CITS4403 Computational Modelling

Lecture 5: Cellular Automata II

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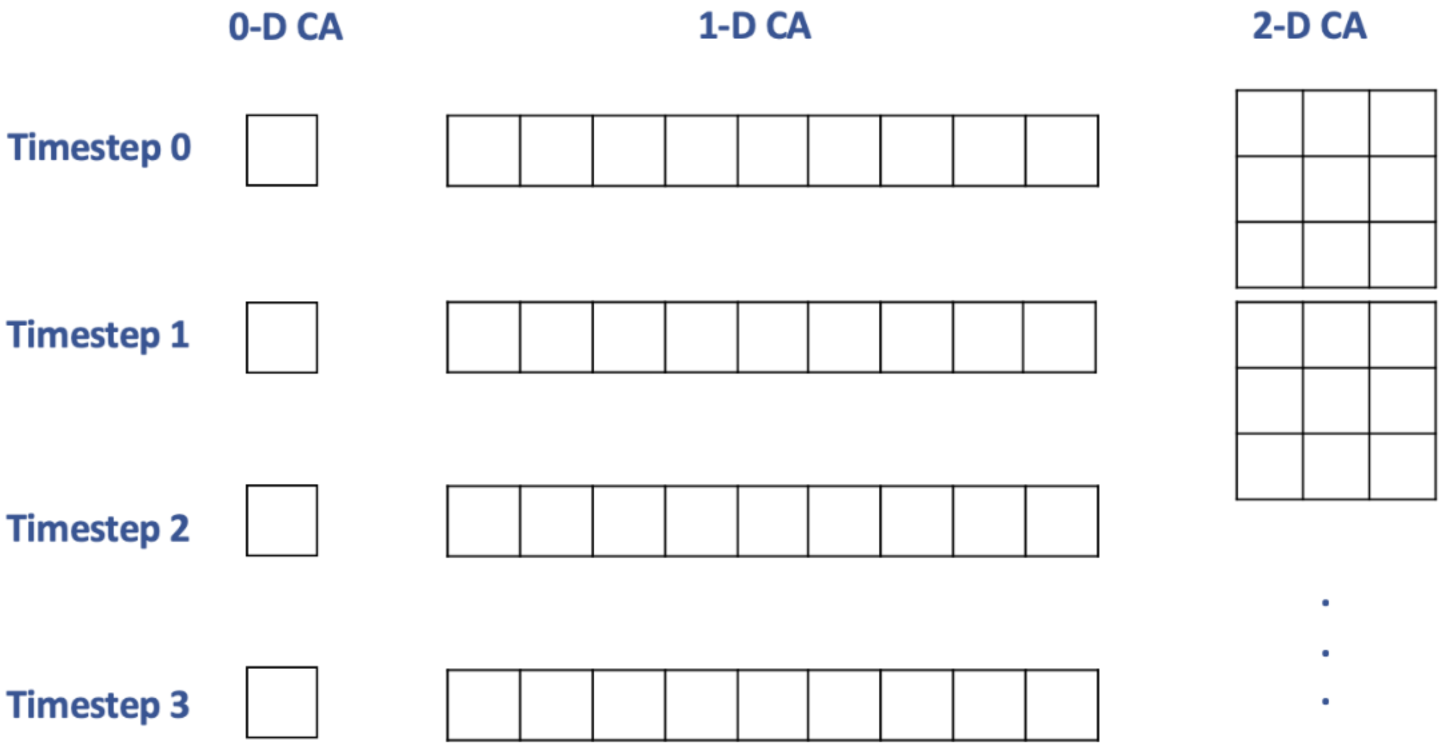
0 LECTURE PLAN

Lecture 5: Cellular Automata II

1. **Recap**
2. Game of Life
   - Implementation
3. Diffusion and Reaction Diffusion

0 Recap

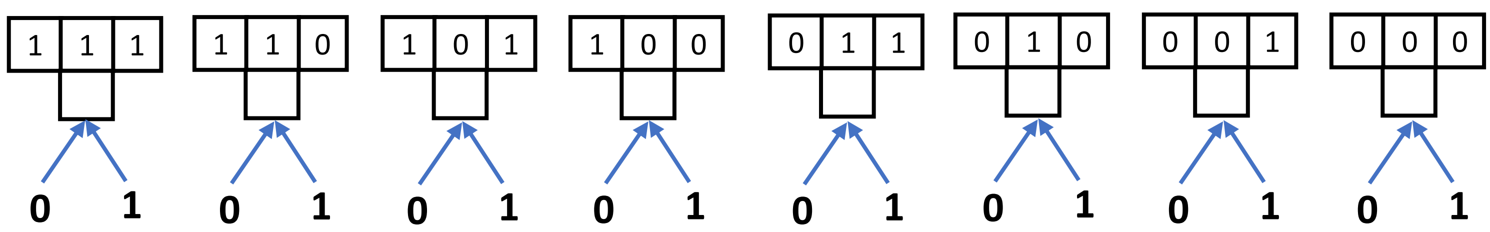
Cellular Automata come in different varieties with **different dimension**



Wolfram's 3-cell neighborhood

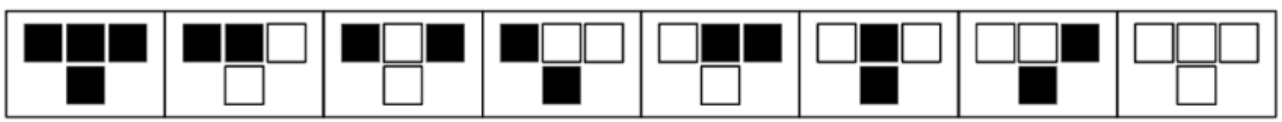
A rule can be summarized that maps from the state of the neighborhood (a tuple of three states) to the next state of the center cell.

In Wolfram's 3-cell neighborhood, we can specify 2^8 *= 256 rules.*



- The top line shows the current states of the left neighbor, the cell itself and the right neighbor (a 3-tuple).
- Below is the new state updated based on the previous state of itself and its two neighbors in the previous generation.

Rule 150



Decimal	7	6	5	4	3	2	1	0
Binary	111	110	101	100	011	010	001	000
Rule	1	0	0	1	0	1	1	0

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2-D Cellular Automata

The cells in Game of Life (GoL) are arranged in a 2-D grid.

- Each cell in the grid has **two** states: *live or dead.*
- **Moore Neighbourhood**: eight neighbours – north, south, east, west and four diagonals.
- GoL evolves over time based on simple fixed rules.

GoL Rules

- The next state of each cell depends on its current state and its number of live neighbours.
- If a cell is alive, it stays alive if it has 2 or 3 alive neighbours and dies otherwise.
- If a cell is dead, it stays dead unless it has exactly 3 alive neighbours.

Simple initial condition yields surprisingly complex behaviours and patterns, e.g. stable pattern, oscillator, spaceships.

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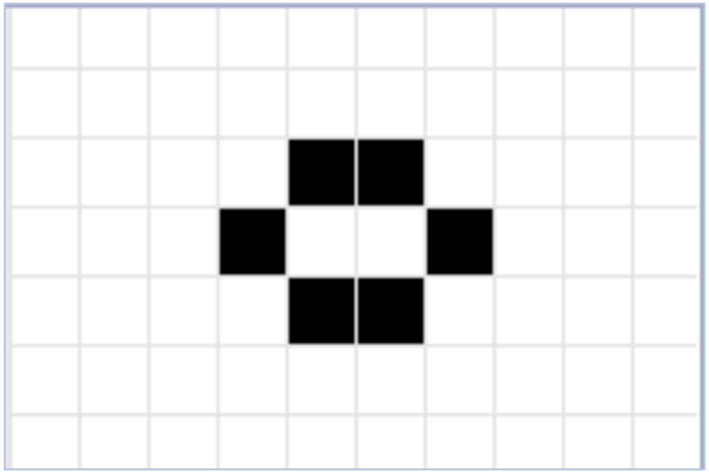
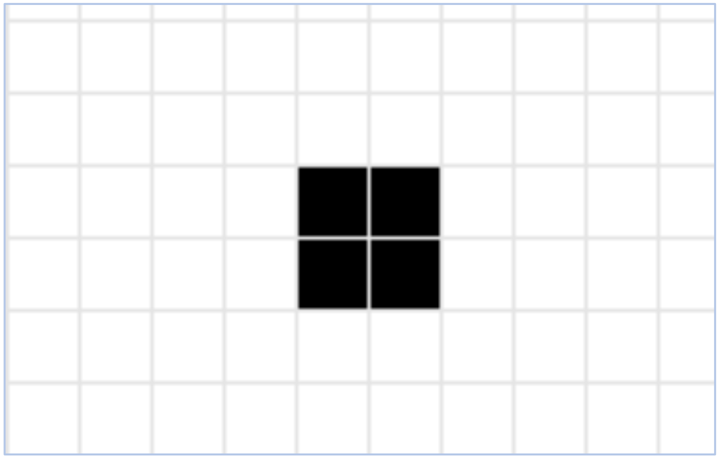
Beehive

6-cell still life – a pattern does not change from one generation to the next.



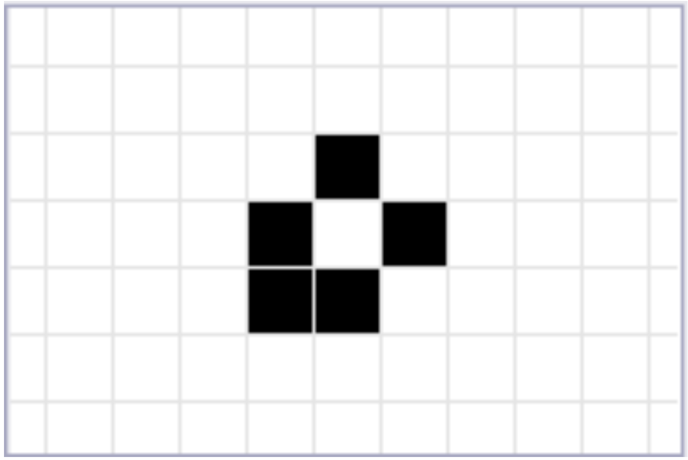
Block

4-cell still life, extremely common and well-known still life



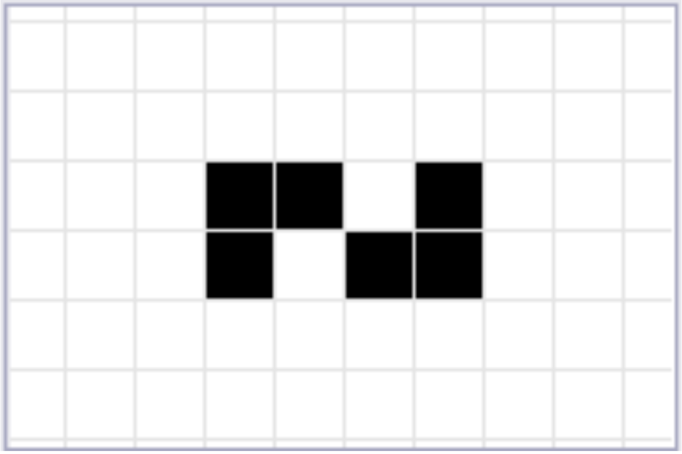
Boat

Only still life with 5 cells



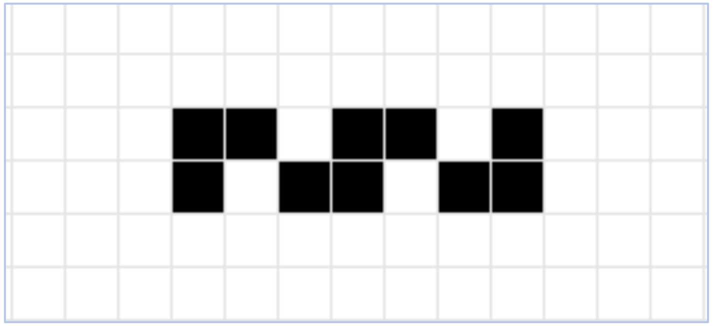
Snake

6-cell still life



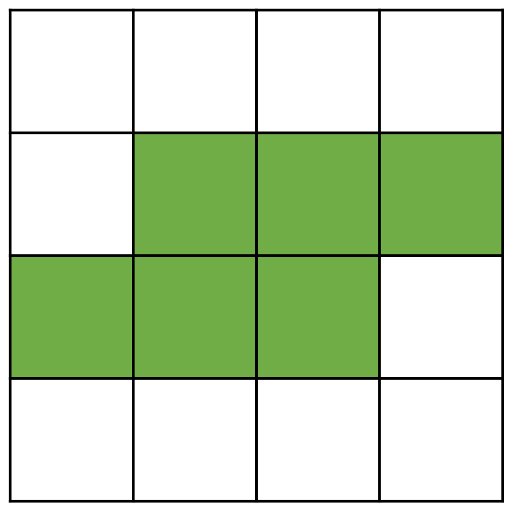
Snake Siamese snake

10-cell still life that consists of two snakes attached together, which can be infinitely extended.



Oscillators

A pattern that repeats itself after a fixed number of generations (known as its period). The term is usually restricted to finite patterns that are not still life, though still life may be thought of as oscillators with period 1.



How does this evolve?

2 Game of Life

- The next state of each cell depends on its current state and its number of live neighbours.
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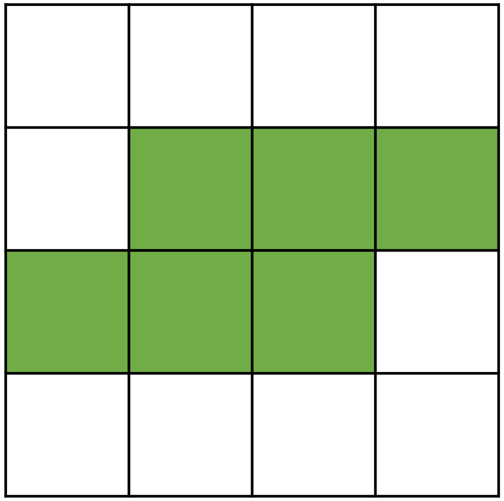

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Game of Life

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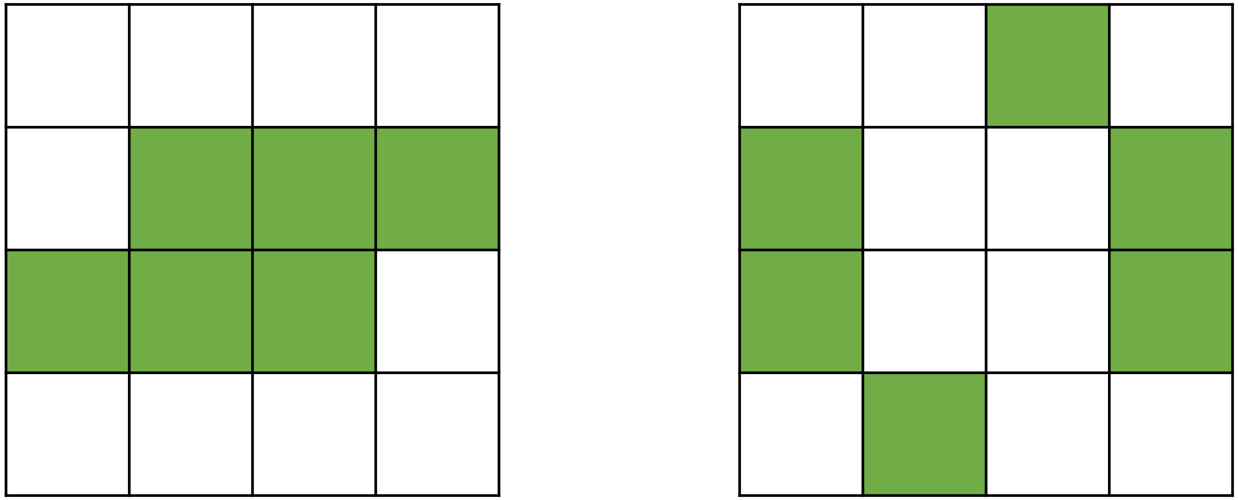

Game of Life

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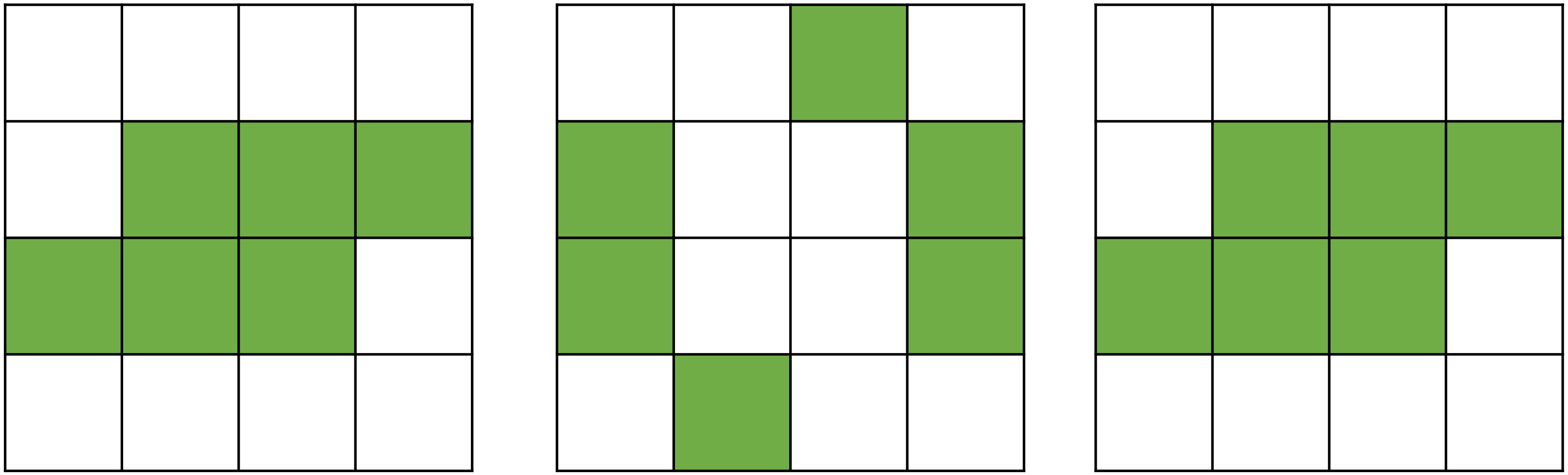
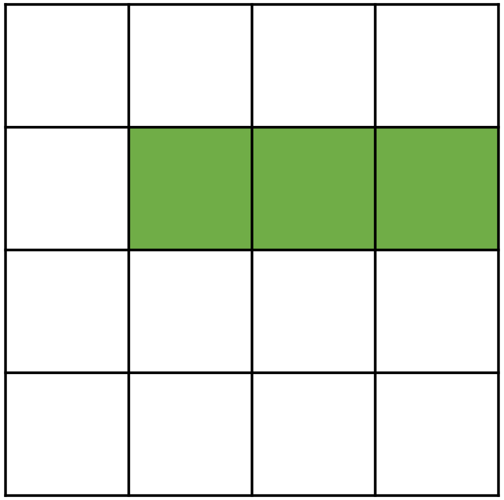
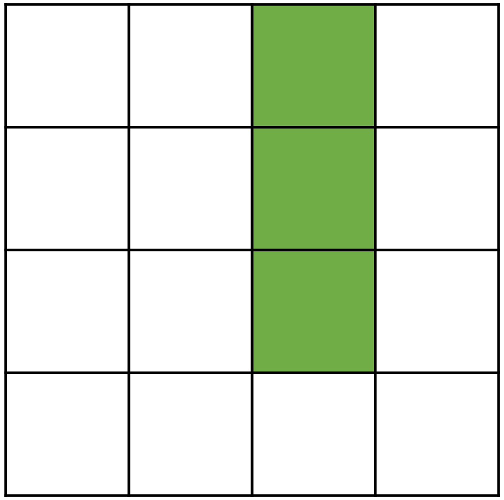


Toad, 6-cell period-2 oscillator

Blinker

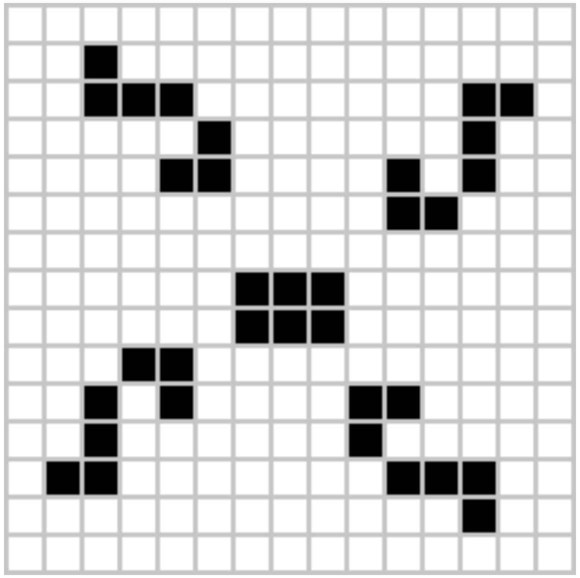
Smallest and most common oscillator, 3-cell period-2.





Dinner table

The first period-12 oscillator to be found.



Spaceship

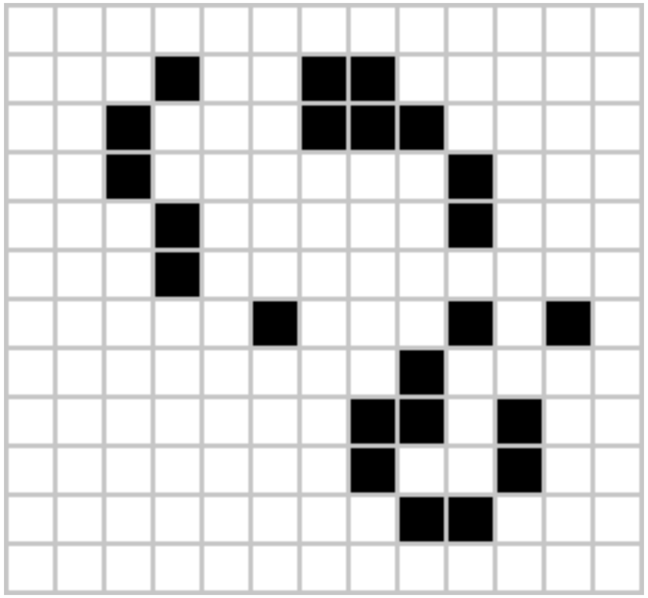
is a finite pattern that returns to its initial state after a number of generations or periods, but in a different location.

Glider, period-4, travels diagonally across the grid

The cells don’t ‘move’, but the pattern of alive cells appear as though a glider is travelling across the background.

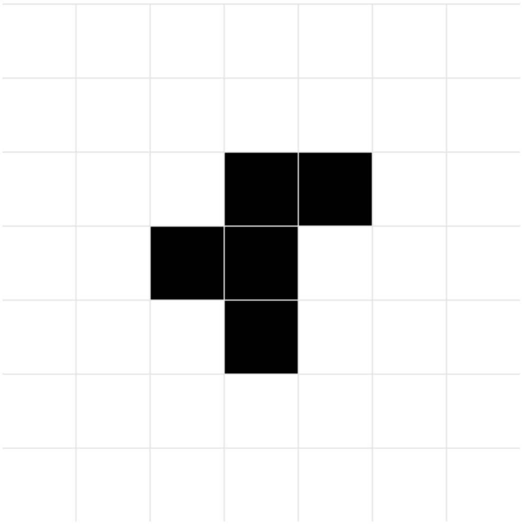
Loafer

20 cell, period-7 spaceship moves orthogonally.



From most initial conditions, GoL quickly reaches a stable state where the number of live cells is nearly constant.

But there are some simple starting conditions that yield a surprising number of live cells and take a long time to settle down. Because these patterns are so long-lived, they are called “**Methuselahs**”.



R-pentomino, 5-cell Methuselahs

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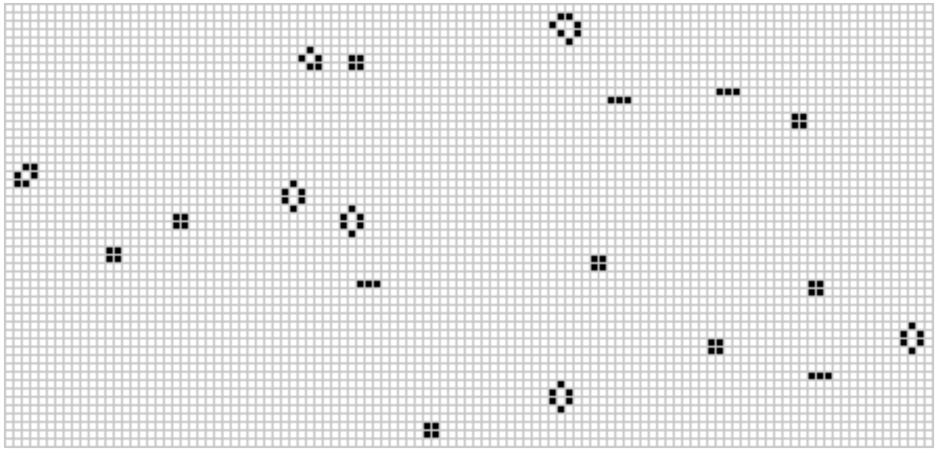

R-pentomino does not **stabilize** until generation 1103, by which time it has a population of 116.

Stabilize: all remaining patterns are either stable, oscillators or gliders that will never collide with another pattern.

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Conway's Conjecture

Conway conjectured that there are no initial patterns that never stabilize. But there are two kinds of patterns that would prove him wrong, "gun" and "puffer train".

Puffer Train

A pattern that moves like a spaceship, except that it leaves debris behind. Thus, a pattern consisting of only a puffer will grow arbitrarily large over time.

Conway’s Conjecture

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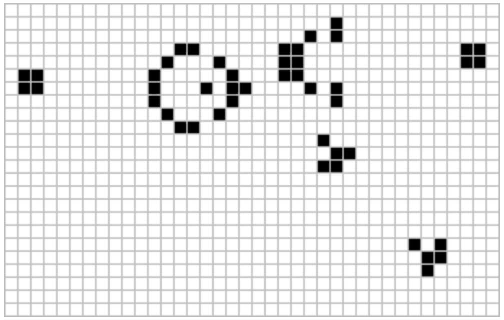
Gosper Glider Gun



First known pattern with unbounded growth of population.

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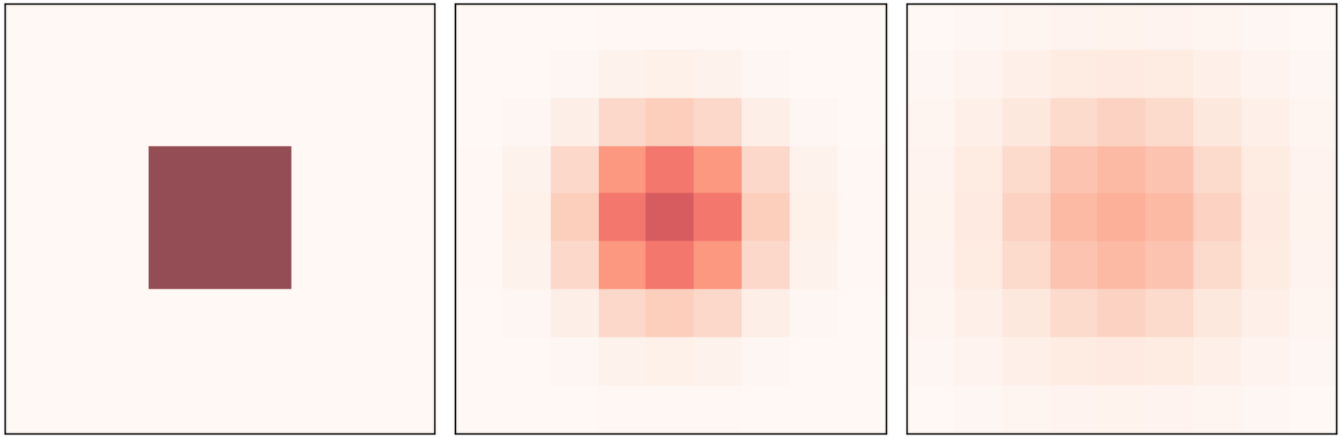
Diffusion

2-D Cellular Automata with state of each cell is a continuous quantity (usually between 0 and 1).

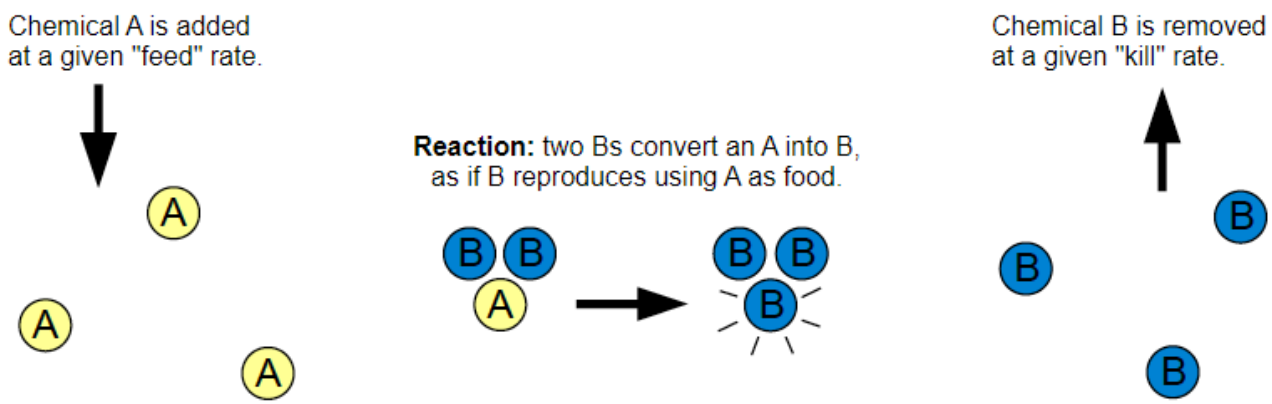
Diffusion process allows concentration to spill over to neighbours.



The chemical spreads from the centre outward, continuing until the concentration is the same everywhere.

Reaction-Diffusion

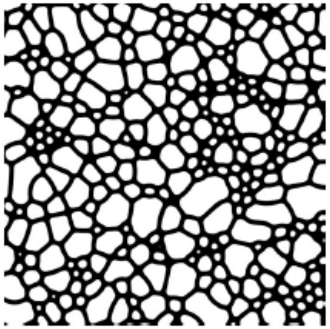
A simulation of two chemicals reacting and diffusing on a 2-D grid.




```
reaction = A * B**2
self.array += ra * cA - reaction + f * (1-A)
self.array2 += rb * cB + reaction - (f+k) * B
```

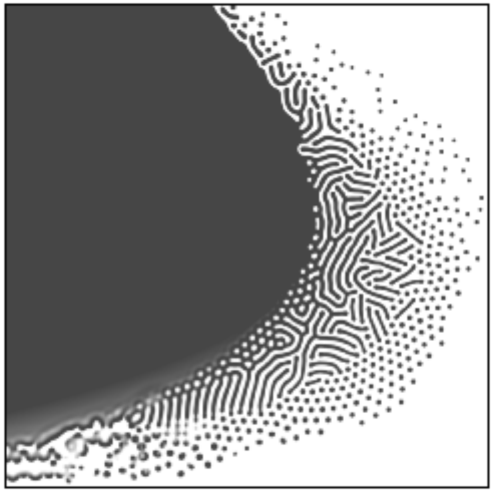
Reaction-Diffusion

Surprisingly complex and dynamic behaviours can arise from these fairly simple rules, and adjusting the two parameters for the feed rate and kill rate can produce a range of different results.



More complex patterns

E.g. the feed and kill rates can vary across the grid to give different patterns in different areas.



kill rate varies along the x axis (from 0.045 to 0.07) and the feed rate varies along the y axis (from 0.01 to 0.1)