EMERGENCE, PROBABILITY, AND REDUCTIONISM

by Frank E. Budenholzer

Abstract. Philosopher-theologian Bernard J. F. Lonergan defines *emergence* as the process in which "otherwise coincidental manifolds of lower conjugate acts invite the higher integration effected by higher conjugate forms" (*Insight*, [1957] 1992, 477). The meaning and implications of Lonergan's concept of emergence are considered in the context of the problem of reductionism in the natural sciences. Examples are taken primarily from physics, chemistry, and biology.

Keywords: emergence; Bernard Lonergan; reductionism; schemes of recurrence.

The so-called problem of reductionism has received considerable attention in religion-science circles in recent years. Here, the main concern is the nature of the human person and the difficult question of the meaning of the soul (Russell, Murphy, Meyering, and Arbib 1999; Brown, Murphy, and Malony 1998; Clayton 2002). On a more philosophical level, however, the question is no less urgent when considering the objects studied in physics, chemistry, biology, and sensitive psychology. Is reductionism primarily a methodology that has allowed science to progress to its current state (methodological reductionism), or does this methodology suggest that the material universe is determined in full by its smallest components, ontological or causal reductionism (Agazzi 1991)? My opinion regarding ontological reductionism is clearly in the negative. Making use of the thought of theologian-philosopher Bernard Lonergan,[1] I suggest that the various levels of reality studied by the physicist, the chemist, the biologist, and the psychologist are equally real and not simply reducible to the lower

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levels. In an earlier essay in *Zygon* (Budenholzer 2003) I argued that we can deal with the seeming impasse of reductionism only if we radically rethink our concept of material reality. The material is not somehow little chunks of imaginable matter, *res extensa*, but ultimately verified intelligibility that is at the same time limited in such aspects as place, time, and number by what Lonergan calls the "empirical residue" ([1957] 1992, 50–56). Each of the various levels of reality consists of an intelligible integration of what on the lower level would simply be random occurrences. Details of this argument are presented in my earlier article (Budenholzer 2003). An anonymous referee of that paper had noted that one of the things lacking was a consideration of Lonergan's concept of emergence. This essay addresses that omission.

THE NATURE OF METAPHYSICAL SPECULATION

Before discussing emergence as such, a preliminary question must be explored. Presumably, when we ask to understand Lonergan's concept of emergence, we are asking for some kind of philosophical explanation. But what is the function of such an explanation? What is it supposed to do that science cannot? First, in asking about emergence we are not hoping to somehow avoid the tough scientific questions. If you want to understand the relationship between subatomic physics and atomic physics, or between atomic physics and chemistry, or between chemistry and the biology of simple life forms, you have to do the science—quantum chromodynamics, quantum chemistry, biochemistry, and molecular biology. There is no shortcut. But if this is the case, what does philosophy have to tell us?

Here Lonergan parts company with many other scholastic philosophers. In a way reminiscent of Descartes and Kant but with a very different outcome, Lonergan argues that by understanding the nature of human knowing itself we can heuristically learn something about the nature of the known (Meynell 1998, 266 ff.). It is not my purpose to examine in detail here the so-called turn to the subject, the basis of Lonergan's epistemology and metaphysics. Although it may seem to some rather naive to presume that an examination of our knowing process can tell us something about the object of that process, to deny it would undermine all of our knowledge, scientific and humanistic. Many areas of presumed knowledge may be in error, but in each case when we believe that we are mistaken, we use the most reasonable approach we can think of to try to rectify the mistake. The knowing process is all we have. So the question would be, in the very nature of the scientific knowing process, are there any clues as to the nature of the known? Specifically, are there any clues to a tiered reality in which we may speak meaningfully of emergence?

Lonergan argues that all knowing, at least in the universe in which we live, involves a triple cord: experience, understanding, and judgment. We experience data such as size, shape, weight, and color. From this experience we seek to gain understanding of the way things operate in either an explanatory mode (things in relation to each other) or a descriptive mode (things in relation to us). In the explanatory mode, we are ultimately seeking to understand basic laws—of physics, chemistry, biology, and so on. We also attempt to understand *things*—unity, identity, wholes such as atoms, molecules, living organisms, or human persons, which we experience and ultimately understand in their oneness. Finally, we may attempt to understand the complex arrangements of things in both space and time—what Lonergan refers to as "schemes of recurrence." Such schemes include everything from our solar system to social and economic systems to the complex artifacts of human ingenuity. However, not all understandings, whether scientific laws, the nature of things that make up our universe, or complex schemes of recurrence, are correct. Ultimately our knowing requires verification.

As explained in my earlier essay (Budenholzer 2003), to describe the properties of things and events Lonergan employs the technical term *conjugates*. "Experiential conjugates are correlatives whose meaning is expressed, at least in the last analysis, by appealing to the content of some human experience" (Lonergan [1957] 1992, 102). Colors and tastes, as well as the categories of descriptive science such as anatomy or geology, are examples of descriptive conjugates. "Pure (or explanatory) conjugates, on the other hand, are correlatives defined implicitly by empirically established correlations, functions, laws, theories, systems" ([1957] 1992, 103). Explanatory conjugates, because they involve things in relation to one other, are implicitly defined by the equations and explanatory networks of the sciences.

Lonergan defines a *thing* as "an intelligible, concrete unity differentiated by experiential and explanatory conjugates" ([1957] 1992, 280). Things exist on various levels and are the unities that are explained—subatomic particles, atoms, molecules, cellular organisms, sensitive organisms, human persons that can transcend themselves in knowing and loving. Science knows each level through the descriptive and explanatory conjugates correlative to the thing under study. The criterion of reality of both conjugates and things is simply their verified intelligibility.

Each level of reality has its own set of explanatory conjugates, which are the particular subject of the science of that level—physics, chemistry, biology, sensitive psychology, and so forth. No set of conjugates or level of things is more real than any other. The real is verified intelligibility at whatever level one is operating. Saying that each level is equally real is not denying the clearly verified conclusion of levels of reality. At each level the random conjugates of the lower level are unified in a higher integration. Chemistry systematizes what would be merely coincidental events on the atomic level, allowing the emergence of an autonomous science of chemistry. Biology is an autonomous science that integrates what would be merely coincidental events on the level of chemistry. The integration of coincidental manifolds at a new level does not take away the autonomy of the lower levels. The reality of the biological organism includes the conjugates of chemistry and physics. Therefore, the most exciting areas of science will be the cross-disciplinary areas—molecular biology and chemical physics, for example. Here science attempts to understand how those lower-level conjugates are systematized at the new level.

This, then, was the primary conclusion of my earlier essay. The real is verified intelligibility. We know things on various levels—subatomic, atomic, molecular, cellular, organismic, and so on. Each level has its own set of descriptive and explanatory conjugates. As verified intelligibility, each level is equally real; no level has ontological priority. At the same time, it also is recognized that successively higher levels systematize what on lower levels would be merely random occurrences. To appropriate what Lonergan suggests is no small step. I suggest that only when we move beyond the criterion of imaginability can we really understand the richness of what science has to teach us.

What does philosophy have to tell us about moving from one level to the next? Can we from an examination of our knowing process gain some understanding of the emergence of new levels of reality? As already noted, we do not expect this understanding to somehow substitute for science. It can, however, help to clarify the larger picture and possibly offer some hint in integrating the conclusions of the various sciences. Before tackling the problem of emergence, we must say something about a topic that at first may seem quite removed from our central topic—statistical inference and the nonsystematic.

In his treatment of empirical method Lonergan considers two basic knowing processes, classical and statistical ([1957] 1992, 23–69). In classical knowing we are attempting to understand, and ultimately affirm, the intelligible content of scientific law.[2] Classical knowing determines what we usually speak of as the laws or theories of nature, at least on the level of physics or chemistry, usually expressed as a mathematical function. On the level of subatomic physics we study quantum chromodynamics, on the level of atomic physics we may speak of quantum electrodynamics, in the world of chemistry we speak of valence and molecular dynamics, and so on as we move up the tiered levels of reality. Classical laws are abstract in the sense that to use them one must add the boundary conditions and other constants of the system to be studied. They are also abstract in that they are normally verified under conditions in which extraneous influences can either be accounted for or presumed not to interfere.

Statistical knowing considers not abstract laws but frequencies and distributions of actual events. The distributions studied by statistical method are normally grouped in some fashion around the moments of the distributions, most frequently the first moment, more commonly known as the average or norm of the distribution. These moments are often defined by classical laws. We may, for example, experimentally determine the charge on the electron. But, as any experimentalist will verify, we determine not one unique electronic charge but a range of values in which we presume the average value somehow represents the real value. We also can determine frequencies of more mundane things. What was the average birth weight of all children born in 2001? What was the average in Taiwan? in Australia? We somehow feel that these two examples are not quite the same, and I agree that they are not. But they are both examples of statistical method, by means of which we determine frequencies of values—which, if the sampling is correct, group around ideal frequencies or norms, in these examples the charge on the electron and the average birth weight.

Here we face a key question in the philosophy of science: What is the nature of statistical inference?[3] Some would argue that statistical inference is simply a way to deal with systems that are beyond our detailed understanding. Presumably, if we could continue to improve our experimental techniques we could determine something very close to the "true" charge on the electron; but we will not be able to determine the "true" birth weight of all children born in the year 2001. Here the determined reductionist may argue that if we had a big enough computer and sophisticated enough physics, chemistry, biology, and related algorithms, we could predict the birth weight of all babies. Abstract laws not only provide verifiable conclusions when taken in relative isolation; they also provide a seamless scheme that completely explains everything. Statistical inference is a method that is, to use a common expression, just a cloak for ignorance.

The generally accepted interpretation of quantum mechanics would seem to indicate the statistical nature of reality on the level of subatomic and atomic physics. A statistical explanation of matter at this level does not imply a lack of intelligibility, but the intelligibility is statistical in nature, involving empirically verifiable distributions of classically defined variables (Heelan 1965). However, even if one does not accept the standard interpretation of quantum mechanics, there are still clearly random events—random in the sense that there is no classical law that brings the events into order. Chance in this sense involves seemingly unrelated trajectories' coming together, whether it be that of the poor fellow whose car is hit by a boulder coming down the mountainside or the random motion of molecules in a gas or liquid.

Earlier we talked of things. A *thing* for Lonergan is "an intelligible, concrete unity differentiated by experiential and explanatory conjugates" ([1957] 1992, 280). *Experiential conjugates* refers to properties of the thing in relation to the knower, and *explanatory conjugates* refers to properties implicitly defined by scientific laws and correlations that consider things in relation to things. Lonergan then makes use of the traditional categories of potency, form, and act. In keeping with Lonergan's starting point of cognitional analysis, these three are related to each other as experience, understanding, and judgment are. Thus, *central form* refers to the source of the intelligibility of a given thing and *conjugate form* to the intelligibility of a given property or conjugate. *Central act* refers to the in-principle verifiable existence of the thing itself and *conjugate act* to that of the properties of the thing.

EMERGENCE

With these definitions we are now ready to define *emergence*. Lonergan defines it as the process in which "otherwise coincidental manifolds of lower conjugate acts invite the higher integration effected by higher conjugate forms" ([1957] 1992, 477). For example, on the level of subatomic physics there exist things such as protons, electrons, and neutrons. "Lower conjugate acts" here refers to the existing properties of these things on this level. These conjugate acts are intelligible, and this intelligibility is in accord with what Lonergan describes as both classical and statistical laws of physics. However, there exists a basic randomness, which on one level a physicist might describe as a collection of random particles or events and Lonergan describes as a "coincidental manifold." However, given the right set of initial circumstances (in other words, the right probabilities), from this random situation (what Lonergan calls "coincidental manifolds of lower conjugate acts") there may emerge a higher integration with its own conjugate form.

What is the nature of these emergent entities? Here Lonergan distinguishes between two levels—schemes of recurrence and new things. As noted earlier, schemes of recurrence refer to intelligible systems that circle in on themselves. If A occurs, then B occurs; if B occurs, then C occurs; and so on to the point that A recurs and the circle begins again ([1957] 1992, 141). Lonergan likes to use the example of the planetary system. Somehow in the development of our area of the Milky Way, there emerged a group of planets that orbit around our Sun. The recurring pattern of the orbits leads to the emergence of a degree of stability in what otherwise would be random movement. Examples of schemes of recurrence are essentially infinite—from the subatomic through the artifacts of human industry to human society and economics. In the emergence of schemes of recurrence, new conjugate forms will arise. We can describe the mechanics of the solar system, the nature of phase changes in chemistry, the symbiotic relationship of plant species, and the nature of business cycles in economics. Yet, as can be seen from the examples given, schemes of recurrence are ontologically reductive. Given the right circumstances, the classical and statistical laws governing the elements of the scheme allow us to predict the nature of the scheme of recurrence.

But besides the emergence of new schemes of recurrence is also the emergence of truly new *things*—now used in Lonergan's technical sense. As noted above, Lonergan defines a thing as "an intelligible, concrete unity differentiated by experiential and explanatory conjugates" ([1957] 1992, 280). In what many consider one of Lonergan's more puzzling chapters, he argues that there are no things within things. This seems to be at odds with the atomic and molecular theory of matter, which is part and parcel of contemporary science. To understand, we must return to our notion of the real as verified intelligibility. An animal is a concrete unit whose basic conjugates are the subject of zoology. The lower-level conjugates of atomic physics (atomic mass and number, electronic structure) are integrated at the new level of chemistry. And the conjugates of chemistry (valence, reactivity, and so forth) are integrated at the level of the biological. Thus, an animal—say, a rabbit—is a unity in which each of the various levels of matter are integrated. On the level of bodies, of course, the rabbit has various organs—heart, liver, brain—but these are all integrated in one living unity, the rabbit. Terms such as *respiration* and *metabolism* refer to this unity/identity/whole that is the particular rabbit.

I mentioned that when talking of schemes of recurrence, or more simply yet of simple aggregates, the new properties (conjugates) that emerge are in principle reducible to the lower-level properties. I can explain the movement of the planetary system solely in terms of the laws of physics. However, when we speak of the emergence of new *things*—atoms, molecules, bacteria, animals, persons—"the higher integration effected by higher conjugate forms" is indicative of a new central form, a new center of intelligibility.

Harold Morowitz comes to a similar point of view using computational techniques:

> . . . you start at one hierarchical level with a set of agents and rules and apply the rules to the agents. If the rules are nonlinear, then what happens every time a computer scientist does this, is that the system goes *combinatorially explosive*—it becomes *transcomputable*: a computer the size and age of the universe cannot handle it. This happens at every level. To solve that problem, one selects a set of pruning rules or selection algorithms or something in that form, and then they select a subset of this combinatoric transcomputability. That subset has a set of properties that defines what is emerging at the next hierarchical level. (Morowitz 2002, 24)

Morowitz goes on to use the example of the Pauli principle[4] as the pruning principle that allows chemistry to emerge from physics.

Here I return to the main conclusion of my earlier essay. If the basic criterion of the real is its imaginability, *res extensa*, the emergence of really new things seems impossible. New things are just large assemblages of basic particles with some sort of organizational principle added. But if the real is verified intelligibility, each level of intelligibility is equally real, and there is the possibility of a higher level of intelligibility ordering the nonsystematic conjugates of the lower level. Are there, in fact, emergent levels of reality? This is a scientific question. However, if we can free ourselves from the myth that the "really real" is little chunks of imaginable matter, the structure of modern science seems to point clearly to levels of intelligibility at which new things emerge.

Note that we are not talking about some sort of vitalism. In *Insight* Lonergan critiques vitalism as not being sufficiently critical of a mechanistic view of reality ([1957] 1992, 505). Vitalism presumes the real to be basically imaginable particles in motion and then adds an ordering principle, a vitalist principle, to allow the emergence of a higher level. For Lonergan, the animal is an intelligible unity that systematizes the lower-level manifolds of physics and chemistry, ordering the lower levels without destroying their autonomy.

EMERGENT PROBABILITY

What is the source of this emergence? Again, the details are up to the scientists to discover. Can the nature of our scientific knowing suggest any clues? Earlier I mentioned schemes of recurrence. However, it is clear that to describe the reality of the world in which we live is to talk not of a few individual schemes of recurrence but of an almost infinite number of interconnected schemes, what Lonergan more modestly calls "a conditioned series of schemes of recurrence" ([1957] 1992, 144). I offered what may have seemed a rather simple example of the planetary system. But this involves cycles of energy exchange with our Sun, leading to periods of light and darkness and the four seasons. On Earth, we also have the cycles described by terrestrial physics, geology, and meteorology. At some point on our planet self-replicating life appeared, leading to the complex cycles studied by the physiologist in the individual organism and by the ecologist in the communities of these organisms. Even more recently an animal emerged that was not only intelligible but also intelligent. What had been the relatively simple cycles of reproduction, nurture, and nest building expanded to the more complex cycles of culture, economy, politics, and religion. Thus, we see that to talk of our world we must talk of intricately nested schemes of recurrence.

In the emergence of a scheme of recurrence, there occurs a very important shift from the probability of emergence to the probability of survival (Lonergan [1957] 1992, 143–44). What is the probability that the disconnected events that could in principle form a scheme of recurrence do in fact converge in such a series? The probability may be quite low. Say event A has probability a, event B probability b, and so on. The probability of everything converging would then be $a \times b \times c \ldots$, normally a rather low probability. However, by definition, a scheme of recurrence is such that the elements get hooked together, so that event A leads to event B, which leads to event C, and finally back again to A. In this case the probability jumps to $a + b + c \ldots$. The cycle has stabilized, and the probability has shifted from a probability of emergence to a probability of survival. The probability of the emergence of our planetary system was quite low. But, given large enough spaces, long enough times, and previous schemes of recurrence, it happened. As professors of mechanics like to tell their students, our planetary system is a chaotic system, and we cannot predict its final fate. That being said, we believe that its survival probability is high enough not to be a major concern.

Thus, the emergence of a scheme of recurrence is determined both by the classical laws describing the individual elements in the scheme and by the statistical probabilities that the various elements will hook together to create the scheme. We are led to Lonergan's notion of *emergent probability*, "the successive realization in accord with successive schedules of probability of a conditioned series of schemes of recurrence" ([1957] 1992, 148).

The foregoing consideration of emergent probability has concentrated on schemes of recurrence. Besides ever more complex and interlocking schemes of recurrence, however, there are also new things ([1957] 1992, 284–87). These things are studied in the semiautonomous disciplines of subatomic physics, atomic physics, chemistry, biology, sensitive psychology, and the human sciences. On one level there exist things T_j with conjugates C_j. For example, things T_j could be the molecules with their chemical properties C_j. These things T_j function within certain schemes of recurrence S_j. Now let us consider a higher-level T_i with conjugates C_i, for example a simple self-replicating cell. From the viewpoint of chemistry, the probability of the various individual chemical events' being involved in cellular biology would be low, and the probability of the aggregate of events that allows a primitive cell to come into existence would be even lower. Yet, given enough time and the necessary underlying successive schemes of recurrence, new things do emerge. These new things T_i, in this case simple cells, emerge with their conjugates C_i, which are the topic of the discipline of microbiology.

If we retain the criterion that the basis of all things is little chunks of matter, the above explanation of emergence sounds like reductionism in different clothing. If, however, we are willing to take the radical step that modern science, especially modern physics, is willing to take—asserting that the real is verified intelligibility and that what we sense, either externally through our sense organs or internally in imagination, are simply data—then no level of intelligibility is somehow more real than another. At the same time, in the developing world in which we live, each new thing implies an integration of what on a lower level would be simply nonsystematic events.

I have already stressed that these metaphysical considerations are a result of considering the foundations of the knowing process itself. There is no exemption from doing the required science. When we compare Lonergan's thought with that of his Thomist or Aristotelian precursors, we can see that even the notion of what counts as a thing is ultimately a scientific question. Atoms, molecules, cells, plants, animals, and human beings are things in Lonergan's sense. Around each has developed an autonomous science, which we call physics, chemistry, cell biology, botany, zoology, and psychology. To say, however, that these areas have their autonomous laws is not to deny that the conjugates of the lower levels are retained. Because new things emerge as the integration of what would be random events on a lower level, it is these lower-level conjugates that are most important to understanding the higher level. Biologists have to study chemistry, and, while a course in subatomic physics would presumably not be deleterious, most biologists can do their biology quite well without referring to subatomic physics.

It should be noted that the boundaries between new things and schemes of recurrence are not always clear (Oyler 1983). A group of molecular biologists recently synthesized a polio virus from readily available organic materials (Cello, Paul, and Wimmer 2002). A good synthetic chemist tinkers with the probabilities to allow higher integrations to emerge. Was what they "created" a living being, a new biological thing? Most biologists would say no. Will scientists in the future be able to synthesize living cells? Probably they will. But it will require no little effort to "tweak" the chemistry such that the probabilities allow this complex new thing, a synthesized living cell, to come into existence.

In all of this the primary concern has been the intelligibility immanent in the phenomena studied by science. The basic understanding of cause is not that of particles in collision, whether molecules in a gas or the exchange of photons in quantum electrodynamics. Cause is simply an intelligible relationship of dependence (Lonergan [1957] 1992, 563). Once again we return to an understanding of the basic nature of the real. If the basic nature of reality is its extension, it is hard to avoid seeing causality as some kind of mechanical causality somehow analogous to colliding particles. The little pieces collide to form bigger pieces and so on, so that the aggregates studied in biology and the human sciences can ultimately be understood as the sum of the pieces. I argue that there is no smallest little piece. Science is about understanding the intelligibility immanent at each level as well as the intelligibility of the new things that emerge as an integration of the lower manifolds. The conjugates of the lower level retain their autonomy and in a real sense determine the nature of the higher integration. At the same time, the intelligibility of the higher integration, whether of a scheme of recurrence or a new thing, sets the limits and causally determines the nature of the integration and the future trajectory of the higher integration.

A question that is continually brought up especially in biological circles is the question of finality. To simply deny direction, whether in the development of individual things (from fertilized egg to the mature animal) or in the history of life (prebiotic and biological evolution) seems impossible. Yet, science also wants to avoid any kind of cosmic pull—a large "magnet" somehow leading matter toward increasingly complex structures. Lonergan's definitions of development and finality attempt to walk this fine line. Development is defined as "the flexible, linked sequence of dynamic and increasingly differentiated higher integrations that meet the tension of successively transformed underlying manifolds through successive applications of the principles of correspondence and emergence" ([1957] 1992, 479). The principle of emergence states that "otherwise coincidental manifolds of lower conjugate acts invite the higher integration effected by higher conjugate forms," and the principle of correspondence states that "significantly differing underlying manifolds require different higher integrations" ([1957] 1992, 477). There is on one hand directionality: the manifold of lower-level conjugates is open to and even calls forth the higher integration. By juggling the probabilities we can now do what the early alchemists only dreamed of doing—transmute elements from one to the other. But the principle of correspondence tells us that we must have the right materials to start with. Life as we know it is based on carbon chemistry. Would it be possible to have life based on other chemistries, say, that of silicon? This is a scientific question to be answered by observation and experiment. But the principle of development tells us something we already know from doing the science. Carbon chemistry allows a range of chemical behaviors that allows the integration of chemical events that we call life. Could silicon do the job? It seems unlikely, but no one wants to rule out possibilities too quickly. What is clear is that the further away we get from a carbon substrate, the more unlikely the emergence of life becomes.

Is there, then, such a thing as finality? Lonergan says yes. There is a dynamic reality in the world we know: "finality is an immanent intelligibility operating through the effective probability of possibility" ([1957] 1992, 474). This directionality is attained through a subtle interplay of statistical and classical law. Thus, there is direction. But finality is not that of the usual, determinist variety. Whether in the development of the cosmos or of the individual and society, there are false starts, breakdowns, and tragedy, but there is also development and direction.

The Current Debate

To many readers of this journal, what has been said may seem strangely out of touch with the current debate. In this section I put Lonergan's thought on reductionism and emergence in the context of at least some aspects of the contemporary conversation.

William Stoeger (1999, 140–41) follows the lead of other philosophers in speaking of "mereological" and "causal" irreducibility. Mereological irreducibility has to do with situations in which the emergent properties cannot be simply reduced to the functioning of the component parts. Chemistry deals with properties of molecules that are not mereologically reducible to the properties of their atomic components. Similar statements could be made about simple cells, complex plants and animals, and ultimately human beings. This is opposed to mereologically reducible systems such as the aggregates studied in geology, the properties involved in phase changes, or the complex biological systems studied in ecology. Things, as defined by Lonergan, are clearly mereologically irreducible.

Causal irreducibility refers to a situation in which the higher level is not explainable simply in terms of the lower-level causes. Are things, in Lonergan's sense, causally irreducible? I would answer yes, but with a caveat. By its very definition, a scheme of recurrence, and even more so a thing, has a certain element of top-down causality. If there were a large enough perturbation, the planets of our solar system could go off in an infinite number of trajectories. However, once hooked into the scheme of recurrence, they are maintained in a particular pattern. In a new thing, a new unity/identity/whole emerges that even more radically holds the emergent reality to a subset of the possible behaviors present before the emergence of the new thing. There can, of course, be breakdowns. The computer I am using, a human-engineered scheme of recurrence, can go amok. Cancer is probably the most egregious example of the failure of an organism to integrate the lower-level conjugate biological and chemical activities. I add the caveat because emergence is not some sort of magic addition when a certain level of complexity is reached. There can emerge new things (new central forms) with mereologically irreducible properties (higher conjugates). But this emergence is strictly limited by the lower-level realities and is in accord with the schedule of probabilities, referred to as emergent probability.

Ernan McMullin (2000, 373–75) suggests another difficulty when talking of emergence. We live in a tiered world in which entities of various levels of complexity already exist. To what level should we assign the capacities that allow integration at a higher level—the lower level or the higher level? For example, the Pauli principle is often cited as the principle that allows the emergence of the periodic table, which is basic to chemistry and ultimately to biology. Does the need to deal with higher-level entities lead to an "enlargement of the lower-level science" (McMullin 2000, 373)? Is the Pauli principle (see note 4), which allows for the formation of atoms, a basic property of subatomic matter or an emergent property of chemical systems? I argue that these are primarily scientific questions. However, this question also brings us back to what I consider the basic problem. If the basic components of reality are the smallest chunks of matter, it would seem somehow logical to "attach" properties such as the Pauli principle to those smallest pieces. This approach is evident in those who argue that experience is a basic component of nature and who therefore feel compelled to talk of an experiential component, even the subatomic level, rather than of experience as a conjugate that emerges in more complex living systems (Griffin 2000, 165ff.). In the intellectualist position outlined here, there is no smallest chunk of which higher-level things are somehow composed, and each level has equal ontological priority and is equally "real."

Much of the current debate has concerned understanding the logical structure of scientific explanation and to what extent it is compatible with a strong reductionist program. The terms most often discussed are *supervenience*, *multiple realizability*, *functionalism*, and what this would imply for the possibility of downward causation.[5]

In the description of emergence given above, higher-level integrations, schemes of recurrence, and new things are realized in the set of lower-level conjugates, which they systematically limit and integrate. Molecular properties are realized in the processes described by the atomic conjugates. Cells are realized in the chemical processes, which are integrated to form the cell. Organisms are realized in integrations of complex cellular, molecular, and atomic conjugates. The conjugates that define the properties of higher-level things are multiply realizable in the sense that there is usually no single underlying manifold in which the higher-level conjugates are uniquely realized. The thermodynamic and kinetic properties of chemical systems are realized through a multitude of atomic-level processes—this is why their calculation always involves a statistical component as well as what has been called a "pruning rule" to constrain the dimensions of the problem. The robustness of living organisms is a result of the multiple realizability of physiological processes on the chemical and cellular levels. Again, no one physical path can explain the complex higher-level phenomena.

However, multiple realizability does not, in itself, preclude a reductionistic explanation, although it may preclude the possibility of our knowing clearly what the reductionistic explanation of a multiply realizable phenomenon is. The precise way in which upper-level explanations are realized at a lower level is a scientific question to be answered on a case-by-case basis. My point is that whatever the nature of the manifold being integrated at the higher level, it is a mistake to give automatic ontological priority to the lower level. Admittedly, this statement is made on epistemological grounds. If the real is presumed to be imaginable particles in motion, it would seem logical to give ontological priority to the smallest piece, and causality will be seen as somehow analogous to collisions of particles. However, if the real is the true—verified intelligibility—there is no level that has automatic ontological priority (why should it?) that is somehow more real than any other. This is the primary argument of my earlier article.

Functionalism seeks to circumvent the problems caused by a rigid reductionism by noting that higher-level causal explanations are functional and are not defined by a particular realization of that function at the micro level. The concept is closely tied to that of multiple realizability. To explain, for example, the evolution of drug resistance in a given bacteria is not to describe a single pathway by which it was realized in one particular instance. The detailed account of a particular pathway does, of course, provide an explanation of a particular case. However, such an explanation is scientifically useful only if it is accompanied by an account of how the same effect can be realized through multiple pathways. The question can also be viewed from the opposite direction. Detailed explanations of particular pathways may also be the realization of quite different functional explanations. Essentially the same microexplanation of bacterial mutation and adaptation may be used to explain quite different macrolevel changes. This is what Theo Meyering (1999, 173) refers to as multiple supervenience. On the epistemological level, multiple realizability, functionalism, and supervenience describe the actual nature of scientific explanation and do seem to provide a kind of middle ground between a strong reductionism and an understanding of emergence such as I have argued for here.

However, such arguments ultimately do not deter the convinced reductionist. At most they suggest that a truly reductive science is so complicated that it may be impossible to have a truly predictive science of the complex. If the real is a huge imaginable network of fundamental particles interacting by some perhaps still not understood laws of nature, we could, in principle, if we had a big enough computer, calculate all future states of the cosmos. But how do we know of these fundamental particles? No one has ever observed them directly. If quantum mechanics and relativity theory have taught us anything, it is that these particles are a far cry from the imaginable hard spheres of traditional atomism. They are, rather, intelligible answers to questions raised in elementary particle physics. There is good evidence that the answers we have are the correct ones, but this is far from certain. What I am suggesting is that this basic criterion of reality—verified intelligibility—has to be used equally at all levels, and to give ontological priority to the smallest unit is uncalled for. Arguments about multiple realizability and multiple supervenience clearly point to intelligible unities at various levels, but, unless there is also a rethinking of the nature of the real, they will be insufficient to deal with the problems raised by reductionism.

Similar statements can be made about the nature of so-called downward causation—the possibility of higher-level, complex systems having causal influence on lower-level systems. Accounts of upward and downward causation are both amply represented in the sciences as actually practiced. Humans create a world of technology, animal populations have a causal effect on their environment, cellular organisms select from their environment those nutrients that will allow them to continue to live, the chemistry of the atmosphere causally determines the distribution of atomic and subatomic events. Again for the hardened reductionist, real top-down causation is hard to imagine. The properties of macro systems are determined by the interactions of their smallest components. However, from my point of view, the emergence of increasingly complex schemes of recurrence and finally of new things opens the way for downward causation; higher-level integrations intelligibly integrate the lower-level conjugates.

I want to stress that emergence takes place in both the development of individual things and the evolution of our world. The development of a fetus implies highly probable schemes of recurrence allowing interaction with the environment (nutrition from the parent, etc.) resulting in the emergence of the formed animal that is very different from the fertilized egg from which it began. Because of the starting materials, the probabilities of the emergence of the formed organism, while not unity, are quite high. In the evolutionary schema, the number of possible outcomes is larger, but the probabilities of emergence are often close to zero. Only with large amounts of space and time does emergent probability allow for the emergence of schemes of recurrence with the open-ended emergence of ever more complex schemes and ultimately new things.

Perhaps this whole edifice still seems somewhat hazy and unreal. To speak of the emergence of a new central form seems quite out of touch with our experience. There is one example of emergence that we all experience, however—the emergence of an idea, the emergence of insight (Lonergan [1957] 1992, 112). The experimentalist discovers a new phenomenon: an unexpected wiggle in what was thought should be a smooth curve. Is it an artifact of the experimental setup? Is it something that should have been expected? Is it something new? More data are collected; curves are drawn; various possibilities are considered. Sometimes slowly, sometimes very quickly, the insight emerges. "I've got it! That's it!" Of course, this new idea has to be verified, initially by the individual scientist and then by the scientific community through publication and testing by peers.

To many writers in the philosophy of science, this emergence of understanding is simply a logical outcome of the data, nothing new. This is not the experience of scientists, however. Some data are discarded as irrelevant; other aspects of the data, while not conclusive, are taken as particularly critical to the new understanding. From what to the uninitiated seems like random marks on a paper, a new understanding emerges. There has been a development in understanding. As any scientist or teacher knows, such developments are not automatic or guaranteed. At the same time, they are not just random. To use an expression from another context, we have to tweak the probabilities. The teacher does this by selectively presenting the data to maximize the chances of the insight's emerging in the student, the scientist by training for years yet keeping an open mind toward the possibility of something new.

Conclusion

Where has this taken us? I have attempted to outline the features of Lonergan's notion of emergence. The treatment is pretty standard from the point of view of Lonergan circles, but I have not been afraid to make statements that might be controversial among Lonergan scholars or that go beyond the words of Lonergan himself. Good secondary resources for more detail include Joseph Flanagan (1997), Philip McShane (1970), and Hugo Meynell (1998). Of course, the best source is Lonergan himself, especially his *Insight* ([1957] 1992).

I hope that those engaged in the science-religion dialogue, as well as philosophers of science in general, will consider what Lonergan has to offer. I want to mention a few key points that should make Lonergan especially appealing to the scientific community. First, Lonergan takes science very seriously. Despite protestations by some philosophers, science is arguably the clearest example of knowing that we have had in the past two centuries. It is for this reason that Lonergan turns to mathematics and science to provide the basis of his cognitional analysis. Lonergan also continually insists that philosophy does not provide a shortcut for scientists. Only scientific study can provide the details of the process of emergence on the levels studied by science.

In both my previous essay and this one I argue that we must abandon imaginability as the criterion of the real. When I was an undergraduate chemistry major, there was a standing joke about what the basic science really was. Psychology was just biology. And biology, of course, was really just chemistry. And chemistry was really just atomic physics, and atomic physics was just subatomic physics, and subatomic physics was just mathematics, and. . . . Where does one stop? Where does one find that final indivisible chunk of matter? I am suggesting that this is the wrong question. There is no smallest indivisible chunk.

It has always struck me that most talk of reductionism is limited to two levels. Psychology is just biology, biology is just chemistry, chemistry is just physics. . . . With the developments in genetic engineering, the big question is whether we are determined by our genes. To take reductionism seriously, we cannot stop at the next lower level. Some would argue that the complexity of our world makes it impossible to penetrate any deeper; there is no computer big enough to make the necessary calculations. This is one answer. In this essay I have suggested looking at another possibility.

In the last analysis Lonergan considered himself to be a theologian, not a philosopher. *Insight* was a preparation to the development of theological methodology (Lonergan 1972; Budenholzer 1984). The latter part of *Insight* and Lonergan's later works are concerned with the nature of ethics, theological method, and the human being's relationship to God. Because of the tiered nature of reality and the emergence of new things with their own sets of classical and statistical laws, it is perfectly legitimate to begin a study on that level. We do not necessarily need physics, chemistry, and biology to study the nature of the love between persons. On the other hand, if we neglect the layered reality that we are, as studied in physics, chemistry, biology, and sensitive psychology, our knowledge of ourselves is only partial and sometimes dangerously so. In this article I have talked mostly of physics, chemistry, and biology. I have only alluded to that higher integration of the biological that is both intelligible and intelligent. There is obviously much more to say about the basic questions of the nature of the human being, a question with which we began this essay. But that must be the subject of yet another article.

NOTES

1. Lonergan's most important work in epistemology and metaphysics, *Insight: A Study of Human Understanding*, was first published in 1957, and many students of Lonergan still use the 1957 or 1958 editions. References in this article are to the 1992 critical edition of the *Collected Works of Bernard Lonergan*. Secondary works that use Lonergan's thought to develop areas in the philosophy of science are relatively few in number. Particularly relevant to this study is the work of William Danaher, *Insight in Chemistry* (1988).
2. Lonergan's use of the word *classical* does not completely conform to the usage of contemporary physicists and chemists, according to which classical usually refers to Newtonian mechanics as opposed to quantum mechanics. In Lonergan's usage, quantum theory has both classical and statistical elements. This can, perhaps, be seen most clearly in those areas of chemical physics in which classical Newtonian physics and quantum mechanics have overlapping areas of applicability. Quantum mechanical results can be compared with the results of Newtonian mechanics only if a classical statistical theory is also included in the calculations (Heelan 1965, 112–21).
3. Relatively little has been written concerning Lonergan's understanding of statistical knowing. An important monograph, though somewhat densely written, is the work by Philip McShane (1970).
4. The Pauli principle is a basic principle of quantum statistics: "When the labels of any two fermions are exchanged, the total wavefunction changes sign. When the labels of any two identical bosons are exchanged, the total wavefunction retains the same sign." While seeming quite abstract, it is this principle that allows the existence of complex structures such as atoms and molecules (Atkins and de Paula 2002, 385).
5. For a good summary of the meaning and implications of supervenience, multiple realizability, functionalism, and downward causation, see Meyering 1999; also Clayton 1999, especially pp. 199–202. For a more detailed consideration of supervenience see Murphy 1998. See also the primary philosophical literature as listed in these articles.

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