

#1-3: Function Calls

CS SCHOLARS – PROGRAMMING

Learning Goals

Identify the **argument(s)** and **returned value** of a function call

Use **libraries** to import functions in categories like math and randomness

Use the **graphics library** to construct images algorithmically

Repeating Actions is Messy

Sometimes we want to perform the same algorithm many times on different inputs.

For example, say we want to personalize a young child's reading material so that it uses their pet's name.

We could copy and paste the first bit of code, then change the necessary parts. But if we're sloppy this might cause errors.

```
pet1 = "Spot"  
pet2 = "Stella"  
pet3 = "Kimchee"
```

```
print("See " + pet1 + ". See " + pet1 +  
      " run. Run, " + pet1 + ", run!")
```

```
print("See " + pet2 + ". See " + pet2 +  
      " run. Run, " + pet2 + ", run!")
```

```
print("See " + pet3 + ". See " + pet1 +  
      " run. Run, " + pet3 + ", run!")
```

Functions Represent Abstract Actions

A better approach is to put the core action being repeated into a **function**.

A function is a code construct that represents an algorithm. We can **define** a function once, then **call** it many times.

We can also use functions that have already been defined by Python.

In this lecture, we'll just focus on calling functions. Next week, we'll learn how to define our own functions.

Function Calls

Call Functions with Parentheses

We've already seen how to call a function on a specific input, because `print` is just a function! This is done using **parentheses**.

```
functionName(input1, input2, ...)
```

The number of inputs provided inside the parentheses depends on how many inputs the function expects. Each input should be an **expression**.

The function call itself is an **expression** as well.

A Few New Functions

To help us explore how functions work, let's introduce a few new functions. These are **built-in functions**, like `print`; that means we can call them in Python directly.

```
abs(-2) # absolute value
```

```
pow(2, 3) # raises a number to the given power
```

```
round(12.4567, 2) # rounds to the given # sig digs
```

Type Functions

There are a few other built-in functions that are helpful to know, as they let you change the type of data values. This is called **type-casting**.

```
int("4") # converts a value to an integer
```

```
float(3) # converts a value to a float
```

```
str(98.9) # converts a value to a string
```

```
bool(0) # converts a value to a Boolean
```

```
type(4 + 3.0) # returns the type of the eventual value
```

```
# uses the names we covered before - int, float, str, bool
```


Activity: Try Calling Functions

You do: try running a few function calls in the interpreter. Do you notice anything interesting that results?

Components of Functions

The functions we call have two core components:

Argument(s) – the values provided inside the parentheses, the **input**

Returned Value – what the function evaluates to after running, the **output**

Arguments Provide the Input

The specific inputs we provide to a function are called **arguments**. These are like the specific bread, peanut butter, and jelly we used in the PB&J algorithm. In the function call `abs(4)`, the argument is `4`.

Arguments are separated by commas and placed between the parentheses of the function call. Functions can require as many (or as few) arguments as needed.

The **positions** of the arguments usually have meaning. In `pow(2, 3)`, the first argument is the base and the second argument is the exponent. In other words, `pow(2, 3)` and `pow(3, 2)` mean two different things.

Receive Output as Returned Value

When a built-in function takes its arguments and runs through its algorithm, we cannot see what it is doing.

When the function is done, it sends back an output as a **returned value**. We usually say a function **returns** a value. This value substitutes in for the function call the same way a variable's value substitutes in for the variable.

For example, the returned value of `pow(2, 3)` is 8.

Missing Returned Values are None

If a function produces no explicit output (usually because it is only used for side effects, like `print`), it still has a returned value. That value is the built-in value `None`.

`None` means that there was no explicit output to be returned. Like `True` and `False`, its meaning is built into Python, so it does not need quotes.

If you try to set a variable to a `print` call, you'll find that the variable holds `None` because `print` has no returned value. Note that `None` does not show up in the interpreter unless you explicitly `print` it; the interpreter just shows a blank instead.

```
>>> None
>>> print(None)
None
```

Activity: Identify the Function Call Parts

Consider the following two function calls. For each function call, what are its **argument(s)** and its **returned value**?

```
round(3.14159, 1)
```

```
print("15", "-", "110")
```

Side Effects Change the State

If `print` doesn't have a returned value, what exactly is it doing?

Recall that a program has a **state** that holds the current information that the program knows (what has been printed, what values do variables hold).

Function calls themselves are expressions, as they evaluate to a data value (the returned value). But sometimes a function changes the program state in an observable way as it is running; for example, it might display values in the interpreter, or modify a file, or produce graphics. This is called a **side effect**.

If we call `pow(2, 3)`, there is no observable side effect. But `print("Hello")` has an observable side effect: it prints "Hello" to the screen.

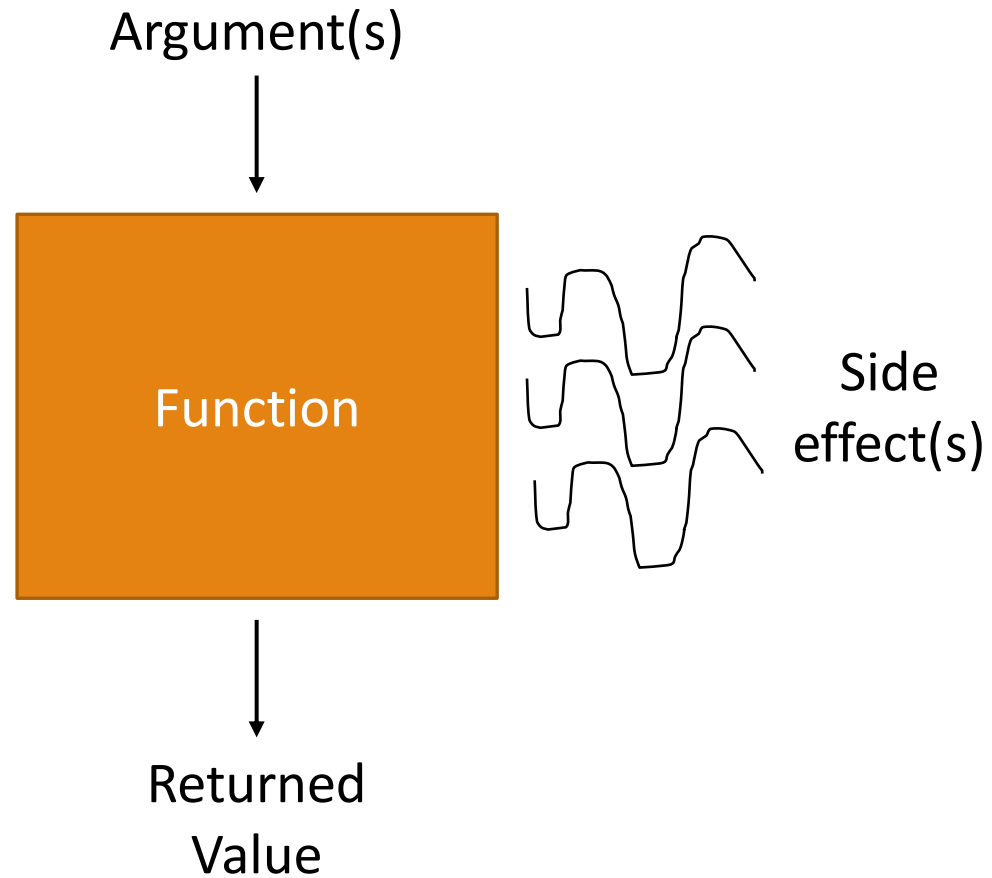
Side Effect(s) vs Returned Value

It's easy to get confused about whether something is a side effect or a returned value. Why are these two components different?

The way we've set up function calls means that there must be **exactly one output**: the returned value. A function call might have no side effects, or one, or many; however, every function call has one returned value.

Importantly, returned values can be saved in a variable and used in **future computations**. Side effects cannot be saved; we simply observe them.

Function Call Process



Function Calls Follow Order of Operations

Function calls evaluate to a single returned value; that means they are **expressions**. Therefore, we can **nest** function calls inside other expressions the same way we nest basic values and operations.

```
print(round(pow(abs(-12), 1/2), 2))
```

Just like in math, functions follow order of operations using parentheses. Start by evaluating the inner-most expressions, `abs(-12)` and `1/2`. Then evaluate the call to `pow`; then evaluate the call to `round`. Finally, evaluate the call to `print`.

Libraries

Import Adds Code from Libraries

The Python language has a ton of pre-built functions, but most aren't included in the built-in package (the one available by default). Most of the functions are organized into separate **libraries**.

To use a function from a library, you must **import** the library. This makes it possible to access the functions and variables in that collection. You can do this with the code:

```
import libraryName
```

All the Python libraries have **documentation** online that describes which functions are available and what they do. Find it by searching docs.python.org/3/. It's better to check the documentation as needed than to try to memorize library functions.

Importing the math Library

For example, we can import the **math** library to add more mathematical capabilities. Note that we must put **math.** in front of each function or variable name we use, to specify it came from that library.

```
import math
math.ceil(6.5) # ceiling of a float number
math.log(64, 2) # finds the log of 64 with base 2
math.radians(90) # converts degrees to radians
math.pi # it's  $\pi$ !
```

Importing the random library

Importing libraries lets us get more creative with programming. For example, the **random** library lets us generate random numbers, which can help produce novel behavior.

```
import random  
random.randint(1, 10) # picks a random int between 1-10 inclusive  
random.random() # picks a random float between 0-1
```

Activity: Try Out Libraries

You do: try importing the math and random libraries in the interpreter and calling functions in them.

What do you notice that's interesting?

Graphics Library

Importing a graphics library

Finally, to get really creative, we can produce graphics with programming! We'll do this with the **tkinter** library, which makes it possible to draw shapes on a separate screen.

```
import tkinter
```

Tkinter Starter Code

We need to run some code before and after our graphics code to make it work.

The `root` is the window. The `canvas` is the thing on the window where we can draw shapes.

The `root.mainloop()` line will tell the window to stay open until we press the X button.

You do: Try copying this code into your editor and running it. You should see a window pop up!

```
import tkinter

root = tkinter.Tk()
canvas = tkinter.Canvas(root,
                        height=400,
                        width=400)
canvas.configure(bd=0, highlightthickness=0)
canvas.pack()

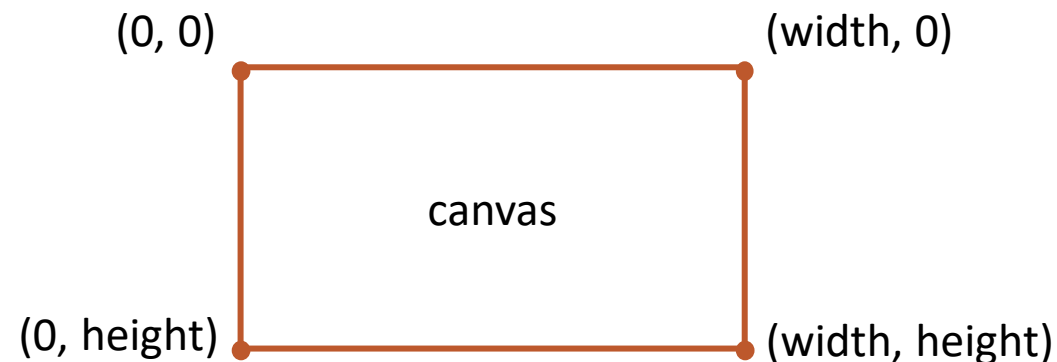
# write your code here

root.mainloop()
```

Coordinates on the Canvas Grow Down-Right

The **canvas** created by the starter code is the thing we'll draw graphics on. It's a two-dimensional grid of pixels. This grid has a pre-set **width** and **height**; the number of pixels from left to right and the number of pixels from top to bottom.

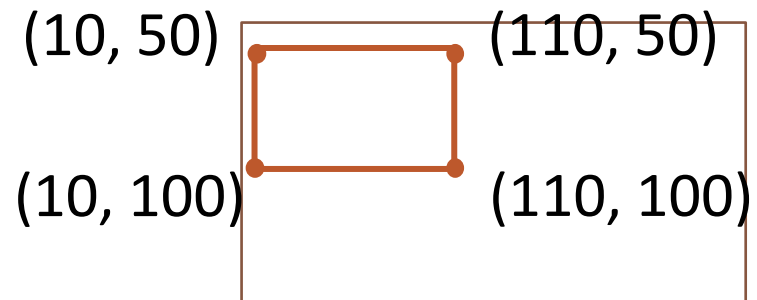
We can refer to pixels on the canvas by their (x, y) coordinates. However, these coordinates are different from coordinates on mathematical graphs – the origin starts at the **top left corner** of the canvas.



Drawing a Rectangle

To draw a rectangle, use the function `canvas.create_rectangle`. This function takes four required arguments: the x and y coordinates of the **left-top** corner, and the x and y coordinates of the **right-bottom** corner. The rectangle will then be drawn between those two points.

```
canvas.create_rectangle(10, 50, 110, 100)
```



Graphics – Side Effects and Returned Values

When the rectangle is drawn on the canvas, we can't use it in future computations. That's a **side effect**.

The graphics function call also returns something – an integer ID associated with the drawn shape. We won't use that value in this class.

Keyword Arguments Add Variety

With the basic parameters, we can only draw outlines of shapes. By adding **keyword arguments**, we can change the properties of these shapes.

A keyword argument is an argument is associated with a specific name instead of a position in the function call. We can put keyword arguments in any order we like as long as they occur after the main arguments.

Keyword arguments can have **default values**, which is why we don't need to include them in every graphics call. To change that default value, include the keyword, followed by **=**, followed by the new value in the function call.

```
canvas.create_rectangle(50, 100, 150, 200, fill="green")
```

Keyword Argument - fill

The `fill` argument can be used on any shape. It uses a string (the name of the color) to change the color of the shape.

```
canvas.create_rectangle(40, 40, 80, 140, fill="red")
```

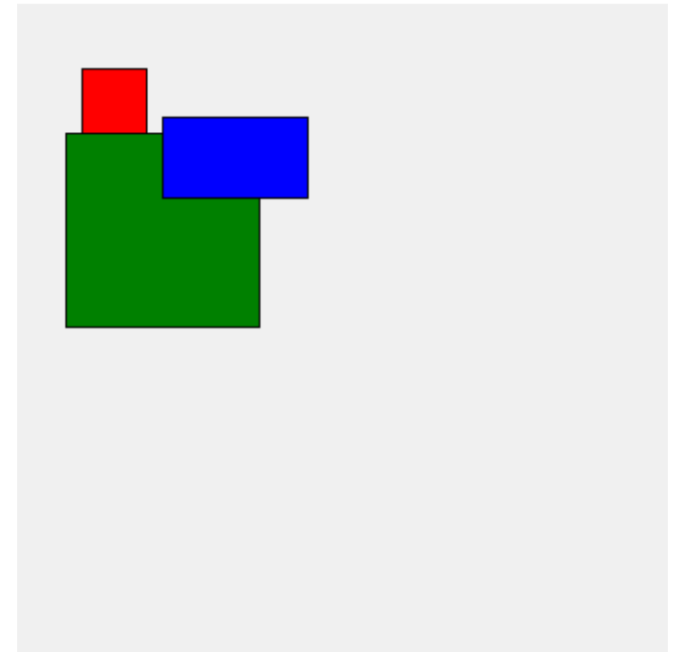
```
canvas.create_rectangle(30, 80, 150, 200, fill="green")
```

```
canvas.create_rectangle(90, 70, 180, 120, fill="blue")
```

Note that when we draw shapes on top of each other, the one on top is the **last one called**. Order matters!

Interested in finding more Tkinter color names? There's a whole databank!

<https://wiki.tcl-lang.org/page/Color+Names%2C+running%2C+all+screens>



Activity: Draw Some Rectangles

Try using `canvas.create_rectangle` and the `fill` keyword argument to draw some rectangles on the Tkinter canvas.

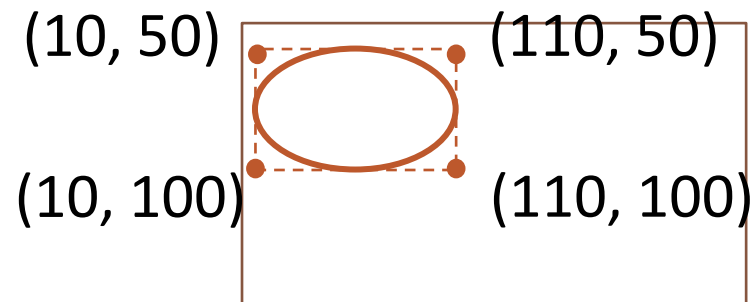
Can you get one of the rectangles to draw as a square?

How about centering one of the rectangles?

Drawing an Oval

We can draw more shapes than just rectangles. To draw an oval, use `create_oval`. This function uses the same parameters as `create_rectangle`, where the coordinates mark the oval's **bounding box**.

```
canvas.create_oval(10, 50, 110, 100)
```



Keyword Argument - width

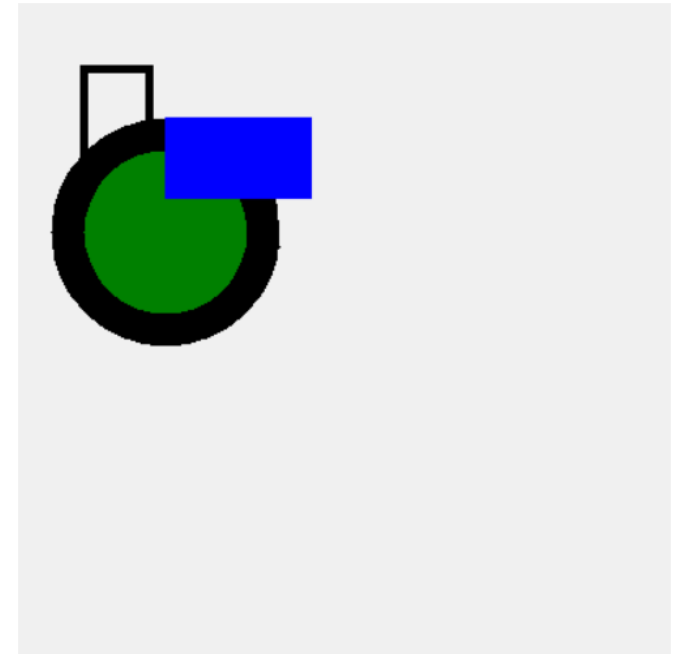
Another keyword argument is `width`, which specifies how many pixels wide the border of the shape should be.

```
canvas.create_rectangle(40, 40, 80, 140, width=5)
```

```
canvas.create_oval(30, 80, 150, 200,  
                  width=20, fill="green")
```

```
canvas.create_rectangle(90, 70, 180, 120,  
                        fill="blue", width=0)
```

Note that setting `width` to `0` removes the border completely.



Drawing Lines

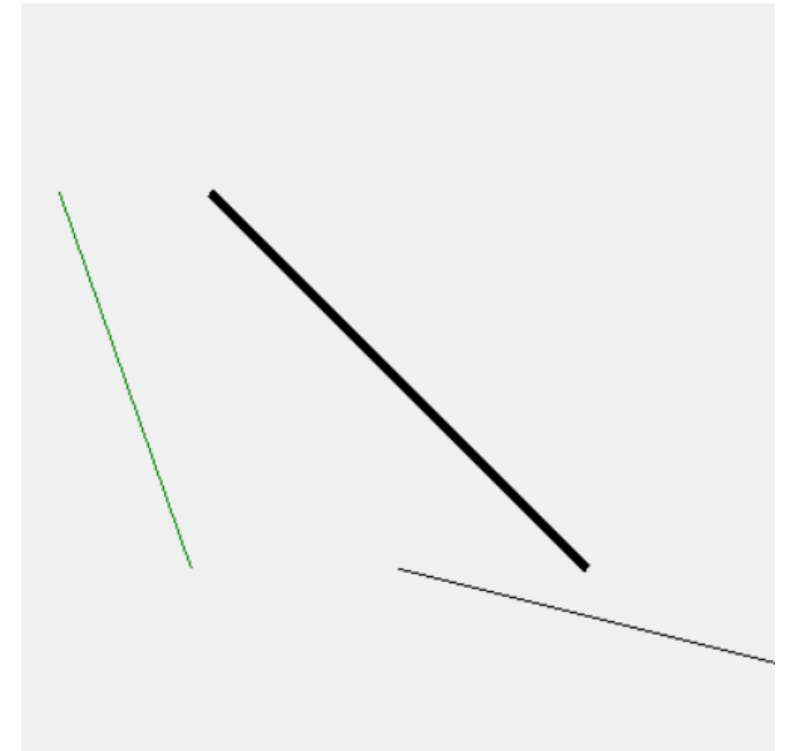
To draw a line on the screen, you specify the two endpoints of the line.

```
canvas.create_line(200, 300, 400, 350)
```

```
canvas.create_line(20, 100, 90, 300, fill="green")
```

```
canvas.create_line(100, 100, 300, 300, width=5)
```

Again, we can use `fill` and `width` to modify the lines.



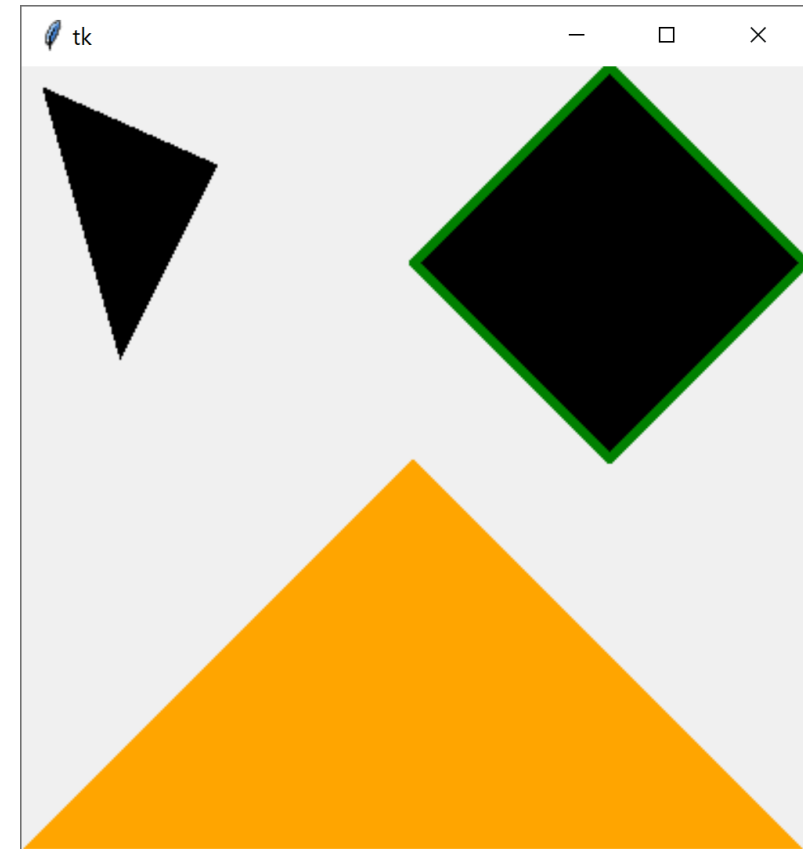
Drawing Polygons

To draw a polygon, you need to specify the coordinates of **each of the polygon's points as an x, y coordinate, in perimeter order**.

The polygon can have as many points as needed but will need at least three points to appear.

```
canvas.create_polygon(10, 10, 50, 150, 100, 50)
canvas.create_polygon(200, 200, 400, 400, 0, 400,
                    fill="orange")
canvas.create_polygon(200, 100, 300, 0, 400, 100, 300, 200,
                    outline="green", width=5)
```

Note here that we've also added a new keyword argument – **outline**, which specifies the color of the shape's outline.



Drawing Text

Drawing text on the canvas works a bit differently from drawing rectangles, ovals, lines, and polygons. We specify only one coordinate – the pixel where the **center** of text will be drawn.

```
canvas.create_text(200, 200, text="Hello World")
```

Although `text` is keyword argument and technically optional, `text` is required in order to draw text at all.

Keyword Argument - font

When drawing text, we can use the keyword argument `font` to change the appearance of the text.

The font parameters takes a string with one to three pieces of information – the font name, the font size, and the font type.

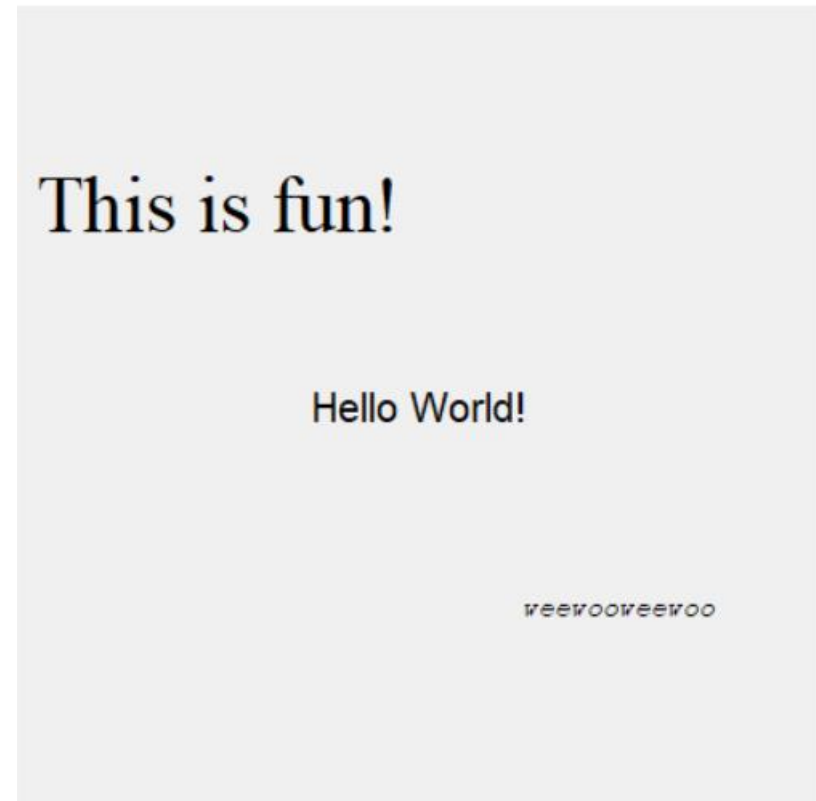
```
canvas.create_text(200, 200, text="Hello World!",  
                  font="Arial")
```

```
canvas.create_text(100, 100, text="This is fun!",  
                  font="Times 30")
```

```
canvas.create_text(300, 300, text="weewooweewoo",  
                  font="Courier 10 italic")
```

You can find a full list of fonts and types here:

<https://effbot.org/tkinterbook/tkinter-widget-styling.htm#fonts>



Keyword Argument - anchor

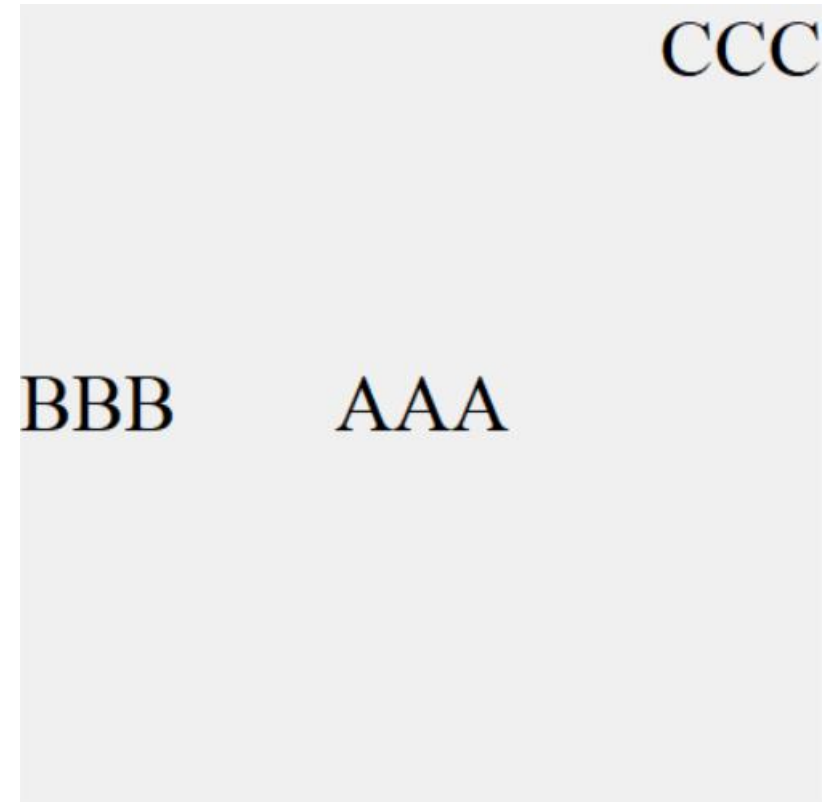
The point used in the `canvas.create_text` call is actually an **anchor** for the text, to describe where it is drawn from. That anchor defaults to the center of the text box, but we can change it to be any compass point instead.

```
canvas.create_text(200, 200, text="AAA",  
                  font="Times 30", anchor="center")
```

```
canvas.create_text(0, 200, text="BBB",  
                  font="Times 30", anchor="w")
```

```
canvas.create_text(400, 0, text="CCC",  
                  font="Times 30", anchor="ne")
```

Note that the anchor describes the **point on the text box** that will correspond to the (x, y) coordinate. Since CCC's anchor is `"ne"` (north-east), the upper-right corner of the text box is placed at (400, 0).



Drawing images

If we want to use a pre-made image in Tkinter, we can load one in as a PhotoImage. This can be created with:

```
img = tkinter.PhotoImage(file="sample.gif")
```

We can resize the image if needed, using **subsample** to make it smaller and **zoom** to make it bigger.

```
img = img.subsample(5) # make the image 5 times smaller
```

```
img = img.zoom(2) # make the image twice as large
```

Unfortunately, PhotoImages can only be .pgm, .ppm, and .gif files. For more filetypes, use the external module Pillow, described in the advanced slides this week.

Drawing images

Once you've created an image, you can draw it with `create_image`. This method takes the x, y coordinates of the image and can have other optional parameters:

```
# the image to be displayed. not really optional...
```

```
canvas.create_image(200, 100, image=imageVar)
```

```
# the anchor point of the coordinate.
```

```
# Same as for text, default "center"
```

```
canvas.create_image(200, 100, image=imageVar, anchor="n")
```

Tkinter Can Do Even More!

There's plenty of things Tkinter can draw and plenty of additional keyword arguments that we haven't covered here.

If you're interested in learning more, check out the Tkinter documentation:

<https://anzelg.github.io/rin2/book2/2405/docs/tkinter/index.html>

Activity: Fun with Tkinter

There are two coding problems on Hw1 (one core, one spicy) that use graphics – drawing The Fence and drawing a robot.

Use the rest of the time in class to get started on these problems!

Learning Goals

Identify the **argument(s)** and **returned value** of a function call

Use **libraries** to import functions in categories like math and randomness

Use the **graphics library** to construct images algorithmically