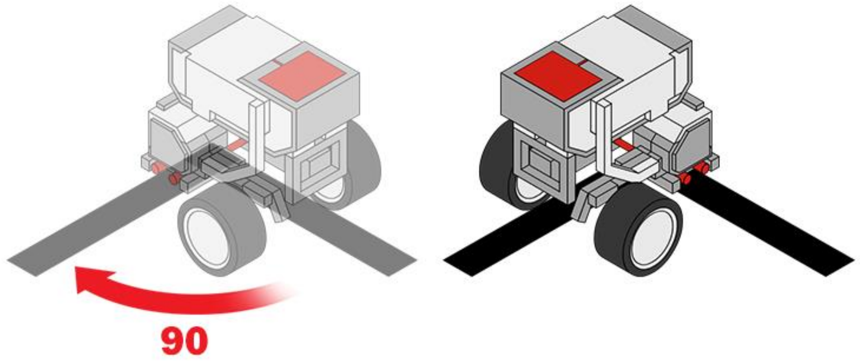
CHAPTER 2
ELEMENTARY PROGRAMMING

ACKNOWLEDGEMENT: THESE SLIDES ARE ADAPTED FROM SLIDES PROVIDED WITH INTRODUCTION TO PROGRAMMING USING PYTHON, LIANG (PEARSON 2013)

NEXT STEP IN PROGRAMMING

- Computations! Support for basic mathematics
- Imagine, computing interest on a loan, dividend on a stock, or even computing an angle to go to a specific location
- Here we make variables that store data and then alter those values which are stored.



EXAMPLE: COMPUTING THE AREA

ComputeArea.py

```
# Assign a value to radius
radius = 20

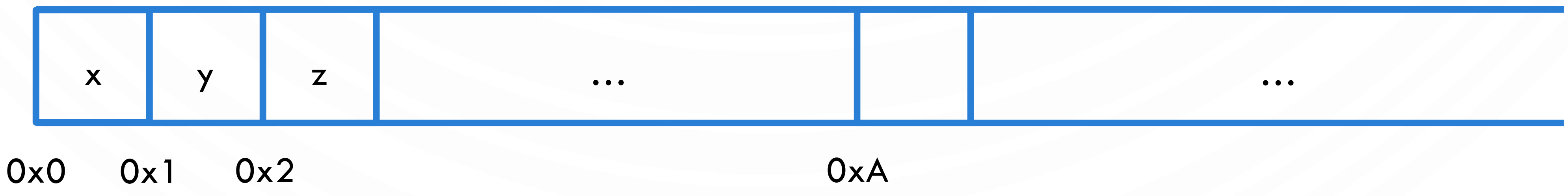
# Compute the area
area = radius * radius * 3.14159

# Display the result
print("The area for a circle with radius",
        radius, "is", area)
```

Lets practice tracing, but first a note on memory

MEMORY

- **Memory** is storage for data and programs
- We will pretend that memory is an infinitely long piece of **tape** separated into different **cells**
- Each cell has an **address**, i.e., a location, and a **value**
- In the computer these values are represented in **binary** (0s and 1s) and addresses are located in **hexadecimal** (base 16, 0x)



EXAMPLE: COMPUTING THE AREA

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radius = 20

# Compute the area
area = radius * radius * 3.14159

# Display the result
print("The area for a circle with radius",
        radius, "is", area)
```

Output

```
The area for a circle with
radius 20 is 1256.636
```

Memory

```
radius: 20
area:   1256.636
```

A special symbol = gives a value to a variable, called assignment.

Actually operations are evaluated in a specific order. Temporary values are stored for these intermediate computations.

`print` can output a series of values separated by a comma. Each value is separated by a space in the output

READING INPUT FROM THE CONSOLE

ComputeArea.py

```
# Assign a value to radius
radius = eval(input("Enter a value for a radius: "))

# Compute the area
area = radius * radius * 3.14159

# Display the result
print("The area for a circle with radius",
      radius, "is", area)
```

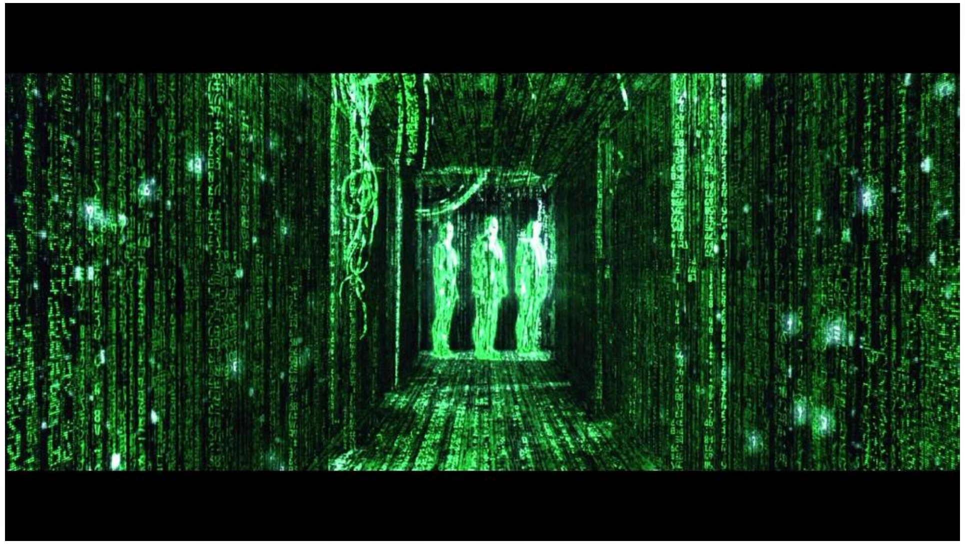
input is a function to collect key strokes from the console

eval is a function that converts those key strokes to a value

REPRESENTING DATA

WHAT ABOUT THE 0S AND 1S?

- Yes, computers operate in 0s and 1s. The python interpreter handles this business for us, but memory also stores values as 0s and 1s
- Memory also stores entirely 0s and 1s
- So what we need to know is how computers do this



INTEGER REPRESENTATION

- First, a look at our number system. It is base 10, meaning we use 10 different symbols (the digits). Lets look at an example number: 1037.

1	0	3	7
$10^3 = 1000$	$10^2 = 100$	$10^1 = 10$	$10^0 = 1$
$1 * 10^3 +$	$0 * 10^2 +$	$3 * 10^1 +$	$7 * 10^0 = 1037$

- And adding we use carry-and-add

	1	0	3	7
+	0	0	4	9
	1	0	8	6

INTEGER REPRESENTATION

- Synonymously, binary numbers work the same way. Except instead of base 10, it is base 2. A digit can only be 0 or 1. Example: 0010 0101

0	0	1	0	0	1	0	1
$2^7 = 128$	$2^6 = 64$	$2^5 = 32$	$2^4 = 16$	$2^3 = 8$	$2^2 = 4$	$2^1 = 2$	$2^0 = 1$
$0 * 2^7 +$	$0 * 2^6 +$	$1 * 2^5 +$	$0 * 2^4 +$	$0 * 2^3 +$	$1 * 2^2 +$	$0 * 2^1 +$	$1 * 2^0 = 37$

- And adding 0010 1010 + 0000 0101

	0	0	1	0	0	1	0	1
+	0	0	0	0	0	1	0	1
	0	0	1	0	1	0	1	0

- Note there are other common number systems: Octal (base 8, digits 0-7) and Hexadecimal (base 16, digits 0-9 and A-F, used for memory addresses)

INTEGER REPRESENTATION

- By limiting the number of bits, we limit the expressiveness of the data type
  - Means that if we only have 2 bits, we can only represent 4 numbers: 00, 01, 10, 11
- A 64 bit number can only represent values from $[-2^{64}, 2^{64})$
- In programming, we must make conscious decisions about this otherwise there can be severe consequences

DATA TYPES

- Overall, data types define the available operations on and range of the data representation. Additionally, it notes how it is stored in memory.
- Right now we have seen:
  - Strings – sequences of characters, e.g., `"Hello"`
  - Floating point numbers – representing real numbers with fractional components, e.g., `3.54`
  - Integers – representing positive and negative whole numbers, e.g., `15`
- I want you to know about these, even though python will hide them from you and treat them fluidly

ACTIVITY

- With a partner
- Convert the binary number 1001 1001 to decimal
- Add the binary number 0101 0101 to 1001 1001 (DO NOT DO THIS IN DECIMAL) and then convert to a decimal number
- Bonus: 0xA1 to decimal, add 0x0E to it and convert to decimal. Hint: 0x means that the number is a hexadecimal (base 16)

VARIABLES AND NAMING

IDENTIFIERS (NAMES)

- An **identifier** is a sequence of characters that consist of letters, digits, underscores (_), and asterisk (*).
- An identifier must start with a letter or an underscore (_).
- An identifier cannot be a reserved word. (See Appendix A, "Python Keywords," for a list of reserved words).
- An identifier can be of any length.

VARIABLES

- A **variable** is a named piece of data (memory). It stores a **value**!
- It has a **type** that defines how the memory is interpreted and what operations are allowed

```
var = value
```

EXPRESSIONS

- **Expressions** are combinations of literals, variables, operations, and function calls that generate new values
- $\frac{3+4x}{5} - \frac{10(y-5)(a+b+c)}{x} + 9\left(\frac{4}{x} + \frac{9+x}{y}\right)$
- is translated to
- `(3+4*x)/5 - 10*(y-5)*(a+b+c)/x + 9*(4/x + (9+x)/y)`

ASSIGNMENT STATEMENTS

- Assignment statements give values to a variable
- `x = 1;                // Assign 1 to x;`
- `radius = 1.0;     // Assign 1.0 to radius;`
- `a = 'A';            // Assign 'A' to a;`

SIMULTANEOUS ASSIGNMENT

- Python allows a shorthand to create/assign multiple variables at a time. Variables and expressions will be comma separated. An example:

```
x, y = (a+b)/2, (a-b)/2
```

NAMED CONSTANTS

- Often, we need constants in programs, e.g., π., whose value never changes.
- Python does not have a special syntax for naming constants. You can simply create a variable to denote a constant. To distinguish a constant from a variable, use all uppercase letters to name a constant.

- `PI = 3.14159`
- `SIZE = 3`

NAMING CONVENTIONS

- Choose meaningful and descriptive names.
- Typically begin with lower case
- Python typically names with underscores separating words (snake casing), but other styles capitalize the first letter of each subsequent word (camel casing):
  - `my_area_variable`
  - `myAreaVariable`
- Constants will be all caps using snake casing: `MY_PI_CONSTANT`
- Be consistent!

LITERALS

- A **literal** is a constant value that appears directly in the program. For example, 34, 1,000,000, and 5.0 are literals in the following statements:

- `i = 34`
- `x = 1000000`
- `d = 5.0`

SCIENTIFIC NOTATION

- Floating-point literals can also be specified in scientific notation, for example, 1.23456e+2, same as 1.23456e2, is equivalent to 123.456, and 1.23456e-2 is equivalent to 0.0123456. E (or e) represents an exponent and it can be either in lowercase or uppercase.

EXPRESSIONS

NUMERIC OPERATORS

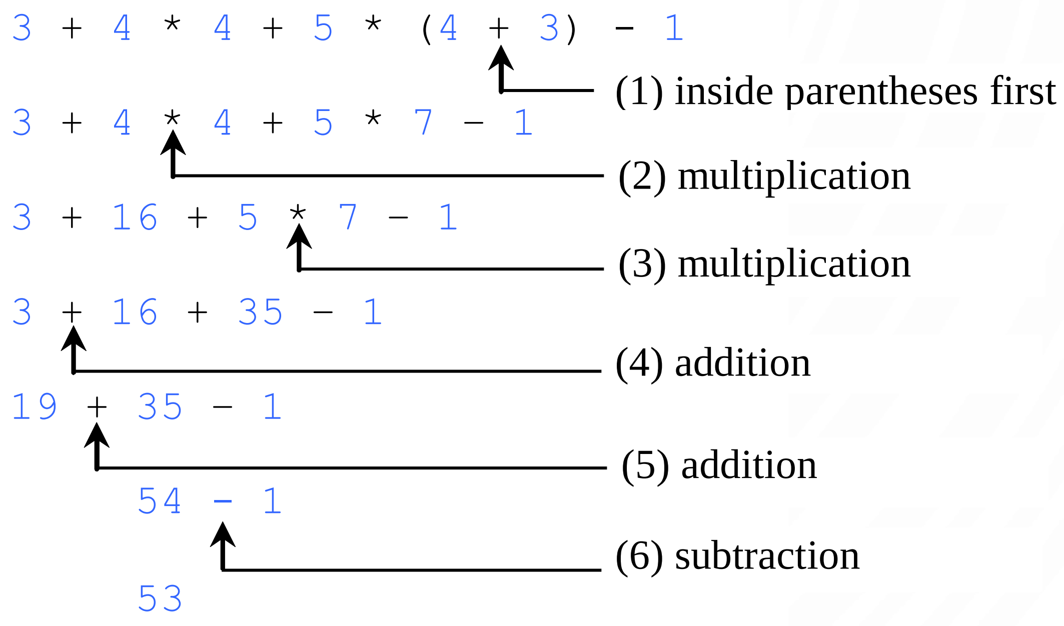
Name	Meaning	Example	Result
+	Addition	34 + 1	35
-	Subtraction	34.0 – 0.1	33.9
*	Multiplication	300 * 30	9000
/	Float Division	1 / 2	0.5
//	Integer Division	1 // 2	0
**	Exponentiation	4 ** 0.5	2.0
%	Remainder	20 % 3	2

INTEGERS DIVISION

- Integers do not store decimals
- Division computes how many times a divisor evenly goes into a number
- Remainder (modulus) computes what is left over
- 5 / 2 yields an integer 2
- 5 % 2 yields 1 (the remainder of the division)
- Practice:
  - What is 3456421 % 2?
  - 25%3?
  - 87%4?

HOW TO EVALUATE AN EXPRESSION

- Though Python has its own way to evaluate an expression behind the scene, the result of a Python expression and its corresponding arithmetic expression are the same.
- Therefore, you can safely apply the arithmetic rules for evaluating a Python expression.



UNDERFLOW AND OVERFLOW

- When a floating-point variable is assigned a value that is too large (in size) to be stored, it causes overflow, a run time exception. Example:
  245 ** 1000
- When a floating-point number is too small (i.e., too close to zero) to be stored, it causes underflow. Python approximates it to zero. So normally you should not be concerned with underflow.
- Questions
  - Why does overflow/underflow occur?
  - What types of applications would we care about them?

EXERCISE

- Write a program to compute the average of three numbers
- Trace the execution in memory if the user enters 3, 5, 7

AUGMENTED ASSIGNMENT OPERATORS

Operator	Name	Example	Equivalent
+=	Addition assignment	i += 8	i = i + 8
-=	Subtraction assignment	i -= 8	i = i - 8
*=	Multiplication assignment	i *= 8	i = i * 8
/=	Float division assignment	i /= 8	i = i / 8
//=	Integer division assignment	i //= 8	i = i // 8
%=	Remainder assignment	i %= 8	i = i % 8
**=	Exponent assignmnet	i **= 8	i = i ** 8

TYPE CONVERSION

TYPE CONVERSION

- Use `int()`, `float()`, `str()` to convert any type to integer, floating-point, or string respectively
- Consider the following statements and their results:
  - `int(4.7)` → 4
  - `float(4)` → 4.0
  - `str(4)` → "4"
- To round floating point numbers use round()
  - `round(4.7)` → 5

EXERCISE

- Write a program to compute sales tax for a purchase.
- How could you alter your program to only store 2 decimal places? Try it!
- Trace your program with a purchase of $100

EXERCISE

- With turtle graphics:
  - Write a program that asks the user to enter an (x, y) coordinate representing the center of a rectangle. Additionally, ask the width and height of the rectangle.
  - Draw the rectangle.

CHAPTER 3
MATH, STRINGS, AND OBJECTS

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MATH MODULE

- Python provides many useful mathematics methods in its Math module for performing common mathematical functions.
- In order to use them we need to understand:
  - What a function is
  - How to use functions
  - Where we look up possible functions to use

EXAMPLES OF MATH MODULE

```
max(2, 3, 4) # Returns a maximum number : in this case 4
min(2, 3, 4) # Returns a minimum number : in this case 2
round(3.51)  # Rounds to its nearest integer
round(3.4)   # Rounds to its nearest integer
abs(-3)      # Returns the absolute value
pow(2, 3)    # Same as 2 ** 3
```

THE MATH FUNCTIONS

Function	Description	Example
fabs(x)	Returns the absolute value of the argument.	fabs(-2) is 2
ceil(x)	Rounds x up to its nearest integer and returns this integer.	ceil(2.1) is 3 ceil(-2.1) is -2
floor(x)	Rounds x down to its nearest integer and returns this integer.	floor(2.1) is 2 floor(-2.1) is -3
exp(x)	Returns the exponential function of x (e^x).	exp(1) is 2.71828
log(x)	Returns the natural logarithm of x.	log(2.71828) is 1.0
log(x, base)	Returns the logarithm of x for the specified base.	log10(10, 10) is 1
sqrt(x)	Returns the square root of x.	sqrt(4.0) is 2
sin(x)	Returns the sine of x. x represents an angle in radians.	sin(3.14159 / 2) is 1 sin(3.14159) is 0
asin(x)	Returns the angle in radians for the inverse of sine.	asin(1.0) is 1.57 asin(0.5) is 0.523599
cos(x)	Returns the cosine of x. x represents an angle in radians.	cos(3.14159 / 2) is 0 cos(3.14159) is -1
acos(x)	Returns the angle in radians for the inverse of cosine.	acos(1.0) is 0 acos(0.5) is 1.0472
tan(x)	Returns the tangent of x. x represents an angle in radians.	tan(3.14159 / 4) is 1 tan(0.0) is 0
fmod(x, y)	Returns the remainder of x/y as double.	fmod(2.4, 1.3) is 1.1
degrees(x)	Converts angle x from radians to degrees	degrees(1.57) is 90
radians(x)	Converts angle x from degrees to radians	radians(90) is 1.57

STRINGS AND CHARACTERS

- A string is a sequence of characters. String literals can be enclosed in matching single quotes (') or double quotes ("). Python does not have a data type for characters. A single-character string represents a character.
- Strings have many methods to use to manipulate their data

```
Letter  = 'A'             # Same as letter = "A"
numChar = '4'             # Same as numChar = "4"
message = "Good morning" # Same as message = 'Good morning'
```

THE STRING CONCATENATION OPERATOR

- You can use the + operator add two numbers. The + operator can also be used to concatenate (combine) two strings. Here are some examples:
- `message = "Welcome " + "to " + "Python"`

READING STRINGS FROM THE CONSOLE

- To read a string from the console, use the input function. For example, the following code reads three strings from the keyboard:

- `s = input("Enter a string: ")`
- `print("s is " + s)`

EXAMPLES OF STRING OBJECT METHODS

- `s = "Welcome"`
- `s1 = s.lower() # Invoke the lower method, stores 'welcome'`
- `s2 = s.upper() # Invoke the upper method, stores 'WELCOME'`

STRIPING BEGINNING AND ENDING WHITESPACE CHARACTERS

- Another useful string method is strip(), which can be used to strip the whitespace characters from the both ends of a string.
- `s = "\t    Welcome      \n"`
- `s1 = s.strip() # Invoke the strip method, s1 stores 'Welcome'`

METHODS

- **Methods** are subroutines that we would like to (re)use again and again in code
- For example, would you like a method to compute $\sqrt{x}$ or write a lengthy algorithm every time you wish to use it?
- Python provides many useful methods. Some we have seen:
  - `print()`, `input()`, `round()`

INTERPRETING FUNCTIONS/METHODS

- Consider the following from the **`Math`** library:

  `sqrt(x)`

- `sqrt` is an *identifier*, i.e., a name, for this method
- `x` is called a **parameter**, or an **argument**. This is the *input* to the method.
- Methods can optionally *output* data too, in this case it will output a number.
- In a few weeks, we will learn to write our own methods. For now, we need to know how to use them.

INTRODUCTION TO OBJECTS AND METHODS

- In Python, all data—including numbers and strings—are actually objects.
- An object is an entity. Each object has an id and a type. Objects of the same kind have the same type. You can use the id function and type function to get these information for an object.

INVOKING A METHOD

- There is a difference between these math functions and how we used **`turtle`**
- Methods sometimes depend on the value of an object/class and sometimes they do not. Common math functions, like `sqrt`, do not need to know anything besides the parameter. However, other things like turtle needs to know where the turtle currently is, so we invoke methods from a variable instead:
- `turtle.forward(100) //Use the variable`

FORMATTING NUMBERS AND STRINGS

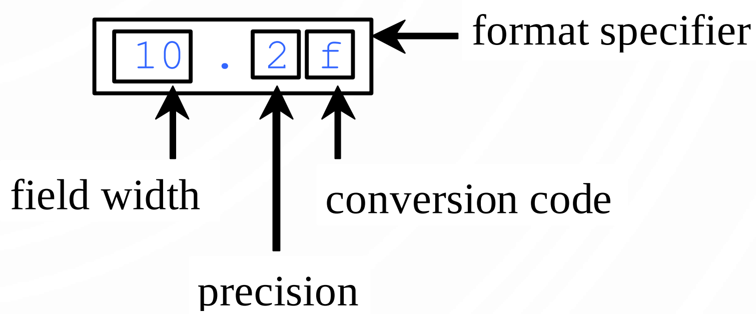
- Often it is desirable to display numbers in certain format. For example, the following code computes the interest, given the amount and the annual interest rate.
- The format function formats a number or a string and returns a string.

```
format(item, format-specifier)
```

FORMATTING FLOATING-POINT NUMBERS

```python
format(57.467657, '10.2f')
format(12345678.923, '10.2f')
format(57.4, '10.2f')
format(57, '10.2f')
```


```
     57.47
12345678.92
     57.40
     57.00
```



FORMATTING IN SCIENTIFIC NOTATION

- If you change the conversion code from f to e, the number will be formatted in scientific notation. For example

```
format(57.467657, '10.2e')
format(0.0033923, '10.2e')
format(57.4, '10.2e')
format(57, '10.2e')
```

```
|←   10   →|
□□5.75e+01
□□3.39e-03
□□5.74e+01
□□5.70e+01
```

FORMATTING AS A PERCENTAGE

- You can use the conversion code % to format numbers as a percentage. For example,

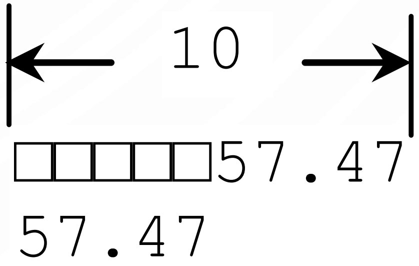
```
format(0.53457, '10.2%')
format(0.0033923, '10.2%')
format(7.4, '10.2%')
format(57, '10.2%')
```

```
|←  10  →|
□□□□53.46%
□□□□□0.34%
□□□740.00%
□□5700.00%
```

JUSTIFYING FORMAT

- By default, the format is right justified. You can put the symbol < in the format specifier to specify that the item is a left justified in the resulting format within the specified width. For example,

```
format(57.467657, '10.2f')
format(57.467657, '<10.2f')
```



FORMATTING STRINGS

- You can use the conversion code s to format a string with a specified width.

  For example,

```
format("Welcome to Python", '20s')
format("Welcome to Python", '<20s')
format("Welcome to Python", '>20s')
```

```
20
Welcome to Python
Welcome to Python
□□□Welcome to Python
```

EXERCISE

- Recall there is more information online and in your book
- I assume you know what is in Ch. 3 of your book
- Write a program that prompts the user to enter a side length and an angle from $(0°, 90°)$ and draws a right triangle accordingly. Label each side length and each angle using the turtle module.