Commentary Traditions and the Evolution of Premodern Religious and Philosophical Systems: A Cross-Cultural Model

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Commentary Traditions and the Evolution of Premodern Religious and Philosophical Systems: A Cross-Cultural Model

Steve Farmer, John B. Henderson, and Peter Robinson
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Update (2014) Steve Farmer

The first draft of the paper published below was written for a conference in Germany on premodern commentary traditions held over seventeen years ago, in 1997. My coauthors were John B. Henderson, the well-known specialist on Chinese cosmologies, and Peter Robinson, a talented computer modelist at NASA-Ames Research Center who translated my flow chart into the algorithm found near the end of the paper.

The paper has always been a favorite of mine, since it was the first ever to attempt to identify and model key mathematical patterns in the evolution of thought. While the model's initial impact on historians was virtually nil — years later its cross-cultural sides did influence Chinese studies1 — the model was well received by mathematicians studying complex systems, which encouraged me to continue the directions established in the paper in later years. Our initial paper limited itself to analyzing fractal-like growths in premodern systems, but we anticipated early on that its findings might be generalized to modeling broader segments of culture — a direction in which I have increasingly turned my attention in recent years (see infra).

I lightly updated the draft in 2002, mainly to include references to studies my collaborators and I had published in the five intervening years. But no major changes have been made since to the paper, which was available on Internet but was never formally published. Over the past seventeen years it has nevertheless slowly gained readers, being downloaded several thousand times a year ever since.

Some topics in the paper were expanded in a long book I published in 1998 on an obscure Latin text from the early printing age, the 900 theses of Giovanni Pico della Mirandola. The text was drawn up in 1486 for a planned debate at Rome de omni re scibili ("on everything knowable") before the Pope and Cardinals and heads of the period's "warring schools." The aim of the debate was to review and partly reconcile all known traditions, prelude as Pico suggested to the Second Coming, in which Christ would still forever all intellectual debates. As is well-known, Pope Innocent VIII forbade the debate, and Pico's 900 theses became the first printed book banned universally by the Church. My interests in this old text lay in Pico's extreme methods and exaggerated fractal-like views of the world, which provided a window to study the growth of similar systems elsewhere, which can be identified in nearly every mature manuscript tradition known.

1 Dirk Meyer, Philosophy on Bamboo: Text and the Production of Meaning in Early China (Studies in the History of Chinese Texts, Brill, 2011.)
Other parts of the paper were included in articles that began as talks at Harvard University, Peking University, and other academic centers in Germany, France, Italy, Holland, Japan, and the US in the first decade of the 2000s. Most importantly, an expanded look at the neurobiological roots of the model appeared in 2002 in a special edition of the Bulletin of the Museum of Far Eastern Antiquities devoted to the study of "correlative cosmologies," as fractal-like systems are known to Sinologists.

In that article, written again with John Henderson and the influential Indologist, Michael Witzel, Wales Professor of Sanskrit at Harvard, we emphasized the model as a framework for studying literate religious and philosophical traditions globally, in new- as well as old-world civilizations.

In that paper we also drew up our first list of predictions that could be used to support or falsify our model — a routine procedure elsewhere in the sciences, but previously nearly unknown in historical studies. The best-known of these predictions pushed the dates of the first writing in India forward over 2000 years — from the time of the Indus Valley civilization (flourished ca. 2600 - 1900 BCE) to the last half of the first millennium BCE.

Two years later the computational linguist Richard Sproat (then at the University of Illinois, and now at Google), joined me and Michael in testing that prediction in a paper that challenged over 130 years of Indological research. The article reviewed masses of archaeological, linguistic, and computational evidence that suggested that the so-called Indus script was incapable of encoding any language, and consisted instead of nonlinguistic symbols of a type found throughout the premodern world. Richard has since expanded our work in a series of brilliant papers adding further statistical and computational evidence in support of our prediction, examining along the way other poorly studied nonlinguistic symbol systems around the world.

One further extension of our results involved what Michael first referred to as a gigantic "No Text Zone" extending throughout the Indian subcontinent, all of Central Asia, southeastern Iran, and southern parts of the Persian Gulf from the start of the 3rd millennium BCE (when proto-Elamite disappeared in Iran) down to last half of the first millennium BCE. At that time the introduction by the Persians throughout their territories of Aramaic triggered massive literate revolutions that radically impacted Indian culture and much wider areas of Eurasia.

A brief annotated bibliography of these and a few other papers related to our model, with links to copies available online, is given at the end of this update.

Given this background, I was happy to accept the invitation from the editors of this journal to publish the old paper that lay at the origins of so much of my later work. Updating an article drafted so long ago had little appeal, so we agreed to publish the article largely in its original form, in part for its historical value, adding this note to provide background on how the model evolved and how it has been expanded to deal with future as well as past events.
The period of the 1980s through late 90s, during which the model evolved, was marked by a long series of remarkable breakthroughs in neurobiology, nonlinear dynamics, fractal geometry, and related fields — for the first time methodologically linking research in areas as outwardly unrelated as astrophysics, meteorology, geology, evolutionary biology, genetics, and the new field of cultural neurobiology I was then exploring. Other major discoveries were being made in philology, especially involving Chinese tomb text finds, that would eventually overturn two thousand years of readings of classical texts long assumed to reflect the genuine thought of figures like "Confucius," "Laozi," and "Zhuangzi," etc., all of whom are now viewed as half-fictional at best. These philological discoveries had a deep impact on the views of textual layering underlying our model, as I have discussed at length elsewhere (Farmer, 2009).

When this research explosion began in the 1980s, I was in the middle of two extended post-docs financed by the National Endowment for the Humanities and Harvard University, the latter spent at the Villa I Tatti, Bernard Berenson's stunning old estate in Florence. During those wonderful leisurely years, I spent as much of my time studying theoretical neurobiology, chaos theory, fractal geometry, and related fields of complex systems as I did working through thousands of forgotten old scholastic texts, looking for clues as to the origins of the elaborate fractal-like structures I kept finding in Pico and his counterparts outside the West.

In neurobiology, Edelman and Mountcastle heavily influenced me in this period, in part due to their elegant models of hierarchically organized brain "maps" critical to all brain functions. Mandelbrot and Bak most impacted my views of the evolution of such fractal or self-similar (or more technically, "self-affine") structures in general. I also gained much a bit later from contacts with one of the pioneers in chaos theory, the mathematician Ralph Abraham of the University of California at Santa Cruz, whose intuitive visual models convinced me that it should be possible to model historical traditions in similar ways. Cosma Shalizi, then at the Santa Fe Institute, provided further support for my modeling ideas in the years right after the paper below appeared.

My early discussions with traditional historical researchers, with a few notable exceptions (the great Ernst Gombrich was one), were less encouraging. Paul Oskar Kristeller, who had dominated Renaissance studies for the past half century, confronted me directly at I Tatti and in later letters. My philological work on Pico was admirable, but I was jeopardizing my career by bringing China and brain studies into the picture. Comparisons of premodern Chinese and Western traditions were spurious, and mixing up discussions of history with brain science were worse. Kristeller aimed a rhetorical question at me that I'll never forget: "What does the brain have to do with the history?!

In Western studies in those days comparative studies were heretical, and Dilthey's views were still common: the Naturwissenschaften and Geisteswissenschaften belonged to totally different spheres of discourse, and would never meet.
What in fact intrigued me most about Pico was that I knew from long discussions with John Henderson, whose classic study of Chinese cosmologies appeared in 1984, that similar fractal-like growths evolved in China roughly in sync with those in the West. My excitement grew when digging through Berenson’s old library at I Tatti, which (reflecting older comparative interests) contained a surprising number of non-Western sources, I ran into my first evidence that fractal (or correlative) structures arose in similar step-like fashions in manuscript traditions not just in Europe and China, but in literate pre-Columbian Mesoamerica as well, in ways that ruled out any possibility of direct transmissions.

Leaving aside the kinds of mystical synchronicities imagined by a Jung or Jaspers, which were totally alien to my ways of thinking, trying to think of scientific ways of explaining those parallels kept me awake for many months.

The answer eventually arose from a joint discovery that John Henderson and I had made involving striking similarities in the exegetical (and especially reconciliative) methods used by premodern scribes, reciters, commentators and exegetes in every part of the world. Due to the precipitous decline of comparative studies after World War II, this topic had never been systematically studied before our work.

My neurobiological studies quickly suggested reasons for those similarities, involving the sharply limited methods that brains have available to integrate conflicting data. This led in turn to the central idea in our paper — that the repetitive or iterative application of those methods to successive layers of stratified traditions provided a cross-cultural “engine,” so to speak, that over long periods transformed the structures of any systems emerging out of those traditions in convergent fractal directions.

Moreover, as I argued in my Pico book, in their most elaborate form these structures began over long periods to reflect ever more perfectly the structure of hierarchical-mirroring (or topographic) brain “maps” critical to all brain processing. The latter issue was being explored theoretically and experimentally by groundbreaking neurobiologists I was then reading, including Mountcastle, Edelman, Merzenich, Fuster, and Goldman-Rakic. The best known result of this odd solipsistic process was the generation of a broad class of abstract "man the microcosm" motifs, whose step-like emergence I have argued can be studied in all literate civilizations (cf. Farmer 1998: 91-6; Farmer et al. 2002; Farmer 2009).

Ways of translating these ideas into computational terms also suggested themselves quickly: the idea that iterative transformations give rise to self-similar (or self-affine) structures is central to all studies of complex systems.

That idea is nowhere expressed more beautifully than in Mandelbrot’s classic *The Fractal Geometry of Nature* (1982). If any system transformed through iterative processes includes significant entropic or dissipative elements — that is, if those systems lose or "leak" part of
their data during their growth — their structures will become increasingly self-similar and complex over time. This is what precisely what we found in the historical systems we were studying, which reached their most extreme developments shortly before the start of their collapse in the later printing and scientific revolutions.

Adumbrations of Dante-like or Pico-like systems were common in late ancient thought, associated most popularly in the West with so-called Neo-Platonic traditions. But nowhere did they attain the purity of form seen in late medieval and early-modern systems like Pico's, which in a sense "summed up" and amplified all the fractal structures they were aware of generated in earlier layers of thought.

The entropic processes required to build simulations of these processes can be readily identified in reciters' memory failures, losses of texts, scribal errors, scholiasts' interpolations, and dozens of other corruptions that philologists face in dealing with heavily layered textual sources.

In the famous historical sketches in his classic mathematical text (Mandelbrot 1982: 405 ff., 419), the founder of fractal geometry revealed his fascination with the same kinds of fractal-like systems that John and I were studying in the historical sphere. Mandelbrot had special interests in Leibniz's monadology and the so-called great chain of being. But misled by his sources (especially Lovejoy), Mandelbrot mistook those structures as oddities of Western thought, overlooking their ubiquity in other premodern cultures and hence not searching for the iterative mechanisms that his own models suggested should underlie them (on this and below, cf. Farmer 1998: 94-5, n. 91).

Once those mechanisms are identified in repetitive exegetical processes, the structural evolution of those systems can be modeled using Mandelbrot's own models of fractal growth. Obvious "tuning" parameters in building such models are provided by changes in rates of information flows, which as other historical researchers (Innis, Havelock, Goody, Ong, etc.) stressed long ago, can be linked to innovations in communication technologies and closely related demographic, social, and institutional factors. If those rates remain similar in two or more traditions, mathematical models predict that the complexities and levels of self-similarity in those traditions (e.g., measured by their "fractal dimensions") will stay more or less in sync in every later period — which is roughly the case we found when we compared the pan-Eurasian growth of religious, philosophical, and cosmological systems in each era after the middle of the first millennium BCE.

As first noted in our paper, that period overlaps with a massive Eurasian expansion of the use of lightweight writing materials, the first synchronizing event in the parallel growth of the abstract philosophical and philosophical systems that evolved in later centuries throughout Eurasia. This period also overlaps with the so-called axial age, as emphasized by Dirk Meyer (citing our work) in his seminal studies of Chinese tomb texts (footnote 1, supra), eliminating the need in explaining axial-age parallels for far-fetched transmissions of the idea of "abstract thought" or the mystical synchronicities of a Jung or Jaspers.
The fact that Mandelbrot missed the links between his models and self-similar structures in history is unfortunate, since his brilliant historical notes demonstrate that historical awareness of those structures helped trigger the first analyses of self-similarities by late nineteenth and twentieth century mathematicians from Cantor and Poincaré to Richardson and Mandelbrot himself.

Mandelbrot hence missed arguably the most remarkable feedback loop in the history of thought, and one moreover that is deeply dependent on his work: Thousands of years of attempts by premodern exegetes to reconcile traditions, methodologically limited by the brain's own fractal structures, led over long periods to the emergence of self-similar cosmological systems whose contemplation by nineteenth century mathematicians helped trigger the birth of fractal geometry — which can be used in turn to model the growth of the systems that led to that birth.

One can take this even deeper, looking at the molecular origins of the fractal structures in the brain, which have recently been proposed as the key to understanding all neural networks — and by extension we would argue the massively scaled brain-culture networks underlying the evolution of thought.2

This self-referential hall of mirrors would have delighted Mandelbrot, whose mathematical work all depending on recursive thinking. From self-similar brain structures to premodern cosmologies that increasingly mirrored those structures, to the contemplation of those cosmologies by 19th century mathematicians, which helped trigger the birth of fractal geometry, which finally suggested ways to model the evolution of those cosmologies and the brain itself: It is fractals all the way.

Details on the rise and fall of premodern systems mirroring these ideas are sketched in the paper that follows, and I won't discuss them further. In the remainder of this update I'd like to suggest quickly ways that our model can be extended in broader directions, modeling the future as well as the past.

In our initial article, we limited ourselves to discussing emergent mathematical patterns in premodern thought. But as we've tried to show more recently, it is possible to generalize our findings using intelligent-agent software to simulate how beliefs in general evolve as rates and quality of information flows change. Among much else, this approach allows probabilistic modeling of future developments in human thought as well as those in the past.

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using the same basic methods used to model climate change or future geological or oceanographic developments (cf. Farmer et al., 2009, 2011-14).

Pursuing this line of reasoning, from 2008-10, Bill Zaumen, an MIT PhD with many decades of experience developing network systems, expanding on my design input, wrote intelligent agent network software to help extend our modeling ideas in new directions. Other responsibilities that have arisen in the last four years have prevented us from taking this part of our work as far as we would like, but we plan to return to it in broadened collaborations soon, adding a graphic-user interface to make our network software (written in Java) accessible to non-programming researchers in comparative history, linguistics, political science, economics, and other fields of the cultural sciences.

A brief paper and a long abstract that describe this part of our work are available via links in the last two items in the short bibliography below.

I want to end by recalling briefly the odd reception that our original paper received when it was drafted so long ago. The organizers of the German conference who invited us to give the paper were so upset by our attempts to introduce into premodern studies unfamiliar recent findings in brain research, nonlinear dynamics, and computer simulations, that at the last minute they suddenly changed the conference format. The papers would not be delivered by their authors, but would be summarized instead in five minutes by an outside interlocutor. The scholar they assigned to our paper didn't summarize it, and showed no signs of having read it, but used her five minutes instead to issue sharp warnings against the use of models in history. She cited as her authority Max Weber, who on this point at least absorbed his lessons from Dilthey well.

The invitation from the editors of this journal to publish our paper seventeen years later reminds us how rapidly the world is changing, due above all to the most massive revolution ever in communication technologies, which was still in its infancy when our original paper was written. As we predicted when we wrote that paper, in the coming decades we can expect far more sophisticated models of the type described in our paper to become standard tools in studies of the evolution of thought. That claim seemed outrageous in 1997 but borders on the obvious today.

If there is one lesson that the cultural neurosciences have taught us, it is that no intellectual production in a deep sense is the creation of one individual. We are all "nodes in the net," so to speak, reflecting in our creations and beliefs the summed outputs of all brains linked to us directly or indirectly via whatever external traditions are available in brain-culture networks orders of magnitude larger than those available to premodern intellectuals.

There are reasons to believe that all cultural systems evolving within such networks obey the same probabilistic laws as all other complex systems. As we argue in this paper, far from being too complex to simulate, as is often claimed, human belief systems are far less complex than countless other systems in other biological sciences, including genetics and neurosciences, in which simulations are critical to most scientific advances.
Given the unprecedented speed with which cultural information and misinformation flows are altering our political, economic, and ideological worlds, we suspect that our ability not only to model the past but to make probabilistic predictions about the future as well may be a requirement to insure the long-term survival of "higher" civilization. As earlier noted, we address these issues in a paper and long abstract available at the end of the bibliography below. Both suggest ways in which our model can be generalized to build probabilistic models of future beliefs as well as those in the past.

We are entering a dangerous period in human civilization, coupled with apparent global upheavals in every aspect of human life. One of the few recent developments that may help us survive lies in our ability to replace narrow parochial with global views of history, backed by sophisticated and testable scientific models, which can hopefully help us weather some of those upheavals in reasonable and humane fashions.

Steve Farmer, PhD
Palo Alto, CA, September 2014

A Brief Annotated Bibliography


A long case study of the kinds of materials that went into the construction of the model. Some supplementary materials online can be found at <http://www.safarmer.com/Pico>.


Devoted to testing the best-known prediction of our model, regarding the non-linguistic nature of the so-called Indus script, following lines of argument introduced in our BMFEA paper. Downloaded several million times in the last decade. Found at <http://www.safarmer.com/fsw2.pdf>.

Farmer, Steve. "Neurobiology, stratified texts, and the evolution of thought: From myths to religions and philosophies." Given in Beijing at the founding conference, co-sponsored by Harvard and Peking Universities, of the International Association for Comparative Mythology, of which I am a Director. The paper traces my work over the last two decades and makes further predictions based on the model involving recent tomb text finds in China.


Introduces the first testable neurobiological model of the origins of primitive myth and religion, which lies at the deepest layer of our historical modeling.

Discusses broader uses of the intelligent-agent modeling software we built in 2009-10, in this case pertinent to how the software can be used to study global shifts in political-religious beliefs. See <http://www.safarmer.com/simulations.version.3.0.pdf>.


Generalizes modeling ideas first conceived in the paper published below to wider historical domains and the future. The same topic is taken up in a book long in progress under the current working title *Brains and history: The evolution of thought*. 

Steve Farmer,* John B. Henderson, and Peter Robinson

Abstract

Parallels in the rise and fall of religious and philosophical traditions are highlighted when those traditions are studied cross-culturally. In literate old-world societies, those parallels included near simultaneities in the initial emergence of abstract theology and philosophy in the mid-first millennium BCE and striking similarities in the patterns of growth and decline in cosmological traditions from late-classical to early-modern times. This paper introduces a general model to explain these parallels, integrating cross-cultural data with abstract representations of nonlinear dissipative systems.

One novel feature of our model is its ability to be implemented in a series of simple computer simulations. In brief, we argue that parallels in the growth of premodern religious and philosophical systems were byproducts of cultural invariances in commentary traditions.

Literary utopias, a seemingly modest form of fiction intended for amusement and contemplation, have had a surprising history. They have been a source of conscious civilizational design that has been taken seriously by some very powerful leaders, more often than not with dire consequences.

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The most important of these invariances involved the methods used by premodern commentators to reconcile highly stratified textual canons. In our model, biologically innate modes of analogical thought, embodied in the earliest canonical texts, are transformed by the repeated application to later traditions of a small set of exegetical techniques. The iterative application of the same techniques in successive layers of tradition, combined with a variety of dissipative forces involved in textual transmission, resulted in the growth of religious and philosophical systems exhibiting emergent self-similar properties.

Classical examples show up in the complex mirroring systems of so-called Neo-Confucian and Neo-Platonic traditions and in closely related Daoist, Buddhist, Hindu, Islamic, Jewish, and Christian scholastic thought. The fact that similar emergent structures can be identified in the literate remains of pre-Columbian Mesoamerican traditions suggests the universal applicability of our model.

Rates and reliability of textual information flows serve as tuning parameters in our model; changes in such variables are used to model the impact of changing technological and historical conditions on the growth of correlative religious and philosophical systems.

We argue that the rapid development of abstract thought that occurred in the Mediterranean, India, and China in the mid-first millennium BCE was linked to expanded use in that period of lightweight writing materials (supplemented, in the case of India, by the development of elaborate oral mnemonics that emerged in part in reaction to that growth). We argue that the rapid decline of high-correlative systems in later stages of the Eastern and Western printing revolutions can be modeled using the theory of self-organized criticality (SOC), which envisions the collapse of self-similar systems as they approach maximal levels of complexity and systematic integrity. We conclude by discussing protocols for our computer simulations and our model’s teaching and research applications.

This working paper was originally given at the Kolloquium zu historischen und methodologischen Aspekten der Kommentierung von Text, held at the University of Heidelberg on 4-6 July 1997. Minor revisions were added in 2002. The suggestion that computer models can simulate the growth and decline of premodern religious and philosophical systems may be the ultimate heresy in an historical field in which theory of any sort is viewed with distrust. We want to emphasize that the model developed in this paper is heuristic in nature; its object is to encourage new approaches to premodern thought, not to replace traditional textual research. Whatever the value of our initial simulations, we are confident that models of the general class discussed below will become standard tools in premodern studies in the coming decades. Please address comments on this paper to saf@safarmer.com.
0.1 Theoretical Framework

This paper describes a general model of the rise and fall of premodern religious and philosophical systems—or, more precisely, those parts of a general model pertinent to literate traditions.\(^1\) One of its novel features is its ability to be implemented in a series of simple but potentially powerful computer simulations. The model originally arose out of textual studies of European and Chinese cosmological traditions, but its ideas are supported as well by data from premodern India, Southeast Asia, the Middle East, and pre- and early-colonial Mesoamerica.\(^2\) The Mesoamerican evidence is especially critical, since it suggests that the parallels treated in the model are not artifacts of direct cross-influences in Eurasian thought.

The model depends on a critical feature of manuscript traditions: processes of transmitting and commenting on those traditions, repeated over long periods, tended to transform their structures in predictable ways.

The parallels discussed in this paper can be pictured as byproducts of two such mechanisms: dissipative or entropic processes (the result of linguistic drift, textual losses, scribal errors, and similar forces) that drained unique information out of those traditions, and repetitive commentarial or scholasticizing processes that simultaneously pumped stereotypical information into them. These two processes, modified by periodic classical revivals or textual “purist” movements, which tended to oppose both of them, provide the abstract engine that drives our model.

Despite its simple dynamics, the model is capable of simulating the growth and collapse of a number of key features of mature premodern traditions—including the emergent growth of nested hierarchies, complex systems of correspondence, and the general property that all parts of reality mirror all others (for one graphic example, see Figure 1 below).

Adopting terms first used in Chinese studies, we refer to these mirroring structures as “correlative systems” or “correlative cosmologies.” The development of these systems can be traced through hundreds of years of so-called Neo-Platonic and Neo-Confucian traditions and in a broad range of Jewish, Buddhist, Christian, Islamic, and Hindu scholastic sources. Elaborate correlative systems can also be identified in the literate

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remains of pre-Columbian Mesoamerica, in which hints survive of the long-range operation of commentarial processes.

Interest in parallel growths in Eurasian thought has increased in recent decades, but to date most studies have stopped at the descriptive level. Our original studies of commentarial processes arose from attempts to understand the dynamic processes driving those parallels. Much of our research has focused on the methods commentators used to reconcile or “syncretize” traditions, since the most elaborate correlative systems arose in epochs in which information flows were accelerating and pressures to harmonize traditions were intense.

Our earliest cross-cultural model was exclusively verbal in nature. The model focused on how the syncretic methods of premodern commentators promoted the growth of correlative systems throughout Eurasia. (A table of such methods and their systematic effects is found in Appendix A, below.) Our attempts to translate our model into computational terms began recently, after we discovered similarities in the dynamics of our model and those involved in evolutionary processes in other fields. (For one algorithm used in our simulations, accompanied by a flow chart, see Appendices B and C, below.)

Mirroring or reflecting properties of the sort found in correlative systems are known to mathematicians as self-similar structures, or “fractals.” The emergence of self-similarities in any evolving system often suggests that the growth of that system can be modeled using the tools of nonlinear dynamics—a collection of closely related fields including fractal geometry, chaos theory, and the theory of complex or self-organizing systems. The use of these tools is most clearly indicated when fractal or self-similar growths arise from the joint action of dissipative and recursive processes—precisely the conditions that we discovered on the historical plane.

In the last twenty years, the models of nonlinear dynamics have allowed researchers to simulate a wide range of phenomena that were previously impervious to mathematical analysis, including developments in the social and cultural sciences.

For reasons discussed at the end of our paper, one class of nonlinear models, involving self-organized criticality or SOC, allows the simulation of not only the growth but the collapse as well of correlative systems—a key feature in the shift from premodern to modern thought.3

3 Early interest in these parallels showed up in George Sarton’s seminal studies in the 1920s of premodern scientific traditions in Eurasia. For more recent examples, see, e.g., Hajime Nakamura, (A Comparative History of Ideas London and New York, 1986), and the papers collected in José Ignacio Cabezón, ed., Scholasticism: Cross-Cultural and Comparative Perspectives (Albany, 1998).

4 For recent overviews of nonlinear dynamics, see, e.g., Garnett P. Williams, Chaos Theory Tamed (Washington, D.C., 1997) and Yaneer Bar-Yam, The Dynamics of Complex Systems (Reading, Massachusetts, 1997). Further on complex systems and self-organized criticality, see the papers collected in
The claim that computer models can simulate anything of interest in religious and philosophical traditions breaks with conventional views of the history of ideas.

Nevertheless, the grounds of that claim are remarkably intuitive. Manuscript traditions were not handed on passively, as traditional textual scholars often imply, but were steadily transformed by commentarial processes. The most important of these processes aimed to free authoritative traditions from internal contradictions or to harmonize them with foreign traditions. Because the reconciliative methods of religious and philosophical commentators were similar worldwide (conditioned by neurobiological constraints), whenever rates of textual information flow were roughly comparable, structural growth in those traditions tended to evolve in similar ways as well. The result is that when two manuscript traditions of similar exegetical “depth” are set side by side, the systematic byproducts seen in each layer of those traditions show strong family resemblances. The longer those traditions develop, the more similar (and self-similar) their abstract byproducts tend to be, no matter how different their specific contents.

The most elaborate parallels of this sort show up in late-medieval thought, which in a sense summed up two thousand years of exegetical transformations. No Western medievalist would be likely to mistake a fourteenth-century scholastic text from Thailand or Tibet for an ancient treatise, no matter how unfamiliar that scholar was with the technical jargon of Thai or Tibetan scholasticism. The long chains of verbal distinctions, nested hierarchies, multilayered analogical structures, and elaborate systems of correspondences in the treatise would quickly give it away as a product of extended commentarial processes.

Most Western scholars could guess the date of the text within a century or two, based on a knowledge of similar structures in a Scotus, or Dante, or similar figure.

What experienced scholars achieve “intuitively,” computer programs can achieve using formal means. A number of simple ways can be devised to compare the complexities of scholastic texts; relatively straightforward measures—counts of “scholastic distinctions” or levels in heaven and hell, or estimates of the degrees of contradiction and/or self-similarities in those texts—serve as markers of the exegetical efforts exerted in compiling the texts. When information flows remain constant, these complexities often correlate closely with the historical age of those traditions.5

Generalizing these views, our paper argues that a long series of parallel developments, beginning in the middle of the first millennium BCE, arose from the stereotypical ways in which manuscript traditions were compiled, transmitted, synthesized, and retransmitted

George A. Cowan, David Pines, and David Meltzer, eds., Complexity: Metaphors, Models, and Reality (Santa Fe, New Mexico, 1994). For other sources on SOC, see note 48.5 On some general means of estimating complexity in evolving systems, see, e.g., Bar-Yam, Dynamics of Complex Systems, pp. 759-81.
by successive waves of theological and philosophical exegetes. Applying the concepts of nonlinear dynamics, it is possible to simulate transformational processes of this nature using relatively simple computer programs. The key to understanding how those simulations work lies in grasping the stratified ways in which canonical traditions tended to evolve.

Computer simulations of this sort have limitations as well as uses. Like models in the physical and biological sciences, they achieve their goals by emphasizing certain data at the expense of others. Our model suggests that whenever information flows in manuscript traditions rose and fell in similar ways, self-similar features in those traditions tended to develop in predictable patterns. But the model doesn’t claim to capture all salient features in those traditions, nor can it predict the appearance of unique elements in them due to the influence of single writers. The model provides a useful cross-cultural framework for studying manuscript traditions, but it cannot replace traditional textual research.

Writing on the limitations as well as uses of nonlinear models, Bar-Yam comments: “A study of universal principles does not replace detailed description of particular complex systems. However, universal principles and tools guide and simplify our inquiries into the study of specifics.”

Nonlinear models can help us picture the self-similar properties in waterfalls, in the rise and fall of stock prices, in the distribution of galaxies, or in the growth of premodern correlative or scholastic systems. But they tell us little about detailed elements in those phenomena—about the behavior of individual drops in the waterfall, the movements of single stocks, the positions of single galaxies in larger clusters, or the contents of individual scholastic systems.

Conversely, the fact that our model “only” predicts the growth of typical features in premodern systems does not diminish its usefulness in providing a cross-cultural framework for studying traditional thought—which cannot emerge from the study of single systems. Whatever its limitations, the model can successfully predict the conditions under which systems like those of a Sankara, Thomas Aquinas, Zhu Xi, or similar writers can be expected to appear.

At a fundamental level, the relationship between models and empirical data is no different in the history of thought than in the physical and biological sciences. The common argument, going back to Dilthey, that history is unique in treating “particulars” and not “universals” is groundless, since even biographies and narrative history involve high-level modeling.

Bar-Yam’s remark that studies of universal principles guide and simplify inquiries into the specifics of complex systems also applies to our work. Our model throws light on minute

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6 *Dynamics of Complex Systems*, p. 2. For what follows, cf. pp. 788-89
acts of textual exegesis whose historical significance is clearest when those acts are viewed cumulatively, through a wide-angle historical lens; investigated at close range, the exegetical (or “scholastic”) distinctions of premodern commentators may seem too trivial to demand serious attention.

An analogy can be drawn to evolutionary biology, in which the accumulation of small mutations over long periods may lead almost imperceptibly to divergent life forms.

Our model pictures similar small mutations arising in religious and philosophical traditions through the force of minute acts of textual exegesis; in this case, however, the general direction of change was not divergent but convergent; the piling up of those acts over long periods resulted in the growth of elaborate correlative systems whose self-similarities became increasingly evident by late traditional times in China, Southeast Asia, India, the Middle East, Europe, and elsewhere.

This paper argues that these parallels were not products of cross-cultural influences or imagined suprahistorical forces (Jungian archetypes and the like), but of mundane processes of transmission operative in all extended manuscript traditions. From this view, exegetical transformations that may seem trivial when viewed in single texts in the aggregate played a dominant role in the evolution of all the world’s “higher” traditions.

0.2 Overview of Detailed Argument

Our argument is divided into four parts:

1. Parallel developments in premodern thought. In our first section (1.1), we argue that a long chain of parallels, stretching from the mid-first millennium BCE to the seventeenth century CE, were byproducts of the inbred and stratified ways in which sacred or semi-sacred traditions evolved. From this view, each new layer of tradition, whether embodied in canonical texts or later commentaries, tended to transform the products of earlier strata in predictable ways.7

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7 The model of textual stratification sketched in our paper is related to, but broader in scope than, the “accretion theory” recently proposed by E. Bruce Brooks and A. Taeko Brooks, *The Original Analects: Sayings of Confucius and His Successors* (New York, 1997). The Brooks model focuses on accretional processes in early canonical sources like the Analects, but it does not focus on the systematic transformations that arose as byproducts of those processes—emerging, for example, from systematic attempts by later redactors to reconcile early strata of those canons with later ones. The analyses of Brooks and Brooks and a number of similar efforts—attempts to “destratify” the Daodejing, the Vedas, the so-called Q document (in New Testament studies), or various Platonic, Aristotelian, or Buddhist texts—ultimately evolved out of nineteenth-century attempts to distinguish textual strata in the Torah or Pentateuch.
Our model links the speed of those transformations to rates of premodern information flows (section 1.2). While many factors affected those rates, the most lasting were tied to developments in literate technologies. Correlation between different stages of culture and the evolution of literate technologies—the emergence of writing, simplified scripts, scrolls and codices, paper, printing, and so on—have been intensely discussed in recent decades, prompted by the long series of revolutions in information technologies in our own era.

Adding a new element to these discussions, we argue that near simultaneities in the first emergence of abstract philosophy and theology in the Mediterranean, India, and China around 500 BCE were tied to a broad diffusion in that era of the use of lightweight writing materials. These materials provided the material preconditions for the growth of manuscript traditions and for the two thousand years of later systematic developments sketched in our paper.

2. The commentarial engine. Our second section (2.1) looks at the mechanisms driving those developments. In brief, we argue that these parallels arose from the repetitive application to sacred and semisacred traditions of a relatively small, and largely culturally invariant, series of commentarial techniques. From a systematic standpoint, the most important of those techniques were reconciliative in nature. These techniques were used by generation after generation of commentators to syncretize opposing or foreign traditions or to harmonize conflicting layers of canonical texts.

This section of our paper illustrates how the same reconciliative methods generated different systematic structures when applied to different types of texts. Thus, when used to harmonize early canonical sources, the same reconciliative strategies could generate abstract pantheons of gods, monotheistic deities, or abstract ethical or cosmological principles, depending on the exact genres of texts being harmonized.

In later traditions, typical products included dualistic or trinitarian concepts of deity, broad systems of correspondences, multileveled pictures of heaven or hell, elaborate emanational systems, and other diagnostic features of scholastic traditions. Over many centuries, higher-level integrations of structures like these gave birth to elaborate multilayered correlative systems—Neo-Platonic, Neo-Confucian, Buddhist, Hindu, Islamic, or Christian cosmologies, etc. — whose levels of self-similarity tended to increase whenever those traditions inbred and grew in complexity.

\[8\] This argument was first developed in Farmer, Syncretism in the West, pp. 78-79, esp. note 52. On claims concerning developments in supposedly purely oral traditions in India, see note 12, below.

\[9\] The cultural invariances of these techniques are traced in our broader model to neurobiological data; for preliminary discussion, see Syncretism in the West, pp. 91-96
3. **Computer simulations of the growth and collapse of premodern systems.**

Our third section (3.1) describes designs for our computer simulations, which draw on nonlinear models used in a variety of nonhistorical fields. Rates of information flow act as tuning parameters in our simulations; adjusting those rates allows us to test parts of our models that link those rates with the growth of correlative systems in the historical sphere.

This section also discusses extensions of our model, applying the concepts of self-organized criticality (SOC) that simulate the collapse of correlative systems in late stages of the Chinese and European printing revolutions, when rates of information flow increased by several orders of magnitude above those seen in earlier centuries.

This section thus suggests ways to link the emergence of more “open” thought systems typical of the modern period with the decline of the “bookish,” and relatively closed systems treated in our model.

4. **Summary and conclusions.**

We add brief comments in our final section (4.1) on some implications of our work. So far as we know, ours is the first model of the evolution of religious or philosophical ideas capable of being implemented in computer simulations.

The principles behind those simulations are simple, and we anticipate that increasingly powerful models of their general class will be constructed in coming decades. The simplicity of those simulations does not prevent them from modeling the growth of complex historical phenomena. In general, the possibility of building such models confirms the view put forward twenty-five years ago in a famous paper by the mathematical biologist Robert May — that nonlinear models driven by simple iterative processes can simulate the behavior of very complex systems.\(^\text{10}\)

Our paper ends by pointing to some practical uses of such simulations for research and teaching purposes.

### 1.1 Parallel Developments in Premodern Thought

Historians have paid increasing attention in the last decade to structural parallels in Eastern and Western intellectual traditions, building on a heritage in comparative studies reaching back to Leibniz.\(^\text{11}\) These parallels show up in all literate religious and philosophical traditions, including those developing in Europe, the Middle East, India, Southeast Asia,

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Paradoxically, near simultaneities in these developments are clearest in the two major old-world regions that had the least contact in premodern times—Europe and China. Since these parallels cannot be explained credibly by direct contacts (e.g., between near contemporaries like Confucius and the early pre-Socratics, or between Zhu Xi and Thomas Aquinas), we will place most of our stress in reviewing those developments on China and Europe. Adopting this approach, we minimize the chances that those parallels can be dismissed as artifacts of direct cross-cultural influences.

Those parallels stretched from the first canonization of sacred texts in the first millennium BCE to the decline of traditional thought starting two thousand years later.

In this section we review five of these parallels, pointing to prima facie evidence that exegetical processes drove each of them. Discussion of specific commentarial methods is reserved for section 2.1; on this issue, see also Appendix A, below.

The emergence of the first textual canons. The first parallel concerns the emergence of the earliest sacred canons in the Middle East, Greece, India, and China. This development can be dated from roughly 700-500 BCE (exact dating here is controversial, but is not critical for our purposes). These ancient canons provided the earliest, and often most sustained, objects of commentary throughout Eurasia, often extending into the modern era.

- In Greece, the earliest religious canon consisted of the Homeric corpus and, to a lesser degree, writings ascribed to Hesiod or legendary poet-priests including Orpheus and Musaeus.
- In China, a similar role was played by early strata of the Analects and pre-Confucian layers of the Five Classics, most notably the Changes, Documents, and Songs.
- In India, analogous roles were served by the Vedas, whose dates are even more disputed than those of Homer or the Chinese classics (some Indologists push the composition of the Vedas back to an improbably early period). The end of the Vedic Age, however, is normally fixed around 600 or 500 BCE.
- Early Middle-Eastern canons or protocanons included parts of the Psalms and early strata of the Torah and Zoroastrian Avestas. Although dating here too is in dispute, widespread agreement exists that these sources reached early canonical forms, after long periods of preliterate gestation, in these same centuries.
- The Egyptian Book of the Coming Forth of Day, or so-called Book of the Dead, while not comprising a canon in the same sense as these other works, also found its first fixed form, including set chapter numbers, in these centuries.

The earliest canons in the Middle East, Greece, India, Southeast Asia, and China differed widely in their genres and specific contents. These differences have discouraged
comparative analyses of these texts or have led to attempts to force-fit them into unitary molds, as exemplified by recent searches for “lost” Chinese epics.

Despite their differences, all these canonical texts were characterized by later commentators in remarkably similar ways — most typically as being encyclopedic in nature and as somehow encompassing all knowledge and truth. These views led later commentators to tie their systems closely to these texts and to spend much energy trying to reconcile their contradictions.

Our model pictures the near simultaneity in the emergence of these canons as a byproduct of a rapid expansion in the mid-first millennium of the use of lightweight writing materials—papyrus or parchment in the Mediterranean, palm leaves and birch bark in India, and bamboo strips and silk in China. Lightweight writing materials provided the necessary foundations for manuscript traditions and for the systematic structures that were later built on those foundations. While direct intellectual contacts were rare in distant Eurasian civilizations and cannot explain most parallel developments, innovations in literate technology moved swiftly and could rapidly transform geographically isolated regions in similar ways.

The fact that stratified manuscript traditions had their origins in roughly the same period everywhere in Eurasia helps explain why developments in these traditions kept more or less in sync over the next two thousand years.\(^\text{12}\)

\(^{12}\) Cf. Farmer, *Syncretism in the West*, pp. 78-79, esp. note 52. We cannot discuss in detail the hotly debated question of when Vedic sources first appeared in literate form; we plan to deal with this question in a future study. In brief, evidence supports the traditional view that oral transmission of canonical texts, backed by powerful mnemonic techniques, played a larger role in India than in most other ancient civilizations; nevertheless, extensive quotations from opposing textual schools in later layers of Vedic traditions (e.g., in the Vedic sutras, dating from the last half of the first millennium BCE), show that the frequent claim that the Vedas were not written down until well into the common era are exaggerated. While material evidence of writing in post-Harappan India does not begin until the mid-third century BCE, strong indirect evidence indicates that literacy began before early layers of the texts ascribed Panini, dated somewhat earlier. Evidence also suggests that the extreme mnemonic techniques used to fix texts in later Vedic times (use of padapatha texts, etc.) may have first developed in reaction to expanding Persian literate influences during the early Achaemenid era in Northwest India (late sixth century BCE). In China, limited use of bamboo strips for writing can be traced to the early Zhou dynasty, but evidence of extensive use of the material doesn't begin until the fourth century BCE—exactly the same period as the explosive growth of manuscript traditions in Greece and the Middle East. In Egypt, papyrus was available as far back as the third millennium BCE, but its export was restricted until the mid-first millennium—indeed, one of the first examples of extensive evidence exists of the use of lightweight writing materials elsewhere in the Middle East. For discussion of the latter evidence, including references to limited earlier uses of such materials, see Raymond P. Dougherty, “Writing Upon Parchment and Papyrus among the Babylonians and the Assyrians,” *Journal of the American Oriental Society* 48 (1928): 109–135. Internal commentaries in Egyptian sources can be identified as early as the mid-third millennium in the so-called pyramid texts, which apparently once existed in perishable as well as durable form; these internal commentaries continued in the coffin texts and Book of the Dead, allowing us to trace conceptual developments in Egyptian funerary texts for over two millennia. Systematic developments in these texts, which we plan to discuss elsewhere, provide strong confirmation of the general model discussed in this paper. The pan-Eurasian diffusion
Near simultaneities in the development of “abstract” thought.

The second parallel involves the simultaneous emergence of classical philosophy and theology in Greece, India, and China from around 550-300 BCE. Abstract theological developments in Hebrew thought also date from this era.

- In Greece, this period opens with the early pre-Socratics and closes with the emergence of the Platonic, Aristotelian, Epicurean, and Stoic schools.
- In China, the period starts with the oldest strata of the Analects and extends through the “hundred schools” to the time of Xunzi, who was born just after our terminal dates.
- In India—following for the moment traditional dating—the period begins with the “historical” Buddha and the Mahavira (reputed founder of Jainism) and closes with the redactors of the philosophical layers of the Upanishads and Vedic sutras.
- While Hebrew traditions did not generate abstract philosophical constructs of the sort found in Greece, India, or China, the first development of abstract monotheism appeared in this period in later strata of the Torah and related texts.

As we point out shortly, this development can be traced to exegetical forces similar to those responsible for the initial growth of abstract philosophy in Greece, India, and China.

The temporal coincidences in this period are often quite remarkable, at least if we accept the traditional dates suggested in ancient sources. According to the most common variation of those dates, to cite one example, we find Confucius, Buddha, and Xenophanes (the first pre-Socratic for whom we have extended fragments) all dying in the same five-year period, 483-479 BCE!

The fact that those dates, and even the historicity of these figures, often rests on shaky grounds does not diminish the impression that powerful forces in this era were

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13 The recent tendency, in both Indian and Chinese scholarship, has been to push these dates significantly forward. Thus recently proposed dates for the “historical” Buddha (if such a figure ever existed), based in part on archaeological evidence, place him as late as the mid-fourth century. See Heinz Bechert, “The Date of the Buddha Reconsidered,” *Indologica Taurinensia* 10 (1981): 29-36, and the remarks in Patrick Olivelle, trans. and ed., *Upanisads* (New York, 1996), xxvi, note 23. Tendencies to push these dates backwards in ancient times were frequently the result of fierce competition between warring schools. Thus if Confucians claimed that their half-legendary founder died in 479 BCE, Chinese Buddhists were naturally inclined to put Buddha's death a few years earlier (e.g., 483 BCE) and the Daoists their mythical founder, Laozi, earlier still (e.g., 602 BCE). Leaving aside this traditional game of one-upmanship, there is no doubt that the temporal window within which classical philosophy began in Greece, India, and China was remarkably narrow—differing by less than a century in the two most distant Eurasian societies, Greece and China.
transforming thought in widely separated cultures in similar ways. Major differences in the varieties of “abstract thought” that emerged in this period suggest that these parallels could not have resulted from direct intellectual contacts, but must have arisen indirect mechanisms of some kind.

Classictists often treat premodern philosophers as “speculative” thinkers, encouraging purely phenomenological accounts of their thought—or what commonly passes for their thought. In contrast to these views, much evidence suggests that most of these thinkers were commentators of one sort or another on earlier canonical texts. The famous remark in Analects 7.1 that Confucius was a transmitter, not an innovator, and sections of the Analects commenting on the Songs and Documents, have recently been assigned to layers of the Analects postdating the “historical” Confucius by a half century; the terse sayings ascribed to Confucius in the text’s earliest strata appear to originate in a period of restricted literacy and not in the literate courtly traditions of later periods of the Warring States era.

No matter whether or not we accept the literal existence of an “historical” Confucius, however, it is clear that by the last half of the fifth century the early compilers of the Analects were deeply involved in commentary on the text’s early strata and on pre-Confucian layers of the Songs and Documents. These exegetical concerns were to dominate intellectual developments in China for well over two thousand years.

The exegetical concerns of early Greek philosophers are less widely recognized than those of early Chinese thinkers; however, as Havelock argued back in the early 1960s, evidence shows that early Greek philosophy largely arose out of commentarial “integrations” of earlier Homeric myth.

Occasionally, as in the case of the four-element theory, we can watch abstract thought arising directly from earlier mythic layers of thought. By the first half of the fifth century, much of pre-Socratic commentary had turned hostile towards older mythic canons—as illustrated in the sharp criticism hurled at Homer and Hesiod in fragments ascribed to Xenophanes or Heraclitus—but commentary it was nevertheless. Claims

14 These accounts are often accompanied by naïve views of the authorship of early philosophical texts, which commonly (as in the case of the Analects) turn out to be highly stratified works. As Karlsgren argued about early Chinese texts, and Havelock about pre-Socratic documents, surviving fragments from this period were typically “worked up” abstractly in the much later documents in which these fragments survive—and hence do not faithfully represent the thought of the figures to whom they are attributed.
15 See Brooks and Brooks, The Original Analects.
17 Thus the abstract four elements commonly ascribed to Empedocles show up in Empedocles frag. 6 as Hera, Zeus, Aidoneus, and Nestis—i.e., as gods of earth, air, fire, and water. Similar shifts from mythic to abstract forms show up in India in China—in the latter case, e.g., in the evolution of the abstract cosmological principle of Tian or “Heaven,” whose earliest pictograms were unambiguously anthropomorphic in form.
that the Homeric corpus was the repository of “everything knowable” remained strong, in fact, long after newer philosophical canons were challenging Homer’s religious authority; thus well into the fourth century BCE, the author (or authors) of the Platonic Ion felt the need to attack the reciters and exegetes of Homer, who continued to portray the Iliad and Odyssey as the source of all human wisdom; ironically, the late-ancient commentators who allegorically “read back” philosophical ideas into Homer were helped by the fact that many of those ideas originally developed in earlier Homeric exegeses.

Similar developments were simultaneously taking place outside China and Greece.

Indologists commonly affirm that exegetical transformations of early Vedic hymns lay at the roots of abstract philosophy in India. This view can be supported by much textual evidence in later strata of the Brahmanas (the earliest Vedic commentaries) and the philosophical layers of the Aranyakas, Upanishads, and Vedic sutras.

In Hebrew culture, similar evidence suggests that the transcendent creator god of later strata of the Torah arose from exegetical integrations by the so-called Priestly redactors of primitive anthropomorphic concepts in earlier levels of the text; syncretic fusions with foreign concepts, drawing on the same strategies, also played a role in this development. The dates of these abstract developments closely parallel those we have noted in China and Greece.

Exegetical integrations of early textual canons, promoted by a rapid pan-Eurasian diffusion of lightweight writing materials (presumably promoted by deeper political and demographic trends) efficiently explain near simultaneities in the first development of “abstract” thought in the mid-first millennium BCE. Religious reformers and early philosophers of the period generated primitive element theories, transcendent and partly deanthropomorphized deities, and abstract ethical or cosmological concepts (ren, dharma, “the Way,” brahman/atman dualities, the Logos, “the idea of the Good,” and so on) by exegetically “working up” conflicting mythic concepts embodied in older levels of tradition. The hermeneutical problems faced by these commentators, and the methods used to solve them, were similar throughout Eurasia; common variations in the systems they created can be explained by differences in the specific canonical texts to which those methods were applied.

Parallels in syncretic system-building in the imperial age.

A third extended series of parallels took place from approximately 300 BCE to 550 CE, the first great syncretic age in Eurasian history. The era was marked by the domination of giant empires in China (collapsing in 220 CE), Rome (in decline from the fourth century CE), and India (falling around 550 CE). On the intellectual plane, the period witnessed a long series of attempts to “work up” classical sources into broad encyclopedic synthes

and higher-level systems.

Some of these syntheses included high-syncretic religions (most prominently, state Confucianism, Mahayana Buddhism, and Christianity, all arising in the same period) and first-level correlative cosmologies like those associated with so-called Neo-Platonism, later Daoism, or the late-ancient predecessors of Neo-Confucianism. In many ways, the great syncretic systems that evolved in this period unified the intellectual world just as the great empires unified the political realm.

In China, the first important work of encyclopedic scope was the *Spring and Autumn Annals of Lu Buwei* (c. 240 BCE), which according to tradition was commissioned by the prime minister of the Qin state that later unified China. In the West, a rough equivalent is found in the Aristotelian corpus, which (according again to tradition) was composed by Plato’s student and the tutor of the unifier of the West, Alexander the Great. The products of these highly stratified compilations were not philosophical abstractions like the early element theories, “the Way,” dharma, or “idea of the Good,” etc., generated in earlier traditions, but high-level syntheses, elaborate systems of correspondence, and (increasingly as the period evolved) complex hierarchies of beings that developed remarkably in sync in Greco-Roman, Indian, and Chinese civilizations.¹⁹

Systematizing tendencies in China declined after the fall of the Latter Han Dynasty at the beginning of the third century CE, but those tendencies continued unabated in the remaining two-and-a-half centuries of the Western Roman Empire. Pagan scholastic systems reached their most elaborate states at the end of this period in monumental exegetical projects like Proclus’s massive Platonic commentaries and *Platonic Theology*—which were aimed at reconciling discordant passages of Platonic scriptures line-by-line, and often word-by-word. The byproduct of Proclus’s efforts was an elaborate correlative system that was not matched in complexity in any Eurasian society before the later middle ages.²⁰

¹⁹ The exegetical origins of these hierarchical systems (manifested in the West in the so-called great chain of being, and in the East in systematic orders of Buddhas, avatars, saints, etc.) is most dramatically demonstrated in the high-syncretic systems that developed in late antiquity along the central Asian borders of Eastern and Western societies—where Buddha, Jesus, and various Zoroastrian and gnostic divinities were organized in complex correlative arrays. See, on this point, the fascinating texts translated in Hans-Joachim Klimkeit, *Gnosis on the Silk Road* (San Francisco, 1993). Just as in similar systems in nonhistorical fields, elaborate fractal growths in history are most common along borders or elsewhere (e.g., at the intersection of trade routes) where opposing forces collide.

²⁰ Given the fact that Socrates and Plato were literally worshipped in the late Academy, the phrase “Platonic scriptures” is no exaggeration. For suggestions of this, see Marinus’s *Life of Proclus*, translated, e.g., in J. L. Rosán, *The Philosophy of Proclus* (New York, 1949). Parallels can be drawn to the worship of Confucius, Laozi, and Buddha in late classical times in China or India. Proclus’s pagan scholasticism was an extreme one that had a deep impact on later Islamic, Jewish, and Christian scholastic traditions. In Proclus’s system, multiple mirror images of pagan gods were assigned to different hierarchical levels as abstract “henads.” The multiplication of these deanthropomorphized gods, who eventually metamorphosed into the Christian hierarchies of angels, developed out of exegetical attempts to reconcile discordant references to classical deities in different parts of the Platonic corpus or its early
A slowdown in systematic developments occurred in China and the West in late antiquity due to the destruction of imperial libraries and other intellectual centers. But large-scale system building resumed with a vengeance throughout Eurasia in the great age of scholasticism, which for our purposes can be dated roughly from 1000-1600 CE. These second-level scholastic systems arose in response to a massive increase in the number of sources that were then available throughout the old world; a series of information explosions occurred in this era that deeply affected every civilization from Europe to Japan, related to increases in travel, a long series of classical revivals, and to technological innovations including the development of printing in the Far East and its eventual transmission to the West. As increasing numbers of sources became available for synthesis, scholastic-correlative systems arose of unprecedented levels of complexity; in response to increased information flows throughout Eurasia, reconciliative impulses overrode all other exegetical concerns.

The cross-cultural similarities in scholastic traditions have often been obscured by parochial attitudes in traditions or by the propaganda of warring schools. Western scholars still often characterize scholasticism as the result of attempts “to reconcile reason with Christian revelation,” obscuring the methodological affinities between Latin scholasticism and movements elsewhere aimed at harmonizing religious and philosophical authorities.

In China, early Neo-Confucians are sometimes denied the “scholastic” or “syncretist” labels on the grounds that they claimed to reject Buddhism and Daoism (no less than rival schools of Confucianism) in order to revive the “pure” sources of Confucian thought; despite these claims, these writers drew heavily on Buddhist and Daoist views in constructing their systems, which from a structural point of view are remarkably similar to scholastic systems in the West. Similar remarks can be made about Vedantic scholastics like Sankara, who attacked the Buddhists while quietly incorporating Buddhist principles in their systems; or about Renaissance classicists (the so-called humanists), whose syncretic excesses were often just as extreme as those of the medieval scholastics they publicly scorned.

In scholastic writers like Shao Yong, Ibn Rushd (Averroës), Albert the Great, and Nichiren in the high middle ages, or extreme syncretists near the end of premodern times like

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commentaries. Similar bifurcations and abstract hypostatizations transformed Eastern gods and cosmological principles in Asian scholastic systems. For some evidence here see, for example, the Thai Buddhist source referenced in note 23.

21 High-scholastic phases of medieval Indian and Islamic traditions would require slightly earlier starting dates. In general, we would argue for greater continuity than is usually acknowledged between late-ancient and medieval scholastic traditions throughout Eurasia.

22 Cf. Farmer, Syncretism in the West, pp. 135-37.
Lama Tsongkhapa in Tibet, Giovanni Pico della Mirandola in Europe, or their syncretic counterparts in Mughal Dynasty India or Ming Dynasty China, correlative systems reached their most extreme expression.

The problems faced by commentators in late-traditional societies were no longer restricted to harmonizing conflicts in a single tradition or handful of traditions; these exegetes were, instead, often forced to reconcile whole traditions en masse. The syncretic pressures on their thought led them to construct cosmologies in which every part of reality was said to reflect every other; these systems allowed them to assign conflicting statements in authorities to different levels of reality, where each statement could be affirmed as being true “in some mode.” Multileveled correlative and allegorical systems, in a limited number of types, show up in Latin scholastics, in literary monuments like Dante’s *Commedia*, and in tens of thousands of Neo-Confucian, Buddhist, Hebrew, and Arabic scholastics who flourished in this era.²³

The links between exegetical processes and the birth of high-correlative systems are demonstrated by the fact that the most elaborate of these systems first appeared in writers who faced the most difficult reconciliative tasks. Those links have been studied most fully in perhaps the most extreme syncretist of all times, the Renaissance philosopher and theologian Giovanni Pico della Mirandola (1463-1494). Pico lived in an era in which four centuries of textual revivals combined with the printing revolution to raise rates of information flow far above those seen in preceding centuries. In late 1486 Pico drew up 900 theses representing the views of the “wise Chaldeans, Arabs, Hebrews, Greeks, Egyptians, and Latins,” subdivided into 28 subtraditions, that he proposed to debate and harmonize at Rome before the pope, cardinals, and leaders of all the “warring schools.” One of Pico’s 900 theses (which he claimed could be broken into 600 separate headings) promised to reconcile Plato and Aristotle in their entirety; others proposed to resolve the most ambiguous questions fought over in all the major schools. In achieving these goals, Pico promised to reveal in his debate three or four methods leading to an understanding “of everything knowable” (*de omni re scibili*).

In planning his project (which he immodestly hinted might trigger the end of the world), Pico was forced to draw on virtually every major reconciliative device found in the previous 2000 years of Eurasian thought. One byproduct of his use of these methods was an abstract picture of the cosmos that was nearly perfectly fractal in structure (see Figure 1).

²³ For a striking fourteenth-century parallel in Southeast Asia to Dante’s high-correlative system, see Frank E. Reynolds and Mani B. Reynolds, trans., *Three Worlds According to King Ruang: A Thai Buddhist Cosmology* (Berkeley, 1982). For an overview of other scholastic traditions, see Cabezón, *Scholasticism: Cross-Cultural and Comparative Perspectives*. 
Pico’s system was closely related to Leibniz’s monadology, developed two centuries later; but in Pico we can see (as we cannot in Leibniz) the exegetical roots of that system exposed. Pico was just one of thousands of writers in fifteenth- and sixteenth-century
Europe, India, Southeast Asia, and the Far East who developed high-correlative systems to harmonize the flood of presyncretized sources that had piled up over the previous 2000 years — completing developments that began with the origins of manuscript traditions in the mid-first millennium BCE. In Pico’s 900 theses, the correlative ideas of medieval Latin, Arabic, and Hebrew scholasticism; of Greek Platonism, Aristotelianism, and Neo-Platonism; and of a wide range of esoteric and magical traditions — each based on syncretic syntheses of even greater antiquity — merged to form a generalized notion of cosmic correspondence. The pressures of thousands of years of reconciling books and traditions resulted in a final metamorphosis of exegesis into cosmology; the idea of cosmic correspondence, embedded in a thoroughly magical world, now lay at the center of reality; in Pico’s words: “Whatever is in all worlds is contained in each one”!

When Pico’s commentators reduced his complex verbal symmetries (see 2.1) into diagrammatic form, the result was a neat fractal portrait of his worlds-within-worlds. Systems with similar structures can be “grown” in computers by repeatedly applying to primitive texts methods similar to those of premodern exegetes — a fact critical to the simulations described at the end of this paper. 24

The collapse of high-correlative systems.

One final parallel involves what Stephen Jay Gould has called “the greatest intellectual transformation in modern Western thinking” 25 — the precipitous decline of correlative systems that occurred between 1550 and 1750.

Some of the reasons for their demise in this period (which has, in fact, been documented in Chinese as well as Western traditions) can be traced to internal developments in manuscript traditions. In the works of late-traditional syncretists, correlative systems became so elaborate that they threatened to collapse under their own weight. With each leap in complexity, those systems became increasingly distant from the original sources involved in their synthesis and from any concepts of nature remotely suggested by empirical observation. Due to the complex correspondences resonating in those systems, moreover, any assault on any side of them—whether of a philological, scientific, religious, or

24 It noteworthy that Benoit Mandelbrot, who first coined the term “fractals,” recognized self-similar or fractal structures in Leibniz and in the so-called great chain of being—although not apparently in premodern systems outside the West. See the historical notes in The Fractal Geometry of Nature, rev. ed. (1983). Mandelbrot was the first to strongly emphasize the general relationship between iteration and the growth of self-similar systems, but given the state of historical studies when he wrote his book, he could not have guessed that similar processes were also responsible for the development of fractal growths in the historical realm. Further on fractals in premodern cultures, see the essay by the mathematical biologist A. L. Goldberger, “Fractals and the Birth of the Gothic: Reflections on the Biologic Basis of Creativity,” Molecular Psychiatry 1, 2 (1996): 99-104, which stresses neurobiological elements in such developments. Cf. Farmer, Syncretism in the West, pp. 93-96.
political nature—potentially became an attack on them as a whole.\textsuperscript{26}

This collapse was obviously also tied to the development of competing mechanistic models that began to develop in the mid sixteenth century; by the middle of the seventeenth century, those models had already had a deep impact on traditions in both Europe and China.

Those systems were attacked from another side by classical “purists” and religious reformers; the goal of these writers was to return thought to what they viewed as the ancient foundations of thought, which they identified with an increasingly narrow body of texts. These attacks were also aided by developments in philology and linguistics; by later stages of the Eastern and Western printing revolutions, all the philological tools were available to begin the tedious job of destratifying traditions, cutting through the exegetical accretions that had gathered in them in the previous two millennia.

The most extreme “purists” and philologists (the groups often overlapped) in China and Europe from the sixteenth through eighteenth centuries busied themselves with peeling off successive layers of traditions to get at what they viewed as the authentic cores lying underneath.\textsuperscript{27} While they left the job unfinished, by the mid-eighteenth century they had achieved enough to discredit high-correlative systems in progressive intellectual circles throughout Eurasia.\textsuperscript{28}

Attacked from many sides, correlative cosmologies began a rapid decline from 1550 to the mid eighteenth century. The collapse occurred more abruptly in Europe than in China, but it occurred in both societies nonetheless. An epitaph of sorts for the two thousand years of exegetes who created these systems was provided by Voltaire in his famous portrait of the “Theologian,” a bitter-end scholastic whose syncretic excesses ultimately led him in skeptical directions:

He had mastered the oriental languages, and was as well informed as possible about

\textsuperscript{26}As James I put it to the Puritans: “No Bishop, no King.” The sensitivity of high-correlative systems to slight perturbations corresponds in the mathematical sphere to the phenomenon of self-organized criticality (SOC). This fact can be exploited in simulations of the collapse of such systems in the early-modern era.

\textsuperscript{27}On parallels between Ming and Qing Dynasty \textit{literati} and their Renaissance “humanist” counterparts, see Henderson, \textit{Chinese Cosmology}, and Benjamin A. Elman, \textit{From Philosophy to Philology} (Cambridge, Mass., 1984).

\textsuperscript{28}Even today, the job of destratifying early textual canons is by no means complete. Studies in the past decade have gone a long way towards destratifying classical Daoist, Confucian, and Indian sources, and fresh research on the New Testament (especially in regard to the so-called \textit{Q} document) has continued that process in biblical studies. However, in the case of the two major philosophical canons in Western thought, ascribed to Plato and Aristotle, the job of destratification has hardly begun. Evidence that research is moving in the right direction can be found in the studies of European classicists like H. Thesleff and a handful of other scholars. When the stratified nature of these canons is widely acknowledged, the impact on historical studies as a whole can be expected to be profound.
the rites of the ancient nations. He knew the Brahmans, the Chaldeans, the fire-worshippers, the Sabeans, the Syrians, the Egyptians as well as the Jews. He was familiar with the variant texts of the Bible. For thirty years he had tried to reconcile the gospels, and bring the fathers into union . . . The difficulty of organizing in his head so many things whose nature is to be confused, and to throw a little light on so many dark clouds, often disheartened him, but as these researches were his professional duties, he devoted himself to them in spite of his disgust. He finally attained to knowledge unknown to most of his colleagues. The more truly learned he became, the more he doubted all he knew. So long as he lived he was tolerant, and as he died he confessed that he had uselessly worn out his life.29

1.2 Cultural Evolution and Rates of Information Flow

In concluding this section, we would like to make one theoretical observation, fairly obvious but rarely emphasized, that is critical to the simulations described later. Much evidence exists that the rise and fall of premodern systems can be closely linked to fluctuations in rates of information flows. In periods of heightened textual flows — in eleventh-century China, for example, accompanying the first widespread use of printing, or in the textual revivals in Europe extending from the twelfth through sixteenth centuries CE—accelerated developments occurred in systematic thought. Returning to a point discussed earlier, we find a related phenomenon in the middle of the first millennium BCE, tied to the expanded use of lightweight writing materials. Similar increases in information flows also occurred in the period of vast political consolidation in the Han Dynasty and Greco-Roman period.

Looking at converse patterns, we find declines in the growth of systematic thought in periods of cultural collapse like those found at the end of classical antiquity, when rates of information flows dropped far below those in earlier or later periods. Dampened rates of development also existed in a handful of premodern societies that possessed lightweight writing materials — including premodern Mesoamerica and ancient Egypt — when the use of the technology was offset by sharply restricted literacy or institutional constraints on the use of texts.

Numerous exegetical artifacts can be identified in the literate traditions of Mesoamerica or Egypt — multilayered conceptions of heaven and hell, protomonotheistic gods, paradoxical dualistic or trinitarian deities, formal systems of correspondences, inbred cyclical models of time, and so on — whose growth can be tied to internal commentaries operating in stratified religious texts like the Popul Vuh or Book of the Dead.30

30 The problem of textual stratification has not been widely discussed in relation to either the Popul Vuh or Egyptian funereal texts, despite much recent philological work on those sources. The existence of both textual strata and internal commentaries in the Popul Vuh shows up clearly in Dennis Tedlock’s standard scholarly translation of that work (New York, 1985), although these phenomena are not noted by Tedlock himself; similar strata also appear in many similar Maya documents, including the so-called Far...
But nowhere in these civilizations do we find the same degree of abstract developments generated in major Eurasian civilizations in the mid-first millennium BCE, which our model links to the expanded use of lightweight writing materials and associated increases in the number and complexity of traditions. The suggestion again is that rates of information flow and the growth of systematic thought were closely coupled.

In at least one special case, involving the collapse of high-correlative systems in the early-modern era, a sustained increase in rates of information flow, and not a decrease, was implicated. In our computational models, the collapse of extreme correlative cosmologies can be simulated by applying the ideas of self-organized criticality (SOC), which posit nonlinear thresholds in the evolution of complex systems; once the complexity of those systems reaches certain levels, those systems begin to collapse.31

It is possible by adjusting rates of information flows to simulate other nonlinearities in the evolution of correlative systems, including the sudden appearance of anti-correlative movements that developed in many periods of antiquity (seen, for example, in the traditions of early Theravada Buddhism, and in similar mystical movements elsewhere).

2.1 The Commentarial Engine

The links between exegetical processes and the evolution of religious and philosophical systems have been noted occasionally in studies of specific traditions, if not in studies of premodern thought in general. One specialist in Vedantic scholasticism, Patricia Y. Mumme, comments:

It is remarkable how metaphysics in Indian thought are so tightly bound to interpretive strategies. The views of reality seen in the various schools are driven by specific strategies of scriptural interpretation. In fact, metaphysical categories are often mirror images of interpretive strategies... It may be a Western bias to assume that a metaphysical system is the goal of philosophy, and that scriptural interpretation is secondary or merely instrumental. From an Indian perspective, an orthodox metaphysical system may be only a by-product of a proper hermeneutical approach to scripture... Western Indologists need to divert some attention from the metaphysical carts in Indian thought in order to give closer scrutiny to the hermeneutical horses that may be driving them.

books of Chilam Balam. R. Faulkner’s standard translations of Egyptian funereal texts are created from hypothetical “ideal” manuscripts, with the result that the heavily stratified internal commentaries in parts of those texts (e.g., in chapter 17 of the Book of the Dead) are badly obscured. For a partial correction of this problem, see the works of Thomas George Allen, Occurrences of Pyramid Texts With Cross Indexes of These and Other Egyptian Mortuary Texts (Chicago, 1950); Allen, The Egyptian Book of the Dead (Chicago, 1960); and Allen, The Book of the Dead or Going Forth By Day: Ideas of the Ancient Egyptians Concerning the Hereafter as Expressed in Their Own Terms (Chicago, 1974).

31 For references, see note 48
As her central example, Mumme points to the way that the use by Sankara (c. 788-820 CE) and his commentators of the “double-truth” supported the Vedantic view of “two [analogical] levels of reality, the ultimately real brahman and the provisionally real realm of maya or avidya.” It can be shown that use of the double-truth as an exegetical device led to precisely the same results in medieval Japanese, Chinese, Islamic, and Christian scholastic traditions.

The most general conclusion of our studies has been that much of systematic thought in premodern literate civilizations—and not just in India—arose from the repetitive use of just such devices.

Commentarial engines left a long series of exegetical artifacts in their wake, ranging from isolated metaphysical principles to multilayered correlative systems; the specific structures generated by those engines depended in part on which layers of traditions they operated upon. Those structures also varied slightly from culture to culture, reflecting in part the specific genres of canonical sources lying at their base; thus, similar exegetical devices might produce monotheistic deities or linear models of time when operating on one series of texts, and abstract metaphysical principles or cyclical models of time when working on others.

While the full range of exegetical techniques was culturally invariant, moreover, the frequency with which individual techniques were used differed from tradition to tradition—leading to further variations in thought. Key selection principles included how easily a technique could resolve textual conflicts in a given tradition and how often authorities in earlier levels of that tradition used the same technique.

These differences, repeated over many centuries, helped generate “path dependencies” in history, helping explain the predominance in one society, tradition, or subtradition of specific variations of correlative systems.

Admittedly, much or even most commentarial discussion was systematically neutral; parts of it, moreover, exhibited strongly anti-systematic tendencies. Moreover, systematic developments in commentarial traditions were often painfully slow, which helps explain why the links between formal exegesis and cosmological developments are often overlooked. Over the long run, however, a dozen or so exegetical devices with strong systematizing features were used so frequently by religious and philosophical exegetes that steady systematic growths were assured. The long-range pattern, holding true in a wide range of traditions, was a gradual increase in the complexity, formality, and systematic

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33 On anti-systematic tendencies in traditional thought, see Henderson, The Construction of Orthodoxy and Heresy; cf. Farmer, Syncretism in the West, chapt. 4.
integrity of correlative thinking.\textsuperscript{34}

Our earlier studies have analyzed the systematic effects of dozens of commentarial methods. (A summary of a number of these methods and effects is found in Appendix A.)

For the purposes of this essay, these methods can be reduced to two major classes: \textit{Integrative methods}, which tended to transform concrete or mythopoeic images into abstract religious and philosophical concepts; and \textit{Correlative methods}, which tended to bifurcate or multiply preexisting religious or philosophical concepts and, when used repeatedly, to foster the growth of formal systems of correspondence.

Some striking examples of integrative methods show up in the earliest strata of traditions, reflecting the efforts of early religious and philosophical exegetes to harmonize heavily layered canonical texts.

In China, supposedly the first commentator to use those methods was Confucius himself (c. 551-479 BCE)—referring, as Brooks and Brooks suggest, to the fictional “Confucius” of later strata of the Analects.\textsuperscript{35} According to tradition, it was Confucius’s goal to restore the great society of the early Zhou era; to accomplish this required that all extant records of the sage rulers be examined to uncover those qualities that made an ideal society possible. Exegetically reworking materials from earlier canonical sources, in particular passages from pre-Confucian levels of the Songs and Documents, early Confucians abstracted general virtues such as \textit{li} (ritual propriety) and \textit{xiao} (filial piety).\textsuperscript{36} This process of abstraction was carried to even a higher level in respect to another virtue, that of “humanity” (\textit{ren}), which in early texts often carries the concrete sense of that which is “manly” or “virile.”\textsuperscript{37}

In the reworking of \textit{ren} ascribed to Confucius, the term was elevated to an abstract plane as a kind of “Virtue of virtues” — defined, like the Platonic “idea of the Good,” or Vedic \textit{dharma}, by still other abstractions. Thus, according to later layers of the Analects, \textit{ren} can be viewed as the ability to practice the five virtues of respectfulness, tolerance, trustworthiness, diligence, and kindness (Analects 17.6). While \textit{ren} in one sense subsumed these virtues, however, hints are given that something remained in it beyond all understanding — even for a sage like Confucius.\textsuperscript{38} Like the \textit{Dao} of classical Daoism, \textit{brahman} of the Upanishads and Vedic sutras, “idea of the Good” of the Platonists, and


\textsuperscript{35} Brooks and Brooks, \textit{The Original Analects}.

\textsuperscript{36} See, for example, \textit{Analects} 2.21, 3.8, and 14.43. Brooks and Brooks argue that much of the Songs and Documents were forgeries written \textit{after} the earliest strata of the Analects, complicating discussion of the exegeses of those texts found in its later strata. Discussion of this issue, which does not affect our main thesis, must be reserved for another place.


\textsuperscript{38} \textit{Analects} 7.33; Schwartz, p. 91.
the transcendent god of late strata of the Torah, ren remained ineffable and mysterious — not fully accessible even to sages and prophets.

Nearly four decades ago, Havelock pointed to similar exegetical mechanisms as the driving force in the development of abstract philosophy in Greece — arising from attempts by the early pre-Socratics to integrate conflicting ideas in the Homeric corpus. The most famous product was the abstract dualism of the theory of Ideas:

You can take a word, justice, city, courage, bed, ship, and treat it as a common name and demand a general definition of it which will cover all the possible poetic instances. But this procedure is sophisticated. It becomes possible only when the spell of the poetic tradition has already been broken… But how, while still working within that tradition, can one start to extrapolate such topics and principles out of the narrative flux? The answer is that you can take similar instances and situations which are severed and scattered through different narrative contexts but which use many of the same words and you can proceed to correlate them and group them and seek for common factors shared by them all…

So another way of putting the mental act of isolation and abstraction is to say it is an act of integration. The saga [here, the Iliad] will contain a thousand aphorisms and instances which describe what a proper and moral person is doing. But they have to be torn out of context, correlated, systematized, unified and harmonized to provide a formula for righteousness. The many acts and events must somehow give way and dissolve into a single unity.39

Integrative processes like these appear in the earliest levels of commentary traditions throughout Eurasia, giving birth to monotheistic gods, abstract cosmological principles, systematic orders of virtues or elements, and dualistic views of reality that provided the bare abstract frameworks for later cosmological developments.

Our second class of exegetical techniques — correlative methods — helped generate many of the entities that filled out those frameworks, eventually giving birth to full-blown correlative systems. These techniques came in many subtypes: allegorical methods, the “double truth,” scholastic distinctions, and others summarized in Appendix A. Despite their differences, all these techniques were based on the same general principle: conflicts in authorities can be resolved if we take their conflicting words to refer not to the same but to analogous concepts standing on different “levels” of reality.40 When traditions were “worked up” over many centuries using such techniques, the eventual result was the construction of high-correlative systems in which every part of reality was said to reflect

39 Havelock, Preface to Plato, p. 218.
40 In part of our model that we do not discuss in this paper, the origins of these correlative techniques are traced to fundamental neurobiological processes. For references, see Farmer, Syncretism in the West, pp. 91–96.
every other.

Perhaps the most common of these correlative techniques was what is widely referred to as “standard” scholastic distinctions, which attempted to reconcile conflicts in authoritative sources by claiming that the same terms appeared in those sources in two or more analogical senses.

Neo-Confucian commentators, for example, reconciled a major conflict between Confucius and Mencius over human nature by claiming that in the conflicting passages Confucius was referring to the tempermental side of human nature, but Mencius to the foundations of human nature.\(^{41}\) Southeast Asian scholastics used identical means to reconcile internal conflicts in the Vedic and Buddhist canons, and Western commentators from Cicero to the Renaissance Platonists to harmonize apparent discord in Plato and Aristotle.

In the visual arts, one famous expression of the technique shows up in Raphael’s famous depiction of the “School of Athens,” where we find Plato holding the *Timaeus* and pointing upwards, while Aristotle holds the *Ethics* and spreads his hand over the world. The point was to emphasize that apparent conflicts in those authorities arose from their primary interests in “higher” and “lower” realities; their outwardly conflicting ideas were complementary, not contradictory.

The more complex the exegetical tasks, the more complicated these correlative methods became. To illustrate this principle, we will limit ourselves to citing two passages from the Renaissance syncretist Giovanni Pico della Mirandola and a third from the Neo-Confucian scholastic, Shao Yong. In both of these writers, the repeated use of this and similar methods led to the construction of unusually elaborate correlative systems.

Our first example, from Pico’s 900 theses, introduces a long chain of correlative distinctions to harmonize conflicting claims in Plato, Plotinus, Proclus, and other authorities as to the cosmic location of “beauty.” Conflicts here, as in the simpler cases discussed above, could be reconciled by invoking a series of verbal modifiers to suggest that different “modes” of beauty existed on different planes of reality.

Reflecting the outrageous scale of Pico’s syncretic system, the result — which is suggestive of computer-generated prose — was arguably the most extreme example of scholastic writing known:

> Beauty exists in God as its cause, in the total intellect truly essentially totally, in the particular intellect truly partially essentially, in the rational soul truly participationally, in the visible accidents of the heavens imagerially essentially totally, in subcelestial

visible qualities imagerially partially essentially, in quantities imagerially participationally. [!] 

The exegetical origins of constructs like these are underlined in another one of Pico’s 900 theses, aimed this time at reconciling apparent conflicts in Pre-Socratic sages over the metaphysical concept of the “one”:

Although there were three [writers] who said that all things are one — Xenophanes, Parmenides, and Melissus — whoever carefully scrutinizes their words will see that the one of Xenophanes is that which is one simply. Parmenides’ one is not the absolute one, as is believed, but is the oneness of being. The one of Melissus is the one that possesses extreme correspondence to Xenophanes’ one. 

The point of this thesis is that secret harmonies lie beneath the outer conflicts in the ancient wisemen — with Xenophanes first revealing God’s oneness, then Parmenides the reflected oneness in creatures, and Melissus finally the negative oneness of non-being or prime matter. One obvious byproduct of Pico’s method was a highly articulated correlative view of reality.

Similar extreme structures show up in the works of the medieval Chinese syncretist Shao Yong. The structural similarities between Shao’s and Pico’s systems, which were both heavy with numerological symbolism, can be illustrated by quoting a few sentences from one of Shao’s larger numerological constructs.

In the following passage, Shao correlates a long series of concepts, including the titles of four of the Chinese classics — the Changes, the Documents, the Songs, and the Spring and Autumn Annals — by arranging all of them in every possible logical sequence. Shao’s motive here was similar to Pico’s when he linked the ideas of Xenophanes and the Eleatics: to suggest that a uniform view of reality was shared by the ancient sages. When linked correlatively, the Chinese classics reveal to us all the principles that govern the world:

The Changes of the Changes means to produce life; the Documents of the Changes means to produce growth; the Songs of the Changes means to produce harvest; the Spring and Autumn Annals of the Changes means to produce storage. The Changes of the Documents means to increase life; the Documents of the Documents means to increase growth; the Songs of the Documents means to increase harvest; the Spring and Autumn Annals of the Documents means to increase storage. 

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42 Theses 5>26 and 3>70 in Farmer, *Syncretism in the West*. The original Latin texts are also provided in that work.

43 Shao Yung, *Huangji jingshi shu* (Book of the Supreme Rules Governing the World) SBBY ed. 5.9a. Not surprisingly, constructs like this in Shao and Pico were also tied to complex numerological structures — which can, in a sense, be abstracted directly from their verbal constructs.
These examples of premodern exegesis are extreme ones, but the strategies that generated them were commonplace.

Many of the most important features of premodern religious, philosophical, and cosmological systems arose from the repeated use of such strategies over millennia. A short list of such developments includes the original birth of monotheistic and transcendental deities; the development of abstract philosophical language and dualistic visions of reality; the growth of Buddhist, Christian, and Hindu trinities (and paradoxical concepts of deity in Mesoamerican thought); the emergence of abstract orders of demons, aeons, henads, angels, saints, and similar divine beings; the development of multilevel mirroring pictures of heaven and hell; the evolution of theories of multiple world creations and destructions; the origins of elaborate typological (linear) and cyclical models of time; and the growth of fully articulated models of man-the-microcosm, which show up in every mature premodern civilization.

Higher-level integrations of ideas like these, arising from the efforts of commentators working over thousands of years, were the primary force behind the growth of multilayered correlative cosmologies that dominated systematic thought in all major world societies until early modern times.44

3.1 Computer Simulations of the Growth and Collapse of Premodern Systems45

In the last several years, we have designed a number of computer simulations capable of implementing and partially testing the ideas described above. Our work here has arisen from combining what we have learned from our textual research with general studies of complex or self-organizing systems. Such studies have made major strides in the past decade, providing a number of algorithms that can be readily adapted by historical modelers.46 Below, we provide a non-technical overview of how those simulations function.

We first realized that simulations of this sort might be constructed in the late 1980s, when we discovered that the evolution of self-similar structures like those we discovered in premodern cosmologies were being intensely studied by mathematicians.

Self-similar or fractal structures can be viewed as the signatures or “footprints” of iterative processes. The discovery of self-similar growths in any evolving system typically suggests that nonlinear dynamics can be applied to modeling the development

44 Cf. Farmer, Syncretism in the West, chapt. 2.
45 An updated version of the following material can be downloaded as a PDF file from http://www.safarmer.com/simulations.pdf.
46 For an overview of modeling techniques involving complex or self-organizing systems, see the references in note 4. For further models related to evolutionary models like ours (in this case, from the biological sciences), see Stuart A. Kauffman, The Origins of Order: Self-Organization and Selection in Evolution (New York and Oxford, 1993).
of that system. As Mandelbrot and others have shown, self-similar structures tend to emerge in systems that are repeatedly transformed by recursive operations — by feedback mechanisms in which the output of each prior transformation becomes the input of each new one.\footnote{Mandelbrot, The Fractal Geometry of Nature; cf. H.-O. Peitgen and P.H. Richter, The Beauty of Fractals: Images of Complex Dynamical Systems (Berlin and New York, 1986), p. 5.}

What we found remarkable this finding was the similarities between the dynamics of such systems and those we found in the historical sphere. Our textual studies suggested that increasing levels of self-similarity in correlative systems were byproducts of the repetitive application to those systems of a small set of exegetical techniques, especially those of a reconciliative or syncretic nature.

This discovery suggested that it might be possible to develop simulations of the growth of correlative systems by adapting nonlinear models already widely used in the biological and physical sciences — fields in which the emergence of similar fractal patterns are well known.

Consider the following sketch of a simple simulation. The simulation can be run in either automatic or interactive modes. In the latter case, a human assistant assuming the role of “apprentice commentator” intervenes at key choice points in the simulation. Using a human assistant enhances the simulation’s value as a teaching device and greatly simplifies computational operations. (In the classroom, we have even used simplified versions of the simulations using nothing but paper, pencils, and a few specially prepared “canonical texts.”)

Certain parts of the simulation (e.g., the “contradiction detectors” mentioned in Step 3) are borrowed from computer models designed to handle complex scheduling tasks for the U.S. space program.\footnote{See, e.g., the papers in Technical Report FIA-92-17, NASA Ames Research Center, Artificial Intelligence Research Branch (May, 1992).} A high-level description of the simulation follows (see Appendix B for a formal expression of the algorithm underlying the simulation):

1. Select \textbf{primitive sets of texts} representing ancient textual genres — short prayers, ritual or magical texts, court poems, epic or lyric poetry, dynastic histories, oracles, etc. Key sentences in the texts (statements about divine forces, human virtues, ritual objects, etc.) are “tagged” as potential objects of exegesis.

2. Sort and randomly combine subsets of these texts to create stratified textual canons. These canons will typically include numerous textual inconsistencies; for example, the tagged statement “god X is Y” may appear in one place in the canon, while “god X is not Y” or “god X is Z,” etc., may appear elsewhere.
3. Apply contradiction detectors, or alternately use a human assistant, to define a prioritized list of exegetical tasks for each textual canon.

4. Select a subset of exegetical strategies out of a larger set using best-fit rules for canons and/or types of exegetical tasks (a human assistant can also be asked to make the selection). Different sets of strategies can be selected to generate competing subtraditions.

   (Reconciliative strategies are of the general type illustrated in Appendix A, the majority of which have obvious correlative features; exegetical strategies of different sorts can be added to model anti-syncretic forces in traditions, which tend to develop in tandem with extreme reconciliative tendencies.)

5. Apply exegetical strategies to a limited subset of exegetical conflicts in the canon. The application of these strategies to a canon generates exegetical artifacts, which normally amplify any existing correlative structure in the texts.

6. Collect exegetical artifacts in commentarial systems, whose basic forms are defined by simple templates.

7. Combine textual canons and commentarial systems to create stratified traditions.

8. Apply textual degradation rules to selected levels of tradition (shuffle or discard parts of texts, etc.) to mimic entropic or dissipative processes in manuscript traditions; different degradation rules can be assigned to canons and commentarial systems.

9. Iterate starting at step 3. Run the simulation until all inconsistencies in the traditions, or in any partitioned sets of those traditions, are eliminated.

While this simulation is admittedly crude, it will generate systematic byproducts that are remarkably similar to those generated by exegetical processes in stratified textual traditions.

Those byproducts tend to grow in complexity with each iteration; simultaneously, their self-similarities and internal consistencies tend to increase. The fact that (1) the textual quality of traditions is degraded after each iteration (Step 8) while (2) correlative structure is repeatedly fed into those traditions (Step 5) ensures that the system will evolve in self-similar way in an emergent fashion. It is, in fact, possible to observe the self-similarities in the system growing in each successive layer of tradition; this mimics the ways in which such structures evolved in premodern traditions.

Due to the use of best-fit rules that link exegetical strategies to exegetical tasks (Step 4), among the first systemic byproducts that arise in the simulation are abstract objects — primitive dualities, monotheistic deities, abstract cosmological principles, primitive sets of elements and virtues, etc. (Depending on the exegetical strategies used, elaborate
pantheons of gods may also emerge.)

Abstract dualistic frameworks then evolve; these are followed by broader cosmological systems, as exegetical artifacts generated in later iterations “fill out” those frameworks.

After a large number of iterations, expanded syncretic-correlative systems (of the sort found in Neo-Confucianism or Neo-Platonism, or similar scholastic traditions) develop that have increasingly complex mirroring structures. Whether those systems are laid out in hierarchical or temporal frameworks (in either cyclical or linear subtypes) depends on which exegetical strategies are driving the system.

When best-fit rules are applied, selected exegetical strategies tend to amplify the most common types of correlative structures found in the earliest levels of a tradition.

The speed with which systematic artifacts arise out of the textual flux is associated with the rate with which inconsistencies are eliminated from the textual canons; this rate can in turn be linked to the degrees of initial contradiction in the texts (determined in Step 3), which vary from canon to canon. Rates of information flows in the system are further associated with the number of exegetical acts performed in each iteration in Step 5 and with the depth of information loss that takes place in each loop in Step 8.

Adjustments to these tuning parameters can be introduced to simulate special historical conditions—developments in literate technologies, increases or decreases in literacy rates, shifts in levels of travel and cultural contact, textual losses and revivals, political expansions and contractions, institutional constraints on information flows, and so on.

So long as the “traditions” being simulated contain high enough levels of contradictions, linguistic output in the simulations (in the form of simple verbal statements) will eventually develop the kinds of proportionalities found in the hyperscholastic verbal constructions of late-traditional syncretists like Shao Yong or Pico (see the examples above)—whose systems, in a sense, “summed up” the results of two millennia of previous commentarial processes.

It is possible to add functions to the simulation to allow the abstraction of numerological features out of those systems as self-similarities grow or to translate the output of those systems into graphic form (of the sort seen in Figure 1). Political, social, and religious “selection algorithms” can be added to the textual degradation rules in Step 8 to simulate some of the historical conditions favoring the survival of one type of tradition over another—including some of the more unsavory institutional controls on thought found pervasively in premodern societies.

More complex versions of the simulation allow modeling not only of the growth of correlative systems but of their collapse as well. When the complexity of certain classes of self-similar systems approach critical thresholds, their sensitivity to even slight

These thresholds are related to the relative ease with which information flows through distant parts of the system, which is linked in turn to the global levels of self-similarity in those systems. At such thresholds, individual elements in the system become sensitive not only to influences from nearby elements but from those in all regions of the system; a classical example in physics involves long-range spin alignments in ferromagnetic systems just below Curie’s point.

The rates with which the rise and fall of such systems occur are controlled by tuning parameters that can be pictured as representing the energy pumped into those systems. The nature of this “energy” will vary depending on the system being modeled. This energy might be food in biology, labor and raw materials in economics, or information flows in historical models like ours. When those rates increase, they can push the complexity of such systems to critical thresholds, causing those systems to begin to collapse in dramatic fashions.

The classical example of this is the collapse of a sandhill, which has been extensively studied experimentally and in computer simulations. As sand is piled higher in the hill, the slope of the hill eventually reaches a critical level; after a certain point, any additional sand added to the pile will cause avalanches of increasingly large magnitude that will eventually push the slope back below the critical level. To put this another way: as the complexity of the sandhill approaches a critical threshold, “communication” between distant regions of the hill increases until the whole system begins to collapse in response to even small perturbations.

Analogies exist here again with the historical behavior of correlative cosmologies, which became increasingly vulnerable to attack the more complex and self-similar those systems became. As Galileo discovered to his cost, as critical thresholds are approached correlative systems become so cohesive that any attack on any one part of the system threatens the whole.

In computer simulations of correlative systems, rates of information flows can be adjusted to ensure that the systems generated in the simulations eventually reach states of self-organized criticality. Simulated scientific, philological, or religious attacks on those systems might be imagined whenever the “conceptual distance” between those systems and earlier levels of tradition, or between those systems and models of empirical reality,
reach critical levels. At that point, special rules can be applied (e.g., to Step 8) to allow those traditions to decompose in a realistic fashion.

It is amusing to imagine simulations in which best-fit rules at critical points cause “flips” in exegetical methods (in Step 4) from syncretic to antisyncretic modes — simulating, in a sense, the historical shift of Voltaire’s bitter-end scholastic from reconciliative to skeptical ways of thinking. Once again, the rates of information flow at such points are key.

4.1 Summary and Conclusions

In this paper we have sketched a model of the structural growth of premodern religious and philosophical systems. In that model, parallel intellectual developments in premodern China, Europe, and other literate civilizations are pictured as byproducts of exegetical processes operating in manuscript traditions over long periods of time.

At the end of the paper, we briefly described abstract representations of our model that can be implemented in simple computer simulations.

In the last decade, we have fine-tuned our model in the classroom to produce a powerful framework for teaching comparative history. We have also considered ways in which future simulations can be used to guide research and to help in historical reconstructions.

We anticipate in particular the use of simulations in helping date chronologically vague or textually depleted areas of premodern history, like those typical of ancient India or Mesoamerica. Even in the absence of other textual evidence, study of the systematic byproducts of commentarial processes can help us date those products and can tell us something about any lost traditions underlying them.

In general, from a consideration of how rates of information flow affect traditions, it is possible to fill in holes in the evolutionary record of one tradition by extrapolating from data available in others. The parallels here with procedures used in evolutionary theory in geology and biology are obvious.

In closing, we want to point out that we recognize that our model may prove troublesome to those who view traditional religious and philosophical systems not as exegetical artifacts but as monuments to unconditioned human “genius.” We hope that this deficiency, if it is one, is offset by a number of historical puzzles that the model efficiently solves.
Appendix A: A Few Systematic Effects of Exegetical Strategies

The following is a short list, intended to be illustrative and not exhaustive, of a few exegetical strategies that had major systematic effects.

The majority of these strategies had a reconciliative purpose: to harmonize traditions, to unveil the hidden unity in canonical sources, to reconcile new traditions with old ones, or to co-opt the ideas of warring traditions or subtraditions.

Which strategies were preferred in different traditions — and hence which types of cosmologies tended to evolve within those traditions — depended in part on (1) the ease with which those methods solved given exegetical tasks and (2) the frequency with which those methods showed up in earlier layers of tradition.

The inbreeding of traditions over long periods resulted in the cross-cultural growth of multilayered correlative systems that by late traditional times exhibited high levels of structural complexity, formal consistency, and self-similarity.

Partially counterbalancing this development were anti-scholastic (or classicist) movements that tended to grow in strength the further traditions drifted from the sense of their base texts; the seesaw battle of syncretic and anti-syncretic forces was a major theme in the history of thought until the final collapse of high-correlative systems in early modern times.

<table>
<thead>
<tr>
<th>EXEGETICAL STRATEGY</th>
<th>DESCRIPTION</th>
<th>TYPICAL BYPRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation of gods from different polytheistic traditions.</td>
<td>Gods of different traditions are pictured as bodily parts or inferior reflections of superior deities for reconciliative ends.</td>
<td>Generation of early pantheons of gods in ancient Egypt, Mesoamerica, India, Greece, etc. Similar tendencies in Chinese folk religion.</td>
</tr>
<tr>
<td>Syncretic fusion of different animistic deities from one or more tradition.</td>
<td>Conflicting concepts of animistic deities are harmonized to create more transcendent gods.</td>
<td>The initial appearance of proto-monotheistic or monotheistic deities.</td>
</tr>
<tr>
<td>Processes of abstraction applied to harmonize diverse references to moral or intellectual concepts in mythic traditions.</td>
<td>Abstract cosmological principles are generated through integrations of conflicting uses of terms in earlier layers of texts.</td>
<td>‘Heaven,’ the ‘Way,’ dharma, Logos, the ‘One,’ Platonic theory of ideas, etc. Abstract dualistic frameworks are created for later cosmic developments.</td>
</tr>
<tr>
<td>EXEGETICAL STRATEGY</td>
<td>DESCRIPTION</td>
<td>TYPICAL BYPRODUCTS</td>
</tr>
<tr>
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</tr>
<tr>
<td>Paradoxical concepts applied to conflicting references to divine beings or abstract cosmological principles.</td>
<td>Conflicting references to divine beings or cosmic principles are identified in paradoxical ways to harmonize texts.</td>
<td>Simultaneously transcendent and immanent gods; paradoxical Confucian-Daoist ‘Way’; Buddhist, Christian, and Hindu trinities; dualistic deities in Tibetan or Mesoamerican traditions, etc.</td>
</tr>
<tr>
<td>Order sages, divine beings, or inferior creatures from different traditions in hierarchical, emanational, or temporal series.</td>
<td>Figures from one or more tradition are fit in a single framework by assigning them to different levels of reality.</td>
<td>Grades of Confucian sages, Buddhist arhats, Hindu avatars, etc.; gnostic aeons and Neo-Platonic henads; orders of demons and angels.</td>
</tr>
<tr>
<td>Syncretic fusion of multiple or conflicting stories concerning ancient sages, philosophers, and tradition founders in a growing canon.</td>
<td>Multiple stories of sages, philosophers, and tradition founders are harmonized by transforming these figures into semi-divine or divine beings.</td>
<td>Eventual transformation of Confucius, Laozi, Socrates, Buddha, Jesus, etc., into semi-divine or cosmic beings.</td>
</tr>
<tr>
<td>Systematic correlations of conflicting references to single deities.</td>
<td>Conflicting references to deities are identified as inferior manifestations of that god.</td>
<td>Abstract schemas of the names and powers of god in Islamic and Christian scholasticism; the kabbalistic sefirot, etc.</td>
</tr>
<tr>
<td>Allegory methods applied in hierarchical frameworks.</td>
<td>Abstract philosophical or religious ideas read out of (or into) non-philosophical works.</td>
<td>Intensified hierarchical visions of reality. Transformations of poetic and other non-philosophical works into cosmological treatises (Homer, the Odes, Spring and Autumn Annals, etc.).</td>
</tr>
<tr>
<td>Allegorical methods applied in a temporal framework (typology).</td>
<td>Concepts or persons in earlier traditions are pictured as imperfect anticipations of concepts or persons in later ones.</td>
<td>Growth of analogical views of time in progressive (linear) frameworks.</td>
</tr>
<tr>
<td>EXEGETICAL STRATEGY</td>
<td>DESCRIPTION</td>
<td>TYPICAL BYPRODUCTS</td>
</tr>
<tr>
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</tr>
<tr>
<td>Compilational or allegorical strategies applied in cyclical temporal frameworks</td>
<td>Conflicting stories, concepts, divine beings, or temporal events in different layers of texts are reconciled by assigning them to different eras in a cyclical temporal framework.</td>
<td>Multiple creations and destructions of the world in Greek or Mesoamerican traditions; concept of divine avatars and multiple Buddhas, etc.; reconciliative use of the “five phases” (wuxing) in Chinese dynastic histories.</td>
</tr>
<tr>
<td>Compilational strategies in hierarchical frameworks.</td>
<td>Conflicting stories, concepts, or cosmological schemes are joined in a hierarchical manner.</td>
<td>Multileveled mirroring visions of heaven and hell in Christian, Buddhist, Hindu, and Mesoamerican traditions; complex faculty psychologies; etc.</td>
</tr>
<tr>
<td>Syncretic syllogisms</td>
<td>Disjoined snippets of texts are conjoined to unveil their hidden unities. Heavy use in Vedic, Neo-Confucian, Midrashic, and other commentarial traditions.</td>
<td>Increased reverence towards holy books; intensified word magic, bibliomancy, etc.</td>
</tr>
<tr>
<td>Standard scholastic distinction</td>
<td>Apparent conflicts in texts are reconciled by adding verbal modifiers as needed to those concepts.</td>
<td>Increasingly complex, correlative, and hierarchical visions of reality in Neo-Confucian, Buddhist, Hindu, Islamic, Jewish, and Christian scholasticism.</td>
</tr>
<tr>
<td>Double-truth’ models</td>
<td>Religious or philosophical authorities are reconciled by distinguishing complementary realms of truth.</td>
<td>Bifurcations of reality in the three-treatise school of Buddhism; similar developments in Neo-Confucian, Vedantic, Averoistic scholasticism, and Latin scholastic traditions.</td>
</tr>
<tr>
<td>Mystical letter/glyph interpretations and anagrammatic manipulations of canonical writings</td>
<td>Mystical letter/glyph interpretations and anagrammatic readings introduced to demonstrate the hidden unity of canonical texts.</td>
<td>Glyphomancy in China, anagrammatic manipulations of texts in India, the Middle East, and the West. Intensified linguistic realism, fusion of mysticism and calligraphy, etc.</td>
</tr>
</tbody>
</table>
Higher-level fusions of systems of correspondences. Presyncretized (correlative) concepts found in earlier texts are conjoined in increasingly abstract forms. Abstract numerologies of the type found in Shao Yong or Joachim of Fiore. Extreme syncretic-correlative systems with amplified magical properties in medieval and early modern times.

For detailed discussion of individual strategies, see Henderson, *Scripture, Canon, and Commentary* and Farmer, *Syncretism in the West*. For discussion of exegetical methods opposing these strategies, see Henderson, *The Construction of Orthodoxy and Heresy*.

**Appendix B: Formal Algorithm/Program Information Flow**

The following box contains a brief formal description of the algorithm used in the simulation described above. Program operators appear in italics; materials transformed by these operators in plain text.

```
Algorithm exegesis-process (prepared_sources)
  primitive_texts = select_subset_from(prepared_sources)
  tagged_primitive_texts = tag_concepts(primitive_texts)
  stratified_textual_canons = randomly sort and recombine_subsets_(tagged_primitive_texts)
  loop until no contradictions
    contradictions = detect_contradictions(stratified_textual_canons)
    exegetical_tasks = prioritize_contradictions(contradictions)
    exegetical_strategies = select_exegetical_strategies(exegetical_tasks)
    exegetical_artifacts = apply(exegetical_strategies, exegetical_tasks)
    commentarial_systems = match_templates_to_artifacts(exegetical_artifacts)
    tradition = combine(commentarial_system, textual_canons)
    dtraditions/dt = apply_degradation_rules(tradition)
    tradition = dtraditions/dt + tradition
  end loop
end algorithm
```
Appendix C: Simulation Flow Chart

Rates of information flow in each step and rates of dissipation defined in step #8 serve as tuning parameters that regulate the system’s linear and nonlinear behaviors. So long as the system remains in the linear domain, the complexity and correlative (or ‘self-similar’) structure of layered textual traditions increase with each iteration.