Principles of Software Construction: Objects, Design, and Concurrency

Introduction to Java

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Administrivia

- Homework 1 due next Thursday 11:59 p.m.
  - Everyone must read and sign our collaboration policy
- First reading assignment due Tuesday
  - Effective Java Items 15 and 16

Outline

I. "Hello World! " explained
II. The type system
III. Quick ‘n’ dirty I/O
IV. A brief introduction to collections

The “simplest” Java Program

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 1: you must use a class even if you aren't doing OO programming

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 2: `main` must be `public`

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 3: `main` must be `static`

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 4: `main` must return `void`

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 5: `main` must declare command line arguments even if unused

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Complication 6: standard I/O requires use of `static` field of `System`

```
class HelloWorld {
    public static void main(String[] args) {
        System.out.println("Hello world!");
    }
}
```

Execution is a bit complicated

- First you **compile** the source file
  - javac `HelloWorld.java`
  - Produces class file `HelloWorld.class`
- Then you launch the program
  - `java HelloWorld`
  - Java Virtual Machine (JVM) executes `main` method

On the bright side…

- Has many good points to balance shortcomings
- Some verbosity is not a bad thing
  - Can reduce errors and increase readability
- Modern IDEs eliminate much of the pain
  - Type `psvm` instead of `public static void main`
- Managed runtime has many advantages
  - Safe, flexible, enables garbage collection
- It may not be best language for Hello World…
  - But Java is very good for large-scale programming!

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Java has a *bipartite* (2-part) type system

Primitives	**Object Reference Types**
`int, long, byte, short, char, float, double, boolean`	Classes, interfaces, arrays, enums, annotations
No identity except their value	Have identity distinct from value
Immutable	Some mutable, some immutable
On stack, exist only when in use	On heap, garbage collected
Can’t achieve unity of expression	Unity of expression with generics
Dirt cheap	More costly

Programming with primitives

A lot like C!

```
public class TrailingZeros {
    public static void main(String[] args) {
        int i = Integer.parseInt(args[0]);
        System.out.println(trailingZerosInFactorial(i));
    }

    static int trailingZerosInFactorial(int i) {
        int result = 0; // Conventional name for return value

        while (i >= 5) {
            i /= 5;       // Same as i = i / 5; Remainder discarded
            result += i;
        }
        return result;
    }
}
```

Primitive type summary

- `int` 32-bit signed integer
- `long` 64-bit signed integer
- `byte` 8-bit signed integer
- `short` 16-bit signed integer
- `char` 16-bit unsigned integer/character
- `float` 32-bit IEEE 754 floating point number
- `double` 64-bit IEEE 754 floating point number
- boolean Boolean value: `true` or `false`

Deficient primitive types

- `byte`, `short` – use `int` instead!
  - `byte` is broken – should have been unsigned
- `float` – use `double` instead!
  - Provides too little precision
  - Only compelling use case is large arrays, especially in resource-constrained environments

Pop Quiz!

What does this fragment print?

```
int[] a = new int[]  { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };

int i;
int sum1 = 0;
for (i = 0; i < a.length; i++) {
    sum1 += a[i];
}

int j;
int sum2 = 0;
for (j = 0; i < a.length; j++) {
    sum2 += a[j];
}

System.out.println(sum1 - sum2);
```

Maybe not what you expect!

```
int[] a = new int[]  { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };

int i;
int sum1 = 0;
for (i = 0; i < a.length; i++) {
    sum1 += a[i];
}
int j;
int sum2 = 0;
for (j = 0; i < a.length; j++) { //  Copy/paste error!
    sum2 += a[j];
}
System.out.println(sum1 - sum2);
```

You might expect it to print 0, but it prints 55

You could fix it like this…

```
int[] a = new int[]  { 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 };

int i;
int sum1 = 0;
for (i = 0; i < a.length; i++) {
    sum1 += a[i];
}
int j;
int sum2 = 0;
for (j = 0; j < a.length; j++) {
    sum2 += a[j];
}

System.out.println(sum1 - sum2);  // Now prints 0, as expected
```

But this fix is far better…

```
int sum1 = 0;
for (int i = 0; i < a.length; i++) {
   sum1 += a[i];
}

int sum2 = 0;
for (int i = 0; i < a.length; i++) {
   sum2 += a[i];
}

System.out.println(sum1 - sum2);  // Prints 0
```

- Reduces scope of index variable to loop
- Shorter and less error prone

This fix is better still!

```
int sum1 = 0;
for (int x : a) {
   sum1 += x;
}

int sum2 = 0;
for (int x : a) {
   sum2 += x;
}

System.out.println(sum1 - sum2); // Prints 0
```

- Eliminates scope of index variable **entirely!**
- Even shorter and less error prone

Lessons from the quiz

- **Minimize scope of local variables** [EJ Item 57]
  - Declare variables at point of use
- Initialize variables in declaration
- Prefer for-each loops to regular `for`-loops
- Use common idioms
- Watch out for *bad smells in code*
  - Such as index variable declared outside loop

Objects

- All non-primitives are represented by objects.
- An **object** is a bundle of state and behavior
- State – the data contained in the object
  - In Java, these are the **fields** of the object
- Behavior – the actions supported by the object
  - In Java, these are called **methods**
  - Method is just OO-speak for function
  - Invoke a method = call a function

Classes

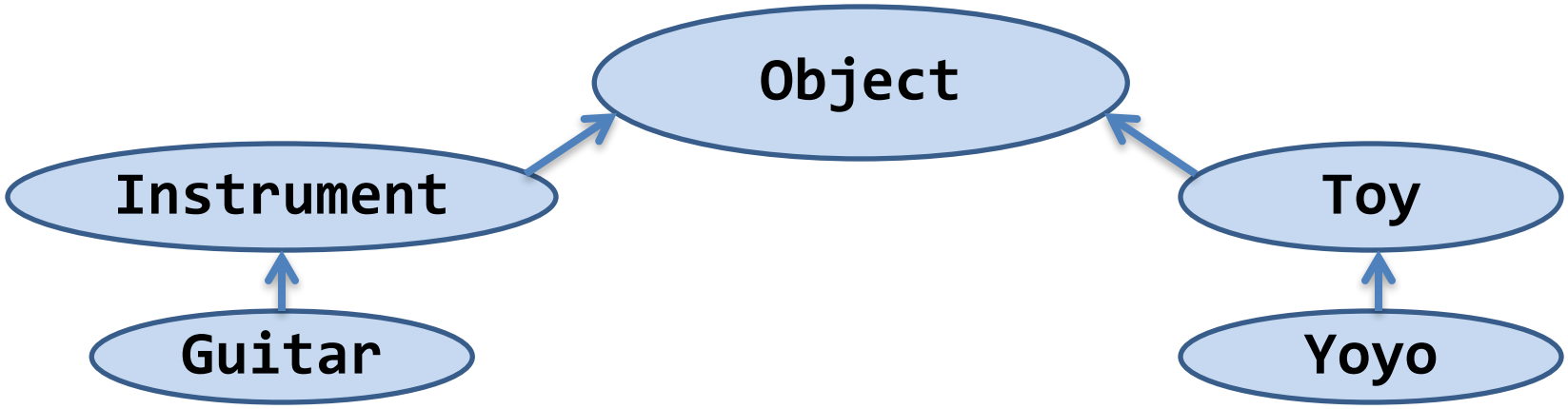
- Every object has a class
  - A class defines methods and fields
  - Methods and fields collectively known as **members**
- Class defines both type and implementation
  - Type ≈ where the object can be used
  - Implementation ≈ how the object does things
- Loosely speaking, the methods of a class are its **Application Programming Interface (API)**
  - Defines how users interact with its instances

The class hierarchy

- The root is Object (all non-primitives are objects)
- All classes except Object have one parent class
  - Specified with an `extends` clause

```
class Guitar extends Instrument { ... }
```

  - If `extends` clause omitted, defaults to `Object`
- A class is an instance of all its superclasses



Implementation inheritance

- A class:
  - Inherits visible fields and methods from its superclasses
  - Can override methods to change their behavior
- Overriding method implementation must obey contract(s) of its superclass(es)
  - Ensures subclass can be used anywhere superclass can
  - Liskov Substitution Principle (LSP)
  - We will talk more about this in a later class

Interface types

- Defines a type without an implementation
- Much more flexible than class types
  - An interface can extend one or more others
  - A class can implement multiple interfaces

Enum types

- Java has object-oriented enums
- In simple form, they look just like C enums:

```
enum Planet { MERCURY, VENUS, EARTH, MARS,
              JUPITER, SATURN, URANUS, NEPTUNE }
```

- But they have **many** advantages!
  - Compile-time type safety
  - Multiple enum types can share value names
  - Can add or reorder without breaking existing uses
  - High-quality `Object` methods are provided
  - Screaming fast collections (`EnumSet`, `EnumMap`)
  - Can iterate over all constants of an enum

Boxed primitives

- Immutable containers for primitive types
- `Boolean`, `Integer`, `Short`, `Long`, `Character`, `Float`, `Double`
- Let you "use" primitives in contexts requiring objects
- **Canonical use case is collections**
- **Don't use boxed primitives unless you have to!**
- Language does *autoboxing* and *auto-unboxing*
  - Blurs but does not eliminate distinction
  - There be dragons!

Comparing values

`x == y` compares the *contents* of `x` and `y`

primitive values: returns true if x and y **have the same value**

objects refs: returns true if x and y **refer to same object**

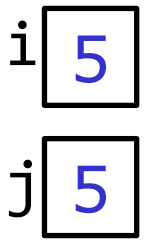
`x.equals(y)` compares the *values of the objects referred to* by `x` and `y`

True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
```

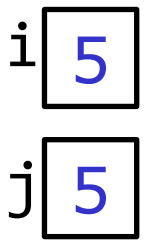
True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
true
```



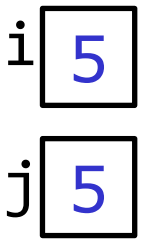
True or false?

```
int i = 5;                      String s = "foo";
int j = 5;                      String t = s;
System.out.println(i == j);     System.out.println(s == t);
---------------------------     ---------------------------
true
```

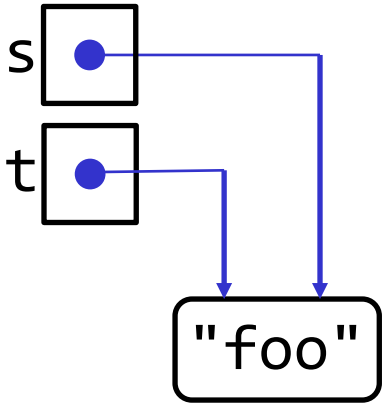


True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
true
```

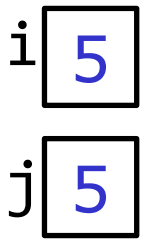



```
String s = "foo";
String t = s;
System.out.println(s == t);
---------------------------
true
```

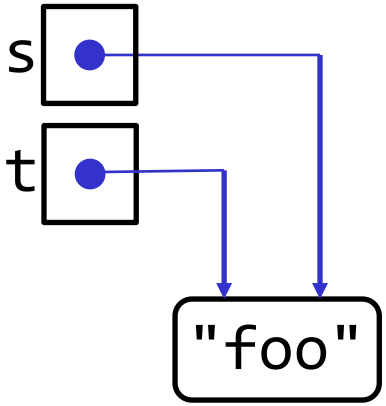


True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
true
```



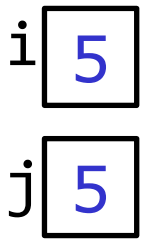

```
String s = "foo";
String t = s;
System.out.println(s == t);
---------------------------
true
```



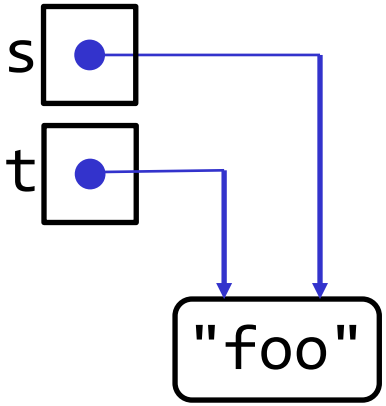

```
String u = "iPhone";
String v = u.toLowerCase();
String w = "iphone";
System.out.println(v == w);
---------------------------
```

True or false?

```
int i = 5;
int j = 5;
System.out.println(i == j);
---------------------------
true
```

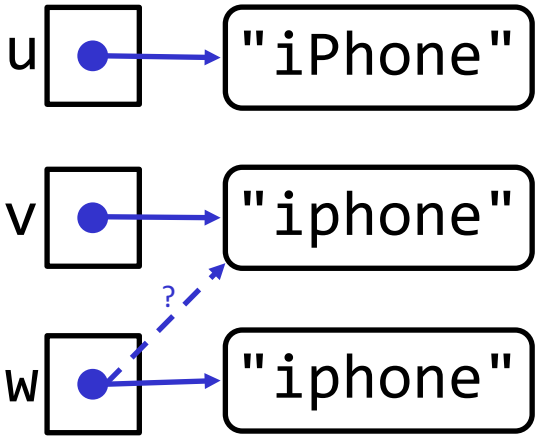



```
String s = "foo";
String t = s;
System.out.println(s == t);
---------------------------
true
```




```
String u = "iPhone";
String v = u.toLowerCase();
String w = "iphone";
System.out.println(v == w);
---------------------------
```

Undefined! (`false` in practice)



The moral

- **Always use `.equals` to compare object refs**
  - (Except for enums, which are special)
  - The == operator can fail silently and unpredictably

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Output

- Unformatted

```
System.out.println("Hello World");
System.out.println("Radius: " + r);
System.out.println(r * Math.cos(theta));
System.out.println();
System.out.print("*");
```

- Formatted

```
System.out.printf("%d * %d = %d%n", a, b, a * b); // Varargs
```

Command line input example

Echos all command line arguments

```
class Echo {
    public static void main(String[] args) {
        for (String arg : args) {
            System.out.print(arg + " ");
        }
    }
}
```

```
$ java Echo Woke up this morning, had them weary
  blues
Woke up this morning, had them weary blues
```

Command line input with parsing

Prints GCD of two command line arguments

```
class Gcd {
    public static void main(String[] args) {
        int i = Integer.parseInt(args[0]);
        int j = Integer.parseInt(args[1]);
        System.out.println(gcd(i, j));
    }

    static int gcd(int i, int j) {
        return i == 0 ? j : gcd(j % i, i);
    }
}

$ java Gcd 11322 35298
666
```

Scanner input

Counts the words on standard input

```
class Wc {
    public static void main(String[] args) {
        Scanner sc = new Scanner(System.in);
        long result = 0;
        while (sc.hasNext()) {
            sc.next(); // Swallow token
            result++;
        }
        System.out.println(result);
    }
}
```

```
$ java Wc < Wc.java
32
```

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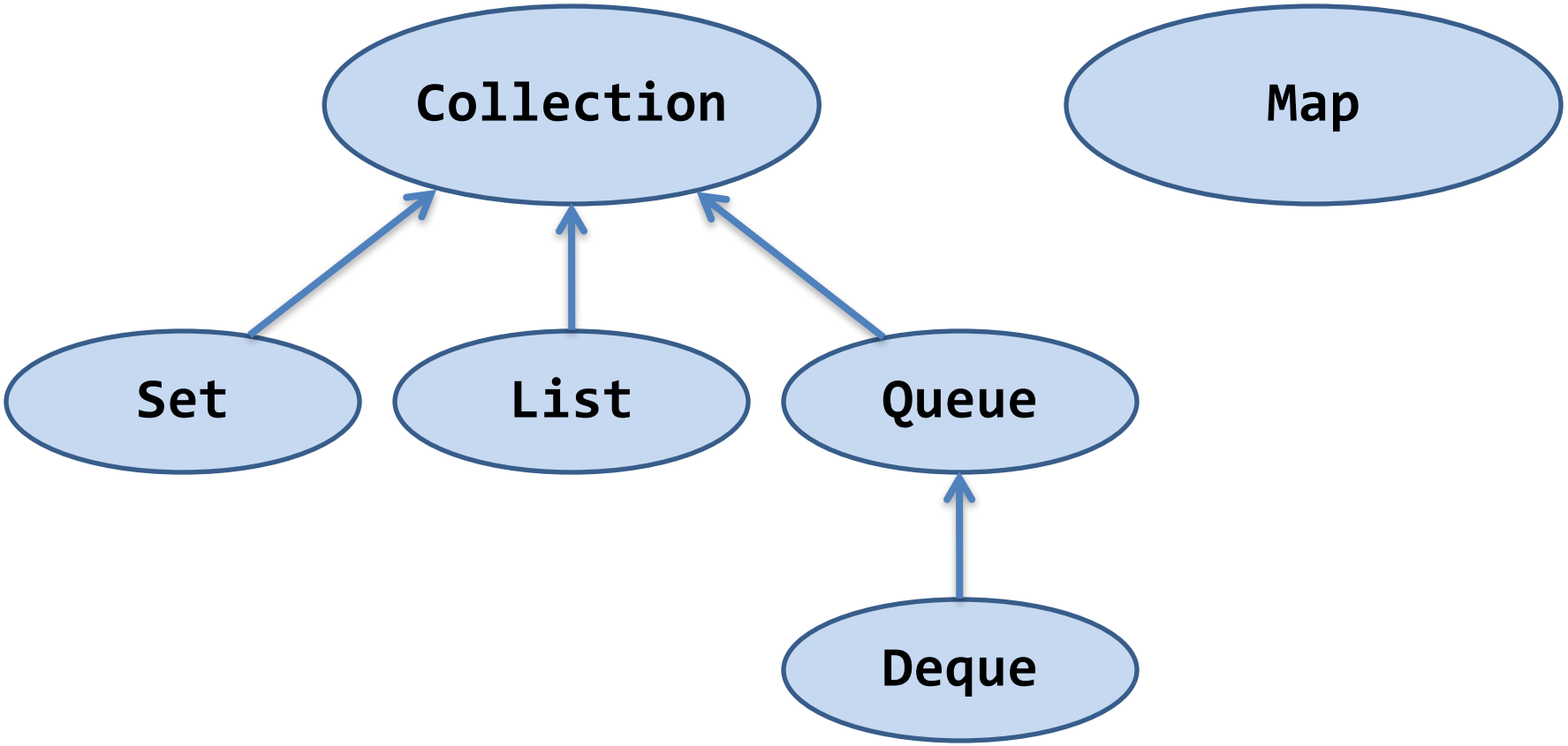
Primary collection interfaces



“Primary” collection implementations

Interface	Implementation
`Set`	`HashSet`
`List`	`ArrayList`
`Queue`	`ArrayDeque`
`Deque`	`ArrayDeque`
(stack)	`ArrayDeque`
`Map`	`HashMap`

Other noteworthy collection implementations

Interface	Implementation(s)

`Set`	`LinkedHashSet`
	`TreeSet`
	`EnumSet`

`Queue`	`PriorityQueue`

`Map`	`LinkedHashMap`
	`TreeMap`
	`EnumMap`

Collections usage example 1

Squeeze duplicate words out of command line

```
public class Squeeze {
    public static void main(String[] args) {
        Set<String> s = new LinkedHashSet<>();
        for (String word : args)
            s.add(word);
        System.out.println(s);
    }
}

$ java Squeeze I came I saw I conquered
[I, came, saw, conquered]
```

Collections usage example 2

Print unique words in lexicographic order

```
public class Lexicon {
   public static void main(String[] args) {
       Set<String> s = new TreeSet<>();
       for (String word : args)
           s.add(word);
       System.out.println(s);
   }
}

$ java Lexicon I came I saw I conquered
[I, came, conquered, saw]
```

Collections usage example 3

Print index of first occurrence of each word

```
class Index {
    public static void main(String[] args) {
        Map<String, Integer> index = new TreeMap<>();

        // Iterate backwards so first occurrence wins
        for (int i = args.length - 1; i >= 0; i--) {
            index.put(args[i], i);
        }
        System.out.println(index);
    }
}
```

```
$ java Index if it is to be it is up to me to do it
{be=4, do=11, if=0, is=2, it=1, me=9, to=3, up=7}
```

More information on collections

- For *much* more information on collections, see the annotated outline:

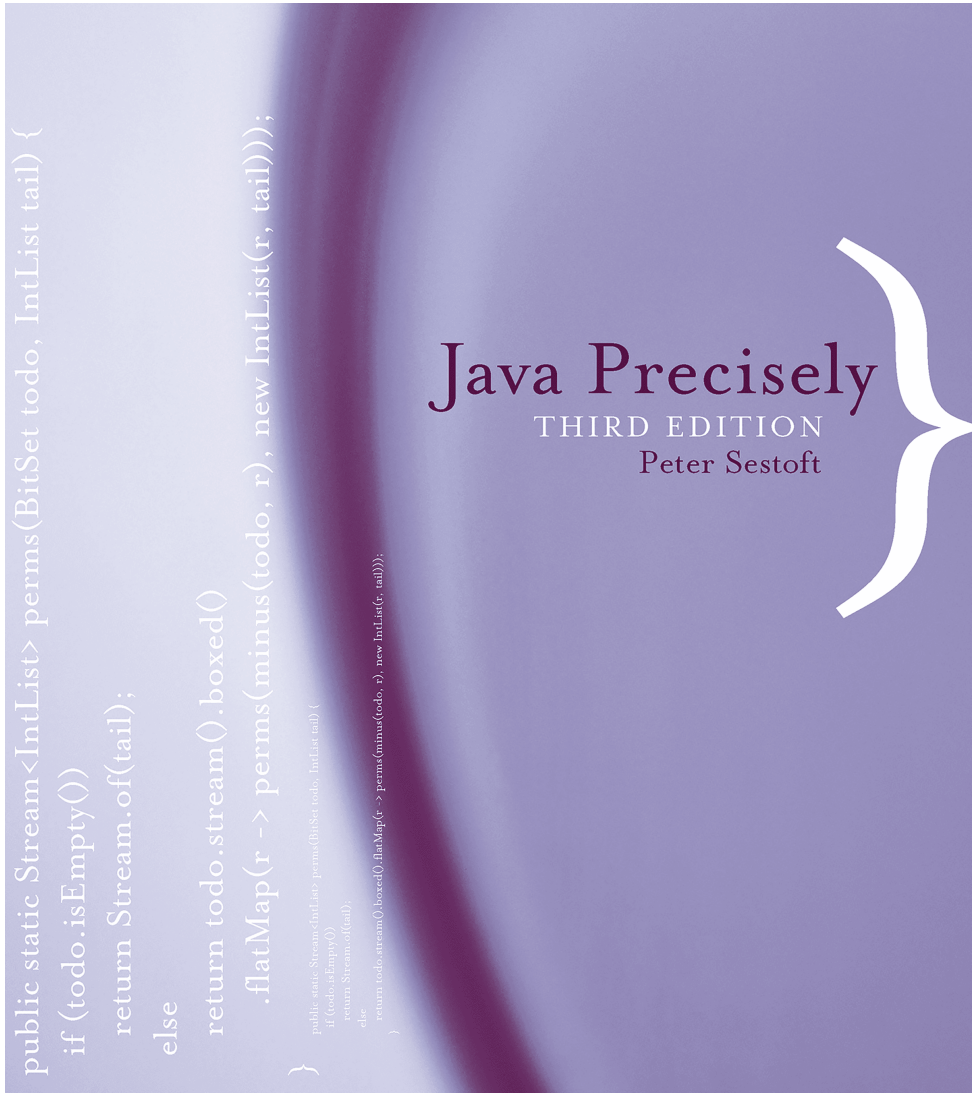
  https://docs.oracle.com/javase/11/docs/technotes/guides/collections/reference.html

- For more info on *any* library class, see javadoc
  - Search web for <fully qualified class name> 8
  - e.g., `java.util.scanner 8`

What about arrays?

- Arrays aren't really a part of the collections framework
- But there is an adapter: `Arrays.asList`
- Arrays and collections don't mix
- If you try to mix them and get compiler warnings, take them seriously
- Generally speaking, prefer collections to arrays
- See *Effective Java* Item 28 for details

To learn Java quickly



Summary

- Java is well suited to large programs; small ones may seem a bit verbose
- Bipartite type system – primitives & object refs
  - Single implementation inheritance
  - Multiple interface inheritance
- A few simple I/O techniques will get you started
- Collections framework is powerful & easy to use