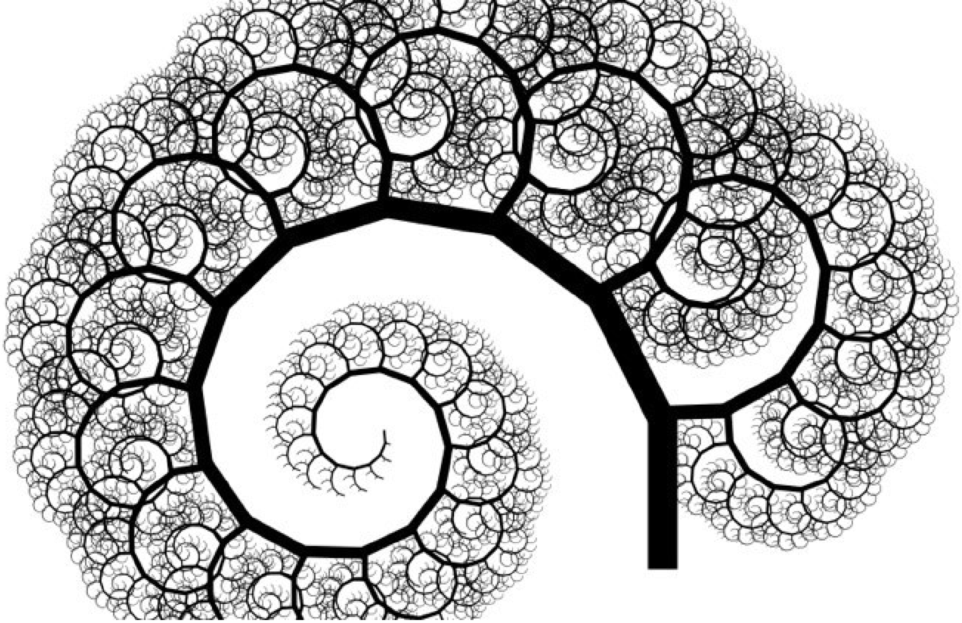
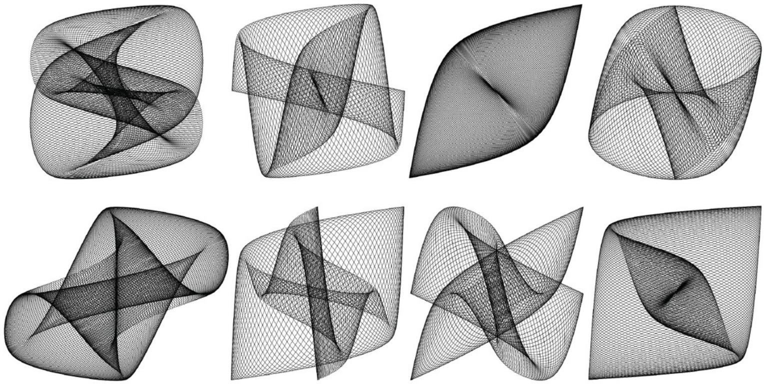
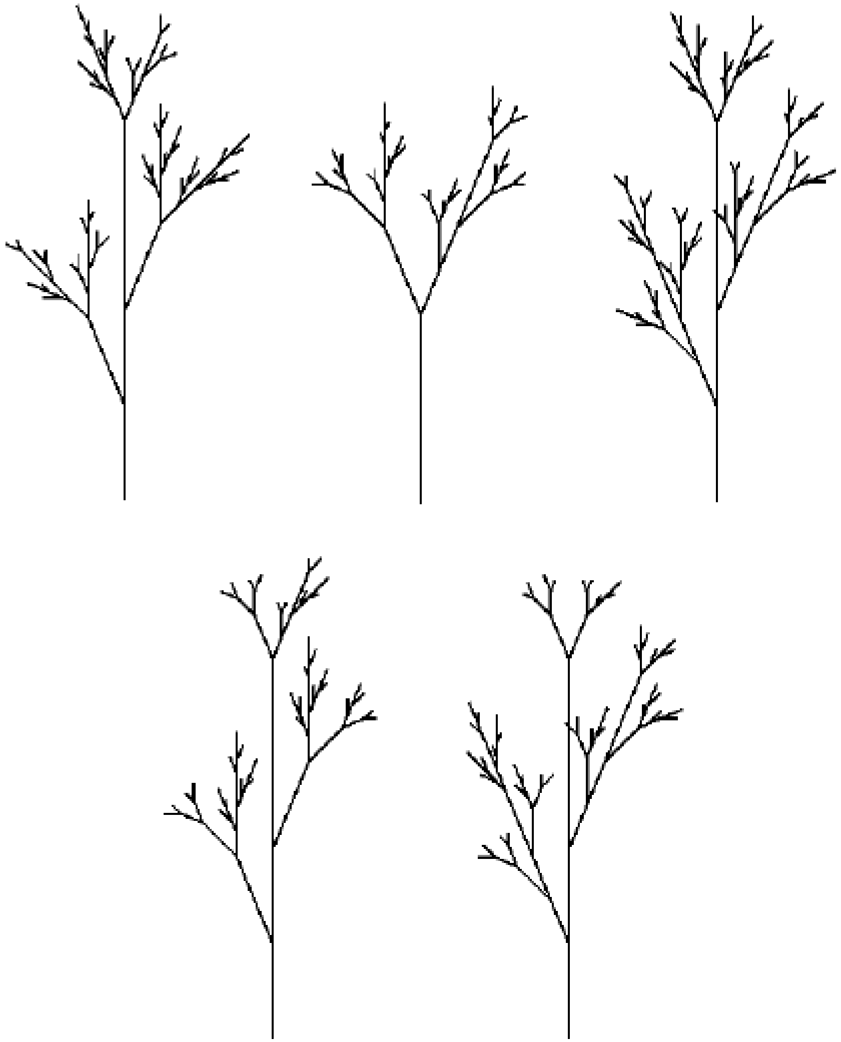




advanced generative algorithms

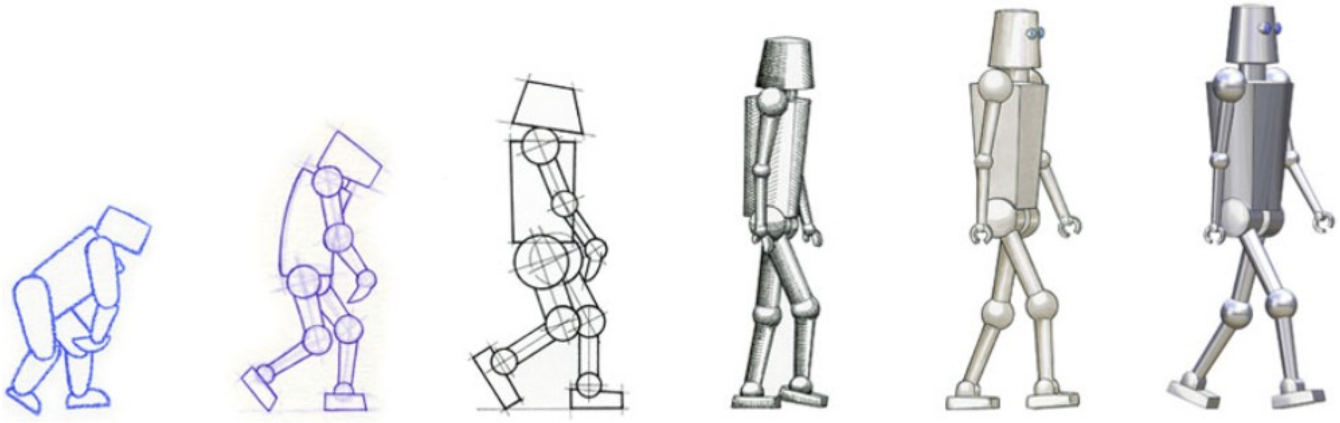
techniques discussed

- Genetic algorithms
- Fractals
- L-systems
- Lissajous curves
- we've already seen:
  - random number generation
  - Perlin noise
  - sin / cosine
  - emergence



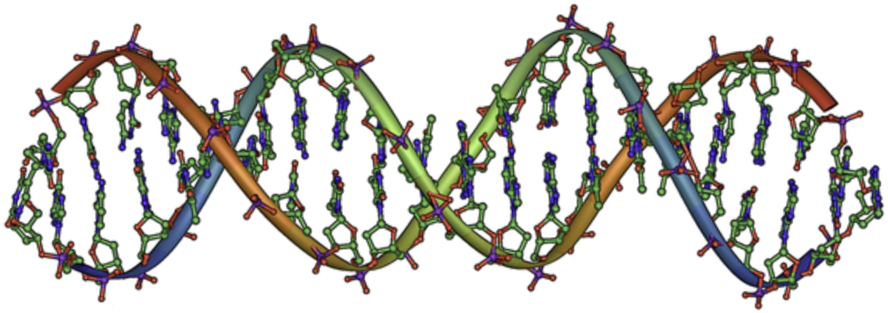
genetic algorithms

- **basic principle** - a set of agents / creatures / ideas / techniques evolve over a period of time



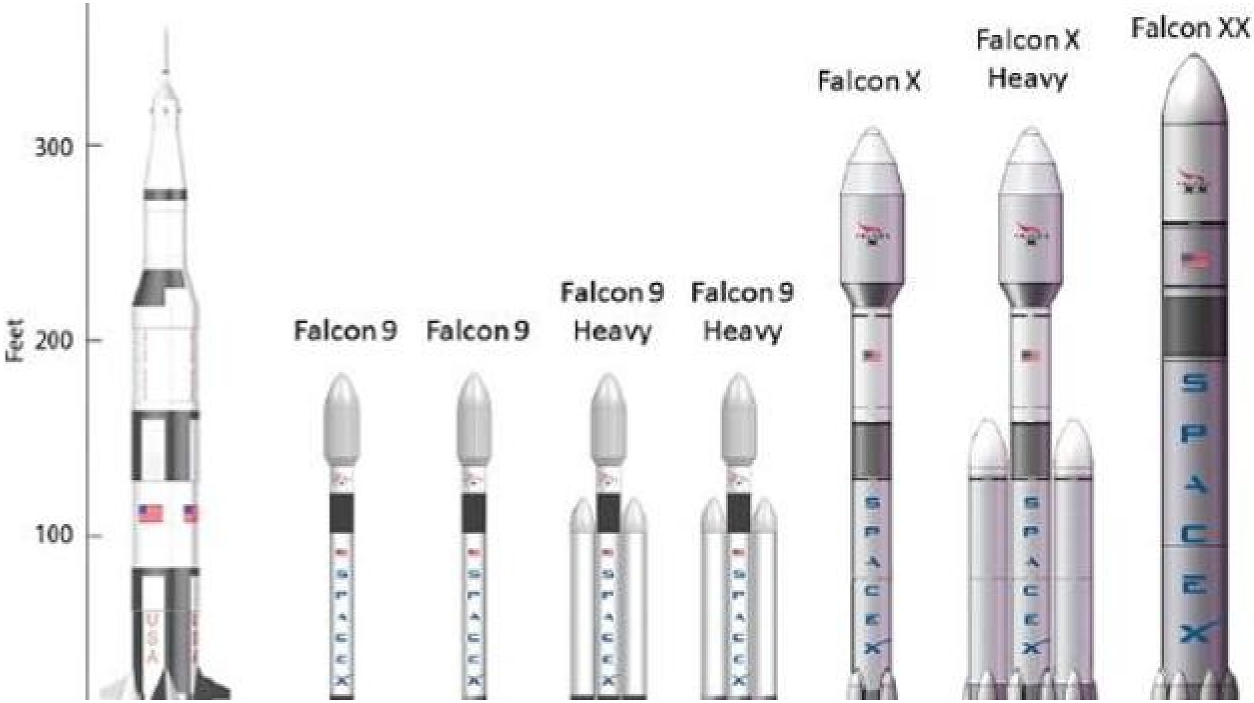
why Genetic Algorithms?

- in math/optimization:
  - When you don’t know how to find a solution, but it’s easy to evaluate any possible solution to a problem
- in art:
  - Can make hybrids of different images / sounds etc., using people as fitness function
  - Or use process of GA itself to generate art
  - Or use it to solve an optimization problem



real world examples

NASA's antenna with best radiation pattern – an “evolved” antenna

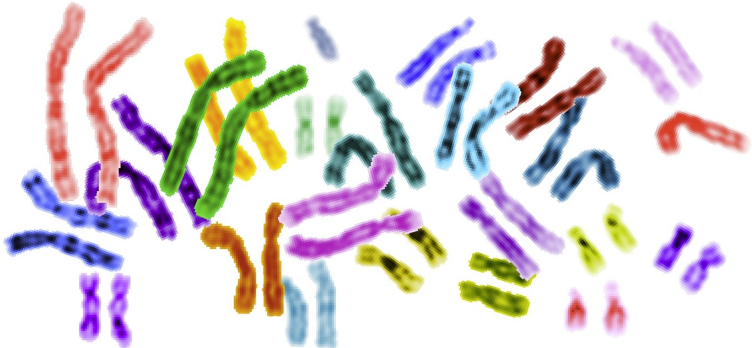


NASA's rocket firing patterns are designed using genetic algorithms

genetic algorithms

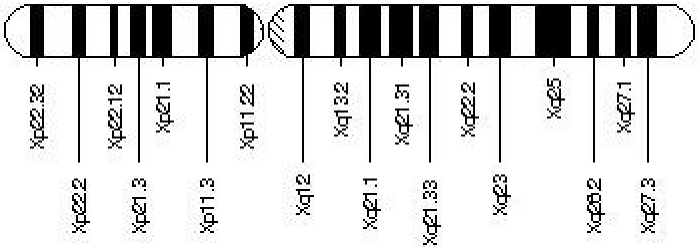
basic ingredients

- **population:** a set of individuals
- **DNA:** each individual has genes which encode some property/action(s)
- **fitness function:** that computes the fitness or quality of any individual
- **reproduction:**
  - crossover + mutation
  - fittest individuals are more likely to be selected for reproduction



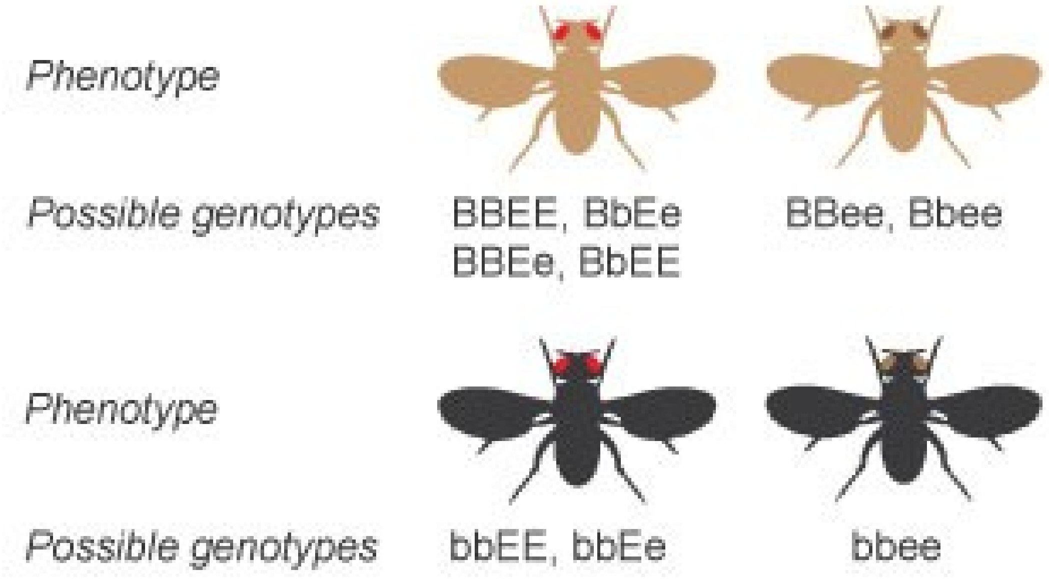
what do genes encode?

real world	virtual world
eye color	RGB values
height	location
number of wings	thruster speed
hair color	shape



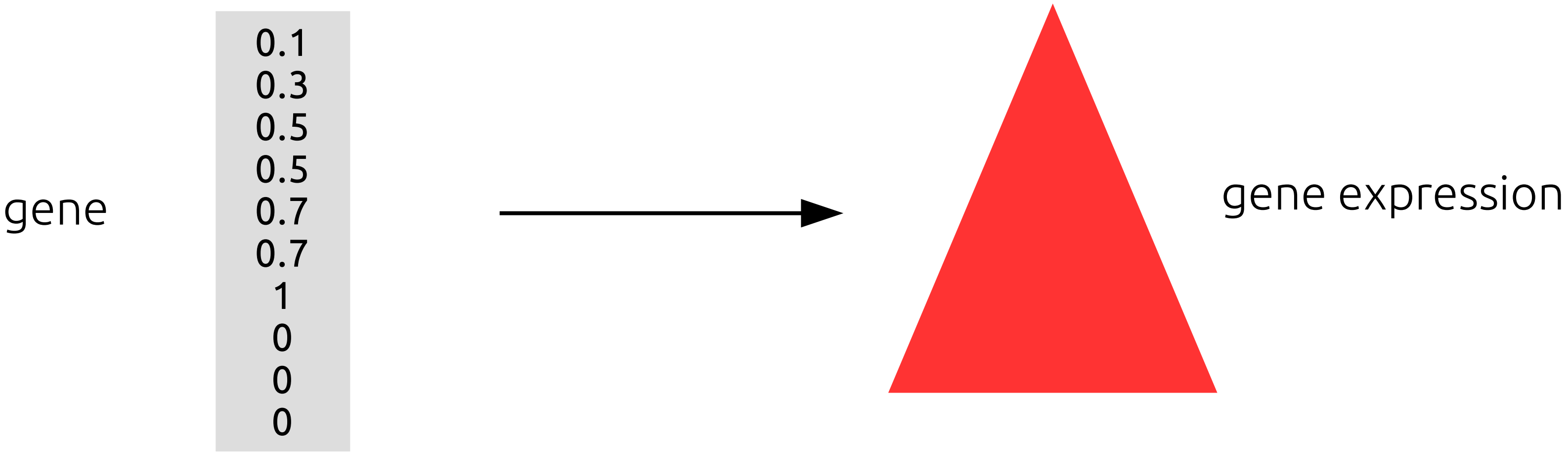
phenotype vs. genotype

in biology



phenotype vs. genotype
in code

genotype	phenotype
float [ ]	location on canvas
float [ ]	speed
ofVector() [ ]	movement sequence
ofTriangle() [ ]	shapes on canvas (an image)



gene

0.1
0.3
0.5
0.5
0.7
0.7
1
0
0
0

gene expression

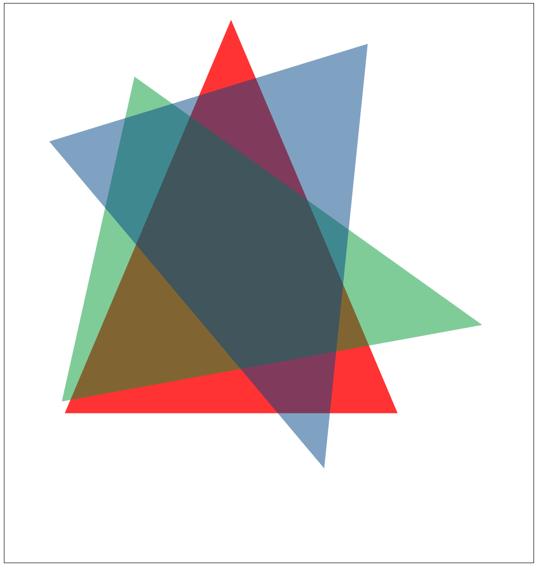
genotype vs. phenotype

genes: float array

0.1	0.2	0.6
0.3	0.6	0.7
0.5	0.9	0.1
0.5	0.2	0.2
0.7	0.4	0.4
0.7	0.5	0.3
1	0	0
0	1	0
0	0	1
0	0.5	0.5

→

an image



genes: float array

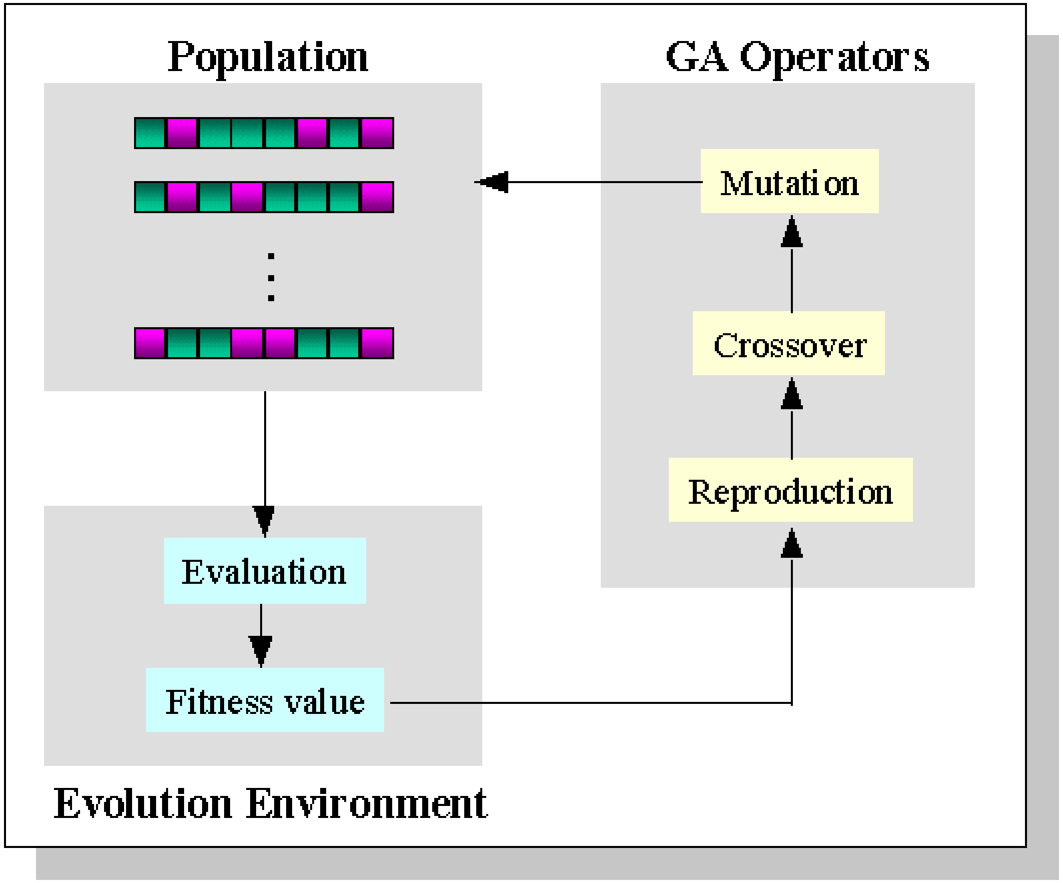
0.2
0.1
0.15
0.7
0.9

→

a string

“hello”

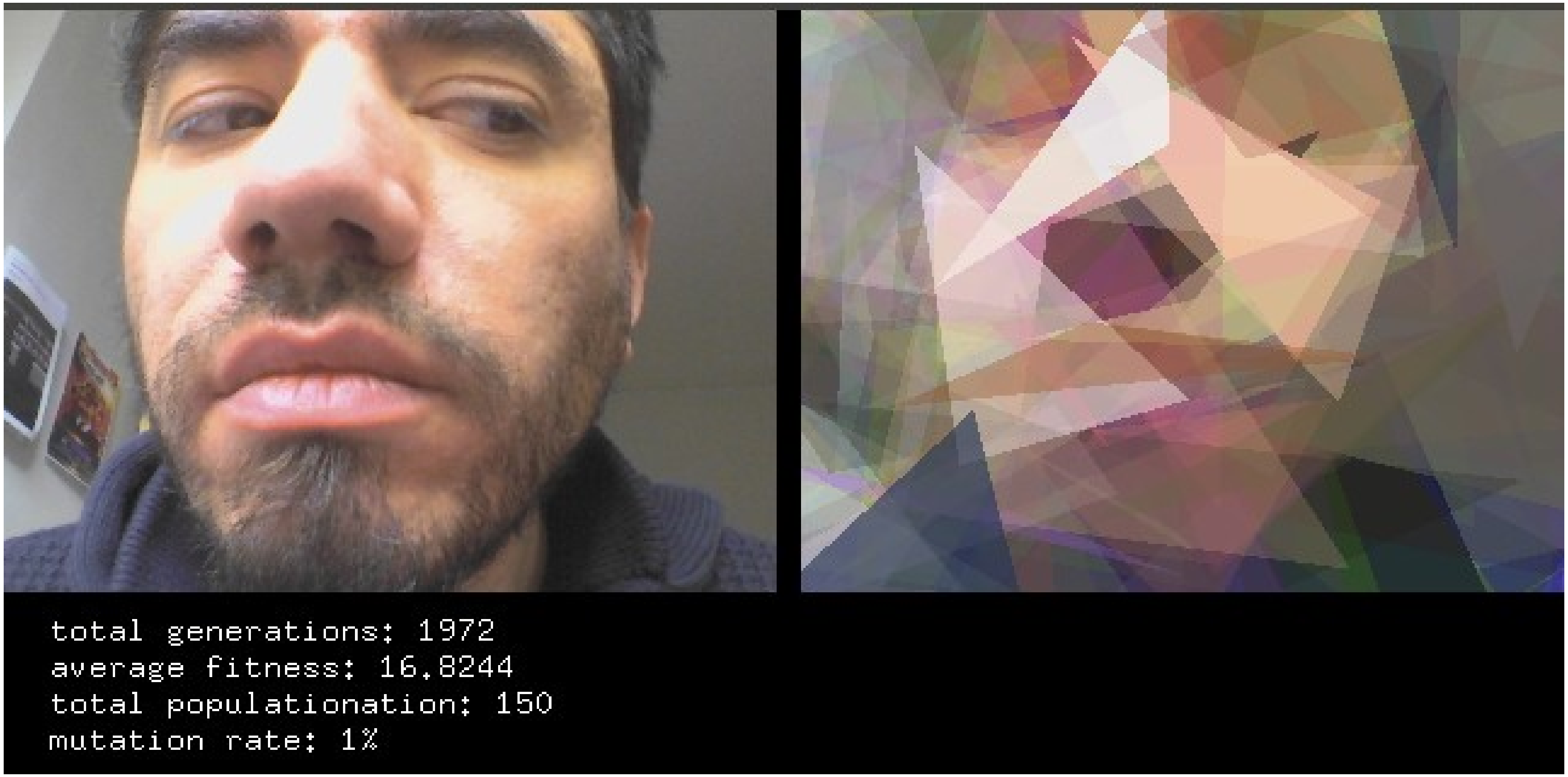
evolutionary pipeline



geneticText
geneticPhotobooth

Nature_Of_Code_SmartRockets
Nature_Of_Code_EvolveFlowField

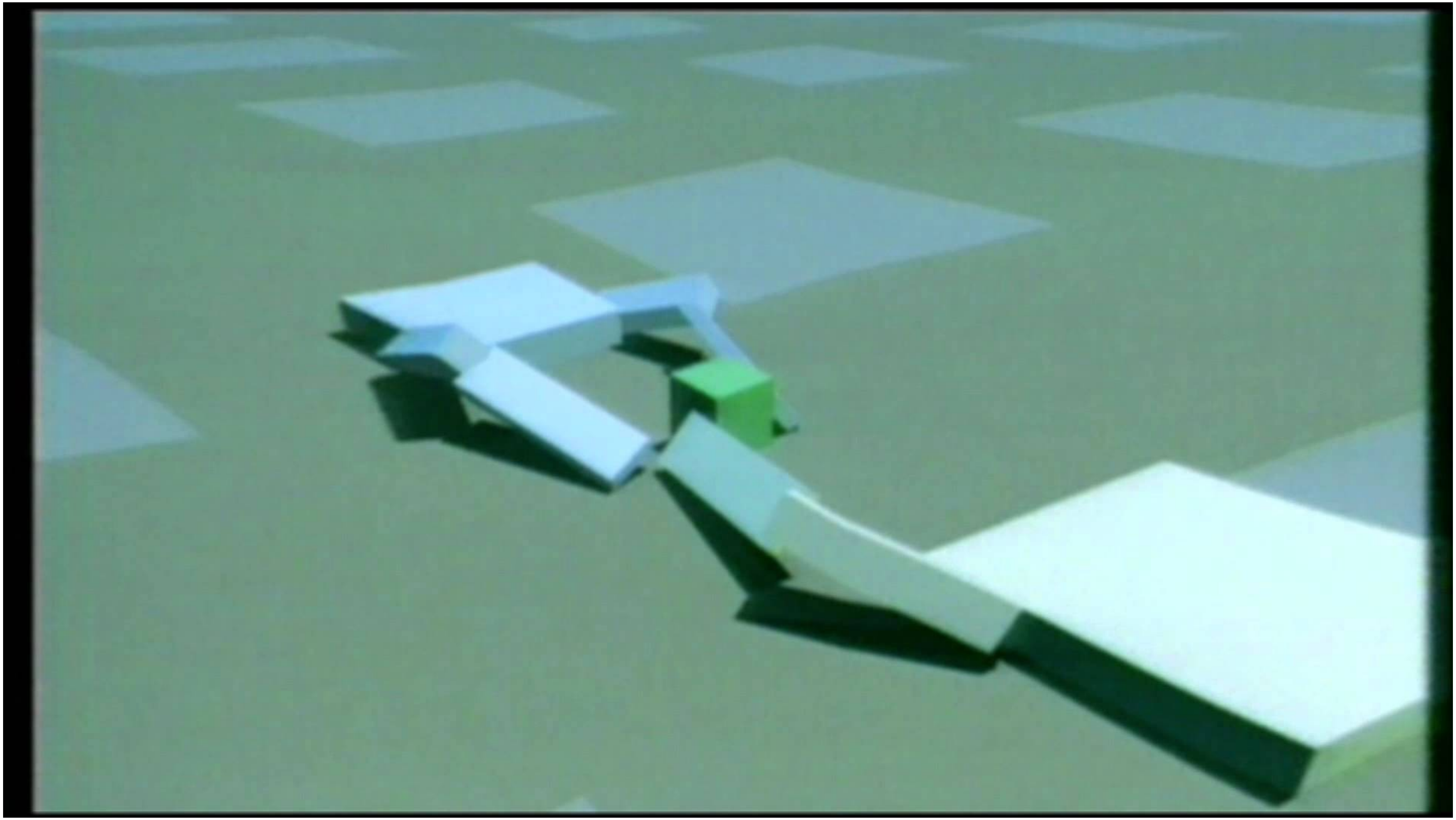
genetic photobooth



```
total generations: 1972
average fitness: 16.8244
total populationation: 150
mutation rate: 1%
```

evolved virtual creatures

by Karl Sims



Karl Sims – evolved virtual creatures

genetic algorithms

as a sculptor's “chisel”

William Latham & Peter Todd

Nature_Of_Code_Faces_interactiveselection

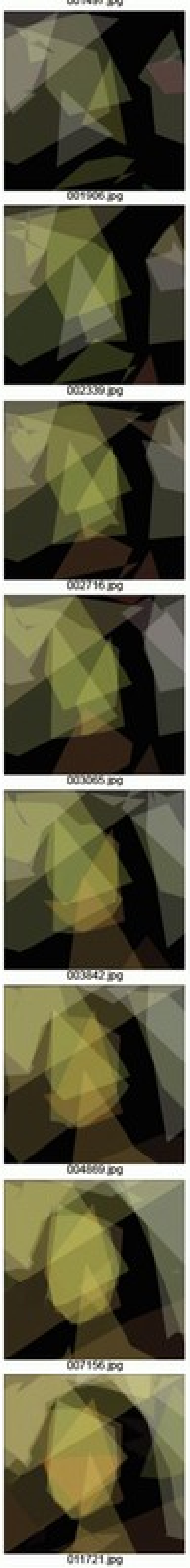
Electric Sheep

genetic algorithms

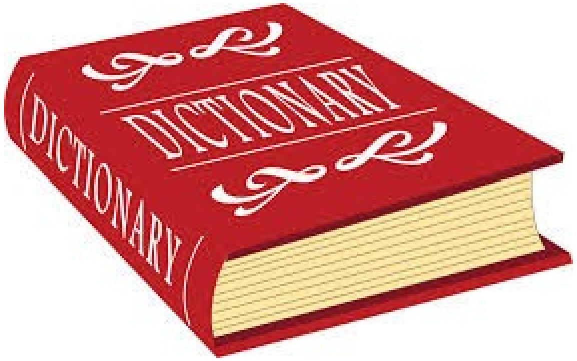
considerations

- sexual vs. asexual reproduction
  - sexual: best n individuals have have babies
  - asexual: individual mutates, if mutation improves fitness changes kept
- variable mutation rate
  - High mutation rate at first, finer later
- picking top % vs. gaussian selection
- interpolating between individuals
  - move smoothly between branches / generations

Evolution of Mona Lisa

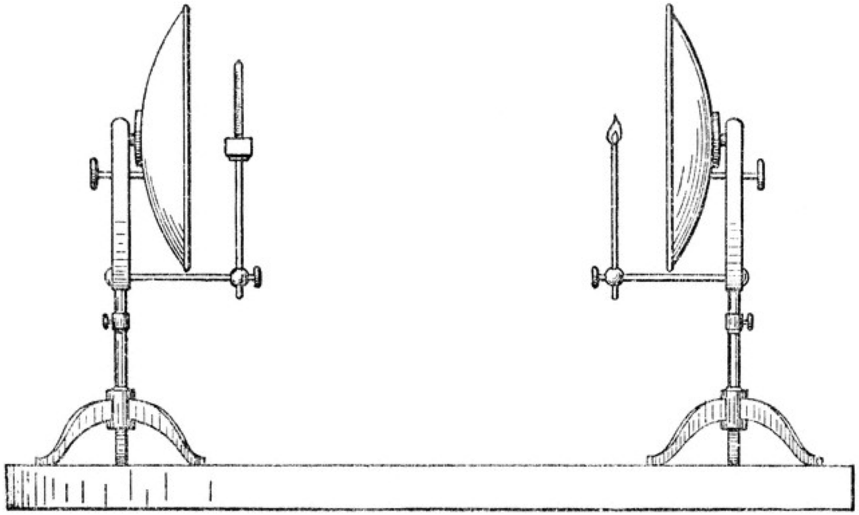


revisiting recursion



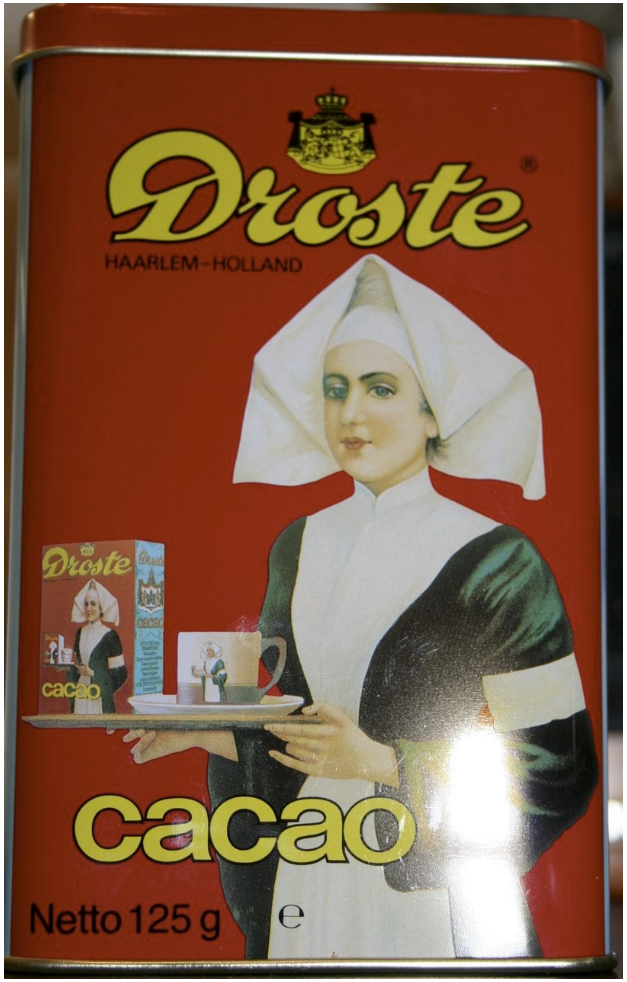
"...when the solution to a problem depends on solutions to smaller instances of the same problem..."

recursion (cont.)



this is how we describe a setting in which objects repeat each other in self-similar ways (ie. mirrors facing each other)"

Droste effect

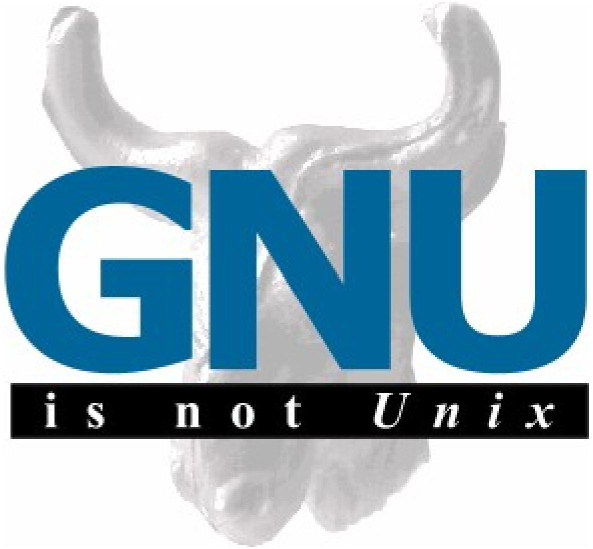


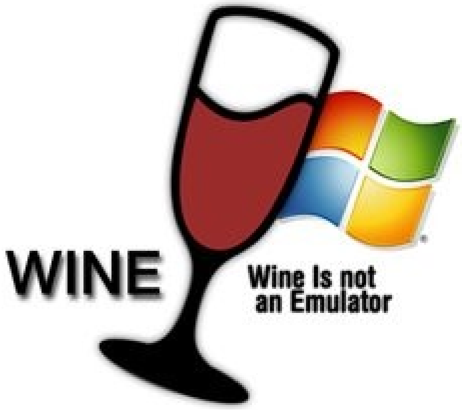
The image contains a smaller copy of itself which in turn contains a smaller copy of itself, which in turn contains a smaller copy of itself, which in turn contains a smaller copy of itself...

Bjork - bachelorette

Bjork - Bachelorette

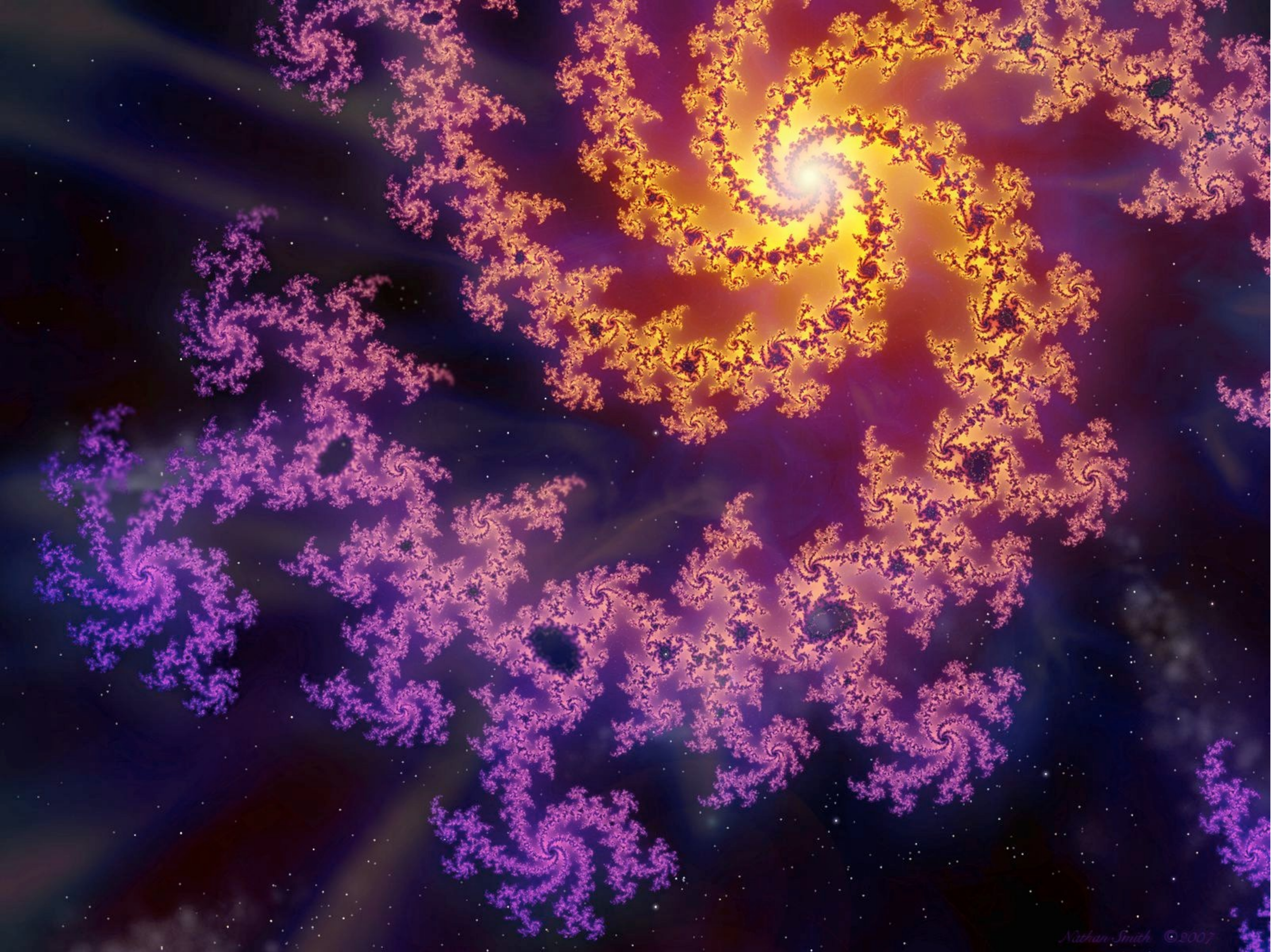
hilarious recursive computing jokes



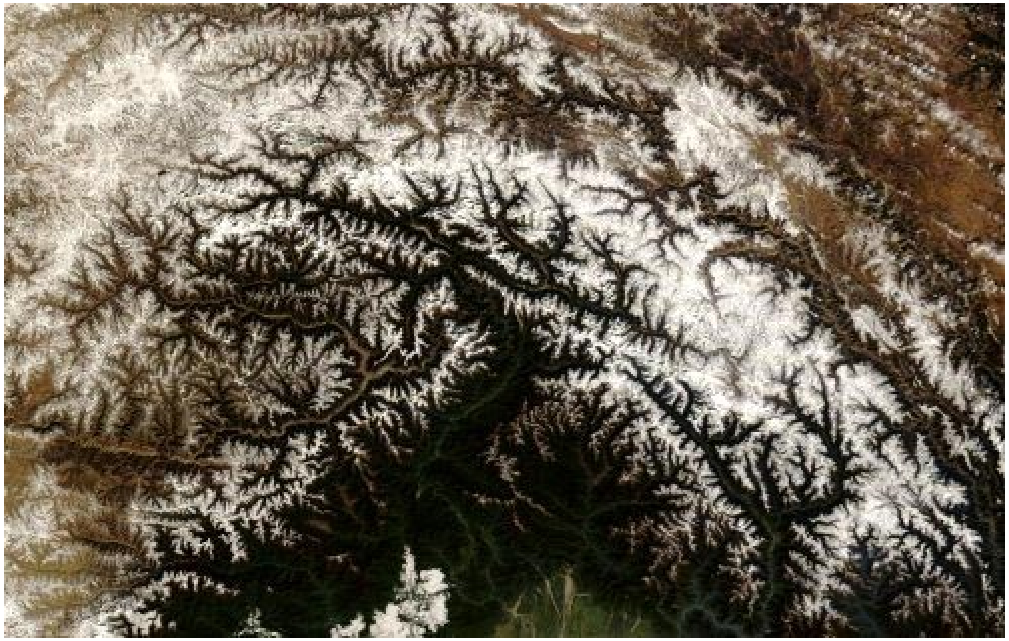


fractals

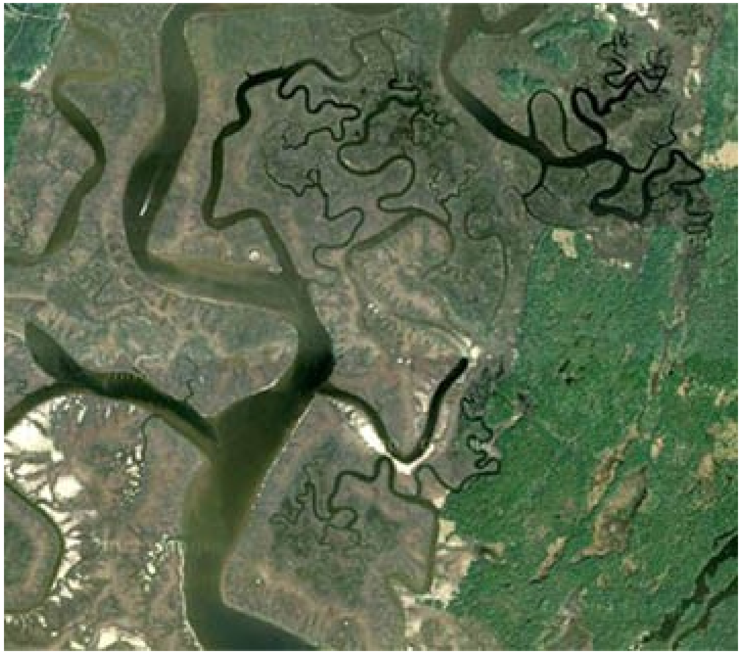
- from Latin “fractus” (broken)
- shapes that repeat on many levels
- these shapes don't even have to be the same on the different levels, as long as they share some similarity features
- they exist everywhere in nature and they are a much more accurate way of describing many of it's phenomena


Nathan Smith ©2007

fractals in nature

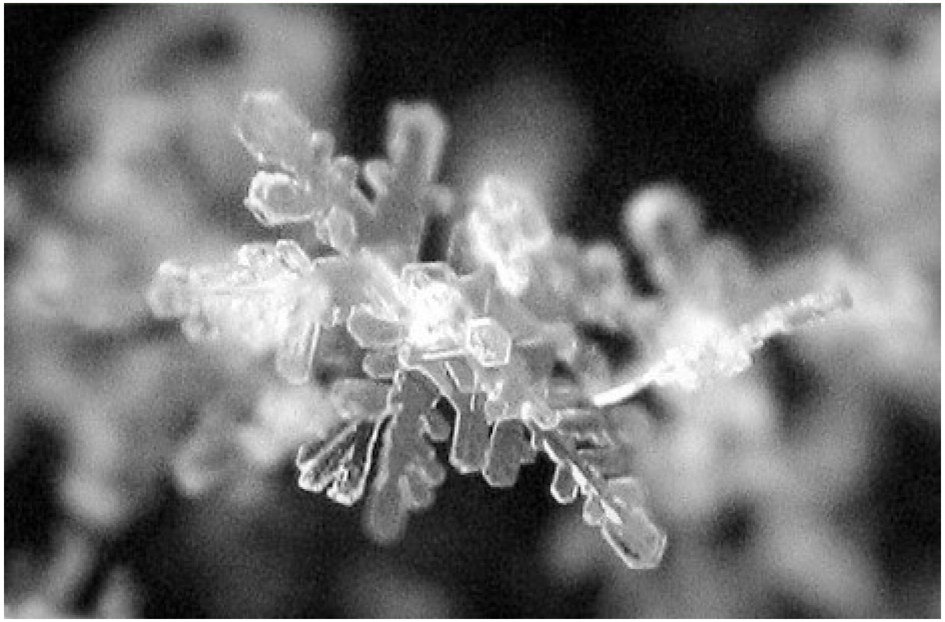


mountains in Thibet



rivers in Georgia

fractals in nature



fractals in nature

edible fractals

beware of infinity!

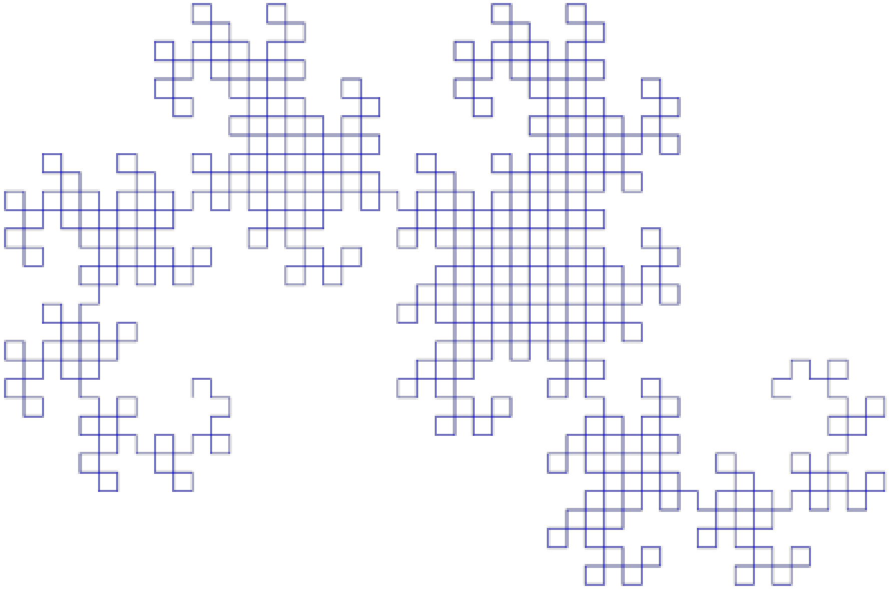
- a computer can't deal with infinity
- one of the central problems of artificial intelligence: “does a problem have a solution or does it continue ad infinitum?”

```
int x = 1;
while (x > 0)
{x++;}
```

recursiveTree

recursion_circles

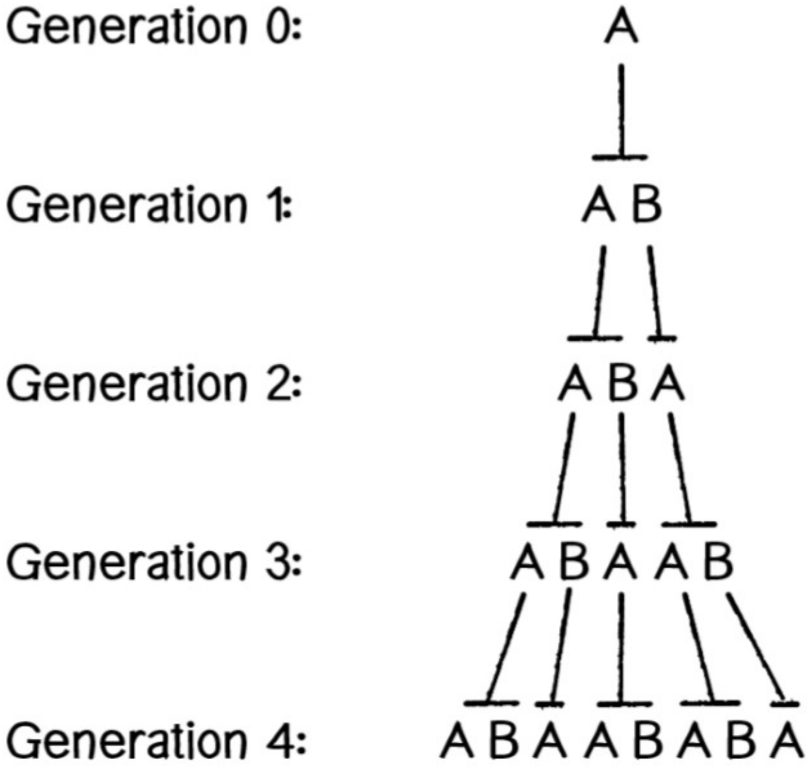
L-systems



Generative grammar

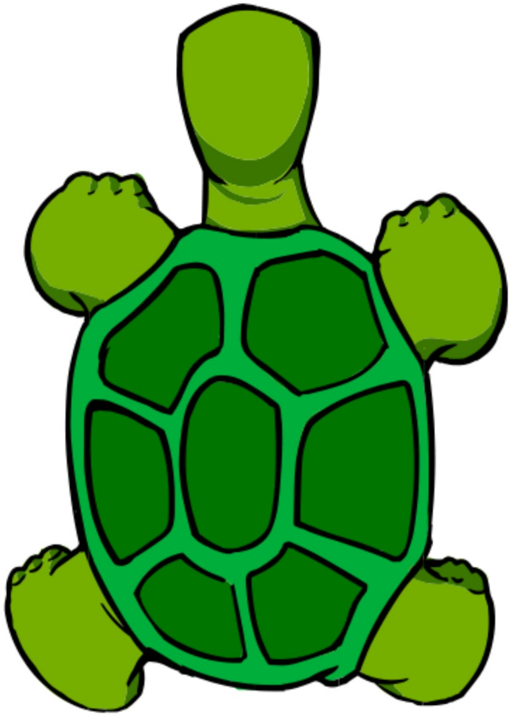
- A set of simple rules about what “token” can be replaced with what.
  - Alphabet: **A B**
  - Axiom: **A**
  - Rules: **(A → AB)**

    (B → A)

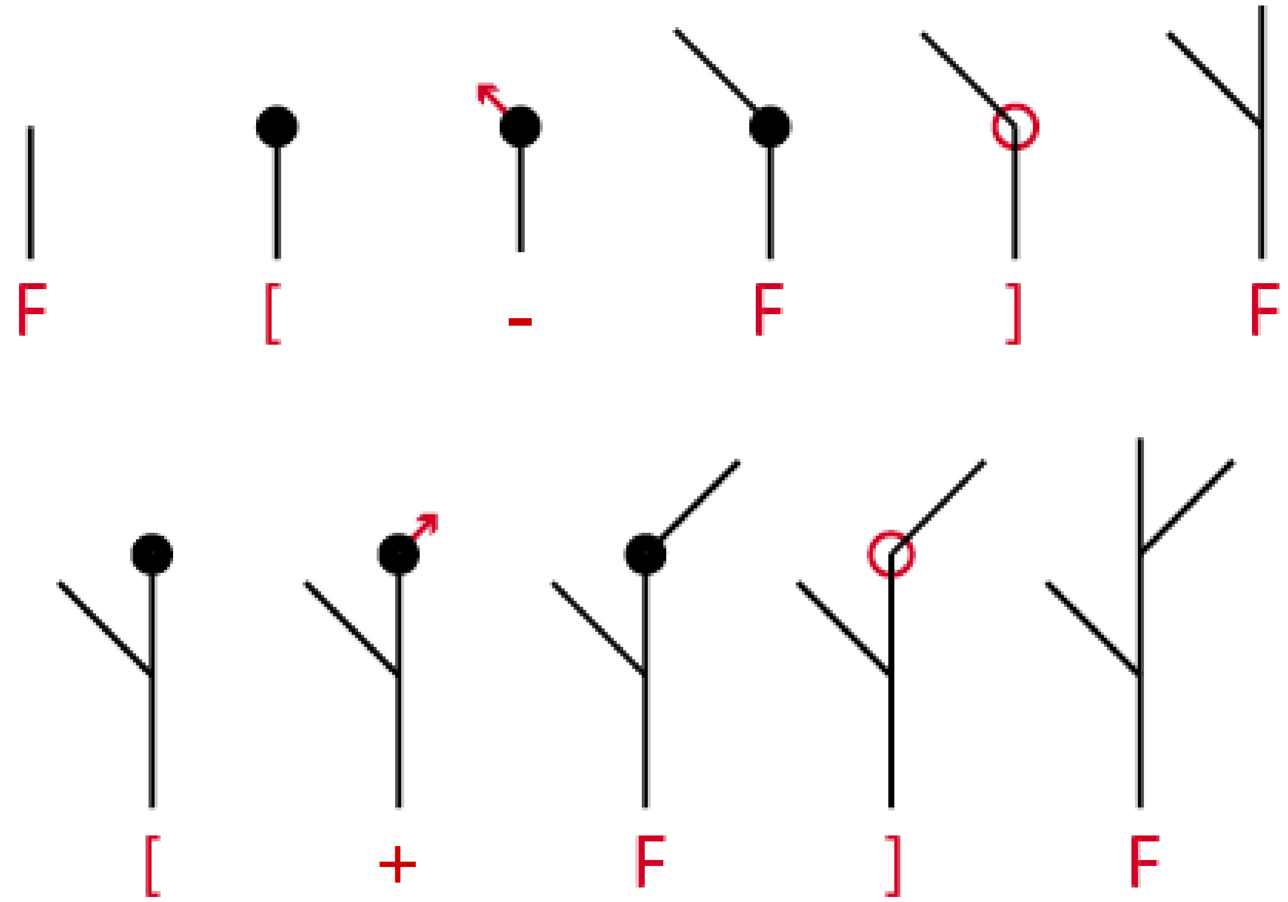


L-system interpretation

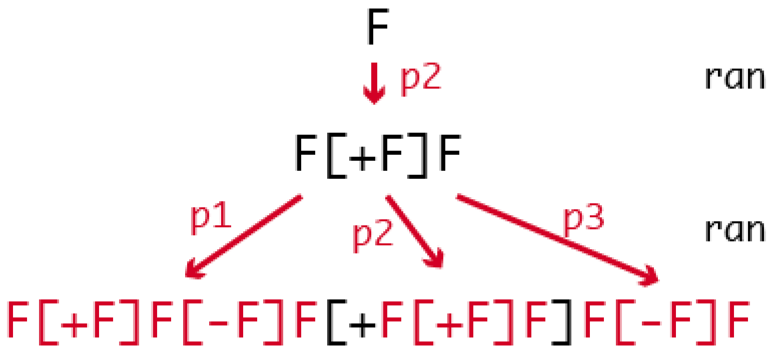
```
F: ofLine(0,0,0,len); ofTranslate(0,len);
G: ofTranslate(0,len);
+: ofRotate(angle);
-: ofRotate(-angle);
[: ofPushMatrix();
]: ofPopMatrix();
```



L-System interpretation



stochastic L-Systems



```
random (1-3) = 2

random (1-3) = 3,2,1
```

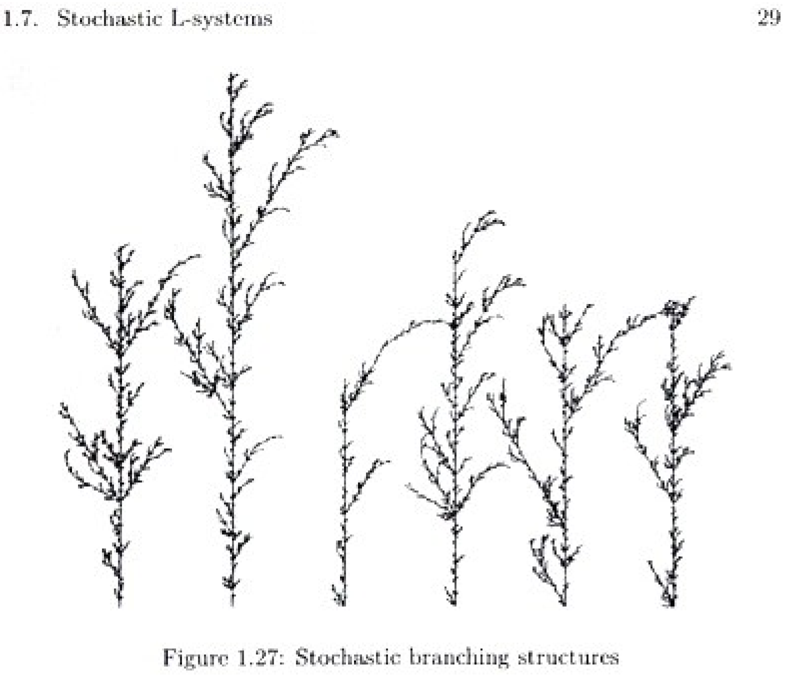
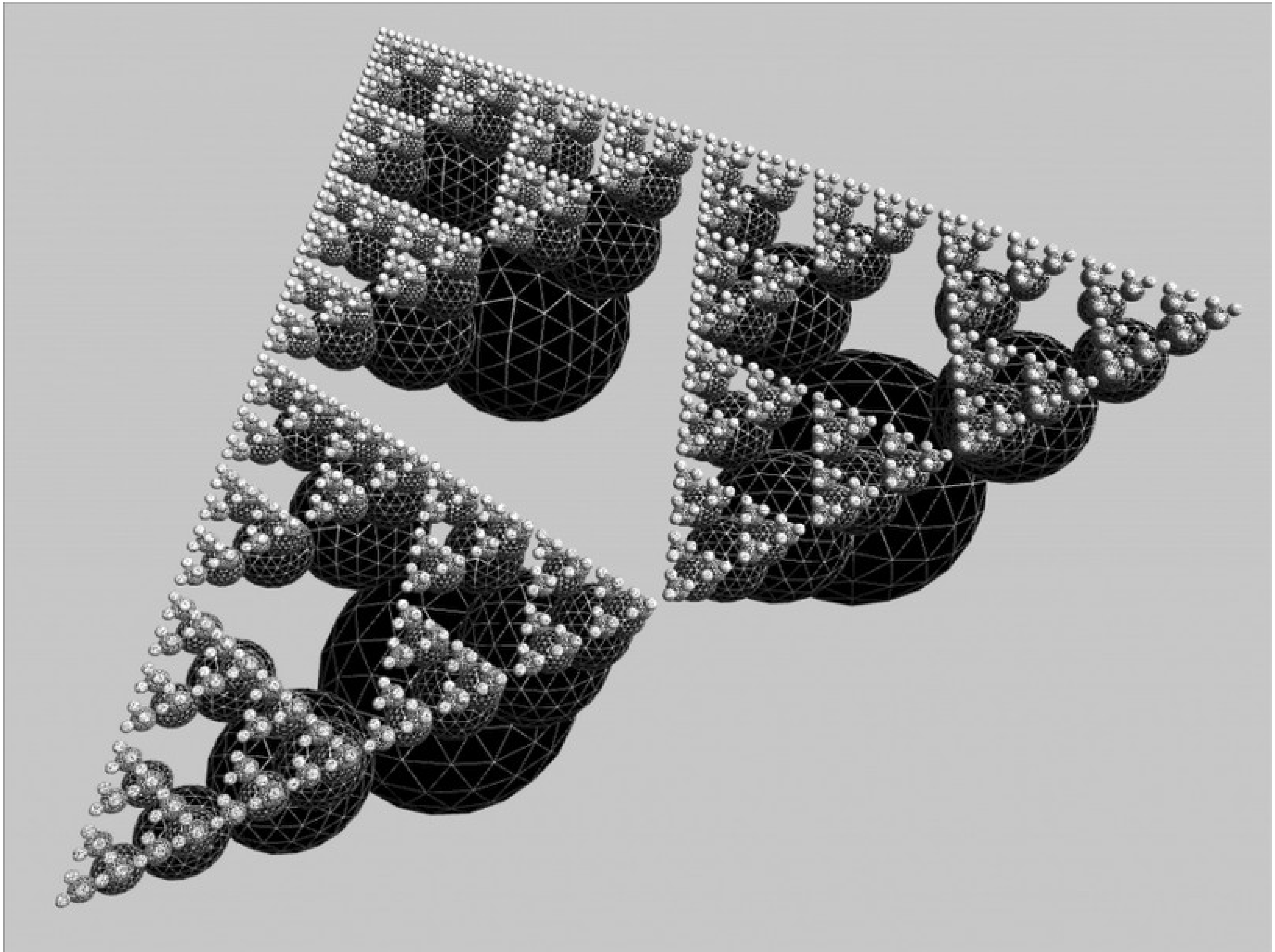
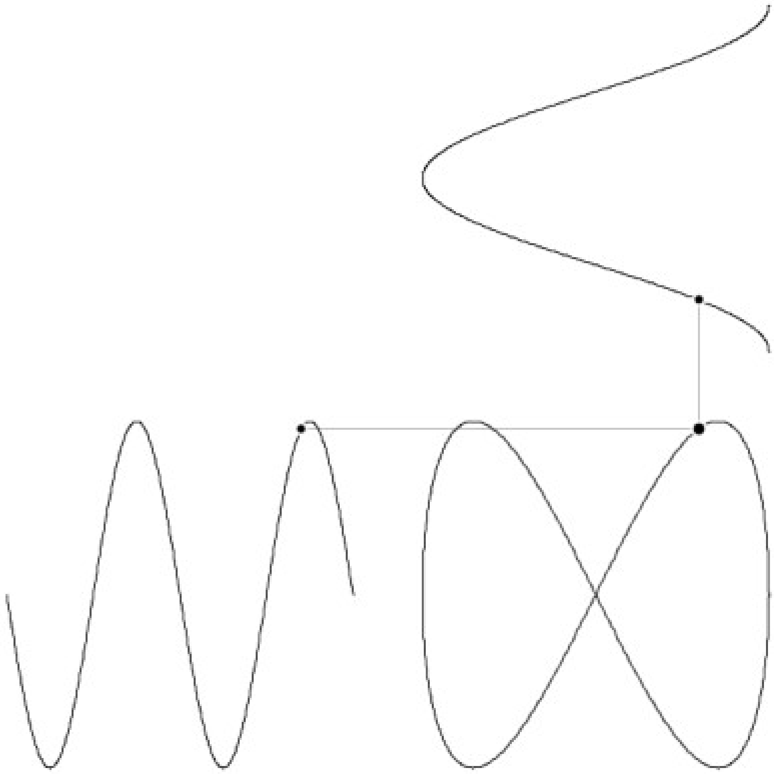

1.7. Stochastic L-systems 29

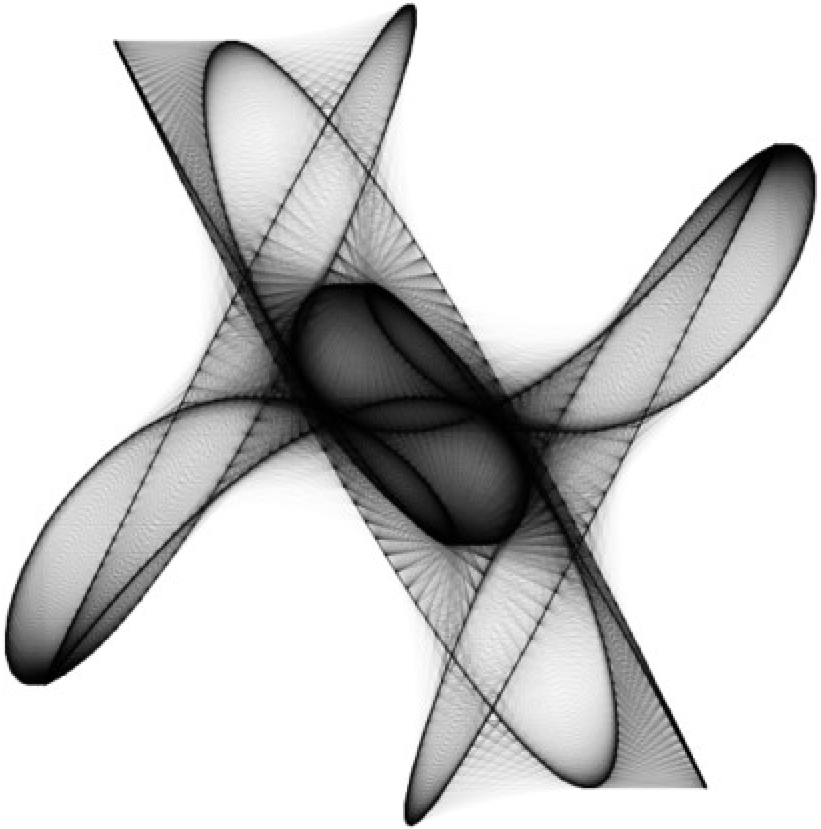
Figure 1.27: Stochastic branching structures

ofxRules



curve drawing with Lissajous





Lissajous_basic
Lissajous_advanced