Monty Python and the Holy Grail (1975)

BBM 101

Introduction to Programming I

Lecture #04 – Introduction to Python and Programming, Control Flow

HACETTEPE UNIVERSITY

Fuat Akal & Erkut Erdem // Fall 2020

Last time... **Introduction to Algorithms**

- An *algorithm* is a recipe for solving a problem.

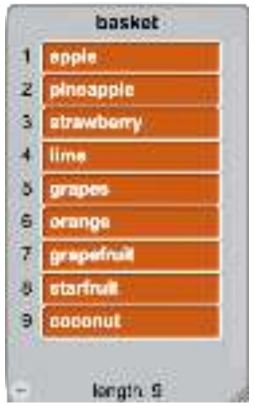
Problem Specification

Input: Some stuff!

OUTPUT: Information about the stuff!

Search Problem

- *Input:*
  - a list of objects
  - a specific object
- *Output:*
  - True if the object is in list
  - False if the object is *not* in list



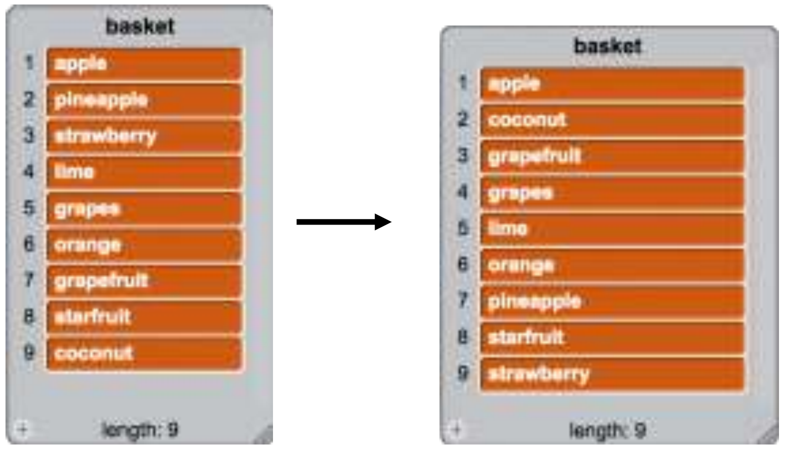
basket

1	apple
2	pineapple
3	strawberry
4	lime
5	grapes
6	orange
7	grapefruit
8	starfruit
9	coconut

length: 9

Sorting Problem

- *Input:*
  - a collection of orderable objects
- *Output:*
  - a collection where each item is in order



basket

1	apple
2	pineapple
3	strawberry
4	lime
5	grapes
6	orange
7	grapefruit
8	starfruit
9	coconut

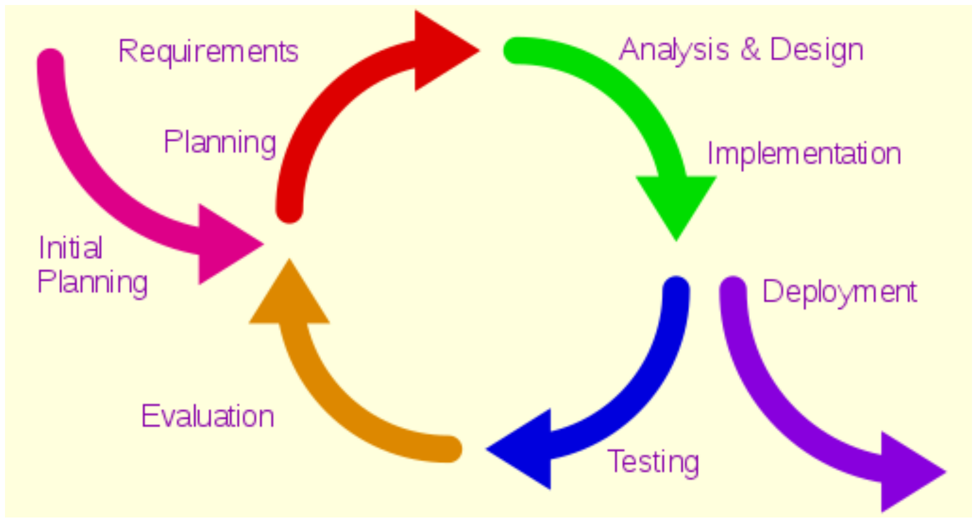
length: 9

→

basket

1	apple
2	coconut
3	grapefruit
4	grapes
5	lime
6	orange
7	pineapple
8	starfruit
9	strawberry

length: 9



Lecture Overview

- Programming languages (PLs)
- Introduction to Python and Programming

Disclaimer: Much of the material and slides for this lecture were borrowed from

—E. Grimson, J. Guttag and C. Terman MIT 6.0001 class

—Ruth Anderson, Michael Ernst and Bill Howe's CSE 140 class

—Swami Iyer's Umass Boston CS110 class

Lecture Overview

- Programming languages (PLs)
- Introduction to Python and Programming

Programming Languages

- Syntax and semantics
- Dimensions of a PL
- Programming paradigms

Programming Languages

- An artificial language designed to express computations that can be performed by a machine, particularly a computer.
- Can be used to create programs that control the behavior of a machine, to express algorithms precisely, or as a mode of human communication.
- **e.g.**, C, C++, Java, Python, Prolog, Haskell, Scala, etc..

Creating Computer Programs

- Each programming language provides a set of primitive operations.
- Each programming language provides mechanisms for combining primitives to form more complex, but legal, expressions.
- Each programming language provides mechanisms for deducing meanings or values associated with computations or expressions.

Aspects of Languages

- Primitive constructs
  - Programming language – numbers, strings, simple operators
  - English – words

- Syntax – which strings of characters and symbols are well-formed
  - Programming language –we’ll get to specifics shortly, but for example 3.2 + 3.2 is a valid C expression
  - English – “cat dog boy” is not syntactically valid, as not in form of acceptable sentence

Aspects of Languages

- Static semantics – which syntactically valid strings have a meaning
  - English – “I are big” has form <noun> <intransitive verb> <noun>, so syntactically valid, but is not valid English because “I” is singular, “are” is plural
  - Programming language – for example, <literal> <operator> <literal> is a valid syntactic form, but 2.3/’abc’ is a static semantic error

Aspects of Languages

- Semantics – what is the meaning associated with a syntactically correct string of symbols with no static semantic errors
  - English – can be ambiguous
    - “They saw the man with the telescope.”
  - Programming languages – always has exactly one meaning
    - But meaning (or value) may not be what programmer intended

Where Can Things Go Wrong?

- Syntactic errors
  - Common but easily caught by computer

- Static semantic errors
  - Some languages check carefully before running, others check while interpreting the program
  - If not caught, behavior of program is unpredictable

- Programs don’t have semantic errors, but meaning may not be what was intended
  - Crashes (stops running)
  - Runs forever
  - Produces an answer, but not programmer’s intent

Our Goal

- Learn the syntax and semantics of a programming language
- Learn how to use those elements to translate “recipes” for solving a problem into a form that the computer can use to do the work for us
- Computational modes of thought enable us to use a suite of methods to solve problems

Dimensions of a Programming Language

Low-level vs. High-level

- Distinction according to the level of abstraction

- In low-level programming languages (e.g. Assembly), the set of instructions used in computations are very simple (nearly at machine level)

- A high-level programming language (e.g. Python, C, Java) has a much richer and more complex set of primitives.

Dimensions of a Programming Language
General vs. Targeted

- Distinction according to the range of applications

- In a general programming language, the set of primitives support a broad range of applications.

- A targeted programming language aims at a very specific set of applications.
  - **e.g.**, MATLAB (matrix laboratory) is a programming language specifically designed for numerical computing (matrix and vector operations)

Dimensions of a Programming Language
Interpreted vs. Compiled

- Distinction according to how the source code is executed

- In interpreted languages (e.g. BASIC), the source code is executed directly at runtime (by the interpreter).
  - Interpreter control the flow of the program by going through each one of the instructions.

- In compiled languages (e.g. C), the source code first needs to be translated into an object code (by the compiler) before the execution.

Programming Language Paradigms

- **Functional**
  - Treats computation as the evaluation of mathematical functions (e.g. Lisp, Scheme, Haskell, etc.)
- **Imperative**
  - Describes computation in terms of statements that change a program state (e.g. FORTRAN, BASIC, Pascal, C, etc.)
- **Logical (declarative)**
  - Expresses the logic of a computation without describing its control flow (e.g. Prolog)
- **Object oriented**
  - Uses "objects" – data structures consisting of data fields and methods together with their interactions – to design applications and computer programs (e.g. C++, Java, C#, Python, etc.)

Lecture Overview

- Programming languages (PLs)

- Introduction to Python and Programming

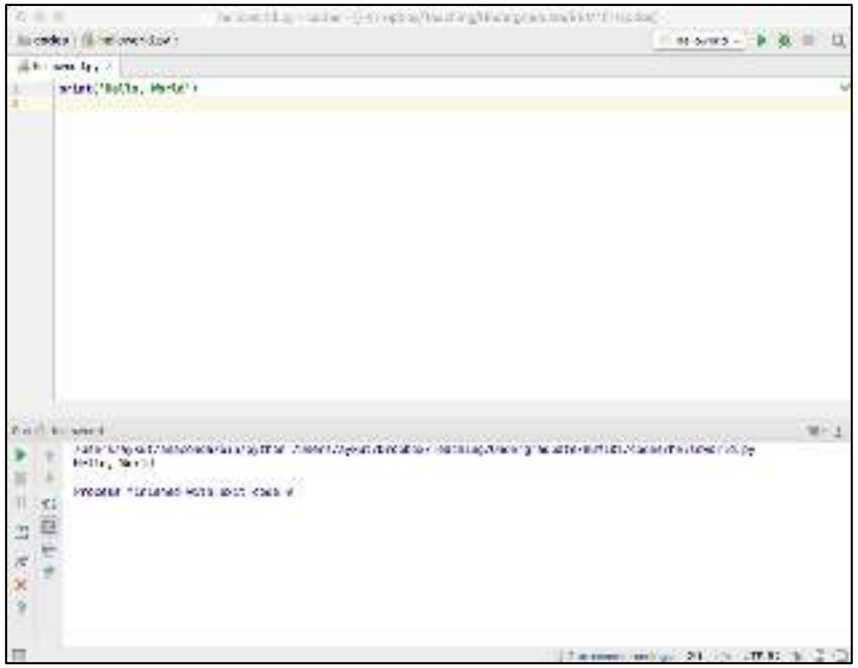
Python

- Python started as a hobby project by Guido Van Rossum and was first released in 1991.

- Python is an interpreted language and not a compiled one, although compilation is a step.
  - Python code is first compiled to what is called *bytecode*

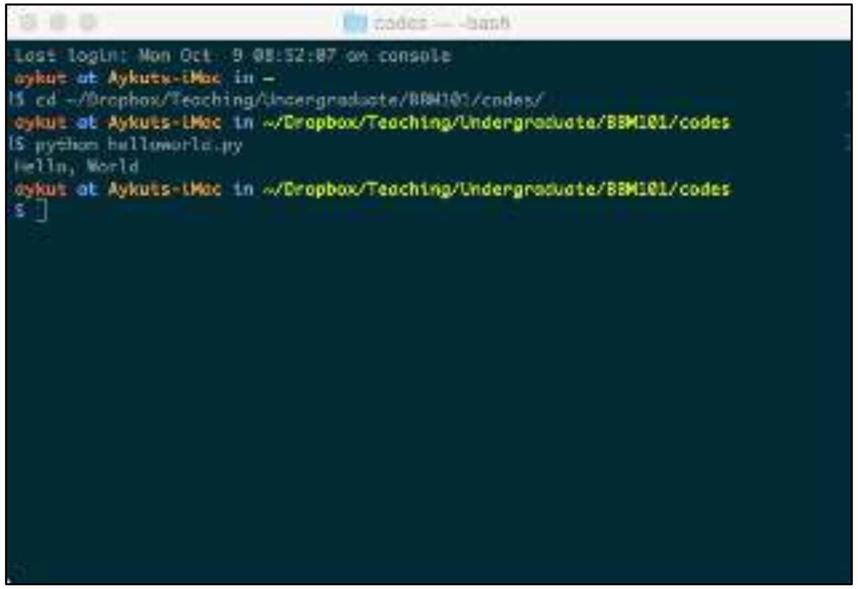
Programming in Python

- Our programming environment
  - Python programming language
  - PyCharm, an integrated development environment (IDE)
  - Terminal



```
print('Hello, World')
```

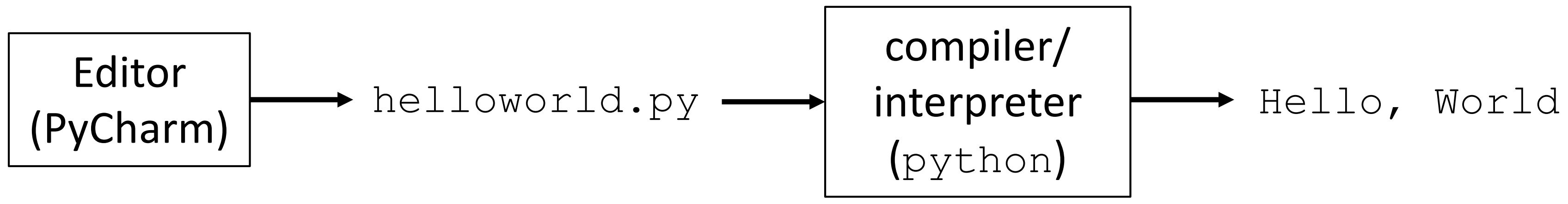
```
[illegible]
Hello, World

Process finished with exit code 0
```



```
Last login: Mon Oct  9 08:52:07 on console
aykut at Aykuts-iMac in ~
$ cd ~/Dropbox/Teaching/Undergraduate/BBM101/codes/
aykut at Aykuts-iMac in ~/Dropbox/Teaching/Undergraduate/BBM101/codes
$ python helloworld.py
Hello, World
aykut at Aykuts-iMac in ~/Dropbox/Teaching/Undergraduate/BBM101/codes
$
```

Programming in Python

- To program in Python
  - Compose a program by typing it into a file named, say, `helloworld.py`
  - Run (or execute) the program by typing `python helloworld.py` in the terminal window



Input and Output

- Bird’s-eye view of a Python program

$$\begin{tikzcd}\text{input} \arrow[r] & \boxed{\texttt{my\_program.py}} \arrow[r] & \text{output}\end{tikzcd}$$

  - **Input types:** command-line arguments, standard input, file input
  - **Output types:** standard output, file output, graphical output, audio output

Input and Output

- Command-line arguments are the inputs we list after a program name when we run the program

```
$ python my_program.py arg_1 arg_2 ... arg_n
```

- The command-line arguments can be accessed within a program, such as `my_program.py` above, via the array (aka list) `sys.argv`[1] as `sys.argv[1], sys.argv[2], . . . , sys.argv[n]`

- The name of the program (`my_program.py`) is stored in `sys.argv[0]`

[1] The `sys` module provides access to variables and functions that interact with the Python interpreter

Input and Output

useargument.py

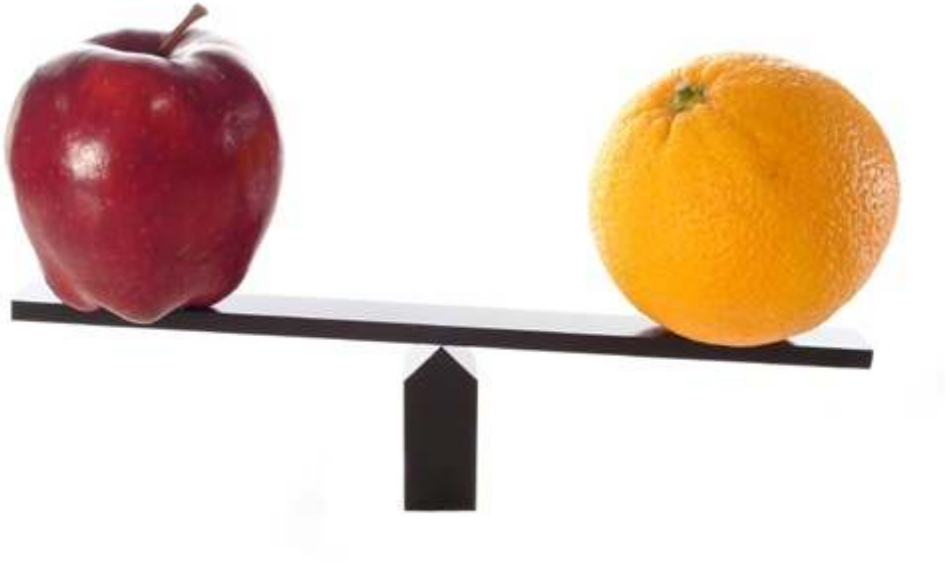
```python
import sys

print('Hi, ', end='')
print(sys.argv[1], end='')
print('. How are you?')
```

```
$ python useargument.py Alice
Hi, Alice. How are you?
$ python useargument.py Bob
Hi, Bob. How are you?
$ python useargument.py Carol
Hi, Carol. How are you?
```

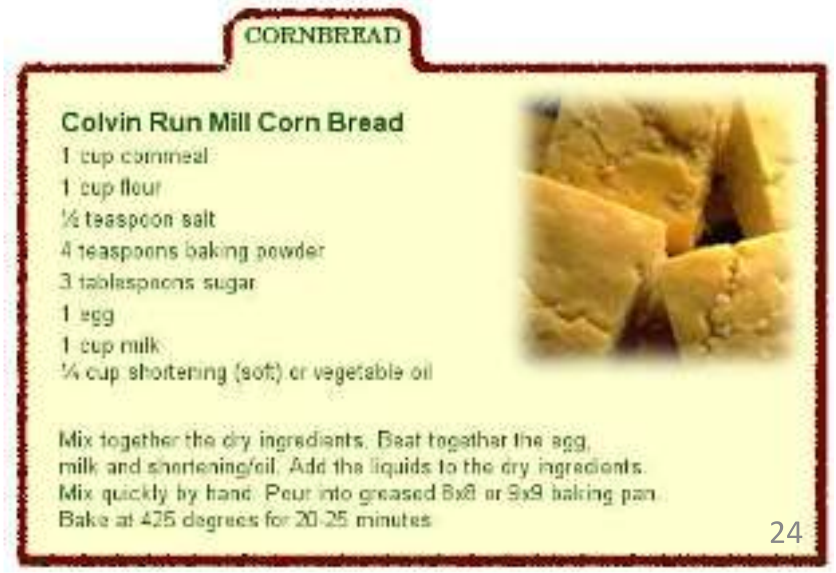
1. Python is like a calculator

2. A variable is a container

3. Different types cannot be compared



4. A program is a recipe



CORNBREAD

Colvin Run Mill Corn Bread

1 cup cornmeal
1 cup flour
½ teaspoon salt
4 teaspoons baking powder
3 tablespoons sugar
1 egg
1 cup milk
¼ cup shortening (soft) or vegetable oil

Mix together the dry ingredients. Beat together the egg, milk and shortening/oil. Add the liquids to the dry ingredients. Mix quickly by hand. Pour into greased 8x8 or 9x9 baking pan. Bake at 425 degrees for 20-25 minutes.

1. Python is Like a Calculator

You Type *Expressions*. Python Computes Their *Values*.

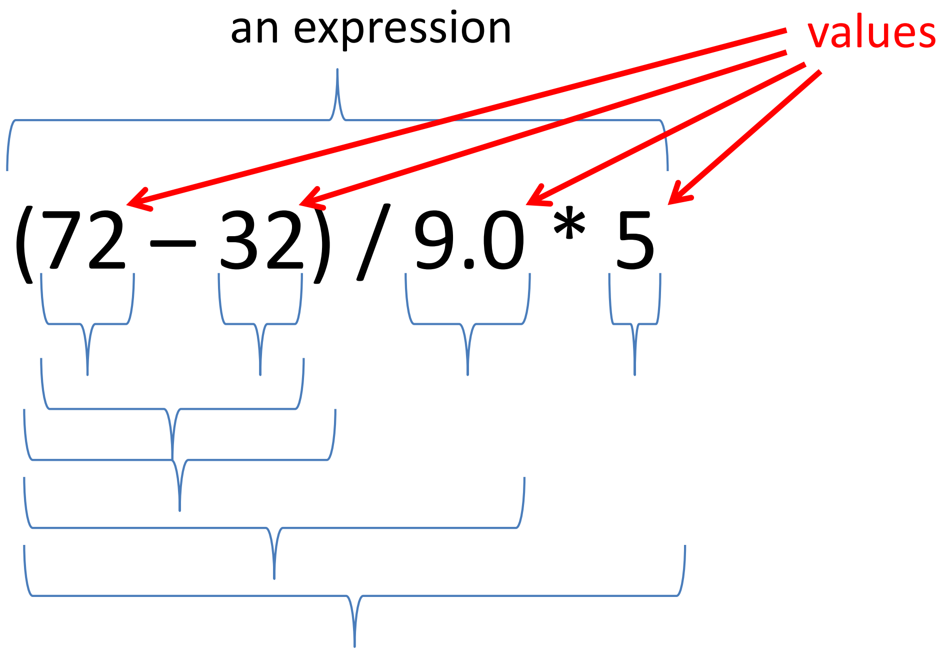
- 5
- 3+4
- 44/2
- 2**3
- 3*4+5*6
- (72 – 32) / 9 * 5

Python has a natural and well-defined set of precedence rules that fully specify the order in which the operators are applied in an expression

- For arithmetic operations, multiplication and division are performed before addition and subtraction
- When arithmetic operations have the same precedence, they are left associative, with the exception of the exponentiation operator **, which is right associative
- We can use parentheses to override precedence rules

An Expression is Evaluated From the Inside Out

- How many expressions are in this Python code?



(72 – 32) / 9.0 * 5

(40) / 9.0 * 5

40 / 9.0 * 5

4.44 * 5

22.2

Another Evaluation Example

(72 – 32) / (9.0 * 5)

(40) / (9.0 * 5)

40 / (9.0 * 5)

40 / (45.0)

40 / 45.0

.888

2. A Variable is a Container

5
myVariable

A variable is a name associated
with a data-type value

Variables Hold Values

- Recall variables from algebra:
  - Let x = 2 …
  - Let y = x …
- To assign a variable, use “*varname* = *expression*”

```
pi = 3.14
pi
var = 6*10**23
22 = x          # Error!
```

No output from an assignment statement

- Not all variable names are permitted!

- Variable names must only be one word (as in no spaces)
- Variable names must be made up of only letters, numbers, and underscore (_)
- Variable names cannot begin with a number

Python is Dynamically Typed

- **Dynamic-typed** languages do not require the explicit declaration of the variables before they are used.
- **Python interpreter** does **type checking** only as the code runs, and the type of a variable is allowed to change over its lifetime.
- In **static-typed** languages (e.g. C++), you have to declare the variable type and any discrepancy like adding a string and an integer is checked during compile time.

Changing Existing Variables ("re-binding" or "re-assigning")

```
x = 2
x
y = x
y
x = 5
x
y
```

- "=" in an assignment is not a promise of eternal equality
  - This is different than the mathematical meaning of "="
- Evaluating an expression gives a new (copy of a) number, rather than changing an existing one

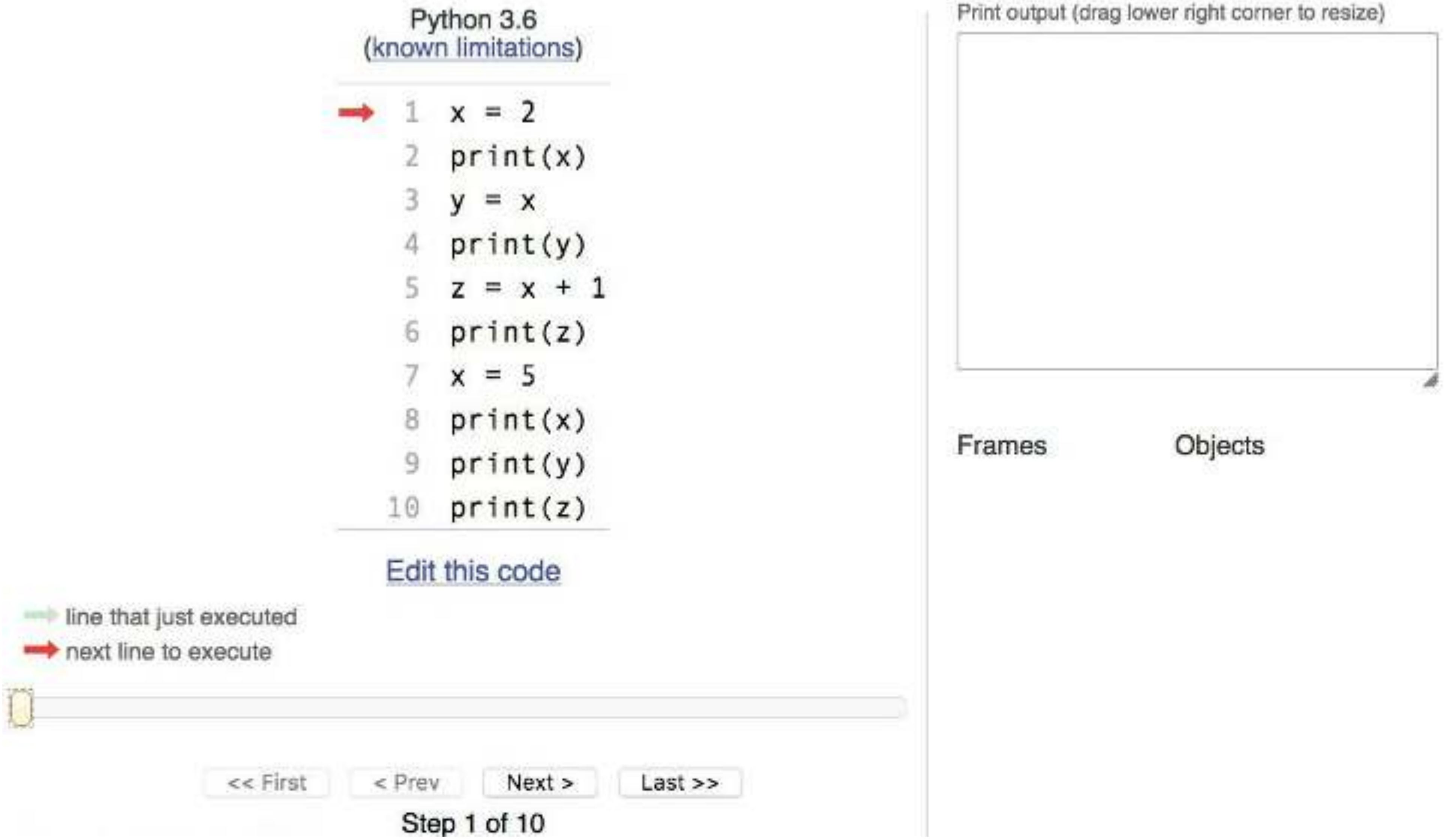
How an Assignment is Executed

1. Evaluate the right-hand side to a value
2. Store that value in the variable

```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

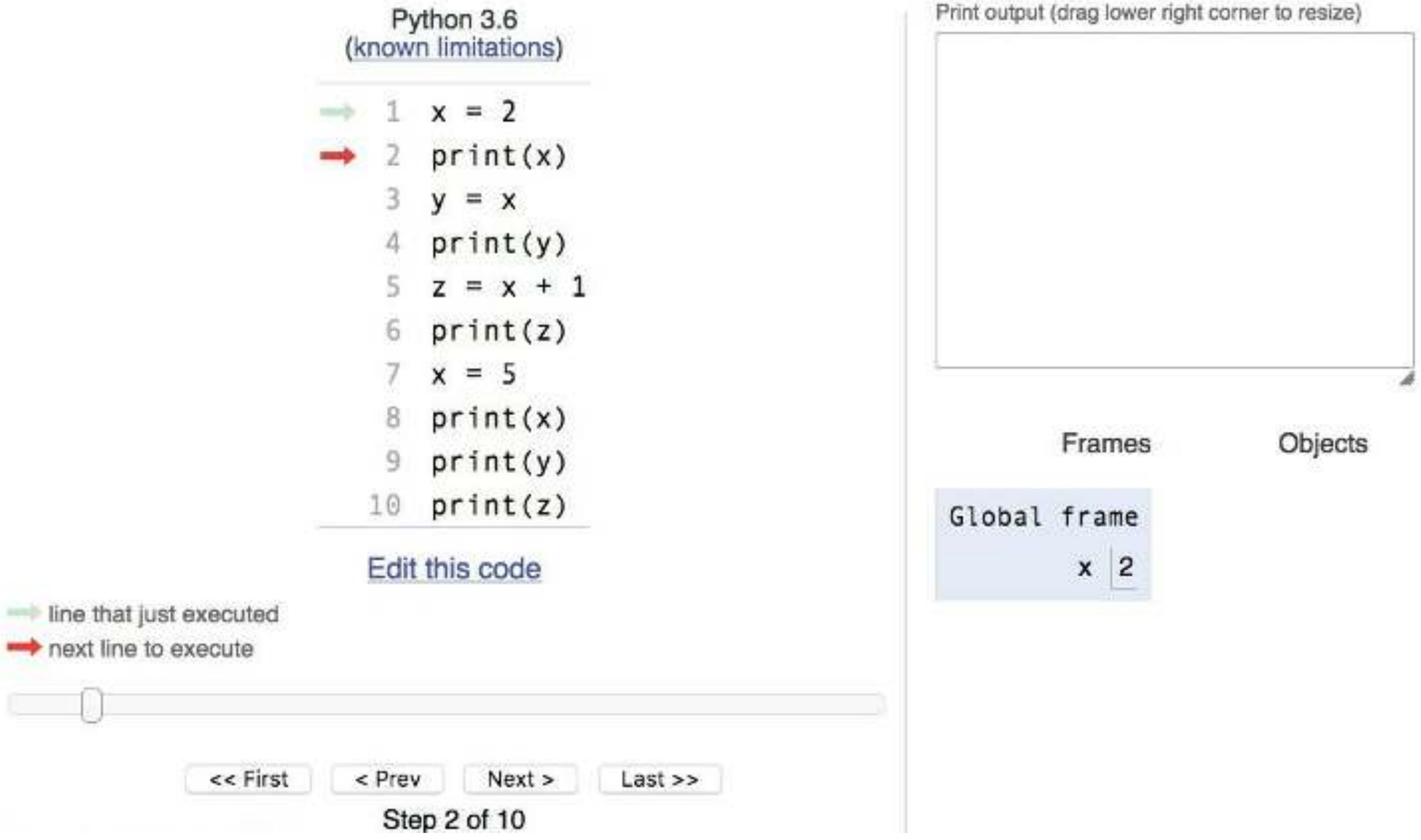
To visualize a program's execution:
http://pythontutor.com

How an Assignment is Executed



```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

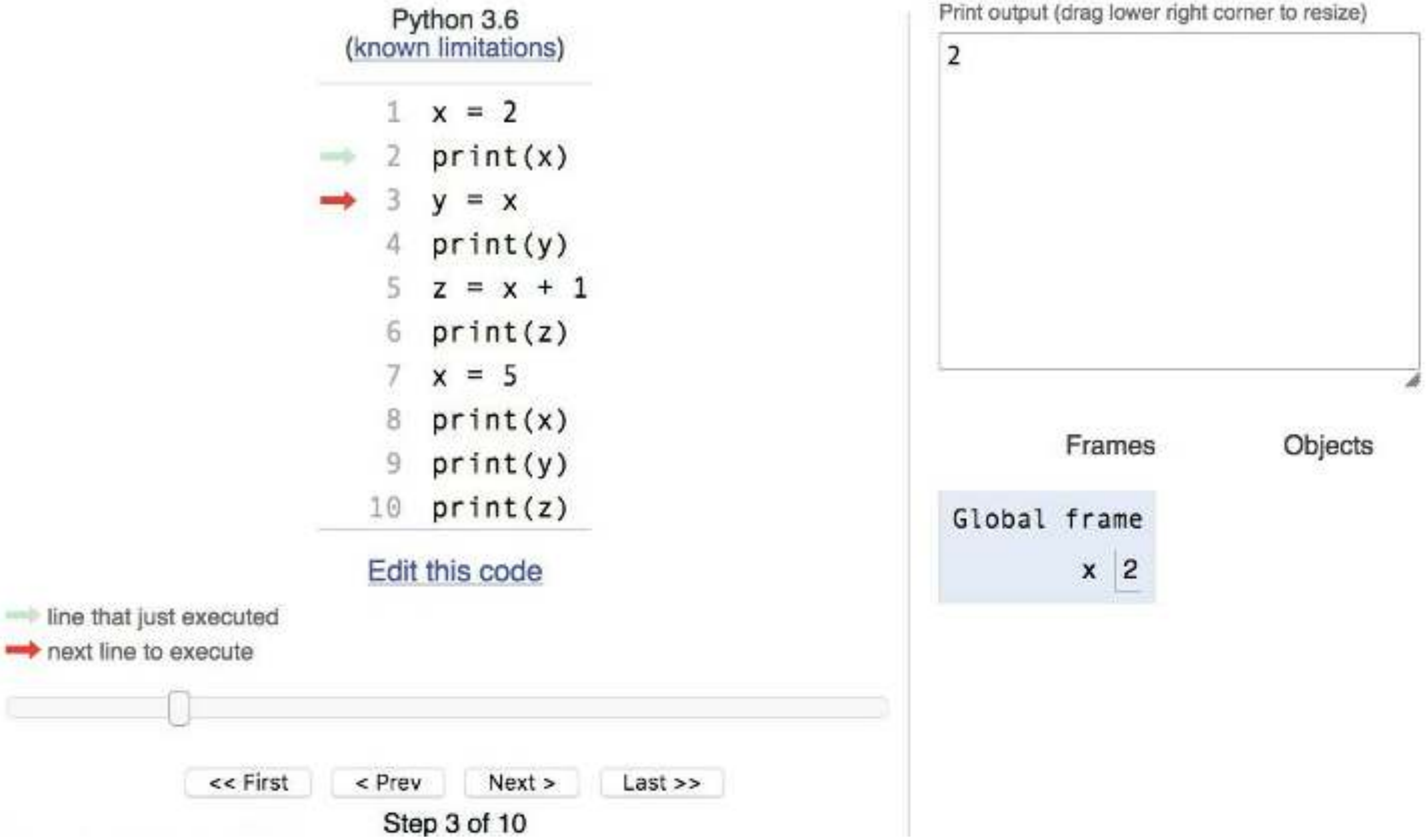
How an Assignment is Executed



```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

```
Global frame
      x  2
```

How an Assignment is Executed

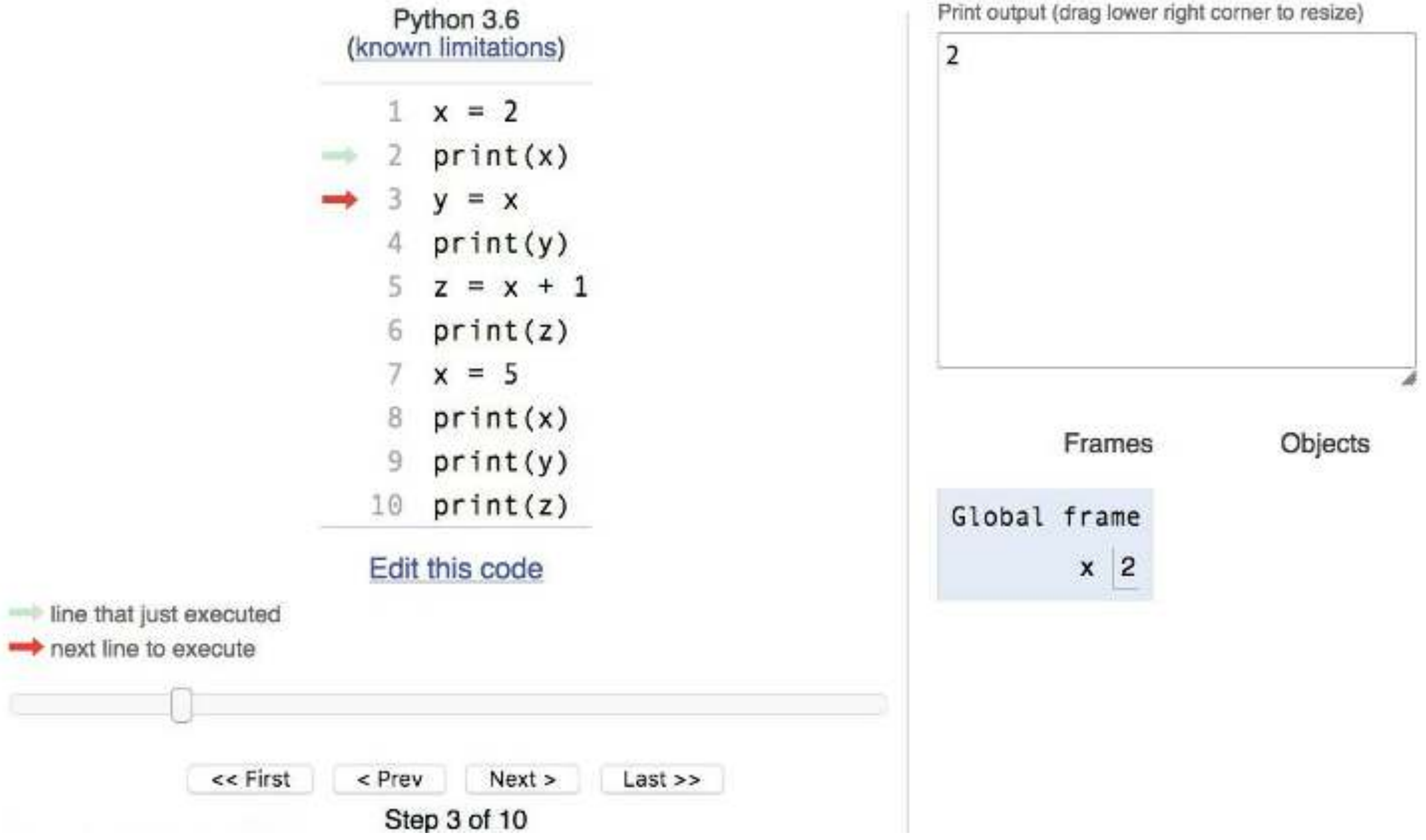


```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

```
2
```

Global frame	
x	2

How an Assignment is Executed

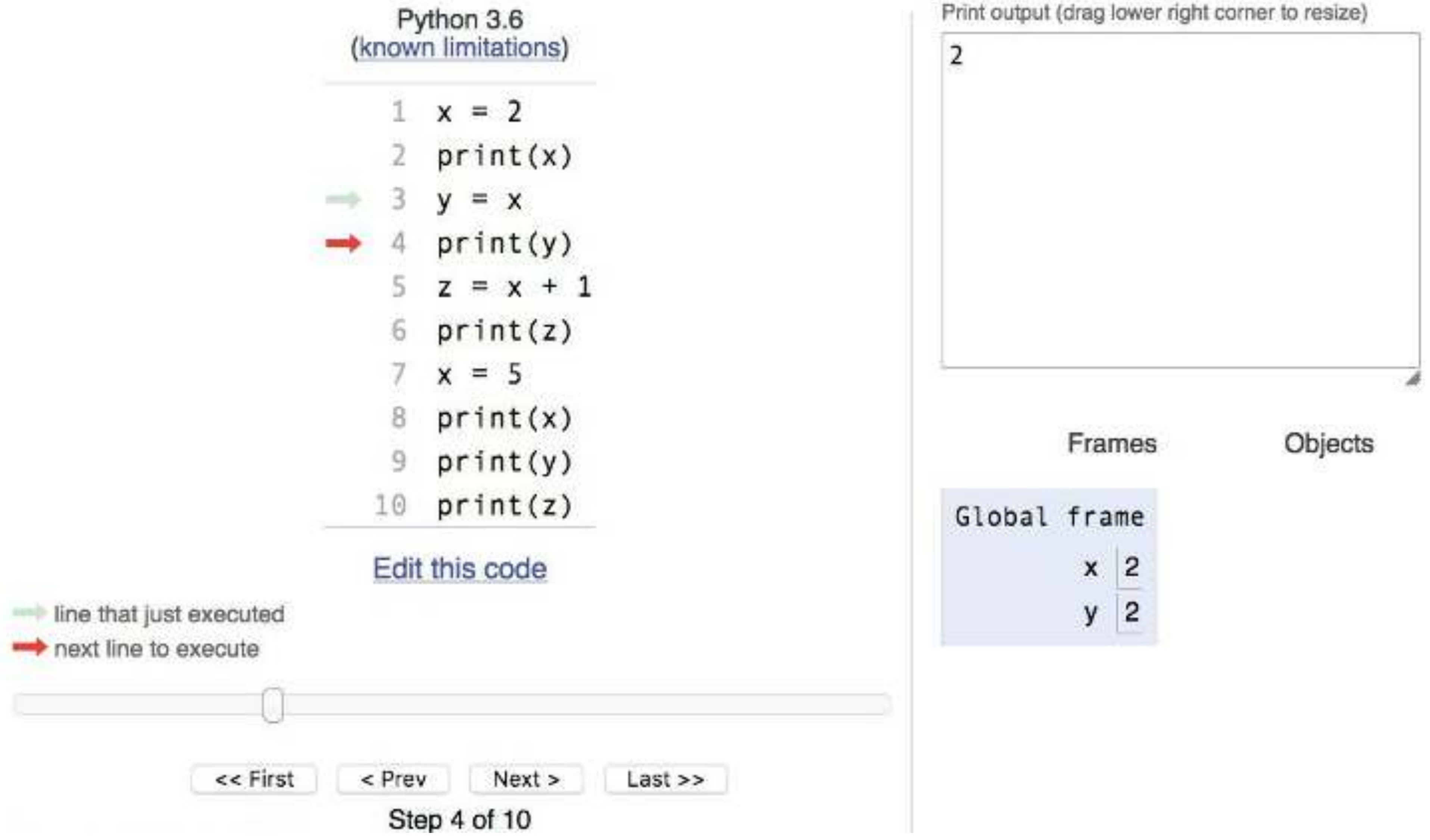


```python
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

```
2
```

Global frame	
x	2

How an Assignment is Executed



Python 3.6
(known limitations)

```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

Edit this code

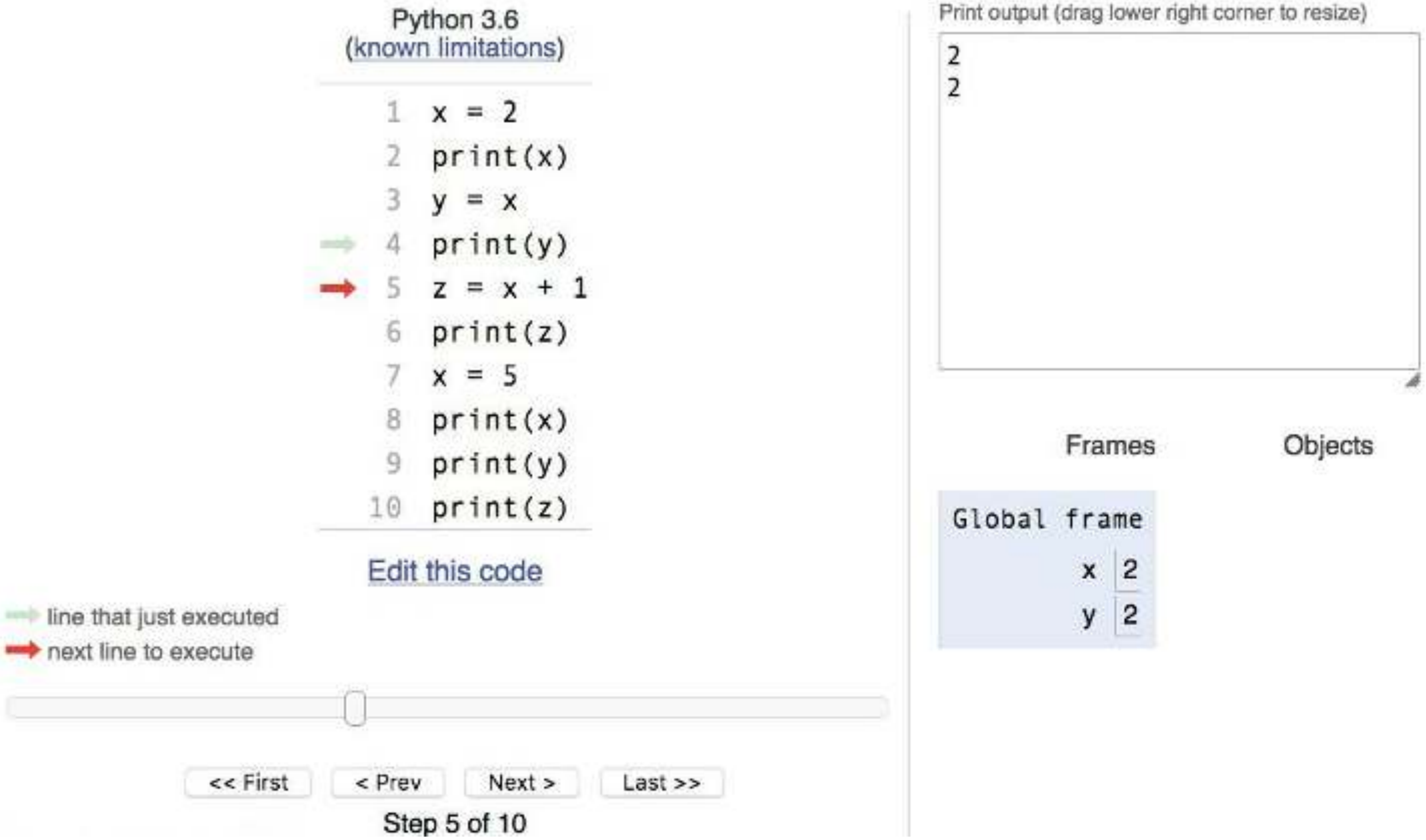
Step 4 of 10

Print output (drag lower right corner to resize)

```
2
```

```
Global frame
      x  2
      y  2
```

How an Assignment is Executed



Python 3.6
(known limitations)

```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

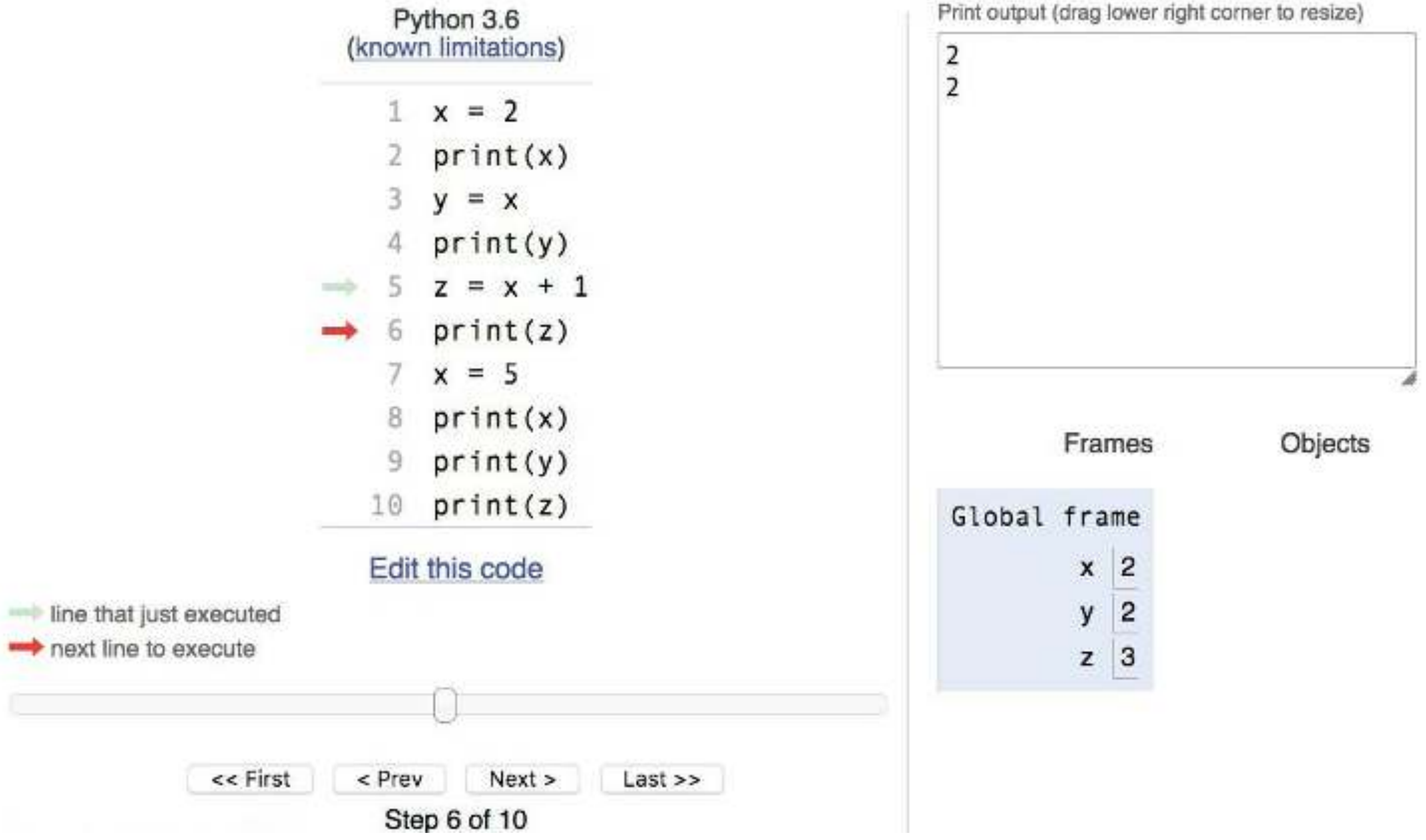
Step 5 of 10

Print output (drag lower right corner to resize)

```
2
2
```

```
Global frame
       x  2
       y  2
```

How an Assignment is Executed



Python 3.6
(known limitations)

```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

Edit this code

➡ line that just executed
➡ next line to execute

<< First   < Prev   Next >   Last >>

Step 6 of 10

Print output (drag lower right corner to resize)

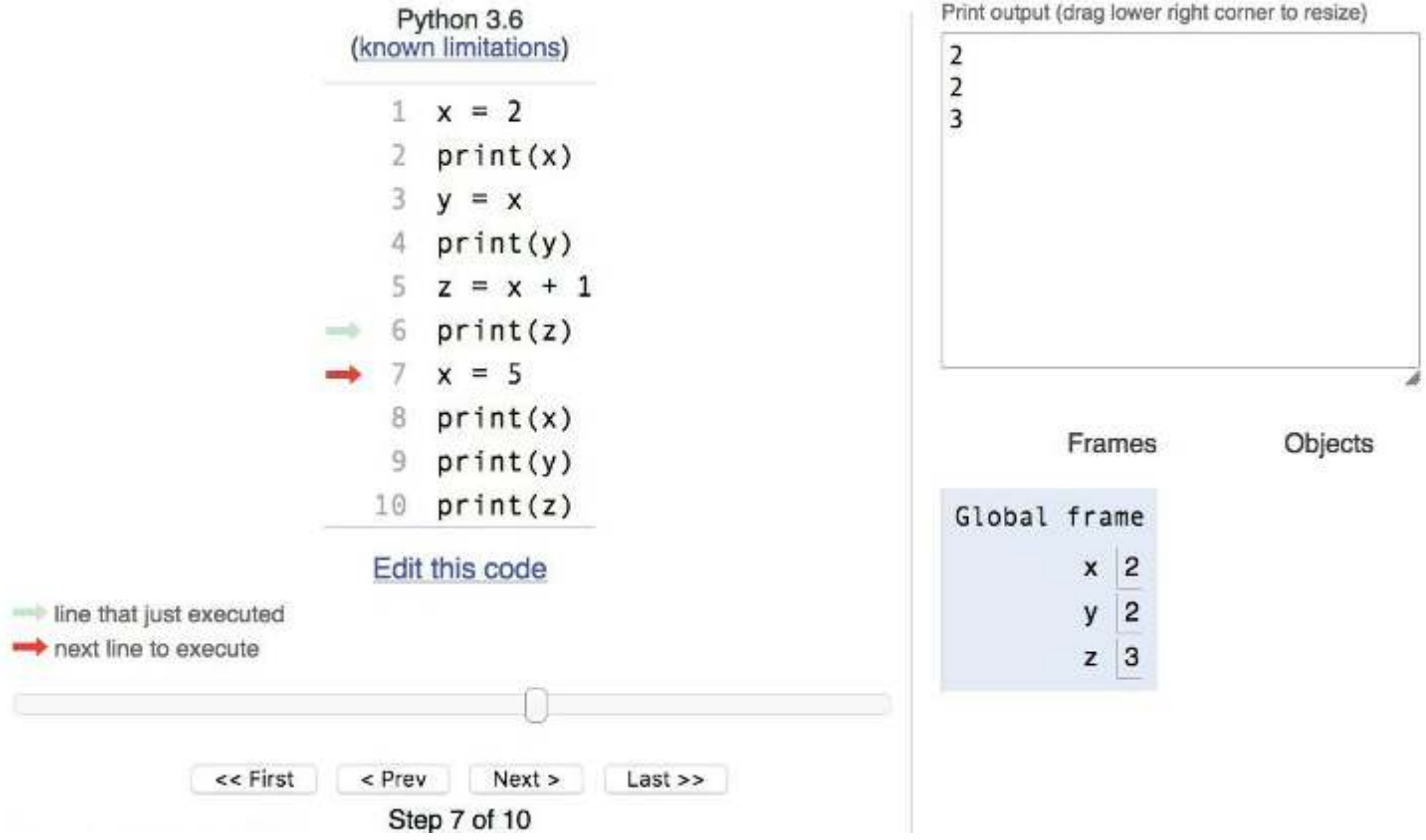
```
2
2
```

Frames   Objects

Global frame

x	2
y	2
z	3

How an Assignment is Executed



Python 3.6
(known limitations)

```python
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

Edit this code

line that just executed
next line to execute

<< First   < Prev   Next >   Last >>

Step 7 of 10

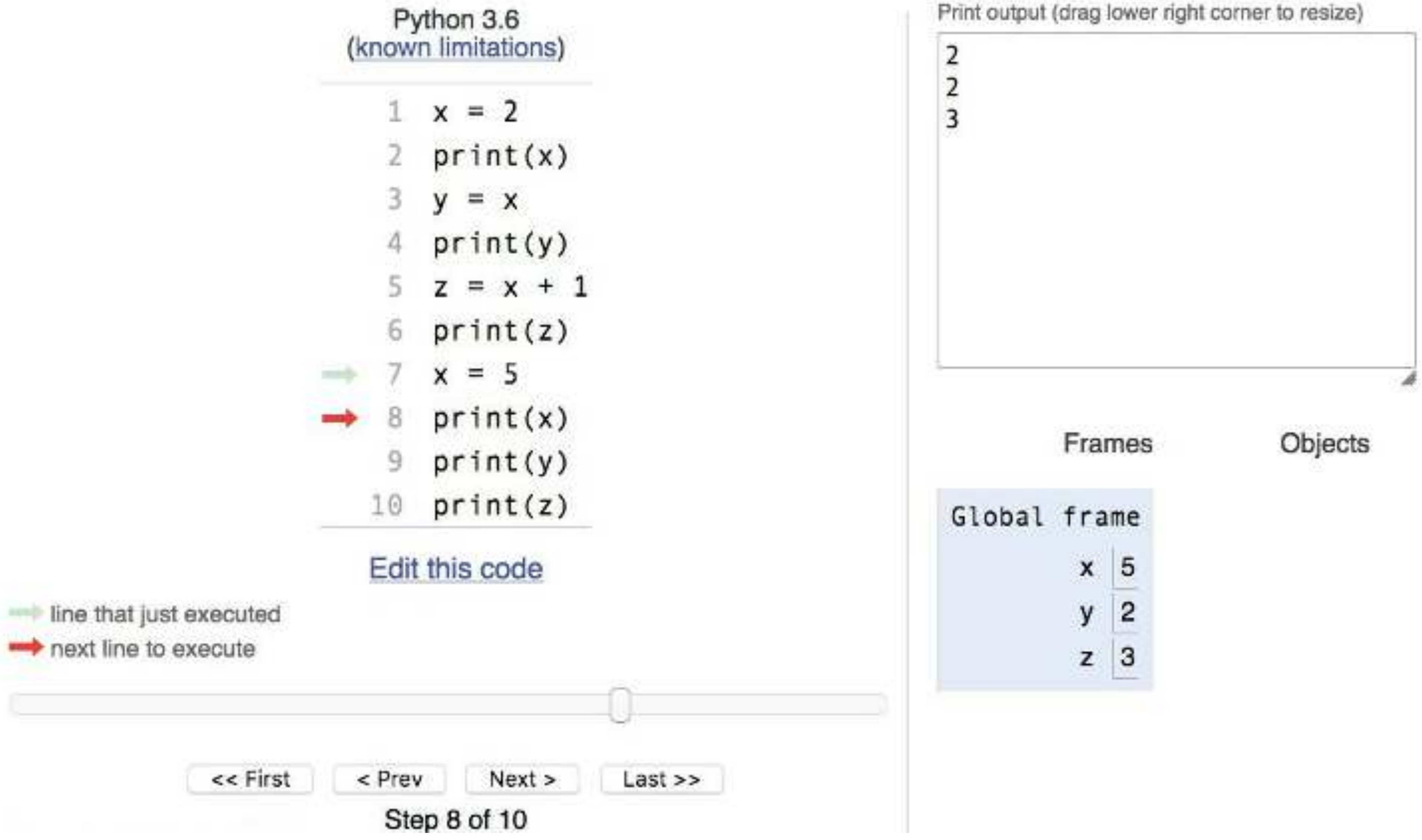
Print output (drag lower right corner to resize)

```
2
2
3
```

Frames   Objects

```
Global frame
          x | 2
          y | 2
          z | 3
```

How an Assignment is Executed



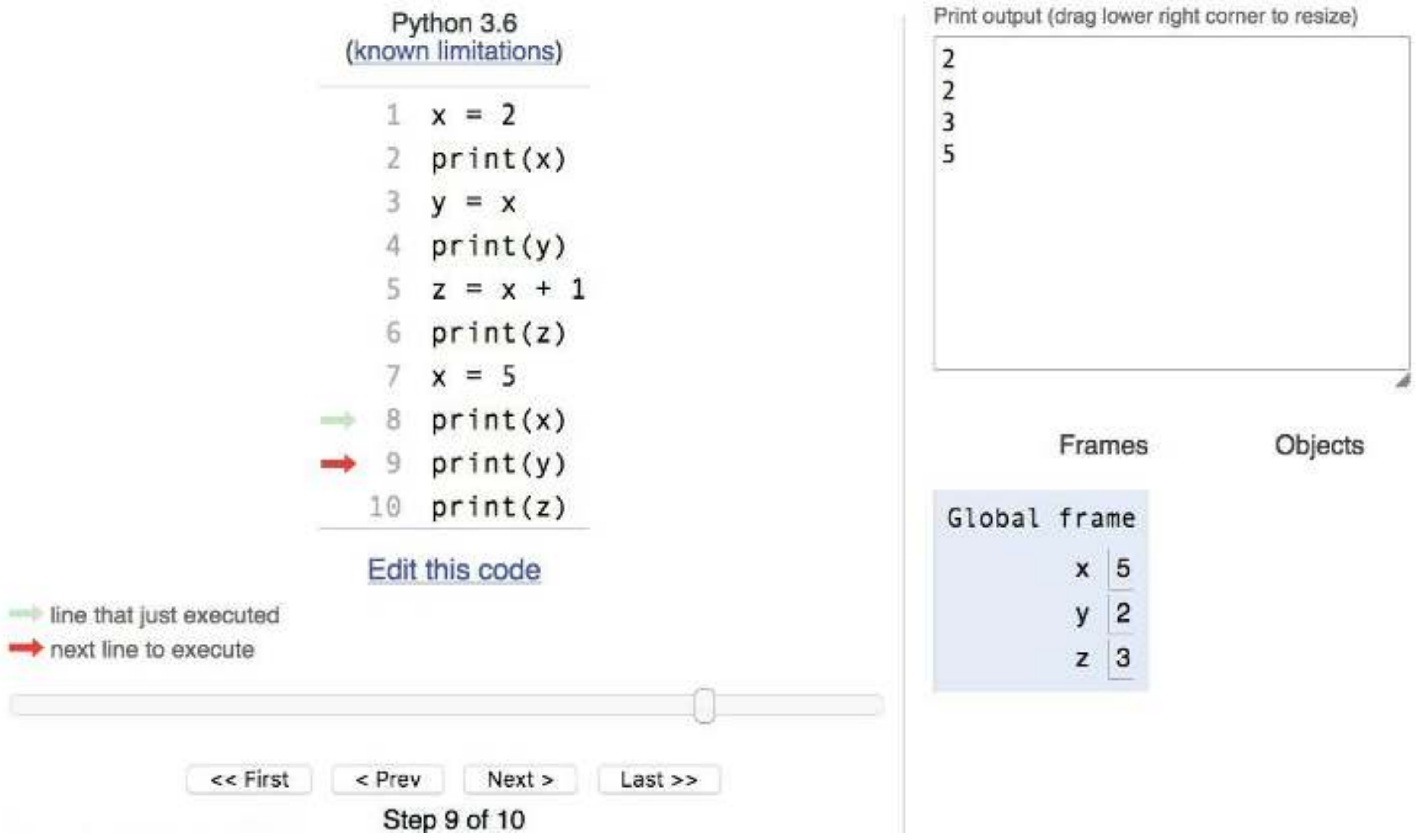
```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

Print output:

```
2
2
3
```

```
Global frame
     x | 5
     y | 2
     z | 3
```

How an Assignment is Executed

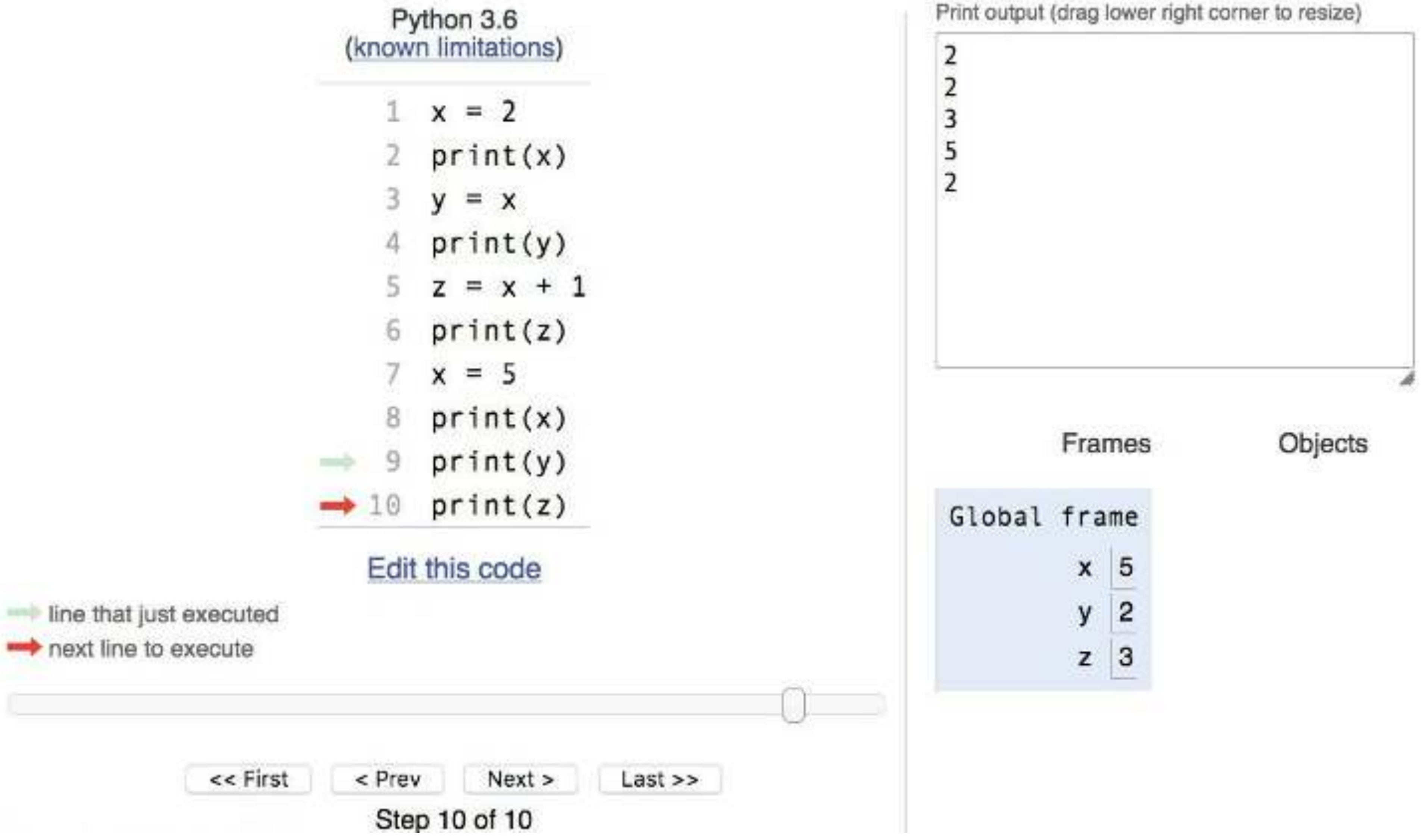


```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

```
2
2
3
5
```

```
Global frame
     x  5
     y  2
     z  3
```

How an Assignment is Executed

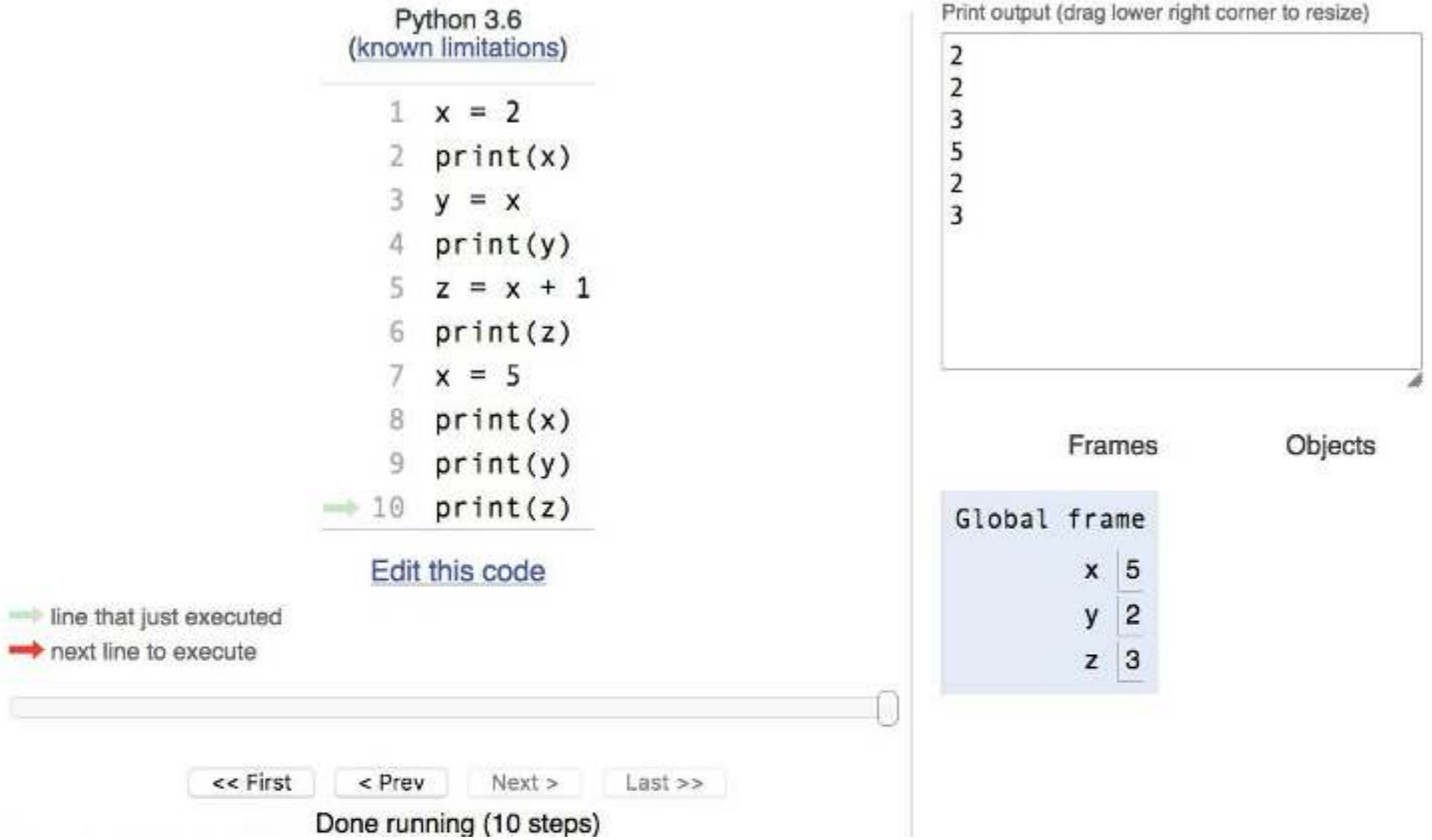


```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

```
2
2
3
5
2
```

```
Global frame
  x  5
  y  2
  z  3
```

How an Assignment is Executed



Python 3.6
(known limitations)

```
x = 2
print(x)
y = x
print(y)
z = x + 1
print(z)
x = 5
print(x)
print(y)
print(z)
```

Edit this code

line that just executed
next line to execute

<< First < Prev Next > Last >>

Done running (10 steps)

Print output (drag lower right corner to resize)

```
2
2
3
5
2
3
```

More Expressions: Conditionals (value is `True` or `False`)

```
22 > 4      # condition, or conditional
22 < 4      # condition, or conditional
22 == 4    …
x = 100    # Assignment, not conditional!
22 = 4     # Error!
x >= 5
x >= 100
x >= 200
not True
not (x >= 200)
3<4 and 5<6
4<3 or 5<6
temp = 72
water_is_liquid = (temp > 32 and temp < 212)
```

Numeric operators: **+**, *****, ******
Boolean operators: **not**, **and**, **or**
Mixed operators: **<**, **>=**, **==**

More Expressions: strings

- A string represents **text**
  - `'Python'`
  - `myString = "BBM 101-Introduction to Programming"`
  - `""`

- Empty string is not the same as an unbound variable
  - `""` and '' are the same

- We can specify tab, newline, backslash, and single quote characters using escape sequences `'\t'`, `'\n'`, `'\\'`, and `'\''`, respectively

Operations:

- **Length:**
  - `len(myString)`

- **Concatenation:**
  - `"Hacettepe" + " " + ' University'`

- **Containment/searching:**
  - `'a' in myString`
  - `"a" in myString`

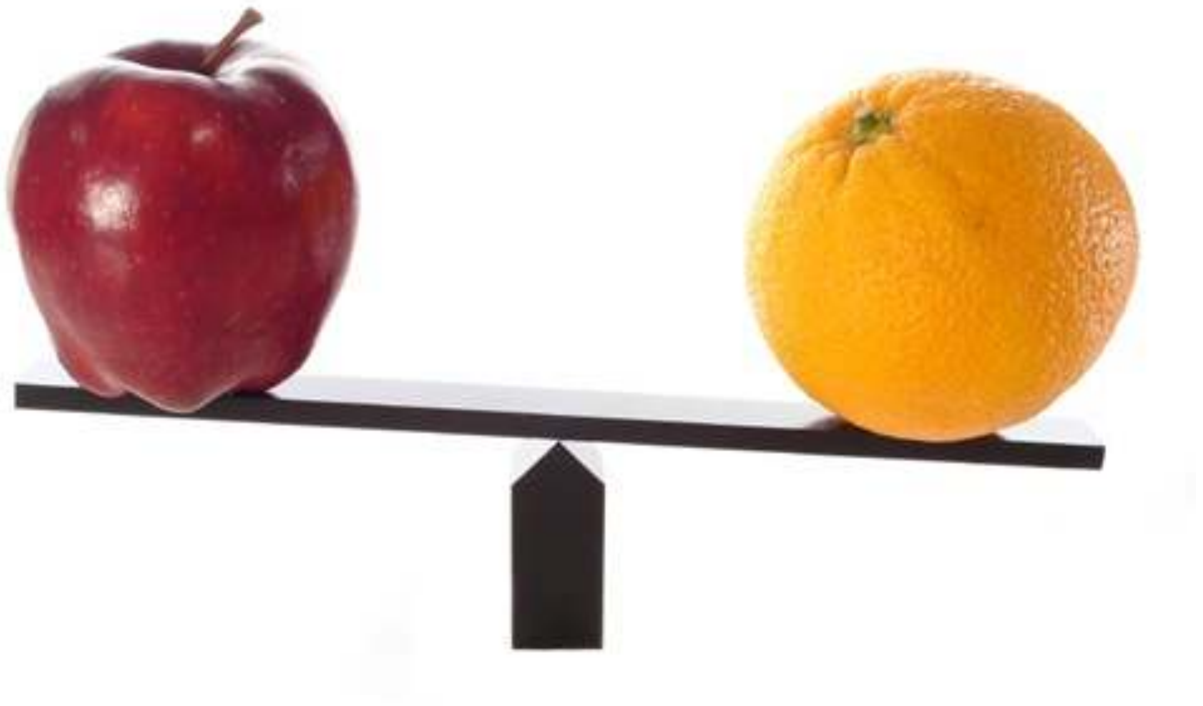
Strings

```
ruler1 = '1'
ruler2 = ruler1 + ' 2 ' + ruler1
ruler3 = ruler2 + ' 3 ' + ruler2
ruler4 = ruler3 + ' 4 ' + ruler3
print(ruler1)
print(ruler2)
print(ruler3)
print(ruler4)
```

```
1
1 2 1
1 2 1 3 1 2 1
1 2 1 3 1 2 1 4 1 2 1 3 1 2 1
```

3. Different Types should not be Compared

```
anInt = 2
aString = "Hacettepe"
anInt == aString                    # Error
```



Types of Values

- Integers (**`int`**): **`-22`**, **`0`**, **`44`**
  - Arithmetic is exact
  - Some funny representations: **`12345678901L`**
- Real numbers (**`float`**, for “floating point”): **`2.718`**, **`3.1415`**
  - Arithmetic is approximate, e.g., **`6.022*10**23`**
- Strings (**`str`**): **`"I love Python"`**, **`" "`**
- Truth values (**`bool`**, for “Boolean”): **`True`**, **`False`**

George Boole

Operations Behave differently on Different Types

```
3.0 + 4.0
3 + 4
3 + 4.0
"3" + "4"          # Concatenation
3 + "4"            # Error
3 + True           # Error
```

Moral: Python only *sometimes* tells you when you do something that does not make sense.

Operations on Different Types

	Python 3.5	Python 2.x
`15.0 / 4.0`	`3.75`	`3.75`
`15 / 4`	`3.75`	`3`
`15.0 / 4`	`3.75`	`3.75`
`15 / 4.0`	`3.75`	`3.75`
`15.0 // 4.0`	`3.0`	
`15 // 4`	`3`	
`15.0 // 4`	`3.0`	
`15 // 4.0`	`3.0`	

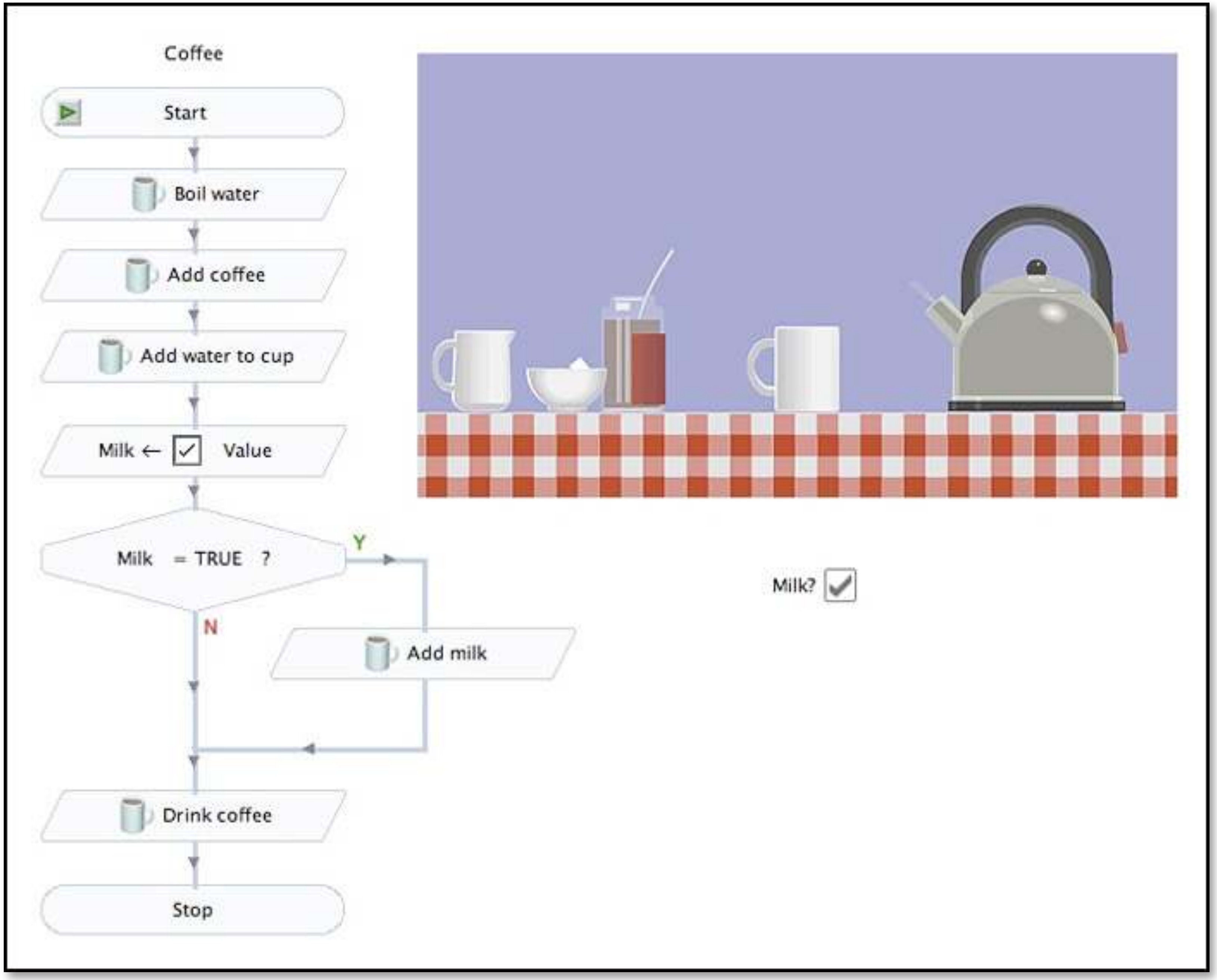
Before Python version 3.5, operand used to determine the type of division.

/ : Division
//: Integer Division

Type Conversion

```
float(15)         15.0
int(15.0)         15
int(15.5)         15
int("15")         15
str(15.5)         15.5
float(15) / 4     3.75
```

A Program is a Recipe



Design the Algorithm Before Coding

- We should think (design the algorithm) before coding
- Algorithmic thinking is the logic. Also, called problem solving
- Coding is the syntax
- Make this a habit
- Some students do not follow this practice and they get challenged in all their courses and careers!

What is a Program?

- A program is a sequence of instructions
- The computer executes one after the other, as if they had been typed to the interpreter
- Saving your work as a program is better than re-typing from scratch

```
x = 1
y = 2
x + y
print(x + y)
print("The sum of", x, "and", y, "is", x+y)
```

The `print()` Statement

- The **`print`** statement always prints one line
  - The next print statement prints below that one
- Write 0 or more expressions after **`print`**, separated by commas
  - In the output, the values are separated by spaces
- Examples:

```
x = 1
y = 2
print(3.1415)
print(2.718, 1.618)
print()
print(20 + 2, 7 * 3, 4 * 5)
print("The sum of", x, end="")
print(" and", y, "is", x+y)
```

```
3.1415
2.718 1.618

22 21 20
The sum of 1 and 2 is 3
```

To avoid newline

Exercise: Convert Temperatures

- Make a temperature conversion chart as the following
- Fahrenheit to Centigrade, for Fahrenheit values of: -40, 0, 32, 68, 98.6, 212
- C = (F - 32) × 5/9
- Output:

```
Fahrenheit Centigrade
-40 -40.0
0 -17.7778
32 0.0
68 20.0
98.6 37.0
212 100.0
```

- You have created a Python program!
- (It doesn’t have to be this tedious, and it won’t be.)

Expressions, Statements, and Programs

- An expression evaluates to a value

```
3 + 4
pi * r**2
```

- A statement causes an effect

```
pi = 3.14159
print(pi)
```

- Expressions appear within other expressions and within statements

```
(fahr – 32) * (5.0 / 9)
print(pi * r**2)
```

- A statement may *not* appear within an expression

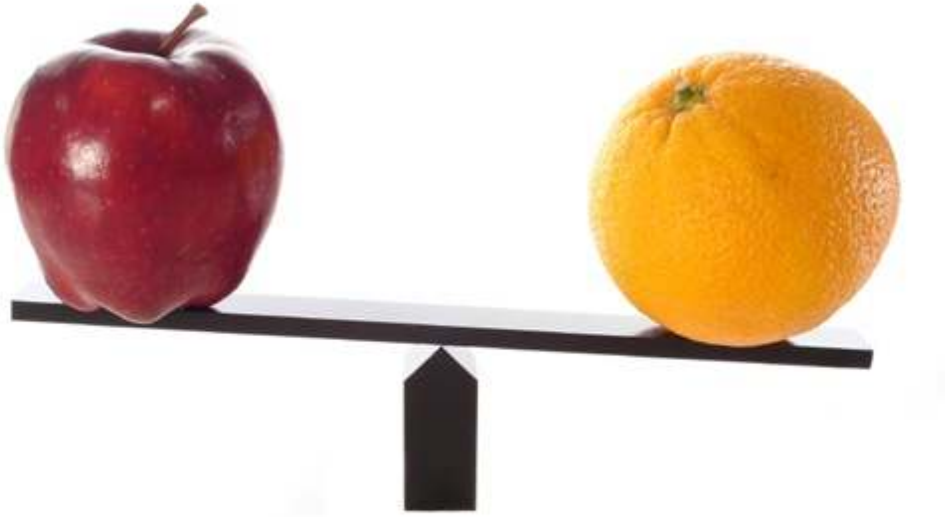
```
3 + print(pi)     # Error!
```

- A program is made up of statements
  - A program should do something or communicate information

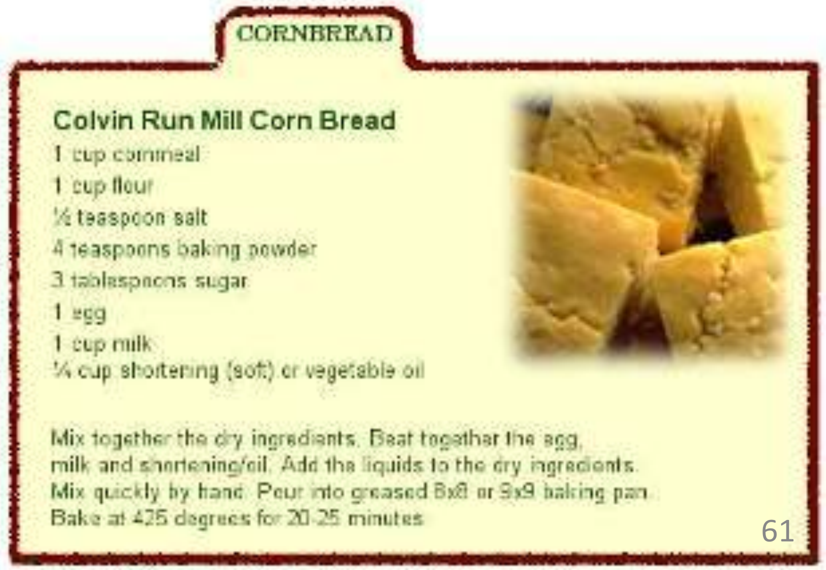
1. Python is like a calculator

2. A variable is a container

3. Different types cannot be compared



4. A program is a recipe


CORNBREAD

Colvin Run Mill Corn Bread

1 cup cornmeal
1 cup flour
½ teaspoon salt
4 teaspoons baking powder
3 tablespoons sugar
1 egg
1 cup milk
¼ cup shortening (soft) or vegetable oil

Mix together the dry ingredients. Beat together the egg, milk and shortening/oil. Add the liquids to the dry ingredients. Mix quickly by hand. Pour into greased 8x8 or 9x9 baking pan. Bake at 425 degrees for 20-25 minutes.

Programming Languages

- A programming language is a “language” to write programs in, such as Python, C, C++, Java

- The concept of programming languages are quite similar

- Python:

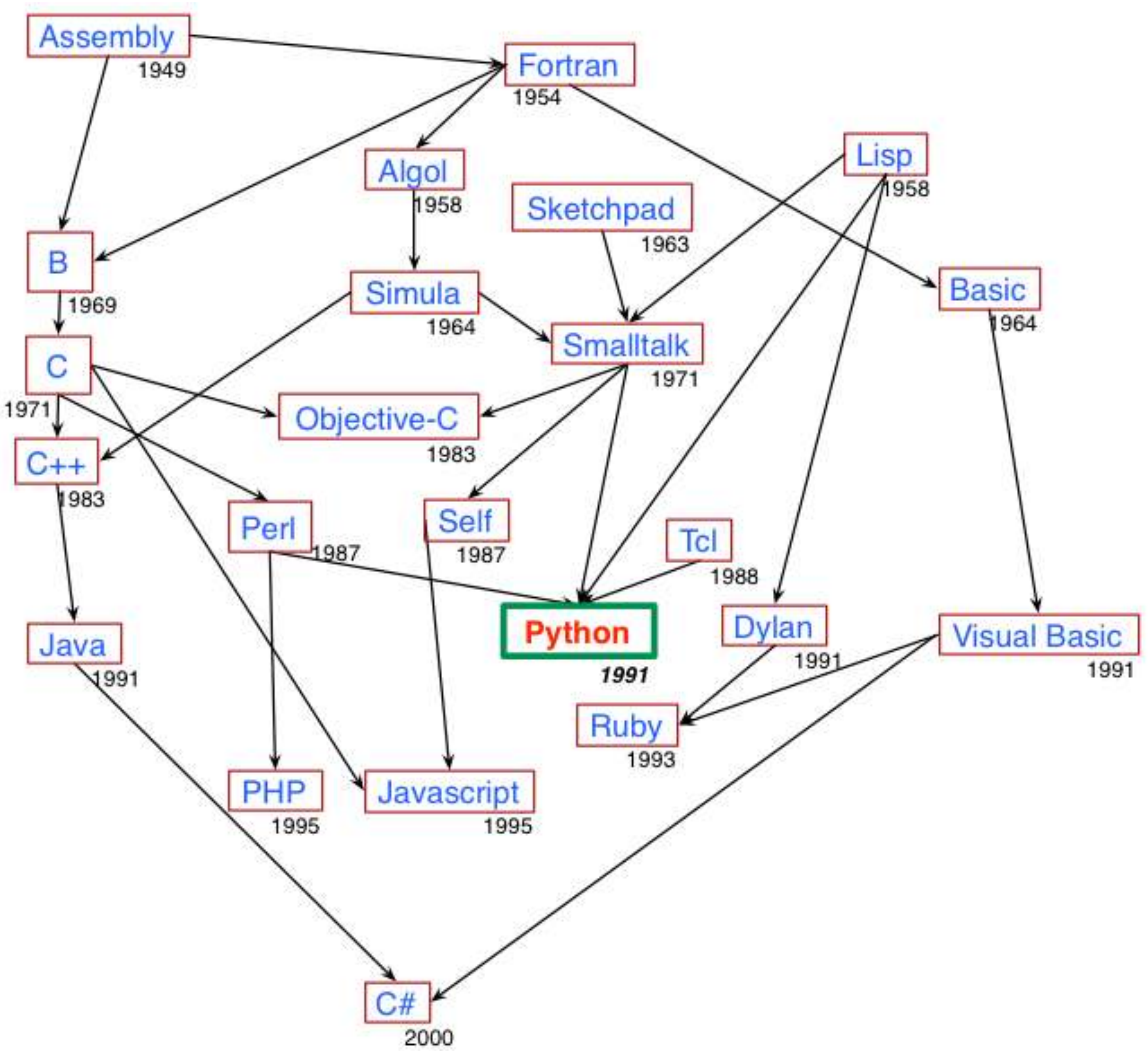
```
print("Hello, World!")
```

- Java:

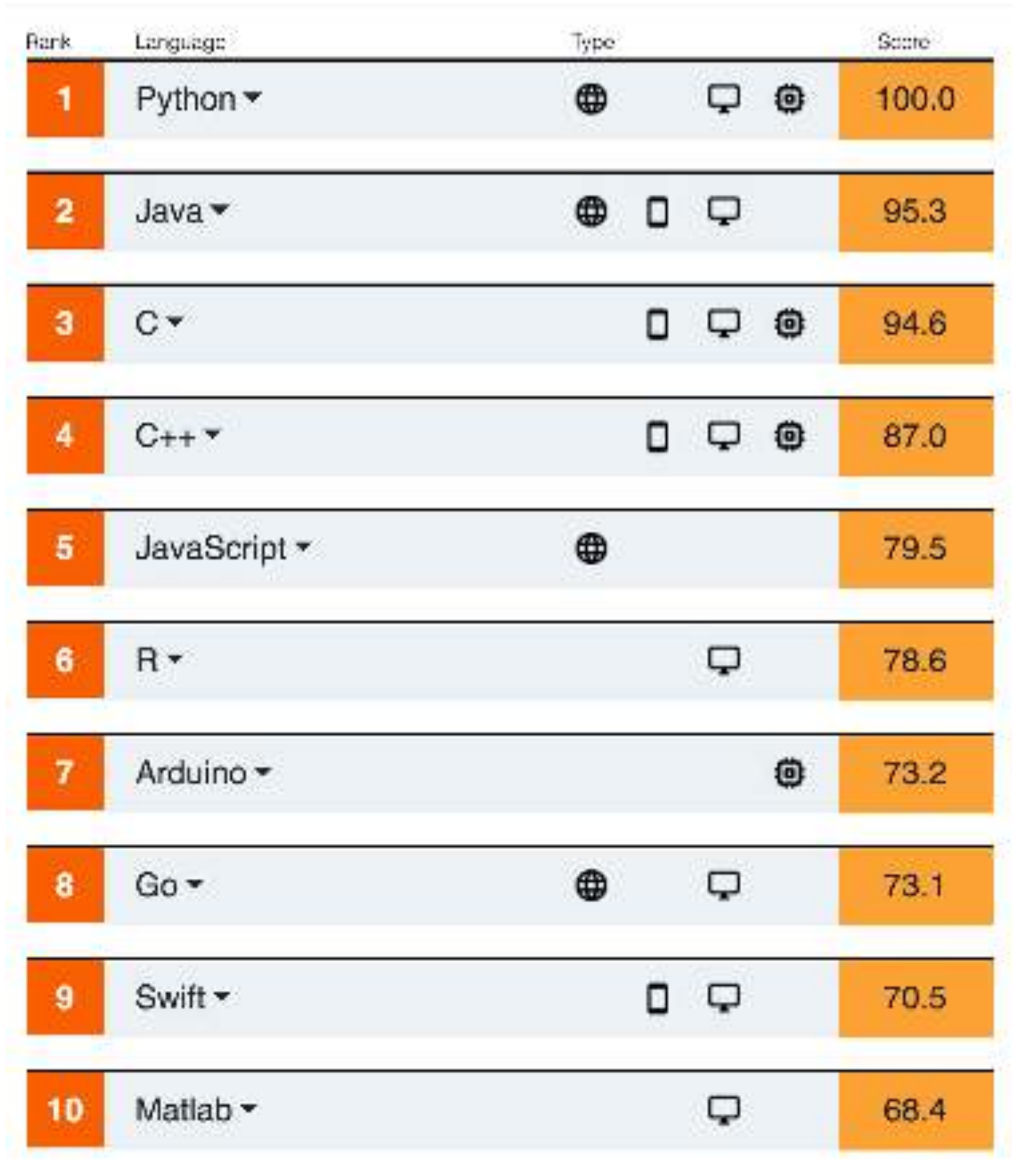
```
public static void main(String[] args) {
    System.out.println("Hello, World!");
}
```

- Python is simpler! That’s why we are learning it first ☺

Evolution of Programming Languages

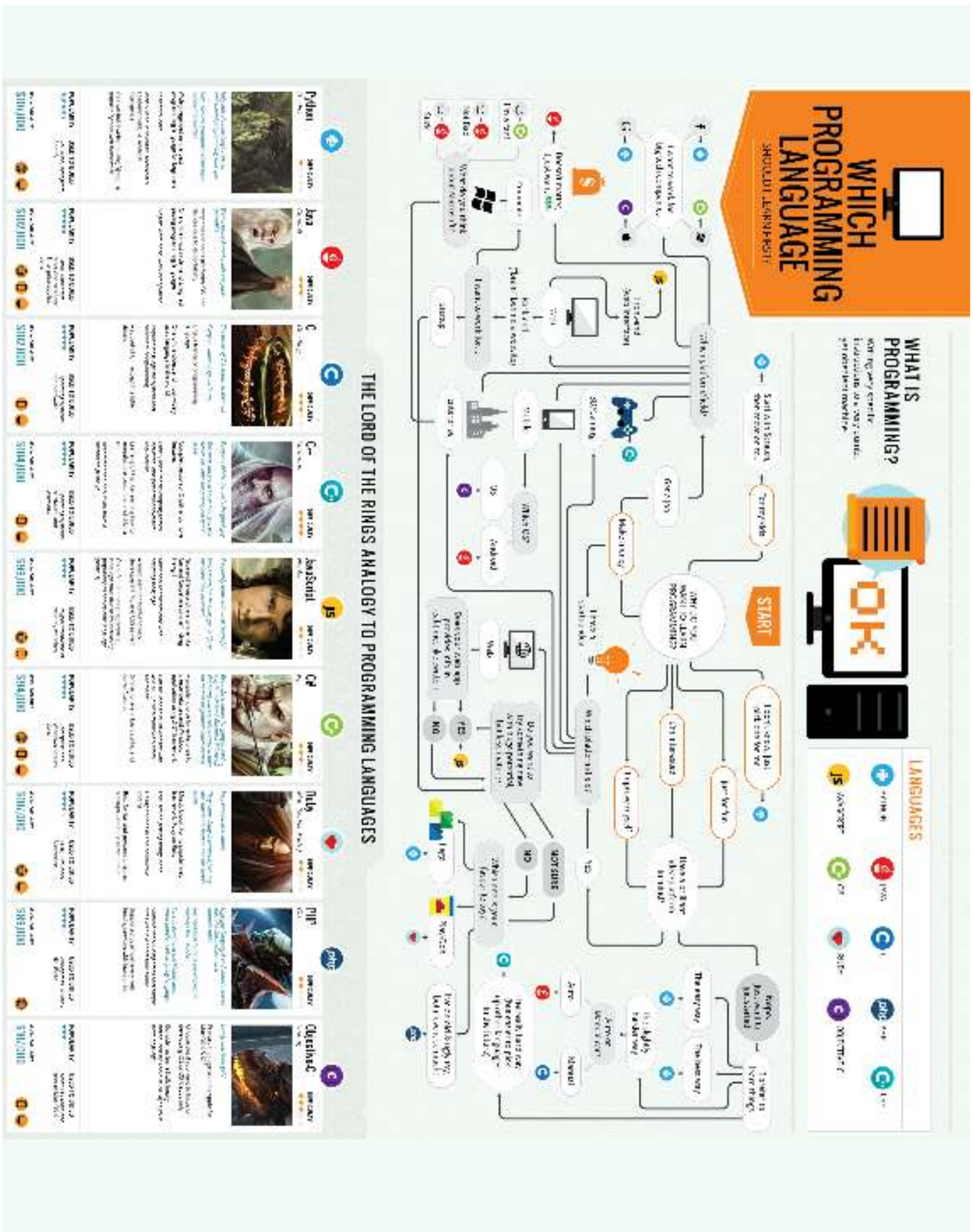


The 2020 Top Programming Languages



Rank	Language	Type	Score
1	Python ▾	🌐 🖥 ⚙	100.0
2	Java ▾	🌐 📱 🖥	95.3
3	C ▾	📱 🖥 ⚙	94.6
4	C++ ▾	📱 🖥 ⚙	87.0
5	JavaScript ▾	🌐	79.5
6	R ▾	🖥	78.6
7	Arduino ▾	⚙	73.2
8	Go ▾	🌐 🖥	73.1
9	Swift ▾	📱 🖥	70.5
10	Matlab ▾	🖥	68.4

https://spectrum.ieee.org/at-work/tech-careers/the-top-programming-language-2020


WHICH PROGRAMMING LANGUAGE SHOULD I LEARN FIRST?
WHAT IS PROGRAMMING?
LANGUAGES
START
THE LORD OF THE RINGS ANALOGY TO PROGRAMMING LANGUAGES
Python
Java
C
C++
JavaScript
C#
Ruby
PHP
Objective-C

http://carlcheo.com/startcoding