

COMP201

Computer Systems & Programming

Lecture #01 – Introduction



KOÇ
UNIVERSITY

Aykut Erdem // Koç University // Spring 2023

A little about me...

Koç University
Associate Professor
2020-now



Hacettepe University
Associate Professor
2010-2020



Universitá Ca' Foscari di Venezia
Post-doctoral Researcher
2008-2010



Middle East Technical University
1997-2008
Ph.D., 2008
M.Sc., 2003
B.Sc., 2001



MIT
Fall 2007
Visiting Student



Virginia Tech
Visiting Research Scholar
Summer 2006



- I explore better ways to understand, interpret and manipulate visual data.
- My research interests span a diverse set of topics, ranging from image editing to visual saliency estimation, and to multimodal learning for integrated vision and language.



Plan For Today

- Course Introduction
- COMP201 Course Policies
- Unix and the Command Line
- Getting Started With C

Disclaimer: Slides for this lecture were borrowed from
—Nick Troccoli's Stanford CS107 class

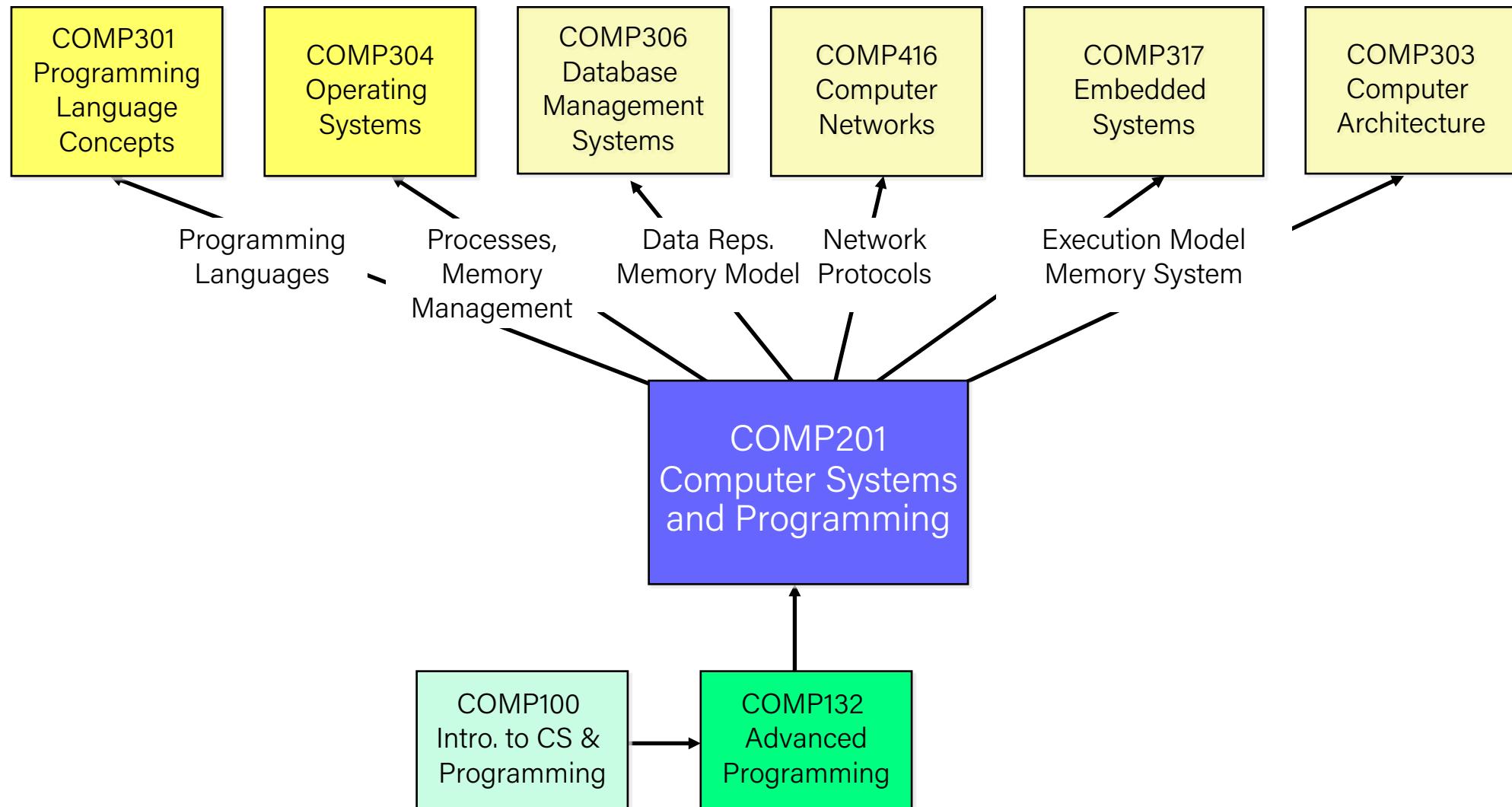
Lecture Plan

- Course Introduction
- COMP201 Course Policies
- Unix and the Command Line
- Getting Started With C

What is COMP201?

- The third course in the line of COMP's introductory programming courses (COMP100, COMP132, and COMP201)
 - COMP100 teaches you the notion of computational thinking and how to solve problems as a programmer (using Python)
 - COMP132 introduces you object-oriented programming paradigm (using Java)
- COMP201 takes you **behind the scenes**:
 - Not quite down to hardware or physics/electromagnetism (that's for later...)
 - It's how things work **inside C++/Python/Java**, and how your programs map onto the components of computer systems
 - Not only does it just feel good to know how these work, it can also inform projects you work on in the future.

Role within COMP Curriculum



What is COMP201?



Computer Systems and Programming

- How languages like C++ and Java represent data under the hood
- How programming structures are encoded in bits and bytes
- How to efficiently manipulate and manage memory
- How computers compile programs
- How cache memories work and how to exploit them to improve the performance of your programs
- Uses the C programming language
- Programming style and software development practices

COMP201 Learning Goals

The goals for COMP201 are for students to gain **mastery** of

- writing C programs with complex use of memory and pointers
- an accurate model of the address space and compile/runtime behavior of C programs

to achieve **competence** in

- translating C to/from assembly
- writing programs that respect the limitations of computer arithmetic
- finding bottlenecks and improving runtime performance
- working effectively in a Unix development environment

and have **exposure** to

- a working understanding of the basics of cache memories

MIT CSAIL  @MIT_CSAIL

"Programming is like cooking: in Python, you use pre-made bolognese sauce; in C++, you start from fresh tomatoes and minced meat; in Assembly, you have a farm where you grow your tomatoes and raise your cow." - [@gv_barroso](#)

h/t @programmerwisdom

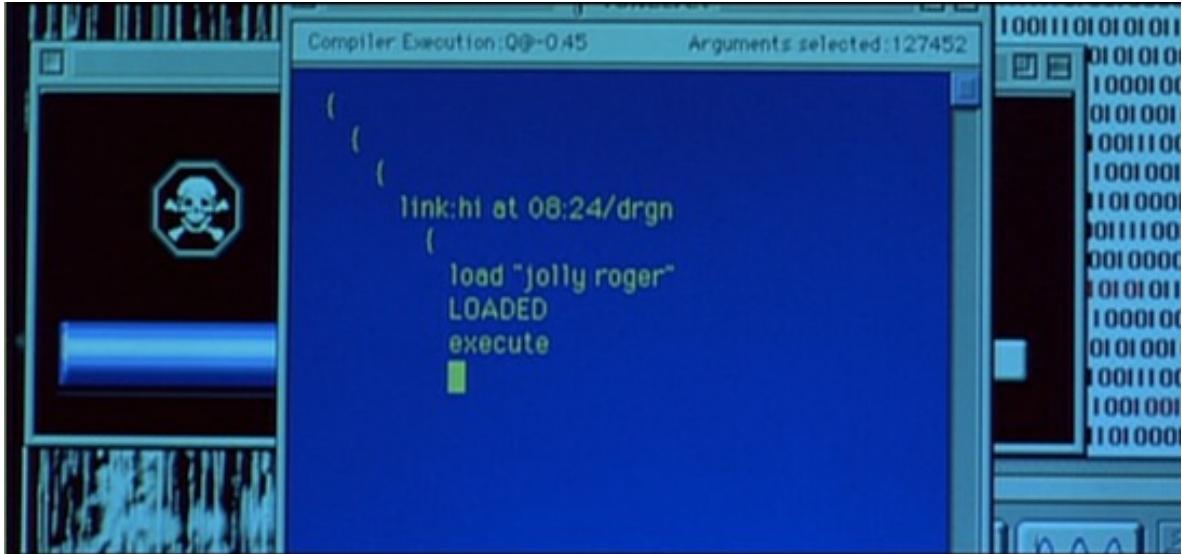
#tuesdaythoughts



5:28 PM · Sep 29, 2020 · TweetDeck

COMP201 Learning Goals

(also learn to identify legitimate programmer scenes in Hollywood movies)



Jeff Goldblum's character saving the world by uploading a virus to the alien mothership
Independence Day, 1996

Two terminal windows are shown. The top window shows a segmentation fault error message: "Program received signal SIGSEGV, Segmentation Fault." The bottom window shows a shell script being run to create a PDF file containing shellcode. The script includes commands like "buf +=", "file = open('ecoin_vuln_notes.pdf', 'wb')", and "f". The shellcode itself is a long string of hex values.

Elliot creating a malicious PDF file, which contains some sort of shellcode that will allow him to take over any Linux computer that opens that file in Evince.
Mr. Robot, S3, Ep9 - eps3.8_stage3.torrent (2017)

Course Overview

1. **Bits and Bytes** - *How can a computer represent integer numbers?*
2. **Chars and C-Strings** - *How can a computer represent and manipulate more complex data like text?*
3. **Pointers, Stack and Heap** – *How can we effectively manage all types of memory in our programs?*
4. **Generics** - *How can we use our knowledge of memory and data representation to write code that works with any data type?*
5. **Assembly** - *How does a computer interpret and execute C programs?*
6. **The Memory Hierarchy** - *How does the memory system is organized as a hierarchy of different storage devices with unique capacities*

Teaching Team



Aykut Erdem



Mert Çökelek



Nafiseh Jabbari Tofighi



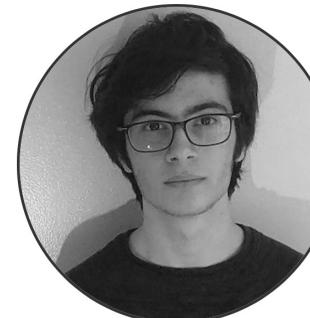
Osman Batur İnce



Beyza Erdogan



Eda Güven



Emir Gencer



Sinan Aghayev

Course Website

<https://aykuterdem.github.io/classes/comp201.s23/>

*lecture videos on Panopto – can be accessed through Blackboard or from the course webpage

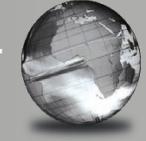
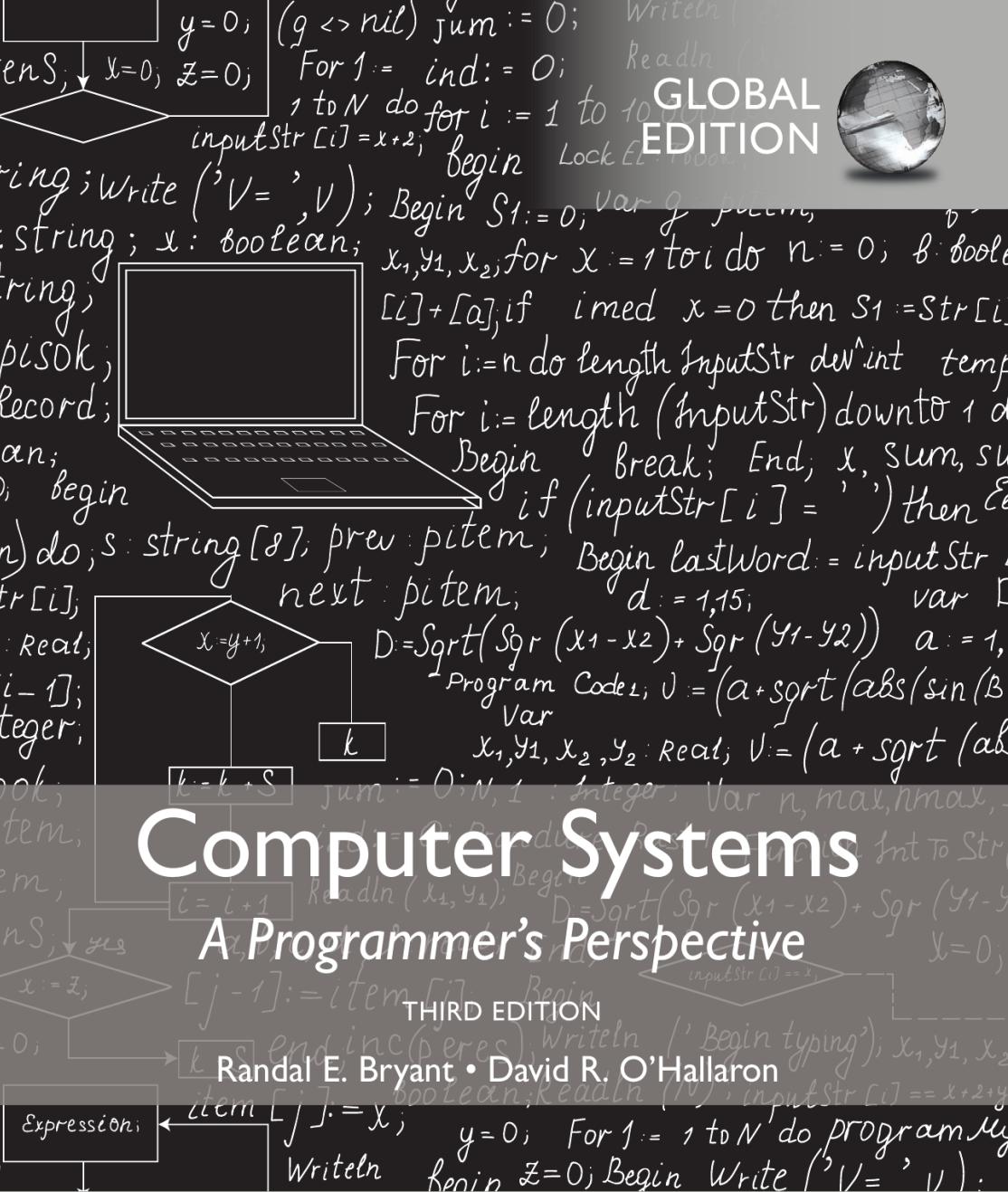
Question Break!

Lecture Plan

- Introduction
- COMP201 Course Policies
- Unix and the Command Line
- Getting Started With C

Textbooks

- *Computer Systems: A Programmer's Perspective* by Bryant & O'Hallaron, 3rd Edition
 - 3rd edition matters – important updates to course materials
- A C programming reference of your choice
 - *The C Programming Language* by Kernighan and Ritchie
 - Other C programming books, websites, or reference sheets



Course Structure

- **Lectures:** understand concepts, see demos
- **Labs:** learn tools, study code, discuss with peers
- **Assignments:** build programming skills, synthesize lecture/lab content

| Monday | Wednesday | Friday |
|---------|-----------|---------|
| Lecture | Lecture | Lab-A-B |

- assg0: out next week, due Mar 16
- C bootcamp: this week (details will be announced soon)

Grading

| | |
|-----|---------------------------|
| 27% | 5 Programming assignments |
| 28% | 9 Labs |
| 20% | Midterm exam |
| 20% | Final exam |
| 5% | Class participation |

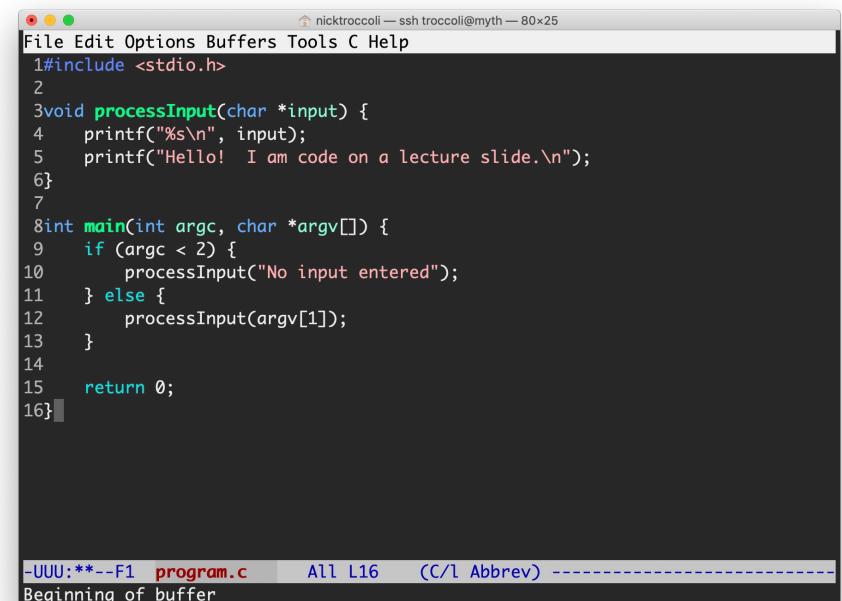
Grading

| | |
|-----|-------------------------|
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Assignments

- 5 programming assignments completed individually using **Unix command line tools**
 - Free software, pre-installed on `linuxpool` cluster dedicated to COMP students
 - GitHub Classroom
 - We will give out starter projects for each assignment
- Graded on **functionality** (*behavior*) and **style** (*elegance*)
 - Functionality graded using *automated tools*, given as point score
 - Style graded via *automated tests* and TA code review,
 - Grades returned via Blackboard

GitHub Classroom



A screenshot of a terminal window titled "nicktroccoli — ssh troccoli@myth — 80x25". The window shows a C program with syntax highlighting. The code defines a `processInput` function that prints the input string and a greeting message. It also defines a `main` function that calls `processInput` with "No input entered" if no arguments are provided, or with the first argument otherwise. The terminal window includes a menu bar with File, Edit, Options, Buffers, Tools, C, and Help. At the bottom, there is status information: "-UUU:***-F1 program.c All L16 (C/l Abbrev) ----- Beginning of buffer".

```
#include <stdio.h>
void processInput(char *input) {
    printf("%s\n", input);
    printf("Hello! I am code on a lecture slide.\n");
}
int main(int argc, char *argv[]) {
    if (argc < 2) {
        processInput("No input entered");
    } else {
        processInput(argv[1]);
    }
    return 0;
}
```

Late Policy

- Start out with **7 grace days**: each late day allows you to submit an assignment without penalty if you have free grace days left.
- Hard deadline: No submissions will be accepted **48 hours after the original due date of an assignment**
- Penalty per day after grace days are exhausted
 - 1 day: 20% off
 - 2 days: 40% off
- Submissions made on Blackboard at 00:01am after the deadline counts as late and are considered as using 1 grace day

Grading

| | |
|-----|-------------------------|
| 27% | Programming assignments |
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Lab Sections

- Weekly 100-minute labs led by a TA, starting *next* Friday.
- Hands-on practice with lecture material and course topics.
GitHub Classroom + `linuxpool.ku.edu.tr`
- Graded on attendance + participation (*verified by submitting lab work*)
 - Two graded part:
 - In-class practice problem (40%)
 - After-class problem (60%)
 - Your lowest 2 scores will be dropped, hence there will be no make-up

According to the Council of Higher Education's decision,
both the lectures and the labs will be delivered **online** until April!

Grading

| | |
|-----|-------------------------|
| 27% | Programming assignments |
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Midterm and Final Exams

- Face-to-face exams
 - Midterm: At week 7, exact date and time will be announced later
 - Final: Date and time will be announced later

Grading

| | |
|-----|-------------------------|
| 27% | Programming assignments |
| 28% | Labs |
| 20% | Midterm exam |
| 20% | Final exam |
| 5% | Class participation |

What foreign TV
series are you
watching now? Just
specify the one that
you enjoy the most!



Question Break!

Getting Help

- Post on the **Discussion Forum at Blackboard**
 - Online discussion forum for students; post questions, answer other students' questions
 - Best for general assignment questions (DON'T POST ASSIGNMENT CODE!)
- Visit **Office Hours**
 - More info to come soon!
- Email the **Course Staff**
 - Best for private matters (e.g. grading questions).

Koç University Honor Code

- For assignments students should be required to digitally add and approve a version of the agreement below.

I hereby declare that I have completed this examination individually, without support from anyone else.

I hereby accept that only the below listed sources are approved to be used during this open-source examination:

- (i) Coursebook,*
- (ii) All material that is made available to students via Blackboard for this course, and*
- (iii) Notes taken by me during lectures.*

I have not used, accessed or taken any unpermitted information from any other source. Hence, all effort belongs to me.

Honor Code and COMP201

- Please help us ensure academic integrity:
 - Indicate any assistance received on HW (books, friends, etc.).
 - Do not look at other people's solution code or answers
 - Do not give your solutions to others or post them on the web or to the forum.
 - Report any inappropriate activity you see performed by others.
- Assignments are checked regularly for similarity with help of automated software tools.
- If you realize that you have made a mistake, you may retract your submission to any assignment at any time, no questions asked. Come to use before we come for you.
- If you need help, please contact us and we will help you.
 - We do not want you to feel any pressure to violate the Honor Code in order to succeed in this course.

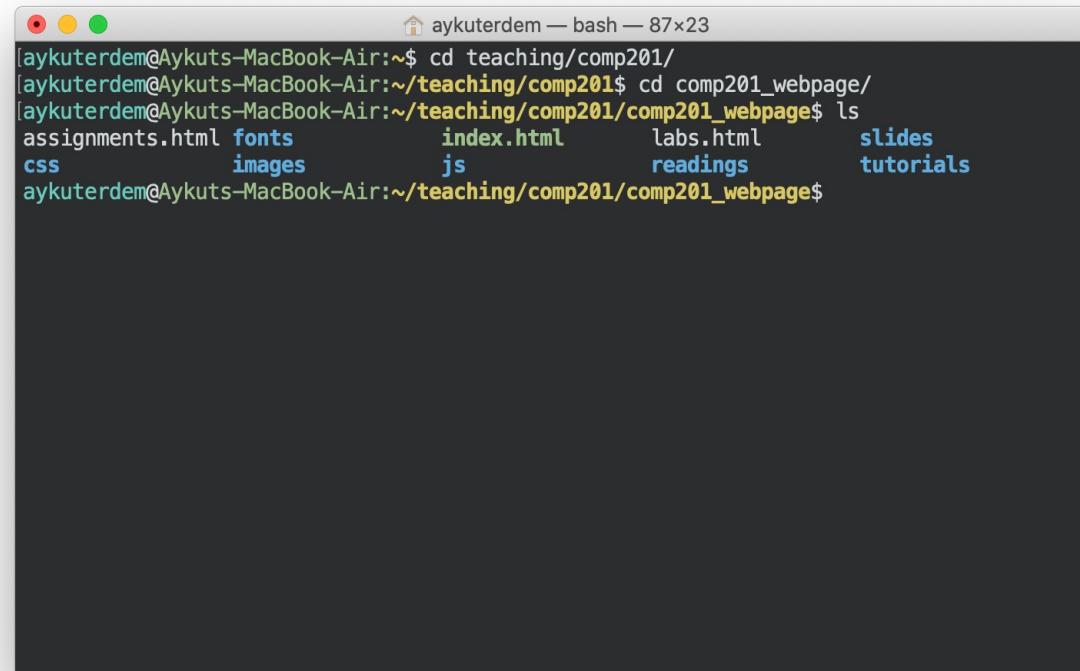
Poll Time

Lecture Plan

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What is Unix?

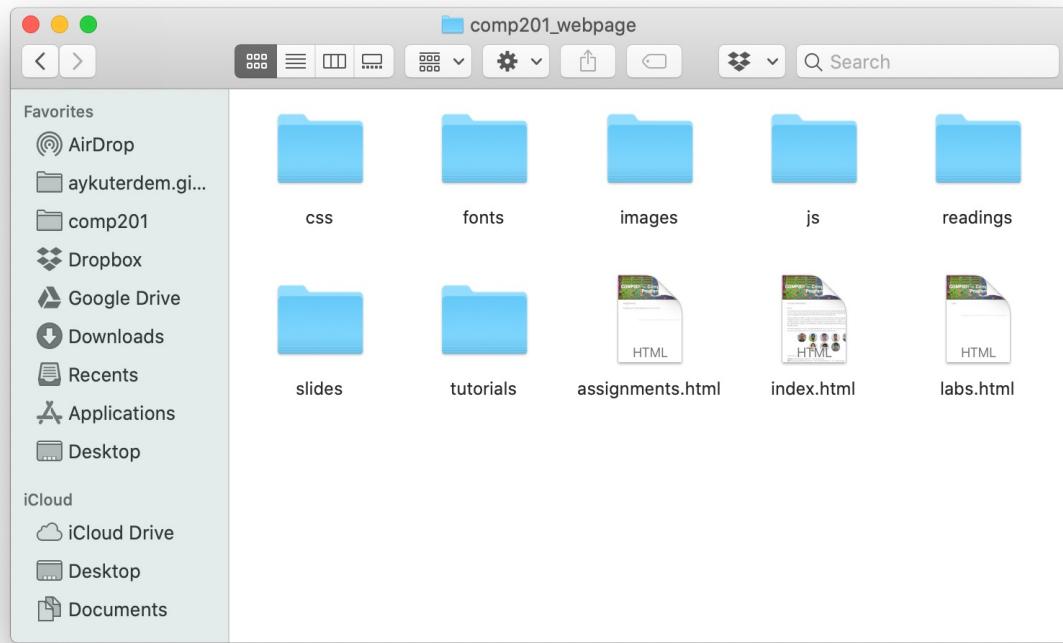
- **Unix**: a set of standards and tools commonly used in software development.
 - macOS and Linux are operating systems built on top of Unix
- You can navigate a Unix system using the **command line** ("terminal")
- Every Unix system works with the same tools and commands



```
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$ ls
assignments.html fonts index.html labs.html slides
css images js readings tutorials
aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$
```

What is the Command Line?

- The **command-line** is a text-based interface (i.e., **terminal** interface) to navigate a computer, instead of a Graphical User Interface (GUI).



Graphical User Interface

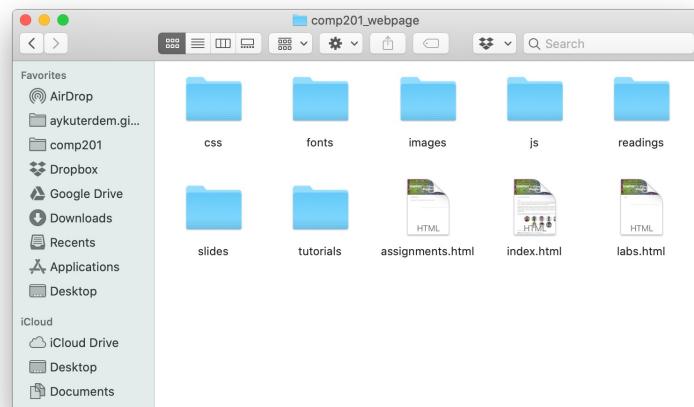
```
[aykuterdem@Aykuts-MacBook-Air:~$ cd teaching/comp201/
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201$ cd comp201_webpage/
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$ ls
assignments.html fonts index.html labs.html slides
css images js readings tutorials
aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$
```

Text-based interface

Command Line vs. GUI

Just like a GUI file explorer interface, a terminal interface:

- shows you a **specific place** on your computer at any given time.
- lets you go **into folders** and **out of folders**.
- lets you **create new files** and **edit files**.
- lets you **execute programs**.



Graphical User Interface

A screenshot of a Mac OS X terminal window titled 'aykuterdem — bash — 87x23'. The window shows a command-line session where the user has navigated to a directory and listed its contents. The terminal output is as follows:

```
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201$ cd comp201_webpage/
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201$ cd comp201_webpage/
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$ ls
assignments.html  fonts      index.html    labs.html    slides
css               images     js           readings   tutorials
[aykuterdem@Aykuts-MacBook-Air:~/teaching/comp201/comp201_webpage$
```

Command-line interface

Why Use Unix / the Command Line?

- You can navigate almost any device using the same tools and commands:
 - Servers
 - Laptops and desktops
 - Embedded devices (Raspberry Pi, etc.)
 - Mobile Devices (Android, etc.)
- Used frequently by software engineers:
 - **Web development:** running servers and web tools on servers
 - **Machine learning:** processing data on servers, running algorithms
 - **Systems:** writing operating systems, networking code and embedded software
 - **Mobile Development:** running tools, managing libraries
 - And more...
- We'll use Unix and the command line to implement and execute our programs.

Demo: Using Unix and the Command Line



Unix Commands Recap

- **cd** – change directories (..)
- **ls** – list directory contents
- **mkdir** – make directory
- **emacs** – open text editor
- **vi** – open text editor
- **rm** – remove file or folder
- **man** – view manual pages



Lab 1:
The Linux Shell
(next week)

See the Resources page of the course website for more commands, and a complete reference.

Learning Unix and the Command Line

- Using Unix and the command line can be intimidating at first:
 - It looks retro!
 - How do I know what to type?
- It's like learning a new language:
 - At first, you may have to constantly look things up (**Resources** page on course website!)
 - It's important to spend as much time as possible (during labs and assignments) building muscle memory with the tools

Question Break!

Additional Reading 1

The screenshot shows a web browser window displaying an article from IEEE Spectrum. The URL in the address bar is <https://spectrum.ieee.org/tech-history/cyberspace/the-strange-birth-and-long-life-of-unix>. The page header includes the IEEE Spectrum logo and navigation links for Engineering Topics, Special Reports, Blogs, Multimedia, The Magazine, Professional Resources, and Search. Below the header, there are links for Feature, History, and Cyberspace, along with a timestamp of 28 Nov 2011 | 21:24 GMT. The main title of the article is "The Strange Birth and Long Life of Unix". A subtitle below it reads "The classic operating system turns 40, and its progeny abound". The author's name, Warren Toomey, is listed with a small profile picture. To the left of the main content area, there is a vertical sidebar with social media sharing icons for YouTube, Facebook, Twitter, LinkedIn, and Google+. The main content area features a black and white photograph of two men working at a computer terminal in a server room. To the right of the photo is a column of text about Ken Thompson and Dennis Ritchie creating the Unix operating system.

Feature | History | Cyberspace

28 Nov 2011 | 21:24 GMT

The Strange Birth and Long Life of Unix

The classic operating system turns 40, and its progeny abound

By Warren Toomey



They say that when one door
closes on you, another opens. People
generally offer this bit of wisdom just
to lend some solace after a
misfortune. But sometimes it's
actually true. It certainly was for Ken
Thompson and the late Dennis
Ritchie, two of the greats of 20th-
century information technology,
when they created the Unix operating
system, now considered one of the
most inspiring and influential pieces
of software ever written.

f t p +

<https://spectrum.ieee.org/tech-history/cyberspace/the-strange-birth-and-long-life-of-unix>

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The C Language

C was created around 1970 to make writing Unix and Unix tools easier.

- Part of the C/C++/Java family of languages (C++ and Java were created later)
- Design principles:
 - Small, simple abstractions of hardware
 - Minimalist aesthetic
 - Prioritizes efficiency and minimalism over safety and high-level abstractions

C vs. C++ and Java

They all share:

- Syntax
- Basic data types
- Arithmetic, relational, and logical operators

C doesn't have:

- More advanced features like operator overloading, default arguments, pass by reference, classes and objects, ADTs, etc.
- Extensive libraries (no graphics, networking, etc.) – this means not much to learn C!
- many compiler and runtime checks (this may cause security vulnerabilities!)

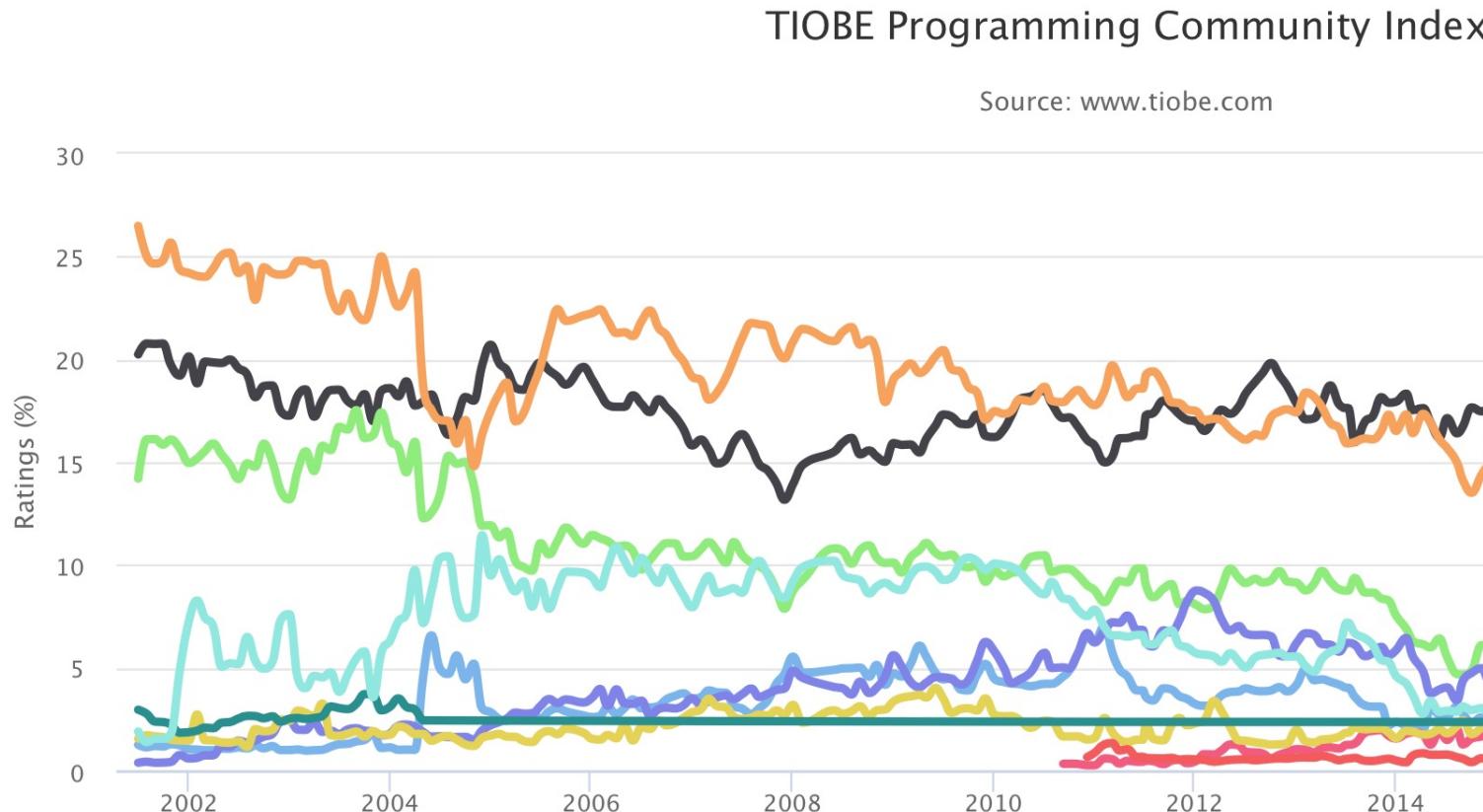
Programming Language Philosophies

- **C is procedural:** you write functions, rather than define new variable types with classes and call methods on objects. C is small, fast and efficient.
- **C++ is procedural, with objects:** you write functions, and define new variable types with classes, and call methods on objects.
- **Python is also procedural, but dynamically typed:** you still write functions and call methods on objects, but the development process is very different.
- **Java is object-oriented:** virtually everything is an object, and everything you write needs to conform to the object-oriented design pattern.

Why C?

- Many tools (and even other languages, like Python!) are built with C.
- C is the language of choice for fast, highly efficient programs.
- C is popular for systems programming (operating systems, networking, etc.)
- C lets you work at a lower level to manipulate and understand the underlying system.

Programming Language Popularity



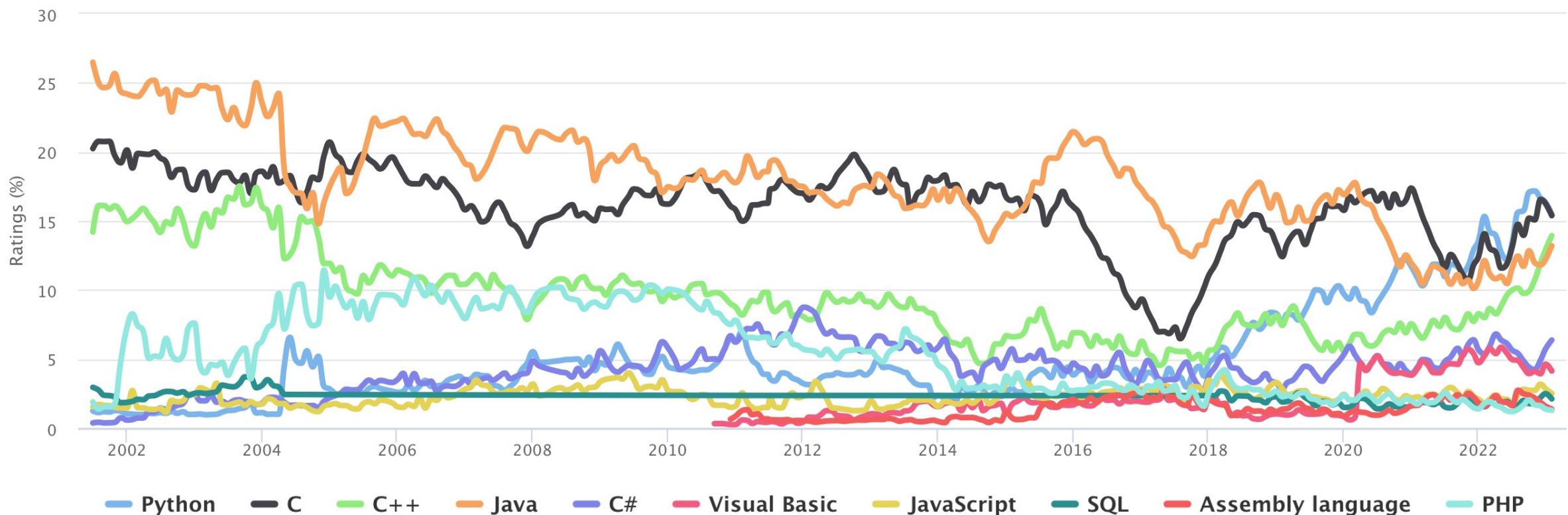
Guess which one is
the C language?

Programming Language Popularity

TIOBE Programming Community Index

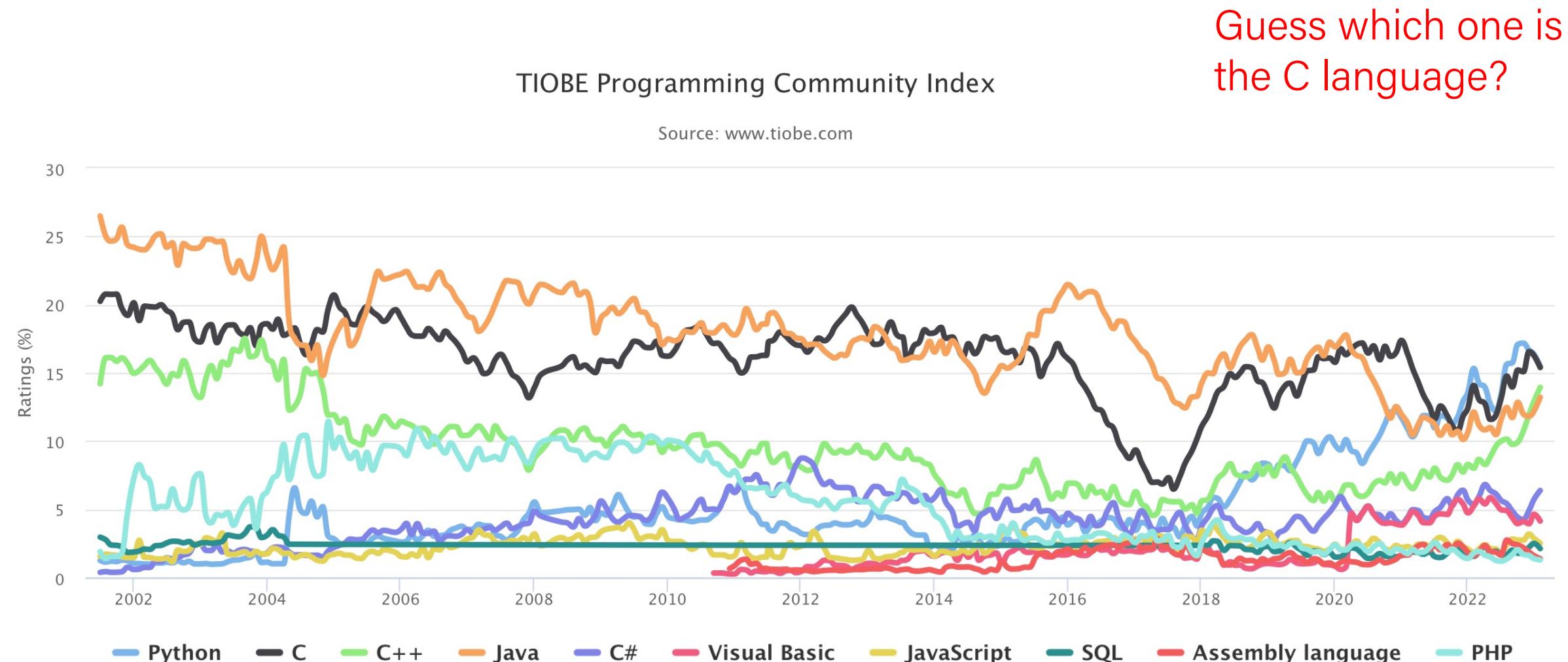
Source: www.tiobe.com

Guess which one is
the C language?



<https://www.tiobe.com/tiobe-index/>

Programming Language Popularity

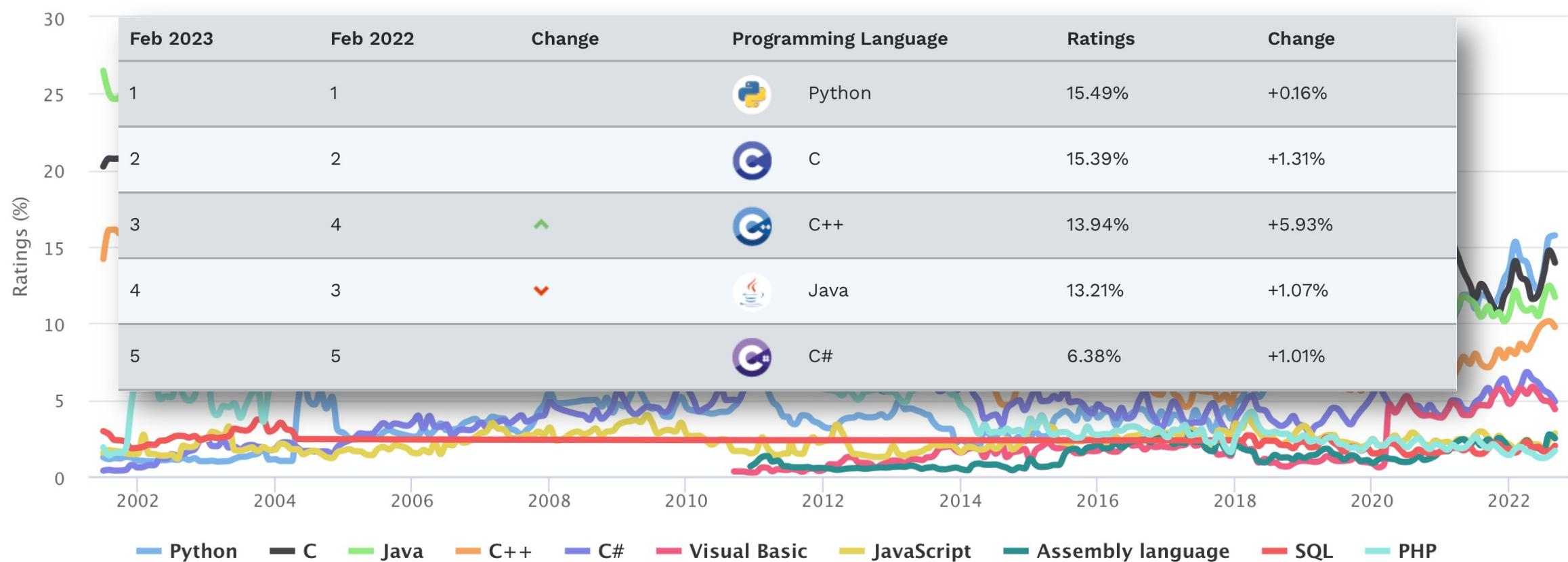


Guess which one is
the C language?

Programming Language Popularity

TIOBE Programming Community Index

Source: www.tiobe.com



<https://www.tiobe.com/tiobe-index/>

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

Program comments

You can write block or inline comments.

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

Import statements

C libraries are written with angle brackets.
Local libraries have quotes:

```
#include "lib.h"
```

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

main function – entry point for the program
Should always return an integer (0 = success)

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

Main parameters - `main` takes two parameters, both relating to the command line arguments used to execute the program.

`argc` is the number of arguments in `argv`
`argv` is an array of arguments (`char *` is C string)

Our First C Program

```
/*
 * hello.c
 * This program prints a welcome message
 * to the user.
 */
#include <stdio.h> // for printf

int main(int argc, char *argv[]) {
    printf("Hello, world!\n");
    return 0;
}
```

printf – prints output to the screen

Familiar Syntax

```
int x = 42 + 7 * -5;                      // variables, types
double pi = 3.14159;
char c = 'Q';                                /* two comment styles */

for (int i = 0; i < 10; i++) {                // for loops
    if (i % 2 == 0) {                         // if statements
        x += i;
    }
}

while (x > 0 && c == 'Q' || b) {           // while loops, logic
    x = x / 2;
    if (x == 42) { return 0; }
}

binky(x, 17, c);                            // function call
```

Boolean Variables

To declare Booleans, (e.g. **bool b = _____**), you must include **stdbool.h**:

```
#include <stdio.h>      // for printf
#include <stdbool.h>    // for bool

int main(int argc, char *argv[]) {
    bool x = 5 > 2 && binky(argc) > 0;
    if (x) {
        printf("Hello, world!\n");
    } else {
        printf("Howdy, world!\n");
    }
    return 0;
}
```

Boolean Expressions

C treats a nonzero value as true, and a zero value as false:

```
#include <stdio.h>

int main(int argc, char *argv[]) {
    int x = 5;
    if (x) {    // true
        printf("Hello, world!\n");
    } else {
        printf("Howdy, world!\n");
    }
    return 0;
}
```

Console Output: printf

```
printf(text, arg1, arg2, arg3);
```

```
// Example
char *classPrefix = "COMP";
int classNumber = 201;
printf("You are in %s%d", classPrefix, classNumber); // You are in COMP201
```

`printf` makes it easy to print out the values of variables or expressions.

If you include *placeholders* in your printed text, `printf` will replace each placeholder *in order* with the values of the parameters passed after the text.

`%s` (string)

`%d` (integer)

`%f` (double)

Additional Reading 2

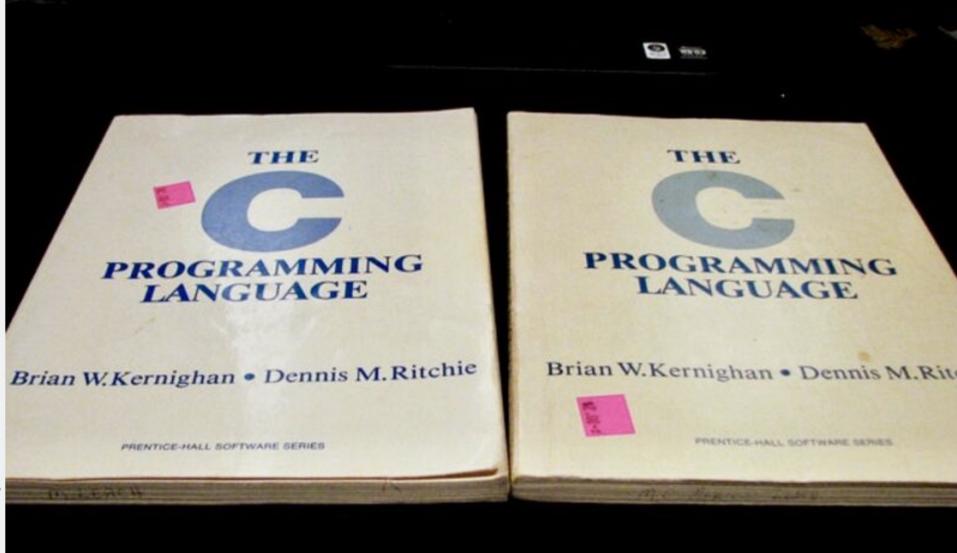
ars TECHNICA

THE ABCS OF C" OR "C: FROM A TO Z"? —

“A damn stupid thing to do”—the origins of C

Today, C may be a lingua franca among programmers. This is its (abridged) history.

RICHARD JENSEN - 12/9/2020, 3:30 PM



Enlarge / As hard as it may be to believe, C was not simply born in wellworn paperback form.

In one form or another, C has influenced the shape of almost every programming language developed since the 1980s. Some languages like C++, C#, and objective C are intended to be direct successors to the language, while other languages have merely adopted and adapted C's syntax. A programmer conversant in

ARS VIDEO

A visit to 42, the free US coding school | Ars Technica



To get into 42 or into a piscine

THE TRUTHS WE UNCOVER.

Open "[https://googleads.g.doubleclick.net/pcs/click?xai=AKAOjssYwdBgMTQwTBPBFRcWpsNx2x1FFnotmBV9KdI...JSzDRPxRSCG66a&fbs_aeid=\[gw_fbsaeid\]&adurl=https://www.condenast.com/commercial&nm=3](https://googleads.g.doubleclick.net/pcs/click?xai=AKAOjssYwdBgMTQwTBPBFRcWpsNx2x1FFnotmBV9KdI...JSzDRPxRSCG66a&fbs_aeid=[gw_fbsaeid]&adurl=https://www.condenast.com/commercial&nm=3)" in a new tab

<https://arstechnica.com/features/2020/12/a-damn-stupid-thing-to-do-the-origins-of-c/>

Question Break!

Writing, Debugging and Compiling

We will use:

- the **vi/emacs** text editor to write our C programs
- the **make** tool to compile our C programs
- the **gdb** debugger to debug our programs
- the **valgrind** tools to debug memory errors and measure program efficiency

Demo: Compiling And Running A C Program



Working On C Programs Recap

- **ssh** – remotely log in to `linuxpool` computers (*later*)
- **Vi/Emacs** – text editor to write and edit C programs
 - Use the mouse to position cursor, scroll, and highlight text
 - `:w` / `Ctl-x Ctl-s` to save, `:q` / `Ctl-x Ctl-c` to quit
- **make** – compile program using provided Makefile
- **`./myprogram`** – run executable program (optionally with arguments)
- **make clean** – remove executables and other compiler files
- Lecture codes are accessible at course webpage

Recap

- COMP201 is a programming class, which uses C to teach you about what goes on under the hood of programming languages and software.
- We'll use Unix and command line tools to write, debug and run our programs.
- Please regularly visit the course website, <https://aykuterdem.github.io/classes/comp201.f22> and follow the announcements on Blackboard.
- **We're looking forward to an exciting semester!**

Next time: *How a computer represents integer numbers? What are the limitations?*

