# Automating Algorithm Design through Genetic Programming Hyper-Heuristicss

Elsa Browning

Division of Science and Mathematics
University of Minnesota, Morris
Morris, Minnesota, USA

April 15, 2017
Morris, MN

# What does the title mean?

- Reducing the human component in algorithm design

https://scratch.mit.edu/discuss/m/topic/200574/

# What does the title mean?

- Reducing the human component in algorithm design
- More work at the beginning, more possibilities

https://scratch.mit.edu/discuss/m/topic/200574/

# What does the title mean?

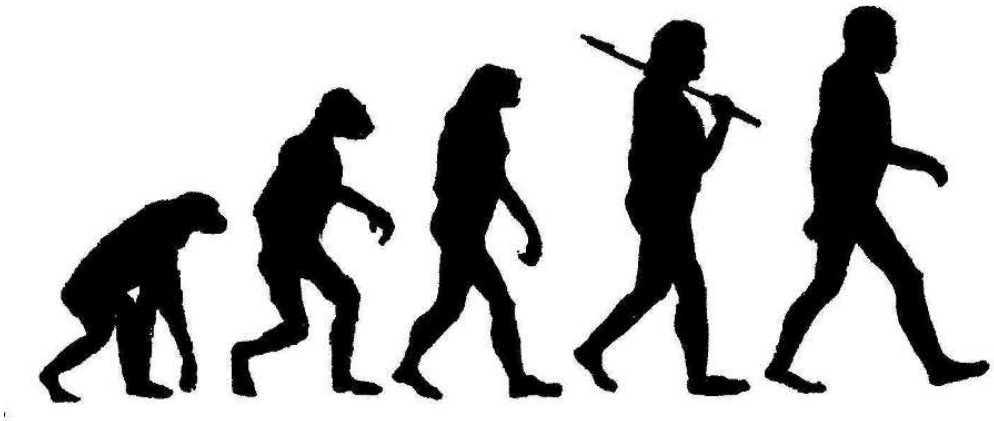
- Reducing the human component in algorithm design
- More work at the beginning, more possibilities
- Genetic programming hyper-heuristics as a method to the madness

https://scratch.mit.edu/discuss/m/topic/200574/

# Outline

# Outline

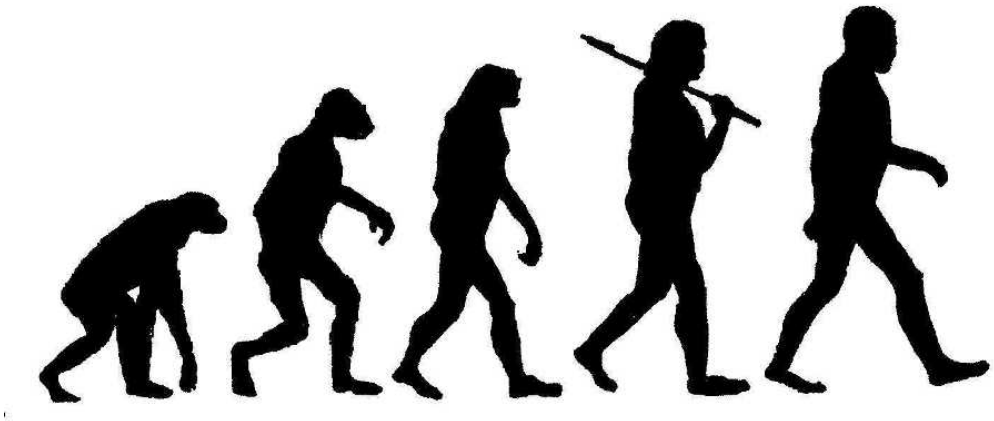
# Evolutionary Computation



https://www.spigotmc.org/attachments/evolution-jpg.137048/

- Subfield of Artificial Intelligence

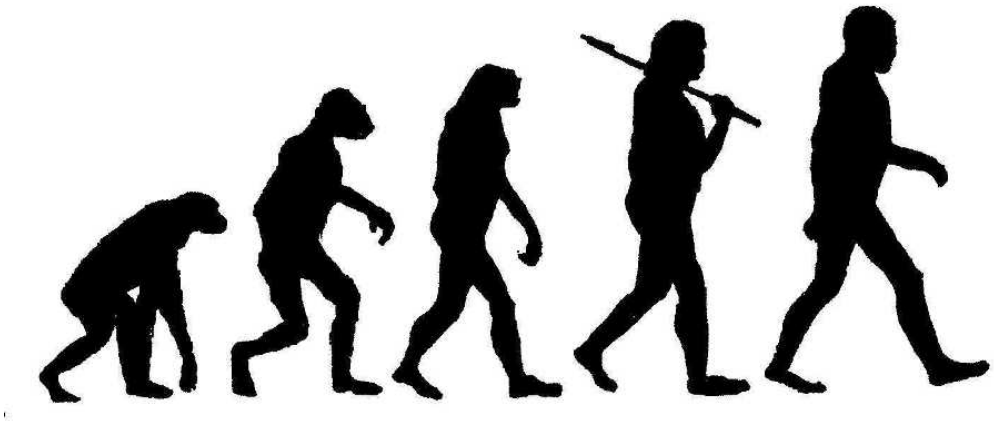
# Evolutionary Computation



https://www.spigotmc.org/attachments/evolution-jpg.137048/

- Subfield of Artificial Intelligence
- Algorithms based on biological evolution

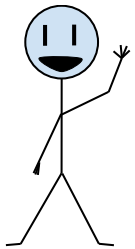
# Evolutionary Computation



https://www.spigotmc.org/attachments/evolution-jpg.137048/

- Subfield of Artificial Intelligence
- Algorithms based on biological evolution
- Uses lots of terminology from biology, doesn't always mean same thing as term means in biology.

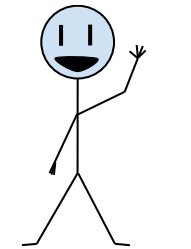
# Evolutionary Computation – Terminology

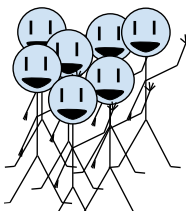


- **Individual** – a potential solution to a problem (or set of problems)

# Evolutionary Computation – Terminology

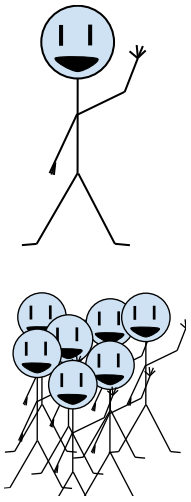
- **Individual** – a potential solution to a problem (or set of problems)
- **Population** – a group of individuals





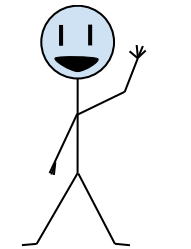
# Evolutionary Computation – Terminology

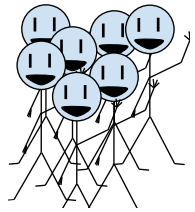
- **Individual** – a potential solution to a problem (or set of problems)
- **Population** – a group of individuals
- **Fit** – how well suited an individual is at solving a problem

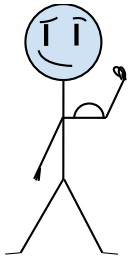


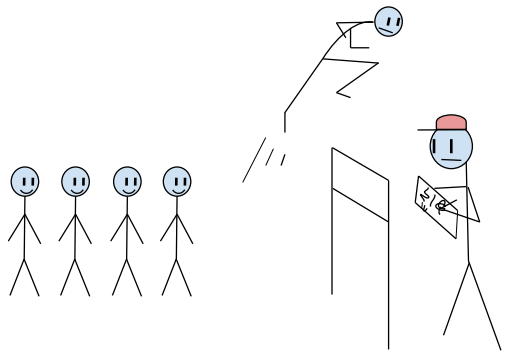
# Evolutionary Computation – Terminology

- **Individual** – a potential solution to a problem (or set of problems)
- **Population** – a group of individuals
- **Fit** – how well suited an individual is at solving a problem
- **Fitness Test** – a set of tests to determine how fit an individual is.









# Evolutionary Computation – Terminology

- **Mutation** – an insertion, deletion, or small change in the code of an individual, creating a new individual

# Evolutionary Computation – Terminology

- **Mutation** – an insertion, deletion, or small change in the code of an individual, creating a new individual
- **Sexual reproduction** – when two or more individuals are munged together to create a new individual

# Evolutionary Computation – Terminology

- **Mutation** – an insertion, deletion, or small change in the code of an individual, creating a new individual
- **Sexual reproduction** – when two or more individuals are munged together to create a new individual
- **Generation** – a population of individuals

# Evolutionary Computation – Terminology

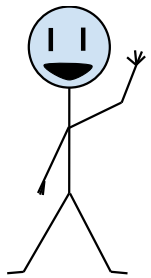
- **Mutation** – an insertion, deletion, or small change in the code of an individual, creating a new individual
- **Sexual reproduction** – when two or more individuals are munged together to create a new individual
- **Generation** – a population of individuals
- **Global optima** – best solution (or solutions) possible

# Evolutionary Computation – Terminology

If individual A experiences a mutation to create individual B, then:

# Evolutionary Computation – Terminology

If individual A experiences a mutation to create individual B, then:

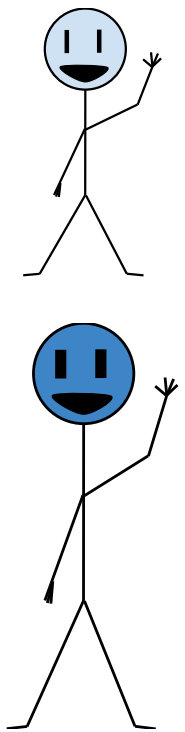


- **Parent** – Individual A

# Evolutionary Computation – Terminology

If individual A experiences a mutation to create individual B, then:

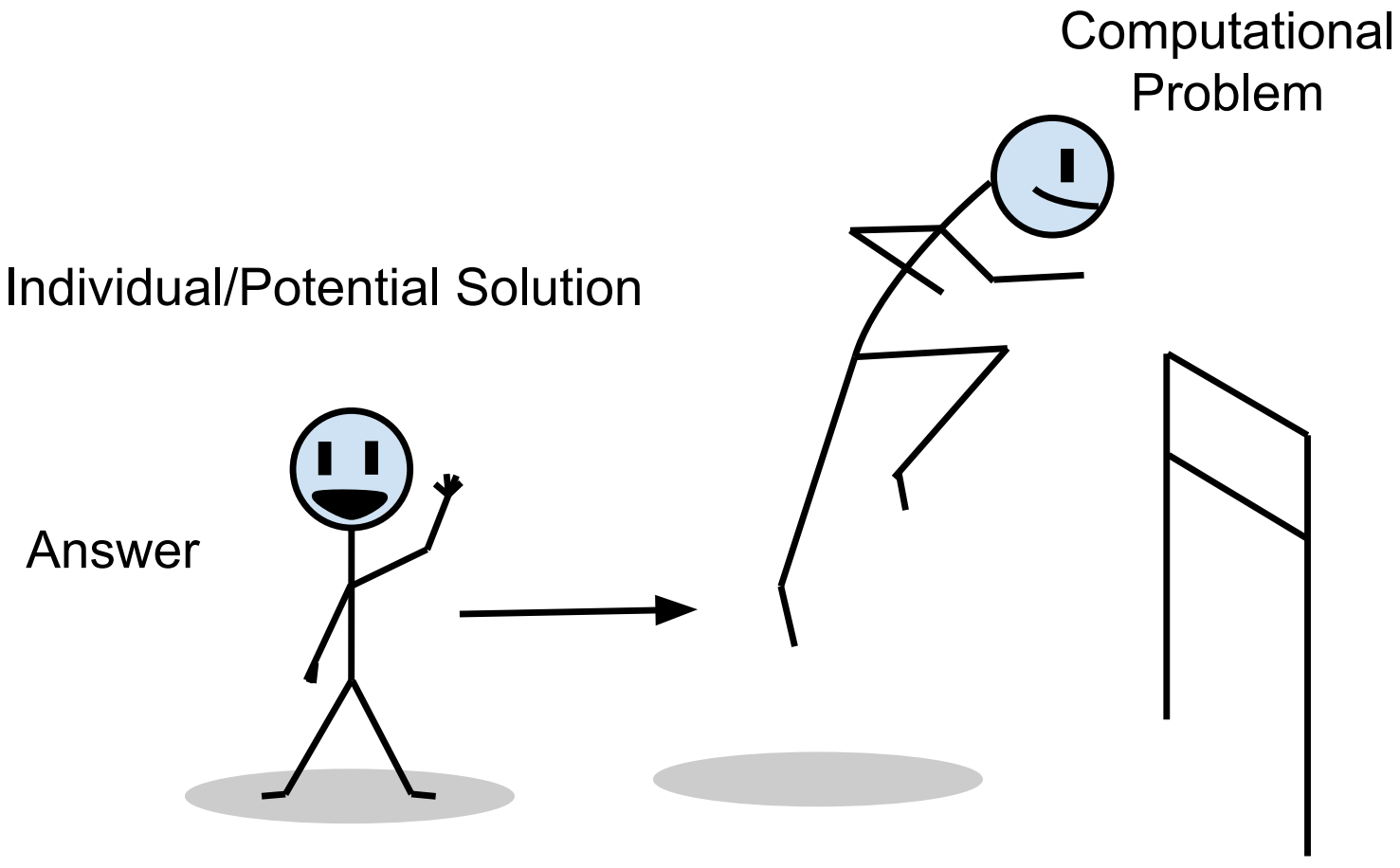
- **Parent** – Individual A
- **Child** – Individual B



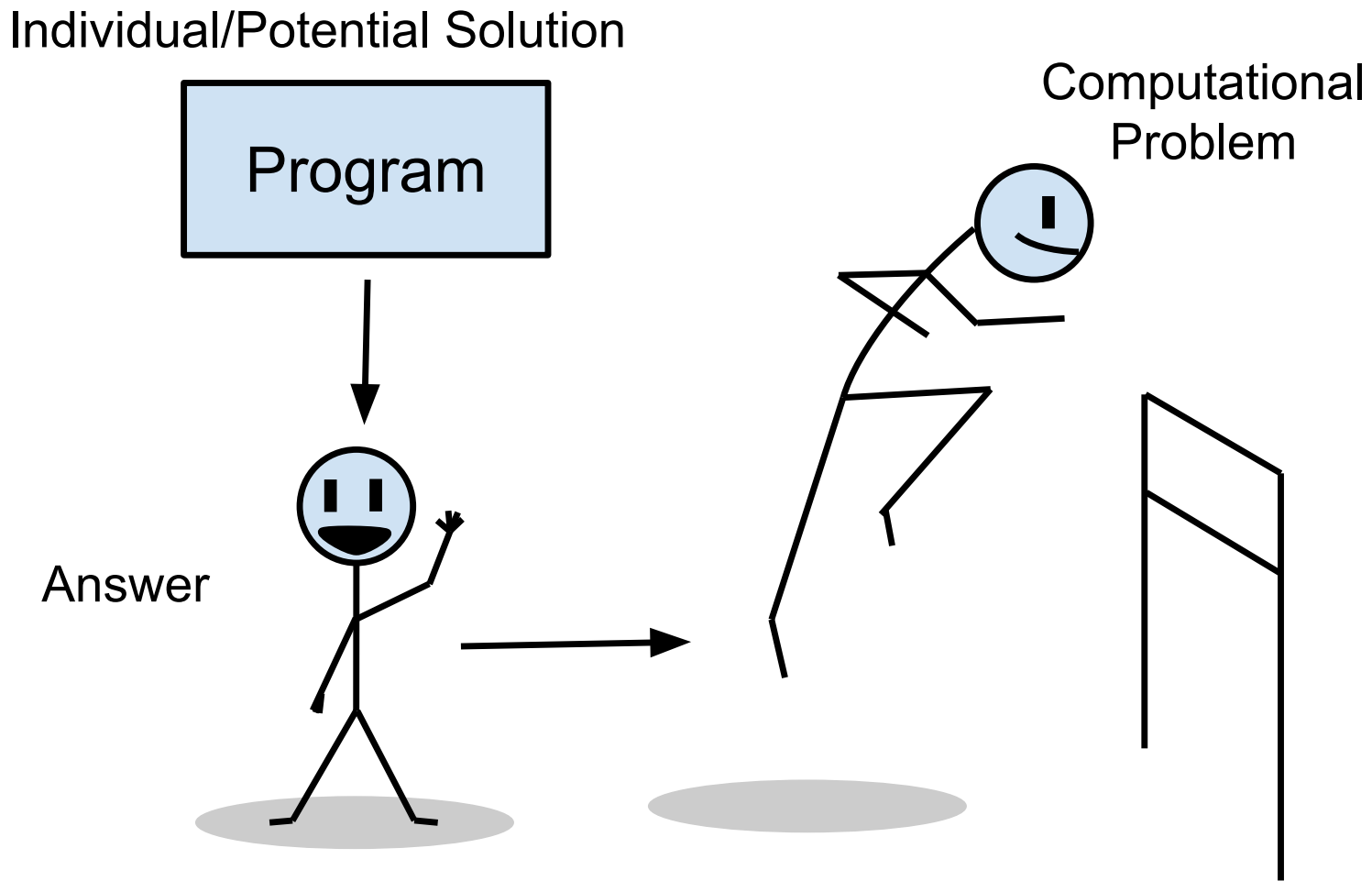
# Genetic Programming

A family of algorithms in Evolutionary Computation that uses biological techniques to create programs to solve computational problems.

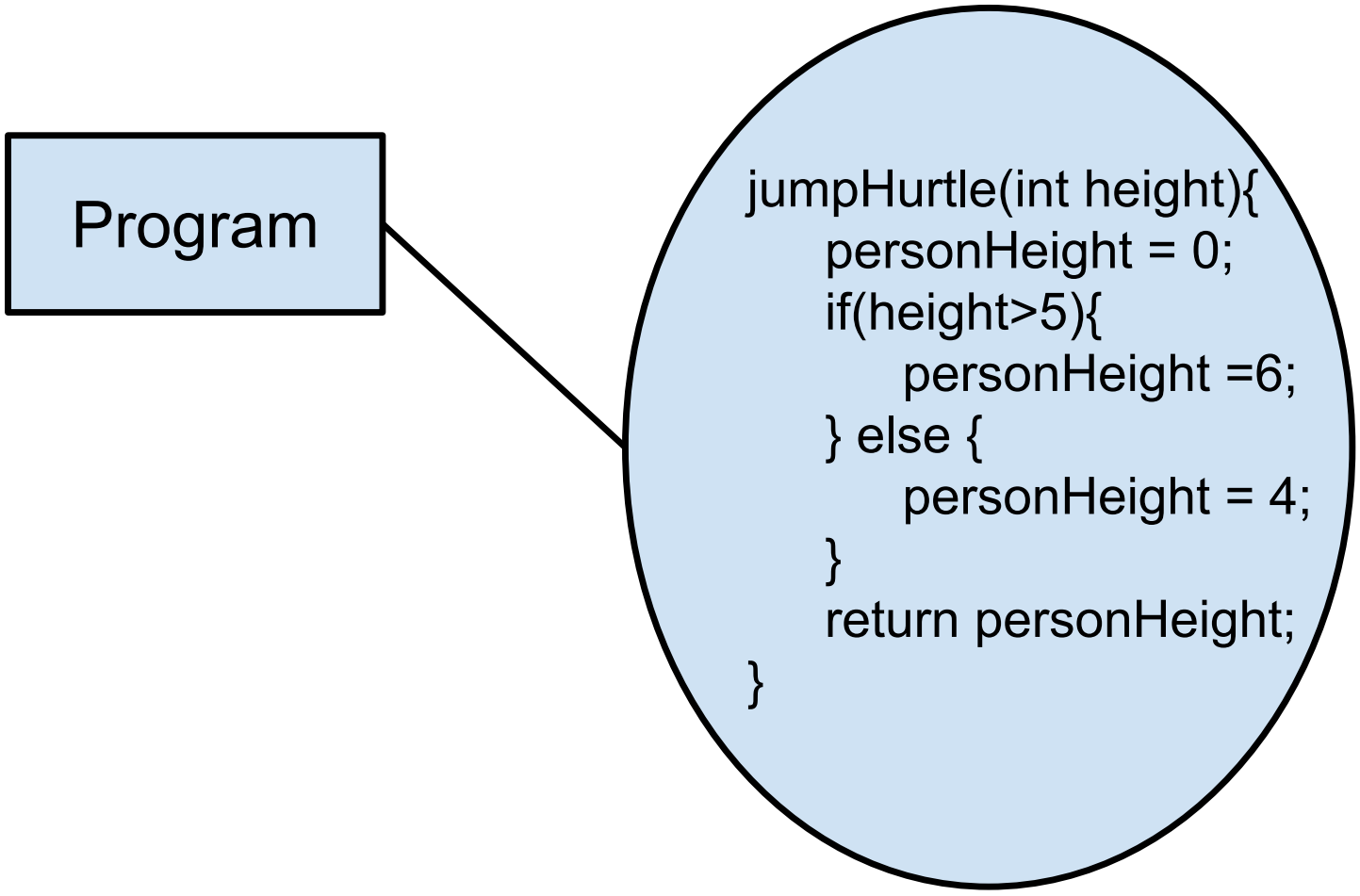
# Genetic Programming



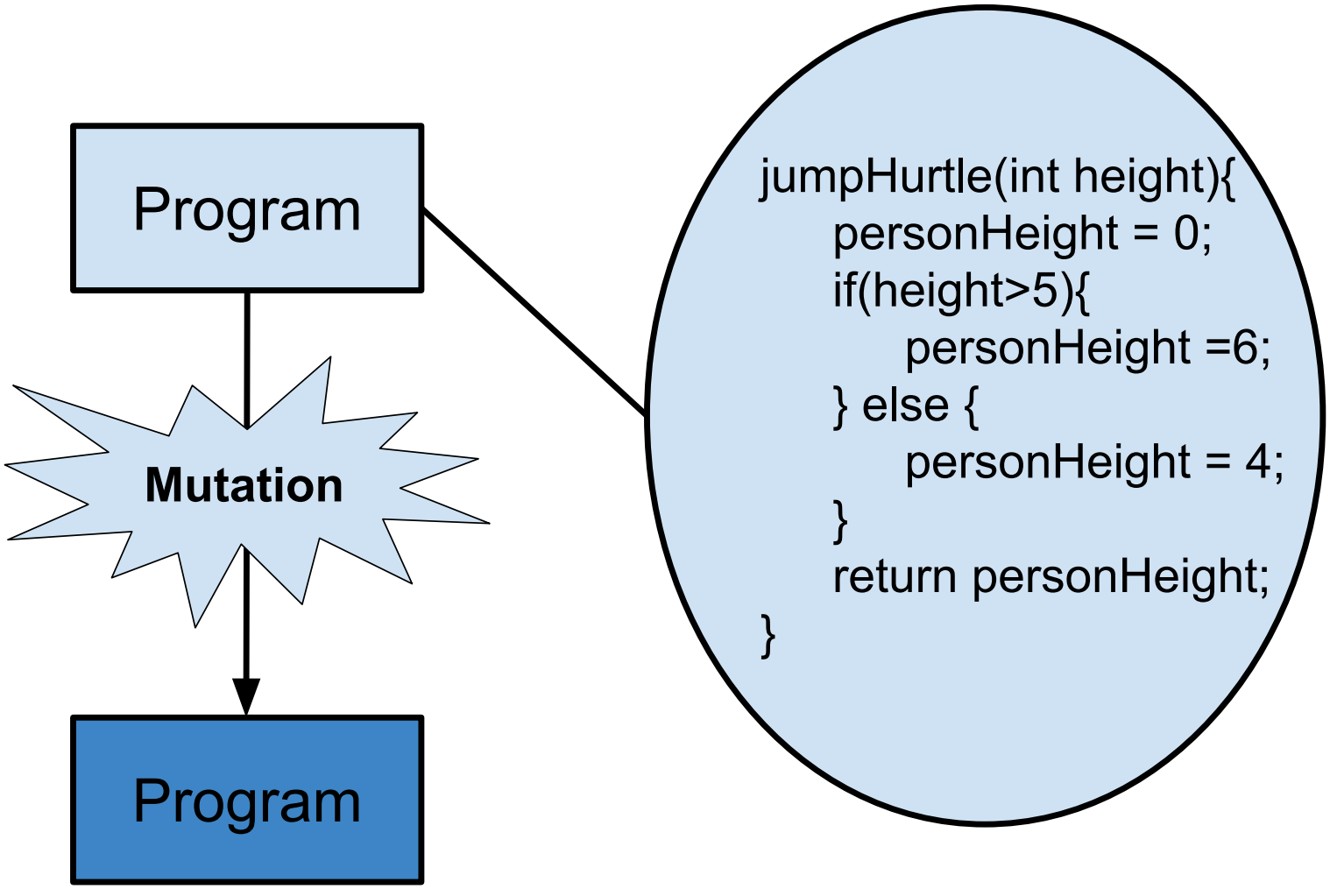
# Genetic Programming



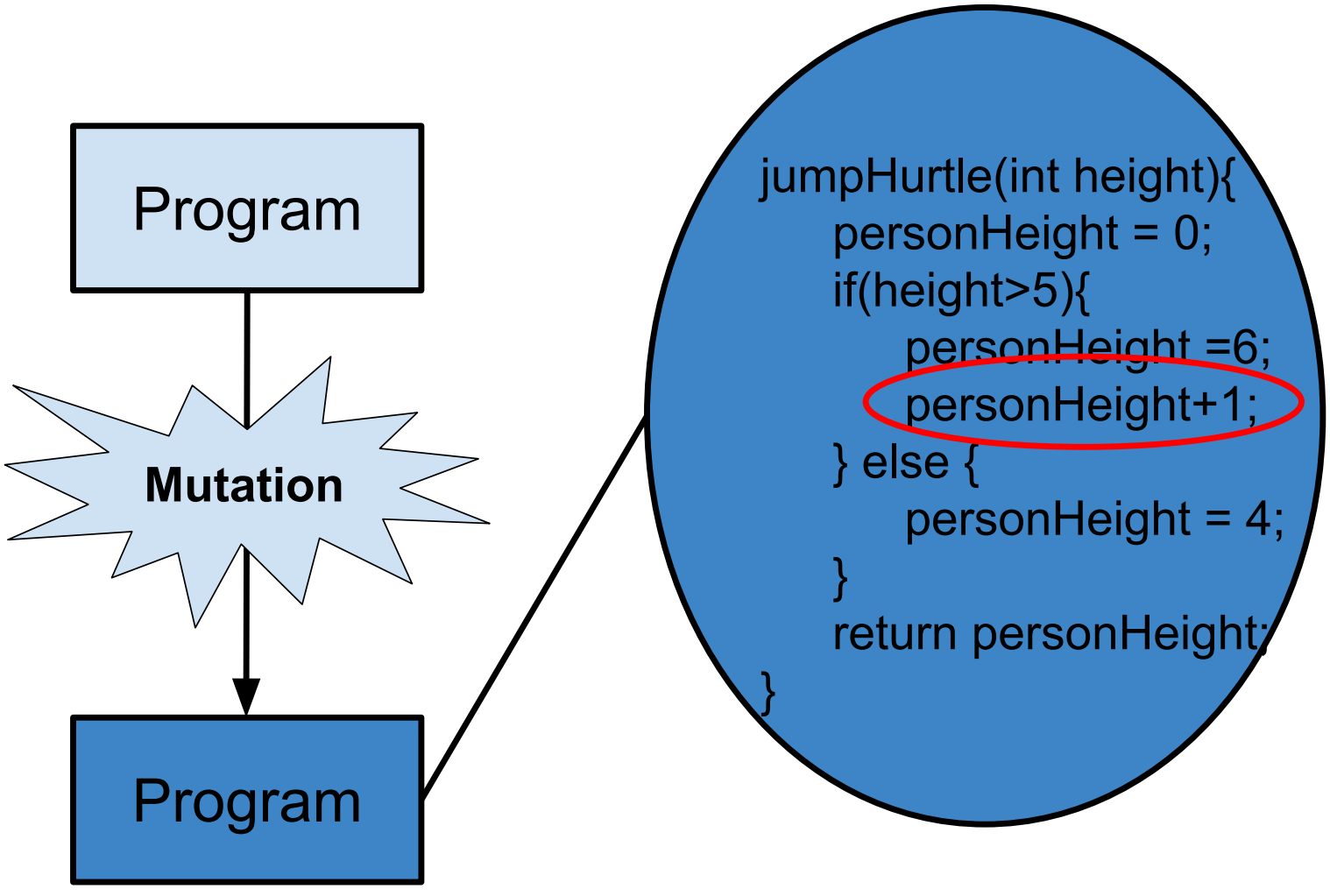
# Genetic Programming



# Genetic Programming



# Genetic Programming



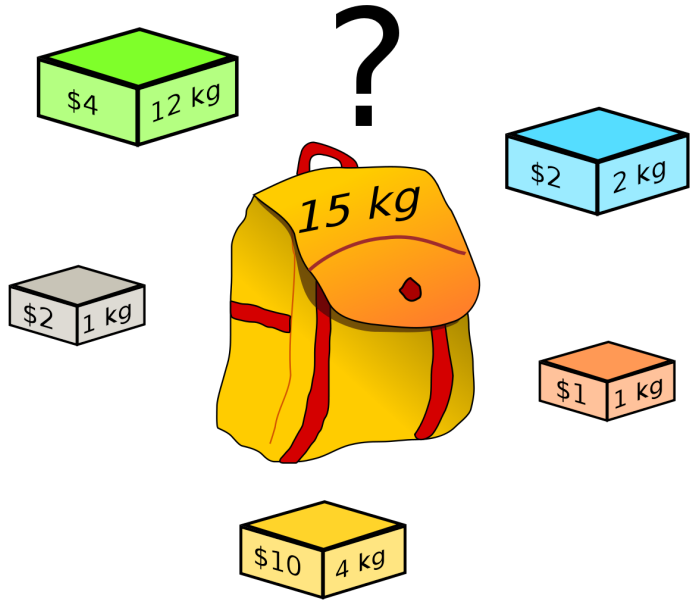
# Outline

# Heuristics

**Heuristics** – a function that ranks alternatives in a search algorithm at each branching step and uses that information to choose which branch to follow.

# Heuristics

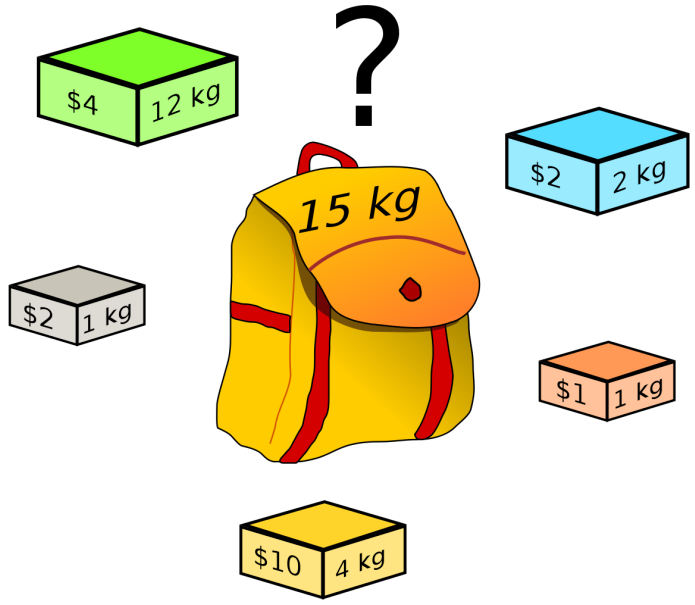
**Heuristics** – a function that ranks alternatives in a search algorithm at each branching step and uses that information to choose which branch to follow.




https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

# Heuristics

“if knapsack is not full, put largest valued item into knapsack. If this item would cause knapsack to be overweight, take the next highest valued item and put it into the knapsack. Repeat until all items are gone"

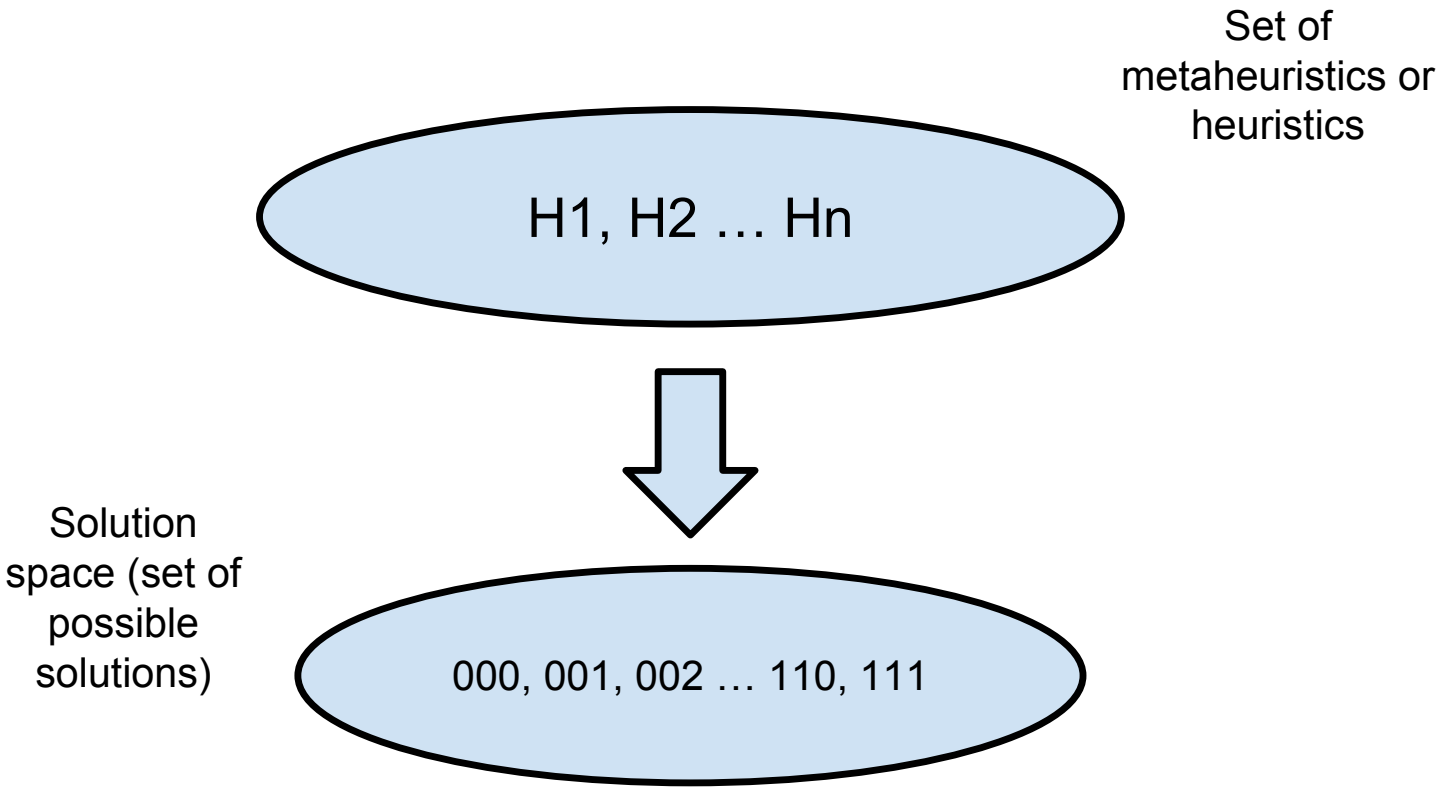



https://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Knapsack.svg/1200px-Knapsack.svg.png

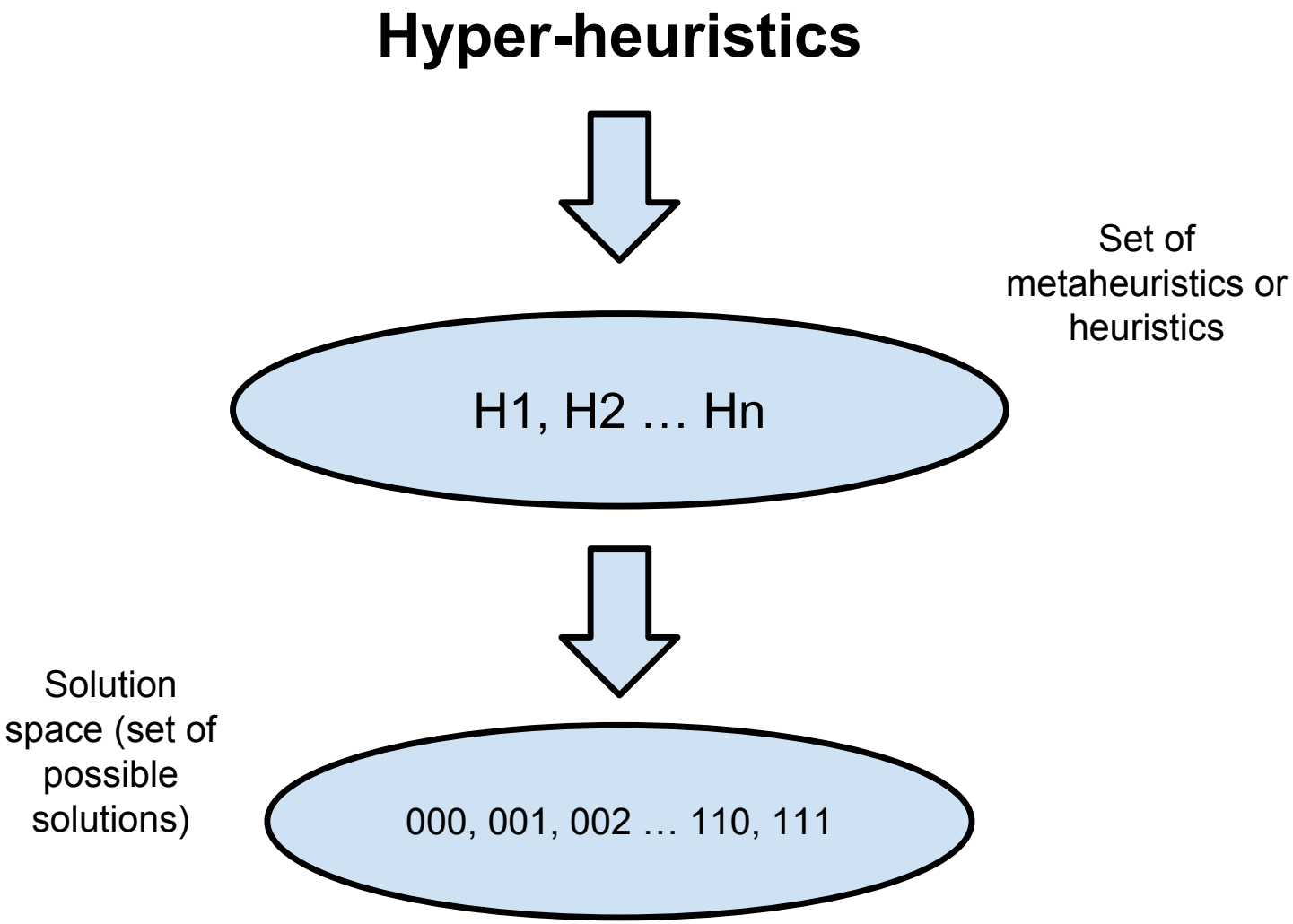
# Metaheuristic

**Metaheuristic** – a heuristic that does not require knowledge about the problem and is not problem specific

# Hyper-heuristics



# Hyper-heuristics



# Hyper-heuristics

**Hyper-heuristics** – heuristic search methods which seek to automate the process of selecting, generating, or adapting several simpler heuristics in order to solve computational search problems.

# Hyper-heuristics

**Hyper-heuristics** – heuristic search methods which seek to automate the process of selecting, generating, or adapting several simpler heuristics in order to solve computational search problems.

**Genetic programming hyper-heuristics** – hyper-heuristics that use genetic programming for the process of selecting, generating, or adapting several simpler heuristics.

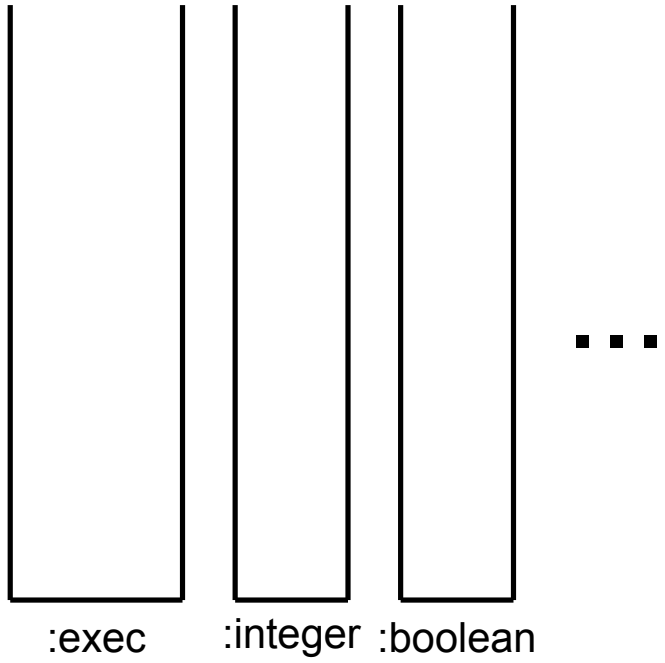
# Outline

# Genetic programming variants

Variations on the structure and setup of a genetic programming system

# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

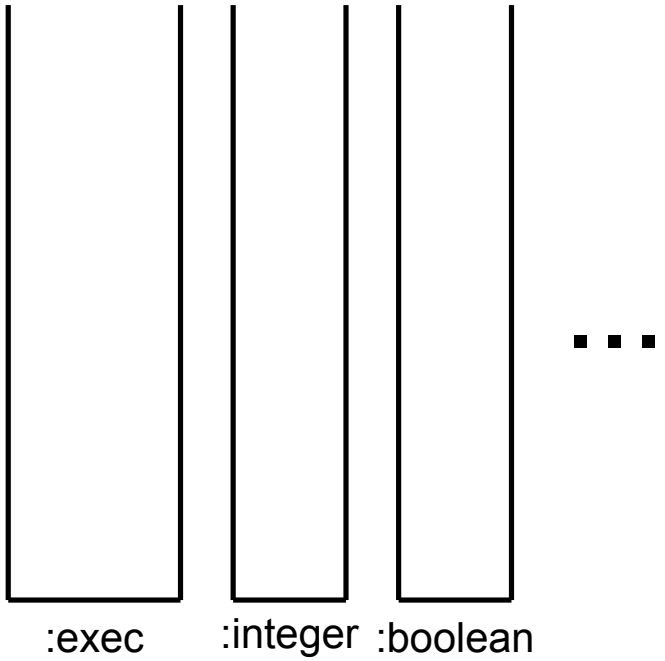


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

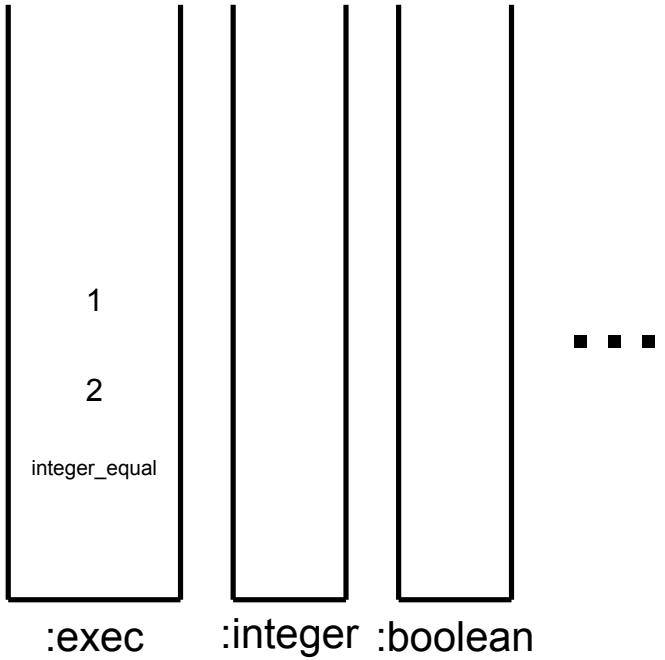


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

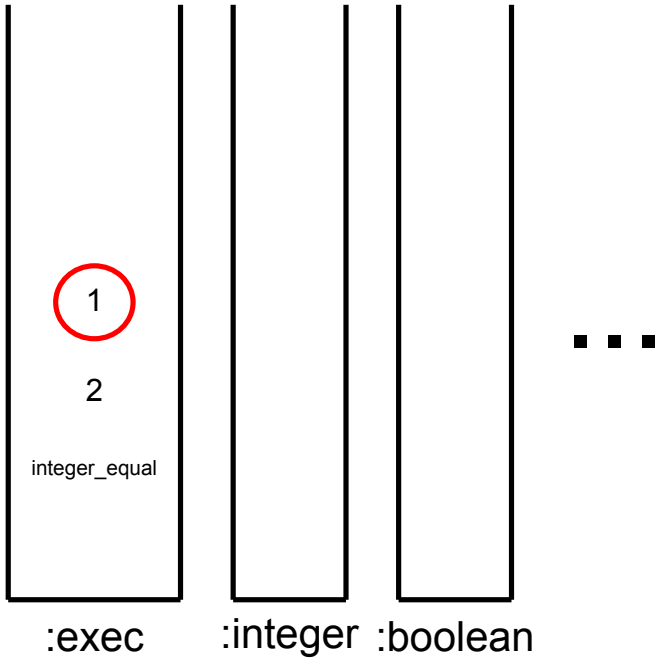


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

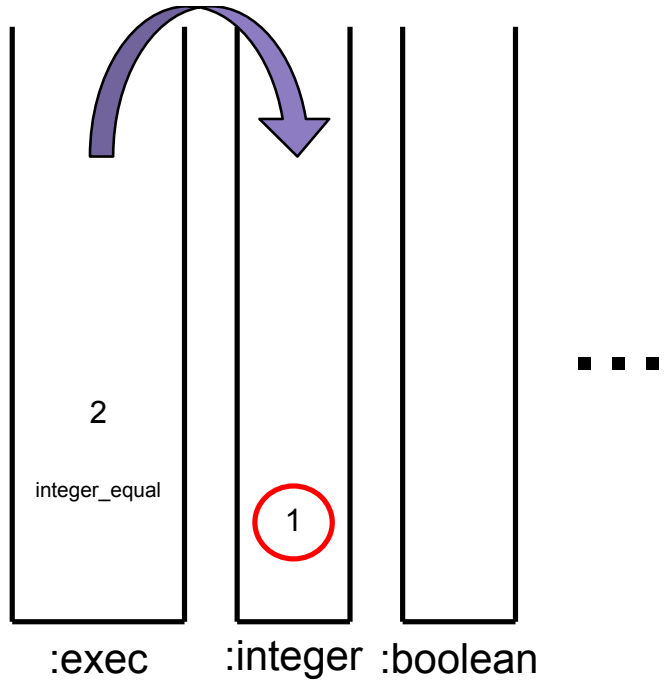


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

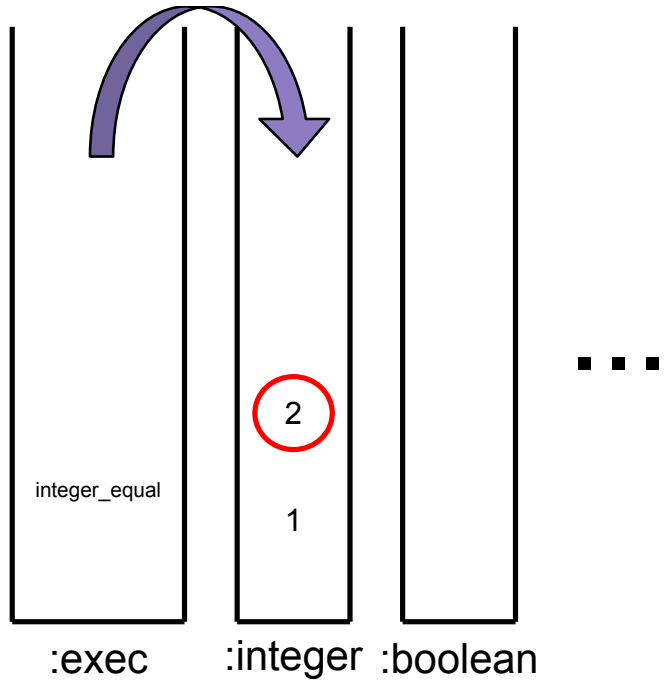


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

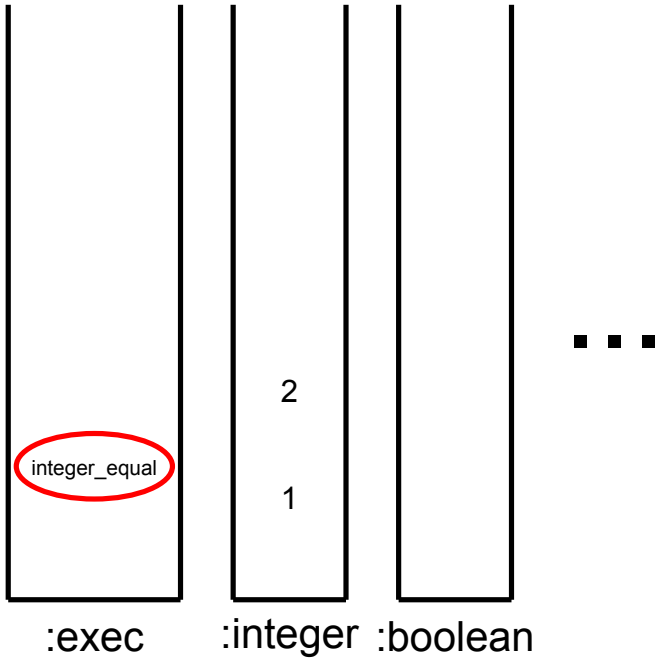


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

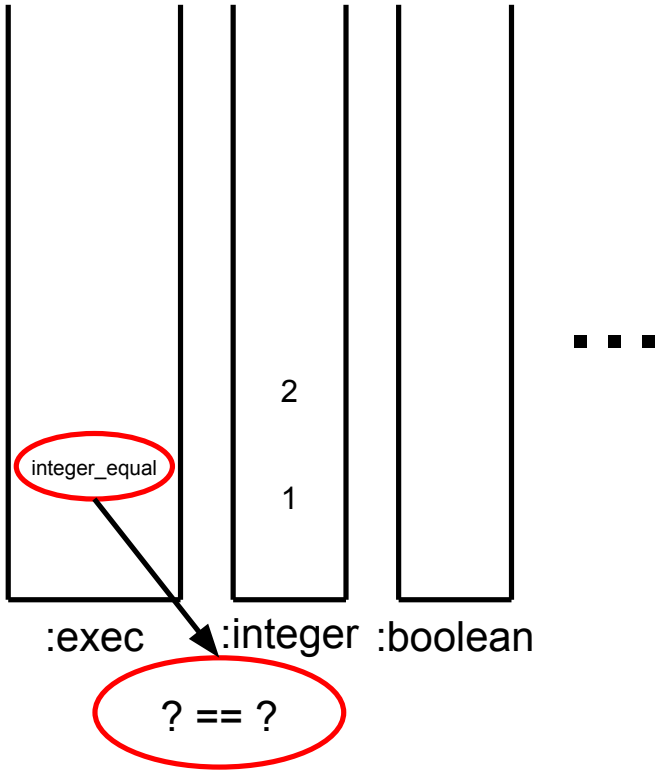


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

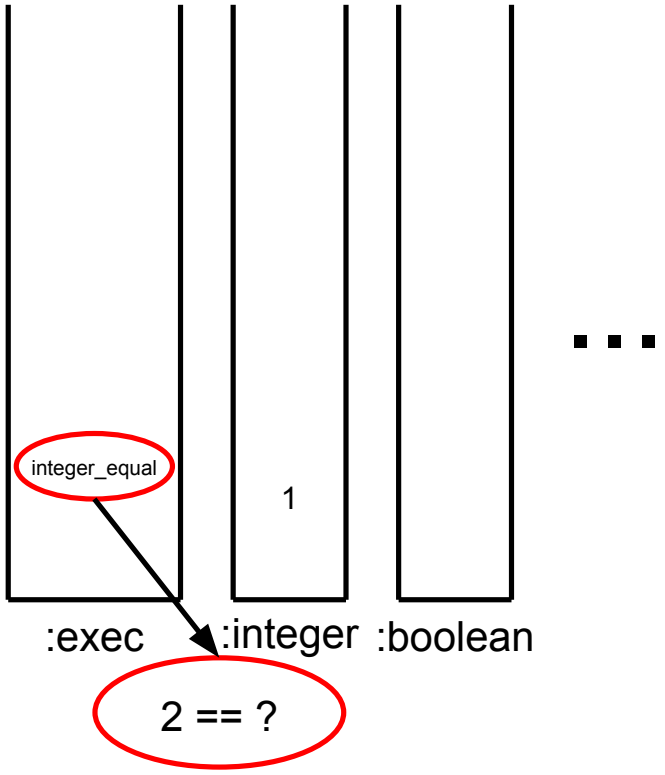


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

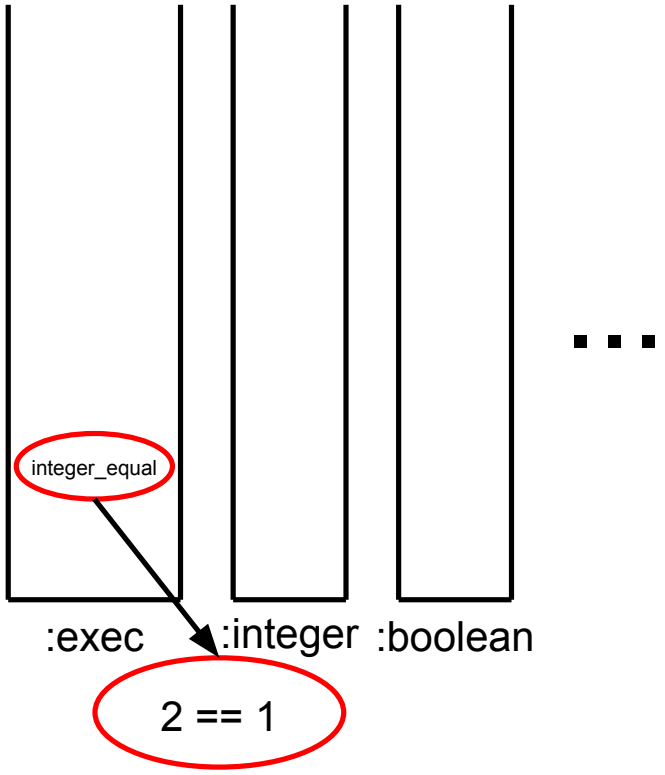


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

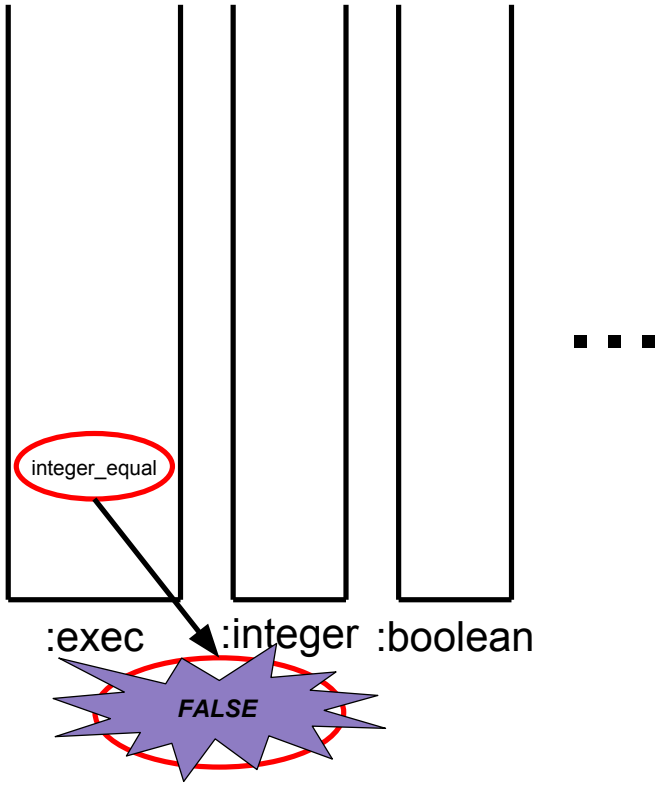


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```

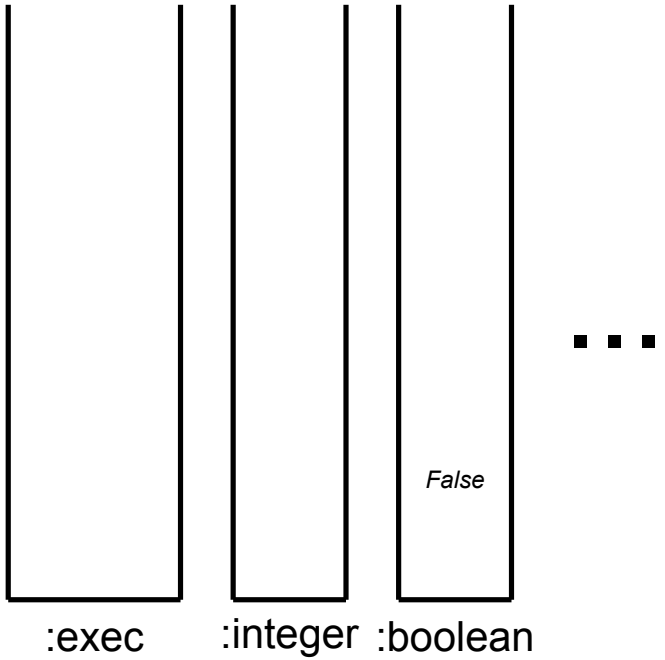


# Stack-based genetic programming

Data-stacks are used for managing input and output of operations.

Programs are represented as linear sequences of literals and instructions. Below is an example of a simple Push program:

```
(1 2 integer_equal)
```



# Outline

# What is Autoconstruction?

- Autoconstruction is a type of GPHH

# What is Autoconstruction?

- Autoconstruction is a type of GPHH
- In most GPHH, the individual programs are evolving, but everything else is specified by the engineer; in autoconstruction, evolution is evolving as well.

# What is Autoconstruction?

- Autoconstruction is a type of GPHH
- In most GPHH, the individual programs are evolving, but everything else is specified by the engineer; in autoconstruction, evolution is evolving as well.
- Programs are responsible for evolving solutions *and* responsible for evolving their offspring.

# AutoDoG

# Outline