Epistemological Perspectives and Considerations
There is no accepted definition of emergence, even among scientists, but few who have seriously studied such phenomena believe it to be an ‘eye-of-the-beholder’ effect. Indeed, it is possible to list criteria that go far toward distinguishing some observation as emergent, regardless of the observer and the time of discovery. (Holland, 2002: 27)

I subscribe to Holland’s view that phenomena – whether compressible or not – exist in the real world independently of the eye of the beholder. This is the essence of scientific realism; it is possible to base truth claims on aspects of the real world, given appropriate research methods. My modification is that I substitute Campbellian Realism in place of the ‘scientific realism’ emanating from philosophies of science rooted in physics (McKelvey, 1999). It is important, however, to also take note of Gell-Mann’s ‘effective complexity’. Designing buildings in California is more complex because of earthquakes. The simpler building codes in, say, Texas, are ineffectively complex for California. On the other hand, one doesn’t need to understand nano-phenomena to build quake-safe structures; these would not be effectively complex either. Building codes – building ‘schemas’ as Gell-Mann (2002: 16) would call them – need to be effectively complex, no more no less.

Effectively complex theorizing and model-building, and doing the kind of research that produces effectively complex managerial schemata, are the objectives of effectively complex scientific method. Philosophies of scientific realism aim to accomplish this. Truth-claims, then, are also effectively complex. As you will see, in Campbellian Realism, while idiosyncratic perceptions of the phenomenal world are recognized, and social construction by scientific communities is accepted, ultimately good science is held accountable to the hard reality of what is real. Postmodernism, constructivism, and relativism undoubtedly surface at the beginning of inquiry, but effective complexity science applied to organizations and management needs to rise above these pseudo-science wishful-thinkings if truth claims are to be valid and believable. Nothing less will do! For the most constructive connection between postmodernism (really poststructuralism) see Cilliers’ book, Complexity and Postmodernism (1998).
CRITIQUE OF POSITIVISM AND POSITIVIST ECONOMICS

Defining logical positivism and logical empiricism

... The word ‘positivist’, like the word ‘bourgeois’, has become more of a derogatory epithet than a useful descriptive concept, and consequently has been largely stripped of whatever agreed meaning it may once have had (Giddens, 1974: ix).

In fact, ‘positivism’ has both strong and weak points and how it is defined has evolved. Positivists worry about the fundamental dilemma of science: How to conduct truth-tests of theories, given that many of their constituent terms are unobservable and unmeasurable, seemingly unreal, and thus beyond the direct first-hand sensory experience of investigators? The term, positivism, was coined by August Comte. He attempted to avoid the dilemma by disallowing into science terms not directly apparent to the human senses. Comte claimed that the goal of science is prediction based only on observable terms (Audi, 1995: 147).

Following Newtonian mechanics, German mechanistic materialism, held that ‘... existence obeys, in its origin, life, and decay, mechanical laws inherent in things themselves, discarding every kind of supernaturalism and idealism in the exploration of natural events’ (Suppe, 1977: 8, quoting Büchner, 1855). It rests on empirical inquiry rather than philosophical speculation, a view in which there is no doubt that a real objective world exists. Materialism gave way to the neo-Kantian view that ‘science is concerned to discover the general forms of structures of sensations; the knowledge science yields of the “external worlds” is seen as webs of logical relations which are not given, but rather exemplified ... in sensory experience’ (Suppe: 9). Thus science discovers not just the structure of matter but rather the logic of the interrelations among the phenomena. This view had become the dominant philosophy of the German scientific community by 1900. By mid nineteenth century Hegel’s philosophy of ‘the identity of reason and reality’ dominated. It proclaimed only ‘reason’ is ‘real’, denying the existence of tangible entities such as earth, water, and fire. The world is purely perception, a matter of the mind!

Mach added the notion that scientific statements must be empirically verifiable, resulting in neopositivism. The excesses of Mach’s approach, which included a rejection of mathematics, subsequently were denied, resulting in a modified positivism (Whitehead and Russell, 1910–1913) that still held to verifiability as a basis of assuring truth but included mathematics as an appropriate expression of scientific laws. During the ensuing decade the main elements of the Received View developed and were published in Carnap’s (1923) first publication. It formally stated the tenets of logical positivism, since it included mathematical, theoretical, and observational languages as well as the separation of theory and observation terms.

By 1910 the Vienna Circle (founded in 1907), a group of Germans trained in logic, mathematics, and physics meeting at the University of Vienna, had accepted the task of considering how to respond to: (1) Hegelian idealism; (2) scientists’ beliefs in mechanistic materialism; (3) neo-Kantian sensory experiencing of the external world; (4) Machian neo-positivism’s emphasis of verification, and finally the crowning blows; (a) Planck’s quantum mechanics; and (b) Einstein’s theory of special relativity, both of which violated determinism, sensory relevance, and verificationism. Their official manifesto, *The Scientific World View: The Vienna Circle*, was published in 1929.1

Responding to the philosophical dilemma, logical positivists founded their epistemology on axiomatic theories, using terms comprising three languages: ‘(1) logical and mathematical terms; (2) theoretical terms; and (3) observation terms’ (Suppe, 1977: 12). Theory terms are unreal, abbreviated representations of phenomena described by the observation terms. *Correspondence rules* (C-rules) assure
theoretical terms are explicitly linked to observation terms. They held that theory terms are unreal and, thus, theoretical explanations of causality are also unreal, leading to the view that theories may be interpreted only as instrumental summaries of empirical results (Hunt, 1991: 276–277). The ‘scientific truth’ in theory terms is ascertained via ‘verification’ in observation terms. Logical positivists attempted to clarify the language of science by expunging metaphysical terms not amenable to direct sensory testing and by insisting that logic terms be verified as to cognitive meaning and truth, thereby ‘ridding it [science] of meaningless assertions by means of the verifiability principle and reconstructing it through formal logic into a precise, ideal language’ (Hunt, 1991: 271).

In his classic statement Schlick (1932/33)² focused on the seeming impossibility of ever knowing whether the external world is different from the metaphysical or transcendent reality of the human senses, that is, cognitive construction or interpretation. In his view the only way to tell if some datum is real or not is to take it away and see if there is a difference. Thus, if I sit once and the chair is there and if I sit again and the chair is not there and I fall, I may conclude the chair is real. This is what Schlick refers to as a testable difference.

Subsequently Nagel (1961), and Hempel (1965), following others, evolved an epistemology focusing on laws, explanation, and theory, known as logical empiricism. It had replaced logical positivism by mid twentieth century. The logical empiricists’ immediately encountered a problem with the verifiability principle, since for a law to be verified it must be empirically proved universally true for all times at all places, an impossibility. Consequently verifiability was abandoned, to be replaced by a somewhat relaxed testability criterion that all propositions have to be amenable to some measure of empirical test, a view eventually championed by Popper (1959) as his falsifiability principle. This modification finally admitted that theory terms could never be directly ‘verified’ empirically.

In responding to the fundamental dilemma, the logical empiricists attempted to deal with the problems identified with the logical positivists’ strict separation of theory and observation terms via the use of C-rules. How to have an ‘unreal’ theory term explicitly defined via C-rules without having the theory term simply be the result of an observable measure of some sort? This would become an operationalist’s treatment of theory – it is whatever is measured (Hempel, 1954). It created the ‘theoreticians dilemma’: (1) If all theory terms can be explicitly defined by reduction to observation terms, then theory terms are unnecessary; and (2) If theory terms cannot be explicitly defined and related to observation terms they are surely unnecessary because they are meaningless (Hempel, 1965: 186). Further, if theory terms are isomorphic to operational measures there is no possibility of using the theory to predict new phenomena, as yet unmeasured.

It is clear that the term ‘positivism’ is now obsolete among modern philosophers of science (de Regt, 1994). Nevertheless, many key ingredients of positivism still remain in good standing among scientific realists, such as: theory terms, observation terms, tangible observables and unobservables, auxiliary hypotheses, causal explanation, empirical reality, testability, incremental corroboration and falsification, and generalizable law-like statements. Though Suppe (1977) wrote the epitaph on positivism and relativism, a positivist legacy remains (McKelvey, 1999). The idea that theories can be unequivocally verified in search for a universal unequivocal ‘Truth’ is gone. The idea that ‘correspondence rules’ can unequivocally connect theory terms to observation terms is gone. The role of axioms as a basis of universal Truth absent empirical tests is negated. The importance of models and experiments is reaffirmed.

The fallacy of positivist economics

The evolutionary aspect of economics originates in attempts by Spencer (1898) and
Friedman (1953) to use Darwinian selectionist theory to justify why only rational firms survive. Samuelson (1947) and Friedman (1953) draw on the mathematics of classical physics, its First Law of Thermodynamics (the conservation of energy law), and the centrality of equilibrium, in attempting to turn economics into a predictive science (Mirowski, 1989). To get economics out of its equilibrium-centric stance, Nelson and Winter (1982) use Darwinian selectionist theory to introduce dynamics into economic ‘Orthodoxy’. More recently, however, Salthe (1993), Rosenberg (1994), and Eldredge (1995) all recast Darwinian selectionist theory as an equilibrium-based theory as well. They conclude that the most significant dynamics in the bio- and econspheres are variances around equilibria in niches remaining stable for millions of years. While Darwinian selection is still important at the tail end of the order-creation process, the ‘self-organization biologists’ (Van de Vijver et al., 1998) see other natural forces surrounding the biosphere as causing the more significant changes in biological entities over the millennia. Self-organization biology enters the mix as an important additional component of bioeconomics.

Hinterberger (1994) critiques economic orthodoxy’s reliance on the equilibrium assumption from a different perspective. In his view, a closer look at both competitive contexts and economic actors uncovers four forces working to disallow the equilibrium assumption:

1 Rapid changes in the competitive context of firms does not allow the kinds of extended equilibria seen in biology and classical physics;
2 There is more and more evidence that the future is best characterized by ‘disorder, instability, diversity, disequilibrium, and nonlinearity’ (p. 37);
3 Firms are likely to experience changing basins of attraction – that is, the effects of different equilibrium tendencies;
4 Agents coevolve to create higher-level structures that become the selection contexts for subsequent agent behaviours.

Hinterberger’s critique comes from the perspective of complexity science. Also from this view, Arthur et al. (1997: 3–4; who draw from Holland, 1988) note that the following characteristics of economies counter the equilibrium assumption essential to predictive mathematics:

1 ‘Dispersed Interaction’ – dispersed, possibly heterogeneous, agents active in parallel;
2 ‘No Global Controller or Cause’ – coevolution of agent interactions;
3 ‘Many Levels of Organization’ – agents at lower levels create contexts at higher levels;
4 ‘Continual Adaptation’ – agents revise their adaptive behaviour continually;
5 ‘Perpetual Novelty’ – by changing in ways that allow them to depend on new resources, agents coevolve with resource changes to occupy new habitats; and
6 ‘Out-of-Equilibrium Dynamics’ – economies operate ‘far from equilibrium’, meaning that economies are induced by the pressure of trade imbalances, individual to individual, firm to firm, country to country, etc.

After reviewing all the chapters, most of which rely on mathematical modelling, the editors ask, ‘…In what way do equilibrium calculations provide insight into emergence?’ (p. 12; my italics). Most chapters miss the essential character of complex adaptive systems stylized in the bullets – heterogeneous agents in far-from-equilibrium systems.

In his book, Dynamics of Markets: Econophysics and Finance, McCauley (2004) observes that in physics a mathematical model is confirmed or not via empirical experiments; the math lives or dies depending on the experiments. In economics McCauley shows that it is not so; economists adhere to their math models whether or not they are empirically confirmed. In economics reliance on the math from equilibrium physics (Mirowski, 1989) amounts to a faith-based would-be science. I offer some specific quotes from McCauley’s book in Table 6.1.

The lack of empirical confirmation of theories and their math formalizations is further confirmed by the quotes of
economists, no less – listed in Table 6.2 – who point to the total disjunction between econometrics and economists’ beliefs in their theories. Economists claim that econometrics is a valid substitute for experiments (where the independent variable can be directly shown to cause the dependent variable – or not). This claim was refuted in a classic test by Lalonde (1986) of whether any of the best econometric models could replicate a real-world experiment.4 They couldn’t!

REALISM

From the positivist legacy a model-centred evolutionary realist epistemology has emerged. Elsewhere (McKelvey, 1999), I argue that model-centred realism accounts to the legacy of positivism and evolutionary realism accounts to the dynamics of science highlighted by relativism, all under the label Campbellian Realism. Campbell’s view may be summarized into a tripartite framework that replaces the historical relativism of Kuhn (1962) and Feyerabend (1975) for the purpose of framing a dynamic realist epistemology. First, much of the literature from Lorenz (1941) forward has focused on the selectionist evolution of the human brain, our cognitive capabilities, and our visual senses (Campbell, 1974); it concludes that these capabilities do indeed give us accurate information about the world we live in (reviewed by Azevedo, 1997).

Second, Campbell (1991) draws on the hermeneuticists’ coherence theory in a selectionist fashion to argue that over time members of a scientific community (as a tribe) attach increased scientific validity to an entity as the meanings given to that entity increasingly cohere across members. This process is based on hermeneuticists’ use of coherence theory to attach meaning to terms (Hendrickx, 1999). This is a version of the social constructionist process of knowledge validation that defines Bhaskar’s (1975) use of transcendental idealism and the sociology of knowledge components in his scientific realist account. The coherentist approach selectively winnows out the worst of the theories and thus approaches a more probable truth.

Third, Campbell (1991) and Bhaskar (1975) combine scientific realism with semantic relativism. Nola (1988) separates relativism into three kinds:

1 ‘Ontological relativism is the view that what exists, whether it be ordinary objects, facts, the entities postulated in science, etc., exists only relative to some relativizer, whether that be a person, a theory or whatever’ (1988: 11) – [ontologically nihilistic].

2 Epistemological relativisms may allege that (1) what is known or believed is relativized to individuals, cultures, or frameworks; (2) what is perceived is relative to some incommensurable
paradigm; (3) there is no general theory of scientific method, form of inquiry, rules of reasoning or evidence that has privileged status (1988: 16–18) – [epistemologically nihilistic].

Semantic relativism holds that truth and falsity are ‘... relativizable to a host of items from individuals to cultures and frameworks. What is relativized is variously sentences, statements, judgements or beliefs’ (1988: 14) – [semantically weak].

Nola observes that Kuhn and Feyerabend espouse both semantic and epistemological relativism. Relativisms familiar to social scientists range across all three kinds, that is, from ontological nihilism to semantic. Campbell clearly considers himself a semantic relativist in addition to being an ontological realist (Campbell and Paller, 1989). This produces an ontologically strong, relativist, dynamic epistemology. In this view the coherence process within a scientific community continually develops in the context of selectionist testing for ontological validity. The socially constructed coherence-enhanced theories of a scientific community are tested against real-world phenomena (the criterion variable against which semantic variances are eventually narrowed and resolved), with a winnowing out of the less ontologically correct theoretical entities. This process, consistent with the strong version of scientific realism proposed by de Regt (1994), does not guarantee error-free ‘Truth’ (Laudan, 1981), but it does move science in the direction of Popper’s (1959) increased verisimilitude (truthlikeness).

Campbellian realism is crucial because elements of positivism and relativism still flourish in social science. Campbell’s is an epistemology: (1) dealing with metaphysical terms, (2) objectivist empirical investigation, (3) recognition of socially constructed meanings of terms, and (4) a dynamic process by which a multiparadigm discipline usually reduces to fewer but more significant theories.

Campbell defines a critical, hypothetical, corrigible, scientific realist selectionist evolutionary epistemology as follows (McKelvey, 1999: 403):

1 A scientific realist postpositivist epistemology that maintains the goal of objectivity in science without excluding metaphysical terms and entities.

---

Table 6.2 Economists on the value of econometrics*

- ‘No economic theory was ever abandoned because it was rejected by some empirical econometric test, nor was a clear cut decision between competing theories made in light of the evidence of such a test.’ (Spanos, 1986: 660)

- ‘Very little of what economists will tell you they know, and almost none of the content of the elementary text, has been discovered by running regressions. Regressions on government-collected data have been used mainly to bolster one theoretical argument over another. But the bolstering they provide is weak, inconclusive, and easily countered by someone else’s regressions.’ (Bergmann, 1987: 192)

- ‘We don’t genuinely take empirical work seriously in economics. It’s not the source by which economists accumulate their opinions, by and large.’ (Leamer in Hendry et al., 1990: 182)

- ‘I invite the reader to try and identify a single instance in which a "deep structural parameter" has been estimated in a way that has affected the profession’s beliefs … . (Summers, 1991: 130)

- ‘No one really believes a scientific assertion in economics based on statistical significance.’ (McCloskey, 1994: 358)

- ‘Most allegedly empirical research in economics is unbelievable, uninteresting or both. It doesn’t get down to the phenomena. It’s satisfied to be publishable or clever. It’s unbelievable unless you have to believe temporarily to get tenure.’ (McCloskey, 1994: 359)

- ‘In economics it takes a theory to kill a theory, facts can only dent a theorist’s hide.’ (Samuelson quoted in Card and Krueger, 1995: 355)

* Collected by Pierpaolo Andriani.
2 A selectionist evolutionary epistemology governing the winnowing out of less probable theories, terms, and beliefs in the search for increased verisimilitude may do so without the danger of systematically replacing metaphysical terms with operational terms.

3 A postrelativist epistemology that incorporates the dynamics of science without abandoning the goal of objectivity.

4 An objectivist selectionist evolutionary epistemology that includes as part of its path toward increased verisimilitude the inclusion of, but also the winnowing out of the more fallible, individual interpretations and social constructions of the meanings of theory terms comprising theories purporting to explain an objective external reality.

The epistemological directions of Campbellian realism have strong foundations in the scientific realist and evolutionary epistemology communities (see Azevedo, 1997). The one singular advantage of realist method is its empirically based, self-correcting approach to the discovery of truth (Holton, 1993). While philosophers never seem to agree exactly on anything, nevertheless, broad consensus does exist that these statements reflect what is best about current philosophy of science. To date evolutionary realism has amassed a considerable body of literature, as reviewed by Hooker (1987) and Azevedo (1997). Along with Campbell and Lawson’s (1997) realist treatment of economics, Azevedo’s book stands as a principal proponent of realist social science.

THE SEMANTIC CONCEPTION

In my development of Campbellian Realism (McKelvey, 1999) I show that model-centredness is a key element of scientific realism, but I do not develop the argument. In this section, I flesh out the development of a model-centred social science by defining the Semantic Conception. As Cartwright put it initially: ‘The route from theory to reality is from theory to model, and then from model to phenomenological law’ (1983: 4). The shift from Cartwright’s earlier view of models as passive reflections of theory and data to ‘models as autonomous agents’ mediating between theory and phenomena reaches fullest expression in Morgan and Morrison (2000), her protégés.

Models may be iconic or formal. Most management scholars live in the shadow of economists and economics departments dominated by economists trained in the context of theoretical (mathematical) economics. Because of the axiomatic justification of theoretical economics, I first discuss the axiomatic conception in epistemology and economists’ dependence on it. Then I turn to the semantic conception, its rejection of the axiomatic definition of science, and its replacement programme.

The axiomatic syntactic tradition

Axioms are defined as self-evident truths comprised of primitive syntactical terms. Thus, in Newton’s second law, $F = ma$: requires understanding mass (being hit by a large truck) and acceleration (being hit by a speeding Ferrari). And the three terms, force, mass, and acceleration cannot be decomposed into smaller physical entities defined by physicists – they are primitive terms this sense (Mirowski, 1989: 223). A formal syntactic language system starts with primitives – basic terms, definitions, and formation rules (e.g. specifying the correct structure of an equation) and syntax – in $F = ma$ the syntax includes $F, m, a, =$ and $\times$ (implicit in the adjoining of $ma$). An axiomatic formal language system includes definitions of what is an axiom, the syntax, and transformation rules whereby other syntactical statements are derived from the axioms. Finally, a formal language system also includes a set of rules governing the connection of the syntax to real phenomena by such things as measures, indicators, operational definitions, and correspondence rules all of which contribute to syntactic meaning.
Based on the work of Pareto, Cournot, Walras, and Bertrand, economics was already translating physicists’ thermodynamics into a mathematicized economics by 1900. By the time logical positivism was established by the Vienna Circle circa 1907 (Hanfling, 1981), science and philosophy of science believed that a common axiomatic syntax underlay much of known science – it connected theories as far removed from each other as motion, heat, electromagnetism, and economics to a common set of primitives. Over the course of the twentieth century, as other sciences became more formalized, positivists took the view that any ‘true’ science ultimately reduced to this axiomatic syntax (Nagel, 1961; Hempel, 1965); this was the origin of the ‘Unity of Science’ movement (Hanfling, 1981).

Now, the axiomatic requirement increasingly strikes many scientists as more straitjacket than paragon of good science. After quantum/relativity theories, even in physics Newtonian mechanics came to be seen as a study of an isolated idealized simplified physical world of point masses, pure vacuums, ideal gases, frictionless surfaces, linear one-way causal flows, and deterministic reductionism (Suppe, 1989: 65–68; Gell-Mann, 1994). But biology continued to be thought – by some – as amenable to axiomatic syntax even into the 1970s (Williams, 1970; Ruse, 1973). In fact, most formal theories in modern biology are not the result of axiomatic syntactic thinking. Biological phenomena do not reduce to axioms. For example, the Hardy–Weinberg ‘law’, the key axiom in the axiomatic treatments of Williams and Ruse is:

\[
p = \frac{AA + 1/2Aa}{N}
\]

where \( p \) is the gene frequency, \( A \) and \( a \) are two alleles or states of a gene, and \( N \) is the number of individuals. But instead of being a fundamental axiom of evolutionary theory, it is now held that this ‘law’, like all the rest of biological phenomena is a result of evolution, not a causal axiom (Beatty, 1981: 404–405).

The so-called axioms of economics also suffer from the same logical flaw as the Hardy–Weinberg law. Economic transactions appear to be represented by what Mirowski refers to as the ‘heat axioms’. Thus, Mirowski shows that a utility gradient in Lagrangian form:

\[
P = \nabla U \cdot \left[ \frac{\partial U}{\partial x} \frac{\partial U}{\partial y} \frac{\partial U}{\partial z} \right] = \{P, P_x, P_y, P_z\}
\]

is of the same form as the basic expression of a force field gradient:

\[
F = \nabla U \cdot \left[ \frac{\partial U}{\partial x} \frac{\partial U}{\partial y} \frac{\partial U}{\partial z} \right] = \{X, Y, Z\}
\]

As Mirowski (1989: 30–33) shows, this expression derives from the axiom \( F = ma \). Suppose that, analogous to the potential or kinetic energy of planetary motion defined by the root axiom \( F = ma \), an individual’s movement through commodity space (analogous to a rock moving through physical space) is \( U = ip \) (where \( i = \) an individual, \( p = \) change in preference). The problem is that Newton’s axiom is part of the causal explanation of planetary motion, but the economists’ axiom could be taken as the result of the evolution of a free market capitalist economy, not as its root cause. This ‘axiom’ is not a self-evident expression that follows an axiomatic syntax common to all ‘real’ sciences. It is the result of how economists think an economy ought to behave, not how economic systems actually behave universally. Economists are notorious for letting ought dominate over is (Redman, 1991). Orthodox economic theory still is defined by axiomatic syntax (Hausman, 1992). It is pretty much a faith-based religion!

**Essential elements of the semantic conception**

Parallel to the fall of The Received View (Putnam’s (1962) term combining logical positivism and logical empiricism) and its
axiomatic conception, and starting with Beth’s (1961) seminal work dating back to
the Second World War, we see the emergence of the ‘Semantic Conception of Theories’
says, ‘The Semantic Conception of Theories today probably is the philosophical analysis
of the nature of theories most widely held among philosophers of science’. I present
four key aspects:

From axioms to phase-spaces
Following Suppe, I will use phase-space instead of Lloyd and Thompson’s state-space
or Suppes’ set-theory. A phase-space is defined as a space enveloping the full range of each
dimension used to describe an entity. Thus, one might have a regression model in which
variables such as size (employees), gross sales, capitalization, production capacity, age,
and performance define each firm in an industry and each variable might range from near
zero to whatever number defines the upper limit on each dimension. These dimensions
form the axes of an \( n \)-dimensional Cartesian phase-space. Phase-spaces are defined by
their dimensions and by all possible configurations across time as well. They may be
defined with or without identifying underlying axioms – the formalized statements of the
theory are not defined by how well they trace back to the axioms but rather by how well they
define phase-spaces across various state transitions. In the semantic conception, the quality
of a science is measured by how well it explains the dynamics of phase-spaces – not
by reduction back to axioms.

Isolated idealized structures
Semantic conception epistemologists observe that scientific theories never represent nor
explain the full complexity of some phenomenon. A theory may claim to provide a
generalized description of the target phenomena, say, the behaviour of a firm, but no
theory ever includes so many variables and statements that it effectively accomplishes
this. A theory (1) ‘does not attempt to describe all aspects of the phenomena in its intended
scope; rather it abstracts certain parameters from the phenomena and attempts to describe
the phenomena in terms of just these abstracted parameters’ (Suppe, 1977: 223); (2) assumes
that the phenomena behave according to the selected parameters included in the theory;
and (3) is typically specified in terms of its several parameters with the full knowledge
that no empirical study or experiment could successfully and completely control all the
complexities that might affect the designated parameters. Suppe (1977: 223–224) says
theories invariably explain isolated idealized systems (his terms). And most importantly,
‘if the theory is adequate it will provide an accurate characterization of what the phe-
omenon would have been had it been an isolated system …’. Using her mapping
metaphor, Azevedo (1997) explains that no map ever attempts to depict the full complex-
ity of the target area – it might focus only on rivers, roads, geographic contours, arable
land, or minerals, and so forth – seeking instead to satisfy the specific interests of the
map maker and its potential users. Similarly for a theory. A theory usually predicts the
progression of the idealized phase-space over time, predicting shifts from one abstraction
to another under the assumed idealized conditions. Needless to say, the foregoing equates
to Gell-Mann’s ‘effective complexity’.

Model-centred science
and bifurcated adequacy tests
Models comprise the core of the semantic conception. In the axiomatic conception: (1)
Theory is developed from its axiomatic base; (2) Semantic interpretation is added to make
it meaningful in, say, physics, thermodynamics, or economics; (3) Theory is used to make
test predictions about the phenomena; and (4) Theory is defined as empirically and
ontologically adequate if it both reduces to the axioms and is instrumentally reliable in
predicting empirical results. In the typical social science approach: (1) Theory is induced
after an investigator has gained an appreciation of some aspect of social behaviour;
(2) An iconic model is often added to give a pictorial (box-&-arrow) view of the interrelation of the variables, show hypothesized path coefficients, or possibly a regression model is formulated; (3) The model develops in parallel with the theory as the latter is tested for empirical adequacy by seeing whether effects predicted by the theory can be discovered in the real-world. In the semantic conception:

(1) Theory, model, and phenomena are viewed as independent entities; (2) Science is bifurcated into two not-unrelated activities, analytical and ontological adequacy. My view of models as centred between theory and phenomena sets them up as autonomous agents, consistent with the various authors in Morgan and Morrison (2000). Consequently, they have two bases of validity:

- **Analytical Adequacy** focuses on the theory–model link. It is important to emphasize that in the semantic conception ‘theory’ is always expressed via a model. ‘Theory’ does not attempt to use its ‘If A, then B’ epistemology to explain ‘real-world’ behaviour. It only explains ‘model’ behaviour. It does its testing in the isolated idealized world of the model. A mathematical or computational model (see Prietula; Tracy; Vidgen and Bull; all this volume) is used to structure up aspects of interest within the full complexity of the real-world phenomena and defined as ‘within the scope’ of the theory – which is to say it has to meet the standards of Gell-Mann’s effective complexity. Thus, a model would not attempt to portray all aspects of, say, school systems – only those within the scope of the theory being developed.

- **Ontological Adequacy** focuses on the model–phenomena link. Developing a model’s ontological adequacy runs parallel with improving the theory–model relationship. How well does the model represent real-world phenomena? *Is it effectively complex?* How well does an idealized wind-tunnel model of an airplane wing represent the behaviour of a full sized wing in a storm? How well does a drug shown to work on ‘idealized’ lab rats work on people of different ages, weights, and genetic variances? If each dimension in the model – called model-substructures – adequately represents an equivalent behavioural effect in the real world, the model is deemed ontologically adequate (McKelvey, 2001).

**Theories as families of models**

A difficulty encountered with the axiomatic conception is the belief that only one theory (or model) concept should build from the underlying axioms. In this sense, only one model can ‘truly’ represent reality in a rigorous science. Given this, a discipline such as evolutionary biology fails as a science. Instead of a single axiomatically rooted theory, as proposed by Williams (1970) and defended by Rosenberg (1985), evolutionary theory is a family of theories including theories explaining the processes of (1) variation; (2) natural selection; (3) heredity; and (4) a taxonomic theory of species (Thompson, 1989: Ch. 1). Even in physics, the theory of light is still represented by two models: wave and particle. Since the semantic conception does not require axiomatic reduction, it tolerates multiple theories and models. Thus, ‘truth’ is not defined in terms of reduction to a single model. Set-theoretical, mathematical, and computational models are considered equal contenders to more formally represent real-world phenomena. In physics both wave and particle models are accepted because they both produce highly reliable predictions. In evolutionary theory there is no single ‘theory’ of evolution. In fact, there are even lesser families of theories (multiple models) within the main families. All social sciences also consist of various families of theories, each having families of competing models within it.

**EXTENDING REALISM TO GELL-MANN’S SECOND REGULARITY**

**Translating chaos into new regularities to be explained**

Gell-Mann (2002) distinguishes between two fundamentally different ‘regularities’ – what Bhaskar (1975) calls ‘underlying generative processes’. As I noted earlier, Gell-Mann sees ‘effective complexity’ as ‘regularities’ or ‘schemas’ found or judged to be useful. They appear as equations in physics, genotypes
in biology, laws and traditions in social science, and business best practices in management or organization science. What is new is Gell-Mann’s recognition of a new scalability-derived regularity. He defines two regularities: (1) the old simplicity of reductionism, equations, linearity, and predictions of classical physics; and (2) the new simplicity of tiny initiating events – what I call ‘butterfly-events’ (based on Lorenz, 1972) – that initiate causal dynamics leading to nonlinearity, similar causal dynamics at multiple levels, power laws, and scale-free theory – what Gell-Mann (2002) calls historical frozen accidents. They are:

1. **Reductionist law-like regularities**: The reductionist causal processes of normal science, which stem predominantly from independent-additive causal processes that are predictable and easily represented by equations (2002: 19) – the data and information much preferred in classical physics and neoclassical economics.

2. **Multilevel scale-free regularities**: Outcomes over time that stem from connectivity and interactive multiplicative causal processes; they are set off by the random occurrence of tiny initiating events that are compounded by positive feedback effects over time; they may have lasting effects and become the ‘frozen accidents’ of history (2002: 20).

The first regularities have been the subject of science and philosophy of science and within the latter, positivism and scientific realism, which I extend to Campbellian realism, all of which are reframed by the Semantic Conception. These are the equilibrium-trending regularities that economists and thence management and organizational researchers have presumed could be lifted over from physics – the science of dead things – to the sciences of living things, particularly neoclassical economics. Where probability substituted for exact physics, Gaussian statistics became the order of the day; and still is.

The second regularities result from the effects of ‘tiny initiating events’ (what Holland (2002: 29) calls ‘small inexpensive inputs’ or ‘lever point phenomena’) – my ‘butterfly-events’. Lots of them occurring in a short time frame can create all of the bifurcation points giving rise to chaos and deterministic chaos theory (Gleick, 1987; Guastello, 1995). The butterfly-events of chaotic histories are never repeated, are not predictable, and can produce significant nonlinear outcomes that may become extreme events. Consequently, descriptions of these systems are at best problematic and easily outside the explanatory/scientific traditions of normal science. The underlying causes are self-organization and emergence – the core concerns of the Santa Fe Institute (SFI) (see for example: Cowan et al., 1994; Holland, 1995; Arthur et al., 1997).

SFI emphasizes the spontaneous coevolution of agents in complex adaptive systems. Agents restructure themselves continuously, leading to new forms of emergent order consisting of patterns of evolved agent attributes and hierarchical structures displaying both upward and downward causal influences. Bak (1996) extends this treatment in his discovery of ‘self-organized criticality’, a process in which butterfly-events can lead to complexity cascades of avalanche proportions best described as an inverse power law (PL). I show how a Pareto distribution turns into an inverse PL when plotted on double-log scales in Figure 6.1. The signature elements are self-organization, emergence and nonlinearity. Kauffman’s (1993) ‘spontaneous order creation’ begins when three elements are present: (1) heterogeneous agents; (2) connections among them; and (3) motives to connect – such as mating, improved fitness, performance, learning, etc. Remove any one element and nothing happens. According to Holland (2002) we recognize emergent phenomena as **multiple level hierarchies**, **bottom-up and top-down causal effects**, and **nonlinearities**. Gell-Mann (2002) concludes by noting that when butterfly-events spiral up such that their effects appear at multiple levels and are magnified, we see self-similarity, scalability, and PLs. Scalability, especially, applies to all living systems (Gell-Mann, 2002).
Seldom in the literature have scientific realists applied their epistemological views to butterfly events and consequences – an exception is *Worldviews, Science and Us: Philosophy and Complexity* (Gershenzon et al., 2007). Underlying most PLs is a causal dynamic explained via scale-free theories. Each theory points to a single generative cause to explain the dynamics at each of however many levels at which the scalability effect applies. Whereas tradition rests on the idea that lower-level dynamics can explain and predict higher-level phenomena and simplicity comes in the form of (usually) linear mathematical equations – i.e. reductionism (Gell-Mann, 2002), scale-free theories point to the same causes operating at multiple levels – the ‘simplicity’ is one theory explaining dynamics at multiple levels. Andriani and McKelvey (2009) apply fifteen of these scale-free theories to organizations.

**Explaining butterfly regularities via scale-free theories**

Many complex systems tend to be ‘self-similar’ across levels. That is, the same dynamics drive order-creation behaviours at multiple levels (West et al., 1997). These processes are called ‘scaling laws’ because they represent dynamics appearing similarly at many orders of magnitude (Zipf, 1949). Scalability results from what Mandelbrot (1982) calls ‘fractal geometry’. Fractals often show Pareto distributions and are signified by PLs. Researchers find PLs in intrafirm decisions, consumer sales, salaries, size of firms, movie profits, director interlocks, biotech networks, and industrial districts, for example – Andriani and McKelvey (2007, 2009) assemble studies about ~140 PLs. They are mostly explained by scale-free theories. They (2009) also identify 15 scale-free theories applying to organizations. From the foregoing, two new complexity thrusts are identifiable.

First, roughly one-third of complexity science theory is missing in organizational and managerial applications to date, i.e. the econophysics phase – PLs and the underlying fractals, scalability, and scale-free theory. Organizations are multilevel phenomena. Almost by definition then, we can take PL signatures as the best evidence we have that emergence dynamics are operating at multiple organizational levels. We know for sure...
that PLs apply at the industry level (Stanley et al., 1996; Axtell, 2001; Glaser, 2009). If PLs are not evident in a particular firm, we can conclude only that ‘emergence’, if it exists at all, is not multilevel. Building from the interacting food-web literature (Pimm, 1982; Solé et al., 2001; McKelvey et al., 2010), we can also conclude that, absent the PL signature, a firm’s emergence dynamics are not capable of keeping it competitive with its changing competitors, suppliers, and customers. Thus, if emergence produces scale-free dynamics, but PLs are not evident, then whatever emergence actually exists is pretty much competitively useless. The bottom line is that PLs are significant indicators of crucially important managerial and organizational dynamics. This puts the practical relevance of current empirical research in an especially bad light. No wonder people say b-schools (and their research) are increasingly irrelevant (Pfeffer and Fong, 2002; Bennis and O’Toole, 2005; Ghoshal, 2005).

Second, organization change and entrepreneurship researchers should be especially interested in scale-free dynamics and related theories. Who more than entrepreneurs wouldn’t like to let loose scale-free dynamics in their firms? Think of how many small entrepreneurial ventures stay that way simply because the emergent growth dynamics they had at the one- or two-level size failed to scale up as levels increased. Think how many large organizations show failing intrapreneurship for the same reason – the hundreds of ‘butterfly-ideas’ never become meaningful butterfly-events, never produce butterfly-effects, and never spiral into multilevel scale-free causal dynamics producing PL signatures. We now have recent research showing that PLs do indeed indicate changing firms (Dahui et al., 2006; Ishikawa, 2006), transition economies (Podobnik et al., 2006), and the UK’s broken industrial economy (McKelvey, forthcoming).

Extant complexity theory applied to organizations and management is silent on both the foregoing points. I think the most important move we could take is to learn how, and then more aggressively, apply scale-free complexity theory to organization change, OD, and entrepreneurship/intrapreneurship. Teaching and preaching complexity theory is useless in our organizational world absent scale-free theory. These points are further elaborated in chapters by Andriani and McKelvey, and Boisot and McKelvey (this volume).

CONCLUSION

Complexity Science Epistemology (CSE) cannot gain ontological and epistemological legitimacy and consequent truth claims by mirroring classical physics, which is to say mirroring its:

1. Lower-bound homogeneity assumption (e.g. all H₂O molecules, as agents, may be treated as similar);
2. Entropy-production based equilibrium-centred math modelling syntactic-equation-based practices;
3. Reductionism and prediction based on instrumental variables (prediction-useful as opposed to explanation-useful); and
4. Reliance on axiomatically-based syntactically-correct math expressions/proofs as opposed to semantically-relevant effectively-complex models.

Instead, CSE has to reflect an ontological jump from Gell-Mann’s First Regularities to his Second Regularities. This means CSE’s truth claims require developing the following – mostly new – epistemologies:

First: CSE shifts from ontologies, models, and epistemologies presumed to be based on constituent elements that are independent and combine additively to ontologies and agent-based computational models in which constituent elements (the agents) show connectivity and can interact so as to produce multiplicative, nonlinear outcomes, which give rise to Gell-Mann’s scalability-based Second Regularities. Complexity science, centred around emergent order-creation and
complexity from the interactions of autonomous heterogeneous agents, has developed an agent-based model-centred epistemology that parallels the social and language connectivities and individual-research-based truth claims emphasized in postmodernism and poststructuralism (Cilliers, 1998).

Second: CSE retains reliance on Campbellian realism and evolutionary epistemology: Campbellian realism – coupled with the Semantic Conception and evolutionary epistemology – bases scientific legitimacy on (a) theories aimed at explaining (and not just predicting) transcendental causal mechanisms or processes (i.e. including variables above and below the human senses); (b) the insertion of effectively-complex models as an essential element of sound epistemology; and (c) the use of changing real-world phenomena as the criterion variable leading to: (i) an evolutionary winnowing out of less plausible social constructions and individual interpretations; as well as (ii) constant updating of truth-claims.

Third: CSE recognizes four basic ontological forms stemming from the Second Regularity – which results in Pareto and PL distributed phenomena. Figure 6.2 depicts a stylized PL distribution. Within this figure we see four kinds of ontologies, each calling for different epistemologies. Since these ontologies are described in more detail by Andriani and McKelvey (this volume), I just describe them briefly here:

1. **Extreme outcomes**: At the lower right we have what Siggelkow (2007) and Andriani and McKelvey call ‘talking pigs’ – really strange, unusual, one-of-a-kind outcomes: a once-a-century #9 earthquake; Walmart and Microsoft (the largest firms in the world in their industries), the Challenger disaster, the Bay of Pigs confrontation between Russia and the U.S., etc. For this ontology, CSE truth claims should come from epistemologies such as hermeneutics and coherence theory (Campbell, 1991; Hendrickx, 1999), multimethod research (Jick, 1979) and abductive reasoning (Peirce, 1935; Hanson, 1958; Paavola, 2004).

2. **Normal distributions**: At the upper left we see the PL representation of the opposite Pareto long tail. This is where we usually see high enough frequencies of some phenomenon that Gaussian statistics applies. While there is only one Walmart at the lower-right, there are millions of Ma&Pa stores at the upper left. CSE truth claims based on Campbellian realism and evolutionary epistemology fit this ontology very well.

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**Figure 6.2 Stylized power-law distribution**
Anderson’s long tail: Also at the upper left, Anderson (2006) describes a variety of phenomena that appear in micro-niches, Amazon book sales being a good example; it can supply one weird book to one idiosyncratic customer and still make a profit from doing so. This perspective has been validated by Brynjolfsson et al. (2006). This epistemology is not well developed.

Horizontal scalability: Going horizontally in Figure 6.2, the ontology is that of, for example, Southwest Airlines going from a start-up regional airline in Texas to now being worth more than all the rest of the US airlines combined (Maxon, 2008). Sam Walton’s initial Ma&Pa-type store grew from very small to extremely large; most stores didn’t. Here the ontology is one of tiny initiating events – sometimes – leading to extreme outcomes. Truth claims here rest on epistemologies yet to be developed since Pareto distributions have been mostly ignored by statisticians and researchers for over a century. Andriani and McKelvey (this volume) describe the ontology in more detail. As power law science develops, a relevant CSE epistemology will presumably follow.

Model-centred science is a two edged sword. On the one hand, formalized models are reaffirmed as a critical element in the already legitimate sciences and receive added legitimacy from the Semantic Conception in philosophy of science. On the other, the more we learn about models as autonomous agents – that offer a third influence on the course of science, in addition to mirroring theory and/or data – the more we see the problematic moulding effects math models have had on social science. In short, math models are mostly inconsistent with living phenomena. A model-centred epistemology based on agent-based computational models (see Prietula; Tracy; Vidgen and Bull; all this volume) (and some math) is required for efficacious management research and practitioner advice giving. It is only a beginning, but I note that CSE truth claims call for radically different ontologies, models, and epistemologies calling for new developments in scientific realism.

NOTES
3 While there is no global controller in bee and ant colonies, firms have CEOs earning $$millions to be in charge. Hence, complexity science applied to organization and management has to deal with varying amounts of global control.
4 Lalonde’s test includes James Heckman’s two-stage method, for which he (Heckman) won the Nobel Prize.
5 Includes ontologically and/or epistemologically nihilistic subjectivist postpositivisms such as ethnomethodology, historicism, radical humanism, phenomenology, semiotics, literary explicationism, hermeneuticism, critical theory, and postmodernism, all of which are ‘post’ positivist and in which subjective and cultural forces dominate ontological reality.
6 Since the SFI complexity approach is discussed elsewhere in this volume, I only touch on it here.
7 ‘A Pareto rank/frequency distribution plotted in terms of double-log scales appears as a PL distribution – an inverse sloping straight line. … PLs often take the form of rank/size expressions such as \( F \sim N^{-\beta} \), where \( F \) is frequency, \( N \) is rank (the variable) and \( \beta \), the exponent, is constant. In exponential functions, e.g. \( p(y) \sim e^{\alpha y} \), the exponent is the variable and \( e \) (Euler number) is constant (quoted from Andriani and McKelvey, this volume).

REFERENCES


