WELCOME!

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

6.100L Lecture 1

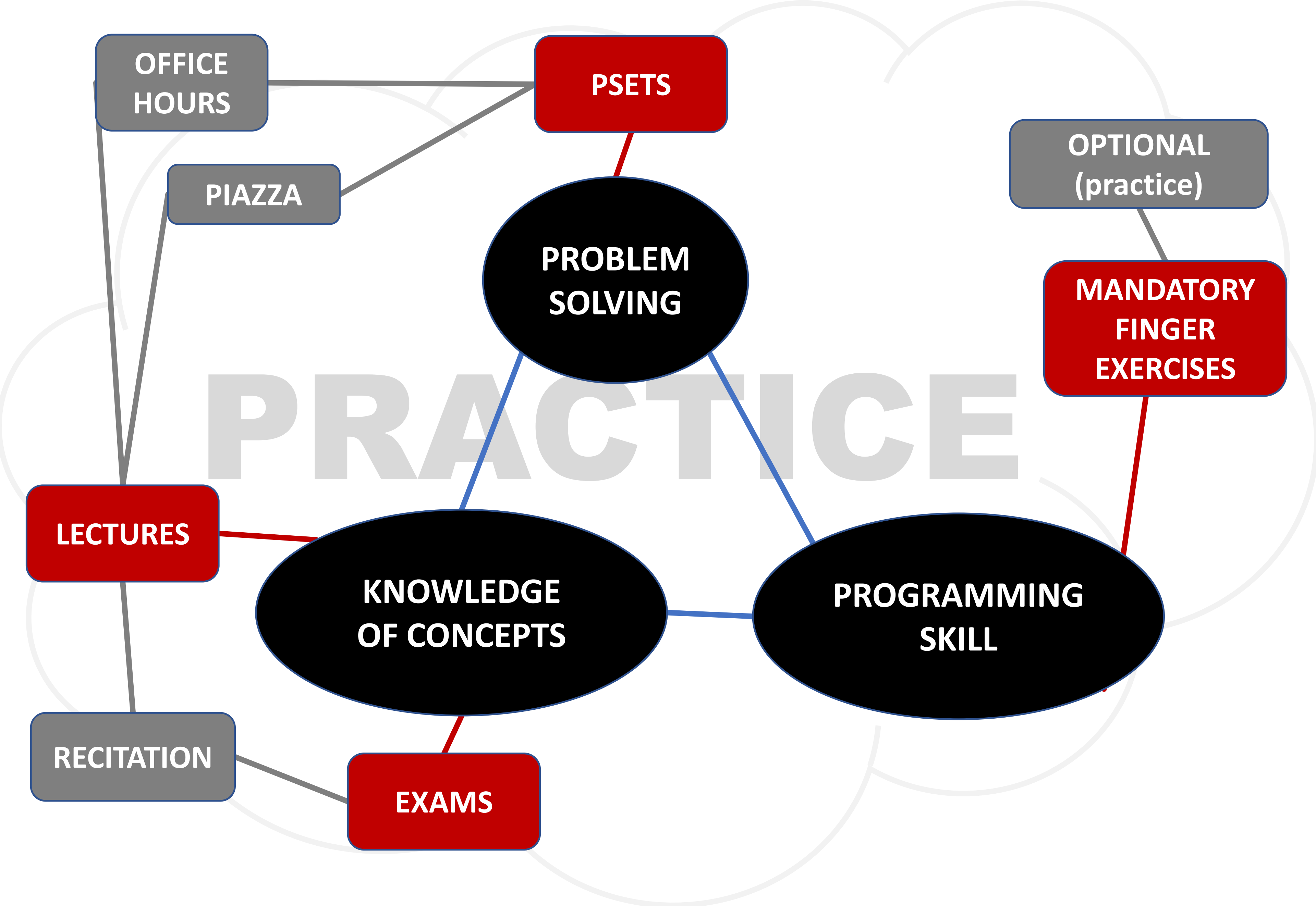
Ana Bell

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

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


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

TOPICS

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

LET’S GOOOOO!

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

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

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4.0035	16.0277	3.997	4.000002

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**

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

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?

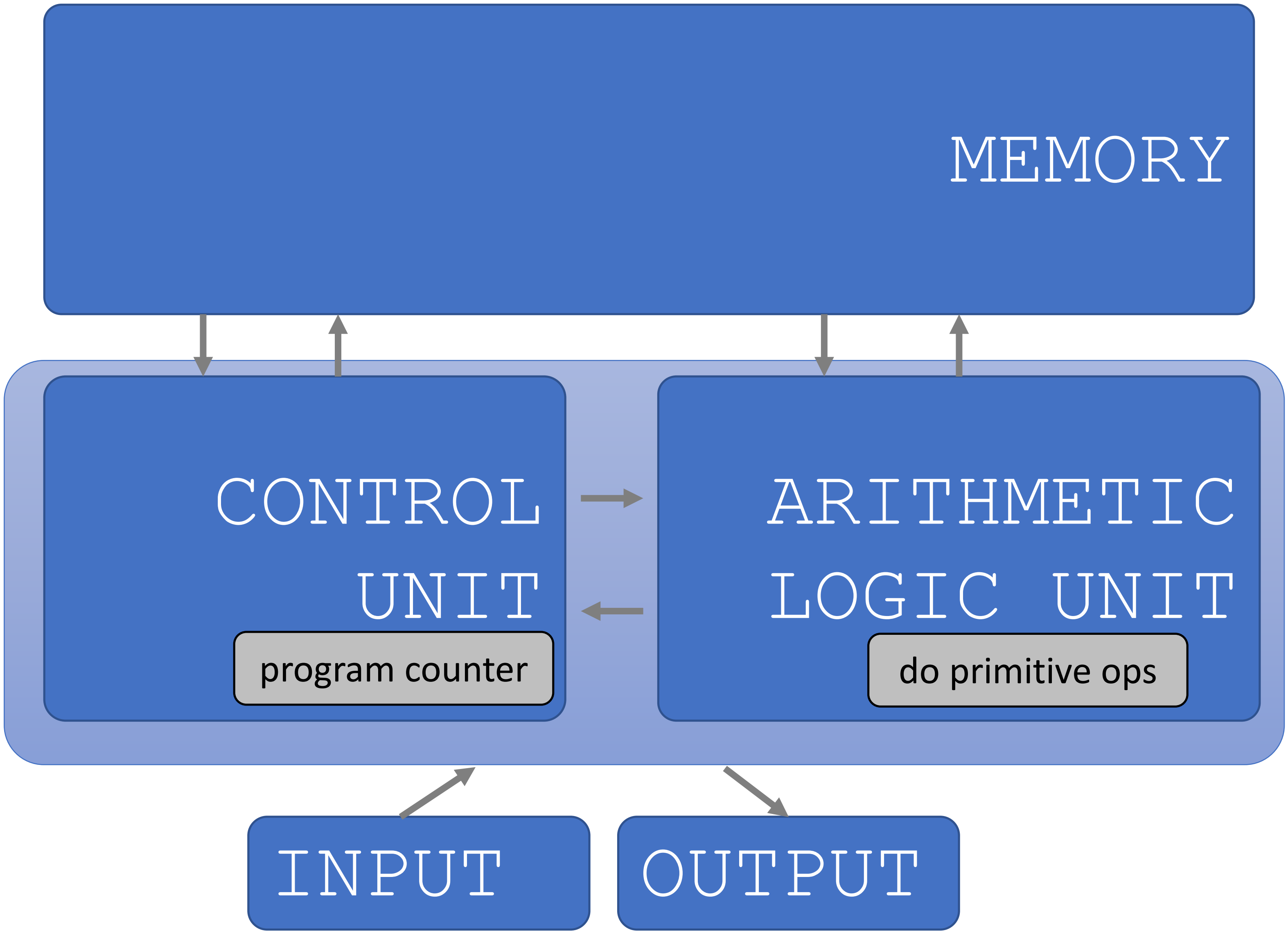
A COMPUTER WILL ONLY DO WHAT YOU TELL IT TO DO

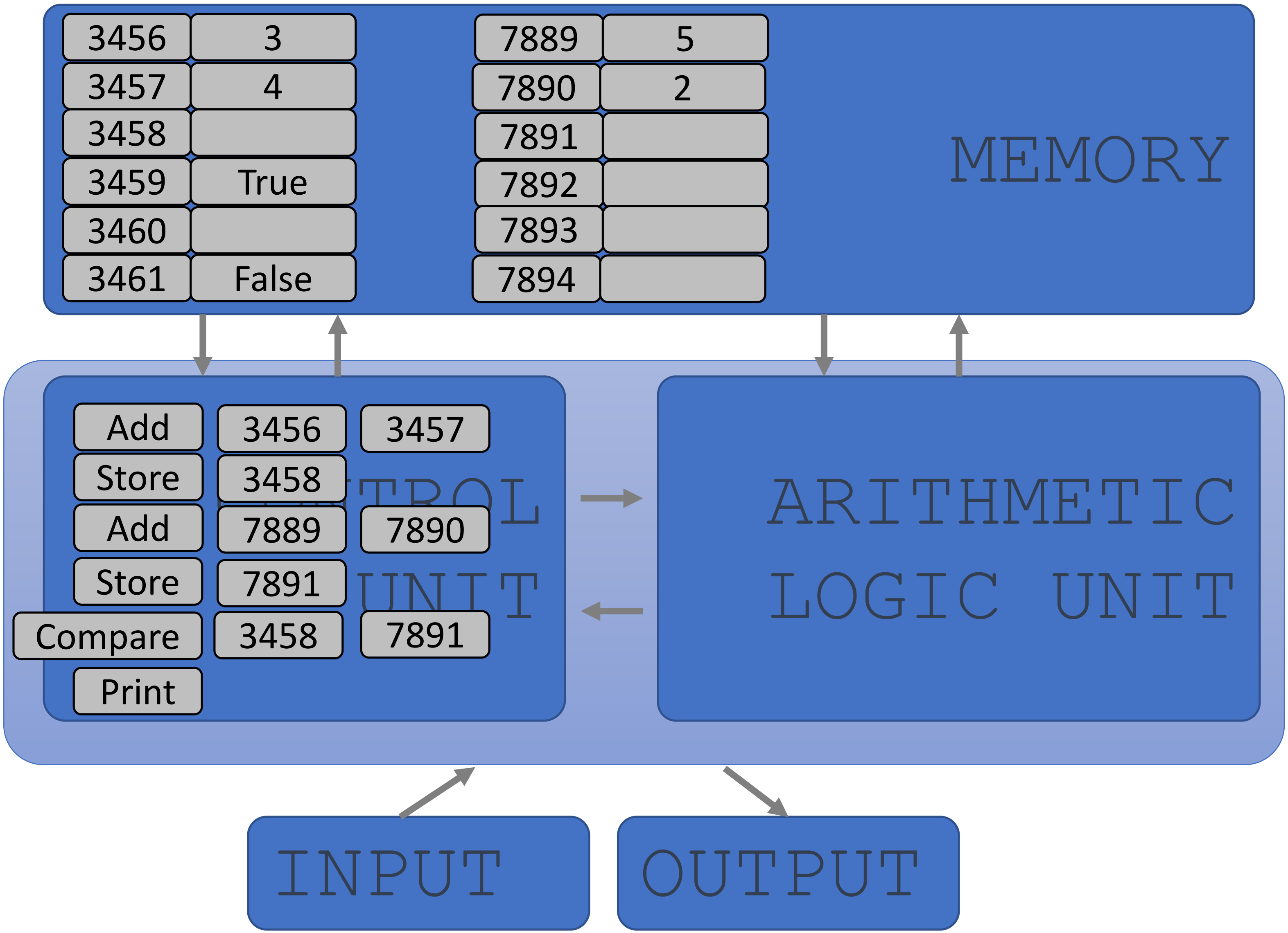
COMPUTERS are MACHINES that EXECUTE ALGORITHMS

- **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

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


MEMORY
CONTROL UNIT
program counter
ARITHMETIC LOGIC UNIT
do primitive ops
INPUT
OUTPUT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INPUT
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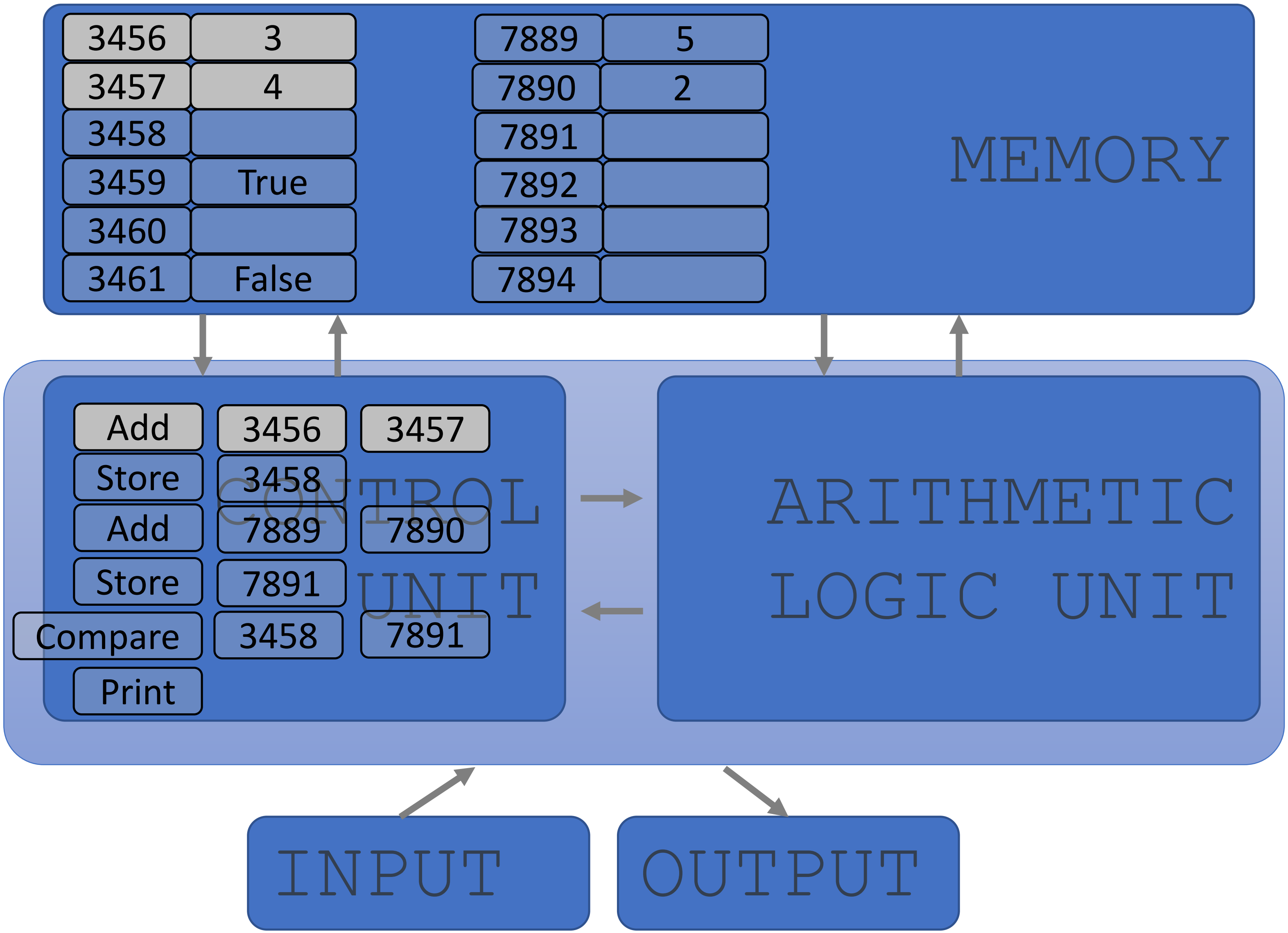
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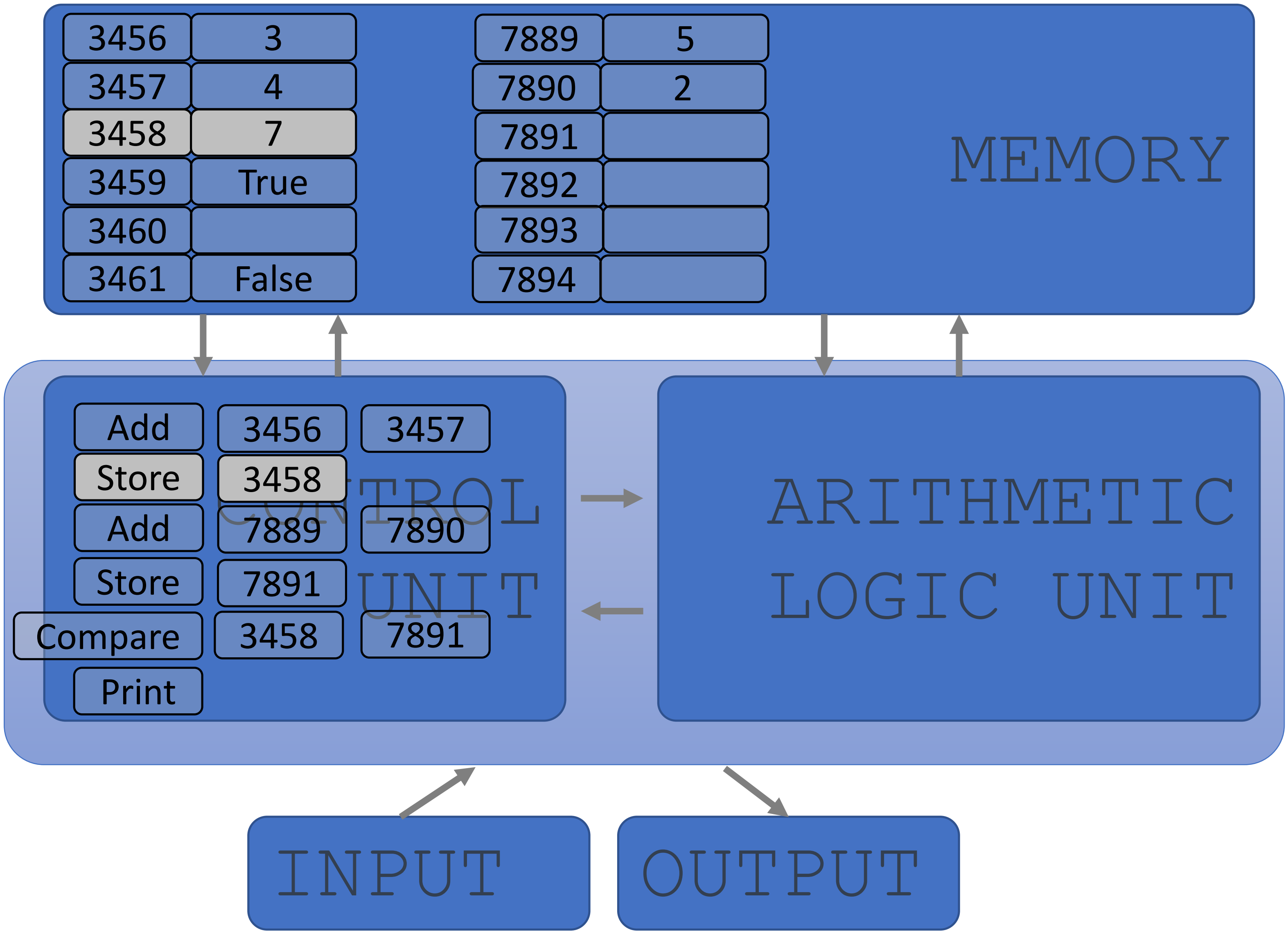
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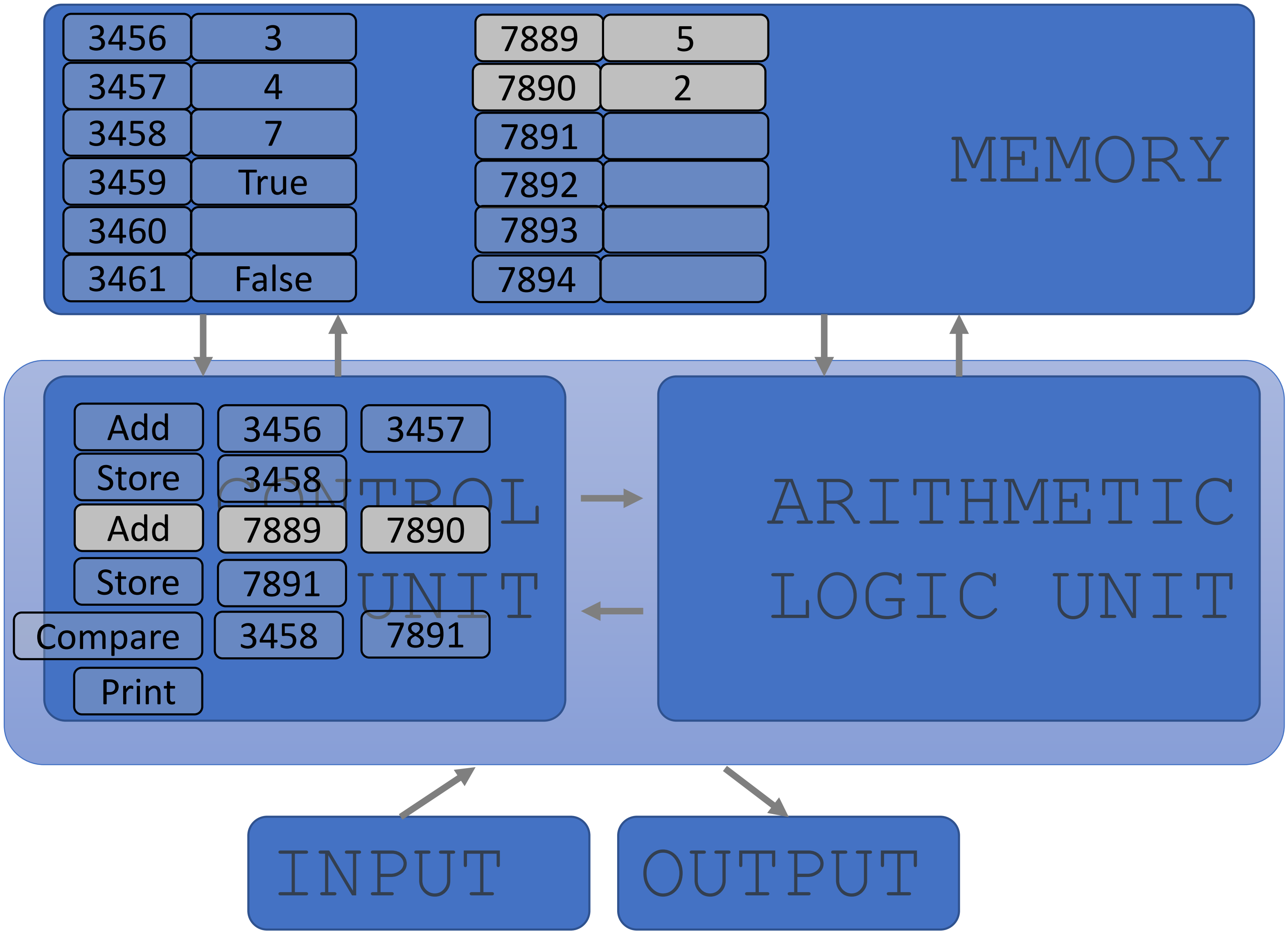
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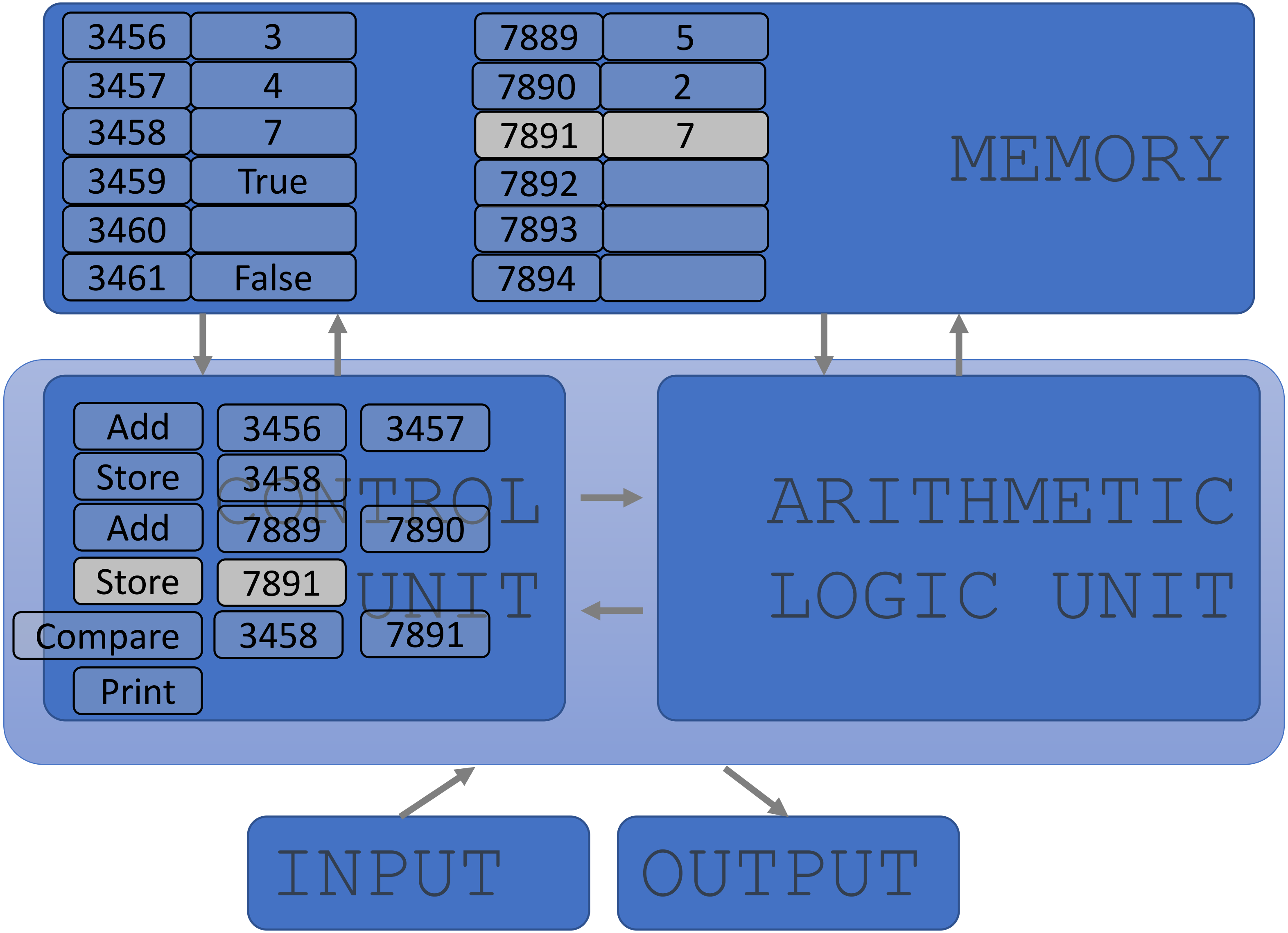

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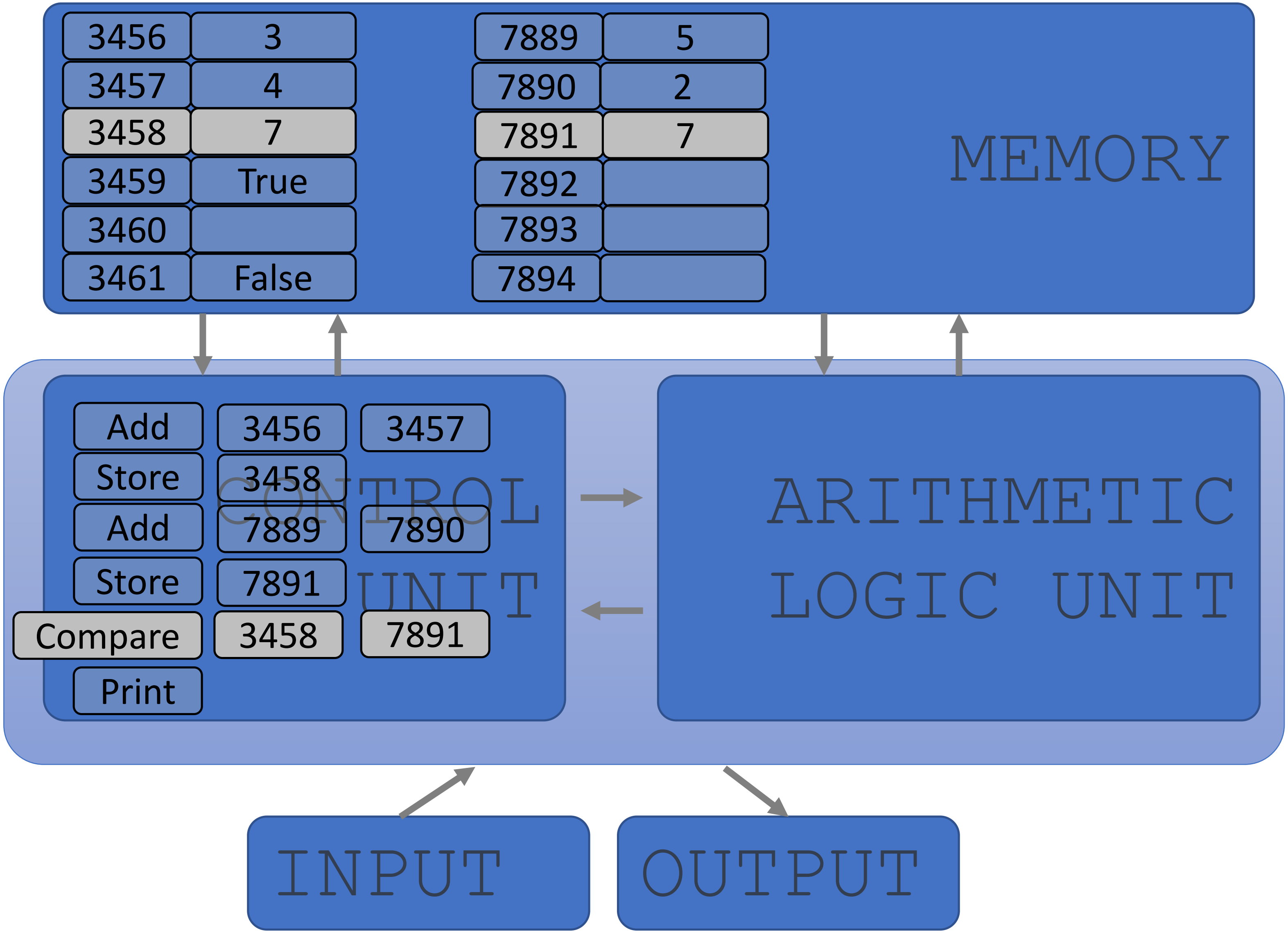
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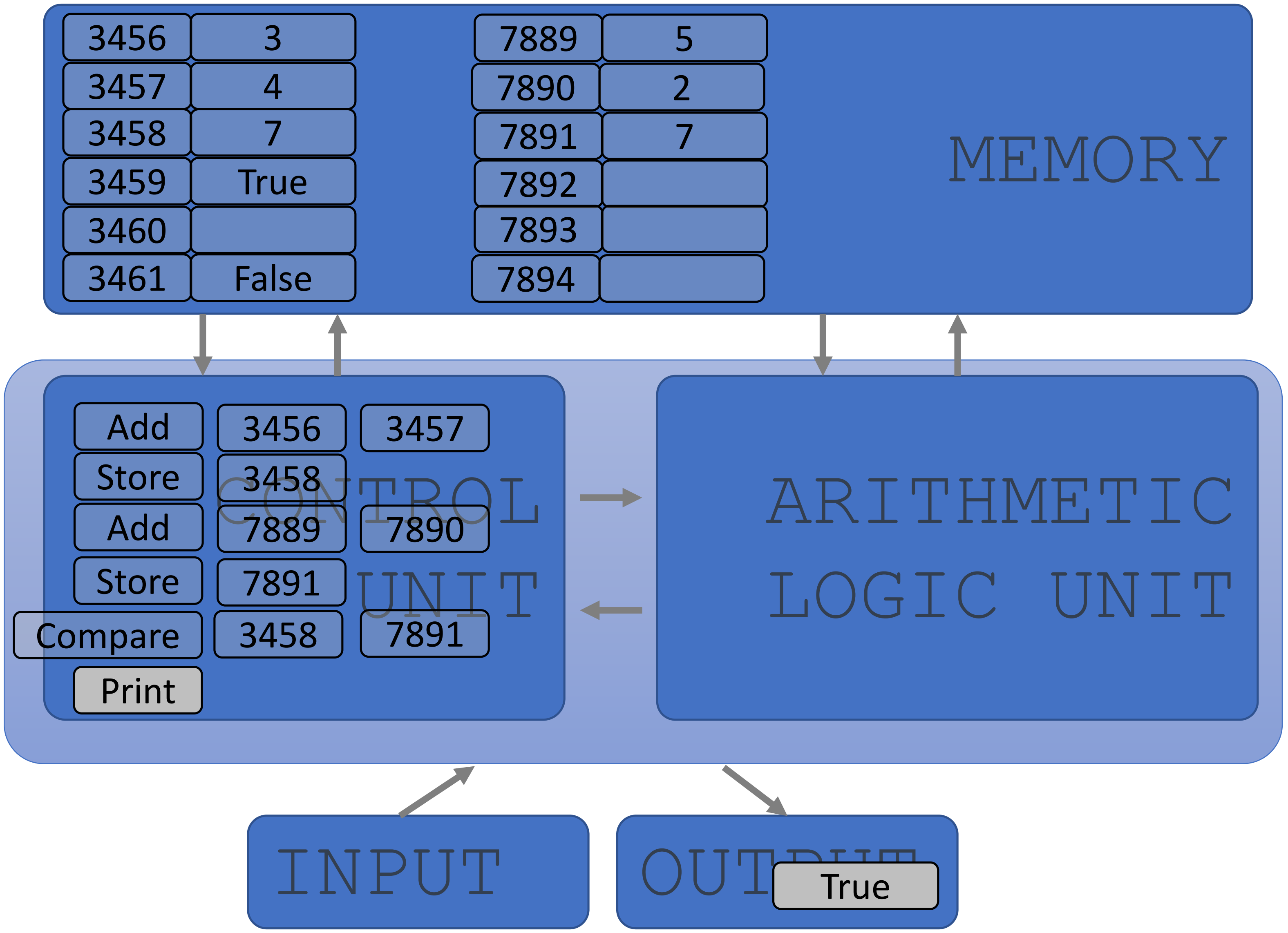

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INPUT
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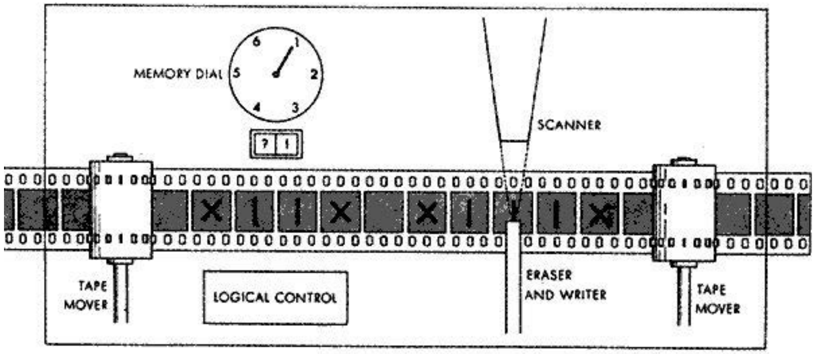
True

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

ASPECTS of LANGUAGES

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

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

- **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

- **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**

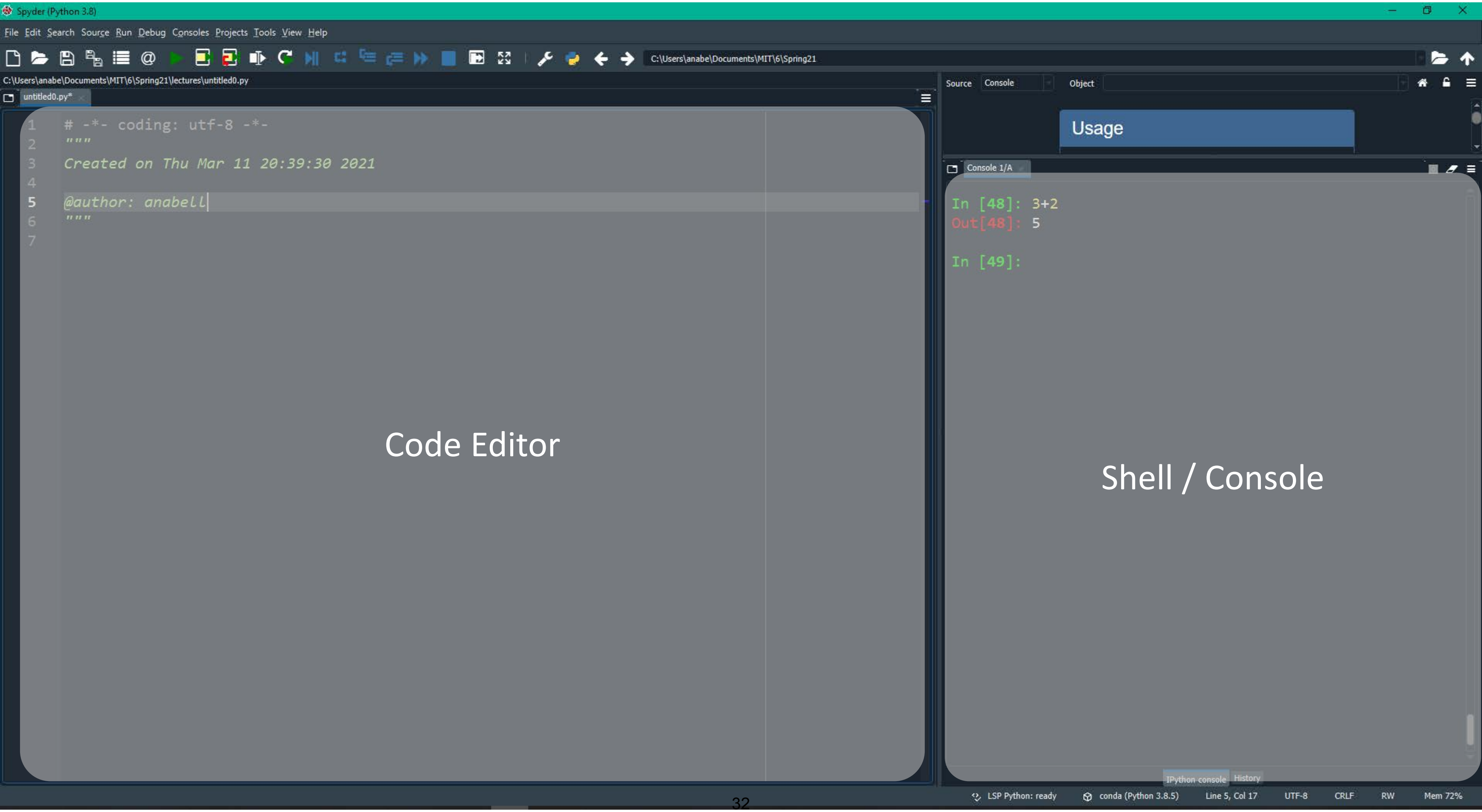
WHERE THINGS GO WRONG

- **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!

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

PROGRAMMING ENVIRONMENT: ANACONDA



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

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"

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

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

YOU TRY IT!

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

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:
  - `float(123)`
  - `round(7.9)`
  - `float(round(7.2))`
  - `int(7.2)`
  - `int(7.9)`

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>`

BIG IDEA

Replace complex expressions by ONE value

Work systematically to evaluate the expression.

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

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)`

OPERATORS on `int` and `float`

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

if both are ints, result is int
if either or both are floats, result is float

- `i/j` → **division**

result is always a float

- `i//j` → **floor division**

What is type of output?

- `i%j` → the **remainder** when `i` is divided by `j`
- `i**j` → `i` to the **power** of `j`

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

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

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

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)

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`

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

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

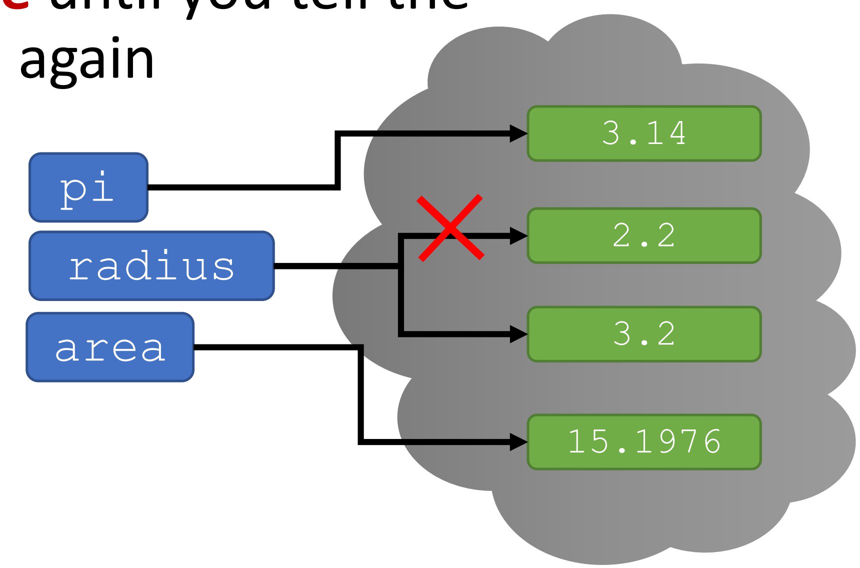
```
#calculate area and circumference of a circle
#using an approximation for pi
pi = 355/113
radius = 2.2
area = pi*(radius**2)
circumference = pi*(radius*2)
```

best

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
```



BIG IDEA

Lines are evaluated one after the other

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

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

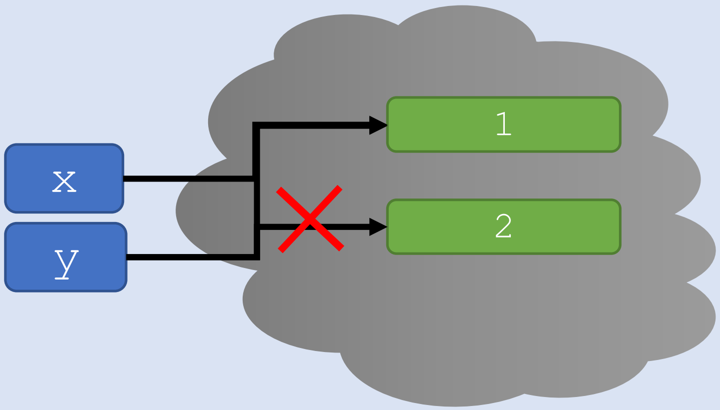
Where did we tell Python to (re)calculate feet?

YOU TRY IT!

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

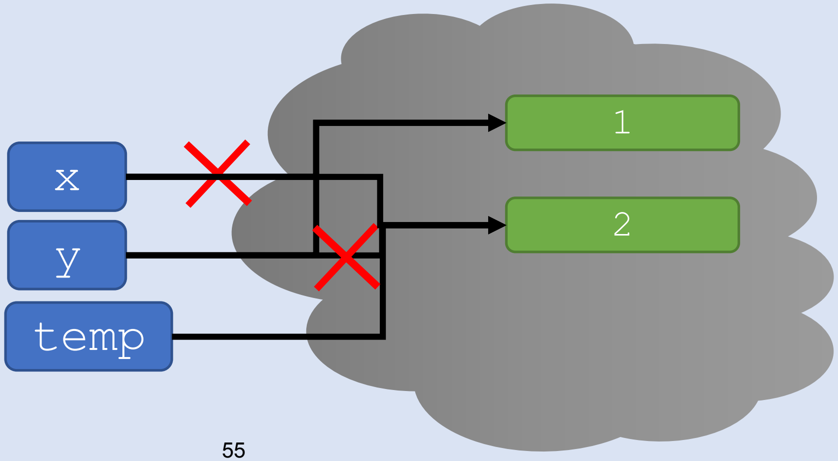
```
x = 1
y = 2

y = x
x = y
```



- Python Tutor to the rescue?

ANSWER:



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**.