CS 106B, Lecture 2
Functions and Strings

reading:

Programming Abstractions in C++, Chapters 2-3

Plan for Today

- Functions
  - Syntax
  - Prototypes
  - Pass by value vs. reference; the const keyword
- Strings
  - Common functions and manipulations
  - C vs. C++ strings

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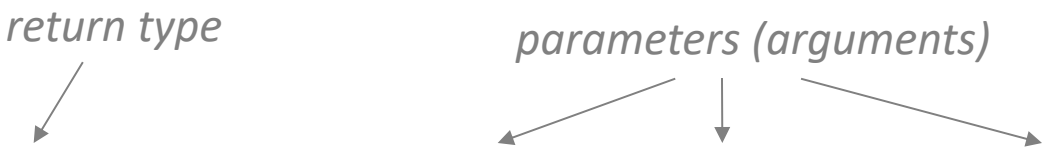
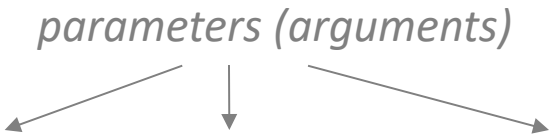
Defining functions

- A C++ **function** is like a Java **method**.




```
type functionName(type name, type name, ..., type name) {
    statement;
    statement;
    ...
    statement;
    return expression;   // if return type is not void
}
```

- Calling a function:




```
functionName(value, value, ..., value);
```

Defining a function

```
#include "console.h"
using namespace std;
const string DRINK_TYPE = "Coke";

// Function Definition and Code
void bottles(int count) {
    cout << count << " bottles of " << DRINK_TYPE << " on the wall." << endl;
    cout << count << " bottles of " << DRINK_TYPE << "." << endl;
    cout << "Take one down, pass it around, " << (count-1) <<
        " bottles of " << DRINK_TYPE << " on the wall." << endl << endl;
}

int main() {
    for (int i = 99; i > 0; i--) {
        bottles(i);
    }
    return 0;
}
```

Declaration order

- **Compiler error**: unable to find the `bottles` function
  - C++ reads the file from top to bottom (unlike Java or Python)

```
int main() {
    for (int i = 99; i > 0; i--) {
        bottles(i);
    }
    return 0;
}


void bottles(int count) {
    cout << count << " bottles of " << DRINK_TYPE << " on the wall." << endl;
    cout << count << " bottles of " << DRINK_TYPE << "." << endl;
    cout << "Take one down, pass it around, " << (count-1) <<
        " bottles of " << DRINK_TYPE << " on the wall." << endl << endl;
}
```

Function prototypes

- Declare the function (without writing its body) at top of program.
- Include everything up to the first curly brace

```
void bottles(int count);  // Function prototype

int main() {
    for (int i = 99; i > 0; i--) {
        bottles(i);
    }
    return 0;
}

void bottles(int count) {
    cout << count << " bottles of " << DRINK_TYPE << " on the wall." << endl;
    cout << count << " bottles of " << DRINK_TYPE << "." << endl;
    cout << "Take one down, pass it around, " << (count-1) <<
        " bottles of " << DRINK_TYPE << " on the wall." << endl << endl;
}
```

Pass by Value

- **value semantics**: In Java and C++, when variables (`int`, `double`) are passed as parameters, their values are copied.
  - Modifying a parameter will not affect the variable passed in.

```
void swap(int a, int b) {
    int temp = a;
    a = b;
    b = temp;
}

int main() {
    int x = 17;
    int y = 35;
    swap(x, y);
    cout << x << "," << y << endl;   // 17,35
    return 0;
}
```

Pass by Reference

- **reference semantics**: If you declare a parameter with an & after its type, it will link the caller and callee function variables to the same place in memory.
  - Modifying a parameter *will* affect the variable passed in.
  - The ampersand is only used in declaration, not in function call
  - **Can't** pass in non-variables

    (e.g. `swap(1, 3)` won't work)
  - Faster for larger types with many elements

```
void swap(int& a, int& b) {
    int temp = a;
    a = b;
    b = temp;
}
int main() {
    int x = 17;
    int y = 35;
    swap(x, y);
    cout << x << ","
      << y << endl; // 35,17
    return 0;
}
```

Const parameters

- What if you want to avoid copying a large variable but don't want to change it?
- Use the **const** keyword to indicate that the parameter won't be changed
  - Usually used with strings and collections
  - Passing in a non-variable (e.g. `printString("hello")`) **does** work

```
void printString(const string& str) {
    cout << "I will print this string" << endl;
    cout << str << endl;
}

int main() {
    printString("This could be a really really long
                string");
}
```

Output parameters

- Can also pass by reference to return multiple items
- What is the minimum and maximum non-creepy age to date?

```
void datingRange(int age, int& min, int& max) {
    min = age / 2 + 7;
    max = (age - 7) * 2;
}

int main() {
    int young;
    int old;
    datingRange(48, young, old);
    cout << "A 48-year-old could date someone from "
         << young << " to " << old " years old." << endl;
}

// A 48-year-old could date someone from
// 31 to 82 years old.
```

http://xkcd.com/314/

Quadratic exercise

- Write a function **`quadratic`** to find roots of quadratic equations.

  $a\,x^2 + b\,x + c = 0$, for some numbers a, b, and c.

  - Find roots using the **quadratic formula**.
  - Example: $x^2 - 3\,x - 4 = 0$
    roots: $x = 4$, $x = -1$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

  - What parameters should our function accept? What should it return?
    - Which parameters should be passed by value, and which by reference?

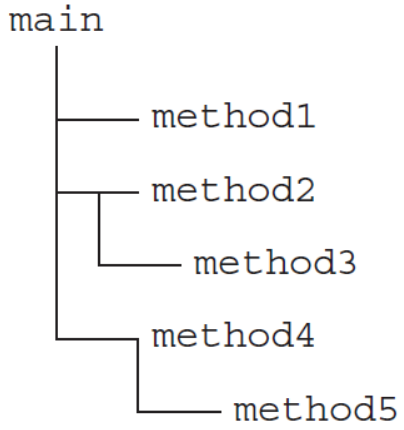
Quadratic solution

```
/*
 * Solves a quadratic equation ax^2 + bx + c = 0,
 * storing the results in output parameters root1 and root2.
 * Assumes that the given equation has two real roots.
 */
void quadratic(double a, double b, double c,
               double& root1, double& root2) {
    double d = sqrt(b * b - 4 * a * c);
    root1 = (-b + d) / (2 * a);
    root2 = (-b - d) / (2 * a);
}
```

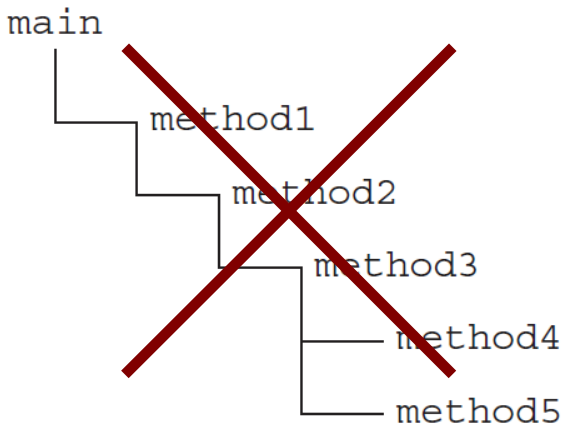
$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Good Decomposition

- Properties of a good function:
  - **Fully performs a single coherent task.**
  - **Does not do too large a share of the work.**
  - Is not unnecessarily connected to other functions.
    - No "chaining" of functions



- The **`main`** function should be a concise summary of the overall program.
  - Basically an overview of the steps needed to solve the problem



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Strings

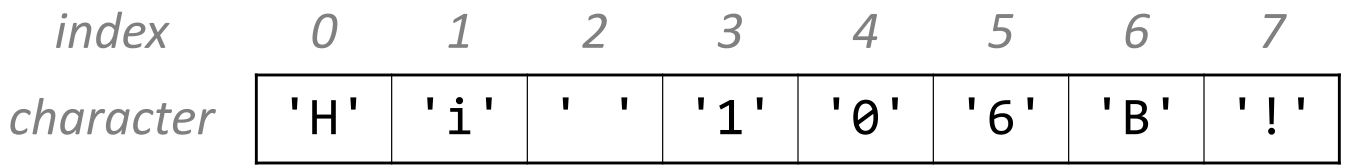
```
#include <string>
...
string s = "hello";
```

- A string is a (possibly empty) sequence of characters.
  - Strings are *mutable* (can be changed) in C++.
  - There are two types of strings in C++. :-/

Characters

- Characters are values of type `char`, with 0-based indices:

```
string s = "Hi 106B!";
```



- Individual characters can be accessed using `[`***`index`***`]` or `at`:

```
char c1 = s[3];                 // '1'
char c2 = s.at(1);              // 'i'
```

- Characters have **ASCII** encodings (integer mappings):

```
cout << (int) s[0] << endl;    // 72
```

Member functions

Member function name	Description
`s.append(str)`	add text to the end of a string
`s.compare(str)`	return <0, 0, or >0 depending on relative ordering
`s.erase(index, length)`	delete text from a string starting at given index
`s.find(str)` `s.rfind(str)`	first or last index where the start of *str* appears in this string (returns `string::npos` if not found)
`s.insert(index, str)`	add text into a string at a given index
`s.length()` or `s.size()`	number of characters in this string
`s.replace(index, len, str)`	replaces *len* chars at given index with new text
`s.substr(start, length)` or `s.substr(start)`	the next *length* characters beginning at *start* (inclusive); if *length* omitted, grabs till end of string

```
string name = "Donald Knuth";
if (name.find("Knu") != string::npos) {
    name.erase(7, 5);              // "Donald "
}
```

Operators

- **Concatenate** using + or += :

```
string s1 = "Ty";
s1 += "ler";                          // "Tyler"
```

- **Compare** using relational operators (ASCII ordering):

```
string s2 = "Kate";              // == != < <= > >=
if (s1 > s2 && s2 != "Joe") {  // true
    ...
}
```

- Strings are **mutable** and can be changed:

```
s1.append(" Jay")                  // "Tyler Jay"
s1.erase(1, 3);                      // "Tr Jay"
s1[4] = '@';                         // "Tr J@y"
```

Stanford library

- `#include "strlib.h"`

Function name	Description
`endsWith(str, suffix)` `startsWith(str, prefix)`	true if string begins or ends with the given text

`integerToString(int)`
`realToString(double)`
`stringToInteger(str)`
`stringToReal(str)`
	convert between numbers and strings

`equalsIgnoreCase(s1, s2)`	true if s1 and s2 have same chars, ignoring casing
`toLowerCase(str)` `toUpperCase(str)`	returns an upper/lowercase version of a string
`trim(str)`	returns string with surrounding whitespace removed

What's the output?

```
void mystery(string a, string& b) {
    a.erase(0, 1);          // erase 1 from index 0
    b += a[0];
    b.insert(3, "FOO");     // insert at index 3
}

int main() { // 01234
    string a = "ashley";
    string b = "taylor";
    mystery(a, b);
    cout << a << " " << b << endl;
    return 0;
}
```

```
// A. shley taylor
// B. ashley taylor
 // C. shley ataylorFOO
 // D. ashley tayFOOlors
// E. shley tayFoolors
```

String exercise

- Write a function **`nameDiamond`** that accepts a string parameter and prints its letters in a "diamond" format as shown below.
  - For example, `nameDiamond("SHREYA")` should print:

```
S
SH
SHR
SHRE
SHREY
SHREYA
 HREYA
  REYA
   EYA
    YA
     A
```

Exercise solution

```
void nameDiamond(string s) {
    int len = s.length();

    // print top half of diamond
    for (int i = 1; i <= len; i++) {
        cout << s.substr(0, i) << endl;
    }

    // print bottom half of diamond
    for (int i = 0; i <= len; i++) {
        for (int j = 0; j < i; j++) { // indent
            cout << " ";              // with spaces
        }
        cout << s.substr(i) << endl;
    }
}
```

C vs. C++ strings

- C++ has two kinds of strings:
  - **C strings** (`char` arrays) and **C++ strings** (`string` objects)

- A string literal such as `"hi there"` is a C string.
  - C strings don't include any methods/behavior shown previously.
    - No member functions like `length`, `find`, or operators.

- Converting between the two types:
  - `string("`***`text`***`")` C string to C++ string
  - ***`string`***`.c_str()` C++ string to C string

C string bugs

- `string s = "hi" + "there";  // C-string + C-string`
- `string s = "hi" + '?';  // C-string + char`
- `string s = "hi" + 41;  // C-string + int`
  - C strings can't be concatenated with +.
  - C-string + char/int produces garbage, not "hi?" or "hi41".
  - **This bug usually manifests in print statements, and you'll see partial strings**
- `string s = "hi";`
  `s += 41;  // "hi)"`
  - Adds character with ASCII value 41, `')'`, doesn't produce `"hi41"`.

- `int n = (int) "42";  // n = 0x7ffdcb08`
  - Bug; sets n to the memory address of the C string `"42"` (ack!).

C string bugs fixed

- `string s = string("hi") + "there";`
- `string s = "hi";  // convert to C++ string`
  `s += "there";`
  - These both compile and work properly.

- `string s = "hi";  // C++ string + char`
  `s += '?';  // "hi?"`
  - Works, because of auto-conversion.

- `s += integerToString(41);  // "hi?41"`
- `int n = stringToInteger("42");  // 42`
  - Explicit string <-> int conversion using Stanford library.

Look Ahead

- Assignment 0 due Thursday
  - Note: I had to make a few changes to the starter code. If you downloaded the ZIP file before 1:40PM Monday, please download it again
  - Qt Creator Installation help session **tomorrow from 8-10pm** in Gates B02

- Sign up for section at cs198.stanford.edu
  - Section signups close **today at 5PM**

Extra slides

Ref param mystery

parameterMysteryBCA

- What is the output of this code?

```
void mystery(int& b, int c, int& a) {
    a++;
    b--;
    c += a;
}

int main() {
    int a = 5;
    int b = 2;
    int c = 8;
    mystery(c, a, b);
    cout << a << " " << b << " " << c << endl;
    return 0;
}
```

```
// A. 5 2 8
// B. 5 3 7
// C. 6 1 8
// D. 6 1 13
// E. other
```

Return mystery

returnMystery1

- What is the output of the following program?

```
int mystery(int b, int c) {
    return c + 2 * b;
}

int main() {
    int a = 4;
    int b = 2;
    int c = 5;

    a = mystery(c, b);
    c = mystery(b, a);
    cout << a << " " << b << " " << c << endl;
    return 0;
}

    //  A.          B.          C.          D.          E.
    //  12 2 16     9 2 10      12 2 8      9 2 12      N/A
```

Default parameters

- You can make a parameter optional by supplying a *default value*:
  - All parameters with default values must appear last in the list.

```
// Prints a line of characters of the given width.
void printLine(int width = 10, char letter = '*') {
    for (int i = 0; i < width; i++) {
        cout << letter;
    }
}

...

printLine(7, '?');    // ???????
printLine(5);         // *****
printLine();          // **********
```

Exercise: BMI

- Write code to calculate 2 people's body mass index (BMI):

$$BMI = \frac{weight}{height^2} \times 703$$

BMI	Category
below 18.5	class 1
18.5 - 24.9	class 2
25.0 - 29.9	class 3
30.0 and up	class 4

- Match the following example output:

```
This program reads data for two people
and computes their Body Mass Index (BMI).

Enter Person 1's information:
height (in inches)? 70.0
weight (in pounds)? 194.25
BMI = 27.8689, class 3

Enter Person 2's information:
height (in inches)? 62.5
weight (in pounds)? 130.5
BMI = 23.4858, class 2

BMI difference = 4.3831
```

BMI solution

```
/* Prints a welcome message explaining the program. */
void introduction() {
    cout << "This program reads data for two people" << endl;
    cout << "and computes their body mass index (BMI)." << endl << endl;
}

/* Computes/returns a person's BMI based on their height and weight. */
double computeBMI(double height, double weight) {
    return weight * 703 / height / height;
}

/* Outputs information about a person's BMI and weight status. */
int bmiClass(double bmi) {
    if (bmi < 18.5) {
        return 1;
    } else if (bmi < 25) {
        return 2;
    } else if (bmi < 30) {
        return 3;
    } else {
        return 4;
    }
}
```

BMI solution, cont'd

```
/* Reads information for one person, computes their BMI, and returns it. */
double person(int number) {
    cout << "Enter person " << number << "'s information:" << endl;
    double height = getReal("height (in inches)? ");
    double weight = getReal("weight (in pounds)? ");
    double bmi = computeBMI(height, weight);
    cout << "BMI = " << bmi << ", class " << bmiClass(bmi) << endl << endl;
    return bmi;
}

/* Main function to run the overall program. */
int main() {
    introduction();
    double bmi1 = person(1);
    double bmi2 = person(2);
    cout << "BMI difference = " << abs(bmi1 - bmi2) << endl;
    return 0;
}
```

Char and cctype

- `#include <cctype>`
  - Useful functions to process `char` values (not entire strings):

Function name	Description
`isalpha(c)` `isalnum(c)` `isdigit(c)` `isspace(c)` `isupper(c)` `ispunct(c)` `islower(c)`	returns `true` if the given character is an alphabetic character from a-z or A-Z, a digit from 0-9, an alphanumeric character (a-z, A-Z, or 0-9), an uppercase letter (A-Z), a space character (space, \t, \n, etc.), or a punctuation character (. , ; !), respectively
`tolower(c)` `toupper(c)`	returns lower/uppercase equivalent of a character

```
//    index 01234567890123456789
string s = "Grace Hopper Bot v2.0";
if (isalpha(s[6]) && isnumer(s[18])
        && isspace(s[5]) && ispunct(s[19])) {
    cout << "Grace Hopper Smash!!" << endl;
}
```