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Philip Anderson on Computers and Emergence

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COMPUTERS HAVE BEEN RESPONSIBLE FOR IMMEASURABLE PROGRESS IN PHYSICS.
BUT CONTRARY TO ASSUMPTIONS, EXPERIMENTALISTS ARE THE HEAVY USERS.

Our experimentalist colleagues get to organize massive data streams into the beautiful false-color pictures we see on the covers of Science and Nature. For us theorists the computer is more of a mixed blessing. Many see it as our substitute; our role is to take the (mostly) known laws of physics and calculate their consequences by letting computers do all the work.

For most systems of interest, however, the basic laws of physics, though not incorrect, are inadequate. The reason is emergence, which says that when a system becomes large and complex enough, its constituents self-organize into arrangements that one could never deduce a priori, even though the laws of physics are obeyed. The obvious example is life, but emergence also acts on a more primitive level. Even the quantum theory of what should be the simplest of all crystalline solids, helium, is still a bit of a mystery.

In an attempt to cope with such problems, some of my colleagues try to do what I said they couldn't: follow all the atoms or electrons as they interact using massive computer simulations. Unfortunately, the number of atoms and the length of time they can be followed are negligible compared with even the tiniest speck of real matter. In addition, they use various assumptions and tricks that tend to predetermine the outcome.

The prestige attached to computers and their erudite gimmicks impresses almost everyone, but especially the simulators. They often believe they have proved that a system – like the little crystal of solid helium – can't possibly behave the way experiments show, therefore there's something dubious about the experiments, and not the simulations. Of course, to the casual observer computer simulations are far more impressive than old-fashioned logic and common sense. But we must remember that a simulation, even if correct, can't really prove anything. Computers will always have limits of error in trying to model the world. In the end logic and pure science, independent of the computer, still get us closest to nature, even without the pretty pictures.

Philip Anderson is a professor at Princeton University and was the recipient of the Nobel Prize in Physics in 1977.