# 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
- Golly App
- *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 of 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)

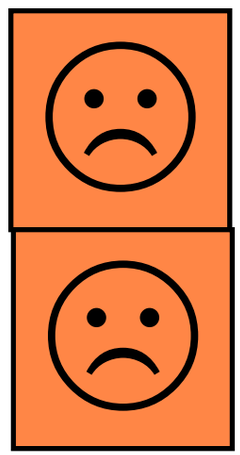
# Elucidation of Rules

- Under-population
- Reproduction
- Stable Neighborhoods
- Over-population

# Under-populated Neighborhoods

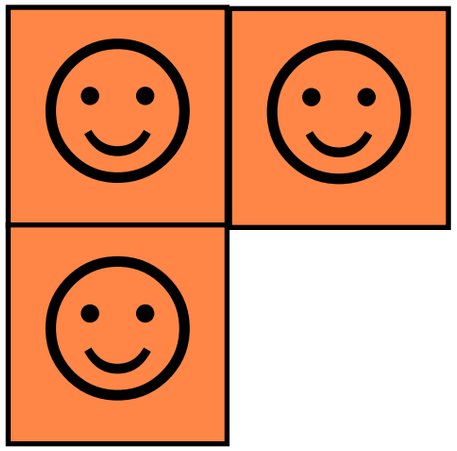
One living cell by itself
gets lonely and dies

and...



Two living cells still get
lonely and die

# Reproductive Neighborhoods



Living cells that each have
two neighbors are happy
and survive

and furthermore...

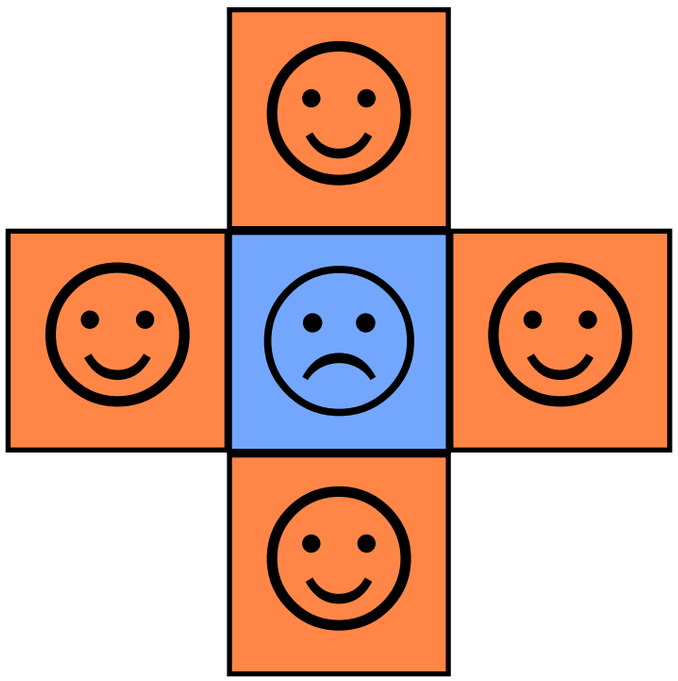
**This** happy neighborhood
gives birth to yet another
happy cell

which results in...

# Stable vs Over-populated Neighborhoods

A stable 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

Apply rules:

- Under-population: NONE
- Over-population: NONE
- Reproduction: NONE

Therefore this neighborhood stays the same.

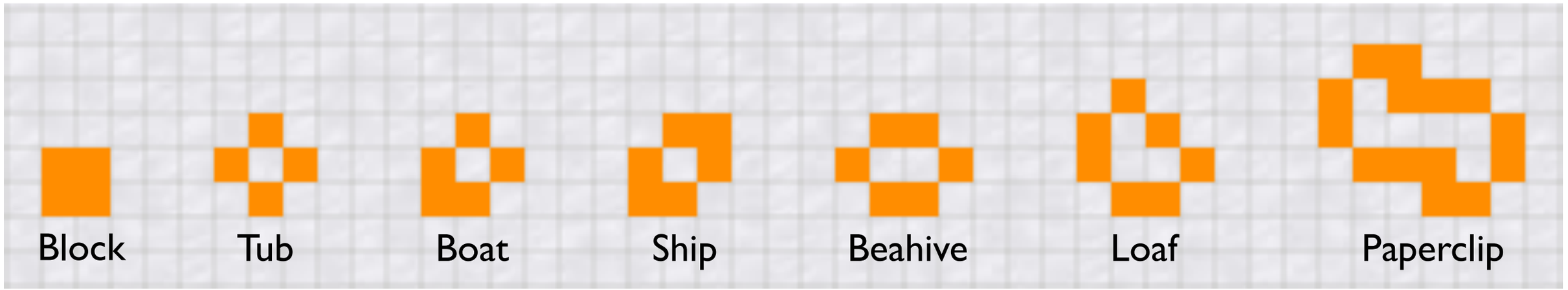
# Still Lifes - Tub

Apply rules:

- Under-population: NONE
- Over-population: NONE
- Reproduction: NONE

Therefore this neighborhood stays the same.

# Still Life Examples



# Oscillators

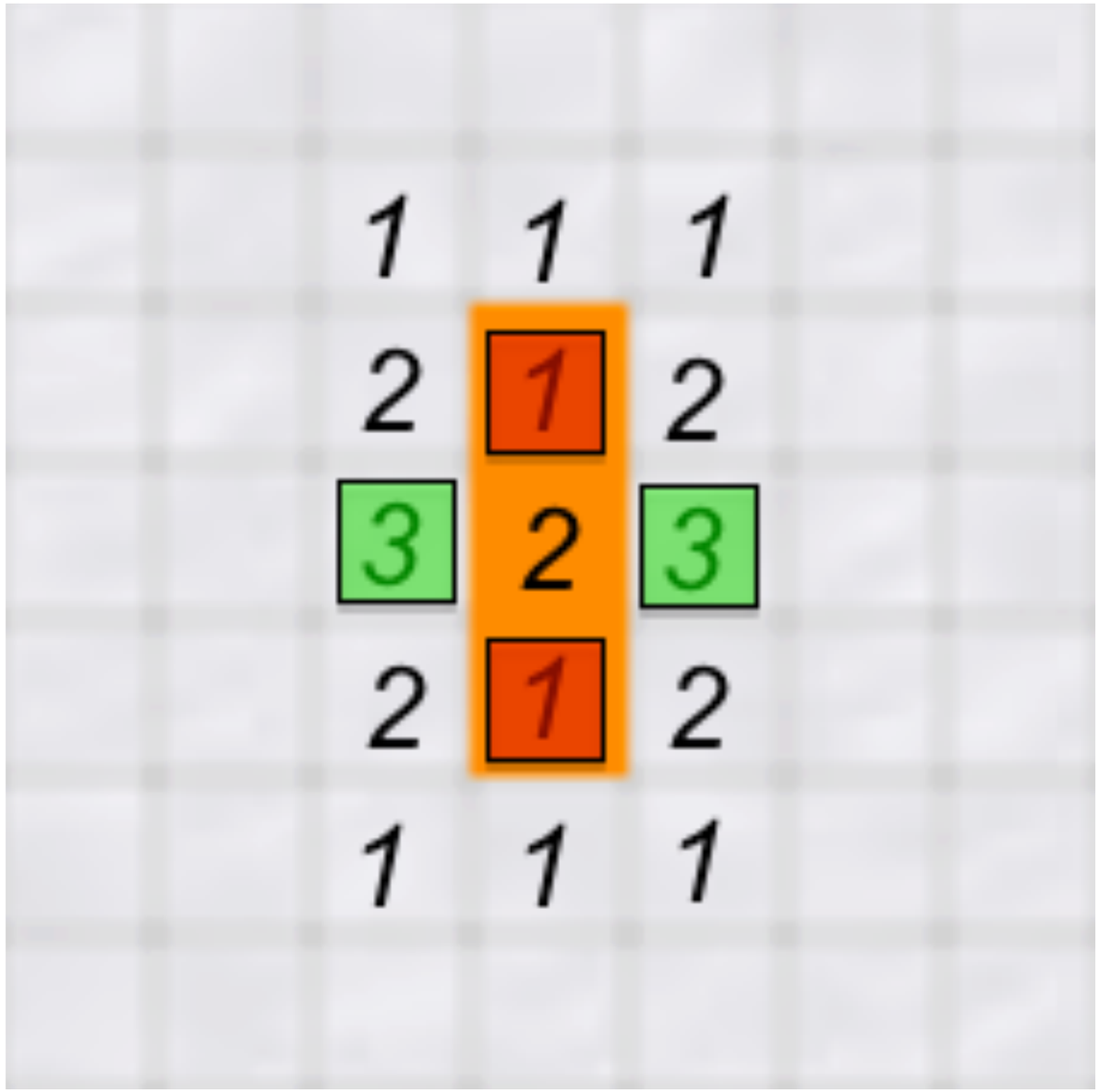
- A sequence of patterns which repeat after a finite number of generations
- Considered a stable neighborhood
- Have a finite period greater than one
- At least 440 listed patterns

# Oscillators - Blinker

Apply rules:

- Under-population: **red** cells die
- Over-population: NONE
- Reproduction: **green** cells become alive

Therefore this neighborhood morphs to...



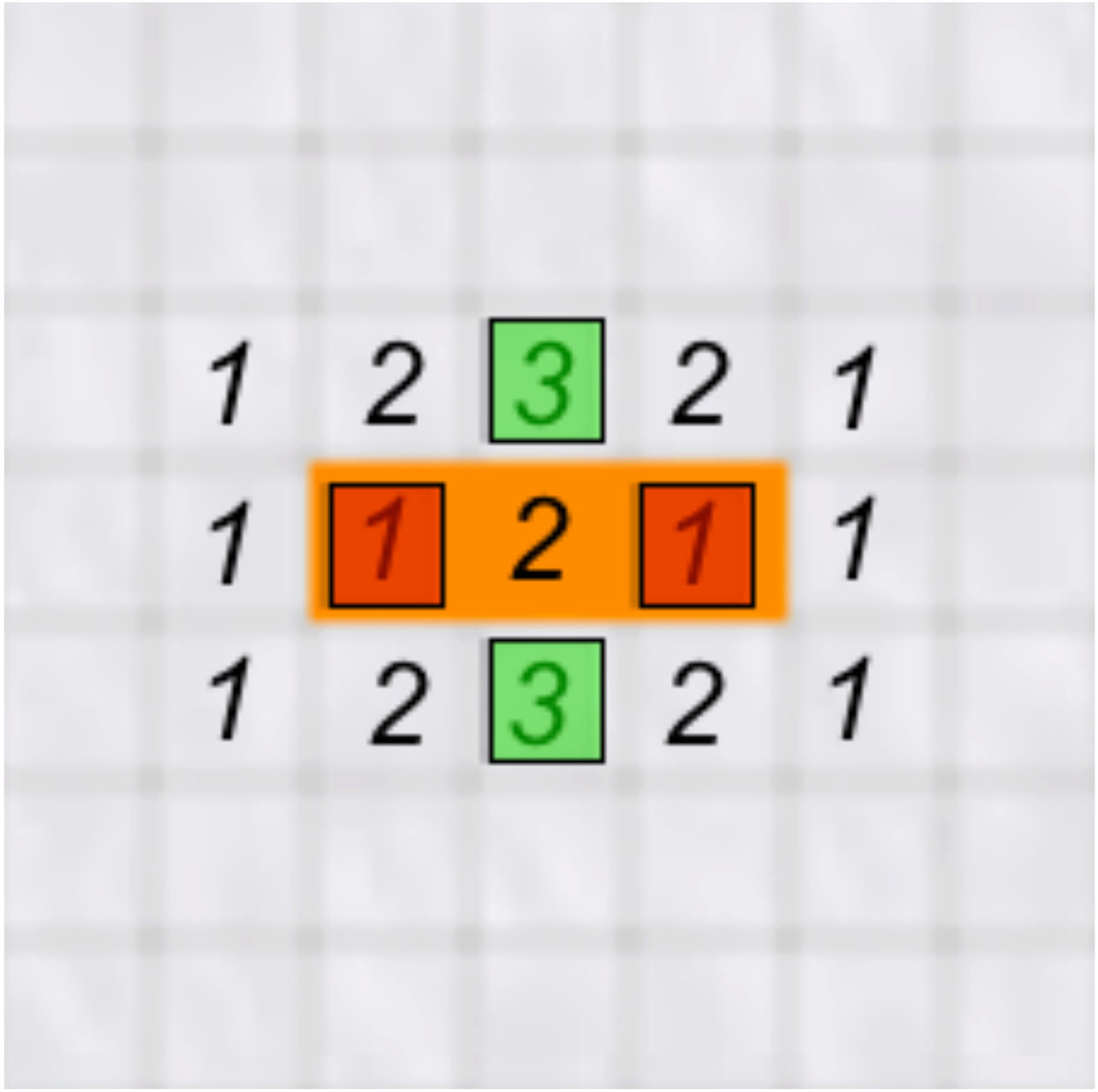
# Oscillators - Blinker

Apply rules:

- Under-population: **red** cells die
- Over-population: NONE
- Reproduction: **green** cells become alive

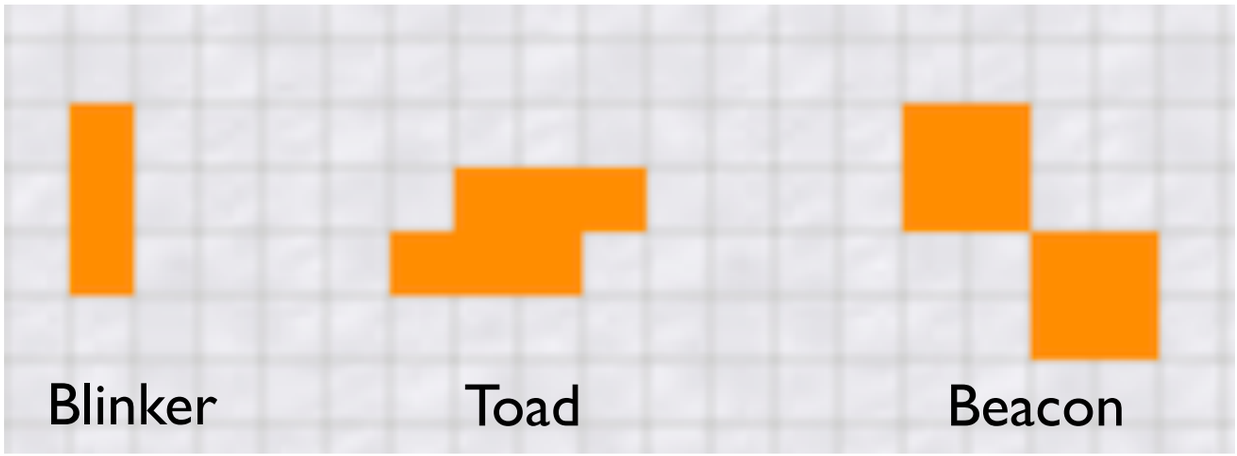
Therefore this neighborhood morphs back to the previous neighborhood.

(And so on to viscosity...)

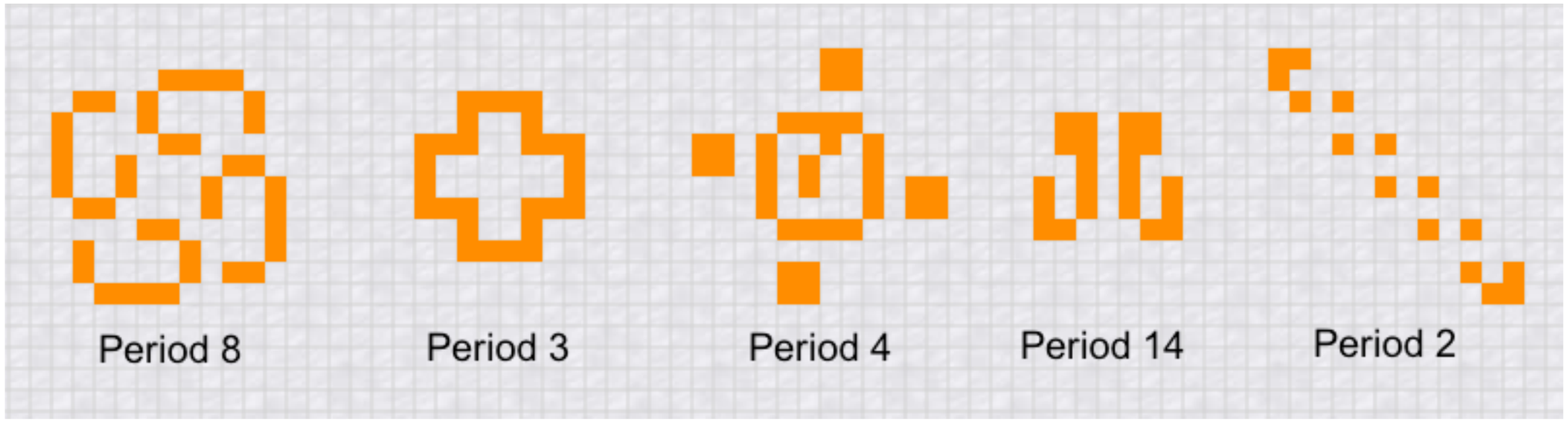


# Oscillator Examples

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



# 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

Apply rules:

- Under-population: **red** cells die
- Over-population: NONE
- Reproduction: **green** cells become alive

Therefore this neighborhood morphs to...

# Spaceships - Glider

Apply rules:

- Under-population: one **red** cell dies
- Over-population: one **red** cell dies
- Reproduction: **green** cells become alive

Therefore this neighborhood morphs to...

# Spaceships - Glider

Apply rules:

- Under-population: **red** cells die
- Over-population: NONE
- Reproduction: **green** cells become alive

This neighborhood, after 2 more generations, morphs back to the original neighborhood,

EXCEPT...translated one cell diagonally to the upper right.

# Spaceship Example

Fish

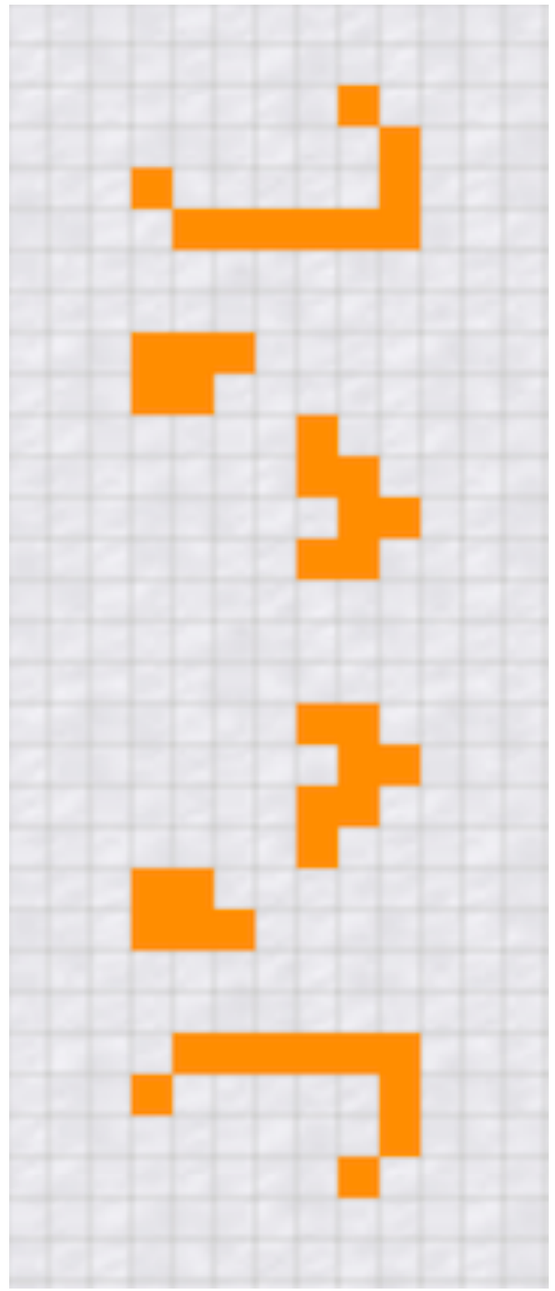
- Elementary spaceship
- Period of 4

# 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

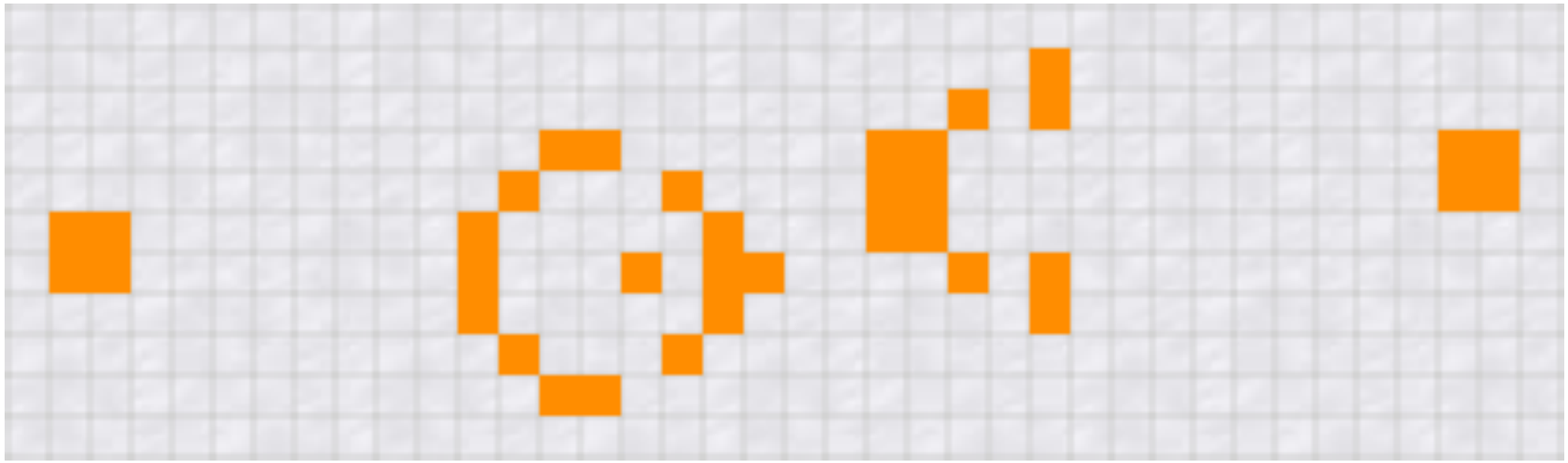
- Named "Puffer 1"
- First puffer pattern discovered
- Period of 32
- Discovered by Bill Gosper in 1971



# Guns

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

# Gun Example



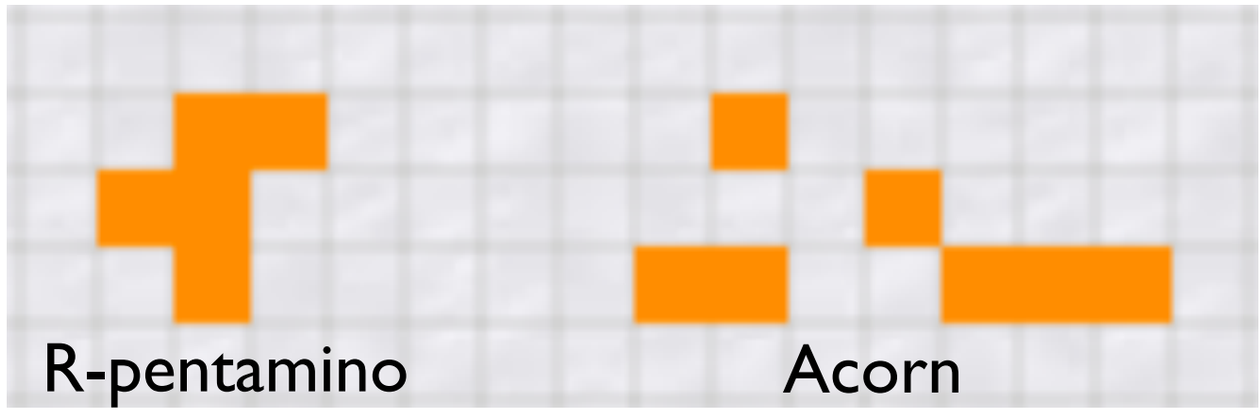
- Named “Gosper Glider Gun”
- First gun pattern discovered
- Period of 30
- Discovered by Bill Gosper in 1971

# 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

# Golly App

- Open Source Desktop Application
- Available for Ubuntu and Mint
- Includes Extensive Library of Patterns
- Uses Efficient Hashlife Algorithm
- Official Website: *golly.sourceforge.net*

# *Epic Game of Life* Video

- Video made by Emanuele Ascani
- Shows Turing complete simulations
- Demonstrates the artistic side of cellular automata
- Watch on YouTube
  *www.youtube.com/watch?v=C2vgICfQawE*

# Resources for Further Study

- Wikipedia - Cellular Automata
  *wikipedia.org/wiki/Cellular_automaton*
- Wikipedia - Conway's *Game of Life*
  *wikipedia.org/wiki/Conway's_Game_of_Life*
- *Game of Life* Wiki
  *conwaylife.com/wiki/Main_Page*
- Javascript *Game of Life* Web App
  *intravisions.com/games/conway*

# *Game of Life* Side Show

(This presentation)

ConwaysLife.pdf

@

*github.com/fractalxaos/barcamp*