Disentangling Complexity in Biology

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Disentangling Complexity in Biology

The discussion by Norman C. Ellstrand and his coauthors (p. 384) of the difficulties surrounding the regulation of hybrids serves as a reminder of how problematic biology becomes when it intersects with policy. Predicting how a biological system—ecosystem, organism, or something else—will behave is much harder than doing the same for a nonliving system, mainly because there are so many exceptions to generalizations about biology. Hybrids can have enhanced vigor and be persistent, or they can be weak, sterile, or both. Their occurrence can hasten the decline of a critically endangered species, or it can save a species. Genotype interacts with the environment to produce phenotype—but poorly understood epigenetic inheritance can substantially intervene. We understand the structure of the influenza virus at the atomic level, but we cannot say whether a mutant form will produce mass casualties until we start counting bodies. What is a policymaker to do?

It's not as if biology were afflicted merely with well-behaved, dependable, and quantifiable uncertainty. The growing focus on complexity in ecology is generating now-famous examples of sudden state changes—tipping points—that confound many attempts to foresee a system's response to a stimulus. Developmental biology affords similar examples. Interactions between genes and other factors are often sensitive to context, and random mutations continually alter that context. Things get only more complicated when one considers interactions between organisms, because most living things—including plants—influence the behavior of others. As for understanding how humans might settle their disagreements, science is still way behind artful diplomacy.

Does this recognition of biology's ornery nature make it less of a science than physics? No, says Sandra D. Mitchell, in a potentially important new book, *Unsimple Truths: Science, Complexity, and Policy* (University of Chicago Press, 2009). Mitchell argues persuasively for a pragmatic and conditional interpretation of what constitutes a scientific law. Even paradigmatic examples such as Galileo's law, which can be used to compute how far an object falls in a given period, are contingent on circumstances. What differentiates the laws of physics from those of biology is first and foremost the stability of the conditions upon which the causal relationship depends.

The laws of biology typically apply in more restricted domains than those of physics or chemistry, which should be no surprise. What is more, the emergent properties that arise in complex systems require biologists to be flexible in the types of measurements they use to establish useful laws, as some systems cannot be dismantled into modules with separable causal powers. "Some complex structures harbor nonmodular, context-sensitive actual causes that can explain their behavior," Mitchell states.

Far from being a counsel of despair, Mitchell's prescription, which she calls integrative pluralism, shows biologists how they can shed "physics envy." Though biological research presents challenges in terms of the amount of data that have to be analyzed, the computing power now available to researchers allows them to discern patterns that might have been invisible a generation ago. And biologists should be able to offer policymakers better tools than the cost-benefit analysis that underlies much of current policy. Biology may have awkward qualities, but it is not beyond science's power to manage them.

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