

# Announcements

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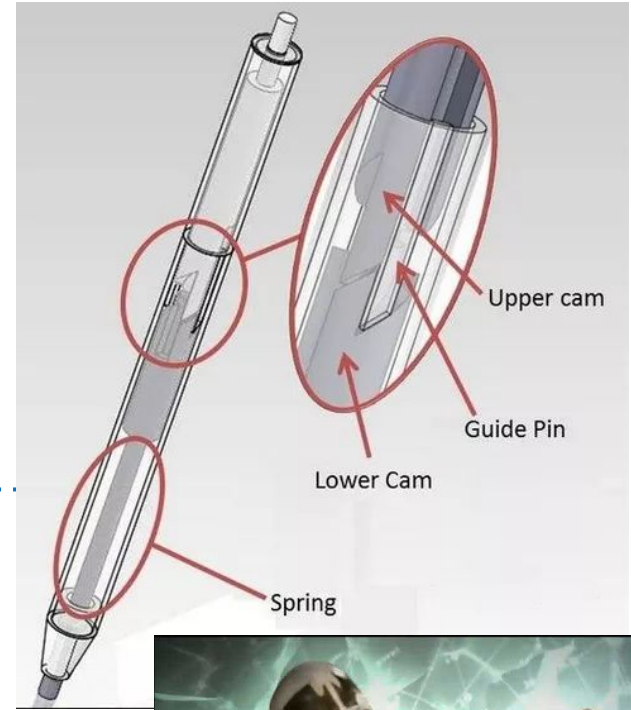
Start project 2 coding ASAP!

- If you haven't make sure you've watched [these videos on getting started](#)
- Phase 1 almost over (early deadline is **today**)
- Read the clarifications here:  
<https://piazza.com/class/j9j0udrxjip758?cid=1616>
- Update your IntelliJ plugin to v1.0.21!

# CS61B, Spring 2018

## Lecture 16: Programming Efficiently

- Programming Efficiently, APIs
- ADT Implementations
- Views



## 61B: Writing Efficient Programs

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“An engineer will do for a dime what any fool will do for a dollar”

-- Paul Hilfinger

Efficiency comes in two flavors:

- Programming cost.
  - How long does it take to develop your programs?
  - How easy is it to read, modify, and maintain your code?
    - More important than you might think!
    - Majority of cost is in maintenance, not development!
- Execution cost (starting next week).
  - How much time does your program take to execute?
  - How much memory does your program require?

Mostly tweaks and improvements, though some bug fixes, too.



# Keeping Programming Costs Low

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Some Java features discussed in 61B:

- Packages.
  - Good: Way of organizing a large project.
  - Bad: Import \* is dangerous!
- Static type checking.
  - Good: Promotes code clarity, very explicit, can prevent some errors.
  - Bad: Very verbose
- Inheritance.
  - Good: Can reuse code.
  - Bad: Can become confusing!

# Keeping Programming Costs Low (Java Features)

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Some Java features discussed in 61B:

- Packages.
  - Good: Keep code organized (in folders). Canonical names for classes and other things.
  - Bad: More work to compile and run.
- Static type checking.
  - Good: Speeds up runtime (no need to runtime type check). Catch errors early (before anybody runs the code).
  - Bad: More verbose code.
- Inheritance (implementation and interface inheritance).
  - Good: Interface inheritance allows subtype polymorphism. Implementation inheritance allows code reuse.
  - Bad: Have to implement all features of an interface (can be many). Makes code harder to read/understand. More that we'll discuss.

# Keeping Programming Costs Low (Programming Practices)

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Modularity: How can I break my problem down into easily understood subproblems?

Invariants: What properties must my algorithm or data structure maintain?

- Many programmers only consider invariants implicitly. Some write them out.

Testing: Create automated code verification tools to bolster (but not prove) correctness.

- A general framework for proving that code is correct is impossible. It's not even possible to prove that a piece of code avoids going into an infinite loop (see the [halting problem](#) if you're curious).

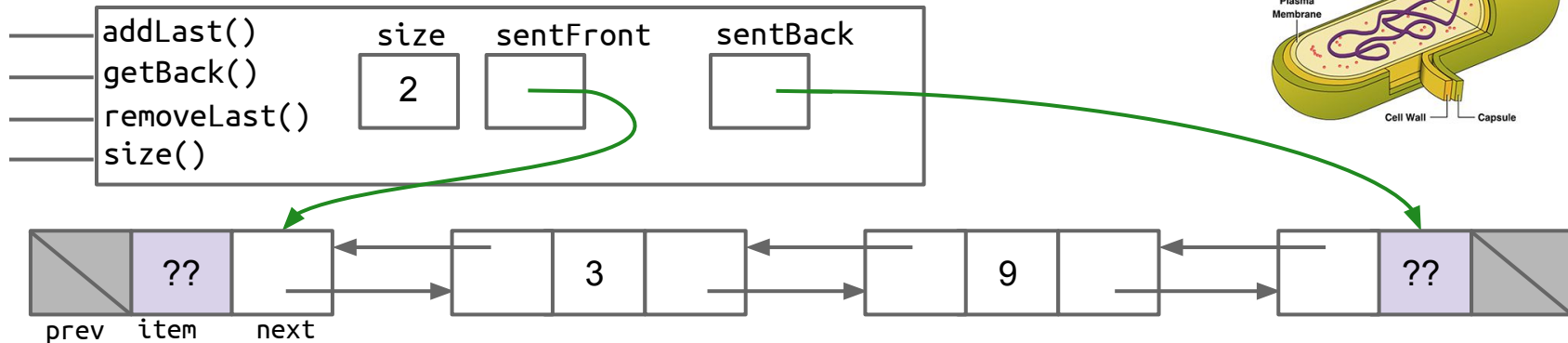
# Modules and Encapsulation (this slide, a blast from the past)

**Module:** A set of methods that work together as a whole to perform some task or set of related tasks.

A module is said to be **encapsulated** if its implementation is completely hidden, and it can be accessed only through a documented interface.

- Example: An Abstract Data Type describes an encapsulated data structure.

Recall, from week 2:



## ADTs and APIs

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The API (Application Programming Interface) of an ADT is the list of constructors and methods, including an informal description of the effect of each.

- Not a precisely defined term. Some real world definitions of API are broader than ours.

API consists of ***syntactic*** and ***semantic*** specification.

- Compiler verifies that syntax is met.
- Tests help verify that semantics are correct.
  - Semantic specification usually written out in English (possibly including usage examples). Mathematically precise formal specifications are somewhat possible but not widespread.



## Example of a Semantic Specification

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A semantic specification of project 2 from two years ago

- Link:

[https://docs.google.com/document/d/17PUw2EffgyU5\\_zQHZ8GV52EhS3NPwUyghFfX6EmJiS4/edit](https://docs.google.com/document/d/17PUw2EffgyU5_zQHZ8GV52EhS3NPwUyghFfX6EmJiS4/edit)

This idea of hiding details from yourself or other programmers is **critically important**!

- This skill is a major divide between struggling and thriving 61B students.
- Struggling students try to fit everything in their head at once.

# Designing an API

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One of the hardest parts about writing a program is deciding on the API.

- Project 2 will give you your only chance to do this in 61B.
- You'll find that it is a challenging task!

In the real world, API decisions are truly momentous.

- If you add a public method or variable, you are saying that it will be available... forever!
- Google and Oracle (owners of Java) lawsuit:
  - Google created their own implementation of some of Java's API.
  - Oracle claimed this was copyright infringement!
  - Google responded that their implementation was "fair use".
  - Lawsuit started in 2010, recently finished (Jury sided with Google)

# Designing an API

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API design and data structure selection can be an iterative process.

- Nice to get it right the first time.
- But if you don't, it's often worth the trouble to refactor your code.
- The majority of your effort will be spent on the design!

Word of warning: `Map<String, Map<Integer, Double>> someMap;`

- Complex data type specifications like this can be a sign that you need to hide more from the class using the `someMap` variable.
- Example: `Map<String, TimeSeries<Double>> someMap;`

```
{FB: 2012: 26, 2013: 55, 2014: 78, 2015: 104,  
AMZN: 1997: 4.5, 1998: 53, 1999: 106, 2000: 15, 2001: 10,  
NFLX: 2003: 0.77, 2004: 1.65, 2005: 3.96, 2006: 3.74,  
GOOGL: 2004: 96 2005: 233, 2006: 230, 2007: 300, 2008: 295}
```

```
{FB: TimeSeries@f83f9182  
AMZN: TimeSeries@087d7f33  
NFLX: TimeSeries@7caaad29,  
GOOGL: TimeSeries@99ffe71c}
```

## API Design Issues. See CS 169 for more.

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Potential pitfalls.

- Too hard (or impossible) to implement.
- Too hard to use, e.g. arguably JavaFX.
- Too general, e.g. the [God object](#). Does too much on its own.
- Too specific, e.g. many libraries for making graphical plots (matplotlib).
- Too narrow, e.g. our early SList had no get(i) method.
- Too wide, e.g. the get(i) method in Deque.
- Too wide, e.g. the java.util.Stack class (more soon).

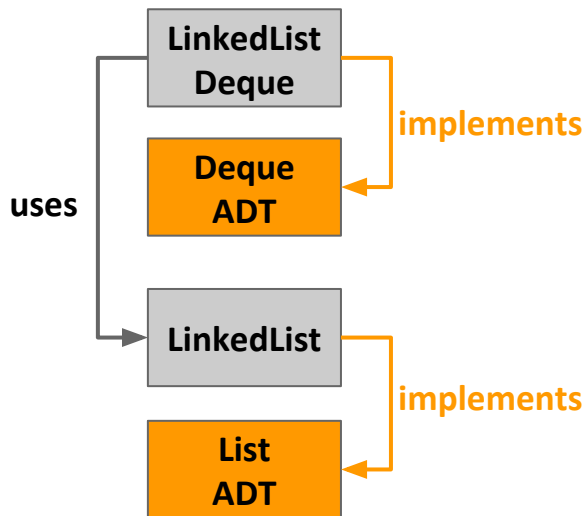
Helpful motto: “Provide to clients the methods they need and no other.” - Joe Armstrong

# ADT Implementations

# ADT Implementation

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- Recall that **ADTs** are implemented using **data structures** (think List vs. Array).
  - Often implemented using existing data structures.
- Examples:
  - LinkedListDeque from project 1 >>>
  - In project 2, you are implementing a **Grid** ADT with existing data structures.
- **Use vs. Implementation**



## Special Case ADTs

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Sometimes, ADTs are special cases of other ADTs. Three common special cases for Lists:

- Queue (also known as a line in America): Supports **enqueue** and **dequeue**.
  - **enqueue**: puts an item at end of queue
  - **dequeue**: removes and returns item at front of queue.
  - Also called a FIFO (first-in, first-out) List.
- Stack: Support **push** and **pop**.
  - **push**: puts things on 'top' of stack
  - **pop**: takes things off the top.
  - Also called a LIFO (last-in, first-out) List.
- Deque: Support **addFront**, **addBack**, **getFront**, **getBack**.

 your old friend from project 1a

## Implementing Special Cases: Extension, Delegation, Adaptation

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Suppose we have a List of some type, say a LinkedList. How do we get a Stack?




# Implementing Special Cases: Extension, Delegation, Adaptation

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Two natural approaches:

- **Extension:**

```
public class ExtensionStack<Item> extends LinkedList<Item> {  
    public void push(Item x) {  
        add(x);  
    }  
}
```



Careful about has-a vs. is-a relationship!  
More soon.

- **Delegation:**

```
public class DelegationStack<Item> {  
    private LinkedList<Item> L = new LinkedList<Item>();  
    public void push(Item x) {  
        L.add(x);  
    }  
}
```

# Implementing Special Cases: Extension, Delegation, Adaptation

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Another (more exotic) approach:

- **Adaptation:**

```
public class StackAdapter<Item> {  
    private List L;  
    public StackAdapter(List<Item> worker) {  
        L = worker;  
    }  
  
    public void push(Item x) {  
        L.add(x);  
    }  
}
```

# Designing ADTs

# Is-A vs. Has-A

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## Is-A:

- Examples:
  - A Square is-a Rectangle.
  - An ArrayList is-a List.
- In linguistics, known as *hyponymy*. ArrayList is a **hyponym** of List.

## Has-A:

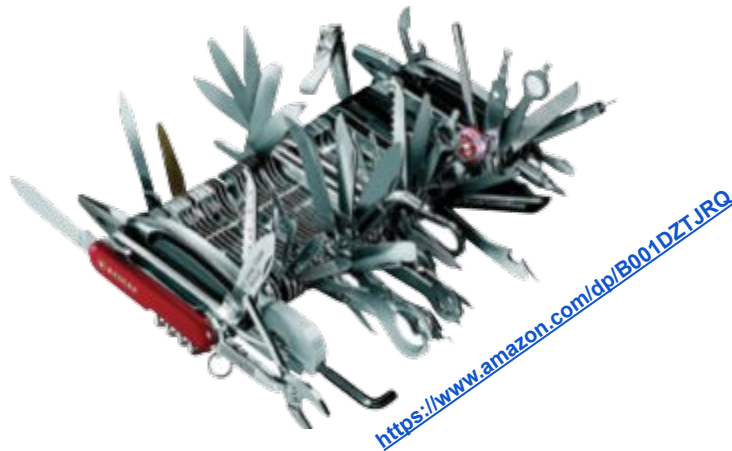
- Examples:
  - Animals have-a Leg.
  - GuitarString has-a ArrayRingBuffer.
- In linguistics, known as *holonymy*. Animals is a **holonym** of Leg.

**Inheritance** relationships should ALWAYS be **is-a** relationships. Can be subtle.

# The `java.util.Stack`: A Prime Example in Bad Design

Created using extension instead of delegation.

- Authors asserted that a Stack IS-A [Vector](#).

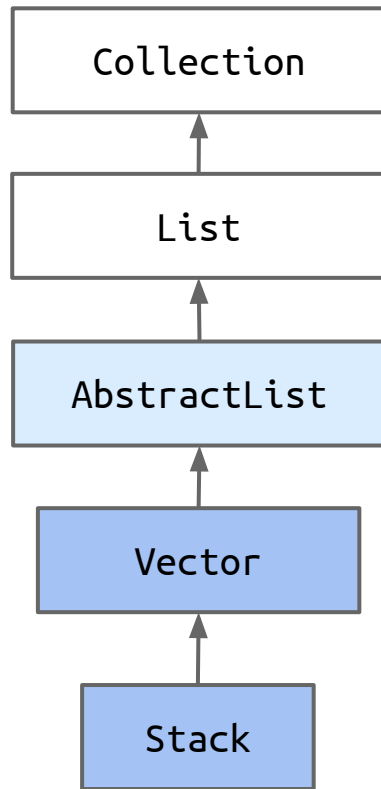


Resulting API:

- Is complex (too wide).
- Is counterintuitive (iterators work backwards).
  - <http://goo.gl/rU064i>

“You wanted a banana but what you got was a gorilla holding the banana and the entire jungle.”

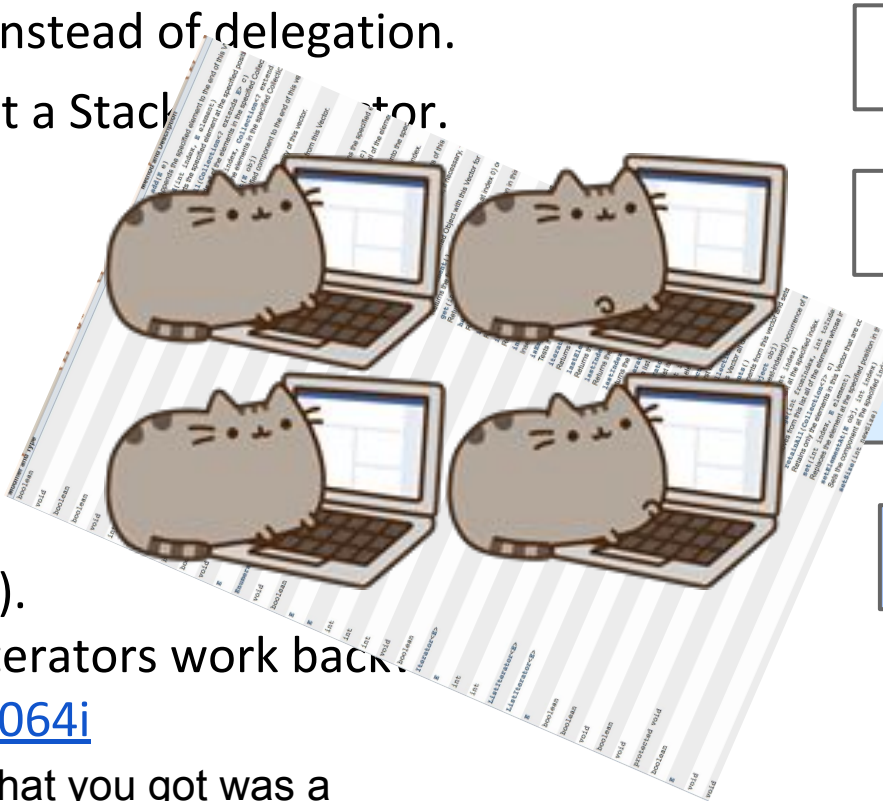
- Joe Armstrong (on OOP)



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# An Even More Subtle Inheritance Pitfall

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Classic example: A Square is-a Rectangle.

```
public class Rectangle {  
    private int width;  
    private int height;  
  
    public Rectangle(int w, int h) {  
        width = w; height = h;  
    }  
  
    /** Sets the width. */  
    public void setWidth(int w) {  
        width = w;  
    }  
  
    /** Sets the height. */  
    public void setHeight(int h) {  
        height = h;  
    }  
}
```

```
public class Square extends Rectangle { ...
```

Deep arguments about program and programming language design result. See the [circle-ellipse](#) problem for more.

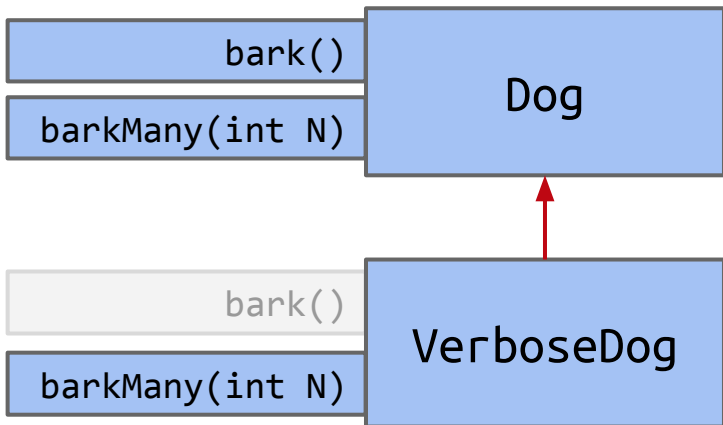
# Implementation Inheritance Breaks Encapsulation

What would `vd.barkMany(3)` output?

c. **Something else.**

- Gets caught in an infinite loop!

(assuming `vd` is a Verbose Dog)



```
public void bark() {
    barkMany(1);
}

public void barkMany(int N) {
    for (int i = 0; i < N; i += 1) {
        System.out.println("bark");
    }
}
```

```
@Override
public void barkMany(int N) {
    System.out.println("As a dog, I say: ");
    for (int i = 0; i < N; i += 1) {
        bark(); ← calls inherited bark method
    }
}
```



# Delegation vs. Extension

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As Josh Bloch puts it in **Effective Java**:

- It is safe to use inheritance within a package, where the subclass and the superclass are under the control of the same programmers.
- It is safe to extend classes specifically designed and documented for extension.
- Inheriting from ordinary concrete classes across package boundaries is dangerous.

When in doubt: Use delegation and write simple forwarding methods for each method.

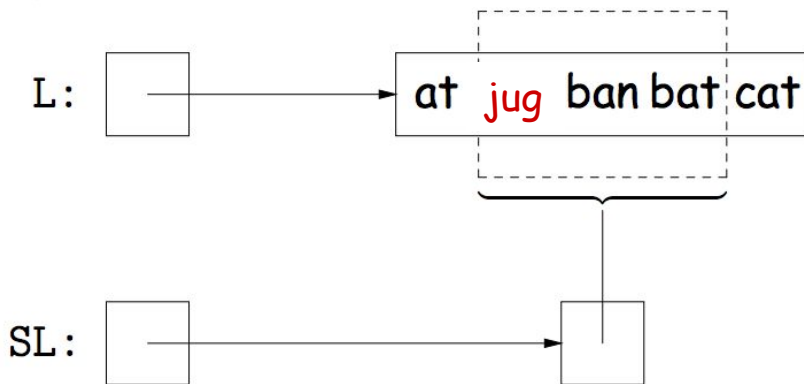
**Views**

# Views into Lists

An alternative representation of an existing object.

- Concrete objects
- Access is limited
- But changes mutate the underlying object!

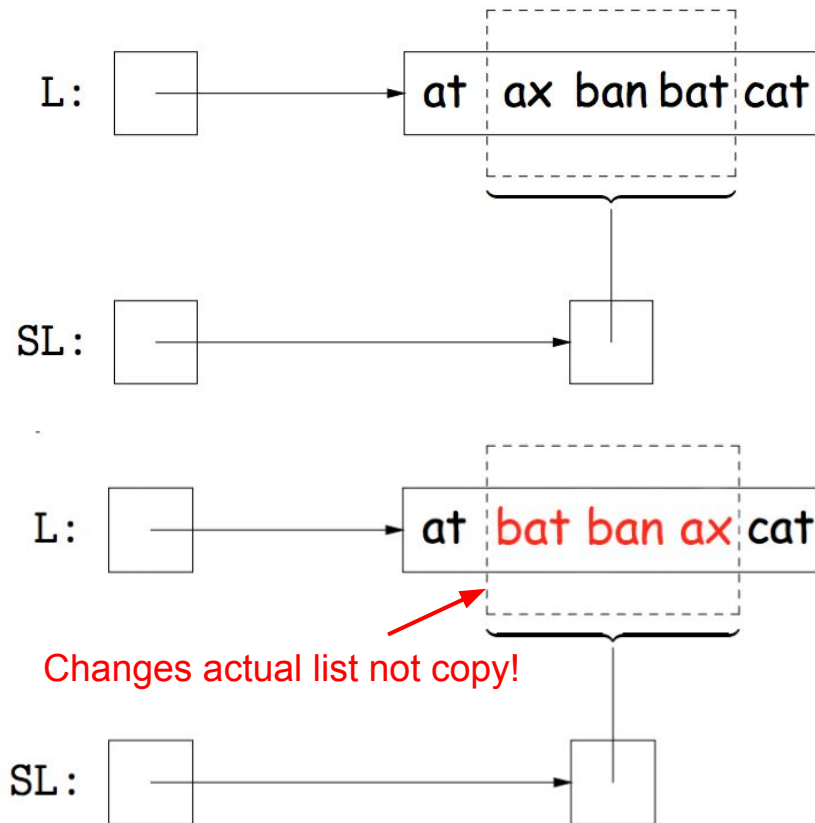
```
/** Create an ArrayList. */  
List<String> L = new ArrayList<>();  
/** Add some items. */  
L.add("at"); L.add("ax"); ...  
/** subList me up fam. */  
List<String> SL = l.subList(1, 4);  
/** Mutate it. */  
SL.set(0, "jug");
```



# Views into Lists

Allows for general functions

```
/** Reverses a List */  
void reverse(List<String> l) {...}  
/** Reverse the sublist no cases */  
reverse(SL);
```



# Views into Lists (Implementation)

How do you return an actual List but still have it affect another List? **Access methods!**

Code is taken from AbstractList w/ exceptions removed

Returns an actual List type

Only store the range of the view

The get/add method uses the surrounding class's get/add methods but limits access to the constructed range.

```
List<Item> sublist(int start, int end) {  
    return new this.Sublist(start, end);  
}  
  
private class Sublist extends AbstractList<Item> {  
    private int start, end;  
    Sublist(int start, int end) { ... }  
  
    public int size() { return end-start; }  
  
    public Item get(int k) //exception if start+k >= end  
    { return AbstractList.this.get(start+k); }  
  
    public void add(int k, Item x) {  
        { AbstractList.this.add(start+k, x); end += 1; }  
        ...  
    }  
}
```


# Views into Maps

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The Map interface provides a number of 'Views' into the Map.

- Views can also save time and space.

```
public interface Map<Key, Value> {  
    ...  
    /* VIEWS */  
    /** The set of all keys. */  
    Set<Key> keySet();  
    /** The multiset of all values. */  
    Collection<Value> values();  
    /** The set of all (key, value) pairs. */  
    Set<Map.Entry<Key, Value>> entrySet();  
    ...  
}
```

 Nested interface!

## Implementation Specific Views

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Occasionally, implementation details may allow for views that are too difficult to implement for an abstract type.

Example:

- The Map has a **keySet()** method. Iteration on the **keySet()** may show keys in any order.
- The TreeMap class has a **navigableKeySet()** method. Iteration on the **navigableKeySet()** gives keys in order.
  - Inefficient with a HashMap, so HashMap does not have this method.

# The Punchline

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APIs are hard to design.

- Proper design pays massive dividends.
- Strive always for code clarity.
- Inheritance is a powerful but dangerous tool.

For the next few weeks: Common high performance implementation some of the most common ADTs. Analysis of those implementations.

- Lists
- Sets
- Maps
- PriorityQueues
- DisjointSets



# Citations

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Title images:

- Ballpoint pen diagram: [https://qph.is.quoracdn.net/main-qimg-ab1f27c758b4c3074800cc0284c93230?convert\\_to\\_webp=true](https://qph.is.quoracdn.net/main-qimg-ab1f27c758b4c3074800cc0284c93230?convert_to_webp=true)
- Dude from ICP: <http://goo.gl/gZZwq9>