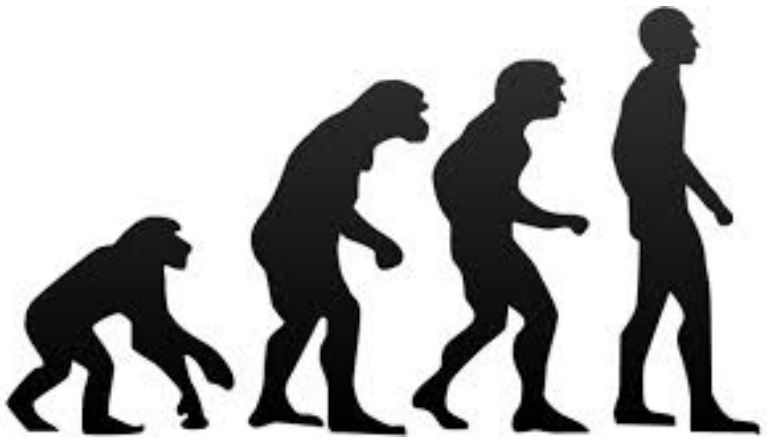
Genetic Algorithm

Alexandre Bergel
University of Chile / Object Profile

http://bergel.eu
http://AgileArtificialIntelligence.github.io



Premise of Genetic Algorithm

Natural selection is pioneered by *Charles Darwin* (1809-1882), biologist who worked on *natural evolution*

"On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life", 1859

"One general low, leading to the advancement of all organic beings, namely, vary, let the strongest live and the weakest die"

— Charles Darwin

“Guess the 3-letter word I have in mind”

Secret word: *cat*

“Guess the 3-letter word I have in mind”

“For each try, I tell you the number of correct letters”

Secret word: *cat*

“cow”

1

“poz”

0

“gaz”

1

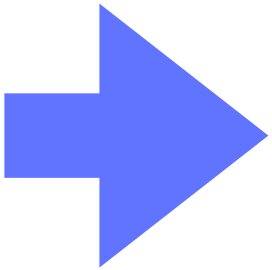
Secret word: *cat*

gaz

cow

gaz

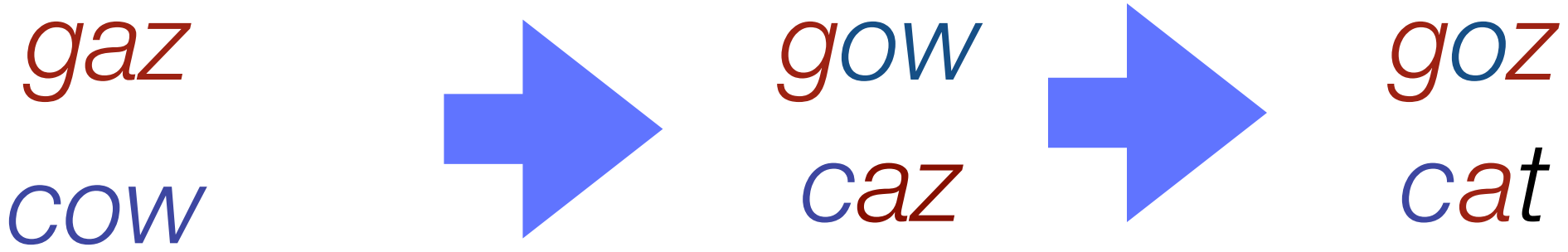
cow



gow

caz

Using genetic operators, the words are combined and some letters are randomly modified


gaz
cow
gow
caz
goz
cat

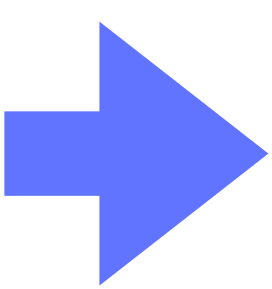
1st generation

2nd generation

3rd generation

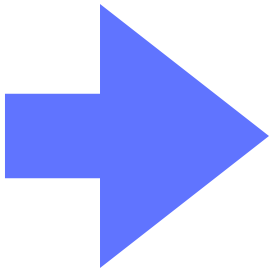
gaz

cow



gow

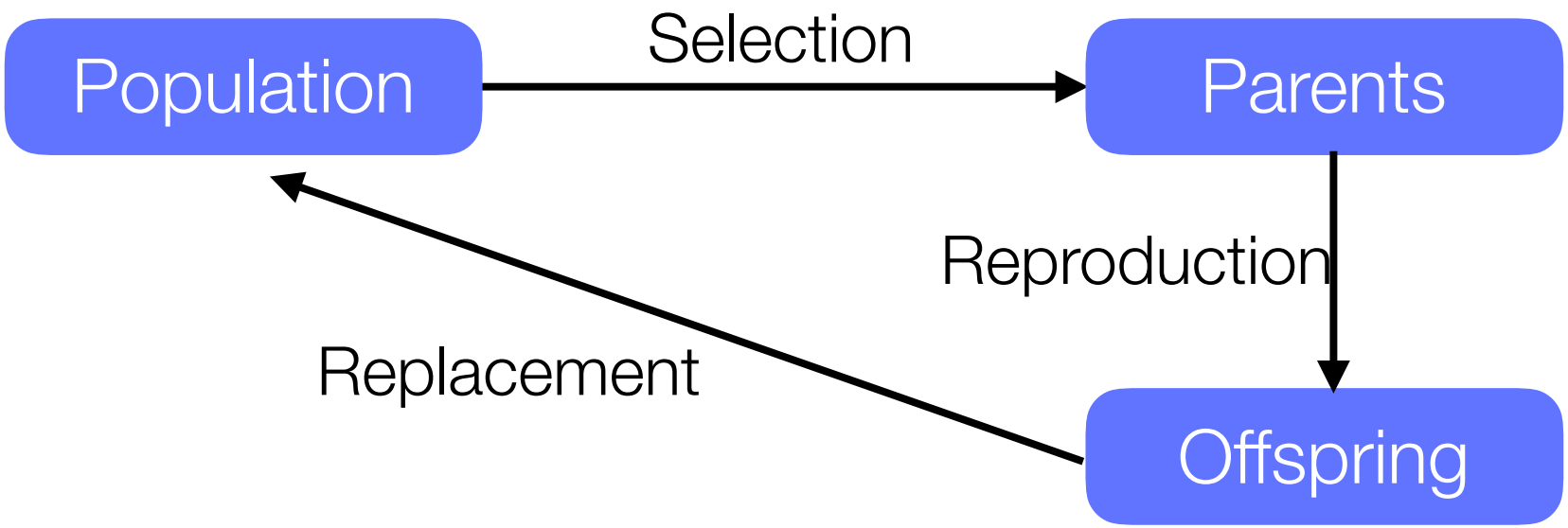
caz



goz

cat

Flow chart of an evolution algorithm



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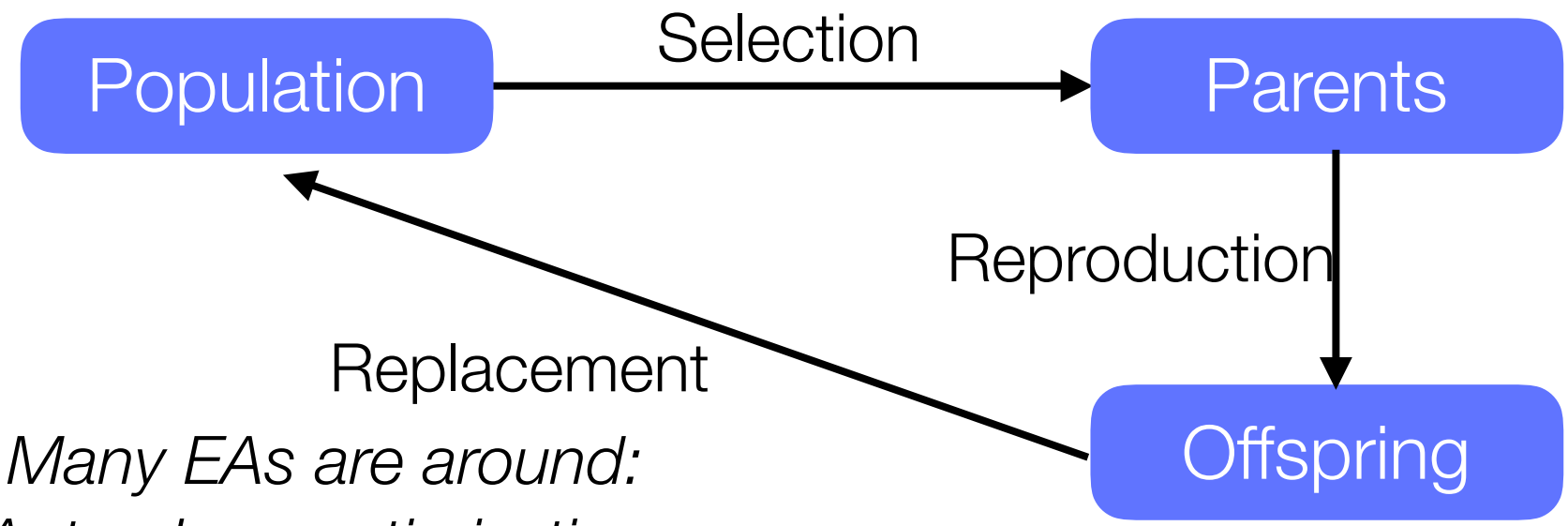
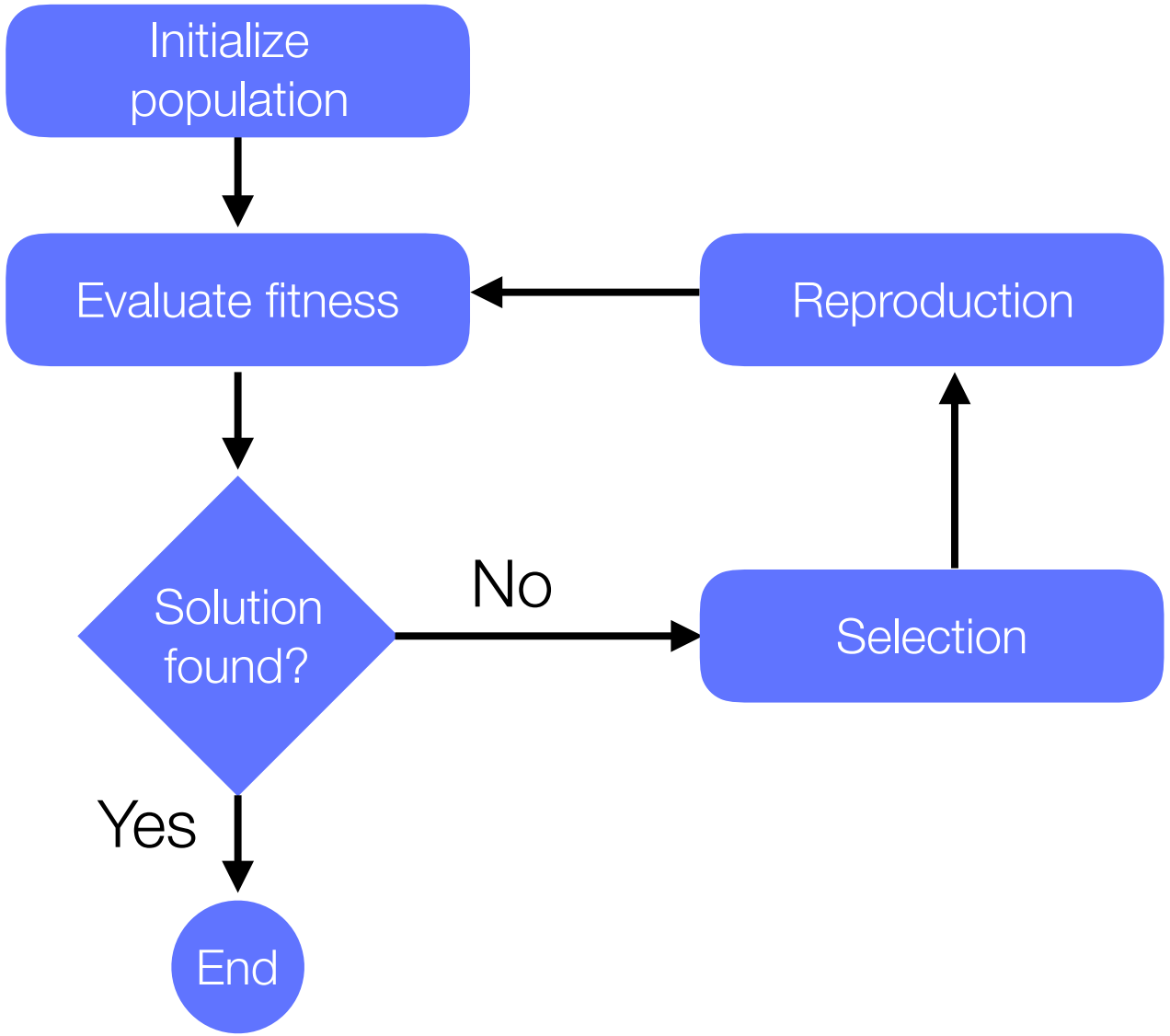


Many EAs are around:
Ant colony optimization,
Artificial immune system,
Cultural algorithms,
Genetic Algorithm,
Genetic Programming,
Grammatical evolution,
…

Flow chart of a genetic algorithm



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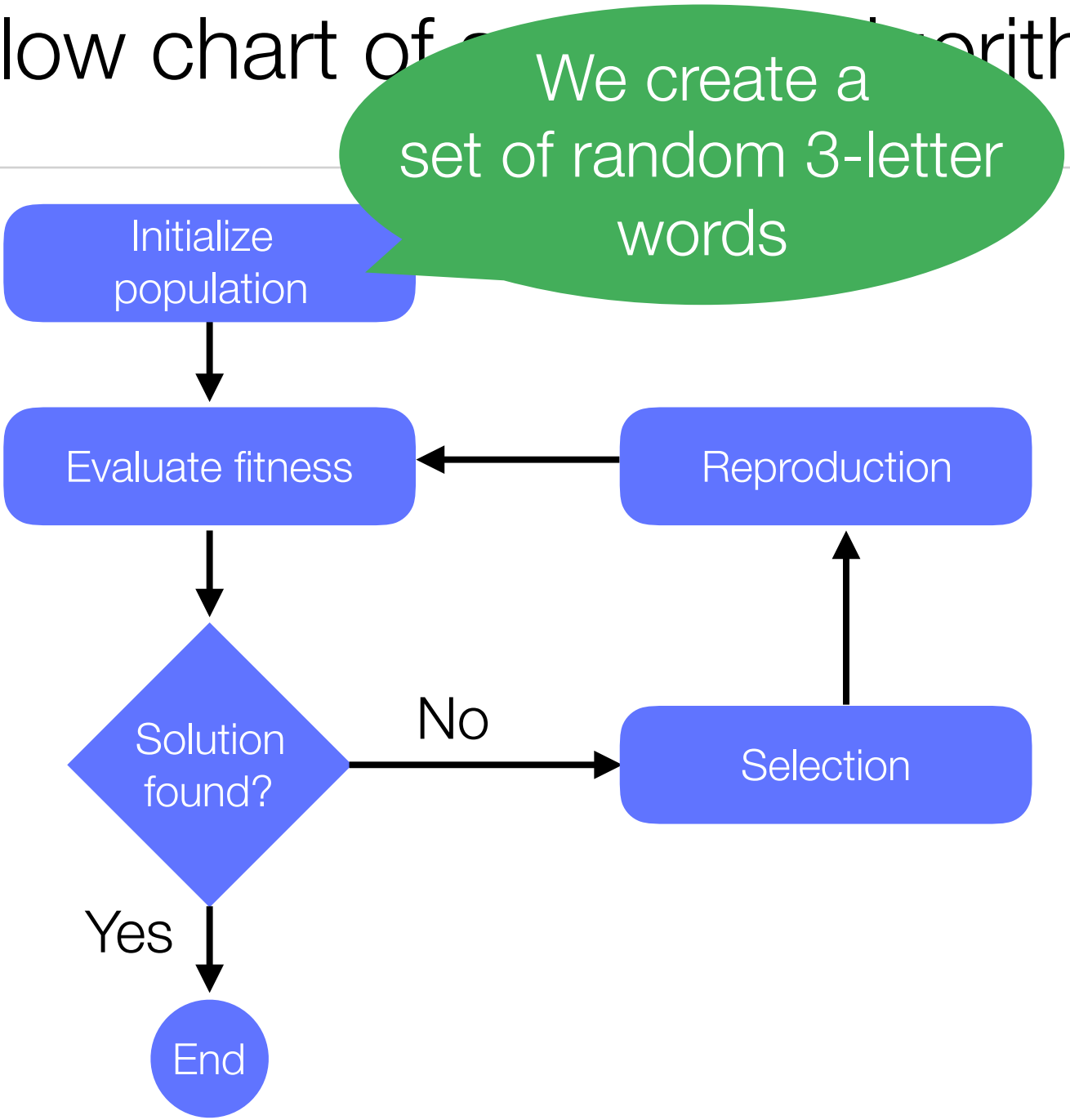

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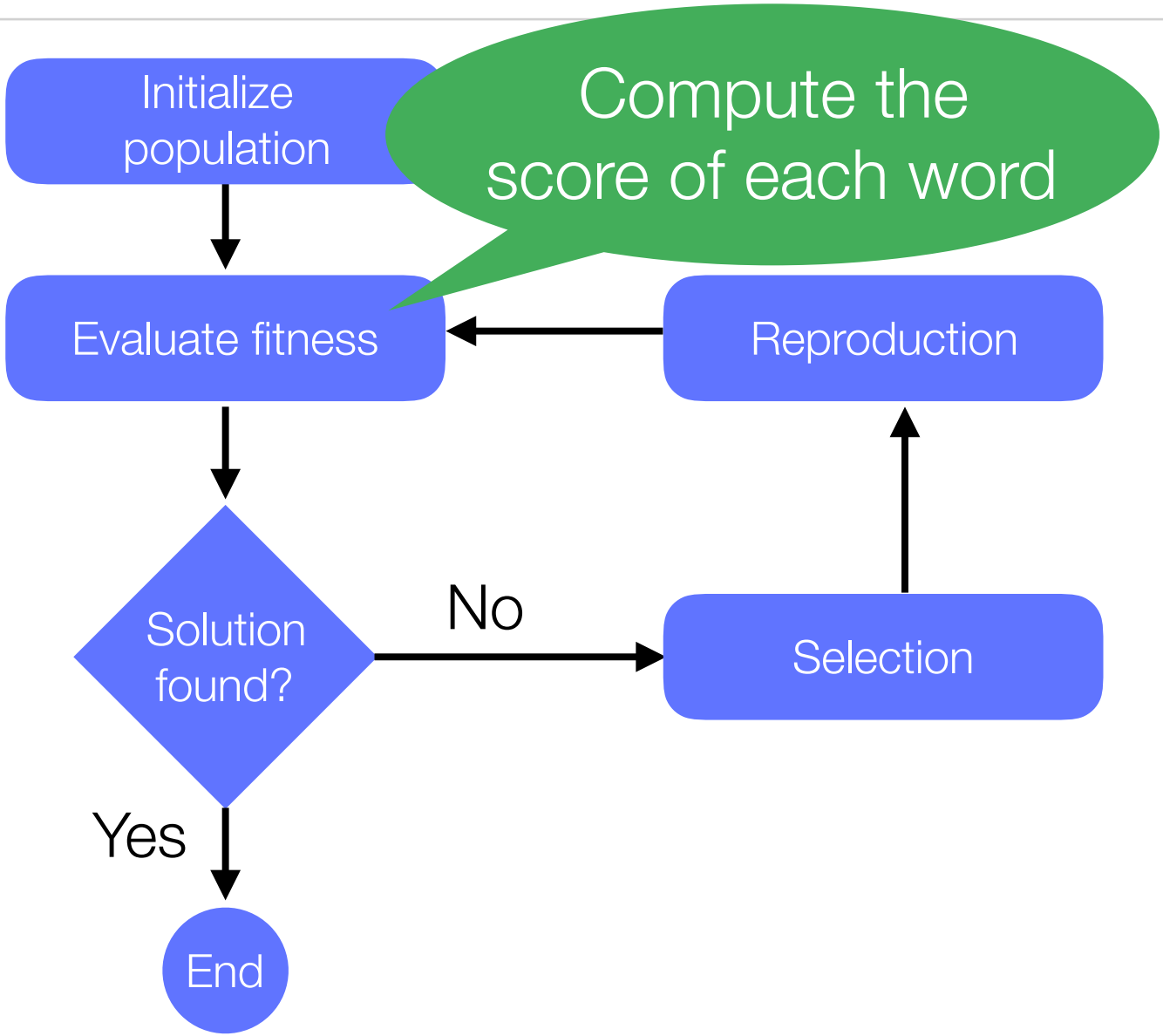

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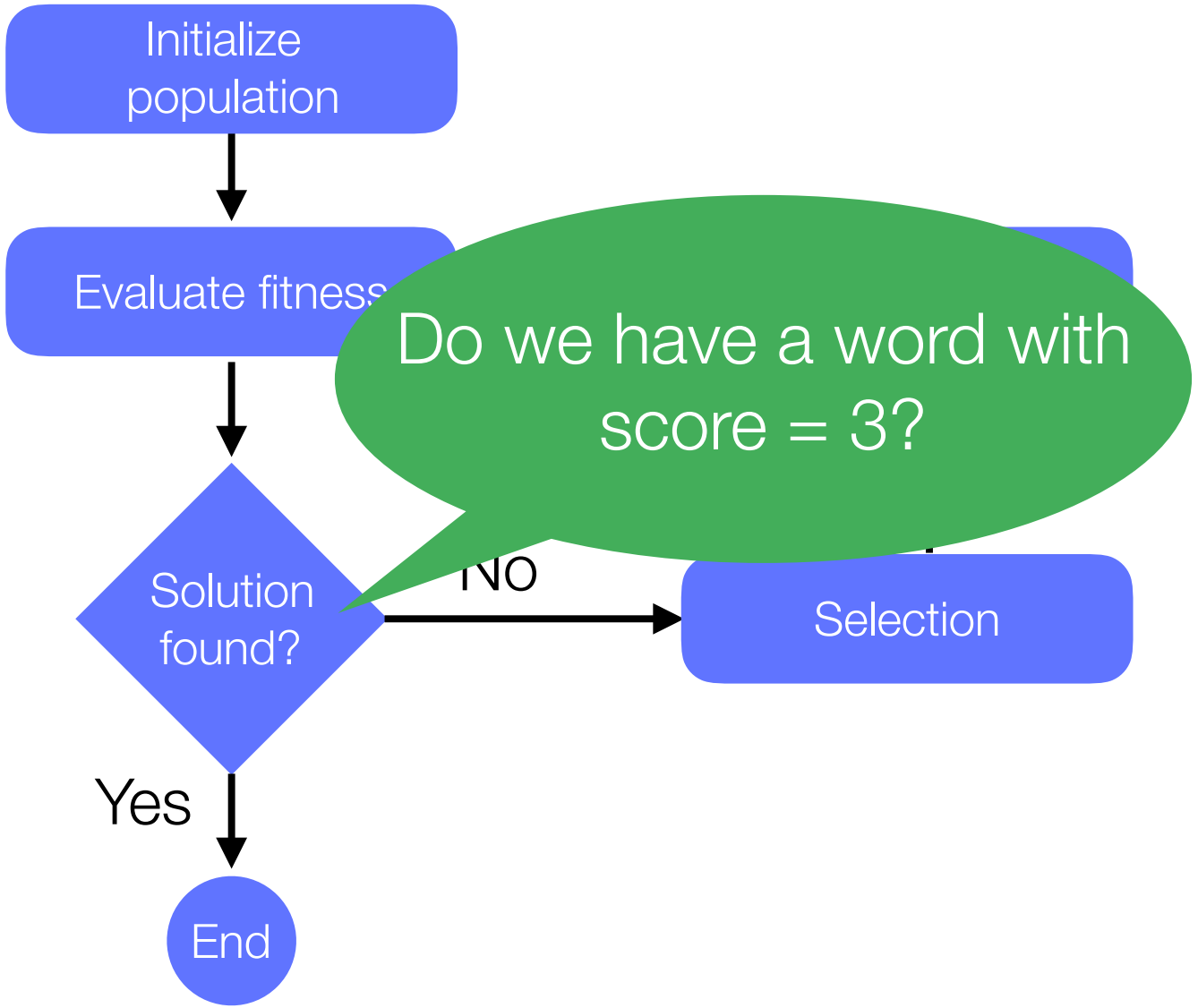

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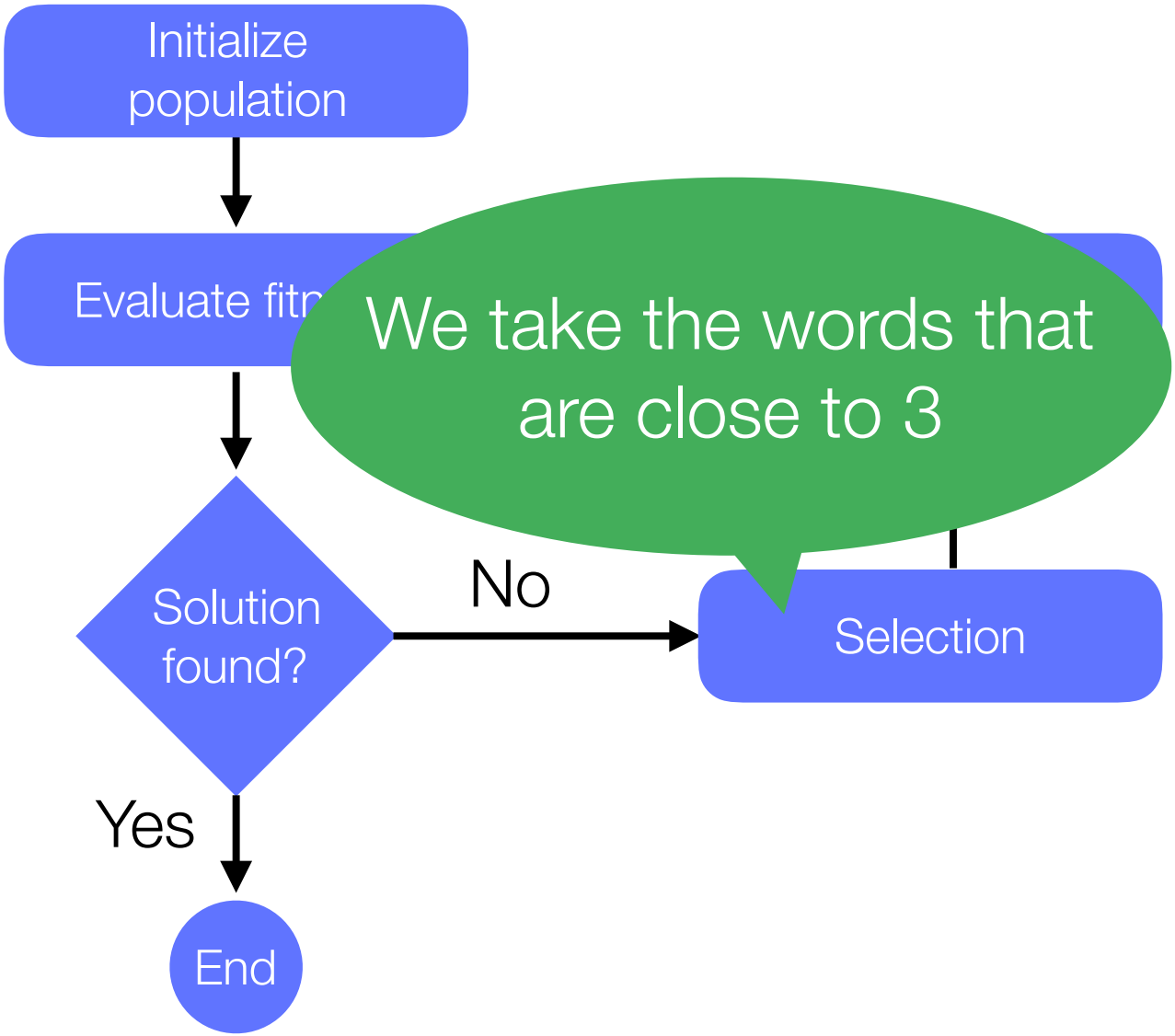

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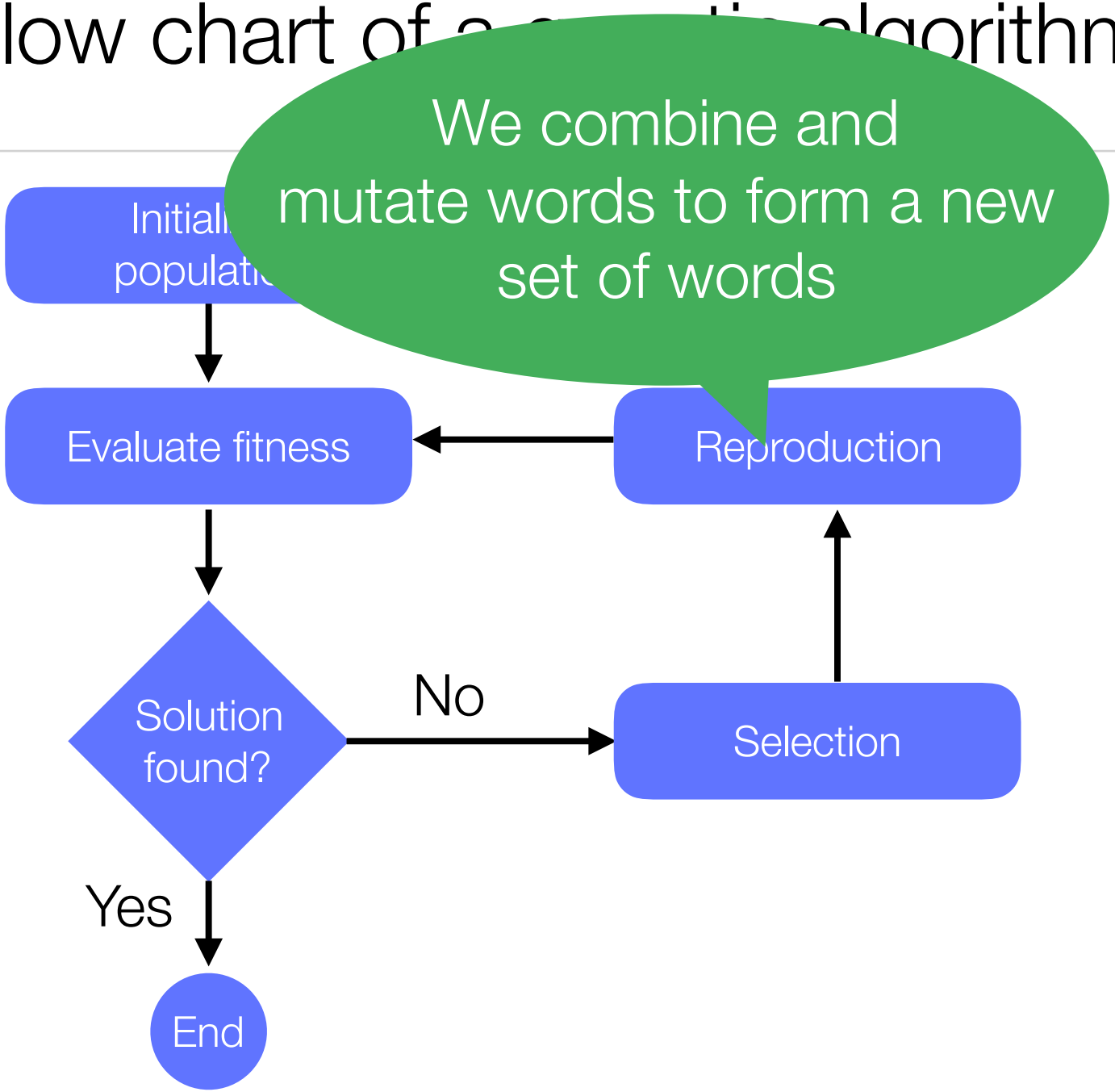

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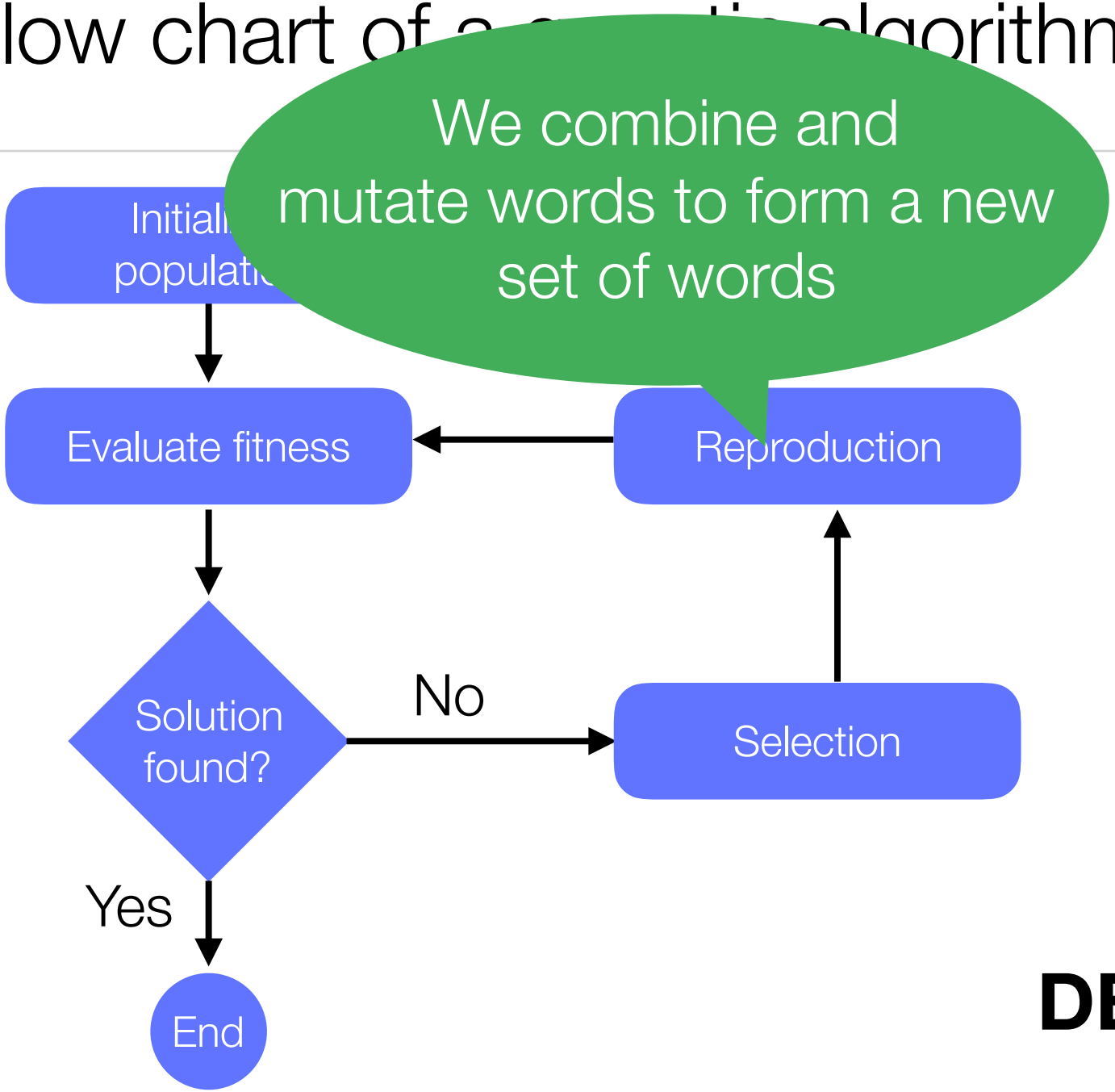


DEMO

Genetic Algorithm in a Nutshell

Evolutionary computation technique that automatically solves problems without specifying the form or structure of the solution in advance

Generally speaking, *genetic algorithms are simulations of evolution*, using biological genetic operations

Finding x such as $f(x) = y$ is maximal, x is a tuple of any arbitrary dimension and domain value, $y \in \mathbb{R}$

Terminology: Individual

An *individual* represents an element in a population

Each individual has a chromosome, composed of *genes*

Gene = index in a chromosome

Allele = value of a gene

Individual

Terminology: Population

A *population* is a set of individuals

Generally, the *population size is fixed* over time. Individuals are replaced at each generation, but the number of individuals remains constants.

All individuals of the population *have the same size*

Terminology: Fitness function

The fitness function evaluates how *fit* an individual is

$f($  $) = y \qquad y \in \mathbb{R}$

The whole idea of genetic algorithm is to search for the individual that maximizes the fitness function

Example: optimizing a server

Consider a server running in Java

The Java virtual machine, which has over 200 options

What are the options that consume the least amount of memory to answer HTTP requests

$$f(x) = y$$

x is a set of options, e.g., `[ -Xgc:parallel, -ms32m, -mx200m]`

y is the amount of memory (in bytes)

$f(x)$ is computed by launching the server using the options and sending 1000 requests

Example: optimizing a server

Consider a server running in Java

The … as over 200 options

W… the least amount of m… ts

We look for the optimal x that minimize f(x)

$$f(x) = y$$

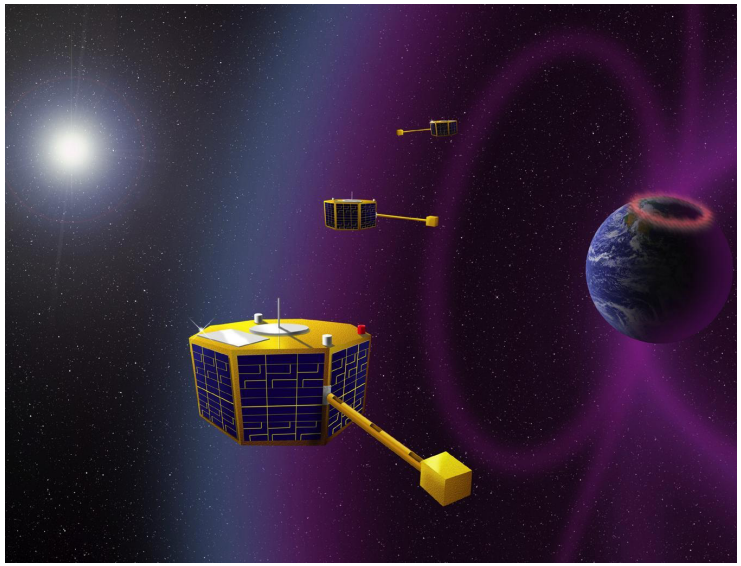
x is a set of options, e.g., `[ -Xgc:parallel, -ms32m, -mx200m]`

y is the amount of memory (in bytes)

$f(x)$ is computed by launching the server using the options and sending 1000 requests

Example: space antenna

Evolved antenna, produced by NASA in 2006.
Used in 3 satellites that take measurement Earth magnetosphere.
Satellites used this antenna to communicate with the ground



Example: space antenna

$$f(x) = y$$

List of commands:
forward(length, radius)
rotate-x(angle)
rotate-y(angle)
rotate-z(angle)

voltage and impedance for radio waves

Automated Antenna Design with Evolutionary Algorithms

Gregory S. Hornby* and Al Globus
University of California Santa Cruz, Mailtop 269-3, NASA Ames Research Center, Moffett Field, CA
Derek S. Linden
JEM Engineering, 8683 Cherry Lane, Laurel, Maryland 20707
Jason D. Lohn
NASA Ames Research Center, Mail Stop 269-1, Moffett Field, CA 94035

https://ti.arc.nasa.gov/m/pub-archive/1244h/1244%20(Hornby).pdf

Example: software testing (1/2)

$$f(x) = y$$

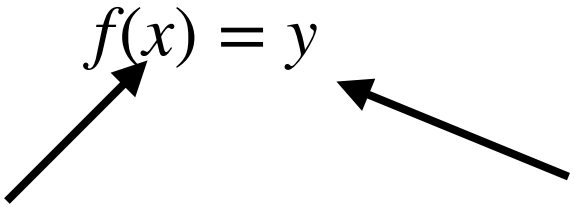
Actions on the user interface (e.g., pressing a button, entering a value in the text field, clicking on a menu)

Number of tested functionalities

Randomly testing an application has many applications:

- Finding functional bugs (i.e., which actions crashes my application)
- Finding dead code (i.e., which part of my application is not used)

Example: software testing (2/2)



List of Smalltalk statements (e.g., sending a message, creating an object)

Number of tested functionalities

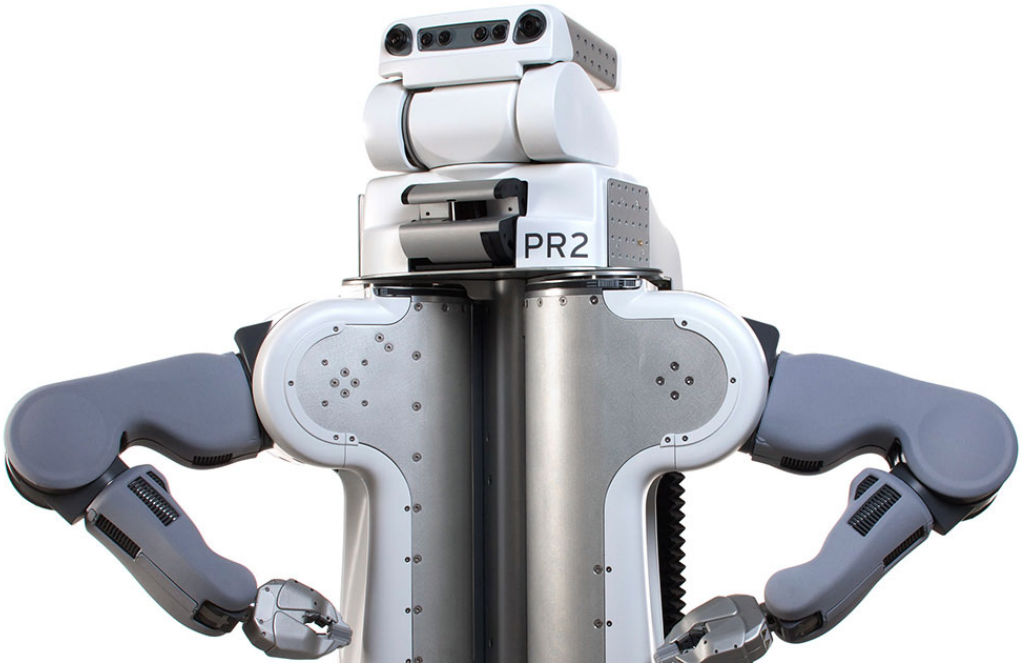
Thanks Lam Research for support this effort!

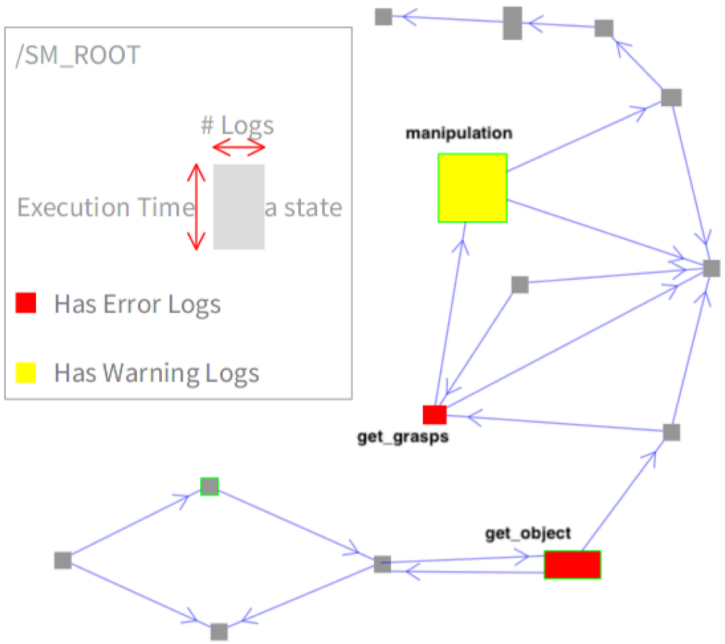
Example: robot testing

$$f(x) = y$$

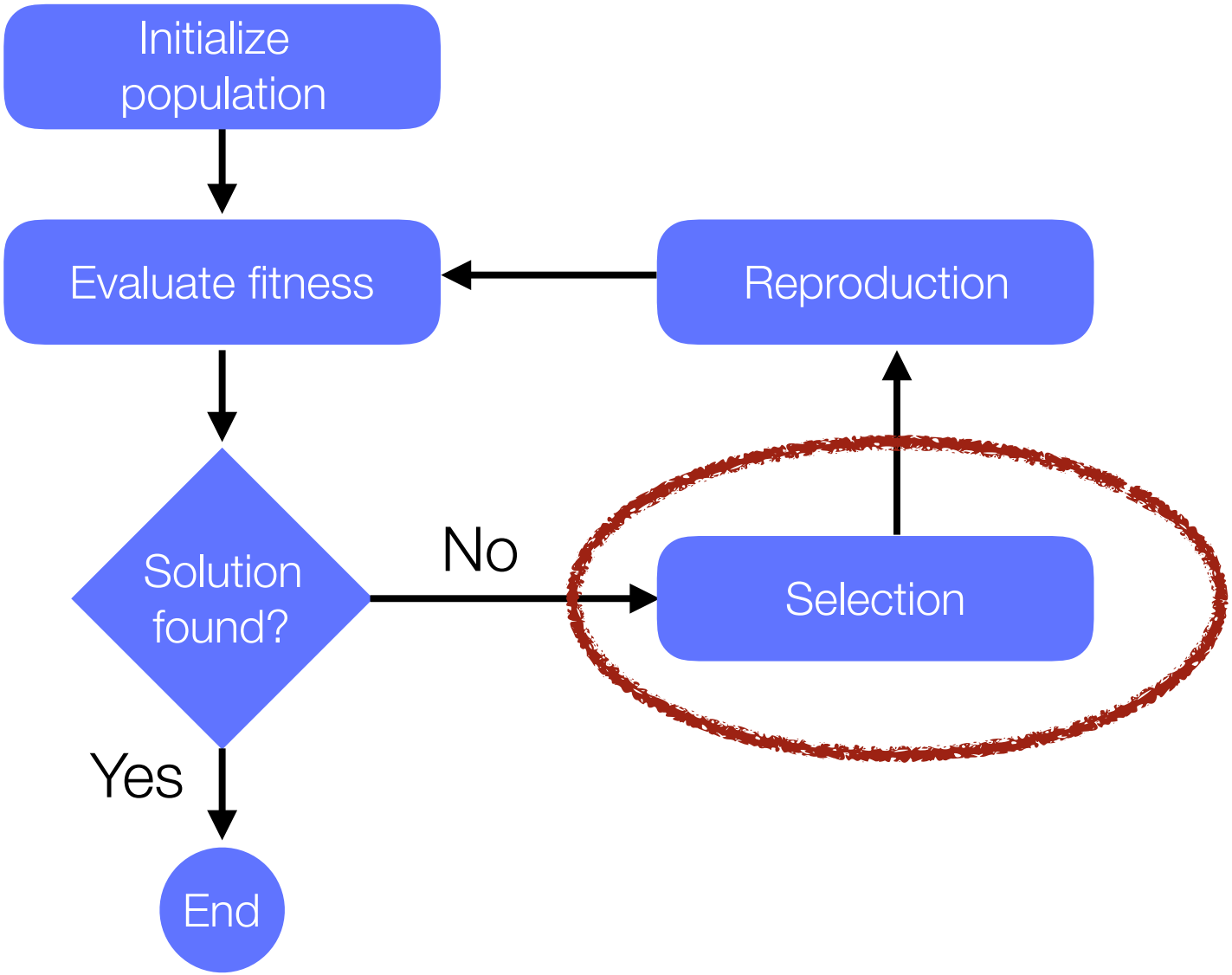
List of random inputs of a robot state

Number of raised warning/errors





Flow - chart of a genetic algorithm



Selection phase

Several selections algorithms have been proposed

The two most popular are

 *Roulette* associates a probability of selection to each individual

 *Tournament* between a set of randomly picked individuals

Tournament 🏆

The tournament selection algorithm:

1 - Choose few individuals (e.g., 5) at random from the population (a tournament)

2 - The individual with the best fitness (the winner) is selected for crossover

The main advantage is to be highly parallelizable across multiple CPU Cores

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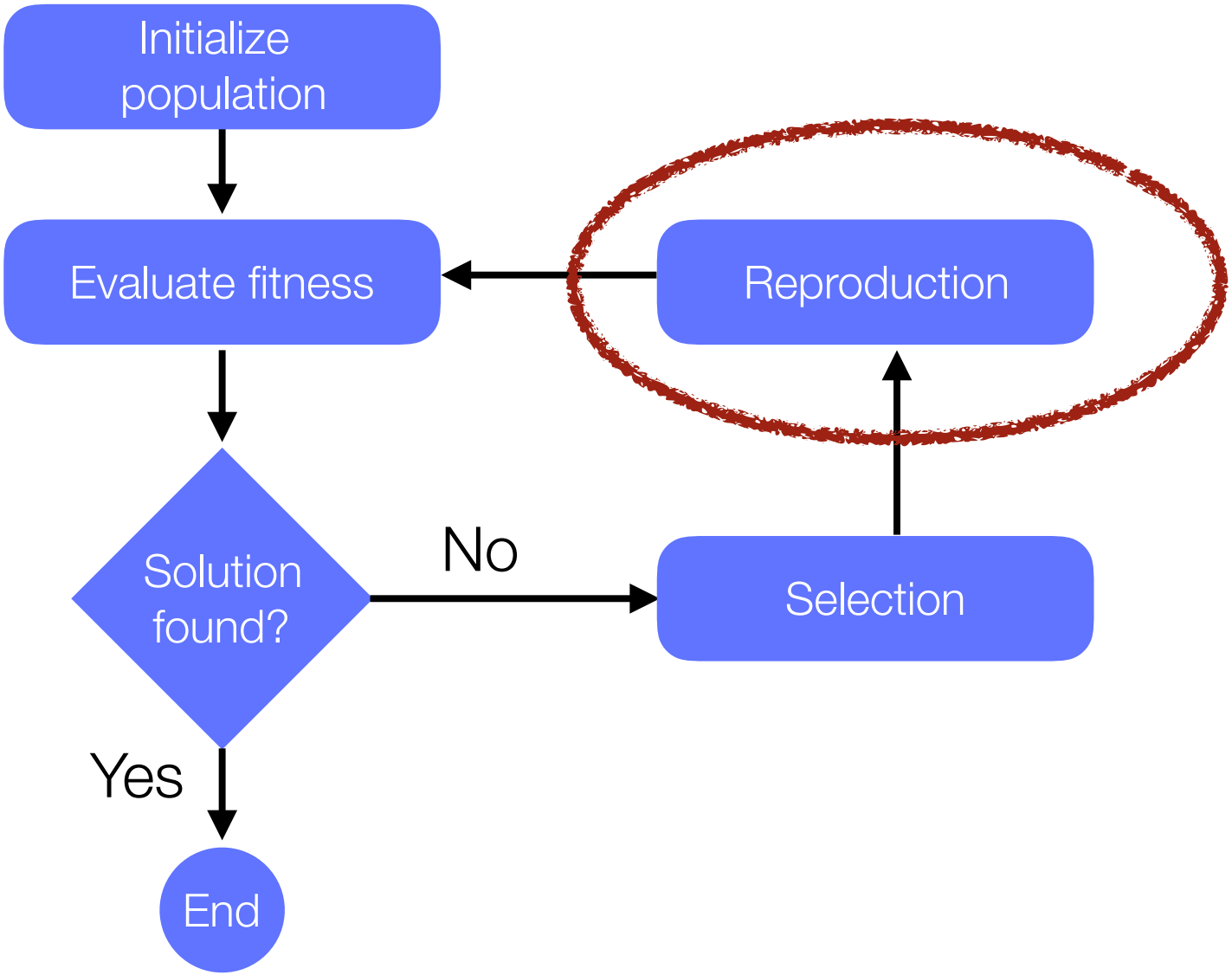

Darwinian Natural Selection

In order to have a natural selection, we need to have:

Heredity: a child receives properties of its parents. In particular, if the parents are robust and can live long enough, then the child should too

Variation: some variation may be introduced in children. Children should not be identical copy of their parents

Selection: some members of a population must have the opportunity to be parents and have offsprings in order to pass their genetic information. Typically referred to as “survival of the fittest”

https://en.wikipedia.org/wiki/Charles_Darwin#/media/File:Charles_Darwin_seated_crop.jpg

Genetic operators: Crossover

Operations that takes two individuals and produces a new one, result of a combination

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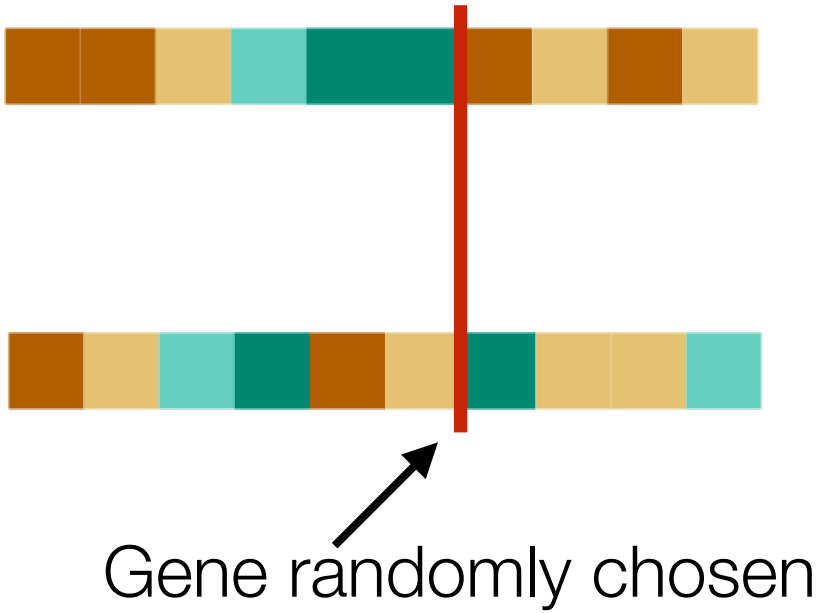

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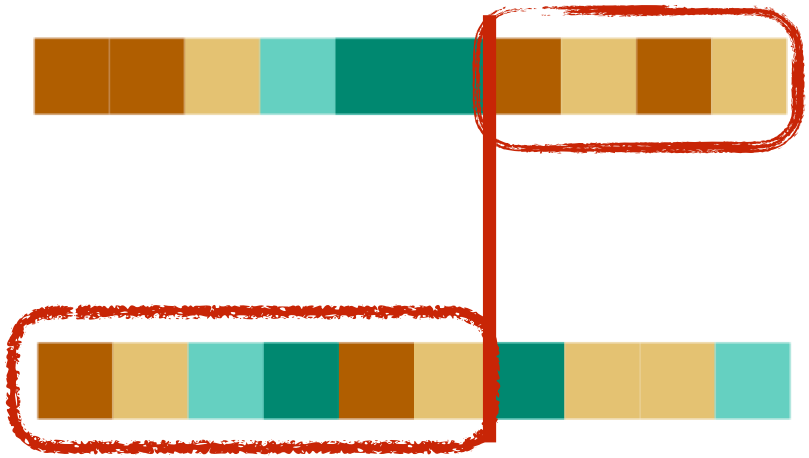

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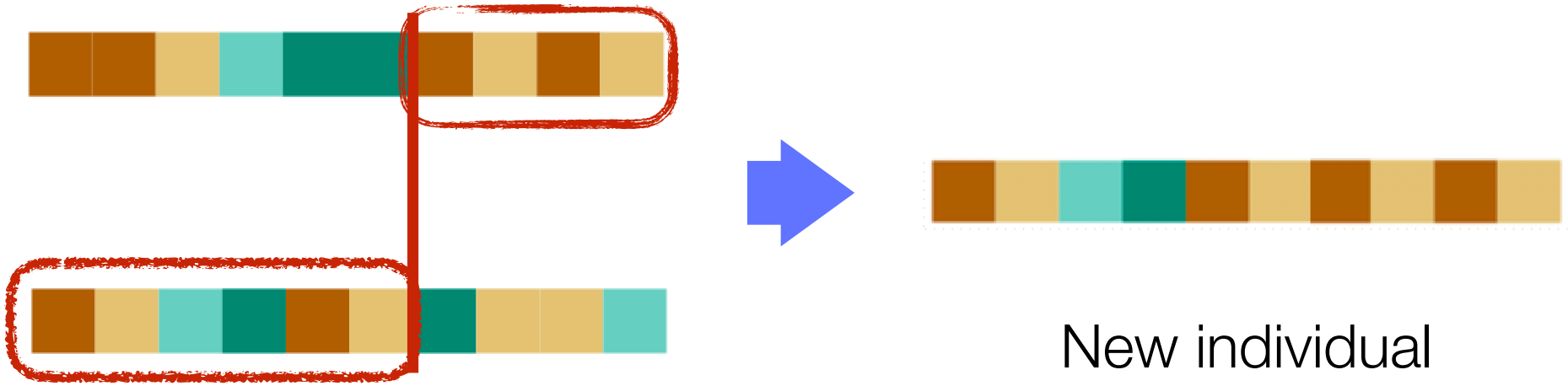
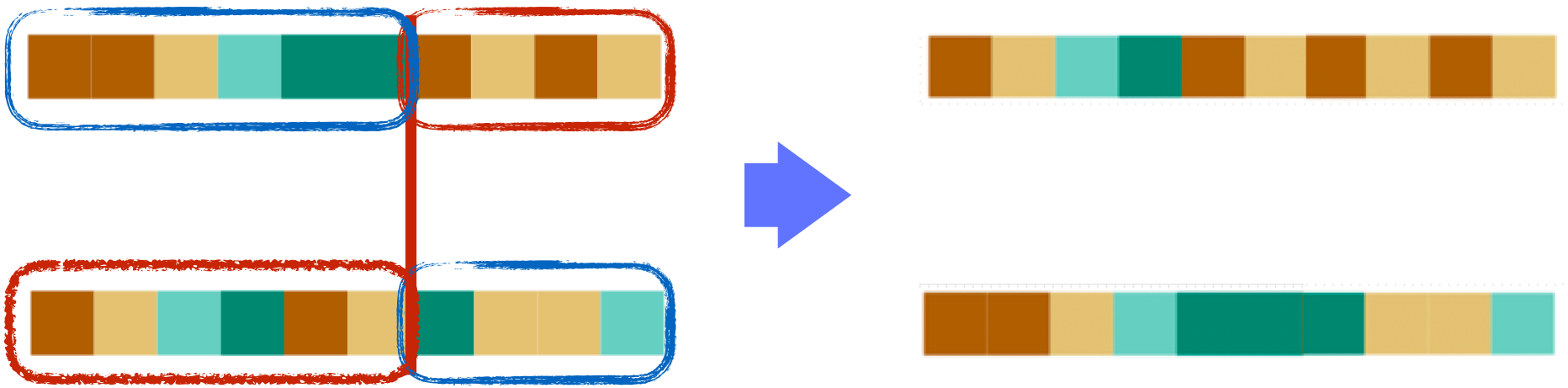


New individual

Genetic operators: Variant of Crossover

Operations that takes two individuals and produces a new one, result of a combination



Two new individuals

Genetic operators: Mutation

Operations that takes two individuals and produces a new one, result of a combination

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Operations that takes two individuals and produces a new one, result of a combination

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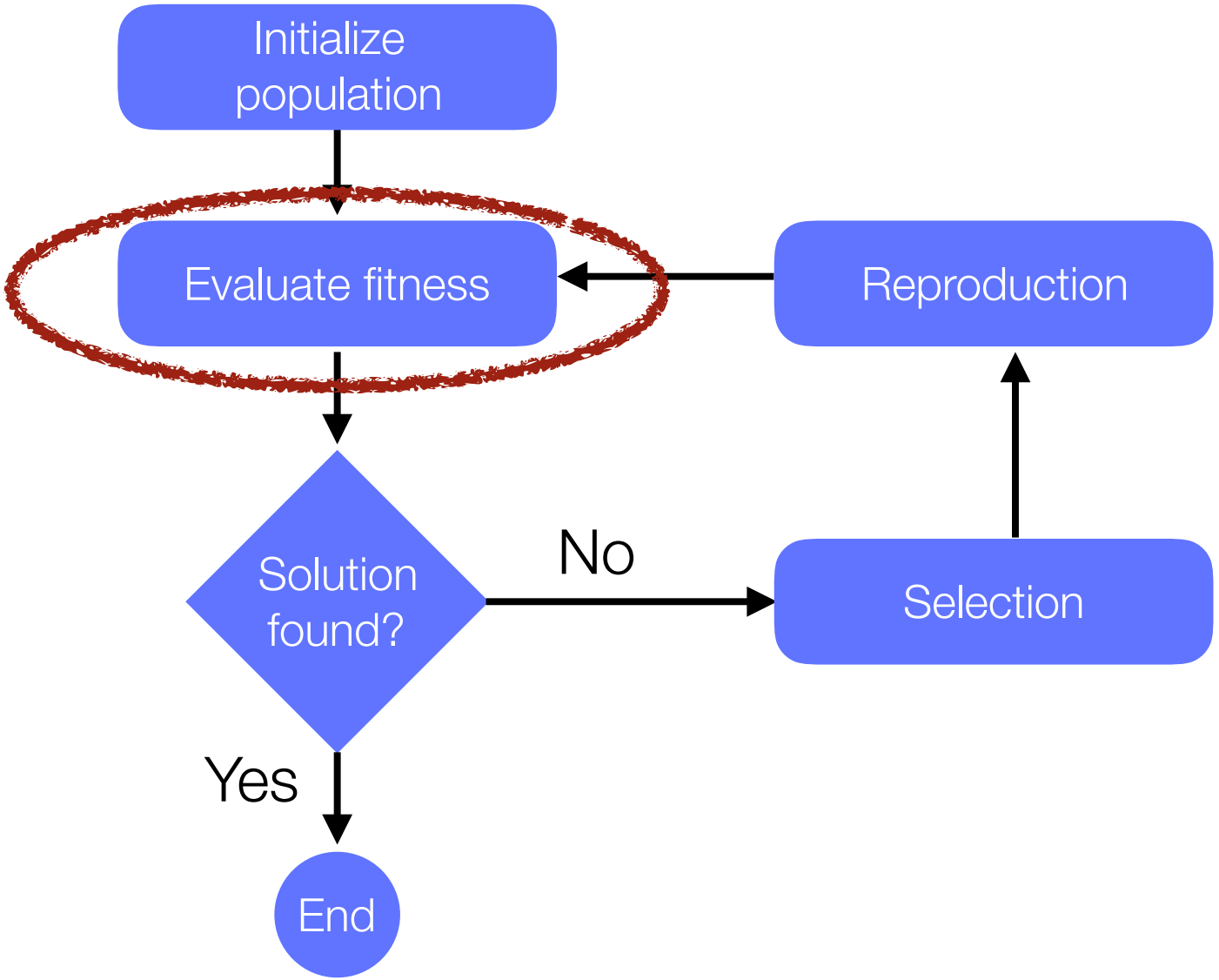

Configuring the algorithm

Mutation rate: % to change a gene when creating a child

Population size: number of individual to consider each time

Number of genes: how many genes contains each individual

Fitness function: Function that tells how good / far an individual is from the (ideal) solution

Some benefits of Genetic Algorithm

GA provides a compelling way to *not be trapped in local optima*

GA allows optimization of systems in which *variables may be discrete or categorical*, and not only continuous

e.g., direction of a robot or characterization of an antenna segment

GA can be combined with *other AI techniques*

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DEMO!

Artificial Intelligence Landscape

GA is often used to solve AI problems in terms of optimization

GA just need a way to say how good a solution is

Deep learning requires many examples

GA is easy to learn and implements

`https://agileartificialintelligence.github.io`

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Thanks Lam RESEARCH