Conway's Game of Life

We all have played games at some point in our lives. Today we shall play Conway's game of life. This is a game where you can only control the initial state of it, but not how it evolves.
It sounds rather boring than the other games you have played, doesn't it? However, you will be soon surprised by how fascinating this game is!

Before getting to the rules of the game, let's talk about the name of this game and its origins.

We have been taught what biologists agree on as the definition of life is in high school. Other than the seven pillars of life description, intellectuals in other scientific fields have pondered on their approach to describe life as well. One such scientist, Alan Turing had this described life as an entity that is capable of self-replication/reproduction and simulate a Turing machine. [A Turing machine is a mathematical model of computation which manipulates the symbols on a strip of a tape according to a set of rules Its simplicity allows for a Turing machine that can simulate the logic of any given algorithm be constructed.] Turing's description of life is possible to simulate in this game.

This is a 2D cellular automaton, a computation model involving evolution of binary states on a grid according to a ruleset. Conway who was very interested in Turing's description, mathematical logic and automata had come up with certain rules/criteria to be met to create an unpredictable automaton. It was later that his automaton was proved to be "alive" in Turing's sense and several others have developed on Conway's game of life with simpler rules.

The rules as for this game are as follows:

1. Any live cell with fewer than two live neighbours die, as if by underpopulation.
2. Any live cell with two or three live neighbours lives on to the next generation.
3. Any live cell with more than three live neighbours dies, as if by overpopulation.
4. Any dead cell with exactly three live neighbours becomes a live cell, as if by reproduction.

You might be of the thought that these rules seem so simple what's the interesting thing about this game. There are many situations where complex phenomena arise because of simple rules which seems rather counter-intuitive. But here's a clear example that you can use to prove it to yourself. With this small ruleset, people have observed the evolution of some initial states to highly stable and self-similar patterns. The universal Turing machine as talked about earlier was constructed by **Paul Rendell** in this game world, making it theoretically possible to simulate all computing algorithms and thus is Turing complete.

It's encouraged that you try making some initial patterns on the grid and observe their evolution or use some of the classic popular patterns whose buttons we have provided below the grid. Do it before reading ahead!!!!

Let's see how intelligent you are. Can you predict what the conclusion of a pattern will be just by looking at it and not applying the algorithm in your head. Give it a try! It is of course rather difficult to do it given we're only humans. However, do you think that a general algorithm can be developed which can identify if a pattern is an evolution of a certain initial state? The answer to is surprisingly NO!

Here's why, In the theory of computation, one of the key problems was the Halting problem. In essence, it's the problem of determining whether a set of input states and a computer program will ever reach an end or not. Alan Turing had proved that a general algorithm cannot be developed to solve this problem for all possible input-program pairs. A nice piece of trivia: this problem and its proofs are similar to Godel's incompleteness theorems which deal with the limits of axiomatic theories such as in the proving of the truth of mathematical statements.

We have mentioned earlier that Game of life is Turing complete. We could again simulate the halting problem with a certain Turing machine within game of life and find that indeed, it's not possible to develop an algorithm to determine whether all input states halt or not. In this case, this is the same as not determining whether the given state is a final state of another given state by a general algorithm. This consequence of halting problem is called Undecidability.

The Turing completeness of the Game of life also implies that, given enough cells, a Turing machine can be built which is in theory, capable of simulating any given algorithm and thus, logic gates and so on, and build what is essentially a computer within the game world.

Hope you're convinced that this is not simply a boring game. This isn't a complete explanation of The Game of life, rather a short discourse for you to get interested in playing it and learning more about it. Please look at the mentioned links if you're interested.

Further reading:

https://youtu.be/Kk2MH9O4pXY a documentary on game of life.

https://en.wikipedia.org/wiki/Conway's_Game_of_Life

https://youtu.be/E8kUJL04ELA

https://youtu.be/C2vgICfQawE some interesting patterns in game of life

http://rendell-attic.org/gol/tm.htm

http://www.cs.unibo.it/~babaoglu/courses/cas00-01/papers/Cellular_Automata/Turing-Machine-Life.pdf

_Universal Turing machine implemented in game of life by Paul Rendell.

https://www.youtube.com/watch?v=O4ndIDcDSGc -Godel's Incompleteness theorem

The Recursive Universe by Poundstone - book recommendation

Turing Machine Universality of the Game of Life by Paul Rendell – book recommendation - proof of universal computation in the Game of Life cellular automaton by using a Turing machine construction