

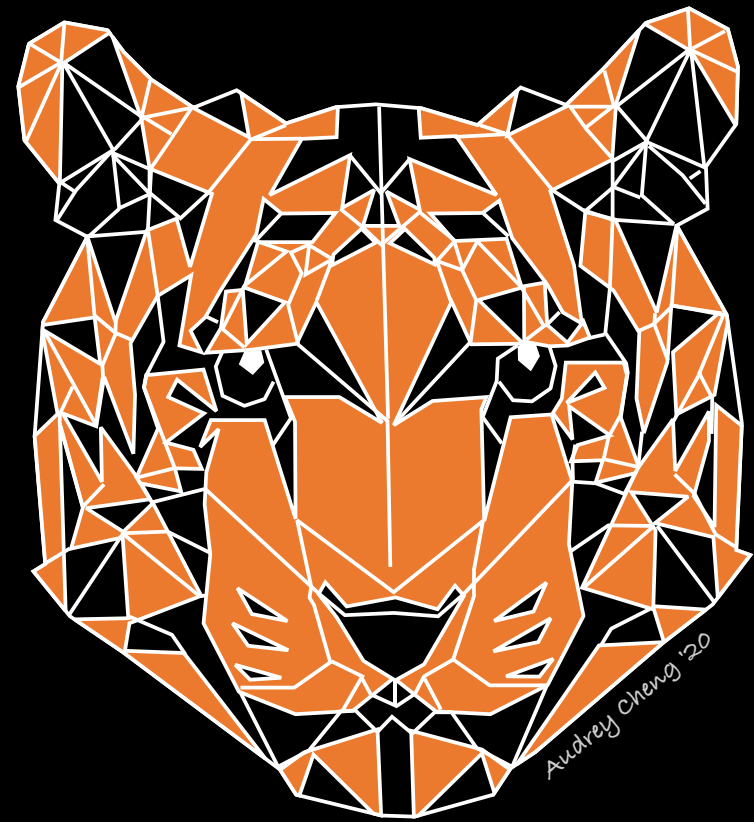
**COS 226, FALL 2021**

**ALGORITHMS**  
and  
**DATA STRUCTURES**

**KEVIN WAYNE · DAN LEYZBERG · JÉRÉMIE LUMBROSO**



# FINE PRINT



*I will be recording lectures and make them available to eligible students, as per university policy.*

*Because of privacy, compliance, and legal considerations, you may not record or redistribute recordings of this class.*



<https://algs4.cs.princeton.edu>

## INTRO TO COS 226

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- ▶ *motivation*
- ▶ *course structure*
- ▶ *assessments*
- ▶ *resources*



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# INTRO TO COS 226


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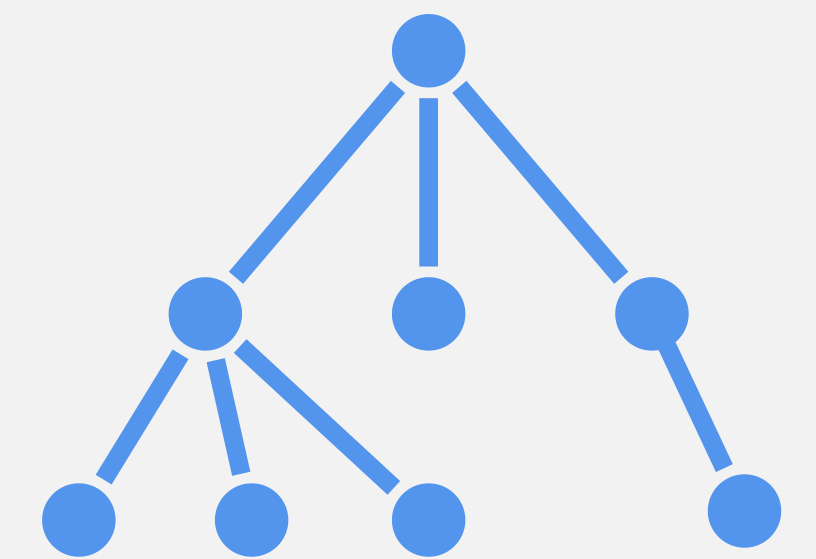
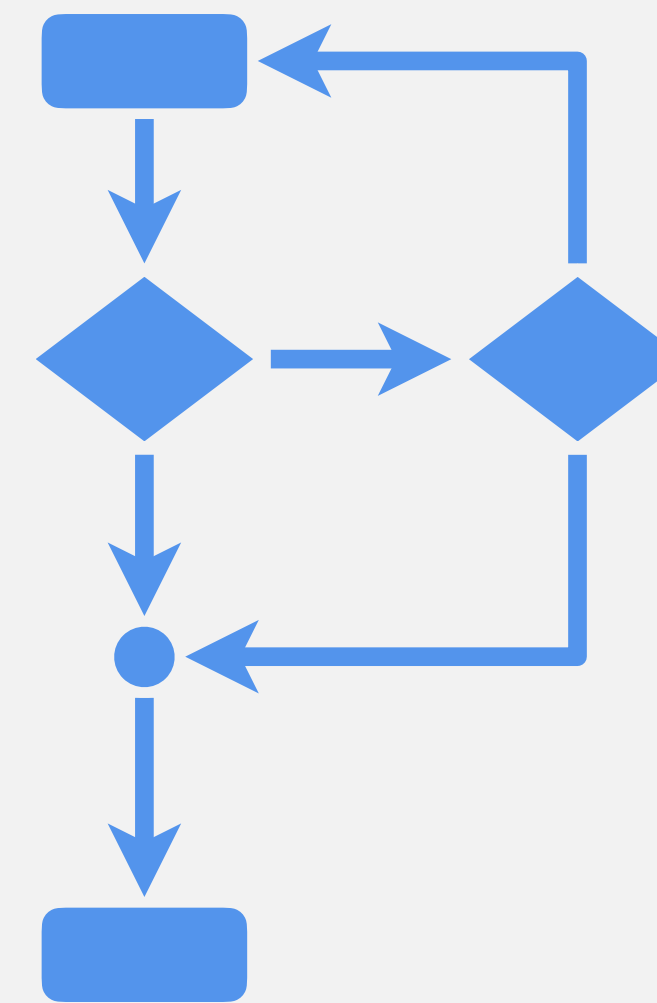
- ▶ *motivation*
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# COS 226 course overview

## What is COS 226?

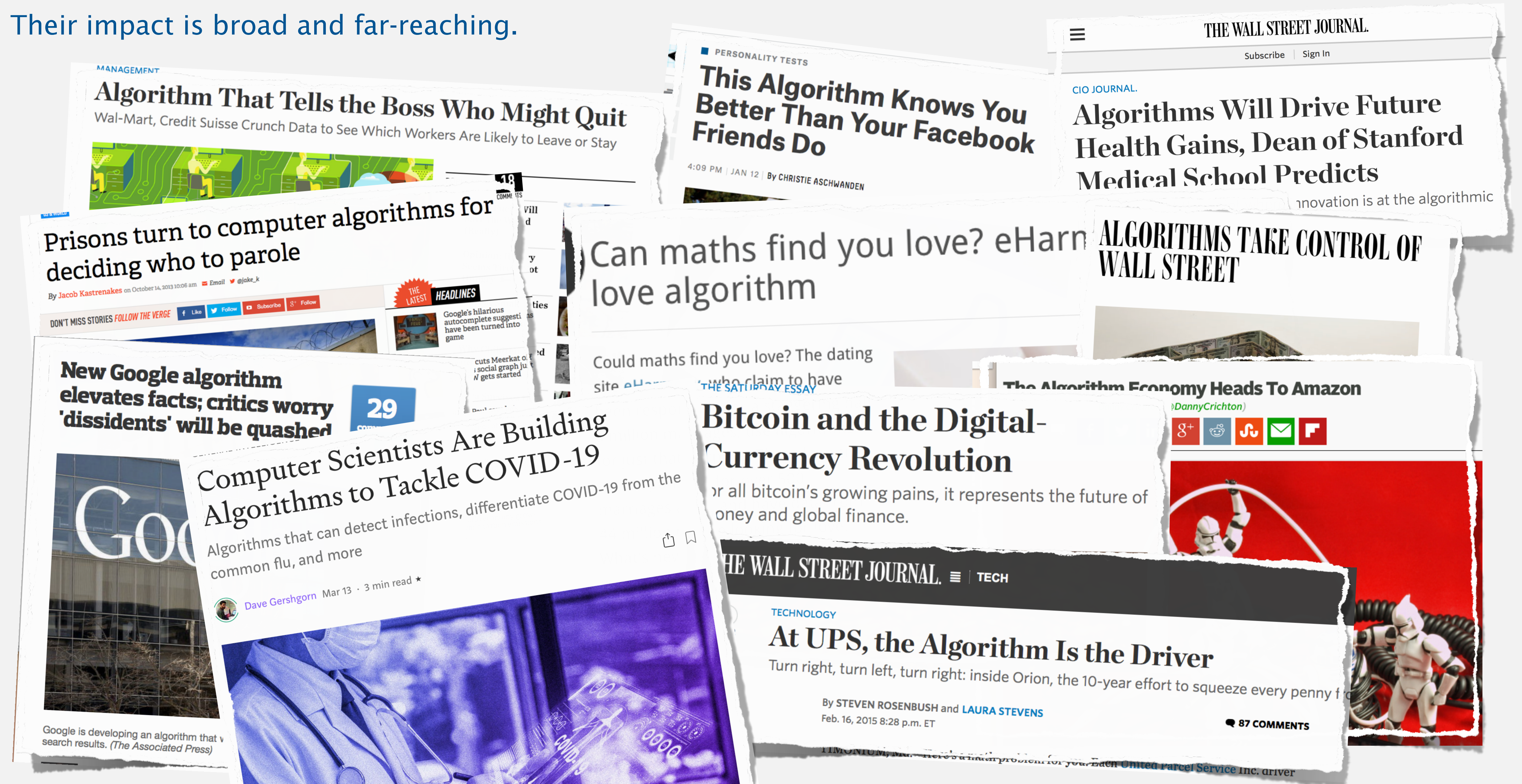
- Intermediate-level survey course.
- Programming and problem solving, with applications.
- **Algorithm:** step-by-step procedure for solving a problem.
- **Data structure:** method for organizing data in a computer.

topic	algorithms and data structures 
data types	<i>stack, queue, union-find</i>
sorting	<i>quicksort, mergesort, heapsort, priority queue</i>
searching	<i>BST, red-black BST, hash table, k-d tree</i>
graphs	<i>BFS, DFS, Prim, Kruskal, Dijkstra, Bellman-Ford</i>
strings	<i>radix sorts, tries, suffix arrays, data compression</i>



# Why study algorithms and data structures?

Their impact is broad and far-reaching.

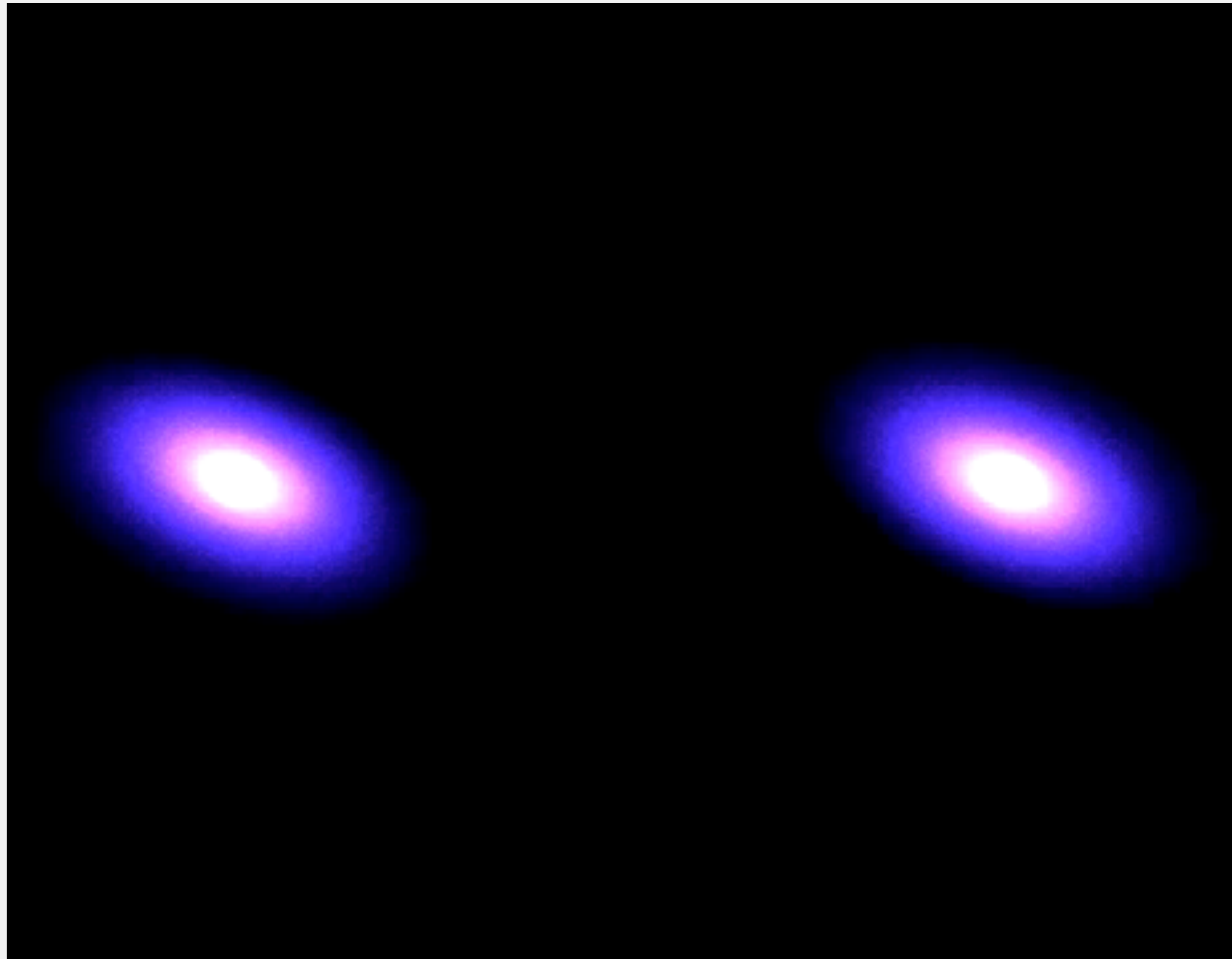


# Why study algorithms and data structures?

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They may unlock the secrets of life and of the universe.



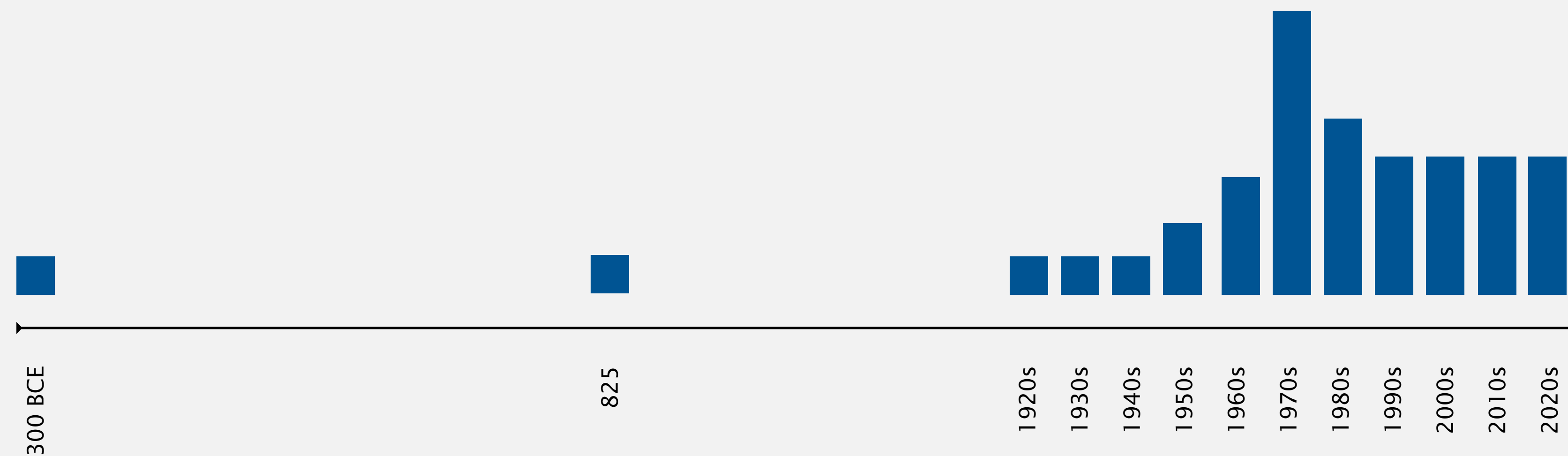
[https://www.youtube.com/watch?v=ua7YIN4eL\\_w](https://www.youtube.com/watch?v=ua7YIN4eL_w)

# Why study algorithms and data structures?

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## Old roots, new opportunities.

- Study of algorithms dates at least to Euclid.
- Named after Muḥammad ibn Mūsā al-Khwārizmī.
- Formalized by Church and Turing in 1930s.
- Some important algorithms were discovered by undergrads in a course like this!

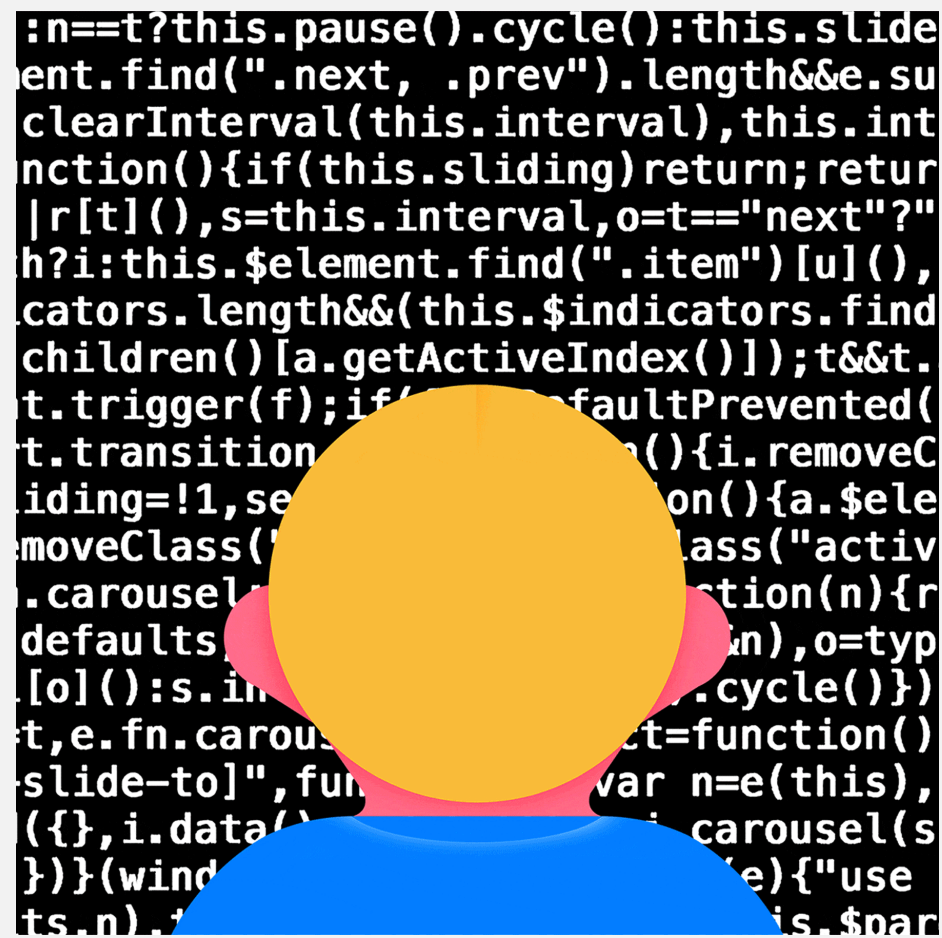




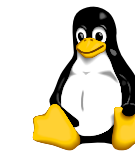
# Why study algorithms and data structures?

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To become a proficient programmer.



*“ I will, in fact, claim that the difference between a bad programmer and a good one is whether [they] consider [their] code or [their] data structures more important. Bad programmers worry about the code. Good programmers worry about **data structures** and their relationships.”* — *Linus Torvalds (architect of Linux and git)*



# Why study algorithms and data structures?

---

For intellectual stimulation.



*“For me, great algorithms are the poetry of computation. Just like verse, they can be terse, allusive, dense, and even mysterious. But once unlocked, they cast a brilliant new light on some aspect of computing.” — Francis Sullivan*

# Why study algorithms and data structures?

For fun and profit.



# Why study algorithms and data structures?

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
- Their impact is broad and far-reaching.
- They may unlock the secrets of life and of the universe.
- Old roots, new opportunities.
- To become a proficient programmer.
- For intellectual stimulation.
- For fun and profit.

Why study anything else?



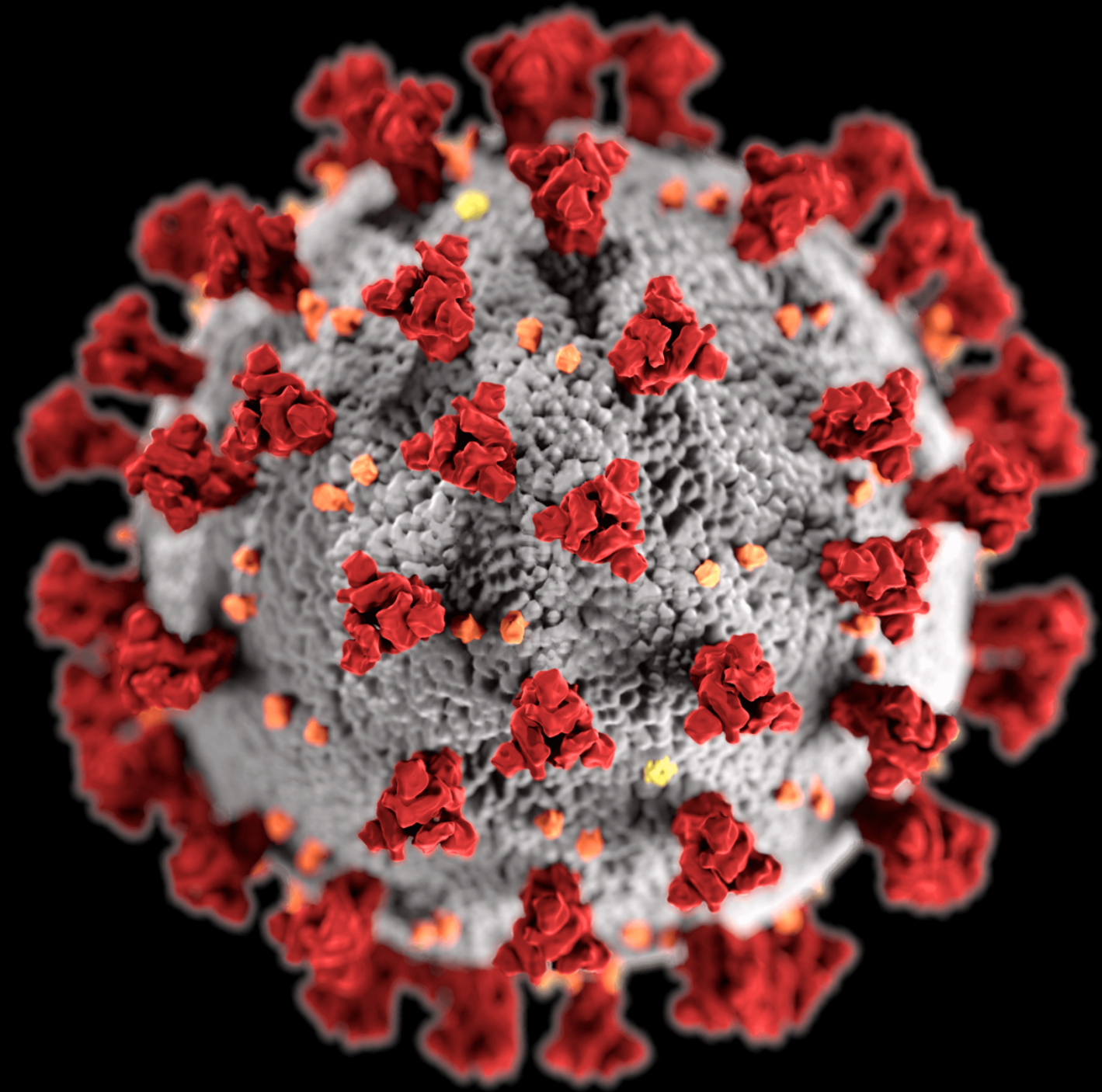
# INTRO TO COS 226

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- ▶ *motivation*
- ▶ ***course structure*** 
- ▶ *assessments*
- ▶ *resources*



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*course format subject to change*

# Lectures

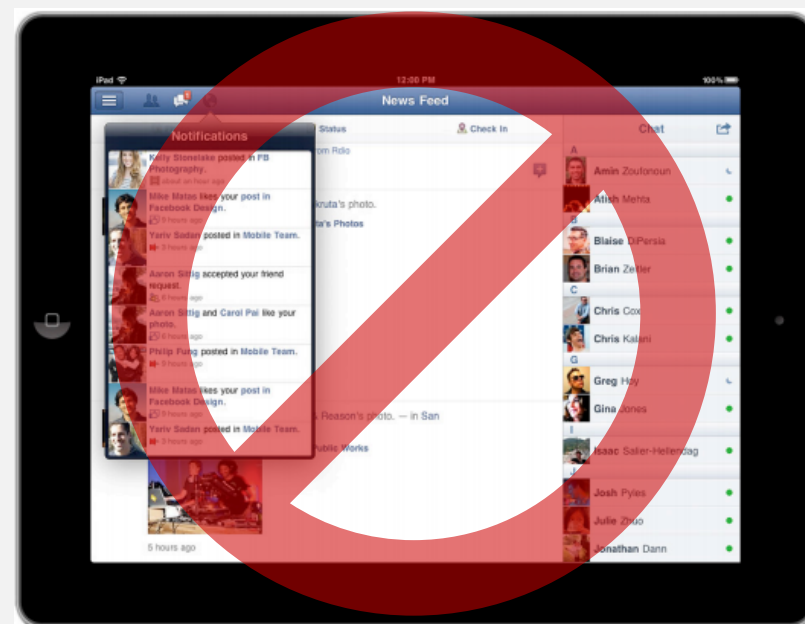
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Live lectures. Introduce new material.

What	When	Where	Who	Office Hours
L01	TTh 11-12:20pm	Friend 101	Kevin Wayne	<i>see web</i>

Electronic devices. Permitted *only* to support lecture.

↑  
viewing slides, taking notes, iClickers, ...



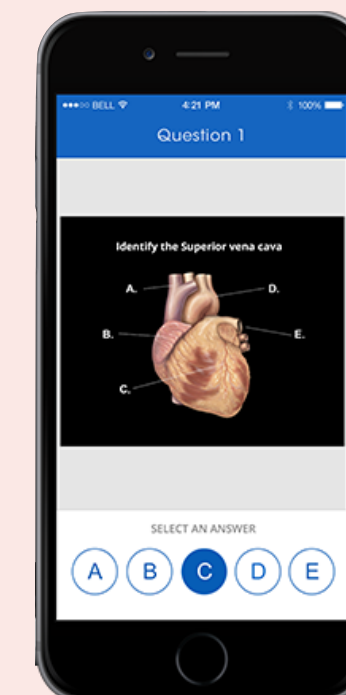
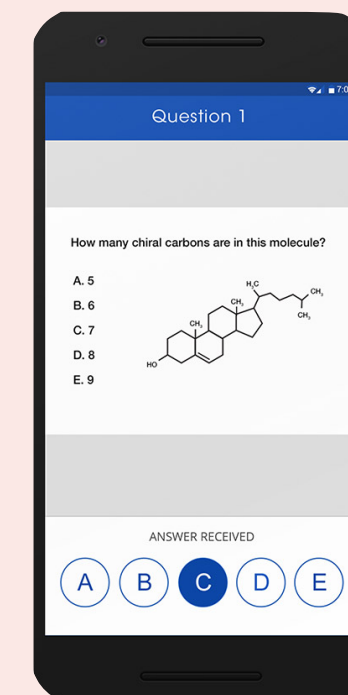
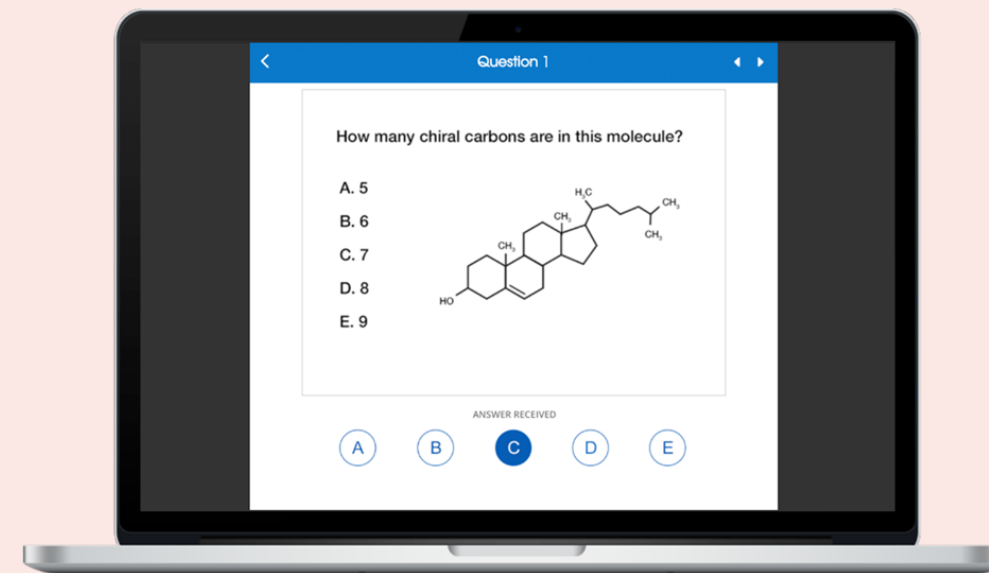
## Student response system (required).

- Multiple choice questions to increase engagement.
- Must register either hardware remote or web/mobile app to receive credit.
- Caveat: use only one device per lecture.

free for Princeton students

## Which iClicker are you using?

- A. Web app.
- B. iPhone app.
- C. Android app.
- D. Hardware remote.





# Precepts

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Active learning. Problem-solving, discussion, assignment prep, ...



Dan Leyzberg ✉



Bob Tarjan ✉



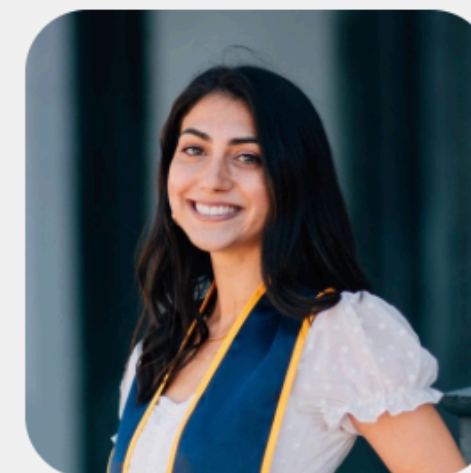
Chloe Qiu ✉



Laura Leal ✉



Max Tchouambe ✉



Morgan Nanez ✉



Yingxi Lin ✉

# Precepts

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What	When	Where	Who
P01	Th 3-4:20pm	Friend 109	Dan Leyzberg
P02	Th 4:30-5:50pm	Friend 109	Dan Leyzberg
P03	Th 7:30-8:50pm	Friend 109	Morgan Nanez
P04	F 11-12:20pm	Friend 109	Laura Leal
P05	F 11-12:20pm	Friend 108	Max Tchouambe
P06	F 11-12:20pm	Friend 009	Bob Tarjan
P07	F 1:30-2:50pm	Friend 109	Yingxi Lin
P08	F 1:30-2:50pm	Friend 108	Chloe Qiu
P10	F 3-4:20pm	Friend 108	Chloe Qiu



# Covid-19 policies

## Face coverings. Abide by university rules. ←

I will be masking through 9/9  
(quarantine exception policy)

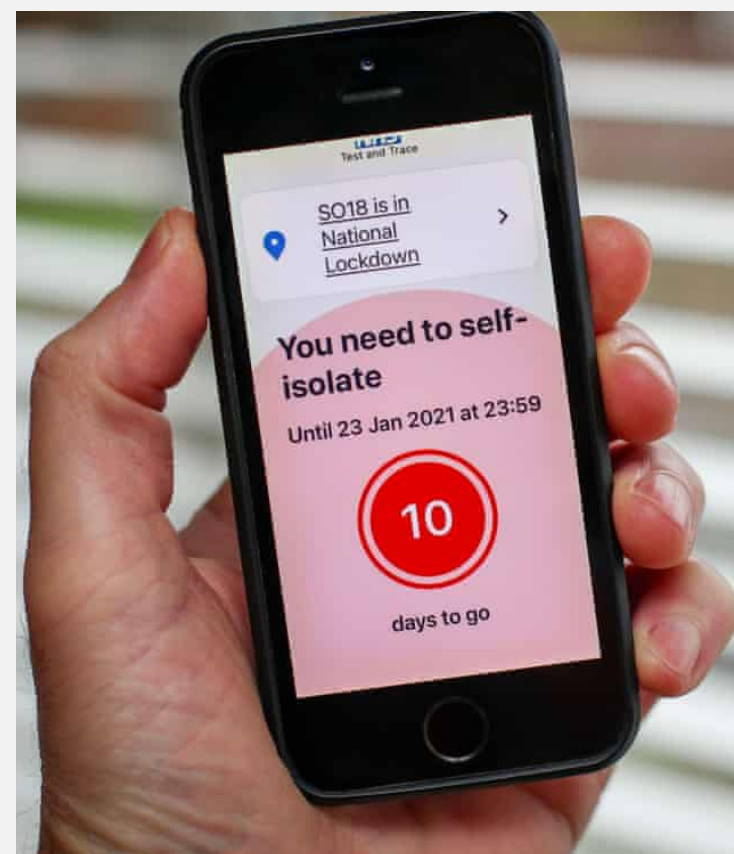
- You must wear a mask over nose and mouth.
- You may lift mask to sip beverage.
- If vaccinated, you may remove mask briefly to ask instructor a question.

← current rules  
(subject to change)

## Symptomatic. Stay home and call UHS.

## Self-isolation for students. Either lecture recordings or Zoom.

## Self-isolation for course staff. Either substitute instructor/preceptor or Zoom.





<https://algs4.cs.princeton.edu>

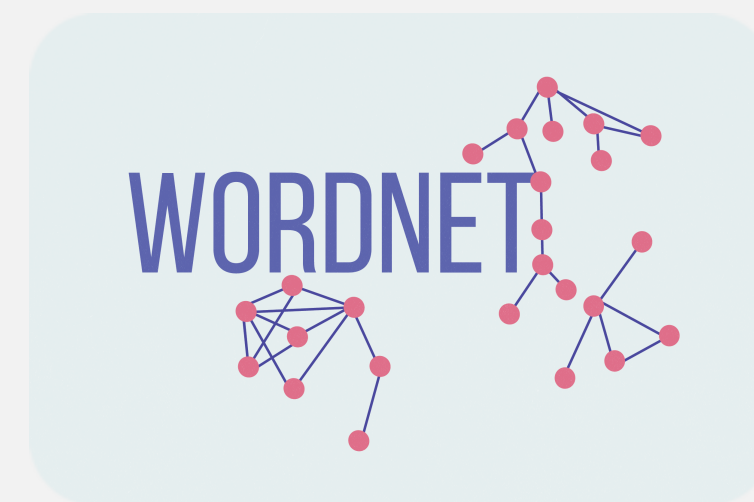
# INTRO TO COS 226

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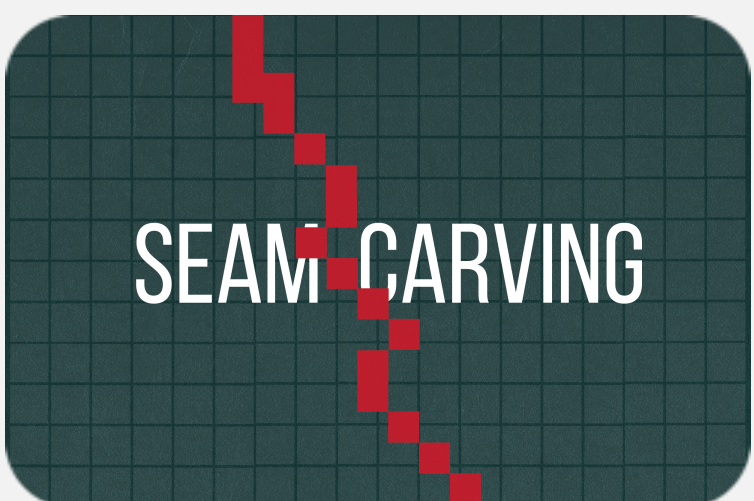
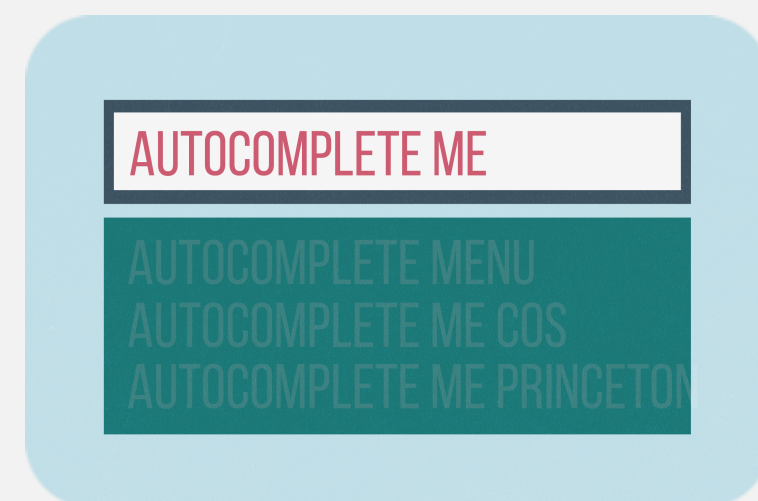
- ▶ *motivation*
- ▶ *course structure*
- ▶ ***assessments***
- ▶ *resources*
- ▶ *union-find*

# Programming assignments

Implement an efficient **algorithm** or **data structure**:



Solve an interesting **application** using a “textbook” algorithm:



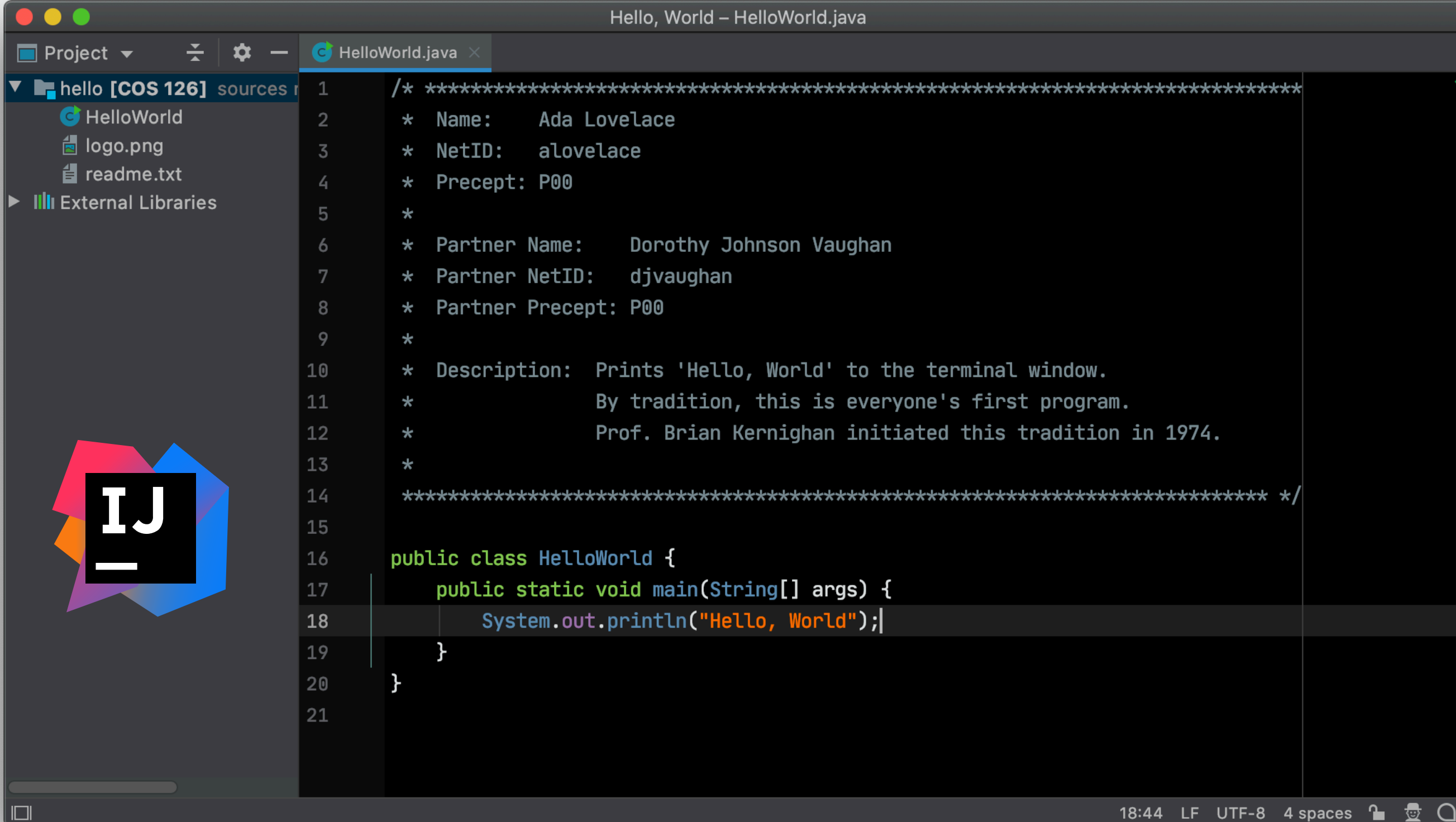
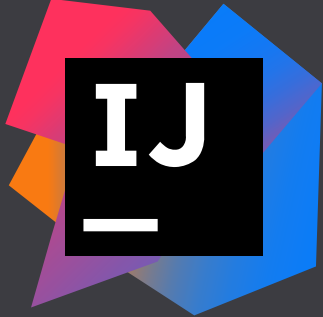
**Pair programming** encouraged on designated assignments.



# Programming environment

Recommended IDE. Custom IntelliJ 2021.1 environment.  upgrade to Fall 2021 version

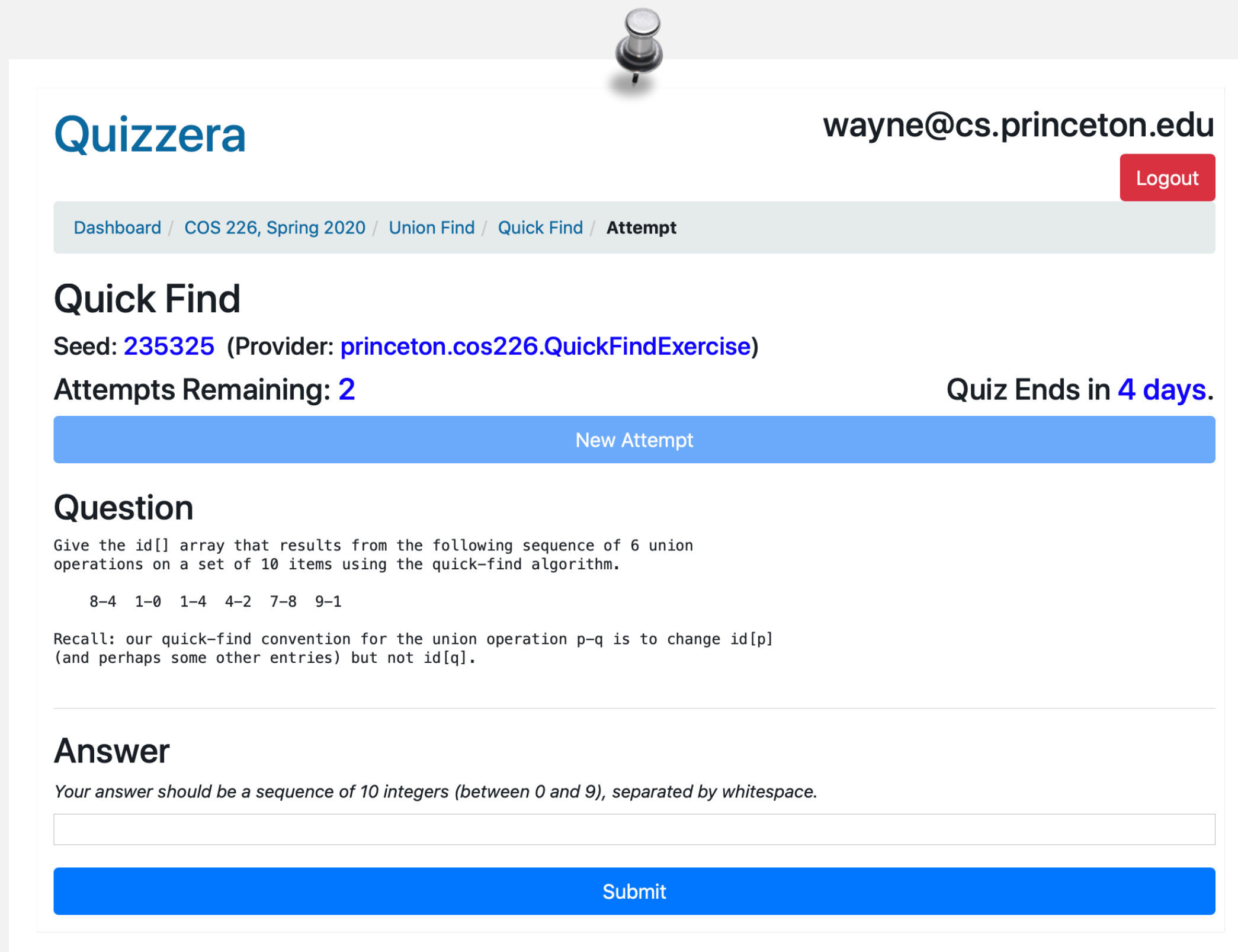
- Embedded Bash terminal.
- Autoformat, autoimport, autocomplete, .....
- Continuous code inspection; integrated Checkstyle and SpotBugs.
- ...



```
1  /* *****  
2  * Name:   Ada Lovelace  
3  * NetID:  alovelace  
4  * Precept: P00  
5  *  
6  * Partner Name:   Dorothy Johnson Vaughan  
7  * Partner NetID:  djvaughan  
8  * Partner Precept: P00  
9  *  
10 * Description: Prints 'Hello, World' to the terminal window.  
11 *               By tradition, this is everyone's first program.  
12 *               Prof. Brian Kernighan initiated this tradition in 1974.  
13 *  
14 ***** */  
15  
16 public class HelloWorld {  
17     public static void main(String[] args) {  
18         System.out.println("Hello, World");  
19     }  
20 }  
21
```

## Quizzera platform.

- 2–3 short questions per lecture.
- Solve using pencil and paper.
- 3 attempts per question (score = max of each question).



The screenshot shows the Quizzera interface for a user named wayne@cs.princeton.edu. The page title is "Quick Find" and it shows 2 attempts remaining. The question asks for the id[] array after a sequence of 6 union operations on a set of 10 items. The operations are: 8-4, 1-0, 1-4, 4-2, 7-8, and 9-1. A recall note explains the quick-find convention for union operations. The answer field is empty, and a "Submit" button is visible at the bottom.

**Quizzera** wayne@cs.princeton.edu [Logout](#)

[Dashboard](#) / [COS 226, Spring 2020](#) / [Union Find](#) / [Quick Find](#) / **Attempt**

### Quick Find

Seed: [235325](#) (Provider: [princeton.cos226.QuickFindExercise](#))

Attempts Remaining: **2** Quiz Ends in **4 days**.

[New Attempt](#)

### Question

Give the `id[]` array that results from the following sequence of 6 union operations on a set of 10 items using the quick-find algorithm.

8-4 1-0 1-4 4-2 7-8 9-1

Recall: our quick-find convention for the union operation  $p-q$  is to change `id[p]` (and perhaps some other entries) but not `id[q]`.

### Answer

Your answer should be a sequence of 10 integers (between 0 and 9), separated by whitespace.

[Submit](#)

## Written exams.

- Questions drawn from lectures, precepts, and quizzes.
- Emphasizes **non-programming** material.

### Q4 Analysis of algorithms

8 Points



Consider a *zig-zag array* that contains the integers 1 through  $n/2$  in ascending order, interleaved with  $n/2$  copies of the integer 0, where  $n$  is an even integer. For example, here is the array when  $n = 16$ :

0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8

#### Q4.1 Selection sort

2 Points

How many *compares* does *selection sort* make to sort a zig-zag array as a function of  $n$ ?

- $\sim \frac{1}{16}n^2$
- $\sim \frac{1}{8}n^2$
- $\sim \frac{1}{4}n^2$
- $\sim \frac{1}{2}n^2$
- $\sim n^2$



# Grading **A+**

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## Programming assignments. **45%**

- Due at 11:59pm on Mondays via TigerFile.
- Collaboration/lateness policies: see web.

## Quizzes. **10%**

- Due at 11:59pm on Fridays via Quizzera.
- Collaboration/lateness policies: see web.

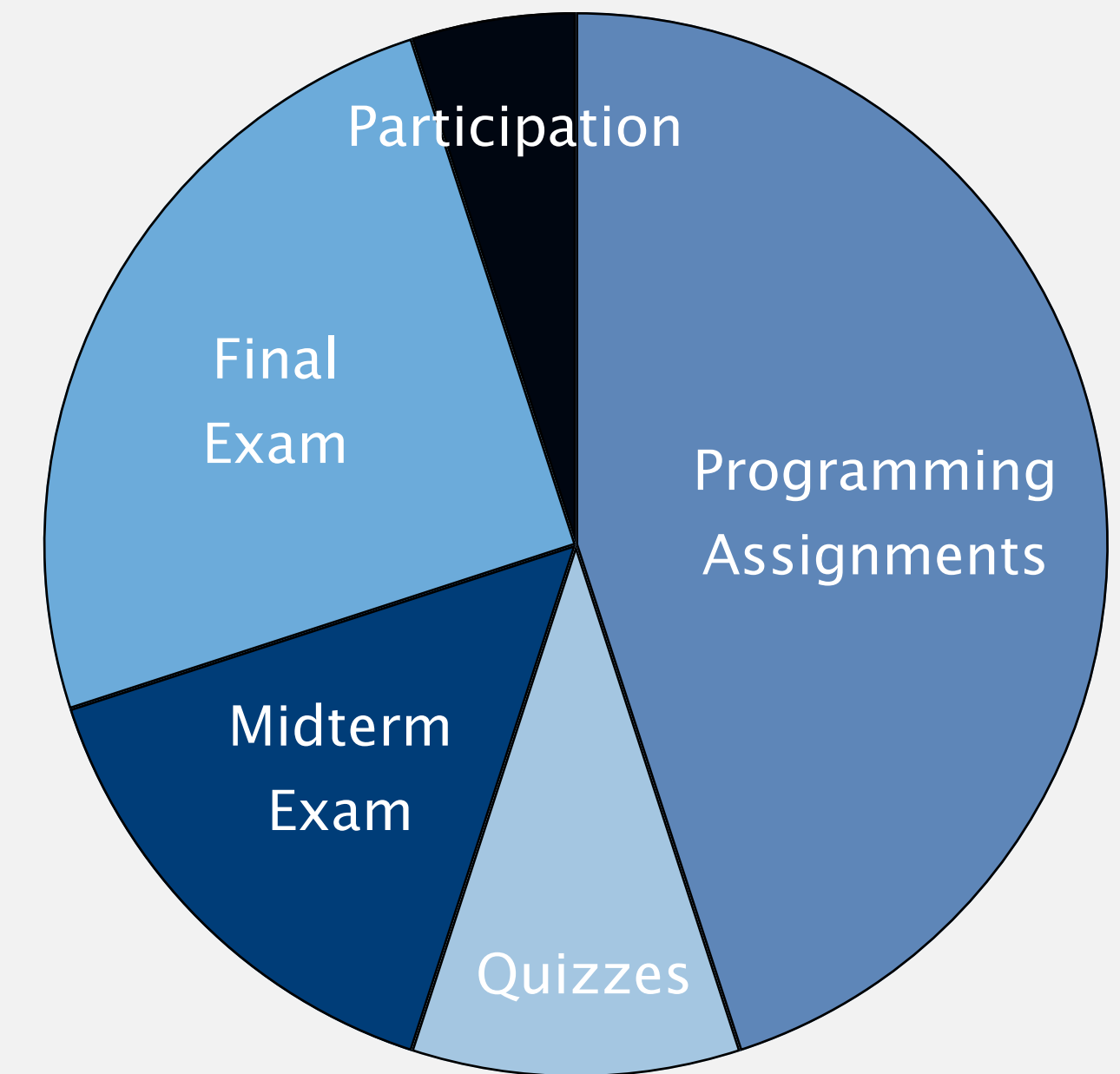
## Exams. **15% + 25%**

- 90-minute take-home midterm on Monday, October 25. ← 8-hour window
- 3-hour in-class final, as scheduled by Registrar.

## Active participation. **5%**

- Answer questions in online discussion forum.
- Participate in precept and lecture.

[ perfect attendance not required to earn 100% of participation points ]





<https://algs4.cs.princeton.edu>

# INTRO TO COS 226

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- ▶ *motivation*
- ▶ *course structure*
- ▶ *assessments*
- ▶ ***resources***

## Resources (textbook)



**Readings (required).** *Algorithms 4<sup>th</sup> edition* by R. Sedgwick and K. Wayne, Addison-Wesley Professional, 2011, ISBN 0–321–57351–X.



4<sup>th</sup> edition (2011)

Available from various vendors and in different formats.

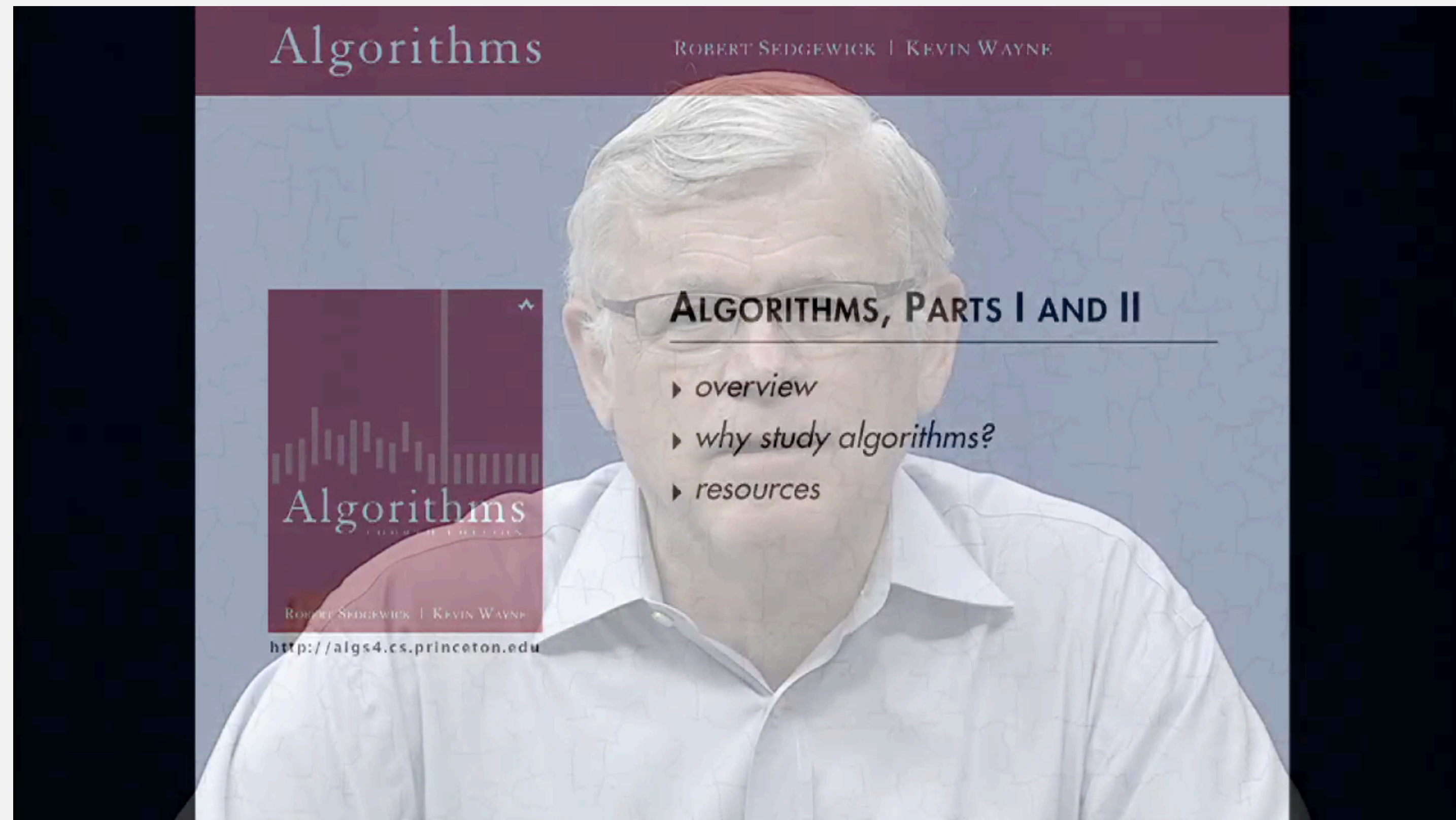
- Amazon: \$75 hardcover, \$55 Kindle, ...
- Labyrinth: \$65 hardcover, \$40 rent.
- ...





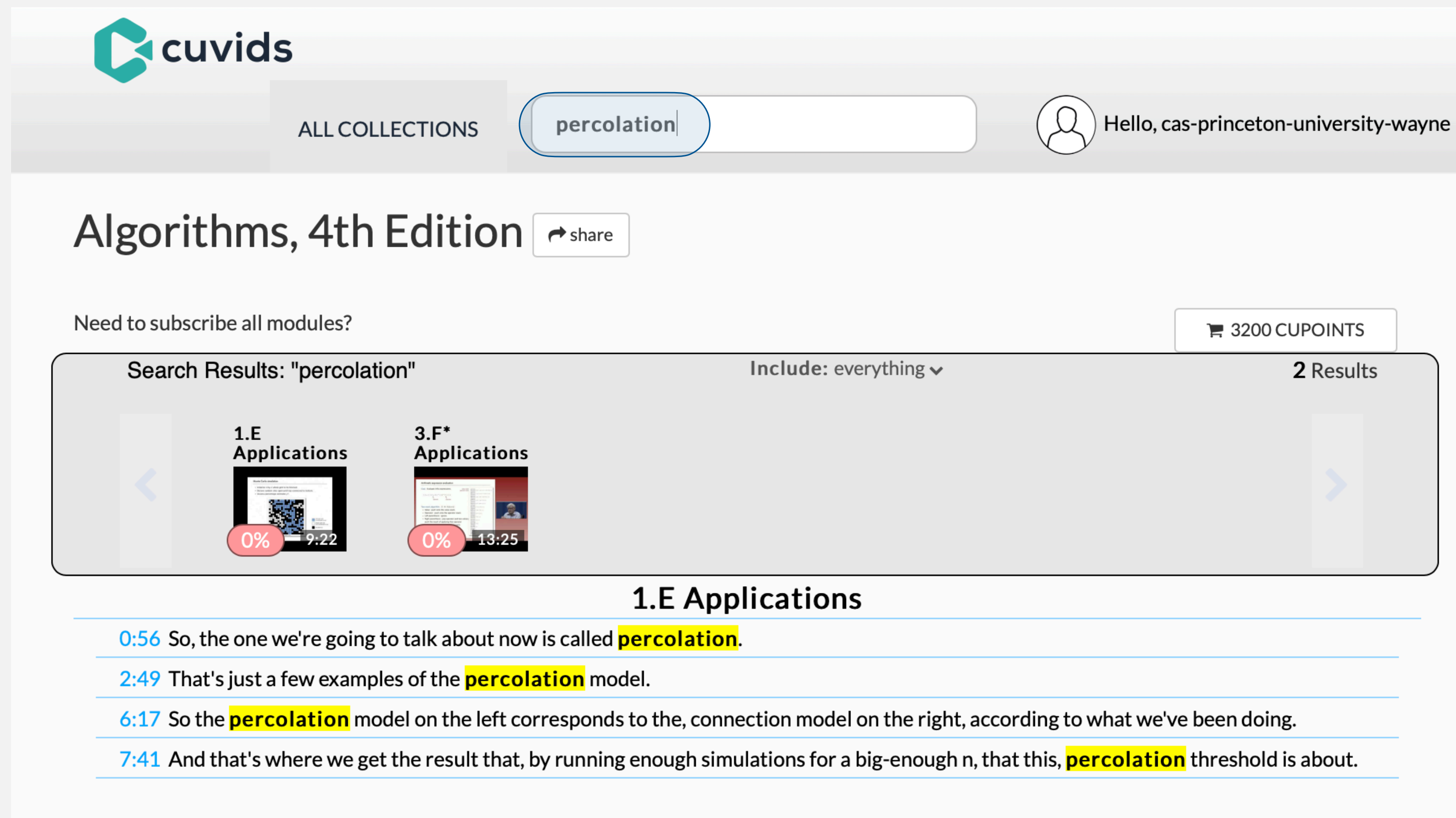
## Studio-produced videos (optional).

- Different perspective.



## Studio-produced videos (optional).

- Different perspective.
- Transcript search.



**cuvids**

ALL COLLECTIONS  Hello, cas-princeton-university-wayne

## Algorithms, 4th Edition [share](#)

Need to subscribe all modules? [3200 CUPOINTS](#)

Search Results: "percolation" Include: everything 2 Results

**1.E Applications** 0% 9:22

**3.F\* Applications** 0% 13:25

### 1.E Applications

[0:56](#) So, the one we're going to talk about now is called **percolation**.

[2:49](#) That's just a few examples of the **percolation** model.

[6:17](#) So the **percolation** model on the left corresponds to the, connection model on the right, according to what we've been doing.

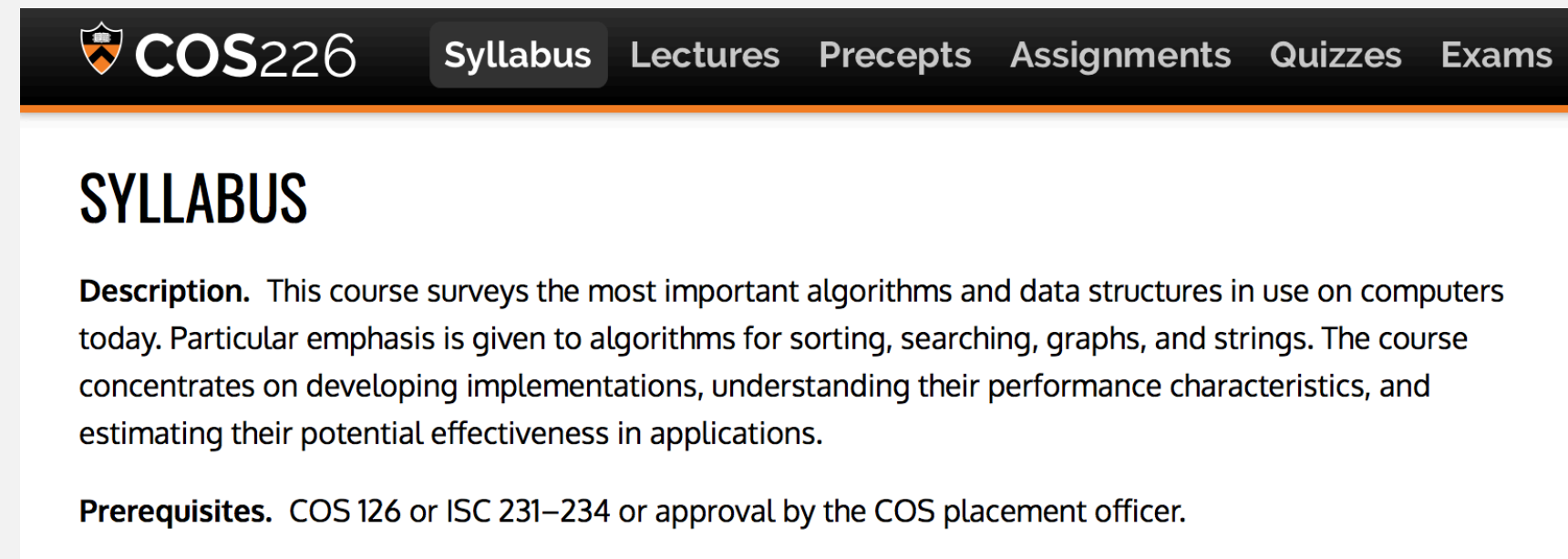
[7:41](#) And that's where we get the result that, by running enough simulations for a big-enough n, that this, **percolation** threshold is about.

## Course content.

- Course info.
- Lecture slides.
- Precept lessons.
- Programming assignments.
- Quizzes.
- Exam archive.

## Booksite.

- Brief summary of content.
- Download code from book.
- APIs and Javadoc.



The screenshot shows the top navigation bar of the COS226 website with links for Syllabus, Lectures, Precepts, Assignments, Quizzes, and Exams. Below the navigation bar is the 'SYLLABUS' section, which includes a description of the course and its prerequisites.

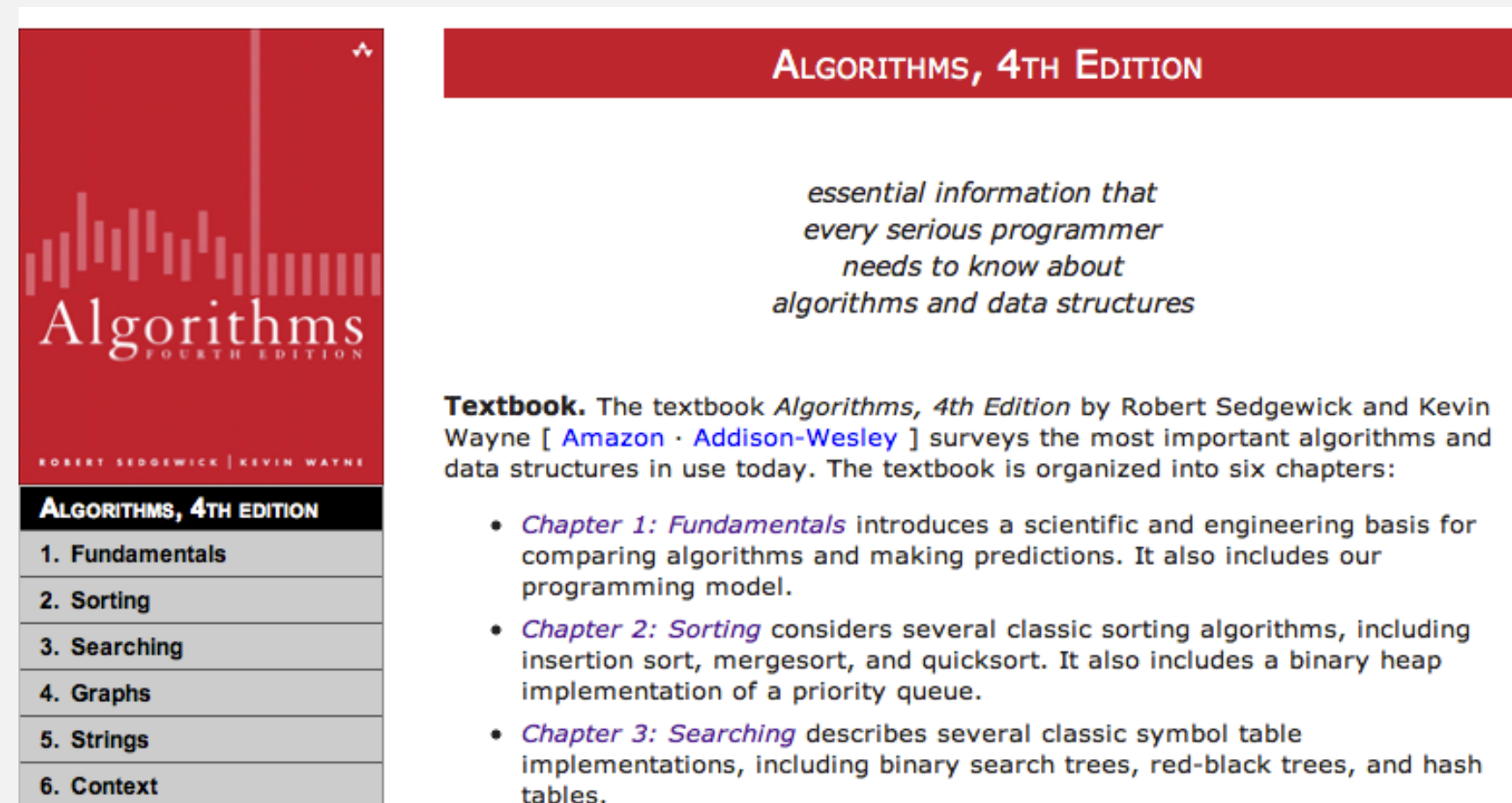
**COS226** Syllabus Lectures Precepts Assignments Quizzes Exams

### SYLLABUS

**Description.** This course surveys the most important algorithms and data structures in use on computers today. Particular emphasis is given to algorithms for sorting, searching, graphs, and strings. The course concentrates on developing implementations, understanding their performance characteristics, and estimating their potential effectiveness in applications.

**Prerequisites.** COS 126 or ISC 231–234 or approval by the COS placement officer.

<https://www.princeton.edu/~cos226>



The screenshot shows the book website for 'Algorithms, 4th Edition' by Robert Sedgwick and Kevin Wayne. It features the book cover on the left and a summary of the book's content on the right.

**ALGORITHMS, 4TH EDITION**

*essential information that every serious programmer needs to know about algorithms and data structures*

**Textbook.** The textbook *Algorithms, 4th Edition* by Robert Sedgwick and Kevin Wayne [ [Amazon](#) · [Addison-Wesley](#) ] surveys the most important algorithms and data structures in use today. The textbook is organized into six chapters:

- **Chapter 1: Fundamentals** introduces a scientific and engineering basis for comparing algorithms and making predictions. It also includes our programming model.
- **Chapter 2: Sorting** considers several classic sorting algorithms, including insertion sort, mergesort, and quicksort. It also includes a binary heap implementation of a priority queue.
- **Chapter 3: Searching** describes several classic symbol table implementations, including binary search trees, red-black trees, and hash tables.

ALGORITHMS, 4TH EDITION
1. Fundamentals
2. Sorting
3. Searching
4. Graphs
5. Strings
6. Context

<https://algs4.cs.princeton.edu>

## Online discussion forum.

- Low latency, low bandwidth.
- Mark post private when necessary.
- See Ed FAQ for guidelines.



<https://us.edstem.org/courses/7744>

## Office hours.

- High bandwidth, high latency.
- See web for schedule.



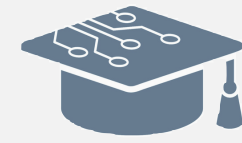
<https://www.princeton.edu/~cos226>











## “Computing laboratory.”

- Undergrad lab TAs.
- For help with debugging.
- See web for schedule.



<https://labta.cs.princeton.edu>



Platform	What
 Ed	<i>discussion forum</i>
 IntelliJ	<i>Java IDE</i>
 Zoom	<i>some office hours</i>
 Quizzera	<i>quizzes</i>
 TigerFile	<i>assignment submissions</i>
 codePost	<i>assignment grading</i>
 Gradescope	<i>exams</i>
 Canvas	<i>check grades</i>
 iClicker	<i>in-class polls</i>
 CUbits	<i>studio-produced videos</i>



# A typical week (excluding this one!)



Sun	Mon	Tue	Wed	Thu	Fri	Sat
5	6	7	8	9	10	11
		Lecture 2 (Union-Find)		Lecture 3 (Analysis)	Precept 2 Quiz 2, 3	
12	13	14	15	16	17	18
	Assignment 1 (Percolation)					

next lecture

again on  
Thursday

support lecture material;  
assignment prep

content based on  
week's material

content based on  
corresponding lectures

## Administrative Q+A

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Not registered? Register ASAP; attend any precept this week.

Change precept? Use TigerHub.

All non-conflicting precepts closed? Contact Colleen Kenny.

Haven't taken COS 126? See COS placement officer.

Placed out of COS 126? Review Sections 1.1–1.2 of Algorithms 4/e.

Additional administrative questions. Ask now, after class, or any time in Ed Discussion.

