ECE 2400 / ENGRD 2140
Computer Systems Programming
Course Overview

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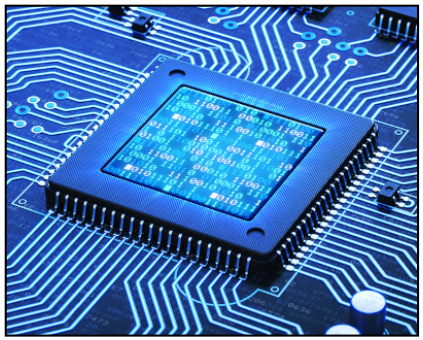
`http://www.csl.cornell.edu/courses/ece2400`

Application-Level Software

System-Level Software

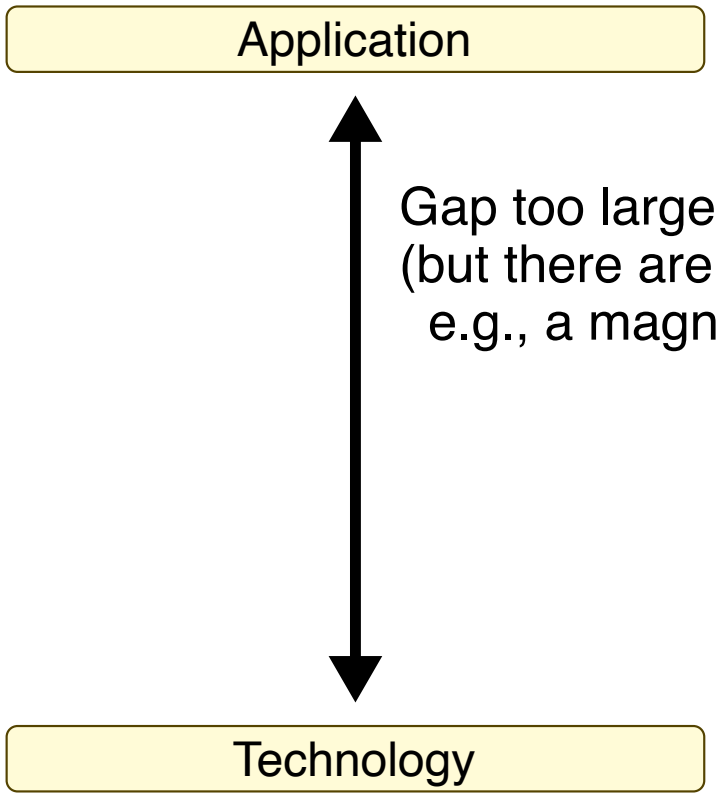


ECE 2400 / ENGRD 2140 Computer Systems Programming

What is Computer Systems Programming?

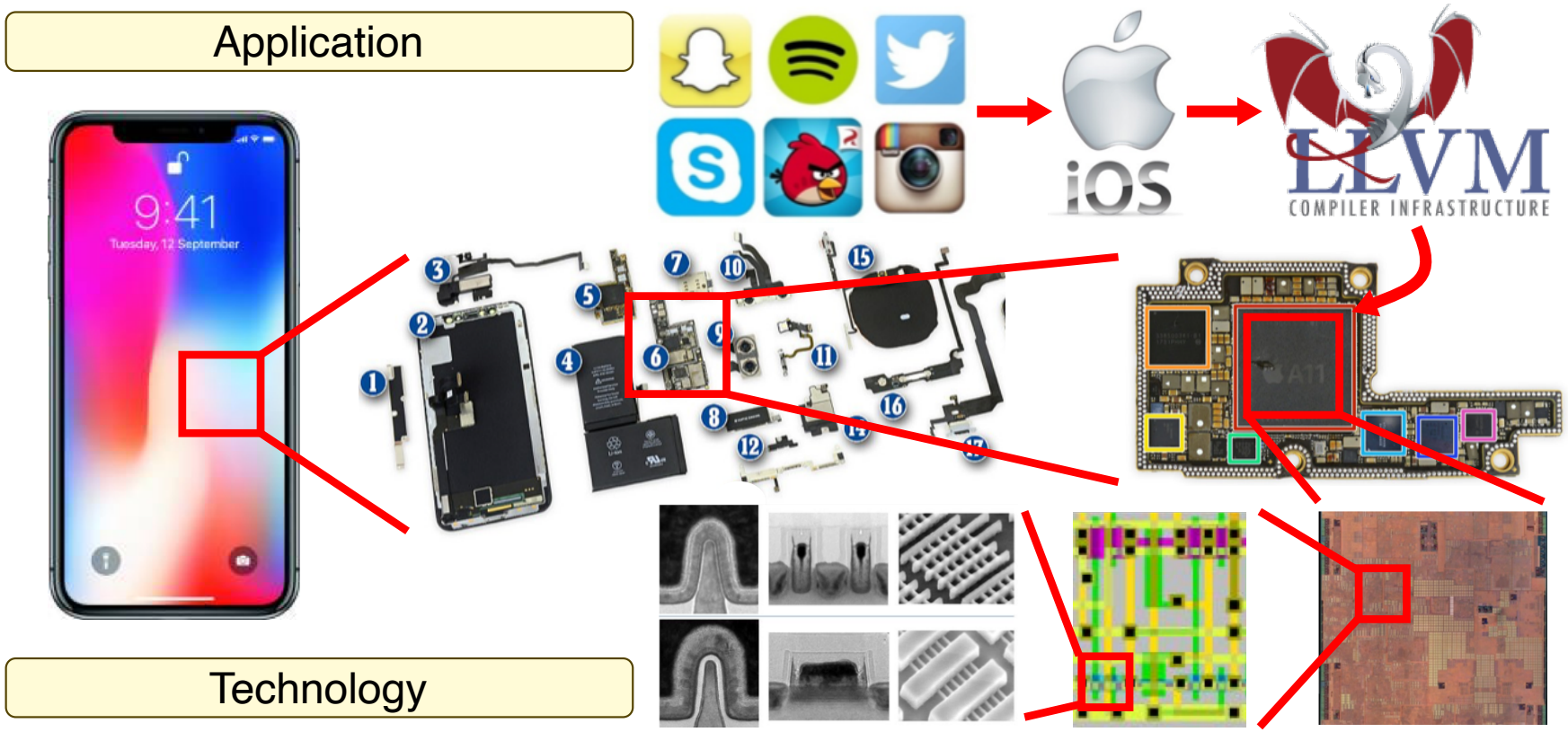
Course Logistics

Applications vs. Technology

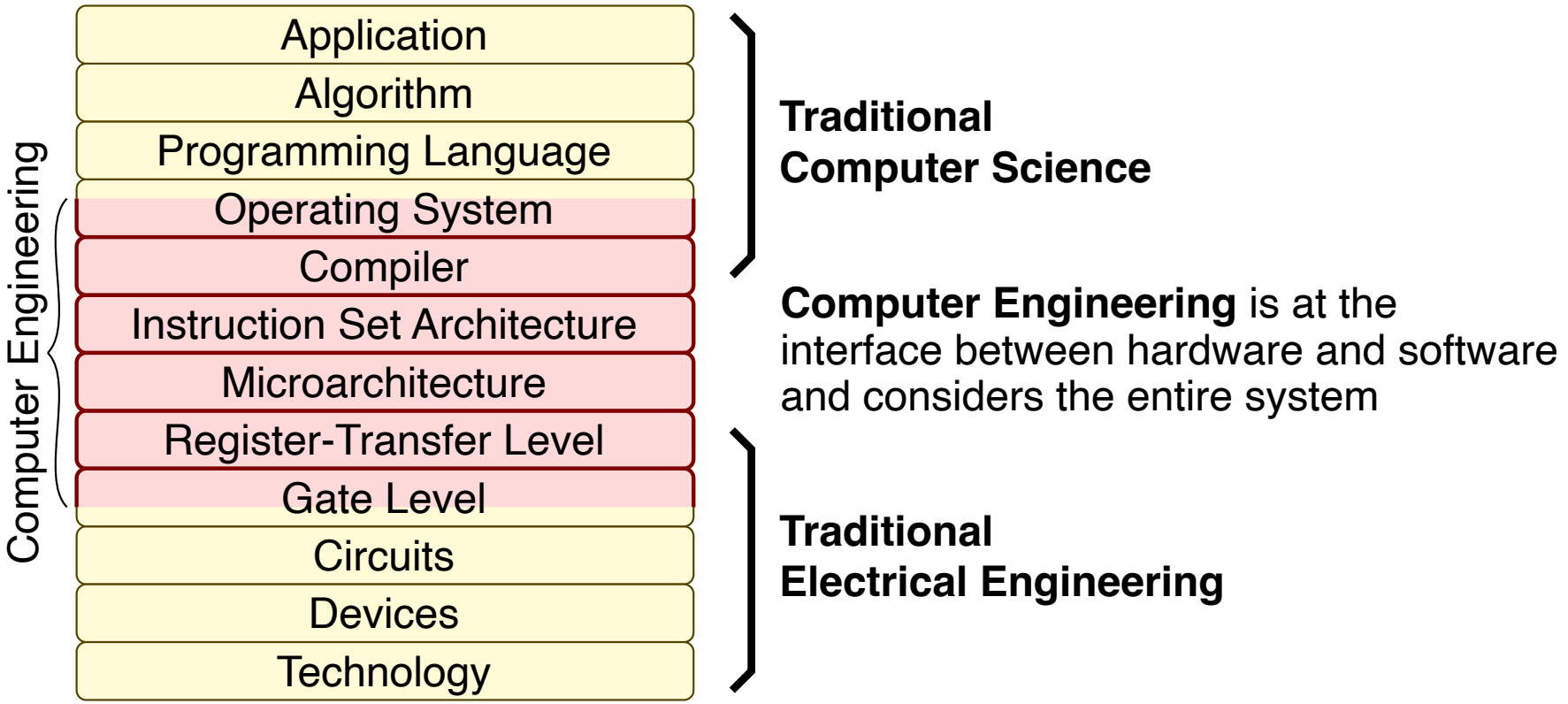


Gap too large to bridge in one step
(but there are exceptions,
e.g., a magnetic compass)

Applications vs. Technology

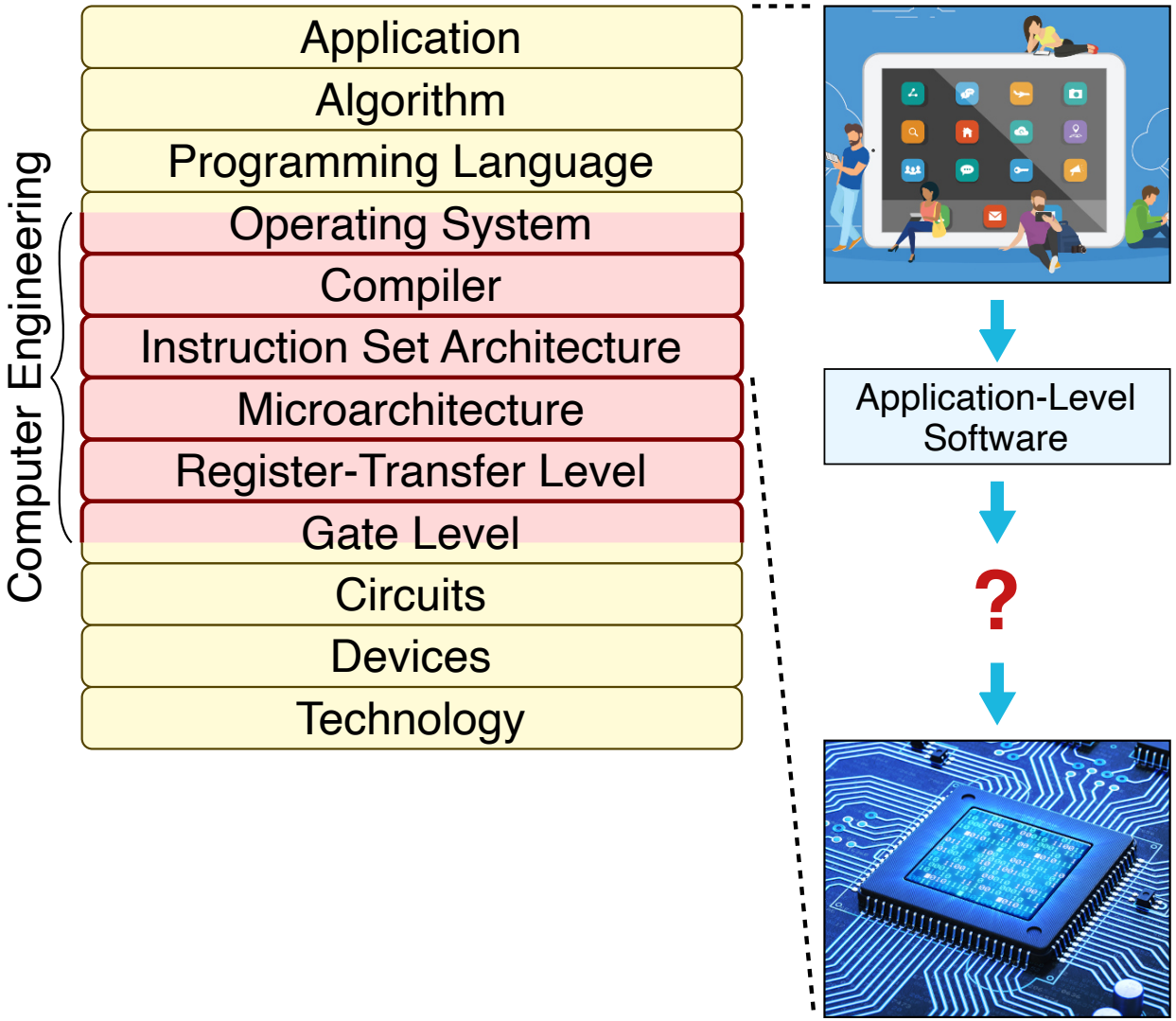


The Computer Systems Stack



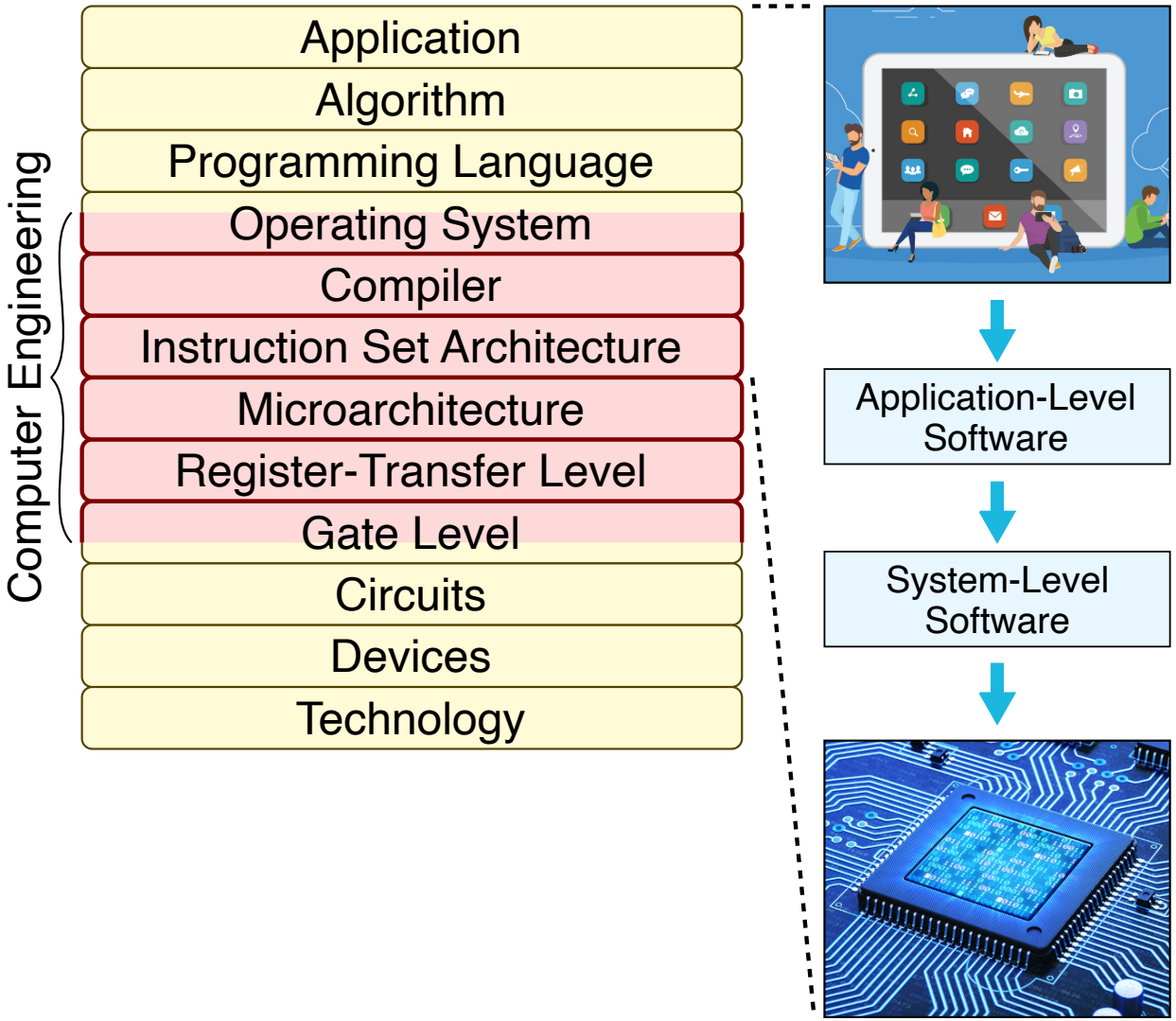
In its broadest definition, computer engineering is the development of the abstraction/implementation layers that allow us to execute information processing applications efficiently using available manufacturing technologies

Python for Application-Level Programming



- High-level, user-facing software
- Enable productively developing applications that provide new functionality to users
- Enable productively collecting, analyzing, visualizing data
- Sometimes called a productivity-level language

C/C++ for System-Level Programming

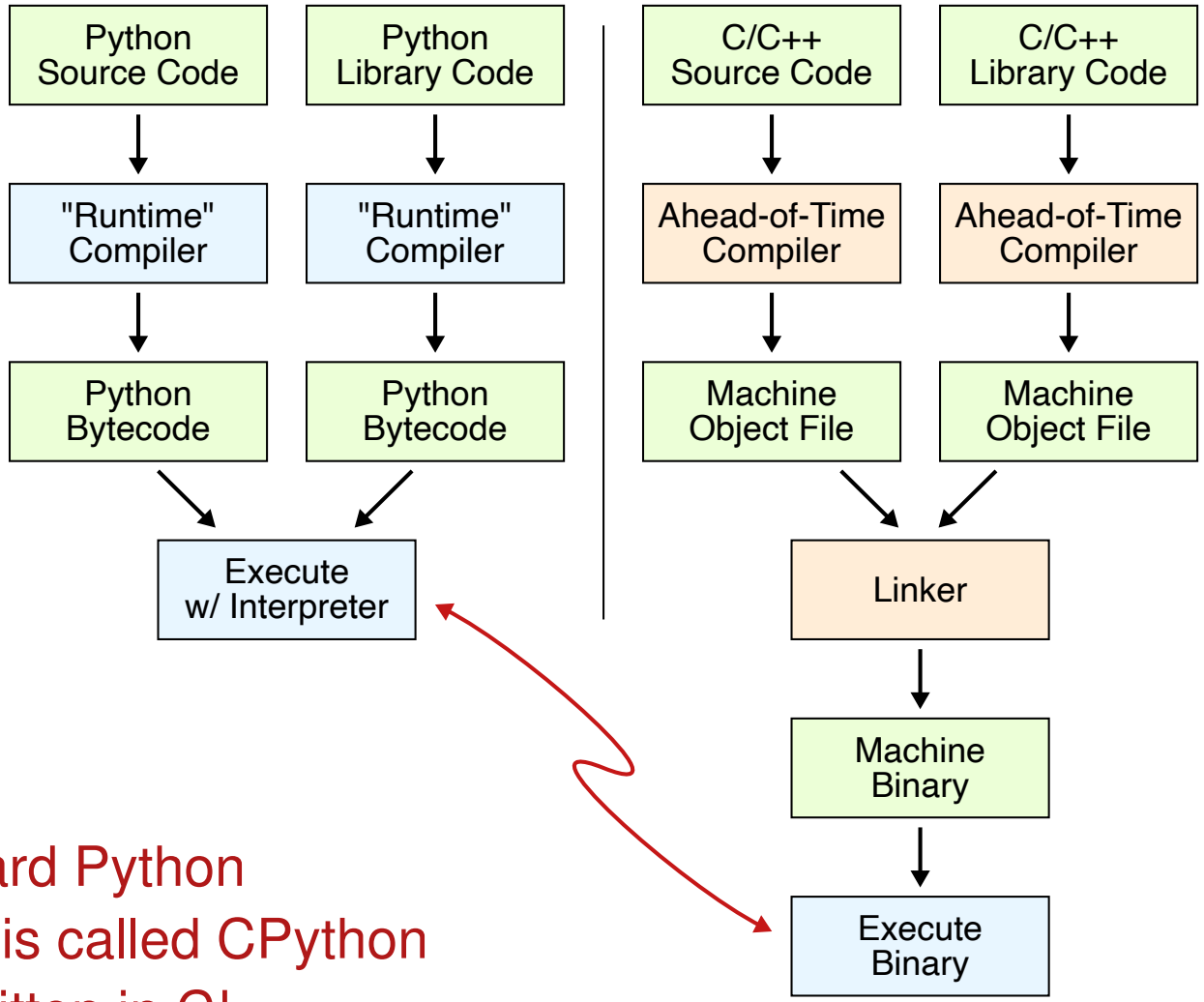


- Connects application software to the low-level computer hardware
- Enables carefully managing performance and resource constraints
- Sometimes called an efficiency-level language

Dynamically Interpreted vs. Statically Compiled

```
def min(a,b):
  if a < b:
    c = a
  else
    c = b
  return c
```

```
LOAD_FAST
LOAD_FAST
COMPARE_OP
POP_JUMP_IF_F
LOAD_FAST
STORE_FAST
JUMP_FORWARD
LOAD_FAST
STORE_FAST
LOAD_FAST
RETURN_VALUE
```



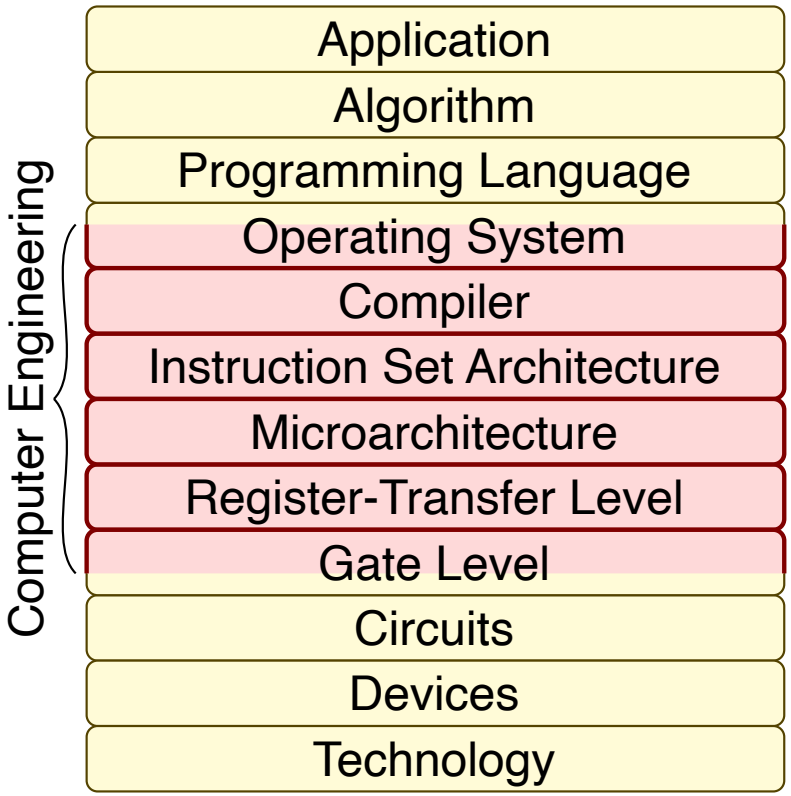

```
int min( int a,
         int b )
{
  int c;
  if ( a < b )
    c = a;
  else
    c = b;
  return c;
}
```

```
pushq %rbp
movq  %rsp,%rbp
cmpl  %esi,%edi
cmovl %edi,%esi
movl  %esi,%eax
popq  %rbp
retq
```

```
1010101
100100010001001
11100111110111
111101001110111
100010011111000
1011101
11000011
```

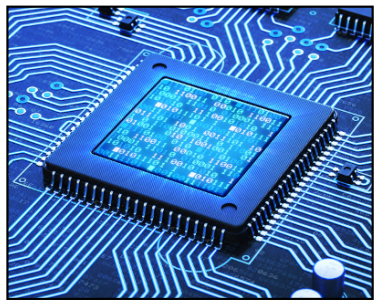
The standard Python interpreter is called CPython and it is written in C!

Computer Systems Programming is Diverse



Application-Level Software

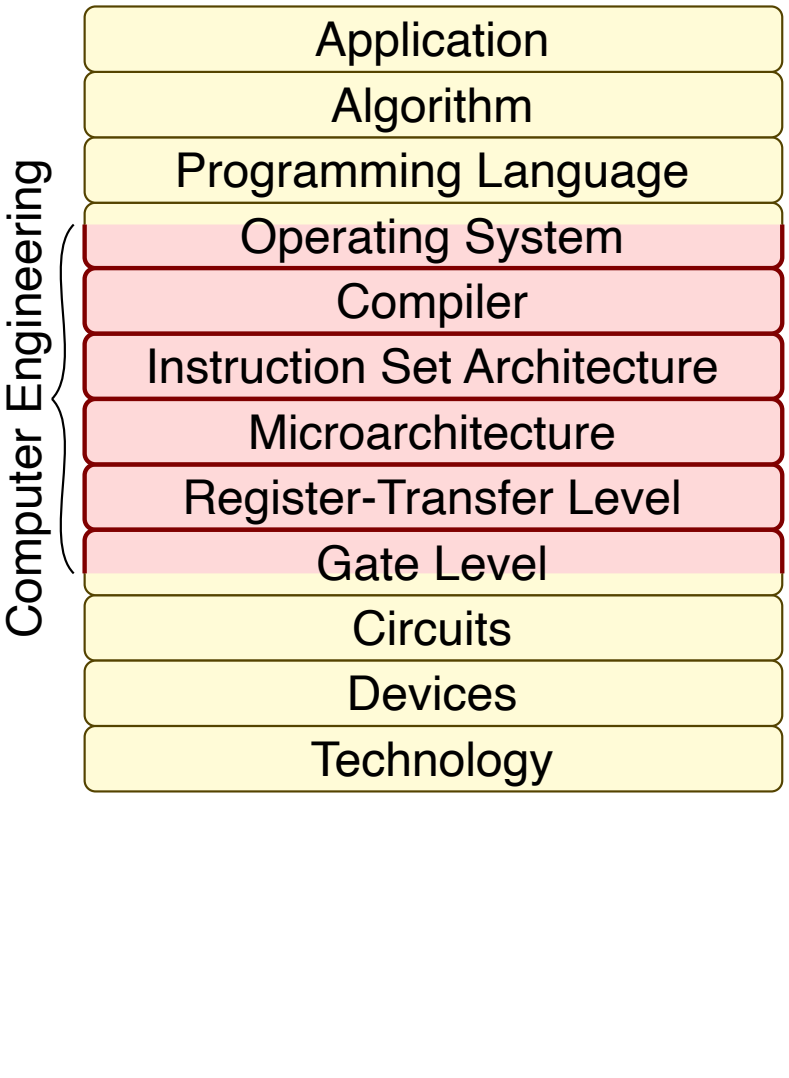
System-Level Software



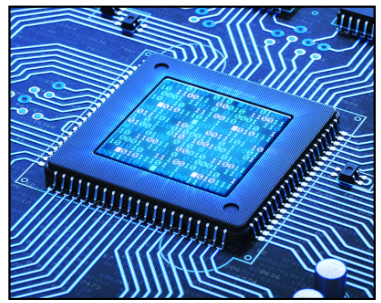
- Python, MATLAB
- Ruby, Javascript
- SQL, LINQ
- NumPy
- GUI frameworks

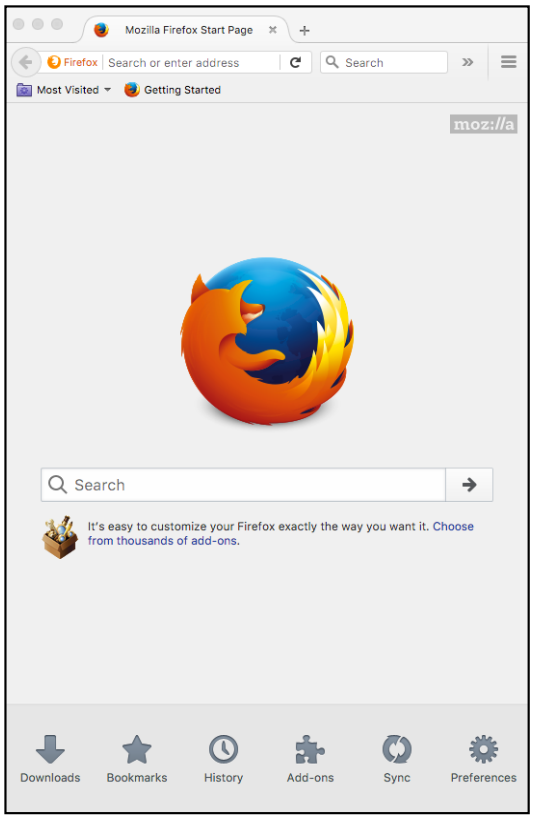
- Interpreters
- Compilers
- Databases
- Numerical libraries
- Operating systems
- Embedded control

Aside: C/C++ for Application-Level Software



Application-Level
&
System-Level
Software





A Tale of Two Programming Languages

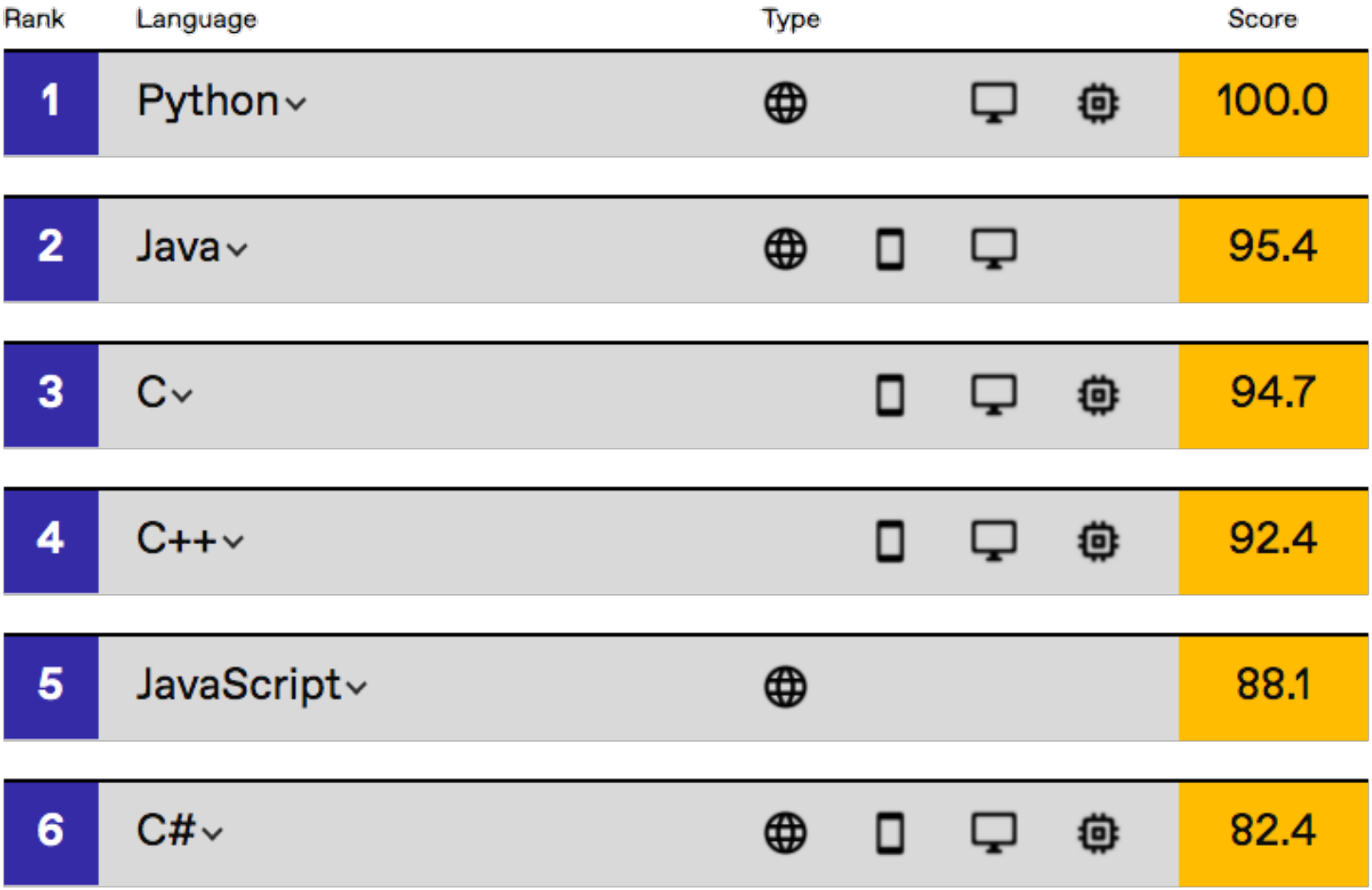
Python Programming Language

- Introduced: 1991
- Most of the machine details are hidden from programmer
- Programmer gives up some control for improved productivity
- Easily supports multiple programming paradigms
- Extensive standard library is included
- Slow and memory inefficient

C/C++ Programming Language

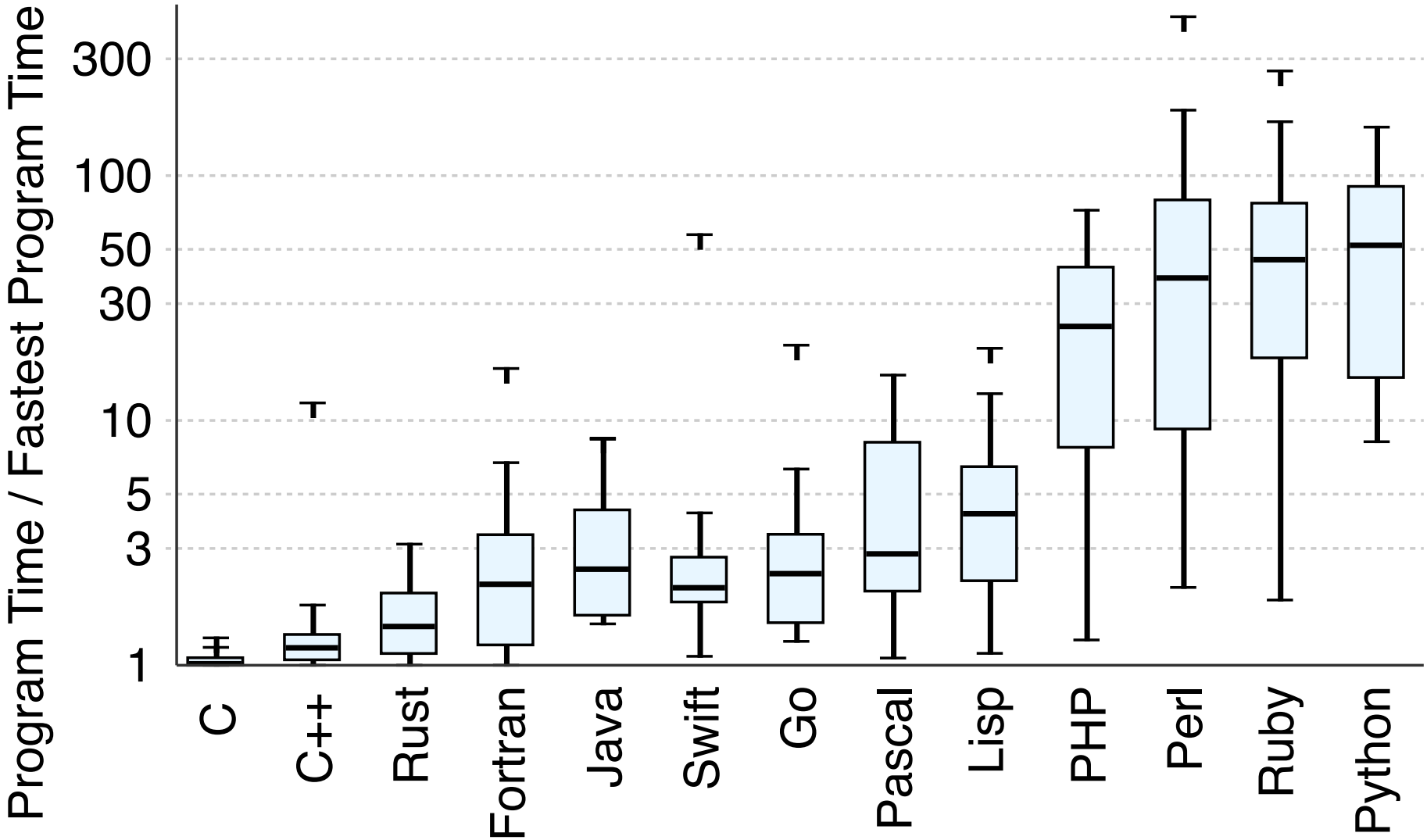
- Introduced: 1972(C), 1979(C++)
- Most of the machine details are exposed to the programmer
- Programmer is in complete control for improved efficiency
- Easily supports multiple programming paradigms
- More limited standard library is included
- Fast and memory efficient

Comparing the Popularity of Python vs. C/C++



The 2021 Top Programming Languages, IEEE Spectrum

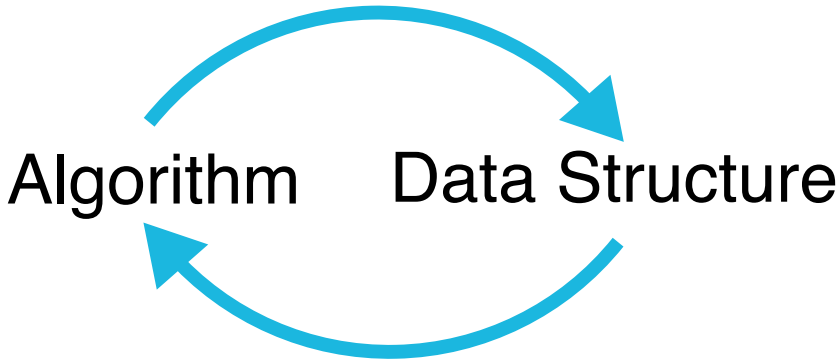
Comparing the Performance of Python vs. C/C++



The Computer Language Benchmarks Game

Program = Algorithm + Data Structure

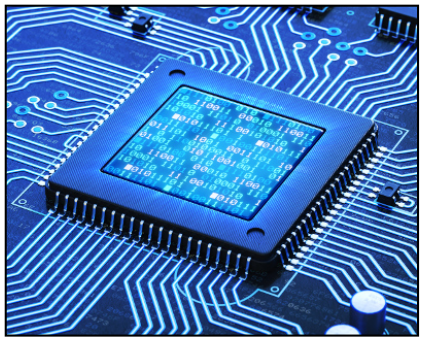
While this course covers C/C++ and system-level programming, this course also builds off of your prior programming experience to further develop your understanding of algorithms and data structures



- **Algorithm:** Clear set of steps to solve any problem instance in a particular class of problems
- **Data Structure:** Way of efficiently organizing and storing data along with operations for accessing and manipulating this data

Application-Level Software

System-Level Software



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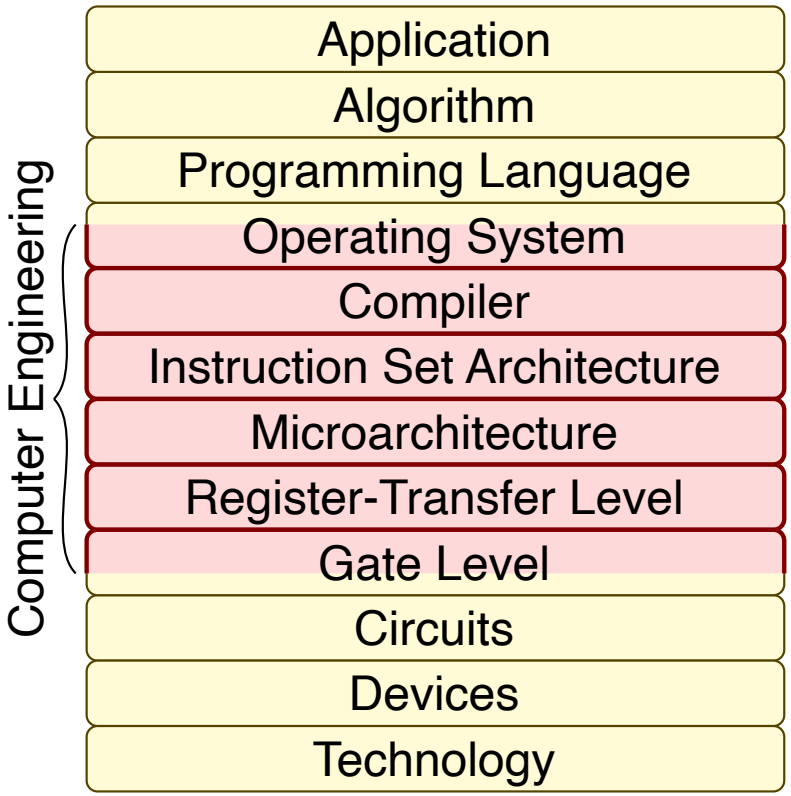
What is Computer Systems Programming?

Course Logistics

ECE 2400 Within the Engineering Curriculum



CS 1110 / CS 1112 Intro to Computing

- ECE 2400 Computer Systems Programming
  - ECE 3140 Embedded Systems
    - ECE 4760 Design with Microcontrollers
    - ECE 4750 Computer Architecture
- ECE 2300 Digital Logic & Computer Org

ECE 2400 is also an ENGRD and thus satisfies the engineering distribution requirement

ECE 2400 can be an excellent way to generally incorporate programming into your non-ECE engineering curriculum

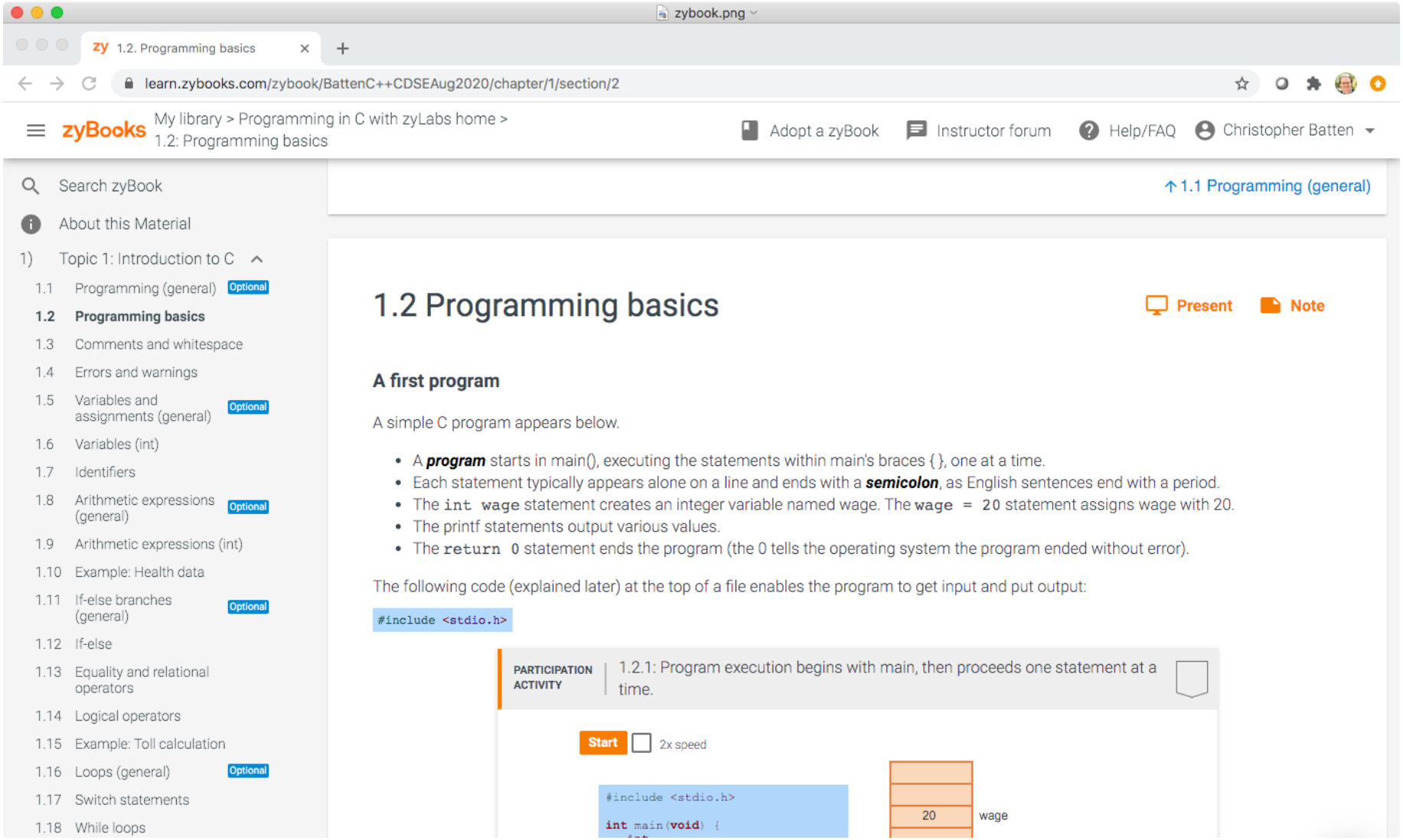
Course Objectives

- **describe** a variety of algorithms and data structures and how to analyze these algorithms and data structures in terms of time and space complexity
- **apply** the C/C++ programming languages to implement algorithms and data structures using different programming paradigms
- **evaluate** algorithm and data structure alternatives and make a compelling qualitative and/or quantitative argument for one approach
- **create** non-trivial C/C++ programs (roughly 1,000 lines of code) and the associated testing strategy from an English language specification
- **write** concise yet comprehensive technical reports that describe a program implemented in C/C++, explain the testing strategy used to verify functionality, and evaluate the program to characterize its performance and memory usage

Course Structure

- **Part 1: Procedural Programming**
  - introduction to C; variables; expressions; functions; conditional & iteration statements; recursion; static types; pointers; arrays; dynamic allocation
- **Part 2: Basic Algorithms and Data Structures**
  - lists; vectors; complexity analysis; sorting algorithms: insertion, selection, merge, quick, radix; ADTs: stacks, queues, priority queues, sets, maps
- **Part 3: Multi-Paradigm Programming**
  - transition to C++; namespaces; flexible function prototypes; references; exceptions; new/delete; *object oriented programming:* C++ classes and inheritance for dynamic polymorphism; *generic programming:* C++ templates for static polymorphism; *concurrent programming:* C++ threads and atomics
- **Part 4: More Algorithms and Data Structures**
  - trees (binary search trees; binary heaps); tables (lookup tables; hash tables); graphs (DFS, BFS, shortest path, minimum spanning trees)

zyBook: Interactive, Online Textbook



Likely Programming Assignments

- **PA1–3: Fundamentals**
  - PA1: Math functions
  - PA2: List and Vector Data Structures
  - PA3: Sorting Algorithms
- **PA4–5: Handwriting Recognition System**
  - PA5: Linear vs. Binary Searching
  - PA5: Trees vs. Tables
- **Every programming assignment involves**
  - C/C++ “agile” programming
  - State-of-the-art tools for build systems, version control, continuous integration, code coverage
  - Performance measurement
  - Short technical report

Spring 2025 Tweaks

- Two-phased Prelims:
  - part 1: by yourself
  - part 2: in groups
  - your prelim score will be a 90/10 weighted average
  - (but your group score cannot lower your grade)
- Who makes these groups?
  - We do. (mostly random)
- How will I get to know my group?
  - a few in-class activities/quizzes
  - these will be announced in advance

Frequently Asked Questions

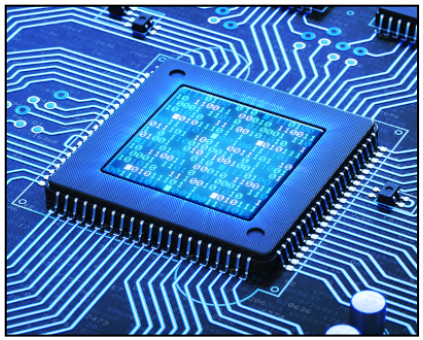
- I have not taken CS 1110 nor CS 1112, can I take this class?
  - We assume some basic programming experience, discuss with instructor
- **ECE Majors –** How does ECE 2400 satisfy degree requirements?
  - ECE 2400 can count as your second ENGRD course
  - ECE 2400 can count as an outside-ECE technical elective
  - ECE 2400 satisfies the ECE advanced programming requirement
- **CS Majors –** Can I use ECE 2400 in place of CS 2110?
  - Yes but you should probably take CS 2110
- **ECE/CS Dual Majors –** Can I use ECE 2400 in place of CS 2110?
  - Yes! (but it may delay your CS affiliation)
- **CS Minors –** Can I use ECE 2400 in place of CS 2110?
  - Absolutely!

Frequently Asked Questions

- **Other Majors –** How does ECE 2400 satisfy degree requirements?
  - ECE 2400 can count as one of your two required ENGRD courses
  - CS 2110 and ECE 2400 are in the same ENGRD category, so you cannot use both of them as your two ENGRD courses
- Can I take both ECE 2400 and CS 2110?
  - Sure! (recall popularity and performance data)

Application-Level Software

System-Level Software



Take-Away Points

- Computer systems programming involves developing software to connect the low-level computer hardware to high-level, user-facing application software and usually requires careful consideration of performance and resource constraints
- We are entering an exciting era where computer systems programming will play a critical role in enabling both cloud computing and the internet-of-things