Confronting Emerging Global Challenges: an Emergent Perspective- February 22,2011 Draft

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Summary

Complex adaptive systems, such as those studied in matter by ICAM and in matter and society by SFI, are of interest because the interaction between their components leads to emergent collective behaviors that are striking different from those of their individual constituents. More is different and we call such behavior *emergent.*. Indeed, we live in an emergent universe, in which the interaction between its parts, be they people or electrons, gives rise to emergent collective behaviors that are not only different from those of the parts separately but are generally unpredictable from knowledge only of those parts and their interactions.

To understand this emergent universe, scientists are replacing the traditional reductionist approach, with its focus using the individual components as basic building blocks, by an emergent perspective, in which the primary focus is on identifying the collective organizing concepts and principles that characterize emergent behavior. As spelled out in more detail below, these are the new basic building blocks--the gateways we need to understand observed collective emergent behavior, be it in quantum matter, biology, the cosmos, ourselves, or the societies in which we live.

In the physical and biological sciences, we carry out experiments in the laboratory and analyze observational data to investigate the regularities that characterize emergent behavior, and ask whether understanding the gateways to emergent behavior in one area might provide us with useful insights into the origins of emergent collective behavior in another. A similar emergent strategy is key to understanding emergent behavior in society, with the principal difference being that it is difficult to carry out experiment and one must often rely on incomplete data is searching for the patterns and regularities that provide clues to the gateways to the emergent behavior under investigation.

An emergent perspective is likewise essential as we confront emerging global challenges—climate change, our troubled educational and infrastructure systems, terrorism, our current global economic meltdown, etc. These are all caused by humans, and in searching for an appropriate emergent response, we properly begin by seeking to identify their origins in societal behavior.

But now there is a difference from simpler systems: their origins are many, not unique. Moreover, because feedback leading to non-linear behavior plays a significant role, these origins are both difficult to identify and nearly impossible to separate. Armed with this emergent perspective, what is the right strategy?

First, keep clearly in mind that because emerging global challenges have no unique cause, it follows that there is no unique or even “best” solution to these. Second, devise emergent strategies for making progress by trying simultaneously many different partial solutions, searching for synergies and feedback among these, inventing new institutions, and above all experiment, experiment, experiment in pursuing these.

Emergence

Emergence is a bulk property. When we bring together the component parts of any system, be it people in a society or matter in bulk, the behavior of the whole is very different from that of its parts, and we call the resulting behavior *emergent.*

From the discovery of novel ordered states in quantum matter to eggs cooking, birds flocking, collective behavior in ant colonies, the development of consciousness in infants, the latest measurements on the early universe, global climate change, or our current global economic meltdown —emergence is all around us.

More matter turns out to be not only different, but is almost always unpredictable from a knowledge of its component parts and their interactions.

We know the simple equations that govern our immediate world, but find these are almost useless in telling us about the emergent behavior we encounter, whether we are working on a problem at the frontiers of science, cooking a meal, or seeking to understand and change societal behavior. So we must conclude that the dream of some twentieth century reductionists [according to Wikipedia, reductionism can either mean (a) an approach to understand the nature of complex things by reducing them to the interactions of their parts, or to simpler or more fundamental things or (b) a philosophical position that a complex system is nothing but the sum of its parts, and that an account of it can be reduced to accounts of individual constituents] --discovering a "Theory of Everything" --is hollow.

Thus matter in bulk acquires properties that are different from those of its fundamental constituents (electrons and nuclei) and we now recognize that a knowledge of their interactions does not make it possible to predict its properties, whether one is trying to determine whether a material becomes, say, a magnet or a novel superconductor, to say nothing of the behavior of a cell in living matter or the behavior of the neurons in the human brain.

Feynman famously said: "life is nothing but the wiggling and jiggling of atoms," but this does not tell us how these gave rise to LUCA, the last universal ancestor that is the progenitor of living matter, to say nothing of its subsequent evolution. It follows that we need to rethink the role of reductionism in understanding emergent behavior in the physical, biological, and social sciences.

An Emergent Perspective and Emergent Strategies

What replaces the reductionist dream? The short answer is an *emergent perspective*—a recognition that understanding emergent behavior requires a change of focus. Instead of adopting the traditional reductionist approach that begins by identifying the individual constituents (quarks, electrons, atoms, individuals) and using these as the basic building blocks for building a model of emergent behavior, focus instead on identifying the collective organizing concepts and principles that characterize emergent behavior, for these are the basic building blocks one needs to understand emergent behavior.

The chef cooking eggs has found through experiment the organizing principles at work that change their state from liquid to semi-solid-(over- easy, shirred, scrambled, omelet, soufflé, fritatta…)-and has learned that the pan, the butter, the temperature of the stove top or oven, the added ingredients, the altitude, and especially the chef—all play a role in determining the outcomes.

The physical scientist studying bulk matter seeks to identify the collective building blocks (symmetry, broken symmetry, effective fields, criticality, feedback, energy landscapes,

frustration, phase transitions, coherent and competing states, universal, scaling, or protected behavior, etc.) that are candidate *gateways to emergence* in the system under investigation, and to understand their range of applicability.

For the physical scientist or the social scientist an emergent strategy involves then the following steps:

•focus on the experimental results--search for regularities (patterns, possible scaling behavior, etc…) in the experimental or observational data obtained by many different probes
*consult one's catalogue of organizing concepts and decide, at a qualitative level, on candidate organizing concepts that might be responsible for the most important experimental regularities
*develop a phenomenological description that incorporates these organizing principles and links the results obtained using different experimental probes
• only then put on a "reductionist" hat-- developing a candidate microscopic "theory" by proposing and solving a simplified "toy" model that embodies the candidate organizing principles.

Both the reductionist and the scientist with an emergent perspective focus on fundamentals. For the reductionist these are the individual constituents of the system, and the forces that couple them. For the "emergentist"—the scientist with an emergent perspective-- the fundamentals are the collective organizing principles that bring about the emergent behavior of the system as a whole.

The difference between a reductionist perspective and an emergent one can also be viewed in terms of starting points and ending points. In considering a new problem that has turned up in the laboratory or is posed by observation, the reductionist focuses at the outset on solving an existing model that incorporates the basic interactions between the individual components of the system. The scientist with an emergent perspective puts on a reductionist hat, but does so very much later, toward the end point of research on the problem, when, through continued attention to the experimental results obtained using a broad spectrum of probes of its emergent behavior, it has been possible to identify the organizing principles that must be incorporated in a candidate model, one that is nearly always quite different from the standard model of the reductionist.

Emerging Societal Challenges

For the citizen and world leader alike, an emergent perspective is essential as we confront emerging global challenges—climate change, our failed educational system, terrorism, our current global economic meltdown, etc. These are all caused by humans, and in searching for an appropriate emergent response, we properly begin by seeking to identify their origins in societal behavior.

But now there is a difference: their origins are many, not unique. Moreover, because feedback leading to non-linear behavior plays a significant role, these origins are both difficult to identify and nearly impossible to separate. Armed with this emergent perspective, what is the right strategy?

Because emerging global challenges have no unique cause, it follows that there is no unique or even "best" solution to these.

Emergent Strategies

Emergent strategies for making progress involve trying simultaneously many different partial solutions, inventing new institutions, and *experiment, experiment, experiment* in pursuing these.

These involve as well *monitoring carefully the results of these different experimental approaches, searching for synergies, and being adaptive*- modifying these as information becomes available on their impact.

Establishing synergies between candidate solutions can accelerate progress, and priority should be given to those that offer promise of solving more than one problem at a time.

Behavior is a significant component of both the problems and their candidate solutions

Behavioral change comes about through education, so *education should play a significant role in every proposed solution*

Experimenting with new approaches and connecting the results can be accelerated by the using the vastly improved communication tools available through the internet.

Sharing "best practice" on the internet enables local groups seeking change to become aware of the "best practice" developed elsewhere, and help them avoid "reinventing the wheel."