Announcements

Midterm 1 is Monday, 2/12, 8-10PM.

- Details here: https://piazza.com/class/j9j0udrxjjp758?cid=1105
- Closed note, except you can bring one front/back handwritten sheet.
- Bring your Berkeley student ID (if you have one).
- Covers material up through inheritance3 (2/7, Wednesday's lecture).

Exam studying:

- Midterm 1 Review Session on Friday 2/9, 8-10PM in 155 Dwinelle
- Midterm 1 Guerilla Section on Saturday 2/10, 12-2PM in 271-275 Soda
- Lecture next Monday will also be an AMA/review thing.

CS61B: 2018

Lecture 11: Libraries

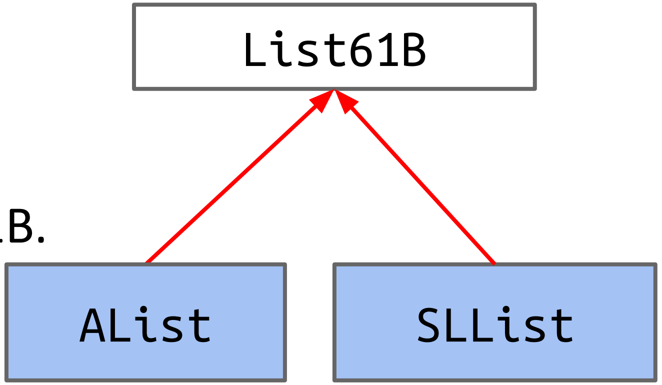
- Java Libraries
- Interfaces and Abstract Classes
- Packages

Java Libraries

Main Story of the Course (so far): Implementing Abstract Data Types

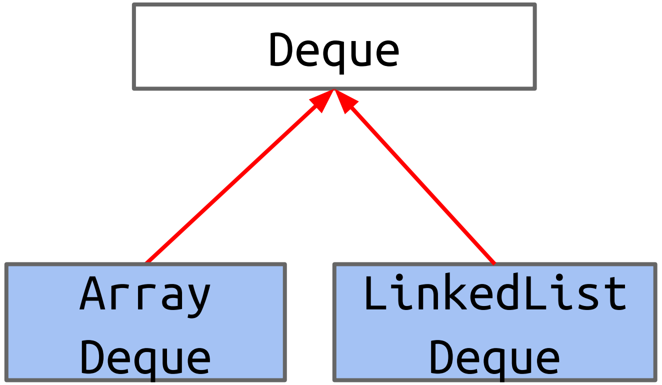
In Lecture:

- Developed ALists and SLLists.
- Created an interface List61B.
  - Modified AList and SLList to implement List61B.
  - List61B provided default methods.



In Projects:

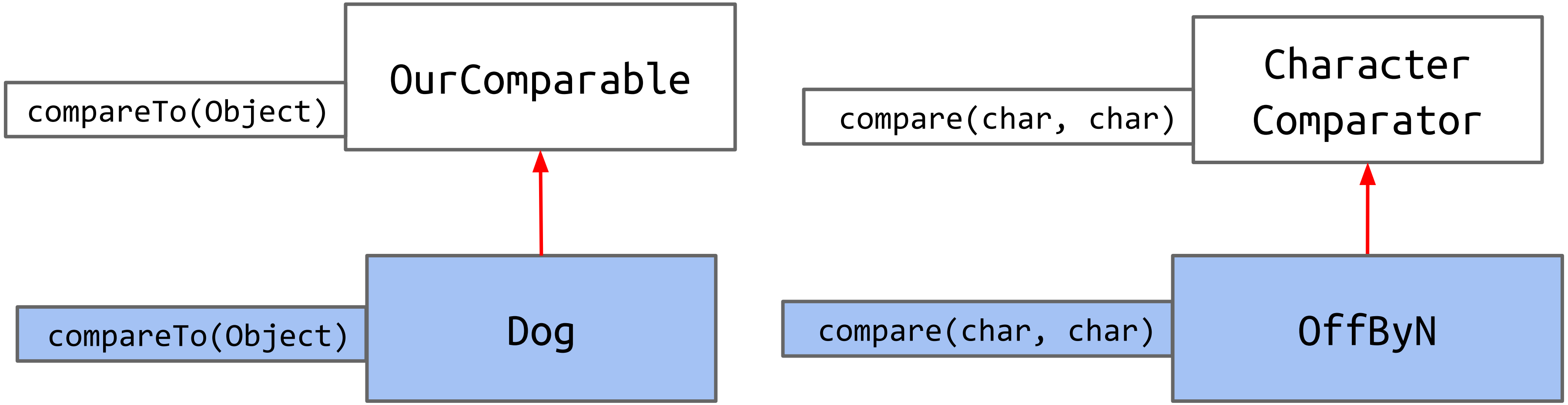
- Developed ArrayDeque and LinkedListDeque.
- Created an interface Deque.
  - Modified AD and LLD to implement Deque.



Side Story: Interface Inheritance for Comparison

Two more uses for interfaces:

- Specify a contract for common behavior shared by many data structures (e.g. implementing OurComparable means Dogs can be compared).
- Provide a way to containerize common functions (e.g. the OffByN CharacterComparator lets us compare two characters in a special way).

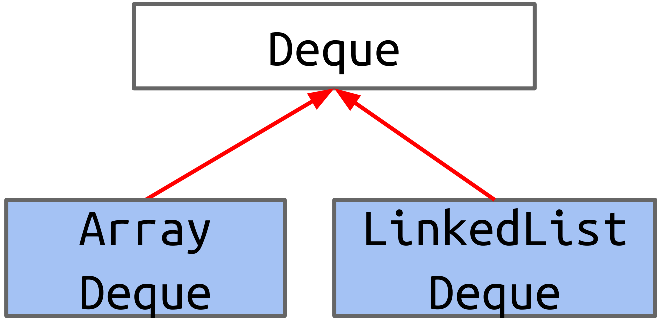


Abstract Data Types

An **Abstract Data Type (ADT)** is defined only by its operations, not by its implementation.

Deque ADT:

- `addFirst(Item x);`
- `addLast(Item x);`
- `boolean isEmpty();`
- `int size();`
- `printDeque();`
- `Item removeFirst();`
- `Item removeLast();`
- `Item get(int index);`



ArrayDeque and LinkedList Deque are implementations of the Deque ADT.

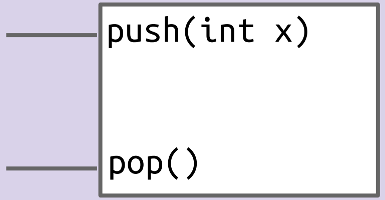
The Stack ADT: yellkey.com/stuff

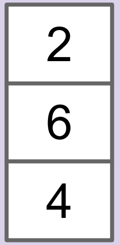
The Stack ADT supports the following operations:

- push(int x): Puts x on top of the stack.
- int pop(): Removes and returns the top item from the stack

Which implementation do you think would result in faster overall performance?

A. Linked List
B. Array





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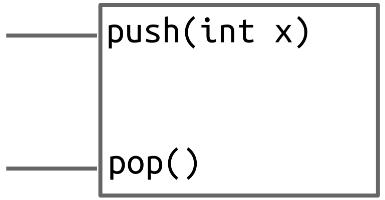
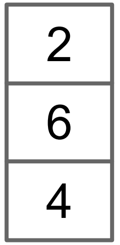




Both are about the same. No resizing for linked lists, so probably a lil faster.

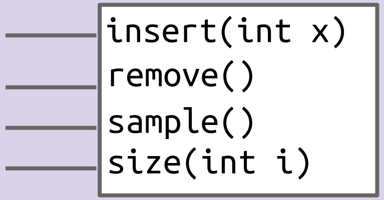
The GrabBag ADT: yellkey.com/yet

The GrabBag ADT supports the following operations:

- insert(int x): Inserts x into the grab bag.
- int remove(): Removes a random item from the bag.
- int sample(): Samples a random item from the bag (without removing!)
- int size(): Number of items in the bag.

Which implementation do you think would result in faster overall performance?

A. Linked List
B. Array



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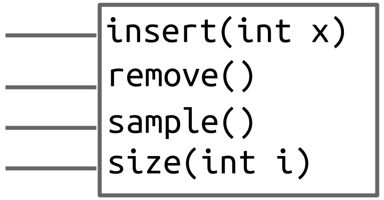
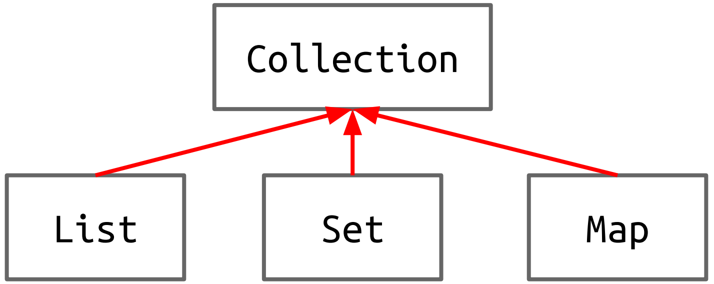


Collections

Among the most important interfaces in the java.util library are those that extend the Collection interface (btw interfaces can extend other interfaces).

- Lists of things.
- Sets of things.
- Mappings between items, e.g. jhug's grade is 88.4.
  - Maps also known as associative arrays, associative lists (in Lisp), symbol tables, dictionaries (in Python).

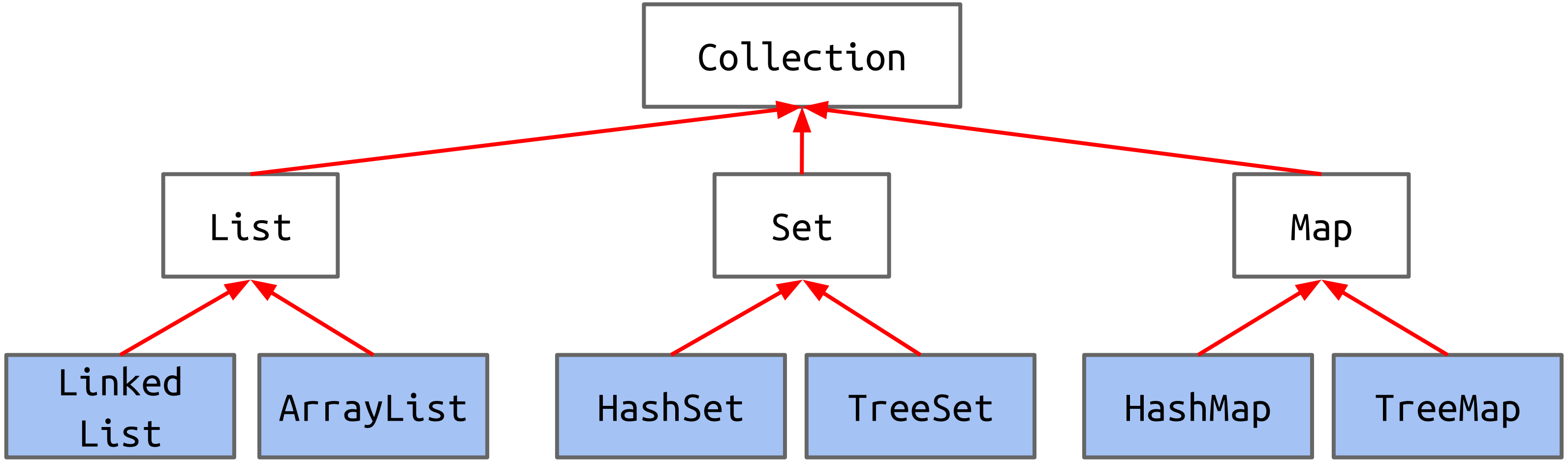


Java Libraries

The built-in java.util package provides a number of useful:

- Interfaces: ADTs (lists, sets, maps, priority queues, etc.) and other stuff.
- Implementations: Concrete classes you can use.

Let's try them out (next slide).



Tasks

3 tasks, given the text of a book:

- Create a list of all words in the book.
- Count the number of unique words.
- Keep track of the number of times that specific words are mentioned.

Example: Using a Set to Count Unique Words

```
public static int countUniqueWords(List<String> words) {
    Set<String> ss = new HashSet<>();
    for (String s : words) {
        ss.add(s);
    }
    return ss.size();
}
```

$\}$ This is known as an "enhanced for loop" or sometimes a foreach loop.

```
public static int countUniqueWords(List<String> words) {
    Set<String> ss = new HashSet<>();
    ss.addAll(words);
    return ss;
}
```

Example: Using a Map to Create Counts of Specific Words

```java
public static Map<String, Integer>
        collectWordCount(List<String> words, List<String> targets) {
    Map<String, Integer> wordCounts = new HashMap<>();
    for (String s : targets) {
        wordCounts.put(s, 0);
    }
    for (String s : words) {
        if (wordCounts.containsKey(s)) {
            int oldCount = wordCounts.get(s);
            wordCounts.put(s, oldCount + 1);
        }
    }
    return wordCounts;
}
```

Java vs. Python

```java
public static Map<String, Integer>
        collectWordCount(List<String> words, List<String> targets) {
    Map<String, Integer> wordCounts = new HashMap<>();
    for (String s : targets) {
        wordCounts.pu
    }
    for (String s : w
        if (wordCount
            int oldCou
            wordCounts
        }
    }
    return wordCounts
}
```

```python
def find_word_count(words, targets):
    word_counts = {}
    for s in targets:
        word_counts[s] = 0

    for s in words:
        if s in word_counts:
            word_counts[s] += 1

    return word_counts
```

Java vs. Python

In every language, there are some features that are “first class citizens”.

- Often a special syntax for creating and using such objects.

Sets, dictionaries, tuples and lists in Python have special syntax.

- These collections to not have a special syntax in Java.
- Idea of “collection literals” was scrapped in 2014.

```
num_legs = {"horse": 4, "dog":
4, "human": 2, "fish": 0}
```

```
Map<String, Integer> numLegs =
new TreeMap<>();
numLegs.put("horse", 4);
numLegs.put("dog", 4);
numLegs.put("human", 2);
numLegs.put("fish", 0);
```

Java vs. Python

In Java, programmer can decide which *implementation* of an *abstract data type* that they want to use.

- Allows power user to explicitly handle engineering tradeoffs.

Example: Basic Hashmaps ops are faster than TreeMaps, but TreeMaps provide efficient operations that involve order (e.g. get all keys less than).

```
Map<String, Integer> numLegs =
new HashMap<>();
numLegs.put("horse", 4);
numLegs.put("dog", 4);
numLegs.put("human", 2);
numLegs.put("fish", 0);
```

```
Map<String, Integer> numLegs =
new TreeMap<>();
numLegs.put("horse", 4);
numLegs.put("dog", 4);
numLegs.put("human", 2);
numLegs.put("fish", 0);
```

Factory Methods for Collections (in Java 9)

In Java 9, factory methods were added to the language.

- Example: `Set<Integer> S = Set.of(3, 4, 5, 6);`
- Similar to `IntList.of()`.
- Allows you to create immutable collections in one line.
  - Cannot add or remove items!
- Underlying implementation is hidden from user (don't know your map is `HashMap`, a `TreeMap`, or something else).

```
Map<String, Integer> numLegs =
new HashMap<>();
numLegs.put("horse", 4);
numLegs.put("dog", 4);
numLegs.put("human", 2);
numLegs.put("fish", 0);
```

```
Map<String, Integer> numLegs =
Map.of("horse", 4, "dog", 4,
"human", 2, "fish", 0);
```

Why Java in 61B?

Arguably, takes less time to write programs, due to features like:

- Static types (provides type checking and helps guide programmer).
- Bias towards interface inheritance leading to cleaner subtype polymorphism.
- Access control modifiers make abstraction barriers more solid.

More efficient code, due to features like:

- Ability to have more control over engineering tradeoffs.
- Single valued arrays lead to better performance.

Basic data structures more closely resemble underlying hardware:

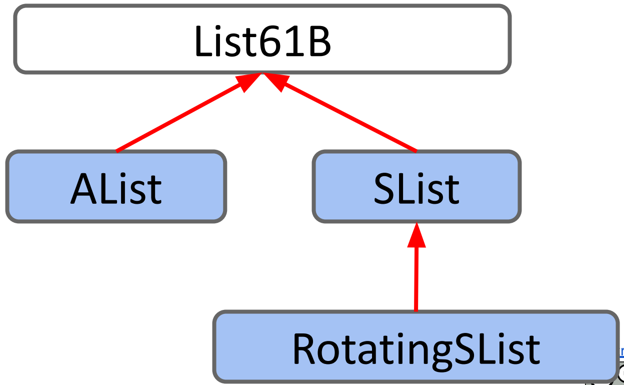
- Would be weird to do ArrayDeque in Python, since there is no need for array resizing. However, in hardware (see 61C), variable length arrays don't exist.

Interfaces and Abstract Classes

Inheritance Summary (So Far)

In the last three lectures we've seen how implements and extends can be used to enable **interface inheritance** and **implementation inheritance**.

- Interface inheritance: What (the class can do).
- Implementation inheritance: How (the class does it).



A Closer Look at Interfaces

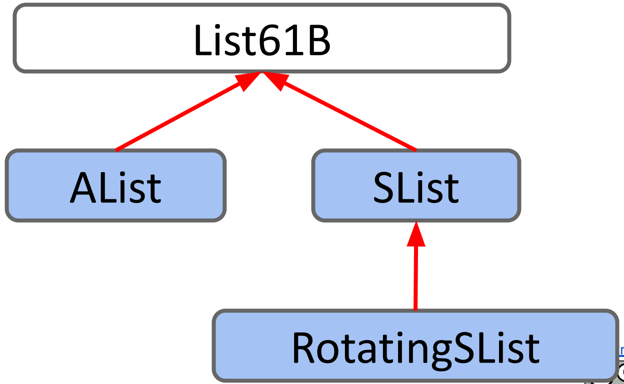
Interfaces may combine a mix of **abstract** and **default** methods.

- Abstract methods are **what**. And must be overridden by subclass.
- Default methods are **how**.

Not explicitly mentioned on a slide before:

- Unless you use the keyword **default**, a method will be **abstract**.
- Unless you specify an access modifier, a method will be **public**.

```
public interface List61B<Item> {
   void insertFront(Item x);
   ...
   default public void print() { ... }
}
```

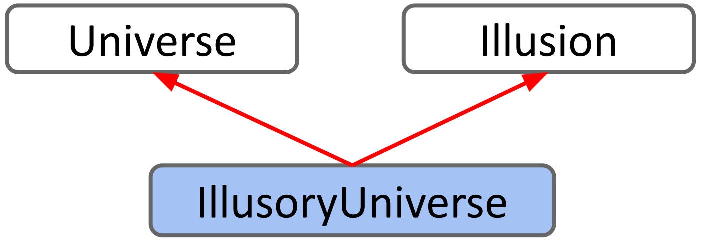


Interfaces, Even More

More interface details:

- Can provide variables, but they are **public static final.**
  - final means the value can never change. Use for constants: G=6.67e-11
- A class can implement multiple interfaces.

```
public interface Universe {
    double gravity = 6.67e-11;
    void update(double dt);
    ...
    default void draw() { ... }
}
```



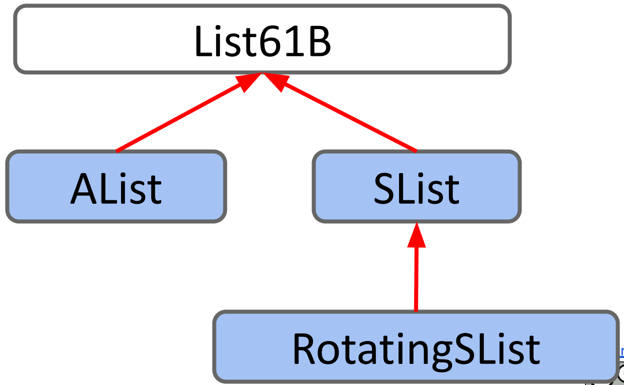
Interface Summary

Interfaces:

- Cannot be instantiated.
- Can provide either **abstract** or **concrete** methods.
    - Use no keyword for abstract methods.
    - Use **default** keyword for concrete methods.
- Can provide only public static final variables.

no instance variables

Java 9 added private methods to interfaces.



Introducing: Abstract Classes

Abstract classes are an intermediate level between interfaces and classes.

- Cannot be instantiated.
- Can provide either **abstract** or **concrete** methods.

Similarities

  - Use **abstract** keyword for abstract methods.
  - Use no keyword for concrete methods.

opposite of interfaces

- Can provide variables (any kind).
- Can provide protected and package private methods [after mt1].

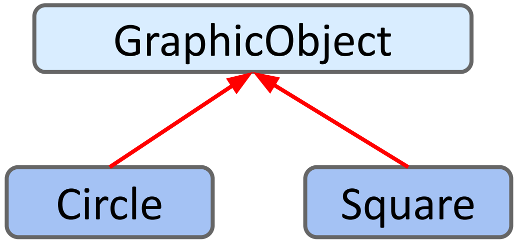
Differences

```java
public abstract class GraphicObject {
    public int x, y;
    ...
    public void moveTo(int newX, int newY) { ... }
    public abstract void draw();
    public abstract void resize();
}
```

Example (From Oracle’s Abstract Class Tutorial)

```
public abstract class GraphicObject {
    public int x, y;
    ...
    public void moveTo(int newX, int newY) { ... }
    public abstract void draw();
    public abstract void resize();
}
```

```
public class Circle extends GraphicObject {
    public void draw() { ... }
    public void resize() { ...  }
}
```



Implementations must override ALL abstract methods.

http://yellkey.com/trouble

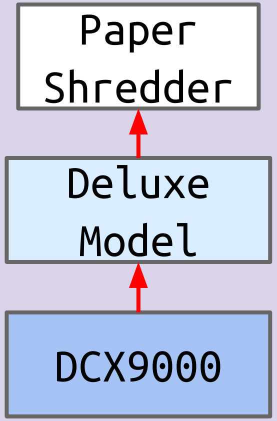
```
public interface PaperShredder {
   void shred(Document d);
   void shredAll(Document[] d);
}
```

```
public abstract class DeluxeModel
      implements PaperShredder {
   public int count = 0;
   public void count() { return count; }

   public shredAll(Document[] d) {
      for (int i = 0; i < d.length; d += 1) {
          shred(d);
      }
   }
   public abstract void connectToWifi();
}
```

How many abstract methods **must** DCX9000 override?

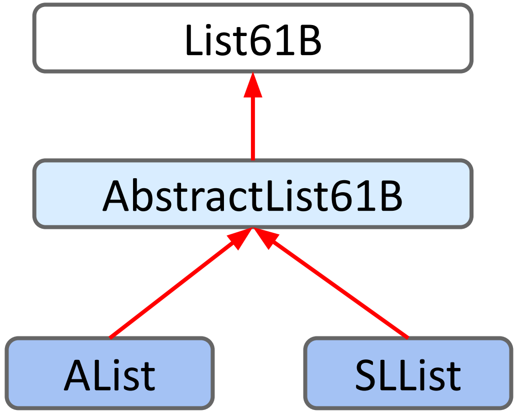
A. 0
B. 1
C. 2
D. 3



Common Use Case: Providing Basics for Interface Implementation

```java
public abstract class AbstractList61B<T>
                 implements List61B<T> {
    int size = 0;
    public AbstractList61B() { size = 0; }
    @Override
    public int size() {
        return size;
    }
}
```

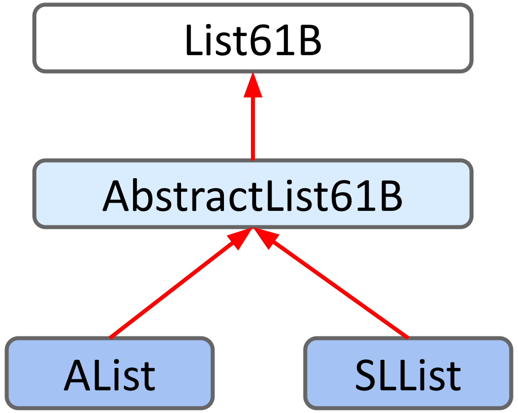
```java
public class AList<T>
             extends AbstractList61B<T> { ...
```



Common Use Case: Providing Basics for Interface Implementation

Abstract classes are often used as partial implementations as interfaces.

- Good: Avoids the need to write a `size()` method or declare a size variable in `AList` and `SLList`.
- Bad: Starts getting confusing to understand where things are defined. May make too strong constraints on the implementations of our concrete classes (e.g. maybe you don’t want a `size` variable).



Summary: Abstract Classes vs. Interfaces

Interfaces:

- Primarily for interface inheritance. Limited implementation inheritance.
- Classes can implement multiple interfaces.

Abstract classes:

- Can do anything an interface can do, and more.
- Subclasses only extend one abstract class.

In my opinion, you should generally prefer interfaces whenever possible.

- Why? More powerful programming language constructs introduce complexity.
- If you're curious, see Oracle's examples of when to use each.

Where Abstract Classes Are Used in Java Standard Libraries

A more accurate hierarchy for lists is shown below.

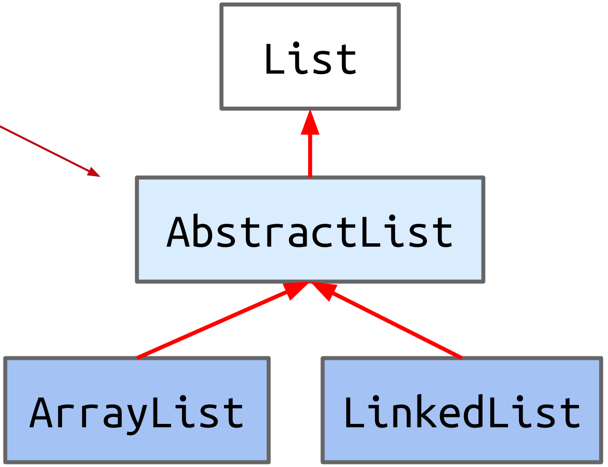
- AbstractList provides default implementations for methods.
- Why not just put them in List itself? No default methods in Java interfaces until 2014, and the AbstractList was public so can't just throw it away.

```
public abstract class AbstractList<E>
   implements List<E> {

    ...

   public boolean add(E e) {
       add(size(), e);
       return true;
   }
}
```

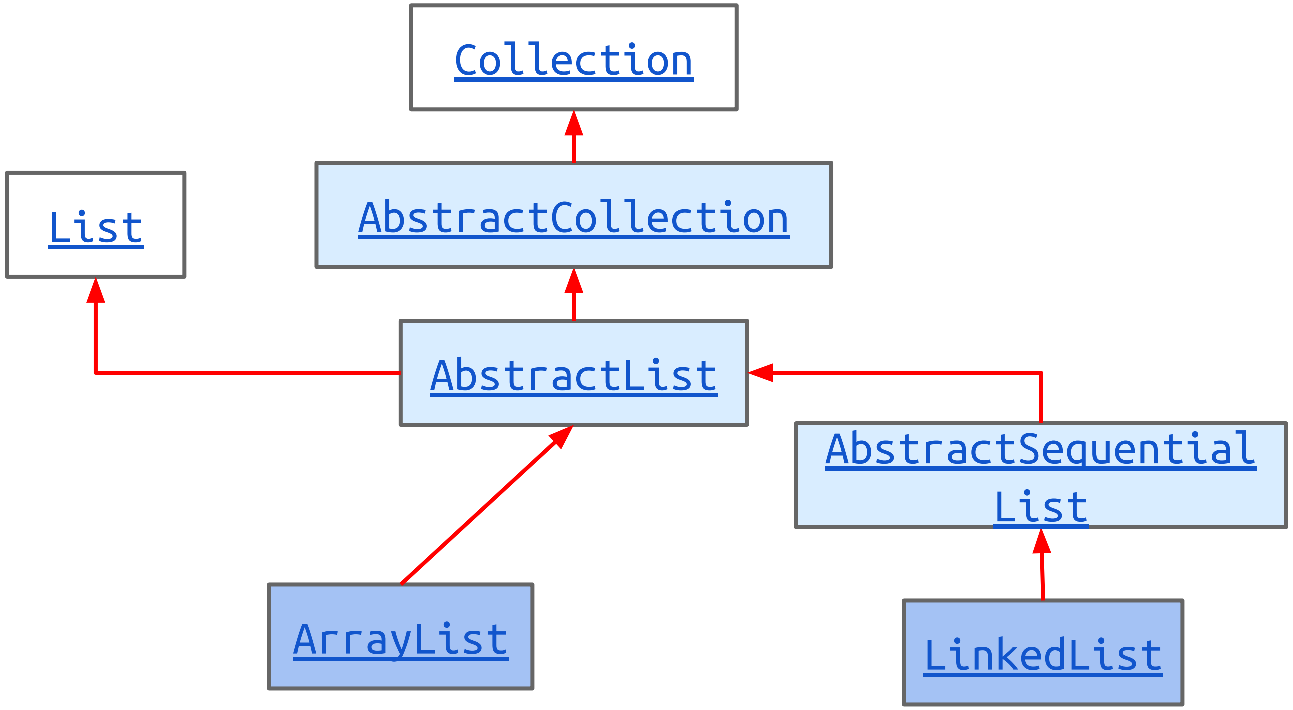
Not absolutely necessary. Default methods could have been in List interface instead.



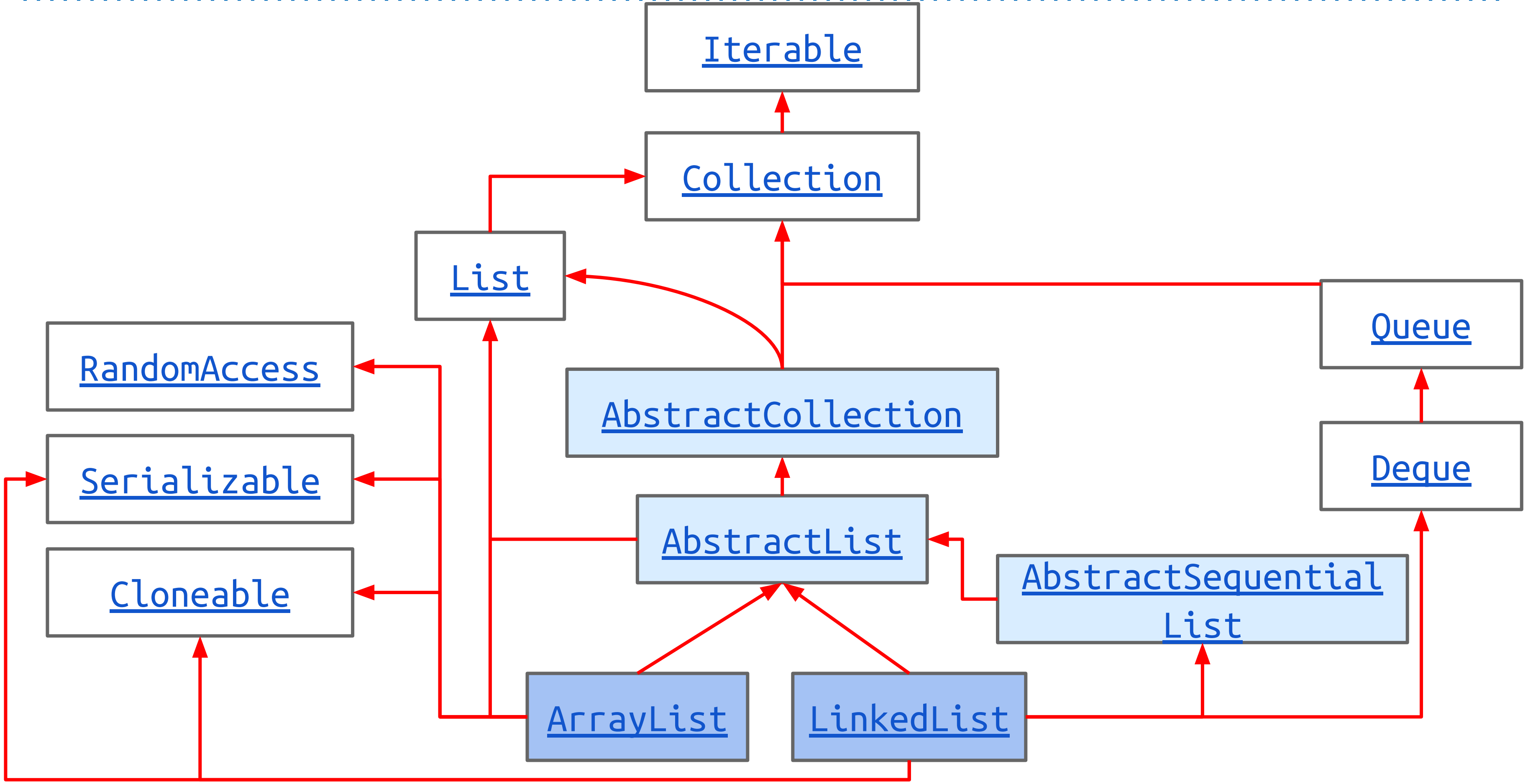
Where Abstract Classes Are Used in Java Standard Libraries

(Most of) the real list hierarchy is shown below.

- This isn't important, but you might find it interesting.
- Click links if you want to browse the source code.



The Whole Shebang



Packages

The Zen of Python

- Beautiful is better than ugly.
- Explicit is better than implicit.
- Simple is better than complex.
- Complex is better than complicated.
- Flat is better than nested.
- Sparse is better than dense.
- Readability counts.
- Special cases aren't special enough to break the rules.
- Although practicality beats purity.
- Errors should never pass silently.
- Unless explicitly silenced.
- In the face of ambiguity, refuse the temptation to guess.
- There should be one-- and preferably only one --obvious way to do it.
- Although that way may not be obvious at first unless you're Dutch.
- Now is better than never.
- Although never is often better than *right* now.
- If the implementation is hard to explain, it's a bad idea.
- If the implementation is easy to explain, it may be a good idea.
- Namespaces are one honking great idea -- let's do more of those!

Canonicalization

What we'd really like is the ability to provide a canonical name for everything.

- ***Canonical representation***: A unique representation for a thing.
- Not-canonical: License plate number (can be reused, can change).
- Canonical: The VIN number JYA3AWC04VA071286 (refers to a specific motorcycle).

In Java, we (attempt to) provide canonicity through by giving every a class a "package name".

- A package is a ***namespace*** that organizes classes and interfaces.
- Today is just a brief look. We'll talk more about packages in two weeks.
- In HW1, after the midterm, we'll make our own.

Packages

To address the fact that classes might share names:

We won't follow this rule. Our code isn't intended for distribution.

- A package is a ***namespace*** that organizes classes and interfaces.
- Naming convention: Package name starts with website address (backwards).

```java
package ug.joshh.animal;

public class Dog {
    private String name;
    private String breed;
    private double size;
```

Dog.java

If used from the outside, use entire ***canonical name***.

```java
ug.joshh.animal.Dog d =
     new ug.joshh.animal.Dog(...);
```

```java
org.junit.Assert.assertEquals(5, 5);
```

If used from another class in same package (e.g. ug.joshh.animal.DogLauncher), can just use ***simple name***.

Importing Classes

Typing out the entire name can be annoying.

- Entire name:

```
ug.joshh.animal.Dog d =
     new ug.joshh.animal.Dog(...);
```

- Can use import statement to provide shorthand notation for usage of a single class in a package.

```
import ug.joshh.animal.Dog;
Dog d = new Dog(...);
```

- Wildcard import: Also possible to import multiple classes, but this is often a bad idea!
    - Use sparingly.

```
import ug.joshh.animal.*;
Dog d = new Dog(...);
```

Dangerous! Will cause compilation error if another * imported class contains Dog.

Importing Static Members

On the previous slide we saw how to import classes.

- Example:

```
import org.junit.Assert;
Assert.assertEquals(5, 5);
```

import static lets us import static members of a class.

- Example:

```
import static org.junit.Assert.assertEquals;
assertEquals(5, 5);
```

We've done this already. This is probably the only wildcard import that you should do in this course.

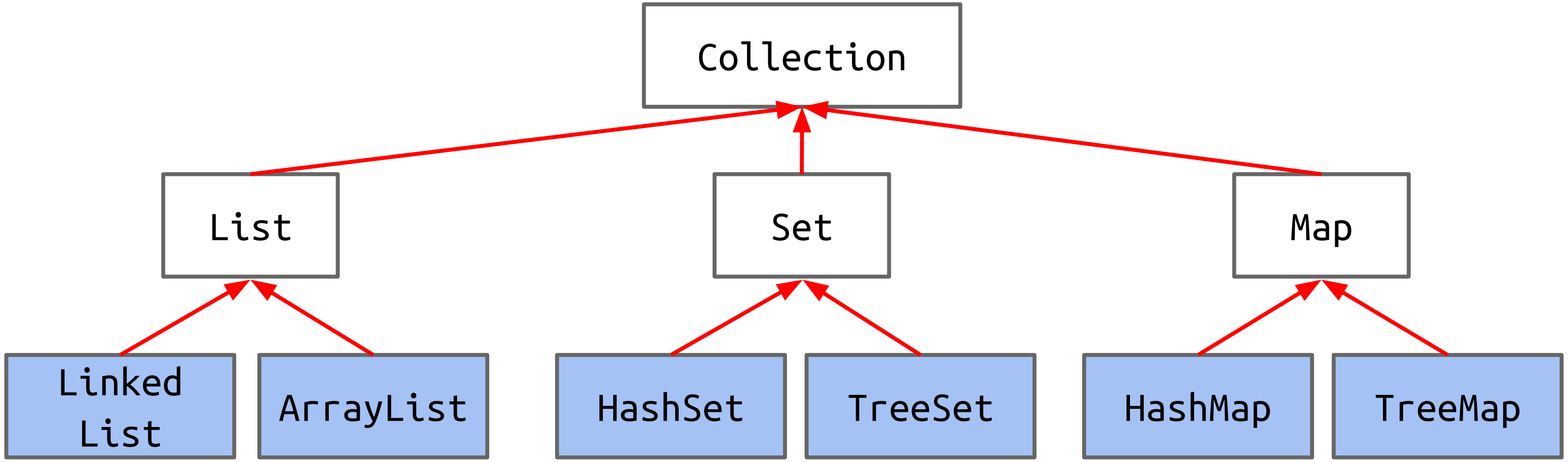
```
import static org.junit.Assert.*;
assertEquals(5, 5);
```

Unlikely that any other library will have any static members with same name as members in org.junit.Assert class

Summary: Java Libraries

The built-in java.util package provides a number of useful:

- Interfaces: ADTs (lists, sets, maps, priority queues, etc.) and other stuff.
- Implementations: Concrete classes you can use.

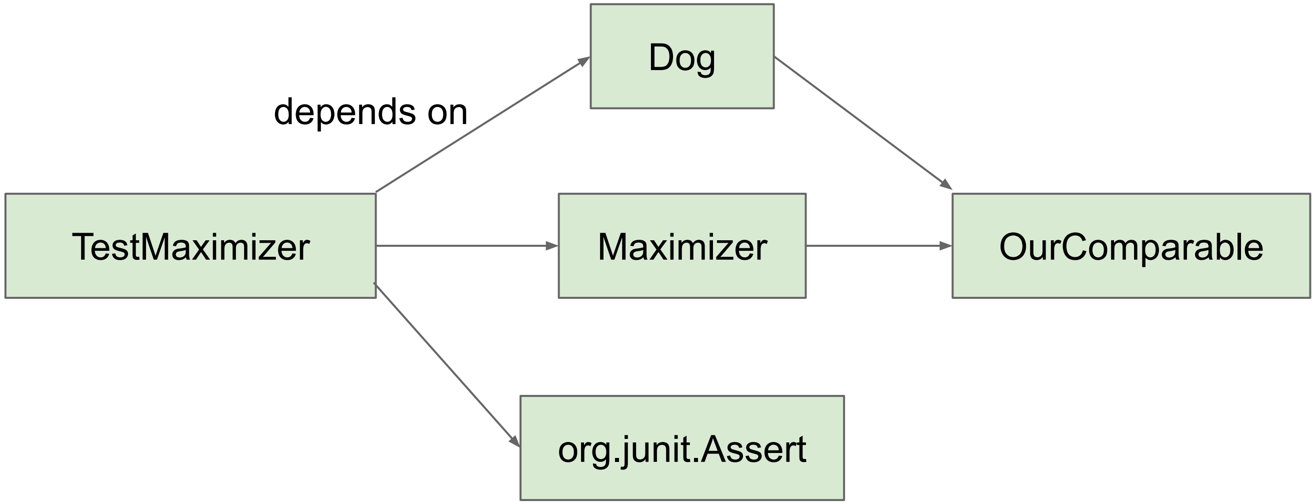


Extra Slides For Command Line Users (no video)

Dependencies

Java classes may be dependent on other classes.

- Dog depends on OurComparable.
- For Dog.java to compile, javac must know where OurComparable.class is.
- For Dog.class to execute, java must know where OurComparable.class is.

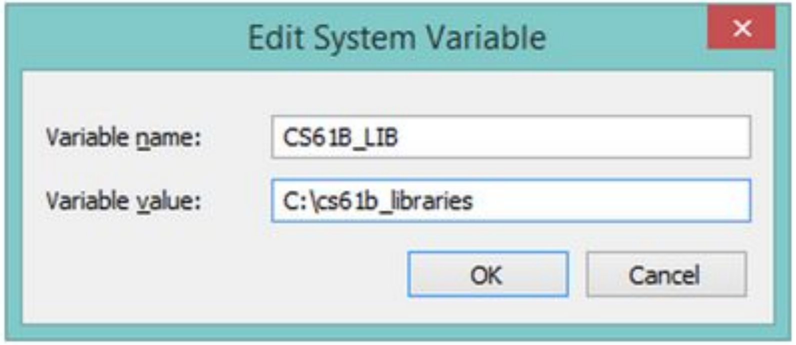


Libraries

At the beginning of the semester, we had you do a bunch of mysterious computer setup stuff in labs 1b, 2b, and 3b.

Question:

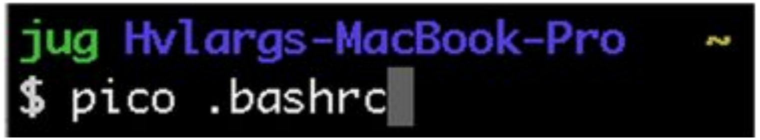
- **How does the Java compiler/interpreter know where to find the libraries we provide in the skeleton repo (e.g. JUnit)?**


Edit System Variable

Variable name: CS61B_LIB

Variable value: C:\cs61b_libraries

- **CLASSPATH:** Set this to `%CLASSPATH%;%CS61B_LIB%\*;.;`


```
jug Hvlargs-MacBook-Pro ~
$ pico .bashrc
```

3. Now add a line to the bottom of your .bashrc file that says **`export CLASSPATH="$CLASSPATH:$CS61B_LIB_DIR:./`**

   This creates an environment variable called CLASSPATH. Everytime you use javac, it will look

Environment Variables

Every program running on your computer has access to the system's "environment variables".

- Windows, Mac OS X, and Linux all provide this functionality.
- Environment variables are all strings.
- Every terminal window has its own environment variables.

Examples from my computer:

- CLASSPATH = `:/home/jug/course-materials-sp16/javalib/*:./`
- `LOGNAME=jug`
- `PWD=/home/jug/Dropbox/61b`

The Java compiler / interpreter (being programs) have access to these variables.

The CLASSPATH

Example from my computer:

- CLASSPATH = `:/home/jug/course-materials-sp16/javalib/*:./`

The Java compiler and interpreter assume there is an environment variable called CLASSPATH, and look in those folders for dependencies.

- In Linux or MacOS, paths are separated by : (colon)
- In Windows, paths are separated by ; (semi-colon)

With classpath above, java and javac check for dependencies in:

- `/home/jug/course-materials-sp16/javalib/*`
- `./`

./ means current directory
../ means directory one up

* means don't just look at .class files but also look inside any .jar file.

The World According to the Interpreter

The java interpreter:

- Gets a command line argument specifying the class to execute (e.g. EnvMap)
- Uses CLASSPATH variable to try to find that file (and dependencies).
  - Example: java looks for EnvMap.class and dependencies in two places:
    - `./`
    - `/Users/jug/work/61b/course-materials/lib/`

```
$ echo $CLASSPATH
:/Users/jug/work/61b/course-materials/lib/*:./
jug ~/work/lectureCode-sp16/lec12/examples
$ java EnvMap
Printing your environment variables:
TERM=xterm-16color
TERM_PROGRAM_VERSION=343
SHLVL=1
```

Paths may be:

- relative, e.g. `./`
- absolute

Note: The echo command is my OS's version of print.

Naming Conflicts. PollEv.com/jhug Text “jhug” to 37607

Suppose we have two copies of Dog.class:

1. ~/work/lectureCode-sp16/lec12/examples/weirdDog/Dog.class
2. ~/work/lectureCode-sp16/lec12/examples/Dog.class

If we run the following command with the CLASSPATH shown, what do you think happens?

A. Runtime error.
B. Random results.
C. Version #1 runs.
D. Version #2 runs.

```
$ echo $CLASSPATH
./weirdDog:./
jug ~/work/lectureCode-sp16/lec12/examples
$ java Dog
```

Reminder: The echo command prints out an environment variable on the next line.

Naming Conflicts Are Resolved in Classpath Order

Suppose we have two copies of Dog.class:

1. **~/work/lectureCode-sp16/lec12/examples/weirdDog/Dog.class**
2. ~/work/lectureCode-sp16/lec12/examples/Dog.class

If we run the following command with the CLASSPATH shown, what do you think happens?

C. Version #1 runs.

```
$ echo $CLASSPATH
./weirdDog:./
jug ~/work/lectureCode-sp16/lec12/examples
$ java Dog
```

Why? The classpath has two entries. At it happens, Java scans for .class folders in the order given, running the first one it finds.

The CLASSPATH Through Command Line

You can instead specify the classpath using the command line argument -cp.

Example: `javac -cp ./:/home/horse/stuff/:../ Moo.java`

- CLASSPATH environment variable totally ignored.
- Instead, Moo.java's dependencies are searched for in:
  - Current directory `./`
  - `/home/horse/stuff`
  - One directory up `../`

As with the CLASSPATH variable, if multiple copies of any Moo.java dependency are found, they are resolved in order of the CLASSPATH.

- Current directory first, then the horse directory, then one directory up.

The CLASSPATH and IntelliJ

If you're using IntelliJ, the CLASSPATH environment variable is irrelevant.

- IntelliJ automatically calls javac and java with the appropriate -cp argument.
- -cp argument that it uses is based on whatever libraries you have specified for the current project.
    - Under the hood, IntelliJ keeps a List of library folders and turns this list into a -cp string anytime you compile or run.

In case you want to see your IntelliJ classpath:

```
import java.net.URL;
import java.net.URLClassLoader;

    public static void main(String[] args) {
        ClassLoader cl = ClassLoader.getSystemClassLoader();

        URL[] urls = ((URLClassLoader)cl).getURLs();

        for(URL url: urls){
            System.out.println(url.getFile());
        }
    }
```

A CLASSPATH Puzzle

- Suppose you submit the following to gradescope:
  - AGTestArrayDeque.class
  - ArrayDeque.java

```
$ echo $CLASSPATH
./:/Users/jug/work/61b/course-materials/lib/*
```

- Suppose that:
  - The Autograder is configured with the CLASSPATH above.
  - The Autograder is run with the command `java Autograder` from a folder which contains all files submitted by the student.
  - All files created by the staff are placed in the folder /Users/jug/work/61b/course-materials/lib/
  - Autograder.class makes calls to methods in AGTestArrayDeque.class.

What happens when `java Autograder` executes?

Package Creation and Invocation Gotchas

Common gotchas for creating and using packages from command line:

- Interpreter (java command) needs class files to be in folder structure that matches package names: ug.joshh.animal package must be in ug/joshh/animal.
  - Pro-tip: Can use javac -d flag to generate the appropriate folders.

```
jug ~/work/lectureCode-sp16/lec12/hugCode/ug/joshh/animal
$ ls
Dog.class   Dog.java
```

- Execution of main methods inside a package requires uses of package name, and must be done from the top folder (e.g. above ug).

```
jug ~/work/lectureCode-sp16/lec12/hugCode/
$ java ug.joshh.animal.DogLauncher
frankie is a barnacle dog weighing 22.0 lbs.
```