Objectives

- Jar Files
- Classpaths
- Abstract Classes
- Interfaces
- Collections

JAR FILES

Jar (Java **Ar**chive) Files

- Archives of Java files
- Package code into a neat bundle to distribute
  - Easier, faster to download
  - Easier for others to use
- `jar` command: create, view, and extract Jar files
  - Works similarly to `tar`
- Run jar file using `java`

```
java -jar myapplication.jar
```

Jar/Tar Commands

- Common options:

Option/ Operations	Meaning
f	The name of the archive **f**ile
c	**C**reate an archive file
x	E**x**tract the archive file
v	**V**erbose
z	**Z**ip (compress)
t	**T**able of contents (list contents)

- Common use:
  - `jar cfz code.jar.gz class_files_directory`
  - `jar xfz code.jar.gz`

Typical Scenario with Jar Files

- “I want to use this third-party (not part of Java library) library in my code”
- You have a *jar* file of the code
- You then add the jar file to your ***classpath***

CLASSPATH

Classpath

- Tells the compiler or JVM where to look for user-defined classes and packages (jar files)
  - Often when using third-party libraries
- Similar to `PYTHONPATH`
- Typically know it needs to be set when there are "Class not found" error messages in your code but you have the appropriate import

Setting the Classpath

- Can specify classpath in command line

```
javac -cp path/to/myjavaclasses MyClass.java
java –cp path/to/myjavaclasses MyClass
```

Can be .class files or jar files

- Can specify the classpath environment variable
  - Edit your `.bash_profile` (or similar) OR
  - Set in terminal

```
CLASSPATH=$CLASSPATH:path/to/myjavaclasses
echo $CLASSPATH
```

Current value of CLASSPATH

Review

- How do we make a class inherit from a parent class?
- How does a class refer to its parent class?
- What does a class inherit from its parent class?
  - What is *not* inherited?
- What are the access modifiers, ordered from least restrictive to most restrictive?
  - What should you consider to know which modifier to use when you make a field? A method?
- How does Java decide which method to call on an object?
  - Example: `chicken[1].feed();`
  - Give name of how decision is made and explain how it works
- Not from last class, before that:
  - How can we check that an object variable is a certain type?
  - How can we specify that an object variable has a different type (e.g., a derived type)?
- Review from Python
  - What are abstract classes and interfaces?
  - How are they useful?

PREVENTING INHERITANCE

Preventing Inheritance: `final` Class

- If you have a class and you do **not** want child/derived classes, you can define the class as `final`

```
public final class Rooster extends Chicken {
        . . .
}
```

- Examples of `final` class: `java.lang.System and java.lang.String`

Preventing Overriding: final Method

- If you don’t want child classes to override a method, you can make that method final

```
class Chicken {
         . . .
         public final String getName() { . . . }
         . . .
}
```

Why would we want to make a method final?
What are possible benefits to us, the compiler, …?

Abstract Classes and Interfaces

Provide abstraction
→ Makes code easier to change, extend, maintain

Note I didn't say that they make code easier to implement or understand.
You need some more experience on that front.

ABSTRACT CLASSES

Abstract Classes

- Classes in that are not fully implemented are *abstract classes*
  - Often: some methods defined, others not defined
    - Partial implementation
  - `public abstract class ZooAnimal`
- Declared but not implemented methods are labeled as `abstract`

```
public abstract void exercise(Environment env);
```

Abstract Classes

- An abstract class can***not*** be instantiated
  - i.e., can’t create an object of that class
  - But can have a constructor!
- Child class of an abstract class can only be instantiated if it overrides and implements **every abstract method** of parent class
  - If child class does not override *all* abstract methods, it is **also abstract**

Abstract Classes

- `static`, `private`, and `final` methods cannot be `abstract`
  - Because cannot be overridden by a child class
- `final` class cannot contain abstract methods
  - Because class cannot be inherited
- A class can be abstract even if it has no abstract methods
  - Use when implementation is incomplete and is meant to serve as a parent class for class(es) that complete the implementation
- Can have array of objects of abstract class
  - JVM will use *dynamic dispatch* for methods

Summary: Defining Abstract Classes

➡ Define a class as `abstract` when have *partial implementation*

- Typically used as a base class for a bunch of classes

INTERFACES

Interfaces

- Pure specification, no implementation
    - A set of requirements for classes to conform to

- Classes can *implement* one *or more* interfaces

A Scenario

- We have a Customer Service Driver program
- Depending on the circumstances, we may want to use different algorithms to determine the service order
- Possible algorithms
  - FIFO
  - HighestPayingFirst
  - CriticalProblemFirst
  - ShortestJobFirst

Design Solution

- Interface `CustomerServiceOrder`
  - `public Customer getNextCustomer();`
  - `public boolean hasNext();`
- Driver program snippet

```
CustomerServiceOrder customerOrder = …;
while( agent.isAvailable() ) {
    if( customerOrder.hasNext() ) {
        Customer next = customerOrder.getNextCustomer();
        agent.handle( next );
    }
}
```

Design Solution

- Classes adhere to (i.e., *implement*) the interface, implementing different algorithms
  - FIFOOrder
  - HighestPayingFirstOrder
  - CriticalProblemFirstOrder
  - ShortestJobFirstOrder
- Assign objects of any of these types to the interface variable

```
CustomerServiceOrder customerOrder = new FIFOOrder();
while( agent.isAvailable() ) {
    if( customerOrder.hasNext() ) {
        Customer next = customerOrder.getNextCustomer();
        agent.handle( next );
    }
}
```

Easily change program behavior with only one change in code

Interface Definitions

- Example: define an interface for an object that is capable of moving:

```
public interface Movable {
        void move(double x, double y);
}
```

- Interface methods are `public` by default
  - Do not *need* to specify methods as `public`

Constants in an Interface

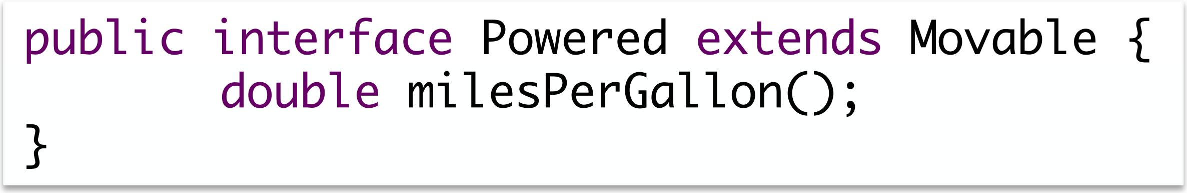
- If a variable is specified in an interface, it is automatically a constant:
  - `public static final variable`

```
public interface Powered extends Movable {
      double SPEED_LIMIT = 95;
      double milesPerGallon();
}
```

- Example: An object that implements `Powered` interface has a constant `SPEED_LIMIT` defined

Interface Definitions and Inheritance

- Can extend interfaces
  - Allows a chain of interfaces that go from general to more specific
- Example:



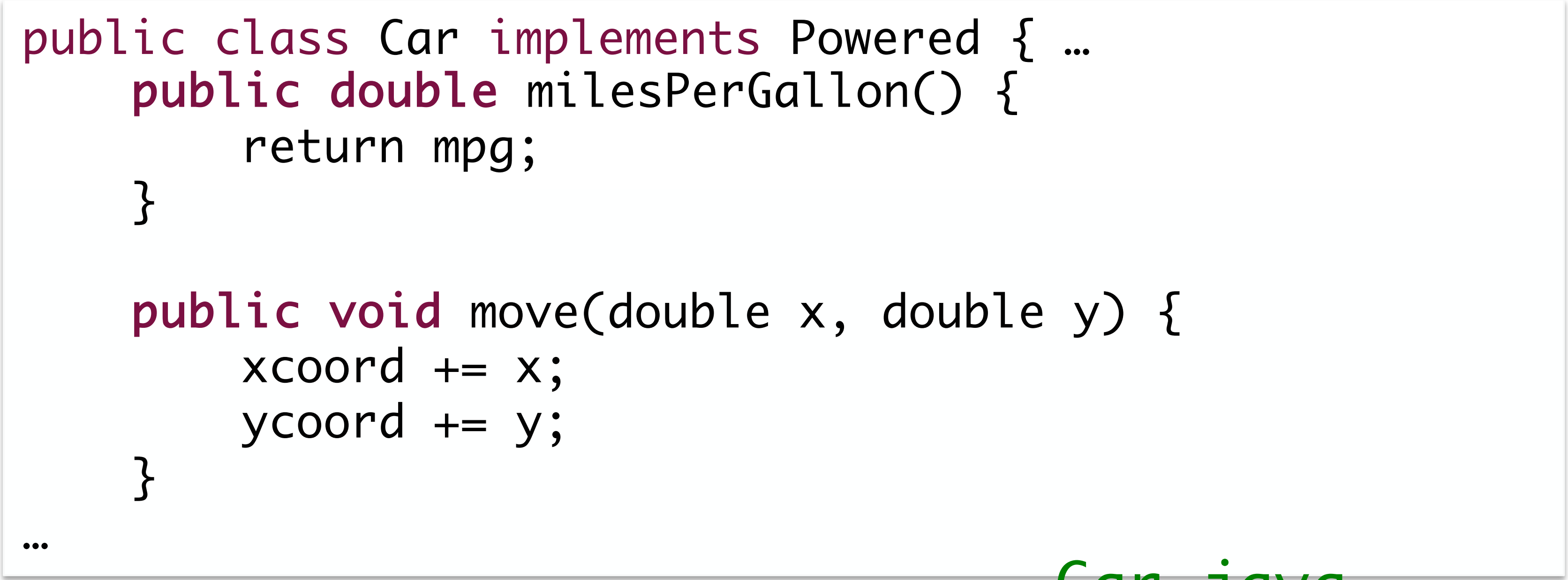
```
public interface Powered extends Movable {
        double milesPerGallon();
}
```

  - A class that implements the Powered interface must have a `milesPerGallon` and `move` method

`Car.java`

Class Implements Interface

- Class needs to implement all methods declared in the interface



```
public class Car implements Powered { …
    public double milesPerGallon() {
        return mpg;
    }

    public void move(double x, double y) {
        xcoord += x;
        ycoord += y;
    }
…
```

Car.java

Multiple Interfaces

- A class can implement *multiple* interfaces
  - Must fulfill the requirements of each interface

```
public final class String implements
      Serializable, Comparable, CharSequence { …
```

- Recall: NOT possible with inheritance
  - A class can only extend (or inherit from) **one** class

Testing for Interfaces

- Can also use the `instanceof` operator to see if an object implements an interface
  - e.g., to determine if an object is movable

```
if (obj instanceof Movable) {
        // runs if obj is an object variable of a class
        // that implements the Movable interface
}
else {
        // runs if obj does not implement the interface
}
```

Interface Object Variables

- Can use an object variable to refer to an object of any class that implements an interface
- Using this object variable, can only access the interface’s methods
- For example…

```
public void aMethod(Object obj) {
    …
    if (obj instanceof Movable) {
          Movable mover = (Movable) obj;
          mover.move(x, y);
    }
}
```

Comparable Interface

- Implemented by String and many other classes
- Uses ***Generics***!
- Interface declaration:

```
public interface Comparable<T>
```

- Declared method:

```
int compareTo(T o)
```

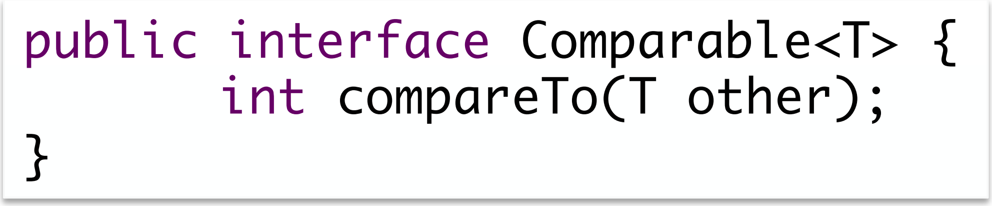
The type it compares

Comparable Interface API/Javadoc

- Specifies what the compareTo method should do
- Says which Java library classes implement Comparable

https://docs.oracle.com/en/java/javase/17/docs/api/java.base/java/lang/Comparable.html

java.lang.Comparable



```
public interface Comparable<T> {
        int compareTo(T other);
}
```

- Any object that implements Comparable must have a method named compareTo()
- Returns:
    - Return a negative integer if this object is less than the object passed as a parameter
    - Return a positive integer if this object is greater than the object passed as a parameter
    - Return a 0 if the two objects are equal

Example Use of an Interface

- Recall: `Arrays.sort(array)`
  - `Arrays.sort` sorts arrays of *any* Object class that implements the `Comparable` interface
    - Overloaded method, so can also pass in arrays of primitive types
- Classes that implement the `Comparable` interface must provide a way to decide if one object is less than, greater than, or equal to another object via the `compareTo` method

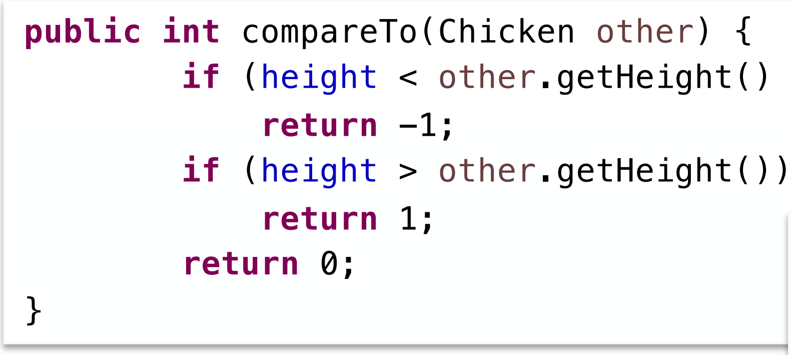
Implementing an Interface with Generics

- In the class definition, specify that the class will implement the interface and specify its type it will accept/operate on.

```
public class Chicken implements Comparable<Chicken>
```

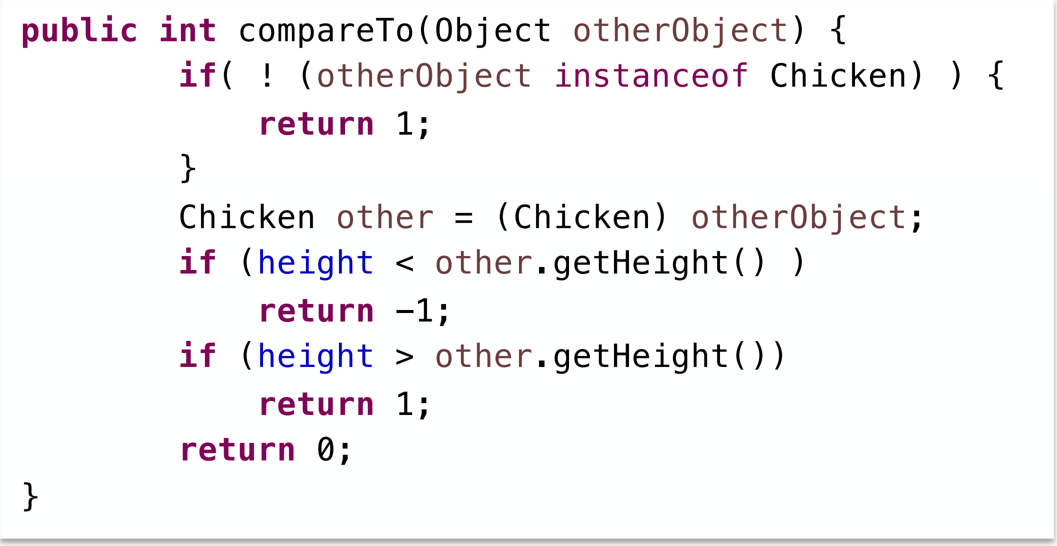
Generics in Comparable

With Generics



```java
public int compareTo(Chicken other) {
        if (height < other.getHeight() )
            return -1;
        if (height > other.getHeight())
            return 1;
        return 0;
}
```

Without Generics



```java
public int compareTo(Object otherObject) {
        if( ! (otherObject instanceof Chicken) ) {
            return 1;
        }
        Chicken other = (Chicken) otherObject;
        if (height < other.getHeight() )
            return -1;
        if (height > other.getHeight())
            return 1;
        return 0;
}
```

Chicken.java

Interface Summary

- Contain only object (*not class*) methods
- All methods are `public`
  - Implied if not explicit
- Fields are constants that are `static` and `final`
- A class can implement multiple interfaces
  - Separated by commas in definition

Benefits of Interfaces

- Abstraction
  - Separate the *interface* from the *implementation*
- Allow easier type substitution
- Classes can implement multiple interfaces

Comparing Interfaces and Abstract Class

Interfaces

- No implementation
- Any class can use
  - (b/c classes can implement multiple interfaces)
- May need to implement methods multiple times
- Adding a method to interface will break classes that implement interface

Abstract Classes

- Contain partial implementation
- Child classes can’t extend/subclass multiple classes
- Can add non-abstract methods without breaking child classes

One Option: Use Both!

- Define interface, e.g., `MyInterface`
- Define abstract class, e.g., `AbstractMyInterface`
  - Implements interface
  - Provides implementation for some methods

Abstract Classes and Interfaces

- Important structures in Java
  - Make code easier to change
- Will return to/apply these ideas throughout the course
- Concepts are used in many languages besides Java

COLLECTIONS

Collections

- Sometimes called ***containers***
- Group multiple elements into a single unit
- Store, retrieve, manipulate, and communicate aggregate data
- Represent data items that form a natural group
  - Poker hand (a collection of cards)
  - Mail folder (a collection of messages)
  - Telephone directory (a mapping of names to phone numbers)

Java Collections Framework

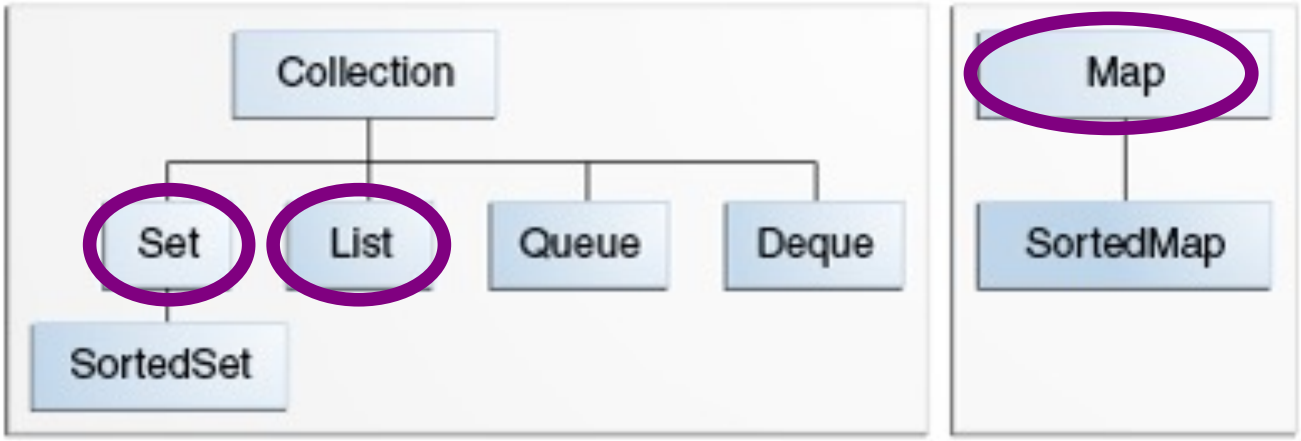
- *Unified architecture* for representing and manipulating collections
- More than arrays
  - More flexible, functionality, dynamic sizing
- In `java.util` package

Collections Framework

- **Interfaces**
  - Abstract data types that represent collections
  - Collections can be manipulated *independently* of implementation
- **Implementations**
  - Concrete implementations of collection interfaces
  - Reusable data structures
- **Algorithms**
  - Methods that perform useful computations on collections, e.g., searching and sorting
  - Reusable functionality
  - ***Polymorphic***: same method can be used on many different implementations of collection interface

Core Collection Interfaces

- Encapsulate different types of collections



LISTS

List Interface

- An *ordered* collection of elements
- Can contain duplicate elements
- Has control over where objects are stored in the list

`List` Interface

- `boolean add(<E> o)`
  - Returns boolean so that List can refuse some elements
    - e.g., refuse adding `null` elements
- `<E> get(int index)`
  - Returns element at the position index
  - Different from Python: no shorthand
    - Can't write ~~`list[pos]`~~
- `int size()`
  - Returns the number of elements in the list
- And more!
  - `contains`, `remove`, `toArray`, …

`List` Interface

<E>: Generics!

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Common List Implementations

- ArrayList
  - Resizable array
- LinkedList

When should you use one vs the other?

How would you find the other implementations of List?

Common `List` Implementations

- `ArrayList`
  - Resizable array
  - Used most frequently
  - Fast

- `LinkedList`
  - Use if adding elements to ends of list
  - Use if often delete from middle of list
  - Implements `Deque` and other methods so that it can be used as a stack or queue

How would you find the other implementations of `List`?

API Notes

- `ArrayList` and `LinkedList` extend from `AbstractList`, which implements `List` interface

Assignment 4

- Start of a simple video game
  - Game class to run
  - GamePiece is parent class of other moving objects
- Can complete everything now
- Due Wednesday before class