The Game of Life—And Looking for Generators

Answer to the 2011 Edge Question: “What scientific concept would improve everybody’s cognitive toolkit?”

(2011) Nick Bostrom

www.nickbostrom.com

The Game of Life is a cellular automaton invented by the British mathematician John Horton Conway in 1970. Many will already be acquainted with Conway’s invention. For those who aren’t, the best way to familiarize yourself with it is to experiment with one of the many free implementations found on the Internet (or better yet, if you have at least rudimentary programming skills, make one yourself).

Basically, there is a grid, and each cell of the grid can be in either of two states: dead or alive. You start by seeding the grid with some initial distribution of live cells. Then you let the system evolve according to three simple rules.

(Birth) A dead cell with exactly three live neighbors becomes a live cell. (Survival) A live cell with two or three neighbors stays alive. (Death) Any other cell dies or remains dead.	 “Gosper’s Glider Gun”

Why is this interesting? Certainly, the Game of Life is not biologically realistic. It doesn’t do anything useful. It isn’t even really a game, in the ordinary sense of the word.

But it’s a brilliant demonstration platform for several important concepts—a virtual “philosophy of science laboratory.” (The philosopher Daniel Dennett has expressed the view that it should be incumbent on every philosophy student to be acquainted with it.) It gives us a microcosm simple enough that we can easily understand how things are happening, yet with sufficient generative power to produce interesting phenomena.

By playing with the Game of Life for an hour, you can develop an intuitive understanding of the following concepts and ideas:

• *Emergent complexity* — How complex patterns can arise from very simple rules.

• *Basic dynamics concepts* — Such as the distinction between laws of nature and initial conditions.

• *Levels of explanation* — You quickly notice patterns (such as "gliders," which are a specific kind of pattern that crawls across the screen) arising that can be efficiently described in higher-level terms but are cumbersome to describe in the language of the basic physics (i.e., in terms of individual pixels being alive or dead) upon which the patterns supervene.

• *Supervenience* — This leads one to think about the relation between different sciences in the real world. Does chemistry, likewise, supervene on physics? Biology on chemistry? The mind on the brain?

• *Concept formation, and carving nature at its joints* — How and why we recognize certain types of patterns and give them names. For instance, in the Game of Life, you can distinguish "still lives," small patterns that are stable and unchanging; "oscillators," patterns that perpetually cycle through a fixed sequence of states; "spaceships," patterns that move across the grid (such as gliders); "guns," stationary patterns that send out an incessant stream of spaceships; and "puffer trains," patterns that move across the grid leaving debris behind. As you begin to form these and other concepts, the chaos on the screen gradually becomes more comprehensible. Developing concepts that carve nature at its joints is the first crucial step toward understanding, not only in the Game of Life but in science and in ordinary life as well.

At a more advanced level, we discover that the Game of Life is Turing complete. That is, it's possible to build a pattern that acts like a Universal Turing Machine (a computer that can simulate any other computer). Thus, any computable function could be implemented in the Game of Life—including perhaps a function that describes a universe like the one we inhabit. It's also possible to build a universal constructor in the Game of Life, a pattern that can build many types of complex objects, including copies of itself. Nonetheless, the structures that evolve into a Game of Life are different from those we find in the real world: Game of Life structures tend to be fragile, in the sense that changing a single cell will often cause them to dissolve. It is interesting to try to figure out exactly what it is about the rules of the Game of Life and the laws of physics that govern our own universe that accounts for these differences.

Conway's Game of Life is perhaps best viewed not as a single shorthand abstraction but rather as a generator of such abstractions. We get a whole bunch of useful abstractions—or at least a recipe for how to generate them—all for the price of one. And this points us to one especially useful shorthand abstraction: the strategy of Looking for Generators. We confront many problems. We can try to solve them one by one. But alternatively, we can try to create a generator that produces solutions to multiple problems.

Consider, for example, the challenge of advancing scientific understanding. We might make progress by directly tackling some random scientific problem. But perhaps we can make more progress by Looking for Generators and focusing our efforts on certain subsets of scientific problems—namely, those whose solutions would do most to facilitate the discovery of many other solutions. In this approach, we would pay most attention to innovations in methodology that can be widely applied; and to the development of scientific instruments that can enable many new experiments; and to improvements in institutional processes, such as peer review, that can help us make decisions about whom to hire, fund, or promote—decisions more closely reflecting true merit.

In the same vein, we would be extremely interested in developing effective biomedical cognitive enhancers and other ways of improving the human thinker—the brain being, after all, the generator par excellence.