'gigantic metabolism of individual life cycles' (see Erikson, E.H. Identity and the Life Cycle: Selected Papers New York: International Universities Press, 1959 or Erikson, E.H., Life History and the Historical Moment New York: Norton, 1975).

[134] Macey, p.171. Foucault's notion of 'bio-power' was interpreted by many to mean that society was in essence a 'superorganism'. Although Foucault would strongly disagree with these analogies, many confused his model with Pierre Teilhard de Chardin's superorganic model of the universe in which a 'geosphere' or the physical universe, was surrounded by a 'biosphere' or the living world, and a 'noosphere' or the world of the mind (see Teilhard de Chardin, P., Christianity and Evolution London: Collins, 1971). (Note that when combined these spheres would result in an 'omega' point at the end of time with the return of Christ. De Chardin's is clearly an asymptotic 'end of history' model which, unsurprisingly, finds its inspiration in religion).

[135] For example, the bodies of scientists became seen as discursive sites in the struggle to control knowledge. Steven Shapin claimed that Robert Boyle's self-control over desire for food and drink was a reflection of his attempt to control nature (see Shapin, S., "The Philosopher and the Chicken: On the Dietetics of Disembodied Knowledge" Science Incarnate: Historical Embodiments of Natural Knowledge, Edited by Christopher Lawrence and Steven Shapin, Chicago: University of Chicago Press, 1998, pp.21-51). Similarly, Newton's fierce protection of his theories can be seen seen in his intense protection of his own body, his hypochondria and fear of women (see Iliffe, R., "Isaac Newton: Lucatello Professor of Mathematics" Science Incarnate: Historical Embodiments of Natural Knowledge, Edited by Christopher Lawrence and Steven Shapin, Chicago: University of Chicago Press, 1998, pp.121-155).

[136] Latour, Pandora's Hope, pp. 195-196.

there is much evidence that biological imperatives guide much social behaviour. Rather the critique here is that socio-biology as such is focused on selection only. These mechanisms were always seen as 'controllers' of behaviour. No where was it recognized that variation in behaviour is both necessary and ongoing in order for it to evolve – that the norms are constantly changing in addition to their being conditioned.[137]

The focus on selection has also resulted in an unwarranted rejection of evolutionary analogies by negativists. Selection facilitated the identification of continuous causal chains, and was first used to great extent by early positivist models bearing the 'evolutionary' moniker. As such, negativists bought-in to seeing evolution as continuous in writing their counter-histories. For example, Spengler denied his model had any connection with evolution whatsoever, and considered Darwinism to be a 'false theory' perhaps in an effort to distance himself from positivists.[138] Also the other unfortunate moniker of 'Social Darwinism' to describe selection within and among societies discredited evolutionary theory in the eyes of negativists.[139] Negativists, lacking a tradition of using the evolutionary analogy, unfortunately dispensed with a model able to describe discontinuous change as well as it could continuity.

---

[137] This critique highlights the tendency authors using socio-biological arguments to focus on cause and selection to the neglect of recurrent variation, biological or otherwise. The classic example is the equating of high IQ with superiority without realizing that the norms which these tests are referenced to are constantly changing (see for example Rushton, P. J., Race, evolution and behavior: a life history perspective New Brunswick, N.J.: Transaction Publishers, 1997). Another example is the popular fear of genetic engineering as a new form of eugenics, without realizing that it will only be successful if it can increase variation in population rather than decrease it. (Sexual reproduction, an evolution of asexual reproduction, has increased the pace of biological evolution by reducing the time to generate variation allowing species, including our own to make 'course-corrections' in rapid succession when presented with environmental challenges).

[138] Spengler, p.72.

[139] See Trigger, B.G., Sociocultural Evolution: Calculation and Contingency Malden, Mass.: Blackwell Publishers, 1998, p.5. The unfortunate misnomer 'Social Darwinism' is a result of the characterization of Darwinism by positivists as an exclusive selection model of political or cultural superiority. Unfortunately, much of the debate surrounding evolutionary theory as applied to culture has been consumed by apologists claiming that evolution can not be equated with progress or superiority (see Naccache, A.F.H., "A Brief

This assumption of evolution-as-continuity even prevailed into the later half of the twentieth century. This was clearly demonstrated by the punctuated equilibria 'controversy' of the 1970s in which Eldredge and Gould essentially stated that evolutionary change in species was abrupt.[140] The claim was considered to be revolutionary at the time, and even thought to challenge to the whole concept of evolution. But in retrospect punctuated equilibria never challenged Darwinian evolution – the basic mechanism of variation and selection was left untouched. The only thing this controversy revealed was how ingrained the assumption was in evolution-as-continuity. In actuality, the difference between a slow or sudden change is a mere issue of scale. *Evolution is as discontinuous as it is continuous.*[141] Indeed, with complete continuity nothing would change, while with complete discontinuity all change would be random.

In conclusion, both positivistic and negativistic modellers have focused on selection to the detriment of variation. Yet these views in themselves are not 'incorrect', they are merely incomplete. The task remains to add variation to existing selection models and this is the focus of the next chapter.

History of Evolution", History and Theory Vol.38, 1999, p.16).

[140] Eldredge, N., Gould, S., "Punctuated Equilibria: an Alternative to Phyletic Gradualism" Models in Paleobiology Edited by T. Schopf, San Francisco: Freeman, Cooper and Co., 1972. Refer also to Eldredge, N., Time Frames: the Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibria New York: Simon and Schuster, 1985. Punctuated equilibria contradicted uniformitarian views that had persisted since the nineteenth century. But on a theoretical level punctuated equilibria is really nothing new. Cuvier (a French biologist of the eighteenth century) can be seen as the first proponent of punctuated equilibria in claiming that species were immutable and could only be destroyed or created by God. Darwin also realized that change can at times be sudden in individuals and in populations. As Ruse argued, the punctuated equilibria controversy might have been 'pumped-up' in the interest of self-promotion (see Ruse, Taking Darwin Seriously). Gould kept modifying this model throughout the rest of his career to include both macro and micro levels and a variety of mechanisms for selection (see Gould, S.J., The Structure of Evolutionary Theory Cambridge MA: The Belknap Press, 2002). Interestingly, Gould never quite made the leap to seeing the evolution of knowledge to work by the same principles. Instead he claimed that evolutionary theory had a Lakatosian 'hard-core' surrounded by malleable tenants subjected to Popperian falsification (p.6). Kuhn is mentioned once, but only to answer charges that the term 'punctuated' was copied from an early edition of *Structure* (p.967) which he admitted to reading in 1962 (see Horgan, p.122).

[141] This ambiguity is reflected in popular culture, where 'evolution' is at times meant to represent slow continuous progress, while at other times is meant to represent 'revolutionary' progress.

Chapter Three ***A fractal evolutionary model of history incorporating variation***

Critiquing without offering an alternative viewpoint is mere pedantry. In this chapter a unique fractal evolutionary model is presented.[142] Evidence indicates that variation is useful in order to account for an unknown future. The *fractum* is formulated here as an entity similar to the paradigm or episteme, yet with variability inherent, allowing the thinkers within to hold ideas to a greater or lesser extent on common themes. The fractum is also separated into distinct phases of variation and selection, essentially combining traditional internalism with externalism. Norms still apply within the scientific fractum, but these too are in transition. With time the fractum grows in structural variation until a revolutionary state is reached, defined here as the point of maximum variation instead of an event arising out of some particular 'cause'. By describing fractal micro and macrocosms, resonances or anti-resonances with respect to their phases can also be seen occurring simultaneously, explaining cases of 'rise within fall' in history. Also the fractum is directional due to entropic energy flow. Entropy also means that the mere presence of a fractum in an environment alters that environment irreversibly. These features combined allow the fractum to enhance the explanatory power of the paradigm or episteme.

To begin, why should variation be considered useful? Could not history be merely the interplay of 'internal' and 'external' forces of varying degree and direction acting upon Newtonian or Epicurean bodies?[143] Perhaps. But such reliance on stark causality is weak when it comes to describing history. Chaos theorists have shown that

[142] This model should be considered 'approximate' instead of 'ideal' because it is meant to describe the evolution of science as it is, rather than how it should be.
[143] Indeed, combined internalist and externalist points of view currently prevail in contemporary histories of science (see Henry, J., The Scientific Revolution and the Origins of Modern Science New York: St.

even simple physical systems with supposedly known initial conditions can at times display unpredictable fluctuations away from the norm.[144]

Then why should we look to evolutionary theory? Evolutionary theory is promising in that there are undeniable parallels between biological and cultural evolutions. The diverse and continually expanding structures of both biological and cultural 'species' suggests a larger pattern at work.[145] For example, consider how languages and dialects, grouped into families, at times grow and then contract with time, all the while shifting in structure.[146] Take also for example, the rise and fall of economic entities both small and large with time, inflating and then deflating into structures different than what they were initially.[147] Even art and architecture have been characterized by the appearance of certain 'schools' or trends that rise and fall over time.

In addition to this, there is evidence that the mechanism of variation is present in systems other than species evolution. For example, the brain is known to develop according to variation and selection principles over numerous stages from birth to death.[148] The brain undergoes periods of 'synaptic blooming' in which great variation in structure is produced. These synapses are then selected based on 'environmental'

Martin's Press, 1997, p.6).

[144] The rapid compounding of error leading to instability is the main phenomenon examined by 'chaos' theorists (see Smith, P., Explaining Chaos Cambridge: Cambridge University Press, 1998, p.18). Henri Poincaré had earlier discovered in his examinations of three-body systems (see Peters, p.135).

[145] See the similar claims made by Cziko, G., Without Miracles: Universal Selection Theory and the Second Darwinian Revolution Cambridge MA: The MIT Press, 1995.

[146] Language also displays variation within existing vocabulary and grammar that allows for descriptions of things or events that have not yet occurred (see Pinker, S., The Language Instinct New York: William Morrow and Company Inc., 1994).

[147] Economies also display variation daily as stock markets fluctuate, with prices displaying variation among a selective 'environment' of buyers.

[148] Edelman, G.M., Tononi, G., A Universe of Consciousness: How Matter becomes Imagination New York: Basic Books, 2000, pp.47, 82-85; Cziko, G., The Things We Do, p.190. On a small scale the variability in each brain is enormous, with the synaptic connections between neurons evolving through stages of 'blooming', or the generation of variation, and 'selection' of these connections based on environmental input. There are approximately 1 billion synapses in the human brain per gene in the

sensory input. A person's brain that is 'blooming' during times of great change may change in structure and give rise to new perspectives. Numerous people 'blooming' in resonance may appear in larger culture as a collection of changing and blooming societal perspectives. This presence of variation in the brain may indicate that the evolution of species may be only the first of such systems discovered using this mechanism.[149]

Yet what use or purpose is there for variation? Variation is strength in an evolutionary system. It allows an entity to 'change course' when presented with unforeseen changes to its environment. With respect to culture, the appearance of multiple perspectives on both small and large scales allows for greater insight than just one perspective alone. For example, the appearance of realism and relativism in the nineteenth century should not be seen as something 'bad', but rather as something that enabled humanity to approach problems from two different perspectives. Hence evolution by variation is purposeful, not in the sense of *telos* imposed by traditional models, but rather as a protective function to account for an unknown future.[150] Indeed, the very existence of evolutionary systems incorporating variation suggests that the future is unpredictable – this being the very opposite of teleological determinism.

Therefore, with variation being taken as axiomatic, how could it best be incorporated into existing selection models such as Kuhn's or Foucault's? Note that the

---

genome (see Ehrlich, P., Human Natures, New York: Penguin Books, 2000, pp. 122-124), suggesting that both nature and nurture play a role in the brain's composition.

[149] The human immune system can also be seen as an evolutionary system that uses variation (see Cziko, G., The Things We Do Cambridge MA: The MIT Press, 2000, p.180). When exposed to a new foreign antigen, the immune system produces an enormous variation of antibodies which are then 'selected' by being able to combine with the antigen. Also A.I. (artificial intelligence) investigators have recently realized that machines using trial and error processes of variation and selection are more powerful than those that come with a pre-programmed set of instructions. Perhaps a truer test of A.I. would not be a Turing test (mimicry), but rather the ability of the machine to generate variation in 'thought' inherently.

[150] Cziko, Without Miracles, p.75. Cziko sees variation and selection as a feedback loop, where cause, or input, can be conditioned over time by altering perceptions of success or failure with respect to effect, or output.

critique given above is not with selection models or equilibrium theories *per se*. There are moments in history when structure is forced to converge. There are moments in history where a balance, stability or equilibrium is observed. However, equilibrium is only ever a temporary situation.[151] Historians need a model in which history is allowed to move away from equilibrium, a model that allows for the descriptions of structural divergence in addition to convergence.[152] Hence variation should be added to selection models *as a movement away from equilibrium.*

Introducing the fractum

Although critiqued for their focus on selection, Kuhn and Foucault's gestalt models make the ideal starting point for a new evolutionary model. The paradigm and episteme were entities bounded in structure and time – critical concepts for the formation of any evolutionary model. Such an entity will be termed henceforth here a '*fractum*' (for reasons which will become clearer later).[153] As seen in **Figure 3-1**, the one-dimensional fractum can be visualized as a quadrilateral stretched-out on structural and temporal Cartesian axes.

---

[151] The term 'equilibrium is only a temporary occurrence' is borrowed from Prigogine, Strengers, Order out of Chaos, p.140.

[152] It should be mentioned here that some theorists did attempt to examine social systems as 'chaotic', hence reducing their reliance on equilibrium. But rarely was history referred to, even if just for heuristic effect. Like Ernst Haeckel had difficulty in describing the entirety of evolutionary biology from observing foetal stages, these chaos theorists had difficulty in relating cultural evolution to the chaotic behaviour of a pendulum (see for example the compendium of 'evolutionary' social analyses found in The Evolutionary vision: toward a unifying paradigm of physical, biological, and sociocultural evolution, edited by Erich Jantsch, Boulder, Colo.: Westview Press, 1981). For those who did reference history, they often still displayed an equilibrium mindset. For example, Immanuel Wallerstein used an 'energy balance' approach to describe the appearance of capitalism (i.e. it was caused by absorbing smaller systems) and its inevitable future demise (as an error) in favour of some form of egalitarianism (see Wallerstein, I., Unthinking Social Science Philadelphia: Temple University Press, 2001). (It is interesting to note that Wallerstein, similar to Steve Fuller, also argued against the splitting of social science into various sub-disciplines without realizing that this may be indicative of evolutionary growth and variation).

[153] Kuhn's definition of the paradigm was criticized for being open-ended, but this has allowed its meaning

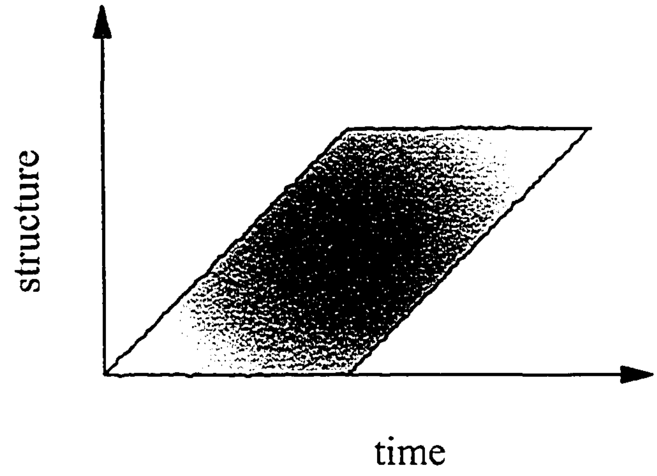

Figure 3-1. The one-dimensional evolutionary fractum. Like the paradigm or episteme, it represents an entity bounded in structure and time with discrete starting and ending points.

The structural axis can be seen as Hegel's dialectical scale of opposites.[154] In the critique, it was pointed out that positivistic and negativistic modellers focused only on selection towards equilibrium giving the impression that all actors within a paradigm or episteme were forced to think only in one way. However, aside from its two equilibrium points, structure within the fractum displays at all times variation. Hence the actors within the fractum, while still having their thoughts constrained within boundaries, are able to hold variations to a greater or lesser degree on common themes within. The 'monolithic' problem is therefore is solved (albeit by paradox) and strict uniformity in thought is no longer demanded.

to evolve and its use in many fields besides historical theory. Likewise the fractum's definition is left open-ended in similar hopes of doing likewise.

[154] This formulation can be considered one-dimensional in that, for the sake of simplicity, only one structural dimension is considered here. However, multiple dimensions would probably give a more accurate picture (i.e. a 1D model uses a dialectic, a 2D model uses two dialectics (a 'trialectic'?) and so on). Ultimately, the fractum should be represented by an expanding and contracting sphere encompassing a multiple number of dialectics (an 'omnilectic'?) surrounding multiple points in time.

The phases of the fractum

By adding variation as an equal and opposite 'phase', the fractum is separated into two distinct phases of variation and selection. These essentially become phases of 'internalism' and 'externalism'. As seen in Figure 3-2, as the fractum begins to grow from its start point, or starting equilibrium, an increase in structural variation can be observed – this being the movement away from equilibrium.[155] This generation of the variation is internal and takes place with little or reference to 'external' pressures. It is important here to state that in the fractal model *variation is inherent to the system itself* and not 'caused' by any external forces. Indeed in biological evolution, increases in variation are seen not when selective pressures are strong but rather when they are weak.[156] However, at some point in time variation in structure reaches a maximum and growth can no longer be sustained. This is the revolution, and after this event selection begins. If variation is characterized by expansion and growth, then selection is characterized by convergence and decline – this being the movement towards equilibrium. During this phase, variations are selected-out based on the 'external' pressures exerted by the environment. Here the environment acts like Latour's collective, exerting a combination of so-called natural and artificial pressures. As time proceeds, structure converges until it reaches an end point, or the ending equilibrium. Hence the 'phases' of the fractum allows for descriptions of internalism and externalism within the same model.

[155] As described in Chapter Two, the 'random' variant is actually constrained within 'species' boundaries.
[156] Brooks, D.R., Wiley, E.O., Evolution as Entropy Chicago: The University of Chicago Press, 1988, p.19.

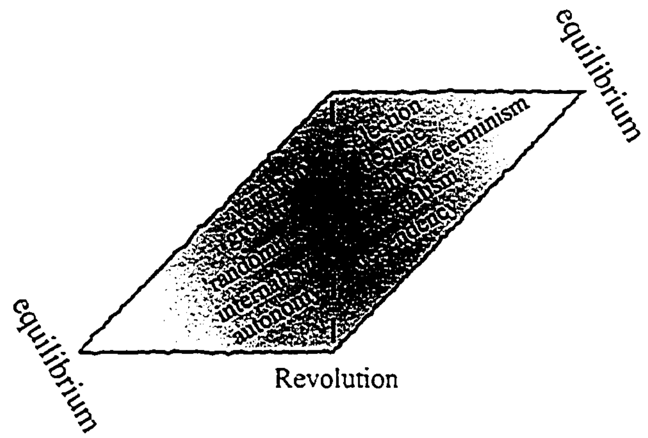

Figure 3-2. The phases of the fractum. The fractum can be visualized as containing two distinct phases of variation and selection, separated by the revolution, which is the point of maximum variation.

The population in the fractum

Inherent variability allows the fractum to contain within it a *population* of variations at any one time. One should expect that, as with other populations, the fractum's population should exhibit some kind of 'rise and fall' trend. Also, in large populations it is typical to see a Gaussian or *normal* frequency distribution with respect to variation in structure.

To start, how is this population containing variation generated within the fractum? Unlike the mechanism of recombinant DNA in biological evolution, the exact mechanism of variation in cultural systems is not yet known. Some have speculated that human societies generate variation within themselves by the 'mutation' or recombination of practices such as the 'errors' generated in learning or transmission.[157] However, such

[157] For example after the initial appearance of wage labour capitalism, it went on to display slightly different variations in different societies and cultures where it was not duplicated in exactly the same way

speculations will be set aside for now. As Darwin has shown, the formulation of an evolutionary model is still possible in the absence of an exact mechanism for variation.

What is known is that evolutionary variation is generally the result of repeated bifurcation, or the appearance of two structures out of one (i.e. one species 'branching' off of the other).[158] Hence, here bifurcations will be the mechanism for generating variation in the fractum as shown in Figure 3-3.

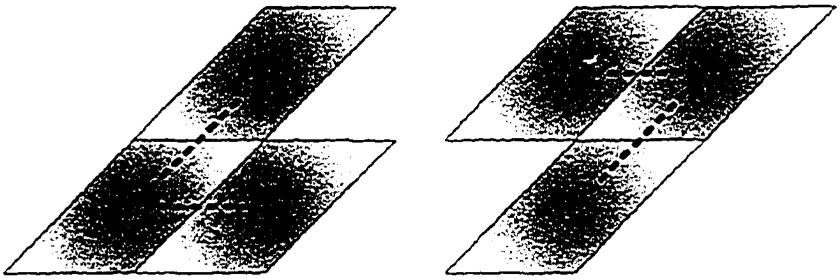

Figure 3-3. Bifurcation and reverse bifurcation processes. Bifurcation generates variation in structure while reverse bifurcation does the opposite. Note the similarity with Latour's schematic in Figure 1-5.

Also shown in Figure 3-3 is the opposite process of reverse bifurcation. With reverse bifurcation there is instead the convergence of two structures into one. Reverse bifurcation does not necessarily mean elimination of one in favour of the other –

(see Runciman, W.G., Confessions of a Reluctant Theorist, New York: Harvester Wheatsheaf, 1989, p.32). See also the claim made that ideas of labour and capitalism took on manifestly different forms in England and Germany due to the unique cultural setting of each (see Biernacki, R., The Fabrication of Labor Berkeley: University of California Press, 1995. One can speculate that variation in science could be generated similarly. Indeed, examinations of the scientific method have revealed that experiments cannot be replicated in exactly the same way twice. This phenomenon has been called experimenter's regress (see Collins, H., Changing Order: Replication and Induction in Scientific Practice London: Sage, 1985 and more recently Collins, H., Pinch, T., The Golem: What You Should Know about Science Cambridge: Cambridge University Press, 1998).

[158] Bifurcations are prevalent in many physical and biological processes (see Prigogine, Stengers, Order, pp.170-176). Indeed, the evolutionary bifurcation of the brain into two separate lobes right and left, may have allowed for changes to occur rapidly and simultaneously in human perspective (i.e. Gestalt).

cooperation or symbiosis can be as equally effective. Hence reverse bifurcation should be seen as the consolidation of two structures into one.

When bifurcation processes are repeated multiple times an enormous amount of structural variation can be generated or eliminated over time. **Figure 3-4** shows a fractum in which structural variation is generated by the repeated bifurcation of smaller fracta. This overlap within results in a population. This variation reaches a maximum at its midpoint, after which structural variation is decreased by the repeated reverse bifurcation of smaller fracta.

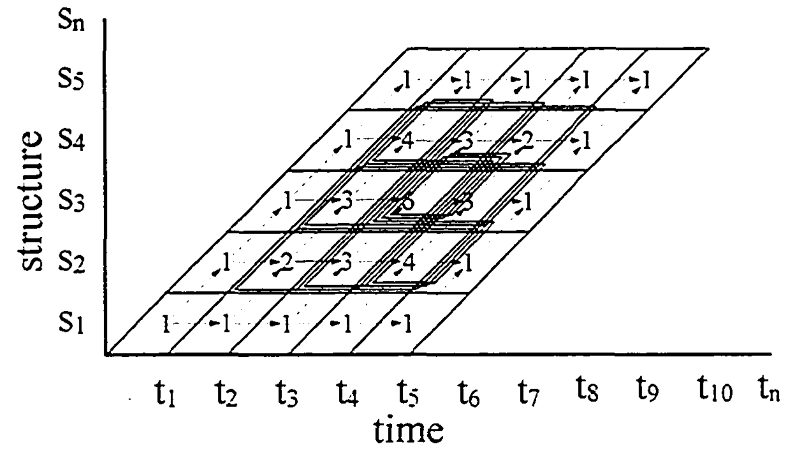

Figure 3-4. An example of a 5 x 5 fractum. Repeated bifurcation results in an increase in variation from time points t_1 to t_5, while repeated reverse bifurcation results in convergence in structure from time points t_5 to t_9. 'Overlapping' fracta can be observed during bifurcation and also during reverse bifurcation.

The numerical population of variations within the fractum can be described graphically. The fractum can be recognized in history by a *cumulative* exponential growth and decline trend as seen in **Figure 3-5**. The generation of variation via bifurcation results in growth in population – this is the so-called 'rise'. The reduction in variation, or selection, results in decline in population – this is the so-called 'fall'. In the fractum these increases and decreases in population are, as a result of the nature of bifurcation, exponential.[159] Hence a sense of accelerating change indicates the presence of a fractum undergoing exponential variation and expansion, while a sense of decelerating change indicates a fractum undergoing exponential selection and convergence.

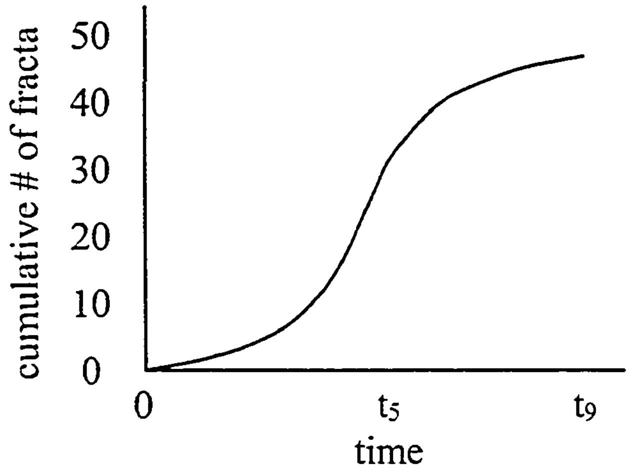

Figure 3-5. Cumulative growth and stagnation in the fractum. The 'cumulative # of fracta' and time points t_1 to t_9 again correlate with those in Figure 3-4. This trend represents the 'rise and fall' of population within the fractum.

Although exceedingly difficult to quantify because of its constantly changing structure, the potential does exist to recognize this trend in history. The 'rise and fall' trend of the fractum closely resembles the 'logistic' curve used to describe growth and stagnation in populations. The exponential growth and decline of populations had been

[159] For example, two bifurcations of one structure into four results in seven cumulative structures (1 + 2 + 4). Two reverse bifurcations of four structures into one also results in seven cumulative structures (4 + 2 + 1). Many trends describing cyclical rise and fall can be converted to this cumulative trend by simply converting the ordinate axis to *cumulative* values over a standard unit of time.

known of since the time of Malthus, but its logistic formulation was only 'discovered' recently when forecasters began quantifying population trends in the 1920s.[160] Since then, the logistic curve has also been used to describe, and to some extent predict, growth and stagnation limits in product life-cycles.[161] More remarkable still is that logistic curves also appear in quantifiable cultural histories.[162] Striking evidence of logistic curves in history can be seen, for example, in the phenomenon of witch burnings throughout Europe from the sixteenth to seventeenth centuries as shown in **Figure 3-6.**

---

[160] Kingsland, p.69, 84. The logistic curve was first defined by Pierre-Francois Verhulst in 1845 but remained in obscurity. In the 1920s it was 'rediscovered' and popularized by Raymond Pearl and Lowell Reed to describe population growth and stagnation in nations. Around the same time, Alfred Lotka also derived this curve by an independent method and used it to describe population ecologies. Interesting to note is that the logistic curve has also been associated with bifurcation equations (see Peters, p.122).
[161] See Mager, p.203 and Mensch, G., Stalemate in Technology Cambridge MA: Ballinger Publishing, 1979 for descriptions as to how logistic curves are used to track typical product life-cycles.
[162] This trend also shows up with technologies. For example, the appearance of Universities in Europe from the eleventh century onwards can be described by logistic curves (see Price, p.25). Also the appearance of German Panther tanks during World War Two followed a logistic curve (based on data given by Hart, S., Hart, R., German Tanks of World War II London: Brown Books, 1998, p.161).

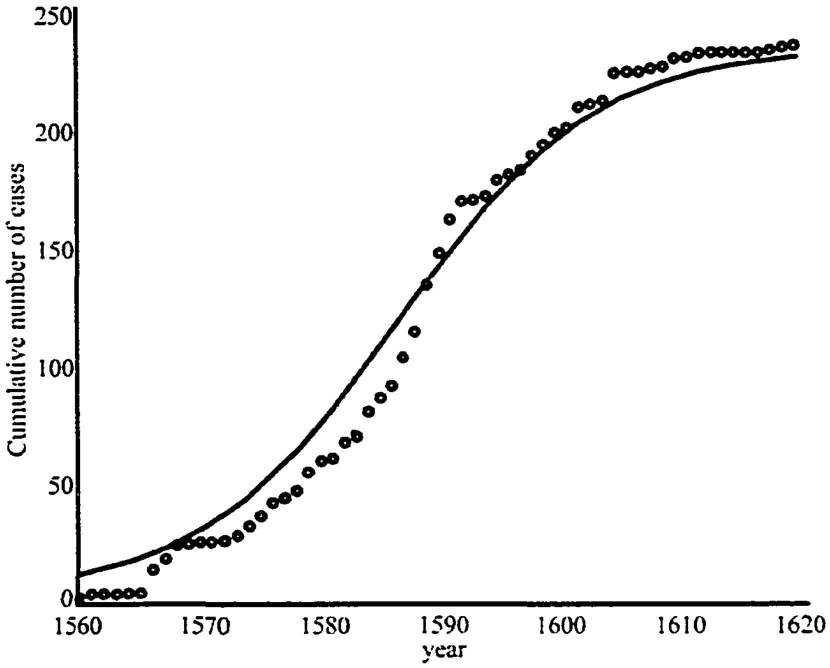

Figure 3-6. Cumulative witch burnings follow a logistic trend.[163] **Note the similarity of this trend with the fractum's 'rise and fall' as shown in Figure 3-5.**

Although not expressly indicated, Latour also observed what could be considered a 'rise and fall' trend when describing the triumph of one scientific enterprise over another (i.e. Pasteur over Pouchet) as seen in Figure 3-7. The appearance of these 'rise and fall' trends in history suggests that historians may find the fractal model applicable for describing the growth and decline in populations of scientific ideas.

[163] Traced from the graph given in Pena, A., "On the Role of Mathematical Biology in Contemporary Historiography" History and Theory Vol.38, 1999, p.113.

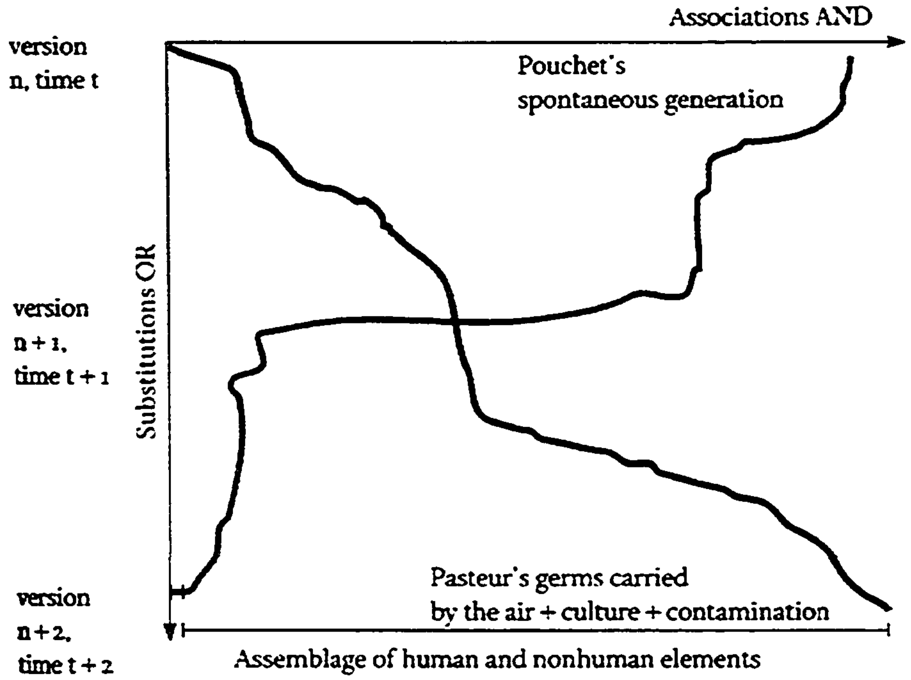

Figure 3-7. Latour's scientific culmination.[164] Rotate this graph counter clockwise by 90 degrees and note that Pasteur's trend resembles a logistic curve. Rotate clockwise by 90 degrees and note that Pouchet's trend also resembles a logistic curve if the structural axis 'the assemblage of human and non-human elements' is inverted. Note that Latour's curves are not based on actual data, but rather a 'feel' for the history.

The identification of a logistic curve in history often leads one to speculate on its future direction. After all, rise should be followed by fall. However, again because the population and structure of that population is changing in the fractum it is difficult to use the logistic curve to predict.[165] The start point is difficult to identify since the population here is small – this is the problem of the 'missing link' in biological evolution. The inflection point, and to a greater extent the end point, are also difficult to define since

[164] From Latour, Pandora's Hope, p.159.

[165] See Price, pp.24, 31, 41-61 for an alternate discussion of the problems associated with prediction. However note that Price at times appears to be confused between linear and cumulative trends. Oscillations

structures here are different than what they were originally. Hence prediction by the logistic curve is limited when undertaken with purely empirical analysis. Perhaps it is better to see the logistic curve capable of predicting a region of structural possibility similar to how Heisenberg's indeterminacy can be used to predict a spatial region of probability for a particle. Prediction is only possible within a structural range and not as a single solution.[166]

The logistic curve represents the fractum's rise and fall in numerical population. But perhaps the more important feature described by the fractum's population is its *normalcy*. Due to overlapping variations, the fractum has a frequency distribution at all times closely resembling a normal curve. This means that most variations are centered about some point of normalcy, while less numerous but more radical variants are found on its fringes. Hence a 'normal' curve can be drawn through the fractum at any time describing the frequency of variations within.

The normal curve is generated by different bifurcations overlapping with each other in structure. With respect to the history of science, the overlap of variations during bifurcation can be seen as cases of multiple discoveries.[167] For example, simultaneous discoveries such as Newton and Leibniz's independent formulation of calculus or Darwin and Wallace's independent formulation of biological evolution, represent overlapping variations arising from different structural 'locations'. The population also displays

---

should never be seen on cumulative curves.

[166] Indeed, prediction can become an evolving fractum in of itself. Prediction still requires processes of variation and selection since complete certainty can never be achieved. Prediction, as an idea, also changes the environment in which it was formed irreversibly. For example, if all could predict a stock market rise then all would buy, forcing a premature and unexpected 'rise'. If all could predict a fall then all would sell, forcing a premature and unexpected 'fall'. New models would have to be developed to predict how the prediction would affect the market and so on.

[167] The eye is an example of a structural variation arising from different and independent 'locations' within evolutionary biology.

overlap during decline. Variations that are the result of reverse bifurcation overlapping structurally can be seen as cases of 'fusion' in the history of science.[168] For example, the development of quantum mechanics can be seen as a fusion of various nuclear theories under a single unifying concept.

But lest one think that normalcy requires science to adhere to certain 'ideals, it should be pointed out that the center of normalcy is constantly changing. As such norms are only temporary. As seen in **Figure 3-8**, the fractum's shifting normalcy can be visualized by plotting its frequency of structure with time. At some initial time the structural distribution is narrow with little or no variation. As variation (and population) increases the structural range of the fractum, the frequency distribution widens and flattens, dragging with it the center of normalcy. During the revolution structural frequency is at its widest, but in its aftermath the range decreases. Structural range continues to decrease until there is little or no variation, again dragging with it the center of normalcy. Hence, norms for science may be applicable, but since they are constantly transient they can no longer be considered 'ideal'.

---

[168] In the history of science this can be represented by the 'fusion' of several different ideas to make a new one (see Golinski, p.16). Again in evolutionary biology, the eye is an example of fusion of different components to make up a single structure.

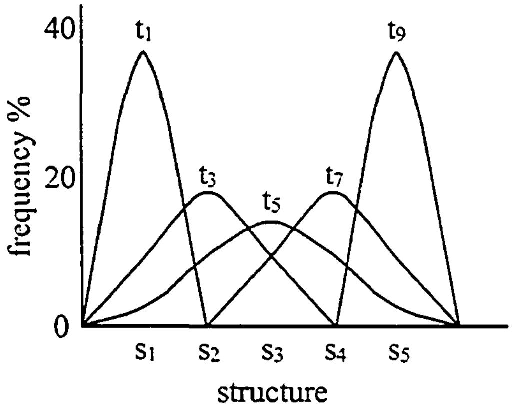

Figure 3-8. The fractum's frequency distribution with time.[169] The time points and structures here correlate with those from Figure 3-4. Initially the structure within the fractum is concentrated. As variation increases the frequency distributions flattens and there is a shift in the center of normalcy. Time point t_5 represents the revolution, or the time of maximum variation, after which the entity again converges on a structure different than what it was originally.

Remarkably, this shifting normalcy with respect to structural frequency is also known to occur in biological evolution. For example, as seen in Figure 3-9 the brains of Ungulates and Carnivores have undergone structural variation with time, and as such the center of 'normalcy' has shifted so that larger brain sizes are now more common than they were in the past.

[169] Note that a minimum time and structural level must be set in order to view a plot like this. In this case the 38% peak structural frequency is derived from setting a minimum at two fractal levels below that observed in Figure 3-4.

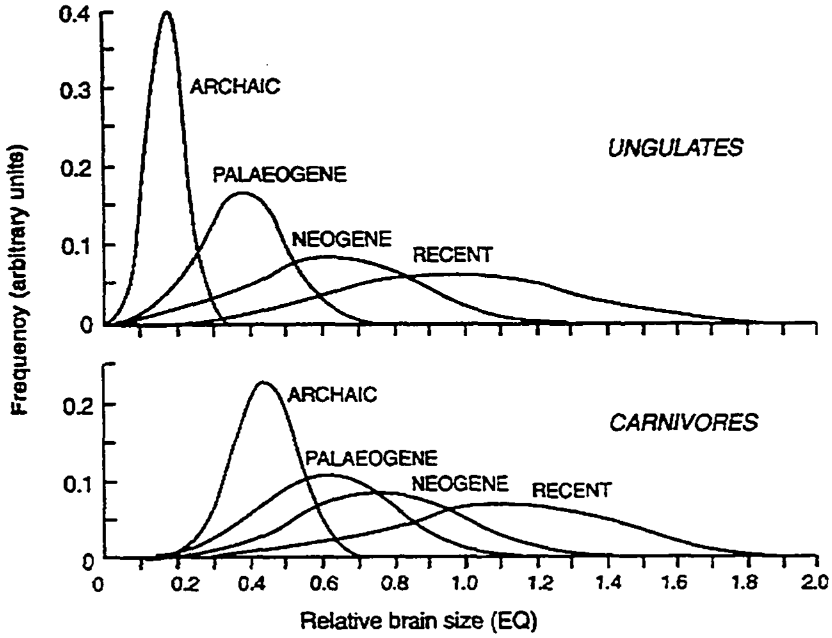

Figure 3-9. Frequency distribution with time as observed in biological evolution.[170] The normal brain size of Ungulates and Carnivores has widened and shifted as variation in structure within the species has grown. Note the similarity of the results with the fractum's frequency distribution in Figure 3-8.

The trends shown in Figure 3-9 suggest that biological structures also increase in variation up to some maximum point. However this maximum is typically seen in evolutionary biology as a 'washing-out' of a structure to the point of being nondescript, instead of leading to a potential bifurcation, or 'revolution'.[171] However, the fractal model also considers the reverse and symmetrical process to occur. Instead of becoming nondescript, the 'species' instead converges on a structure different than the one on which it started.

[170] From Gould, S.J., "An Operational Notion of Directionality" The Philosophy of Biology, edited by David L. Hull and Michael Ruse, Oxford: Oxford University Press, 1998.

[171] Genetic frequency is also known to display a 'collapsing' normal curve in populations as it becomes 'washed-out' in successive generations (see Gluesing, G.R., Abdel-Hameed, F., "Impact of Neutral Mutations on Evolution" Evolutionary Models and Studies in Human Diversity, Edited by Sol Tax,

The concept of shifting normalcy also solves the 'problem' of the random variation. As described previously, Toulmin and Ruse argued that the 'random' variation renders the evolutionary analogy inapplicable to science because scientific thoughts are not random. However, normalcy helps to explain why this 'problem' is misconstrued. By definition a variant must be based on some sort of normal archetype thus rendering it random *only within a set of boundaries.* In other words variations must arise from a continuum and not from out of a vacuum, with the region of possibility being constrained by the species boundaries. For example, dogs generate different variants of dogs, but never variants of cats. This allows a structure that has worked in the past to be reasonably carried into the future. In the fractal model the normal curve represents at all times the 'archaeological plane' which forms the basis for further variation. In the history of science the archaeological plane can be seen as the 'tacit' knowledge passed down from master to apprentice.[172] To paraphrase Newton, all scientists 'stand on the shoulders' of other scientists.

The fractal revolution

As in Kuhn or Foucault's models, the concept of 'revolution' is also important in the fractal model. However, instead of the revolution or epistemic shift being 'caused' by anomalies, the revolution in the fractum is simply defined as the point of maximum variation marking the transition from variation to selection. That the revolution is one discrete point in time provides an advantage over models such as Kuhn's, where the 'revolution' was confusingly taken to mean the actual event *and* its aftermath.

Chicago: Mouton Publishers, 1978, p.142).
[172] Polanyi, M., Personal Knowledge Chicago: University of Chicago Press, 1958.

To reiterate, the revolution in the fractum marks the transition from 'randomness' (i.e. internalism) to causality (i.e. externalism) and as such 'cause' can not be ascribed to the revolution in a traditional sense. However, this aspect of the fractal model can be liberating for the historian, allowing each revolution to be analysed in its own right instead of having to ascribe to it certain 'factors' which lead to it.

As in Kuhn or Foucault's models, there is also a major discontinuity in the fractal revolution. The fractum's structure is continuous during growth and the generation of variation since it contains at all times elements of the original structure. Likewise during convergence and selection the fractum's structure is continuous in that it contains at all times elements of the final structure. However as seen in **Figure 3-10** discontinuity occurs at the revolution. This is the point where there is a break in structure with respect to *both* the original and final structures. For example, after the revolution, the fractum no longer contains all elements of the original structure and thus becomes discontinuous with the past. Likewise, prior to the revolution the structure does not contain all elements of the final structure and is thus discontinuous with the future. This agrees with the sense given by Kuhn that during revolutions, some power of explanation is lost in addition to being gained.

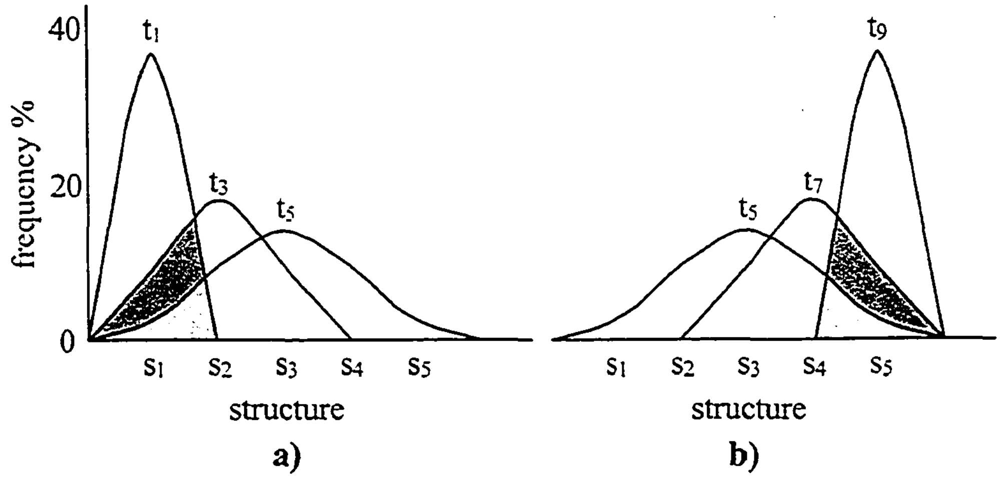

Figure 3-10. Continuity and discontinuity within the fractum. The time points and structures here again correlate with those from Figure 3-4. a) During the generation of variation the fractum incorporates at all times a portion of the original structure as indicated by the shaded areas. b) During selection (i.e. post-revolution) continuity with the past is lost, but the structure, again as indicated by the shaded areas, is continuous with the future.

That the fractum incorporates both continuity and discontinuity is encouraging. As described previously, concepts of both continuity and discontinuity have been used often by historians of science.[173] Typically positivists rejected discontinuity, but could never completely dispense with it in describing the 'morphing' of knowledge.[174] Conversely negativists typically rejected continuity, but could never completely dispense with it in their narratives.[175] The fractum's uniting of both continuity and discontinuity

[173] See again Lindberg, "Conceptions of the Scientific Revolution from Bacon to Butterfield".
[174] This dichotomy can be seen with most positivists. For example, Kuhn claimed that new paradigms developed out of the old therefore saving continuity (see Kuhn, Structure, p.149)., yet his revolution was an incommensurable (discontinuous) event. Also Mayr argued in favour of continuity stating that biological science had experienced continual growth, yet he wrote that "...the history of science is characterized by wide swings of the pendulum" and that progress required the abandonment of ideas that "...had previously been dominant." (see Mayr, pp.844, 856).
[175] Foucault strove to render the past unfamiliar, or discontinuous with the present, in a counter reaction to prevailing positivist histories that attempted to render the past familiar and continuous (see White, "Foucault Decoded", p.51). Foucault can be seen as the Cuvier of history in that although his methodology demanded structural continuity within epistemes, it required no temporal continuity between them.

within one model allows these two opposing views to be reconciled.

The fractal micro and macrocosms

Up to now, the fractum has been described as a single entity. However, it should be obvious by this point that it is actually comprised of smaller fracta, and conversely, combines with others to comprise of larger fracta as seen in **Figure 3-11.** This phenomenon of 'boxes within boxes' is termed 'fractal' because it contains identical structures at both large and small scales.[176] For example, when 'zoomed-in' on a small fractal structure is indistinguishable from its larger structure.[177]

However, a thread of long-term continuity can be seen in many of Foucault's works (see Rabinow, p.9). Indeed, Foucault's considering the shift from one episteme to the next to be immediate and discontinuous may have been for methodological purposes only. Continuity can also be found in subsequent discursive analyses. For example, Peter Dear argued that despite the novelty of new ideas in the Scientific Revolution, continuities are still seen with the past in concepts of experiment and mathematics (see Dear, pp.2-3, 26, 40).

[176] As in naturally occurring fractal patterns, the fractal model here also requires some definition of minimum and maximum scales.

[177] Peters, p.9. For example, graphs of most stocks over daily, weekly, monthly or yearly time periods are almost indistinguishable in an absence of structural and temporal labels.

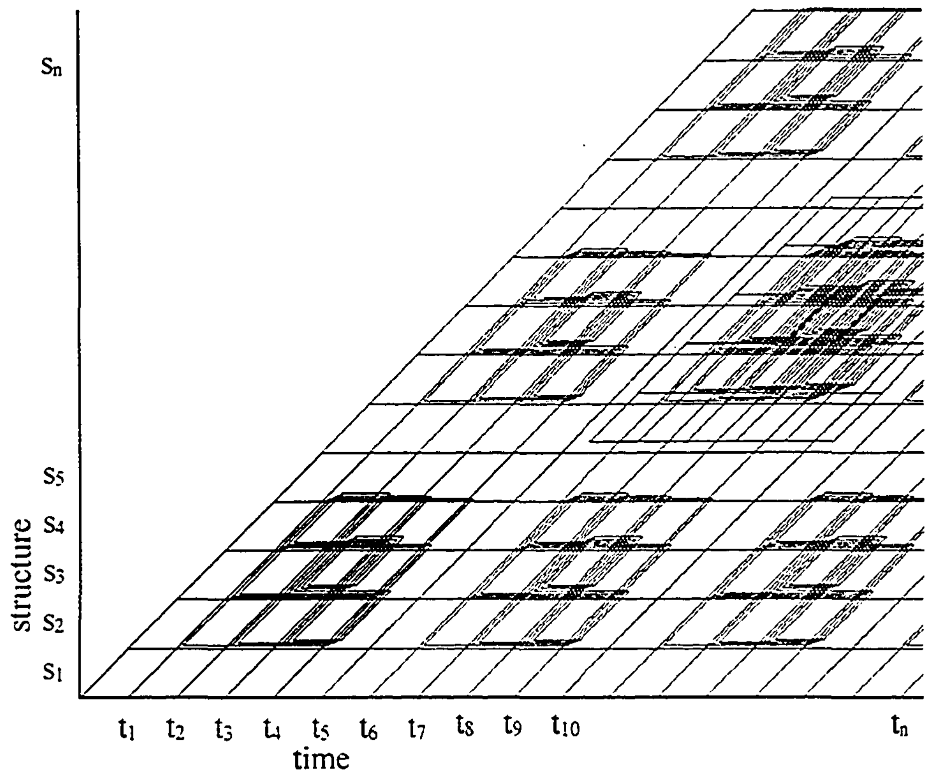

Figure 3-11. The fractal micro and macrocosms. The 5 x 5 fractum of Figure 3-4 is both composed of smaller fracta *and* combines with others of similar scale to comprise a larger fractum. This can be extended larger or smaller.

A fractal structure may be very useful for describing history since it allows one to define micro and macrocosms all within the same model.[178] Indeed, concepts of the micro and macrocosms have been used in many of the histories mentioned here.[179] For example, Spengler described how an individual both experienced and contributed to the

[178] See Gaddis, J., L., The Landscape of History: How Historians Map the Past Oxford: Oxford University Press, 2002. Gaddis calls for a fractal approach to history, so that the micro can be used to map the macro and vice-versa. Interestingly, he also draws parallels between the study of history and that of evolution. However, Gaddis sees the purpose of history as being to identify, and therefore provide a pathway towards an ideal equilibrium in society (the end of time?) and thus ultimately fails to appreciate a truly evolutionary view of structure and time. Also Gaddis is focused on causality, ranking causes by their relative importance, and in doing so remains attached to a selection model of history. (Note that my fractal model was formulated prior to the reading of Gaddis' book).

[179] In addition to histories, present day social 'sciences' such as economics, sociology, linguistics and psychology are also rife with microscopic and macroscopic themes.

sum of his culture in the *Micro-* and *Makro-kosmos*.[180] Similarly, Fernand Braudel and the *Annales* School can be seen to have described micro and macrocosms with their geographic, societal and individual 'levels' of analyses.[181] Also Kuhn, inspired by Fleck, referred to the paradigm "as an individual mind writ large".[182] Indeed a fractal approach with embedded micro and macrocosms may be very useful in describing history.

A fractal structure of micro and macrocosms is also an excellent fit for an evolutionary model, since evolutionary systems are decidedly fractal with respect to structure and time. Consider how biological entities are grouped into phyla, classes, orders, families, genera, and species, each composed of and comprising of smaller and larger entities which 'rise and fall' respectively.

Another major advantage with a fractal approach is that it allows one to describe simultaneously occurring 'phases' of history. Because each fractum is composed of smaller fracta, *phases of variation and selection can occur simultaneously.* In other words a 'rise' can appear within a larger 'fall'. Conversely a 'fall' can appear within a larger 'rise'. Hence there can be variation occurring within larger scale selection, and selection occurring within larger scale variation as seen in **Figure 3-12**.

---

[180] Spengler, pp.87-114.
[181] Braudel, *La Méditerranée*.
[182] Kuhn as quoted in his preface to the translation of Fleck, Genesis and Development of Scientific Fact, p. x.

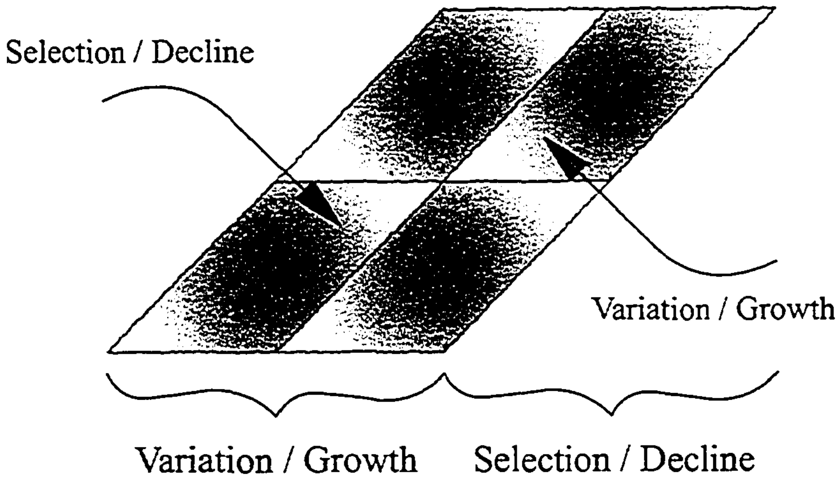

Figure 3-12. Simultaneous occurrence of variation and selection in the fractum. Selection and decline can occur simultaneously with larger scale variation and growth. Conversely variation and growth can occur simultaneously with larger scale selection and decline.

With simultaneous occurrence, the historian is able to describe certain historical events that 'resonate', or are in-phase with each other. For example, the near simultaneous occurrence of the Renaissance, the Reformation and the Scientific Revolution can be seen as resonating revolutions within a larger scale 'revolution' in Western culture. There are also times in history where there is resonance in equilibrium points. For example, consider how the dearth of learning resonated with Feudalism within the larger scale 'anti-revolution' known as the Dark Ages. However, also due to simultaneous occurrence, the historian is also able to identify trends that do not resonate or are 'out of phase'. For example, the 'rise' of the Carolingian Revolution during the 'fall' of the Dark Ages can be seen as a smaller event out of phase with larger structures.

Simultaneous occurrence also allows the evolutionary modeller to reconcile 'Lamarckian' and 'Darwinian' approaches. As described earlier, with Lamarckian or somatic models, the entity can change after it has been 'born' in response to environmental conditions, while with Darwinian or genetic models, the entity has no ability to change once it has been 'born'.[183] In isolation, the fractum is Darwinian: it generates variation that is then subjected to selection. However, when the Darwinian fractum is seen as composed of smaller fracta, it can be seen that variation and selection in structure occurs at all times throughout its 'lifetime' – something more akin to Lamarckism.[184]

Also due to simultaneous phases of variation and selection, the fractal model is able to better reconcile continuity and discontinuity. From the point of view of a small scale fractum, the revolution is a discontinuous event. But when the small fractum is seen as a part of a larger fractum, discontinuous events can become continuous. For example, when viewed on a small scale Kuhn's scientific paradigms are discontinuous. However, if they are considered part of a larger 'scientific' paradigm (i.e. one beginning with Greek 'science') they can instead be seen as continuous. Similarly, when viewed on a small scale Foucault's epistemes appear discontinuous. But when viewed from a larger scale (i.e. one encompassing all Western European thought) they can instead be seen as continuous. Hence simultaneous occurrence allows for discontinuous events on a small scale to become continuous on a larger scale. Positivists and negativists are free to reinterpret incommensurability as simply a 'species' boundary that is commensurable on a larger familial level.

Simultaneous occurrence also provides an advantage when describing structural boundaries. The historian relies heavily on boundaries that are difficult to define both in

---

[183] In the twentieth century in evolutionary biology Lamarckism was discredited since it is assumed that genes can not change during a person's lifetime. This assumption is now in dispute since certain environmental conditions can turn genes 'on' or 'off' (see Ridley, Matt, "What Makes You Who You Are", Time Magazine, Jun 2, 2003).

structure and time. One could even argue that such boundaries as identified are themselves only temporal and therefore arbitrary, implying that they are therefore not 'real'. Parallels can be seen with biological evolution, where the definitions of species are never quite fixed and have been known to change depending on prevailing scientific interpretation.[185] The fractal model is also subject to interpretation, but since starting or ending points within can be expanded or contracted, it provides an enormous amount of flexibility to the historian. For example, defining where science began (and will end) depends on how one describes starting and ending structures. If one's structural definition of science includes 'the pursuit of technology by craftsmen' then perhaps it can be seen as being born in the mid-sixteenth century and carrying on into the nineteenth century. If one's structural definition of science includes 'the pursuit of truth by amateurs', then it can perhaps be seen as being 'born' in the mid-seventeenth century and as 'dying' in the mid-twentieth century. In the fractal model both these structures can be analysed separately, or they can be combined by recognizing a bifurcation of structures around the mid-seventeenth century.[186] Hence the fractal model is able to give enormous flexibility when it comes to defining boundaries.

Entropic energy flow in the fractum

Up until now the fractum has been described largely as an isolated entity with little reference to its environment, except during selection. However, the environment now comes into play in the form of energy flow. Energy, manifested in economic, social,

---

[184] Darwin and Lamarck were similar in that they claimed that entities were able to change over the course of their lifetimes. Where they differed was the 'lifetime' they were viewing.
[185] See Ehrlich, pp.90-91.
[186] Similarly, the appearance of 'techno science' in the mid-twentieth century could be seen as a bifurcation

cultural, or intellectual forms, is what gives 'life' to the fractum. When there is surplus energy available, the fractum is able to generate variation. When energy is no longer available, it is subject to selection. It is common to see periods of great variation in human activity simultaneously with a surplus of economic energy and conversely a selection or merging of these activities when surplus is withdrawn.[187]

The energy described here is entropic. Entropy is a concept borrowed from thermodynamics that describes the 'usefulness' of energy. Energy low in entropy is concentrated and highly ordered, while energy high in entropy is diffuse and chaotic.[188] The fractum's boundaries represent the enclosure of a system in which entropy tends to a maximum as energy is exchanged internally. However, the fractum is essentially an open system. As seen in **Figure 3-13** the fractum receives across its boundaries a certain *quantum* of highly concentrated energy.[189] The fractum, like other evolving entities uses this highly concentrated energy to increase in complexity, or generate variation.[190] However, when the quantum of energy is exhausted, variation can no longer be sustained and selection begins. At this time the energy, now higher in entropy (or more diffuse) flows out of the fractum's boundaries, with the fractum eventually reaching equilibrium, or 'heat death' with respect to its environment.

---

of 'science' into two distinctly different structures.

[187] The spinning-off of new companies in times of surplus and the merging of new companies in time of withdrawal indicate evolutionary growth and decline in economic systems.

[188] Entropy was formulated as part of the Second Law of Thermodynamics by Rudolph Clausius (ca. 1854) to explain the unidirectional flow of heat from hot to cold.

[189] The term 'quantum' is used because it implies that energy is delivered to the fractum in discrete packets.

[190] Entropic energy flow appears alongside an increase in 'complexity' in evolutionary systems. It has been speculated that an increase in complexity mitigates increases in entropy within closed systems. In other words, variation – or differentiation into parts – may be necessary to slow the increase in entropy (see Brooks, Wiley, p.369; Interestingly, Brooks and Wiley also reject views of evolution as tending towards equilibrium *and* the random variant).

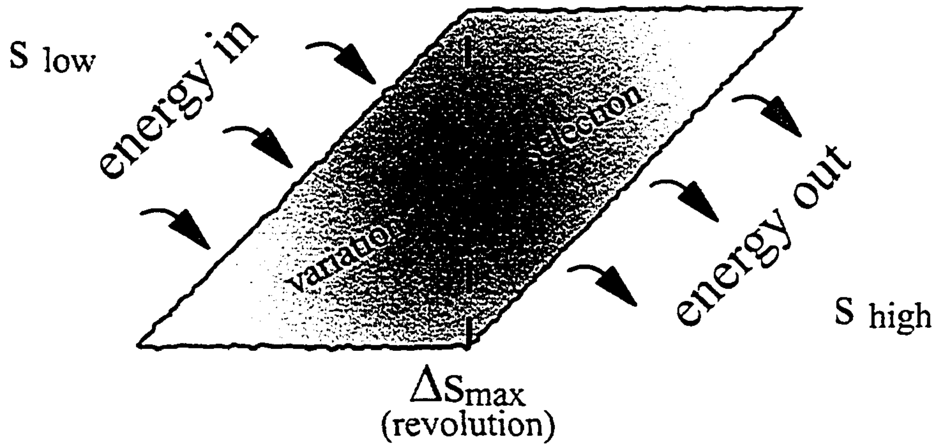

Figure 3-13. The energy flow through the fractum. 'S' represents a quantification of entropy. Energy enters in concentrated form and is used to generate variation. The revolution is a time of maximum change in entropy, after which energy leaves the fractum in more diffuse form.

Curiously, the concept of entropy has been used previously in both positivist and negativist historical models. For example, Spencer considered 'efficiency' to be the minimization of entropy, forcing sensible existences to achieve greater and greater levels of perfection, while conversely, Spengler used the entropic analogy to predict the inevitable 'heat death' of Western culture.[191]

However, here entropy will take on a different character. Entopic energy flow is important in that correlates precisely with the previous descriptions of 'internalism' and 'externalism' in the fractum.[192] When the fractum receives the quantum of energy from the environment, it in effect becomes autonomous from it. This is also seen as a state of 'artificiality' with respect to the environment. However, once the quantum is exhausted

[191] See Spengler, pp.216-220.
[192] It is important in the evolutionary model to track ideas as separate entities since ideas and authors often evolve in opposite directions.

the fractum 'returns to reality' and is then subjected to selection by its environment.[193] At this point externalism prevails. This correlates well with claims by internalists that ideas were autonomous from their social environments, and with claims by externalists that ideas were solely conditioned by their social environments (or autonomous from their authors). These opposing views of internalism and externalism are now united in the fractal model.

Entropic energy flow is also useful in describing the effect of the fractum on its environment. As energy flows through the fractum it increases in entropy and hence is returned to the environment more diffuse than it was initially. Hence, *the presence of any fractum in an environment changes that environment irreversibly.*[194] Most positivistic or negativistic models with predetermined stages failed to take into account how environments change due to the presence of 'actors' in those environments.[195] In the history of science it is undeniable that ideas exert influence upon the intellectual environments in which they are formed.[196]

Entropic energy flow is also useful for describing history in that it is *directional.* In thermodynamics, entropic energy will only flow in one direction from hot to cold. As mentioned previously, the energy in the fractum also flows in a certain direction. This is revealed structurally in that the final structure of the fractum is different than its initial

---

[193] Evidence of autonomy can also be seen in language and economics. Meaning in language is for a time autonomous from an external environment and therefore self-referent (post-structuralism) before having to return to some level of 'reality (structuralism). Economic systems can also display periods of autonomy, or 'irrational exuberance' before returning to some level of reality (i.e. crashes or 'corrections').

[194] Although well intentioned, most environmental theories are unwilling to recognise that humanity and its products *are also evolving parts of nature* and that the mere presence of humanity in an environment changes that environment irreversibly.

[195] One exception was Latour's 'collective' which was influenced by the entities that existed within it. Latour claimed that collectives often showed signs of 'drift' and recognized that entities within the collective appear not only to be changed by it, but also change the collective (see Latour, Pandora's Hope, pp.89, 195). The 'push and pull' relationship between scientific discovery and technological innovation is evidence of entities taking and returning energy to the intellectual environments in which they formed.

structure. Hence there is an overall pattern in the fractum which repeats but is not cyclical. In other words, the historical pattern repeats but history does not. However, it is important to note that this directionality is not the same as teleological determinism. Like the flow of heat, energy in the fractum flows in a direction 'anywhere but here' and does not follow any one specific path. As such, the direction of the fractum is revealed only *after* the revolution. After the revolution the 'winners' are then decided by traditional causality and with hindsight (i.e. presentism) the initial variations can be arranged on the newly identified dialectic accordingly.[197] Hence the directionality of the fractum allows the historian to establish trends at least in part without having to rely on 'cause'.

Directionality is not only important for structure in the fractum, but it is also important for the whole of history. An entropic view of time renders history *irreversible.* This is because entropic energy cannot be 'reversed' to the way it was without increasing overall entropy further. Hence if one *could* rewind and replay history, it is probable that a different result would occur every time even if all initial conditions were identical.[198] This agrees with the sense brought forth by Foucault, that the present is only one of many possible outcomes of the past. Latour also expressed an entropic view of time claiming that "...time's arrow moves irreversibly forward".[199] If this is so, then history is critical

---

[196] Environments may be larger scale fracta.

[197] In other words, variation proceeds along multiple dialectics, but the dialectics are not revealed (or made obvious) until *after* selection begins.

[198] This view contrasts with the Newtonian worldview of time as linear and reversible, or no different running forwards or backwards. From this it was assumed that if only all initial conditions were known then all would be determinable (i.e. Laplace's Demon). Views of linear time persisted well into the twentieth century, and include Einstein's relativity theory. (Prigogine considered Einstein's model to be a "static, timeless view of the universe". See Prigogine, Stengers, Order; p.215).

[199] Latour, Pandora's Hope, p.171. Latour considered historicity to be the "linear...and sedimentary succession [of time]" which basically recapitulated Kierkegaard's observation that life is lived forwards but only understood backwards.

insofar as understanding how the larger *system* works, but not insofar as identifying 'factors' or ideal points of reference, since these may only be applicable in terms of statistical probability based on the unique conditions of emergence that we are presently privileged to.[200]

As an aside, entropic energy flow also has implications for the historian's perception of time. If time is proportional to the change in entropy, then the revolution, as the point of maximum change in entropy, is where the greatest quantity of time is 'used-up'.[201] Conceptually, *the more change there is, the more time is 'used-up'.* This is perhaps what gives historians a sense of the fullness of time and great discontinuity with the past during revolutions, since it is here where time may deviate furthest from linearity. Conversely, the anti-revolution is a compounding of very little change and a subsequent emptiness of time.

Conclusion

To sum, a new evolutionary model has been presented here which has greater potential than either the paradigm or episteme in describing history. Taking variation to be useful to evolving systems, a new historical entity called the *fractum* has been designed. The fractum's inherent variability means that the actors within are no longer required to have strict uniformity in thought. Also, in having equal phases of variation

---

200 Physicist Stephen Hawking also agrees with the entropic time, stating that its direction remains at all times forward during both expansion and contraction phases of the universe (see Hawking, S., A Brief History of Time New York: Bantam Books, 1988).

201 The rate of entropy generation (S) is defined in terms of units of energy (E) divided by units of mass (M) and thermodynamic temperature (T). Based on dimensional analysis, S is proportional to time (t) in that E is equivalent to M times area (A) divided by t^2 (for a discussion on the principles of entropy see Cengel, Y., Boles, M., Thermodynamics: An engineering approach New York: McGraw-Hill, 1989, pp.249-324). In a sense, time is 'used-up' in an entropic process, in that it takes more time to produce an equivalent amount of work energy after a state of high entropy is reached than was required previously (for

and selection, the fractum is able to describe both internalism and externalism respectively. Also with a shifting normalcy the fractum, the 'norms' of science are constantly in transition. The revolution, defined as the point of maximum variation, no longer needs traditional causality or 'factors' for it to occur. If the fractum is seen as a microcosm within a macrocosm, then all phases of the fractum can occur simultaneously. The energy flow through the fractum, being entropic, allows the historian to describe directionality, and how the mere presence of a fractum in its environment changes that environment irreversibly. Together all these features improve upon the explanatory power of the paradigm and episteme. But the true test in the history itself.

---

closed systems).

Chapter Four *Revision*

In this chapter the models of Kuhn and Foucault will be revisited in terms of the fractal model. Kuhn's model is found to match closely, with normal science representing the period of growth and variation in the fractum, and the post-revolution resolution as the period of selection. Foucault's model also matches well, in that epistemic shifts are times of maximum variation in thought, while 'post-shift' periods are times of selection. However, the fractal model has greater explanatory potential than either Kuhn's or Foucault's due to its recognition of variation as inherent.

In revisiting the Copernican Revolution, the fractal model describes Copernicus's *De Revolutionibus* as appearing at a time of maximum variation within Ptolemaic cosmology. Shortly after, there was a bifurcation in conceptions of the cosmos which resulted in new heliocentric *and* geocentric gestalts. It wasn't until the mid-seventeenth century that directionality was revealed as being in favor of heliocentrism. After this there was a fusion of geocentric concepts into heliocentrism, and by the early nineteenth century the entire fractum converged on a final equilibrium that ultimately dissolved into the larger intellectual environment.

But let us begin by revisiting Kuhn's model. To reiterate, Kuhn envisioned scientific paradigms arising out of 'pre-paradigmatic' states. Once established, paradigms would expand 'normally' to explain phenomena conditioned by their gestalt, or worldview. However, anomalous phenomena that resisted assimilation could at times spark a revolution. These revolutions resulted in a shift, which would see the old paradigm replaced by the new, after which normal science would begin anew. Science then proceeded through successive paradigms, each implicitly coming closer to some form of truth.

Revisiting Kuhn's model in terms of the fractal model, the 'pre-paradigmatic' state can be seen as an environment containing a certain quantum of surplus energy. This quantum is what allows new gestalts, scientific or otherwise to appear. Once emergent, the paradigm-as-fractum undergoes expansion and variation in structure akin to Kuhn's 'normal science' where the paradigm is filled-in by 'game playing'. The structural limits of the fractum expand during this phase but are still continuous with its original structure. However, a 'revolutionary' state is eventually reached during which the fractum is at a high degree of variability. Again agreeing with Kuhn's model, a discontinuity occurs during the revolution along with the appearance of a new gestalt (i.e. bifurcation). During the resolution of the revolution, selection, or decline begins in the old fractum, while in the new fractum 'normal science', or growth and variation begins anew. With the disappearance of the old, the 'winner' of the revolution allows one to some extent speculate on the historical directionality of science.

Although the fractal model shares many features with Kuhn's, it goes on to describe more. If normal science is seen as the expansion of variation about a shifting normalcy, more freedom is given to the thinkers within to 'think outside the box'. Scientists are allowed to hold to a greater or lesser extent variations in thought on common themes. Variations inherent in the fractal model can also be recognized as a divergence of structure instead of being seen as a miscellany of unrelated false truths or errors. Also, variations within do not necessarily have to be 'scientific'. The only requirement is that they appear in a direction opposite to existing structures along dialectical axes. As for revolutionary science, Kuhn's model is somewhat confusing in that the 'revolution' is the actual revolutionary event *and* its aftermath.[202] By confusing the revolution with its aftermath, there is tension in Kuhn's model between the immediate incommensurable paradigm-shift and the length of time it takes for resolution. However, in the fractal model the revolution is one moment in time. This allows for a clearer distinction to be made between phases of variation and selection in the old and new gestalts. Also in the fractal model the new and old *must* occur simultaneously in time. Hence there is simultaneous appearance of variation and selection – of normal science simultaneously with revolutionary science. Also, since smaller fracta are embedded inside of larger fracta, discontinuous revolutions can be continuous at larger levels. Expanding the fractal structure larger also allows for the appearance of *third* gestalts during revolutions instead of assuming there is a simple linear progression from one paradigm to the next.

An additional advantage with the fractal model is that it allows the historian to track energy flow both into and out of the gestalt. With respect to the environment in which they are formed, Kuhn's paradigms were largely 'internal' in nature. In other words the larger cultural environment played little role in the composition of scientific knowledge. The fractal model agrees with this in that it displays an 'internal' phase of variation where scientific knowledge is created with little reference to 'external' influences (i.e. autonomy). But it is different in that it allows 'external' pressures, including those from the larger cultural environment, a role in forming knowledge during the phase of selection. Also the fractum is allowed to change its environment, by returning to it the quantum of energy initially received in a more diffuse state. Hence the fractum combines 'internalism' with 'externalism' and is allowed to exert influence on its

[202] Kuhn, Structure, pp.144-159.

environment. Also using an entropic energy approach, the revolution no longer requires traditional causality. Each revolution can be examined as an event in its own right. If revolutionary causality must be sought, then it can instead be seen as the exhaustion of the quantum of initial energy.

With respect to directionality, Kuhn considered the normal / revolutionary cycle to be an iterative process approaching some sort of equilibrium (i.e. the 'end' of revolutionary science). However, the fractal model only has temporary equilibrium points with the dialectic changing direction after each point is reached. Hence, only a certain type of truth is captured at the 'end of science', and further structural evolution is expected *beyond science* into another as of yet unknown and unnamed technique of knowledge production.[203]

In a similar manner Foucault's model can be revised in terms of the fractal model. To reiterate, Foucault envisioned Western 'thought' as proceeding through epistemes, each being characterized by an intellectual structure seemingly unrelated to the last. Once a new episteme replaced the old, it conditioned the thoughts of those within unconsciously. The transition from one episteme to the next was immediate and wholesale, and although 'cause' was not directly assigned, Foucault implied that the reason was philosophical impasse.[204] Indeed, unless changes were made in the next episteme, Foucault predicted that the understanding of the human condition would descend into obscurity.

If the episteme is seen as a fractum then parallels can again be found. Although

---

[203] Indeed such future variations may already exist, but their success or failure will not be revealed until the next revolution.
[204] For example, Foucault discussed at great length the 'limitations' of the Classical episteme (Foucault, Order, pp.208-249), which could only be breached by the creative desire of humankind (note the similarity

not stated directly, Foucault's epistemes-as-fracta have 'conditions of emergence' related to surplus energy. For example, new epistemes arose at times of surplus economic wealth in Europe – the Classical episteme in the wake of overseas exploitation, the Modern episteme after the first Industrial Revolution and the Contemporary episteme after the second Industrial Revolution. The episteme also follows a pattern of variation followed by decline. Although Foucault does not describe growth in epistemes, the appearance of new ways of thinking at the time of epistemic shifts implies that it is during this 'revolution' when they have grown to their highest degree of variability. For example, Foucault identified 'borderline' figures that seemed to straddle both epistemes simultaneously, such as Cervantes, who seemed both a Renaissance and Classical thinker, Adam Smith, who was both a Classical and Modern thinker, and Freud, who was both a Modern and Contemporary thinker. The presence of these borderline figures indicates that variation in thought may be highest near epistemic shifts. Also, Foucault uses a fractal structure of micro and macrocosms in describing how power structures are reified and supported on scales both small and large.

After the epistemic shift, the unconscious conditioning of the mind by an episteme can be seen as representing a selection phase where there is a convergence in intellectual structures. As for the revolution or epistemic shift itself, the exhaustion of the quantum of energy closely agrees with Foucault's causal ambiguity. Indeed, the epistemic shift can be seen as 'caused' by the exhaustion of the original quantum of 'external' philosophical energy.

Hence Foucault's model is also quite close to the fractal model. Yet the fractal model again goes on to describe more. Foucault's model only considered post-epistemic

---

with Bergson here).

shift selection history. He focused on how the episteme conditioned, or selected, thoughts so that all would think in the same way. Although not disagreeing with this analysis, the fractal model also demands a phase of growth and variation. If the epistemes were allowed to expand in structure before selecting thoughts, then they would not have to have such an overall 'monolithic' character. Also if epistemes-as-fracta were allowed to occur simultaneously with others, then their 'births' could actually occur much earlier, and their 'deaths' much later than the discontinuous epistemic breakpoints suggested. In other words, the Renaissance, Classical, Modern and Contemporary epistemes could all, for a time, exist together simultaneously as variations within the entirety of Western thought. Also the transition from one episteme to the next, while still discontinuous, could be continuous within this larger-scale structure. Again if seen from a larger scale, the path from one episteme to the next would not have to be linear, but could rather follow multiple paths with the possible appearance of *third* epistemes during shifts.

Furthermore, Foucault did not allow the actors within an episteme to change their environments.[205] However in the fractal model, the energy exchange through various actors within an episteme-as-fractum allows those actors to change their environments irreversibly. Finally, Foucault considered the Western episteme to be declining towards an 'end-point' (unless remedied). The fractal model sees only temporary equilibrium as an 'end-point' and instead suggests that ongoing variation will result in evolution beyond the 'Western' thought structure altogether. However, the direction will not be revealed

[205] However discourse could also represent an energy exchange between an entity and its 'reality'. For example, when the entity, or signified, receives a certain quantum of energy from 'reality' it becomes autonomous from this reality and generates self-referent variations. When the quantum is exhausted, the discourse is forced to return to 'reality', and variations on meanings are subjected to selection. Also the

until the next revolution or epistemic shift. As seen in **Figure 4-1**, both Kuhn and Foucault's models can be reinterpreted in terms of the fractal model.

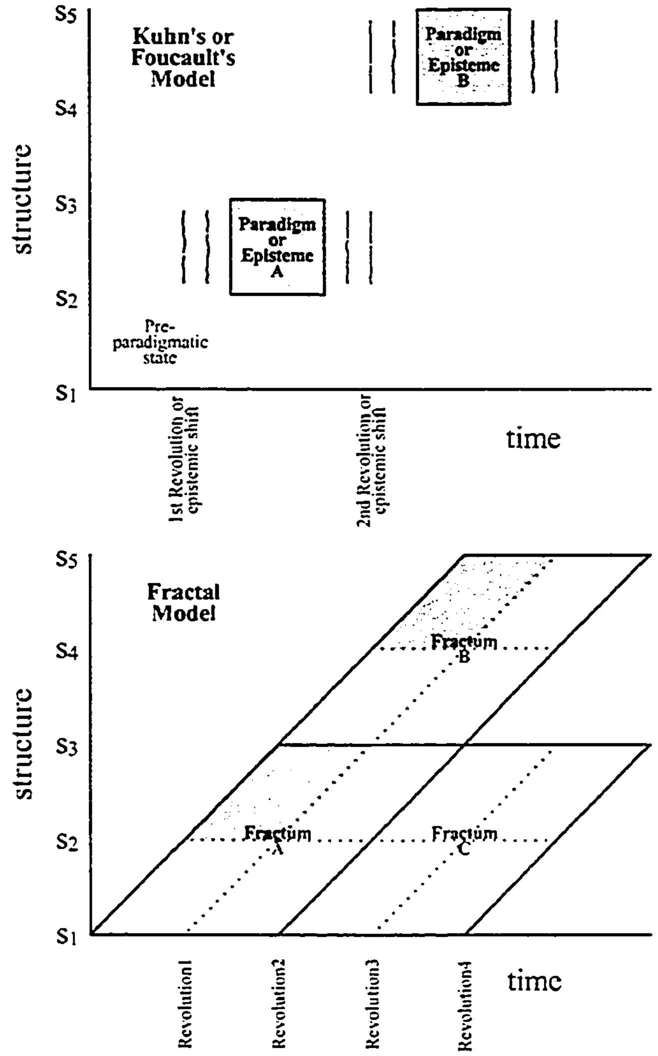

Figure 4-1. Revisiting Kuhn and Foucault's models in terms of the fractal model. The shaded areas represent the structures Kuhn and Foucault examined when describing their paradigms or epistemes. In Kuhn's or Foucault's model Paradigm or Episteme B is seemingly unrelated to Paradigm or Episteme A, but this is due to the neglect of variation within paradigms or epistemes. In the fractal model, variation occurs on both small and large scales. Fractum B is discontinuous with Fractum A on a small scale, but is still continuous on a large scale. Also due to large-scale bifurcation there is the possibility of a *third* fractum appearing (fractum C) during revolutions.

---

energy returned to this 'reality' during selection changes it irreversibly.

Revisiting the Copernican Revolution

With Kuhn and Foucault's models re-examined, it is now possible to examine a test case in history. The Copernican Revolution was a period in history when cosmological theories began incorporating elements of heliocentrism in opposition to geocentrism.[206] As seen in **Figure 4-2**, the entity bounded in structure and time commonly known as the 'Copernican Revolution' can be described as a fractum containing various 'scientific' models of the cosmos from approximately 1450 to 1810. This fractum has been transposed onto the one-dimensional structural dialectical axis of 'geocentrism' versus 'heliocentism', and can be seen to comprise of four smaller fracta called the First and Second Ptolemaic, and the First and Second Copernican fracta.

[206] This is an excellent test case in that it gives a clear one-dimensional dialectic by which to examine structure. Also its treatment in literature has been extensive, including its use in Kuhn's *Structure*.

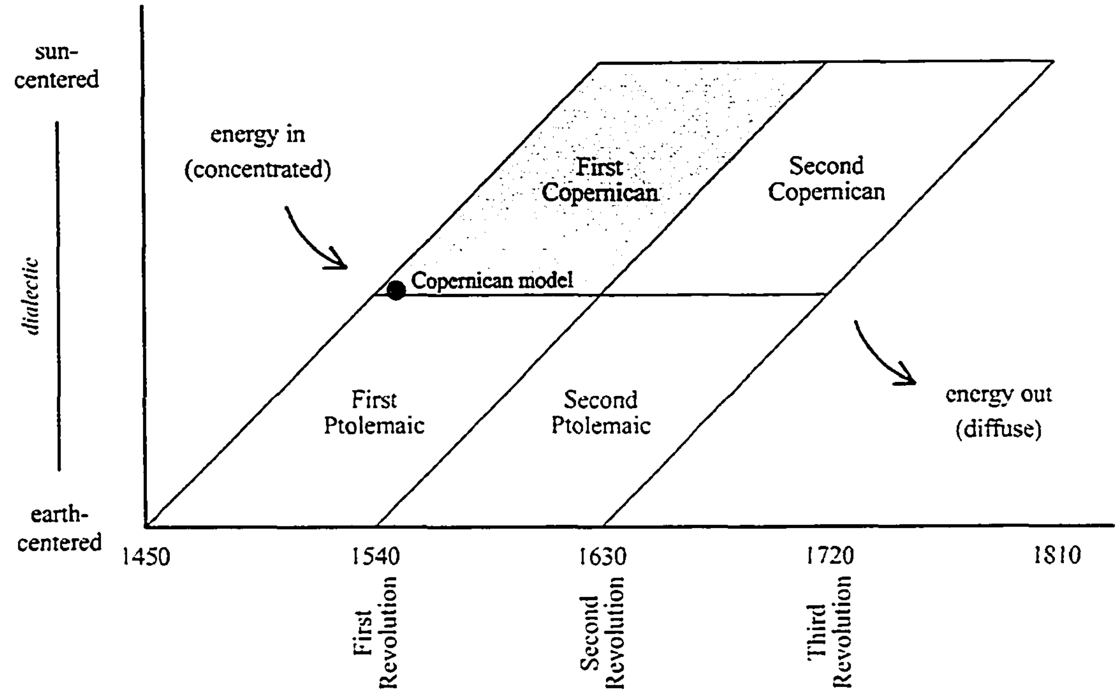

Figure 4-2. The Copernican Revolution. The large fractum is the entire 'Copernican Revolution' bounding cosmological theories from approximately 1450 to 1810. This is comprised of four smaller fracta, two earth-centered and two sun-centered gestalts, each containing distinct phases of variation and selection. In the fractal model, the 'Revolution' actually consisted of three revolutions, the largest occurring around 1630 due to resonance. Also the initial bifurcation resulted in a third fractum, the Second Ptolemaic, that rivalled the First Copernican. The shaded area represents the structures and times examined by traditional analyses of the Copernican Revolution.

From 1450 onwards, the surplus of wealth in Western Europe allowed for variations on existing structures to be developed in all facets of culture. Some of this surplus energy undoubtedly found its way into intellectual pursuits. This quantum of surplus intellectual energy appeared, for example, in the form of translations of Greek and Arabic manuscripts, the founding of universities, and the emergence of natural philosophers.[207] In the fractal model, this quantum did not 'cause' the Copernican Revolution, rather the energy contained within allowed for new variations to appear on existing themes. Indeed, 'scientific' ideas were only one type of variation that appeared at this time as evidenced by the simultaneous appearance of Humanism, Neo-Platonism, and Natural Magic.

Specifically within Ptolemaic cosmology, this quantum of surplus energy also allowed for variations to appear on existing themes. The addition of over a dozen subsystems to Ptolemy's model by the 1500s by numerous authors, primarily geared to referencing motion to the sun, can be seen as the expansion of variation and growth within this fractum – henceforth termed the *First Ptolemaic* fractum.[208] The appearance of heliocentrism can be seen as a unique variation arising out of existing Ptolemaic cosmological themes of the sixteenth century. When Copernicus first conceived of his idea (ca. 1510-1514) Ptolemaic cosmology itself was in a growth phase just nearing its maximum point of variation. Indeed, Copernicus's *De Revolutionibus* of 1543 was still contingent with existing astronomical theories, incorporating many standard elements such as the use of the finite sphere of fixed stars, eccentric points, and epicycles.[209] Even diurnal rotation had precedent, with John Buridan and Nicole Oresme having written on this subject as early as the fourteenth century. Copernicus did not even derive his theory

---

[207] Grant, E., The foundations of modern science in the middle ages Cambridge: Cambridge University Press, 1996. These are typically described as 'factors' leading to, or causing, the Copernican Revolution. With respect to ancient manuscripts, Copernicus referenced Aristarchus' sun-centered model in order to bolster his own. Copernicus may also have been influenced by earlier Arab Scholars' criticisms of Ptolemy (see Barker,P., Ariew,R., Revolution and Continuity, Washington: CUA Press, 1991, pp. 3-6).

[208] Kuhn, The Copernican Revolution, pp.114, 137. Kuhn would claim that the anomalies (i.e. the difficulty in predicting Easter) were what caused this variation, whereas the fractal model would consider the anomalies of Easter to merely have revealed the extent of the variation.

[209] See Westman, R.S., "Proof, poetics, and patronage: Copernicus's preface to *De Revolutionibus*" Reappraisals of the Scientific Revolution, Edited by David C. Lindberg and Robert S. Westman, Cambridge: Cambridge University Press, 1990, p.170.

from any new astronomical observations.

However the exhaustion of the quantum available to the First Ptolemaic fractum occurred around 1540 and new variation could no longer be sustained. To reiterate, anomalies were not the cause of revolutions. Indeed, all astronomers at this time were grappling with the same anomalies. Rather different interpretations of anomalies merely served to reveal the extent of variation generated within. The exhaustion of the quantum forced the First Ptolemaic fractum to exist on internal energy alone. The concentrated energy that had initially entered was now being returned to the larger environment in a more diffuse form. For example, the translations of Greek and Arabic manuscripts, at first confined to a small population of educated peoples, were now diffusing into the environment, appearing even in the vernacular. At this point the fractum was about to enter into a selection phase.

This period of maximum variation just prior to selection can be seen as the *First* Copernican Revolution. As described above, the Copernican variant developed by 'normal science' within the Ptolemaic tradition. However at the point of revolution, we see a bifurcation, or a branching off of a First Copernican fractum from the old. With the underlying dialectic between earth and sun-centered models now revealed, Copernicus's model can be arranged next to others as being on the fringes of normalcy within the First Ptolemaic fractum.[210] Other models can similarly be arranged according to the strength of their 'leaning' towards either earth or sun-centered models.

Hence, not only was Copernicus's model a radical variant within the Ptolemaic

[210] There was also a chance that Copernicus's variation may have been accepted by some astronomers as merely an attempt to 'save the appearances'. In the forward to *De Revolutionibus*, Andreas Osiander claimed heliocentrism was merely a model and did not reflect reality. However, Copernicus did indeed believe in the reality of his system (Henry, p.10).

tradition, but it was also the starting point for a new sun-centered gestalt, henceforth termed the *First Copernican* fractum.[211] After 1540 the First Copernican fractum began to grow and generate variation. The initial growth of this fractum was admittedly slow, taking decades to garner support (slow initial growth is a feature of exponential growth).[212] Yet by 1570 Copernicanism began to show signs of noticeable support from so-called 'realists'.[213] A new court structure provided the quantum of surplus energy required to sustain new growth.[214] Indeed heliocentrism continued to expand in structure into the 1600s, evidenced by the appearance of the new variations published by Johannes Kepler in *Mysterium cosmographicum* (1596) and *Astronomia nova* (1609), and those published by Galileo Galilei in *Sidereus Nuncius* (1610), *Dialogo* (1632) and *Discorsi* (1638). These works appeared alongside others that assimilated, or rationalized old and new phenomena to great aesthetic appeal within heliocentrism by a process of 'normal' science.

In contrast, the First Ptolemaic fractum began to show signs of decline after 1540. In the aftermath of the First Copernican Revolution, the First Copernican and First Ptolemaic fracta were 'out of phase', so to speak. Despite the fact that the competing models at this time were nearly equal in explanatory or predictive power, and that both had approximately equal aesthetic properties, Ptolemaic models were forced to justify themselves next to a competitor. For example, the observation of Nova in the late sixteenth century, troubling to both Ptolemaic and Copernican models, seemed to hit the

---

[211] In other words, Copernicus was both the 'last' great Ptolemaic astronomer and the 'first' great Copernican astronomer.
[212] Henry, p.12. Before 1600 it is estimated that Copernicus's model had only gained a handful of supporters.
[213] Crowe, M.J., Theories of the World from Antiquity to the Copernican Revolution Mineola: Dover Publications, 2001, p.79.
[214] Henry, pp.11-12.

Ptolemaic fractum harder. This revealed that the First Ptolemaic fractum had entered a selection phase next to the First Copernican's growth in variation.

However, decline was seen only in the First Ptolemaic fractum. Usually missed in linear models such as Kuhn's or Foucault's is that in a bifurcation, *two* new entities are formed out of one. Hence, the First Ptolemaic fractum actually bifurcated into a First Copernican fractum and a *Second Ptolemaic* fractum. This Second Ptolemaic fractum developed alongside the First Copernican fractum, and also enjoyed a period of considerable growth and variation after 1540.[215] For example, the new geocentric modelling of Tycho Brahe, also supported by the new court structure, can be seen as representing growth and variation within a new Ptolemaic tradition. Like the First Copernican fractum, it was also able to incorporate new 'anomalies' as they appeared. Brahe's model, published in *De mundi* (1588), described a system with the planets revolving around the sun, and the sun, moon and celestial sphere revolving about the earth which was essentially analogous and mathematically equivalent to Copernicus's.[216] Other variants appeared within this Second Ptolemaic fractum, which differed from earlier geocentric models in that more emphasis was placed on 'realism'. Proponents theorized using different combinations of existing philosophical and mathematical tools, even including elliptical orbits.[217] This 'third' fractum also indicates that the First Copernican revolution was a large scale bifurcaton, and that while a discontinuous event

[215] Although the Second Ptolemaic fractum is given the same structural range on the dialectical axis, it is actually slightly different than the First. This shows the limitations of a purely one-dimensional analysis. In actuality, the fractum could also be generating variation in structure simultaneously on a second dialectical axis, meaning that its direction would twist with time instead of taking a planar path. Indeed, the appearances of debates over absolute rest versus absolute motion, corporeal bodies versus non-corporeal, the universe as finite versus infinite, space as a vacuum versus a continuum, and also the bifurcation between science and philosophy suggests that indeed multiple dialectics were appearing at this time.
[216] Kuhn, The Copernican Revolution, p.204.
[217] Applebaum, W., "Keplerian Astronomy after Kepler" History of Science Vol. 34, Pt. 3, No. 105,

on a small scale, it can also be seen as the continuous generation of variation on a larger scale. Indeed as revealed later in the twentieth century, both heliocentric and geocentric gestalts shared structural continuities such as absolute notions of time and space.

For a brief moment in time, all three entities of the first bifurcation existed simultaneously. Hence in the early seventeenth century, three fracta existed simultaneously within the larger-scale fractum – the Fist Ptolemaic, the First Copernican and the Second Ptolemaic. Indeed, for a time in the seventeenth century Ptolemaic, Copernican and Tychonic astronomy were taught side by side in many universities.[218]

However, by 1630 the quantum available to sustain growth and variation in the First Copernican and Second Ptolemaic fracta had become exhausted. With this exhaustion, the energy of these fracta began diffusing back into the larger environment appearing in the form of individual collectors as smaller 'courts' in of themselves. This point of maximum variation in the First Copernican and Second Ptolemaic fracta can be considered the *Second* Copernican Revolution. The Second Copernican Revolution was more significant than the First. Both Copernican and Ptolemaic fracta had reached points of maximum variation, with support for each about equally represented on a normal distribution across the entire spectrum of cosmology. But because the revolutions within each fractum resonated with each other, the result was larger-scale revolution than what was observed during the First.

The Second Copernican Revolution was also notable for several other distinct events. The first was the complete disappearance of the First Ptolemaic fractum. Due to successive selection events, this fractum had by 1630 completely dissolved back into the

---

September 1996, p.457.
[218] Kuhn, The Copernican Revolution, p.227.

intellectual environment (or reached equilibrium), exemplified by the weakening and fading away of the Aristotelian tradition. For example, by 1630 the number of astronomers still clinging to the idea of the solid celestial sphere was negligible.[219] Another was the entering into the selection phase of the Second Ptolemaic fractum *and* the First Copernican fractum, with variations developed within each being subjected to selection based upon a new environment of 'reality'. For example, the models of both Tycho and Kepler were subjected to a new intellectual environment which demanded models represent reality instead of merely attempting to 'save' the appearances. The environment of selection was also composed of 'external' elements such as the judgements of religious authorities (i.e. Jesuits), or in the case of the new science, the authority of gentlemen. Another was the appearance of a *Second Copernican* fractum as a 'fusion' of Second Ptolemaic and First Copernican structures in the direction of heliocentrism. For example, a 'fusion' of the Aristotelian sense of observation with the concept of individual experimentation as a valid form of witnessing appeared in the form of scientific reporting.[220] This Second Copernican fractum was slightly different than the First in that its variations were characterized by structures of experimentalism, mechanical philosophies and mathematization.

Hence from 1630 to 1720 the First Copernican and Second Ptolemaic fracta, being subjected to successive selection events, faded away to equilibria. After this time no more new models were seen developing in these gestalts. However, the Second Copernican fractum enjoyed a period of growth and variation at this time. A new energy environment, appearing in the form of scientific societies such as the Royal Society of

---

[219] Applebaum, p.475.
[220] See again Dear, <u>Discipline and Experience</u>.

London (c.1660) and the *Académie Royale des Sciences* (c.1666) provided the surplus quantum of energy by which new variations could be generated on existing themes. The greatest example of variation arising out of this environment, often considered the traditional culmination of the Copernican Revolution, was the appearance of Isaac Newton's *Principia* in 1687. Here Newton used the new concept of gravity in a mathematical proof of orbits to both predict and retrodict celestial positions with great accuracy. Although quick to catch on in England, Newtonianism took some time to penetrate continental Europe.[221] However, by 1720 variations within this Second Copernican fractum had grown and were flourishing throughout the Western world both within and 'external' to science.

By 1720, the quantum of energy provided by the scientific societies again had become exhausted. The energy provided by scientific societies had become diffuse, and the works of 'amateur' scientists had to become largely self-supporting. Traditionally known as the Newtonian Revolution, this can be considered the *Third* Copernican Revolution in the fractal model. After this revolution, the Second Copernican fractum was subjected to selection and convergence in structure in the direction of mathematization and experimentation. For example, the unmathematized and unverified speculations of Hooke and Descartes fell by the wayside, while the mathematical proofs such as Newton's and Halley's were applauded. By 1810, after successive selection events, the Second Copernican fractum had converged on one final structure of heliocentrism. Indeed by 1810, the larger-scale fractum encompassing the entire 'Copernican Revolution' had run its course and reached equilibrium. At this equilibrium

---

[221] Dobbs, B.T., Jacob, M.C., Newton and the Culture of Newtonianism New York: Humanity Books, 1998.

point the knowledge created and contained within the entire fractum spanning from 1450 to 1810 had completely dissolved back into its, and became indistinguishable from its larger intellectual environment. As such, by the early nineteenth century all educated peoples believed that the earth orbited about the sun.[222] Of course, cosmological models kept on evolving from this point onwards in the direction of an infinite, and later a relative universe, but these variants could no longer be mapped along a simple geocentric / heliocentric dialectic. The Copernican Revolution had ended.

In conclusion, Kuhn and Foucault's models were found to agree closely with the fractal model. However, the fractal model went on to explain more. By allowing variation within the paradigm or episteme, the fractum no longer demanded strict uniformity of its actors. Also the principle of bifurcation allowed for the possibility of third paradigms or epistemes to appear during a revolution. By allowing the simultaneous occurrence of fracta, variation and selection occurred concurrently and discontinuity within continuity could also be explained. Also by using an entropic energy approach, the fractum was allowed to exert an irreversible influence on its environment. The fractal model did not refute Kuhn or Foucault, but rather it expanded on the potential of the paradigm or episteme to describe history.

Indeed this was the case in describing the Copernican Revolution. The Copernican Revolution was described in the fractal model as a large-scale fractum composed of four smaller fracta – two Copernican and two Ptolemaic. The actual 'Copernican Revolution' itself was actually composed of three separate revolutions, each one being a point of maximum variation and exhaustion of surplus energy. After each

---

[222] Although the restrictions placed on *De Revolutionibus* by the Church in 1616 were not lifted until 1822

revolution, energy was returned to the larger environment in a state more diffuse than at which it entered. During the first revolution, Copernicus's model revealed a heliocentric / geocentric dialectic and could henceforth be seen either as a radical variant within the Ptolemaic tradition, or the starting point for further heliocentric variants. What followed was a bifurcation of the Ptolemaic tradition into both new heliocentric *and* geocentric gestalts. After the second revolution, both these fracta were subject to selection until there was a fusion of geocentric concepts in the direction of heliocentrism. A new heliocentric fractum also appeared at this time that underwent growth and variation characterized by mathematization and experimentation. However, by the end of the eighteenth century the large scale fractum representing the entire Copernican Revolution was declining, eventually reaching a final structure different than at what it had started. Cosmological theories continued to evolve along new dialectics but the Copernican Revolution itself had ended.

This revisiting of the Copernican Revolution demonstrated that the fractal model does correspond well with historical events as well as giving greater insight into the evolution of scientific knowledge.

(see Kuhn, The Copernican Revolution, p.199).

Conclusion

Most models of science from the nineteenth century onwards have either had an affiliation with *positivism* or *negativism*. In other words they have either assumed the history of science to be a growth towards some ideal state, or a decline to some non-ideal state. Such assumptions in themselves are not 'wrong'. There are episodes in history when science increases in capability. There are episodes in history when science misleads. However, focusing on the 'rise' or 'fall' of science alone is incomplete due to the tendency to render variations as 'errors', and to also to ignore the critical role variations play in evolving systems.

The fractal model demonstrates clearly that when variation is added to selection models, descriptive power is increased dramatically. The presence of variation at all times within the fractum solves the 'monolithic' problem by allowing thinkers within to have differences to a greater or lesser extent on common themes. Also the separation of the fractum into phases of variation and selection combines internalism with externalism into one model. Variation also requires a population with shifting normalcy, and hence 'norms' are allowed in scientific fracta as long as they too evolve with time. By defining the 'revolution' as a period of maximum variation, there is no longer a need to ascribe to it traditional causality. Also variation facilitates fractal descriptions of micro- and macro-phases in which fracta display at times resonance or anti-resonance (i.e. a 'rise within a fall' or a 'fall within a rise'). Finally the fractum exhibits entropic energy flow, which provides it with *directionality* and also demands that the presence of any fractum in an environment alters that environment irreversibly – something which selection models with pre-determined phases failed to take into account.

The fractal model does not refute past selection models, rather it confirms them and then goes on to describe more. This was seen in the close correlation of the fractal model with Kuhn's paradigm and Foucault's episteme, then moving beyond this correlation to describe aspects of history that neither predecessor could do satisfactorily.

This descriptive power of the fractal model was demonstrated in a revisiting of the Copernican Revolution. Copernicus's model was shown as a unique variation on the central themes of Ptolemaic cosmology of the early sixteenth century. Up to this time Ptolemaic cosmology had been enjoying an 'internal' phase of variation until a revolution and bifurcation in conceptions of the cosmos occurred. For a time geocentric variants continued to appear, exemplified by Tycho Brahe's geocentric conception. But under 'external' selective pressures, the norms slowly evolved in a direction favouring heliocentrism. At the end of the Copernican Revolution the 'macrocosm' converged on a final heliocentric structure, in the process returning diffuse energy to its larger intellectual environment and eventually reaching equilibrium.

Hence the fractal model succeeds in providing a new evolutionary model of historical change in science by giving variation an importance equal to that of selection. This inclusion of variation provides historians with an enhanced ability to describe history that had hitherto not been possible. This leads one to speculate as to what other historical events could be successfully revisited in terms of the fractal model?

Epilogue

Kuhn's model was intended to describe the evolution of science but the 'paradigm shift' soon became used to describe a special kind of change. If able to survive forthcoming selection events (i.e. like a thesis defence), it is hoped that this fractal model may also find wider usage.

History as a field of study has displayed and currently displays incredible variation from inception to the present. These variations have been subjected to selection over time according to what constitutes 'good' or 'bad' history. Although important, debates surrounding what constitutes 'good' or 'bad' history may have inadvertently hidden the usefulness of this variation. Perhaps the most important outcome of post-modernity is the recognition of the unavoidable existence of multiple perspectives in historical analyses. Now there is no question that the historian's mind is conditioned by various tropes which prevents one single story from ever being told. Some historians see this divergence as 'bad' and offer up remedies such as self-critical analysis (i.e. classic negativism). Attempts such as these are not 'wrong' in of themselves. Simply, the focus of the fractal model is somewhat different. Here the variations generated by the tropes exemplify the ongoing recurrence of variation in evolving systems. The tropes allow for a population of historians to contain a certain amount of variation in perspective at any one time. At times the proliferation of these variations is indicative of a growth phase in our understanding of history. From an evolutionary system's point of view, variation gives greater understanding than one viewpoint could alone. When selection comes again – and it will – this variation becomes useful in and of itself, allowing elements of history, and the value generated by its study, to survive unforeseen future challenges.

Take for example the history of positivism and negativism provided in Chapter One. Since its inception in the mid-nineteenth century, the history of science has followed a pattern of evolution through variation and selection on the dialectical axis of positivism and negativism. Throughout the nineteenth century growth in the field was coupled with increasing variation in structure. With the bifurcation of positivism into negativism and a new positivism around 1900, three different perspectives existed simultaneously. A point of maximum variation in both positivistic and negativistic models occurred around 1960, concurrent with large-scale revolution. Since 1960, there appears to be selection, or a fusion of positivism into negativism and a convergence in structure in favour of negativism. Yet what lies beyond this positivism / negativism dialectic? We will have to wait for the next revolution for this to be revealed.

BIBLIOGRAPHY

Applebaum, W., "Keplerian Astronomy after Kepler" History of Science Vol. 34, Pt. 3, No. 105, September 1996, pp.451-504

Bailey, K.D., Social Entropy Theory, New York: State University of New York Press, 1990

Barker,P., Ariew,R., Revolution and Continuity, Washington: CUA Press, 1991

Bender, F. L., Karl Marx: The Essential Writings London: Westview Press, 1972

Bergson, H., Creative Evolution Westport: Greenview Press, 1977 [1907]

Berlin, I., Three Critics of the Enlightenment Princeton: Princeton University Press, 2000

Biagioli, M., "Galileo the Emblem-Maker" Isis (81), 1990, pp.230-258

Biagioli, M., "Galileo's System of Patronage" History of Science (28), 1990, pp.1-62

Biernacki, R., The Fabrication of Labor Berkeley: University of California Press, 1995

Blake, R. M., Theories of Scientific Method : the Renaissance through the Nineteenth century New York : Gordon and Breach, 1989

Bowler, P.J., Evolution: The History of an Idea Berkeley: University of California Press, 1983

Braudel, F., La Méditerranée et le monde méditerranéen à l'époque de Philippe II Paris: Colin, 1949

Brooks, D.R., Wiley, E.O., Evolution as Entropy Chicago: The University of Chicago Press, 1988

Burke, P., Varieties of Cultural History Ithaca: Cornell University Press, 1997

Butterfield, H., The Origins of Modern Science, 1300-1800 London: Bell, 1949

Callon, M., "Some elements of a sociology of translation: domestication of the scallops and the fishermen of St Bireuc Bay" Power, Action and Belief, edited by J. Law, 1986, pp.196-233

Canguilhem, G., A Vital Rationalist: Selected Writings from Georges Canguilhem Edited by Francois Delaporte, New York: Zone Books, 1994

Cengel, Y., Boles, M., Thermodynamics: An engineering approach New York: McGraw-

Hill, 1989

Cohen, H. F., The Scientific Revolution: a Historiographical Inquiry Chicago: University of Chicago Press, 1994.

Collins, H., Changing Order: Replication and Induction in Scientific Practice London: Sage, 1985

Collins, H., Pinch, T., The Golem: What You Should Know about Science Cambridge: Cambridge University Press, 1998

Comte, A., Cours de philosophie positive (The Positive Philosophy) New York: AMS Press, 1974 [1830-42]

Crowe, M.J., Theories of the World from Antiquity to the Copernican Revolution Mineola: Dover Publications, 2001

Cunningham, A., Williams, P., "De-centering the 'big picture': The Origins of Modern Science and the modern origins of science" British Journal for the History of Science (26), 1993, pp.407-432

Cziko, G., The Things We Do Cambridge MA: The MIT Press, 2000

Cziko, G., Without Miracles: Universal Selection Theory and the Second Darwinian Revolution Cambridge MA: The MIT Press, 1995

Darwin, C., On the origin of species by means of natural selection Peterborough, Ont.: Broadview Press, 2003 [1859]

Darwin, C., R., The Variation of Animals and Plants under Domestication New York: AMS Press, 1972 [1868]

Daston, L., "The Language of Strange Facts in Early Modern Science" Inscribing Science: Scientific Texts and the Materiality of Communication, Edited by Timothy Lenoir, Stanford: Stanford University Press, 1998, pp.20-38

Dawkins, R., The Selfish Gene Oxford: Oxford University Press, 1976; Wilson, E.O., On Human Nature Cambridge MA: Harvard University Press, 1978

Dear, P., Discipline and Experience: The Mathematical Way in the Scientific Revolution Chicago: University of Chicago Press, 1995

Dobbs, B.T., Jacob, M.C., Newton and the Culture of Newtonianism New York: Humanity Books, 1998

Duhem, P., M., M., La Théorie Physique: son Objet, sa Structure (The Aim and Structure of Physical Theory) New York, Atheneum, 1962 [1906]

Eagleton, T., Literary Theory: An Introduction Oxford: Basil Blackwell, 1983

Eamon, W., Science and the Secrets of Nature Princeton: Princeton University Press, 1994

Edelman, G.M., Tononi, G., A Universe of Consciousness: How Matter becomes Imagination New York: Basic Books, 2000

Ehrlich, P., Human Natures, New York: Penguin Books, 2000

Eldredge, N., Gould, S., "Punctuated Equilibria: an Alternative to Phyletic Gradualism" Models in Paleobiology Edited by T. Schopf, San Francisco: Freeman, Cooper and Co., 1972

Eldredge, N., Time Frames: the Rethinking of Darwinian Evolution and the Theory of Punctuated Equilibria New York: Simon and Schuster, 1985

Erikson, E.H. Identity and the Life Cycle: Selected Papers New York: International Universities Press, 1959

Erikson, E.H., Life History and the Historical Moment New York: Norton, 1975

Feyerabend, P.,K., Knowledge, Science and Relativism, Philosophical Papers Volume 3, edited by John Preston, Cambridge: Cambridge University Press, 1999

Feyerabend, P.K., Against Method London: Verso, 1988 [1975]

Findlen, P., Possessing Nature: Museums, Collecting and Scientific Culture in Early Modern Italy Berkeley: University of California Press, 1994

Fleck, L., The Genesis and Development of a Scientific Fact Chicago: University of Chicago Press, [1935] 1979

Foucault, M., Histoire de la sexualité: La volonte de savoir Paris: Gallimard, 1976 (L'usage des plaisirs, 1984; Le souci de soi, 1984)

Foucault, M., L'archeologie du savoir Paris : Gallimard, 1969

Foucault, M., Les Mots et les choses: Une archéologie des science Paris: Gallimard, 1966

Foucault, M., The Order of Things New York: Vintage Books, 1970

Foucault, M., The Order of Things: An Archeology of the Human Sciences New York: Vintage Books, 1970

Freud, S., Drei Abhandlungen zur Sexualtheorie (Three Essays on the Theory of Sexuality), translated and edited by James Strachey, New York: Basic Books, 2000 [1905]

Fukuyama, F., The End of History and the Last Man New York: Free Press, 1992

Fuller, S., Thomas Kuhn: a Philosophical History for Our Times Chicago: The University of Chicago Press, 2000

Gaddis, J., L., The Landscape of History: How Historians Map the Past Oxford: Oxford University Press, 2002

Gluesing, G.R., Abdel-Hameed, F., "Impact of Neutral Mutations on Evolution" Evolutionary Models and Studies in Human Diversity, Edited by Sol Tax, Chicago: Mouton Publishers, 1978

Goldstein, J.S., Long Cycles: Prosperity and War in the Modern Age New Haven: Yale University Press, 1988

Golinski, J., Making Natural Knowledge: Constructivism and the History of Science Cambridge: Cambridge University Press, 1998

Gould, S.J., "An Operational Notion of Directionality" The Philosophy of Biology, edited by David L. Hull and Michael Ruse, Oxford: Oxford University Press, 1998

Gould, S.J., The Structure of Evolutionary Theory Cambridge MA: The Belknap Press, 2002

Graham, L.R., "The Socio-political Roots of Boris Hessen: Soviet Marxism and the History of Science" Social Studies of Science (15), 1985, pp.705-722

Grant, E., The foundations of modern science in the middle ages Cambridge: Cambridge University Press, 1996

Hacking, I., "Michel Foucault's Immature Science" Nôus, Vol.13, No.1, pp.39-51

Hall, A.R., The Scientific Revolution 1500-1800 London: Longmans, 1954

Hart, S., Hart, R., German Tanks of World War II London: Brown Books, 1998

Hawking, S., A Brief History of Time New York: Bantam Books, 1988

Hegel, G.W.F., Phänomenologie des Geistes (Phenomenology of Spirit) Indianapolis: Hackett Pub. Co., 2001 [1807]

Heidegger, M., "The Age of the World Picture" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York: New York. University Press, 1997, pp. 70-88

Henry, J., The Scientific Revolution and the Origins of Modern Science New York: St. Martin's Press, 1997

Herder, J.G., Ideen zur Philosophie der Geschichte der Menschheit (Outline of a Philosophy of the History of Man) München: C. Hanser, 2002 [1800]

Hessen, B., "The Socio-Economic Roots of Newton's Principia" Science at the Cross Roads, Edited by N.I. Bukharin London: Frank Cass, 1971 [1930], pp.149-212

Holton, G., Thematic Origins of Scientific Thought Cambridge MA: Harvard University Press, 1973

Horgan, J. The End of Science New York: Broadway Books, 1996

Horkheimer, M., Adorno, T., "The Culture Industry: Enlightenment as Mass Deception", The Dialectic of Enlightenment New York: Herder and Herder, 1944

Hull, D., L., Science and Selection: Essays on Biological Evolution and the Philosophy of Science Cambridge: Cambridge University Press, 2001

Hull, D.L., "Studying the Study of Science Scientifically" Perspectives on Science Volume 6, Number 3, 1998, pp.209-231

Iliffe, R., "Isaac Newton: Lucatello Professor of Mathematics" Science Incarnate: Historical Embodiments of Natural Knowledge, Edited by Christopher Lawrence and Steven Shapin, Chicago: University of Chicago Press, 1998, pp.121-155

Jantsch, E., The Evolutionary vision: toward a unifying paradigm of physical, biological, and sociocultural evolution Boulder, Colo.: Westview Press, 1981

Jung, C.G., Contributions to Analytical Psychology New York: Harcourt, Brace and Co., 1928

Kant, I., Kritik der reinen Vernunft (Critique of Pure Reason) New York: Palgrave Macmillan, 2003 [1781]

Keller, E.F., "Feminism and Science" Feminism and Science Edited by Evelyn Fox Keller and Helen E. Longino, Oxford: Oxford University Press, 1996, pp.28-40

Kennedy, P., M., The Rise and Fall of the Great Powers: Economic Change and Military Conflict from 1500 to 2000 New York: Random House, 1987

Kindleberger, C.P., Manias, Panics and Crashes: A History of Financial Crises New

York: John Wiley and Sons Inc., 1996 (3rd ed)

Kingsland, S. E., Modeling Nature Chicago: The University of Chicago Press, 1985

Kitcher, P., The Advancement of Science Oxford: Oxford University Press, 1993

Koyré, A., From Closed World to Infinite Universe Baltimore: John Hopkins University Press, 1957

Kuhn, T. S., The Copernican Revolution: Planetary Astronomy in the Development of Western Thought Cambridge: Harvard University Press, 1957

Kuhn, T., "The Road Since Structure" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York: New York University Press, 1997, pp.231-248

Kuhn, T.S., "The Function of Dogma in Scientific Research" Scientific Knowledge, Edited by Janet Kourany, Wadsworth, 1987

Kuhn, T.S., The Structure of Scientific Revolutions Chicago: University of Chicago Press, 1962

Lakatos, I., Mathematics, science and epistemology Cambridge: Cambridge University Press, 1978

Lamarck, J. B., Philosophie zoologique, ou, Exposition des considérations relative à l'histoire naturelle des animaux (Zoological philosophy : an exposition with regard to the natural history of animals) Paris: Chez Dentu [et] L'Auteur, 1809

Latour, B., Pandora's Hope: Essays on the Reality of Science Studies Cambridge MA, 1999

Latour, B., The Pasteurization of France Cambridge, Mass.: Harvard University Press, 1988

Latour, B., Woolgar, S., Laboratory Life: The Social Construction of Scientific Facts Beverly Hills: Sage, 1979

Laudan, L., "Explaining the Success of Science: Beyond Epistemic Realism and Relativism" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York: New York University Press, 1997

Laudan, L., Progress and its Problems: Towards a Theory of Scientific Growth Berkeley: University of California Press, 1977

Lenoir, T., "Inscription Practices and Materialities of Communication" Inscribing Science: Scientific Texts and the Materiality of Communication Stanford: Stanford

University Press, 1998

Lenzer, G., Auguste Comte and positivism: the essential writings New York, Harper & Row, 1975

Lindberg, D., "Conceptions of the Scientific Revolution from Bacon to Butterfield: A Preliminary Sketch" Reappraisals of the Scientific Revolution, Edited by David C. Lindberg and Robert Westman, Chicago: University of Chicago Press, 1990, pp.1-26

Lorenz, K., On Aggression London: Methuen & Co. Ltd., 1966

Macey, D., The Lives of Michel Foucault London: Hutchinson, 1993

Mach, E., Mechanik in ihrer Entwickelung (The Science of Mechanics: a Critical and Historical Account of its Development) LaSalle, Ill., Open Court Pub., 1960 [1893]

Mager, N.H., The Kondratieff Waves New York: Praeger, 1987

Major-Poetzl, P., Michel Foucault's Archaeology of Western Culture Chapel Hill: The University of North Carolina Press, 1983

Malthus, T. R., On Population New York: Random House, 1960 [1798]

Marcuse, H., Counterrevolution and revolt London: Allen Lane, 1972

Marx, K., Kapital (Capital) Oxford: Oxford University Press, 1995 [1867]

Mayr, E., The Growth of Biological Thought Cambridge MA: The Belknap Press, 1982

Mead, M., Coming of age in Samoa: a psychological study of primitive youth for Western civilization New York: Blue Ribbon Books, 1928

Mensch, G., Stalemate in Technology Cambridge MA: Ballinger Publishing, 1979

Merchant, C., The Death of Nature: Women, Ecology and the Scientific Revolution San Francisco: Harper, 1980

Merquior, J. G., Foucault London: Fontana, 1985

Merton, R.K., "Science, Technology, and Society in 17^{th} century England" Osiris (4), 1938

Merton, R.K., "Science and Technology in a Democratic Order" Journal of Legal and Political Sociology 1, 1942: pp.115-126

Merton, R.K., The Sociology of Science: Theoretical and Empirical Investigations

Chicago: The University of Chicago Press, 1973

Naccache, A.F.H., "A Brief History of Evolution", History and Theory Vol.38, 1999

Needham, J., The Grand Titration: Science and Society in East and West London: Allen & Unwin, 1969

Nietzsche, F. W., Der Wille zur Macht (The Will to Power) New York: Random House, 1968 [1901]

Novick, P., That Noble Dream Cambridge: Cambridge University Press, 1988

Pena, A., "On the Role of Mathematical Biology in Contemporary Historiography" History and Theory Vol.38, 1999

Peters, E.E., Chaos and Order in the Capital Markets New York: John Wiley and Sons, 1991

Pinker, S., The Language Instinct New York: William Morrow and Company Inc., 1994

Polanyi, M., Personal Knowledge Chicago: University of Chicago Press, 1958

Popper, K.R., The Poverty of Historicism London: Routledge & K.Paul, 1957

Popper, K.R., The Logic of Scientific Discovery London: Hutchinson, 1959

Postman, N., Technopoly: the Surrender of Culture to Technology New York: Knopf, 1992

Prakash, G., Another Reason: Science and the Imagination of Modern India Princeton: Princeton University Press, 1999

Price, D.J., Little Science, Big Science…and Beyond New York: Columbia University Press, 1986

Prigogine, I., Stengers, I., Order out of Chaos New York: Bantam Books, 1984

Quine, W.V., From a Logical Point of View Cambridge MA: Harvard University Press, 1953

Rabinow, P., The Foucault Reader New York: Pantheon, 1984

Richards, R.J., "Theories of Scientific Change" Science and the Quest for Reality, Edited by Alfred I. Tauber, New York, New York University Press, 1997, pp.203-227

Richards, R.J., Darwin and the Emergence of Evolutionary Theories of Mind and

Behavior Chicago : University of Chicago Press, 1987

Ridley, Matt, "What Makes You Who You Are", Time Magazine, Jun 2, 2003

Rosseau, G.S., "Whose Enlightenment? Not Man's: The case of Michel Foucault" Eighteenth century Studies, Volume 6, Issue 2 (Winter 1972-1973), 238-256

Runciman, W.G., Confessions of a Reluctant Theorist, New York: Harvester Wheatsheaf, 1989

Ruse, M., Evolutionary Naturalism London: Routledge, 1995

Ruse, M., Taking Darwin Seriously New York: Prometheus Books, 1998 [1986]

Rushton, P. J., Race, evolution and behavior: a life history perspective New Brunswick, N.J.: Transaction Publishers, 1997

Said, E., Orientalism New York: Pantheon Books, 1978

Saul, J. R., On Equilibrium Toronto: Viking, 2001

Schiebinger, L., "Why Mammals are Called Mammals: Gender Politics in Eighteenth century Natural History" Feminism and Science edited by Evelyn Fox Keller and Helen E. Longino, Oxford: Oxford University Press, 1996, pp.137-153

Schiebinger, L., Nature's Body. Gender in the Making of Modern Science Boston: Beacon Press, 1993

Shapin, S., "History of Science and its Sociological Reconstructions" History of Science (20), 1982, pp.157-211

Shapin, S., "The Philosopher and the Chicken: On the Dietetics of Disembodied Knowledge" Science Incarnate: Historical Embodiments of Natural Knowledge, Edited by Christopher Lawrence and Steven Shapin, Chicago: University of Chicago Press, 1998, pp.21-51

Shapin, S., "Understanding the Merton Thesis" Isis (79), 1988, pp.594-605

Shapin, S., A Social History of Truth Chicago: University of Chicago Press, 1994

Shapin, S., Schaffer, S., Leviathan and the Air Pump: Hobbes, Boyle, and the Experimental Life Princeton: Princeton University Press, 1985

Smith, A., An Inquiry into the Nature and Causes of the Wealth of Nations New York: The Modern library, 1985 [1776]

Smith, P., Explaining Chaos Cambridge: Cambridge University Press, 1998

Spencer, H., First principles (Edition 3d impression) London: Williams & Norgate, 1910 [1862]

Spencer, H., Structure, Function and Evolution London: Michael Joseph, 1971

Spengler, O., Untergang des Abendlandes (The Decline of the West) New York: The Modern Library, 1962 [1918]

Stallybrass, W., White, A., The Politics and Poetics of Transgression Ithaca: Cornell University Press, 1986

Stent, G.S., The Coming of the Golden Age: a View of the End of Progress Garden City, N.Y: Natural History Press, 1969

Taureck, B., Michel Foucault, Hamburg: Rowohlt, 1997

Teilhard de Chardin, P., Christianity and Evolution London: Collins, 1971

Toulmin, Human Understanding Oxford: Clarendon Press, 1972

Traweek, S., "Faultlines" Doing Science and Culture, Edited by Roddey Reid and Sharon Traweek, New York: Routledge, 2000, pp.21-48

Trigger, B.G., Sociocultural Evolution: Calculation and Contingency Malden, Mass.: Blackwell Publishers, 1998

Vico, G., The New Science of Giambattista Vico Ithaca: Cornell University Press, 1948 [1744, 3rd edition)

Wallerstein, I., Unthinking Social Science Philadelphia: Temple University Press, 2001

Westman, R.S., "Proof, poetics, and patronage: Copernicus's preface to *De Revolutionibus*" Reappraisals of the Scientific Revolution, Edited by David C. Lindberg and Robert S. Westman, Cambridge: Cambridge University Press, 1990

Whewell, W., History of the Inductive Sciences, from the Earliest to the Present Time New York: D. Appleton, 1858

White, H., "Foucault Decoded": Notes from Underground" History and Theory, Vol.12, No.1, 1973, pp.23-54

White, H., "The Burden of History" History and Theory, Vol.5, 1966, pp.111-134

Whitehead, A. N., Science and the Modern World New York: Free Press, 1967 [1925]

Wright, C., Philosophical Discussions New York, B. Franklin, 1971 [1877]

Yates, F.A., "The Hermetic Tradition in Renaissance Science" Art Science and History in the Renaissance, Edited by Charles S. Singleton, Baltimore: John Hopkins Press, 1967

Zilsel, E., "The Sociological Roots of Science" American Journal of Sociology (47), 1942, pp.245-279