On the Origin of e-species

Jonatan Gómez Perdomo
jgomezpe@unal.edu.co
ALIFE Research Group
Universidad Nacional de Colombia

Life

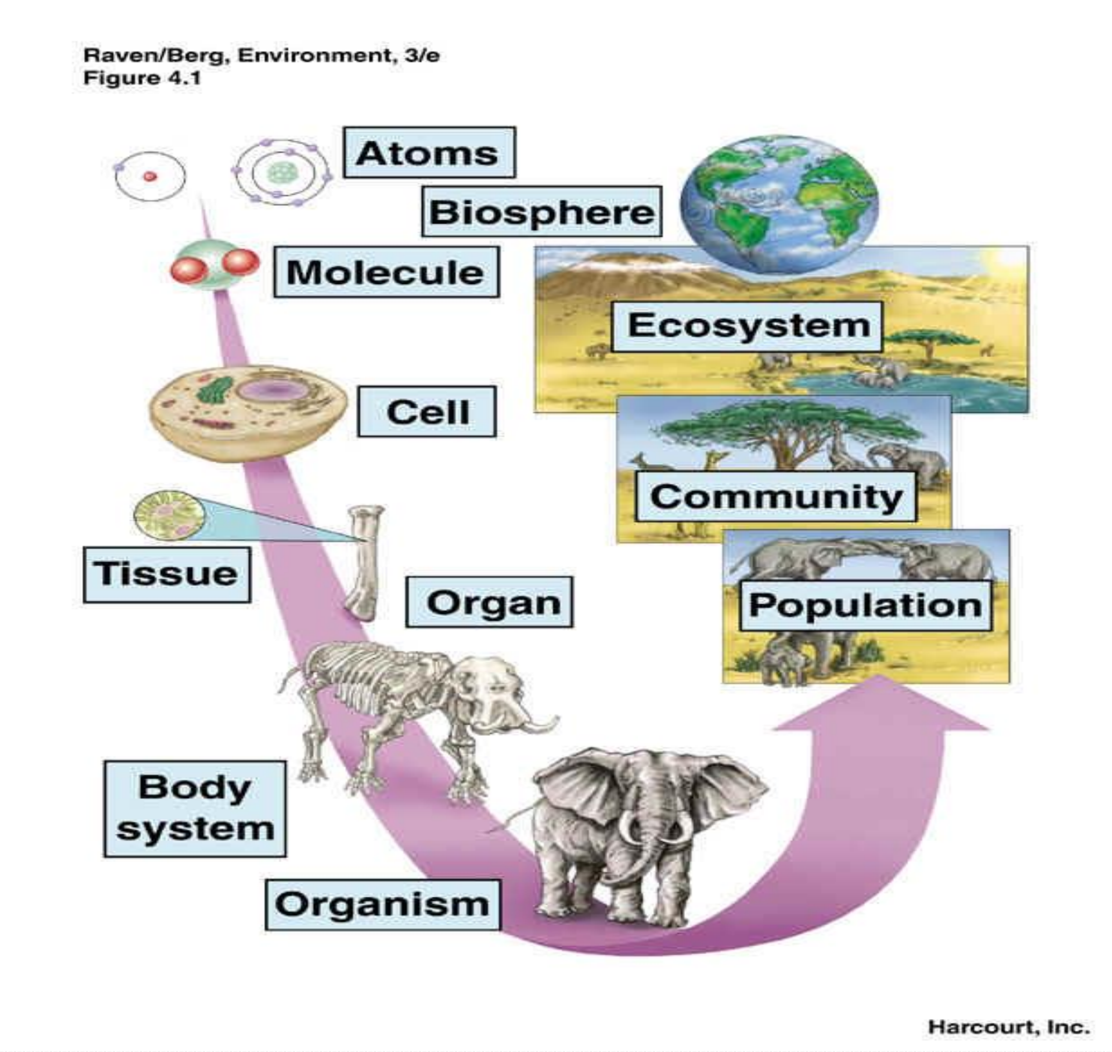
This topic is highly controversial

- An organismic state characterized by capacity for metabolism, growth, reaction to stimuli, and reproduction (*Merriam-Webster Definition)*

Life: What About?

- Mule — cannot self-reproduce; cannot evolve
- Virus — cannot self-reproduce; does not have a metabolism
- Prion — like a virus; no self-representation but itself

Life: Organization



Life: Characterization

A pattern in space-time

Reproduction - Autopoeisis

Recombining instructions set

Metabolism

Interaction with the Environment

Life: Characterization

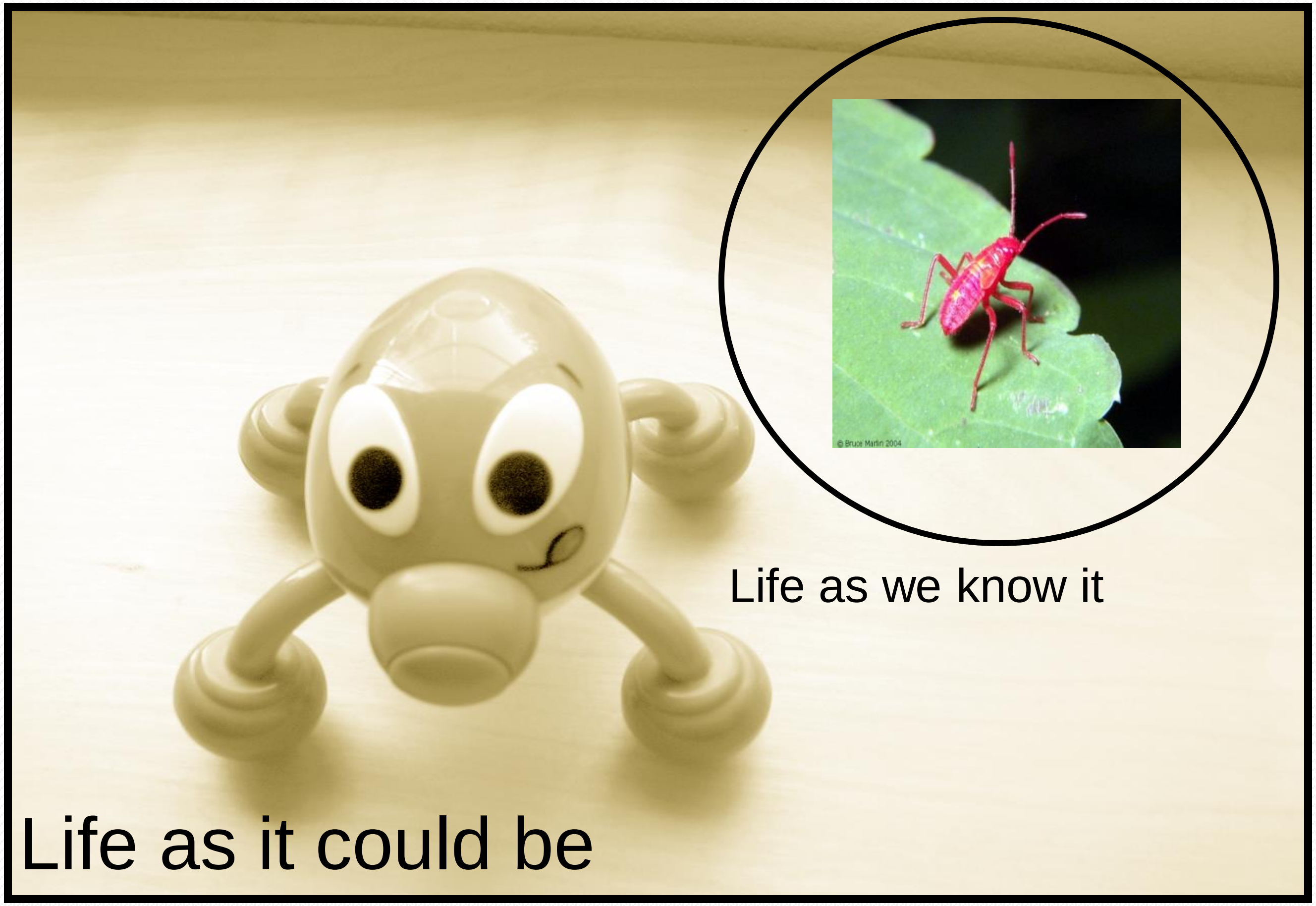
Interdependence of parts

Stability under perturbation

Ability to evolve

Homeostasis

Life: Space



Artificial Life

Relatively new research area in computer sciences that studies and recreates systems related to life by using computer simulations, robotics and bio chemistry

Chris Langton, 1987

Traditional Biology: Method

1. Analytic
2. Top-down

Starts from the top (e.g. organism level) and seeks for explanations in terms of lower level entities

Artificial Life: Method

1. Synthetic
2. Bottom up: starts at the bottom (e.g. molecular level)

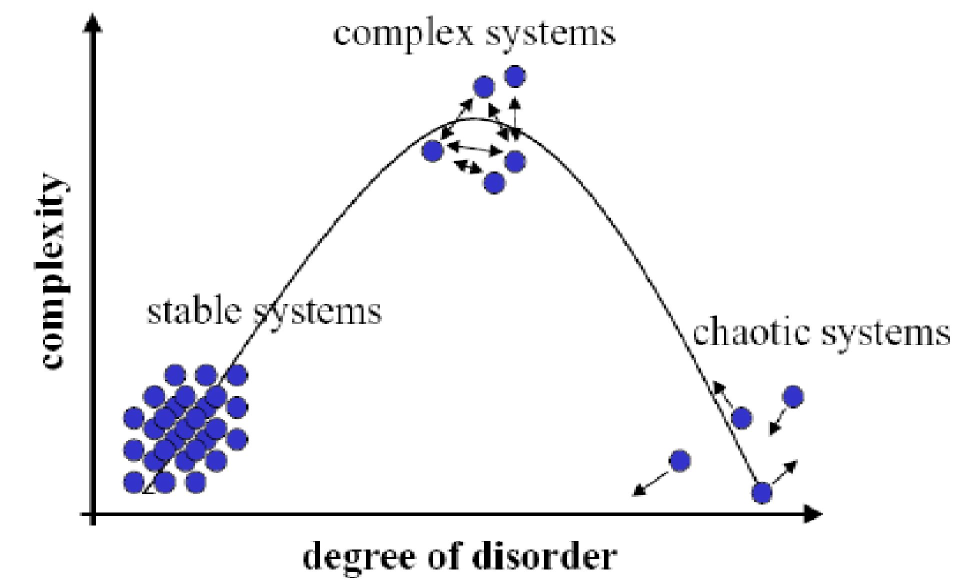
It works by synthesizing complex systems from many simple local interacting entities.

Artificial Life: Concepts

Complex Systems

Emergence and self-organization

Local rules usually defined as dynamic systems



Dynamic System

Evolves in time according to a set of rules

- What changes in time is a variable (e.g. Position, concentration, temperature, …)
- Present conditions determine the future.
- Rules are usually nonlinear (e.g. set of diff. eq. Defining rates of change)
- There may be many interacting variables

Sierpinski Triangle

Algorithm

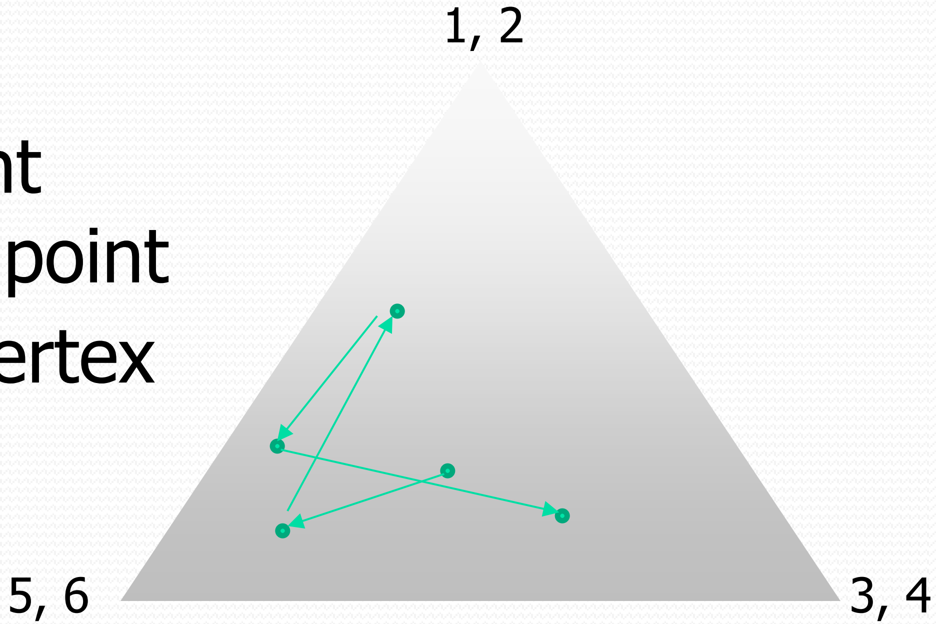
Draw a random point

… .

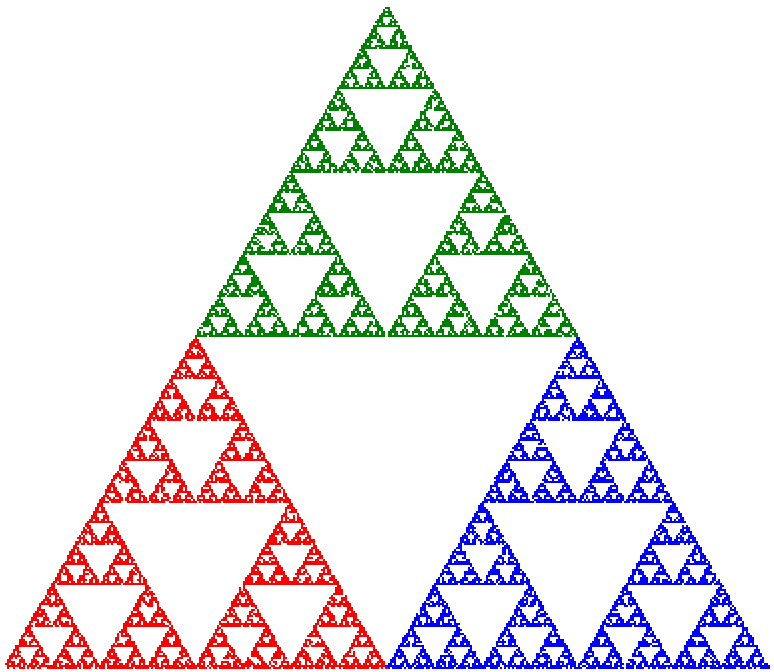
Throw a dice

Draw the middle point between the current point and the associated vertex

Go line 2

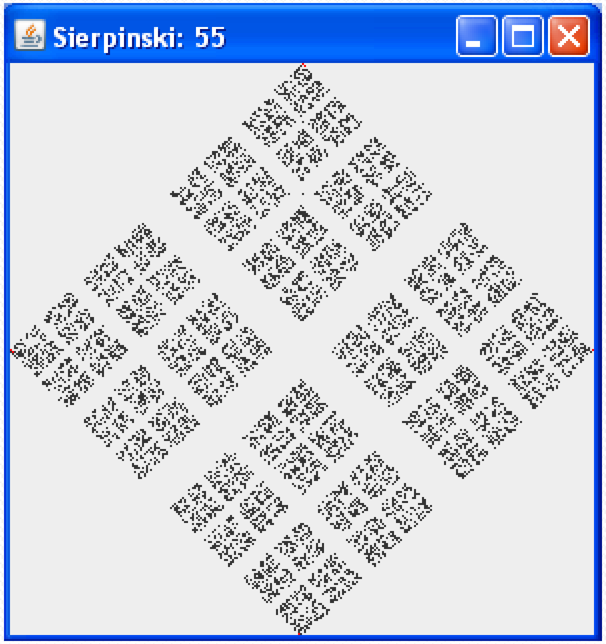


Sierpinski Triangle

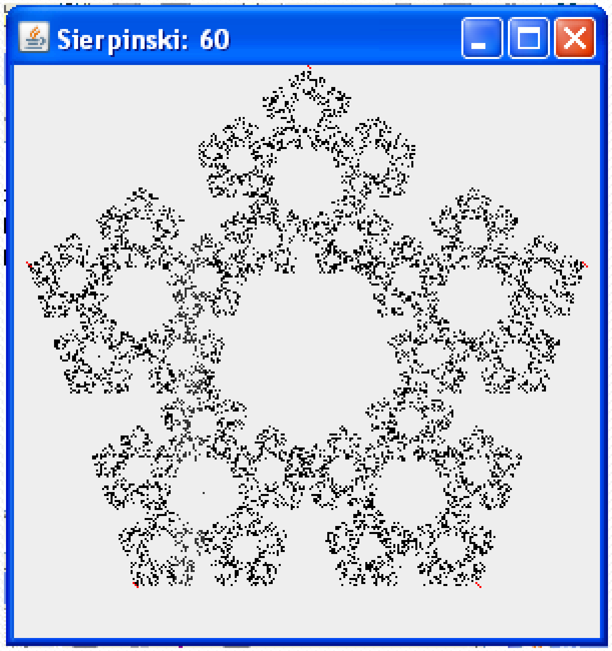


[Demo]

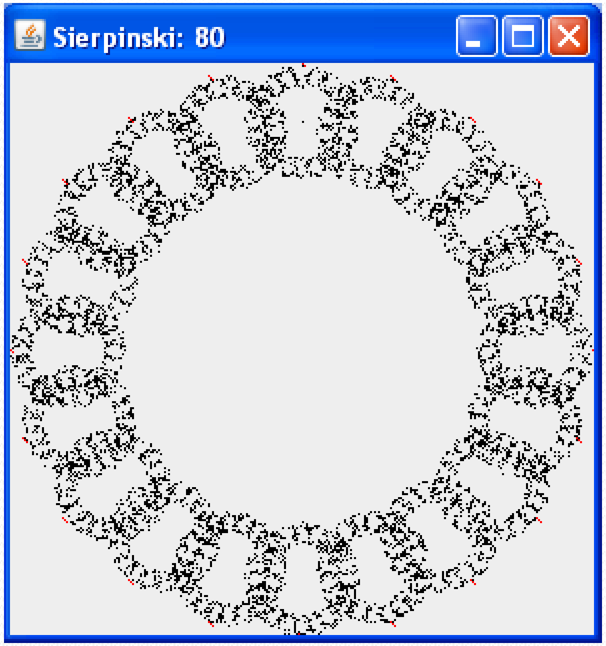
Beyond Sierpinski



Square



Pentagon



20-sides

Rand Gravitational Clustering

Data Clustering is viewed as a dynamic system

Points change in time and group themself according to some dynamic rules

Clusters emerge from the dynamic behavior of the data points

No optimization approach

Rand Gravitational Clustering

Non hierarchical approach, Robust and Unsupervised Clustering approach

Each point is moved using the gravitational force exerted by another single object over it and Newton’s second motion law

$$F(t) = \frac{G m_x m_y}{d\left(x(t), y(t)\right)^2}$$

$$x(t+1) = x(t) + \vec{d}\,\frac{G}{\left\|\vec{d}\right\|^3}$$

Video

Rand Gravitational Clustering

Algorithm 13 Randomized Gravitational Clustering

RGC(x, **G**, $\triangle(G)$, **M**, ε)

for i=1 **to** n **do** *// each data point is a candidate cluster*
  MAKE(i)
for i=1 **to** M **do** *// iterations performed by the algorithm*
  for j=1 **to** n **do** *// moving each data point*
    k = random point index such that $k \neq j$ *// selecting another data point*
    MOVE(x_j , x_k) (see Eq (6.22)) *//Move both points*
    if dist(x_j , x_k) $\leq \varepsilon$ **then** UNION(j, k) *// merging cluster if possible*
  G = (1-$\triangle(G)$)*G *// Cooling the system*
for i=1 **to** n **do** *// organizing the final clusters*
  FIND(i)
return disjoint-sets

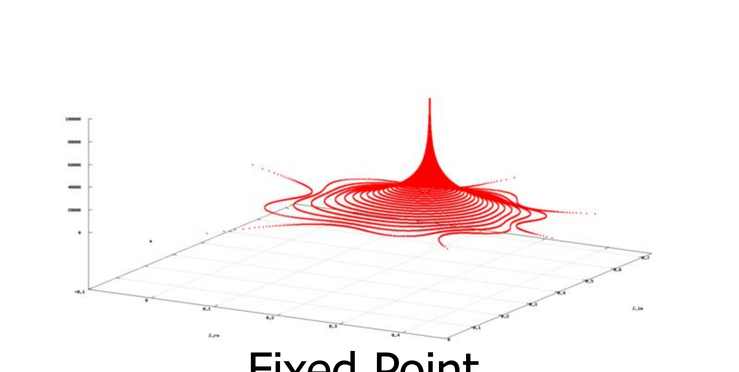
Algorithm 14 Cluster Extraction.

GETCLUSTERS(clusters, α, n)

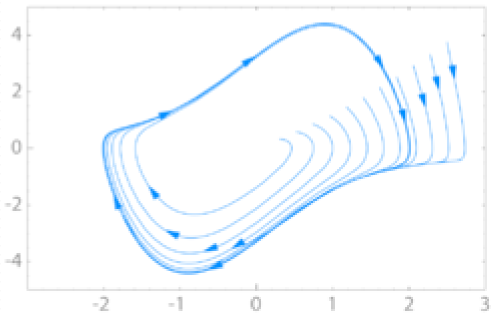
newClusters = $\emptyset$
MIN_POINTS = αn
for i=0 **to** number of clusters **do**
  if size($cluster_i$) $\geq$MIN_POINTS **then**
    newClusters = newClusters $\cup$ { $cluster_i$ }
return newClusters

Dynamic System: Attractors

Atracctor



Fixed Point

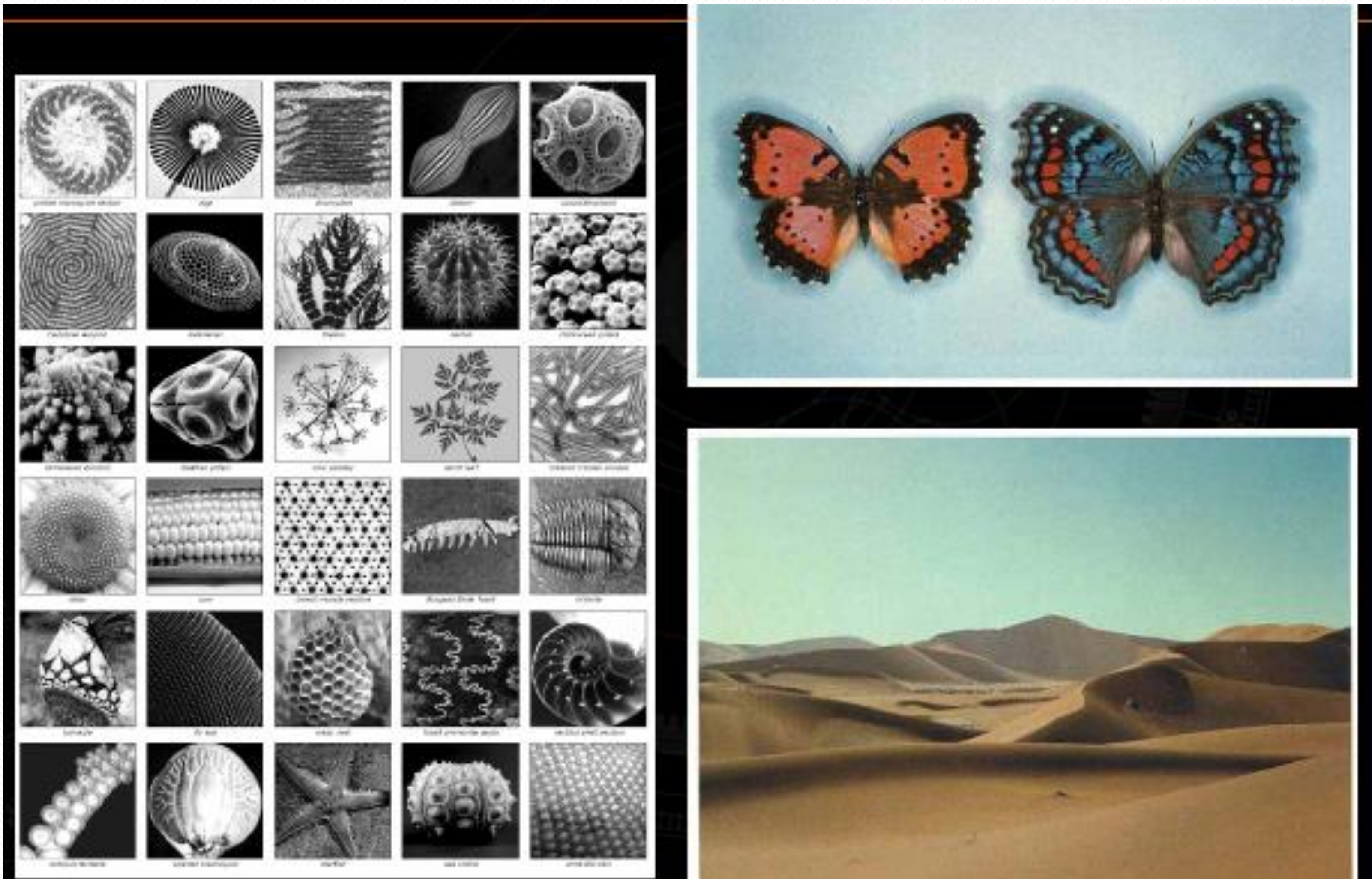


Limit Cycle

Strange

Video

Natural Patterns

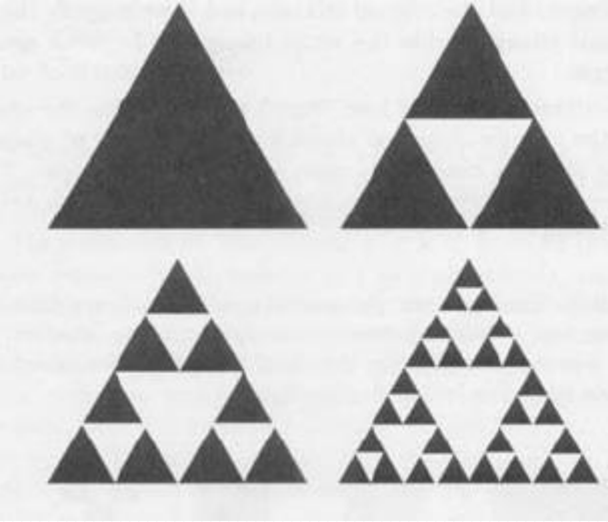


Fractals

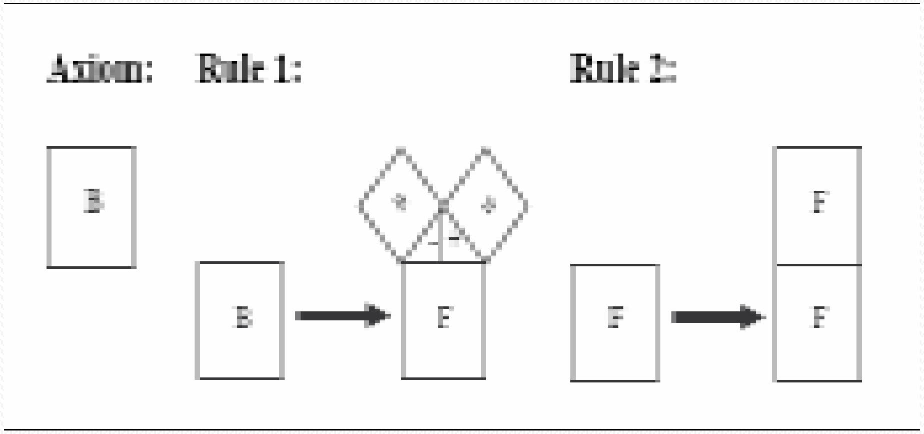
Lindenmayer Systems

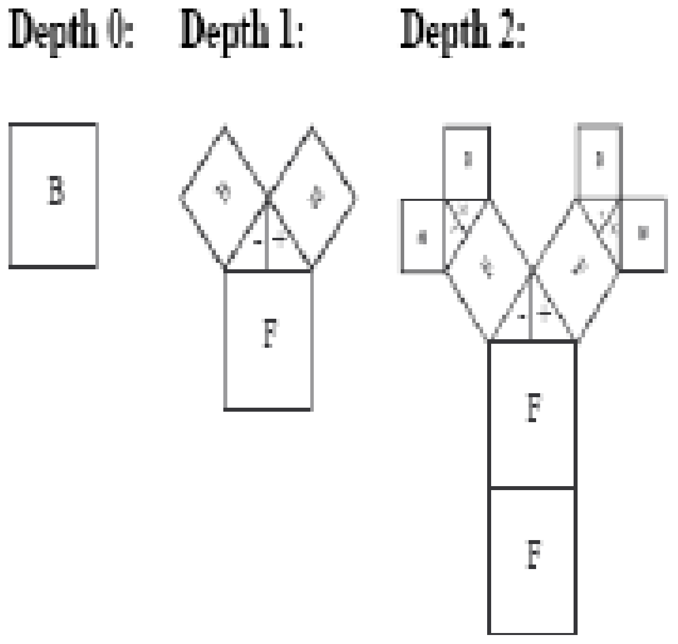
Production Systems (Grammar)

Example: Replace any filled triangle (left) with the three smaller filled triangles leaving empty the center (right)

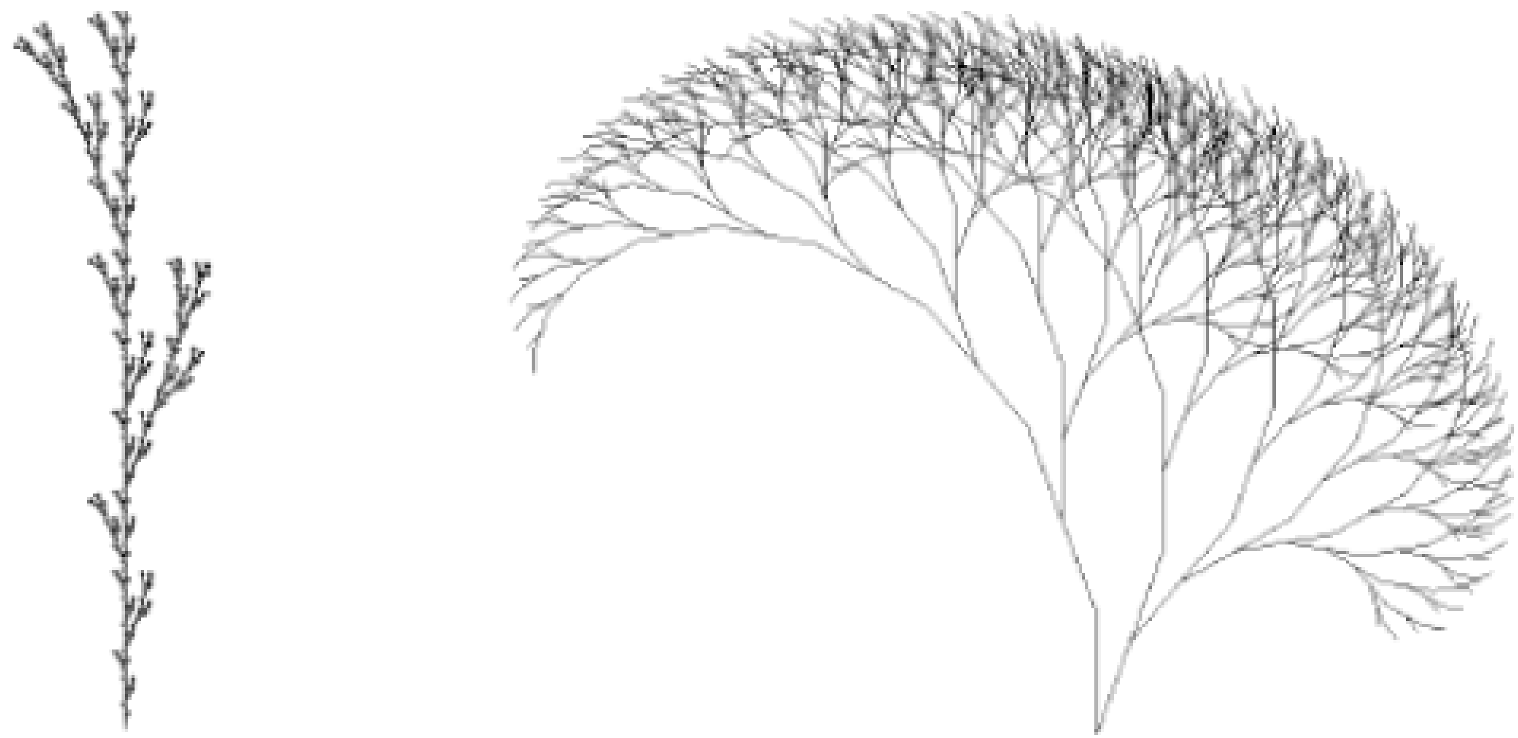


Lindenmayer Systems



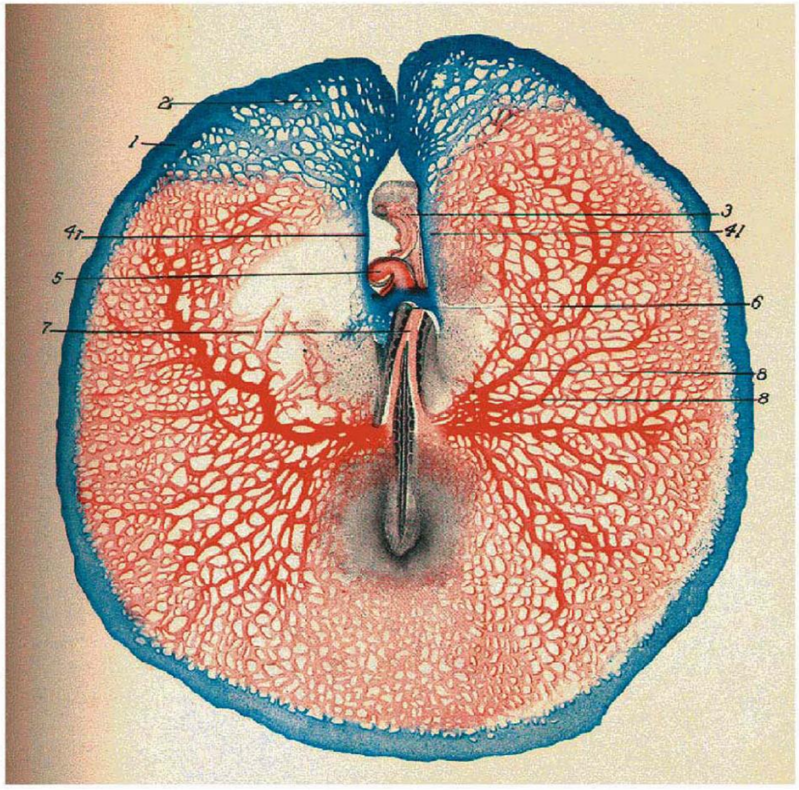


Lindenmayer Systems

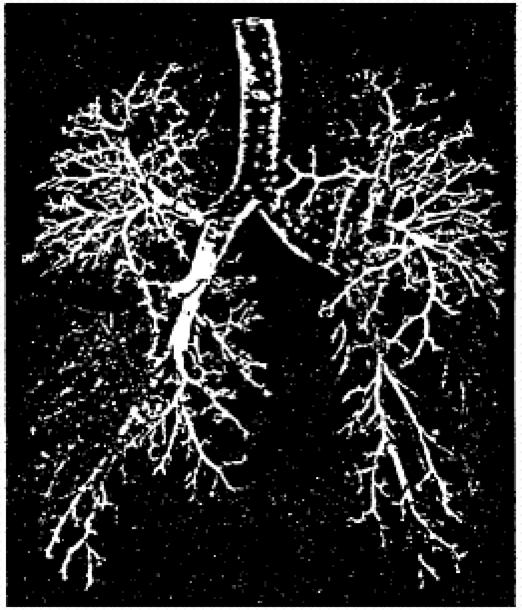


Video

Looks like



DEVELOPMENTAL BIOLOGY, Eighth Edition, Part 1, C



[Video]

Reaction/Diffusion Systems

a(x, t), b(x, t): activator, inhibitor concentrations

s: Auto-catalysis capability of cell

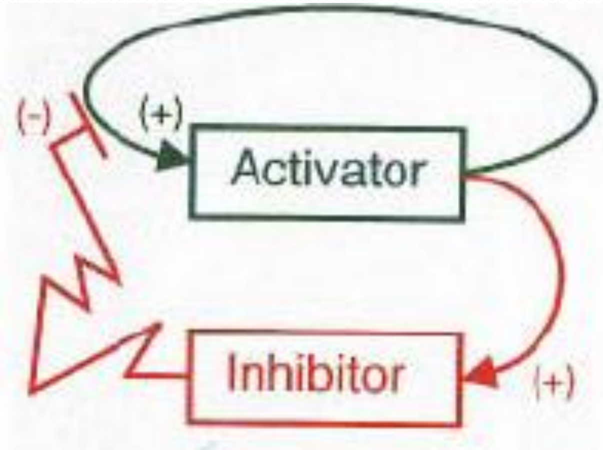
Da, Db: diffusion constants

ra, rb: decay rates

ba, bb: Basic production activator/inhibitor

sa2/b: no lineal auto-catalitic influence

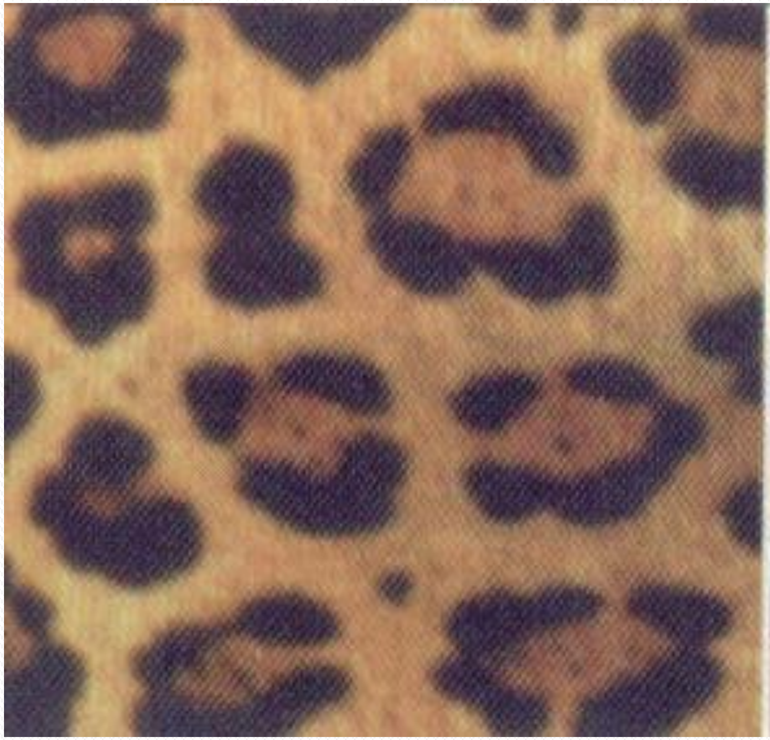
raa: removing rate (proportional to concentration)

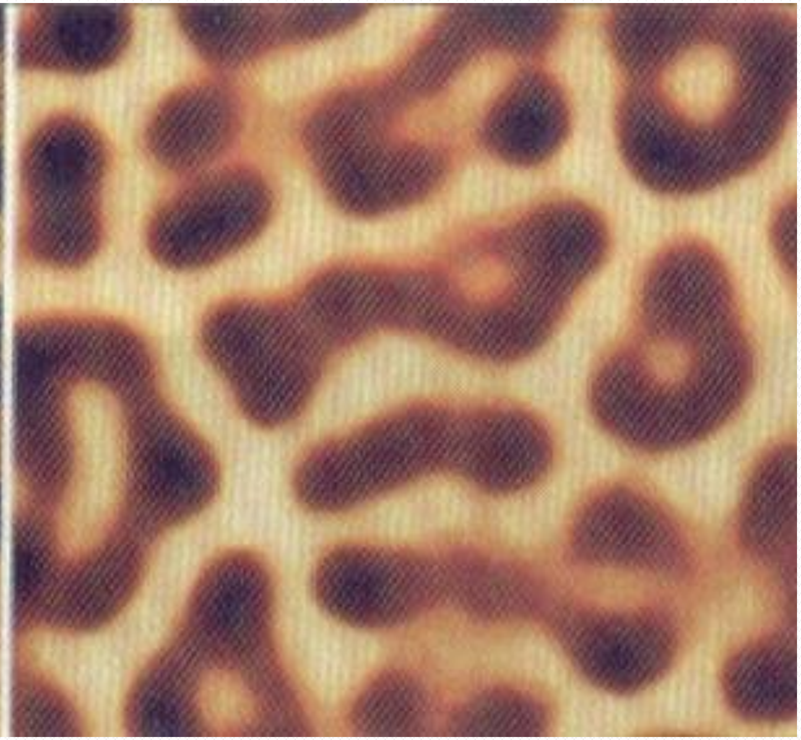


$$\frac{\partial a}{\partial t} = s\left(\frac{a^2}{b} + b_a\right) - r_a a + D_a \frac{\partial^2 a}{\partial x^2}$$

$$\frac{\partial b}{\partial t} = s a^2 - r_a b + b_b + D_b \frac{\partial^2 b}{\partial x^2}$$

Reaction/Diffusion Systems

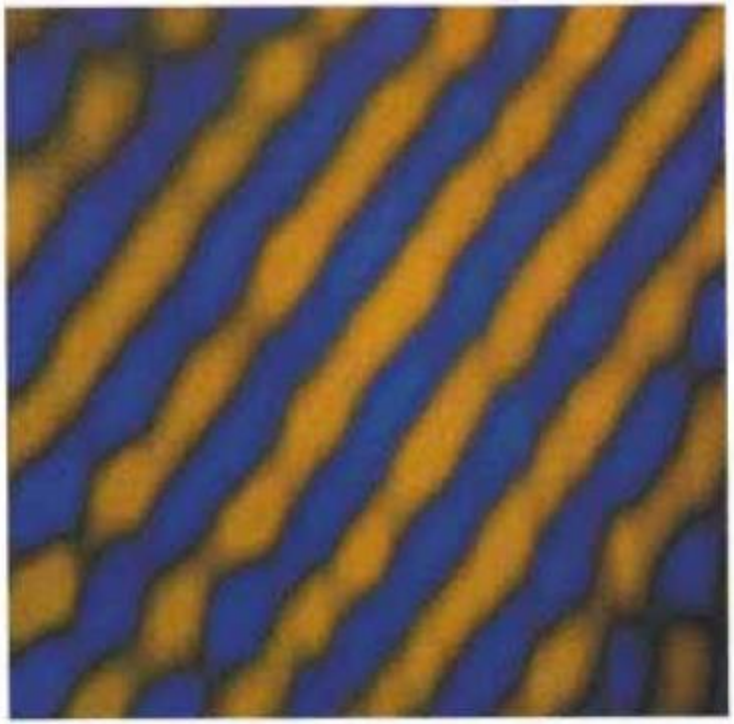


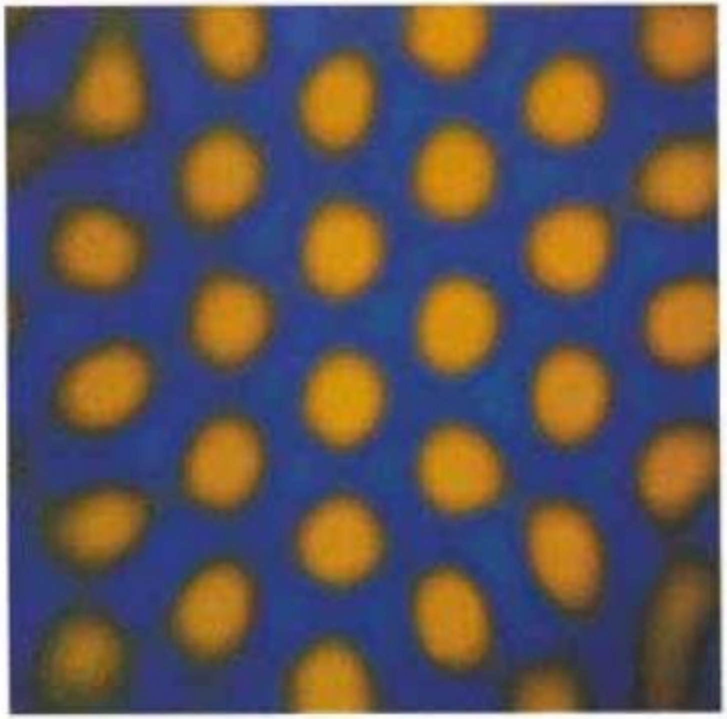


Cheeta motif Chemical motif

Reaction/Diffusion Systems

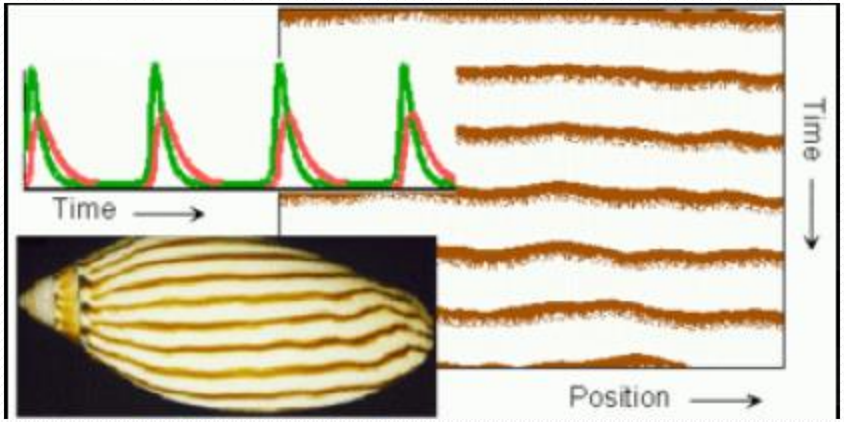
Motifs

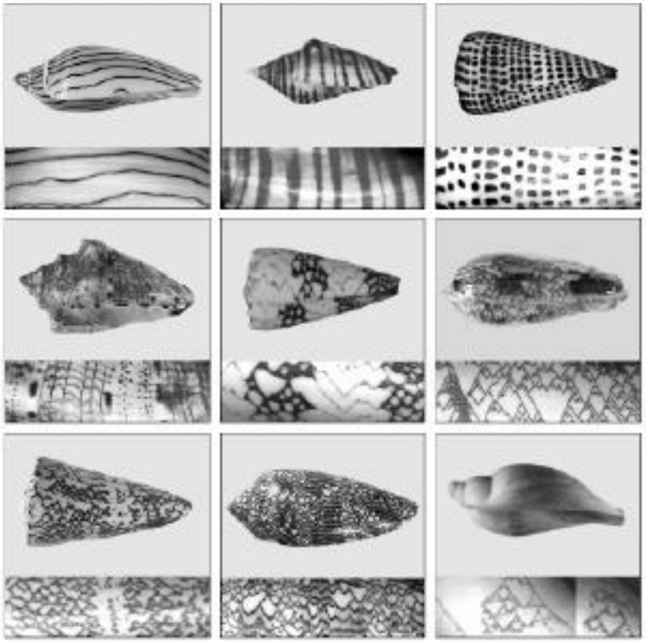




Demo

Reaction/Diffusion Systems





Reaction/Diffusion Systems

We are developing a virtual central nervous system growing mechanism based on reaction/difussion systems.

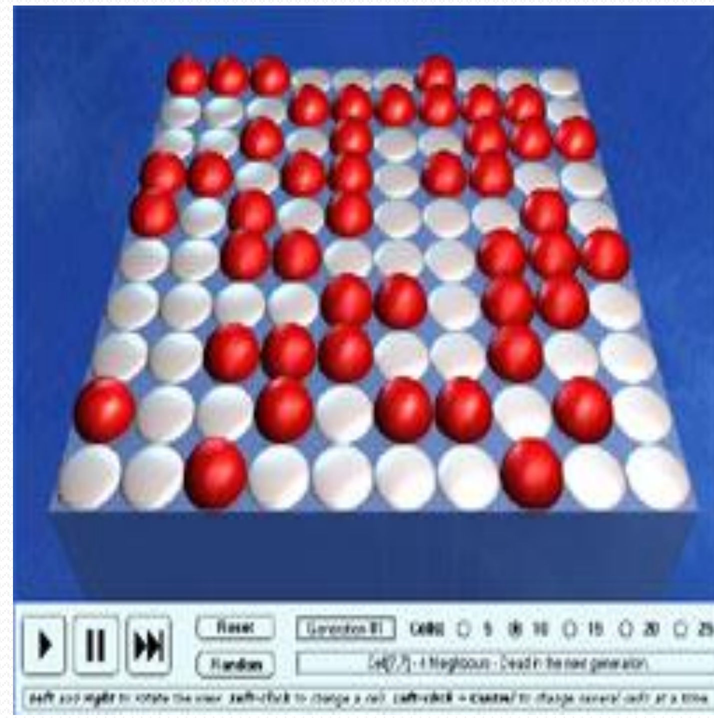
Each neuron locates other neurons, sensors and actuators by expanding nerve cells according to the activator/inhibitor concentrations induced by such elements.

Cellular Automata

Lattice, each cell taking a finite possible set of values

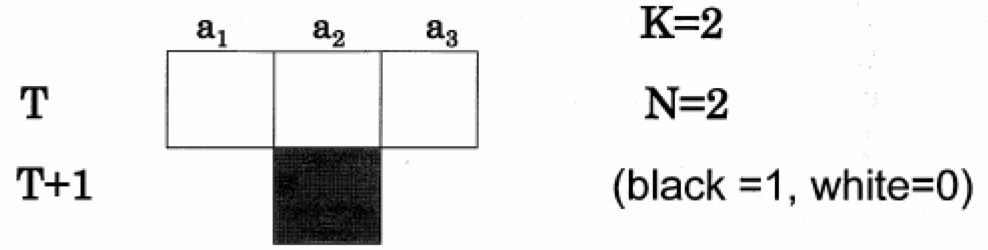
Value of each cell changes in the same discrete synchronous way

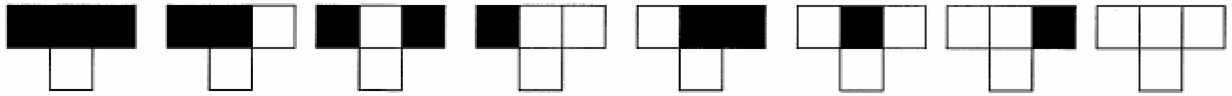
Change depends only on the neighboor cells (possibly including itself)



Cellular Automata

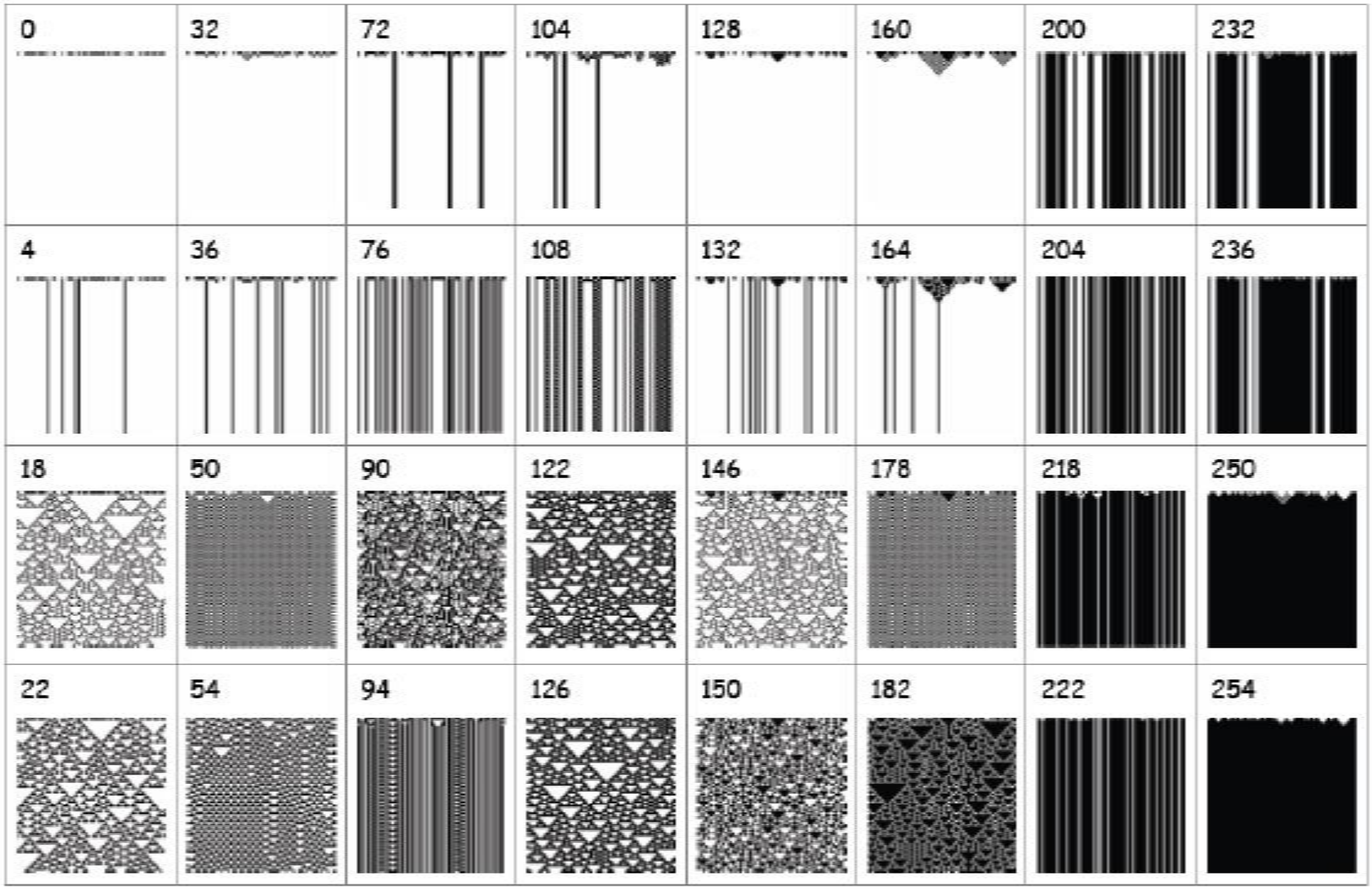
1 Dimensional





Cellular Automata

Space-time Diagram



Video

Game of Life

2 dimensional

1. Any live cell with fewer than two live neighbours dies, as if caused 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.

Demo

Cellular Automata

We develop a Wireless Sensor Network coordination mechanism based on a non regular cellular automaton that is able to improve the performance of the WSN

We combine CA with evolutionary algorithms for inducing diversity in the EA population. We are able to simulate sort of Cambrian Explosion and Massive extinction mechanisms.

Cellular Automata

We define a Cellular automaton and agent concepts for simulating the life cycle of the PapillomaVirus Variant 16 and its interaction with the immune system for inducing cervical cancer.

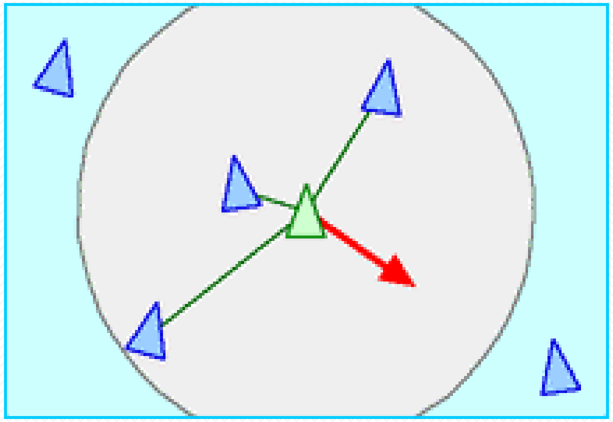
We use an hexagonal cellular automaton for simulating the life cycle of a cell.

Cellular Automata

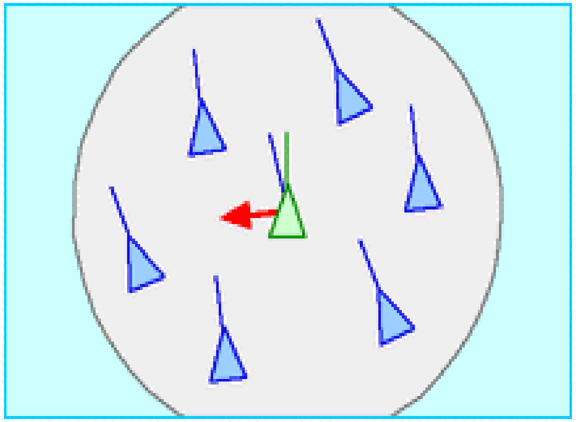
We use an hexagonal cellular automaton for simulating the horizontal transcription process (plasmid transference) in bacteria and study antibiotic resistence.

Collective Behaviour - Boids

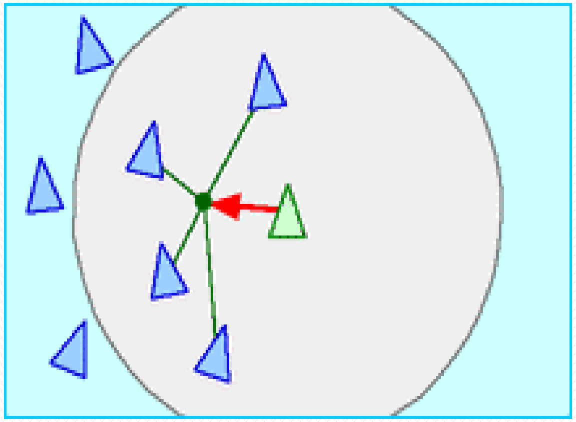
Separation



Alignment



Cohesion



Video

Collective Behaviour - Termites

Simple Units able to solve (optimization) problems

Stigma based communication (pheromone)

Video

Collective Behaviour - Termites

We combine ants (termites) ideas with Q-learning and Language Game theory for designing a Self failure detection and repairing mechanism (Autonomic computing)

Video

Collective Behaviour - Robots

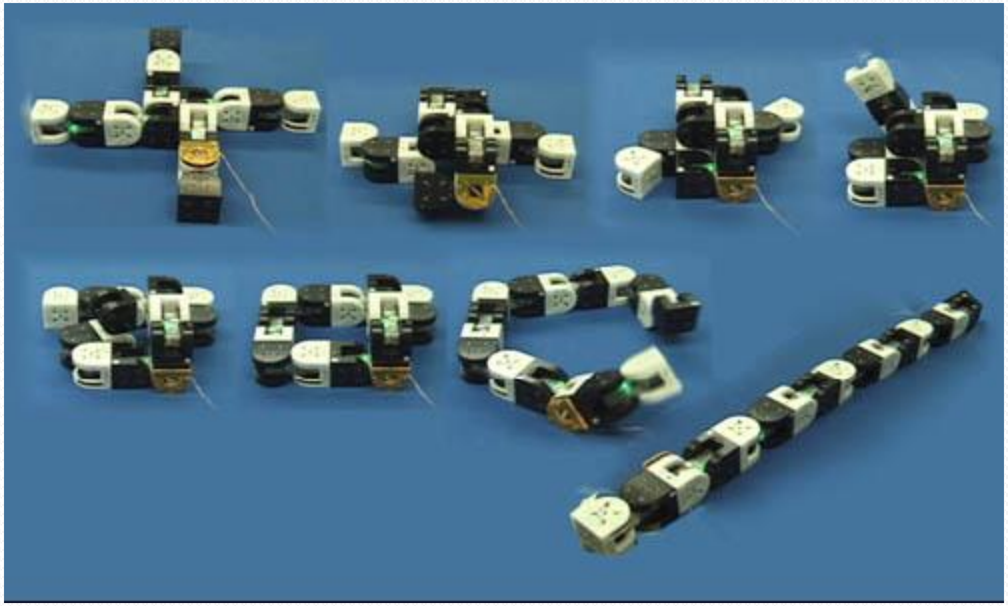
We develop a simulation framework for studying collective robotics and applied it to robot-soccer.

We develop a previous version of the robot-soccers and we are developing an improved version of such robot-soccers

Video

Modular Robots

Simple Cooperative Robots



Video

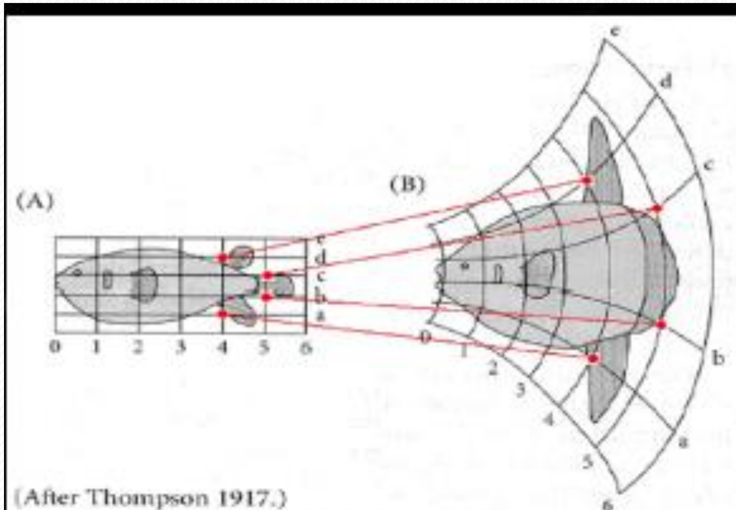
Modular Robots

We develop a Modular Robot that combines Central Pattern Generator (sinusoidal waves) with Hormone inspired communication for moving the robot in odd terrains and avoid obstacles.

Video

Video 2

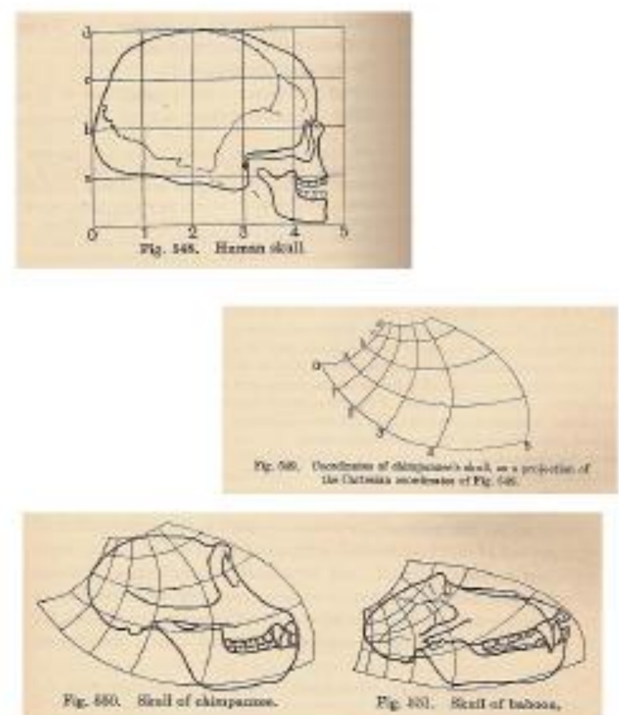
Transformation



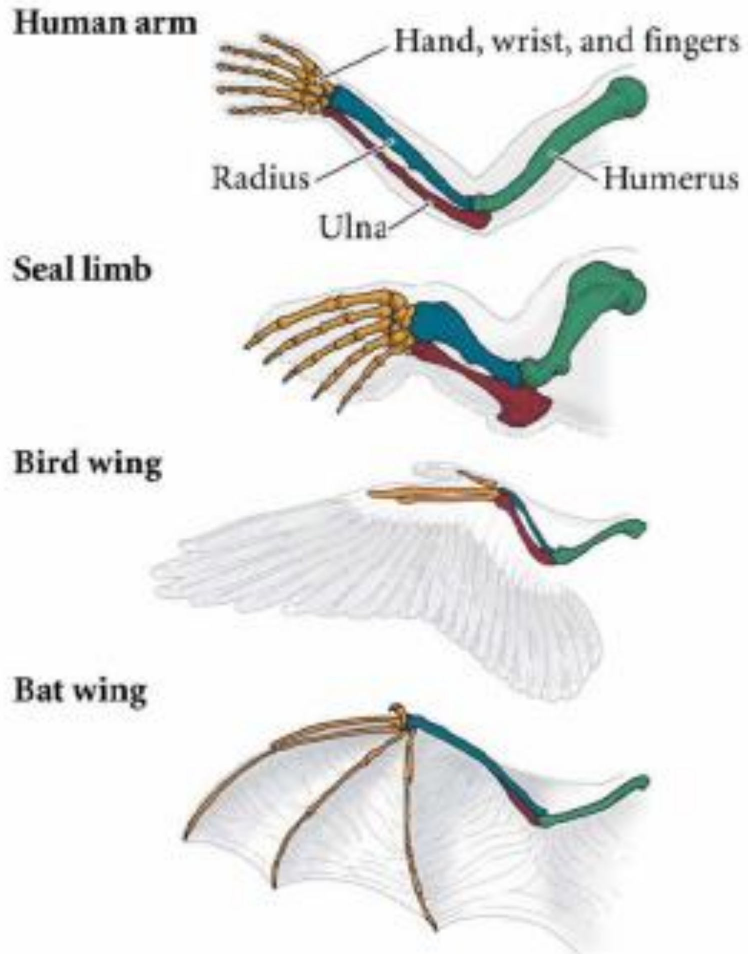
(After Thompson 1917.)

Theory of transformation:

Comparison of related morphological forms (Thompson, 1917)



Transformation



Bio-inspired Robots

We design a robot that uses organic waste and a colony of bacteria as source of energy

We are developing a mini-robot that uses vibration for moving and such organic waste and colony of bacteria as source of energy

Video

Evolution: Darwin Pond

Designed by Jeffrey Ventrella (1996)

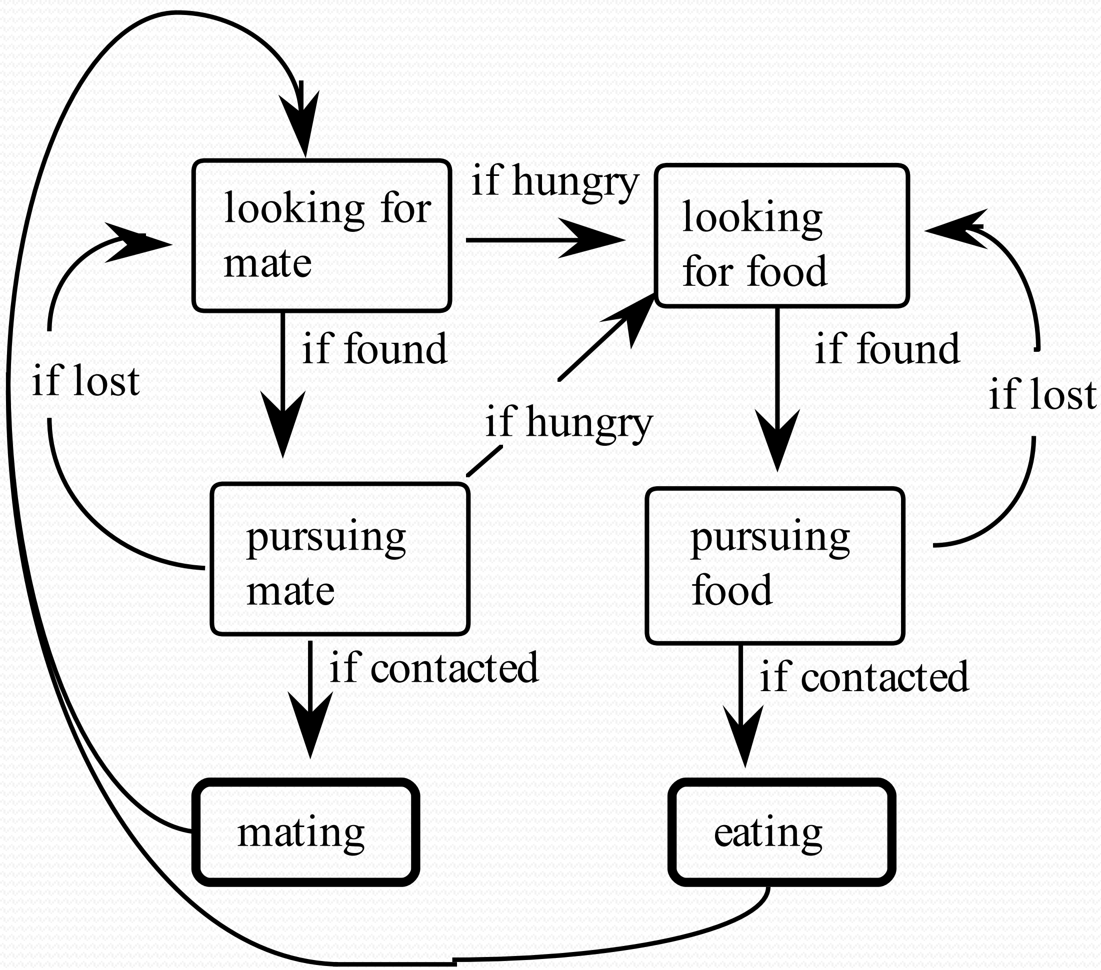
Simulation of “swimmers”

Evolving behaviors and form

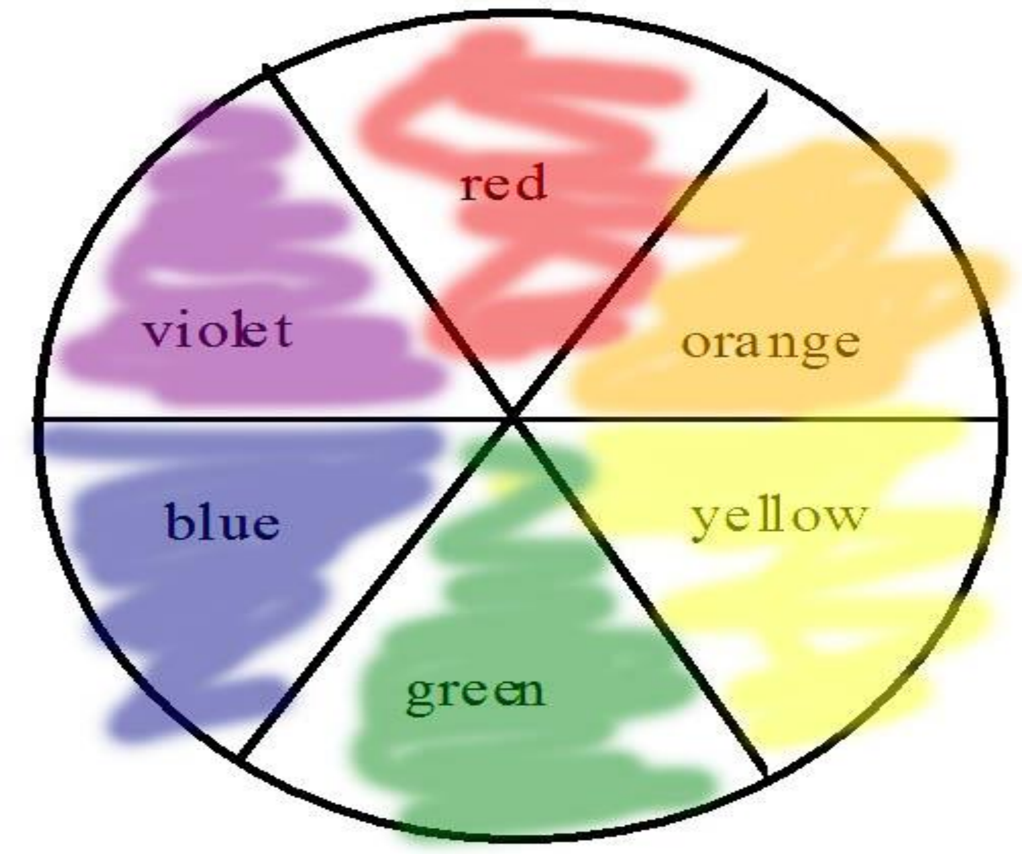
Phenotype is defined by color, age, legs

Purpose of swimmers: Eat and Sex

Evolution: Darwin Pond



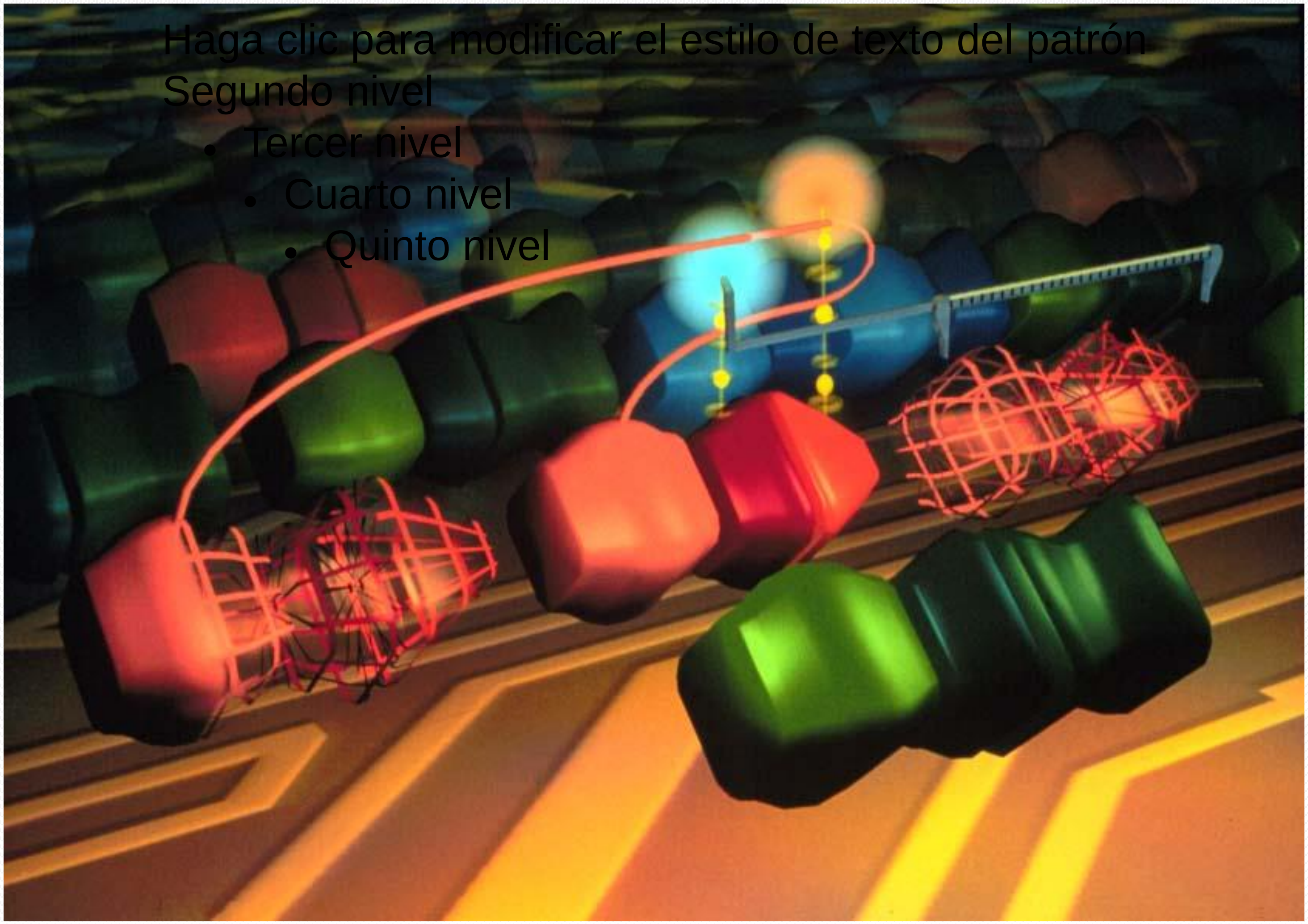
Evolution: Darwin Pond



Evolution: Darwin Pond

Video

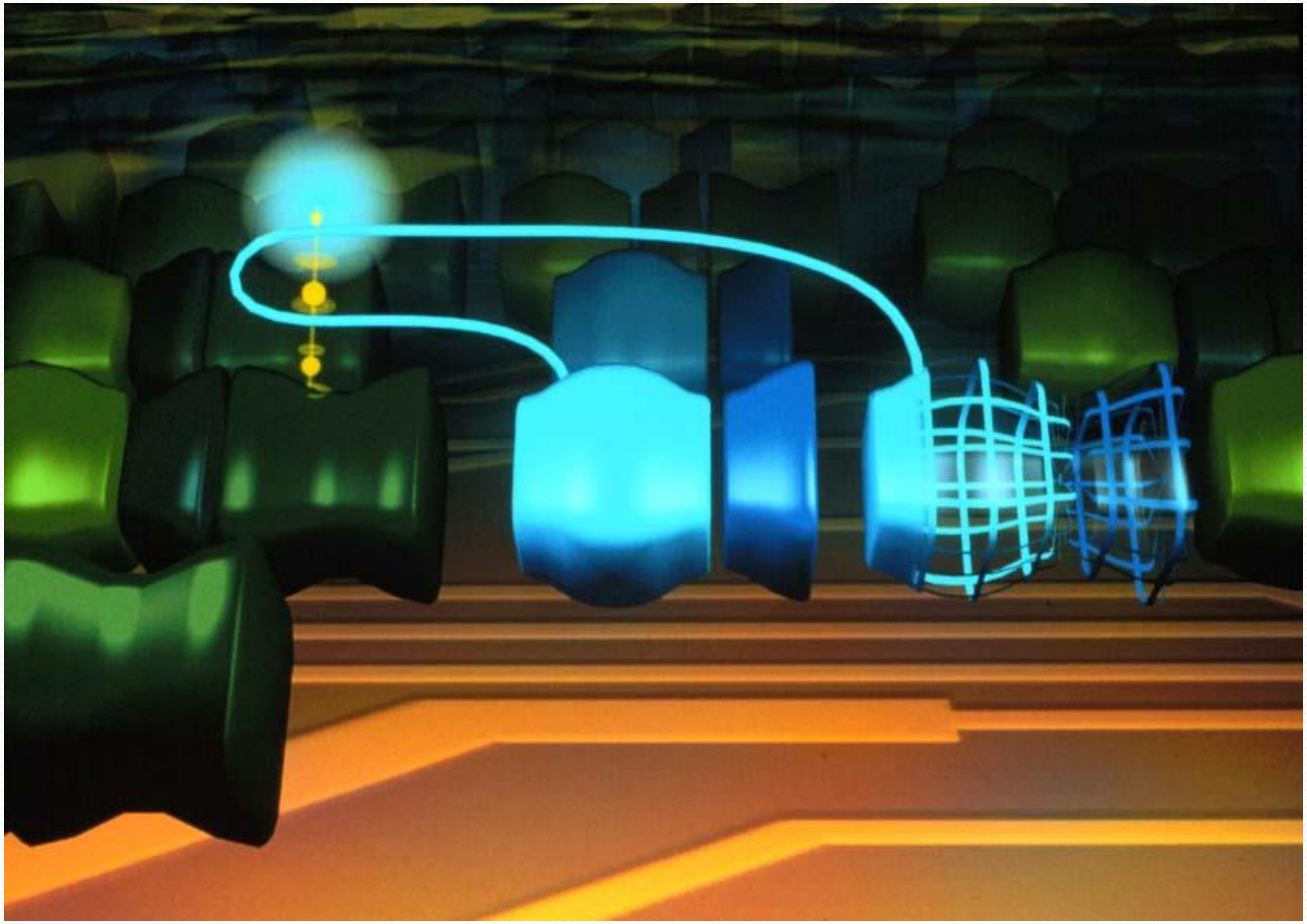
Tierra

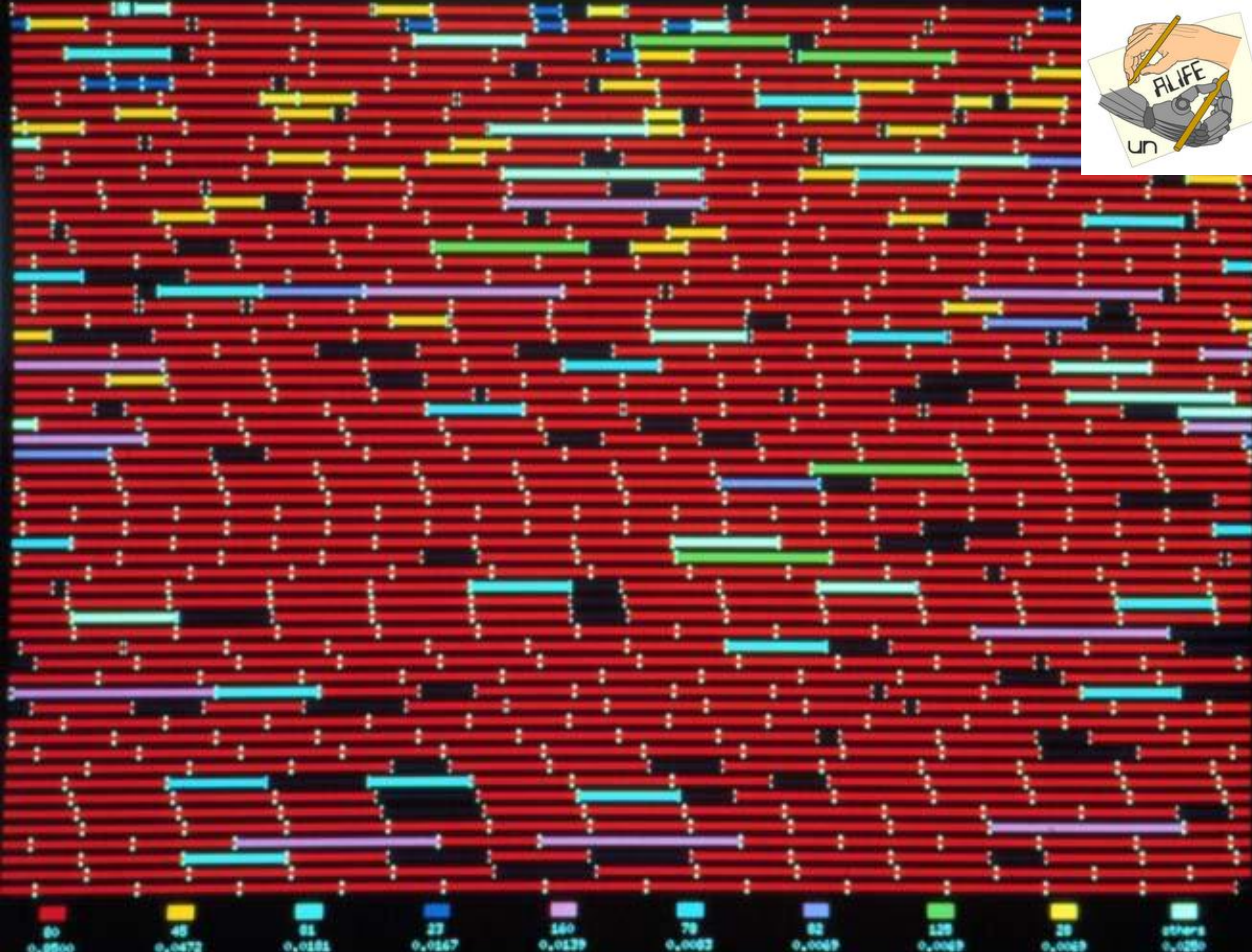

Haga clic para modificar el estilo de texto del patrón
Segundo nivel
Tercer nivel
Cuarto nivel
Quinto nivel

Tierra: Life

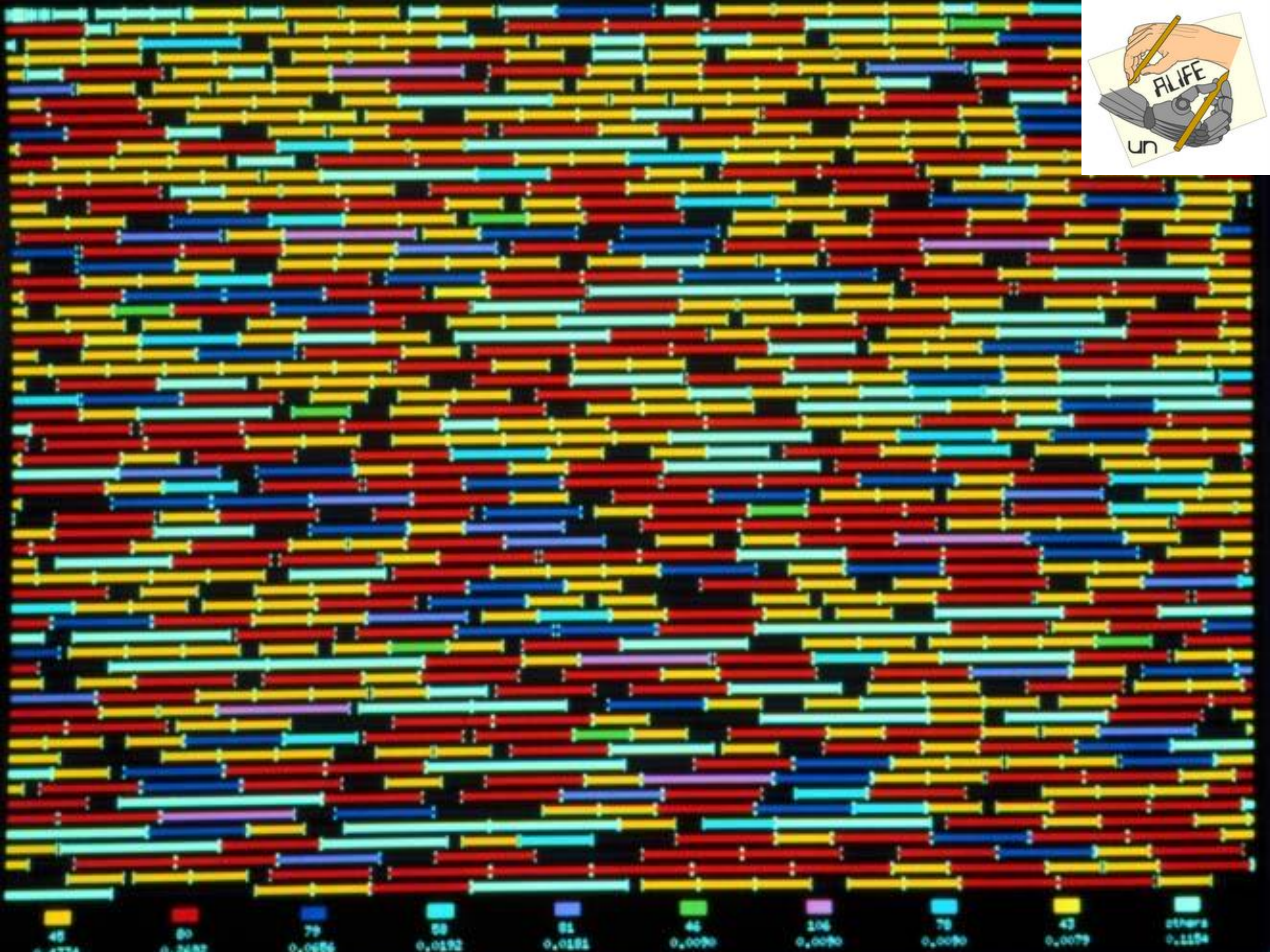
Tierra: Mutation and Death

Tierra: Parasite





45
27
160
others



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43
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others
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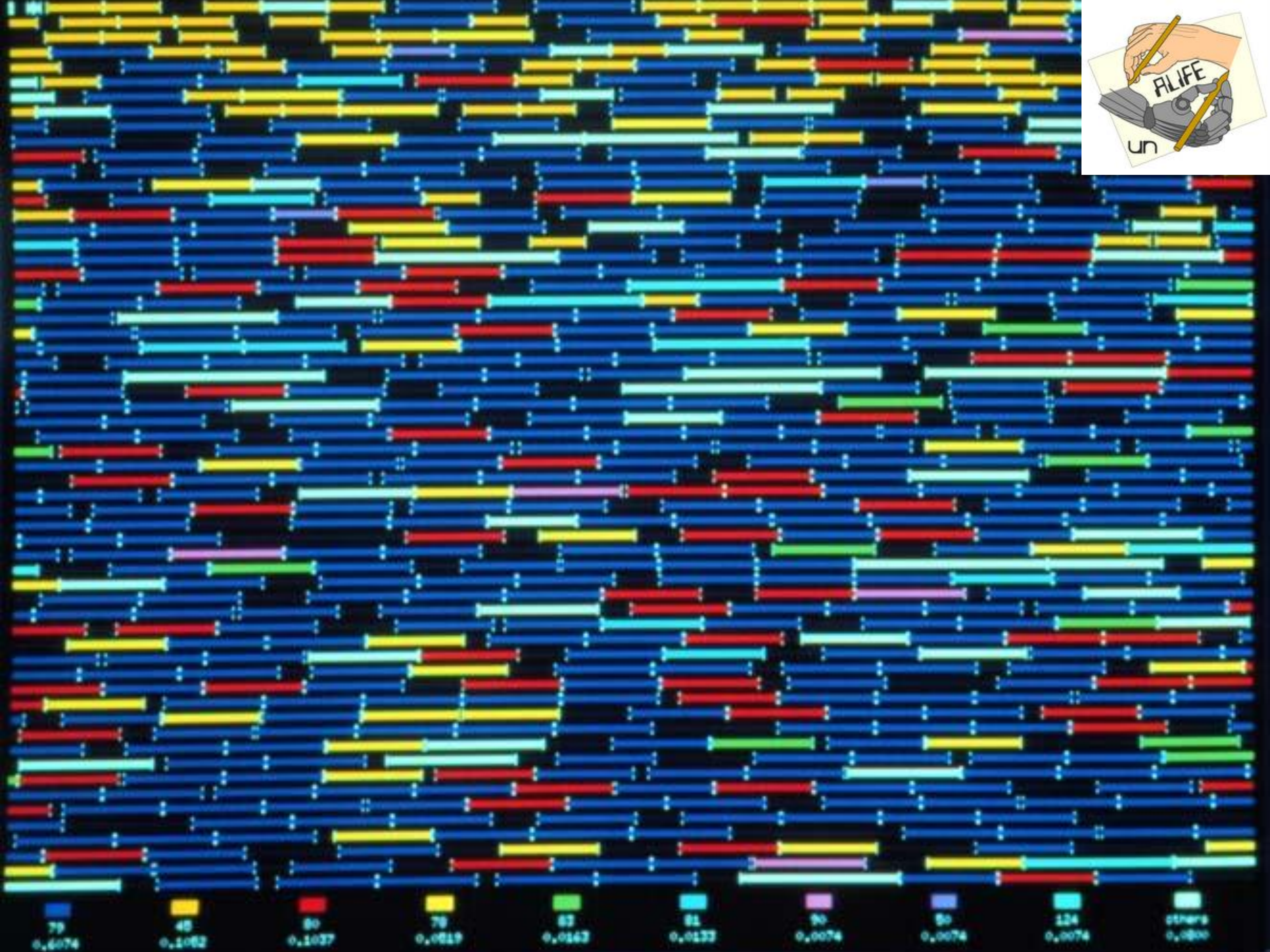
79
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83
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90
50
124
others

Evolution

We design a new evolutionary algorithm that uses chaotic behaviour for adapting the probability of applying the genetic operators

We develop a system that uses such EA and fuctional rewitting concepts for inducing functional programs

Evolution

We are using such EA for obtaining near optimal solutions to optimization problems like Two Steps Distribution Chain Problem, The Quadratic Assignment Problem

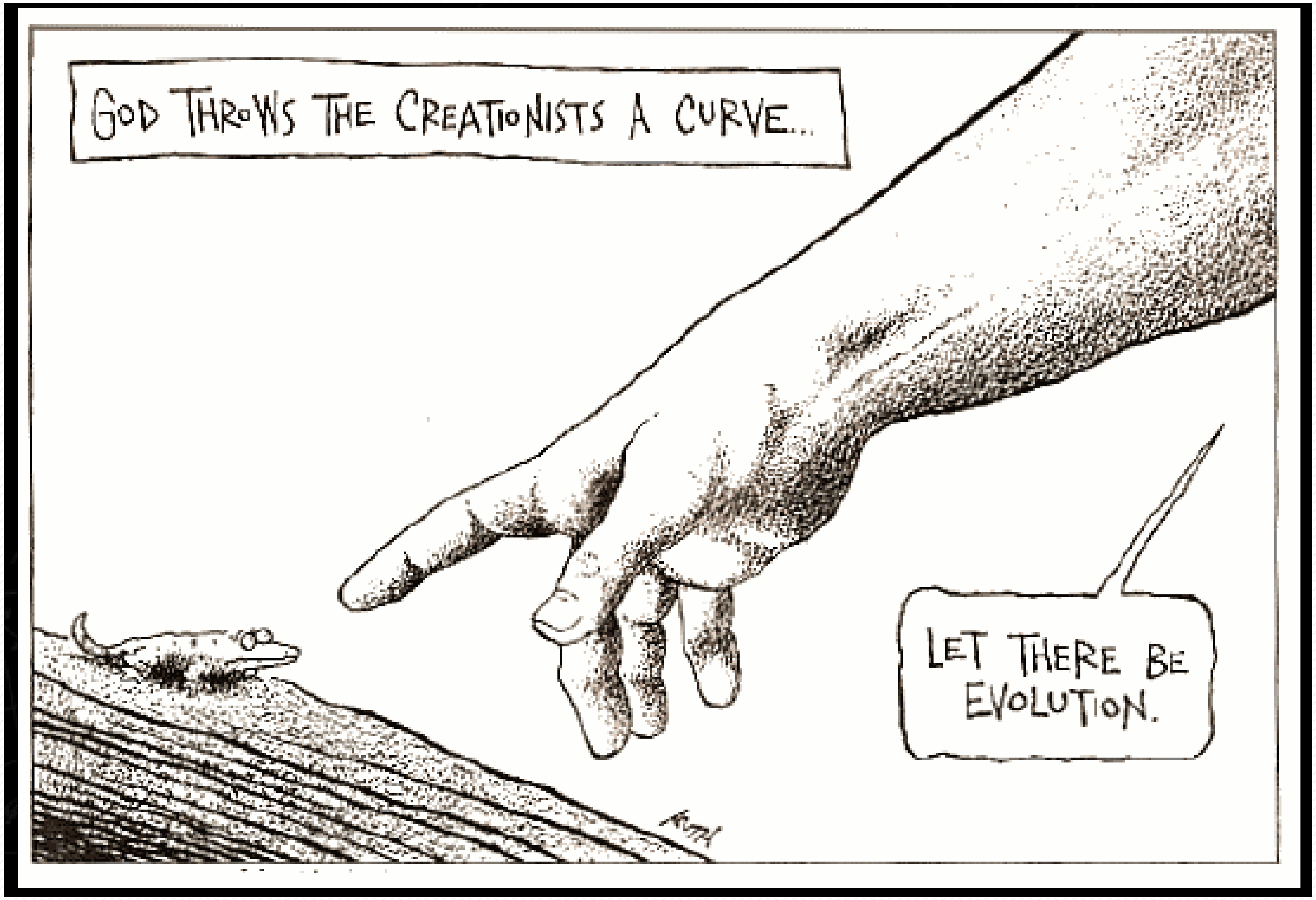
We use it for studying the prisoner dilemma and some other related theory of games problems.

Evolution

We are extending such EA not for just adjusting the probabilities but for evolving the genetic operators (Meta-evolution)

We are combining EA with neural networks for solving general artificial intelligence problems

God and Alife



Video