APS106

UNIVERSITY OF TORONTO

writing your own function.

Week 2 | Lecture 2 (2.2)

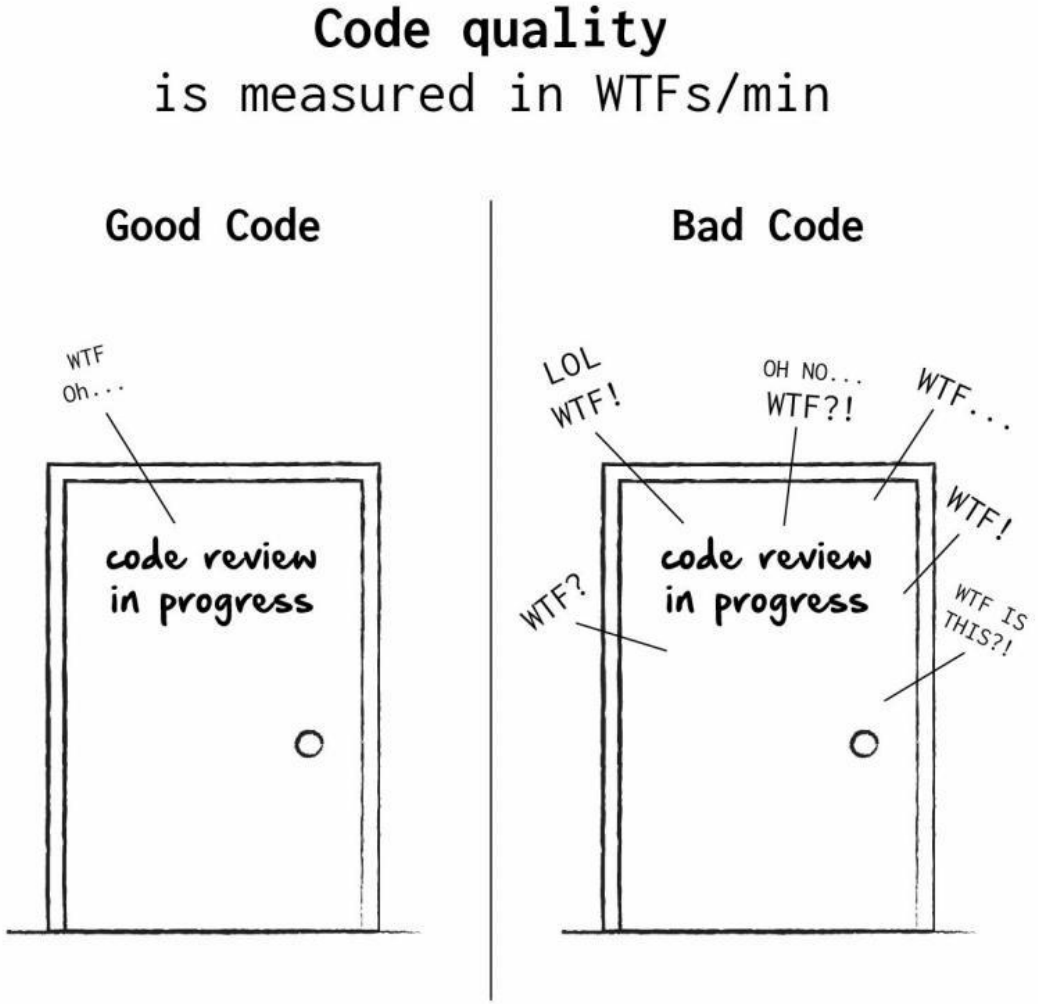
if nothing else, write #cleancode

This Week's Content

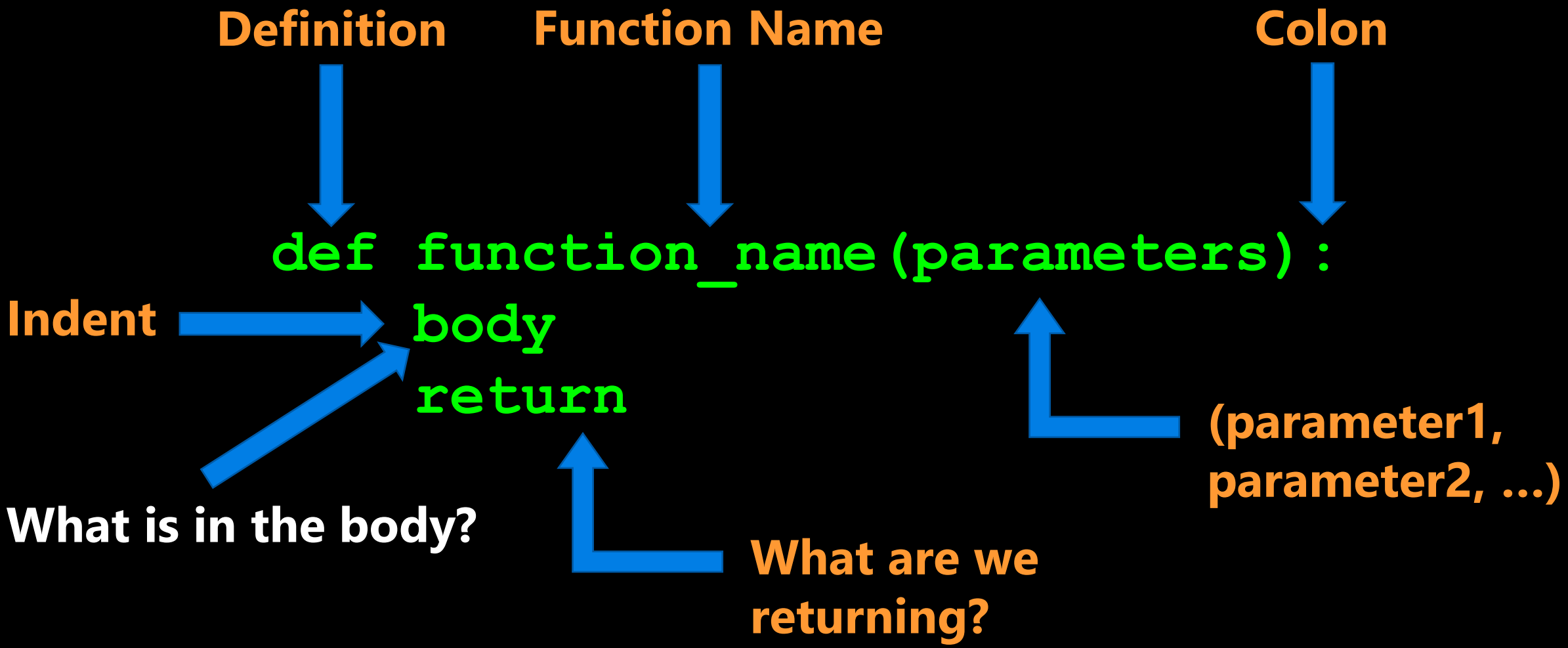
- **Lecture 2.1**
  - Functions, input & output, importing modules
  - Reading: Chapter 3
- **Lecture 2.2**
  - **Defining your own function**
  - **Reading: Chapter 3**
- **Lecture 2.3**
  - Engineering design
  - Design Problem: Forward Kinematics

Defining Your Own Functions

- The real power of functions is in defining your own.
- Good programs typically consist of many small functions that call each other.
- If you have a function that does **only one thing** (like calculate the sine of an angle), it is likely not too large.
- If its not too large, it will be easy to test and maintain.



Function Definitions



Function Definitions

```
def function_body(parameters):
    body
```

- **def** - is a keyword, standing for "definition". All function definitions must begin with **def**. The **def** statement must end with a colon.
- **function_name** - is the name you will use to call the function (like sin, abs but you need to create your own name).
- **parameters** - are the variables that get values when you call the function. You can have 0 or more parameters, separated by commas. Must be in parenthesis.
- **body** - body is a sequence of commands like we've already seen (assignment, multiplication, function calls).
- Important: all the lines of body must be indented. That is how Python knows that they are part of the function.

Calling Functions

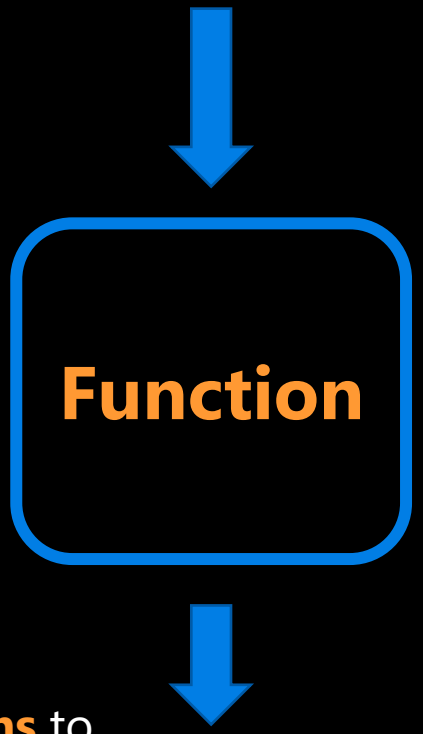
- The general form of a function call:

```
function_name(arguments)
function_name()
function_name
```

Would not result in a function call.

- Terminology
  - *argument*: a value given to a function.
  - *pass*: to provide an argument to a function.
  - *call*: ask Python to execute a function (by name).
  - *return*: give a value back to where the function was called from.

The stuff we **pass** to the function. **Arguments**



Call Function **()**

The stuff the function **returns** to us after we **call** it. **Returns**

Function Definitions

```
def function_name(parameters):
    body
    return
```

```
def square(x):
    return x * x
```

`x` is the parameter.

Calling Functions

```
function_name(arguments)
```

```
square(2)
```

`2` is the argument (data) passed to the `square` function.

Function Definitions

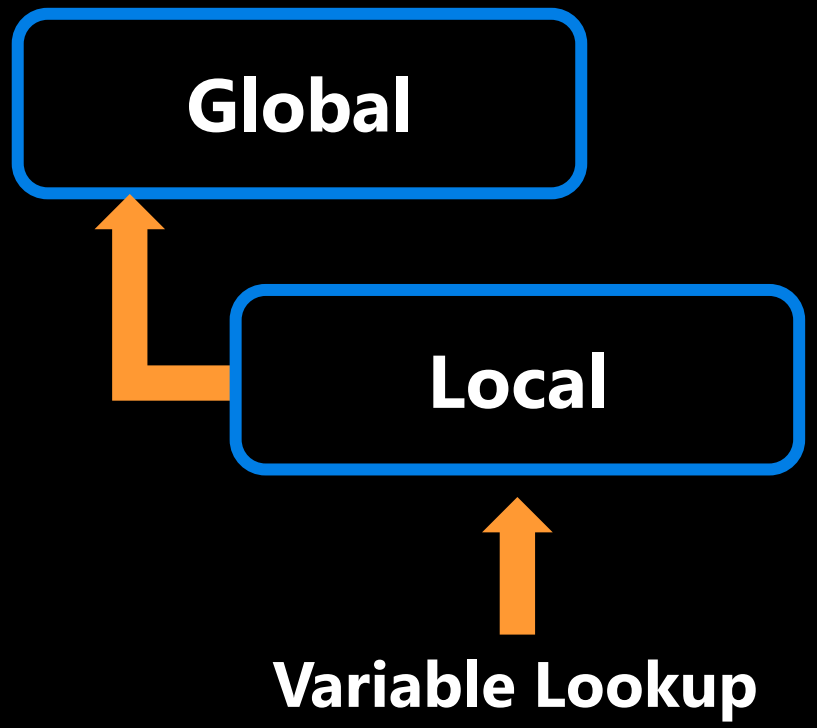
```
def function_name(parameters):
    1. """DOCSTRING""" (optional)
    2. Code that does the thing
    3. return expression
       The return statement is
       optional and if it is not
       included, it's the same as
       writing return None
```

Open your notebook

Click Link:
1. Defining Your Own Functions

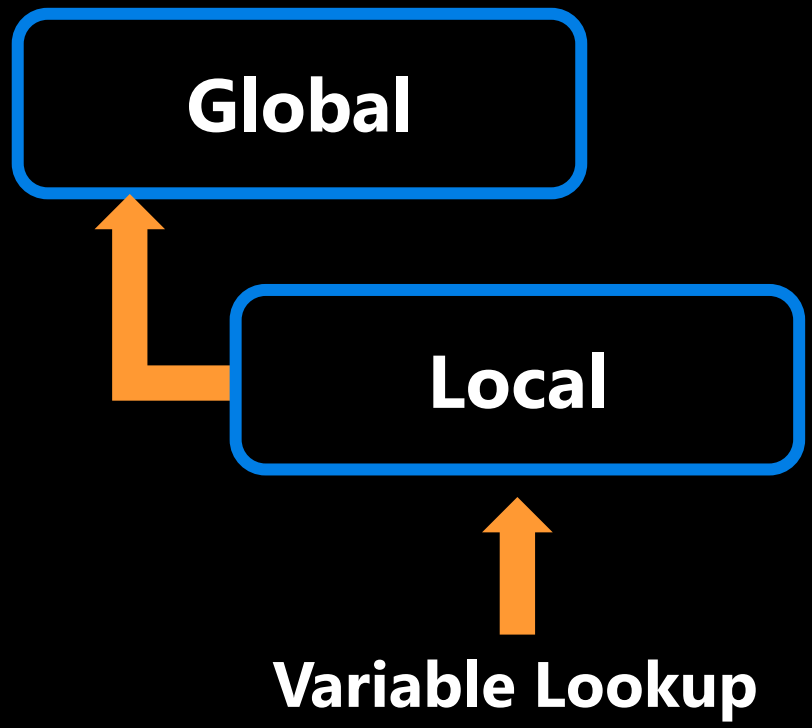
Variable Scope

- A variable is only available from inside the region it is created, which is called the variable's scope.
- Python has four different scopes, and we will discuss the two most important for this course.
- Local Scope
- Global Scope



Variable Scope

- **Local Scope**
- Whenever you define a variable within a function, its scope lies **ONLY** within the function.
- It is accessible from the point at which it is defined until the end of the function and exists for as long as the function is executing.
- This means its value cannot be changed or even accessed from outside the function.



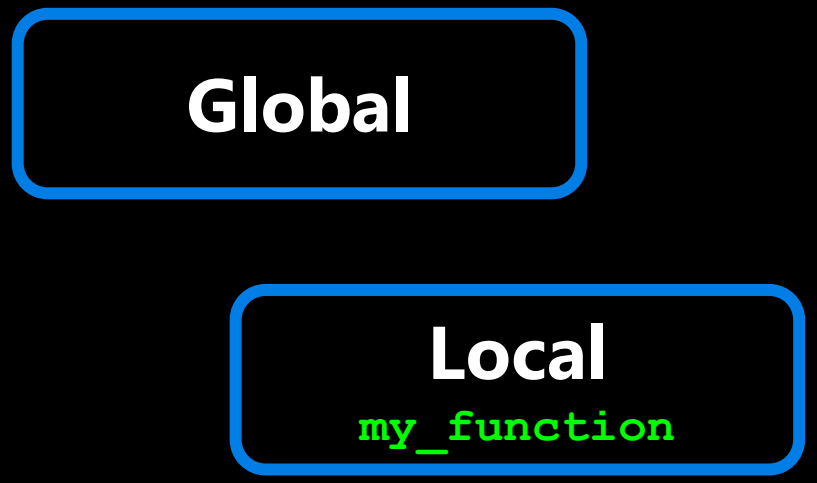
Variable Scope

- Local Scope

```
def my_function():
    name = 'Sebastian'

my_function()

print(name)
```



Variable Scope

- **Local Scope**

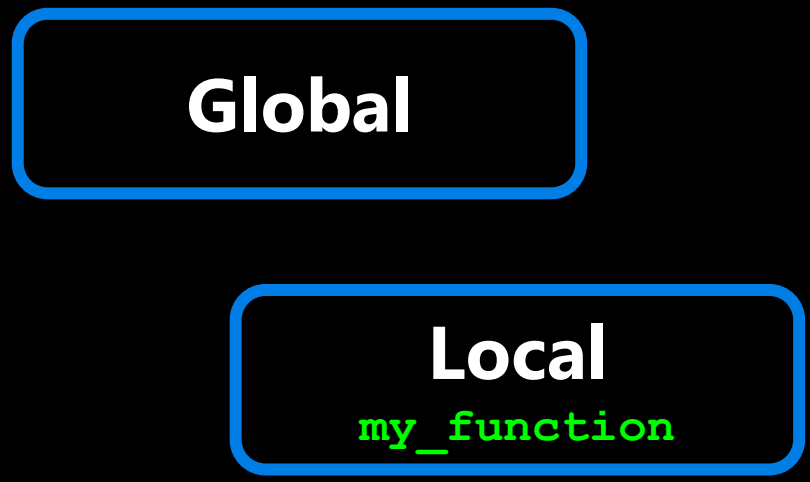
```
def my_function():
    name = 'Sebastian'

my_function()

print(name)

>>> Error
```

`name` is local to the function and not accessible outside in the global scope.



Variable Scope

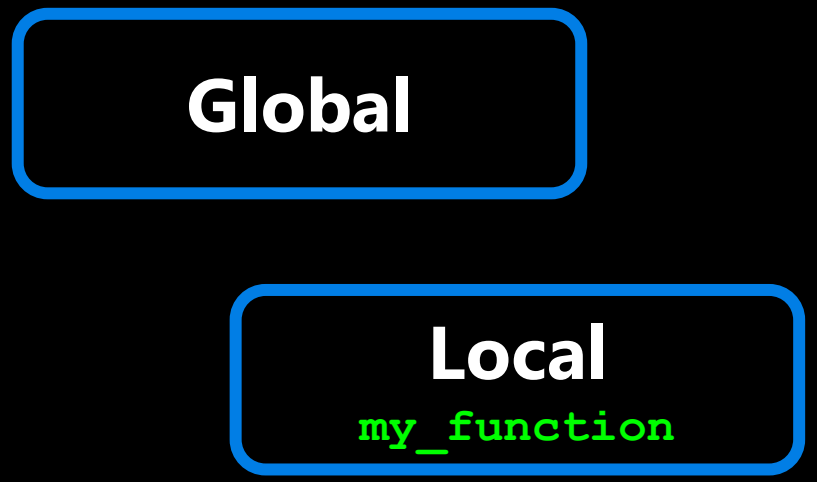
- Local Scope

```
def my_function():
    name = 'Sebastian'

my_function()

print(name)

>>> Error
```



Variable Scope

- Local Scope

```
def my_function():
    name = 'Sebastian'

my_function()

print(name)

>>> Error
```

Global

Local
my_function

Variable Scope

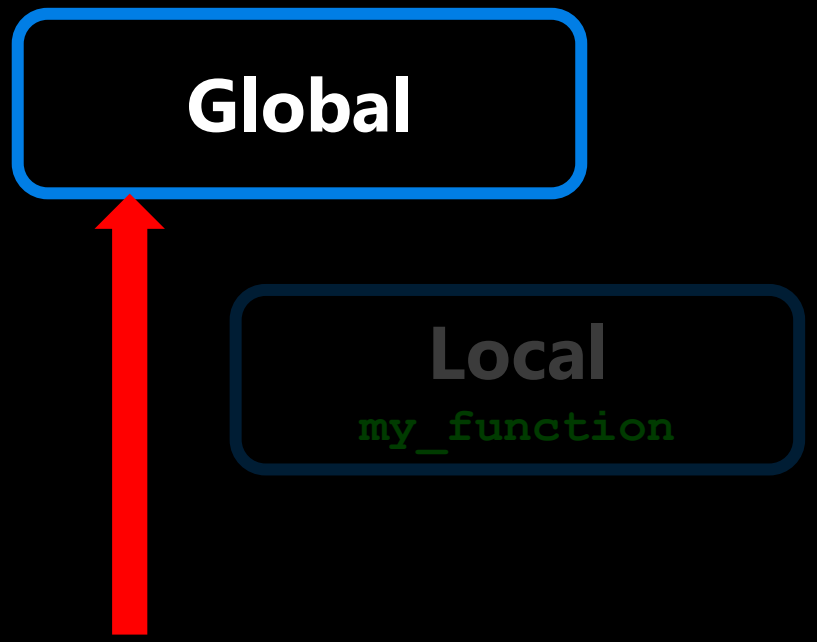
- Local Scope

```
def my_function():
    name = 'Sebastian'

my_function()

print(name)

>>> Error
```



Variable Lookup
- Is `name` in global?
- No (Done)

Variable Scope

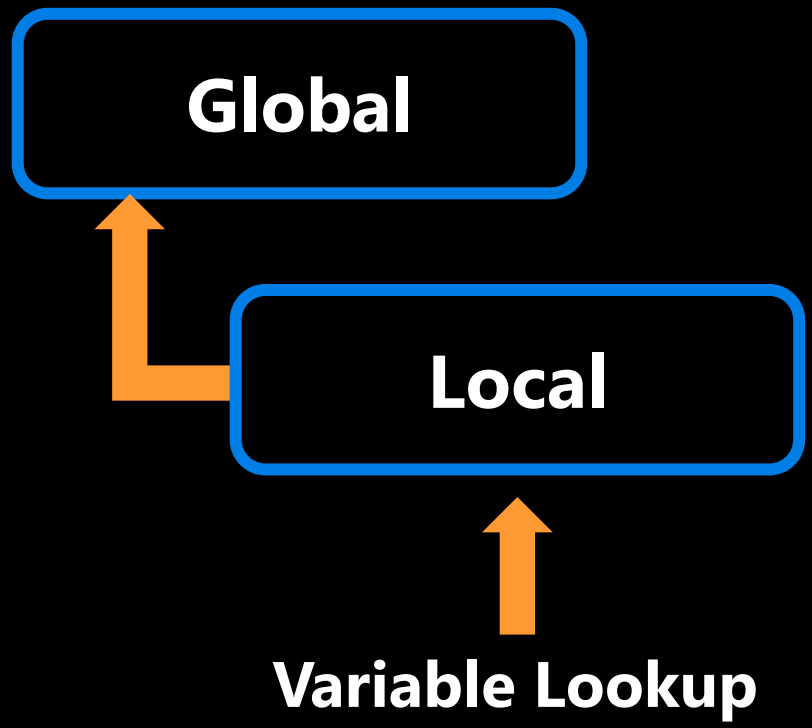
- **Local Scope**
- Whenever you define a variable within a function, its scope lies **ONLY** within the function.
- It is accessible from the point at which it is defined until the end of the function and exists for as long as the function is executing.
- This means its value cannot be changed or even accessed from outside the function.

Open your notebook

Click Link:
2. Local Scope

Variable Scope

- **Global Scope**
- Whenever a variable is defined outside any function, it becomes a global variable, and its scope is anywhere within the program.
- This means that variables and functions defined outside of a function are accessible inside of a function.



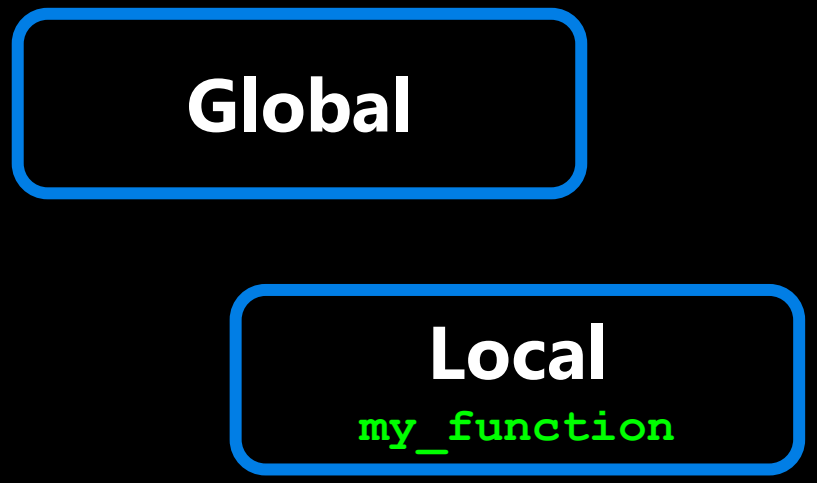
Variable Scope

- Global Scope

```
def my_function():
    print(name)


name = 'Sebastian'

my_function()
```



Variable Scope

- **Global Scope**

```
def my_function():
    print(name)


name = 'Sebastian'

my_function()

>>> Sebastian
```

Notice that `name` is not defined anywhere in the function.

Global

Local
`my_function`

`name` is in the global scope and is accessible inside the function.

Variable Scope

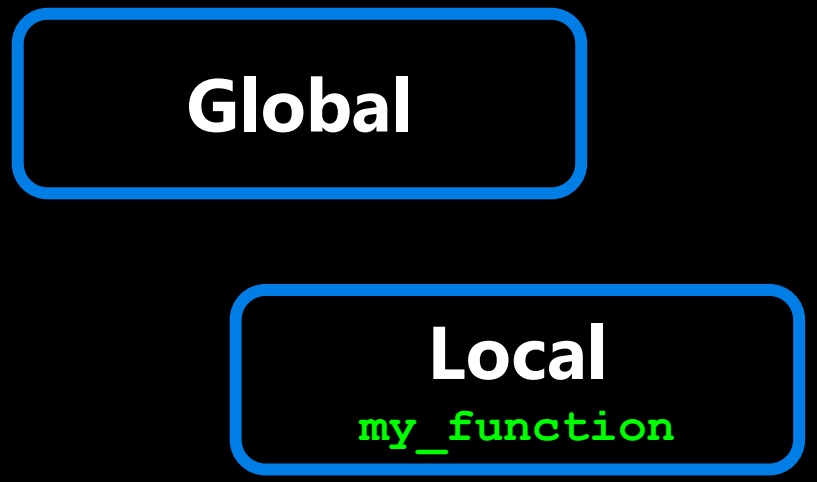
- Global Scope

```
def my_function():
    print(name)


name = 'Sebastian'

my_function()

>>> Sebastian
```



Variable Scope

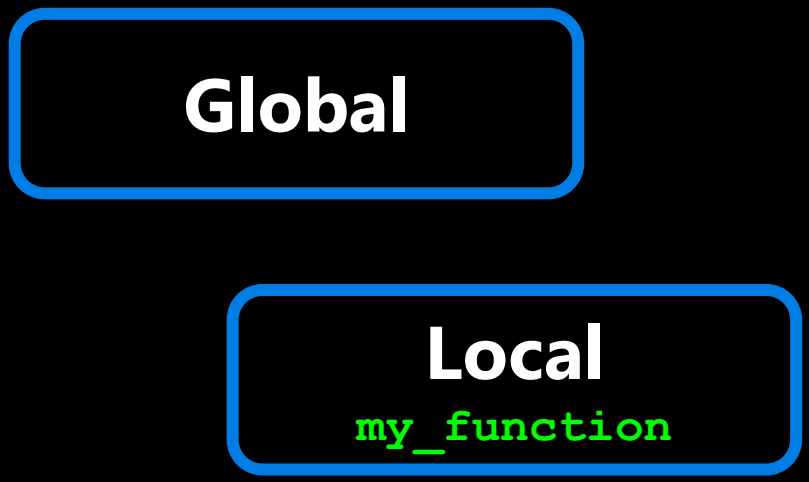
- Global Scope

```
def my_function():
    print(name)


name = 'Sebastian'

my_function()

>>> Sebastian
```



Variable Scope

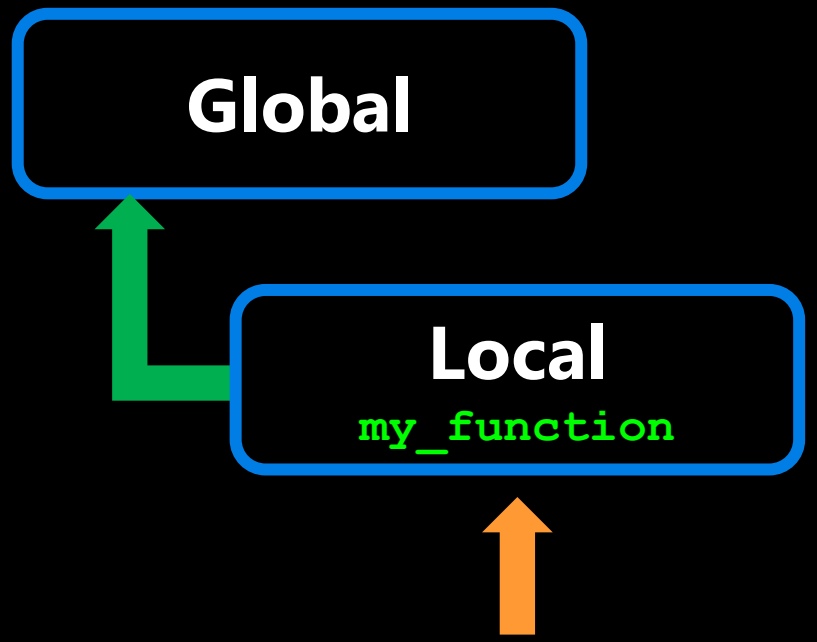
- Global Scope

```
def my_function():
    print(name)


name = 'Sebastian'

my_function()

>>> Sebastian
```



Variable Lookup

- Is `name` in local?
- No
- Is name in global?
- Yes (Done)

Variable Scope

- Global Scope

```
def my_function():
    name = 'Ben'
    print(name)

name = 'Sebastian'

my_function()
```

Global

Local
my_function

Variable Scope

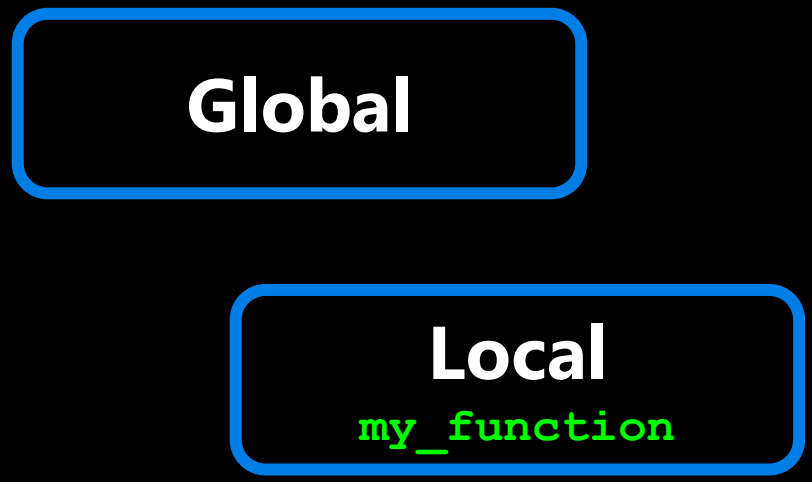
- Global Scope

```
def my_function():
    name = 'Ben'
    print(name)

name = 'Sebastian'

my_function()

>>> Ben
```



`name` is in the local and global scope. Python will use the local version.

Variable Scope

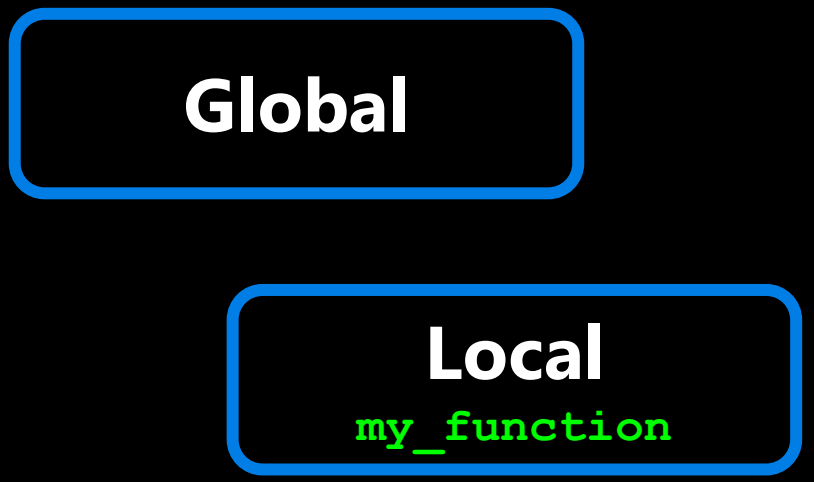
- Global Scope

```
def my_function():
    name = 'Ben'
    print(name)

name = 'Sebastian'

my_function()

>>> Ben
```



Variable Scope

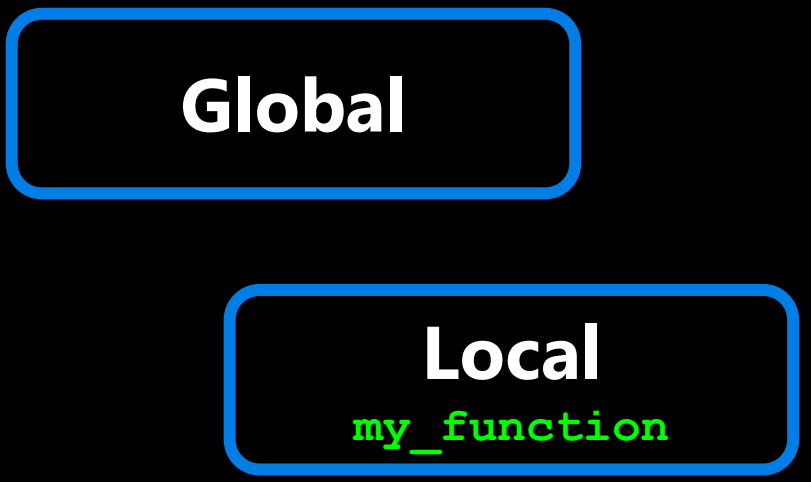
- Global Scope

```
def my_function():
    name = 'Ben'
    print(name)

name = 'Sebastian'

my_function()

>>> Ben
```



Variable Scope

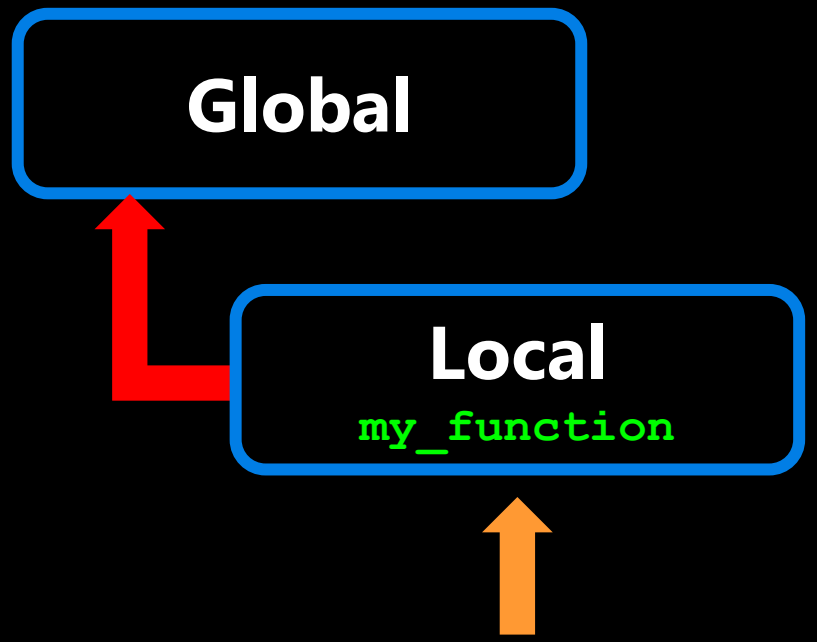
- Global Scope

```
def my_function():
    name = 'Ben'
    print(name)

name = 'Sebastian'

my_function()

>>> Ben
```



Variable Lookup

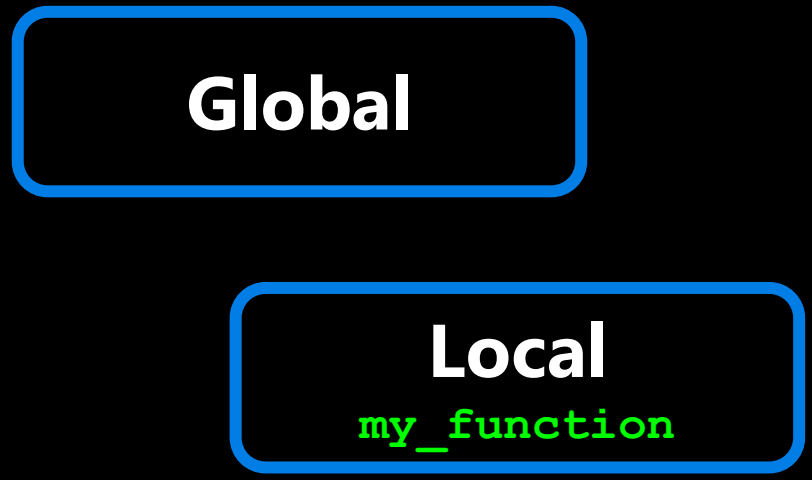
- Is name in local?
- Yes (Done)

Variable Scope

- Global Scope

```
def my_function():
    print(name)

my_function()
```



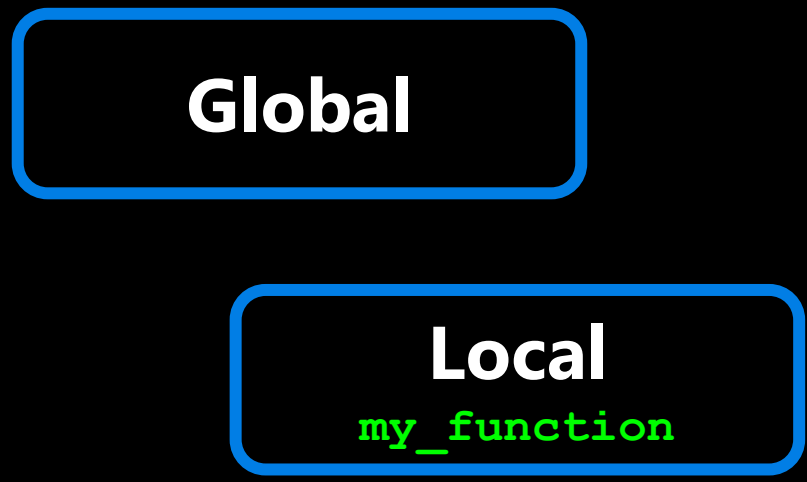
Variable Scope

- **Global Scope**

```
def my_function():
    print(name)

my_function()

>>> Error
```



`name` is not defined in the local or global scope.

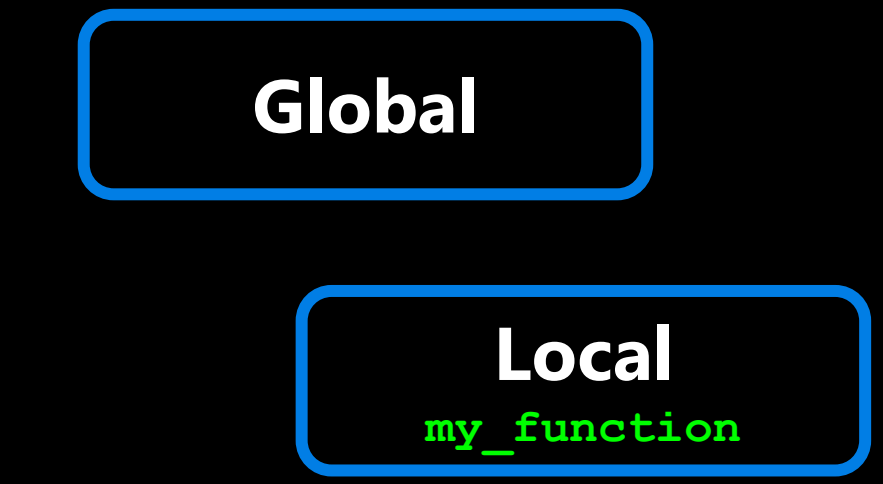
Variable Scope

- Global Scope

```
def my_function():
    print(name)

my_function()

>>> Error
```



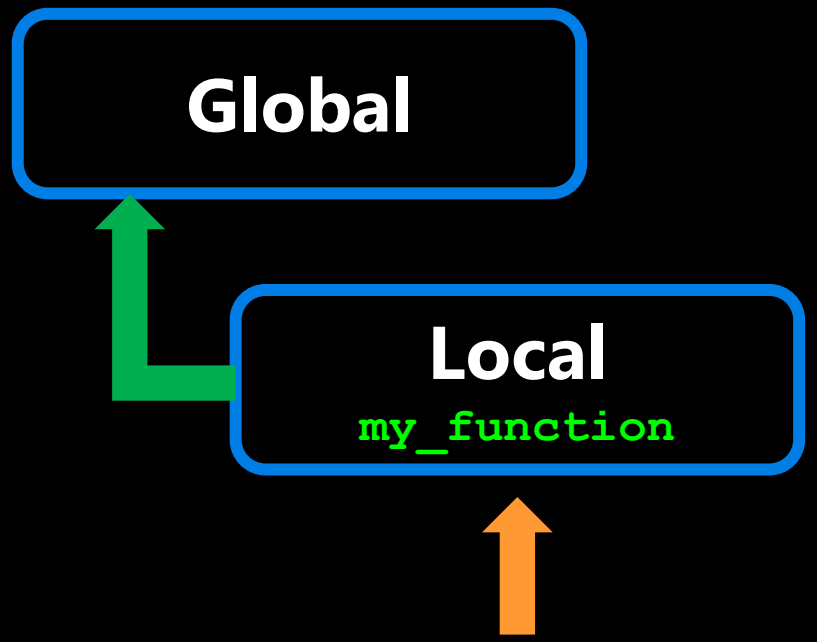
Variable Scope

- Global Scope

```
def my_function():
    print(name)

my_function()

>>> Error
```



Variable Lookup

- Is `name` in local?
- No
- Is name in global?
- No

Variable Scope

- **Global Scope**
- Whenever a variable is defined outside any function, it becomes a global variable, and its scope is anywhere within the program.
- This means that variables and functions defined outside of a function are accessible inside of a function.

Open your notebook

Click Link:
3. Global Scope

Design Recipe

- How do we go about writing a function?
- You should follow these six steps.

1. **Examples** (What do you want your function calls to look like?)
2. **Type Contract** (Specify the type(s) of parameters and return values)
3. **Header** (Decide on the name of the function)
4. **Description** (Write a short description of what the function does)
5. **Body** (Write the code that actually does the thing that you want)
6. **Test** (Verify the function using examples)

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

1. **Examples** (What do you want your function calls to look like?)

```
celsius = convert_to_celsius(32)

celsius = convert_to_celsius(212)

celsius = convert_to_celsius(98.6)
```

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

2. Type Contract (Specify the type(s) of parameters and return values)

```
def convert_to_celsius(degrees_f):
    """
    ...
    """

    ... Do something

    return degrees_c
```

What types are passed in?

What types are returned?

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

2. Type Contract (Specify the type(s) of parameters and return values)

```
def convert_to_celsius(degrees_f):
    """
    (number) -> number
    """

    ... Do something

    return degrees_c
```

What types are passed in? Number

What types are returned? Number

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

3. Header (Decide on the name of the function and parameters)

```
def convert_to_celsius(degrees_f):
    """
    (number) -> number
    """

    ... Do something

    return degrees_c
```

(you probably already did this in step 1)

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

4. Description (Write a short description of what the function does)

```
def convert_to_celsius(degrees_f):
    """
    (number) -> number
    Return the temperature in degrees Celsius corresponding to
    the degrees Fahrenheit passed in.
    """

    ... Do something

    return degrees_c
```

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

5. **Body** (Write the code that actually does the thing that you want)

```
def convert_to_celsius(degrees_f):
    """
    (number) -> number
    Return the temperature in degrees Celsius corresponding to
    the degrees Fahrenheit passed in.
    """

    degrees_c = (degrees_f - 32) * 5 / 9

    return degrees_c
```

Design Recipe

- **Write a function that converts from Fahrenheit to Celsius.**

6. **Test** (Verify the function using examples)
   - Run all the examples that you created in Step 1.
   - Testing is so important.
   - In industry, you'll be expected to provide tests for everything.

```
celsius = convert_to_celsius(32) # celsius should be 0

celsius = convert_to_celsius(212) # celsius should be 100

celsius = convert_to_celsius(98.6) # celsius should be 37.0
```

Design Recipe

- How do we do about writing a function?
- You should follow these six steps.

1. **Type**
2. **Contract**
3. **Header**
4. **Description**
5. **Body**
6. **Test**

Open your notebook

Click Link:
4. Design Recipe

Docstring

- A Python documentation string, commonly known as **docstring**, helps you understand the capabilities of a function (or module, class).

This is the docstring

```
def convert_to_celsius(degrees_f):
    """
    (number) -> number
    Return the temperature in degrees Celsius corresponding to
    the degrees Fahrenheit passed in.
    """

    degrees_c = (degrees_f - 32) * 5 / 9

    return degrees_c
```

Docstring

- As we saw before, `help()` prints information about a function.
- The help function actually prints out the **"docstring"** that we write as part of a function definition.
- For the function we just wrote, we could type:

```
help(convert_to_celsius)
```

```
>>>
Help on function convert_to_celsius in module __main__:

convert_to_celsius(degrees_f)
    (number) -> number
    Return the temperature in degrees Celsius corresponding to the degrees
    Fahrenheit passed in
```

Docstring

- These are the most popular Docstrings format available.

Formatting Type	Description
NumPy/SciPy docstrings	Combination of reStructured and GoogleDocstrings and supported by Sphinx
PyDoc	Standard documentation module for Python and supported by Sphinx
EpyDoc	Render Epytext as series of HTML documents and a tool for generating API documentation for Python modules based on their Docstrings
Google Docstrings	Google's Style

Docstring

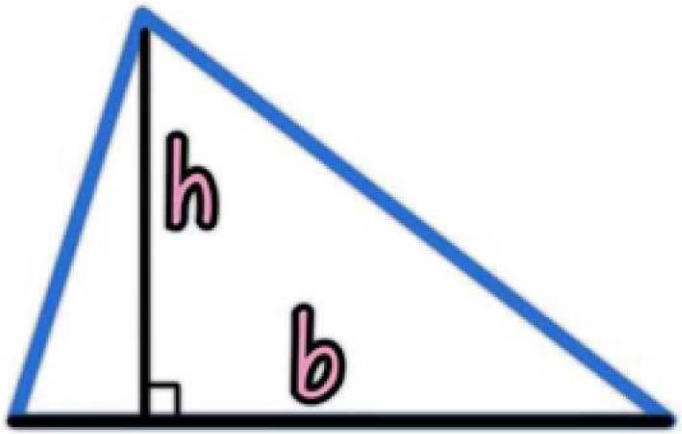
- This can be very valuable:
  - For other programmers to figure out what a function is supposed to do.
  - For you in the future when you have forgotten what you wrote (this happens a lot!).
- You should write a **docstring** for every function!
- Remember good vs bad code review.

Open your notebook

Click Link:
5. Docstring

Breakout Session 1

- Following the Design Recipe, write a function to calculate the area of a triangle.



$$\text{Area} = \frac{1}{2} \times b \times h = \frac{bh}{2}$$

Open your notebook

Click Link:
6. Breakout Session 1

More Stuff You Can Do With Functions

- **Nested Function Calls**

```
print(3 + 7 + abs(-5))
```

Function

Function

- **Calling Functions within Functions**

Function Definition

```
def my_function():
    print("Hello from a function")
```

Function

Open your notebook

Click Link:

7. Nested Function Calls
8. Calling Functions within Functions

`print` v.s. `return`

- The difference between print and return is point of confusion year after year.
- So, let's be proactive and address this.

`return`

`print`

`print`

- **Use cases**
- Debugging.
- Displaying messages to users.

`return`

- **Use cases**
- Used to end the execution of the function call and "return" the result.

print

```
def square(x):
    output = x * x
    print(output)
```

```
>>> square(2)
2
```

return

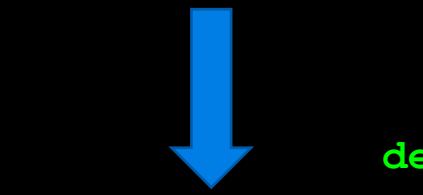
```
def square(x):
    output = x * x
    return output
```

```
>>> square(2)
2
```

print

The stuff we **pass** to the function.

Arguments: 2



```
def square(x):
    output = x * x
    print(output)
```

Function `square`

The stuff the function **returns** to us after we **call** it.

Returns: `None`

return

The stuff we **pass** to the function.

Arguments: 2

```
def square(x):
    output = x * x
    return output
```

Function `square`

The stuff the function **returns** to us after we **call** it.

Returns: `4`

print v.s. return

```
def square(x):
    output = x * x
    print(output)
```

```
def square(x):
    output = x * x
    print(output)
    return None
```

These two functions return the same thing.

Open your notebook

Click Link:
5. print v.s. return

From Functions to Programs

- The recipe we discussed earlier highlights a few of the realities about programming whether for individual functions or for large pieces of software.

1. A formal design process (or even a recipe) can help.
   - Especially when you are writing a large program with many programmers, it is easy to get lost.
   - In fact, it is more often impossible to hold the entire program in your head.
   - Having a process helps you to figure out where you are and what you should do next.

From Functions to Programs

- The recipe we discussed earlier highlights a few of the realities about programming whether for individual functions or for large pieces of software.

2. Functions can be written and then their insides can be forgotten about.

- Do you know how Python calculates **sin()**?
- Do you care?
- You can successfully use functions without knowing how they are implemented if you know what they take in and what they return.
- This is very important for large projects.

From Functions to Programs

- The recipe we discussed earlier highlights a few of the realities about programming whether for individual functions or for large pieces of software.

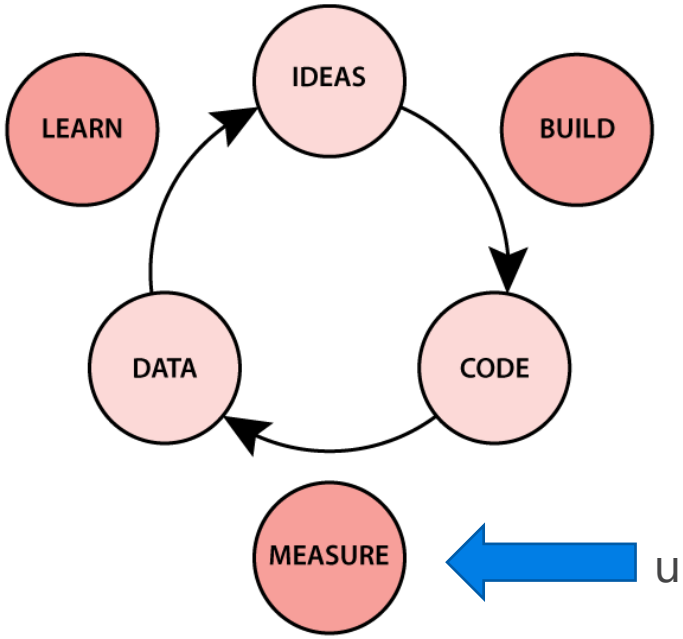
3. Start with examples.
   - This helps in communication with the client, helps (a lot) to figure out what the problem really is, and is the core for testing your code.

A Design Process for Programming

- APS111/112, a key part of engineering is the design of objects, processes, and systems.
- **Programming** is the design, implementation, testing, and documentation of a piece of software that solves a particular problem.
- The software might be part of a larger system (e.g., the avionics software of an aircraft, the accounting or human resources software of a business), but it represents the solution to a design problem (or part of a design problem).

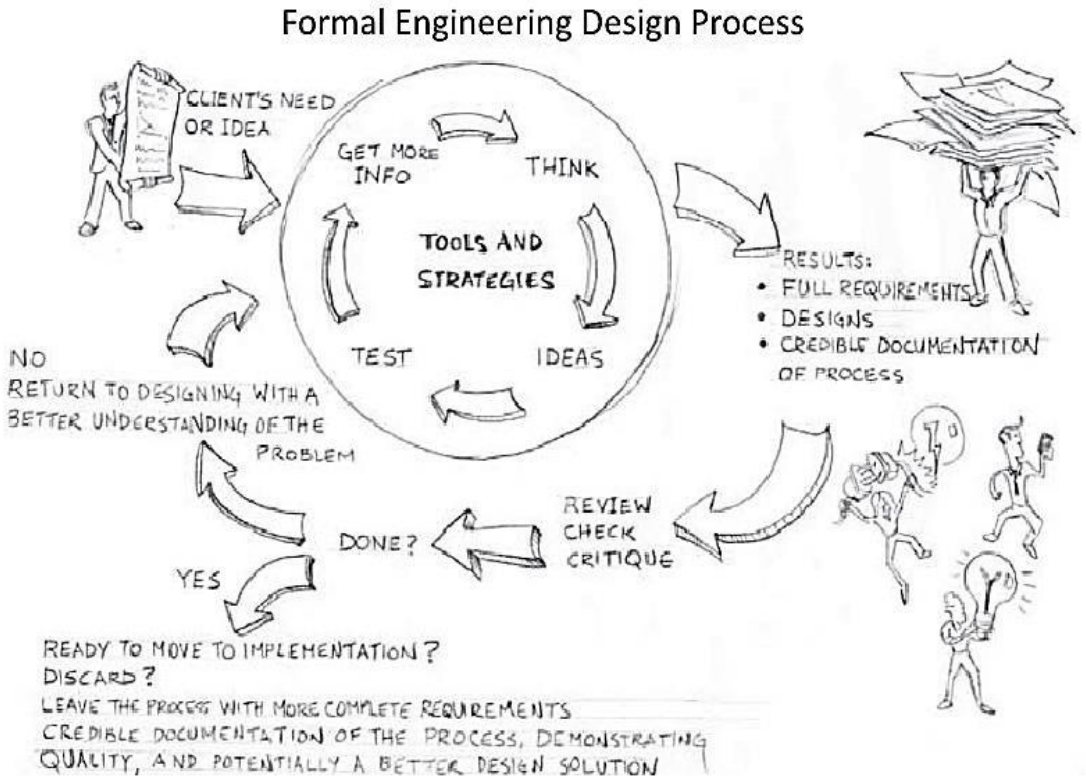
A Design Process for Programming

- We will approach programing as an engineering design process and adapt the process you have already seen in APS111/112.



Design is iterative.

Taken from: Designing Engineers: An Introductory Text



A Design Process for Programming

- In the next lecture, we are going to talk about a detailed design process for programming, based on the engineering design processes that are key to any engineering.
- The steps are as follows:
- **Define the Problem.**
- **Define Test Cases.**
- **Generate Multiple Solutions.**
- **Select a Solution.**
- **Implement the Solution.**
- **Perform Final Testing.**

A Design Process for Programming

- **Define the Problem.**
- Write down what the problem actually is.

A Design Process for Programming

- **Define Test Cases.**
- Create some examples that reflect your code solving the problem: input and output.

A Design Process for Programming

- **Generate Multiple Solutions.**
- At this point a "solution" consists of an algorithm plan (the high-level sequence steps defining what your algorithm will do) and a programming plan (the high-level sequence of steps that you will take to code the algorithm).

A Design Process for Programming

- **Select a Solution.**
- Based on the different algorithm and programming plans, decide which is the most promising.

A Design Process for Programming

- **Implement the Solution.**
- Start to execute your programming plan.
- Test as you go!
- You may realize that your algorithm plan doesn't solve the problem, or even that you do not understand the problem.
- If so, go back to earlier steps.

A Design Process for Programming

- **Perform Final Testing.**
- Make sure that your original test cases as well as any others that you have thought up work.

A Design Process for Programming

- It is critical to realize that programming is:
  - Iterative: you will go back and change your algorithm/programming plan. You will write some code during Step 3: you might not be able to define a solution without writing some code to solve part of the problem. You will move back-and-forth in this process.
  - This process is a lot about finding your own mistakes: even for good programmers, most of their time is spent testing and debugging!

Lecture Recap

Practice!

- The syntax of function definitions.
- Variable Scope.
- A design recipe for writing functions.
- Nested function calls.
- Calling functions from within functions.
- An Engineering Design Process for Programming.

- See Chapter 3 of the textbook.

- More on engineering design next lecture!

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writing your own function.

Week 2 | Lecture 2 (2.2)

if nothing else, write #cleancode