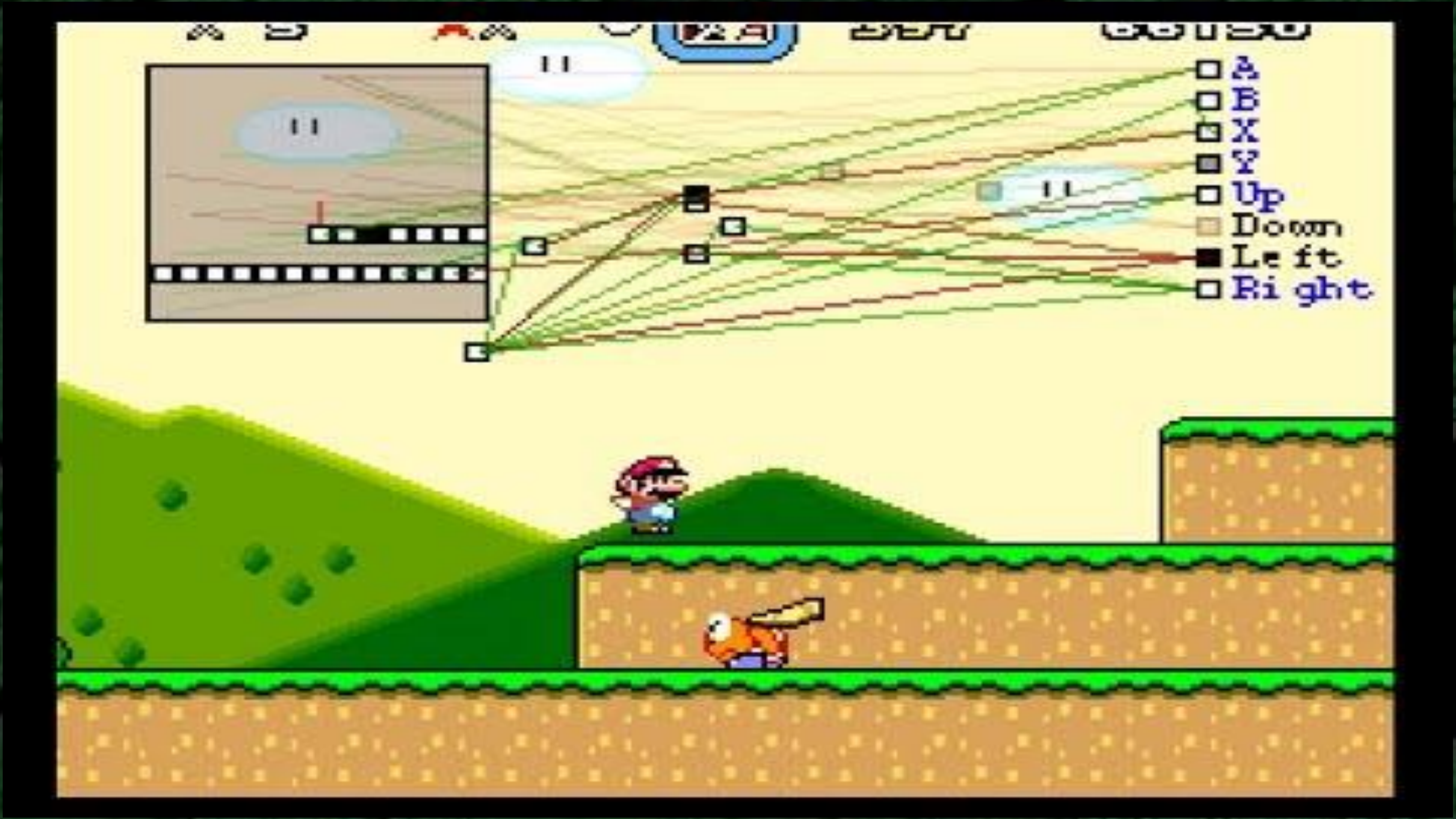
Genetic Algorithms

Presentation by Eli Hodges

Based on the paper by Eli Hodges

What to Expect

- The patrons of genetic algorithms
- How to implement genetic algorithms
- Applications of genetic algorithms in practical contexts


A
B
X
Y
Up
Down
Left
Right

What is a genetic algorithm?

- Optimization search
- Designed to simulate biology using natural selection
  - Mimics key phases of natural selection
- Converges to numerous solutions of equal efficiency

Evolution by Natural Selection

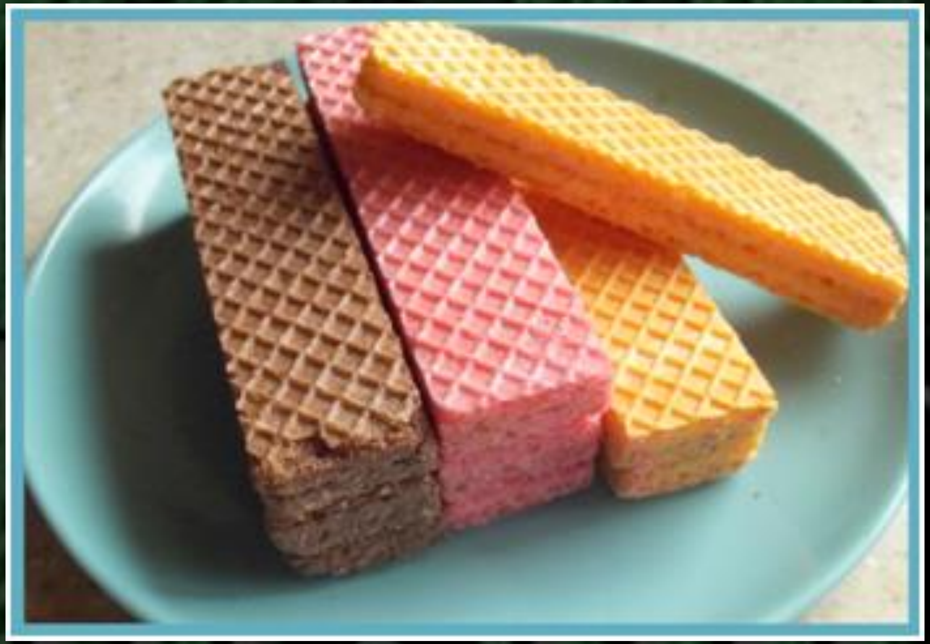
- Presented in the 1859
  - "On the Origin of Species by means of Natural Selection"
- Founded on four principals
  - Variation
  - Overproduction
  - Adaptation
  - Descent with Modification

Evolution

The process of changing through time. Modern species are the result of millennia of small changes driven by natural selection.

Natural selection

- A process of natural elimination
- Organisms are selected to continue their lineage based on traits that make them more fit for their current environment
- Survival of the fittest
  - … Of the given set.



Variation

- Variation exists within the population of all organisms
- Multiple genetic characteristics allow organisms to adapt to various situations
- Nature selects for or against specific genetic characteristics.

Overproduction

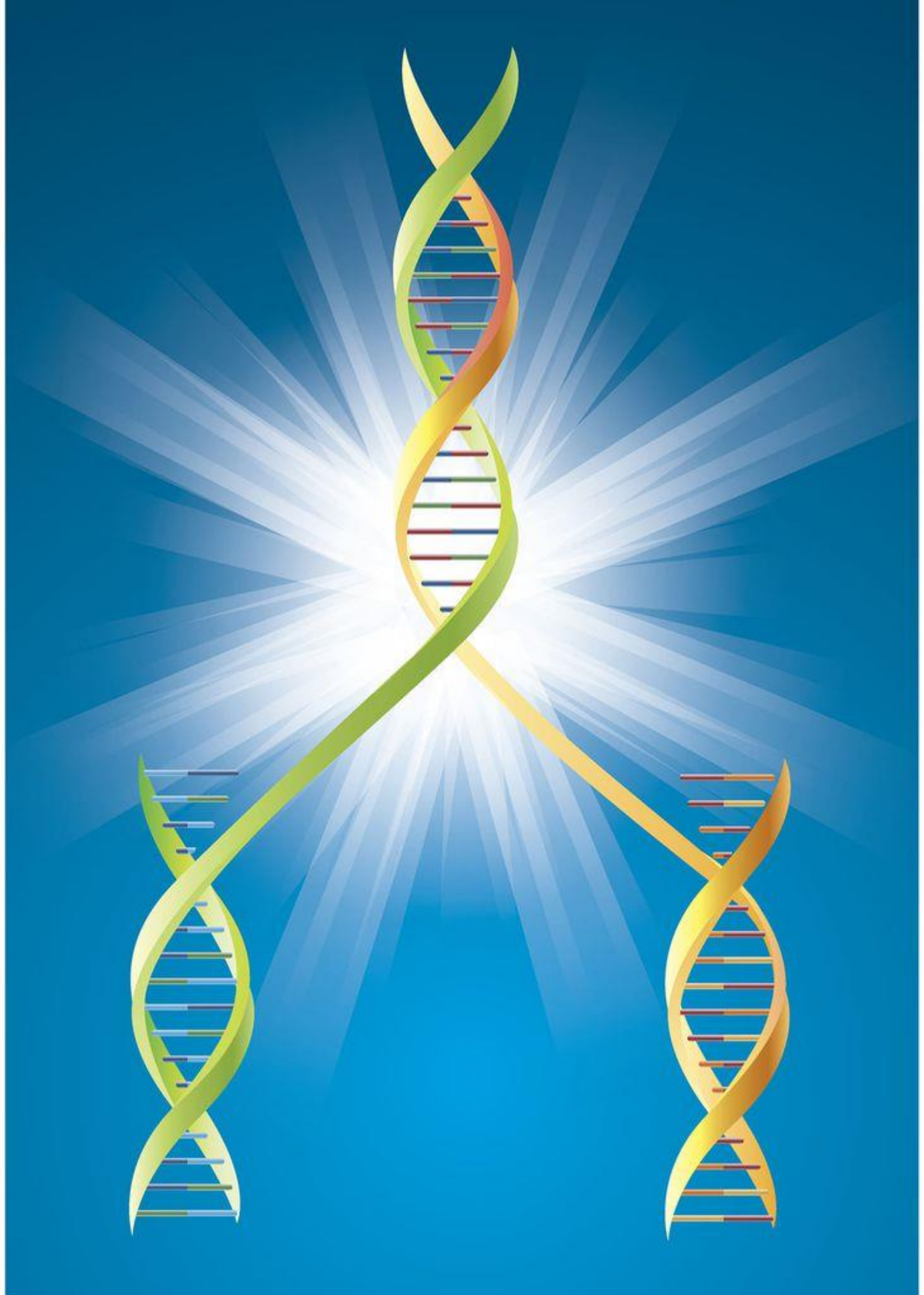
- Each species in a population exceeds its sustainable size within a particular environment or habitat.
- A result of increased birthrate or reduced deathrate

Adaptation

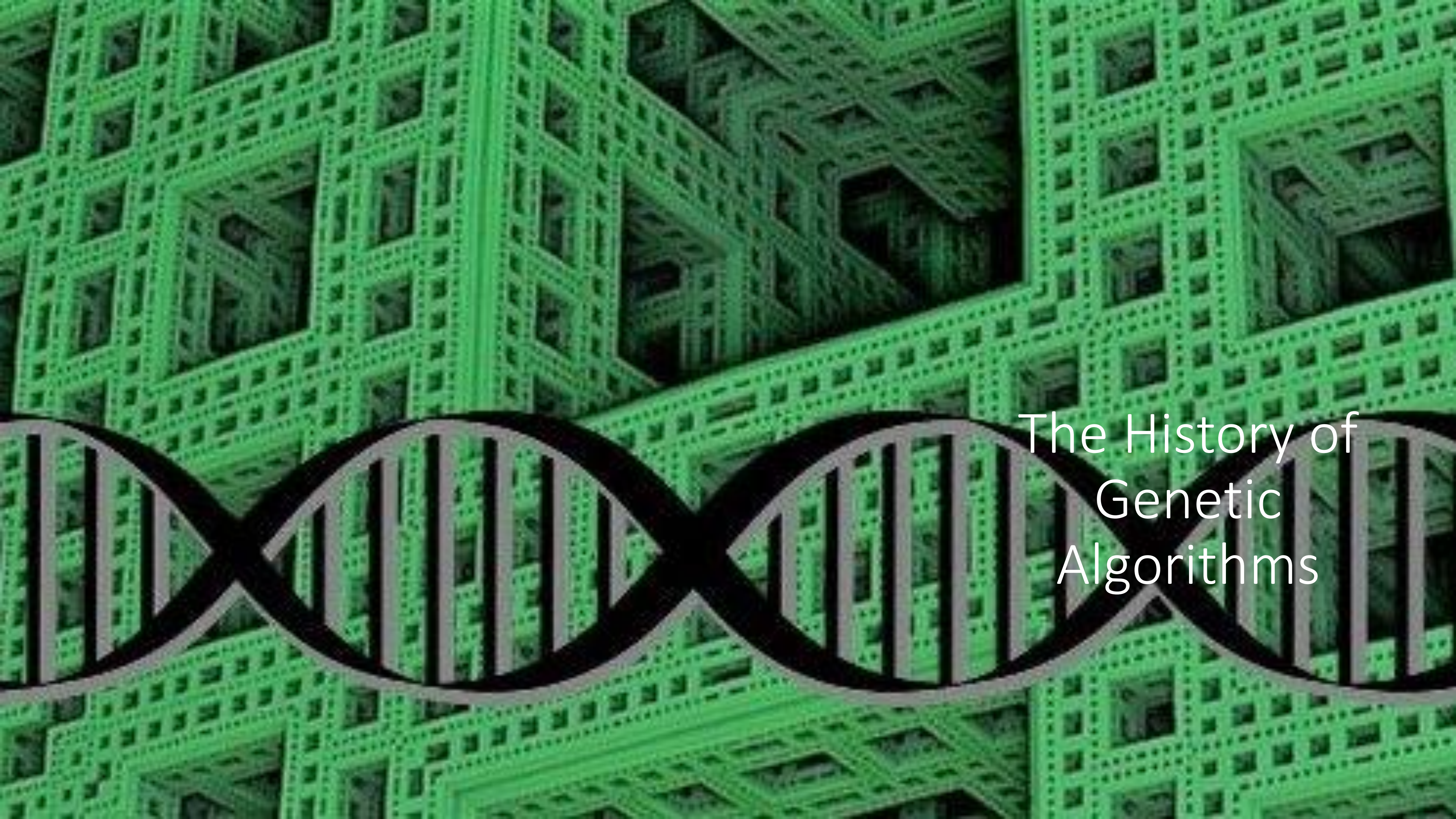
- Considered the result of natural selection
- Unfit individuals are culled until only adapted organisms remain

Descent with Modification

- The passage of traits from parent to offspring
- The mechanic of which evolution 'actually happens'



The History of Genetic Algorithms



Alan Turing

Alan Turing

- First to mention evolution in a computational context
  - In "Computing Machinery and Intelligence"
  - As a response to Ada Lovelace
  - Was a result of a thought experiment.
    - Tangential to the purpose of the paper

Alan Turing

- Compared an ideal mechanical brain to an “atomic pile of super-critical size”

- Natural selection as a model
  - Structure of the child machine --- Hereditary Material
  - Changes in structure --- Mutations in nature
  - Natural Selection --- Judgement of the Experimenter

- Concept was completely mechanical, no automation involved

Nils Aall Barricelli

Nils Aall Barricelli

- Attempted to simulate evolution
- Used punch card programming
- Emulated random number generation by shuffling decks of cards

Alex Fraser

Alex Fraser

- Simulated evolution to the same effect as Barricelli
- Garnered much more acclaim for his work
- Tuned the selection phase to select for a specific trait

Hans-Joachim Bremermann

Hans-Joachim Bremermann

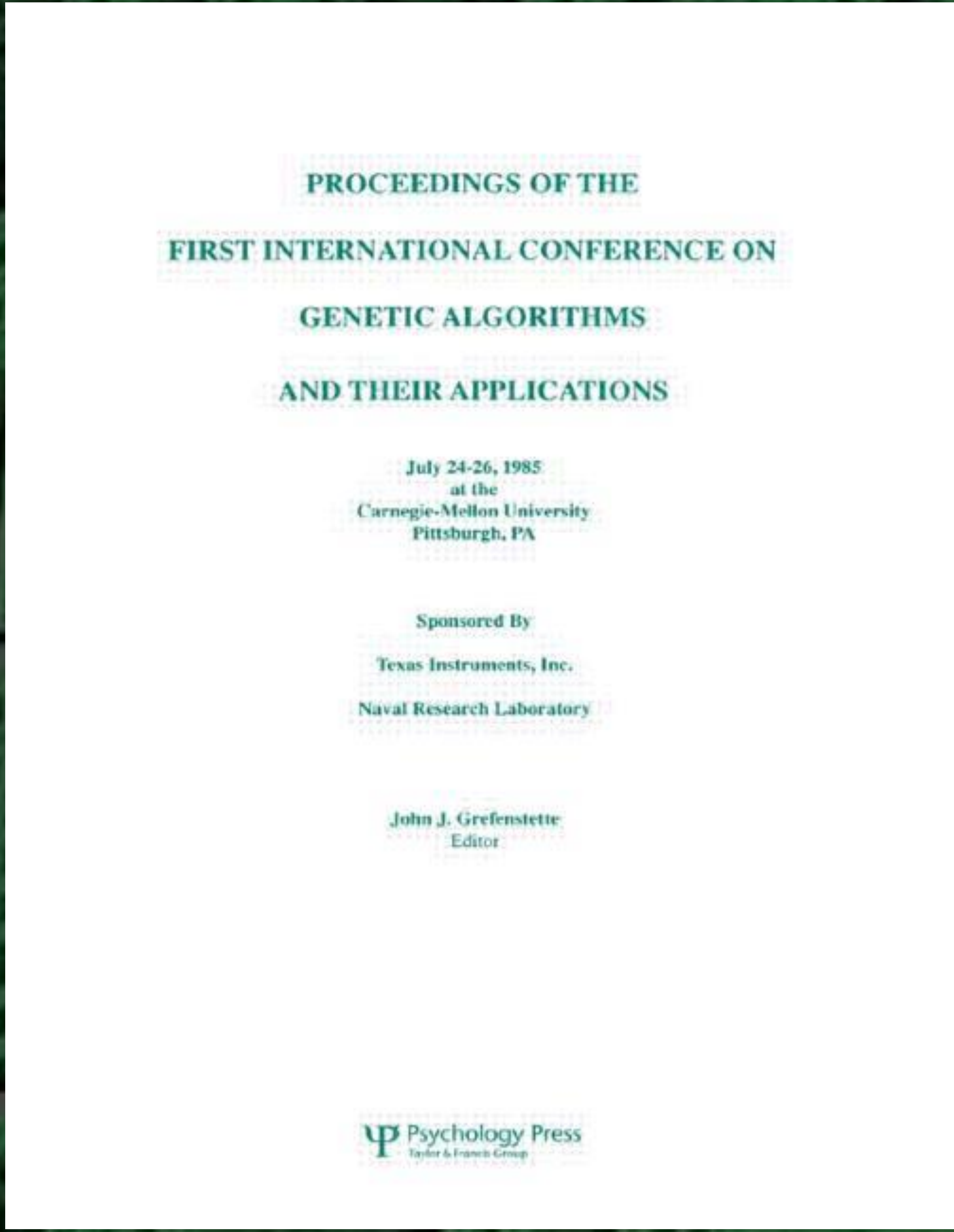
- Considered natural selection from a problem soving context
- Initial population of solutions
- Bremmermans’ limit

Ingo Rechenberg

and Hans-Paul Schwefel

Ingo Rechenberg and Hans-Paul Schwefel

- Work was done independently, but with similar conclusions
- Developed “Evolutionary Strategies”
  - Solved complex engineering problems



PROCEEDINGS OF THE

FIRST INTERNATIONAL CONFERENCE ON

GENETIC ALGORITHMS

AND THEIR APPLICATIONS

July 24-26, 1985
at the
Carnegie-Mellon University
Pittsburgh, PA

Sponsored By

Texas Instruments, Inc.

Naval Research Laboratory

John J. Grefenstette
Editor

Psychology Press
Taylor & Francis Group

-1985-

First international Conference on Genetic Algorithms

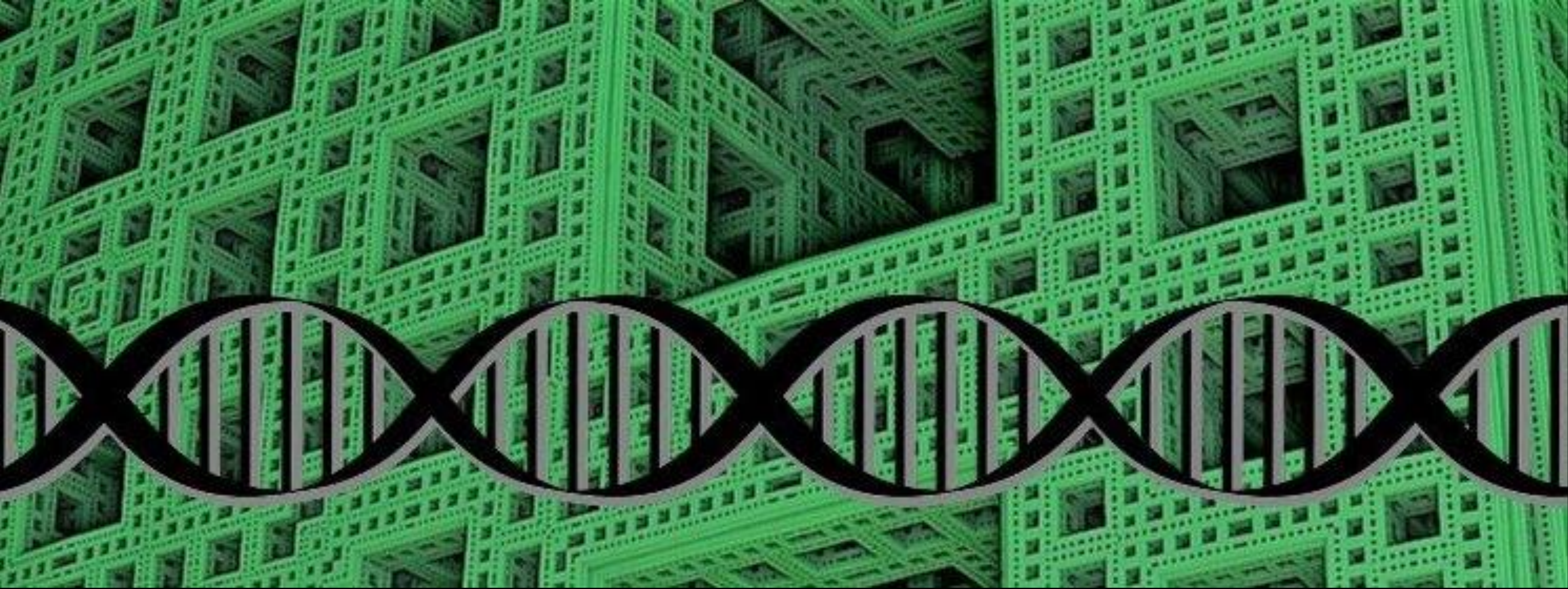

Selections and
Corrections

Implementation

Like parent, like child

- Intended to mechanically simulate evolution to a purpose

- Segmented into several distinct phases
  - Initialization of population
  - The Fitness Function
  - Selection
  - Crossover
  - Mutation



Vocabulary

Individual

- In Biology: A single, separate organism distinguished from others of a same kind
- In our context: An individual solution distinguished from other solutions though its derived tactics
- In both: Characterized by genes organized into chromosomes

Gene

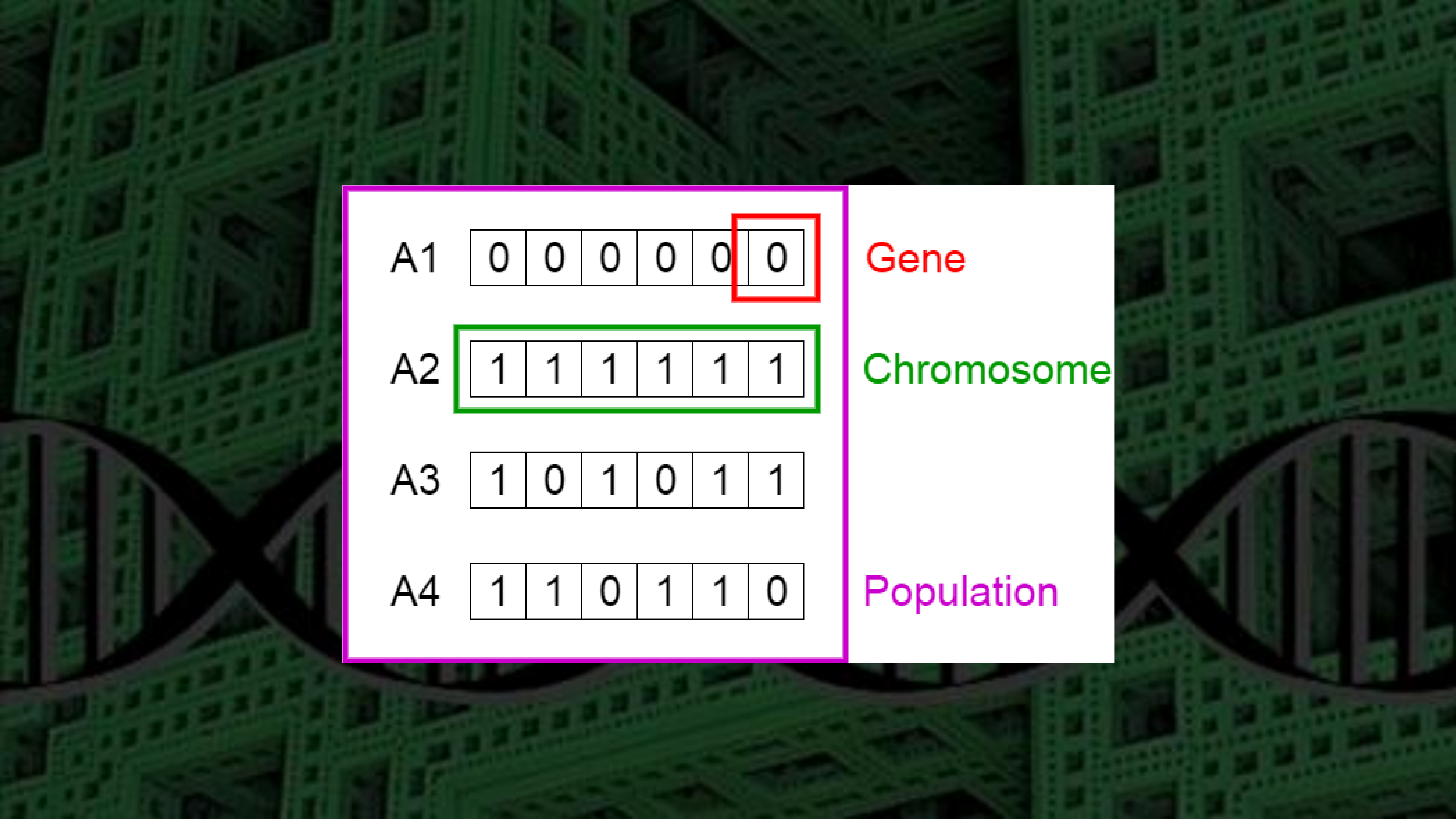
- In Biology: A structure of nucleotide ‘tuples’ that parameterize genetic information
- In our context: A single value, usually binary, that parameterizes synthetic genetic information
- In both: Strung together to construct chromosomes

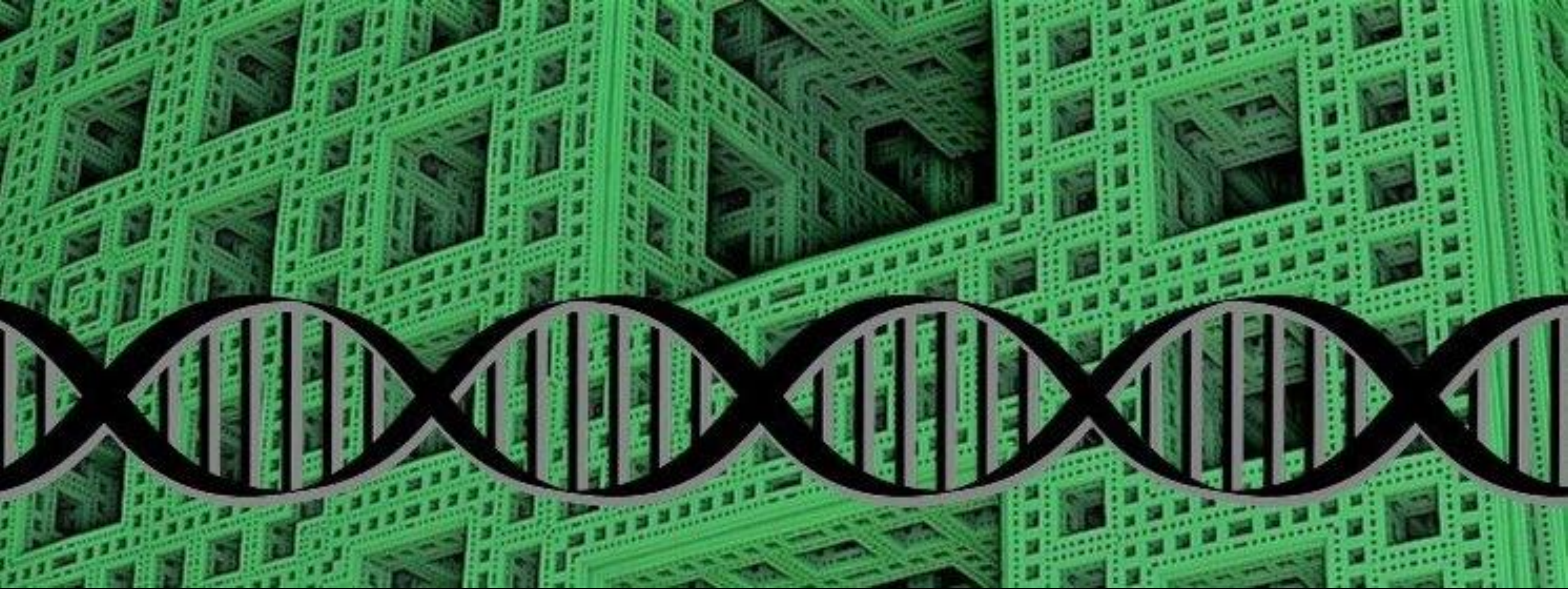
Chromosome

- In Biology: A string of genes with part or all of an individual’s genetic material
- In our context: A string of genes that contain all genes associated with the given solution
- In both: Split and recombined to pass genetic information to children

Population

- In Biology: A group of individuals that interbreed and live in the same place at the same time
- In our context: A collection of individuals comprising a given solution set
- In both: A combined collection of individuals in a given context


A1 0 0 0 0 0 0
A2 1 1 1 1 1 1
A3 1 0 1 0 1 1
A4 1 1 0 1 1 0
Gene
Chromosome
Population



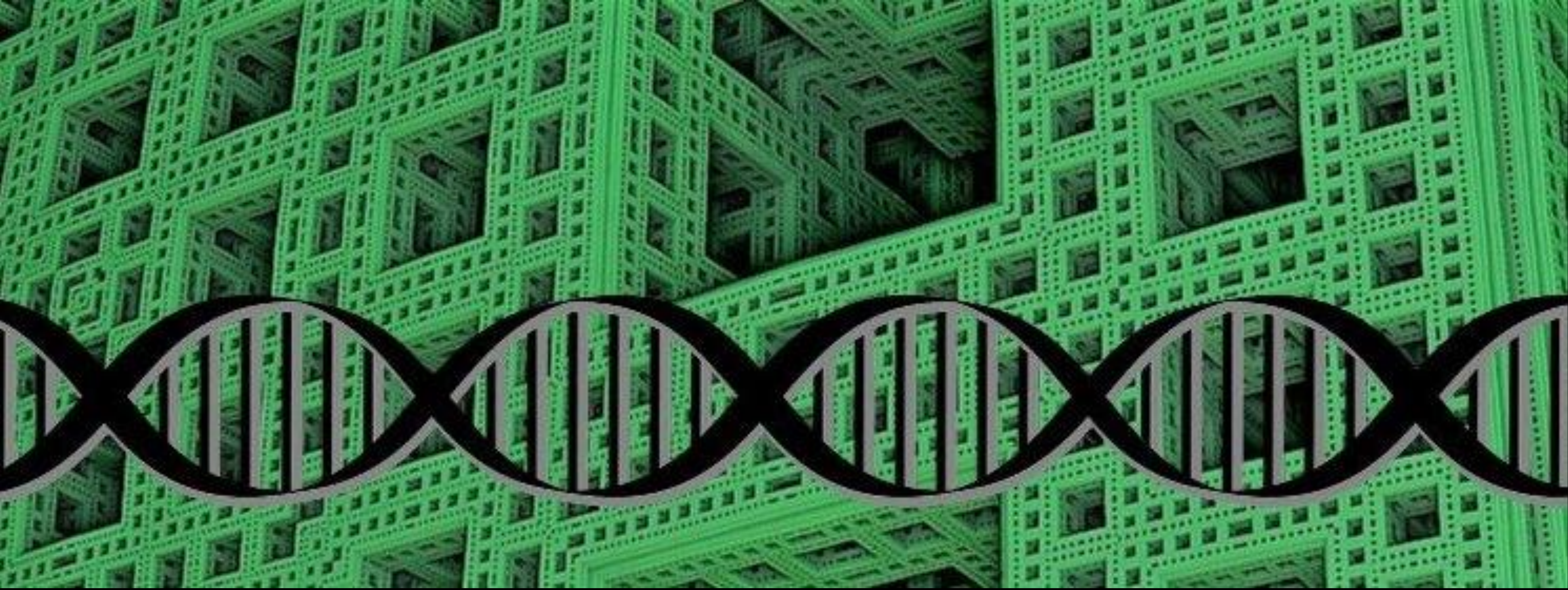
The Fitness Function

Fitness

- Determines how successful a given solution is at problem completion
- Uniquely implemented for each problem set


Gen 0 species 71 genome 1 (23%)
Fitness: 528 Max Fitness: 528
DONUT PLAINS 1
Down
Left
Right

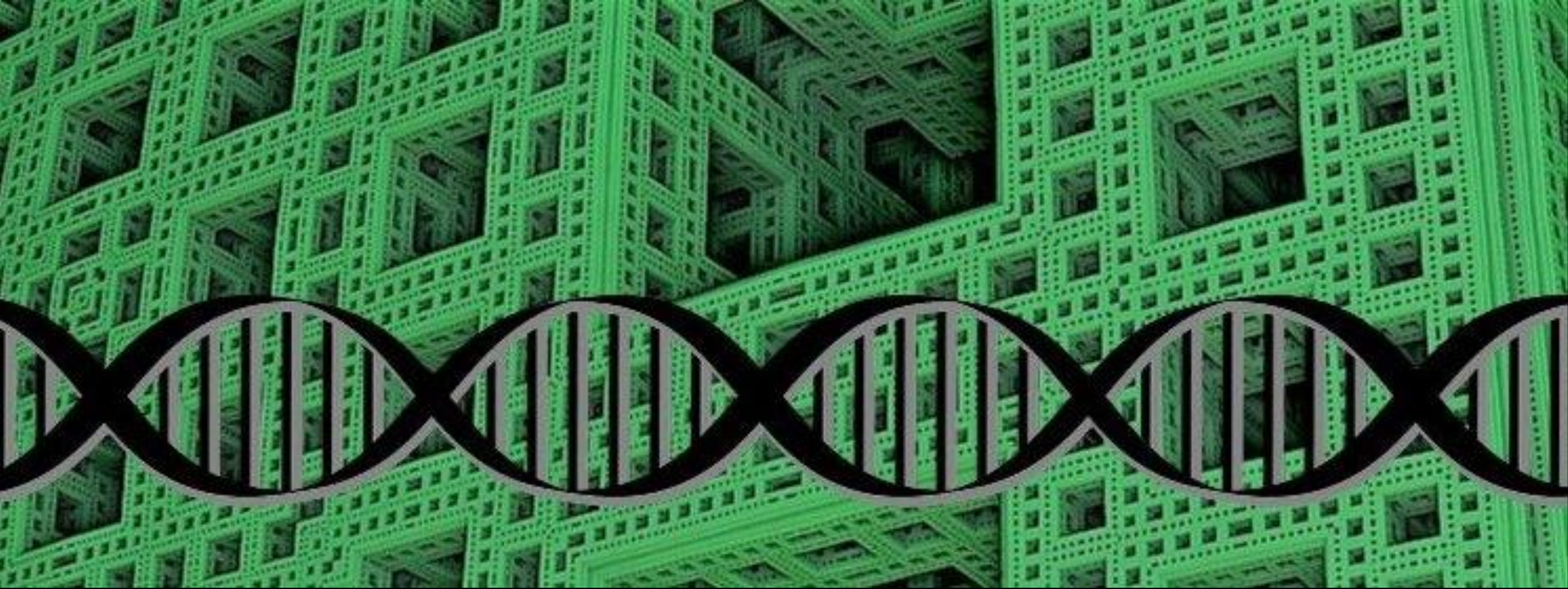
Fitness



Selection

Selection

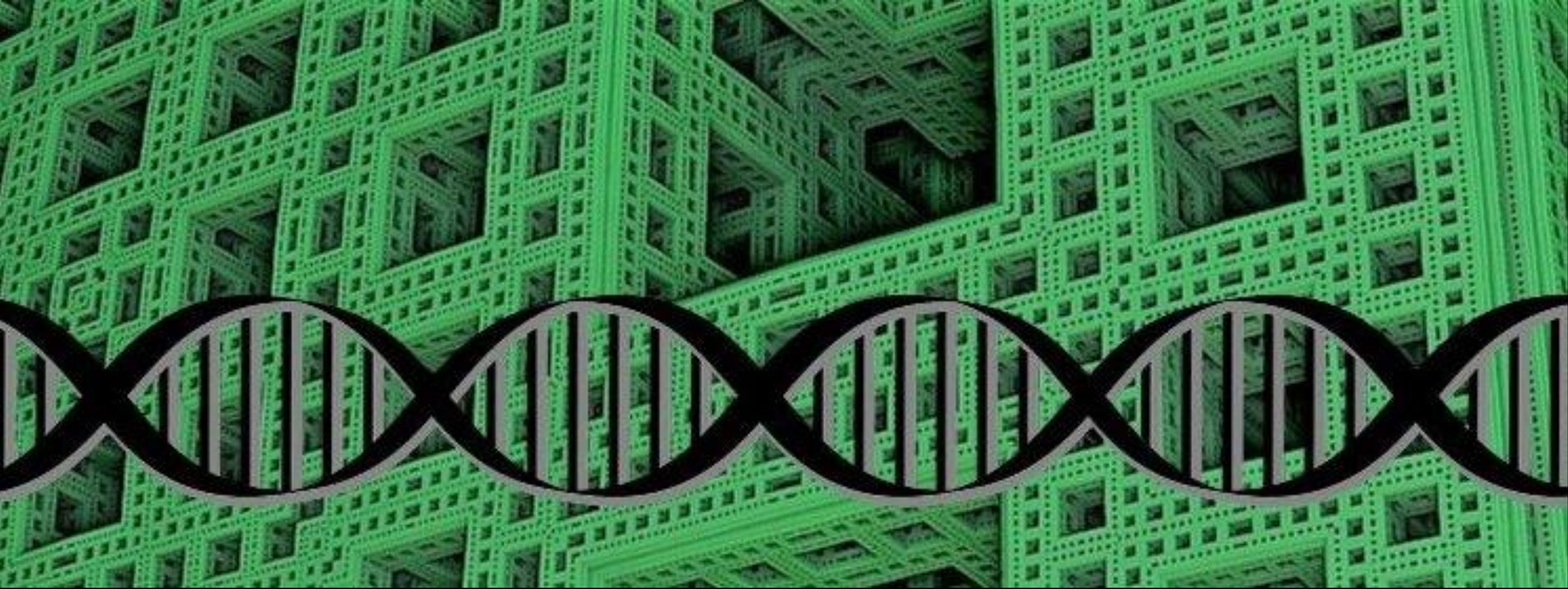
- A result of fitness
- Probabilistic
  - Higher fitness scores have a higher probability of selection
- Non-orthogenetic without heuristics
  - Desirable traits –tend- to have higher fitness score



Vocabulary Lightning Round

Parents

- In Biology: Two individuals who have conceived/sired a child and whose genes have therefore transmitted to the child
- In our context: Two individuals who have been assigned each other, and together progress to the crossover phase
- In both: Pairs of individuals whose genes are passed on to the next generation of the population

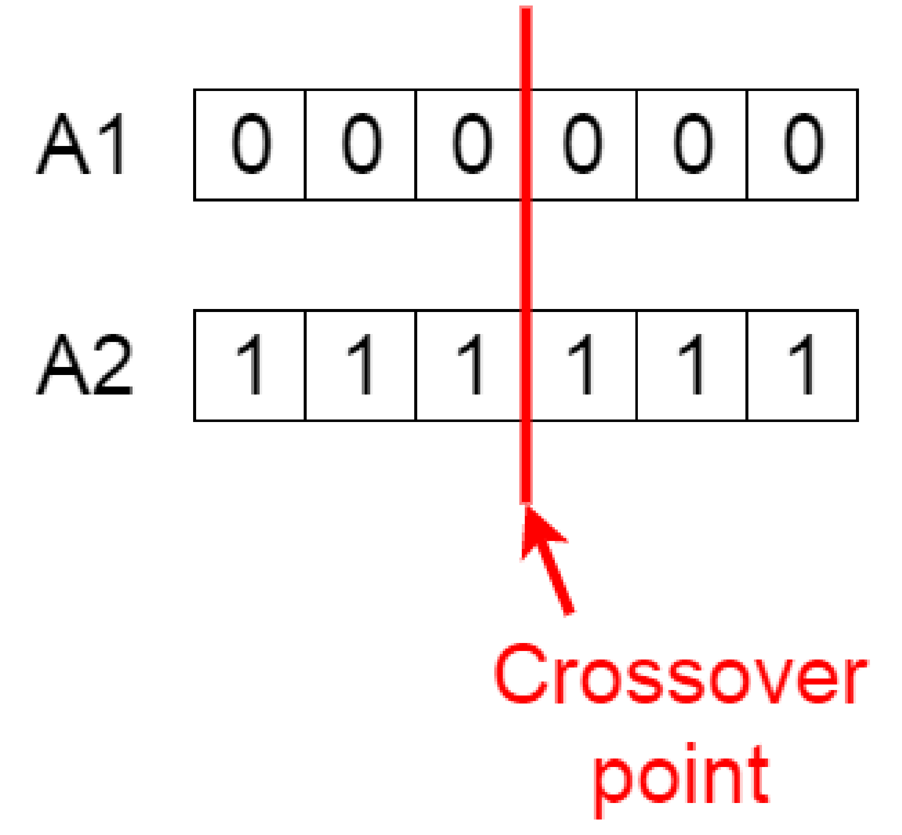


Crossover

Crossover

- The most important phase of the genetic algorithm process
- Crossover point is chosen at random

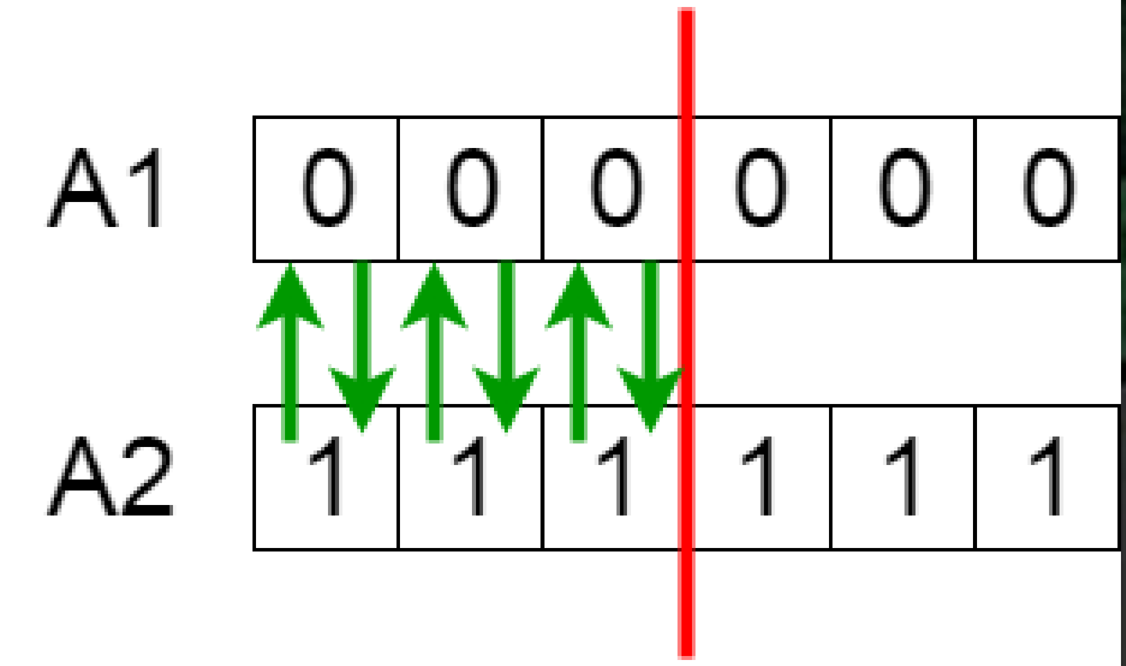
Crossover



Crossover

- Two children are each given half of their parents genes

Crossover

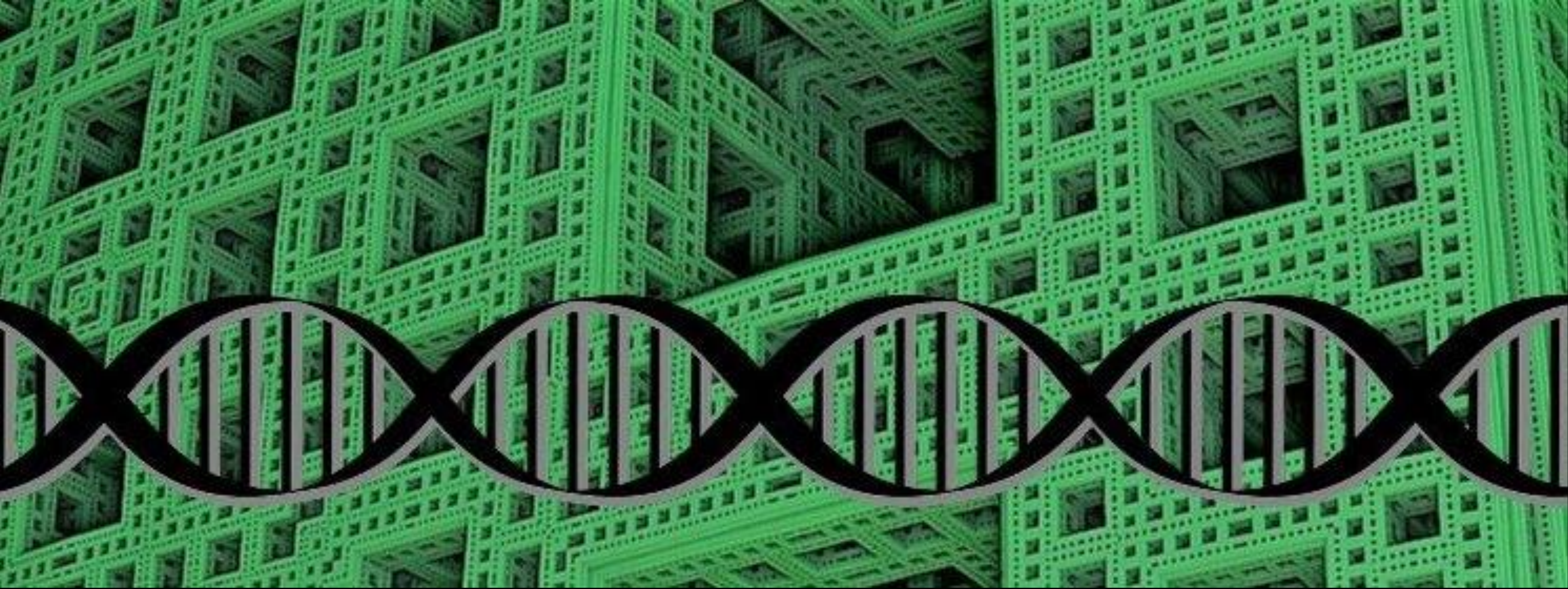


Crossover

- The parents are removed from the population
- The children replace their parents

Crossover

A5	1	1	1	0	0	0
A6	0	0	0	1	1	1



Mutation

Mutation

- Occurs probabilistically at a rate determined by the developer

Before Mutation

A5	1	1	1	0	0	0

After Mutation

A5	1	1	0	1	1	0

Setting the Mutation Rate

- If the rate is too high, it can discard rare and valuable solutions
- If the rate is too low, it can cause limited diversity.
  - Early convergence
- Important to uncover solutions that haven't been considered

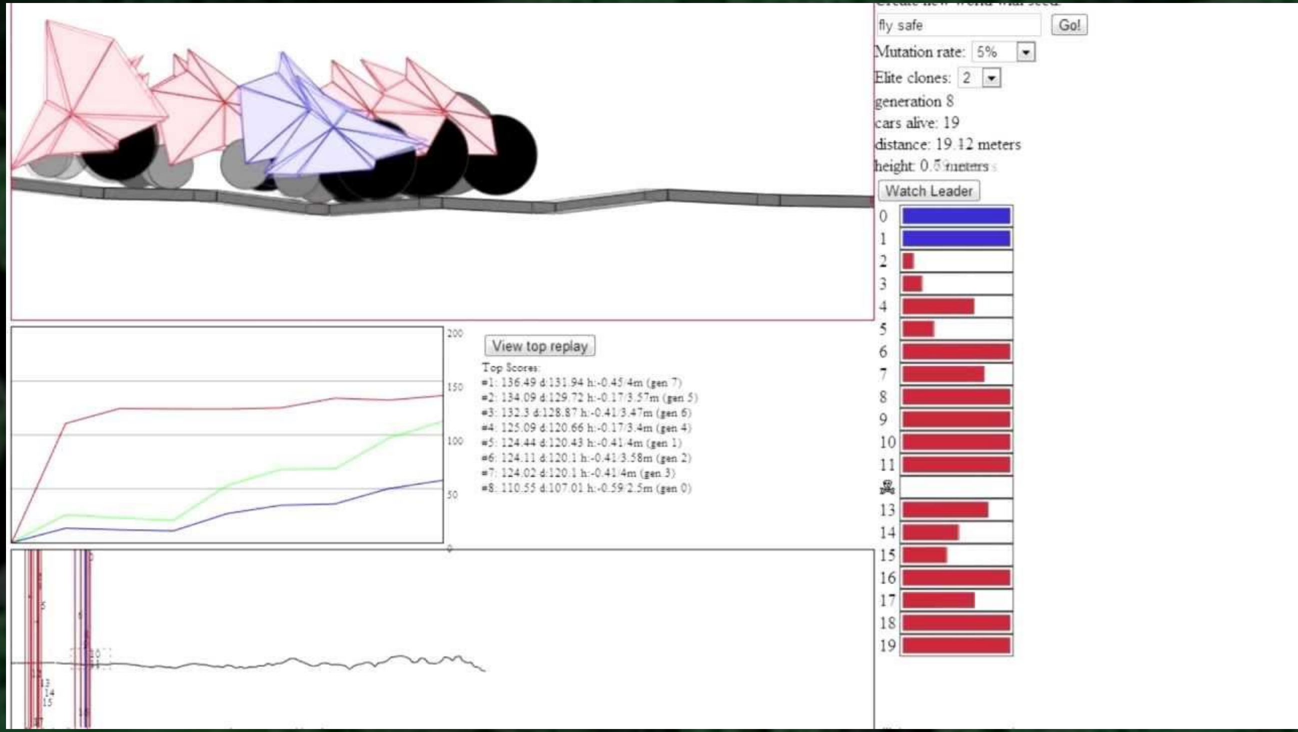
Evolution by Design

Practical Applications

- 2006 NASA ‘Evolved Antenna

Practical Applications

- https://rednuht.org/genetic_cars_2/



Other Practical Applications

- Polymer design
- Vehicle body structuring
- Video game strategy generation
- Encryption generation
- Logistical route building
- Market Forecasting…
- General Purpose AI… ?

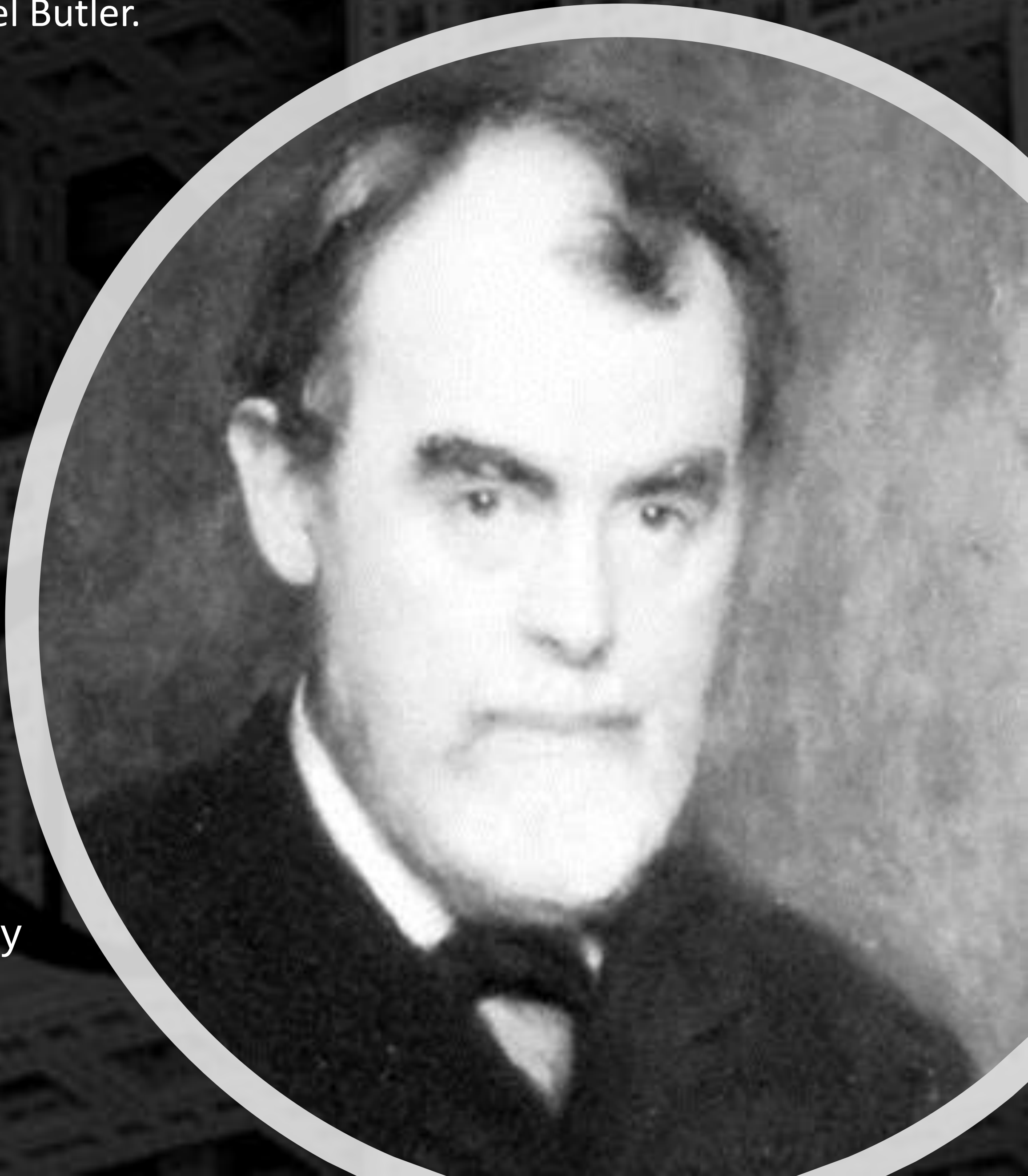
Evolution…
Without control?

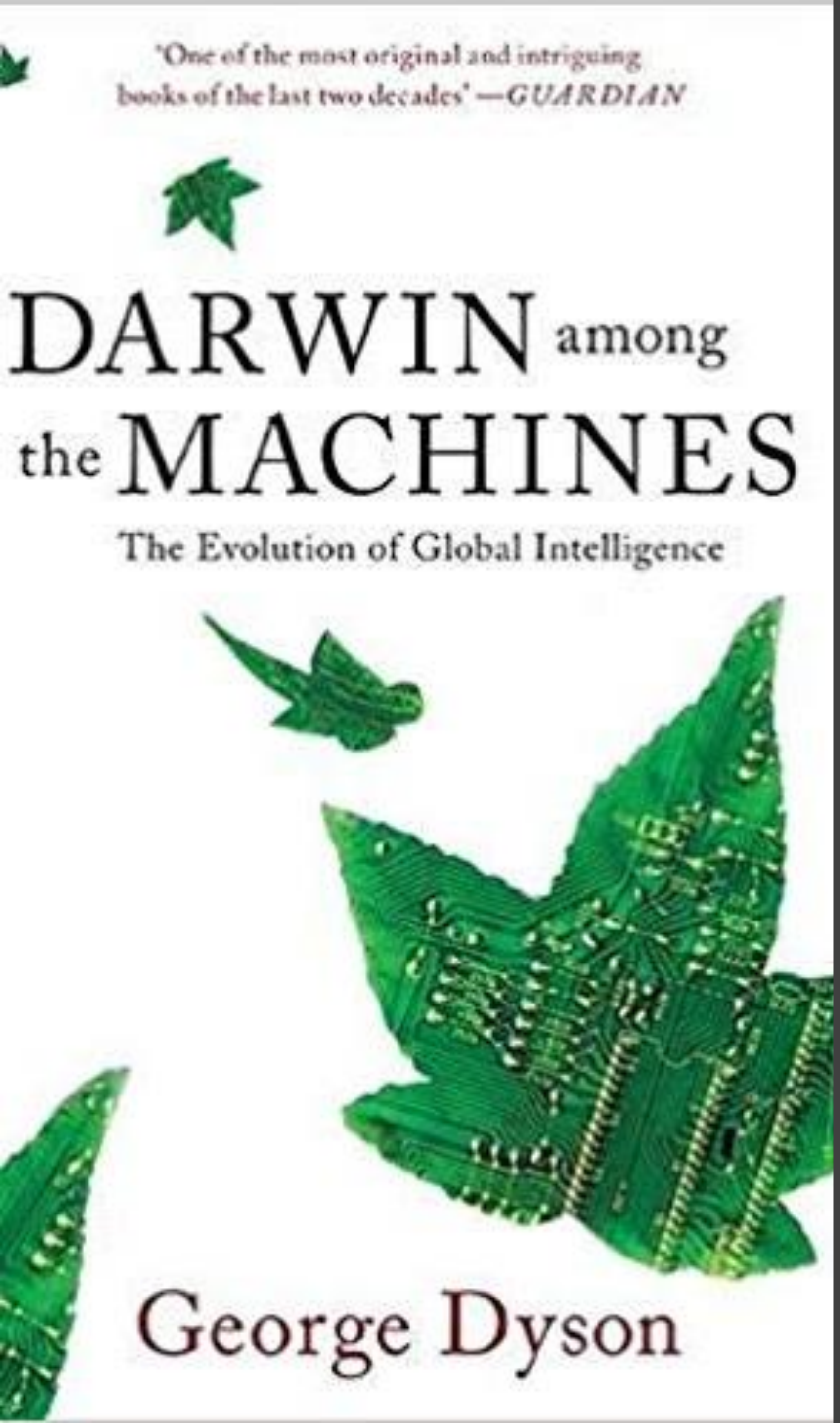
“Darwin among the machines” 1963, Samuel Butler.

Christchurch, New Zealand

Day by day, however, the machines are gaining ground upon us… but that the time will come when the machines will hold true supremacy over us is what no person of a truly philosophic mind can for a moment question

War to the death should be instantly proclaimed against them. Every machine of every sort should be destroyed by the well-wisher of his species. Let there be no exceptions made, no quarter shown; let us at once go back to the primeval condition of the race.

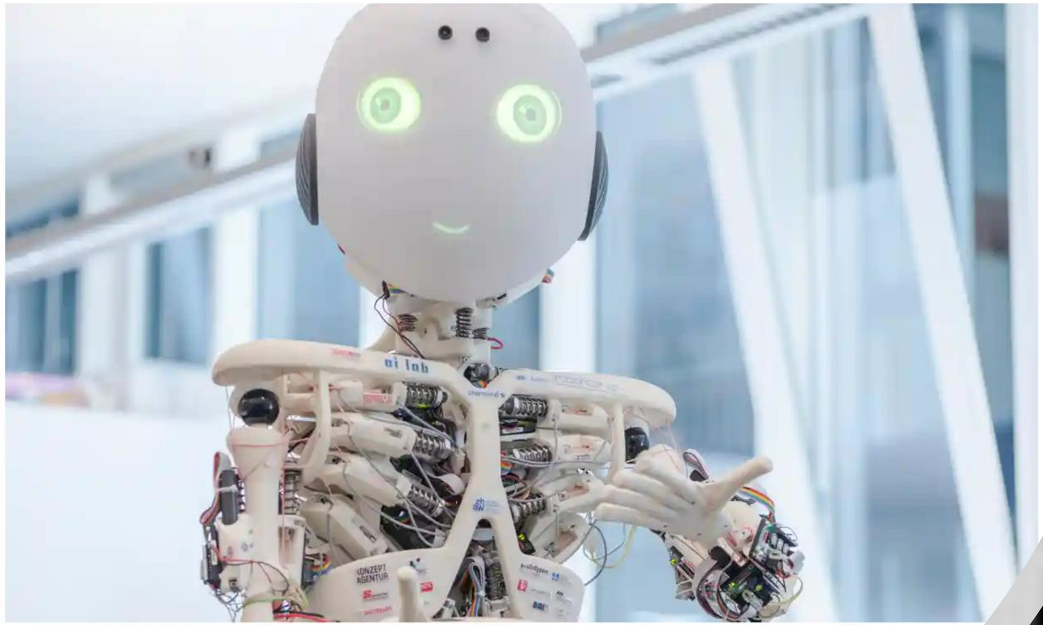




What mind, if any, will become apprehensive of the great coiling of ideas now under way is not a meaningless question, but it is still too early in the game to expect an answer that is meaningful to us

Robots could learn human values by reading stories, research suggests

Scientists have been running tests where artificial intelligences cultivate appropriate social behaviour by responding to simple narratives



▲ Kindness calculus … the ROBOY humanoid robot (not involved in the Quixote experiment). Photograph: F
Tham/Corbis

More than 70 years ago, Isaac Asimov dreamed up his three laws o
ich insisted, above all, that "a robot may not injure a huma
inaction, allow a human being to come to harm"
d that "the development of full arti

- https://www.theguardian.com/books/2016/feb/18/robots-could-learn-human-values-by-reading-stories-research-suggests

Conclusion