

Conway's Life

It's a Wonderful Day in
the Neighborhood

An introduction to cellular automata

Topic Outline

- Cellular Automata
- Conway's *Game of Life*
- *Game of Life* Rules
- Classification of Patterns
- *Epic* Conway video
- Resources for further study

What is Cellular Automata?

- A discrete modeling process
- Studied in computer science, mathematics, physics, complexity science, theoretical biology and microstructure modeling
- Concept discovered in 1940's by Stanislaw Ulam and John von Neumann
- Conway's *Game of Life* most well known cellular automata

A Cellular Automation Consists of

- A regular, n-dimensional grid of cells
- A finite set of cell states (on/off, alive/dead, red/green/blue, etc.)
- A set of rules for determining a cell's next state based on its own state and the state of the cells in its surrounding neighborhood

Conway's *Game of Life*

- Computationally universal - Turing complete
- Played on infinite, orthogonal 2 dimensional grid
- 2 possible cell states: alive or dead
- Martin Gardner first published *Game of Life* in October 1970 issue of *Scientific American*

Game of Life Rules

A living cell dies if it has

- fewer than two live neighbors (under-population), or
- more than three live neighbors (over-population)

A dead (unoccupied) cell comes alive if it has

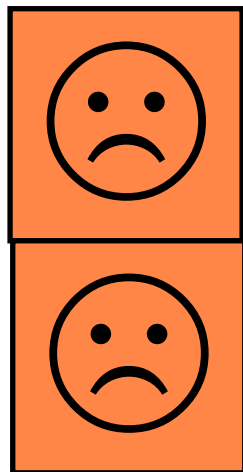
- exactly three live neighbors (reproduction)

Lonely Cells



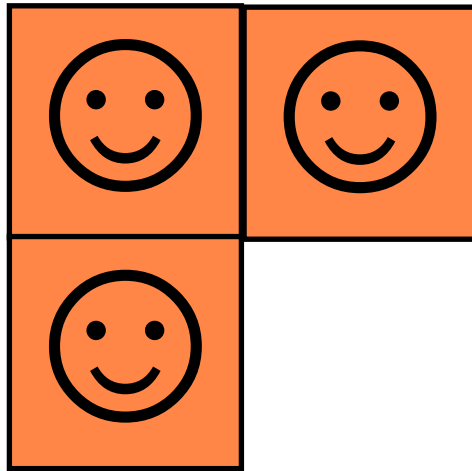
One living cell by itself
gets lonely and dies

and...



Two living cells still get
lonely and die

Happy Cells



Living cells that each have
two neighbors are happy
and survive

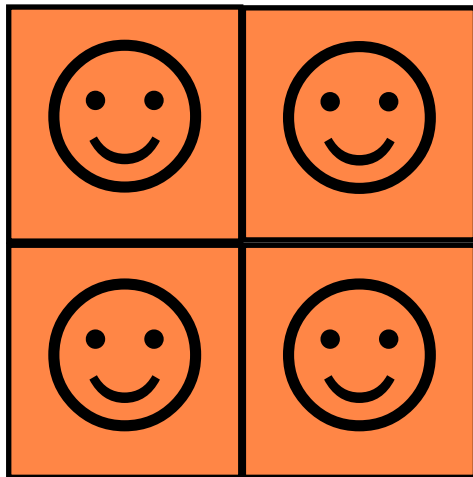
and furthermore...



This happy neighborhood
gives birth to yet another
happy cell

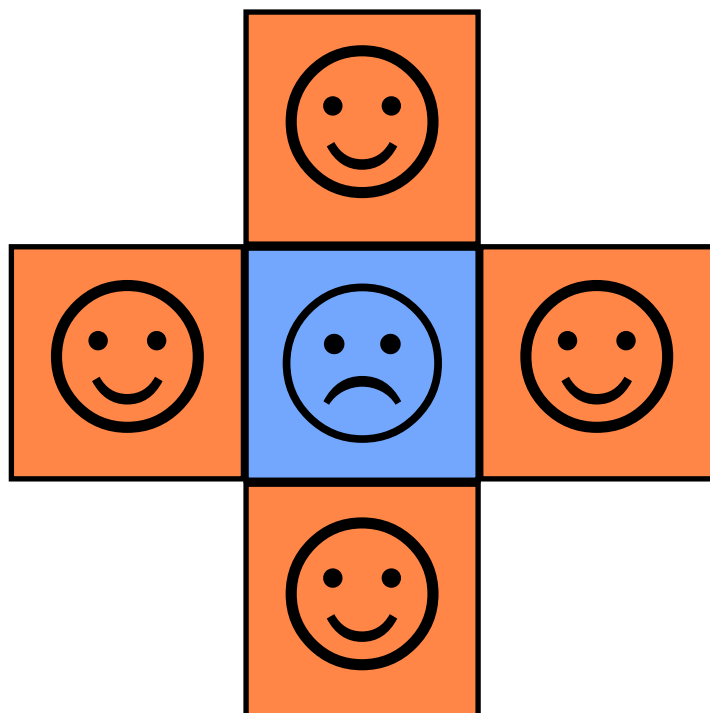
which results in...

Happy vs Overcrowded Neighborhoods



A happy neighborhood
where everyone has
three happy neighbors

however...



This unhappy cell has too
many neighbors and dies

Catagories of Patterns

Pattern	~# known
Still Life	213
Oscillator	440
Spaceship	108
Puffer	22
Gun	35
Methuselah	37
Switch Engine	3

Still Lives

- Stay the same from generation to generation
- Considered stable neighborhoods
- Have period one (when viewed as an Oscillator)
- At least 213 listed patterns

Still Lives - Block

A living cell dies if it has

- fewer than two live neighbors (under-population), or
- more than three live neighbors (over-population)

A dead cell comes alive if it has

- exactly three live neighbors (reproduction)



Still Lifes - Tub

A living cell dies if it has

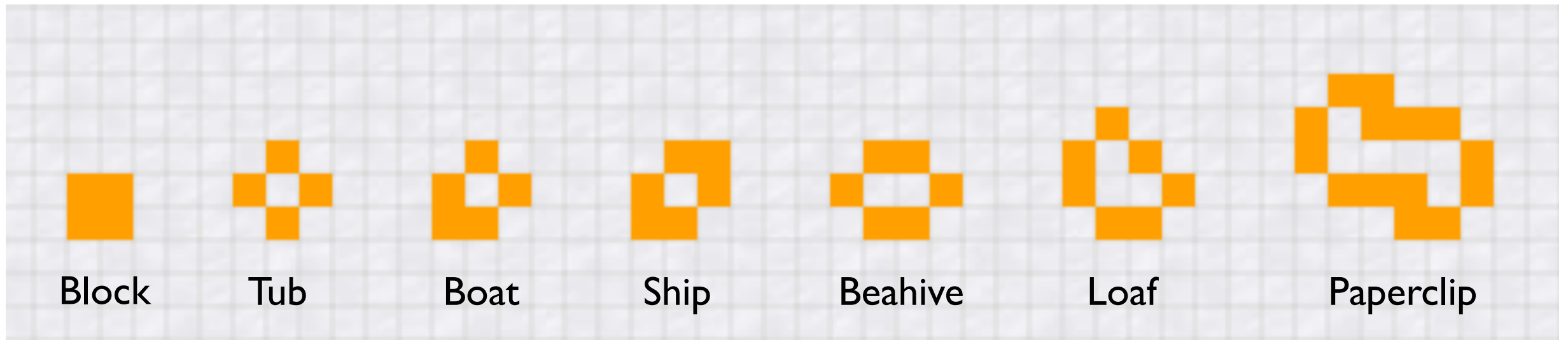
- fewer than two live neighbors (under-population), or
- more than three live neighbors (over-population)

A dead cell comes alive if it has

- exactly three live neighbors (reproduction)



Still Life Examples



Oscillators

- A series of patterns which repeat after a finite number of generations
- Considered a stable neighborhood
- Have a finite period greater than one
- At least 440 listed patterns

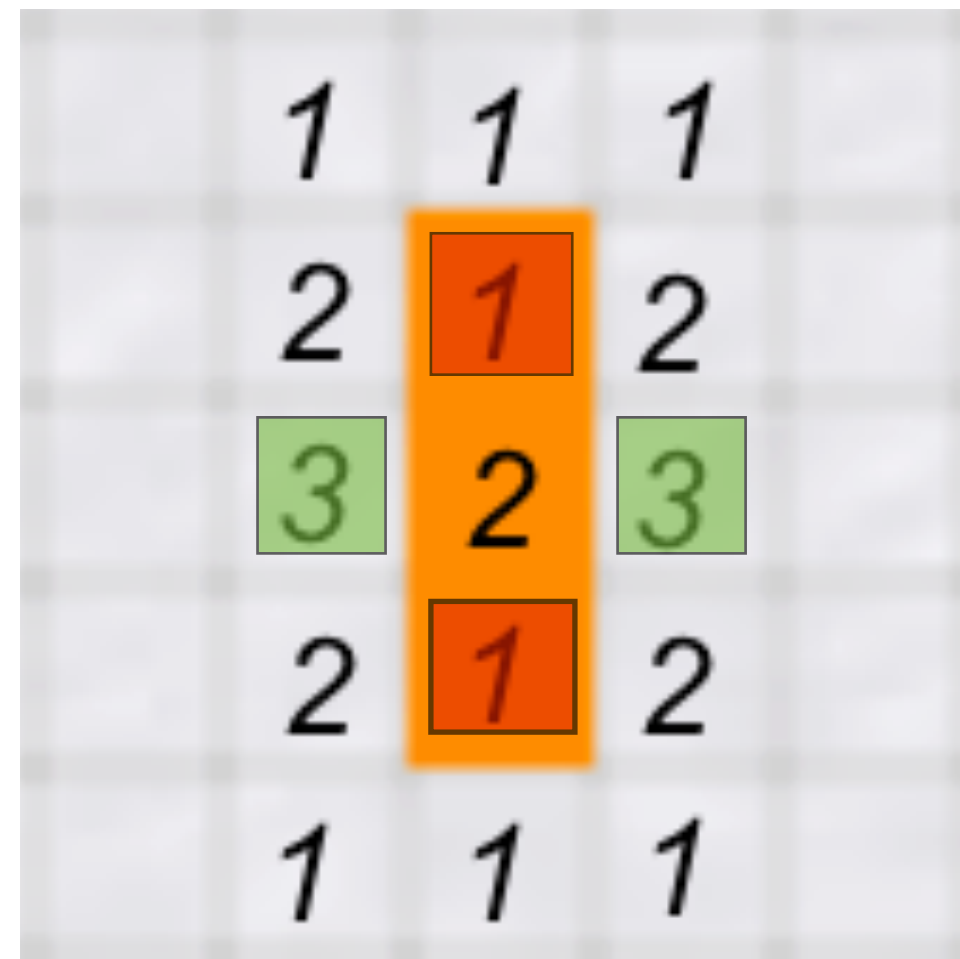
Oscillators - Blinker

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- more than three live neighbors (over-population)

A dead cell comes alive if it has

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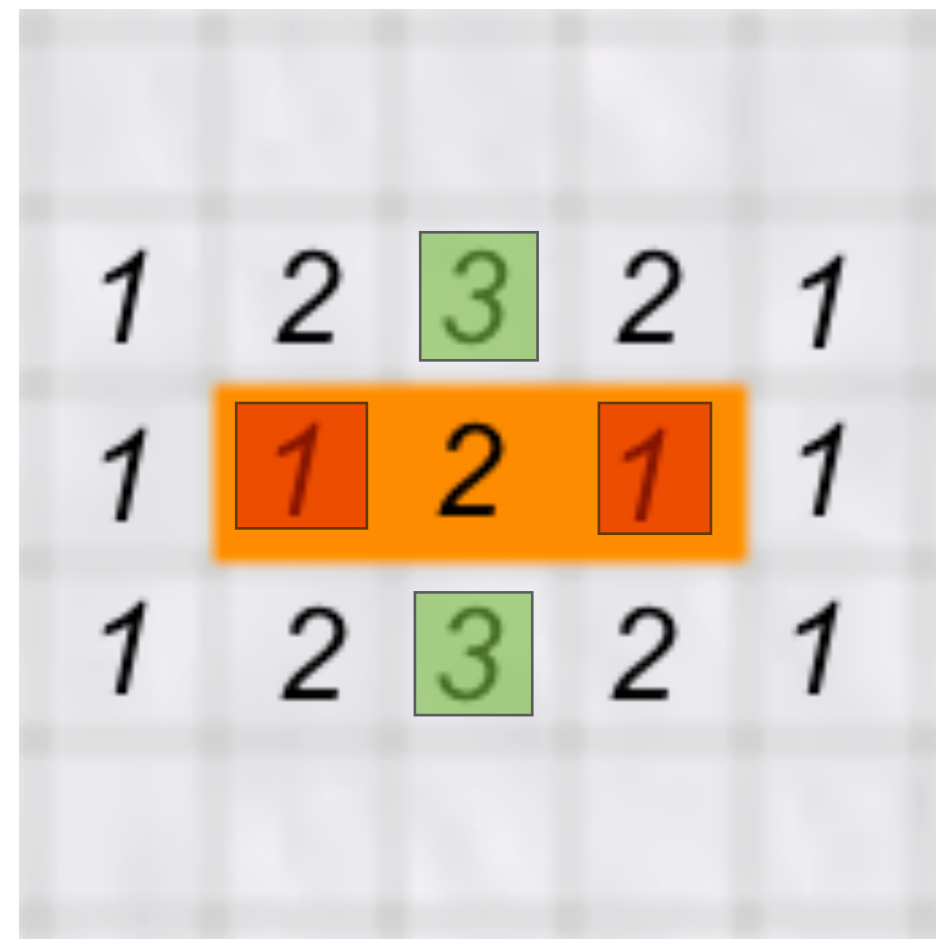
Oscillators - Blinker

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Oscillator Examples

- Simple Oscillators with a period of 2
 - Blinker
 - Toad
 - Beacon
- Curious Oscillators



Spaceships

- A series of patterns which, like oscillators, repeat after a finite number of generations
- Unlike oscillators, migrate across the grid
- Have finite period greater than one
- At least 108 listed patterns

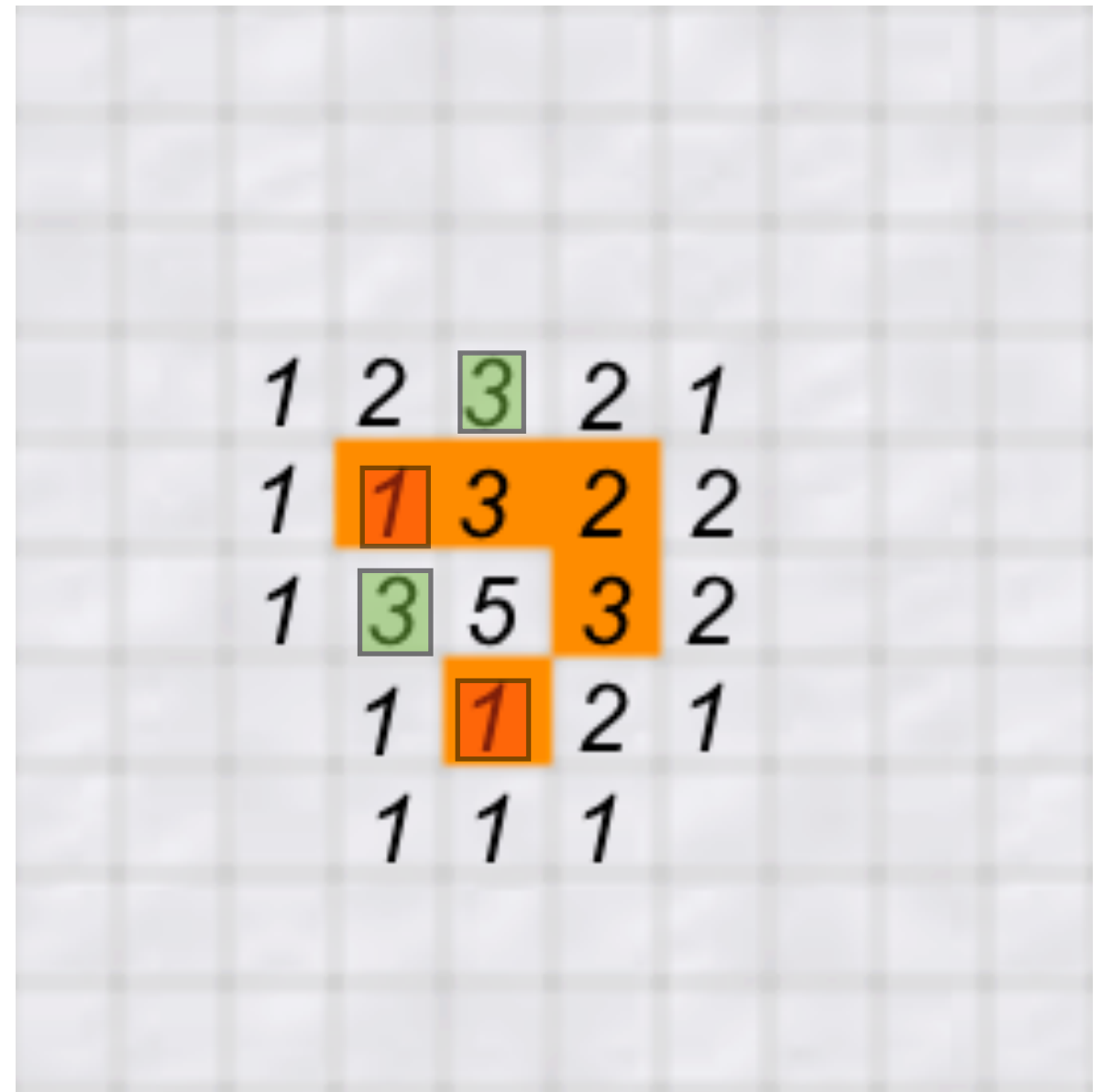
Spaceships - Glider

A living cell dies if it has

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A dead cell comes alive if it has

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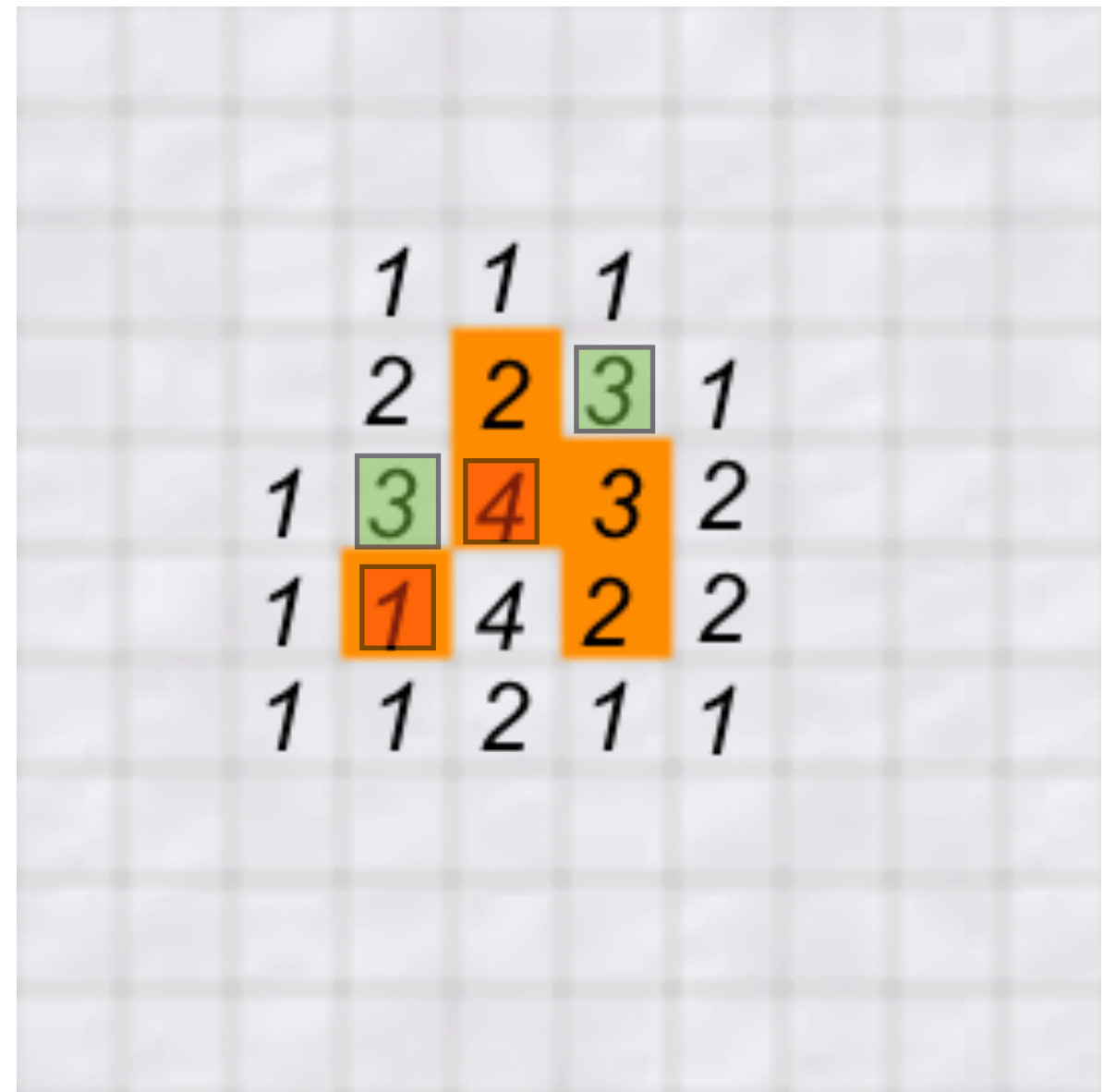
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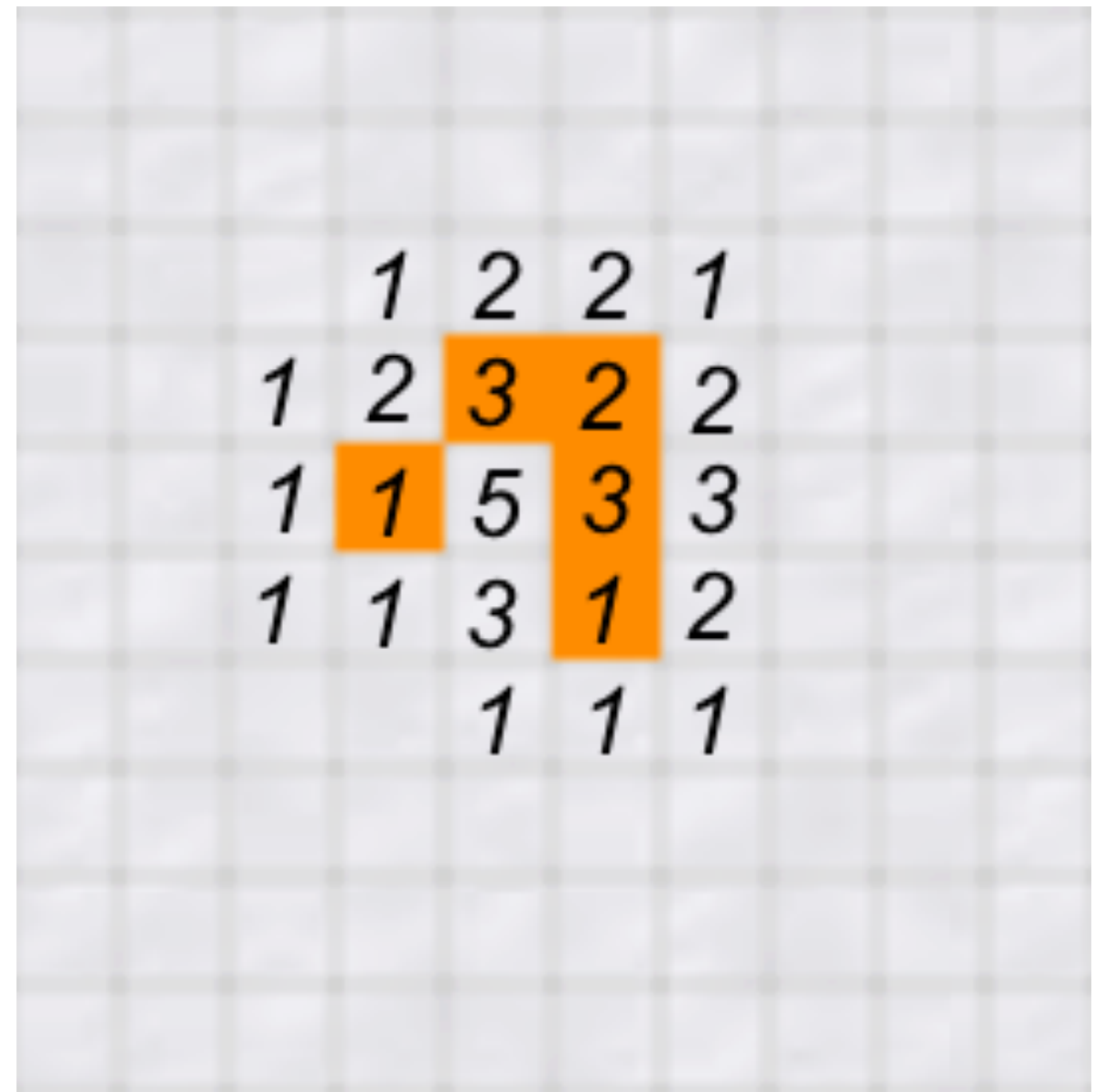
Spaceships - Glider

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Spaceship Example

Fish

- elementary spaceship
- period of 4

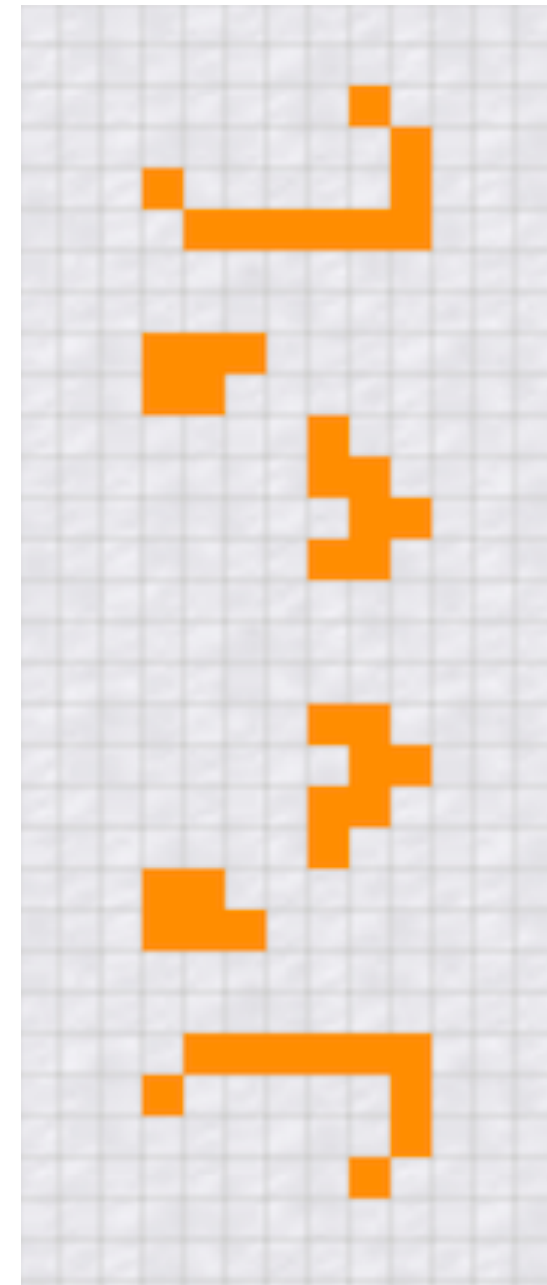


Puffers

- Like spaceships, migrate across the grid
- Leave a trail of debris
- Have a finite period greater than one
- At least 22 listed patterns

Puffer Example

- Named “Puffer 1”
- First puffer to be discovered
- Discovered by Bill Gosper in 1971

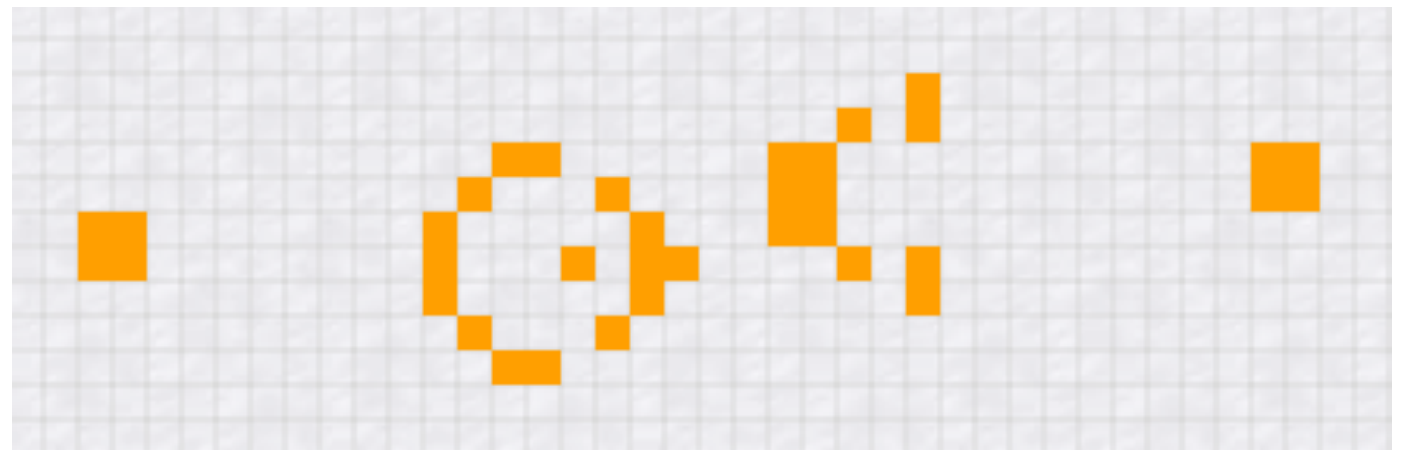


Guns

- Behave similar to an oscillator
- Produce spaceships
- Have a finite period greater than one
- At least 35 listed patterns

Gun Example

- Gosper glider gun
- First gun discovered
- Discovered by Bill Gosper in 1971



Methuselahs

- Morph through many, many generations
- Eventually die out or stabilize into constellations of still lifes and oscillators
- At least 37 listed patterns

Methuselah Examples

- R-pentamino - stabilizes after 1103 generations
- Acorn - stabilizes after 5206 generations



Switch Engines

- Behave similar to puffers
- Migrate across the grid
- Lay down a pattern of blocks as they migrate
- At least 2 listed patterns

Switch Engine Example

- Simple switch engine predecessor



Epic *Game of Life*

- Video made by Emanuele Ascani
- Shows Turing complete simulations
- Demonstrates the artistic side of cellular automata
- Watch on YouTube
<https://www.youtube.com/watch?v=C2vglCfQawE>

Resources for Further Study

- Wikipedia - Cellular Automata
https://en.wikipedia.org/wiki/Cellular_automaton
- Wikipedia - Conway's *Game of Life*
https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life
- *Game of Life* Wiki
http://www.conwaylife.com/wiki/Main_Page
- Javascript *Game of Life* Web App
<http://www.intravisions.com/games/conway/conway.html>

Game of Life Side Show

[http://github.com/fractalxaos/
barcamp/ConwaysLife.pdf](http://github.com/fractalxaos/barcamp/ConwaysLife.pdf)