

COS 226, SPRING 2021

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

KEVIN WAYNE · MAIA GINSBURG · DAN LEYZBERG



PRINCETON  
UNIVERSITY

# PLEASE TURN ON YOUR CAMERA



  
Unmute ^


  
Start Video ^


  
Security

  
Participants 1 ^

  
Chat

  
Share Screen ^

  
Polling

  
Record


  
Breakout Rooms


  
End





# PLEASE UNMUTE AND MAKE SOME NOISE





  
Unmute ^


  
Stop Video ^


  
Security


  
Participants 1 ^


  
Chat

  
Share Screen ^

  
Polling

  
Record

  
Breakout Rooms

  
Reactions

**End**

# PLEASE MUTE

## QUIET PLEASE


# RECORDING


## SESSION IN PROGRESS

  
Mute

  
Stop Video

  
Security

 1  
Participants


  
Chat

  
Share Screen

  
Polling

  
Record

  
Breakout Rooms

  
Reactions

End

# FINE PRINT



*I will be recording our class sessions to ensure that they are available to students regardless of their geographic location and time zone. Please contact me if you wish to be edited out of any recording in which you appear.*

*Because of privacy, compliance, and legal considerations, you may not post recording of this class online or share them with anyone other than students enrolled in this course.*





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

## INTRO TO COS 226

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



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

# INTRO TO COS 226

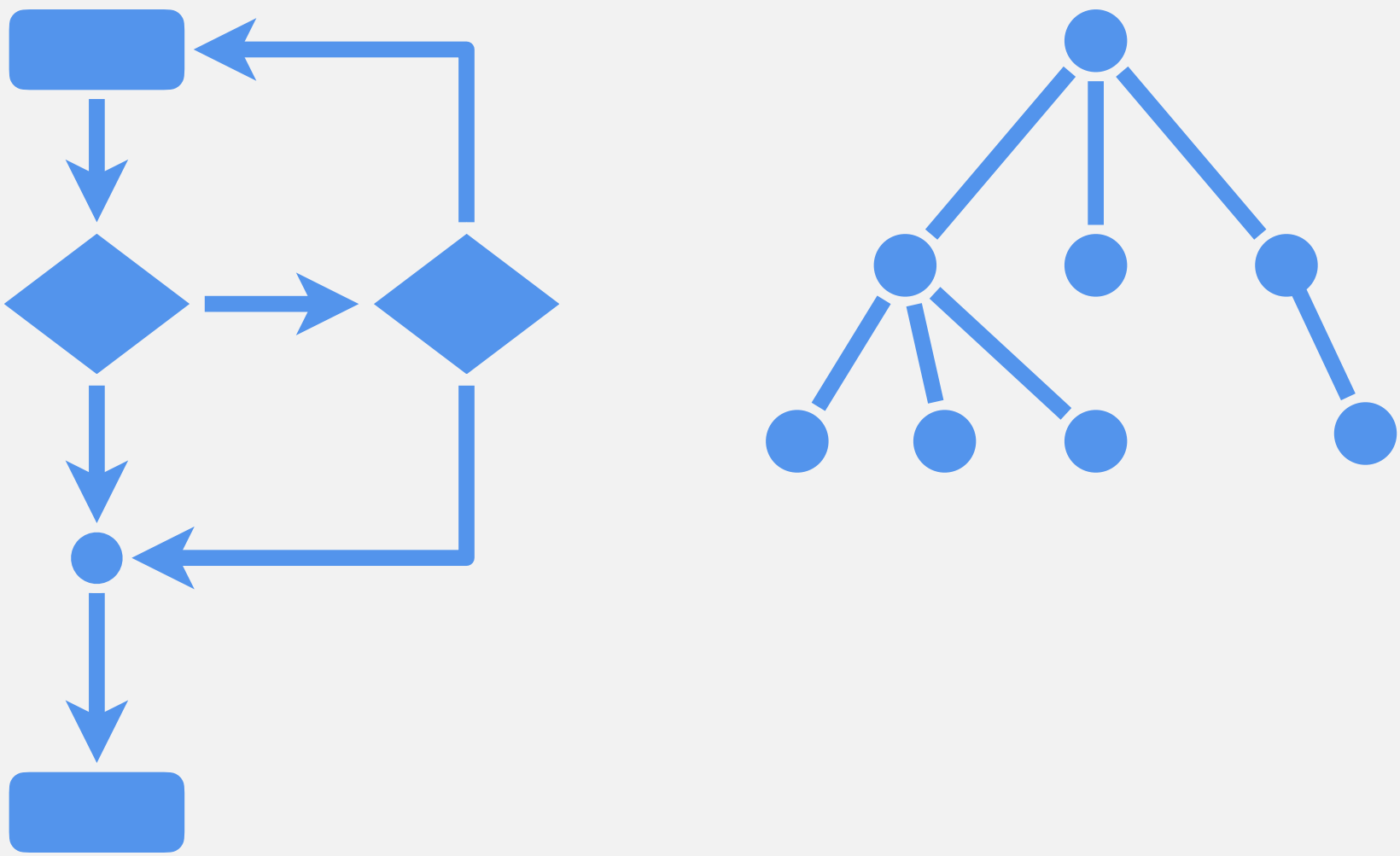
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- ▶ *motivation*
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# COS 226 course overview

## 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.

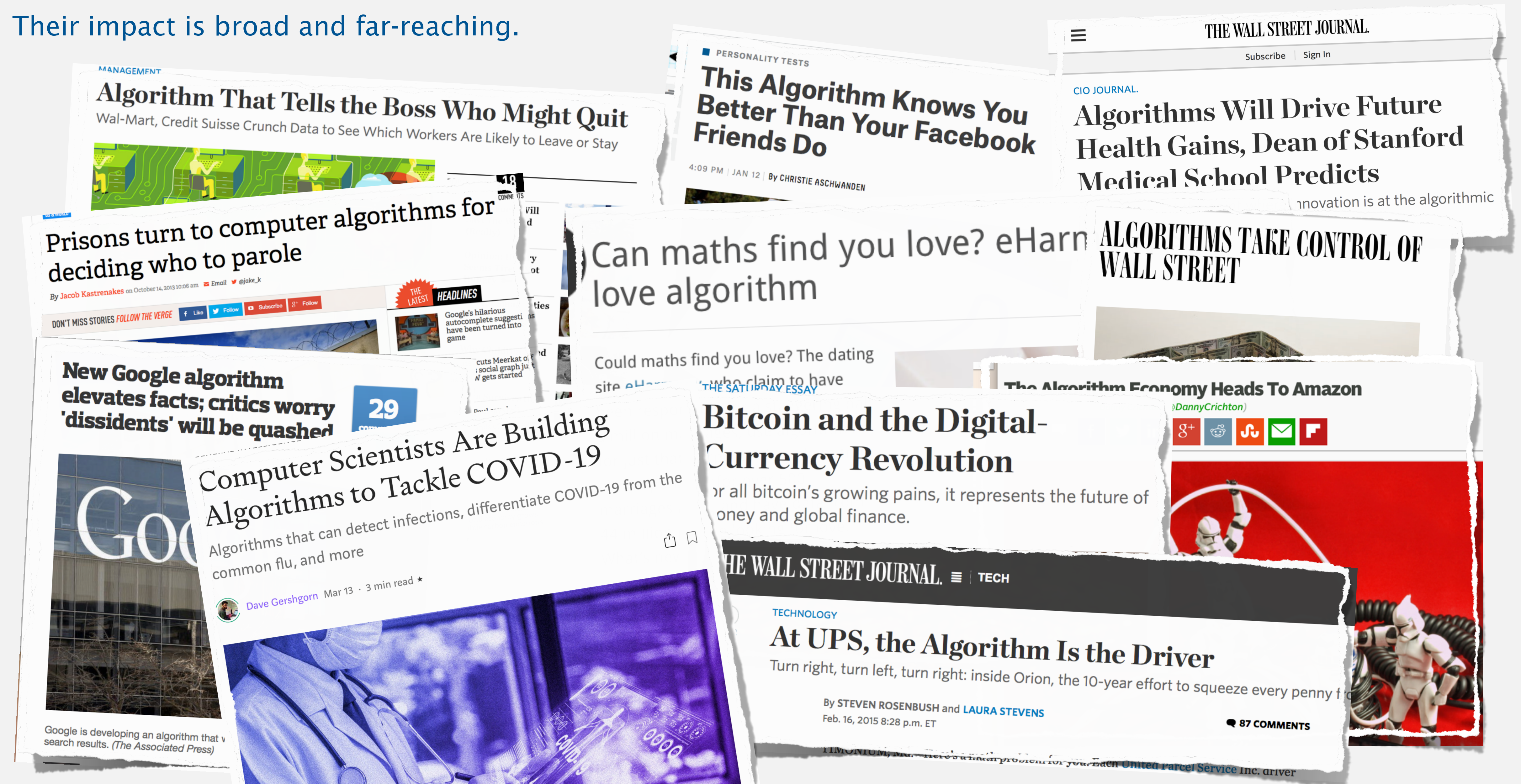


topic	algorithms and data structures 
data types	stack, queue, union-find
sorting	quicksort, mergesort, heapsort, priority queue
searching	BST, red-black BST, hash table, k-d tree
graphs	BFS, DFS, Prim, Kruskal, Dijkstra, Ford-Fulkerson
strings	radix sorts, tries, suffix arrays, data compression



# Why study algorithms and data structures?

Their impact is broad and far-reaching.



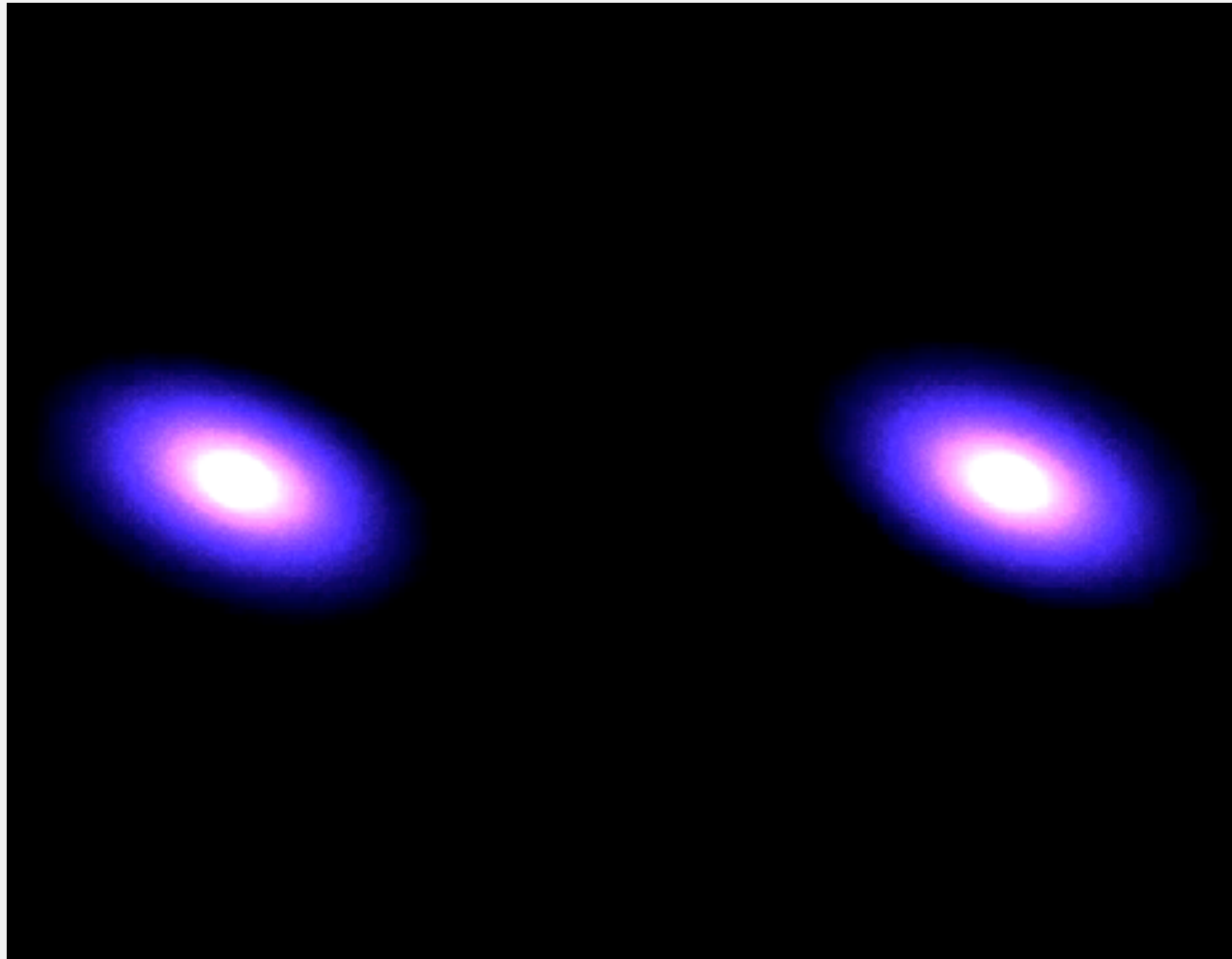


# Why study algorithms and data structures?

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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)

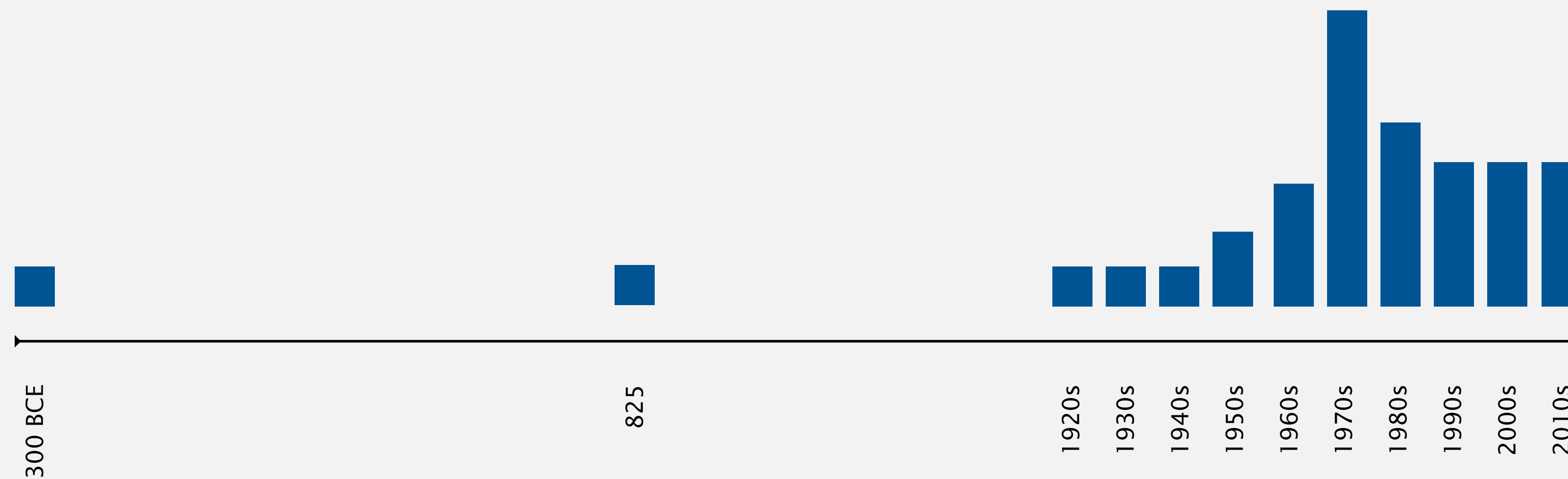


# Why study algorithms and data structures?

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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!



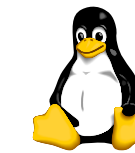
# Why study algorithms and data structures?

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To become a proficient programmer.

```
:n==t?this.pause().cycle():this.slide
ent.find(".next, .prev").length&&e.su
clearInterval(this.interval),this.int
nction(){if(this.sliding)return;retur
|r[t](),s=this.interval,o=t=="next"?
h?i:this.$element.find(".item")[u](),
cators.length&&(this.$indicators.find
children()[a.getActiveIndex()]);t&&t.
t.trigger(f);if(/<\/>defaultPrevented(
t.transition(n){i.removeC
iding=!1,se on(){a.$ele
moveClass("active","acti
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defaults(n),o=typ
[o]():s.in .cycle()})
t,e.fn.carousel=function()
slide-to]",fun var n=e(this),
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}))}(wind e){use
ts,n). is.$par
```

*“ 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?

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For intellectual stimulation.

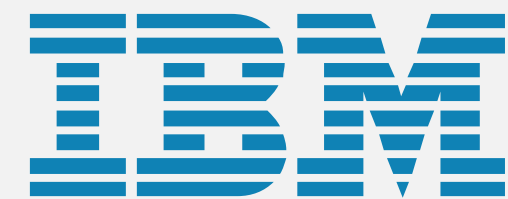


*“For me, **great algorithms are the poetry of computation.** Just like verse, they can be terse, allusive, dense, and even mysterious. But once unlocked, they cast a brilliant new light on some aspect of computing.” — Francis Sullivan*

# Why study algorithms and data structures?

For fun and profit.

Google



NVIDIA®



Adobe



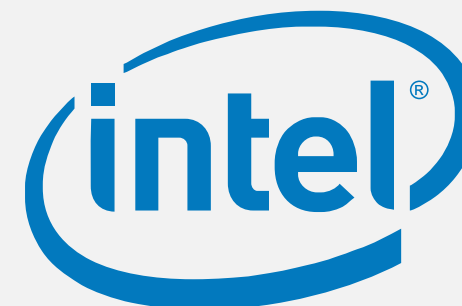
UBER



ORACLE®

YAHOO!®

amazon



Microsoft®





# 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.




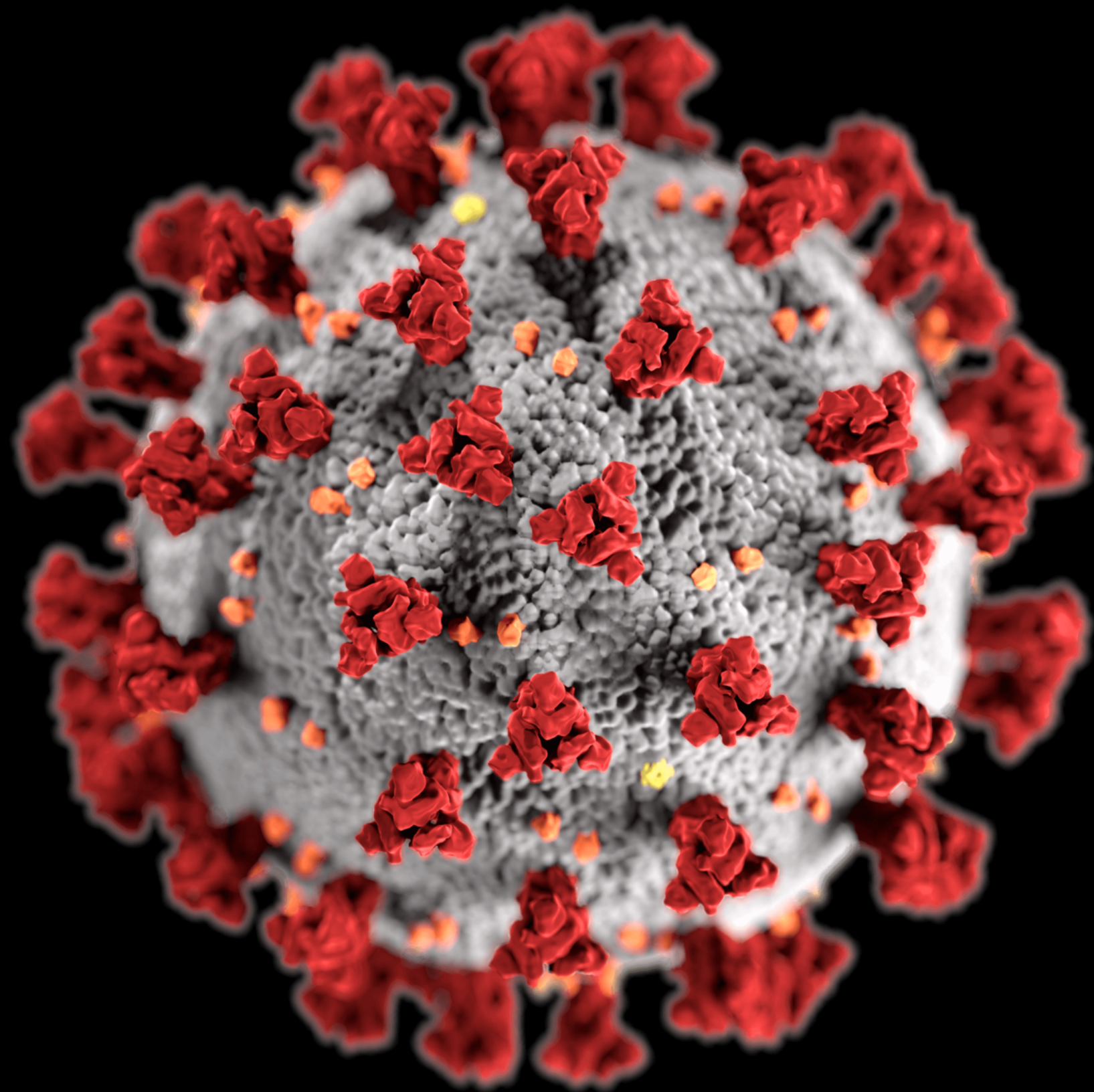


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# INTRO TO COS 226

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




*course format subject to change  
(but will remain 100% remote)*



# Lectures

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Live lectures. Introduce new material.

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

Attendance. Required.  can be waived if living in a distant time zone

Zoom links. Available via Canvas.

Zoom recordings. Available via Canvas.



Live questions during lecture. Raise hand and unmute.

Side channel for questions during lecture. Ed Discussion.

Live questions after lecture. Stay in Zoom.

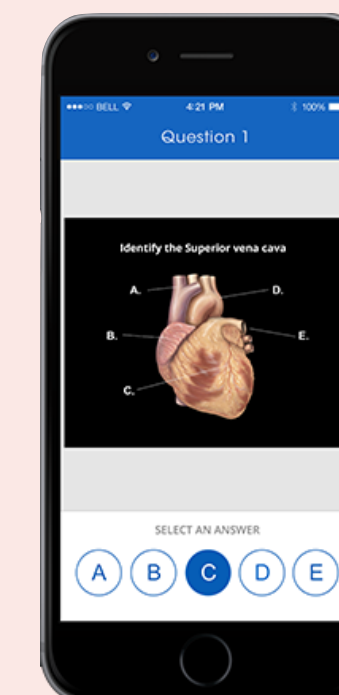
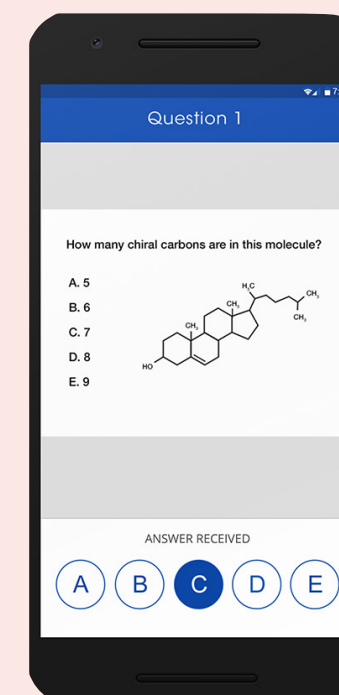
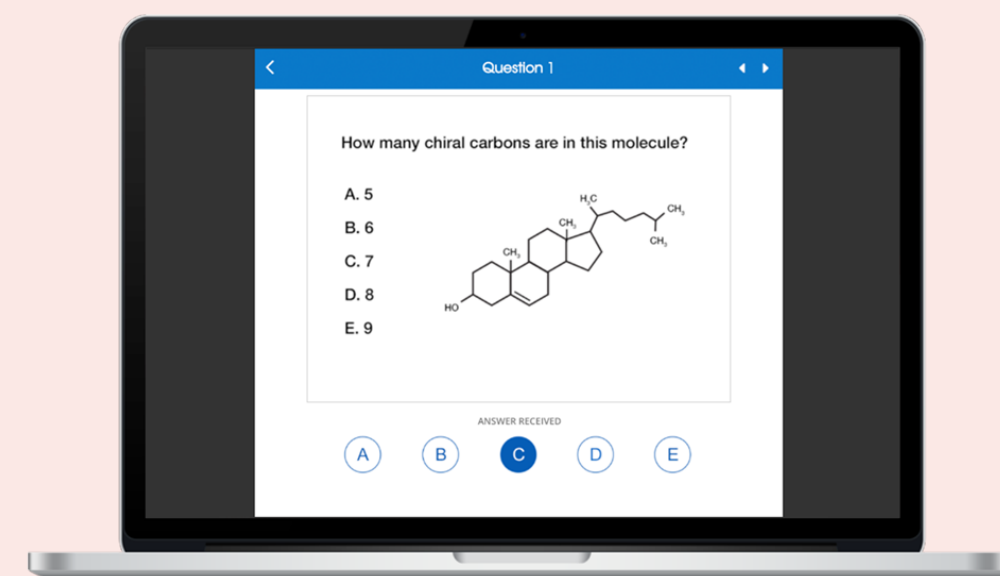


## Student response system (required).

- Multiple choice questions to increase engagement.
- Register iClicker Reef  using your Princeton email address.  must purchase subscription (after 2-week trial period)

## Which iClicker are you using?

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



# Precepts

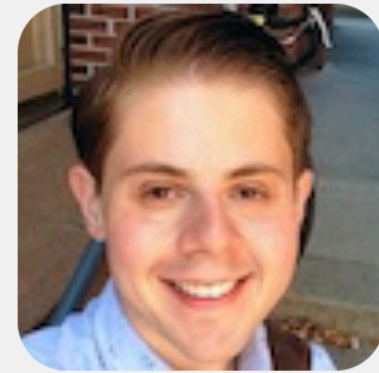
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Problem-solving, discussion, assignment prep, ...



**Maia Ginsburg** ✉

Faculty  
Instructor



**Dan Leyzberg** ✉

Faculty  
Instructor



**Qingchen Dang** ✉

Graduate Student  
Preceptor



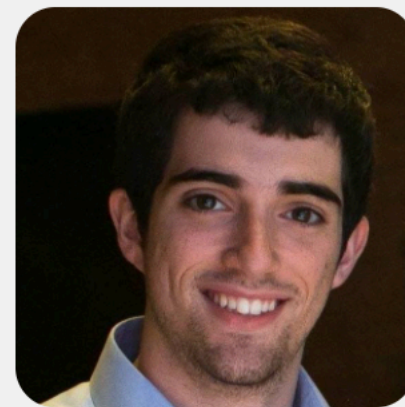
**Akash Gaonkar** ✉

Graduate Student  
Preceptor



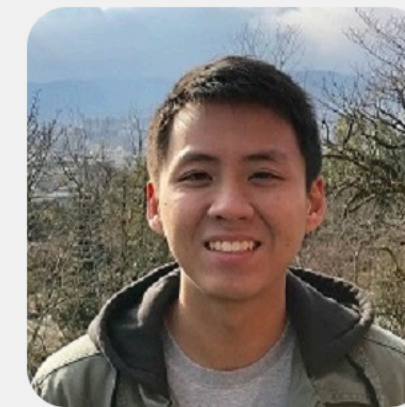
**Danqi Liao** ✉

Graduate Student  
Preceptor



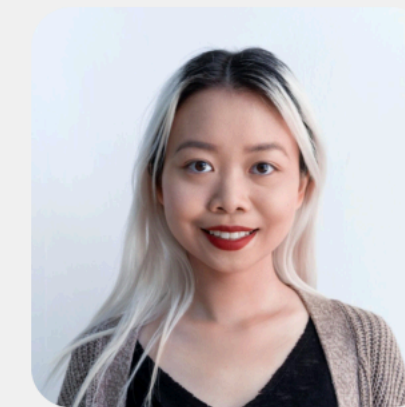
**Lahav Lipson** ✉

Graduate Student  
Preceptor



**Victor Ongkowijaya** ✉

Graduate Student  
Preceptor












**Chloe Qiu** ✉

Graduate Student  
Preceptor

# Precepts

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What	When	Where	Who	Office Hours
P01	Th 3–4:20pm		Dan Leyzberg	<i>see web</i>
P02	Th 4:30–5:50pm		Victor Ongkowijaya	<i>see web</i>
P03	F 11–12:20pm		Qingchen Dang	<i>see web</i>
P04	F 11–12:20pm		Maia Ginsburg	<i>see web</i>
P05	F 1:30–2:50pm		Lahav Lipson	<i>see web</i>
P06	F 1:30–2:50pm		Akash Gaonkar	<i>see web</i>
P07	F 3–4:20pm		Danqi Liao	<i>see web</i>
P08	F 3–4:20pm		Dan Leyzberg	<i>see web</i>
P10	Th 7:30–8:50pm		Chloe Qiu	<i>see web</i>



# INTRO TO COS 226

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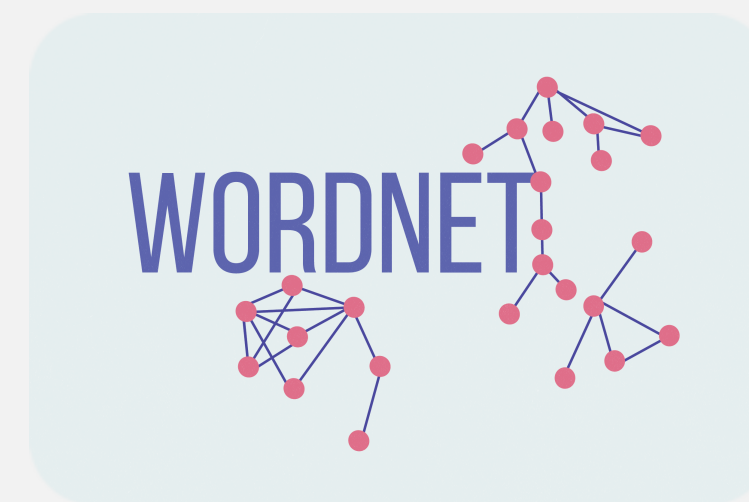
- ▶ *motivation*
- ▶ *course structure*
- ▶ ***assessments***
- ▶ *resources*
- ▶ *union-find*



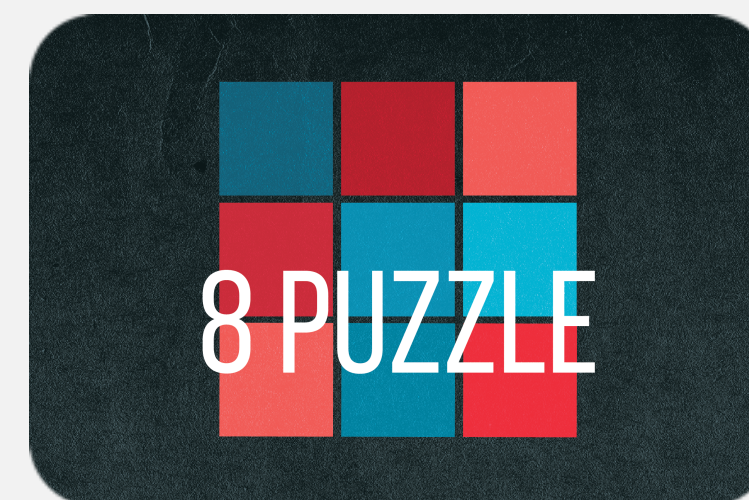
# Programming assignments

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



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



**Pair programming** (via Zoom) encouraged on designated assignments.

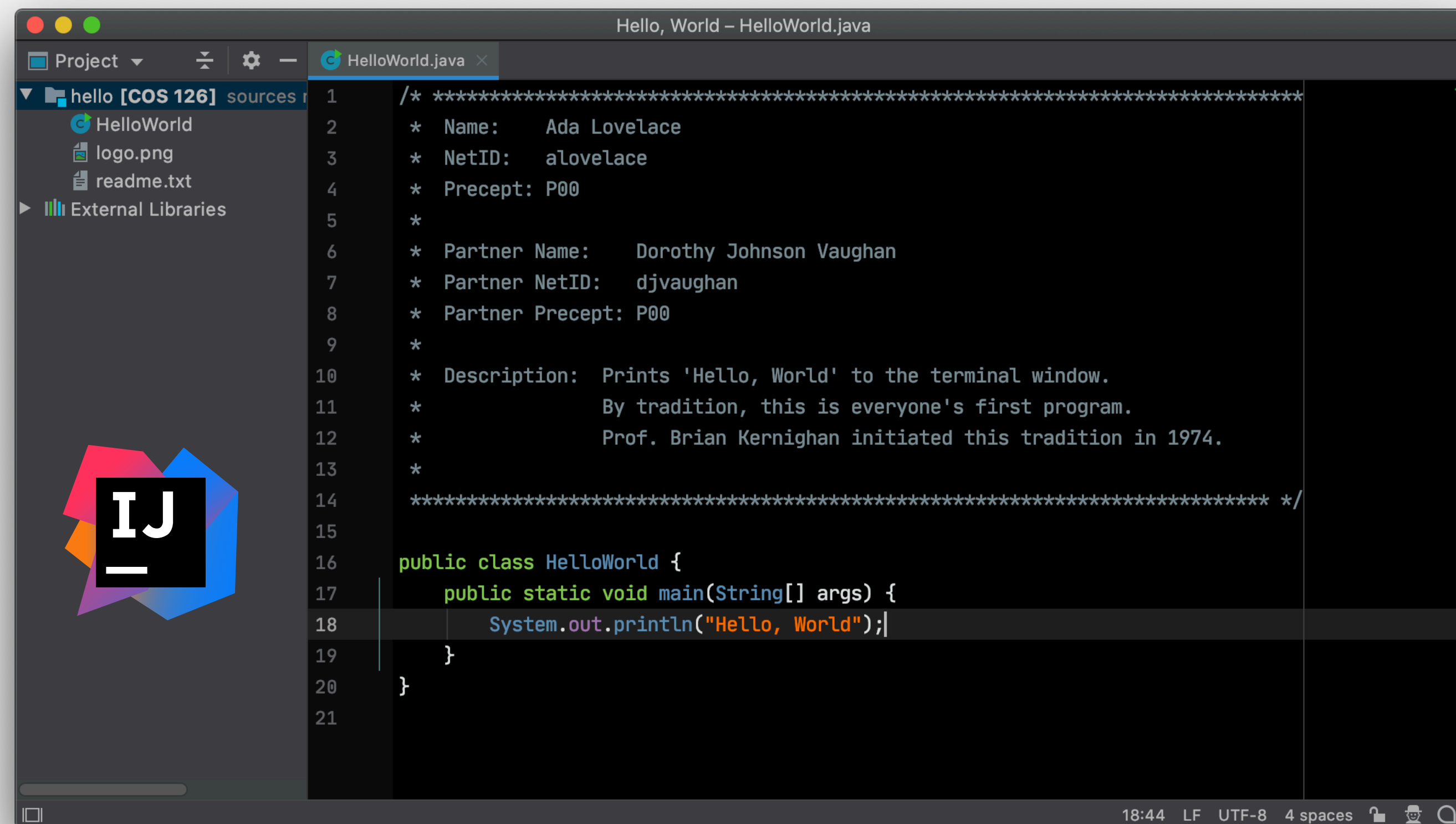




# Programming environment


**Recommended IDE.** Custom IntelliJ 2020.1 environment.  upgrade to Fall 2020 version

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



## Quizzera platform.

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



### 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.

### Final Exam



STUDENT NAME

Search students by name or email...



### Q1 Initialization

3 Points

*This exam has 16 questions (including this one) worth a total of 100 points. You have 180 minutes, plus a 10-minute grace period. The Gradescope timer starts at 190 minutes, which includes the 10-minute grace period.*



# 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.

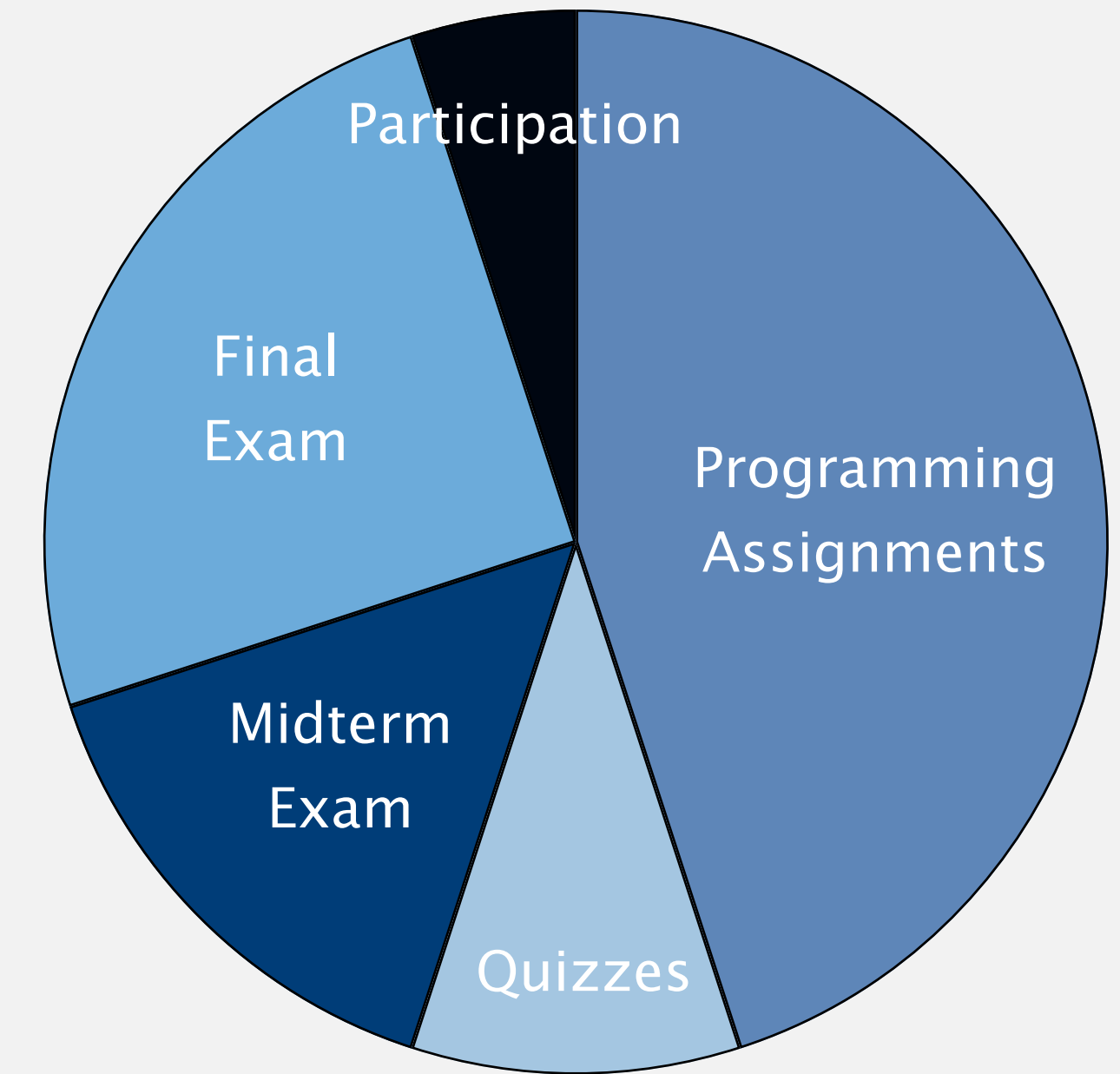
## Exams. 15% + 25%

- 90-minute midterm on Monday, March 22. ← 24-hour window
- 3-hour final, as scheduled by Registrar.

## Active participation. 5%

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

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





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# INTRO TO COS 226

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## Resources (textbook)

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



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

Available from various vendors and formats.

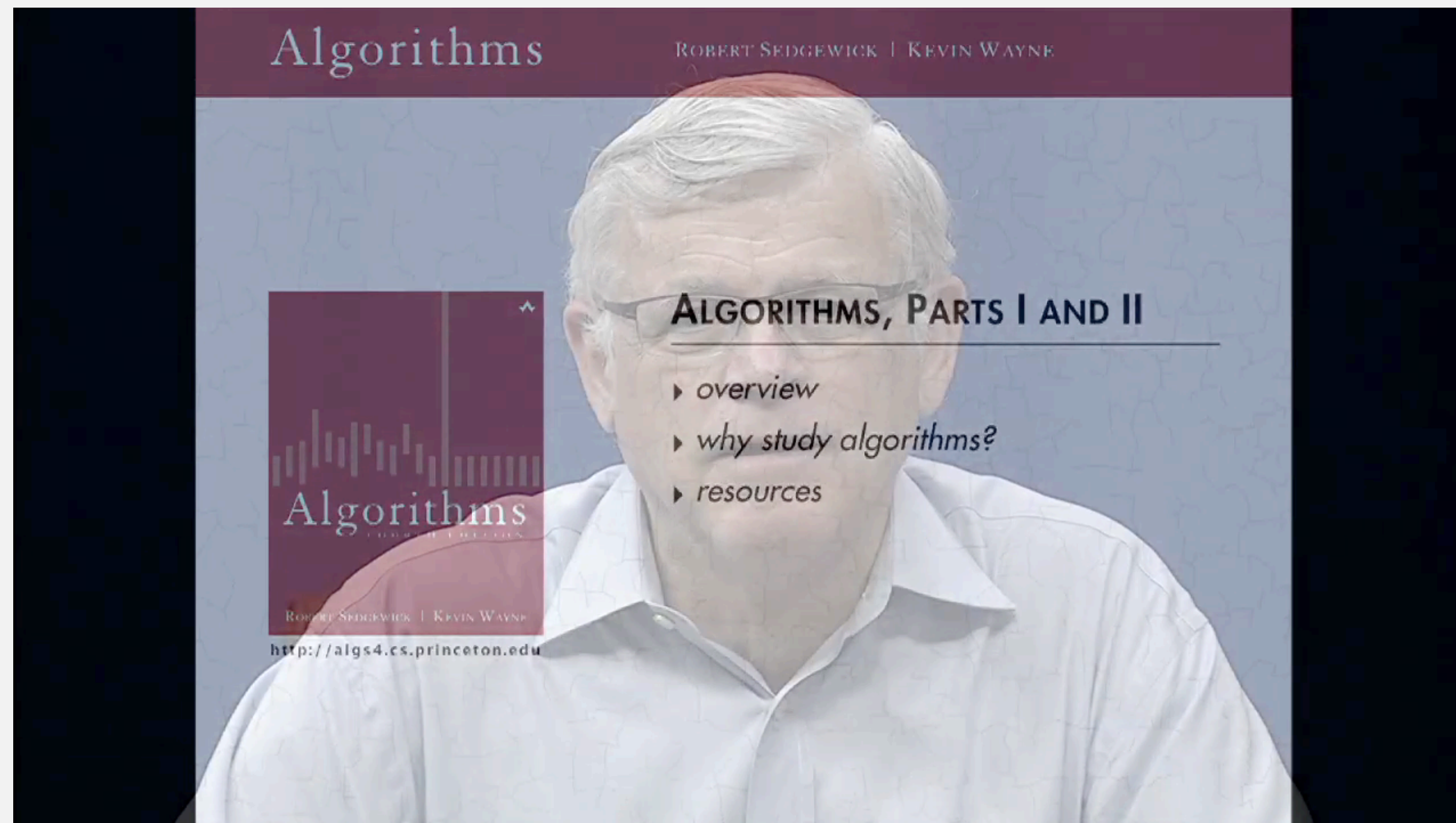
- Amazon: \$85 hardcover, \$55 Kindle, ...
- Labyrinth: \$65 hardcover, \$40 rent.
- Safari Tech Books Online, \$0.





## Studio-produced videos (optional).

- Different perspective.





# Resources (studio-produced videos)

## Studio-produced videos (optional).

- Different perspective.
- Transcript search.


The screenshot shows the cuvids website interface. At the top, there's a header with the cuvids logo, a navigation bar with 'ALL COLLECTIONS' and a search bar containing 'percolation', and a user profile section with a person icon and the text 'Hello, cas-princeton-university-wayne'. Below the header, the main content area displays 'Algorithms, 4th Edition' with a share button. A message 'Need to subscribe all modules?' is shown next to a shopping cart icon labeled '3200 CUPOINTS'. The search results section, titled 'Search Results: "percolation"', shows 'Include: everything' and '2 Results'. Two video thumbnails are displayed: '1.E Applications' (9:22) and '3.F\* Applications' (13:25), both with a '0%' progress indicator. Below the thumbnails, the video '1.E Applications' is selected, and its transcript is shown with timestamps and text: '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.', and '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.'

<https://cuvideos.io/app/course/2>

# Resources (web)

## Course content.

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



SyllabusLecturesPreceptsAssignmentsQuizzesExams

### SYLLABUS

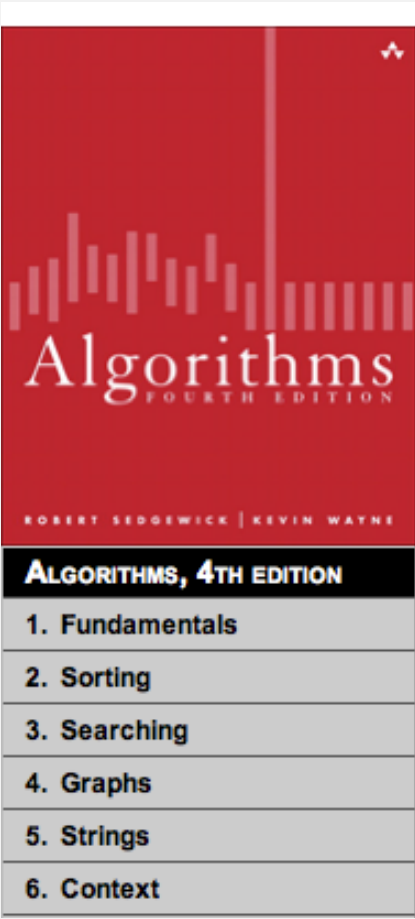
**Description.** This course surveys the most important algorithms and data structures in use on computers today. Particular emphasis is given to algorithms for sorting, searching, graphs, and strings. The course concentrates on developing implementations, understanding their performance characteristics,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

## Booksite.

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



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 Sedgewick 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.

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

# Resources (people)

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## Online discussion forum.

- Low latency, low bandwidth.
- See Ed Discussion for guidelines.
- Use Ed; do not email course staff.



<https://us.edstem.org/courses/3294>

## 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>

# A typical week (including this one!)



Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
		Lecture 1 (Union-Find)		Lecture 2 (Analysis)	Precept 1 Quiz 0, 1, 2	
7	8	9	10	11	12	13
	Assignment 1 (Percolation)					

you are here!

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 (Zoom links in Canvas).

**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 in Zoom; ask anytime in Ed Discussion.

