Reduction, Emergence and Critical Thinking

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It's not unusual to find scientists and philosophers endorsing reductionism: the belief that elementary particles and forces determine everything in the world (e.g. biology, geology, your reaction to this article). It's true that elementary particles and forces underlie everything in the material world. Without them you wouldn't be reading this!

Reductionism, however, is a stronger thesis. It's a claim about the ultimate structure of nature being completely determined by the complex play of elementary particles and forces. This is a strong claim with troubling implications: What is the status of ethics, moral responsibility, free will, creativity? Are these merely subjectively experienced effects of the underlying action of particles and forces? Under reductionism, it's difficult, if not impossible, to make room for these qualities of human agency as genuine if nature is structured reductively.

On the other hand, it's not unusual to fine scientists and philosophers endorsing emergence: the belief that physics, chemistry, biology, geology, physiology and (by implication at least) human behavior are more than just the action of elementary particles and forces.

However, there are two kinds of emergence usually discussed in the reduction/emergence debates. The first is radical emergence. This is the belief that novel laws, properties and processes come from nowhere in the sense that they aren't based on elementary particles and forces. The second kind is epistemic emergence. This is the belief that chemical, biological and social phenomena, say, are not explainable or derivable from elementary particles and forces. This failure could be due to some kind of epistemic limitation such as a lack of computational or descriptive power.

Epistemic emergence is rather banal because it is ubiquitous. As a matter of scientific practice and necessity we are often forced to use higher-level descriptions for chemical, biological and social phenomena because elementary particle physics descriptions make no sense of higher-level situations. Yet, this means that ontologically, nature can be reductively structured while we're still forced to higher-level descriptions. Epistemic emergence is consistent with a reductively structured world!

Radical emergence, however, is very problematic as it is irrelevant to the sciences. Much of our scientific work is aimed at unifying and connecting phenomena. But radical emergence is a claim that nature is disunified and disconnected. This is both mysterious and prima facie inconsistent with our experience of a coherent world.

A Forced Choice

In trying to understand nature as far as we can scientifically, reductionism appears to be the only viable alternative. The candidate for ontological reduction is relatively clear in the debates–our most fundamental theory of physics. Meanwhile, the alternative for an ontological account of the world's order, radical emergence, is obscure, mysterious or irrelevant. Ontological reduction appears to win by default.

This is an example of a forced choice fallacy. Such a fallacy occurs whenever the options for choice are reduced so that viable options for debate are left out. If you've ever been in an argument that amounted to "I'm right, so you must be wrong!", then you've experienced a forced choice. There may be viable alternatives left out of the argument, one of which is that both people are wrong!

What if there is a viable option for ontological emergence missing from most of the typical reduction/emergence debates?

A Pattern for Robust Emergence

Although physics is often thought of as being a reductionistic science, it actually offers an exemplary pattern for interlevel relations that is a viable alternative to the forced-choice framing described above. This pattern has been called contextual emergence by those of us developing this approach. Contextual emergence's distinctiveness can be seen in the following framework organizing the three alternatives:

Ontological Reduction: Properties and behaviors in a lower level or underlying domain (including its laws) offer by themselves both necessary and sufficient conditions for properties and behaviors at a higher level.

Contextual emergence: Properties and behaviors in a lower level or underlying domain (including its laws) offer some necessary but no sufficient conditions for properties and behaviors at a higher level. Higher levels or target domains provide the needed extra conditions.

Radical emergence: Properties and behaviors in a lower level or domain (including its laws) offer neither necessary nor sufficient conditions for properties and behaviors at a higher level.

Contextual emergence describes situations where the constituents and laws belonging to the supposed fundamental level or underlying domain of reality contribute some necessary but no sufficient conditions for entities and properties in the target domain, or higher level. For instance, the domain of elementary particles contributes some of the necessary conditions for the existence of the properties and behaviors of water flowing through a faucet. No elementary particles, no flowing water! On the other hand, the existence of elementary particles and their laws do not guarantee that flowing fluids will exist. The total set of sufficient conditions for flowing fluids is, itself, contingent rather than necessary, and involves more conditions than are found in the domain of elementary particles and forces.

As another example of contextual emergence, consider Rayleigh-Bénard convection. Elementary particles and forces establish the possibilities for there to be fluids of many kinds, motions of many kinds, etc. Yet by themselves elementary particles and forces don't enable the existence of specific fluid motions. Elementary particles and forces only fix the total set of possibilities. To get convection requires several contingent conditions: a specific fluid, a space the fluid occupies, a temperature differential in presence of gravity, action of all fluid molecules acting on all fluid molecules, and so forth. None of these conditions are fixed by elementary particles and forces; these conditions are only allowed rather than determined.

This is the pattern of contextual emergence in physics. There are no new forces that come out of nowhere, so no radical emergence. Nevertheless, the underlying domain of particles and forces don't contain all the conditions necessary and sufficient for convection to actually happen in an actual system.

A Broad Pattern

The contextual emergence pattern of relationships extends beyond physics. Consider an example from biology. The placement of hair and feather follicles on animal bodies is highly ordered. Yet, the genome doesn't direct exact location of individual follicles. It turns out that the genetics controlling follicle generation is shaped by larger-scale mechanical forces determining typical distance between neighbouring follicles.

The developing skin has two layers, an epithelial layer forming the epidermis lying on top of the dermis. The underlying dermis contracts locally causing the epithelial cells to bend forming slight dome shapes where follicles form. These dermal contractions cause compressive stress in the overlying epithelial cells. Two interesting things happen from this compressive stress. First, the dermal contractions break the symmetry of the random distribution of the overlying epithelial cells ordering them spatially. Second the mechanical forces activate the genetic machinery producing follicles. Otherwise, the genetic machinery for follicle production never turns on.

The upshot is that larger-scale mechanical forces provide a stability condition sufficient to trigger follicle formation in an ordered array. The underlying genetic machinery provides some of the necessary conditions for patterned follicle formation. The larger-scale mechanical forces due to dermal contraction provide the additional necessary and sufficient conditions for patterned follicle formation.

As another example, consider machine learning, a particular sub-branch of artificial intelligence that has generated a lot of recent interest. Machine learning typically involves designing a neural network model and training that model on a set of data relevant for a specific application such as facial recognition. The training data set represents an environment the machine learning model is exposed to and is to "learn" from.

What research shows is that the performance of machine learning models is very sensitive to their training data sets. The type and quality of the learning environment greatly determines the model performance in its target environment. There is the famous example of the MIT machine learning system trained on a large data set of faces that then failed to recognize the faces of black females in the actual world. The lack of a sufficiently representative sample of faces in the training data set led to failure in the target task of facial recognition.

In machine learning, the architecture of the neural network provides some of the necessary conditions for its performance. The data environments for learning and target tasks provide the rest of the necessary and sufficient conditions for actual performance of machine learning models.

This is a particularly interesting example because there are actually three different interrelated levels: (1) The hardware level that provides some necessary but no sufficient conditions for its own functionality. (2) The software level at which the neural network is implemented providing the rest of the necessary and sufficient conditions for specific hardware function. And (3) the learning and target environments that provide the needed necessary and sufficient conditions for performance of the machine learning model.

The general pattern of contextual emergence is a combination of bottom-up and top-down features through which complex phenomena arise. This is a pattern of interlevel or interrelational influence.

The Big Picture and Critical Thinking

Now return to the framing of reduction-emergence debates as a forced choice between the plausible-sounding ontological reduction and implausible-sounding radical emergence. This framing leaves out the important role context plays in the origin and existence of phenomena. In other words it leaves out at least one viable alternative for ontological emergence: Contextual emergence!

Here we have an important point about critical thinking. If a debate is framed in such a way that a viable alternative is missing (e.g., reduction-emergence debates leaving out contextual emergence), then we will not be able to think well about the issues involved in the debate. Nor is the debate capable of being concluded in a sound fashion.

There is a second point about critical thinking to note, here. Contextual emergence is a pattern for the structuring of reality that is noticed when we make explicit what is often left implicit. In this case the role of contexts and the stability conditions of contexts that provide the structure for how elementary particles and forces come to concrete expression. So contextual emergence is also an exercise in critical thinking. The more we are aware of all the factors that go into the concrete actualization of the wide range of possibilities provided by elementary particles and forces, the more we can see that the ontological structure of reality is more subtle than the reductionist claims and more interesting!

Moreover, the forced choice between ontological reduction and radical emergence not only leaves out important possibilities, it also has consequences for bigger questions-concerns we have regarding consciousness, free will, ethics and creativity. For instance, in a reductively structured world human "activity," "thought," and "consciousness" are just effects of the complex play of elementary particles and forces. There is no genuine ethics, just the consequences of elementary particle physics. Consciousness is just the accidental byproduct of the complex play of elementary particles and forces. Even the creative thought and work to develop the standard model of elementary particle physics is just the effect of those very particles!

On the other hand, a radical emergence world would leave us with consciousness, thought and values as totally separate from the material world. Not only would there be no discernible relationship between thought and values and the material world, it would be an absolute mystery as to why there is any coherence between thought and action that has an impact on material objects!

Hence, critical thinking doesn't exist in an ontologically reductive world and appears irrelevant in a radically emergent world. A contextually emergent world, on the other hand, would be a more unified world than that of radical emergence while making room for genuine consciousness, thought, free will and moral responsibility missing from ontological reduction. Perhaps this is the best home for critical thinking. After all, critical thinking is contextually relevant thinking!

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