FUNDAMENTALS

CS62

DATA STRUCTURES AND ADVANCED PROGRAMMING

1: Introduction & Object-Oriented Programming

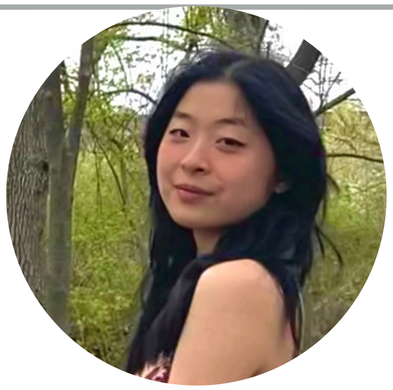
Alexandra Papoutsaki
she/her/hers

Lecture 1: Introduction & Object-Oriented Programming

- Introductions
- Motivation
- Logistics
- Object-Oriented Programming Paradigm
- Java Basics

Some slides adopted from Princeton C0S226 course, Algorithms, 4th Edition, Oracle tutorials

Our team



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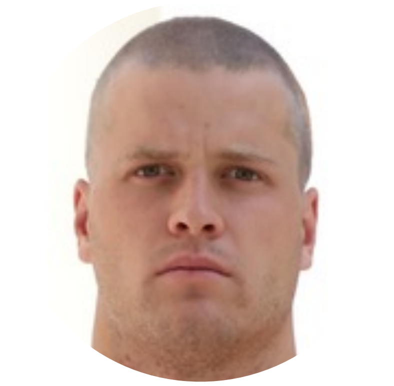

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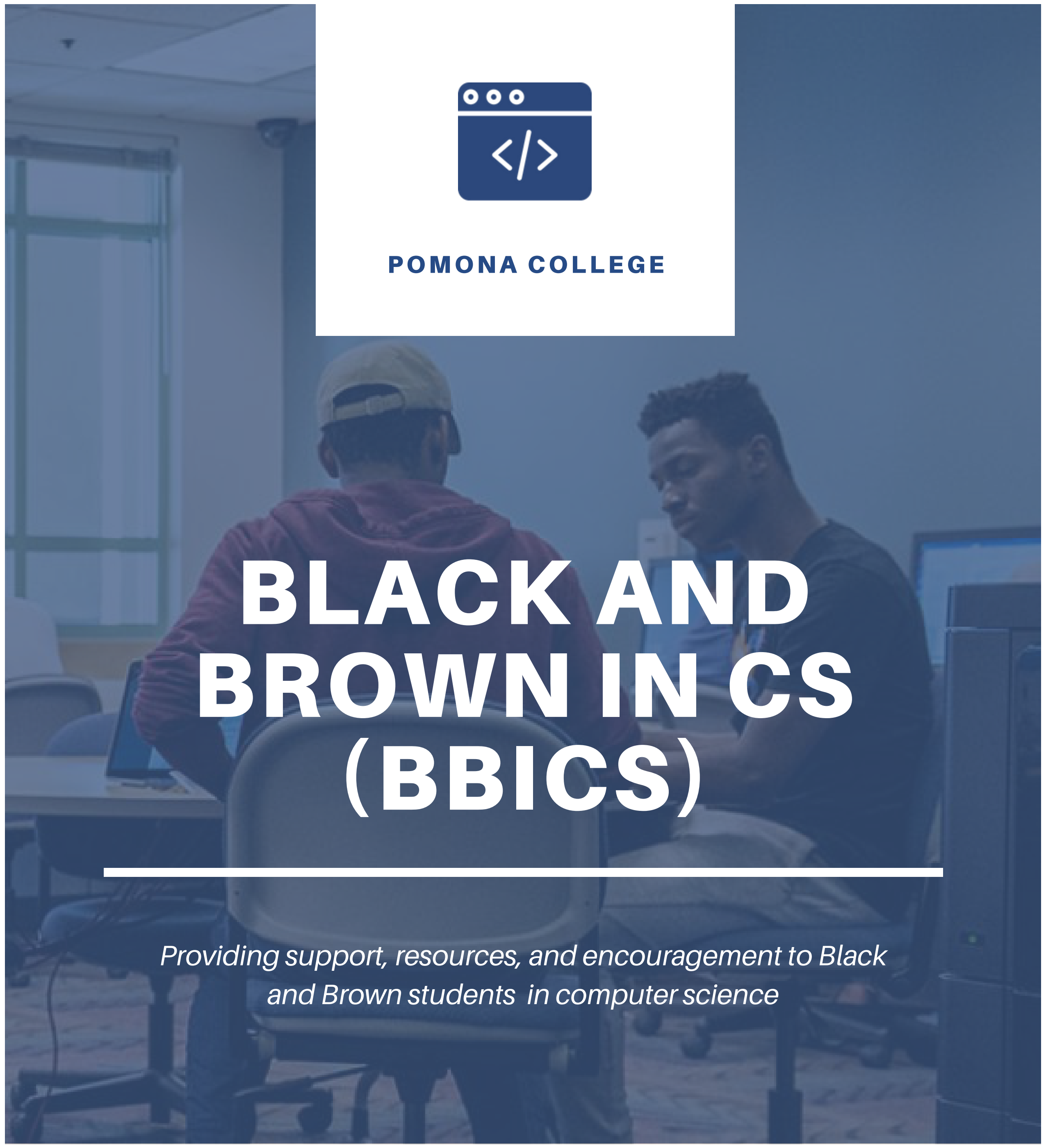
Slack Channels

- If registered, already invited to cs62-fa2023 channel in Pomona College Students Slack workspace.
    - You will find the invitation in the Pomona Students workspace http://slack.pomona.edu
- Department-wide slack workspace: https://tinyurl.com/PomonaCSSlack

Liaisons

- Anjali Nuggehalli
- Grace Li
- Verrels Lukman Eugeneo
- Vivien Song
- Xinyi Xu

INTRODUCTIONS


POMONA COLLEGE
BLACK AND BROWN IN CS (BBICS)
Providing support, resources, and encouragement to Black and Brown students in computer science

Contact: Blessing Adomakoh, Hasana Parker, Claudio Castillio, Tesfa Asmara

What's your programming background?

- CS51P
- CS51A
- AP

Sakai Survey Due this Friday at 5pm

- “Getting to know you”

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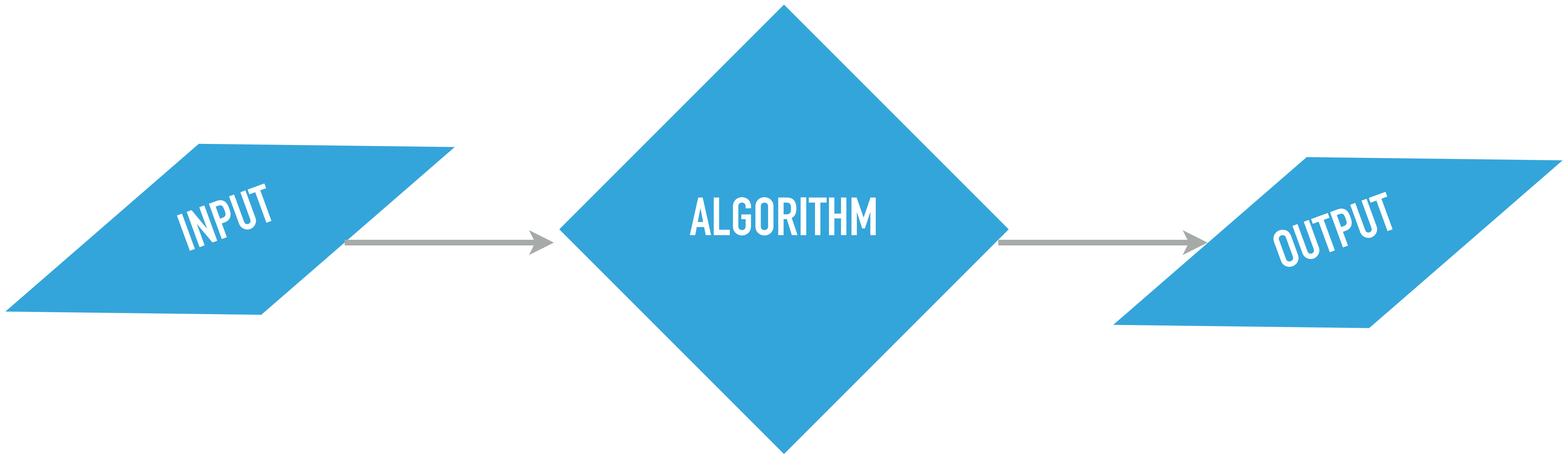
What is CS62?

- Beginner to intermediate-level course
- Data structures: Emphasis on how to organize data in a computer based on problem needs
- Advanced Programming: Emphasis on how to write efficient algorithms for modern applications following the Object-Oriented Programming (OOP) paradigm

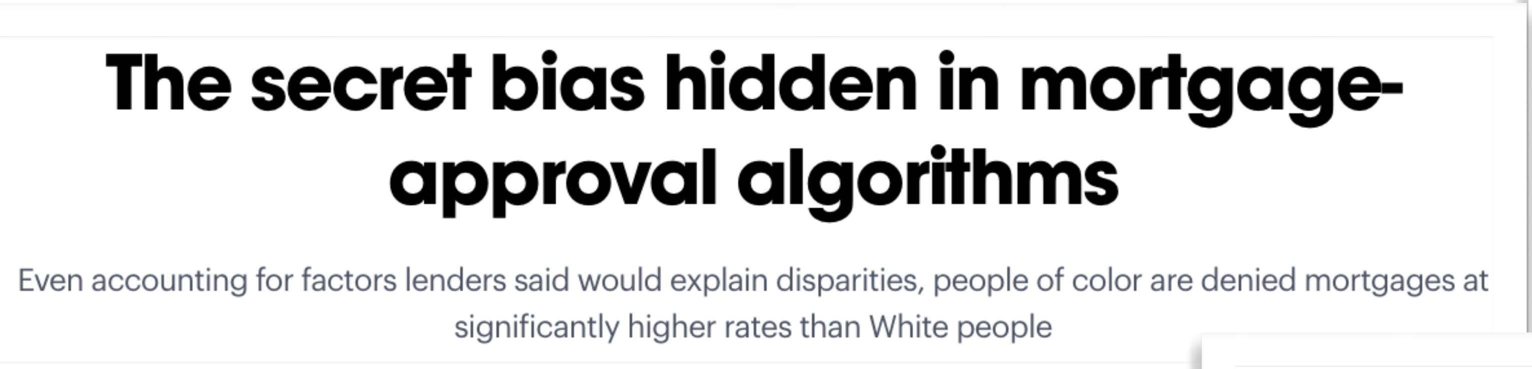
Why study data structures and algorithms?

- The essence of any program
- Their impact is broad and far-reaching
- For intellectual stimulation
- To become a proficient programmer
- For fun and profit
- To major/minor in Computer Science

The essence of any program

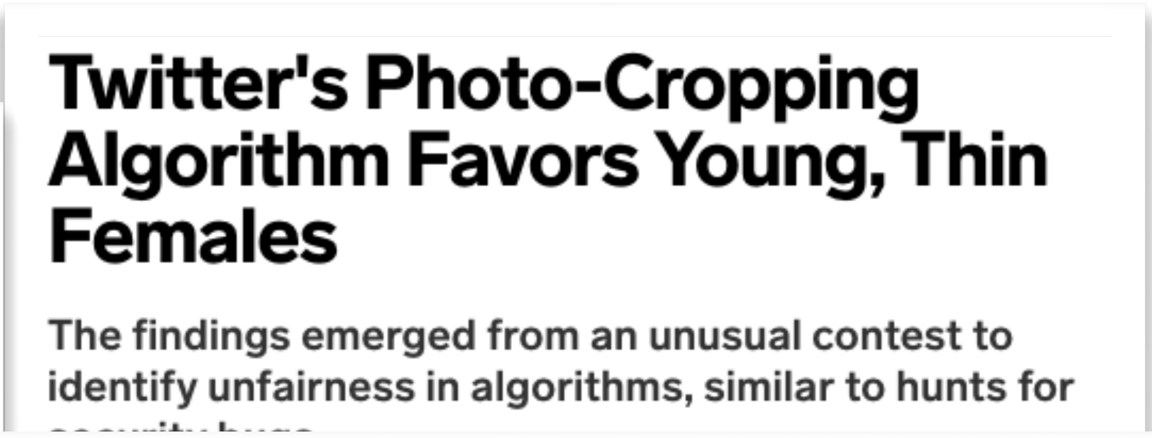


Their impact is broad and far-reaching



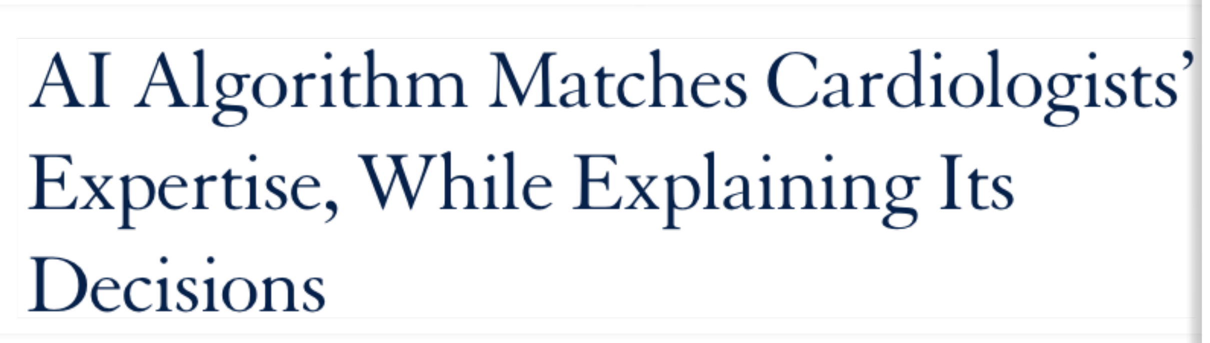
The secret bias hidden in mortgage-approval algorithms

Even accounting for factors lenders said would explain disparities, people of color are denied mortgages at significantly higher rates than White people

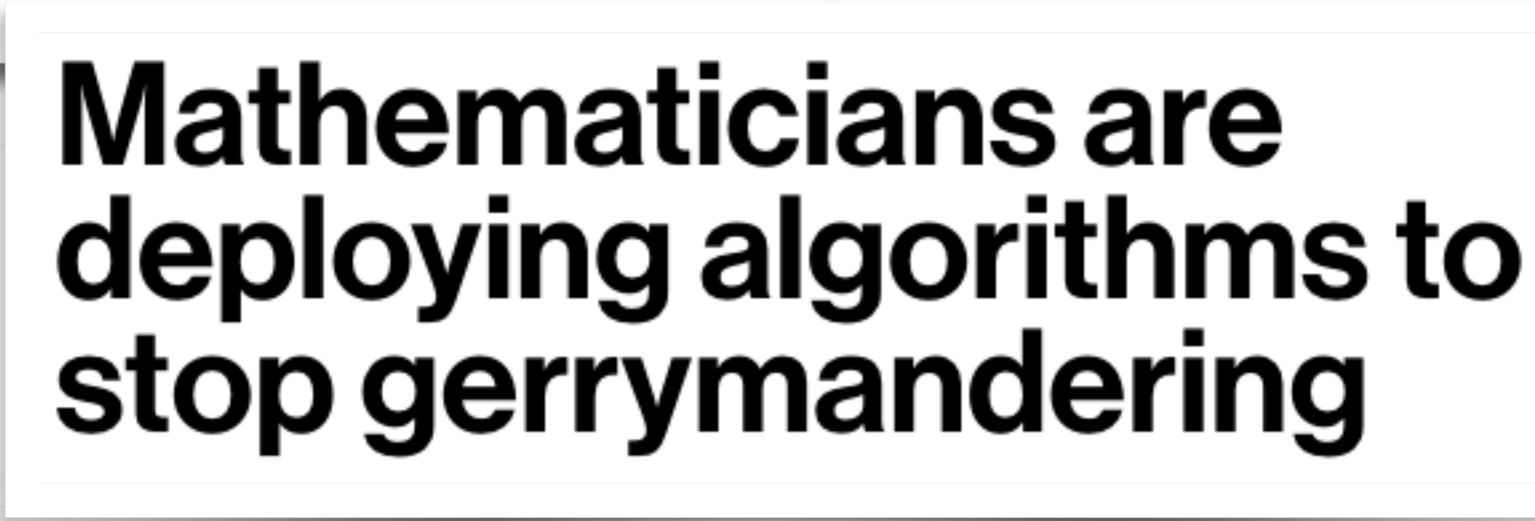


Twitter's Photo-Cropping Algorithm Favors Young, Thin Females

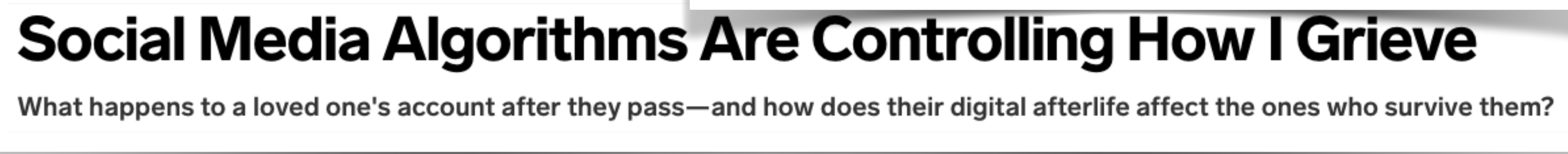
The findings emerged from an unusual contest to identify unfairness in algorithms, similar to hunts for



AI Algorithm Matches Cardiologists' Expertise, While Explaining Its Decisions



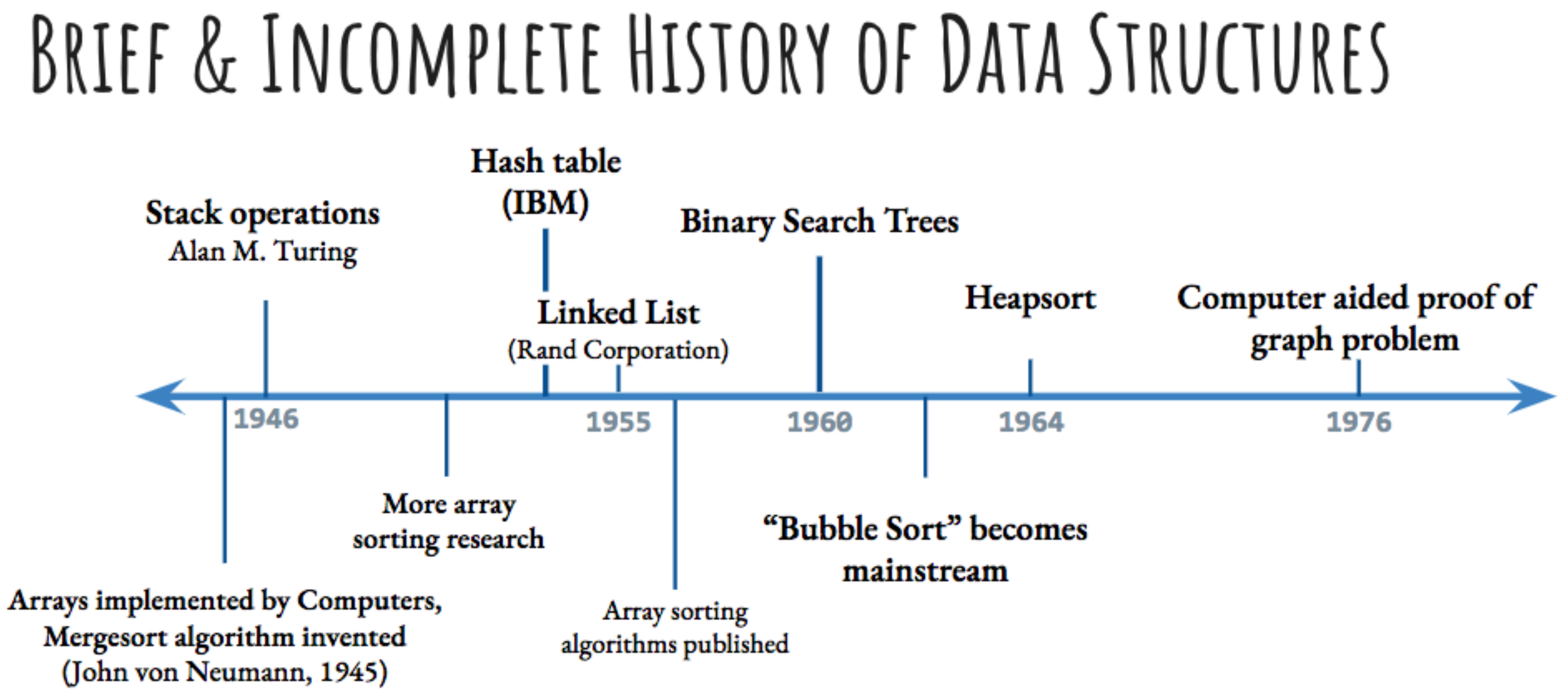
Mathematicians are deploying algorithms to stop gerrymandering



Social Media Algorithms Are Controlling How I Grieve

What happens to a loved one's account after they pass—and how does their digital afterlife affect the ones who survive them?

For intellectual stimulation


Brief & Incomplete History of Data Structures
Stack operations
Alan M. Turing
Hash table
(IBM)
Binary Search Trees
Linked List
(Rand Corporation)
Heapsort
Computer aided proof of graph problem
1946
1955
1960
1964
1976
More array sorting research
"Bubble Sort" becomes mainstream
Arrays implemented by Computers, Mergesort algorithm invented (John von Neumann, 1945)
Array sorting algorithms published

http://macbookandheels.com/algorithm/2018/10/31/teachingds/

- "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, The Joy of Algorithms

To be a proficient programmer

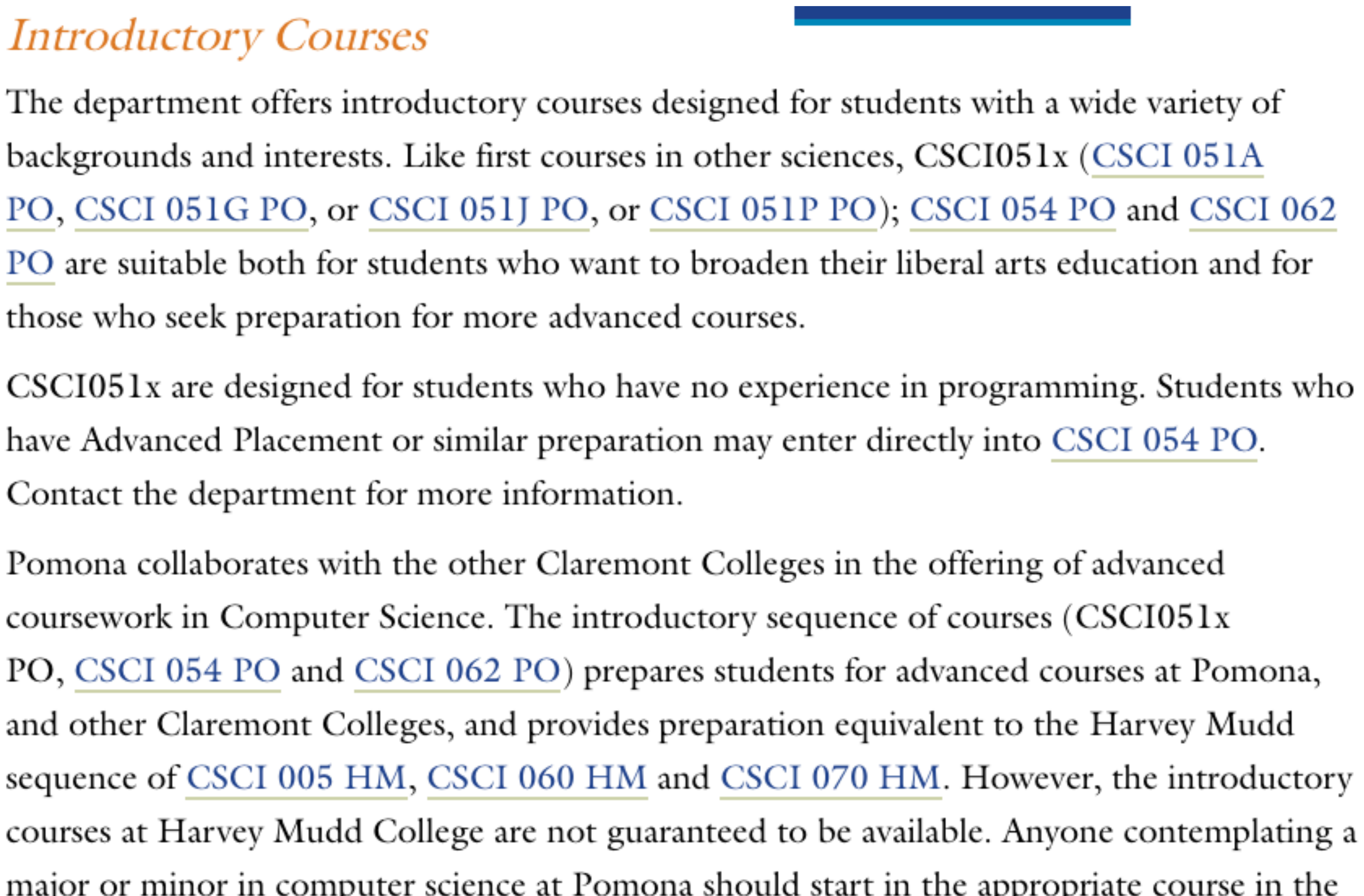
- "Bad programmers worry about the code. Good programmers worry about data structures and their relationships"
  Linus Torvalds (architect of Linux and git)
- "Algorithms + Data Structures = Programs"
  Niklaus Wirth

MOTIVATION

For fun and profit

https://www.pinterest.com/pin/89931323793521544/

To major/minor in Computer Science



Introductory Courses

The department offers introductory courses designed for students with a wide variety of backgrounds and interests. Like first courses in other sciences, CSCI051x (CSCI 051A PO, CSCI 051G PO, or CSCI 051J PO, or CSCI 051P PO); CSCI 054 PO and CSCI 062 PO are suitable both for students who want to broaden their liberal arts education and for those who seek preparation for more advanced courses.

CSCI051x are designed for students who have no experience in programming. Students who have Advanced Placement or similar preparation may enter directly into CSCI 054 PO. Contact the department for more information.

Pomona collaborates with the other Claremont Colleges in the offering of advanced coursework in Computer Science. The introductory sequence of courses (CSCI051x PO, CSCI 054 PO and CSCI 062 PO) prepares students for advanced courses at Pomona, and other Claremont Colleges, and provides preparation equivalent to the Harvey Mudd sequence of CSCI 005 HM, CSCI 060 HM and CSCI 070 HM. However, the introductory courses at Harvey Mudd College are not guaranteed to be available. Anyone contemplating a major or minor in computer science at Pomona should start in the appropriate course in the

A quick overview of lecture topics

Topic	Data Structures/Algorithms
Fundamentals	Arrays
Basic Data Structures	ArrayLists, Linked Lists, Stacks, Queues
Sorting	Bubblesort, Selection sort, Insertion Sort, Shellsort, Quicksort, Mergesort, Heapsort, Heaps, Priority Queues
Searching	BSTs, red-black trees, 2-3 search trees, hash tables
Graphs	BFS, DFS, Prim, Kruskal, Dijsktra

The advanced programming side of CS62

- In contrast to CS51, labs and assignments will typically be different.
- Labs are shorter and deliverables are due Friday midnight.
- Assignments are week- or two weeks-long, due on Thursday midnight.
- Some assignments will be partner assignments.
- Labs will mostly teach you tools:
  - VS Code, Debugger, Unit testing, git, CLI.
- Assignments will be deliberately vague and will be **using** data structures to solve interesting problems.
  - Realistically, no one will hire you and give you the steps to solve a problem.
  - But we are here to help you understand how to approach problems!

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Prerequisites

- Officially, CSCI054 at Pomona
- We assume you are comfortable with moderate-size programs
  - Loops
  - Conditionals
  - Procedures/methods/functions
  - Objects
  - Recursion
- Comfortable with proofs
- Familiar with concepts of time/memory efficiency

DON'T WORRY!
REVIEW DURING FIRST TWO WEEKS

How can I succeed in CS62?

- Sleep well the night before, eat, come to class, be on time
- Take notes, participate, ask questions, don’t stay confused
- Review slides and do the assigned reading/problems after each lecture
- Start the assignments early
- Use the tools we learn in the lab (e.g., Debugger)
- Practice writing code on paper
- Learn how to read and write documentation
- Come to office hours/mentor sessions
  - But ask for help *after* you have tried solving a problem by yourself
- Did I say start early?

How can I be a good citizen in CS062?

- Use laptops/tablets/phones/other fancy electronics only for note taking.
- Be mindful when in office hours/mentor sessions of the number of other students waiting for help.
    - Come with specific questions!
- TAs are students, too. Respect their time outside mentor sessions.
- We encourage collaboration but we want you to submit your own code.
- We monitor assignments for plagiarism. This includes using code from other students, websites, or tools like chatGPT.
    - Academic dishonesty cases are reported to the Dean of Students and can lead to failure of assignments/exams/entire course.
    - If unsure about what's allowed, talk to me.

What will my average week look like?

- MW lectures.
- Wednesday quizzes, starting next week.
- Weekly assignments due on Thursday midnight.
- Friday labs (mandatory) due on Friday midnight.

BUDGET AT LEAST 8 HOURS OUTSIDE THE CLASSROOM

Grading summary

- Weekly Programming Assignments: 30%
  - Five free days - can use on one assignment or across different assignments. Let me know before the deadline if you will take a late day pass.
    - If group assignment, both partners have to use a free day
- Midterm I: 15%
- Midterm II: 15%
- Final Exam: 25%
- Quizzes: 10%
  - Will automatically drop lowest scoring quiz
- Labs: 5%
  - No late submissions

More information: http://www.cs.pomona.edu/classes/cs62/

Resources

- Recommended but not required textbook: Algorithms 4th edition by R. Sedgewick and K. Wayne, Addison-Wesley Professional, 2011, ISBN 0–321–57351–X.
- Booksite: http://algs4.cs.princeton.edu/
  - Brief summary of content
  - Exercises
  - Code
- Slack channel: monitored by the entire staff.
- Github/gradescope: for version control and to submit assignments - you cannot make your code publicly available.
- Office hours: MW 2:45-4pm, T 1:30-2:30pm, Th 1-4pm
- Mentor sessions: TBD
- Course website: http://www.cs.pomona.edu/classes/cs62/

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What is Object-Oriented Programming (OOP)?

- “a method of implementation in which programs are organized as cooperative collections of **objects**, each of which represents an **instance** of some **class**, and whose classes are all members of a hierarchy of classes united via **inheritance** relationships”. Grady Booch
- Popular OOP languages: Java, C++, C#, Python (kinda).

What is an object?

- A software bundle of related state (data) and behavior (procedures working on that data).
- Can have a physical existence e.g., a customer, a ticket, a car, a post.
- Can have an intangible conceptual existence e.g., a meeting, a process.
- State: the individual characteristics stored in **fields** (or variables).
    - e.g., an object that represents a bicycle has fields for storing its current speed (18mph) and gear (5th)
- Behavior: **methods** operate on internal state of objects and serve as the primary mechanism for object-to-object communication.
    - e.g., change gear, apply brakes, speed up or down, etc.

What is a class?

- A blueprint or prototype from which objects are created.
- An object is an instance of a class and the process of creating it is called instantiation.

Practice Time

- Models of real-world objects contain ___ and ___.
- A software object's state is stored in ___.
- A software object's behavior is exposed through ___.
- A blueprint for a software object is called a ___.

Answers

- Models of real-world objects contain **fields** and **methods**.
- A software object's state is stored in **fields**.
- A software object's behavior is exposed through **methods**.
- A blueprint for a software object is called a **class**.

https://docs.oracle.com/javase/tutorial/java/concepts/QandE/answers.html

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Declaring classes

```
public class MyClass {

    // field, constructor, and method declarations

}
```

- Class name is a noun and capitalized by convention.
- The class body is surrounded by curly braces.

A possible implementation of a bicycle class in Java

```java
/**
 * Represents a bicycle
 * @author https://docs.oracle.com/javase/tutorial/java/concepts/class.html
*/
public class Bicycle {

    //instance variables
    private int cadence = 0;
    private int speed = 0;
    private int gear = 1;

    public void changeCadence(int newValue) {
         cadence = newValue;
    }

    public void changeGear(int newValue) {
         gear = newValue;
    }

    public void changeSpeed(int change) {
         speed = speed + change;
    }

    public int getCadence() {
         return cadence;
    }

    public void printGear() {
      System.out.println("Gear:" + gear);
    }

    public String toString() {
         return "cadence:" + cadence + " speed:" + speed + " gear:" + gear;
    }
}
```

- All code in a Java program must belong to a class.
- // comment within a line.
- /* multi-line comment.*/
- /**documentation comment (JavaDoc).*/
- The source code is saved in `.java` files.
- The name of the class should match the name of the source file e.g., `Bicycle.java`.
- Curly braces (`{` and `}`) are used to surround bodies of classes, methods, and loops.
- Statements end with a semicolon (`;`).
- Fields `cadence`, `speed`, `gear` represent the state of a bicycle object.
- Methods `changeCadence`, `changeGear`, etc. define how the object will interact with the world.
- `System.out.println` is Java's way of printing a string to the console.
- Override `toString` if you want to change how objects are printed.
- To run your code you will need a special method called `main` - there is no main in the `Bicycle` class.
- You can have a `main` method per class. Typically one of them will control the program and the rest will be used to test each class.

Bicycle Demo program

```java
/**
 * Basic demonstration of how to work with bicycle objects
 * @author https://docs.oracle.com/javase/tutorial/java/concepts/class.html
 *
 */

public class BicycleDemo {
    public static void main(String[] args) {

        // Create two different Bicycle objects
        Bicycle bike1 = new Bicycle();
        Bicycle bike2 = new Bicycle();

        System.out.println(bike1);

        // Invoke methods on those objects
        bike1.changeCadence(50);
        bike1.changeSpeed(10);
        bike1.changeGear(2);
        bike1.printGear();
        System.out.println(bike1);

        bike2.changeCadence(50);
        bike2.changeSpeed(10);
        bike2.changeGear(2);
        bike2.changeCadence(40);
        bike2.changeSpeed(-10);
        bike2.changeGear(3);
        bike2.printGear();
        System.out.println(bike1);
        System.out.println(bike2);


    }
}
```

- In the `main` method, we instantiate two objects of type `Bicycle` with the `new` keyword, that is two new bicycles are being brought into this world.
- Object name + dot operator + method/variable to create a reference to an object's method/field
  - e.g., `bike1.changeCadence(50);`
- `Void` methods do not return anything.
  - `printGear` is `void`
- `System.out.println(someObject)` calls the `toString` method of the class `someObject` belongs to.

WHAT WILL THIS PROGRAM PRINT?

```
cadence:0 speed:0 gear:1
Gear:2
cadence:50 speed:10 gear:2
Gear:3
cadence:50 speed:10 gear:2
cadence:40 speed:0 gear:3
```

Access Modifiers

- `public` modifier - the field/method is accessible from all classes.
- `private` modifier - the field/method is accessible only within its own class.
- More that we will learn later…

Variables

- Containers for storing data values.
- Java is statically-typed: all variables must be declared along with their data type before they can be used.
  - e.g., `int cadence = 0;`
  - e.g., `String name;`
- Data types: primitives, classes, interfaces, and arrays.

Instance variables (non-static or member fields)

- Declared in a class but outside of any method.
- Each object has its own **unique copy** of the variable. E.g.,

```
public class Bicycle {

    private int cadence = 0;
    private int speed = 0;
    private int gear = 1;
}
```

- Invoked as `myObject.variableName`
- It’s always a good idea to keep them `private`

Static variables (class fields)

- Declared with the `static` modifier.
- All objects share the same copy. E.g.,

```
public class Bicycle {

    public static int numberOfBicycles;
}
```

- Invoked as `ClassName.variableName`

USE SPARINGLY!

Local variables

- Declared within a method.
- Destroyed after the execution of the method.
- Can only be accessed within the method.
- No access modifier.
- `public int countToTen() {`

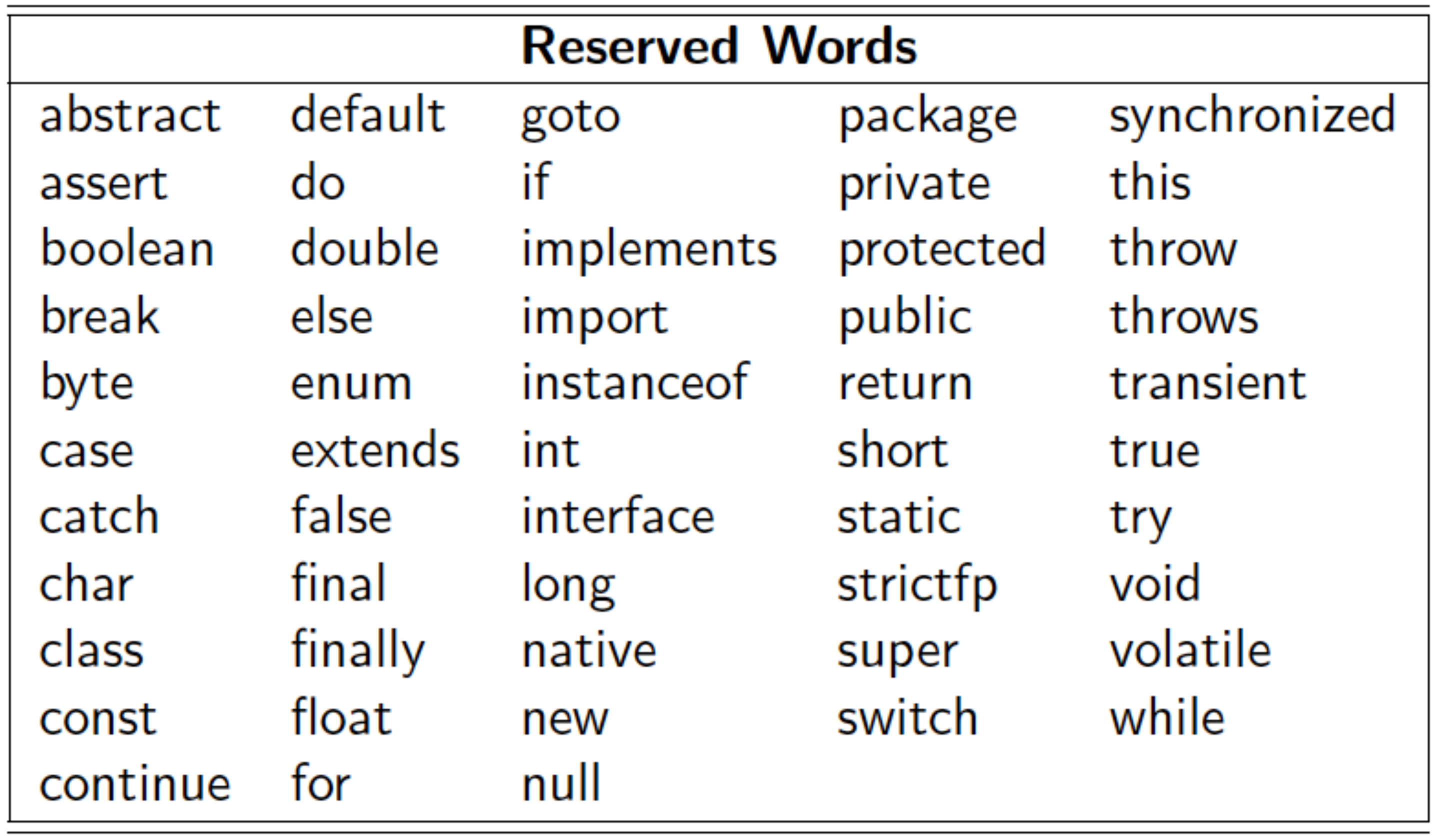
```
    int counter = 0;
    //…
}
```

Naming Variables

- Variable names are case-sensitive.
- No white space.
- Start with small letter.
- Subsequent characters can be letters, digits, $, or _.
- Use full words that make sense.
- If name contains more than two words, capitalize the first letter of each subsequent word. e.g., `numberOfBicycles`.
- If your variable is a constant, capitalize everything. e.g., `PI`.

Identifier

- The name of a class, interface, method, or variable.
- Each category has its own naming conventions.



Reserved Words				
abstract	default	goto	package	synchronized
assert	do	if	private	this
boolean	double	implements	protected	throw
break	else	import	public	throws
byte	enum	instanceof	return	transient
case	extends	int	short	true
catch	false	interface	static	try
char	final	long	strictfp	void
class	finally	native	super	volatile
const	float	new	switch	while
continue	for	null		

Primitive Data Types

- Java supports 8 primitive data types.
- Primitives use a small amount of memory to represent a single item of data and support certain operations on its value.
- All data of same primitive data type use the same amount of memory.
- Cannot be used to instantiate type variables, that is no `new` keyword.
- Have corresponding object “wrapper” types:
  - `Integer`, `Double`, `Float`, `Boolean`, etc.

Primitive Data Types

Type	Bits	Default	Example
`byte`	8	0	`byte b = 10;`
`short`	16	0	`short s = 2;`
`int`	32	0	`int i = 47;`
`long`	64	0L	`long l = 4747L;`
`float`	32	0.0f	`float f = 47.0f;`
`double`	64	0.0	`double d = 47.0;`
`char`	16	'\u0000'	`char c = 'a';`
`boolean`	1	`false`	`boolean fun = true;`

The compiler will assign default values to uninitialized instance and static fields.
If you do not initialize local variables you will run into a compile-time error!

The most important primitive data types to know

- `int` - for integers.
- `double` - for real numbers.
- `boolean` - for the set of values {`true`, `false`}.
- `char` - for alphanumeric characters and symbols.

- **STRINGS ARE NOT PRIMITIVES**
  - instead use class `String`.

Classes

- Main data types in Java.
  - e.g., `String`.
- Thousands more coming with Java by default.
- You can instantiate your own with the `new` keyword.
  - `Bicycle myBike = new Bicycle();`
- Contain fields (can be a primitive or class type) and methods.
- Respond to messages to communicate with the outside world by invoking methods.
- Reference default value is `null`.

A vocabulary refresher for variables

- Declaration: state the type of variable and its identifier. A variable can only be declared once. E.g., `int x;`
- Initialization: the first time a variable takes a value. E.g., `x = 3;`
  - Can be combined with declaration, e.g., `int y = 3;`
- Assignment: discarding the old value and replacing it with a new. E.g., `x = 2;`
- Static or instance variables are automatically initialized with default values, i.e. null for references to objects, 0 for int, false for boolean, etc.
- Local variables are not automatically initialized and your code won't compile if you have not initialized them and you are trying to use them. E.g.,

```java
public void foo() {
    int x;
    System.out.println(x);
    //The local variable x might not have been initialized
}
```

Practice Time

Consider the following class:

```
public class IdentifyMyParts {
    public static int x = 7;
    public int y = 3;
}
```

a. What are the class/static variables?

b. What are the instance/member variables?

c. What is the output from the following code:

```
IdentifyMyParts a = new IdentifyMyParts();
IdentifyMyParts b = new IdentifyMyParts();
a.y = 5;
b.y = 6;
a.x = 1;
b.x = 2;
System.out.println("a.y = " + a.y);
System.out.println("b.y = " + b.y);
System.out.println("a.x = " + a.x);
System.out.println("b.x = " + b.x);
System.out.println("IdentifyMyParts.x = " + IdentifyMyParts.x);
```

Answers

```
a. x

b. y

c. a.y = 5
   b.y = 6
   a.x = 2
   b.x = 2
   IdentifyMyParts.x = 2
```

https://docs.oracle.com/javase/tutorial/java/javaOO/QandE/creating-answers.html

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Readings:

- Oracle's guide: What Is an Object? What Is a Class?
  https://docs.oracle.com/javase/tutorial/java/concepts/index.html
- Classes and Objects: https://docs.oracle.com/javase/tutorial/java/javaOO/index.html
- Variables: https://docs.oracle.com/javase/tutorial/java/nutsandbolts/variables.html

Code

- Lecture 1 code

Practice Problems:

- How would you model the ticketing system for a local movie theater in OOP?