FUNDAMENTALS

CS062

DATA STRUCTURES AND ADVANCED PROGRAMMING

1: Introduction & Object-Oriented Programming

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LECTURES

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LABS

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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- Jason Rodolitz
- Cecilia Sanborn
- Huey Sun

Who are you?

- College
- Year
- Major
- Enrolled in class
- Permed
- CS51P/CS51J/AP

MAKE SURE TO USE THE SIGN-IN SHEET FOR THE FIRST TWO LECTURES

INTRODUCTIONS

Take an index card and write down...

- Why are you taking this course?
- What do you hope to get out of the course?

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What is CS062?

- 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?

- 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
- To major/minor in Computer Science

Their impact is broad and far-reaching

What will it take for us to trust algorithms?

What People Hate Being Managed by Algorithms, Accor Study of Uber Drive

by Mareike Möhlmann and Ola Henfridsson

Algorithms Aid Search for Source of Spacetime Rumbles

MOTHERBOARD
TECH BY VICE

Flawed Algorithms Are Grading Millions of Students' Essays

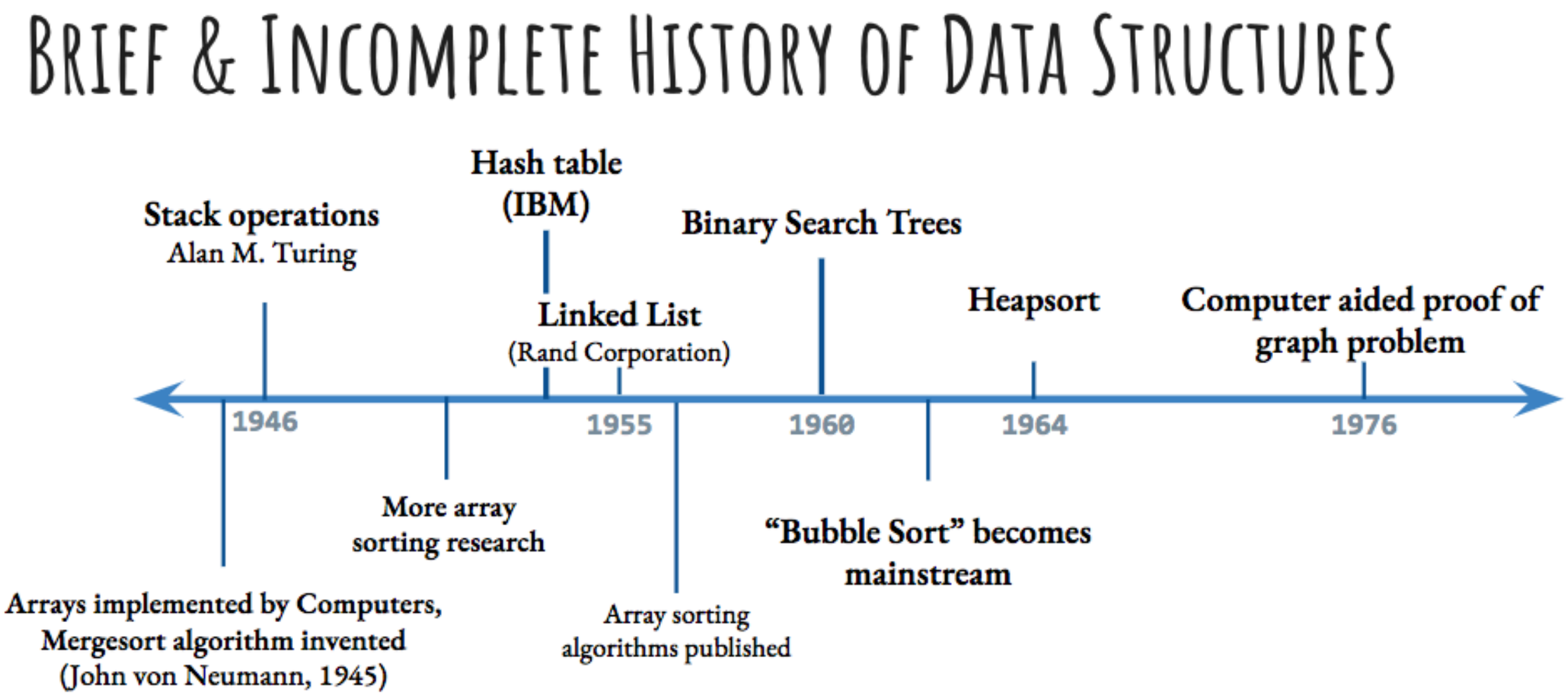
Fooled by gibberish and highly susceptible to human bias, automated essay-scoring systems are being increasingly adopted, a Motherboard investigation has found

How Healthcare Is Using Big Data And AI To Cure Disease

Nicole Martin Contributor
AI & Big Data
I write about technology, data and privacy.

They may unlock the secrets of life and of the universe

Old roots, new opportunities



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

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

For intellectual stimulation

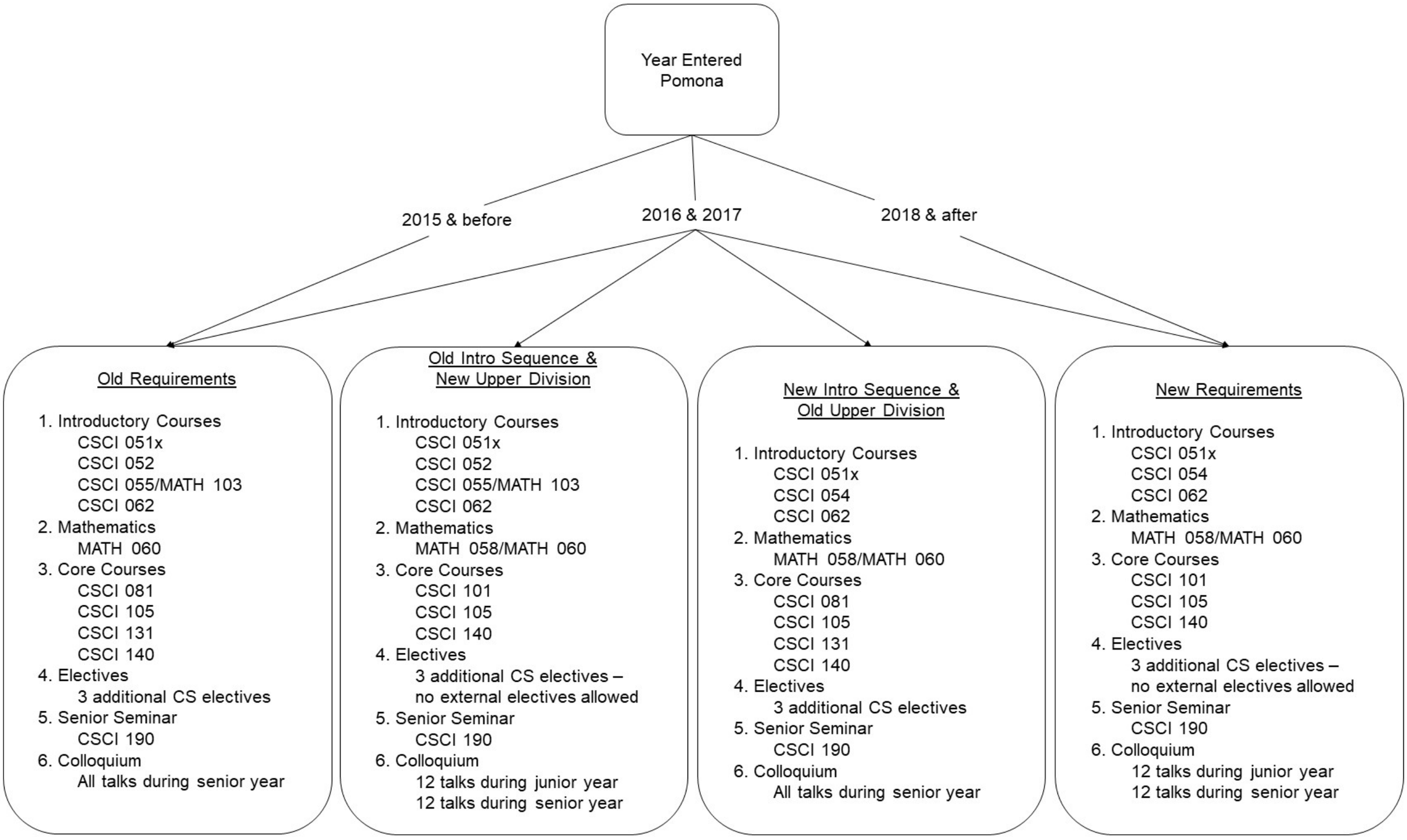
- “For me, great algorithms are the poetry of computation. Just like verse, they can be terse, allusive, dense, and even mysterious. But once unlocked, they cast a brilliant new light on some aspect of computing.”

Francis Sullivan, The Joy of Algorithms

For fun and profit

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

To major/minor in Computer Science



A quick overview of lecture topics

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

The advanced programming side of CS62

- In contrast to CS51, labs and assignments will typically be different.
- Labs are shorter and deliverables are due Wednesday midnight.
- Assignments are week-long, due on Tuesday midnight.
- Labs will mostly teach you tools:
  - CLI, Eclipse, Debugger, Unit testing, git, profiling, etc
- In some labs you will *implement* data structures that we see in lectures.
- Assignments will be *deliberately* vague and will be *using* data structures to solve interesting problems.
  - No one will hire you and give you the solution to a problem.

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Prerequisites

- Officially, CS054/CS052 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 CS062?

- Have breakfast, 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?

- Don’t use laptops/tablets/phones/other fancy electronics
  - Unless you have an accommodation
- 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.
- Follow the departmental academic honesty policy
  - That’s non-negotiable and we use software to detect plagiarism

What will my average week look like?

- MWF lectures.
- Friday quizzes.
- Wednesday labs (mandatory) due on Wednesday midnight.
- Weekly assignments due on Tuesday midnight.

BUDGET AT LEAST 8 HOURS OUTSIDE THE CLASSROOM

Grading summary

- Weekly Programming Assignments: 35%
  - 3^n % penalty for each late day
  - Can take a 3-day extension once - *use wisely*
- Midterm I: 15% (in lab)
- Midterm II: 15% (in lab)
- Final Exam: 25%
- Quizzes: 5%
  - Can skip one quiz - *use wisely*
- Labs: 5%

More information: http://www.cs.pomona.edu/classes/cs062/

Resources

- 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
- Piazza discussion forum: monitored by the entire staff.
- Github: to submit assignments - you cannot make your code publicly available.
- Office hours:
  - Papoutsaki - MF 2-5 pm and by appointment. Edmunds 222
  - Kampe - TW 10am-12pm Edmunds 128. TW 4-5:30pm Edmunds 229
- Mentor sessions: 6-10 pm, T 6-9 pm, W 8-10 pm, Sa 1-3 pm, Su 8-10 pm, in Edmunds 227
- Course website: http://www.cs.pomona.edu/classes/cs062/

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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 and behavior.
- Can have a physical existence e.g., a customer, a ticket, a car.
- Can have an intangible conceptual existence e.g., a meeting, a process.

- State: characteristic properties and their values modeled as **fields**.
  - e.g., a bicycle has variables for 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);

    }
}
```

- 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
```

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.,

```
private 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.,

```
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 variables?

b. What are the instance 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

Practice Problems:

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