PIC 10A: Week 2a

Section 1C, Winter 2016

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v1.0

Announcements

- Quiz1 this Wednesday during lecture
- HW1 due Wednesday, 11 PM
  - Submit online at ccle.ucla.edu
- Learning Objectives, Section 1
  - We just finished section 1! Refer to learning objectives handout to see material that you are expected to understand
  - PDF is on course webpage, under "Learning Objectives":
    - http://www.math.ucla.edu/~mikel/teaching/pic10a/

Reminders

- Lecture recordings (bruincast)
  - http://www2.oid.ucla.edu/webcasts/courses/2015-2016/2016winter/comptng10a-1
- My TA Page (where I post discussion slides/notes)
  - www.eric-kim.net/teaching/pic10a_page/
- ccle.ucla.edu
  - You submit your homeworks here!

Today

- What is a programming language?
  - High Level vs Low Level
- Compilation Process
  - Preprocessor, Compiler, Assembler, Linker
- Libraries
- Intro to C++

What is a Programming Language?

- (Wikipedia): "A formal constructed language designed to communicate instructions to a machine, particularly a computer."
- Popular Languages: C/C++, Python, Java, Ruby, Javascript, Matlab, …
- Each language has its pros and cons, but in principle, they can all accomplish any task

Pro tip: Once you learn ~2 languages well, then you can pick up a new language in a few weekends!
Lots of shared concepts between languages.

A (brief) history of programming languages

Old days: Writing in assembly

- **Recall**: different CPU's have different architectures, each with their own assembly language
- **Example**: Intel chips use x86_64 assembly language, others may use MIPS assembly.
- Back in the day, programmers wrote programs for a ***particular*** architecture

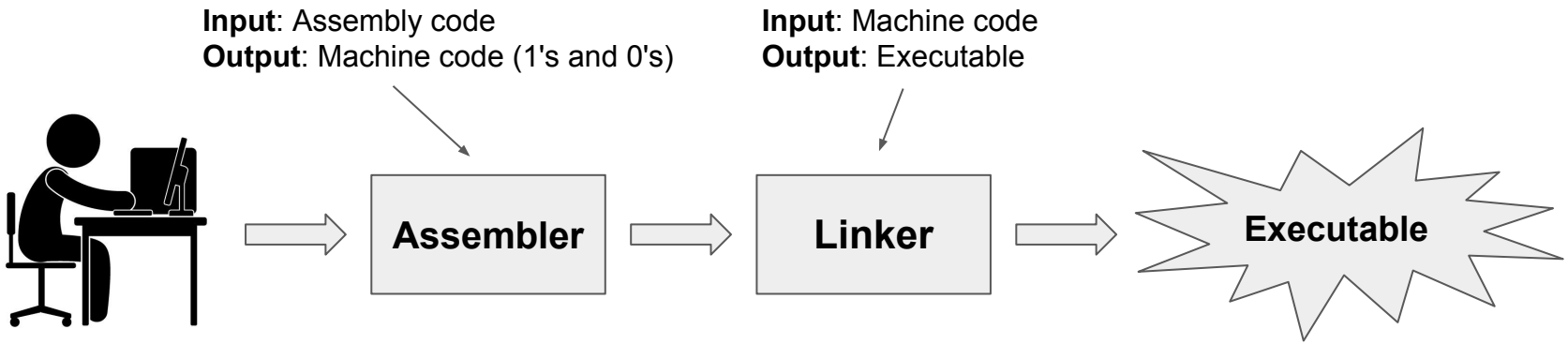
Example: Porting a blackjack game

- Say I programmed a blackjack game for my computer that runs architecture **X**.
- My friend wants my blackjack game, but their machine uses architecture **Y**.
- Can't just copy the code and give to my friend!
- Have to **rewrite** the **entire** blackjack game in the assembly language supported by architecture **Y**
    - Called "porting"

Programming languages save the day...

- People designed higher-level programming languages (ie C++, Python) to **abstract away** architecture-specific details
- Rather than program in an **architecture-specific** language (ie x86_64), instead program in an abstract, **architecture-independent** language (ie C++)

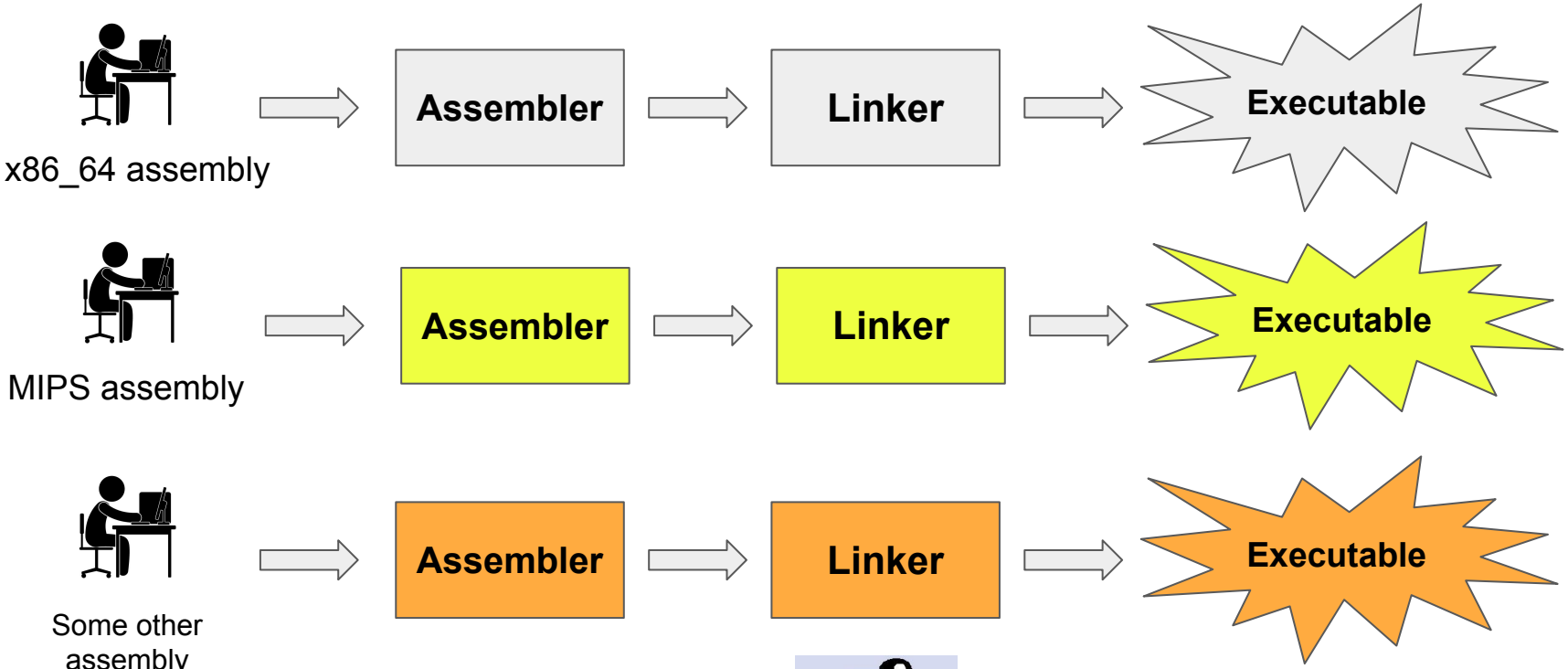
Old way



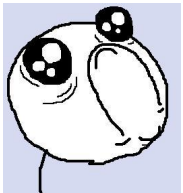
Me: Writing in x86_64 assembly

Problem: My assembly code only works for architectures using x86_64!
Porting to other architectures means a complete rewrite!

Old way: Porting

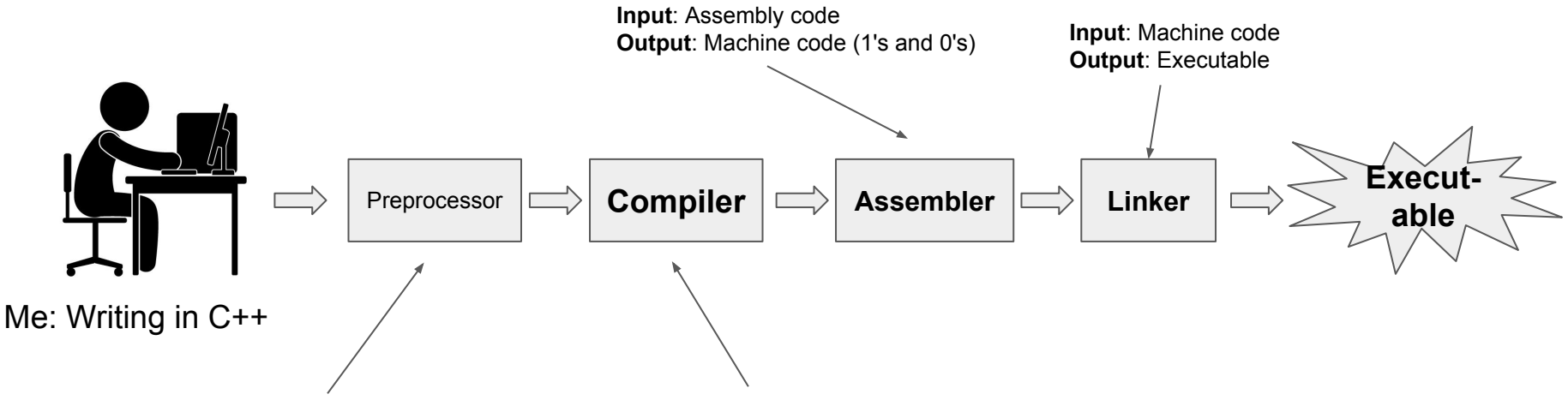


I have to write the same program **multiple times**!

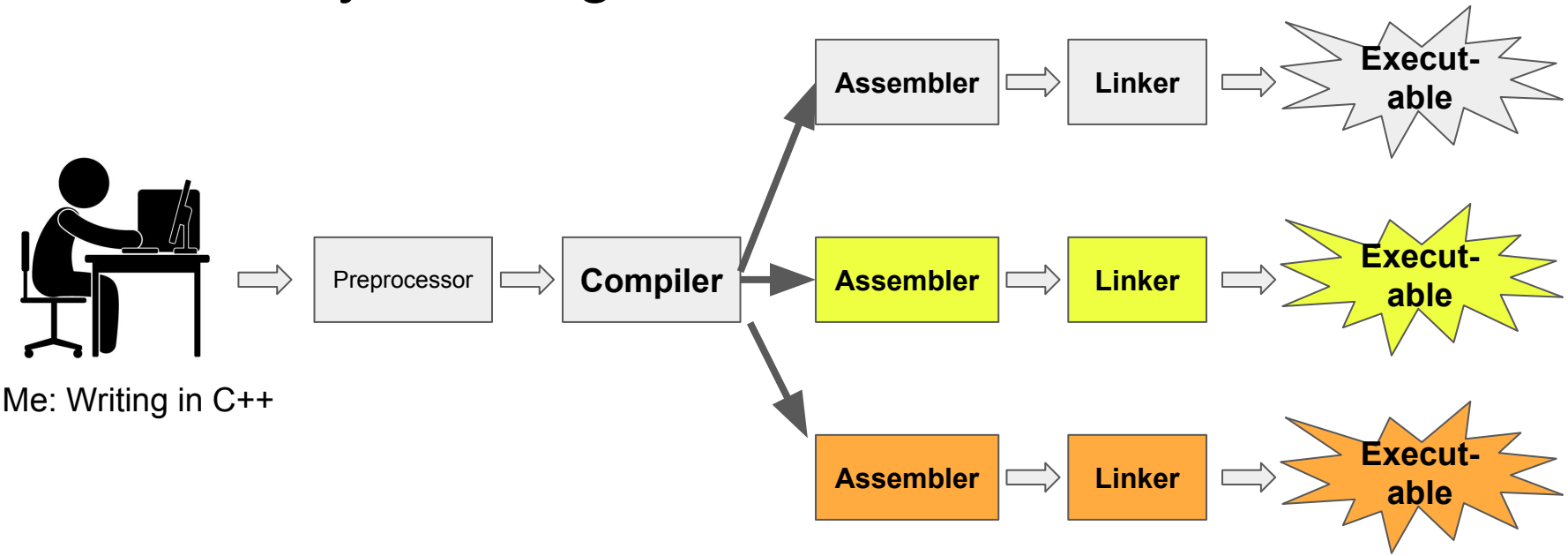


[Each color: Different architecture]

Modern way


Input: Assembly code
Output: Machine code (1's and 0's)
Input: Machine code
Output: Executable
Preprocessor
Compiler
Assembler
Linker
Execut-able
Me: Writing in C++
Input: My code (ie C++)
Output: "Transformed", expanded code. Still C++.
Input: Code (ie C++)
Output: Assembly language (ie x86_64)

Modern way: Porting



Me: Writing in C++

My life is **easier**: only write my program once (in C++).

New job: Someone has to write a *compiler* that can support multiple architectures.

[Each color is a different architecture]

What is a compiler?

- **Input**: Code in a "human-convenient" language, ie C++/Java
- **Output**: Assembly language code
- Good compilers are able to target many popular architectures
- Additional Features
  - Optimize code to make faster
    - "Free" speed improvements! No action from programmer
  - Detect syntactical errors, output meaningful error messages to programmer
    - Ex: "x" is an undefined identifier.

High vs Low level programming languages

- Most programming languages can be grouped into two categories: High level vs Low level
- To generalize: high vs low is a **tradeoff** between speed/efficiency of your program and convenience for writing programs.

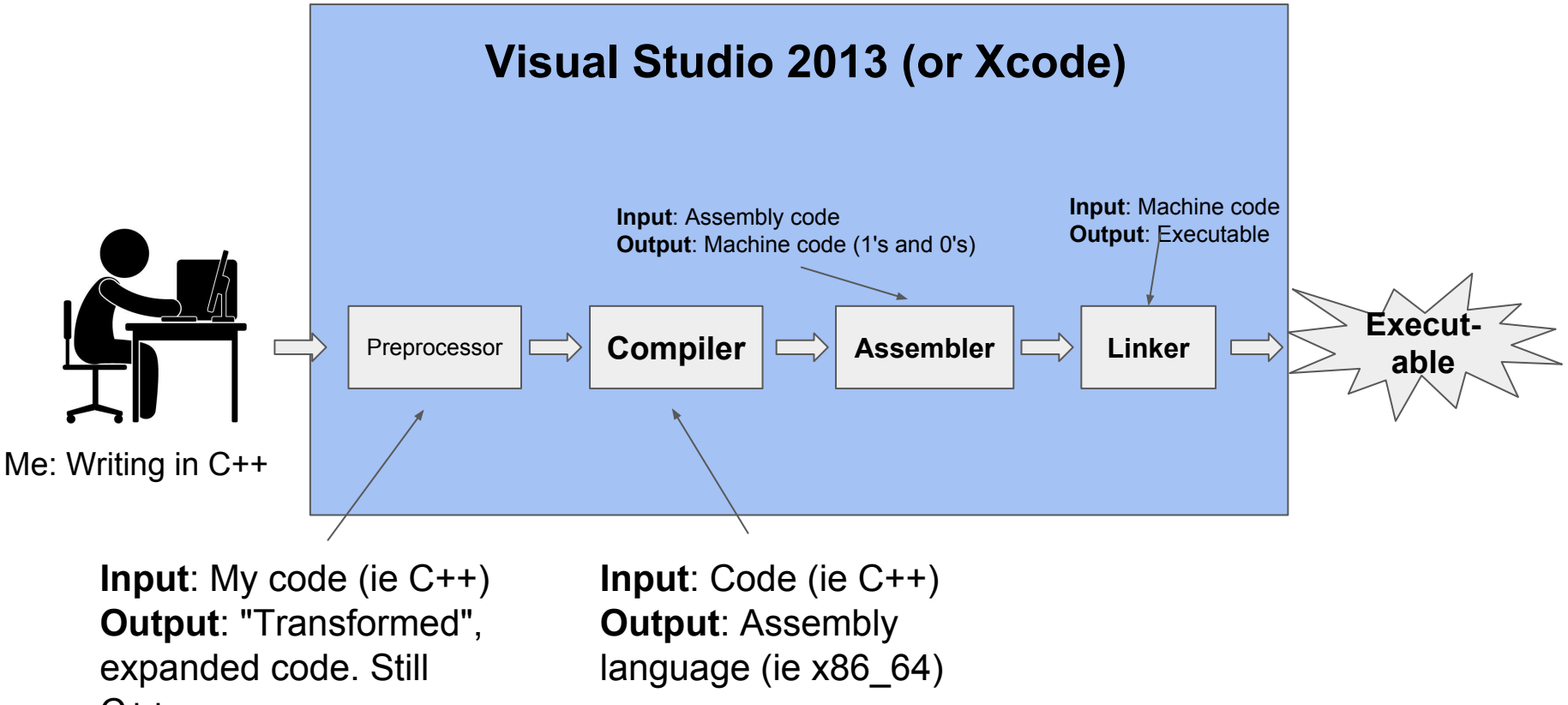
High Level Programming Language

- Examples: Python, Java, Matlab, Javascript
- Designed to make programming ***easier***
- **Pros**: Easy to *quickly* prototype things in these languages
- **Cons**: Programs tend to run slower than low-level languages.
    - Ex: A program written in Matlab can be **~10-100x slower** than the equivalent program written in C++.
- In practice: Many people/companies first program their product in a high-level language.
    - Then, rewrite the code causing performance bottlenecks in C/C++.

Low Level Programming Language

- Examples: C, C++. "systems" languages.
- Sacrifices programmer convenience for speed
  - Forces you to manually keep track of things that higher-level languages manage for you
- **Pros**: Can write extremely efficient programs (if you're proficient/skilled).
- **Cons**: Programming is a slower, more laborious task. Many more opportunities to make mistakes.

Where does Visual Studio fit in?



C++: Dissecting a simple program

C++, line by line

Question: What happens when I try to compile+run this program?

```
#include <iostream>
using namespace std;
// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

Answer: Simply outputs "Hi!" to the user, then exits immediately.

C++, line by line: include

Include statement.
Purpose: Unlocks additional functionality for the program.

Syntax: #include LIBRARYNAME

```
#include <iostream>

using namespace std;
// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

What is a Library?

- A library is collection of code that has functionality that will likely be useful to other programs.
  - Share/reuse code, rather than reinvent the wheel!
- Example: If you want your program to have a user interface (ie windows, buttons), then you'll need to find a **graphical user interface library** (GUI).
- Example: If you want your program to recognize faces in a picture, you'll want to use a **face detection library**, rather than write your detector from scratch.
- Lots of people release libraries online that are free to use!
  - Open source code: code that is free for use by anyone

C++ Standard Libraries

- Most languages (including C++) offer standard, "built-in" libraries
  - Common: File reading/writing, text manipulation, core data structures
- Popular C++ standard libraries include:
  - iostream, string, random
- List of standard libraries here:
  - http://en.cppreference.com/w/cpp/header

iostream

- Purpose: "...defines the standard **input/output** stream objects."
- The documentation about iostream says it defines: cin, **cout**, cerr, clog
  - http://www.cplusplus.com/reference/iostream/
- So, including iostream tells our program that **cout** *exists*.

What if we removed the include?

Question: What happens if I try to compile this program?

Answer: The program doesn't compile!
Error: "cout" is an undeclared identifier.

```
#include <iostream>

using namespace std;
// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

Aside: cout vs cin vs cerr vs clog

- cout: "Console Out", aka "standard out"
  - Writing to cout -> output text to user
- cin: "Console In", aka "standard in"
  - Reading from cin -> get text/number input from user
- cerr: "Console Error", aka "standard error"
  - Writing to cerr -> output warnings/error-messages
- clog: "Console Log"
  - Writing to clog -> output text relating to logging/debugging/whatever-you-like

In this class: focus on cout and cin.

Note: cerr, clog are meant for programmer, not for the user.

C++, line by line: namespaces

Purpose: Introduces variables/functions from a *namespace* into your program.

Syntax: using namespace ID;

```
#include <iostream>

using namespace std;

// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

using namespace std;

- Tells compiler we are using the "standard namespace"
  - std: "standard"
- Imports all of the functions/variables that a namespace **defines**
- **Example**: the `std` namespace defines `cout` and `cin`
  - More generally: all C++ standard library identifiers live in the `std` namespace

(In this class, we won't go over namespaces too in-depth, at least not now)

What if we remove "using namespace std;"?

Question: What happens when I try to compile+run this code?

```
#include <iostream>

using namespace std;

// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

Answer: Program doesn't compile!
Error message: cout is an undeclared identifier.

With/Without using namespace std

```cpp
#include <iostream>
using namespace std;
// Will print "Hi!" to the screen.
int main() {
  cout << "Hi!\n";
  return 0;
}
```

With

```cpp
#include <iostream>
// Will print "Hi!" to the screen.
int main() {
  std::cout << "Hi!\n";
  return 0;
}
```

Without

Verdict: "using namespace std;" simply lets us not have to type "std::" a bunch of times.

std::cout means to access the identifier "cout" from the namespace "std".
Anything that the C++ **standard library** defines lives in the **std namespace**.

C++ line by line: Comments

Comment
Purpose: Provide information or explanation useful for a programmer/reader.

Computer **ignores** everything you put in a comment.

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

// Will print "Hi!" to the screen.

int main() {
  cout << "Hi!\n";
  return 0;
}
```

C++ line by line: Comments

Question: What happens when I try to compile+run this program?

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

// Will print "Hi!" to the screen.

int main() {
  // cout << "meow" << endl;
  cout << "Hi!\n";
  return 0;
}
```

Answer: Compiles correctly, and outputs "Hi".
The "meow" isn't output because it's part of a **comment**.

Multiple ways to comment

```
// (1) Single line comments must always start
//     with two forward slashes.

/* (2) Anything in here is
       considered to be
a comment.
*/
```

(1) Single-line comments
(2) Multi-line comments

C++ line by line: the main() function

main
Purpose: Contains code that actually runs when you run the executable.

```
#include <iostream>
using namespace std;
// Will print "Hi!" to the screen.

int main() {
  cout << "Hi!\n";
  return 0;
}
```

The main() function

- The *return value* of the main function is known as the **status code**
- As convention, 0 means that the program terminated normally.
- non-zero return values (ie -1) mean that the program exited abnormally
    - Examples: File wasn't found, invalid input, etc.

C++ line by line: cout

Purpose: Output text to the user.

`cout`: Console output
Defined by: `<iostream>`

```
#include <iostream>
using namespace std;
// Will print "Hi!" to the screen.
int main() {

  cout << "Hi!\n";

  return 0;
}
```

cout: Chaining

- Can chain "<<" together to output multiple things
- Example: `cout << "I am taking " << 3 << " classes this quarter.\n";`
- Outputs: `I am taking 3 classes this quarter.`

cout: numbers

- cout understands numbers as well!
- Examples:

```
cout << "I am " << 26 << " years old.";
```
Outputs:
```
I am 26 years old.
```

```
cout << "There are " << 42+57 << " red balloons.";
```
Outputs:
```
There are 99 red balloons.
```

"Special" characters, ie \n, \t,

- We've seen that "\n" is special: it creates a new line. Known as the new-line **escape sequence**.
- Other escape sequences:
  - \t Tab
  - \" Double-quote
  - \' Single-quote
  - \\ Back-slash

Exercises: cout

Question: What do the following output? If it errors, explain the error.

```
cout << "For" << "No\n";
cout << "One";
```

Answer:

```
ForNo
One
```

```
cout << "Toe\n";
cout << "\n" << "To " << "Toe";
```

Answer:

```
Toe

To Toe
```

Exercises: cout

Question: What do the following output? If it errors, explain the error.

```
cout << ""Hello"" << "Goodbye";
```

Answer:

```
Compile error!
The word Hello is not
contained within double-
quotation marks, so it
doesn't make sense.
```

```
cout << "Revolution " << "3+6";
```

Answer:

```
Revolution 3+6
```

Exercises: cout

Question: Write some code that will exactly generate the following output:

```
I "love" waking up at 6 AM!
```

Answer:

```
cout << "I \"love\" waking up at 6 AM!";
```

Exercises: cout

Question: Write some code that will exactly generate the following output:

```
I "love" waking up at 6 AM!
```

Question: Is the following answer correct?

```
cout << "I " << " << "love" << " << " waking up at 6 AM!";
```

Answer: Nope! This will actually error.

```
cout << "I " << " << "love" << " << " waking up at 6 AM!";
```

String 1 String 2

Uhoh, what's that?
Error!

cout: endl

- Alternative to typing "\n" a bunch of times: endl
  - Stands for: "end line"

```
cout << "Hi there\n" << "Face here";
```

outputs the same thing as:

```
cout << "Hi there" << endl << "Face here";
```

Output:

```
Hi there
Face here
```

String Literal

- To create a string literal, wrap some text with double quotation marks
- Examples: "Hi there", "3+4", "bye\n" are all **string literals**
    - We've been creating string literals all along!

String Literals

- Important: Computer will not "execute" contents of string literals. Leaves the contents as-is.
- Example: `cout << "3+4";`
  - Outputs: 3+4, not 7
- **Exception**: Escape sequences. `\n, \t, \\, \", \'`
  - Example: `cout << "hi\nthere";`
  - The `\n` is **expanded** out to a new-line.

Exercise

Question: Write some code that outputs the following:

```
I put
a newline \n there!
```

Answer:

```
cout << "I put\n" << "a newline \\n there!";
```

or:

```
cout << "I put" << endl << "a newline \\n there!";
```

(Unused Slides)

A (brief) history of computers

- The earliest "computers" were initially devices designed to specifically solve a specific problem
  - Example: Tide-predicting machine, 1872. Used rotating wheels and pulleys to evaluate trigonometric sums. Analog device.
- Breakthrough: General-purpose computers. 1930's/1940's
  - Devices that can be **programmed** to solve ***any*** problem
  - Don't need to design+build a separate device for each problem you want to solve
- General-purpose computers used to take up entire rooms
  - Now, fit in your pocket!

Early Programming Languages

- Early general-purpose computers used punch cards to enter in programs
- Laborious procedure
  - (1) Write down program on paper
  - (2) Enter program line-by-line onto (many) punch cards
  - (3) Feed your stack of punch cards into computer, run, and cross your fingers
-

Lecture Question (Fri, 1/8)

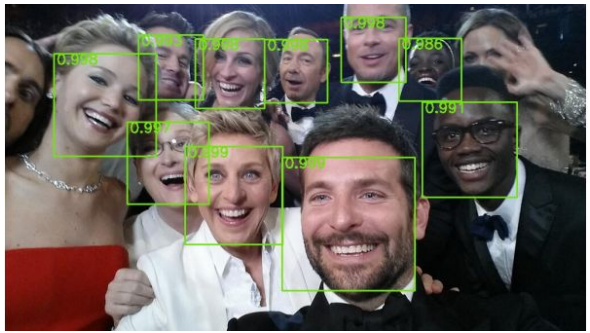
Q: Suppose your C++ installation is missing an important library file, one that defines a symbol you use in your code. Assuming that your code is otherwise correct, when you try to convert your code to a functional program and run it, "who" will complain?

(A) The source file
(B) The editor
(C) The preprocessor
(D) The compiler
(E) The linker (or dynamic linker)
(F) The executable
(G) The register
(H) The loader

Answer: E

Using Libraries: Case Study

- Scenario: I want to write a program that, given a photo, tags all of the people, and displays it with a snazzy user interface (UI).
  - To make things concrete, suppose I'm using Python



- Libraries I would likely need:
  - A GUI library to allow my app to have an interactive UI
    - Tkinter
  - A face detection library, ideally w/ a pretrained face detector
    - OpenCV
  - Oops, OpenCV requires me to install two more libraries: numpy and scipy
    - numpy: Library to perform fast matrix/vector operations
    - scipy: Library that contains a ton of useful functions for scientific computing
      - Ex: optimization toolbox, statistical modeling

Library "**dependencies**"