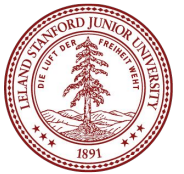
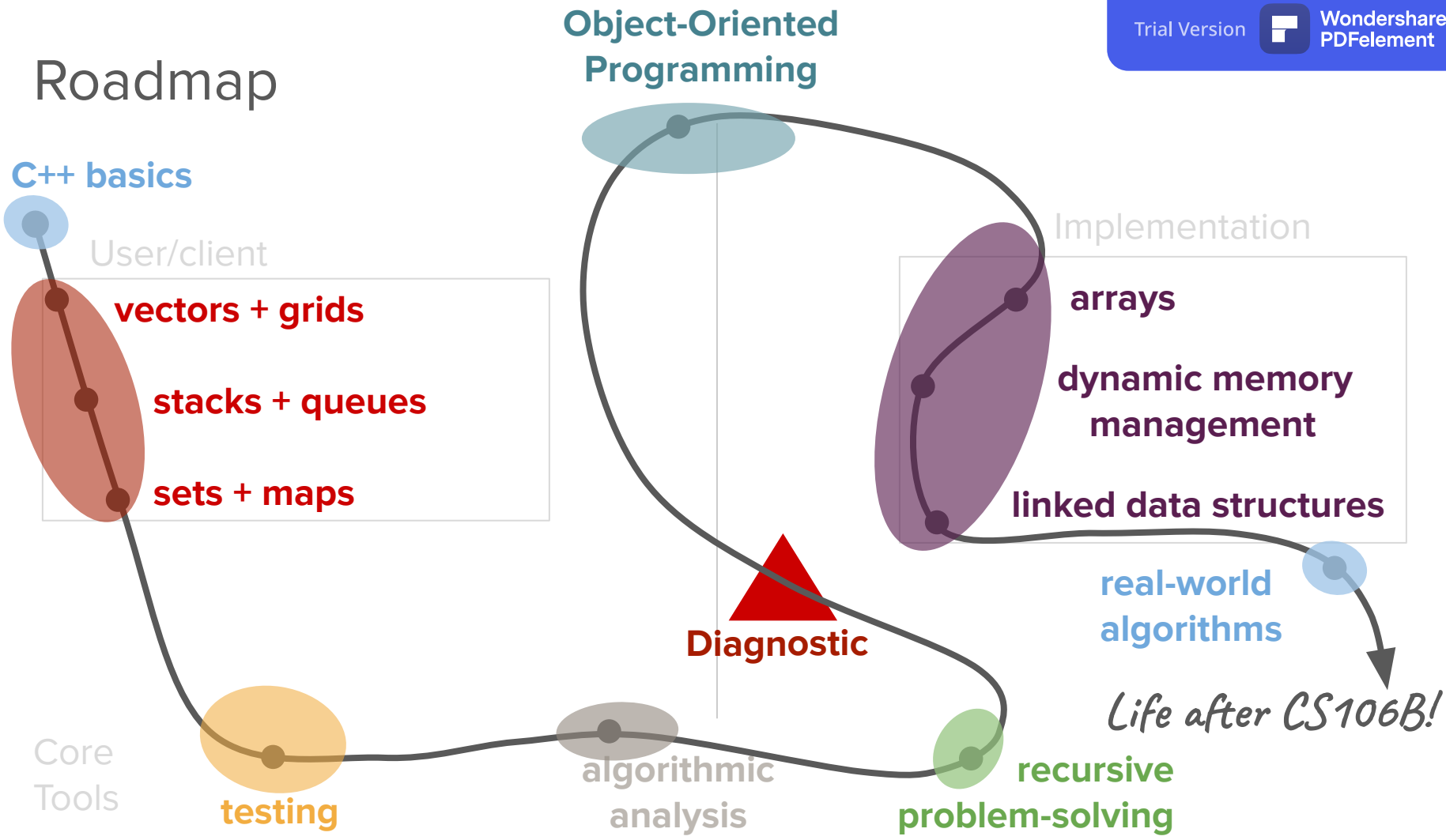
Programming Fundamentals in C++

What programming language are you most comfortable with?

(put your answers the chat)



Roadmap



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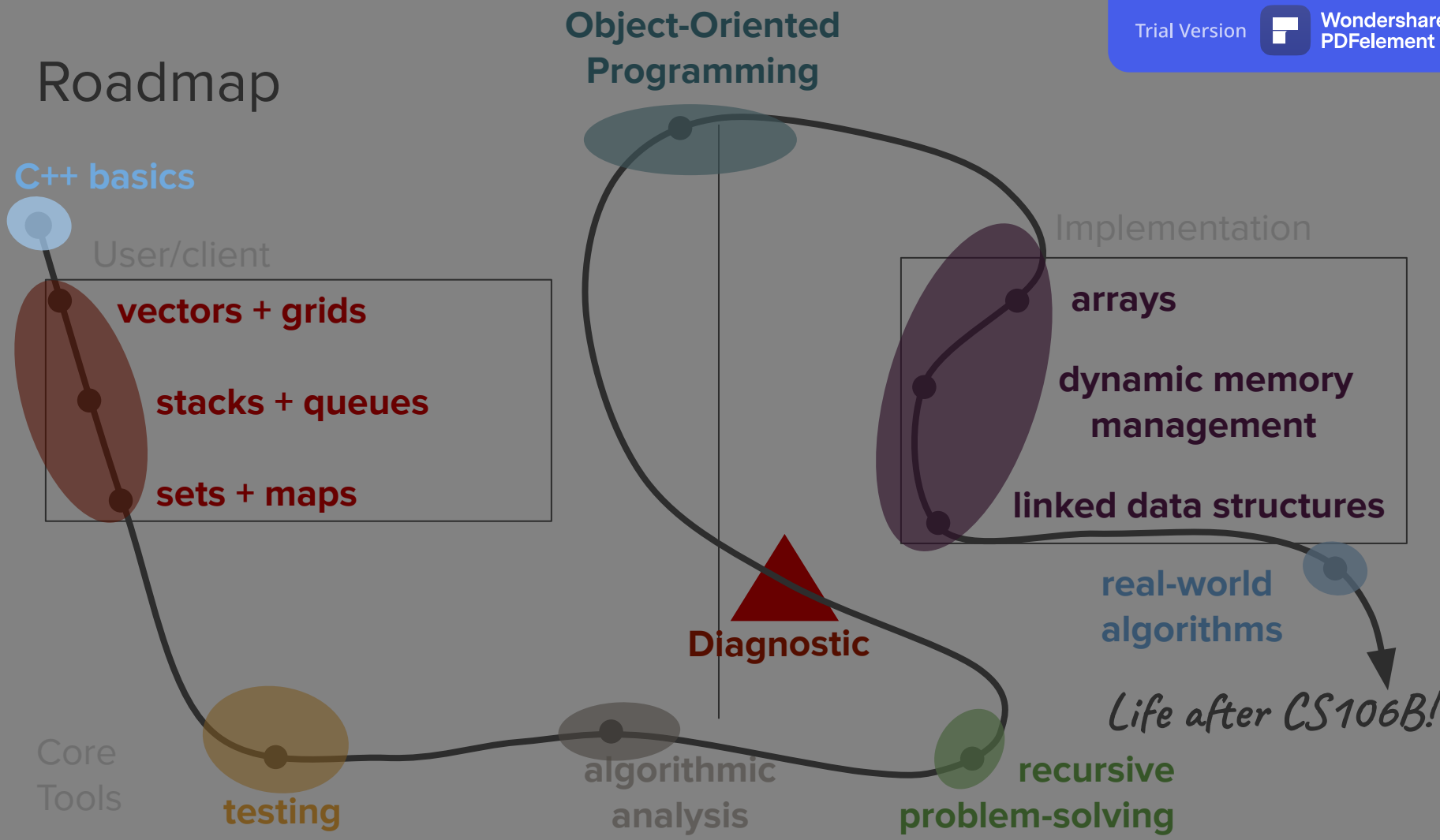


Today's questions

Why C++?

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

How do we test code in CS106B?

What's next?

Why C++?

Review: 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!

- If you're coming from a language like Python, the syntax will take some getting used to.

  Like learning the grammer and rules of a new language, typos are expected. But don't let this get in the way of working toward literacy!

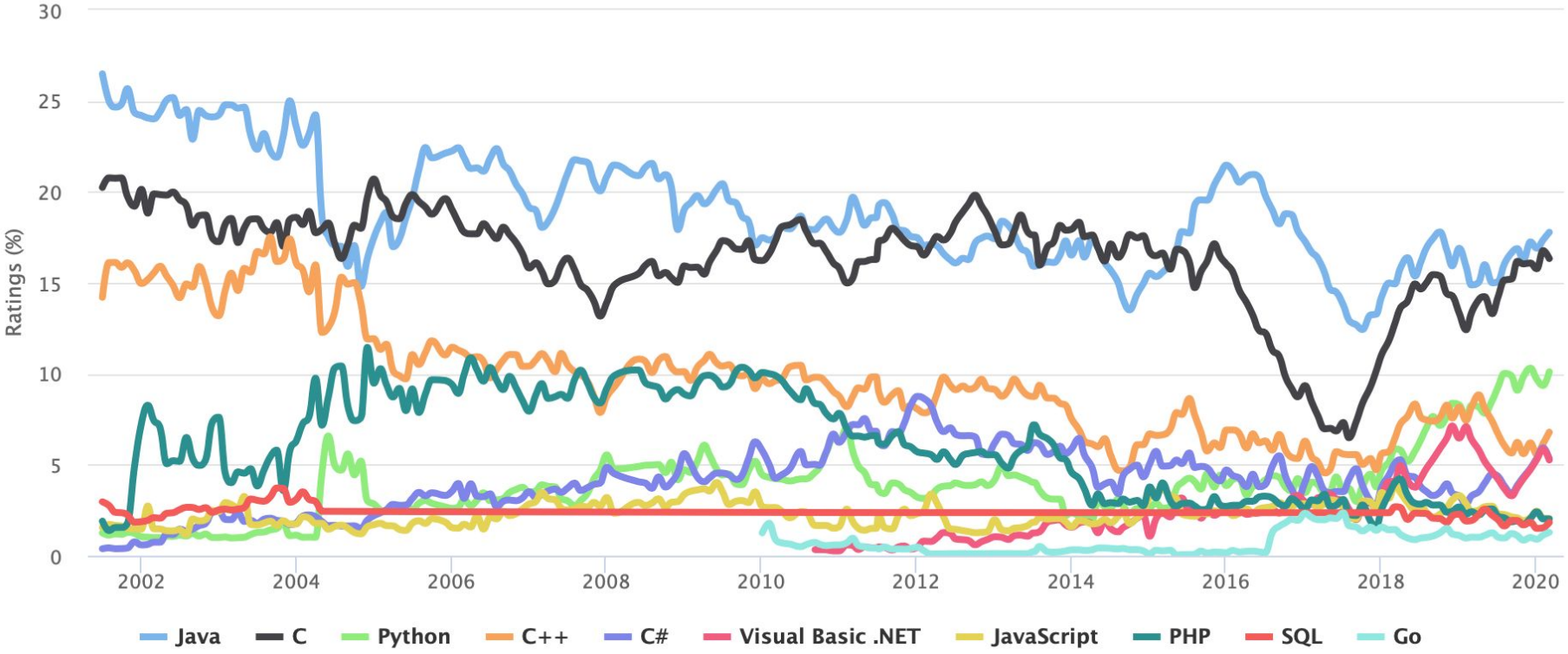
错别字是意料之中的 不要让这个妨碍到你的识字率

Zoom Poll!

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

TIOBE Programming Community Index

Source: www.tiobe.com



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
- C++ has been an object-oriented language from the beginning
  - We will spend the middle portion of this class talking about the paradigm of object-oriented programming
- C++ is quite mature and has become complex enough that it is challenging to master the language
  - Our goal in this class will be to help you become literate in C++ as a second programming language

C++ Benefits and Drawbacks

Benefits

- C++ is **fast**
  - Get ready for the Python vs C++ speed showdown during Assignment 1!
- C++ is **popular**
  - Many companies and research projects use C++ and it is common for coding interviews to be conducted in C++
- C++ is **powerful**
  - C++ brings you closer to the raw computing power that your computer has to offer

Drawbacks

- C++ is **complex**
  - We will rely on the Stanford C++ libraries to provide a friendlier level of abstraction
  - In the future, you may choose to explore the *standard* libraries
- C++ can be **dangerous**
  - "With great power comes great responsibility"

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

Get ready for a whirlwind tour!

Comments, Includes, and Console (控制台) 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.

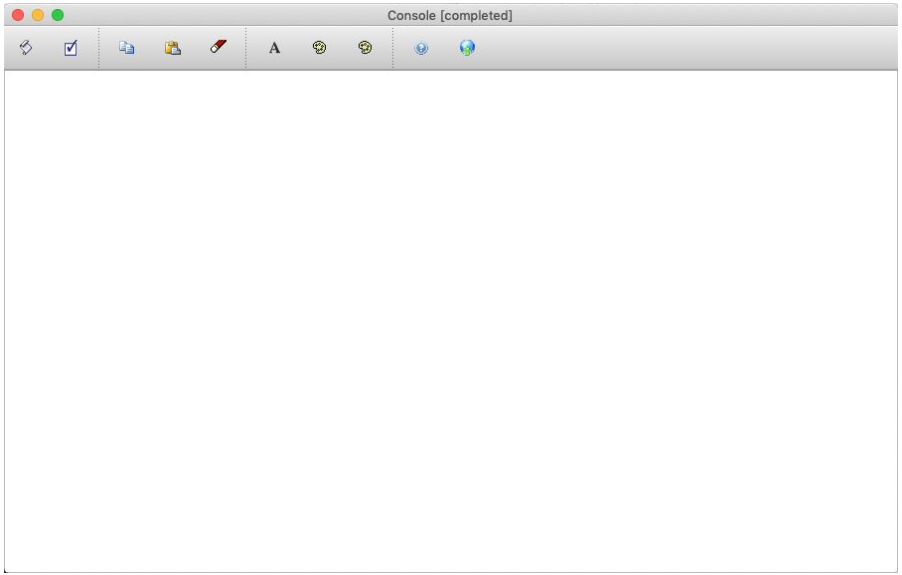
 */
```

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 (编辑器) aware (知道) 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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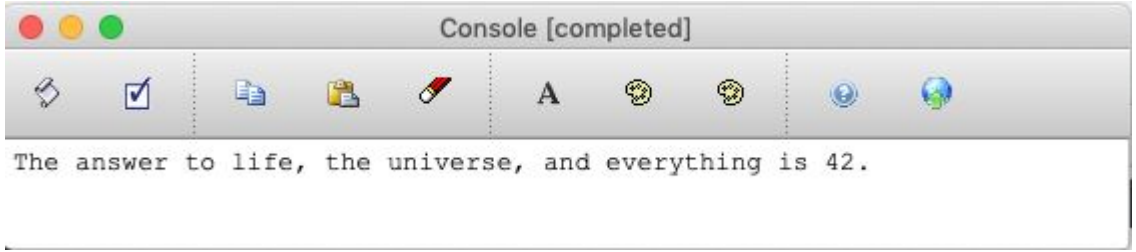
- In C++, the way that you get information to the console is by using the **`cout`** keyword and angle bracket operators (**<<**).

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



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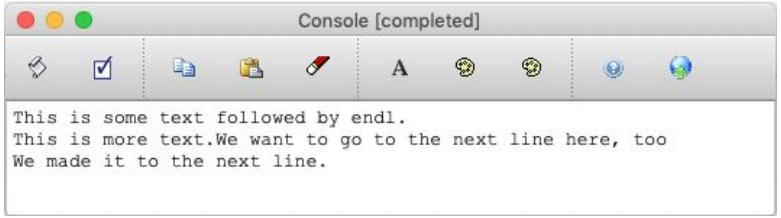
- The **`endl`** is necessary to put the cursor on a different line. Here is an example with and without the **`endl`** keyword.

```
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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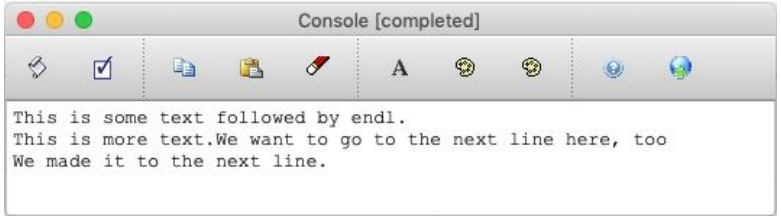

Note: In C++, all programming statements must end in a semicolon.

Variables and Types

Variables

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

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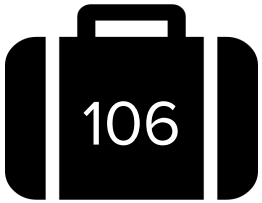


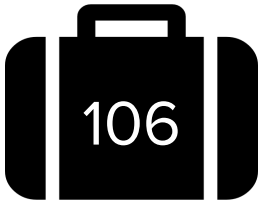
classNum

tuesdayTemp

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.



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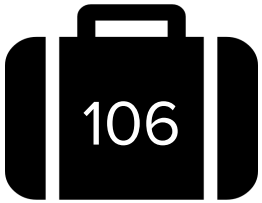
Variables

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

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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- Examples of types in C++
  - `int`

42

106

-3

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.
- Examples of types in C++
  - `int`
  - `double`

1.06

4.00

-18.3454545

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.
- Examples of types in C++
  - `int`
  - `double`
  - `string`

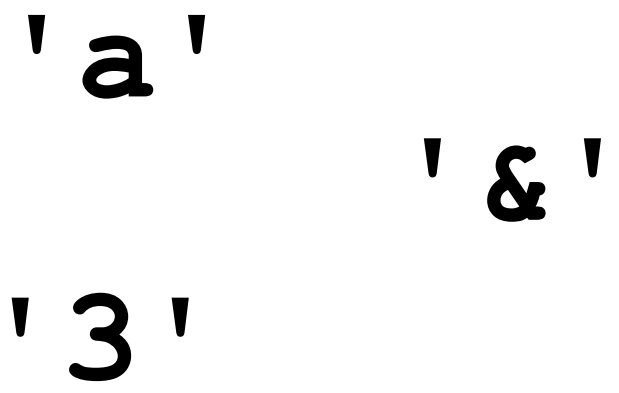
`"Hello, World!"`

`"CS106B"`

`"I love computer science <3"`

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.
- Examples of types in C++
  - `int`
  - `double`
  - `string`
  - `char`

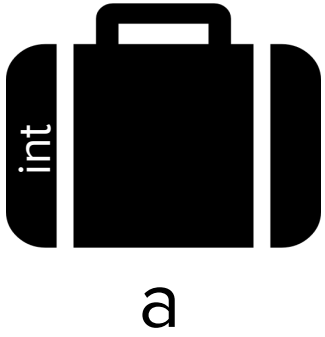


Types

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

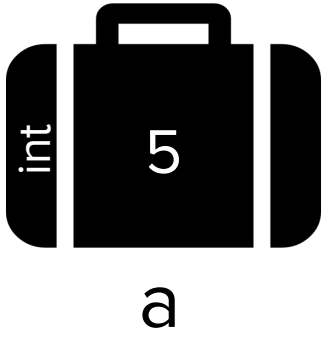
Typed Variables

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



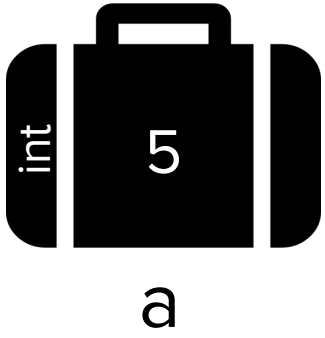
Typed Variables

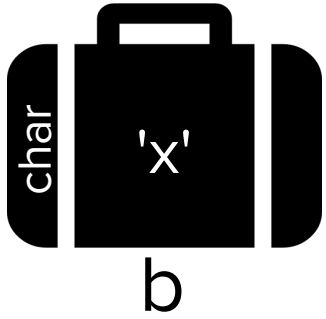
```
int a; // declare a new integer variable
a = 5; // initialize the variable value
```



Typed Variables

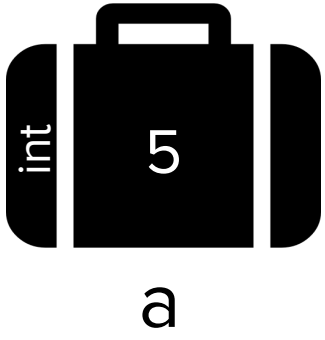
```
int a; // declare a new integer variable
a = 5; // initialize the variable value
char b = 'x'; // b is a char ("character")
```

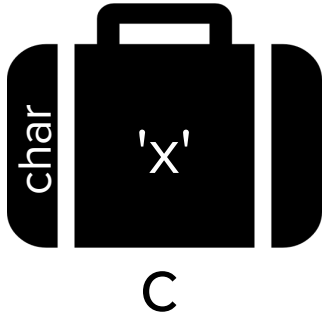


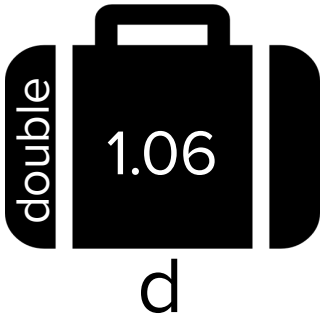


Typed Variables

```
int a; // declare a new integer variable
a = 5; // initialize the variable value
char c = 'x'; // b is a char ("character")
double d = 1.06; // d is a double, a type
used to represent decimal numbers
```







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string s = "this is a C++ string";
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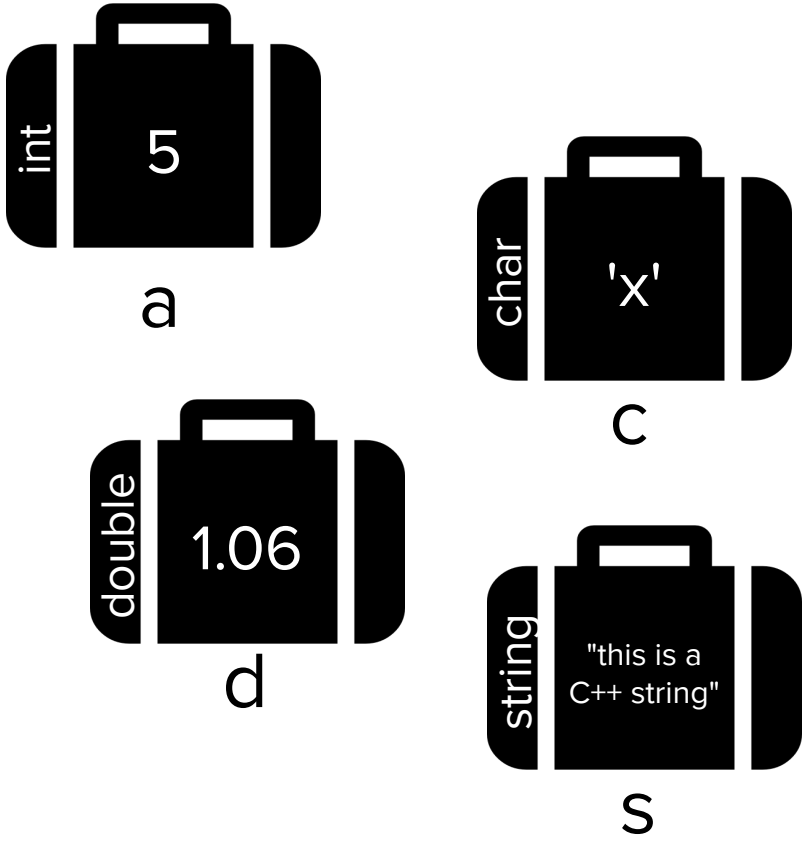

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string s = "this is a C++ string";
double a = 4.2; // ERROR! You cannot
redefine a variable to be another type
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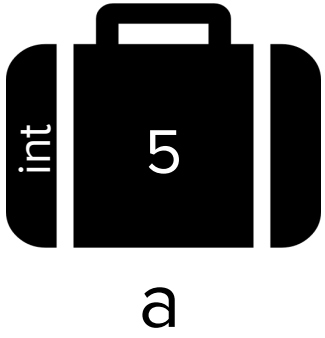

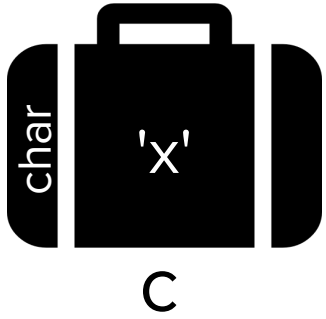

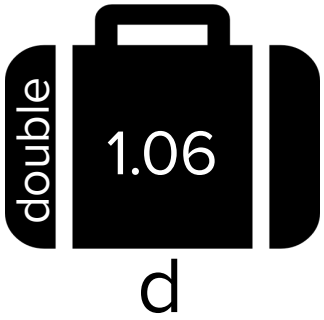

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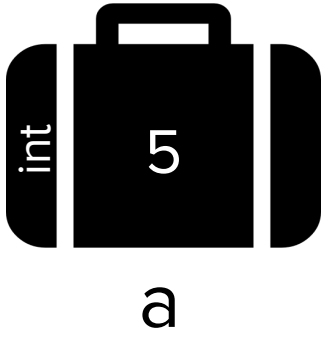
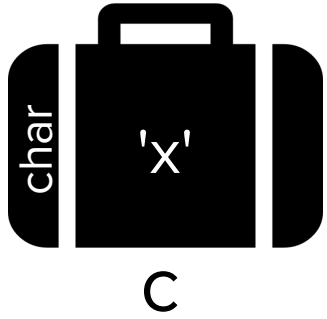
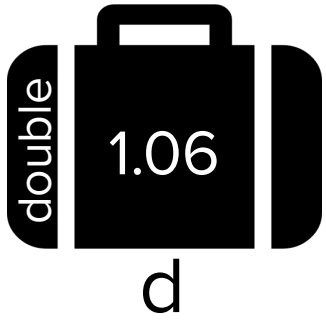
int a = 12; // ERROR! You do not need the type when re-assigning a variable
```







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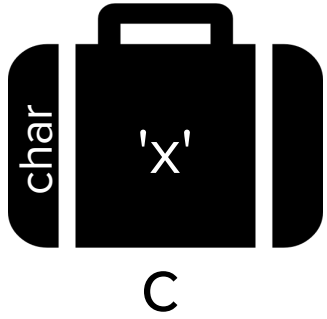
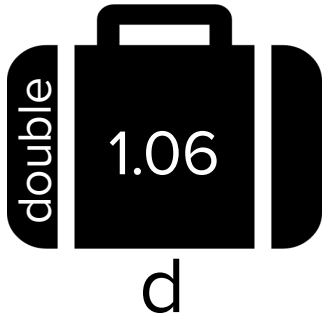
string s = "this is a C++ string";
double a = 4.2; // ERROR! You cannot redefine a variable to be another type
int a = 12; // ERROR! You do not need the type when re-assigning a variable
a = 12; // this is okay, updates variable value
```

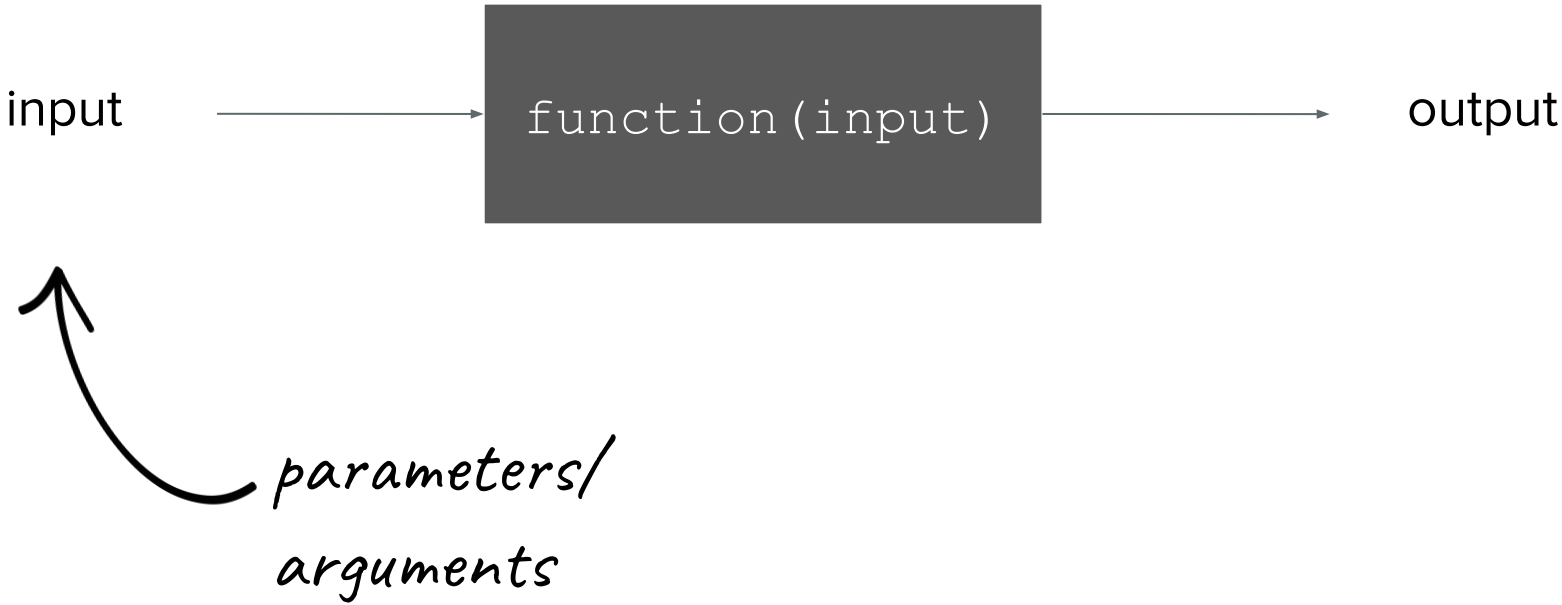




Functions and Parameters

Anatomy of a function

Anatomy of a function



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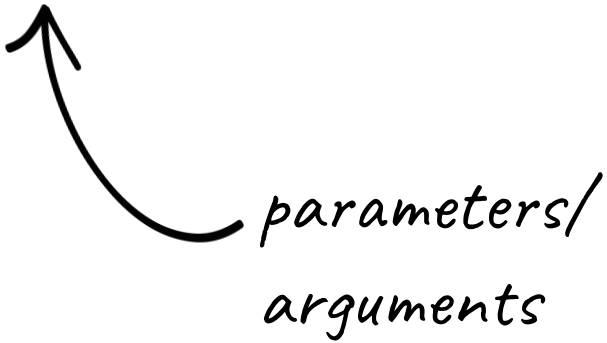


Definition

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

Anatomy of a function

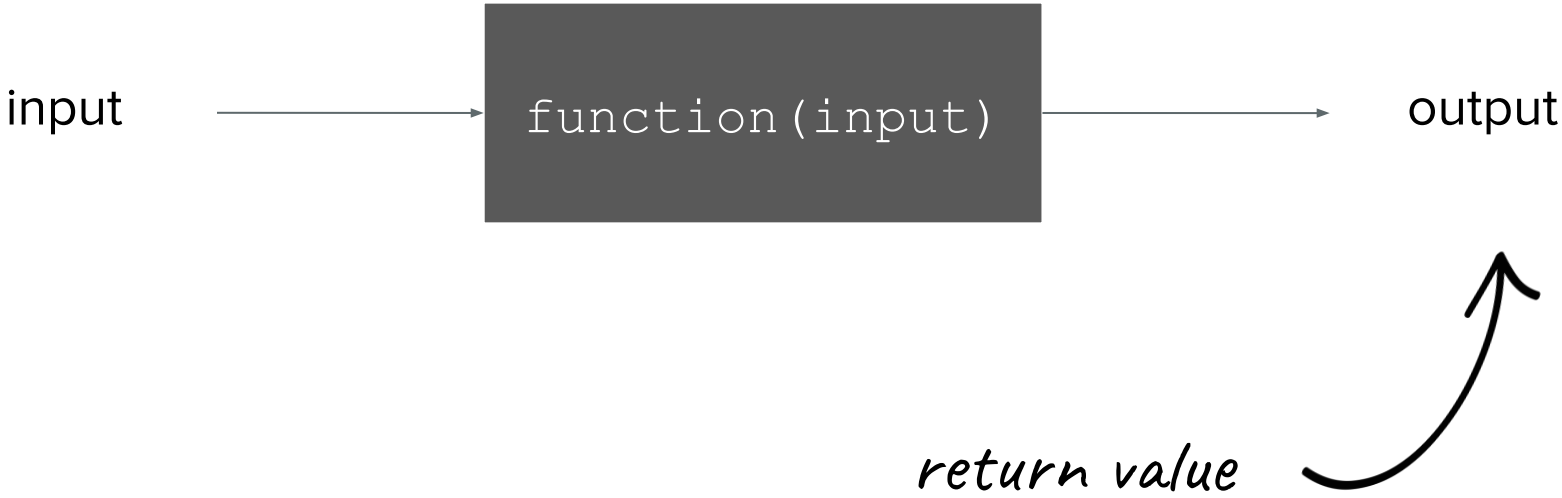
parameters/
arguments

Definition

argument(s)

The values passed into your function and assigned to its parameter variables

Anatomy of a function



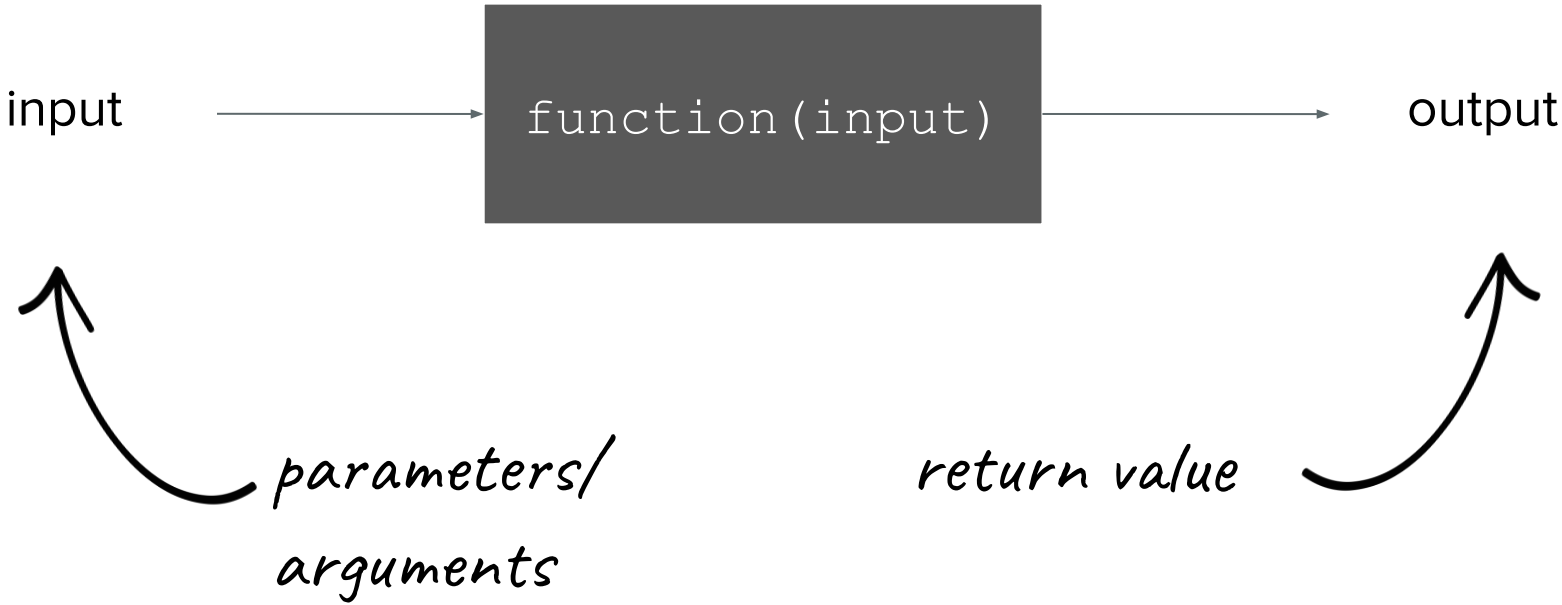
Anatomy of a function

Definition

return value

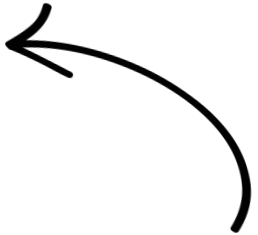
The value that your function hands back to the “calling” function

Anatomy of a function



Anatomy of a function

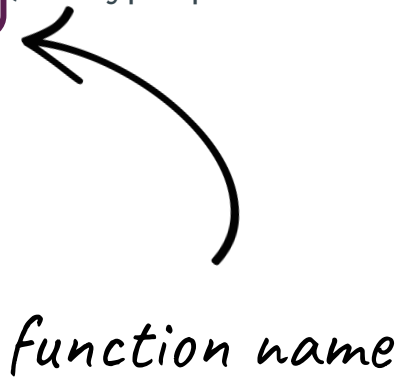
```
returnType functionName(varType parameter1, varType parameter2, ...);
```



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

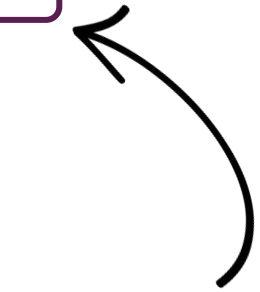
```
returnType functionName(varType parameter1, varType parameter2, ...);
```

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.

input expected (parameters)

Anatomy of a function

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



output expected
(return type)

Anatomy of a function

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

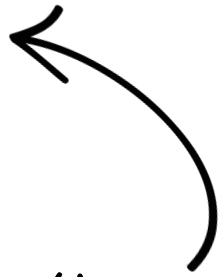
output expected (return type)

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

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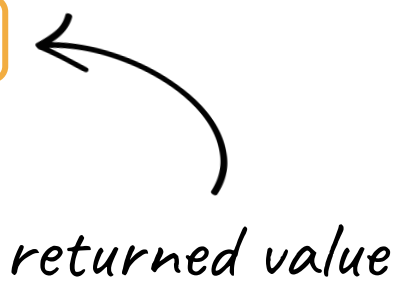

Function Example

```
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;
    return sum / 2;
}


int main(){
    double mid = average(10.6, 7.2);
    cout << mid << endl;
    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;
    return sum / 2;
}

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

parameters

return value

arguments

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;
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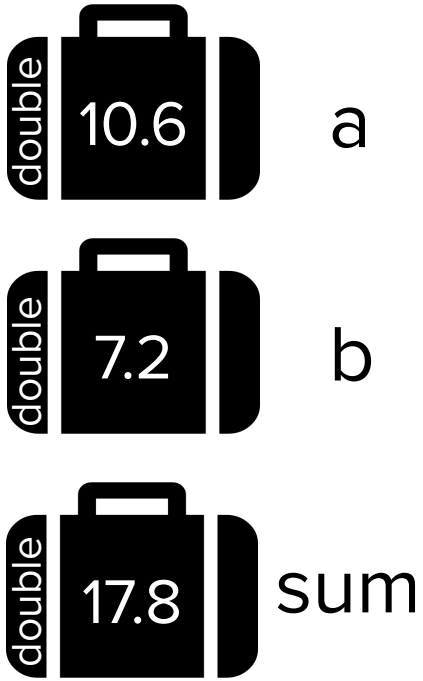
```

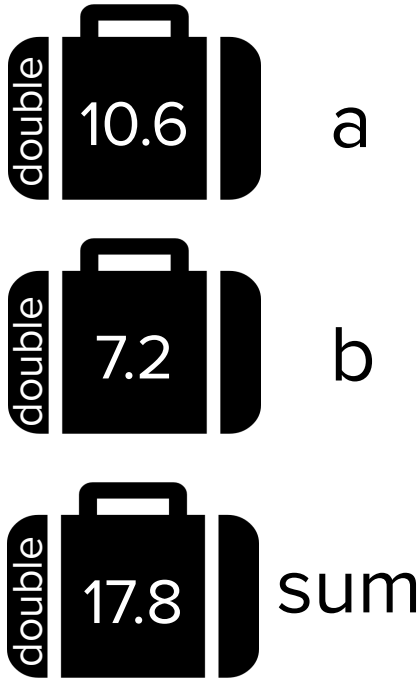


Function Example

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

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 tomorrow!

Mid-Lecture Announcements Break!

Announcements

- Complete the C++ survey and help us plan tomorrow's lecture!
- Fill out your section time preferences by today at 5pm PDT.
  - Make sure to check what time you've been assigned tomorrow morning.
- Finish Assignment 0 by Wednesday at 11:59 pm local time.
  - If you're running into issues with Qt Creator, come to the Qt Installation Help Session tonight at 7pm PDT. Join the QueueStatus here to get help.
- Assignment 1 will be released later today, 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 6-7pm PDT on Wednesday evening to help folks get started on the assignment.

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

- 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.

- 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

- 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

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- 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;
  ...
}
```

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;
  ...
}
```

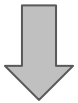
The `updateStatement` happens after each loop, but *before* **`testExpression`** is evaluated.

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;
  ...
}
```

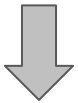


```
for (int i = 0; i < 3; i++) {
  cout << i << endl;
}
```

`for` loops

- `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;
  ...
}
```



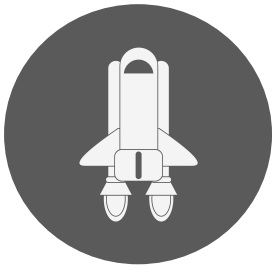
```
for (int i = 0; i < 3; i++) {
  cout << i << endl;
}
```

```
Output:
0
1
2
```

Interactive Example

Try it for yourself!

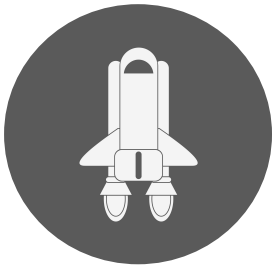
Write a program that prints out the calls for a spaceship that is about to launch. Countdown the numbers from 10 to 1 and then write “Liftoff.”



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

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
```

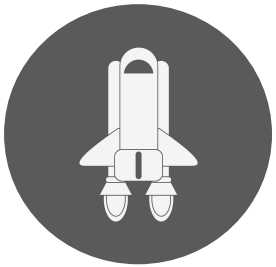
```python
def main():
    for i in range(10, 0, -1):
        print(i)
    print ("Liftoff")

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.”



```
10
9
8
7
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1
Liftoff
```

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

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

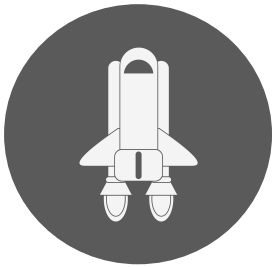
Python

```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.”



```
10
9
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1
Liftoff
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def main():
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if __name__ == "__main__":
    main()
```

Python

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

int mai
    /* 
    retu

}
```

Breakout Rooms!

C++

How do we test code in CS106B?

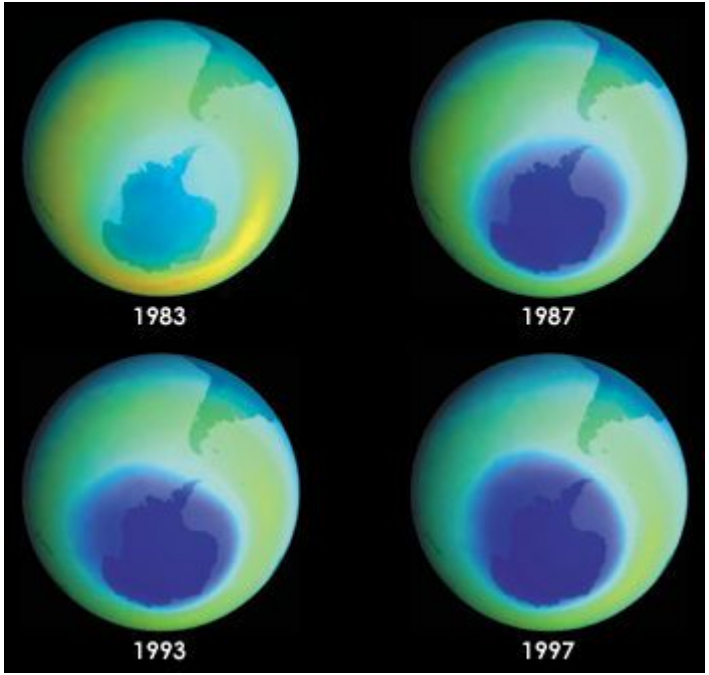
Testing

Software and cathedrals are much the same – first we build them, then we pray.
– Sam Redwine

Why is testing important?

Why is testing important?

The hole in the ozone layer over Antarctica remained undetected for a long period of time because the data analysis software used by NASA in its project to map the ozone layer had been **designed to ignore values that deviated greatly from expected measurements.**



Source: https://royal.pingdom.com/10-historical-software-bugs-with-extreme-consequences/

Why is testing important?

In 1996, a European Ariane 5 rocket was set to deliver a payload of satellites into Earth orbit, but problems with the software caused the launch rocket to veer off its path a mere 37 seconds after launch. The problem was the result of **code reuse from the launch system's predecessor, Ariane 4, which had very different flight conditions from Ariane 5.**

Source: https://royal.pingdom.com/10-historical-software-bugs-with-extreme-consequences/

Why is testing important?

A 2002 study commissioned by the National Institute of Standards and Technology (referred to here) **found that software bugs cost the U.S. economy $59.5 billion every year** (imagine the global costs…). The study estimated that more than a third of that amount, $22.2 billion, **could be eliminated by improved testing.**

Source: https://royal.pingdom.com/10-historical-software-bugs-with-extreme-consequences/

Why is testing important?

- Testing can save money
- Testing can save lives
- Testing can prevent disasters
- **Testing is a programmer's responsibility.**
  - You must think about ethical considerations when you develop code that impacts people.

What are good testing strategies?

What are good testing strategies?

- Write tests that cover a wide variety of use cases for your function!

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- Write tests that cover a wide variety of use cases for your function!
  - Use your critical thinking and analysis skills to identify a diverse range of possible ways in which your code might be used.

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- Consider:
  - Basic use cases
  - Edge cases

Testing strategies

- Write tests that cover a wide variety of use cases for your function!

- Consider:
  - Basic use cases
  - Edge cases

Definition

edge case
Uses of your function/program that represent extreme situations

Testing strategies

- Write tests that cover a wide variety of use cases for your function!
- Consider:
  - Basic use cases
  - Edge cases

For example, if your function takes in an integer parameter, test what happens if the value that is passed in negative, zero, a large positive number, etc!

Definition

edge case

Uses of your function/program that represent extreme situations

SimpleTest

What is SimpleTest?

- SimpleTest is a C++ library developed by some of the lecturers here at Stanford that allows standalone, C++ unit testing
- For those of you coming from CS106A in Python, this is similar in functionality to the **doctest** infrastructure that you learned
- We will see SimpleTest a lot this quarter! You will learn how to write good, comprehensive suites of tests using this library, starting from the very first assignment.

How does SimpleTest work?

CS106B Testing Guide

– make sure to read it!

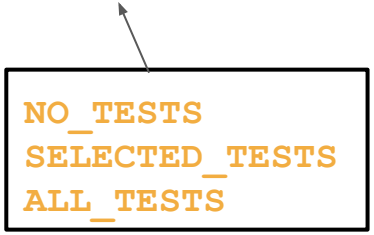
How does SimpleTest work?

main.cpp

```
#include "testing/SimpleTest.h"
#include "all-examples.h"

int main()
{
    if (runSimpleTests(SELECTED_TESTS)) {
        return 0;
    }

    return 0;
}
```



How does SimpleTest work?

main.cpp

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#include "testing/SimpleTest.h"
#include "all-examples.h"

int main()
{
    if (runSimpleTests(SELECTED_TESTS)) {
        return 0;
    }

    return 0;
}
```

all-examples.cpp

```
#include "testing/SimpleTest.h"

int factorial (int num);

int factorial (int num){
     /* Implementation here */
}

PROVIDED_TEST("Some provided tests."){
     EXPECT_EQUAL(factor(12), 16);
     EXPECT(isPerfect(6));
     EXPECT(!isPerfect(12));
}

STUDENT_TEST("student wrote this test"){
     // student tests go here!
}
```

How does SimpleTest work?

main.cpp

```
#include "testing/SimpleTest.h"
#include "all-examples.h"

int main()
{
    if (runSimpleTests(SELECTED_TESTS)) {
        return 0;
    }

    return 0;
}
```

all-examples.cpp

```
#include "testing/SimpleTest.h"

int factorial (int num);

int factorial (int num){
     /* Implementation here */
}

PROVIDED_TEST("Some provided tests."){
     EXPECT_EQUAL(factorial(1), 1);
     EXPECT_EQUAL(factorial(2), 2);
     EXPECT_EQUAL(factorial(3), 6);
     EXPECT_EQUAL(factorial(4), 24);
}

STUDENT_TEST("student wrote this test"){
     // student tests go here!
}
```

How does SimpleTest work?

main.cpp

```
#include "testing/Simpl
#include "all-example

int main()
{
    if (runSimpleTest
        return 0;
    }

    return 0;
}
```

all-examples.cpp

```
                    ing/SimpleTest.h"

                    (int num);

                    (int num){
                    entation here */


                    "Some provided tests."){
                    UAL(factorial(1), 1);
                    UAL(factorial(2), 2);
                    UAL(factorial(3), 6);
                    EQUAL(factorial(4), 24);


STUDENT_TEST("student wrote this test"){
    // student tests go here!
}
```

What’s next?

Strings, Vectors, C++ Review