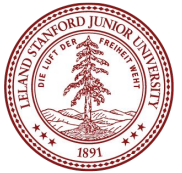
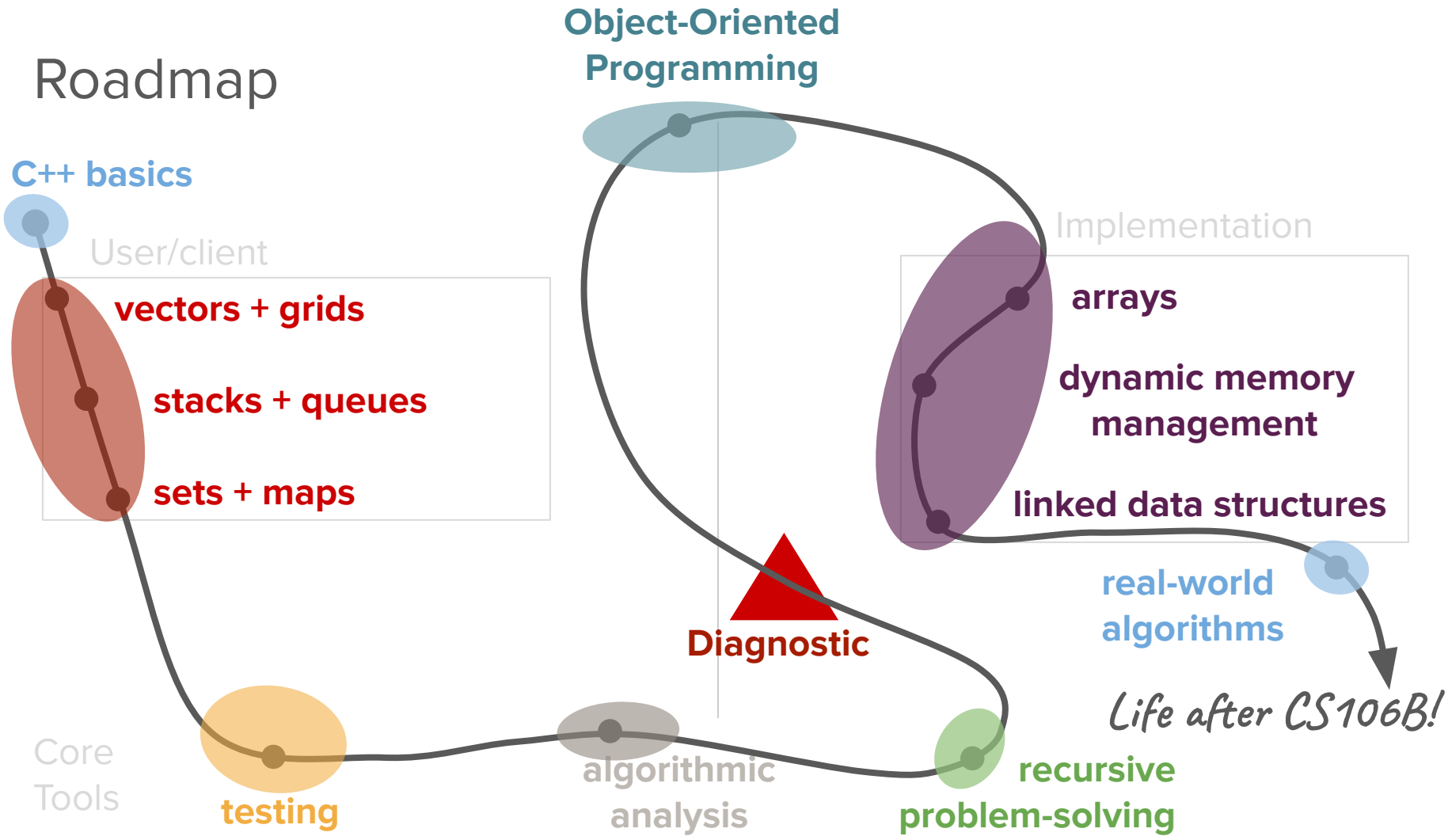
Programming Fundamentals in C++

What programming language are you most comfortable with?

(put your answers the chat)



Roadmap


Object-Oriented Programming
C++ basics
User/client
vectors + grids
stacks + queues
sets + maps
Implementation
arrays
dynamic memory management
linked data structures
real-world algorithms
Diagnostic
Life after CS106B!
Core Tools
testing
algorithmic analysis
recursive problem-solving

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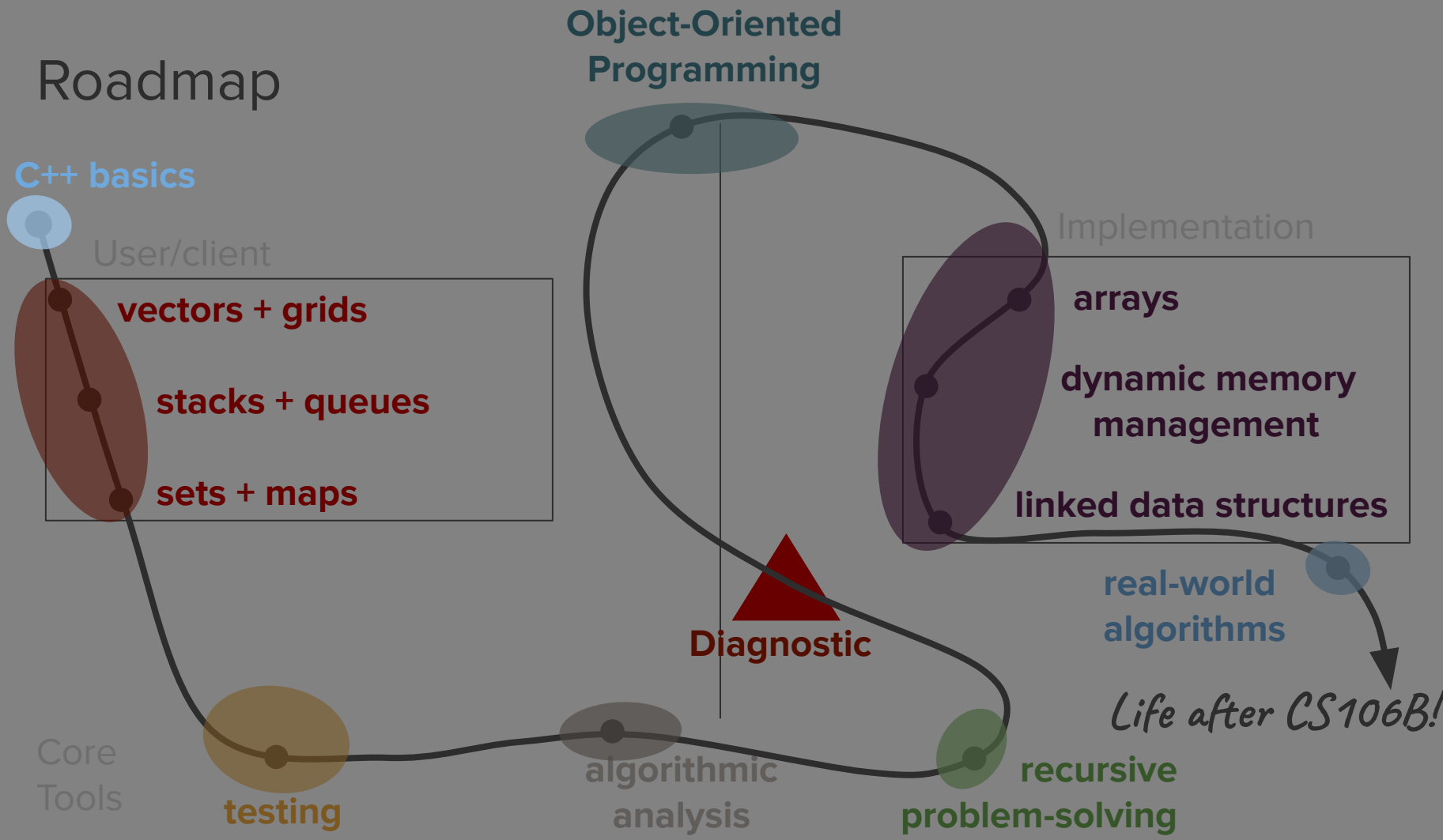
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Today's questions

Why C++?

What do core programming fundamentals look like in C++?

What's next?

Why C++?

How is C++ different from other languages?

- C++ is a compiled language (vs. interpreted)
  - This means that before running a C++ program, you must first compile it to machine code.

How is C++ different from other languages?

- C++ is a compiled language (vs. interpreted)

- C++ is gives us access to lower-level computing resources (e.g. more direct control over computer memory)
  - This makes it a great tool for better understanding abstractions!

How is C++ different from other languages?

- C++ is a compiled language (vs. interpreted)
- C++ is gives us access to lower-level computing resources (e.g. more direct control over computer memory)
- If you're coming from a language like Python, the syntax will take some getting used to.
  - Like learning the grammar and rules of a new language, typos are expected. But don't let this get in the way of working toward literacy!

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Demo program!

The structure of a program

```cpp
#include <iostream>
#include "console.h"
using namespace std;

// The C++ compiler will look for a function
// called “main”
int main() {
   cout << "Hello, world!" << endl;
   return 0;  // must return an int to indicate
              // successful program completion
}
```

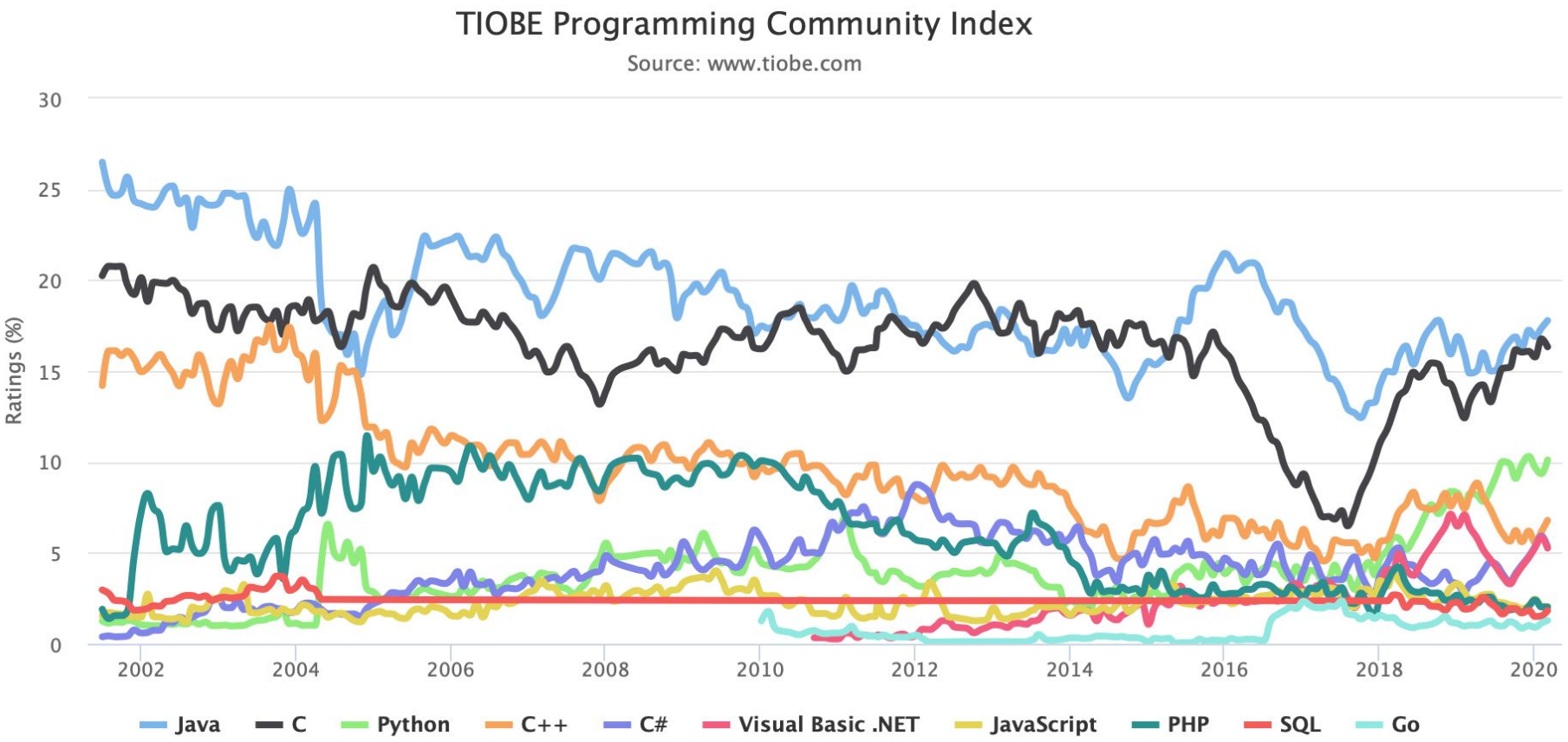
C++

```python
import sys


# This function does not need to be called “main”
def main():
   print('Hello, world!')


if __name__ == '__main__':
    # Any function that gets placed here will get
    # called when you run the program with
    # `python3 helloworld.py`
    main()
```

Python

Zoom Poll!

Where does C++ rank among the popular programming languages of the world?


TIOBE Programming Community Index
Source: www.tiobe.com
Ratings (%)
30
25
20
15
10
5
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2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Java
C
Python
C++
C#
Visual Basic .NET
JavaScript
PHP
SQL
Go

C++ Overview

If someone claims to have the perfect programming language,
he is either a fool or a salesman or both.
– *Bjarne Stroustrup*, Inventor of C++

C++ History

- C++ is a high-performance, robust (and complex) language built on top of the C programming language (originally named *C with Classes*)
  - Bjarne Stroustrup, the inventor of C++, chose to build on top of C because it was fast, powerful, and widely-used

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  - Our goal in this class will be to help you become literate in C++ as a second programming language

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- C++ can be **dangerous**
  - "With great power comes great responsibility"

What do core programming fundamentals look like in C++?

What do core programming fundamentals look like in C++?

Get ready for a whirlwind tour!

Comments, Includes, and Console Output

Comments

- Single-line comments

```
// Two forward slashes comment out the rest of the line

cout << "Hello, World!" << endl; // everything past the double-slash is a comment
```

- Multi-line comments

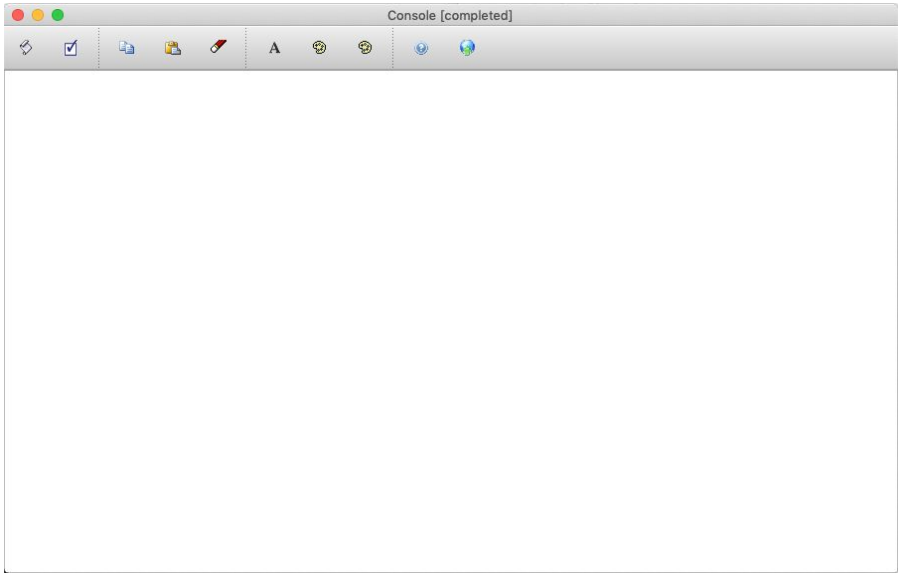
```
/* This is a multi-line comment.

 * It begins and ends with an asterisk-slash.

 */
```

Includes

- Utilizing code written by other programmers is one of the most powerful things that you can do when writing code.
- In order to make the compiler aware of other code libraries or other code files that you want to use, you must ***include a header file.*** There are two ways that you can do so:
  - `#include <iostream>`
    - Use of the angle bracket operators is usually reserved for code from the C++ Standard library
  - `#include "console.h"`
    - Use of the quotes is usually reserved for code from the Stanford C++ libraries, or code in files that you have written yourself

Console Output

- The console is the main venue that we will use in this class to communicate information from a program to the user of the program.



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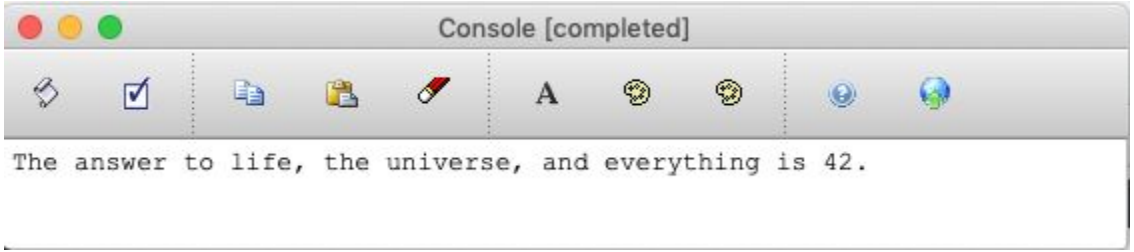
```
cout << "The answer to life, the universe, and everything is " << 42 << "." << endl;
```



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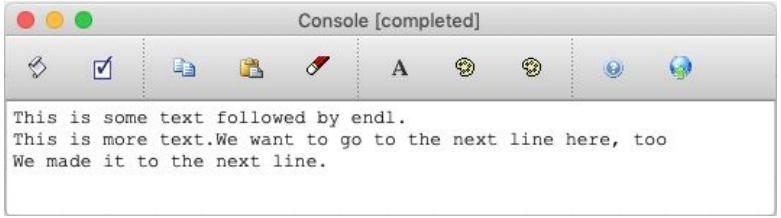
```
cout << "This is some text followed by endl." << endl;
cout << "This is more text.";
cout << "We want to go to the next line here, too" << endl;
cout << "We made it to the next line." << endl;
```



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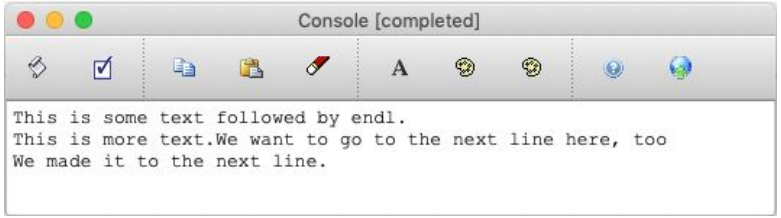

Note: In C++, all programming statements must end in a semicolon.

Variables and Types

Variables

- A way for code to store information by associating a value with a name

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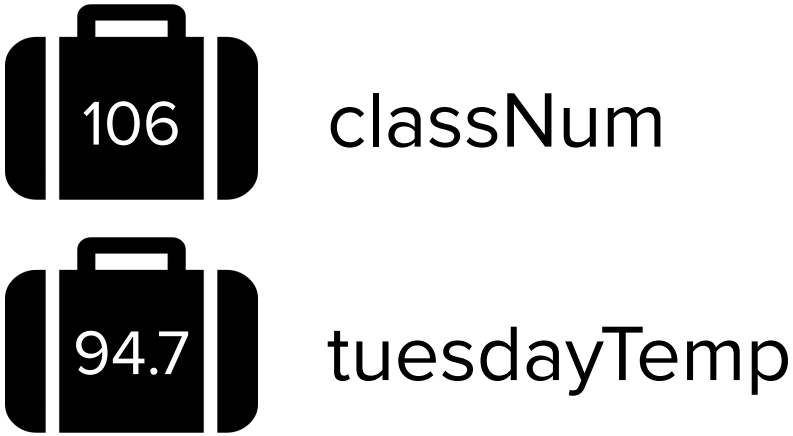
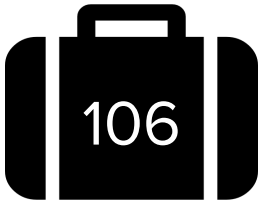


Variables

- A way for code to store information by associating a value with a name

We will think of a variable as a named container storing a value.



classNum

tuesdayTemp

Variables

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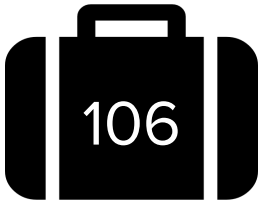
Note: C++ uses the camelCase naming convention



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Variables

- A way for code to store information by associating a value with a name
- **Variables are perhaps one of the most fundamental aspects of programming! Without variables, the expressive power of our computer programs would be severely degraded.**

Types

- As you should know from prior programming classes, all variables have a type associated with them, where the type describes the representation of the variable.

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  - `int` (or `long`)

42

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Types

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- Examples of types in C++
  - `int` (or `long`)
  - `double`

```
1.06
4.00
-18.3454545
```

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- Examples of types in C++
  - `int` (or `long`)
  - `double`
  - `string`

`"Hello, World!"`

`"CS106B"`

```
"I love computer
science <3"
```

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- Examples of types in C++
  - `int` (or `long`)
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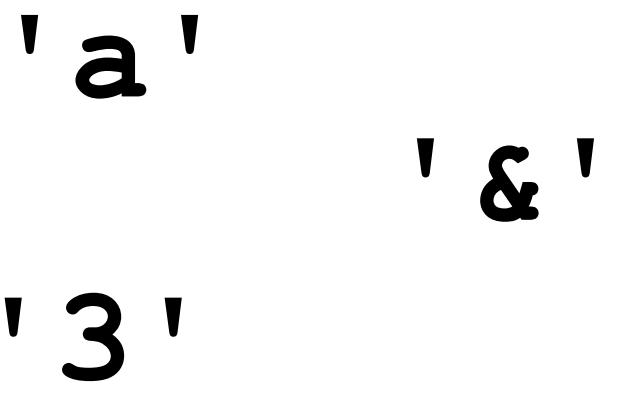
  - `char`



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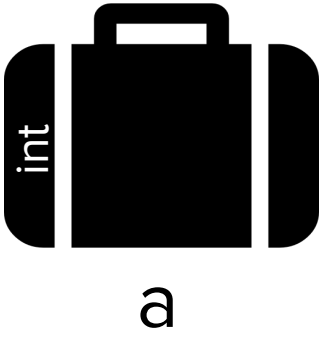
- Examples of types in C++
  - `int` (or `long`)
  - `double`
  - `string`
  - `char`
- **In C++, *all types must be explicitly defined when the variable is created, and a variable cannot change its type*.**

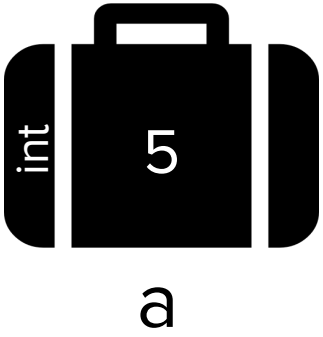
Typed Variables

```
int a; // declare a new integer variable
```



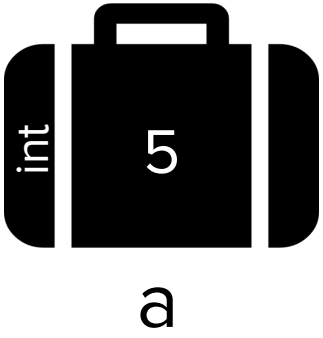
Typed Variables

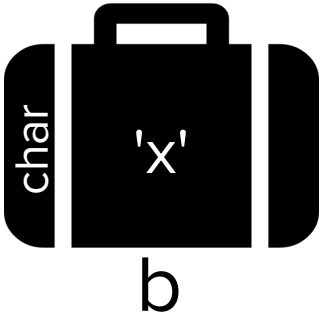
```
int a; // declare a new integer variable
a = 5; // initialize the variable value
```



Typed Variables

```
int a; // declare a new integer variable
a = 5; // initialize the variable value
char b = 'x'; // b is a char
("character")
```





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int a; // declare a new integer variable
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double d = 1.06; // d is a double, a type
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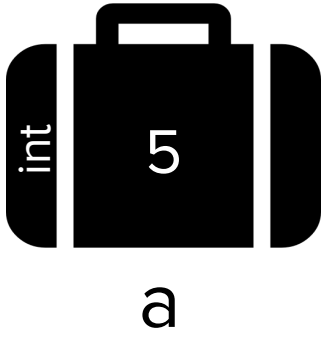

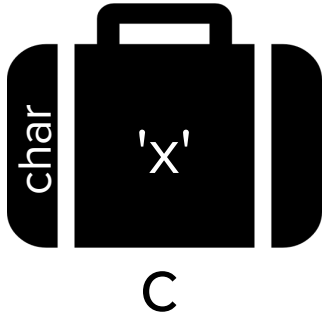

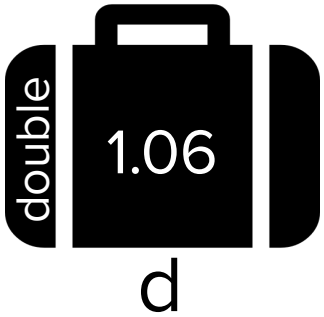

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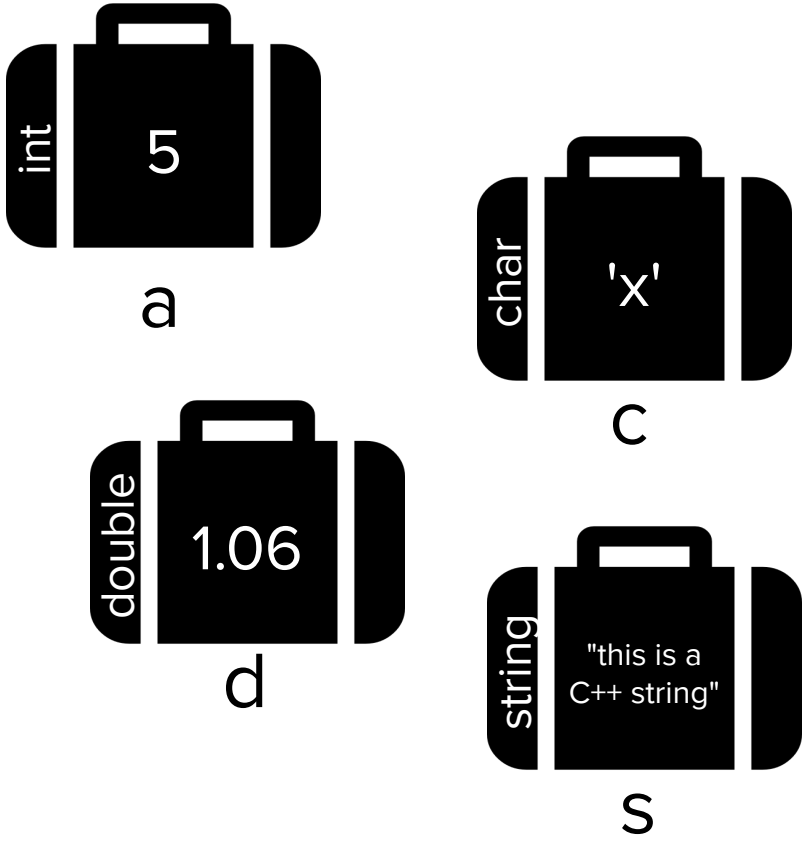

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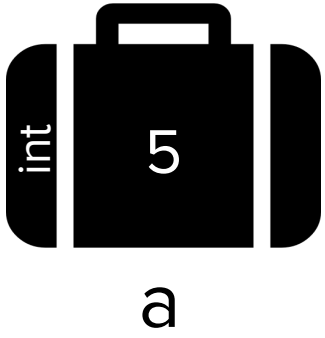

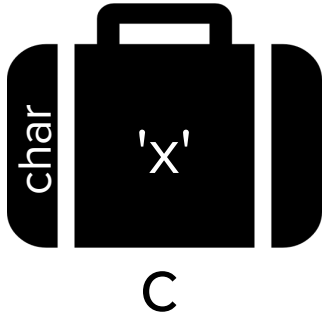

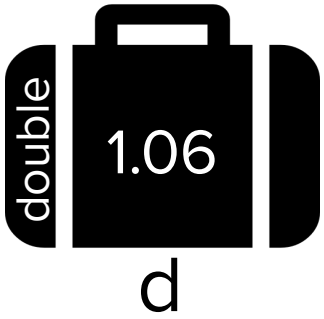

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int a = 12; // ERROR! You do not need the type when re-assigning a variable
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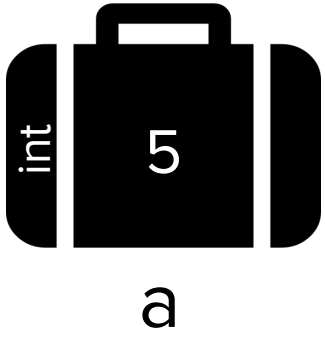

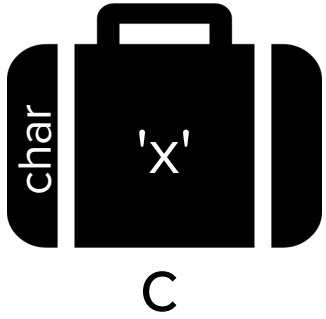

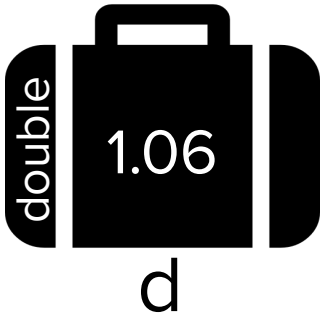

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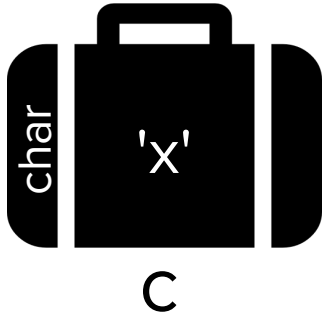
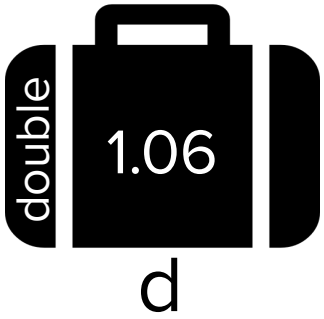
int a = 12; // ERROR! You do not need the type when re-assigning a variable
a = 12; // this is okay, updates variable value
```





Mid-Lecture Announcements Break!

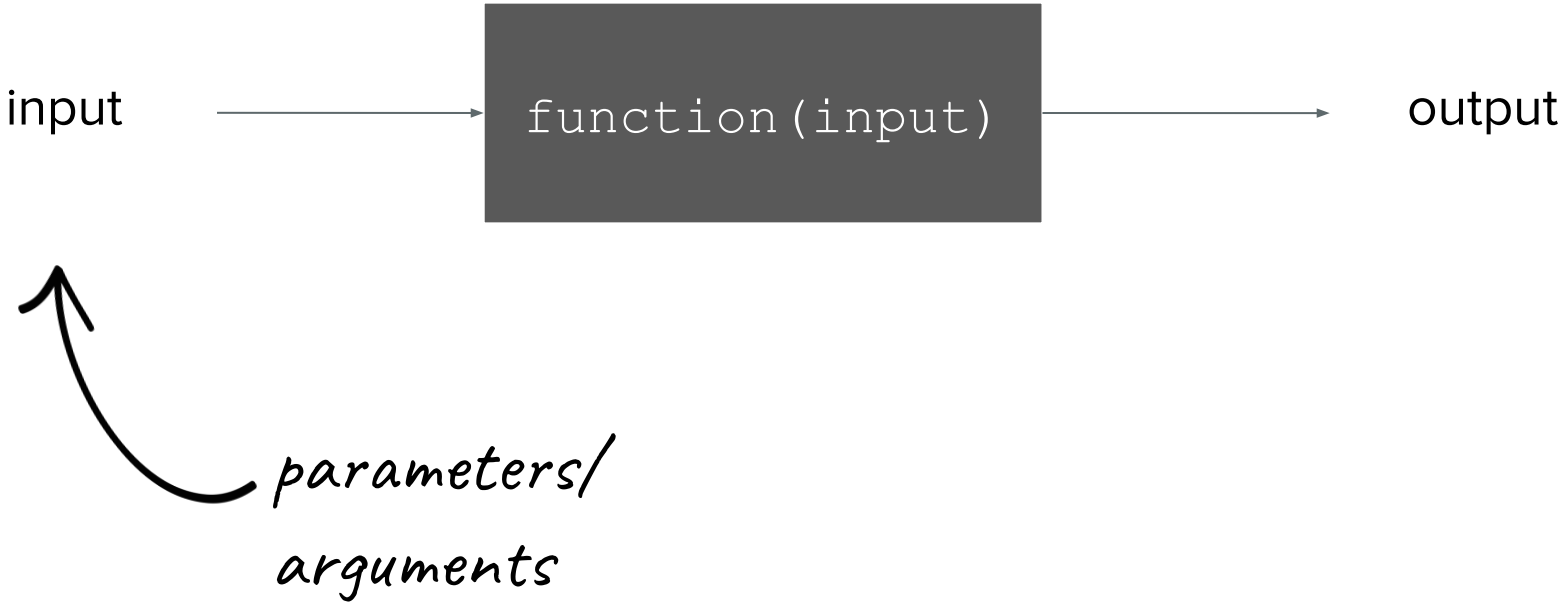
Announcements

- Complete the C++ survey and help us plan tomorrow's lecture!
- Fill out your section time preferences by Sunday at 5pm PDT (opens tomorrow at 5pm PDT).
- Finish Assignment 0 by Friday at 11:59 pm PDT.
  - If you're running into issues with Qt Creator, come to the Qt Installation Help Session Thursday at 5pm PDT. Join at the LaIR link (cs198.stanford.edu/lair) to get help.
- Assignment 1 will be released Friday, and after this lecture is over, you will have the skills you need to get started on the first part!
  - There be a YEAH (Your Early Assignment Help) session held from 12:30-1:30pm PDT on Monday afternoon to help folks get started.

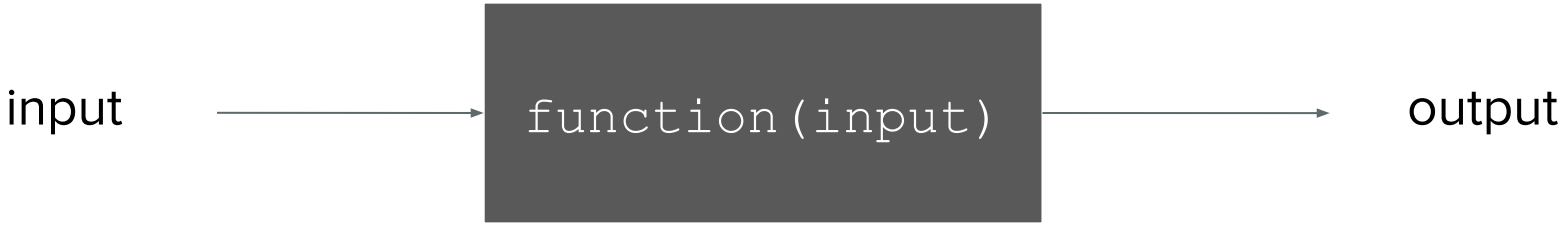
Functions and Parameters

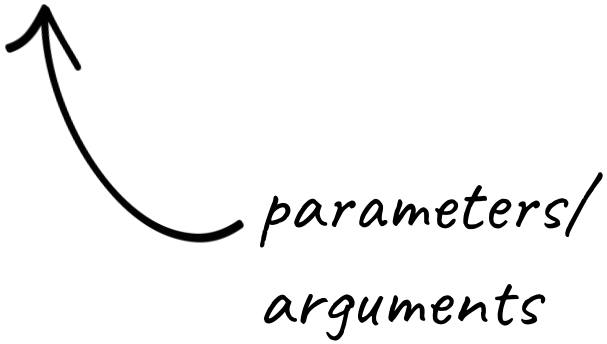
Anatomy of a function

Anatomy of a function



Anatomy of a function





Definition

parameter(s)
One or more variables that your function expects as input

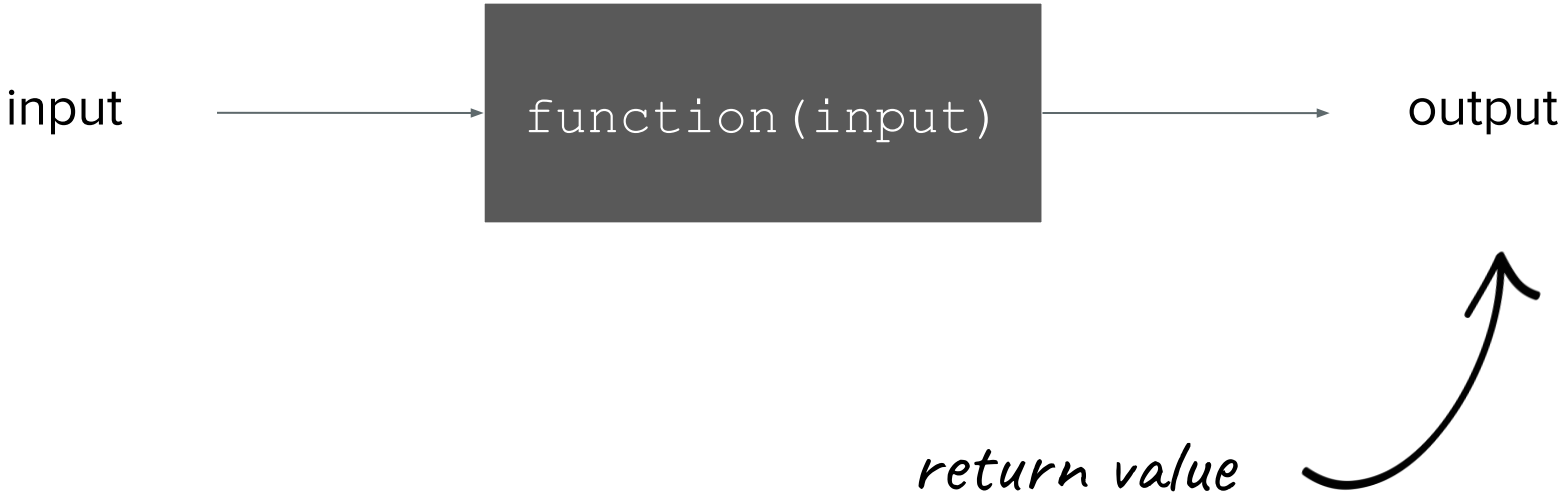
Anatomy of a function

parameters/
arguments

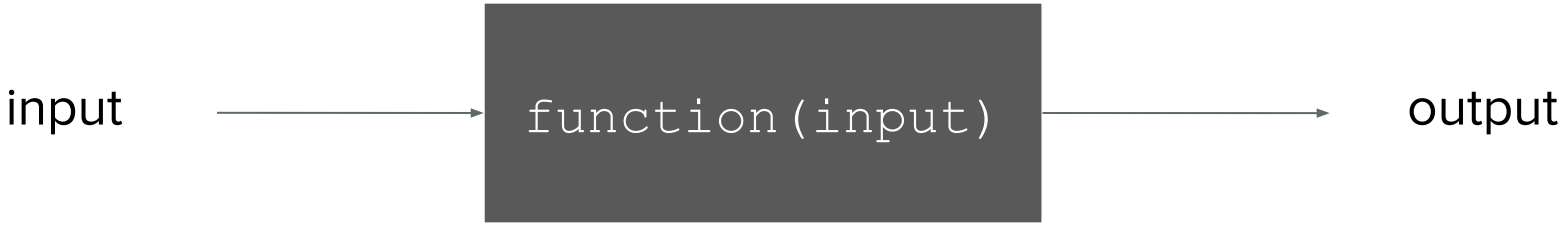
Definition

argument(s)
The values passed into your function and assigned to its parameter variables

Anatomy of a function



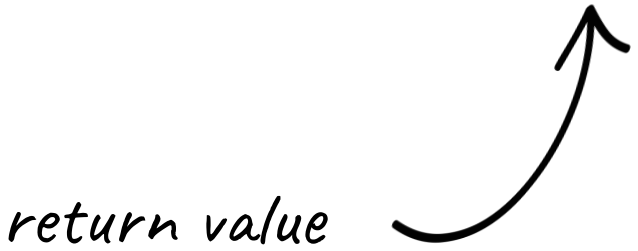
Anatomy of a function



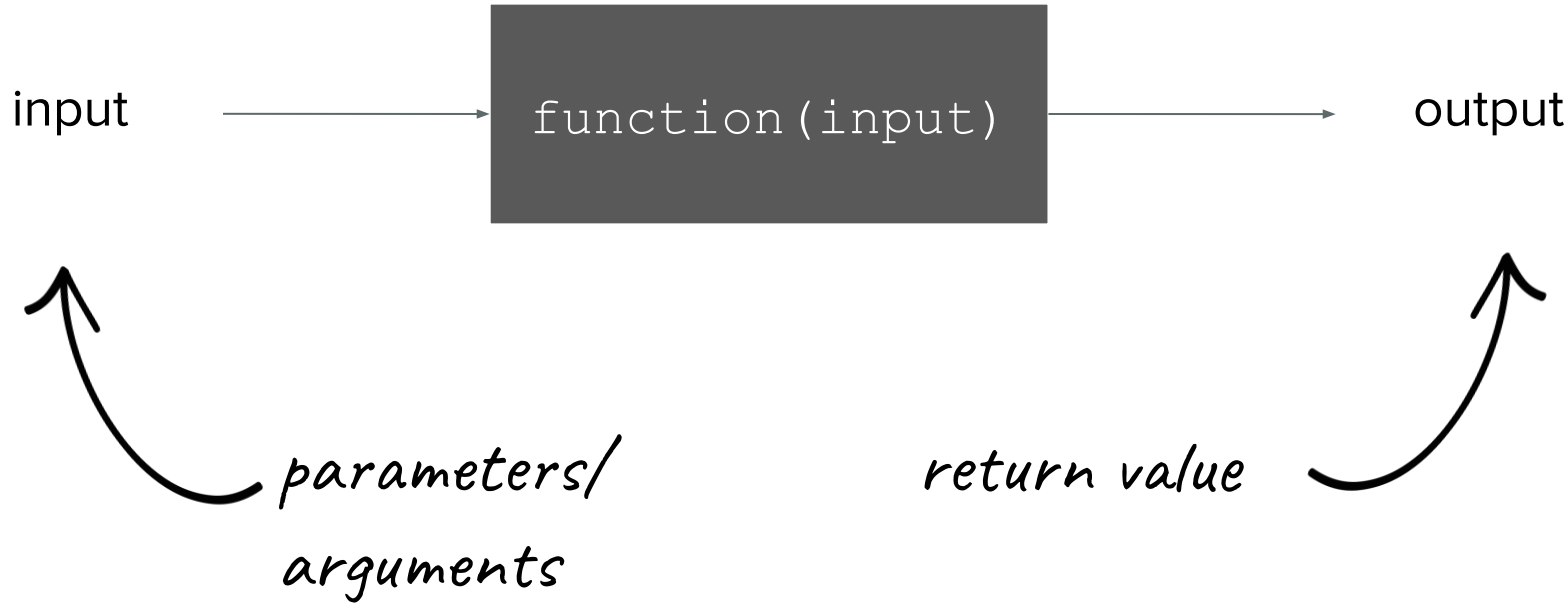
Definition

return value

The value that your function hands back to the “calling” function

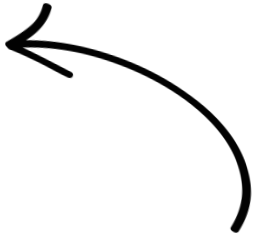


Anatomy of a function



Anatomy of a function

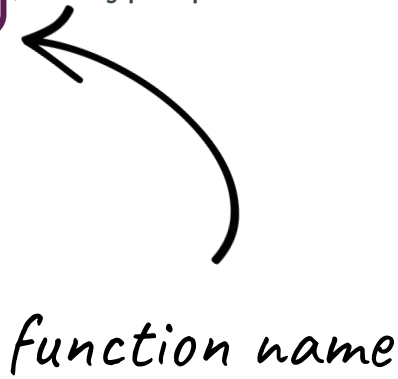
```
returnType functionName(varType parameter1, varType parameter2, ...);
```



function prototype

Anatomy of a function

```
returnType functionName(varType parameter1, varType parameter2, ...);
```



Anatomy of a function

```
returnType functionName(varType parameter1, varType parameter2, ...);
```

input expected (parameters)

Anatomy of a function

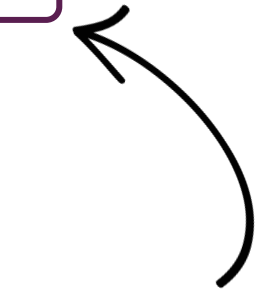
```
returnType functionName(varType parameter1, varType parameter2, ...);
```

input expected (parameters)

Notice that these look very similar to variable declarations! You can think of parameters as a special set of local variables that belong to a function.

Anatomy of a function

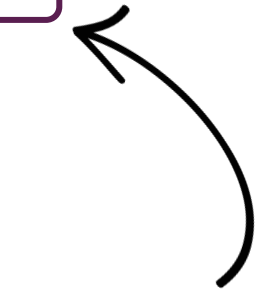
```
returnType functionName(varType parameter1, varType parameter2, ...);
```



output expected
(return type)

Anatomy of a function

```
returnType functionName(varType parameter1, varType parameter2, ...);
```



output expected (return type)

How do you designate a function that doesn't return a value? You can use the special void keyword. Note that this type is only applicable for return types, not parameters/variables.

Anatomy of a function

```
returnType functionName(varType parameter1, varType parameter2, ...);
```

```
returnType functionName(varType parameter1, varType parameter2, ...) {
    returnType variable = /* Some fancy code. */
    /* Some more code to actually do things. */
    return variable;
}
```

function definition

Anatomy of a function

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returnType functionName(varType parameter1, varType parameter2, ...);


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    returnType variable = /* Some fancy code. */
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}
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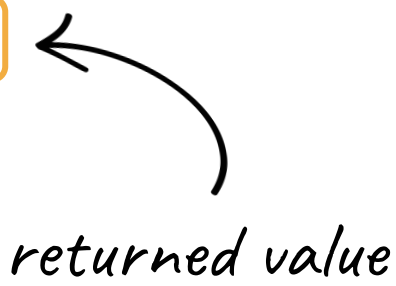

Function Example

```
double average(double a, double b){
    double sum = a + b;
    return sum / 2;
}


int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    return 0;
}
```

Function Example

```
double average(double a, double b){
    double sum = a + b;
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}


int main(){
    double mid = average(10.6, 7.2);
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    return 0;
}
```

Order matters! A function must always be defined before it is called.

Function Example

```
double average(double a, double b){
    double sum = a + b;
    return sum / 2;
}
```

callee

(called function)

```
int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    return 0;
}
```

caller

(calling function)

Function Example

```
double average(double a, double b){
    double sum = a + b;
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}

int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    return 0;
}
```

parameters

return value

arguments

Function Example

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double average(double a, double b){
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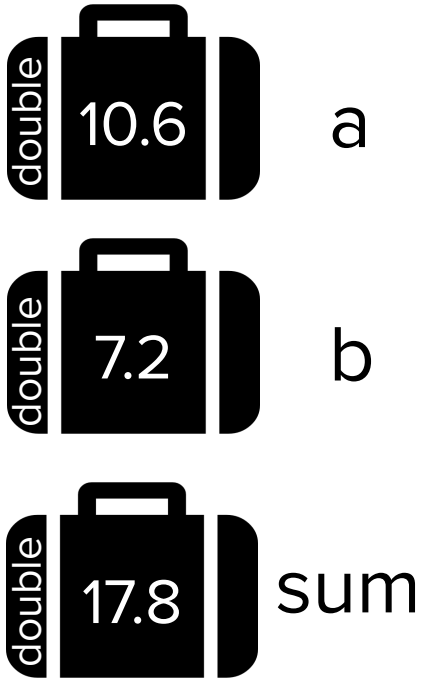
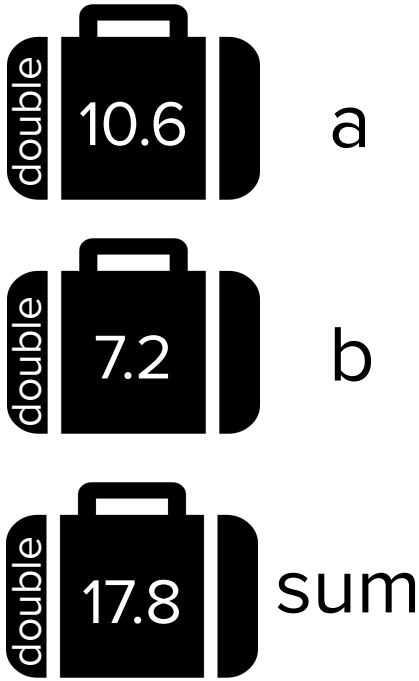


Function Example

These variables only exist inside **`average()`**!

```
double average(double a, double b){
    double sum = a + b;
    return sum / 2;
}


int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    return 0;
}
```



Function Example

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Function Example

```
double average(double a, double b){
    double sum = a + b;
    return sum / 2;
}


int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    return 0;
}
```

This variable only exists inside **`main()`**!

Pass by Value

```
// C++:
#include<iostream>
using namespace std;

int doubleValue(int x) {
    x *= 2;
    return x;
}

int main() {
    int myValue = 5;
    int result = doubleValue(myValue);

    cout << "myValue: " << myValue << " ";
    cout << "result: " << result << endl;
}
```

Zoom Poll!

What is the console output of this block of code?

Pass by Value

```
// C++:
#include<iostream>
using namespace std;

int doubleValue(int x) {
    x *= 2;
    return x;
}

int main() {
    int myValue = 5;
    int result = doubleValue(myValue);

    cout << "myValue: " << myValue << " ";
    cout << "result: " << result << endl;
}
```

myValue: 5 result: 10

Why is this the case?

Pass by Value

```
// C++:
#include<iostream>
using namespace std;

int doubleValue(int x) {
    x *= 2;
    return x;
}

int main() {
    int myValue = 5;
    int result = doubleValue(myValue);

    cout << "myValue: " << myValue << " ";
    cout << "result: " << result << endl;
}
```

- The reason for the output is that the parameter **`x`** was passed to the **`doubleValue`** function *by value*, meaning that the variable **`x`** is a *copy* of the variable passed in. Changing it inside the function does *not* change the value in the calling function.
- Pass-by-value is the default mode of operation when it comes to parameters in C++
- C++ also supports a different, more nuanced way of passing parameters – we will see this in the next lecture!

Control Flow

Boolean Expressions

Expression	Meaning
`a < b`	**a** is less than **b**
`a <= b`	**a** is less than or equal to **b**
`a > b`	**a** is greater than **b**
`a >= b`	**a** is greater than or equal to **b**
`a == b`	**a** is equal to **b**
`a != b`	**a** is not equal to **b**

Operator	Meaning
`a && b`	Both **a** AND **b** are **`true`**
`a || b`	Either **a** OR **b** are **`true`**
`!a`	If **a** is **`true`**, returns **`false`**, and vice-versa

Conditional Statements

- The C++ **`if`** statement tests a boolean expression and runs a block of code if the expression is **`true`**, and, optionally, runs a different block of code if the expression is **`false`**. The **`if`** statement has the following format:
  - ```
    if (expression) {
      statements if expression is true
    } else {
      statements if expression is false
    }
    ```

Note: The parentheses around expression are required.
    ```

Conditional Statements

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  - ```
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    }
    ```

Note: The parentheses around expression are required.

- In Python, a block is defined as an indentation level, where *whitespace* is important. C++ does not have any whitespace restrictions, so blocks are denoted with curly braces, **`{`** to begin a block, and **`}`** to end a block.
- Blocks are used primarily for conditional statements, functions, and loops.
    ```

Conditional Statements

- The C++ **`if`** statement tests a boolean expression and runs a block of code if the expression is **`true`**, and, optionally, runs a different block of code if the expression is **`false`**. The **`if`** statement has the following format:
  - ```
    if (expression) {
      statements if expression is true
    } else {
      statements if expression is false
    }
    ```

- Additional else if statements can be used to check for additional conditions as well
  - ```
    if (expression1) {
      statements if expression1 is true
    } else if (expression2) {
      statements if expression2 is true
    } else {
      statements if neither expression1 nor expression2 is true
    }
    ```

`while` loops

- Loops allow you to repeat the execution of a certain block of code multiple times

`while` loops

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- **`while`** loops are great when you want to continue executing something until a certain condition is met and you don't know exactly how many times you want to iterate for

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- **`while`** loops are great when you want to continue executing something until a certain condition is met and you don't know exactly how many times you want to iterate for

```
while (expression) {
  statement;
  statement;
  ...
}
```

Execution continues until expression evaluates to false

`while` loops

- Loops allow you to repeat the execution of a certain block of code multiple times
- **`while`** loops are great when you want to continue executing something until a certain condition is met and you don't know exactly how many times you want to iterate for

```
while (expression) {
  statement;
  statement;
  ...
}
```

```
int i = 0;
while (i < 5) {
  cout << i << endl;
  i++;
}
```

```
Output:
0
1
2
3
4
```

`while` loops

- Loops allow you to repeat the execution of a certain block of code multiple times
- **`while`** loops are great when you want to continue executing something until a certain condition is met and you don't know exactly how many times you want to iterate for

```
while (expression) {
  statement;
  statement;
  ...
}
```

```
int i = 0;
while (i < 5) {
  cout << i << endl;
  i++;
}
```

Output:

```
0
1
2
3
4
```

Note: The **`i++`** increments the variable **`i`** by **1**, and is the reason C++ got its name! (and there is a corresponding decrement operator, **`--`**, as in **`i--`**).

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code
- `for` loop syntax in C++ can look a little strange, let's investigate!

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code

```
for (initializationStatement; testExpression; updateStatement) {
  statement;
  statement;
  ...
}
```

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code

```
for (initializationStatement; testExpression; updateStatement) {
  statement;
  statement;
  ...
}
```

The `initializationStatement` happens at the beginning of the loop, and initializes a variable.

E.g., `int i = 0`.

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code

```
for (initializationStatement; testExpression; updateStatement) {
  statement;
  statement;
  ...
}
```

The `testExpression` is evaluated initially, and after each run through the loop, and if it is `true`, the loop continues for another iteration.

E.g., `i < 3`.

`for` loops

- **`for`** loops are great when you have a known, fixed number of times that you want to execute a block of code

```
for (initializationStatement; testExpression; updateStatement) {
  statement;
  statement;
  ...
}
```

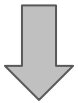
The **`updateStatement`** happens after each loop, but *before* **`testExpression`** is evaluated.

E.g., **i++**.

`for` loops

- `for` loops are great when you have a known, fixed number of times that you want to execute a block of code

```
for (initializationStatement; testExpression; updateStatement) {
  statement;
  statement;
  ...
}
```



```
for (int i = 0; i < 3; i++) {
  cout << i << endl;
}
```

`for` loops

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  statement;
  statement;
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```
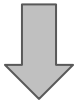



```
for (int i = 0; i < 3; i++) {
  cout << i << endl;
}
```

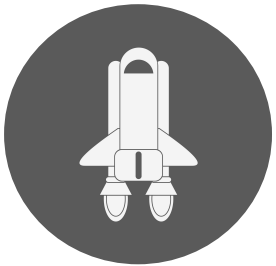
```
Output:
0
1
2
```

Interactive Example

[Breakout Room + Ed Workspaces]

Try it for yourself!

Write a program that prints out the calls for a spaceship that is about to launch. Countdown the numbers from 10 to 1 and then write “Liftoff.”



```
10
9
8
7
6
5
4
3
2
1
Liftoff
```

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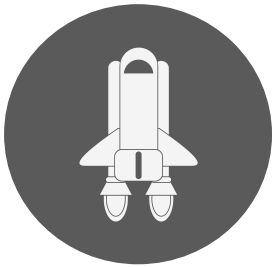


```
10
9
8
7
6
5
4
3
2
1
Liftoff
```

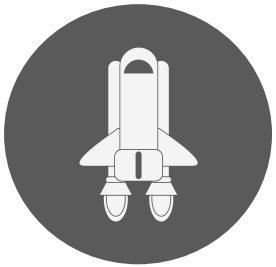
```python
def main():
    for i in range(10, 0, -1):
        print(i)
    print ("Liftoff")

if __name__ == "__main__":
    main()
```

Python

Try it for yourself!

Write a program that prints out the calls for a spaceship that is about to launch. Countdown the numbers from 10 to 1 and then write “Liftoff.”



```
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9
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Liftoff
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if __name__ == "__main__":
    main()
```

Python

```cpp
#include <iostream>
using namespace std;

int main() {
    /* TODO: Your code goes here! */

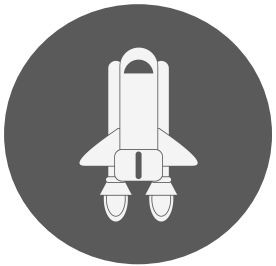
    return 0;

}
```

C++

Try it for yourself!

Write a program that prints out the calls for a spaceship that is about to launch. Countdown the numbers from 10 to 1 and then write “Liftoff.”



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9
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```

Python

```cpp
#include <iostream>
using namespace std;

int mai
    /* 
    retu

}
```

Breakout Rooms!

C++

What’s next?

Strings, Testing, C++ Review