

# Responsible Citizenship in a Technological Democracy

## Note 12: Complex Systems

Each of the previous Notes in this series has dealt with well established science or engineering concepts. This Note is different in that it will discuss a relatively new concept where the terminology isn't settled, what's important and what's not hasn't been agreed upon, and where there are some really bright people who think it's all just bunk. To make it worse, it has some philosophical overtones, so humanists and social scientists have waded into the fray before the science and engineering issues have been settled – not that humanists and social scientists shouldn't have a say, but it would help if everyone was arguing about the same thing, and they aren't. Finally, so you can calibrate what you're about to read, I am not an expert in the subject, not by a long shot.

With all of those caveats, why am I making you read this? Because I think it is going to become really important in your lifetimes. So, even if I unintentionally lead you a bit astray, at least you'll know that the issue exists.

The topic is complex systems. Just to illustrate how young and unsettled this topic is, there isn't an agreed upon definition of what that means. For our purposes, however, I will consider a system to be “complex” if it's not possible to predict all of its behaviors from the behaviors and relationships of its components. Let's elevate that to a concept:

**Concept:** A system will be considered to be *complex* if it is impossible to predict all of its behaviors from the behaviors and relationships of its components.

By the way, the word “system” is being used in the same sense as in Note 4 on systems. It is something made from a collection of simpler things – usually called components, parts, or subsystems. The parts have relations among them that let the assemblage accomplish some function.

Note the definition says that it is “impossible” to predict a complex system's behavior. Not just hard to predict, but impossible! How might that happen? There are several possibilities, but one way is for the system to have so many components, each with it's own complicated behavior and each interacting with a very large number of other components. In such a case, simply the number of possibilities becomes overwhelming and, like the testing of all the configurations of 1's and 0's in my laptop's memory, impractical. The human brain is probably a good example of such a complex system. With a billion or so neurons, each with a rich set of electrical and chemical signals to thousands of other neurons, it's at best unlikely that we can predict Bill Wulf's personality from a knowledge of how a neuron works and their connectivity.

**Concept:** A system's behavior that was not predicted is called an *emergent behavior* or an *emergent property*.

The reason for raising the issue of complex systems is that we are now beginning to build systems that appear to be complex in this technical sense, and we are modifying natural complex systems. Some of our larger computer systems exhibit emergent behaviors, for example. Current attempts to “remediate” the Everglades are an example of modifying a natural complex system. The emerging field of “systems biology” – which is essentially trying to engineer biological-like things from scratch – will undoubtedly involve complex systems. It’s possible that the Law of Unintended Consequences is, in fact, just an earlier way of talking about emergent behaviors such as the loopholes in tax law.

The problem is we don’t know how to design systems with useful emergent properties, and without useless or destructive ones. Nature does it by evolution, or “natural selection” as Darwin called it. Properties emerge, and if they are useful they give the organism an advantage and so they tend to be propagated; if they are useless or destructive, they disadvantage the organism, and aren’t propagated. But that’s an awfully slow way to design a system.

In Note 6 we discussed the “engineering method”, and even opined that it was not a bad way to think about policy formation. Unfortunately, the engineering method as described there doesn’t account for the design of complex systems with emergent properties. We can see the consequences of this in software – carefully designed systems using this methodology still contain “bugs”, many of which are really just unanticipated emergent properties. Even following the engineering method probably wouldn’t eliminate loopholes from the tax code.

Will a new engineering method emerge, or will we just have to learn to live with surprises, both good and bad, in our future systems? Good question.

### **Aside: The Philosophical Overtones**

The scientific program for the last several centuries has been built on the premise called “reductionism” – a belief that more complex things can be understood by understanding their constituent parts. So the macroscopic properties of a substance can be understood in terms of its chemical structure – the molecules that make it up. The molecules are understood in terms of their constituent atoms. Atoms are understood in terms of electrons, protons and neutrons. And so on. Some philosophically worry that this basic premise of the scientific program is undermined by the idea of emergent properties; others, eager to knock science off its haughty high horse, gleefully embrace it.

I tried to dodge this philosophical squabble by emphasizing prediction rather than explanation. In the field I know best, computers, we are increasingly surprised by emergent behaviors, by behaviors we did not intentionally design into the system. But once we see them we can explain them in terms of the properties of the system’s components. At least in my experience, the growth of complex systems and emergent behaviors is not a threat to reductionism. Maybe we can’t predict emergent properties, but we can explain them once we see them.

## Policy Relevance

As Neils Bohr said, prediction is difficult, especially about the future<sup>1</sup>. So we are out on a limb here. But consider two cases: either we find an engineering method, faster than natural selection, that at least prevents destructive emergent properties of complex systems, or we don't.

Suppose we find such a method, then the sky is the limit. We could confidently build ever more complex systems – robots with super-human intelligence, re-engineered ecosystems with properties better than nature gave us, tax codes or liability laws that are really fair and effective, maybe even synthetic life, etc. Those are all fanciful ideas and there is no way to know whether they are even possible, but the point is that if we were confident that they had no downsides, there are lots of reasons to pursue them.

But suppose we don't find such a method. Then there are at least two things we need to deal with. First, our personal expectations, and even our legal system, will have to recognize that some things are beyond the control of those who design complex systems. However careful they are, they could not predict all the behaviors of their design, and can't reasonably be held accountable for them. If you asked for it and it had an unexpected behavior, well, "shit happens".

Second, we have to decide whether there are some things we shouldn't do. If there is an argument against genetic engineering, this is it. All biological systems are complex systems, as we tinker with them we won't predict all their behaviors and some of those behaviors may be destructive. We should have reservations about the current attempts to remediate the Everglades – which is an exquisitely complex system. Although one can deplore what we've done to it already by "draining the swamp" to build homes for retirees, we should also be concerned that we won't predict some destructive emergent properties of our current meddling with it.

Examples like that of the Everglades are especially troubling since not doing something is, in fact, doing something! Which is worse, the status quo, which may also have future surprising emergent properties, or the planned remediation and its surprising emergent properties?

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<sup>1</sup> Many, including the author, thought this was a Yogi Berra quote. It sounds like him! But, no, it is from the physicist Neils Bohr.