# Lecture 16: Wrap-up

CS 106L, Winter ‘20

# Today’s Agenda

- Assn2
- Cool new features in C++17, C++20
- Future directions in CS

# Assignment 2

# Milestone 2

- Due tonight!
- Let us know if you need extra time :)

# Const-correctness

If you call a function on a **const** object, that function must be **const**

```
void global_func(const Obj& a, const Obj& b) {
   a.foo();
   b.foo();
}

Obj::foo() const {         // needs to be const, or compilation error
    ...
}
```

# Indexing ([])

If key exists, returns reference to mapped value.
Otherwise, returns default value.
Hint: what does the **insert** function do?

```
template <typename K, typename M, typename H>
std::pair<typename HashMap<K, M, H>::iterator, bool> HashMap<K, M, H>::insert(const value_type& value) {
    const auto& [key, mapped] = value;
    auto [prev, node_to_edit] = find_node(key);
    size_t index = _hash_function(key) % bucket_count();

    if (node_to_edit != nullptr) {
        return {make_iterator(node_to_edit), false};
    }

    auto temp = new node(value, _buckets_array[index]);
    _buckets_array[index] = temp;

    ++_size;
    return {make_iterator(temp), true};
}
```

# Stream Insertion (<<)

If you have the elements **1, 3, 5, 7, 9**:
need to generate “{1, 3, 5, 7, 9}”       (note: no comma on last element!)

How to do it? Try **stringstreams** (detailed in Lecture 4). There are also alternative solutions.

```
std::ostringstream oss(“a”);
oss << “bcdef”;
std::string out = oss.str();   // “abcdef”
```

# Equality (==)

How to check map equality?

Hint: you only need to loop through one HashMap.

# Move Constructor

## Reminder: moving a vector

```
vector<T>(vector<T>&& other) :
     _size(std::move(other._size)),
     _capacity(std::move(other._capacity)) {
     // steal the other array 🕵️
     _elems = std::move(other._elems);

     other._elems = nullptr;
     other._size = 0;
}
```

Just set everything equal to **std::move**(other.attr).

# Move Assignment

Very similar, except we set everything **=** instead of initializer list

```
vector<T>::operator=(vector<T>&& other) {
     _size = std::move(other._size),
     _capacity = std::move(other._capacity),
     _elems = std::move(other._elems)
     // steal the other array 🕵️
     other._elems = nullptr;
     other._size = 0;
}
```

# Variadic templates

(C++11)

# Variadic templates

Allow for templates with a **variable** number of arguments!

```
template<typename T>
T adder(T v) {
  return v;
}

template<typename T, typename... Args>
T adder(T first, Args... args) {
  return first + adder(args...);
}

adder(5, 6, 7, 8)          // 26
```

# How does it work?

Overload resolution!

```
template<typename T>
T adder(T v) {                               // this one is called when there is
  return v;                                  // 1 argument
}

template<typename T, typename... Args>
T adder(T first, Args... args) {             // this one is called when there are
  return first + adder(args...);             // >=2 arguments
}
```

# Spaceship operator

(C++17)

# Spaceship operator

Writing this boilerplate code is annoying:

```cpp
struct IntWrapper {
  int value;
  IntWrapper(int value): value{value} { }
  bool operator==(const IntWrapper& rhs) const { return value == rhs.value; }
  bool operator!=(const IntWrapper& rhs) const { return !(*this == rhs);     }
  bool operator<(const IntWrapper& rhs)  const { return value < rhs.value;  }
  bool operator<=(const IntWrapper& rhs) const { return !(rhs < *this);      }
  bool operator>(const IntWrapper& rhs)  const { return rhs < *this;         }
  bool operator>=(const IntWrapper& rhs) const { return !(*this < rhs);      }
};
```

# Spaceship operator

If you write a single ⇔ operator, everything will be autogenerated for you

```
struct IntWrapper {
  int value;
  IntWrapper(int value): value(value) { }
  auto operator<=>(const int& rhs) auto {
      return value <=> rhs;
  }
};


IntWrapper(5) < IntWrapper(7)       // returns true
```

# Spaceship operator

Basically, return -1, 0, or 1 as appropriate:

```
struct IntWrapper {
  int value;
  IntWrapper(int value): value(value) { }
  auto operator<=>(const int& rhs) auto {
      if (value < rhs) return -1;
      else if (value == rhs) return 0;
      else return 1;
  }
};


IntWrapper(5) < IntWrapper(7)       // returns true
```

# Designated initializers

(C++20)

# Better struct initialization syntax!

Non-specified values → default initialization

```
struct A {
  int x;
  int y;
  int z = 123;
};

A a {.x = 1, .z = 2}; // a.x == 1, a.y == 0, a.z == 2
```

# [[likely]]

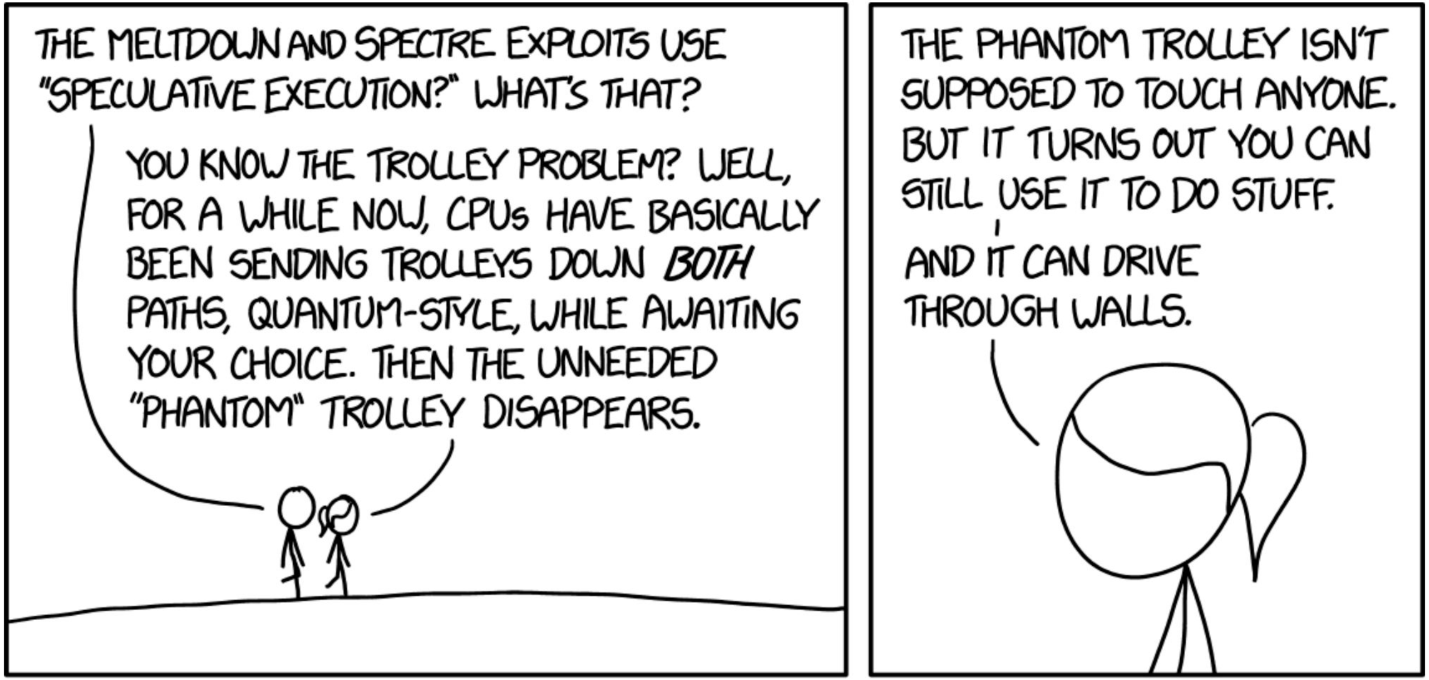
(C++20)

# “Compiler, we have a problem...”

Use the **[[likely]]** operator to mark things that probably will run...

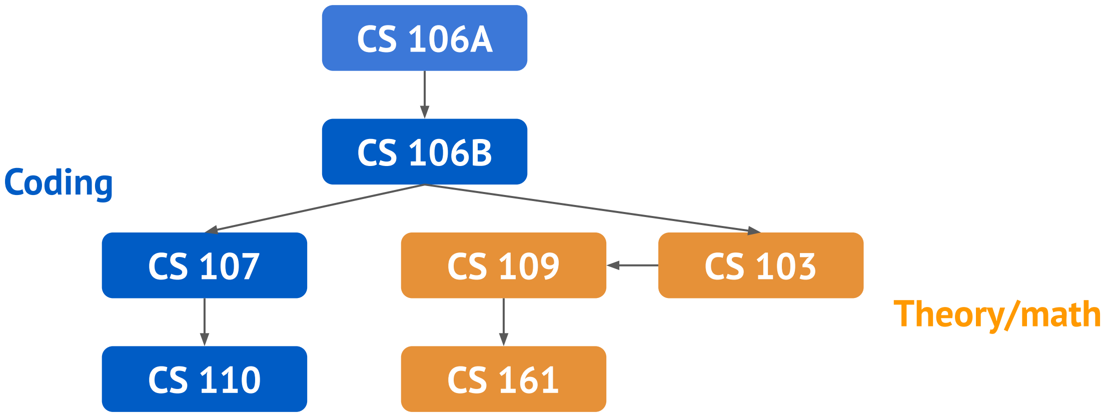
```
int random = get_random_number_between_x_and_y(0, 100);
[[likely]] if (random > 0) {
  // body of if statement; efficiency will be prioritized
}

[[unlikely]] if (random == 0) {
  // body of if statement; efficiency will not be prioritized
}
```

# How does this work?

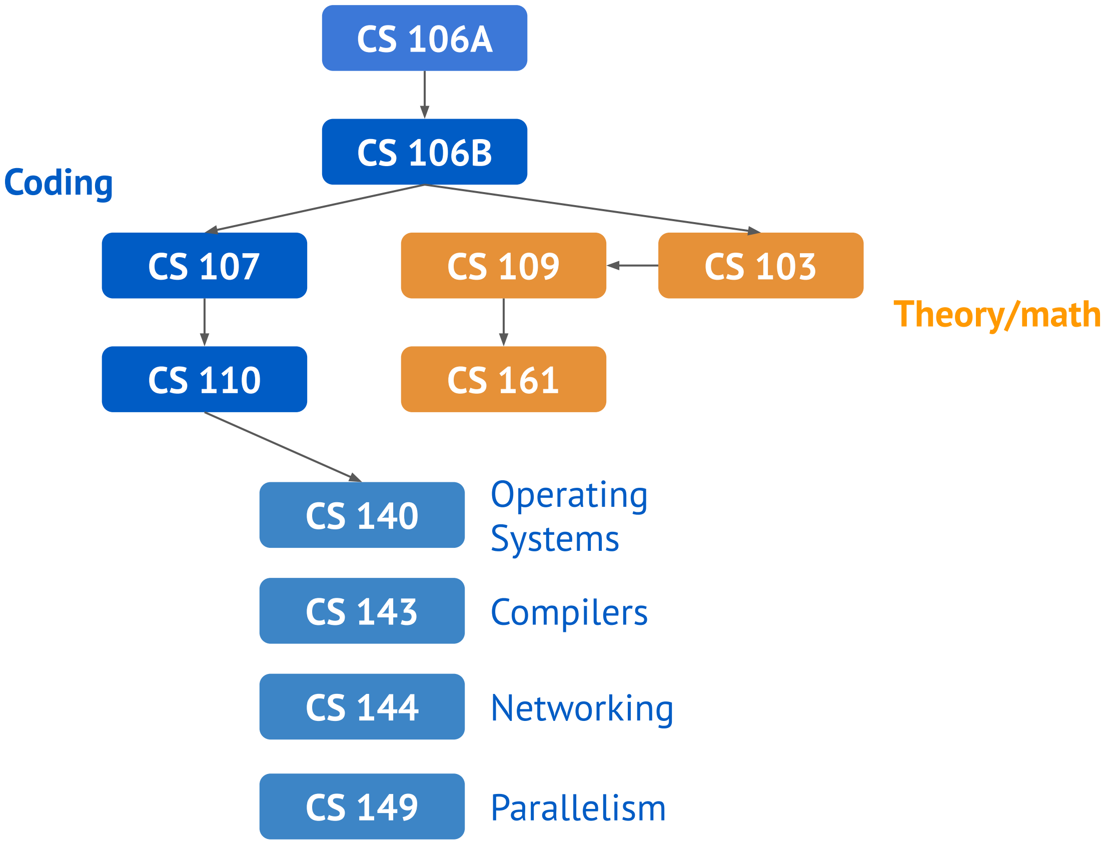

THE MELTDOWN AND SPECTRE EXPLOITS USE "SPECULATIVE EXECUTION?" WHAT'S THAT?
YOU KNOW THE TROLLEY PROBLEM? WELL, FOR A WHILE NOW, CPUs HAVE BASICALLY BEEN SENDING TROLLEYS DOWN BOTH PATHS, QUANTUM-STYLE, WHILE AWAITING YOUR CHOICE. THEN THE UNNEEDED "PHANTOM" TROLLEY DISAPPEARS.
THE PHANTOM TROLLEY ISN'T SUPPOSED TO TOUCH ANYONE. BUT IT TURNS OUT YOU CAN STILL USE IT TO DO STUFF.
AND IT CAN DRIVE THROUGH WALLS.

xkcd.com/1938/

# Future Directions in CS


CS 106A
CS 106B
Coding
CS 107
CS 109
CS 103
Theory/math
CS 110
CS 161

# Systems


CS 106A
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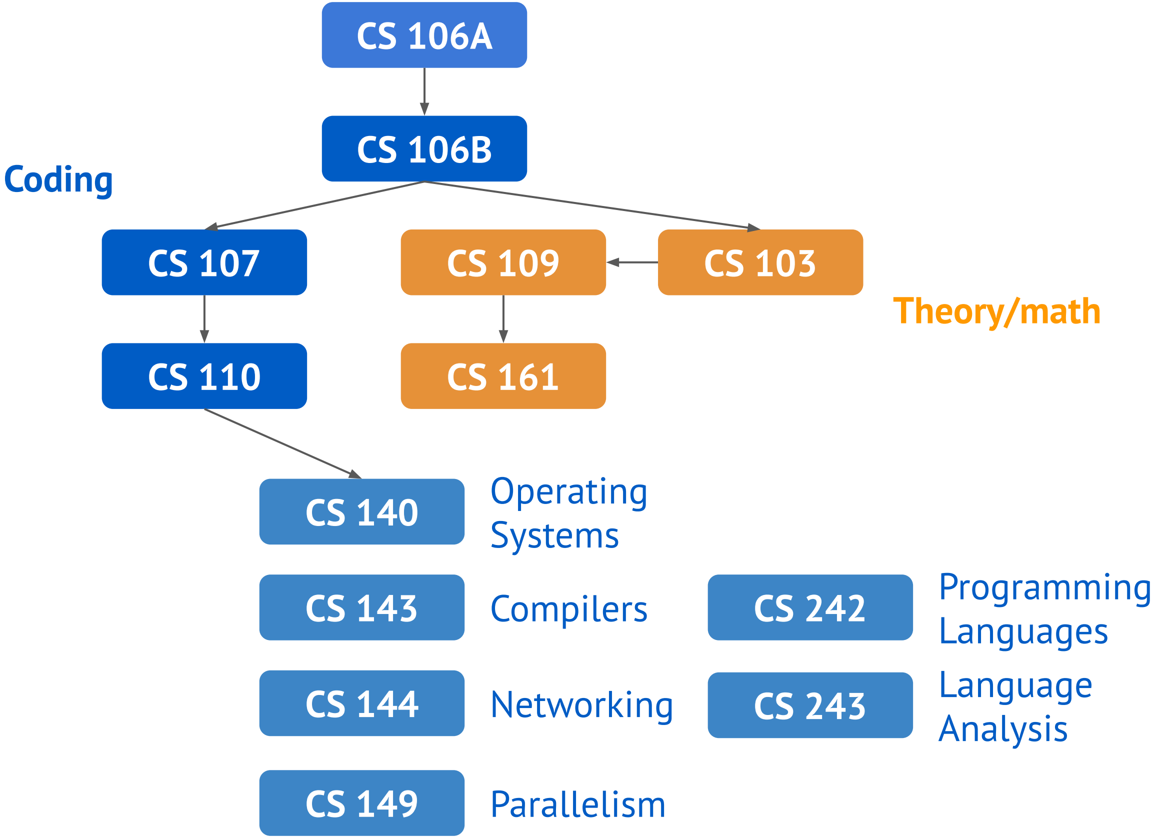
CS 110
CS 161
CS 140
Operating Systems
CS 143
Compilers
CS 144
Networking
CS 149
Parallelism

# Systems



CS 106A

CS 106B

Coding

CS 107

CS 110

CS 109

CS 103

Theory/math

CS 161

CS 140 Operating Systems

CS 143 Compilers

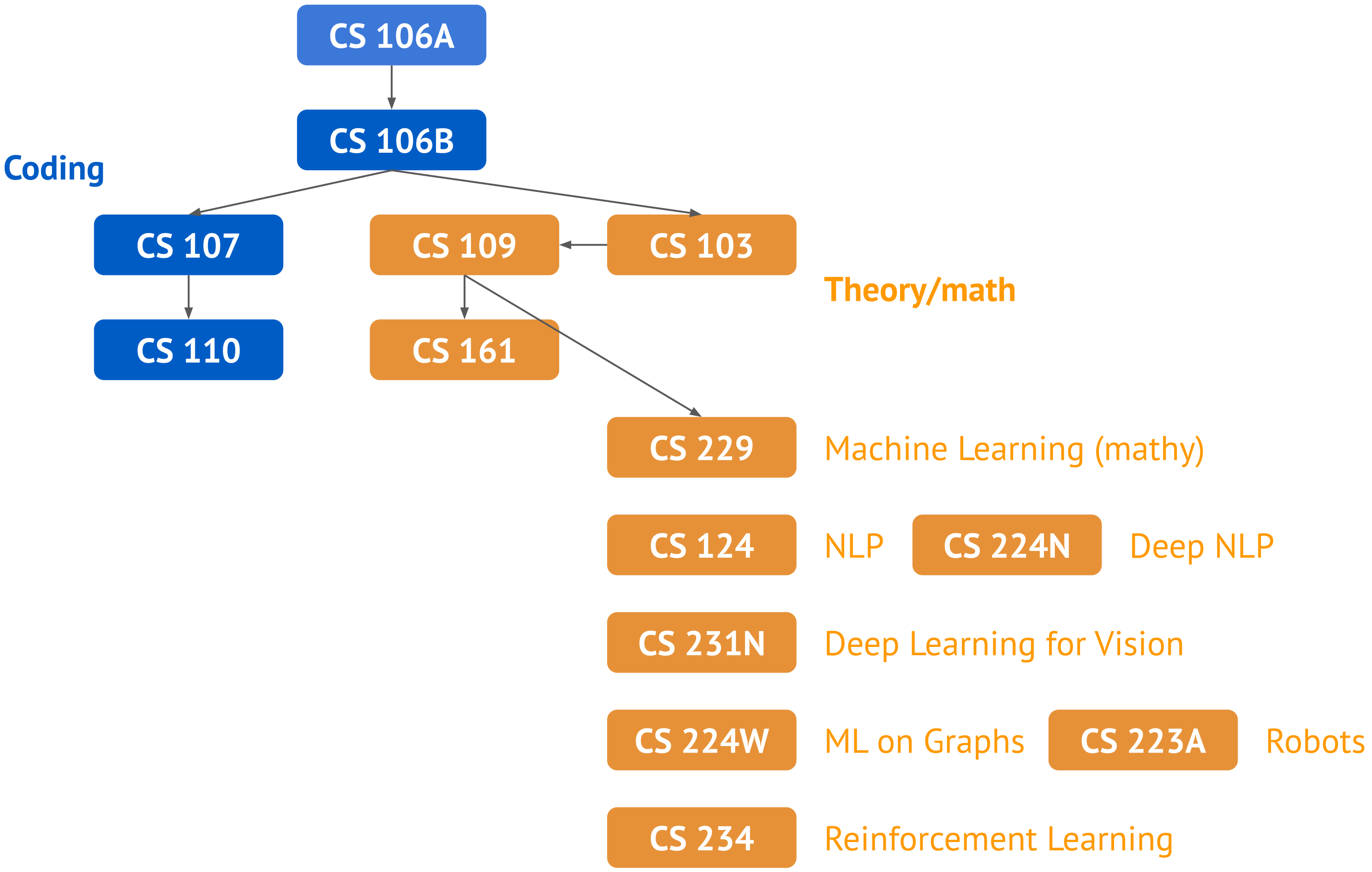
CS 144 Networking

CS 149 Parallelism

CS 242 Programming Languages

CS 243 Language Analysis

# AI



CS 106A

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Coding

CS 107

CS 110

CS 109

CS 103

CS 161

Theory/math

CS 229 Machine Learning (mathy)

CS 124 NLP

CS 224N Deep NLP

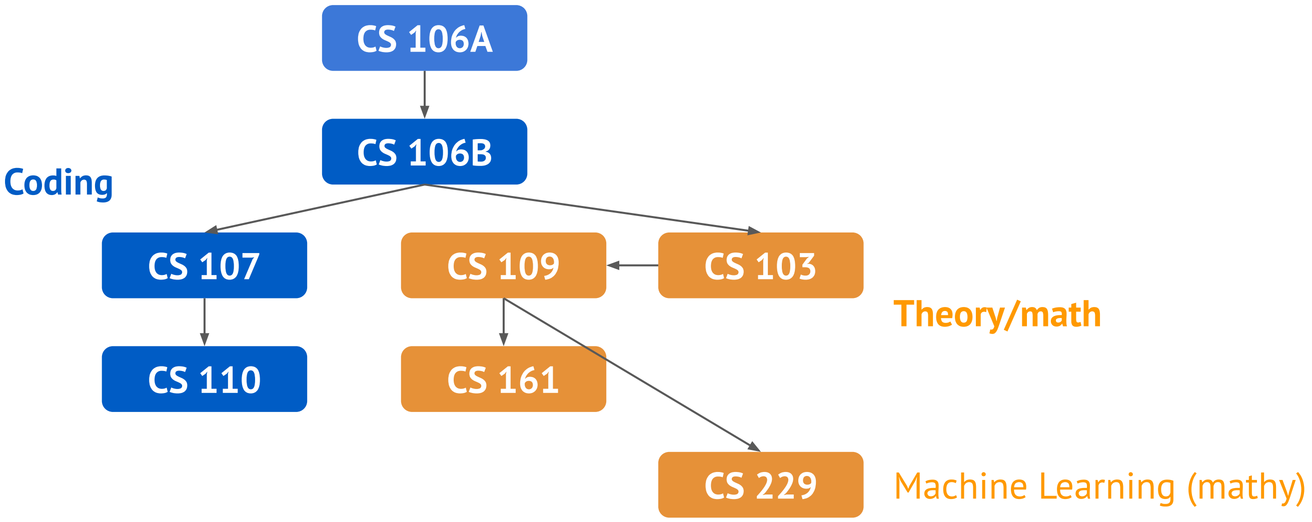
CS 231N Deep Learning for Vision

CS 224W ML on Graphs

CS 223A Robots

CS 234 Reinforcement Learning

# AI



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CS 229 Machine Learning (mathy)

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CS 231N Deep Learning for Vision

CS 224W ML on Graphs

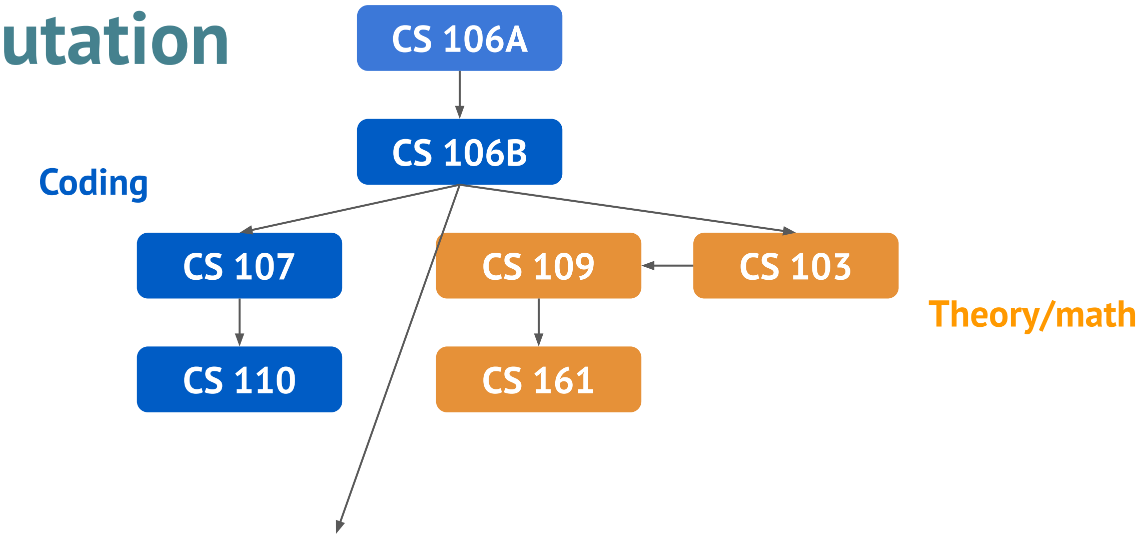
CS 223A Robots

CS 234 Reinforcement Learning

**Advanced courses:**

- CS 229M: Statistical machine learning theory
- CS 329D: ML under distributional shift
- CS 468: ML in non-euclidean spaces

# Biocomputation



CS 106A

CS 106B

Coding

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CS 110

CS 109

CS 103

CS 161

Theory/math

| | |
|---|---|
| CS 274 | Representations and Algorithms for Computational Molecular Biology |
| CS 279 | Biomolecules |
| CS 275 | Translational Informatics |

# Other fields

- **Theory:** theory of computation, crypto, algorithm design
- **HCI:** interface design, Going Viral

# Interdisciplinary

- **CS 209:** Law, Bias, and Algorithms (with LAW)
  - (what can we do to make our systems more fair and transparent?)
- **CS 275B:** Computational Music Analysis (with MUSIC)
- **CS 342**: Building for Digital Health (with MED)

# Going Forward from CS106L

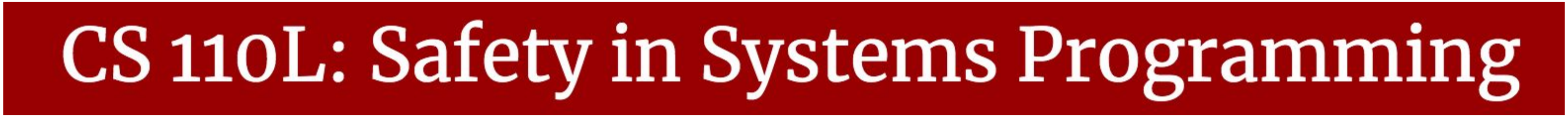
## CS110: Principles of Computer Systems

Winter 2021

Mo/We/Fr 1pm-2:20pm PDT via Zoom (link on Canvas)

(Uses a *lot* of C++.)

# Going Forward from CS106L



CS 110L: Safety in Systems Programming

(Covers **Rust**—a powerful language which offers C++ performance, without the unsafe stuff. In Spring!)

# Going Forward from CS106L

## CS 41: The Python Programming Language

Tuesday & Thursday @ 2:30pm - 3:50pm

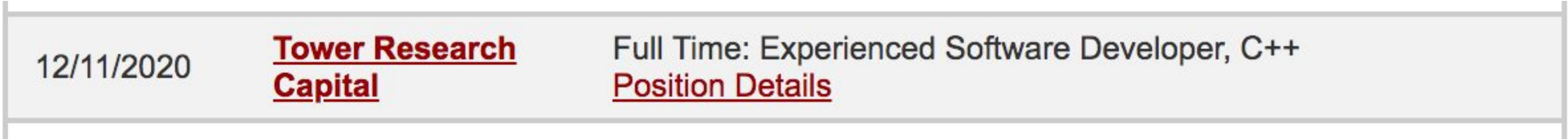
Join URL: See you in Spring!

Contribute to our Spotify Playlist!

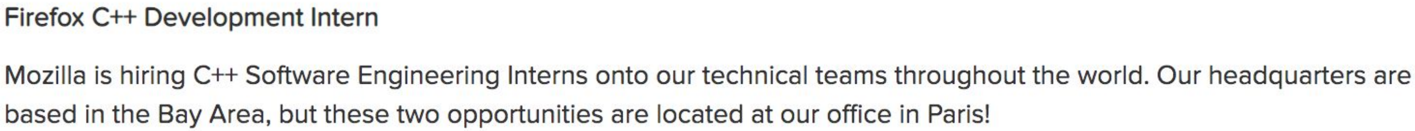
(**Python**—a powerful language that needs no introduction. Taught in Spring, or sign up to be a TA)

# Going Forward from CS106L

Get a job with your C++ skills!



| | | |
|---|---|---|
| 12/11/2020 | Tower Research Capital | Full Time: Experienced Software Developer, C++<br>Position Details |



Firefox C++ Development Intern

Mozilla is hiring C++ Software Engineering Interns onto our technical teams throughout the world. Our headquarters are based in the Bay Area, but these two opportunities are located at our office in Paris!

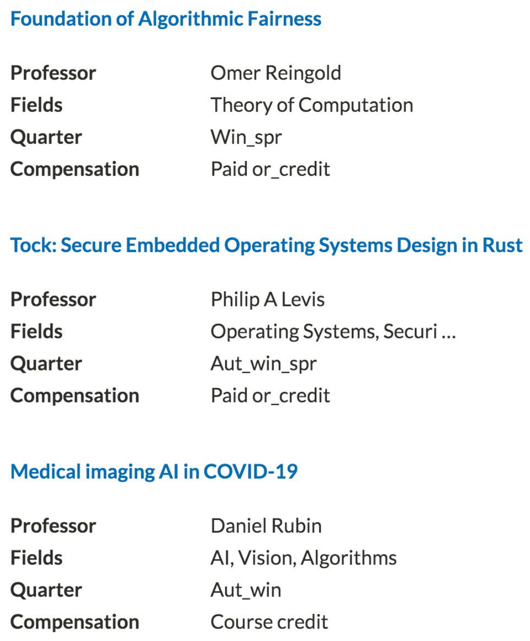
FACEBOOK Careers

Software Engineer, Intern/Co-op Responsibilities

- Code high-volume software using primarily C++ and Java

# Research: CURIS

- Research projects in all areas of CS!
- Projects are available all year; applications close soon



Foundation of Algorithmic Fairness

| | |
|---|---|
| **Professor** | Omer Reingold |
| **Fields** | Theory of Computation |
| **Quarter** | Win_spr |
| **Compensation** | Paid or_credit |

Tock: Secure Embedded Operating Systems Design in Rust

| | |
|---|---|
| **Professor** | Philip A Levis |
| **Fields** | Operating Systems, Securi ... |
| **Quarter** | Aut_win_spr |
| **Compensation** | Paid or_credit |

Medical imaging AI in COVID-19

| | |
|---|---|
| **Professor** | Daniel Rubin |
| **Fields** | AI, Vision, Algorithms |
| **Quarter** | Aut_win |
| **Compensation** | Course credit |

# Thank you

for all of your support