

# BU Summer Challenge 2

## Computer Science

Instructor: Karan Vombatkere  
July 2023





# Course Overview

1. **Computer Science basics** - What is Computer Science? Software vs. Hardware, What is an Algorithm? What tasks can be automated? Data representation, Abstractions
2. **Python programming** - Data types, variables, conditionals, loops, functions, classes, recursion
3. **Exposure to breadth of CS topics** - Artificial Intelligence, Algorithmic theory, Search and optimization, Natural Language Processing,

**Reference Book:** Algorithms to Live By (Brian Christian and Tom Griffiths)

**Group project - final presentations on July 21**

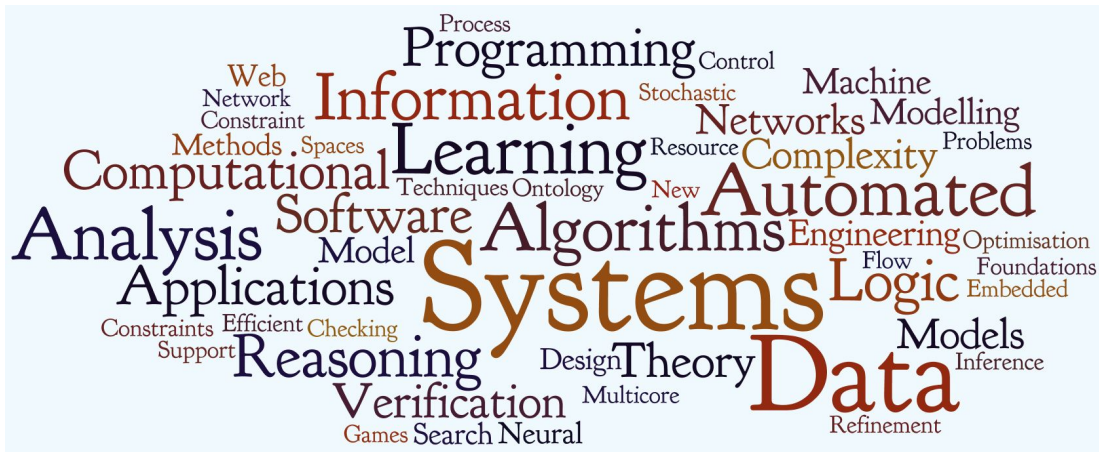
**No assignments or grades!**



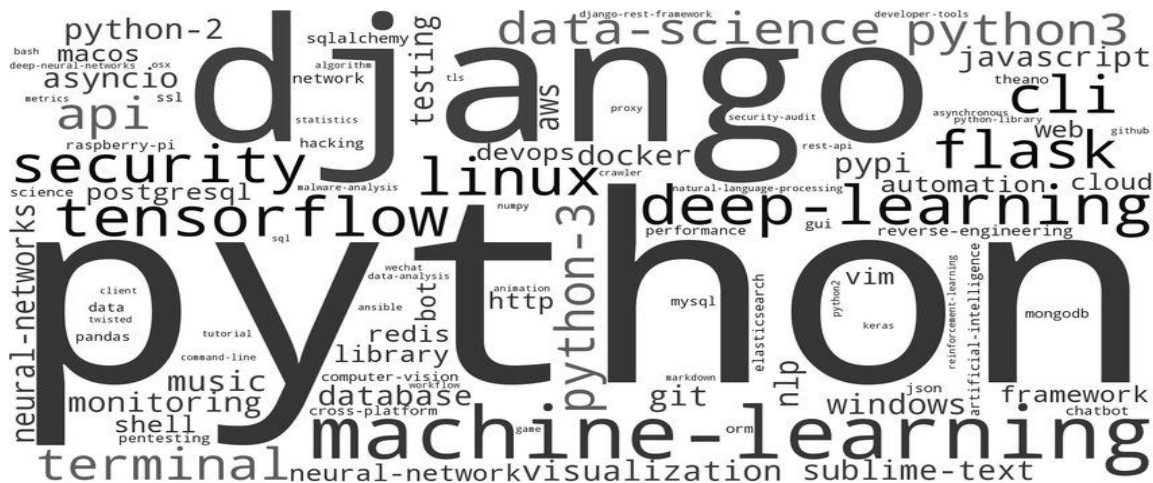
# Introductions + Group Activity

- Introduce yourself (name, class, hometown)
  - Why are you interested in this course?
  - Application of Computer Science that interests you
- 
- **Sorting Game**
    - Split into two groups and stand in a line.
    - You are only allowed to communicate with the person to your immediate left/right.
    - The goal is to sort yourselves in alphabetical order by first name.

# What is Computer Science?



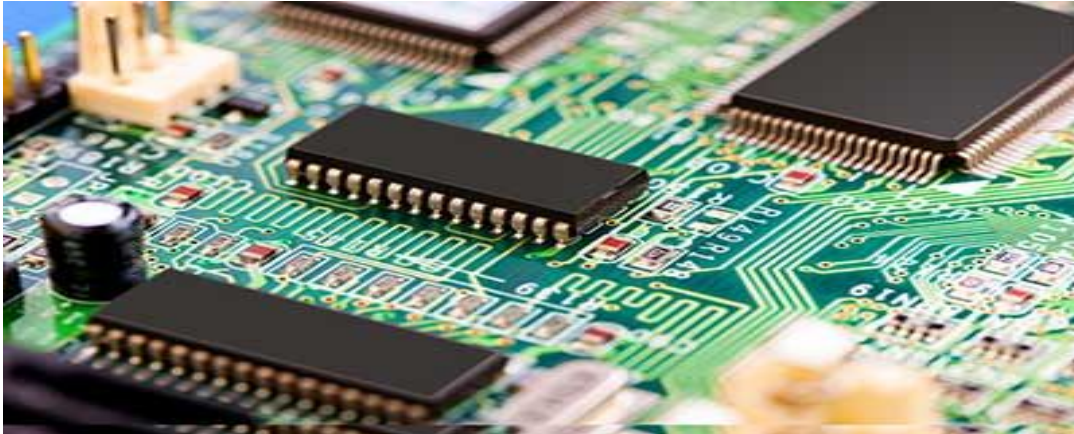
- Areas of Computer Science
- Software vs. Hardware
- Data and Representations
- Computation and algorithms



- Programming Languages
- Applications of Computer Science

# Computer Hardware

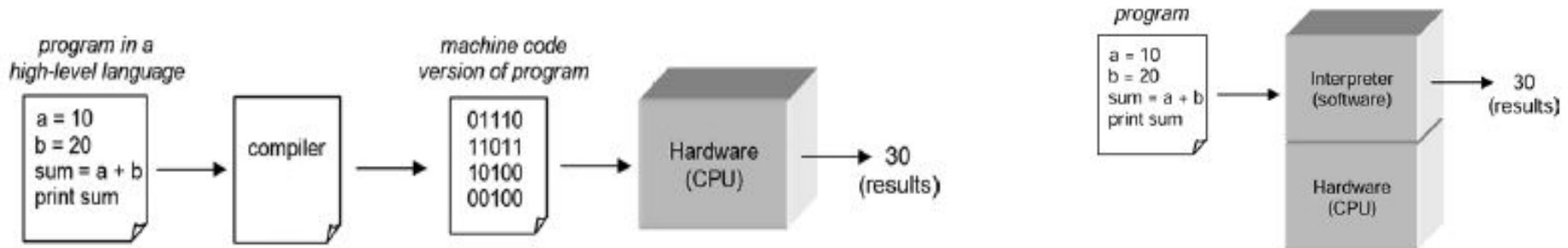
- Central Processing Unit and Main Memory
- Peripheral Components: Keyboard, Monitor, Printer
- Transistors and Integrated Circuits
  - Simple electronic ON/OFF switches





# Computer Software

- **Operating system:** Machine code, CPU
- **Low-level vs. High-level language**
- **Compilers and Interpreters**
  - *A compiler is a translator program that translates programs directly into machine code to be executed by the CPU. An interpreter executes program instructions in place of ("running on top of") the CPU.*
- **Syntax:** Set of characters and the acceptable sequences of those characters
- **Semantics:** Meaning associated with characters





# Representing Data - Digitization

- **Decimal system - Base 10**
  - Regular numbers with 9 digits
- **Binary System - Base 2**
  - ON/OFF switches - 0 or 1
  - **Bit:** Binary Digit
  - **Byte:** Group of bits, usually consisting of 8 bits

## Binary to Decimal

$2^{10}$	$2^9$	$2^8$	$2^7$	$2^6$	$2^5$	$2^4$	$2^3$	$2^2$	$2^1$	$2^0$
1024	512	256	128	64	32	16	8	4	2	1

				1	0	1	1	0	0	1
--	--	--	--	---	---	---	---	---	---	---

$$1011001_2 = 1 \times 64 + 1 \times 16 + 1 \times 8 + 1 \times 1 = 89$$



# Man, Cabbage, Goat, Wolf Problem





# Man, Cabbage, Goat, Wolf Problem

A man with a wolf, a goat, and a cabbage must cross a river by boat. The boat can carry only the man and a single item.

If left unattended together, the wolf would eat the goat, or the goat would eat the cabbage. How can they cross the river without anything being eaten?

- What is important and relevant?
- Representations and abstraction
- What is a solution?
  - Solution finding algorithm



# Computational Problem Solving

- **Problem:** what are we trying to solve? what is the goal?
- **Constraints:** what is allowed?
- **Representation:** capture all the relevant aspects of the problem
- **Algorithm:** technique to solve the problem
- **Time and Computational Resources:** can we solve it quickly?



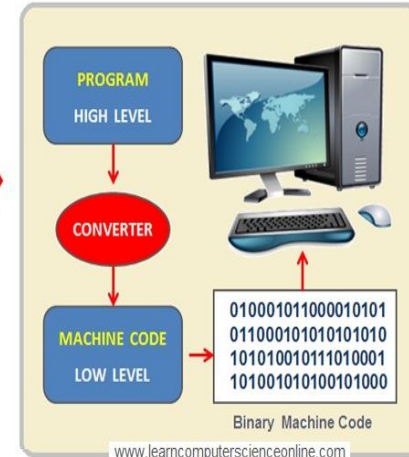
# Python Programming

- ★ All computer programs take some **input data**, **process the data** and then **output results**
- ★ **Variables:** A variable is a name that is assigned to a value.
- ★ **Data Types:** The three types of data most commonly used in Python are **int**, **float**, and **string**
- ★ **Operators:** Python supports arithmetic and logical operators like addition (+), subtraction (-), multiplication (\*) and exponentiation (\*\*).
- ★ **Input and Output:** The **input()** command can be used to obtain user input, and the **print()** function is used to output data.

## What is Computer Program ?

Computer Program :

```
int main()
{
    // Variable declaration
    int a, b, sum;
    // Take two numbers as input from the
    // user
    scanf("%d %d", &a, &b);
    // Add the numbers and assign the value
    // to some variable
    sum = a + b;
    // Use the calculated value
    printf("%d\n", sum);
    return 0;
    // End of program
}
```





# Python's Encoding Scheme

- Python uses the UTF-8, an 8-bit encoding scheme. For example, 'A' is encoded as **01000001 (65)** and 'a' is encoded as **01100001 (97)**.
- The **ord** function converts a character to its UTF-8 encoding (**ord('A') = 65**), and the **chr** function converts a number to its character encoding (**chr(97) = 'a'**)

Space	00100000	32	A	01000001	65
!	00100001	33	B	01000010	66
"	00100010	34	C	01000011	67
#	00100011	35	.		
.			.		
.			Z	01011010	90
0	00110000	48	a	01100001	97
1	00110001	49	b	01100010	98
2	00110010	50	c	01100011	99
.			.		
.			.		
9	00111001	57	z	01111010	122

Numeric Value	String Value
01111100	001100010011001000110100
<u>          </u>	<u>          </u> <u>          </u> <u>          </u>
124	'1' '2' '4'

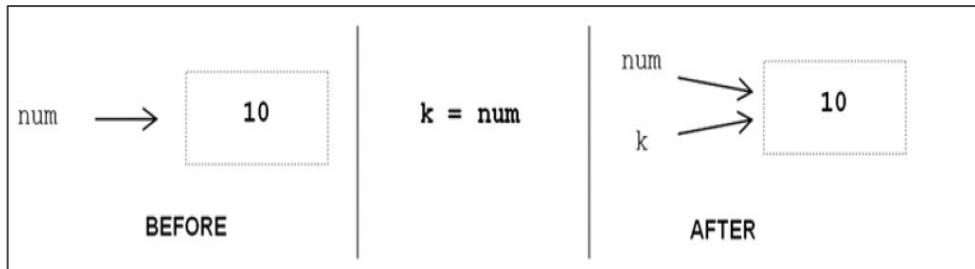
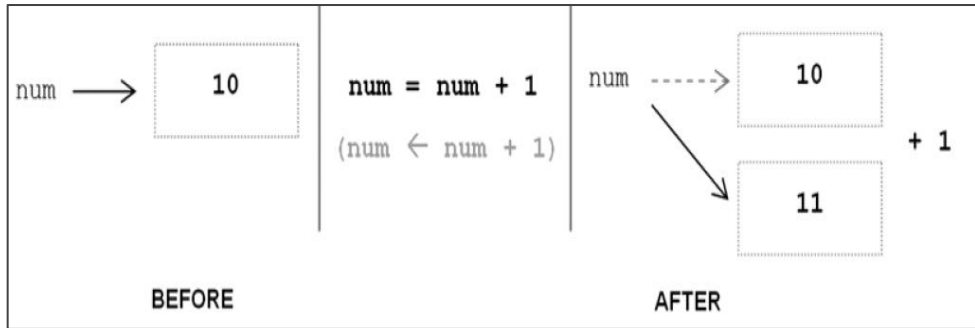


# Control Characters

- Special characters that are not displayed on the screen.
- *Control* the display of output
- Control characters do not have a corresponding keyboard character and represented by a combination of characters called an *escape sequence*.
- The backslash (\) serves as the escape character in Python.
- For example, the escape sequence '\n', represents the *newline control character*, used to begin a new screen line.

Escape Sequence	Meaning
\a	Bell
\b	Backspace
\f	Formfeed
\n	NewLine
\r	Carriage Return
\t	Horizontal Tab
\v	Vertical Tab
\newline	Backslash and NewLine Ignored

- ❖ A variable is a name (identifier) that is associated with a particular value.
- ❖ It can be assigned different values during a programs execution.
- ❖ Wherever a variable appears in a program (except on the left-hand side of an assignment statement), it is the value associated with the variable that is used , and not the variable's name.
- ❖ Variables are assigned values using the **assignment operator (=)**.
- ❖ Variables can be assigned to the values of other variables.





# Identifiers and Keywords

- ❖ An **Identifier** is a sequence of one or more characters used to provide a name for a given program element.

Valid Identifiers	Invalid Identifiers	Reason Invalid
totalSales	'totalSales'	quotes not allowed
totalsales	total sales	spaces not allowed
salesFor2010	2010Sales	cannot begin with a digit
sales_for_2010	_2010Sales	should not begin with an underscore

- ❖ A **Keyword** is an identifier that has a predefined meaning, and cannot be used as a regular identifier.

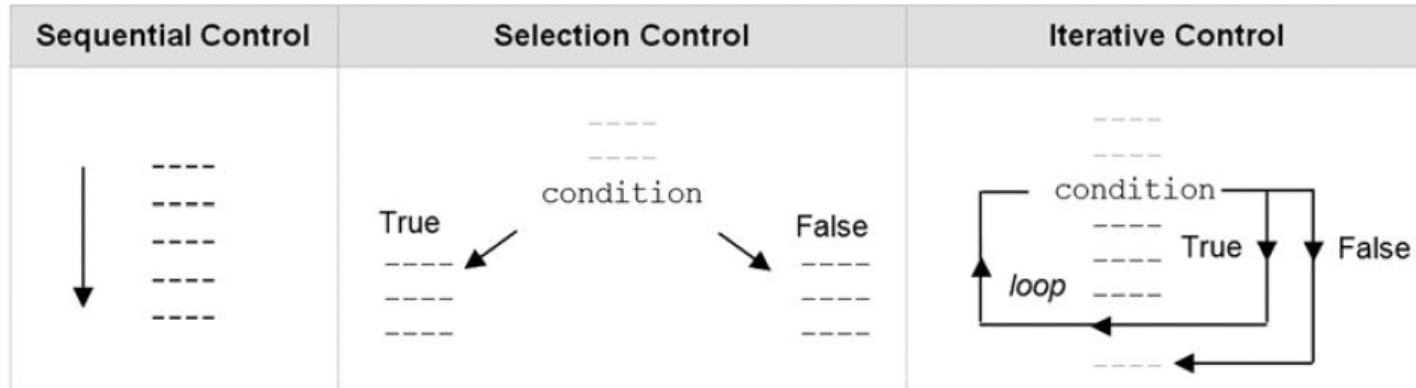
and	as	assert	break	class	continue	def
del	elif	else	except	finally	for	from
global	if	import	in	is	lambda	nonlocal
not	or	pass	raise	return	try	while
with	yield	false	none	true		





# Control Structures: Loops and Conditionals

- ❖ **Control flow** is the order that instructions are executed in a program. A control statement is a statement that determines the control flow of a set of instructions.
- ❖ There are three fundamental forms of control that programming languages provide—sequential control, selection control, and iterative control.





# Boolean Expressions (Conditions)

- ❖ The Boolean data type contains two Boolean values, denoted as **True** and **False** in Python.
- ❖ A Boolean expression is an expression that evaluates to a Boolean value. Boolean expressions are used to denote the conditions for selection and iterative control statements.

Relational Operators	Example	Result
<code>==</code> equal	<code>10 == 10</code>	True
<code>!=</code> not equal	<code>10 != 10</code>	False
<code>&lt;</code> less than	<code>10 &lt; 20</code>	True
<code>&gt;</code> greater than	<code>'Alan' &gt; 'Brenda'</code>	False
<code>&lt;=</code> less than or equal to	<code>10 &lt;= 10</code>	True
<code>&gt;=</code> greater than or equal to	<code>'A' &gt;= 'D'</code>	False



# If-Else Statements

- ❖ An if statement is a selection control statement based on the value of a given Boolean expression.
- ❖ One fairly unique aspect of Python is that the amount of indentation of each program line is significant - indentation is used to associate and group statements

if statement	Example use	
<pre>if condition:     statements else:     statements</pre>	<pre>if grade &gt;= 70:     print('passing grade') else:     print('failing grade')</pre>	<pre>if grade == 100:     print('perfect score!')</pre>



# If-Else Statements

First **clause**  
of if statement

```
if which == 'F':
```

**header**

```
    converted_temp = (temp - 32) * 5/9  
    print(temp, 'degrees Fahrenheit equals',  
          converted_temp, 'degrees Celsius')
```

**suite**

Second **clause**  
of if statement

```
else:
```

**header**

```
    converted_temp = (9/5 * temp) + 32  
  
    print(temp, 'degrees Celsius equals',  
          converted_temp, 'degrees Fahrenheit')
```

**suite**

# If-Else Statements

Valid indentation		Invalid indentation	
(a) <pre>if condition:     statement     statement else:     statement     statement</pre>	(b) <pre>if condition:     statement     statement else:     statement     statement</pre>	(c) <pre>if condition:     statement     statement else:     statement     statement</pre>	(d) <pre>if condition:     statement     statement else:     statement     statement</pre>

Nested if statements	Example use
<pre>if condition:     statements else:     if condition:         statements     else:         if condition:             statements         etc.</pre>	<pre>if grade &gt;= 90:     print('Grade of A') else:     if grade &gt;= 80:         print('Grade of B')     else:         if grade &gt;= 70:             print('Grade of C')         else:             if grade &gt;= 60:                 print('Grade of D')             else:                 print('Grade of F')</pre>



# While Loops

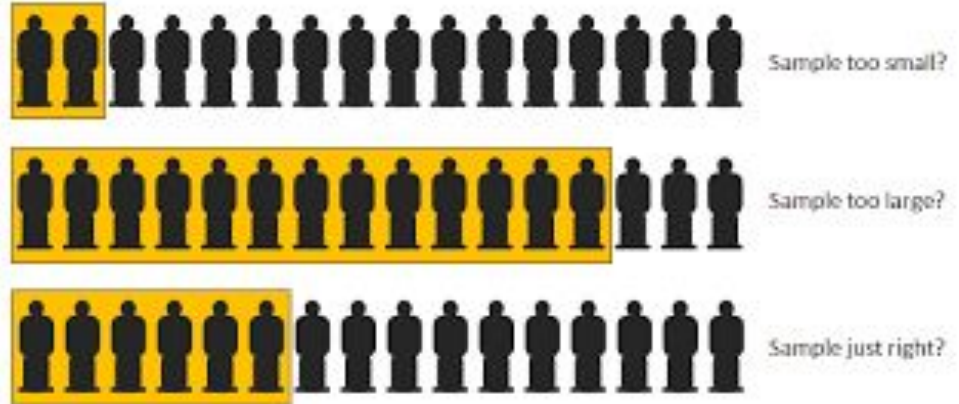
A **while** statement is an iterative control statement that repeatedly executes a set of statements based on a provided Boolean expression (condition). All iterative control needed in a program can be achieved by use of the while statement.

while statement	Example use
<pre>while condition:     suite</pre>	<pre>sum = 0 current = 1  n = int(input('Enter value: '))  while current &lt;= n:     sum = sum + current     current = current + 1</pre>



# Optimal Stopping

- ❖ **Secretary Problem:** Group Activity
- ❖ Finding a Fiance
- ❖ Parking a Car
- ❖ House Selling



Why is decision making hard?

What assumptions do we have in each of these problems?

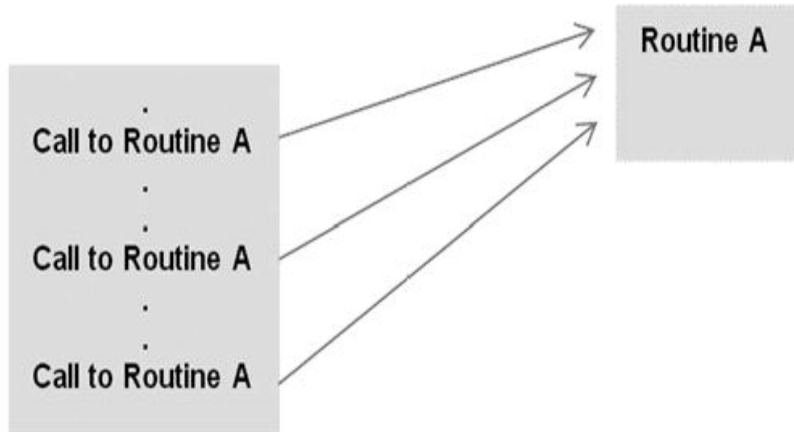
Why do people usually stop earlier?

[Numberphile Video](#)



# Python Functions

A **program routine** is a named group of instructions that accomplishes some task. A routine may be invoked (called) as many times as needed in a given program. A **function** is Python's version of a program routine.



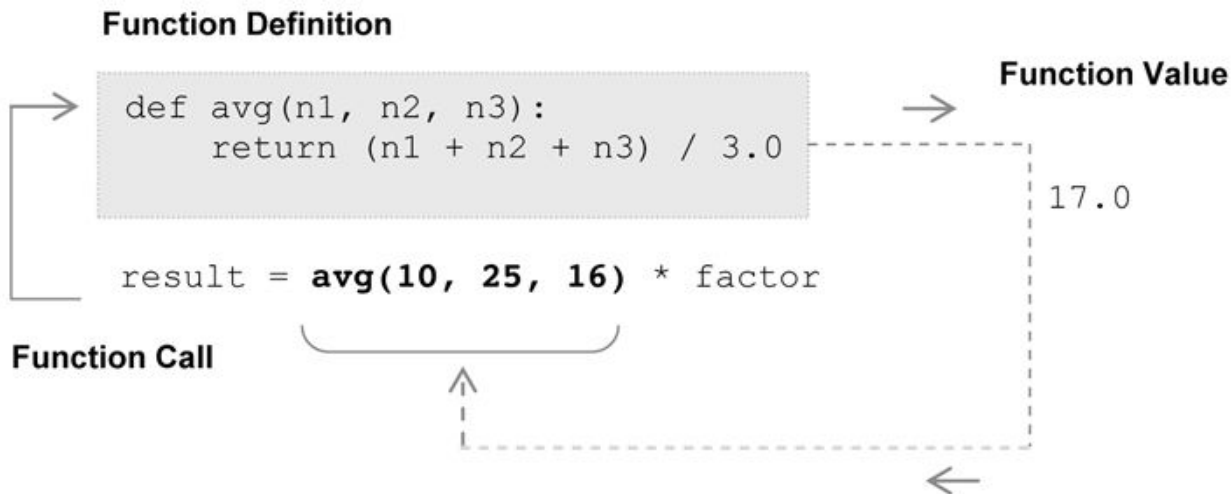
Function Header ➤ `def avg (n1, n2, n3) :`  
Function Body (suite) ➤ `{`  
`-----`  
`-----`  
`-----`  
`-----`  
`}`





# Python Functions

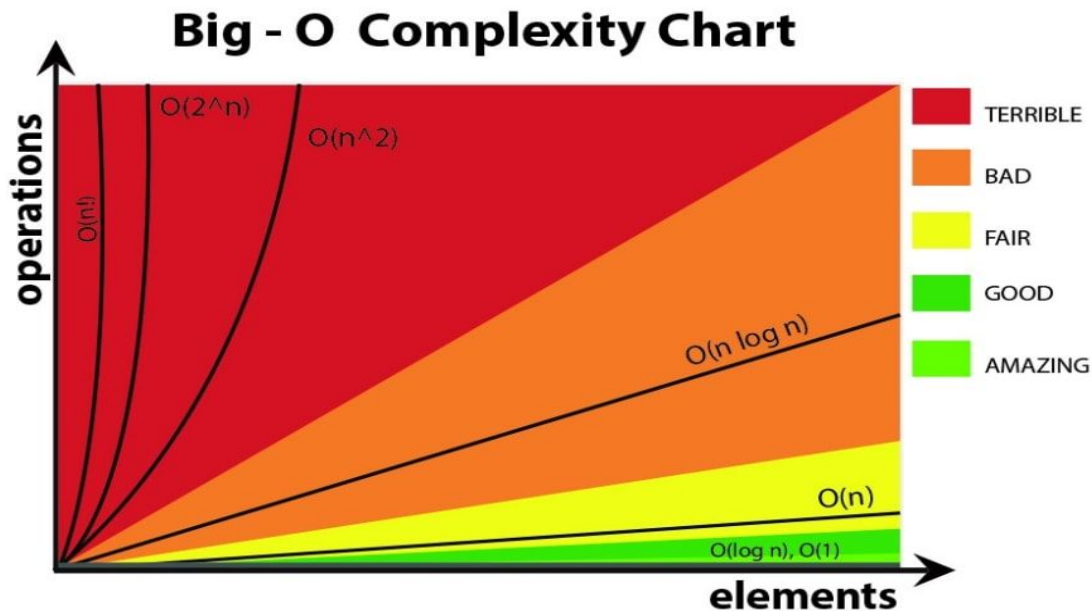
**Arguments** are the values passed to functions to be operated on. Parameters are the “placeholder” names for the arguments passed.





# Sorting

- ❖ Why is sorting important?
- ❖ Examples of sorting
- ❖ Algorithmic time complexity
  - Efficiency
  - Big-O Notation

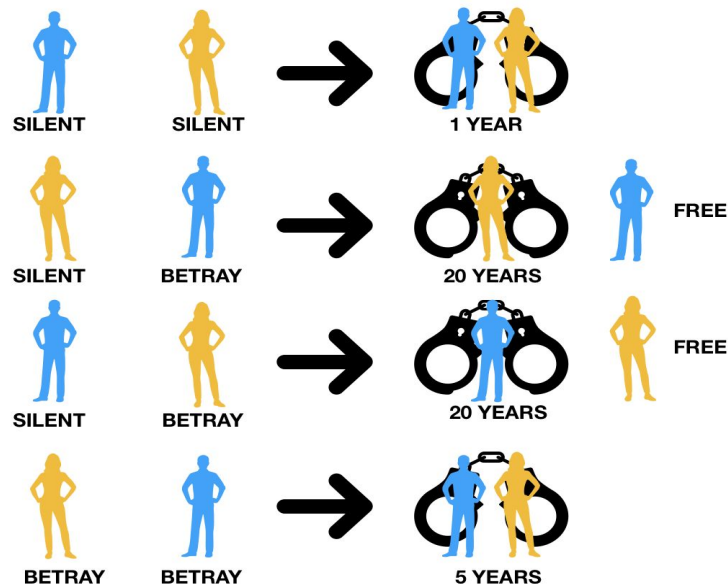




# Game Theory

- ❖ Two-player zero-sum games
  - Tic Tac Toe
  - Chess
- ❖ Equilibrium and dominant strategies
  - **Prisoner's Dilemma**
  - Rock-paper-scissors
- ❖ Tragedy of the Commons
- ❖ Algorithmic Game Theory
  - Cooperation vs. Competition
  - Selfish-routing

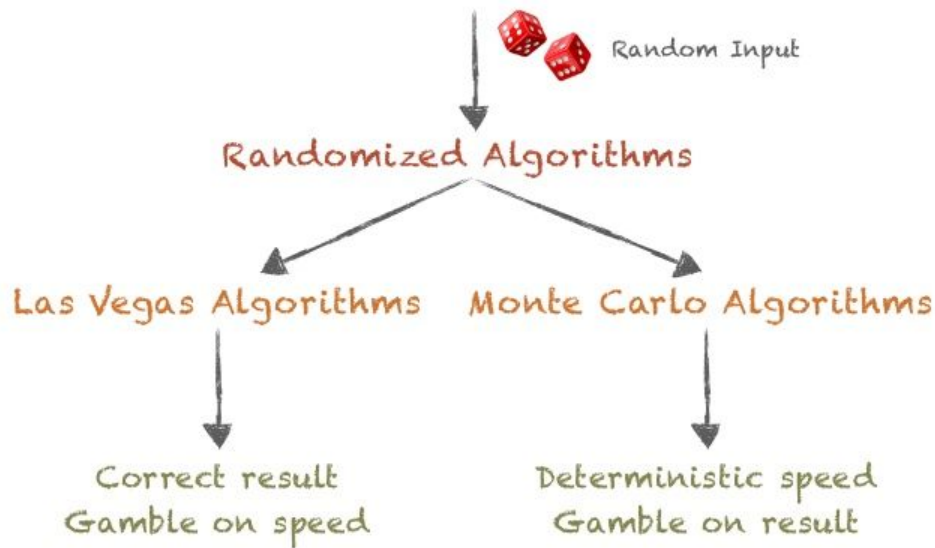
## PRISONER'S DILEMMA





# Randomness

- ❖ A **randomized algorithm** is one that uses a random number to solve a problem.
- ❖ Monte Carlo vs. Las Vegas Algorithms
  - Correctness vs. Running time
- ❖ Median Finding
- ❖ Random Graph Models





# Probability - Bayes' Rule

- ❖ Conditional Probability
- ❖ Prior Beliefs
- ❖ [3Blue1Brown Video](#)

## LIKELIHOOD

The probability of "B" being True, given "A" is True

## PRIOR

The probability "A" being True. This is the knowledge.

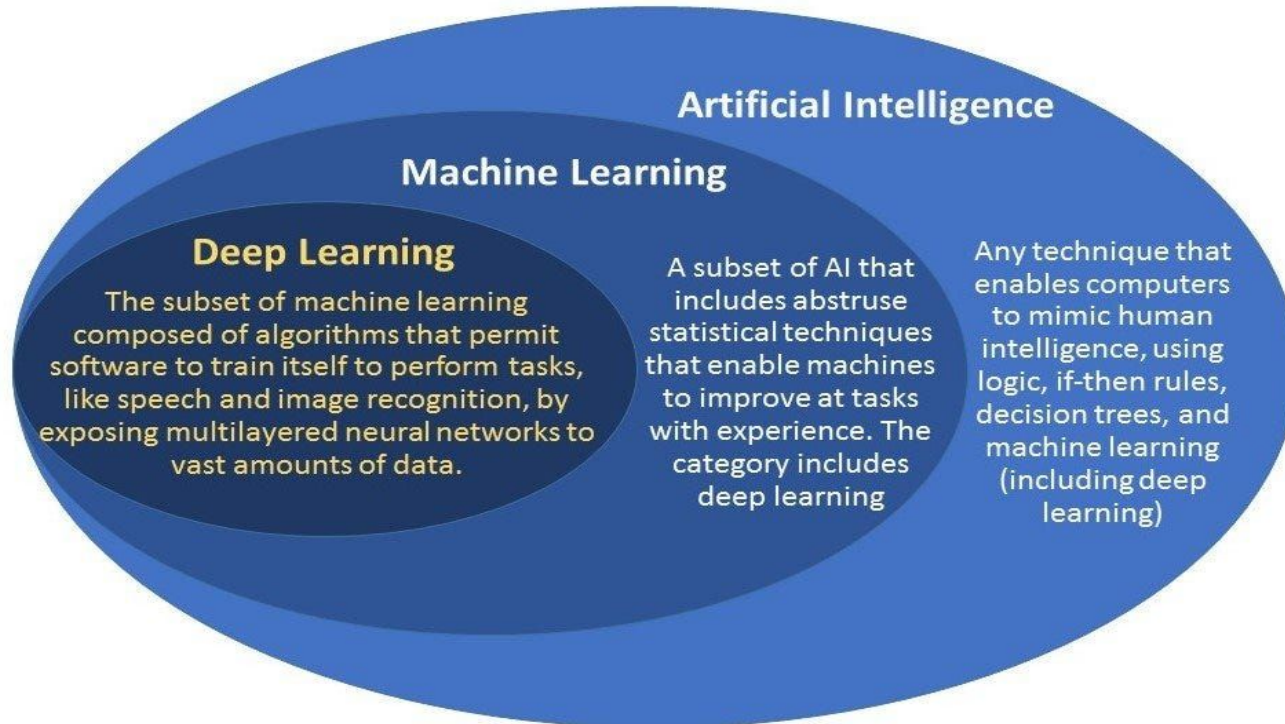
$$P(A|B) = \frac{P(B|A).P(A)}{P(B)}$$

**POSTERIOR**  
The probability of "A" being True, given "B" is True

**MARGINALIZATION**  
The probability "B" being True.



# Artificial Intelligence and Machine Learning



# Artificial Intelligence and Machine Learning

