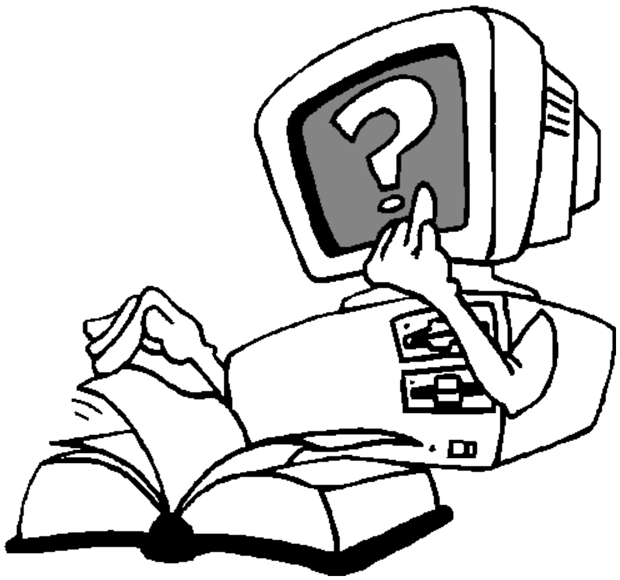
Welcome to 6.00.1x

OVERVIEW OF COURSE

- learn computational modes of thinking
- master the art of computational problem solving
- make computers do what you want them to do



https://ohthehumanityblog.files.wordpress.com/2014/09/computerthink.gif

TOPICS

- represent knowledge with **data structures**
- **iteration and recursion** as computational metaphors
- **abstraction** of procedures and data types
- **organize and modularize** systems using object classes and methods
- different classes of **algorithms**, searching and sorting
- **complexity** of algorithms

WHAT DOES A COMPUTER DO

- Fundamentally:
  - performs **calculations**
    a billion calculations per second!
      two operations in same time light travels 1 foot
  - **remembers** results
    100s of gigabytes of storage!
      typical machine could hold 1.5M books of standard size
- What kinds of calculations?
  - **built-in** to the language
  - ones that **you define** as the programmer

SIMPLE CALCULATIONS ENOUGH?

- Searching the World Wide Web
  - 45B pages; 1000 words/page; 10 operations/word to find
  - Need 5.2 days to find something using simple operations
- Playing chess
  - Average of 35 moves/setting; look ahead 6 moves; 1.8B boards to check; 100 operations/choice
  - 30 minutes to decide each move
- Good algorithm design also needed to accomplish a task!

ENOUGH STORAGE?

- What if we could just pre-compute information and then look up the answer
  - Playing chess as an example
    - Experts suggest 10^123 different possible games
    - Only 10^80 atoms in the observable universe

ARE THERE LIMITS?

- Despite its speed and size, a computer does have limitations
  - Some problems still too complex
    - Accurate weather prediction at a local scale
    - Cracking encryption schemes
  - Some problems are fundamentally impossible to compute
    - Predicting whether a piece of code will always halt with an answer for any input

TYPES OF KNOWLEDGE

- computers know what you tell them
- **declarative knowledge** is **statements of fact**.
  - there is candy taped to the underside of one chair
- **imperative knowledge** is a **recipe** or “how-to” knowledge
  1) face the students at the front of the room
  2) count up 3 rows
  3) start from the middle section’s left side
  4) count to the right 1 chair
  5) reach under chair and find it

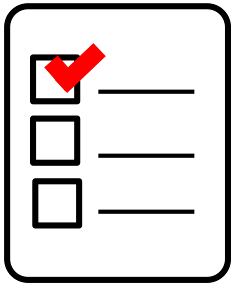
A NUMERICAL EXAMPLE

- square root of a number `x` is `y` such that `y*y = x`
- recipe for deducing square root of number `x` (e.g. 16)
  1) Start with a **guess**, `g`
  2) If `g*g` is **close enough** to `x`, stop and say `g` is the answer
  3) Otherwise make a **new guess** by averaging `g` and `x/g`
  4) Using the new guess, **repeat** process until close enough

g	g*g	x/g	(g+x/g)/2
3	9	5.333	4.1667
4.1667	17.36	3.837	4.0035
4.0035	16.0277	3.997	4.000002

WHAT IS A RECIPE

1) sequence of simple **steps**



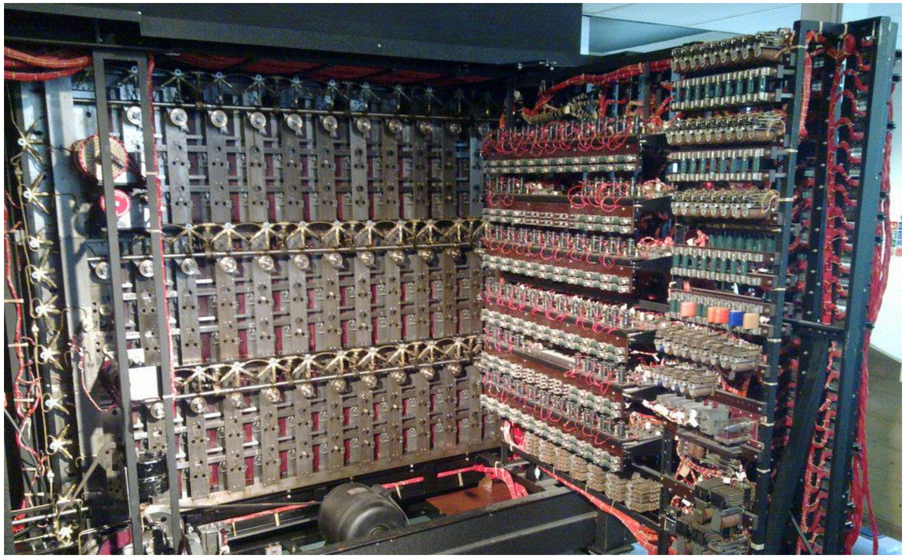
2) **flow of control** process that specifies when each step is executed

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

Steps 1+2+3 = an **algorithm**!

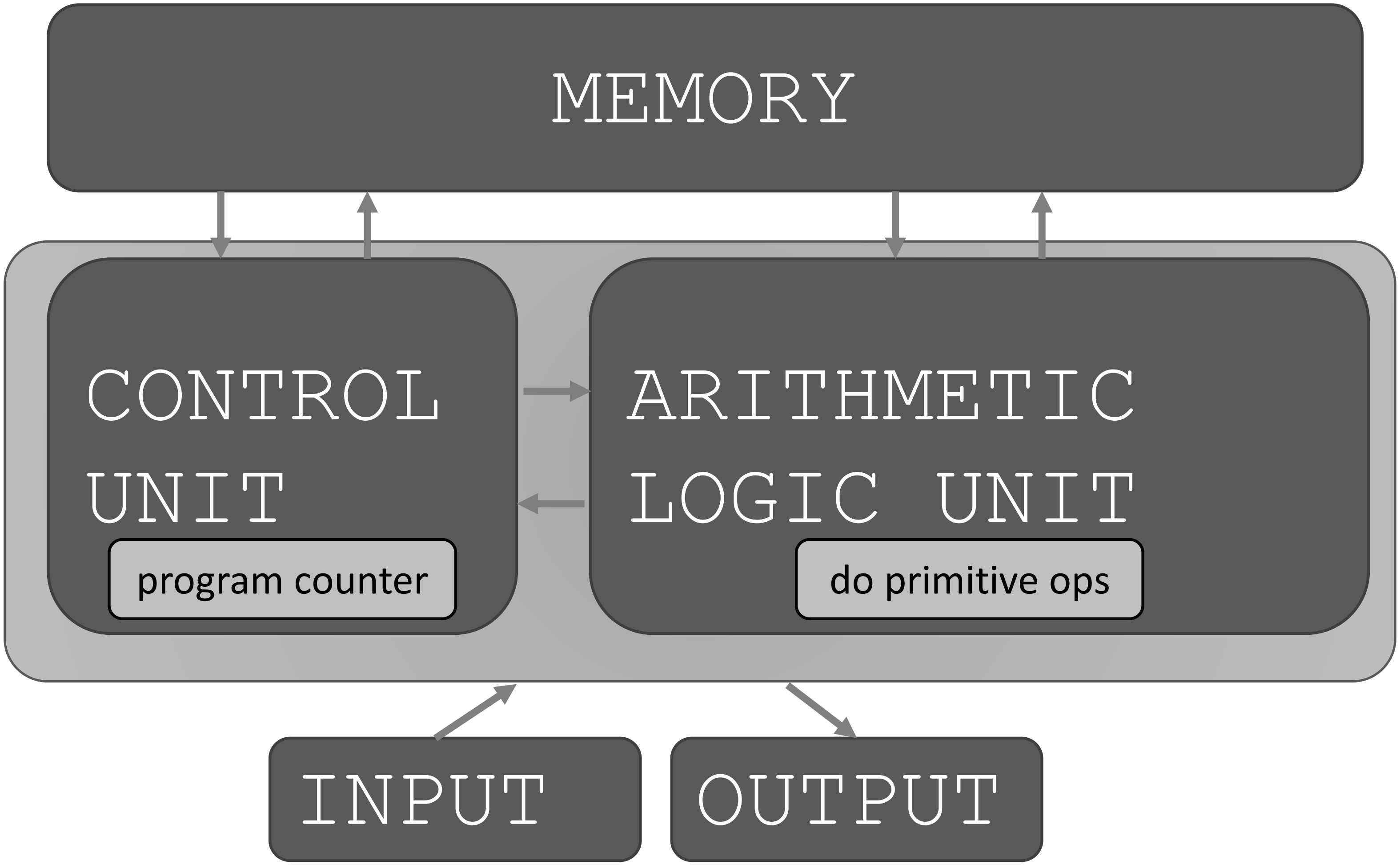
COMPUTERS ARE MACHINES

- how to capture a recipe in a mechanical process
- **fixed program** computer
  - calculator
  - Alan Turing's Bombe
- **stored program** computer
  - machine stores and executes instructions



http://www.upgradenrepair.com/computerparts/computerparts.htm

BASIC MACHINE ARCHITECTURE

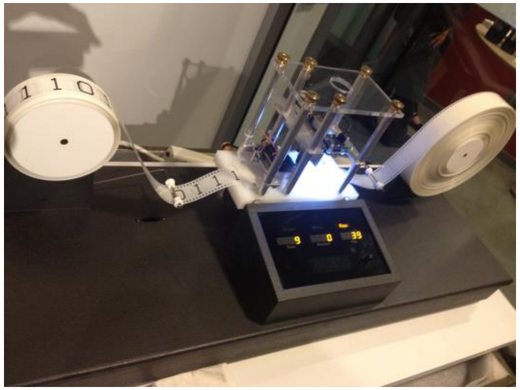


STORED PROGRAM COMPUTER

- sequence of **instructions stored** inside computer
  - built from predefined set of primitive instructions
    1) arithmetic and logic
    2) simple tests
    3) moving data
- special program (interpreter) **executes each instruction in order**
  - use tests to change flow of control through sequence
  - stop when done

BASIC PRIMITIVES

- Turing showed you can **compute anything** using 6 primitives
- modern programming languages have more convenient set of primitives
- can abstract methods to **create new primitives**
- anything computable in one language is computable in any other programming language

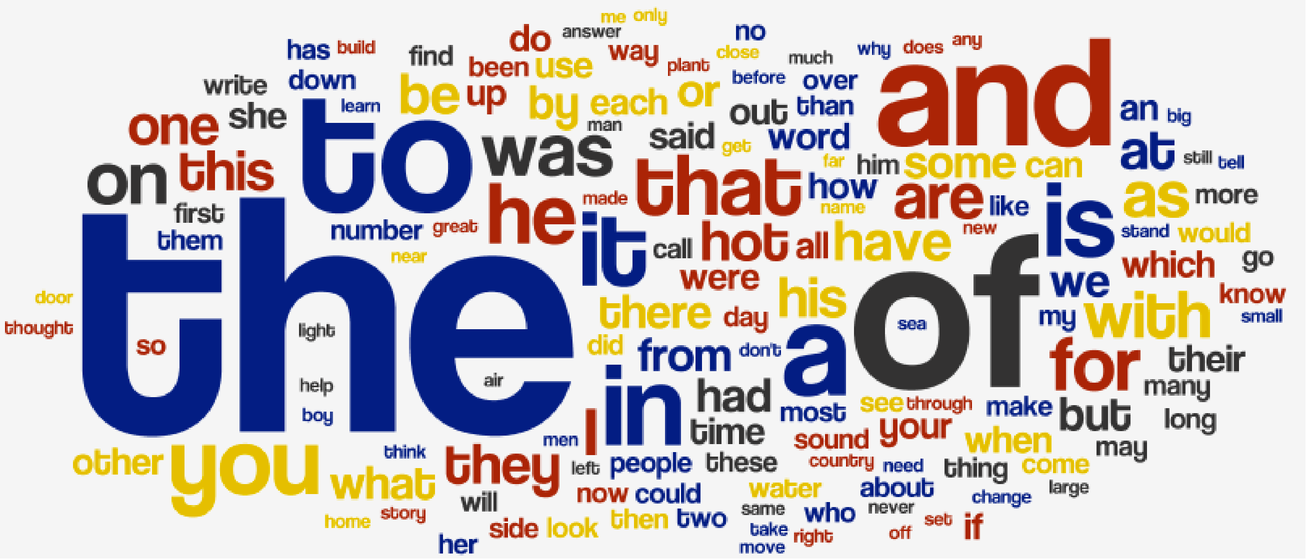


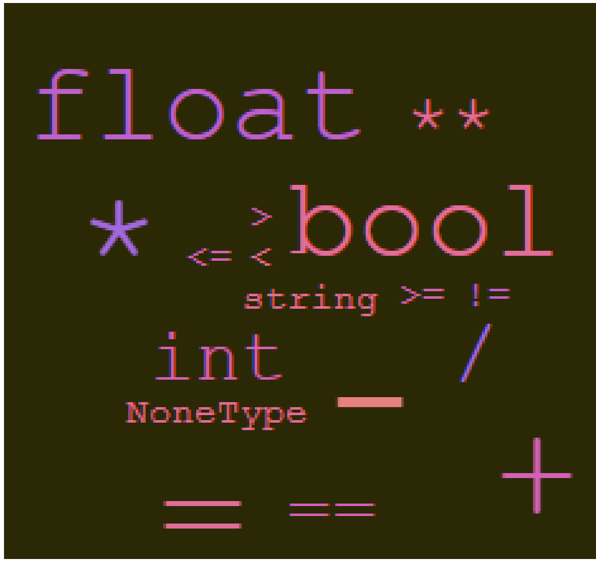
CREATING RECIPES

- a programming language provides a set of primitive **operations**
- **expressions** are complex but legal combinations of primitives in a programming language
- expressions and computations have **values** and meanings in a programming language

ASPECTS OF LANGUAGES

- **primitive constructs**
  - English: words
  - programming language: numbers, strings, simple operators





ASPECTS OF LANGUAGE

- **syntax**
  - English: `"cat dog boy"` → not syntactically valid
    `"cat hugs boy"` → syntactically valid
  - programming language: `"hi"5` → not syntactically valid
    `3.2*5` → syntactically valid

ASPECTS OF LANGUAGES

- **static semantics** is which syntactically valid strings have meaning
  - English: `"I are hungry"` → syntactically valid
    but static semantic error
  - programming language: `3.2*5` → syntactically valid
    `3+"hi"` → static semantic error

ASPECTS OF LANGUAGES

- **semantics** is the meaning associated with a syntactically correct string of symbols with no static semantic errors
  - English: can have many meanings –
    - `“Flying planes can be dangerous”`
    - `“This reading lamp hasn’t uttered a word since I bought it?”`
  - programming languages: have only one meaning but may not be what programmer intended

Semantics： Assign a meaning to a string;
Static semantics: Determines whether a string has a meaning.

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 semantic errors but **different meaning than what programmer intended**
  - program crashes, stops running
  - program runs forever
  - program gives an answer but different than expected

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
- Learn computational modes of thought to enable us to leverage a suite of methods to solve complex problems

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

OBJECTS

- programs manipulate **data objects**
- objects have a **type** that defines the kinds of things programs can do to them
- objects are
  - scalar (cannot be subdivided)
  - non-scalar (have internal structure that can be accessed)

SCALAR OBJECTS

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

```
In [1]: type(5)
Out[1]: int

In [2]: type(3.0)
Out[2]: float
```

what you write into the Python shell

what shows after hitting enter

TYPE CONVERSIONS (CAST)

- can **convert object of one type to another**
- `float(3)` converts integer `3` to float `3.0`
- `int(3.9)` truncates float `3.9` to integer `3`

PRINTING TO CONSOLE

- To show output from code to a user, use `print` command

```
In [11]: 3+2
Out[11]: 5

In [12]: print(3+2)
5
```

no 'Out' because no value returned, just something printed

EXPRESSIONS

- **combine objects and operators** to form expressions
- an expression has a **value**, which has a type
- syntax for a simple expression

```
<object> <operator> <object>
```

OPERATORS ON ints and floats

- `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 float

- `i//j` → **int division**

  - result is int, quotient without remainder

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

SIMPLE OPERATIONS

- parentheses used to tell Python to do these operations first
  - 3*5+1 evaluates to 16
  - 3*(5+1) evaluates to 18
- **operator precedence** without parentheses
  - **
  - *
  - /
  - + and – executed left to right, as appear in expression

BINDING VARIABLES AND VALUES

- equal sign is an **assignment** of a value to a variable name

variable

value

```
pi = 3.14159
pi_approx = 22/7
```

If use 22//7, value of expression is 3

- value stored in computer memory
- an assignment binds name to value
- retrieve value associated with name or variable by invoking the name, by typing `pi`

ABSTRACTING EXPRESSIONS

- why **give names** to values of expressions?
- **reuse names** instead of values
- easier to change code later

```
pi = 3.14159
radius = 2.2
area = pi*(radius**2)
```

PROGRAMMING vs MATH

- in programming, you do not "solve for x"

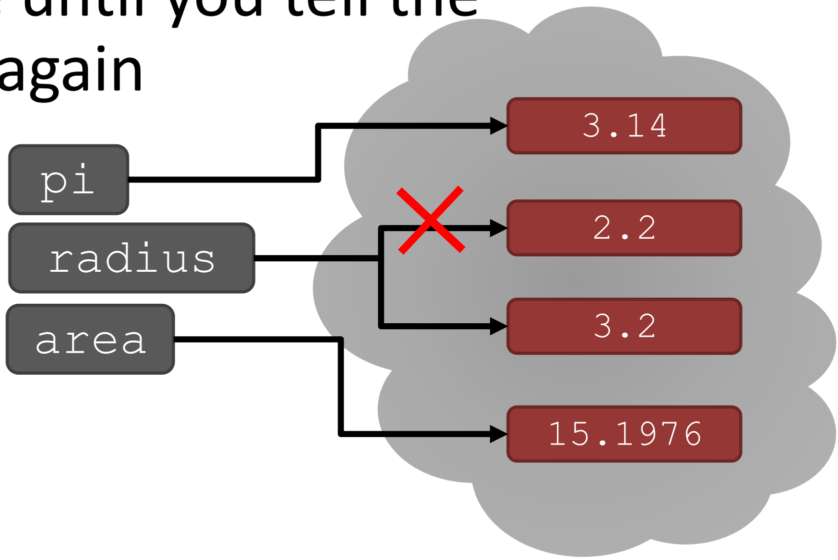
```
pi = 3.14159
radius = 2.2
# area of circle
area = pi*(radius**2)
radius = radius+1
```

an assignment
- value on the right
- name on the left
- equivalent is `radius += 1`

CHANGING 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
```



COMPARISON OPERATORS ON `int` and `float`

- `i` and `j` are any variable names

`i>j`

`i>=j`

`i<j`

`i<=j`

`i==j` → **equality** test, `True` if `i` equals `j`

`i!=j` → **inequality** test, `True` if `i` not equal to `j`

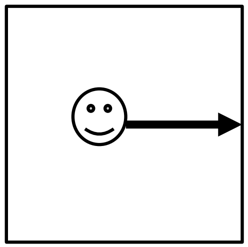
LOGIC OPERATORS ON bools

- `a` and `b` are any variable names

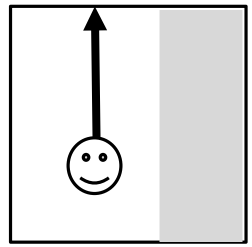
`not a` → `True` if `a` is `False`
`False` if `a` is `True`

`a and b` → `True` if both are `True`

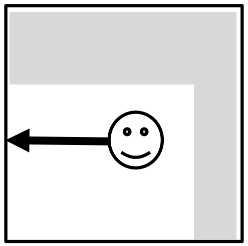
`a or b` → `True` if either or both are `True`



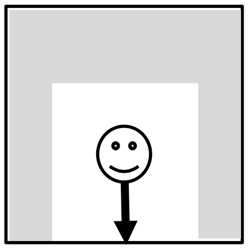
If right clear,
go right



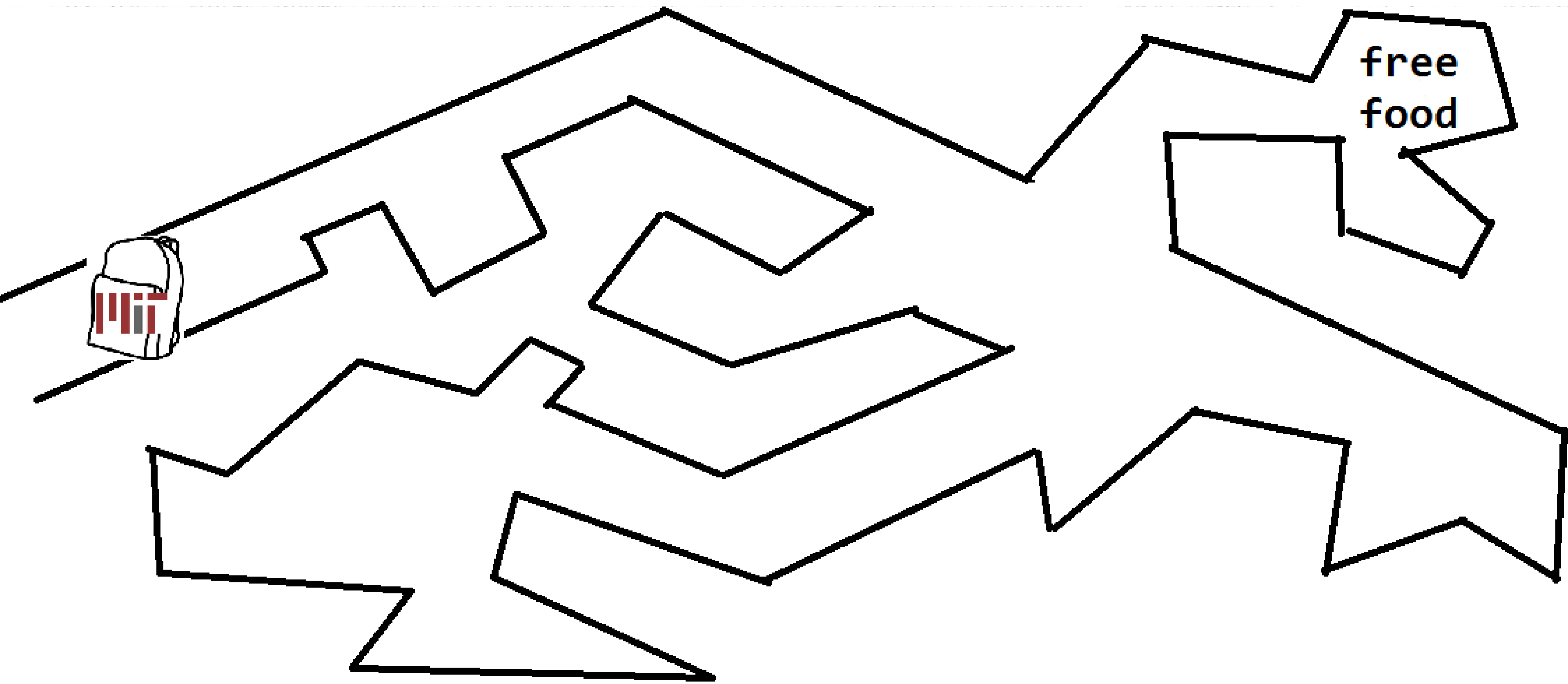
If right blocked,
go forward



If right and
front blocked,
go left

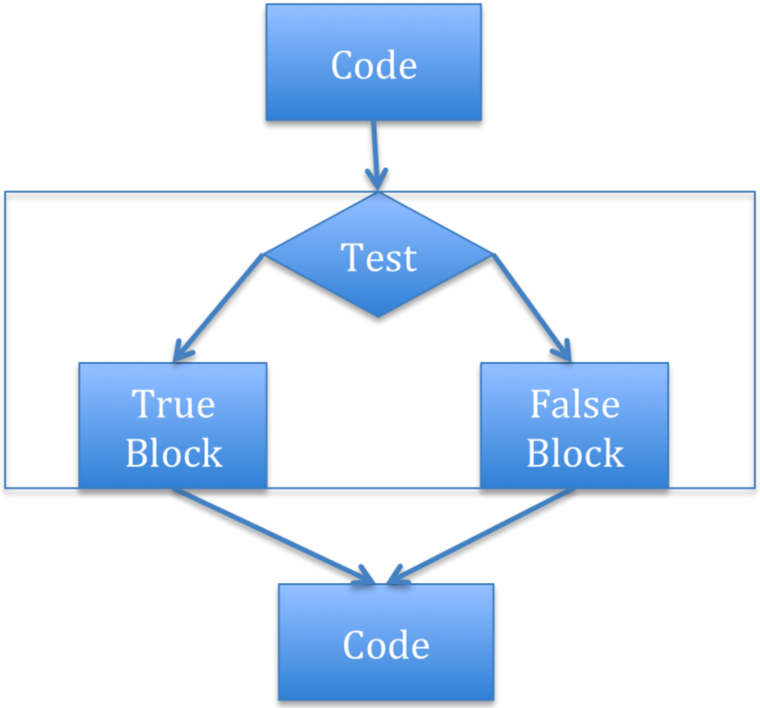


If right , front,
left blocked,
go back



BRANCHING PROGRAMS

- The simplest branching statement is a **conditional**
  - A test (expression that evaluates to `True` or `False`)
  - A block of code to execute if the test is `True`
  - An optional block of code to execute if the test is `False`



A SIMPLE EXAMPLE

```
x = int(input('Enter an integer: '))
if x%2 == 0:
    print(‘’)
    print('Even')
else:
    print(‘’)
    print('Odd')
print(’Done with conditional')
```

SOME OBSERVATIONS

- The expression `x%2 == 0` evaluates to `True` when the remainder of `x` divided by `2` is `0`
- Note that `==` is used for comparison, since `=` is reserved for assignment
- The indentation is important – each indented set of expressions denotes a block of instructions
    - For example, if the last statement were indented, it would be executed as part of the `else` block of code
- Note how this indentation provides a visual structure that reflects the semantic structure of the program

NESTED CONDITIONALS

```
if x%2 == 0:
    if x%3 == 0:
        print('Divisible by 2 and 3')
    else:
        print('Divisible by 2 and not by 3')
elif x%3 == 0:
    print('Divisible by 3 and not by 2')
```

COMPOUND BOOLEANS

```
if x < y and x < z:
    print('x is least')
elif y < z:
    print('y is least')
else:
    print('z is least')
```

CONTROL FLOW - BRANCHING

```
if <condition>:
    <expression>
    <expression>
    ...
```

```
if <condition>:
    <expression>
    <expression>
    ...
else:
    <expression>
    <expression>
    ...
```

```
if <condition>:
    <expression>
    <expression>
    ...
elif <condition>:
    <expression>
    <expression>
    ...
else:
    <expression>
    <expression>
    ...
```

- `<condition>` has a value `True` or `False`
- evaluate expressions in that block if `<condition>` is `True`

INDENTATION

- matters in Python
- how you denote blocks of code

```
x = float(input("Enter a number for x: "))
y = float(input("Enter a number for y: "))
if x == y:
    print("x and y are equal”)
    if y != 0:
        print("therefore, x / y is", x/y)
elif x < y:
    print("x is smaller”)
else:
    print("y is smaller”)
print("thanks!”)
```

= VS ==

```
x = float(input("Enter a number for x: "))
y = float(input("Enter a number for y: "))
if x == y:
    print("x and y are equal”)
    if y != 0:
        print("therefore, x / y is", x/y)
elif x < y:
    print("x is smaller”)
else:
    print("y is smaller”)
print("thanks!”)
```

What if x = y here?
get a SyntaxError

WHAT HAVE WE ADDED?

- Branching programs allow us to make choices and do different things
- But still the case that at most, each statement gets executed once.
- So maximum time to run the program depends only on the length of the program
- These programs run in **constant time**