Principles of Software Construction: Objects, Design, and Concurrency

Refactoring & Anti-patterns

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Reading Quiz Canvas

Lecture 10 Quiz, password “patterns”

Midterm Review

- Thoughts/Opinions?

Some reflections:

- Is OO *required* for encapsulation?
- Github Actions can run tests, but tests can only show <u>incorrect</u> code.
- Drawing control-flow diagrams for coverage helps
- Interaction diagrams: think about the actual code.
    - E.g., you can't skip a class when returning a value.

Today: Patterns, anti-patterns, and refactoring

- Patterns: using and choosing between them.
- Antipatterns and refactoring
  - Sidequest on equals, toString, typecasting
- Several other useful patterns

Refactoring: Any functionality-preserving rewrite or restructure.

Refactoring

- Any functionality-preserving restructuring
  - That is, the semantics of the program <u>do not change</u>, but the syntax does
  - Why might this be useful?

Refactoring

- Any functionality-preserving restructuring
  - That is, the semantics of the program do not change, but the syntax does
  - Why might this be useful?
    - What was the problem again? How would you fix it?

```
class Player {
    Board board;
    /* in code somewhere… */ this.getSquare(n);
    Square getSquare(String name) { // named monopoly squares
        for (Square s: board.getSquares())
            if (s.getName().equals(name))
                return s;
        return null;
}}
```

Refactoring and Anti-Patterns

- Often, all the functionality is correct, but the organization is bad
  - High coupling, high redundancy, poor cohesion, god classes, …
- Refactoring is the principal tool to improve structure
  - Automated refactorings even guarantee correctness
  - A series of refactorings is usually enough to introduce design patterns

Refactoring and Anti-Patterns

- Often, all the functionality is correct, but the organization is bad
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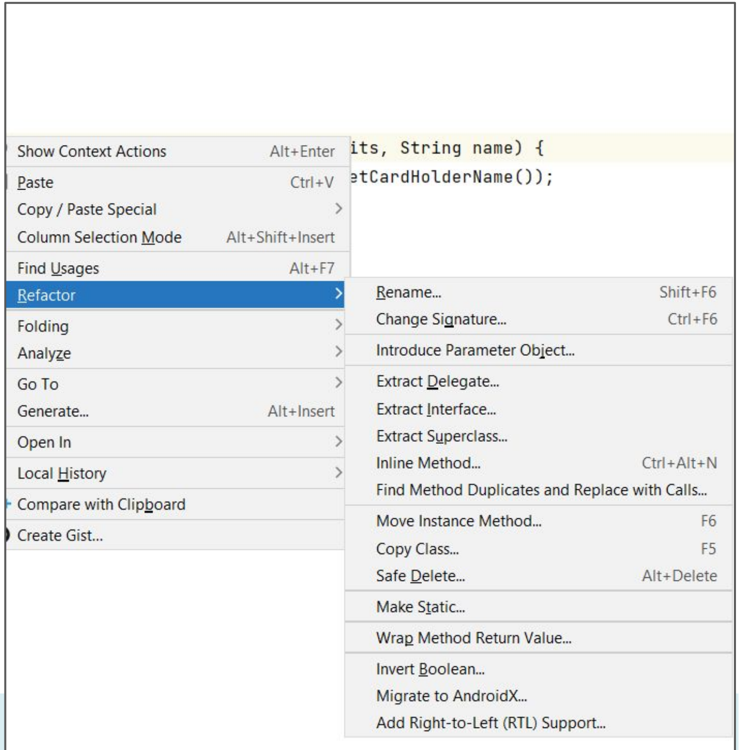
- Refactoring is the principal tool to improve structure
  - Automated refactorings even guarantee correctness
  - A series of refactorings is usually enough to introduce design patterns
- In an upcoming recitation, you’ll analyze such a system and making primarily refactoring changes
  - “primarily”, because sometimes you do need to alter things slightly.

Refactoring: IDE Support

- Many IDEs offer *automated* refactoring
  - Have you used any?

Refactoring: IDE Support

- Many IDEs offer *automated* refactoring
  - Rename class, method, variable
  - Extract method/inline method
  - Extract interface
  - Move method (up, down, laterally)
  - Replace duplicates



Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Can you think of examples?

Anti-patterns

- We have talked a fair bit about bad design heuristics
  - High coupling, low cohesion, law of demeter, …
- You will see a much larger vocabulary of related issues
  - Commonly called code/design “smells”
  - Worthwhile reads:
    - **A short overview: https://refactoring.guru/refactoring/smells**
    - Wikipedia: https://en.wikipedia.org/wiki/Anti-pattern#Software_engineering
    - Book on the topic (no required reading): Refactoring for Software Design Smells: Managing Technical Debt, Suryanarayana, Samarthyam and Sharma
      - S.O. summary: https://stackoverflow.com/a/27567960

Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Where do they come from?

Anti-patterns

Anti-patterns are *common* forms of bad/no-design

- Where do they come from?
- Two common causes:
  - Design issues that manifest as bad/unmaintainable code
  - Poorly written/evolved code that leads to bad design

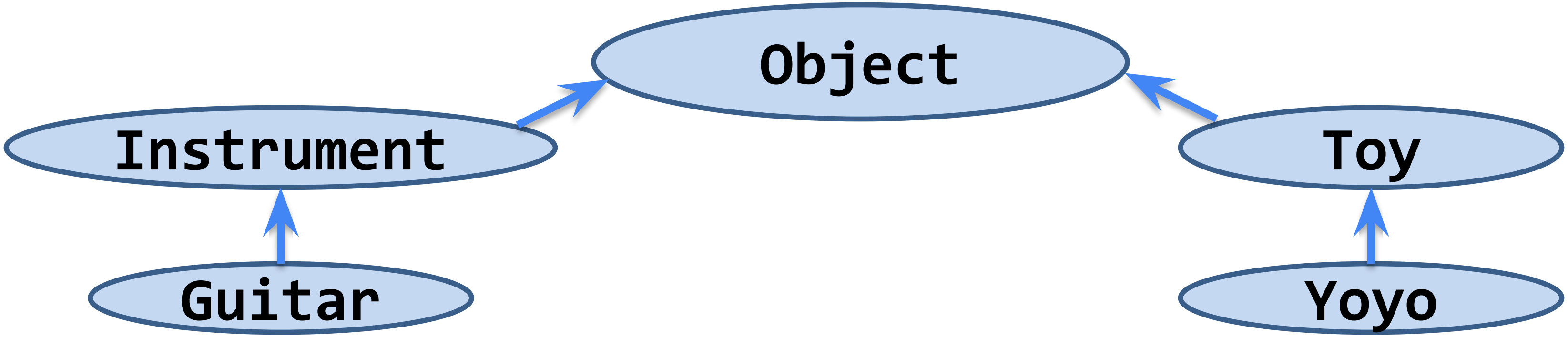
Let’s See a Few Examples (in VSCode)

- Frogger
  - As a system grows, refactoring can help preserve cohesion
  - Refactoring: move method
- PersonRecords
  - Introducing new constructs in the face of growing complexity
  - Refactorings: extract methods, create class, rename

While we’re on the subject of objects and equality.

The Java 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



Methods common to all objects

- How do collections know how to test objects for **equality**?
  - Why did this work:

```
for(Person p: this.records) {
    if(p.equals(newP)) {
      …
```

- How do they know how to **hash** and **print** them?
- The relevant methods are all present on `Object`
  - `equals` - returns true if the two objects are “equal”
  - `hashCode` - returns an `int` that must be equal for equal objects, and is likely to differ on unequal objects
  - `toString` - returns a printable string representation (default is gross: Type and hashcode)

Comparing values

`x == y` compares x and y "directly":

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

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

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

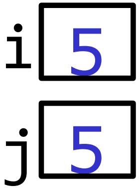
* Assuming it makes sense to do so for the objects in question

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
```



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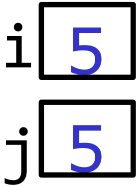


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String t = s;
System.out.println(s == t);
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```

True or false?

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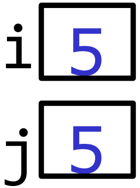


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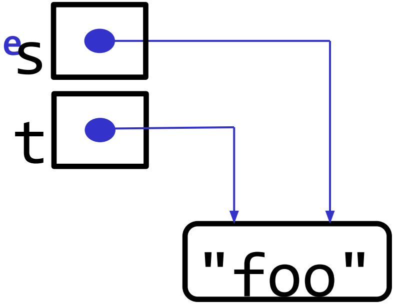

True or false?

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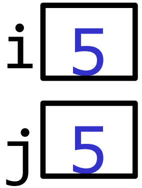


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String s = "foo";
String t = s;
System.out.println(s == t);
---------------------------
```
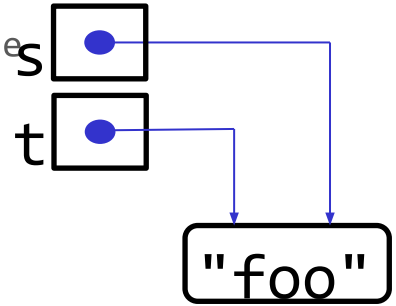
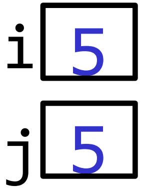

true




```
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
```

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String s = "foo";
String t = s;
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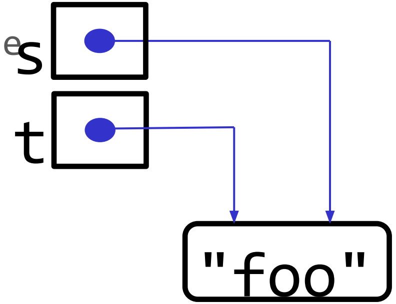
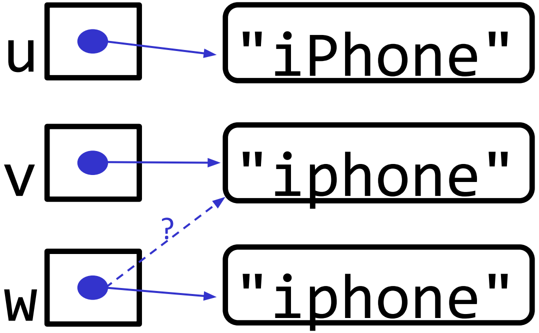



```
String u = "iPhone";
String v = u.toLowerCase();
String w = "iphone";
System.out.println(v == w);
-----------------------------
```

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 when applied to object references**
  - Same goes for the `!=` operator

Overriding `Object` implementations

- No need to override `equals` and `hashCode` if you want identity semantics
  - When in doubt, don't override them
  - It's easy to get it wrong
  - ‘record’ in Java gives you equals for free, neato!
- Nearly always override `toString`
  - `println` invokes it automatically
  - Why settle for ugly?

Overriding `toString` is easy and beneficial

```
final class PhoneNumber {
    private final short areaCode;
    private final short prefix;
    private final short lineNumber;
     ...
    @Override public String toString() {
        return String.format("(%03d) %03d-%04d",
            areaCode, prefix, lineNumber);
    }
}

Number jenny = ...;
System.out.println(jenny);
```

Prints: `(707) 867-5309`

Typescript notes.

There is also a `toString`.

Equality is a funny thing: == (equality) vs === (strict equality)

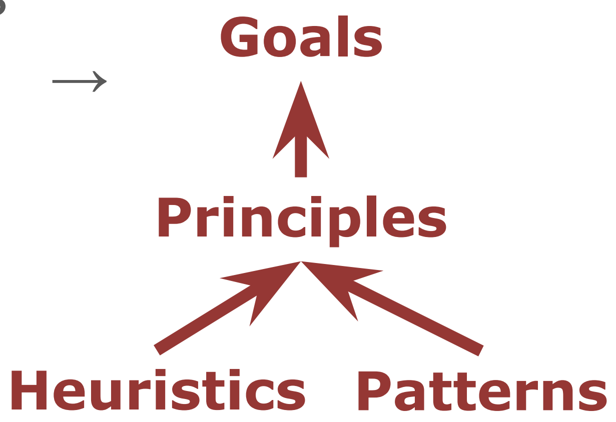
- Typescript requires that you compare things that are the same type, so this distinction is SLIGHTLY less important.
- Javascript lets you do `10 == ‘10’ // true`
- Style guideline: always use ===, avoid surprises!

Equivalent behavior for, say, Collections, is a bit trickier (no off-the-shelf equivalent of `equals`, but many ways to get it).

Back to anti-patterns/refactoring

Anti-patterns

- Kind of like the evil twins of design patterns
- Similar to the design hierarchy on the right, →
  we want to think of both:
  - The design principles they run against
  - The low-level “heuristics” to detect them in code
    - Including many “code smells”
- As before, a pattern language helps
  - Many of these can be (re)paired with a correct pattern



Anti-patterns

What defeats good principles?

- Bad encapsulation violates ______
- Bad modularization violates ______
- Bad abstraction violates ______
- Bad inheritance/hierarchy violates ______

Anti-patterns

What defeats good principles?

- Bad encapsulation violates information hiding
- Bad modularization violates coupling
- Bad abstraction violates cohesion
- Bad inheritance/hierarchy violates representational gap

Anti-patterns

What heuristics give it away?

- Bad encapsulation, violates information hiding
  - public fields should be private; interface leaks implementation details; lack of interface
- Bad modularization, violates coupling
  - related methods in different places, or vice versa; very large interface; “god” class
- Bad abstraction, violates cohesion
  - Not exposing relevant functionality; near-identical classes; too many responsibilities
- Bad inheritance/hierarchy
  - Violating behavioral subtyping; unnecessary inheritance; very large hierarchies (too wide or too deep)

Code Smells

Not necessarily bad, but worthwhile indicators to check. If problematic, these often point to design problems

- Long methods, large classes. Suggests bad abstraction
  - Tend to evolve over time; requires restructuring
- Inheritance despite low coupling (“refused bequest”)
  - Replace with delegation, or rebalance hierarchy
- ‘instanceof’ (or ‘switch’) instead of polymorphism
- Overly similar classes, hierarchies
- Any change requires lots of edits
  - High coupling across classes (“shotgun surgery”), or heavily entangled implementation (intra-class)

Code Smells

More code smells:

- Excessive, unused hierarchies
- Operations posing as classes
- Data classes
  - Tricky: not always bad, but ideally distinguish from regular classes (e.g., ‘record’), and assign responsibilities if any exist (think: FlashCard did equality checking)
- Heavy usage of one class’ data from another (“feature envy”, “inappropriate intimacy”; poor coupling)
- Long chains of calls needed to do anything (law of demeter)
- A class that only delegates work

Anti-patterns

- You can detect them from either side
  - Pick a design principle, look for violations
  - Identify “weird” code and figure out the design flaw

Anti-patterns

- You can detect them from either side
  - Pick a design principle, look for violations
  - Identify “weird” code and figure out the design flaw
- All fairly easy to spot on their own
  - But multiple anti-patterns can be tangled up
  - How do you approach that?

Refactoring and Anti-patterns

Identifying multiple design problems

- Make a list
  - Read the code, record anything that stands out
    - Pay attention to class names and their (apparent) interfaces
    - Make note of repetitive code (esp. across methods)
  - Draw a diagram, using a tool or by hand
    - Spot duplication, (lack of) interfaces, strange inheritance
  - This takes **practice**
- <u>Don’t solve every problem</u>
  - Many issues are orthogonal
    - Or, at least, you can improve things somewhat
  - When issues intersect, prioritize fixing **interfaces**

Refactoring

So where is “refactoring” in all this?

- It’s what comes next.
- Most design issues can be resolved with one or more functionality-preserving transformation(s)
  - Too many parameters? Merge relevant ones into object and/or replace with method calls.
  - Two near-identical classes? Find the common interface
    - Then merge their signatures using renamings, parameterization
    - Then, delete one if useless, or extract a shared super-class, or compose both with shared object

More useful patterns! Remember that long parameter list?

Fluent APIs / Cascade Pattern

Setting up Complex Objects

Long constructors, lots of optional parameters, long lists of statements

```
Option find = OptionBuilder
    .withArgName("file")
    .hasArg()
    .withDescription("search..." )
    .create("find");
```

```
client.getItem('user-table')
    .setHashKey('userId', 'userA')
    .setRangeKey('column', '@')
    .execute()
    .then(function(data) {
        ...
    })
```

Liquid APIs

Each method changes state, then returns `this`

(Immutable version: Return modified copy)

```
class OptBuilder {
    private String argName = "";
    private boolean hasArg = false;
    ...
    OptBuilder withArgName(String n) {
    this.argName = n;
    return this;
    }
    OptBuilder hasArg() {
    this.hasArg = true;
    return this;
    }
    ...
    Option create() {
    return new Option(argName,
             hasArgs, ...)
    }
}
```

Python: Named parameters

```
parser = argparse.ArgumentParser(description='Process some integers.')
parser.add_argument('integers', metavar='N', type=int, nargs='+',
                    help='an integer for the accumulator')
parser.add_argument('--sum', dest='accumulate', action='store_const',
                    const=sum, default=max,
                     help='sum the integers (default: find the max)')
```

JavaScript: JSON Objects

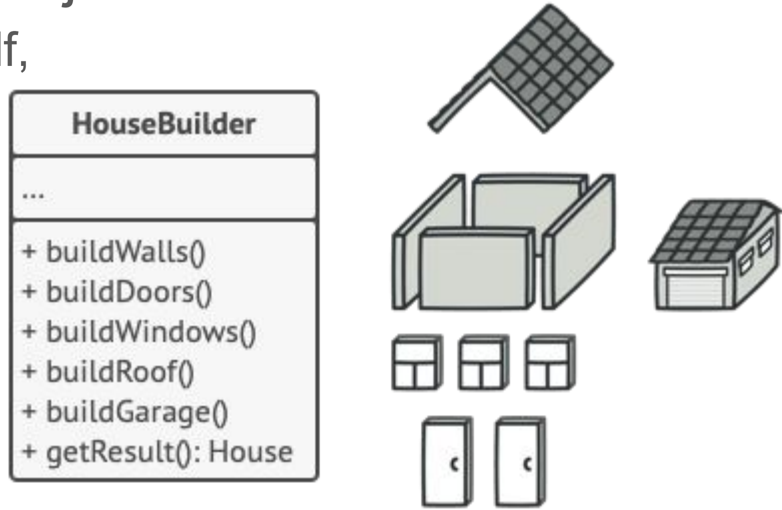
```
var argv = require('yargs/yargs')(process.argv.slice(2))
  .option('size', {
    alias: 's',
    describe: 'choose a size',
    choices: ['xs', 's', 'm', 'l', 'xl']
  })
   .argv
```

Notice the combination of cascading and complex JSON parameters

Under the Hood: Builder Pattern

When creating many variations of a complex object:

- Assign assembling work to a Builder object
  - When cascading, the builder returns itself, modified on every update
  - Offers a method that generates the resulting object
- Direct clients to *only* use the Builder
  - E.g., hide the constructor



https://refactoring.guru/design-patterns/builder

Fluent APIs: Discussion and Tradeoffs

Problem: Complex initialization and configuration

Advantages:

- Fairly readable code
- Can check individual arguments
- Avoid untyped complex arguments

Disadvantages:

- Runtime error checking of constraints and mandatory arguments
- Extra complexity in implementation
- Not always obvious how to terminate
- Possibly harder to debug

Iterator Pattern & Streams

(what's up with `for(Person p : this.records)`?)

Traversing a collection

- Since Java 1.0:

```java
  Vector arguments = …;
  for (int i = 0; i < arguments.size(); ++i) {
    System.out.println(arguments.get(i));
  }
```

- Java 1.5: enhanced for loop

```java
List<String> arguments = …;
for (String s : arguments) {
  System.out.println(s);
}
```

- Works for every implementation of `Iterable`

```java
public interface Iterable<E> {
  public Iterator<E> iterator();
}
public interface Iterator<E> {
  boolean hasNext();
  E next();
  void remove();
```

- In JavaScript (ES6)

```javascript
let arguments = …
for (const s of arguments) {
  console.log(s)
}
```

- Works for every implementation with a “magic” function `[Symbol.iterator]` providing an iterator

```typescript
interface Iterator<T> {
  next(value?: any): IteratorResult<T>;
  return?(value?: any): IteratorResult<T>;
  throw?(e?: any): IteratorResult<T>;
}
interface IteratorReturnResult<TReturn> {
  done: true;
  value: TReturn;
}
```

The Iterator Idea

Iterate over elements in arbitrary data structures (lists, sets, trees) without having to know internals

Typical interface:

```
interface Iterator<E> {
  boolean hasNext();
  E next();
}
```

(in Java also remove)

Using an iterator

Can be used explicitly

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator(); it.hasNext();  ) {
  String s = it.next();
  System.out.println(s);
}
```

Often used with magic syntax:

```
for (String s : arguments)
for (const s of arguments)
```

Java: Getting an Iterator

```
public interface Collection<E> extends Iterable<E> {
  boolean      add(E e);
  boolean      addAll(Collection<? extends E> c);
  boolean      remove(Object e);
  boolean      removeAll(Collection<?> c);
  boolean      retainAll(Collection<?> c);
  boolean      contains(Object e);
  boolean      containsAll(Collection<?> c);
  void         clear();
  int          size();
  boolean      isEmpty();
  Iterator<E> iterator();
  Object[]     toArray()
  <T> T[]      toArray(T[] a);
  …
}
```

Defines an interface for creating an Iterator,
but allows Collection implementation to decide which Iterator to create.

Iterators for everything

```
public class Pair<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }









}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

An Iterator implementation for Pairs

```
public class Pair<E> implements Iterable<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }
  public Iterator<E> iterator() {
    return new PairIterator();
  }
  private class PairIterator implements Iterator<E> {
    private boolean seenFirst = false, seenSecond = false;
    public  boolean hasNext() { return !seenSecond; }
    public  E next() {
      if (!seenFirst)  { seenFirst  = true; return first;  }
      if (!seenSecond) { seenSecond = true; return second; }
      throw new NoSuchElementException();
    }
    public void remove() {
      throw new UnsupportedOperationException();
    }
  }
}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

Iterator design pattern

- Problem: Clients need uniform strategy to access all elements in a container, independent of the container type
  - Order is unspecified, but access every element once
- Solution: A strategy pattern for iteration
- Consequences:
  - Hides internal implementation of underlying container
  - Easy to change container type
  - Facilitates communication between parts of the program

Iterator and FlashCards?

Streams

Stream ~ Iterator – a sequence of objects

- Typically provide operations to produce new stream from old stream (map, flatMap, filter) and operations on all elements (fold, sum) – using higher-order functions/strategy
  - Often provide efficient/parallel implementations (subtype polymorphism)
- Built-in in Java since Java 8; basics in Node libraries in JavaScript

```java
List<String>results = stream.map(Object::toString)
                    .filter(s -> pattern.matcher(s).matches())
                    .collect(Collectors.toList());
```

```java
int sum = numbers.parallelStream().reduce(0, Integer::sum);
```

```javascript
for (let [odd, even] in numbers.split(n => n % 2, n => !(n % 2)).zip()) {
    console.log(`odd = ${odd}, even = ${even}`);  // [1, 2], [3, 4], ...
  }
```

```javascript
Stream(people).filter({age: 23}).flatMap("children").map("firstName")
   .distinct().filter(/a.*/i).join(", ");
```

Summary

- Practice recognizing anti-patterns, applying design patterns
  - Read lots of code, think about alternatives
- Learn a vocabulary of anti-patterns
  - Think about both (what goes against) design principles and lower-level heuristics
  - Practice, practice, practice