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The Concept of Emergence in Social Science:

Its History and Importance

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The terms "emergence" and "emergent property" date from the last quarter of the nineteenth century. However, the general idea behind these terms is older. It is redolent, for example, of the "law of the transformation of quantity into quality" laid down by G.W.F. Hegel in his *Logic* and subsequently taken up by Karl Marx and Frederick Engels. The philosopher Auguste Comte (1853, Vol. 2: 181) wrote of irreducible properties: "Society is no more decomposable into individuals than a geometrical surface is into lines, or a line into points." The idea of emergence was also hinted at by John Stuart Mill (1843, Bk 3, Ch. 6, Para. 2) with his idea of "heteropathetic" causation.

The word "emergent" in this context was first suggested by the philosopher George Lewes (1875, Ch. 3: 412). Subsequently, the philosopher of biology Conwy Lloyd Morgan (1927, 1933) wrote extensively on the topic. Following Mill and Lewes, Morgan (1927: 3–4) defined emergent properties as "unpredictable" and "non-additive" results of complex processes. In more detail, Morgan (1932: 253) explained:

> the hypothesis is that when certain items of "stuff," say $o\ p\ q$, enter into some relational organization R in unity of "substance," the whole $R(o\ p\ q)$ has some "properties" which could not be deduced from prior knowledge of the properties of o, p, and q taken severally.

Morgan saw such properties as crucial to evolution in its most meaningful and creative sense, where (Morgan, 1927: 112):

> the emphasis is not on the unfolding of something already in being but on the outspringing of something that has hitherto not been in being. It is in this sense only that the noun may carry the adjective "emergent."

For Morgan, evolution creates a hierarchy of increasing richness and complexity in integral systems "as new kinds of relatedness" successively emerge (Morgan, 1927: 203). Also for Morgan, the "non-additive" character of complex systems must involve a shift from mechanistic to organic metaphors: "precedence should now be given to organism rather than to mechanism—to organization rather than aggregation" (Morgan, 1933: 58).

Morgan's formulation of the concept was explicitly acknowledged by a group of philosophers in the 1920s. Prominent among these was Samuel Alexander (1920) at the University of Manchester in the UK and Alfred Whitehead (1926) at Harvard University in the USA. The psychologist and philosopher William McDougall (1929) was conspicuous in the presentation and development of the concept. Similar ideas also appeared independently at the time. The American philosopher Roy Sellars (1922) developed the notion of "creative synthesis" to explain how new properties could emerge in complex systems. Accordingly, a set of ideas were established in philosophy in Britain and America in the 1920s that are remarkably redolent of the ideas that emerged later in complexity theory in the 1990s.

However, this earlier wave of complexity thinking did not last very long. Within philosophy, ontological speculation about the nature and properties of reality became highly unpopular, as positivism grew in influence in the interwar period. Positivists believe that "metaphysical" propositions that are not directly grounded on experience are "unscientific." The ontological concerns of Morgan, Alexander, Whitehead, McDougall, and Sellars were dismissed—along with the concept of emergence—as metaphysical and useless speculation.

Nevertheless, despite this setback, the concept of emergence did have an enduring impact. It survived at the fringes of biology and social science until its rediscovery later in the twentieth century.

PAST IMPACTS OF EMERGENCE ON THE SOCIAL SCIENCES

One of the first social scientists to be influenced by Morgan was the institutional economist Thorstein Veblen. Morgan visited Chicago in 1896 and Veblen was crucially influenced by his ideas (Dorfman, 1934; Hodgson, 1998; Tilman, 1996). The influence of Morgan is evident in Veblen's treatment of institutions as phenomena that are dependent on individuals but are not reducible to them.

Prior to Veblen, many social scientists believed that social phenomena could be understood in terms of the biological characteristics of the populations involved. Human society, it was thought, could evolve no more rapidly than the individuals themselves. From such a standpoint, the rapid evolution of human civilization could only be explained if there were some Lamarckian process by which acquired characteristics could be inherited. Otherwise, there would be no explanation of the rapid evolution of the human genetic material that supposedly correlated with the evolution of human civilization in a few thousand years. Like other anti-Lamarckians, Morgan challenged this, arguing that the inheritance of acquired characteristics was not plausible. But this anti-Lamarckian standpoint created a problem: if there was no inheritance of acquired characteristics, then how could the relatively rapid evolution of civilization be explained?

Morgan (1896: 340) resolved this problem by suggesting that evolution occurs both at the level of human genes and at the level of human social institutions. These social institutions act as a storehouse of accumulating and evolving social customs, technology, and knowledge. Furthermore, as this cultural heritage itself evolves, it provides a new cultural and institutional environment for the development of each human individual. This evolving social environment unleashes new possibilities for each person, even if human nature and the human genetic endowment remained more or less the same. As a Darwinian opponent of the Lamarckian theory of biological inheritance, Morgan argued that it was not the human genetic endowment that had evolved significantly in the last few centuries, but the human social environment.

Morgan's Darwinian understanding of evolution led him to promote the idea of an emergent level of socioeconomic evolution that was not explicable exclusively in terms of the biological characteristics of the individuals involved. Evolution occurs at this emergent level as well, and without any necessary change in human biotic characteristics. Accordingly, the crucial concepts of emergence and emergent properties were liberated by the insistence of a barrier between acquired habit and biotic inheritance. The biological and the social spheres became partially autonomous, but linked, levels of analysis. On this basis, in later works, Morgan developed the philosophical concept of emergence.

Veblen did not use the concept of emergence explicitly. Nevertheless, it is striking that after 1896 the concept of the "natural selection of institutions" began to appear explicitly in his work. Furthermore, some passages in his writings read almost as rephrased versions of Morgan's texts (Hodgson, 1998).

Following Veblen, the concept of emergence assumed a marginal existence in Anglophone social science. There are a few rare examples from economics. The institutional economist Morris Copeland (1927) mentioned Morgan's concept of emergent properties. While at Columbia University, the New Zealand economist Ralph Souter (1933: 111) discussed the importance of emergent properties, acknowledging its precedent in Morgan and Alexander. He criticized the Austrian school of economics for its omission of emergent properties: Austrian economists proclaim an individualistic ontology and methodology, and insufficiently acknowledge the existence of emergent properties at the systemic level. The English institutional economist John A. Hobson (1936: 216) wrote in his book on Veblen:

> Emergent evolution brings unpredictable novelties into the processes of history, and disorder, hazard, chance, are brought into the play of energetic action.

A more significant aftermath of Morgan's influence on Veblen was inexplicit, yet massive in its reverberations. The institutional economist Wesley Mitchell, formerly a student of Veblen, established himself as the leading American economist in the interwar period. At this time, macroeconomics was not yet established as a subdiscipline; mainstream economics was microeconomic in character.

Mitchell tried to break from this individualist foundation. In his 1924 Presidential Address to the American Economic Association, Mitchell (1937: 26) argued that economists need not begin with a theory of individual behavior but with the statistical observation of "mass phenomena." Mitchell (1937: 30) explained that this was possible "because institutions standardize behavior, and thereby facilitate statistical procedure." Mitchell thus hinted at a process of social conformism that stabilized behavior in an institutional context. To rephrase this in the language of emergence and complexity: Mitchell and others saw complex systems involving positive feedback effects that led to relatively stable emergent phenomena at the macroeconomic level.

Mitchell and his colleagues in the US National Bureau for Economic Research in the 1920s and 1930s played a vital role in the development of national income accounting. They suggested that aggregate, macroeconomic phenomena have an ontological and empirical legitimacy. Arguably, these developments prepared some of the groundwork for the Keynesian revolution in economics. Through the development of national income accounting, the work of Mitchell and his colleagues helped to establish modern macroeconomics, and in particular influenced and inspired the macroeconomics of Keynes (Mirowski, 1989: 307; Colander & Landreth, 1996: 141). Although the concept of emergence was implicit rather than explicit in these intellectual developments, we can trace the origins of this line of thinking in Veblen's break from reductionism and his establishment of institutions as units of analysis.

Elsewhere, the concept of emergence found a small refuge in sociology. Talcott Parsons came to Harvard University in 1927 and was influenced there by Whitehead. Parsons took on board aspects of Whitehead's organicist ontology and saw the existence of emergent properties as "a measure of the organicism of the system" (1937: 749). However, although Parsons played a role in preserving the concept, his use of the term was idiosyncratic and unclear.

As noted above, the idea of emergence was largely submerged in the positivist and reductionist phase of Anglo-American science in the inter-war period (Ross, 1991). Although his use of such terminology was at odds with Morgan's original concept, Parsons helped to keep the concept of emergence alive during this difficult period.

THE RE-EMERGENCE OF EMERGENCE

After the Second World War, Michael Polanyi (1967), Sir Karl Popper (1974), Ernst Mayr (1985), and several others rehabilitated the idea of emergent properties. The concept had never entirely disappeared, but it took the decline of positivism to provide an opportunity for its redevelopment. One of those involved in this process was the great polymath Michael Polanyi. Perhaps significantly, Polanyi had worked in both the natural and the social sciences. His classic book on tacit knowledge has a chapter titled "emergence," in which he wrote:

> you cannot derive a vocabulary from phonetics; you cannot derive the grammar of language from its vocabulary; a correct use of grammar does not account for good style; and a good style does not provide the content of a piece of prose. ... it is impossible to represent the organizing principles of a higher level by the laws governing its isolated particulars. (Polanyi, 1967: 36)

Another person who played a crucial part in the rediscovery of the concept was the philosophically inclined biologist Ernst Mayr. He argued that the characteristics of a complex system:

> cannot (not even in theory) be deduced from the most complete knowledge of the components, taken separately or in other partial combinations. In other words, when such systems are assembled from their components, new characteristics of the new whole emerge that could not have been predicted from a knowledge of the components. (Mayr, 1985: 58)

Like his predecessors, Mayr established that the existence of emergent properties at a particular level of reality means that explanations cannot be reduced entirely to components and phenomena at lower levels. He wrote:

> Recognition of the importance of emergence demonstrates, of course, the invalidity of extreme reductionism. By the time we have dissected an organism down to atoms and elementary particles we have lost everything that is characteristic of a living system. (Mayr, 1985: 58)

We are reminded of the words of William Wordsworth in his poem "The Tables Turned":

> Sweet is the lore which Nature brings;
> Our meddling intellect
> Mishapes the beauteous form of things: –
> We murder to dissect.

After these statements by Polanyi, Popper, and Mayr, the development of the story of emergence was to take another turn. By the 1980s, the development of computer technology had greatly facilitated the simulation of nonlinear dynamic systems. This led to a related development known as chaos theory.

Working on nonlinear mathematical systems, chaos theorists have shown that tiny changes in crucial parameters can lead to dramatic consequences, known as the "Butterfly Effect—the notion that a butterfly stirring the air today in Peking can transform storm systems next month in New York" (Gleick, 1988: 8). There are parallels here with the account of "bifurcation points" in the work of Prigogine and Stengers (1984). After behaving deterministically, a system may reach a bifurcation point where it is inherently impossible to determine which direction change may take; a small and imperceptible disturbance could lead the system in one direction rather than another.

Accordingly, chaos theory suggests that apparent novelty may arise from a deterministic nonlinear system. From an apparently deterministic starting point, we are led to novelty and quasi-randomness. Consequently, even if we knew the basic equations governing the system, we would not necessarily be able to predict the outcome reliably. The estimation of "initial conditions" can never be accurate enough. This does not simply undermine the possibility of prediction: in addition, the idea of a reductionist explanation of the whole in terms of the behavior of its component parts is challenged. As a result, the system can be seen to have emergent properties that are not reducible to those of its constituent parts.

Chaos theory was closely followed by another phase in the history of the concept of emergence. This work was centered at the Santa Fe Institute (Arthur, 1995; Arthur *et al.*, 1997; Anderson *et al.*, 1988; Kauffman, 1993, 1995; Holland, 1998; Waldrop, 1992). Instead of focusing largely on disorder and chaos, complexity theorists at Santa Fe and elsewhere also stressed the emergence of "order out of chaos" and the sustained behavior of complex systems "at the edge of chaos" (Cohen & Stewart, 1994). One clear outcome of the work of the Santa Fe Institute has been to bring respectability and prominence to the concept of emergence, even in disciplines where it had been neglected.

Part of the impact of this work has been achieved through the use of powerful, heuristic computer simulations. Many such simulations have created artificial social worlds, in which modeled agents interact in various ways, often to create surprising, systemic outcomes. Much of this work shows the emergence of order and other "higher-level" properties in complex systems. Reviewing the modeling of such "artificial worlds," David Lane (1993: 90) writes that a main thrust "is to discover whether (and under what conditions) histories exhibit interesting emergent properties." His extensive review of the literature in the area suggests that there are many examples of artificial worlds displaying such attributes.

THE CRITIQUE OF REDUCTIONISM

At this stage we can take stock. Although the concept of emergence is over 100 years old, its rise to prominence has not been steady. The first three decades of the twentieth century saw relatively sophisticated developments of the concept in the sphere of philosophy. Many of these earlier insights and debates have since been neglected and are worth revisiting. In the last two decades of the twentieth century, the concept of emergence was brought from the margins into the limelight of discussion of the evolution of complex systems. Computer simulations have powered much of this recent work.

However, these developments involve a powerful challenge to prevailing conceptions of how both the natural and the social sciences should work. The impact of this challenge is not yet widely appreciated. Furthermore, old habits die hard, and the old ways of thinking about science have strong adherents. The most important issue over which this debate between the old and the new science is articulated is the question of reductionism.

Reductionism sometimes involves the notion that wholes must be explained entirely in terms of their elemental, constituent parts. More generally, reductionism can be defined as the idea that all aspects of a complex phenomenon must be explained solely in terms of one level, or type of unit. According to this view, there are no autonomous levels of analysis other than this elemental foundation, and no emergent properties on which different levels of analysis can be based.

Consider biology. Although many biologists acknowledge the existence of emergent properties, there are many theorists and practitioners who still cling to the view that all biological phenomena can and should be explained in terms of "lower-level" components, such as genes.

Furthermore, reductionism is still conspicuous in social science today and typically appears as methodological individualism. This tends to be defined as "the doctrine that all social phenomena (their structure and their change) are in principle explicable only in terms of individuals—their properties, goals, and beliefs" (Elster, 1982: 453). It is thus alleged that explanations of socioeconomic phenomena must be reduced to properties of constituent individuals and relations between them. Allied to this is the sustained attempt since the 1960s to found macroeconomics on "sound microfoundations." This "microfoundations revolution" meant the rejection of much of Keynesian macroeconomics. Indeed, it is the antithesis of the approach discussed above, as developed by the institutionalist and Keynesian economists of the 1920s and 1930s.

Reductionism should be distinguished from *reduction*. Reduction involves the partial decomposition of elements at one level into parts at a different level. Measurement is an act of reduction. The general idea of a reduction to parts is not being overturned here. Some degree of reduction to elemental units is inevitable. Science cannot proceed without some dissection and some analysis of parts. However, although some partial reduction is inevitable and desirable, a complete analytical reduction is both impossible and a philosophically dogmatic diversion. What is important to stress is that the process of analysis cannot be extended to the most elementary subatomic particles presently known to science, or even to individuals in economics or genes in biology. A complete reduction would be hopeless and interminable. Reduction is necessary to some extent, but it can never be complete. As Popper (1974: 260) has declared:

> there is almost always an unresolved residue left by even the most successful attempts at reduction.

Essentially, if socioeconomic systems have emergent properties, then reductionism is confounded. Emergent properties by definition are not entirely explicable in terms of constituent elements at a more basic level. Accordingly, the idea of explaining the macro behavior of socioeconomic systems completely in terms of individuals and individual actions (methodological individualism) is misconceived. Similarly, explanations of macroeconomic phenomena completely in terms of microeconomic postulates (the microfoundations project) are confounded. There are strong arguments to suggest that neither methodological individualism (Udéhn, 1987) nor the microfoundations project (Rizvi, 1994) can ever be successful in reducing all features of the system to its micro components. Given this incipient failure, in explaining complex systems we may be obliged to rely on emergent properties at a higher (macro) level.

In general, reductionism is clearly countered by the notion that complex systems display emergent properties at different levels that cannot be completely reduced to or explained wholly in terms of another level. By contrast, antireductionism generally emphasizes emergent properties at higher levels of analysis that cannot be reduced to constituent elements.

EMERGENCE DISTINGUISHED FROM SUPERVENIENCE

The concept of supervenience was developed by Alexander Rosenberg (1976, 1985) in both economics and biology. In part, this alternative and weaker concept is a symptom of a reluctance by some to adopt the concept of emergence. Supervenience applies to the situation where the identity of two or more entities at the macro level does not assume identity at the constituent micro level, but identity at the micro level does guarantee identity at the macro level. In this case the macro level can be said to be supervenient. Accordingly, similar properties at the macro level cannot all be explained by a single set of micro-level components, but identical configurations of micro-level components all give rise to identical macro-level phenomena. The concept of supervenience is used to defend a qualified form of reductionism. Supervenience retains the ontological priority of the micro level over other, higher levels.

By contrast, modern concepts of emergence suggest that different outcomes are possible with near identical configurations and interactions of micro-level elements. As chaos theory suggests, tiny, seemingly insignificant differences can lead to quite different systemic outcomes. In chaotic systems, almost exact identity at the micro level does not guarantee identity at the macro level, and supervenience is eluded. Notably, the supervenience concept was developed before chaos theory posed a severe challenge to reductionism. The possibility of a high degree of context sensitivity undermines the application of the supervenience concept.

Accordingly, in biology, identical genes do not lead to identical organisms or behaviors. The biologist Conrad Waddington (1975: vi) showed that in evolution the genetic makeup of organisms (their genotype) does not generally give rise to similar characteristics (phenotypes). This is partly because "genotypes, which influence behavior, thus have an effect on the nature of the selective pressures on the phenotype to which they give rise." This introduces "an inescapable indeterminism" in evolutionary theory. In a similar vein, Cohen and Stewart (1994: 3) give a related set of examples and cases. They argue that "simplicity of form, function, or behavior emerge from complexities on lower levels because of the action of external constraints."

The fact that different outcomes are possible with near identical configurations and interactions of micro-level elements confounds the concept of supervenience. It is no longer tenable to infer from almost exact identity at the micro level some identity at the macro level.

CONCLUSIONS

One of the reasons that the concept of emergence is important for social science is that it provides a necessary means to focus on higher-level units and relations and to avoid the potentially intractable problem of analytical reduction to lower-level units.

However, while emergent properties provide indispensable hooks to bring analysis up to a higher level, we must never lose sight of the dependence of these higher-level properties on lower-level units. Indeed, if it were possible to explain a higher-level phenomenon entirely in terms of lower-level units, then we should do so (Bunge, 1980). Biology cannot ignore chemistry and macroeconomics cannot ignore the microeconomics of individuals and firms. Emergence does not give license to neglect the constituent elements of which an entity or structure is composed.

What is required is the development of a methodology that is sensitive to the "marks of emergence in their most telling form." As Kyriakos Kontopoulos (1993: 22–3) elaborates further, the marks of an emergent property include its novelty, its association with a new set of relations, the stability and boundedness of these relations, and the emergence of new laws or principles applicable to this entity. We find emergent properties in any complex, evolving system, throughout the natural and the social realm.

The theory of emergence offers a nonreductionist account of complex phenomena. Indeed, with emergent properties a reductionist account is impossible. We are just beginning to grasp the full implications of this, although, as we have seen, the concept of emergence has been around for more than 100 years.

At the beginning of the twenty-first century, we are presented with an exciting agenda of research in which philosophical concepts such as emergence can find their place and impact within the flowering sciences of complexity. At least as far as the social sciences go, we are just at the beginning of this process.

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