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Peter A. Corning

Emergence in Evolution and the Causal Role of Synergy

If reductionism and a search for deterministic, predictive 'laws' of nature represented the dominant research strategy – and world view – of the scientific community during the 20th century, 'emergence' has become a major theme, if not the dominant approach in the 21st century, reflecting a major shift of focus toward the study of complexity and complex systems. However, this important 'climate change' in the scientific enterprise has been accompanied by much confusion and debate about what exactly emergence is. How do you know it when you see it? Or don't see it? What are its defining properties? Is it possible to predict emergence? And is there more to emergence than meets the eye? Beyond these meta-theoretical issues, there is a deep question that is often skirted, or even ignored. How do we explain emergence? Why does emergence emerge?

Here, I will briefly recount the history of this important concept and will address some of the many questions that surround it. I will also consider the distinction between reductionist and holistic approaches to the subject, as well as the distinction between epistemological and ontological emergence (that is, the ability to deduce or predict emergence versus the concrete reality of an emergent phenomenon). I will argue that living systems are irreducibly emergent in both senses and that biological evolution has quintessentially been a creative emergent process that is fully consistent with modern (Darwinian) evolutionary theory. Furthermore, as I will explain, novel 'synergies' of various kinds have been responsible for the 'progressive' evolution of more complex living systems over time. The selective advantages associated with emergent, synergistic effects have played a major causal role in the evolutionary process.

A Brief History of the Concept of Emergence

The concept of emergence is hardly new. It is, in fact, a venerable idea that can be traced back to the late 19th and early 20th centuries. The term was coined during an earlier upsurge of interest in the evolution of wholes, or, more precisely, what was viewed unabashedly in those days as evolutionary 'progress' – a trend toward new levels of organization and complexity over time, culminating in mental phenomena and the human mind. This long-ago episode, part of the early history of evolutionary theory, is not well-known today, or at least not fully appreciated. However, it provides a theoretical context and offers some important insights into what can legitimately be called the re-emergence of emergence.

According to the philosopher David Blitz in his in-depth history of emergence,[1] the term “emergent” was coined by the pioneer psychologist George Henry Lewes in his multi-volume *Problems of Life and Mind* (1874–1879).[2] Like many post-Darwinian scientists of that period, Lewes viewed the evolution of the human mind as a formidable conundrum. Some evolutionists, like Alfred Russel Wallace (the co-discoverer of natural selection), opted for a dualistic explanation. They claimed that the mind is the product of a supernatural agency. But Lewes, following John Stuart Mill’s lead, argued to the contrary that certain phenomena in nature produce what he called ‘qualitative novelty’ – material changes that cannot be expressed in simple quantitative terms; they are emergents rather than resultants. To quote Lewes:

> Every resultant is either a sum or a difference of the cooperant forces; their sum, when their directions are the same – their difference, when their directions are contrary. Further, every resultant is clearly traceable in its components, because these are homogeneous and commensurable […]. It is otherwise with emergents, when, instead of adding measurable motion to measurable motion, or things of one kind to other individuals of their kind, there is a co-operation of things of unlike kinds […]. The emergent is unlike its components in so far as these are incommensurable, and it cannot be reduced to their sum or their difference.[3]

Years earlier, John Stuart Mill had used the example of water to illustrate essentially the same idea: “The chemical combination of two substances produces, as is well known, a third substance with properties different from those of either of the two substances separately, or of both of them taken together.”[4] Both Mill and Lewes, however, were resurrecting an argument from their illustrious predecessor: More than 2000 years earlier, Aristotle wrote a philosophical treatise, later renamed the *Metaphysics*, about the significance of ‘wholes’ in relation to their ‘parts’. Aristotle stated: “The whole is something over and above its parts, and not just the sum of them all […].”[5] So the ontological distinction between parts and wholes was not exactly a new idea in the 19th century. The difference was that the late-Victorian theorists framed the parts-wholes relationship within the context of the theory of evolution and the challenge of accounting for biological complexity.

The basic quandary for holistic theorists of that era was that evolutionary theory as formulated by Darwin did not allow for radically new phenomena in nature, like (presumably) the human mind. As every first-year biology student these days knows, Darwin was a convinced gradualist who frequently quoted the popular

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[1] David Blitz: *Emergent Evolution. Qualitative Novelty and the Levels of Reality*, Dordrecht: Kluwer Academic Publishers 1992.

[2] George Henry Lewes: *Problems of Life and Mind,* vol. 1–5, London: Truebner 1874–1879.

[3] Ibid., p. 413.

[4] John Stuart Mill: *A System of Logic Ratiocinative and Inductive*, London: John W. Parker and Son 1872 [1843], p. 371.

[5] Aristotle: *τὰ μετὰ τὰ φυσικά*, engl.: *Aristotle’s Metaphysics,* trans. by Hippocrates G. Apostle, Bloomington, IN: Indiana University Press 1996, Book H, 1045:8–10.

canon of his day, *natura non facit saltum* – nature does not make leaps.[6] Indeed, Darwin rejected the very idea of sharp discontinuities in nature. In *The Origin of Species*, Darwin emphasized what he called the "Law of Continuity," and he repeatedly stressed the incremental nature of evolutionary change, which he termed "descent with modification." Darwin believed that this principle applied to the evolution of the human mind as well. In the *Descent of Man*, he asserted that the difference between the human mind and that of 'lower' animals was "one of degree and not of kind."[7]

Many theorists of his era viewed Darwin's explanation as unsatisfactory, or at least incomplete, and the theory of emergent evolution was advanced as a way to reconcile Darwin's gradualism with the appearance of 'qualitative novelties' and, equally important, with Herbert Spencer's notion, following Jean-Baptiste de Lamarck, of an inherent, energy-driven trend in evolution toward new levels of organization (a concept I address more fully below). Emergent evolution had several prominent adherents, but the leading theorist of this school was the comparative psychologist and prolific writer, Conwy Lloyd Morgan, who ultimately published three volumes on the subject: *Emergent Evolution* (1923), *Life, Mind, and Spirit* (1926), and *The Emergence of Novelty* (1933).[8]

The main tenets of Lloyd Morgan's paradigm will sound familiar to modern-day wholists: quantitative, incremental changes can lead to qualitative changes that are different from, and irreducible to, their parts. By their very nature, moreover, such wholes are unpredictable. Though higher-level, emergent phenomena may arise from lower-level parts, there may also be "return action," or what Lloyd Morgan also called "supervenience" ("downward causation" in today's parlance). But most important, Lloyd Morgan argued that the evolutionary process has an underlying progressive tendency because emergent phenomena lead in due course to new levels of reality.

It was a grand vision, but what did it explain? As Blitz observed, it was not a causal theory: "Emergent evolution related the domains studied by the sciences of physics, chemistry, biology, and psychology – a philosophical task not undertaken by any one of them – but did not propose mechanisms of change specific to any one of them – a scientific task which philosophy could not undertake."[9] Indeed, Lloyd Morgan ultimately embraced a metaphysical teleology that portrayed the evolutionary process as an unfolding of inherent tendencies, which he associated

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[6] The phrase appears no less than five times in *The Origin of Species.* Charles R[obert] Darwin: *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, Baltimore, MD: Penguin 1968 [1859].

[7] Charles R[obert] Darwin: *The Descent of Man, and Selection in Relation to Sex*, New York, NY: A. L. Burt 1874 [1871], Ch. I, p. 70.

[8] Conwy Lloyd Morgan: *Emergent Evolution*, London: Williams and Norgate 1923. Idem: *Life, Mind, and Spirit*, London: Williams and Norgate 1926. Idem: *The Emergence of Novelty*, New York, NY: Henry Holt and Co. 1933. Other theorists in this vein included Samuel Alexander, Roy Wood Sellars, C[harlie] D[unbar] Broad, Arthur Lovejoy, William Morton Wheeler, and Jan Christiaan Smuts (one-time Prime Minister of South Africa).

[9] Blitz: *Emergent Evolution* (note 1), p. 100.

with a creative divinity (shades of Herbert Spencer, Henri Bergson, Pierre Teilhard de Chardin and other orthogenetic and 'vitalistic' theorists, not to mention some of today's complexity theorists).

Jan Smuts's visionary book *Holism and Evolution* also deserves mention, not least because he was apparently the one who coined the term "holism" (from the Greek word for wholes).[10] But, following Morgan, Smuts's concept of "holistic selection" was pointedly non-Darwinian. He posited an inherent developmental tendency in evolution – an underlying whole-making "force". As Smuts put it:

> The creation of wholes, and ever more highly organized wholes […] is an inherent character of the universe. There is not a mere vague indefinite creative energy or tendency at work in the world. This energy or tendency has specific characters, the most fundamental of which is whole-making […]. Wholeness is the most characteristic expression of the nature of the universe in its forward movement in time. It marks the line of evolutionary progress. And Holism is the inner driving force behind that progress.[11]

The Triumph of Reductionism

In sum, emergent evolution in the hands of Lloyd Morgan, Smuts, and others of that era was orthogenetic and deemed to be somehow self-propelled. It was not really a scientific theory, though the boundary line was not so sharply delineated back then. But far more damaging to the cause of emergent evolution was the rise of the science of genetics in the 1920s and 1930s and the triumph of an analytical, experimental method in biology. In its most strident form, reductionism swept aside the basic claim of emergent evolutionists that wholes have irreducible properties that cannot be fully understood or predicted by examining the parts alone.

Critics like Stephen C. Pepper, Charles Baylis, William McDougall, Rudolf Carnap, and Bertrand Russell claimed that emergent qualities were merely epiphenomena and of no scientific significance. Russell, for instance, argued that analysis "enables us to arrive at a structure such that the properties of the complex can be inferred from those of the parts."[12] While the reductionists conceded that it was not currently possible, in many cases, for science to make such inferences and predictions, this shortcoming was a reflection of the state of the art in science and not of some deep property in nature itself. In time, it was said, reductionism would be able to give a full accounting for emergent phenomena.

Indeed, as the 20th century proceeded, many scientists came to view the concept of emergence as being completely outside the realm of science. Thus, the Nobel physicist Steven Weinberg in his book *Dreams of a Final Theory* assured us that all the "arrows of explanation" in science point downward and converge at the

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[10] Jan Christiaan Smuts: *Holism and Evolution*, New York, NY: Macmillan Co. 1926.

[11] Ibid., p. 99.

[12] Bertrand Russell: *The Analysis of Matter*, London: Allen and Unwin 1927, pp. 285–286.

quantum level of reality, where, he claimed, it will ultimately be possible to unify all the laws of physics and provide a universal, logically tight "theory of everything" (as some of Weinberg's loose-tongued colleagues have characterized it).[13] Evolutionary biologist Edward Wilson, in his book *Consilience: The Unity of Knowledge*, concurred: "Nature is organized by simple universal laws of physics to which all other laws and principles can be reduced."[14] Wilson also made the breathtaking assertion that "all tangible phenomena, from the birth of stars to the workings of social institutions, are ultimately reducible, however long and tortuous the sequences, to the laws of physics."[15] He characterized emergent holism as a "mystical concept."[16]

To be sure, there were also numerous contrarians during this era, scientists who continued to insist on the ontological reality of complex, emergent systems as products of Darwinian evolution. In the 1930s, for example, embryologist Joseph Needham advanced the idea of "integrative levels" in nature and argued for "the existence of [different] levels of organization in the universe, successive forms of order in a scale of complexity and organization."[17] A decade later, the biologist Julian Huxley, a principal architect of the 'modern synthesis' in evolutionary biology, sought to define evolution as a continuous process from star-dust to human society. Among other things, Huxley asserted that "now and again there is a sudden rapid passage to a totally new and more comprehensive type of order or organization, with quite new emergent properties, and involving quite new methods of further evolution."[18] Biologist Alex B. Novikoff also defended the idea of emergent levels of reality in a much-cited 1945 article in *Science* entitled "The Concept of Integrative Levels in Biology."[19]

The growth of the new science of ecology in the 1930s also stimulated interest in whole systems and macro-level relationships. There was much talk among pioneer ecologists, such as Charles Elton, Arthur G. Tansley, Raymond Lindemann, G. Evelyn Hutchinson, and others, about how the natural world is an integrated 'economy,' a biological 'community,' and even, for some theorists, a "quasi-organism" (Tansley). Ironically enough, the seminal concept of an ecosystem, which has since become a centerpiece of modern ecology, was originally conceived by Tansley

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[13] Steven Weinberg: *Dreams of a Final Theory*, New York, NY: Pantheon Books 1992.

[14] Edward O. Wilson: *Consilience. The Unity of Knowledge*, New York, NY: Alfred A. Knopf 1998, p. 55.

[15] Ibid., p. 266.

[16] Quoted in Frank Miele: "The Ionian Instauration", in: *Skeptic* 6 (1998) 1, pp. 76–85, p. 79.

[17] Joseph Needham: *Integrative Levels. A Reevaluation of the Idea of Progress*, Oxford: Clarendon Press 1937, p. 234.

[18] Julian Sorell Huxley/Thomas Henry Huxley: *Evolution and Ethics: 1893–1943*, London: The Pilot Press 1947, p. 120.

[19] Alex Benjamin Novikoff: "The Concept of Integrative Levels in Biology", in: *Science* 101 (1945), pp. 209–215.

in the context of his belated conversion to reductionism. "Wholes," he wrote, "are in *analysis* nothing but the synthesized actions of the components in associations."[20]

Finally, there was the so-called systems movement, whose members were inspired by the aspiration of biologist Ludwig von Bertalanffy for what he termed a "general system theory."[21] Indeed, the Society for General Systems Research (now known as the International Society for the Systems Sciences) included many distinguished scientists of the time: Kenneth Boulding, Ross Ashby, Anatol Rapoport, Heinz von Foerster, Herbert Simon, Robert Rosen, Paul Weiss, James Grier Miller, and others. Nevertheless, in the wake of the discovery of the double helix and the genetic code, reductionism became the dominant scientific paradigm in biology during much of the 20th century, and a gene-centered approach, generally known as neo-Darwinism, came to be widely accepted as the theoretical foundation of evolutionary theory.[22]

The Re-Emergence of Emergence

It is difficult to attach a date to the re-emergence of emergence as a legitimate, mainstream concept, but it roughly coincided with the growth of scientific interest in the phenomenon of complexity and the development of new, non-linear mathematical tools – particularly chaos theory and dynamical systems theory – which allow scientists to model the interactions within complex, dynamic systems in new and insightful ways. Among other things, complexity theory gave mathematical legitimacy to the idea that processes involving the interactions among many parts may be at once deterministic yet for various reasons unpredictable. (One oft-noted constraint, for instance, is the way in which initial conditions – the historical context – may greatly influence later outcomes in unforeseeable ways.)

One of the benchmarks associated with the re-emergence of emergence was the work of the Nobel psychobiologist Roger Sperry.[23] He wrote on mental phenom-

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[20] Arthur Tansley: "The Classification of Vegetation and the Concept of Development" in: *Journal of Ecology* 8 (1920) 2, pp 118–149; qtd. in Donald Worster: *Nature's Economy. A History of Ecological Ideas*, Cambridge: Cambridge University Press 1977, p. 301.

[21] Karl Ludwig von Bertalanffy: *Das biologische Weltbild (1949)*, Bd. 1, engl. *Problems of Life: An Evaluation of Modern Biological Thought*, New York, NY: John Wiley 1952. Idem: *General System Theory: Foundations, Development, Applications*, New York, NY: George Braziller 1968.

[22] For a detailed analysis and rebuttal of this paradigm, see Peter A. Corning: *Holistic Darwinism. Synergy, Cybernetics, and the Bioeconomics of Evolution*, Chicago, IL: University of Chicago Press 2005. Idem: "Rotating the Necker Cube. A Bioeconomic Approach to Cooperation and the Causal Role of Synergy in Evolution", in: *Journal of Bioeconomics* 15 (2013), pp. 171–193.

[23] Roger Wolcott Sperry: *Problems Outstanding in the Evolution of Brain Function*, James Arthur Lecture Series, New York, NY: American Museum of Natural History 1964. Idem: "A Modified Concept of Consciousness", *Psychological Review* 76 (1969), pp. 532–536. Idem: "In Defense of Mentalism and Emergent Interaction", in: *The Journal of Mind and Behavior,* 12 (1991) 2, pp. 221–246. Idem: "Holding Course Amid Shifting Paradigms", in: Willis Harman/Jane Clark (eds.): *New Metaphysical Foundations of Modern Science,* Sausalito, CA: Institute of Noetic Sciences 1994, pp. 97–121.

ena and the role of what he was the first to call "downward causation" in complex systems like the human brain. Sperry also adopted Lloyd Morgan's term "supervenience."[24] Meanwhile, in physics Hermann Haken and his colleagues broke new ground with "synergetics," the science of dynamic, 'cooperative' phenomena in the physical realm. Over the past 40-odd years, synergetics has produced a large body of holistic theory.[25]

In the United States, much of the work on the subject of emergence has been fueled by the resources and leadership of the Santa Fe Institute. Beginning in the mid-1980s, the Institute's annual proceedings have contained many articles related to this subject over the years, and a number of the scholars associated with the Institute have published books on complexity and emergence.[26] The well-known theoretical biologist Stuart Kauffman, for instance, has theorized that life is an emergent phenomenon in the sense that it represents a 'spontaneous crystallization' of pre-biotic molecules that can catalyze networks of reactions. Life is a collective property of a system of interacting molecules, says Kauffman. "The whole is greater than the sum of its parts."[27]

Since the 1990s there has been a growing flood of books and articles on emergence, including a scholarly journal devoted to the subject called *Emergence: Com-*

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[24] Psychologist Donald Campbell, who is most widely known for the concept of downward causation, may have invented the term independently. Donald T. Campbell: "Downward Causation in Hierarchically Organized Biological Systems", in: Francisco José Ayala/Theodosius Dobzhansky (eds.): *Studies in the Philosophy of Biology,* Berkeley, CA: University of California Press 1974, pp. 85–90.

[25] See e.g., Hermann Haken (ed.): *Cooperative Phenomena*, New York, NY: Springer 1973. Idem: *Cooperative Effects. Progress in Synergetics*, New York, NY: American Elsevier 1974. Idem: *Synergetics. An Introduction. Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry, and Biology*, Berlin: Springer 1977. Idem: *Advanced Synergetics. Instability Hierarchies of Self-Organizing Systems and Devices*, Berlin: Springer 1983. Idem/Michael Stadler (eds.): *Synergetics of Cognition*, Berlin: Springer 1990. J. A. Scott Kelso et al.: *Dynamic Patterns in Complex Systems*, proceedings of a conference in honor of Hermann Haken on the occasion of his 60th birthday, Singapore: World Scientific 1988. Later, Haken would venture into the study of neurological and cognitive phenomena as well. The term "synergetics" was also coined independently by the well-known engineer and polymath Buckminster Fuller, designer of, among other things, the geodesic dome and was used as the title of his speculative, multi-disciplinary work *Synergetics:* R[ichard] Buckminster Fuller in collaboration with Edgar J. Applewhite: *Synergetics. Explaining the Geometry of Thinking*, 2 vol., New York, NY: Macmillan Publishing Co. 1975, 1979.

[26] See especially Stuart A. Kauffman: *The Origins of Order. Self-Organization and Selection in Evolution*, New York, NY: Oxford University Press 1993. Idem: *At Home in the Universe: The Search for the Laws of Self-Organization and Complexity,* New York, NY: Oxford University Press 1995. Idem: *Investigations*, New York, NY: Oxford University Press 2000. Idem: *Reinventing the Sacred. A New View of Science, Reason, and the Sacred*, New York, NY: Basic Books 2008. John L. Casti: *Complexification. Explaining a Paradoxical World Through the Science of Surprise,* New York, NY: Harper Perennial 1995. Idem: *Would-be Worlds. How Simulation is Changing the Frontiers of Science,* New York, NY: John Wiley 1997. John H. Holland: *Hidden Order. How Adaptation Builds Complexity*, Reading, MA: Helix Books (Addison-Wesley) 1995. Idem: *Emergence. From Chaos to Order*, Reading, MA: Helix Books (Addison-Wesley) 1998. See also Roger Lewin: *Complexity. Life at the Edge of Chaos*, New York, NY: Macmillan 1992. Mitchell M. Waldrop: *Complexity. The Emerging Science at the Edge of Order and Chaos*, New York, NY: Simon & Schuster 1992.

[27] Kauffman: *At Home in the Universe* (note 26), pp. 23–24.

plexity & Organization. However, many of the new generation of emergence theorists have pursued a search for some deterministic 'law' or laws of evolution, an enterprise that could be traced back to the 19th-century British polymath Herbert Spencer and his energy-centered "universal law of evolution."[28] Thus, the physicist Ilya Prigogine derived a "universal law of evolution" from an improbable analogy with the formation of self-ordered Bénard cells (which he characterized as "dissipative structures") in a pan of water when it is heated. He called it an "autocatalytic theory" of evolution.[29]

Kauffman, in his early writings, likewise aspired to the discovery of the underlying laws of evolution. In his 1995 book, *At Home in the Universe*, Kauffman asserted that "Order is not accidental, that vast veins of order lie at hand. Laws of complexity spontaneously generate much of the order of the natural world. […] Order, vast and generative, arises naturally."[30] He called it "order for free."[31] In a later book, Kauffman further speculated about a possible "fourth law of thermodynamics," an inherent, energy-driven tendency in nature toward greater diversity. [32] Kauffman's law was, in effect, an update of Spencer's law. (However, it should also be noted that, in his 2008 book, Kauffman fully embraced the Darwinian paradigm and has now become a champion of 'Darwinian' emergence.)

There have been many other variations on this theme in recent years, with numerous theorists invoking inherent, self-organizing tendencies in nature to explain emergence. Computer scientist and algorithm pioneer John Holland asks, "How do living systems emerge from the laws of physics and chemistry? Can we explain consciousness as an emergent property of certain kinds of physical systems?"[33] Francis Heylighen and his colleagues claim that evolution leads to the 'spontaneous emergence' of systems with higher orders of complexity.[34] Mark Buchanan discerns a 'law of universality' in evolution from our cosmic origins to economic societies as a consequence of self-organized criticality,[35] after Per Bak and his colleagues.[36]

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[28] Herbert Spencer: "The Development Hypothesis" [1852], reprinted in: idem: *Essays. Scientific, Political and Speculative*, New York, NY: Appleton 1892, pp. 1–10.

[29] Ilya Prigogine: "Time, Structure and Fluctuation", in: *Science* 201 (1978), pp. 777–784. Idem: *From Being to Becoming. Time and Complexity in the Physical Sciences*, San Francisco, CA: W. H. Freeman 1980. Idem/Gregoire Nicolis/Agnessa Babloyantz: "Thermodynamics of Evolution (I)", *Physics Today* 25 (1972), pp. 23–28. Idem: "Thermodynamics of Evolution (II)", in: *Physics Today* 25 (1972), pp. 38–44. Gregoire Nicolis/Ilya Prigogine: *Self-Organization in Nonequilibrium Systems*, New York, NY: John Wiley 1977. Idem: *Exploring Complexity*, New York, NY: W. H. Freeman 1989. Idem: "Biological Order, Structure and Instabilities", in: *Quarterly Review of Biophysics* 4 (1971), pp. 107–148.

[30] Kauffman: *At Home in the Universe* (note 26), p. 8, p. 25.

[31] Ibid., p. 71, *passim*.

[32] Kauffman: *Investigations* (note 26), p 5.

[33] Holland: *Emergence* (note 26), p. 2.

[34] See Francis Heylighen/Johan Bollen/Alexander Riegler (eds.): *The Evolution of Complexity. The Violet Book of Einstein* meets *Magritte,* Dordrecht: Kluwer Academic Press 1999.

[35] See Mark Buchanan: *Ubiquity. The Science of History…Or Why the World is Simpler Than We Think*, London: Weidenfeld & Nicolson 2000.

[36] See Per Bak/Kan Chen: "Self-Organized Criticality", in: *Scientific American* 261 (1991) 1, pp. 46–53.

Steve Grand views the emergence of networks as a self-propelled, autocatalytic process.[37] Albert-László Barabási invokes 'far reaching natural laws' that, he believes, govern the emergence of networks.[38] Niels Gregersen and his contributors see an 'innate spontaneity' in the emergence of complexity.[39] And Harold Morowitz finds himself in sympathy with Teilhard de Chardin (and others) in believing that there is "something deeper" in the "orderly unfolding" of the universe.[40]

All of these grand visions can be called reductionist in the sense that they posit some underlying, inherent force, agency, tendency, or 'law' that is said to determine the course of the evolutionary process, or at least shape the evolution of complexity. Emergence is thus treated as an epiphenomenon. In effect, these theorists explain away the very thing that needs to be explained – namely, the contingent nature and fundamentally functional, adaptive properties of living systems.[41]

The Problem of Defining Emergence

Despite the proliferation of publications on emergence in recent decades, there is also much disagreement about how to define it. It is not at all clear what the term denotes or, more importantly, how emergence emerges. One problem is that the term is frequently used in every-day language as a synonym for 'appearance', or 'growth', as distinct from a parts-whole relationship. Thus, one of the dictionaries I consulted defined the term strictly in perceptual terms and gave as an example 'the sun emerged from behind a cloud.' Even the Oxford English Dictionary, which offered four alternative definitions, gives precedence to the version that would include a submarine which submerges and then re-emerges. Indeed, even avowed, complexity theorists commonly use the term (perhaps unwittingly) in both ways. Thus, the subtitle of Mitchell Waldrop's book *Complexity* is *The Emerging Science at the Edge of Order and Chaos*.[42]

Some theorists take the position that emergence does not exist if it is not perceived; it must be apparent to an observer. But what is a 'whole' – how do you know it when you see it, or don't see it? You cannot see a water molecule, after all. And is the mere perception of a whole – a 'gestalt' experience – sufficient, or even necessary? Then, there is the continuing debate about the predictability of emer-

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[37] See Steve Grand: *Creation. Life and How to Make It*, Cambridge, MA: Harvard University Press 2001.

[38] Albert-László Barabási: *Linked. The New Science of Networks*, Cambridge, MA: Perseus Books 2002.

[39] Nils Henrik Gregersen (ed.): *From Complexity to Life. Explaining the Emergence of Life and Meaning*, New York, NY: Oxford University Press 2002.

[40] See Harold J. Morowitz: *The Emergence of Everything*, Oxford: Oxford University Press 2002, p. 16.

[41] For an extended discussion of this issue, see Evelyn Fox Keller: "The Disappearance of Function from 'Self-organizing Systems,'", in: Fred Boogerd/Frank Bruggeman/Jan-Henrik Hoffmeyr/Hans V. Westerhoff (eds.): *Systems Biology*, Amsterdam: Elsevier 2007, pp. 303–317.

[42] Waldrop: *Complexity* (note 26).

gence. John Casti, like Lewes and Lloyd Morgan, associated emergence with dynamic systems whose behaviors arise from the interaction among its parts and cannot be predicted from knowledge about the parts in isolation.[43] John Holland, by contrast, described emergence in reductionist terms as "much coming from little" and imposed the criterion that it must be the product of self-organization, not centralized control.[44] Thus, Holland tacitly contradicted Casti's criterion that the behavior of the whole is irreducible and unpredictable.

In a similar vein, Francis Crick explains in a 1994 book that "The scientific meaning of emergent, or at least the one I use, assumes that, while the whole may not be the simple sum of its separate parts, its behavior can, at least in principle, be *understood* from the nature and behavior of its parts *plus* the knowledge of how all these parts interact." He illustrates with an example from elementary chemistry. The benzene molecule is made of six carbon atoms arranged in a ring with a hydrogen atom attached to each. It has many distinctive chemical properties, but these can be explained, he claims, in terms of quantum mechanics."[45] And, he concludes: "It is curious that nobody derives some mystical satisfaction by saying 'the benzene molecule is more than the sum of its parts' […]." [46]

In short, contradictory opinions about the nature of emergence abound. Indeed, the debate has become even more convoluted in such disciplines as philosophy and sociology.[47] There is no universally acknowledged definition of emergence, nor even a consensus about such legendary examples as water. And if emergence cannot be defined in concrete terms – so that you know it when you see it – how can it be measured or explained?

As Jeffrey Goldstein concluded in the inaugural issue of the journal *Emergence*, "Emergence functions not so much as an explanation but rather as a descriptive term pointing to the patterns, structures or properties that are exhibited on the macro-scale."[48] *Emergence* editor Michael Lissack, in his article for the same issue, acknowledged that "It is less then an organized, rigorous theory than a collection of ideas that have in common the notion that within dynamic patterns there may be underlying simplicity that can, in part, be discovered through large quantities of computer power […] and through analytical, logical and conceptual developments

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[43] Casti: *Would-be Worlds* (note 26).

[44] Holland: *Emergence* (note 26).

[45] Francis Crick: *The Astonishing Hypothesis. The Scientific Search for the Soul*, New York, NY: Charles Scribner's Sons 1994, p. 11.

[46] Ibid.

[47] See, for example, Mario Bunge: *Emergence and Convergence. Qualitative Novelty and the Unity of Knowledge*, Toronto: University of Toronto Press 2003. Philip Clayton/Paul Davies, (eds.): *The Re-Emergence of Emergence. The Emergentist Hypothesis from Science to Religion*, Oxford: Oxford University Press 2006. Mark A. Bedau/Paul Humphreys (eds.): *Emergence. Contemporary Readings in Philosophy and Science*, Cambridge, MA: MIT Press 2008. Poe Yu-ze Wan: "Emergence à la Systems Theory. Epistemological *Totalausschluss* or Ontological Novelty?", in: *Philosophy of the Social Sciences*, 41 (2011) 2, pp. 178–210.

[48] Jeffrey Goldstein: "Emergence as a Construct. History and Issues", in: *Emergence* 1 (1999) 1, pp. 49–72, p. 58.

[…]."[49] Emergence theorist Philip Clayton is even more emphatic: "Emergence itself is not a scientific theory."[50] It is, in effect, a descriptive label for a class of phenomena with common properties.

Re-Defining Emergence

How can all this be sorted out? The place to start, I believe, is with the more inclusive concept of "synergy."[51] Very broadly, synergy refers to the *combined or cooperative effects produced by the relationships among various forces, particles, elements, parts or individuals in a given context – effects that are not otherwise attainable.* The term is derived from the Greek word *synergos*, meaning to 'working together' or, literally, to 'co-operating.' Synergy is often associated with the cliché "the whole is greater than the sum of its parts" (which, as noted earlier, dates back to Aristotle in the *Metaphysics*), but this is actually a rather narrow and even misleading characterization. In fact, synergy comes in many different forms. Sometimes wholes are not greater than the sum of their parts, just different. Furthermore, there are many different kinds of synergy: synergies of scale, functional complementarities, threshold effects, a division of labor, and so on.[52]

Accordingly, some of the confusion surrounding the term emergence might be reduced, if not dissolved, by limiting its scope. Rather than using it loosely as a synonym for synergy, gestalt effects, or perceptions, etc., I propose that emergent phenomena be strictly defined, in accordance with its original meaning, as a subset of the vast (and still expanding) universe of cooperative (synergistic) interactions that are found both in nature and in human societies – and in the cosmos for that matter. In this definition, emergence would be confined to those synergistic wholes that are composed of things of "unlike kind" (following Lewes's original definition). It would also be limited to "qualitative novelties" (after both Lewes and Lloyd Morgan), i.e., synergistic effects that are generated by various interactions, including functional complementarities or some combination of labor. In this more limited definition, all emergent phenomena produce synergistic effects, but many synergies do not entail emergence.[53] In other words, emergent effects should

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[49] Michael R. Lissack: "Complexity. The Science, its Vocabulary, and its Relation to Organizations", in: *Emergence* 1 (1999) 1, pp. 110–125, p. 112.

[50] Philip Clayton: "Why Emergence Matters", in: Brian G. Henning/Adam C. Scarfe (eds.): *Beyond Mechanism: Putting Life Back Into Biology*, Lanham, MD: Lexington Books 2013, pp. 75–91, p. 77.

[51] This concept is treated in depth in several of my works. See Peter A. Corning: *The Synergism Hypothesis. A Theory of Progressive Evolution*, New York, NY: McGraw-Hill 1983. Idem: *Nature's Magic. Synergy in Evolution and the Fate of Humankind*, New York, NY: Cambridge University Press 2003. Idem: *Holistic Darwinism* (note 22).

[52] For more on the many different kinds of synergy, see Corning: *Nature's Magic* (note 51). Idem: *Holistic Darwinism* (note 22), and the update in idem: "Rotating the Necker Cube" (note 22).

[53] More on this can be found in Corning: *Nature's Magic* (note 51). Idem: *Holistic Darwinism* (note 22).

be associated specifically with contexts in which constituent parts with different properties are modified, reshaped or transformed by their participation in the whole and produce combined effects. Thus, water and benzene molecules are unambiguous examples of emergent phenomena. And so is the human body. Our ten trillion or so cells are specialized into some 250 different cell types that perform a vast array of important functions in relation to the operation of the whole. Indeed, in biological systems (and in technological wholes like automobiles), the properties of the parts are very often shaped by their functions for the whole. There is a functional relationship between the parts and the whole.

On the other hand, in accordance with the Lewes/Lloyd Morgan definition, a sand pile or a river would not be viewed as emergent phenomena. If you've seen one water molecule you've seen them all.[54] Terrence Deacon refers to such aggregative phenomena as "first order emergence,"[55] but this conflates two radically different kinds of properties – additive and non-additive (or interactional) – and contradicts the original definition (by Lewes). Indeed, the term emergence loses its usefulness if it includes everything in the universe above the level of Higgs bosons.[56]

Must the synergies be perceived/observed in order to qualify as emergent effects, as some theorists claim? Emphatically not. The synergies associated with (ontological) emergence are 'real' and measurable, even if nobody is in the proverbial forest to observe the tree falling. As for the claim that emergent effects can only be the result of self-organization, again, this is definitely not true. There is a fundamental distinction between self-organized processes (or, more precisely, what should be called 'self-ordered' processes) and wholes that are products of *functional organization* (as in organ systems or human-designed systems). In contrast with, say, crystals, living systems and human systems are largely shaped by 'instructions' (functional information) and by cybernetic control processes. They are not, for the most part, self-ordered; they are predominately organized by processes that are purposeful (teleonomic) in nature and that rely on "control information."[57]

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[54] Philosopher William Wimsatt draws a useful distinction between "aggregative" phenomena with collective properties and emergent phenomena. William C. Wimsatt: "Aggregate, Composed, and Evolved Systems. Reductionistic Heuristics as Means to More Holistic Theories", in: *Biology and Philosophy* 21 (2006) 5, pp. 667–702.

[55] See Terrence W. Deacon: "The Hierarchic Logic of Emergence. Untangling the Interdependence of Evolution and Self Organization", in: Bruce H. Weber/David J. Depew (eds.): *Evolution and Learning. The Baldwin Effect Reconsidered*, Cambridge, MA: MIT Press 2003, pp. 273–308.

[56] See also the discussions in Bruce H. Weber: "Complex Systems Dynamics in Evolution and Emergent Processes", in: Brian G. Henning/Adam C. Scarfe (eds.): *Beyond Mechanism. Putting Life Back Into Biology*, Lanham, MD: Lexington Books 2013, pp. 67–74. Lawrence Cahoone: "The Irreducibility of Life to Mentality. Biosemiotics or Emergence?," in: ibid., pp. 169–179. Clayton: "Why Emergence Matters" (note 50).

[57] I define control information as "the capacity to control the capacity to do work – the ability to control the acquisition, disposition and utilization of matter/energy in cybernetic systems." Peter A. Corning: "Control Information Theory. The 'Missing Link' in the Science of Cybernetics", in: *Systems Research and Behavioral Science* 24 (2007), pp. 297–311.

Consider this example: A modern automobile consists of some 15–20,000 parts (depending upon the car and how you count). If all of these parts were to be thrown together into one great 'heap' (also a favorite word of Aristotle in the *Metaphysics*), they could be described as ordered in the sense that they are not randomly distributed across the face of the earth (or the universe). Nevertheless, they do not constitute a car. They are merely an 'aggregate.' They become an 'organized,' emergent phenomenon – a useable whole that acts as a whole – only when the parts are assembled in a very precise (purposeful) way. As a disorganized heap, they are indeed nothing more than the sum of the parts. But when they are properly organized, they produce a type of synergy (emergent effects) that the parts alone cannot. In other words, there is a categorical distinction between a benzene molecule (after Crick) or a Bénard cell (after Ilya Prigogine) and an evolved purposeful, dynamic system whose collective behavior cannot be predicted from an understanding of the parts. As Kauffman points out, living systems are both epistemologically and ontologically emergent.[58] Among other things, they have a degree of autonomy or 'agency' in the sense of being self-regulating and perhaps self-adapting.

It should also be noted that there is a major theoretical segue involved in the modernized version of reductionism espoused by Wilson, Crick, and others. In its 19th- and early 20th-century incarnation, reductionism meant an understanding of the 'parts' – period. Modern-day reductionists, by contrast, speak of the parts *and* their 'interactions.' But the interactions among the parts (and between the parts and their environments) *are* 'the system.' The whole is not something that floats on top of it all. So this cannot properly be called reductionism; it is 'systems science' deeply disguised. Indeed, the interactions among the parts may be far more important to the understanding of how a system works than the nature of the parts alone.

Accordingly, living systems are irreducibly emergent phenomena. Their causal dynamics are shaped by their cumulative past history of over some 3.8 billion years, as well as their current environmental context(s), their functional organization, and, over the course of time, the downward causation that the whole exerts on the character of the parts via both natural selection and the purposeful actions of the whole, what I refer to as "teleonomic selection."[59] Moreover, their collective properties and actions – the synergies that living systems exhibit –provide the explanation for the evolution of biological complexity.

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[58] See Kauffman: *Reinventing the Sacred* (note 26).

[59] See Corning: *The Synergism Hypothesis* (note 51). Idem: *Holistic Darwinism* (note 22). Idem: "Evolution 'On Purpose'. How Behaviour Has Shaped the Evolutionary Process", in: *Biological Journal of the Linnean Society* 112 (2014), pp. 242–260.

The Synergism Hypothesis

How, then, do we explain the “progressive evolution” of emergent phenomena in nature as I have defined the term here – namely, the organisms and “superorganisms” (to borrow Spencer’s term) that are the products of billions of years of biological and socio-cultural evolution? Let us start with the concept of natural selection. Natural selection is actually a metaphor for an important aspect, or property of the ongoing evolutionary process. Darwin’s inspiration for his metaphor was the ‘artificial selection’ practiced by animal breeders. It is really an umbrella concept that refers to whatever functionally-significant factors (as opposed to historical contingencies, fortuitous effects, or physical laws) are responsible in a given context for causing differential survival and reproduction. Properly conceptualized, these causal factors are always relational; they are defined both by organism(s), their environment(s), and by the interactions between them.

Hence, one cannot (technically) speak of ‘mechanisms’ or fix on a particular ‘selection pressure’ in explaining the workings of natural selection; these are only shorthand expressions. One must focus on the interactions that occur within an organism and between the organism and its environment, inclusive of other organisms. Natural selection as a *causal agency* refers to the bioeconomic ‘payoffs’ in a given organism-environment relationship – in other words, the functional consequences for survival and reproduction produced by adaptively significant changes.

The Synergism Hypothesis represents an extension of this line of reasoning.[60] I refer to it as ‘holistic Darwinism’ because the focus is on the selection of ‘wholes’ and the combinations of genes that produce those wholes. Simply stated, cooperative interactions of various kinds, however they may occur, can produce novel combined effects, synergies that in turn become the causes of differential selection. The parts responsible for producing the synergies (and their genes) become interdependent ‘units’ of evolutionary change. In other words, the ‘payoffs’ associated with various synergistic effects in a given context constitute the underlying cause of cooperative relationships and their complex organization in nature. The synergy produced by the ‘whole’ provides the functional benefits that may differentially favor the survival and reproduction of the ‘parts.’ Although it may seem like backwards logic, the thesis is that functional synergy is the underlying cause of cooperation and organization in living systems, not the other way around; in evolution, over the course of time effects are also causes. So it is really, at heart, an economic theory of emergent complexity in evolution and applies both to biological and socio-cultural evolution.

Because this view of evolution may seem like an alien idea, let me restate it in a slightly different way. The functional (adaptive/survival) effects produced by cooperation, and organization, are the very cause of complexity in evolution. The mechanism underlying the evolution of complex systems is none other than the com-

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[60] See Corning: *The Synergism Hypothesis* (note 51). Idem: *Nature’s Magic* (note 51). Idem: *Holistic Darwinism* (note 22).

bined functional effects that these systems produce, i.e., the payoffs. The synergies are the proximate causes of natural selection – or "synergistic selection" in biologist John Maynard Smith's felicitous turn of phrase.[61] Synergistic effects represent an independent source of the variations that may be 'acted upon' by natural selection. It is, to repeat, a bioeconomic theory of complexity in evolution.

In fact, this paradigm is very similar to the way economists tell us that markets work in human societies. When a new 'widget' is developed, its ultimate fate – its survival and reproductive success, so to speak – is ultimately determined by how well it succeeds in the marketplace. If the widget sells well, the 'supply' is likely to increase, or so economic theory tells us. If not, the widget will soon go extinct. Many factors – internal and external – may contribute to these synergies. Moreover, the economic synergies are always historically contingent and situation specific. They are not the predictable product of a prime mover or the inexorable outcome of some self-organizing fractal dynamic, much less the working out of deterministic laws of economic evolution. So there is a cultural analogue to natural selection in the emergence of complex human systems as well.

An Illustration: Sponges as Synergistic Systems

Sponges, one of the simplest and most genealogically primitive emergent complex organisms in nature, may provide a useful illustration.[62] Sponges come in many different sizes and shapes, but the 'model' sponge looks like an urn or a vase. They are often confused with plants because they are immobile and have no internal organs, no mouth, no gut, no sensory apparatus, nor even a nervous system. They are more like a colony of cooperating independent cells. Sponges even have their own separate classification (Porifera or 'pore-bearers'), and they may in fact have evolved separately from other animals.

Sponges also earn their living in one of the simplest possible ways, as filter feeders. They pull water into an internal cavity through large pores in their 'skin', which consists of an outer layer of epithelial cells and a gelatinous inner layer with a skeleton of thin, bony 'spicules'. The sponge's internal cavity is in turn lined with a layer of specialized collar cells (choanocytes) that are equipped with whip-like flagella and numerous filaments. These collar cells combine forces to move the water through the sponge and then push it out through a large opening at the top called an osculum. As the water passes through the sponge, the collar cell filaments extract

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[61] John Maynard Smith: "The Evolution of Social Behavior – a Classification of Models", in: The King's College Sociobiology Group (eds.): *Current Problems in Sociobiology,* Cambridge: Cambridge University Press 1982, pp. 28–44.

[62] The following discussion is synthesized from Patricia R. Bergquist: *Sponges*, Berkeley, CA: University of California Press 1978. John David George/Jennifer J. George: *Marine Life*, New York, NY: John Wiley & Sons 1979. Edward F. Ricketts/Jack Calvin/Joel W. Hedgpeth: *Between Pacific Tides*, Stanford, CA: Stanford University Press 1985 [1939]. Helena Curtis/N. Sue Barnes: *Biology*, New York, NY: Worth Publishers ^{5}1989.

oxygen and food particles (microbes and organic debris of various kinds). These vital nutrients are then distributed to the non-feeding cells via another specialized set of mobile transporter cells called amoebocytes. The amoebocytes are also responsible for carrying waste and for manufacturing and distributing various kinds of skeletal materials, such as calcium carbonate, silica, spongin (a tough protein-like substance), or some combination of these, depending upon the type of sponge.

Reproduction in sponges is also (typically) a cooperative effort. Although the freshwater forms frequently reproduce asexually (often by casting off 'gemmules' that are somewhat like seed pods), most sponges are hermaphrodites, meaning that they produce both sperm cells and eggs. The sperm cells are launched into the sponge's cavity and are ejected through the osculum in the hope that they will find their way to another sponge's cavity. When a sperm is lucky enough to enter a recipient sponge, it may be captured by one of the collar cells and then transferred to an amoebocyte, which in turn carries it to an awaiting egg. Eventually, the fertilized egg will become a free-swimming larva and will venture out on its own to find an appropriate site for developing into a new adult. It is really a unique reproductive system.

And that is all there is to understanding how sponges work, except perhaps for the chemicals they produce to repel potential predators. The division of labor in sponges involves only six cell-types: epithelial cells, pore cells, choanocytes, amoebocytes and two kinds of sex cells. Some larger sponges also have specialized cells that aid in opening and closing their oscula. The point, though, is that even the minimal level of complexity found in sponges is tied directly to the functional effects that the various parts produce together – the synergies. Each part is specialized for the role it plays in the system. Each part is also completely dependent upon the other parts; no part could exist without the services of the others, and only together can they survive and reproduce successfully. Furthermore, the properties and capabilities of each part cannot be understood without reference to its role in the operation of the system as a whole. Nor can we understand the whole without an appreciation of how the parts work together.

In fact, sponges display several different forms of synergy: functional complementarities, a combination (division) of labor, synergies of scale, and even structural (gestalt) synergies.[63] For instance, the shape of the (classic) sponge with its exit opening located at the top utilizes physics to help pull water through its cavity, rather like the updraft in a chimney. As a result, a sponge can typically process a quantity of water equal to its own volume in less than ten seconds. Likewise, in the larger sponges (some taller than a human) the internal walls may be elaborately folded. This has the effect of greatly increasing the surface area available for filtering and feeding, in order to meet the increased nutritional needs of a larger organism.

How do we know this is a synergistic system? Just take away a major part, say the amoebocytes or the collar cells or the epithelial cells or skeletal spicules. Sponges could not exist without the synergy that their parts produce together. By the same

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[63] See Corning: *Nature's Magic* (note 51), pp. 119–122.

token, imagine what would happen if one were to change its accustomed environment, say by putting a sponge into a nutrient-free swimming pool, or into an ice pack. Any theory of complexity based on the operation of deterministic laws cannot deal with the effects of different contexts, but a functional (economic) theory focused on synergistic relationships can.[64]

The Synergism Hypothesis asserts that it was the functional synergies (i.e., the economic benefits, broadly defined) that were responsible for the evolution of sponges, not some hidden law of complexity. Indeed, there is some evidence that sponges originated as a symbiotic union between a primitive host and the once-independent ancestors of the choanocytes. About 150 species of very similar one-celled choanoflagellates, some free-swimming and others that attach themselves to a substrate, still exist today. There is even circumstantial evidence that indicates the choanoflagellates are themselves a product of a symbiotic union between an ancient protozoan and free-swimming spirochetes.[65]

Emergence Theory versus Natural Selection

One major alternative to the Synergism Hypothesis should be briefly mentioned here and critiqued. I am referring to biologist Robert G. B. Reid's important 2007 book, *Biological Emergences: Evolution by Natural Experiment.* In a nutshell, Reid claims that emergence in evolution has been the result of an autonomous experiment and that natural selection has played no significant role. In fact, it has often been a hindrance, Reid argues. According to him 'freedom' from ecological competition and natural selection has been an important facilitator of emergence, and the contribution of natural selection to the history of life on Earth has been confined largely to 'fine-tuning' and 'stabilizing' the innovations that arise from what he characterizes as an internally guided process. In other words, autonomous emergence is where the real action is in evolution, and natural selection has been only a bit player. As Reid puts it, Darwin got it "fundamentally wrong."[66] Once basic organismal integrity and homeostatic capabilities evolved, evolution could go forward as an independent process with natural selection as a mere 'obstacle'. At best, natural selection is 'irrelevant' to the explanation of emergence and progressive evolution.

How can we resolve these two contradictory explanations of biological emergence and complexity? In part, the answer can be found lurking inside a huge blind spot in Reid's paradigm – a rather surprising case of denial by such a deeply in-

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[64] A similar test for synergy can also be applied to human technologies, such as the automobile. In any 'aggregate' like a sand pile, if you remove some of the grains, you will still have a sand pile. But with an automobile, if you remove a major part – say a wheel, or the alternator, or the driver for that matter – you will no longer have a functioning whole.

[65] Michael A. Sleigh: *Protozoa and Other Protists*, London: Edward Arnold 1989.

[66] All quotes Robert G. B. Reid: *Biological Emergences. Evolution by Natural Experiment*, Cambridge, MA: MIT Press 2007, p. xiii.

formed physiologist. In effect, Reid assumes away (or implicitly discounts) what I call the 'ground-zero' premise of evolutionary biology, namely, that life on Earth is a highly contingent, often precarious, ongoing experiment and that survival and reproduction are inescapable daily challenges. Life is quintessentially a 'survival enterprise' in which an array of basic needs must continuously be served. 'Differential survival and reproduction' as a result of functional (adaptive) variations, i.e., natural selection, is a ubiquitous process. Reid's core assumption, that basic homeostasis and organismal integrity create an internal autonomy, a self-contained, protected experimental laboratory, is fundamentally flawed. All organisms are inextricably embedded in and interact with their many diverse (and changeable) environments and, moreover, depend upon an array of external resources (and conditions) to maintain themselves. They are never free from these environmental influences and constraints.

Reid fully recognizes the functional (adaptive) properties of living systems. He speaks repeatedly of "adaptation," "adaptability" and "functionality" (physiology is all about functions, he tells us), and "workability" and "does it work?"[67] More importantly, he portrays emergence as a process that by its very nature improves adaptability. Emergent innovations facilitate survival and reproduction, he says. Reid also acknowledges experimentation as a fundamental feature of the evolutionary process. "Evolution by Natural Experiment" is the subtitle of his book, after all. He tells us that: "Given a choice among similar individuals, those whose wholes are slightly greater than the sum of their parts will out-compete those whose wholes are slightly less."[68] In other words, differential survival is inevitable, and failure is always an option.

Nevertheless, Reid claims that natural selection has played no significant role in producing these remarkable functional properties. It is a self-directed process. How can it be that natural selection was *not* a party to this important trial-and-error dynamic? In fact it was, but Reid truncates its role by re-defining natural selection so that it refers only to *external* ecological competition and predation. Natural selection really was a key player after all, but Reid hides its vital role in emergent evolution under a semantic cloak. Some of the most important evolutionary biologists of the 20th century, such as Julian Huxley, Theodosius Dobzhansky, and Ernst Mayr, fully appreciated that 'internal selection' (as Huxley characterized it) is an important subset of natural selection, insofar as it results in differential survival and reproduction as a consequence of functional variations.

Accordingly, the bottom-line question is this: Can the evolution of complexity be attributed to synergistic emergence or to natural selection? The answer, of course, is both. The middle-ground in this debate can perhaps best be found in Mayr's characterization of evolution as a "two-step, tandem process,"[69] meaning (1) innovations from whatever source (from genes to emergent wholes) coupled with

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[67] Ibid., pp. 139–140.

[68] Ibid., p. 197.

[69] Ernst Mayr: *What Evolution Is,* New York, NY: Basic Books 2001, pp. 119–120.

(2) differential survival and reproduction based on the functional consequences of these innovations. To repeat, both the organism and its environment as well as the interactions and relationships between them are inextricably involved in determining the outcomes.

The Two Faces of Janus

The novelist and polymath Arthur Koestler, in his landmark 1969 volume *Beyond Reductionism: New Perspectives in the Life Sciences* (coedited with John R. Smythies),[70] deployed a metaphor that was meant to convey the idea that both reductionism and holism are essential to a full understanding of living systems. Janus, the Roman god of entries, exits, and doorways, has traditionally been portrayed as a head with two faces looking in opposite directions –in and out, past and future, forward and back, and, for Koestler, upward and downward.

Emergence (at least as defined here) is neither a mystical concept nor is it a threat to reductionist science, much less being an autonomous agency. However, a holistic approach to emergence and evolution also has a major contribution to make. In accordance with the Synergism Hypothesis, it is the emergent, synergistic effects produced by wholes that are the very cause of the evolution of complexity in nature over time. As Clayton puts it, "Complex forms of organization produce new forms of causation in the natural world."[71] Indeed, the functional effects produced by wholes have much to do with explaining the parts. In this light, perhaps the time has come to embrace the full import of Koestler's famous metaphor; in fact, both faces of Janus are indispensable to a full understanding of the dynamics of the evolutionary process.[72] Evolutionary emergence is therefore not something that is epiphenomenal or disconnected from the causal dynamics of the evolutionary process; it is an integral part of it.

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[70] Arthur Koestler/John R. Smythies (eds.): *Beyond Reductionism. New Perspectives in the Life Sciences*, London: Hutchinson 1969.

[71] Clayton: "Why Emergence Matters" (note 50), p. 76.

[72] For an elaboration on this theme, see Arthur Koestler: *Janus. A Summing Up*, New York, NY: Random House 1978.