6.100L Introduction to Computer Science and Programming Using Python
Fall 2022

SUMMARY

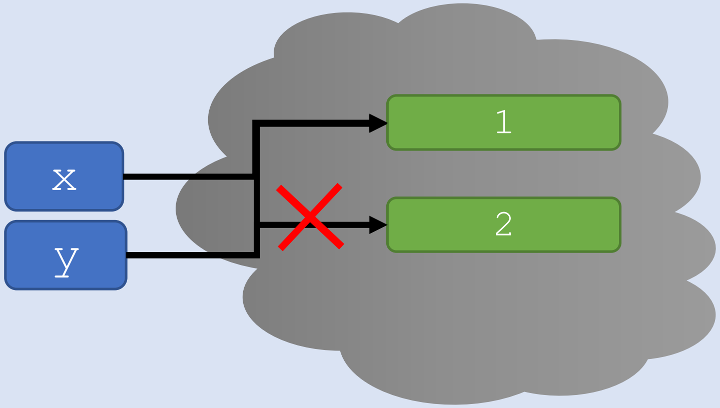
- Objects
  - Objects in memory have **types**.
  - Types tell Python what **operations** you can do with the objects.
  - **Expressions evaluate to one value** and involve objects and operations.
  - Variables bind names to objects.
  - = sign is an assignment, for ex. `var = type(5*4)`
- Programs
  - Programs only **do what you tell them to do**.
  - Lines of code are executed **in order**.
  - Good variable names and comments help you **read code later**.

YOU TRY IT!

- Swap values of x and y without binding the numbers directly. Debug (aka fix) this code.

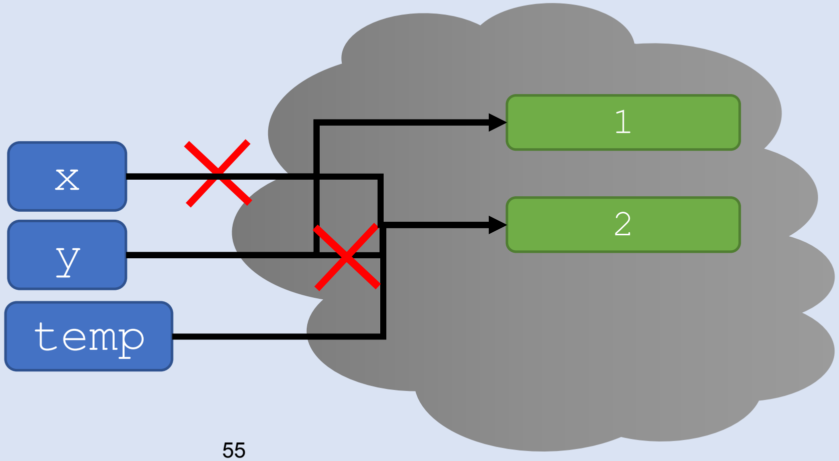
```
x = 1
y = 2

y = x
x = y
```



- Python Tutor to the rescue?

ANSWER:



YOU TRY IT!

- These 3 lines are executed in order. What are the values of `meters` and `feet` variables at each line in the code?

```
meters = 100
feet = 3.2808 * meters
meters = 200
```

ANSWER:

Let’s use PythonTutor to figure out what is going on

- Follow along with this Python Tutor LINK

Where did we tell Python to (re)calculate feet?

BIG IDEA

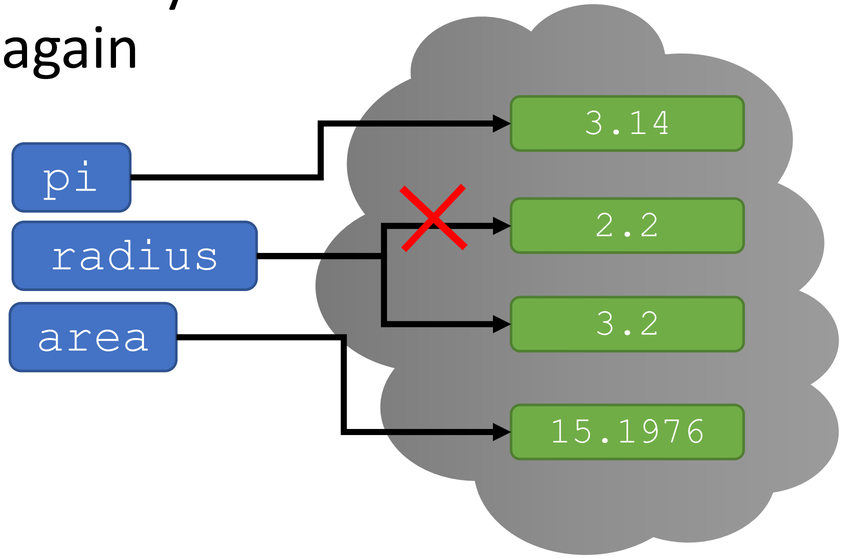
Lines are evaluated one after the other

No skipping around, yet.
We’ll see how lines can be skipped/repeated later.

CHANGE BINDINGS

- Can **re-bind** variable names using new assignment statements
- Previous value may still stored in memory but lost the handle for it
- Value for **area does not change** until you tell the computer to do the calculation again

```
pi = 3.14
radius = 2.2
area = pi*(radius**2)
radius = radius+1
```



WHAT IS BEST CODE STYLE?

```
#do calculations
a = 355/113 *(2.2**2)
c = 355/113 *(2.2*2)
```

meh

```
p = 355/113
r = 2.2
#multiply p with r squared
a = p*(r**2)
#multiply p with r times 2
c = p*(r*2)
```

ok

```
#calculate area and circumference of a circle
#using an approximation for pi
pi = 355/113
radius = 2.2
area = pi*(radius**2)
circumference = pi*(radius*2)
```

best

ABSTRACTING EXPRESSIONS

- Why **give names** to values of expressions?
  - To **reuse names** instead of values
  - Makes code easier to read and modify
- Choose variable names wisely
  - Code needs to read
  - Today, tomorrow, next year
  - By you and others
  - You'll be fine if you stick to letters, underscores, don't start with a number

```
#Compute approximate value for pi
pi = 355/113
radius = 2.2
area = pi*(radius**2)
circumference = pi*(radius*2)
```

comments start with a # and are not part of code executed – used to tell others what your code is doing

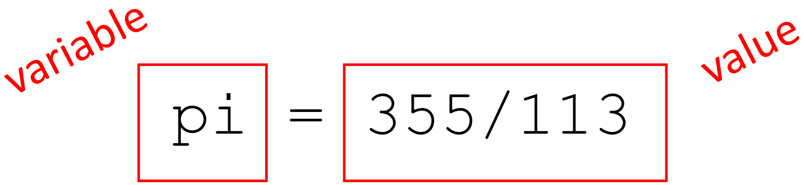
an assignment
* expression on right
* variable name on left

YOU TRY IT!

- Which of these are allowed in Python? Type them in the console to check.
  - `x = 6`
  - `6 = x`
  - `x*y = 3+4`
  - `xy = 3+4`

BINDING VARIABLES to VALUES

- In CS, the equal sign is an **assignment**
  - One value to one variable name
  - Equal sign is **not equality**, not “solve for x”
- An assignment binds a value to a name



variable

`pi = 355/113`

value

- **Step 1:** Compute the value on the **right hand side** (the VALUE)
  - Value stored in computer memory
- **Step 2:** Store it (bind it) to the **left hand side** (the VARIABLE)
  - Retrieve value associated with name by invoking the name (typing it out)

VARIABLES

- Computer science variables are **different** than math variables
- **Math variables**
  - Abstract
  - Can **represent many values**

```
a + 2 = b - 1
```

```
x * x = y
```

x represents all square roots

- **CS variables**
  - Is bound to **one single value** at a given time
  - Can be bound to an expression
    (but expressions evaluate to one value!)

```
a = b + 1
```

```
m = 10
F = m*9.98
```

one variable

one value

SO MANY OBJECTS, what to do with them?!

temp = 100.4

a = 2

go = True

b = -0.3

flag = False

x = 123

n = 17

small = 0.001

SIMPLE OPERATIONS

- Parentheses tell Python to do these operations first
  - Like math!
- **Operator precedence** without parentheses

`**`	
`* / %`	executed left to right, as appear in expression
`+ -`	executed left to right, as appear in expression

OPERATORS on `int` and `float`

- `i+j` → the **sum**
- `i-j` → the **difference**
- `i*j` → the **product**
- `i/j` → **division**

if both are ints, result is int

if either or both are floats, result is float

result is always a float

- `i//j` → **floor division**
- `i%j` → the **remainder** when `i` is divided by `j`

What is type of output?

- `i**j` → `i` to the **power** of `j`

YOU TRY IT!

- In your console, find the values of the following expressions:
    - `(13-4) / (12*12)`
    - `type(4*3)`
    - `type(4.0*3)`
    - `int(1/2)`

EXAMPLES

- `>>>  3+2`
- `5`
- `>>> (4+2)*6-1`
- `35`
- `>>> type((4+2)*6-1)`
- `int`
- `>>> float((4+2)*6-1)`
- `35.0`

Do computations left to right – like in math!

Do computations inside parens first, left to right

Take care about what operations you are doing

BIG IDEA

Replace complex expressions by ONE value

Work systematically to evaluate the expression.

EXPRESSIONS

- **Combine objects and operators** to form expressions
  - 3+2
  - 5/3
- An expression has a **value**, which has a type
  - 3+2 has value 5 and type int
  - 5/3 has value 1.666667 and type float
- Python evaluates expressions and stores the value. It doesn’t store expressions!

- Syntax for a simple expression

  `<object> <operator> <object>`

YOU TRY IT!

- In your console, find the type of:
  - `float(123)`
  - `round(7.9)`
  - `float(round(7.2))`
  - `int(7.2)`
  - `int(7.9)`

TYPE CONVERSIONS (CASTING)

- Can **convert object of one type to another**
  - `float(3)` casts the int `3` to float `3.0`
  - `int(3.9)` casts (note the truncation!) the float `3.9` to int `3`
- Some operations perform implicit casts
  - `round(3.9)` returns the int `4`

YOU TRY IT!

- In your console, find the type of:
  - `1234`
  - `8.99`
  - `9.0`
  - `True`
  - `False`

int

0, 1, 2, …
300, 301 …
-1, -2, -3, …
-400, -401, …

float

0.0, …, 0.21, …
1.0, …, 3.14, …
-1.22, …, -500.0 , …

bool

True
False

NoneType

None

SCALAR OBJECTS

- `int` – represent **integers**, ex. `5, -100`
- `float` – represent **real numbers**, ex. `3.27, 2.0`
- `bool` – represent **Boolean** values `True` and `False`
- `NoneType` – **special** and has one value, `None`
- Can use `type()` to see the type of an object

```
>>> type(5)
int
>>> type(3.0)
float
```

what you write into the Python shell

what shows after hitting enter

OBJECTS

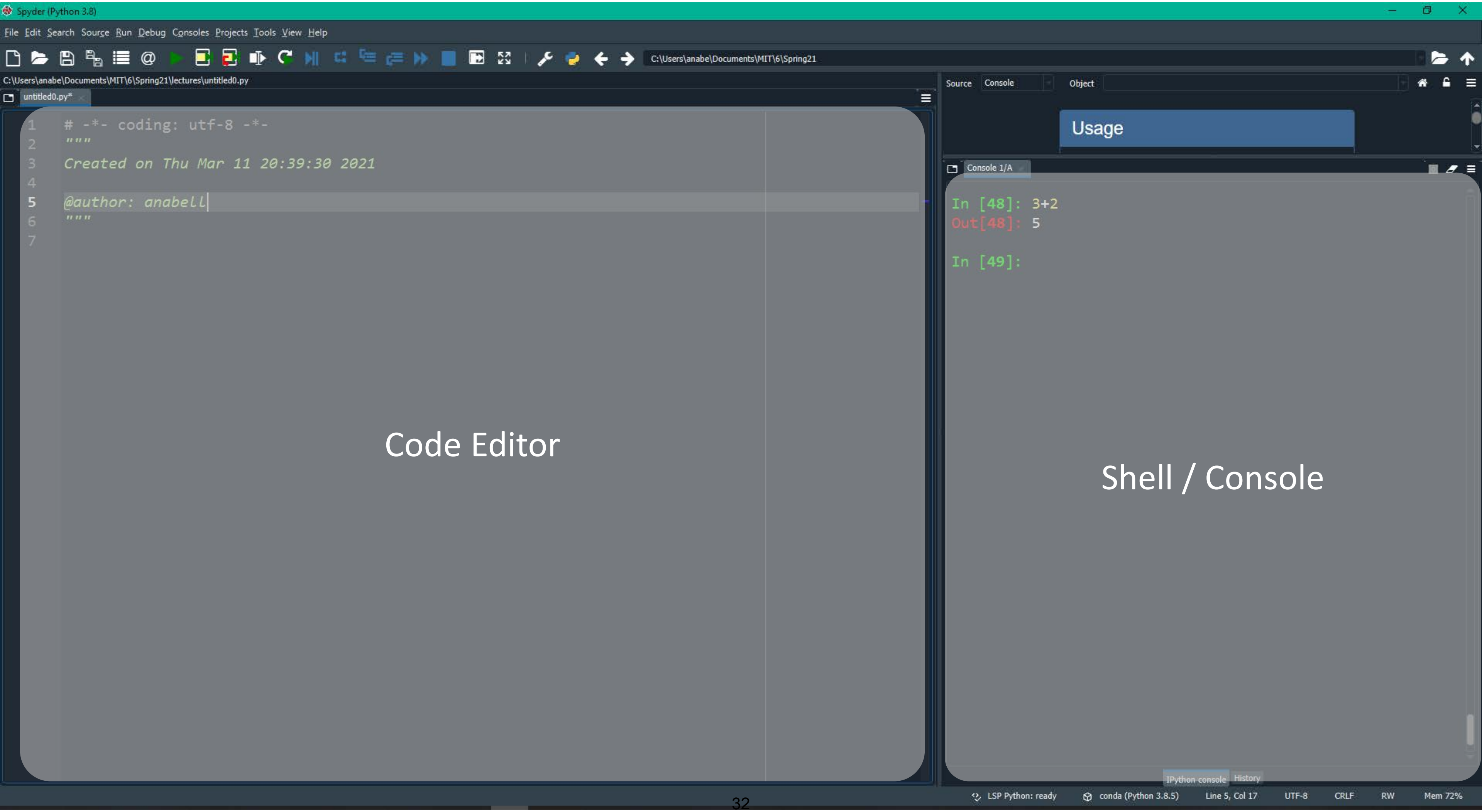
- **Scalar** (cannot be subdivided)
  - Numbers: 8.3, 2
  - Truth value: True, False

- **Non-scalar** (have internal structure that can be accessed)
  - Lists
  - Dictionaries
  - Sequence of characters: "abc"

OBJECTS

- Programs manipulate **data objects**
- Objects have a **type** that defines the kinds of things programs can do to them
    - `30`
        - Is a number
        - We can add/sub/mult/div/exp/etc
    - `'Ana'`
        - Is a sequence of characters (aka a string)
        - We can grab substrings, but we can't divide it by a number

PROGRAMMING ENVIRONMENT: ANACONDA



```
# -*- coding: utf-8 -*-
"""
Created on Thu Mar 11 20:39:30 2021

@author: anabell
"""

```

```
In [48]: 3+2
Out[48]: 5

In [49]:
```

PYTHON PROGRAMS

- A **program** is a sequence of definitions and commands
  - Definitions **evaluated**
  - Commands **executed** by Python interpreter in a shell
- **Commands** (statements) instruct interpreter to do something
- Can be typed directly in a **shell** or stored in a **file** that is read into the shell and evaluated
  - Problem Set 0 will introduce you to these in Anaconda

WHERE THINGS GO WRONG

- **Syntactic errors**
  - Common and easily caught
- **Static semantic errors**
  - Some languages check for these before running program
  - Can cause unpredictable behavior
- No linguistic errors, but **different meaning than what programmer intended**
  - Program crashes, stops running
  - Program runs forever
  - Program gives an answer, but it’s wrong!

ASPECTS of LANGUAGES

- **Semantics**: the meaning associated with a syntactically correct string of symbols with no static semantic errors
- English: can have many meanings "`The chicken is ready to eat.`"
- Programs have only one meaning
- **But the meaning may not be what programmer intended**

ASPECTS of LANGUAGES

- **Static semantics**: which syntactically valid strings have meaning
  - English: `"I are hungry"` → syntactically valid
    but static semantic error
  - PL: `"hi"+5` → syntactically valid
    but static semantic error

ASPECTS of LANGUAGES

- **Syntax**
  - English: "cat dog boy" → not syntactically valid

    "cat hugs boy" → syntactically valid
  - Programming language: "hi"5 → not syntactically valid

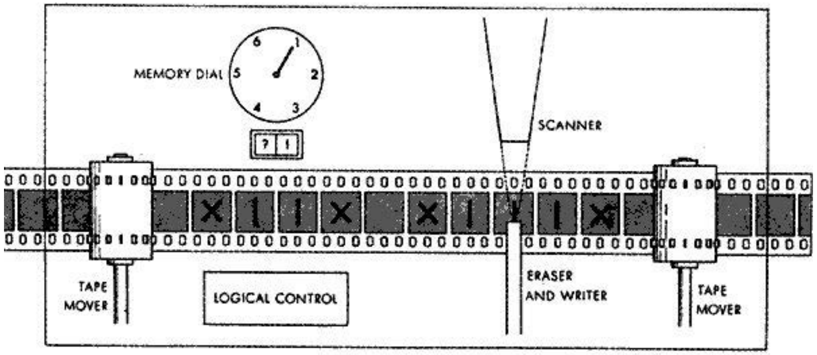
    "hi"*5 → syntactically valid

ASPECTS of LANGUAGES

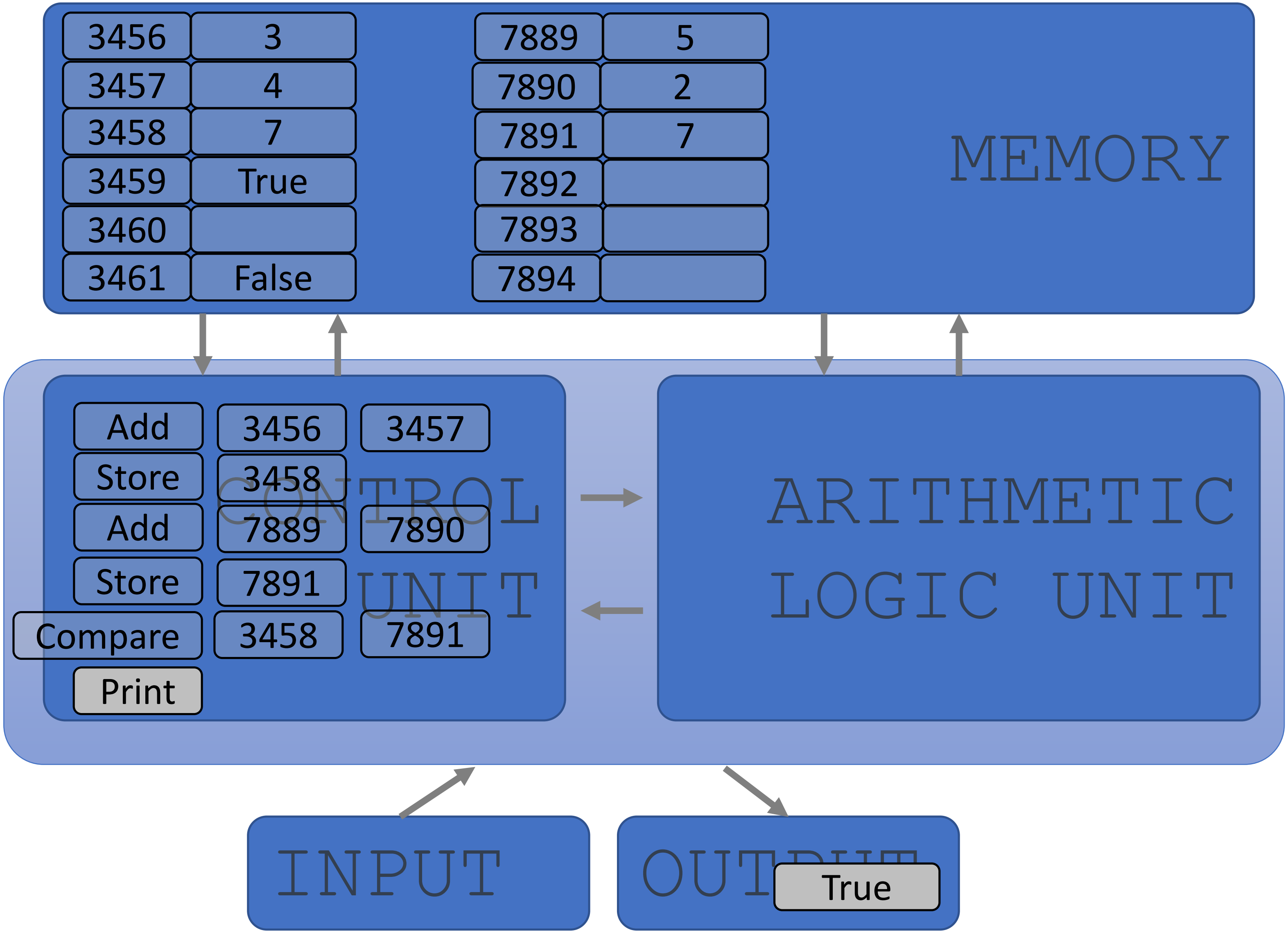
- **Primitive constructs**
  - English: words
  - Programming language: numbers, strings, simple operators

BASIC PRIMITIVES

- Turing showed that you can **compute anything** with a very simple machine with only 6 primitives: left, right, print, scan, erase, no op



- Real programming languages have
  - More convenient set of primitives
  - Ways to combine primitives to **create new primitives**
- Anything computable in one language is computable in any other programming language

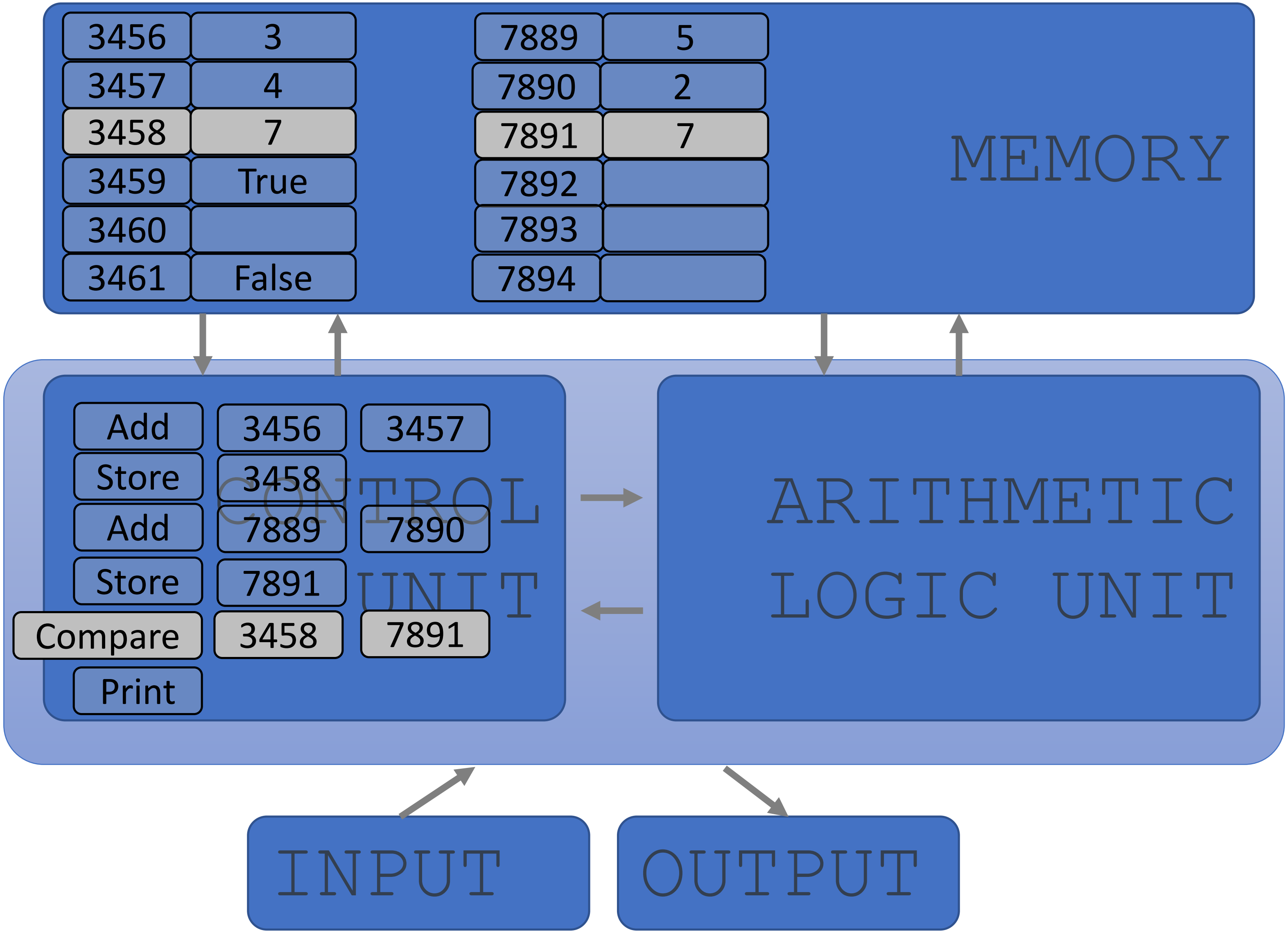


3456	3
3457	4
3458	7
3459	True
3460	
3461	False

7889	5
7890	2
7891	7
7892	
7893	
7894	

```
Add 3456 3457
Store 3458
Add 7889 7890
Store 7891
Compare 3458 7891
Print
```

True



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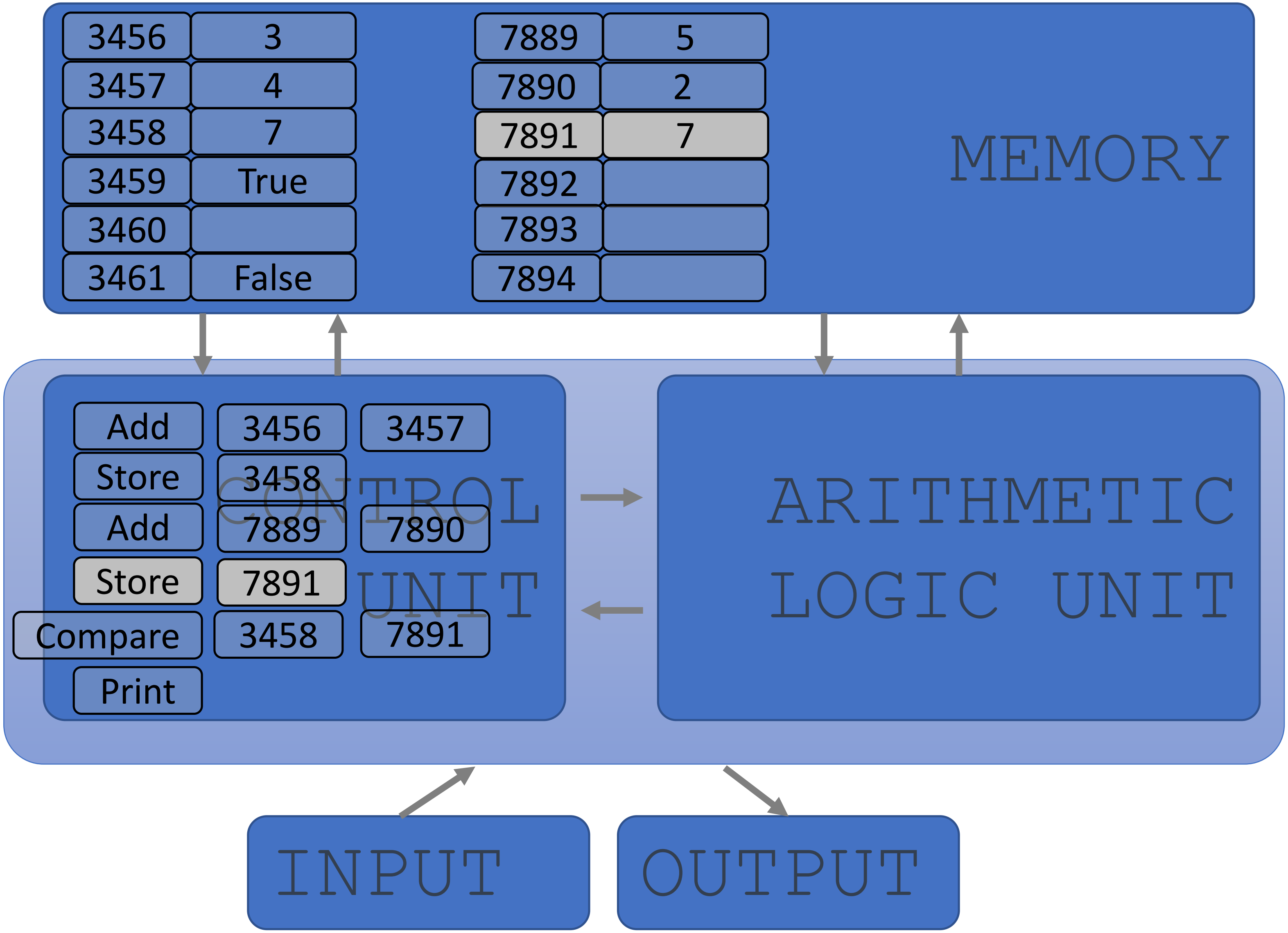

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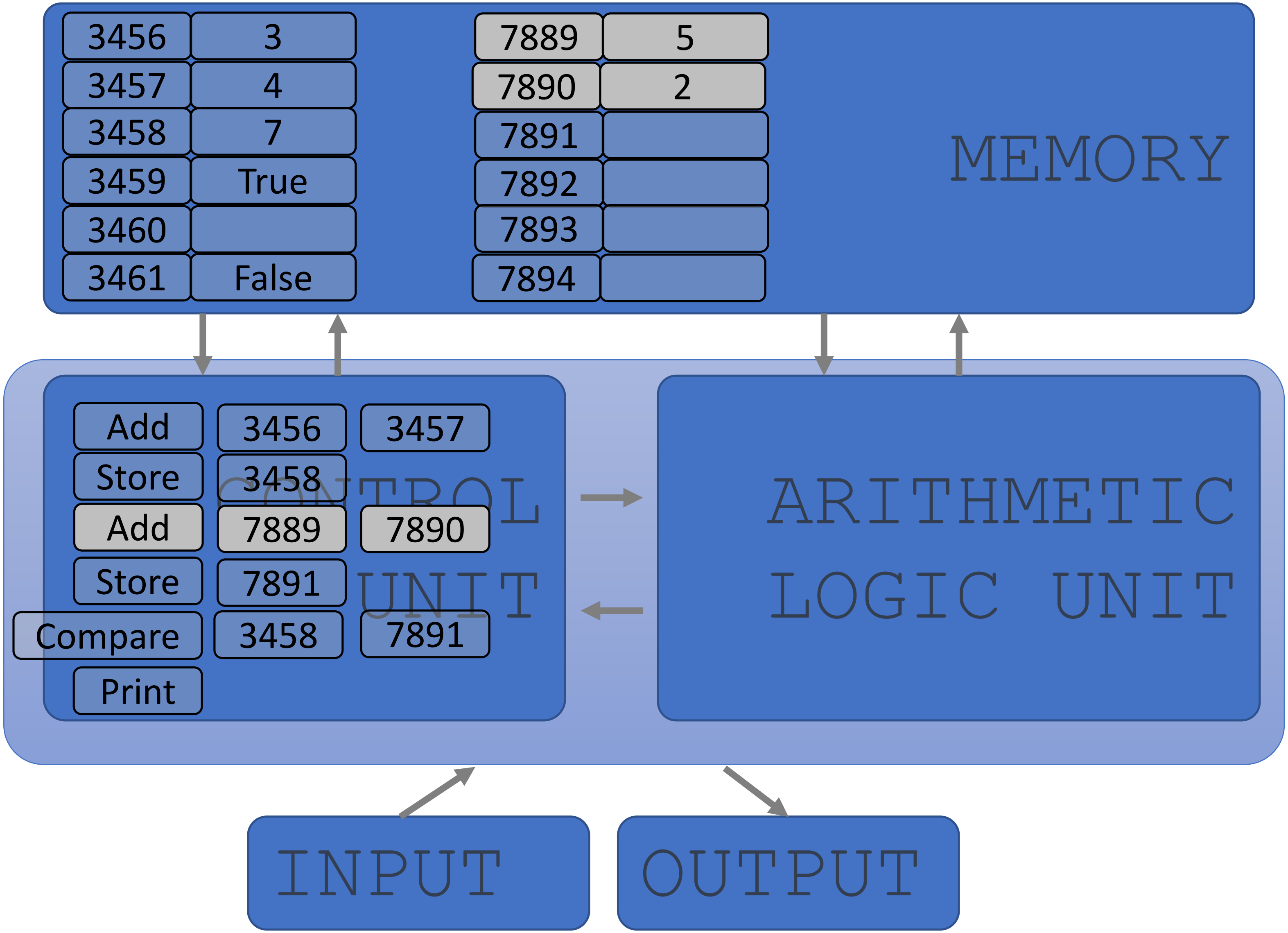

MEMORY

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CONTROL UNIT

Add	3456	3457
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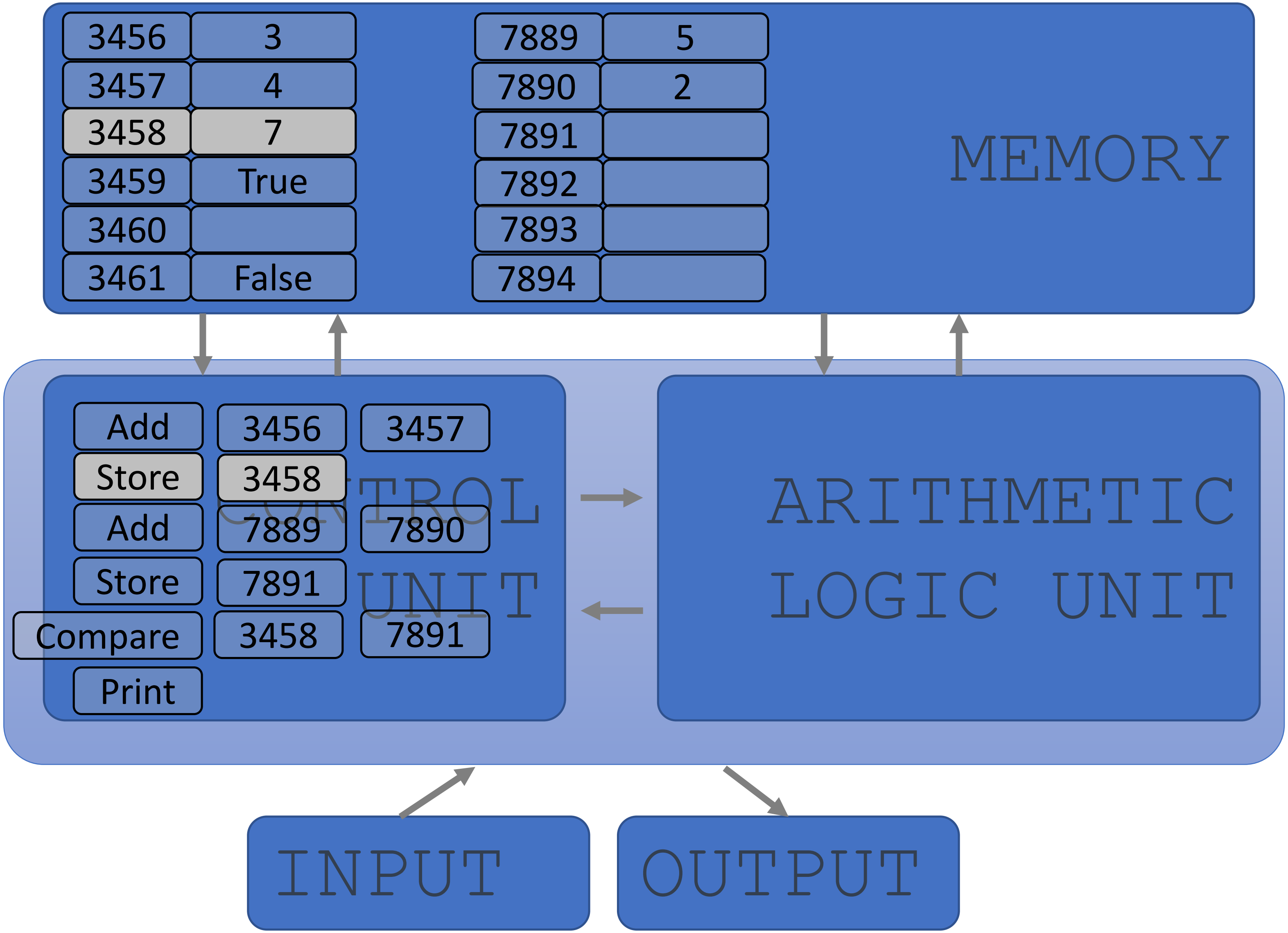
Add	7889	7890
Store	7891	
Compare	3458	7891
Print		

ARITHMETIC LOGIC UNIT

INPUT

OUTPUT



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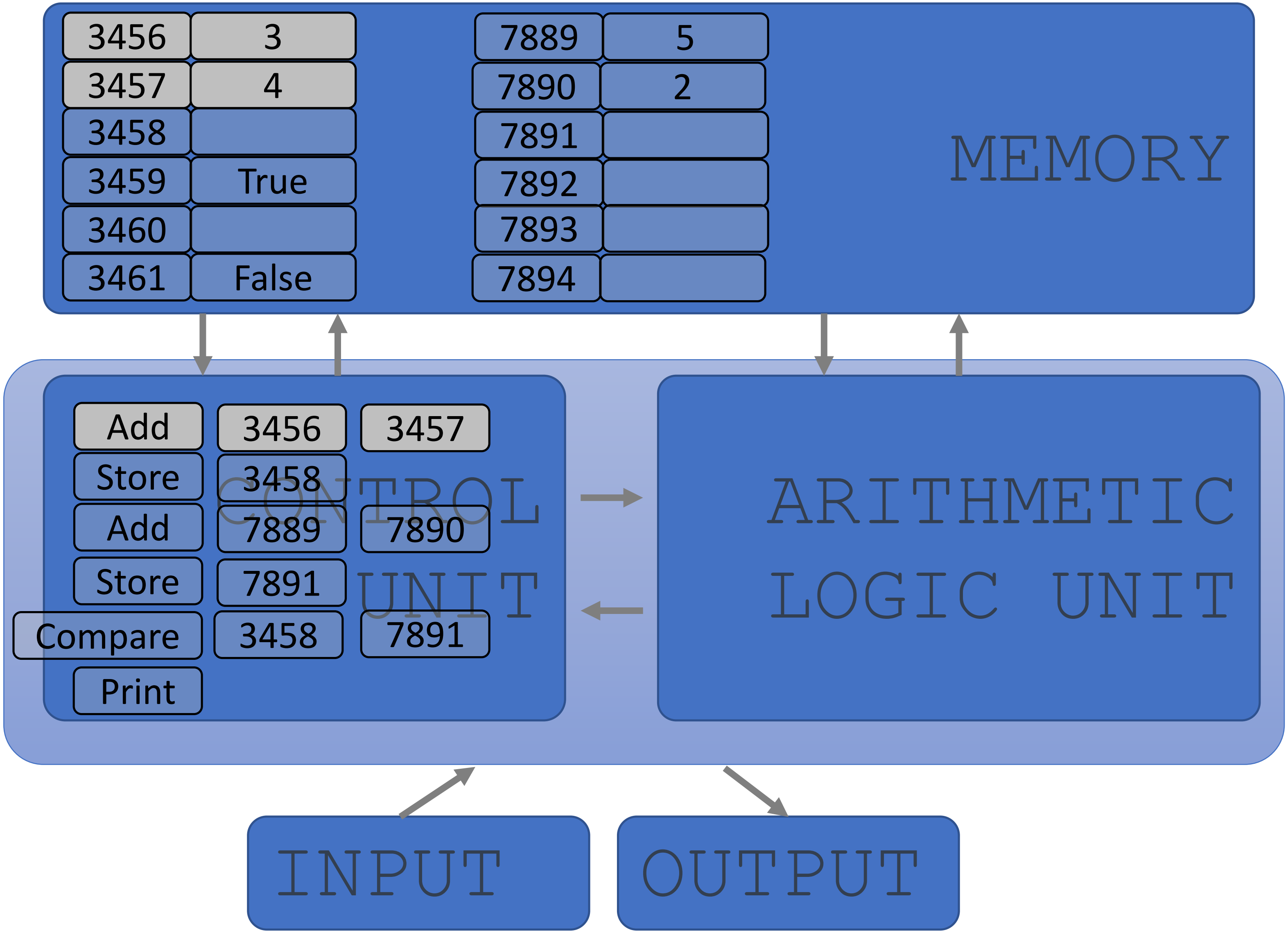

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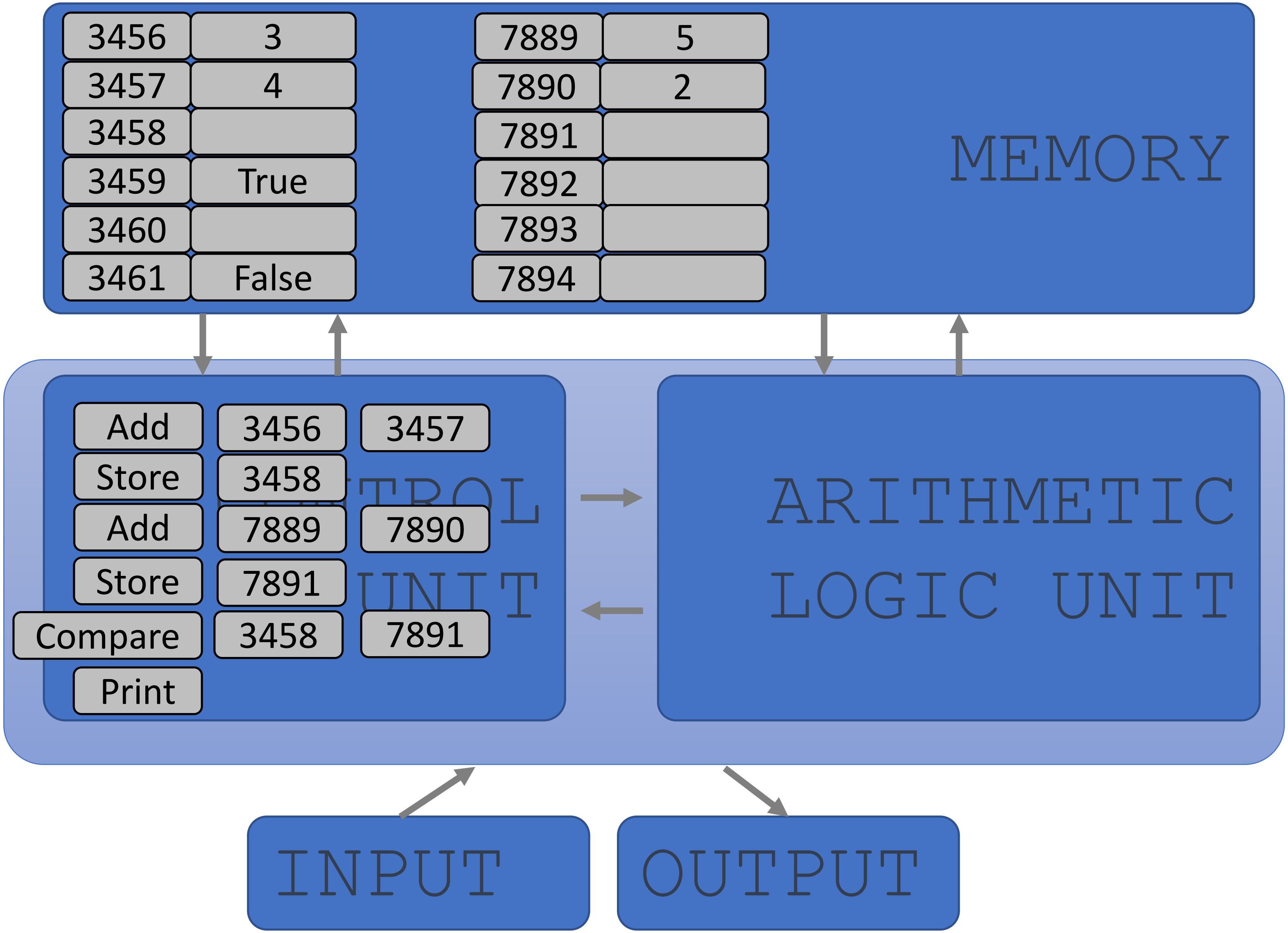
ARITHMETIC LOGIC UNIT

INPUT

OUTPUT



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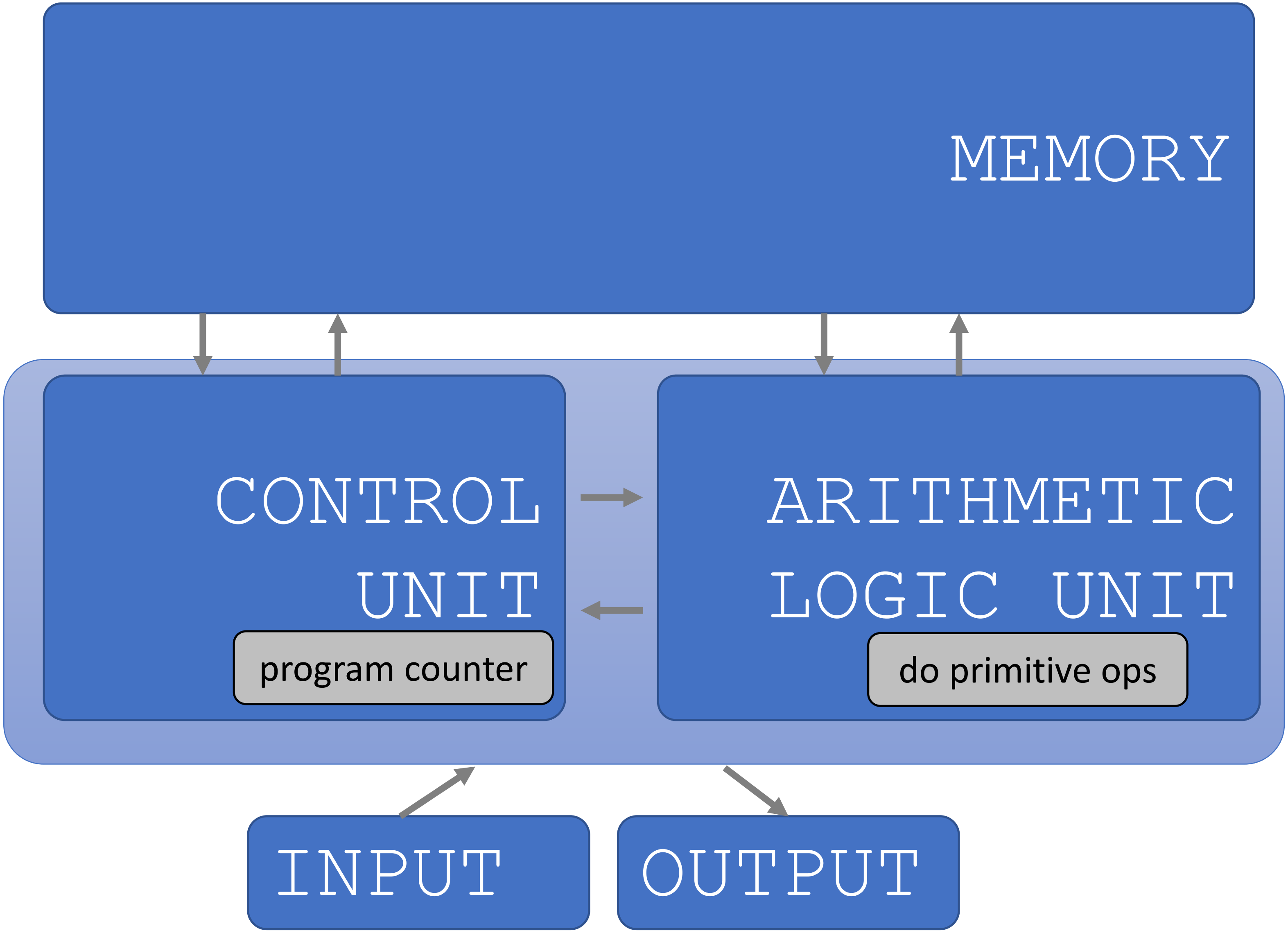

MEMORY

CONTROL UNIT

program counter

ARITHMETIC LOGIC UNIT

do primitive ops

INPUT

OUTPUT

STORED PROGRAM COMPUTER

- Sequence of **instructions stored** inside computer
  - Built from predefined set of primitive instructions

1) Arithmetic and logical
2) Simple tests
3) Moving data

- Special program (interpreter) **executes each instruction in order**
  - Use tests to change flow of control through sequence
  - Stops when it runs out of instructions or executes a halt instruction

COMPUTERS are MACHINES that EXECUTE ALGORITHMS

- **Fixed program** computer
  - Fixed set of algorithms
  - What we had until 1940’s
- **Stored program** computer
  - Machine stores and executes instructions
- **Key insight**: Programs are no different from other kinds of data

A COMPUTER WILL ONLY DO WHAT YOU TELL IT TO DO

COMPUTERS are MACHINES that EXECUTE ALGORITHMS

- Two things computers do:
  - Performs simple **operations**
    100s of billions per second!
  - **Remembers** results

  100s of gigabytes of storage!
- What kinds of calculations?
  - **Built-in** to the machine, e.g., +
  - Ones that **you define** as the programmer
- The BIG IDEA here?

ALGORITHMS are RECIPES / RECIPES are ALGORITHMS

- Bake cake from a box
  - 1) Mix dry ingredients
  - 2) Add eggs and milk
  - 3) Pour mixture in a pan
  - 4) Bake at 350F for 5 minutes
  - 5) Stick a toothpick in the cake
    - 6a) If toothpick does not come out clean, repeat step 4 and 5
    - 6b) Otherwise, take pan out of the oven
  - 7) Eat

WE HAVE an ALGORITHM

1) Sequence of simple **steps**

2) **Flow of control** process that specifies when each step is executed

3) A means of determining **when to stop**

NUMERICAL EXAMPLE

- Square root of a number `x` is `y` such that `y*y = x`
- Start with a **guess**, `g`
  1) If `g*g` is **close enough** to `x`, stop and say `g` is the answer
  2) Otherwise make a **new guess** by averaging `g` and `x/g`
  3) Using the new guess, **repeat** process until close enough
- Let's try it for x = 16 and an initial guess of 3

g	g*g	x/g	(g+x/g)/2
3	9	16/3	4.17
4.17	17.36	3.837	4.0035
4.0035	16.0277	3.997	4.000002

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TYPES of KNOWLEDGE

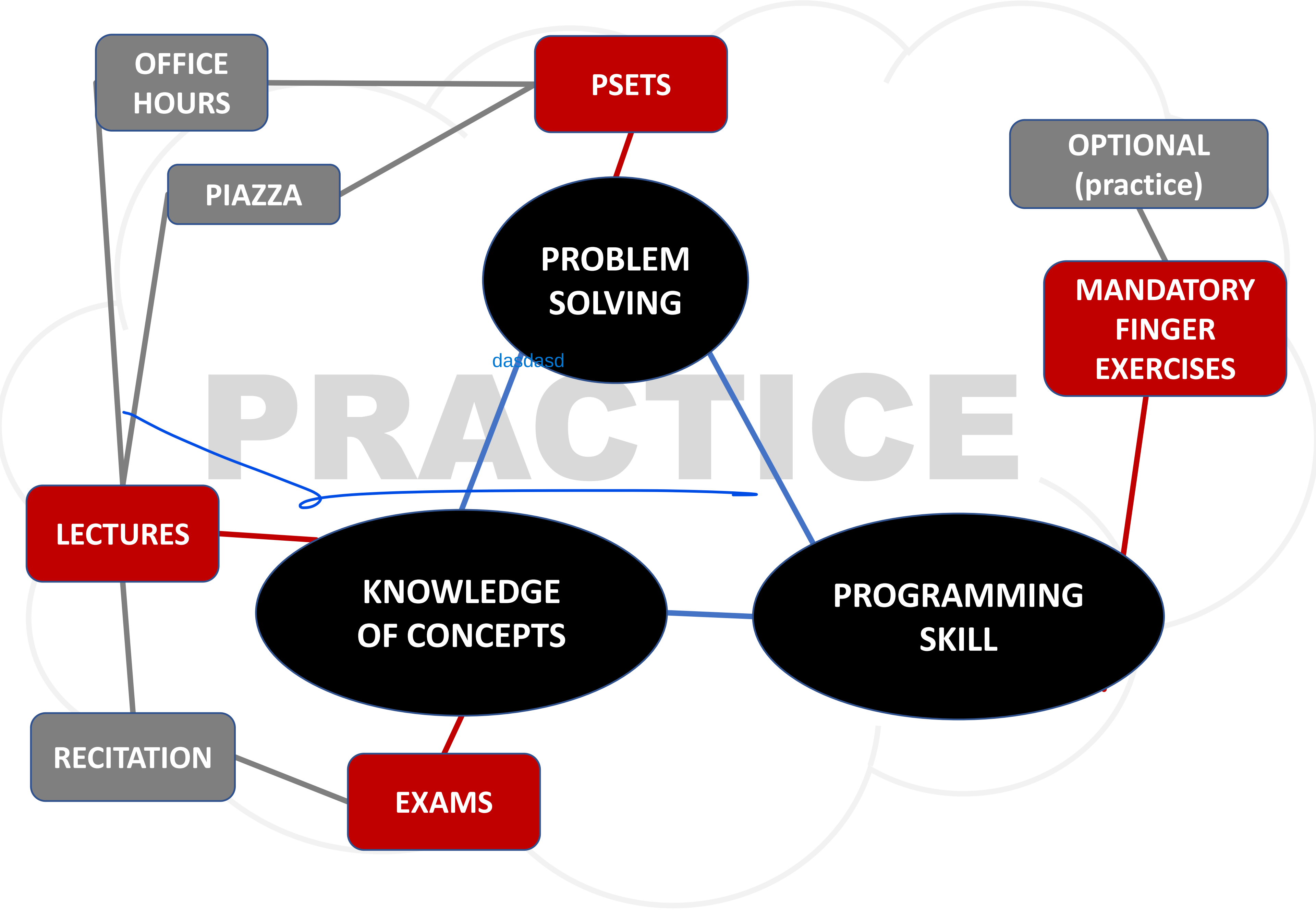
- **Declarative knowledge** is **statements of fact**
- **Imperative knowledge** is a **recipe** or “how-to”

- Programming is about writing recipes to generate facts

LET’S GOOOOO!

TOPICS

- Solving problems using **computation**
- Python **programming language**
- Organizing **modular programs**
- Some simple but important **algorithms**
- Algorithmic **complexity**


OFFICE HOURS
PSETS
PIAZZA
OPTIONAL (practice)
PROBLEM SOLVING
MANDATORY FINGER EXERCISES
dasdasd
PRACTICE
LECTURES
KNOWLEDGE OF CONCEPTS
PROGRAMMING SKILL
RECITATION
EXAMS

WHY COME TO CLASS?

- You get out of this course what you put into it
- Lectures
  - **Intuition** for concept
  - **Teach** you the concept
  - **Ask** me questions!
  - **Examples** of concept
  - Opportunity to
    practice practice practice
  - Repeat

TODAY

- Course info
- What is computation
- Python basics
  - Mathematical operations
  - Python variables and types
- NOTE: **slides and code files up before each lecture**
  - Highly encourage you to download them before class
  - Take notes and run code files when I do
  - Do the in-class “You try it” breaks
  - Class will not be recorded
  - Class will be live-Zoomed for those sick/quarantine

WELCOME!

(download slides and .py files from the class site to follow along)

6.100L Lecture 1

Ana Bell