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 originally discovered in 1940‘s by Stanislaw Ulam and John von Neumann
- Sometimes considered the biggest waste of time in computer science

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 generation state
- Next state determined by present state and the state the 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)

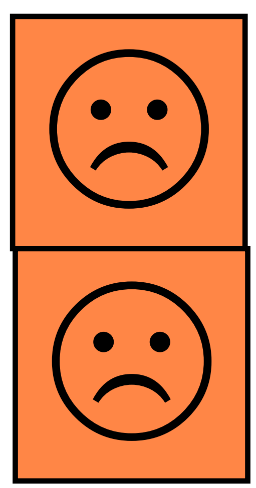
A dead (unoccupied) cell comes alive if it has

- exactly three live neighbors (reproduction)

Lonely Cells

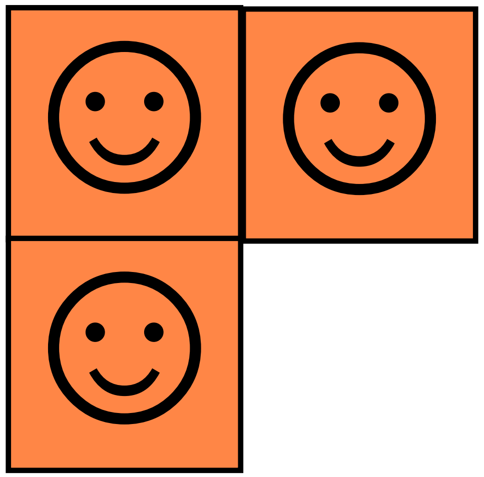
One living cell by itself
gets lonely and dies

and...



Two living cells still get
lonely and die

Happy Cells



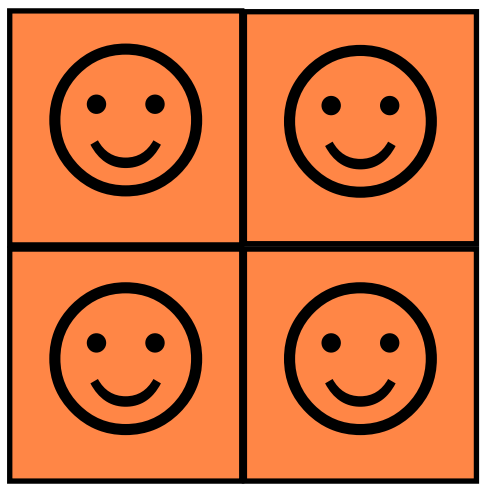
Living cells that each have two neighbors are happy and survive

and furthermore...

This happy neighborhood gives birth to yet another happy cell

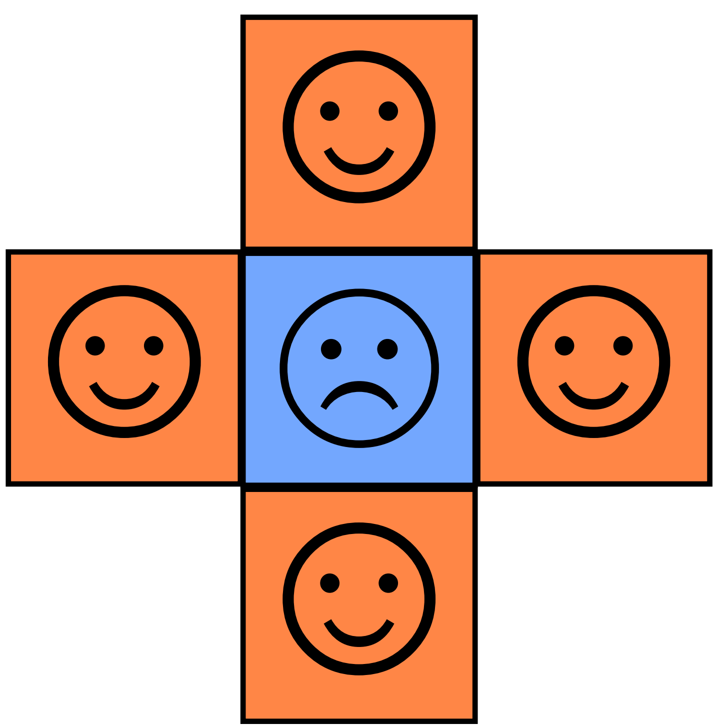
which results in...

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 Lifes

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

Still Lifes - 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

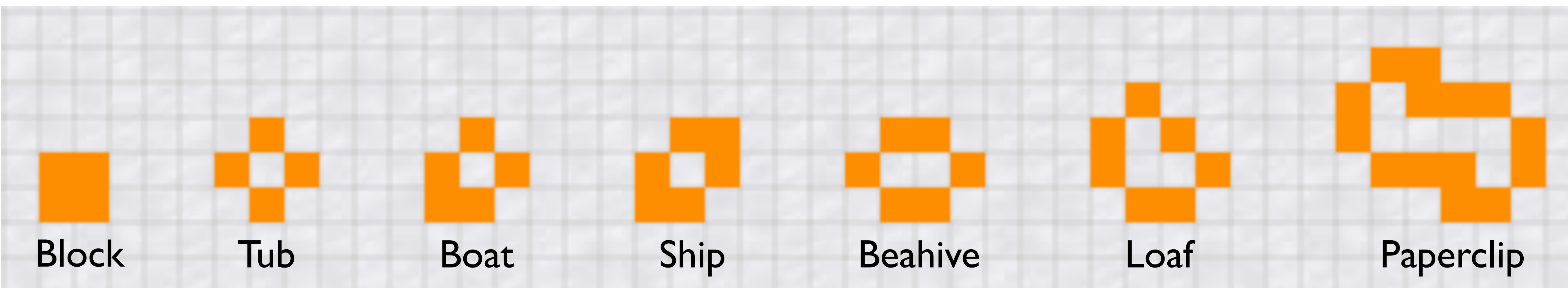
A living cell dies if it has

- 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 sequence 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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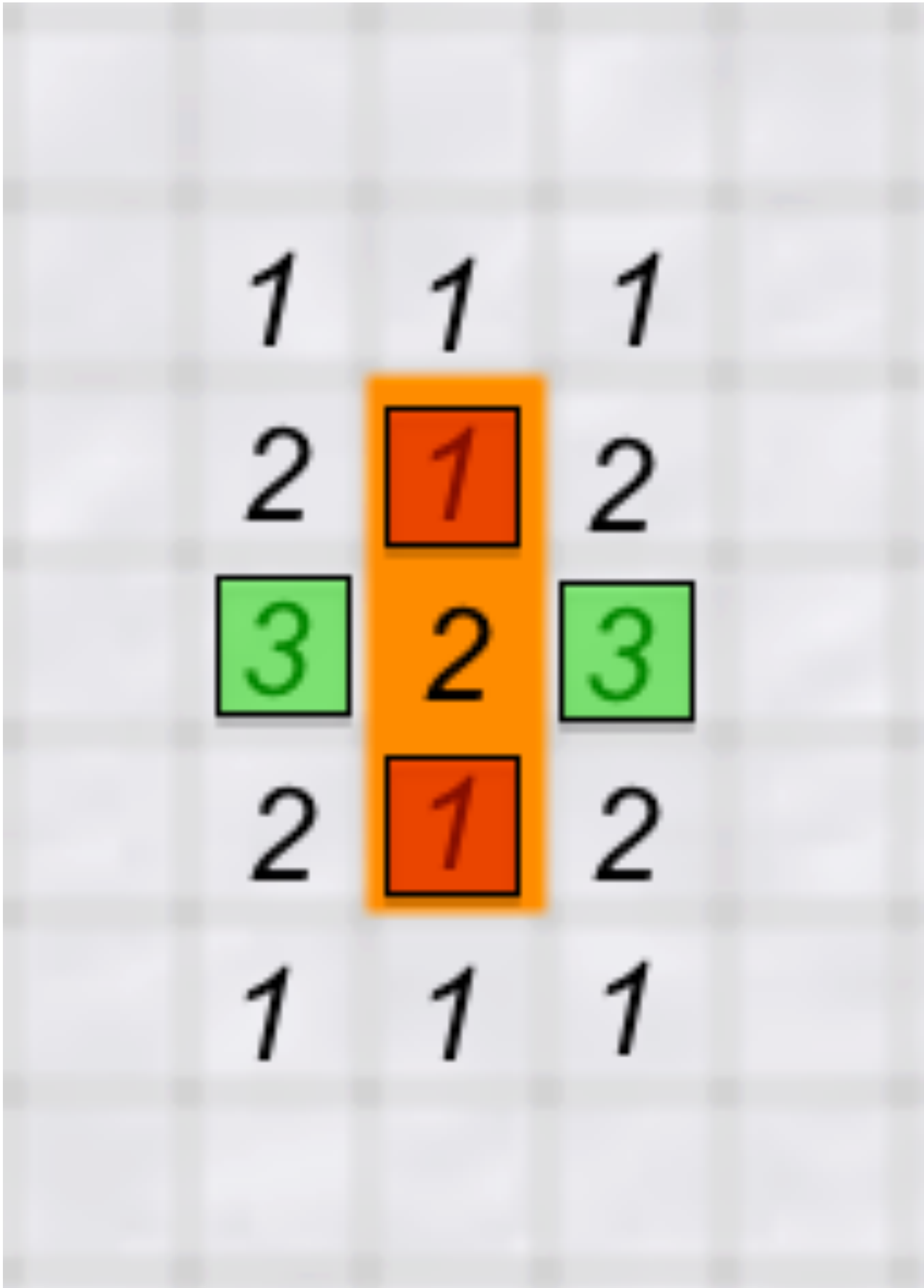

Oscillators - Blinker

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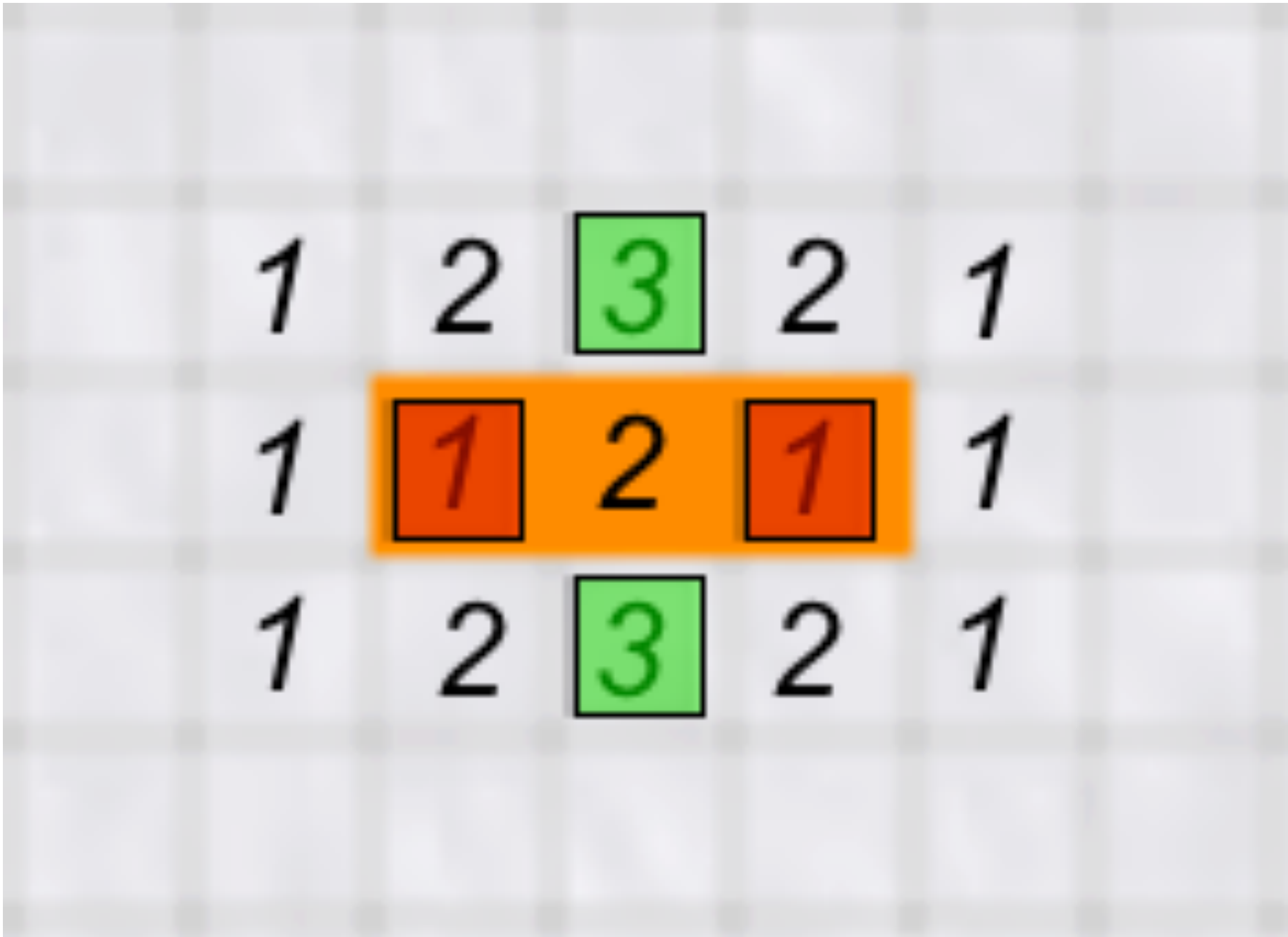
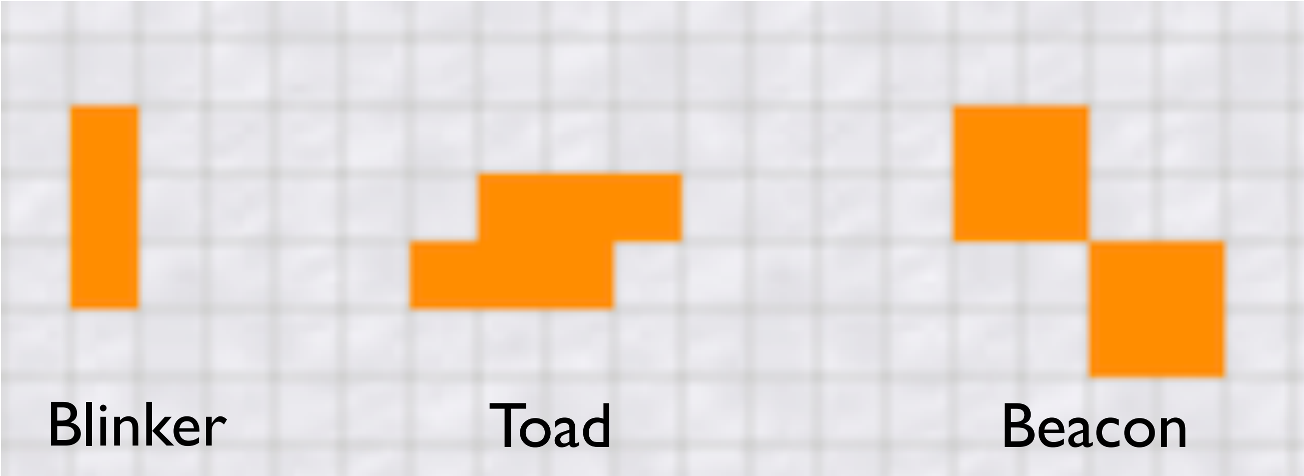


Oscillator Examples

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



Spaceships

- A sequence 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

- 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)

Spaceships - Glider

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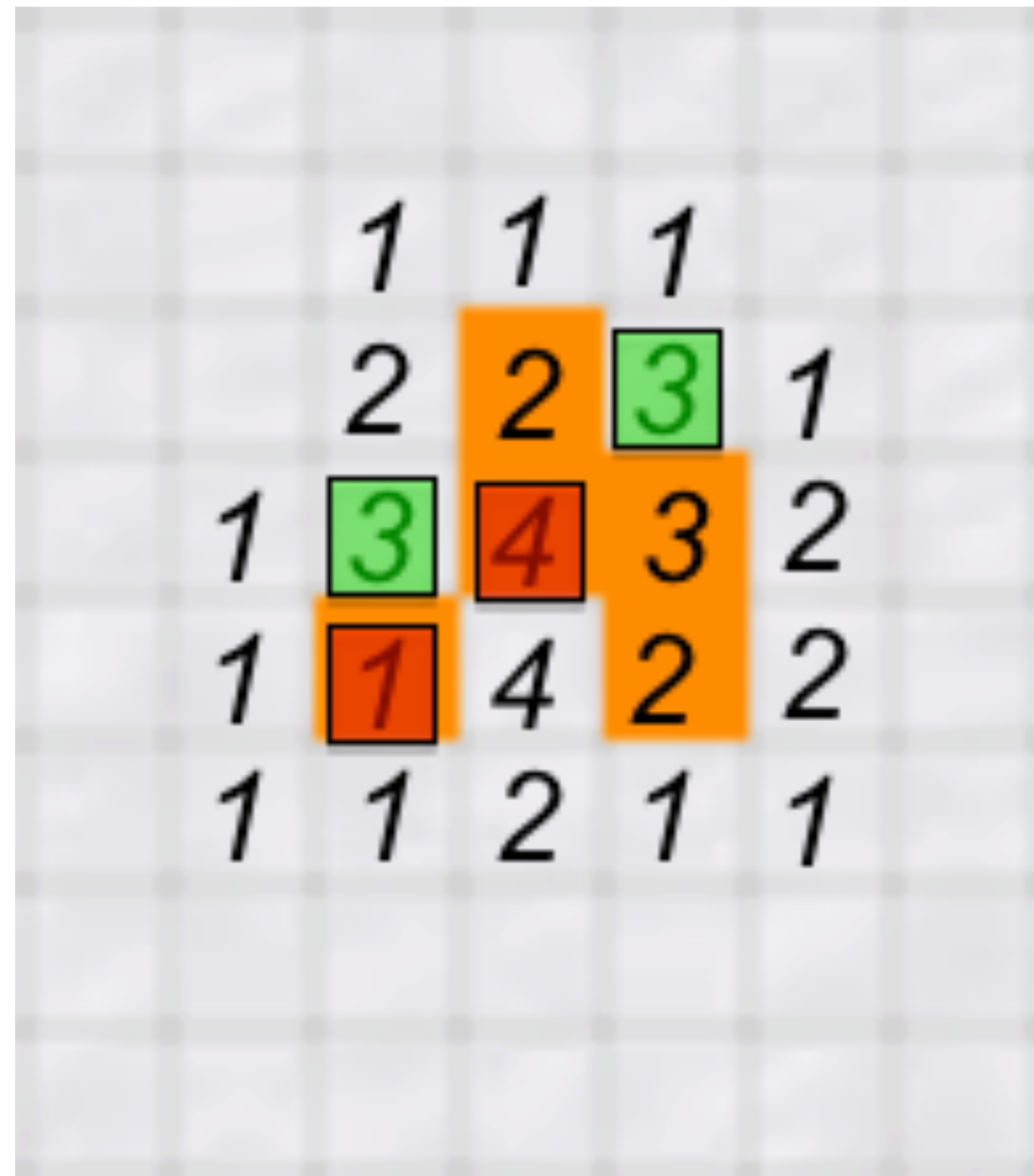

Spaceships - Glider

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Spaceship Example

Fish

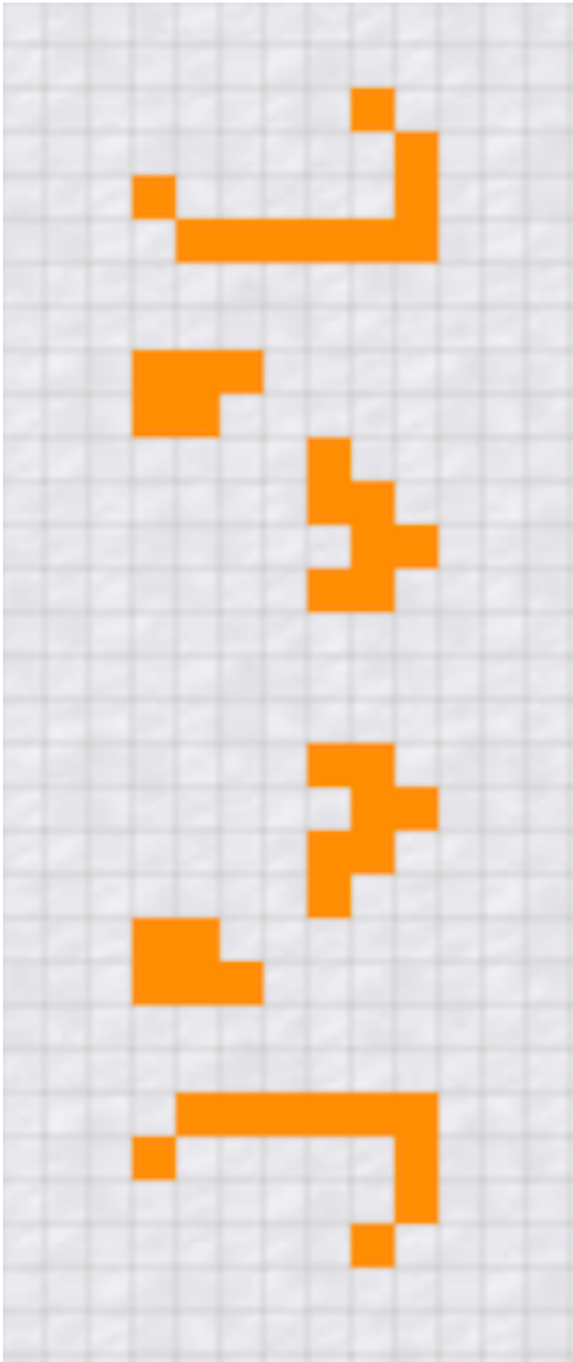
- elementary spaceship
- period of 4

Puffers

- Similar to spaceships
- Migrate across the grid leaving a trail of debris
- Have a finite period greater than one
- At least 22 listed patterns

Puffer Example

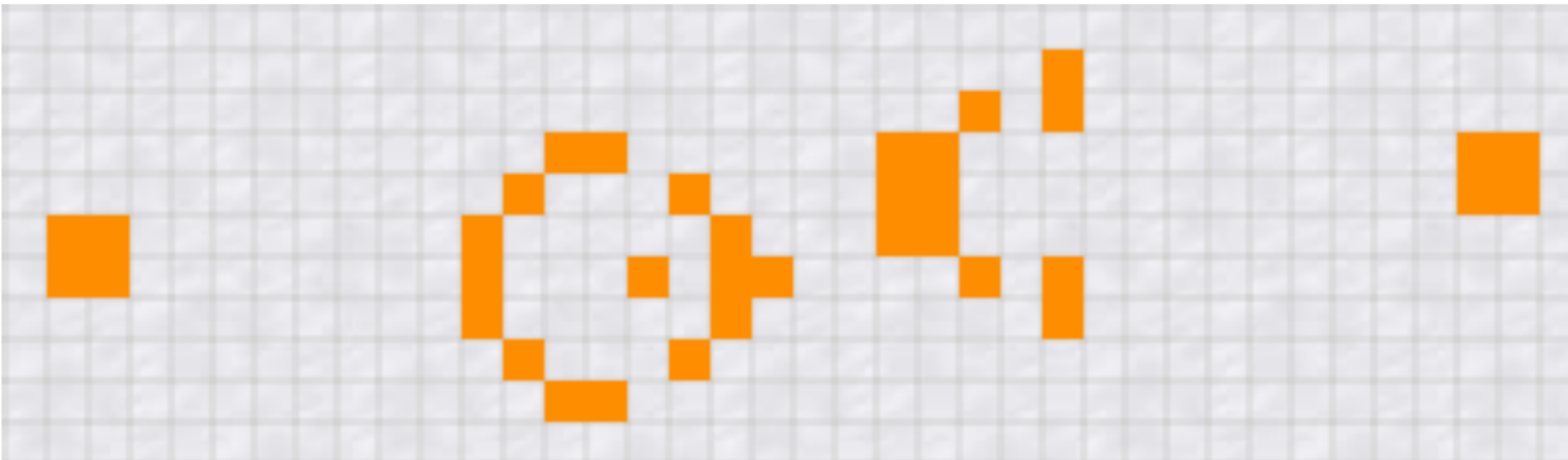
- Named "Puffer 1"
- First puffer to be discovered
- Discovered by Bill Gosper in 1971



Guns

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

Gun Example



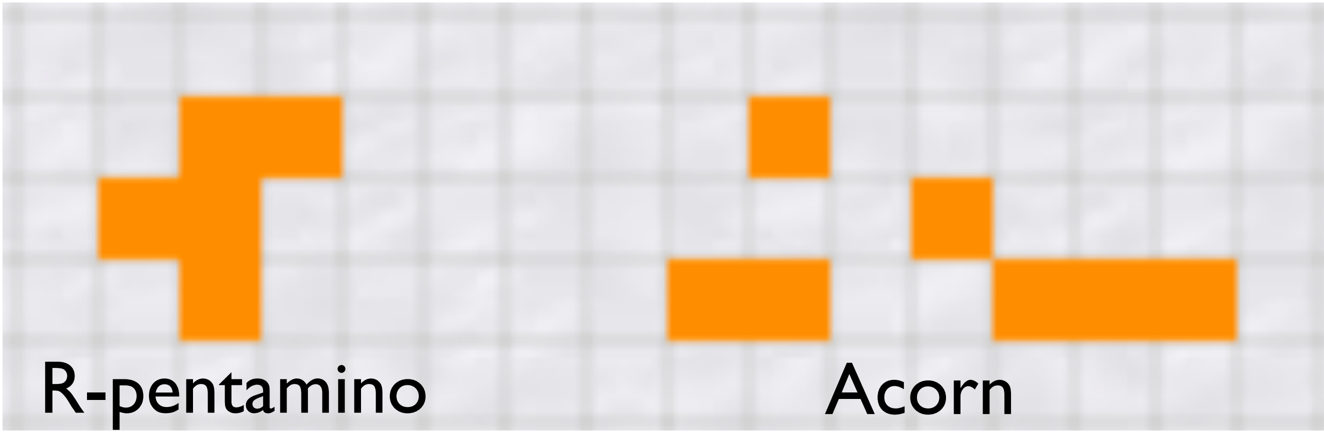
- Gosper glider gun
- First gun discovered
- Discovered by Bill Gosper in 1971

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, 10 cell switch engine predecessor
- Begins laying blocks after 354 generations

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=C2vgICfQawE

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