Structural Design Patterns

CSE260, Computer Science B: Honors

Stony Brook University

http://www.cs.stonybrook.edu/~cse260

Structural Design Patterns

- Design patterns that ease the **design** by identifying a simple way to realize relationships between entities.
  - *Decorator pattern*: adds additional functionality to a class at runtime where subclassing would result in an exponential rise of new classes.
  - *Adapter pattern*: "*adapts*" one interface for a class into one that a client expects.
  - *Facade pattern*: creates a simplified interface of an existing interface to ease usage for common tasks.
  - *Flyweight pattern*: a high quantity of objects share a common properties object to save space.
  - *Bridge pattern*: decouples an abstraction from its implementation so that the two can vary independently.

Common Design Patterns

Creational	Structural	Behavioral
• Factory • Singleton • Builder • Prototype	• Decorator • Adapter • Facade • Flyweight • Bridge	• Strategy • Template • Observer • Command • Iterator • State

Textbook: Head First Design Patterns

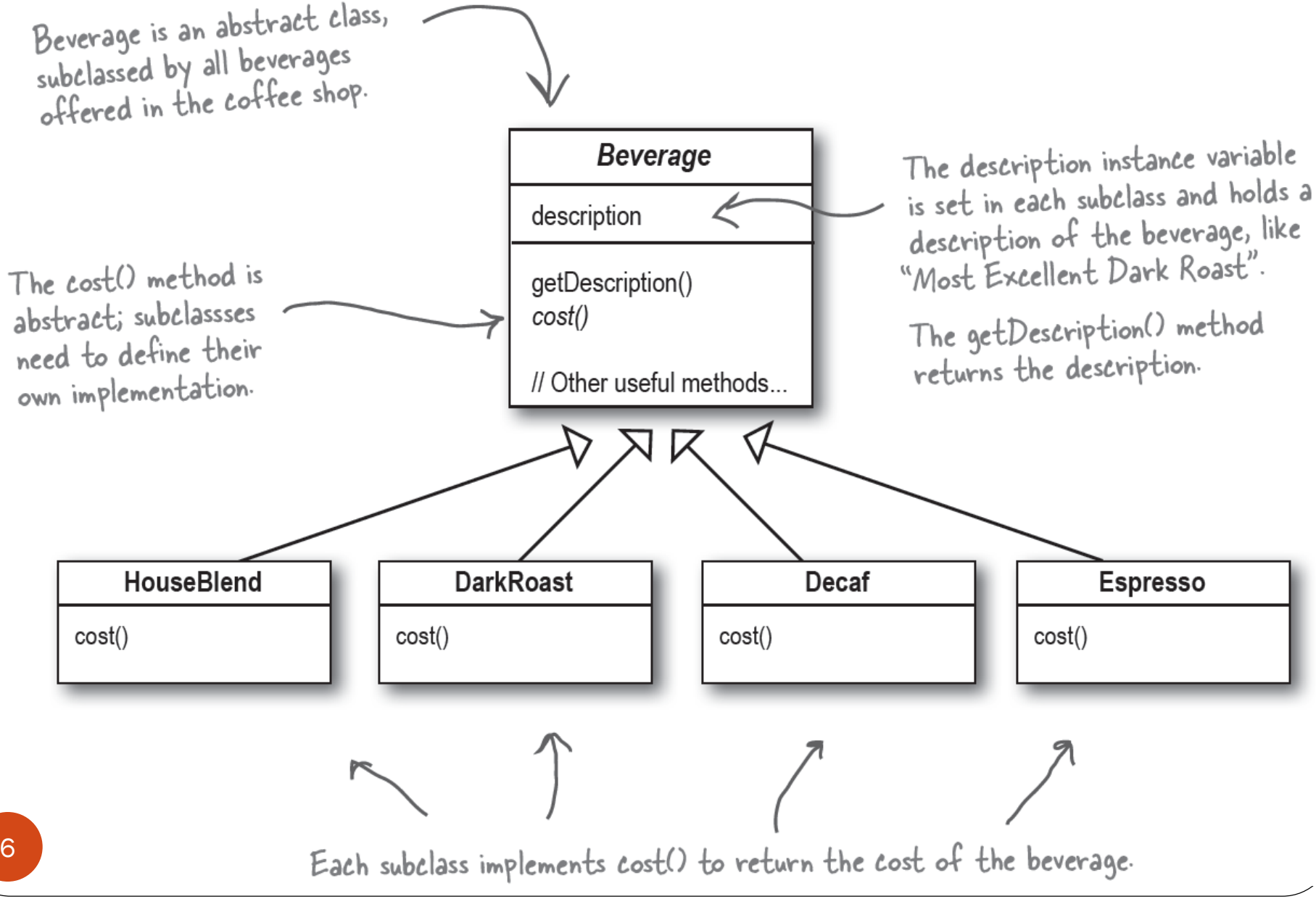
The Decorator Pattern

- Attaches additional responsibilities to an object dynamically.
  - i.e. decorating an object
- Decorators provide a flexible alternative to sub-classing for extending functionality.
- How?
  - By wrapping an object
- Works on the principle that classes should be open to extension but closed to modification.

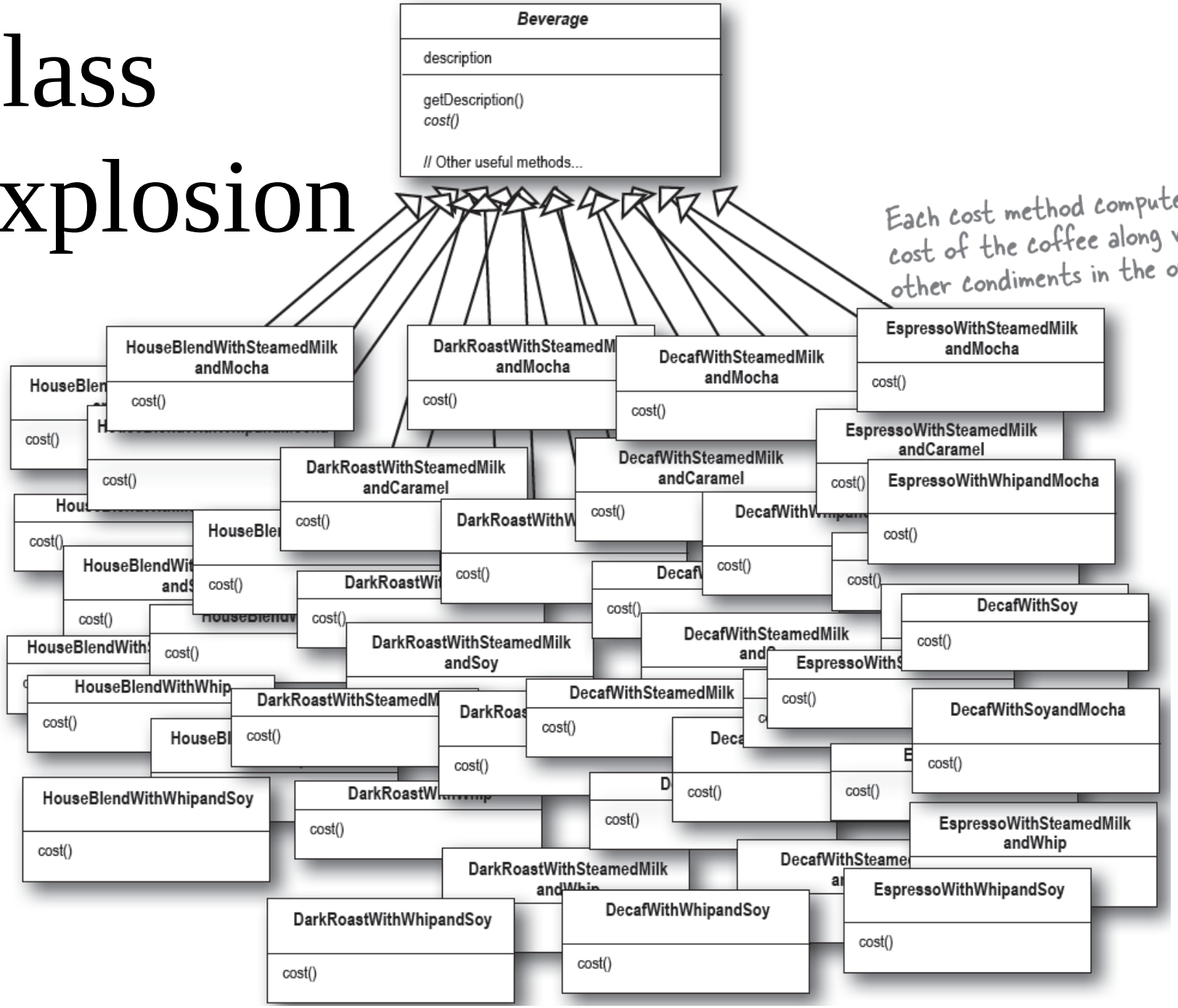
Decorator Goal

- Allow classes to be **easily extended** to incorporate new behavior without modifying existing code.
- What do we get if we accomplish this?
  - Designs that are resilient to change and flexible enough to take on new functionality to meet changing requirements.

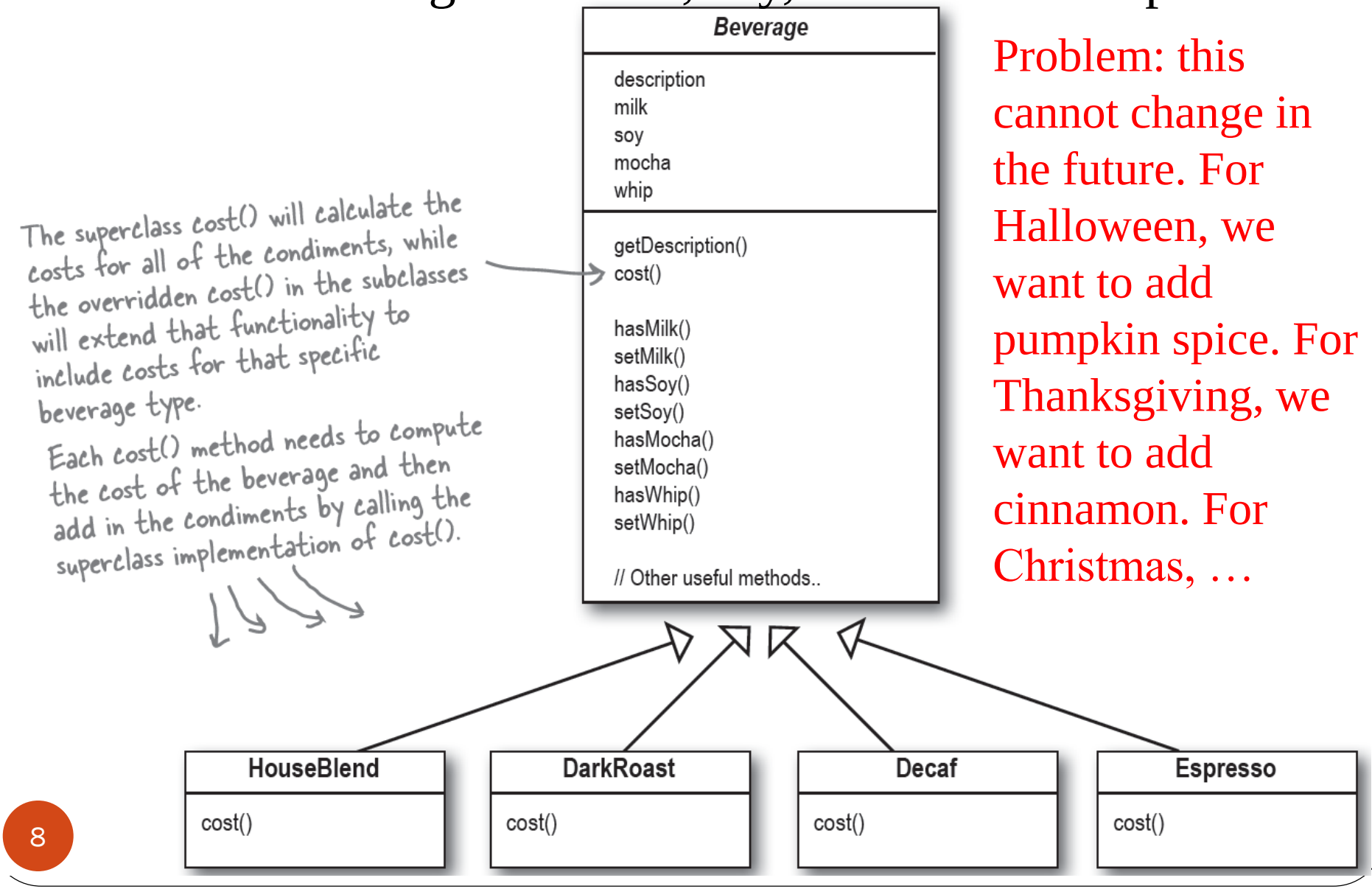
Starbuzz Coffee



Class Explosion



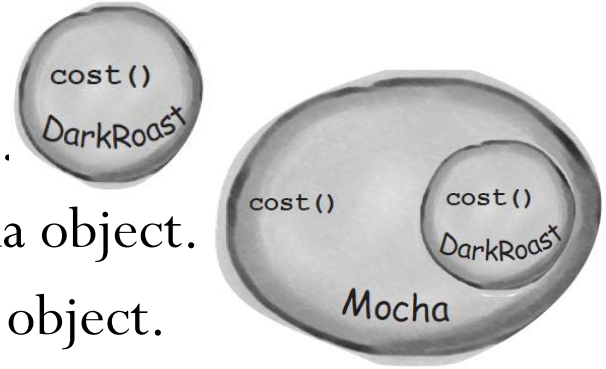
One Solution: **Add instance variables** to represent whether or not each beverage has milk, soy, mocha and whip.



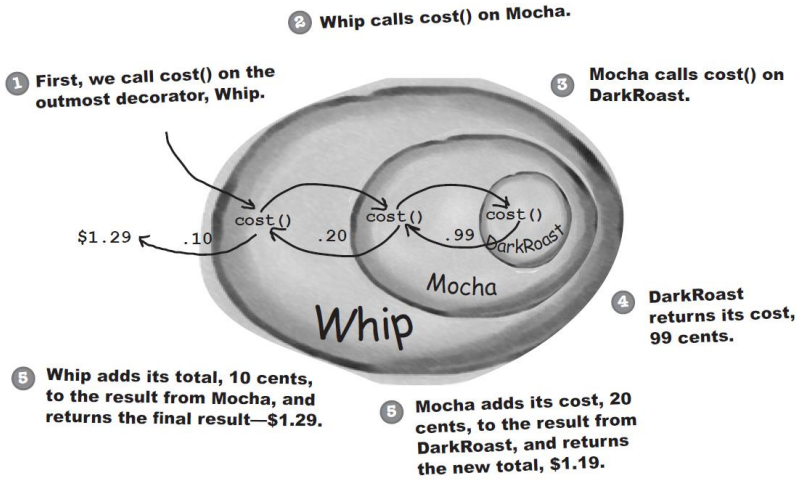
Problem: this cannot change in the future. For Halloween, we want to add pumpkin spice. For Thanksgiving, we want to add cinnamon. For Christmas, …

Decorator pattern

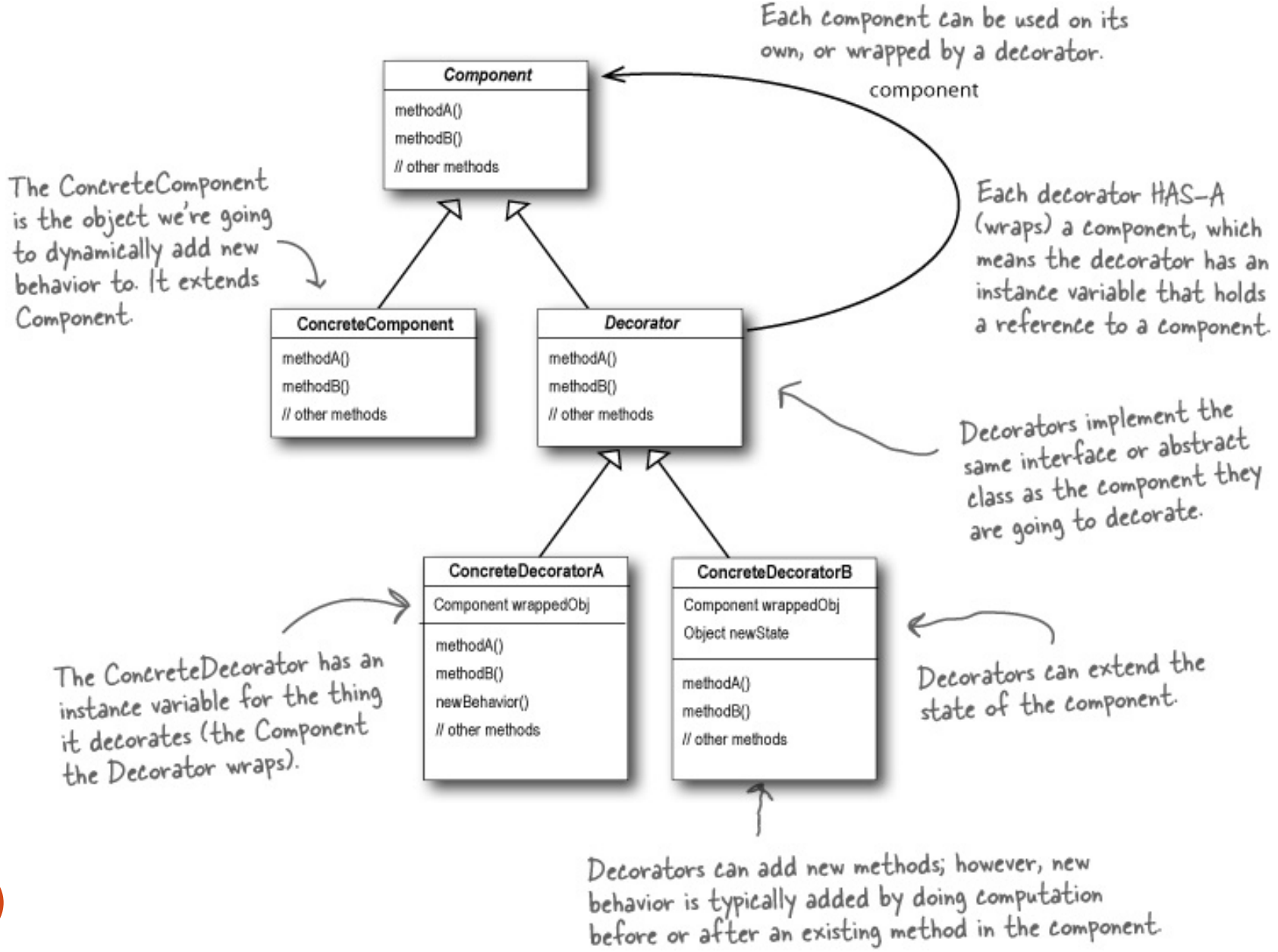
- We'll start with a beverage and "***decorate***" it with the condiments at runtime.
  - For example, if the customer wants a Dark Roast with Mocha and Whip, then we'll:

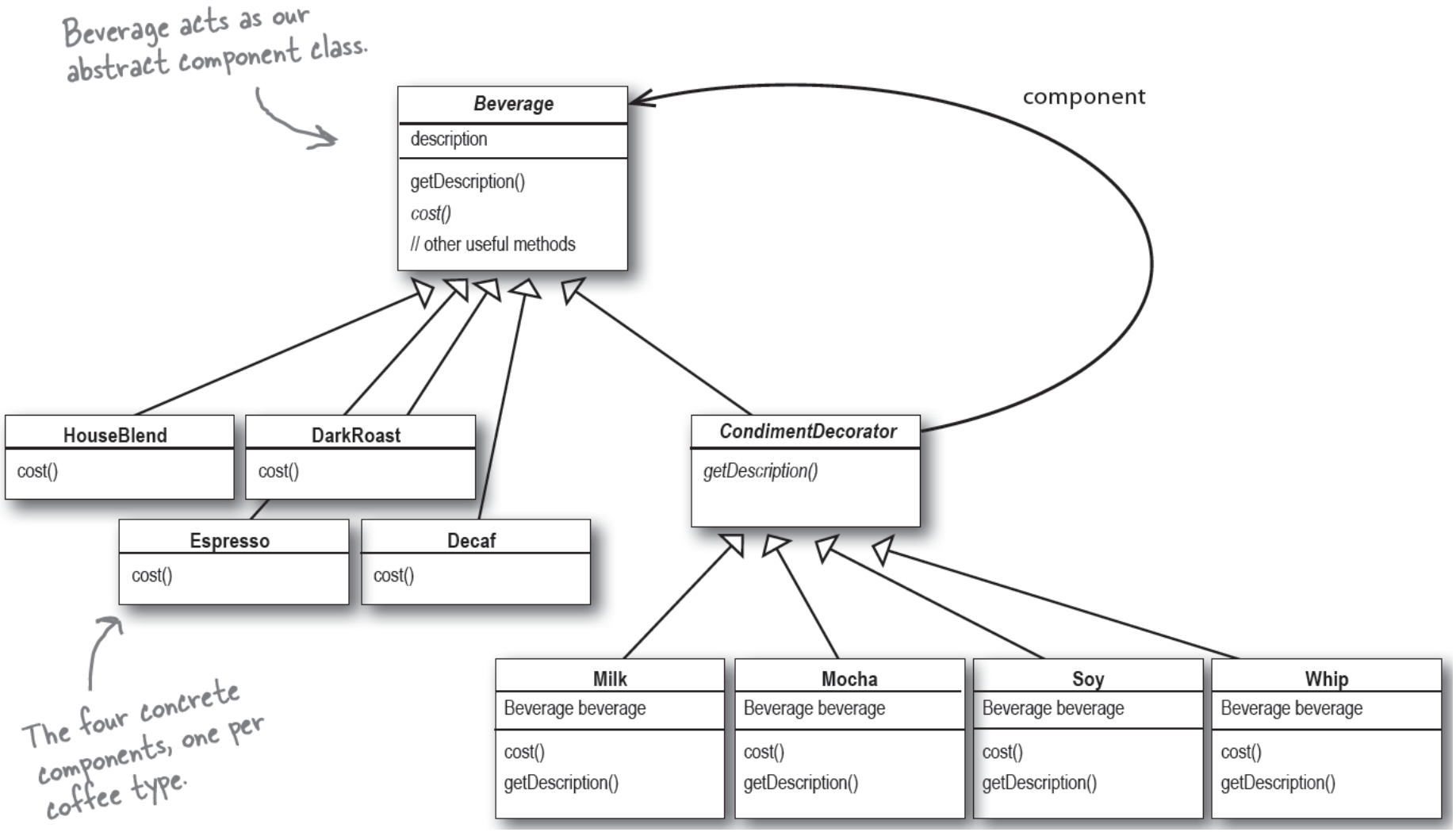


1. Take a DarkRoast object.
2. Decorate it with a Mocha object.
3. Decorate it with a Whip object.
4. Call the cost() method and rely on delegation to add on the condiment costs.



Decorators **Override** Functionality

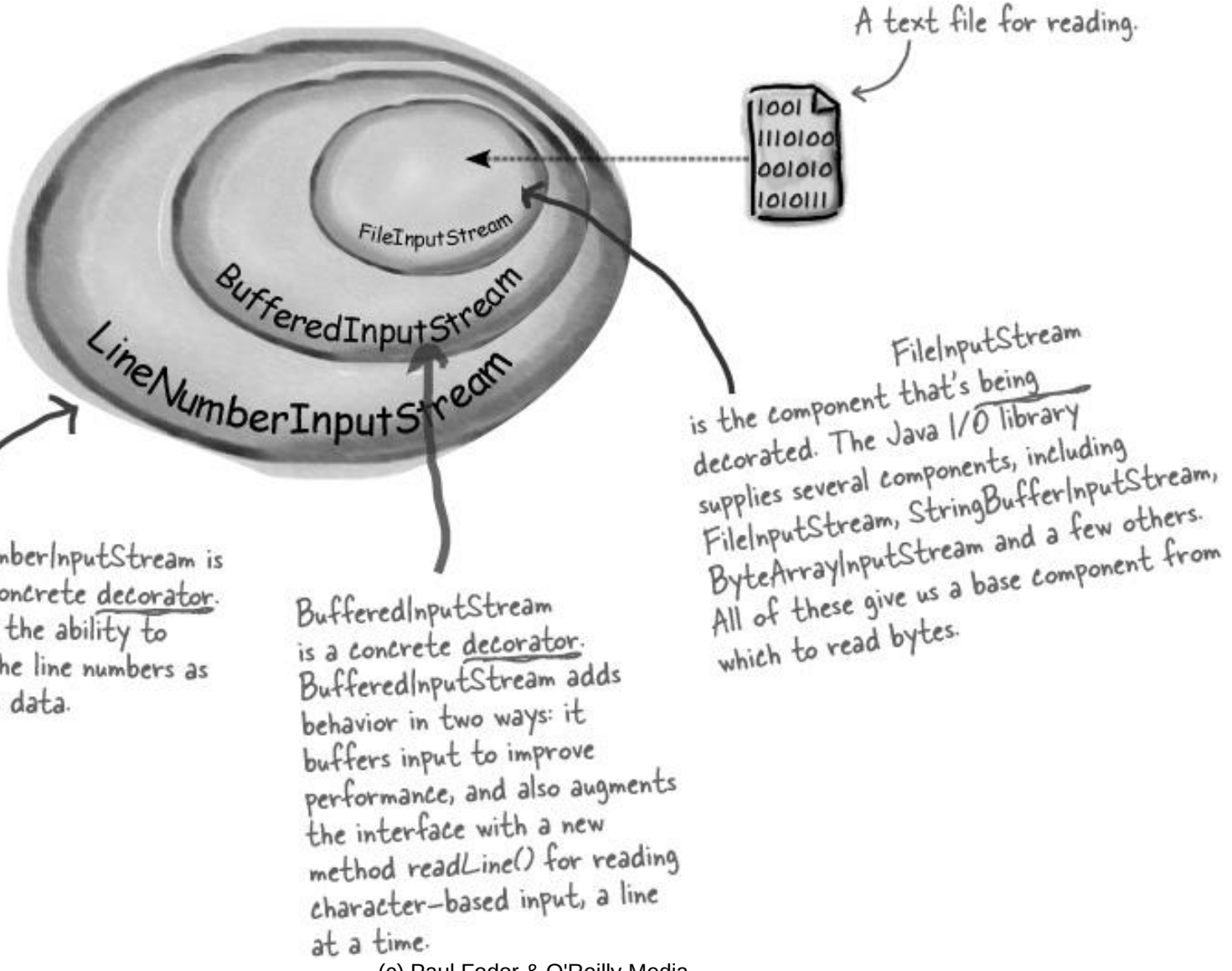




```
public abstract class Beverage {
  String description = "Unknown Beverage";
  public String getDescription() {
    return description;
  }
  public abstract double cost();
}
public class HouseBlend extends Beverage {
  public HouseBlend() {
    description = "HouseBlend";
  }
  public double cost() {
    return 1.99;
  }
}
public abstract class CondimentDecorator extends Beverage {
  protected Beverage beverage;
  public abstract String getDescription();
}
public class Mocha extends CondimentDecorator {
  public Mocha(Beverage beverage) {
    this.beverage = beverage;
  }
  public String getDescription() {
    return beverage.getDescription() + ", Mocha";
  }
  public double cost() {
    return 0.20 + beverage.cost();
  }
}
```

```
public class StarbuzzCoffee {
  public static void main(String args[]) {
    Beverage beverage = new HouseBlend();
    System.out.println(beverage.getDescription()
      + " $" + beverage.cost());
    Beverage beverage2 = new Mocha(beverage);
    beverage2 = new Sugar(beverage2);
    beverage2 = new Whip(beverage2);
    beverage2 = new Whip(beverage2);
    System.out.println(beverage2.getDescription()
      + " $" + beverage2.cost());
    Beverage beverage3 = new Soy(
                             new Mocha(
                             new Whip(
                             new HouseBlend())));
    System.out.println(beverage3.getDescription()
      + " $" + beverage3.cost());
  }
}
```

Java's IO Library



```
// The Window interface class
public interface Window {
    public void draw(); // Draws the Window
    public String getDescription(); // Returns a description
}
// Extension of a simple Window without any scrollbars
class SimpleWindow implements Window {
    public void draw() {
        // Draw window
    }
    public String getDescription() {
        return "simple window";
    }
}
// abstract decorator class - it implements Window
abstract class WindowDecorator implements Window {
    protected Window windowToBeDecorated;
    public WindowDecorator (Window windowToBeDecorated) {
        this.windowToBeDecorated = windowToBeDecorated;
    }
    public void draw() {
        windowToBeDecorated.draw(); //Delegation
    }
```

```
    public String getDescription() {
        return windowToBeDecorated.getDescription();//Delegation
    }
}
// The first concrete decorator - adds vertical scrollbar
class VerticalScrollBarDecorator extends WindowDecorator {
    public VerticalScrollBarDecorator(Window windowToBeDecorated){
        super(windowToBeDecorated);
    }
    @Override
    public void draw() {
        super.draw();
        drawVerticalScrollBar();
    }
    private void drawVerticalScrollBar() {
        // Draw the vertical scrollbar
    }
    @Override
    public String getDescription() {
        return super.getDescription()
              + ", including vertical scrollbars";
    }
}
```

```
// The second concrete decorator - adds horizontal scrollbar
class HorizontalScrollBarDecorator extends WindowDecorator {
    public HorizontalScrollBarDecorator(Window windowToBeDecorated){
        super(windowToBeDecorated);
    }
    @Override
    public void draw() {
        super.draw();
        drawHorizontalScrollBar();
    }
    private void drawHorizontalScrollBar() {
        // Draw the horizontal scrollbar
    }
    @Override
    public String getDescription() {
        return super.getDescription()
              + ", including horizontal scrollbars";
    }
}
```

```
public class DecoratedWindowTest {
    public static void main(String[] args) {
        // Create a decorated Window with horizontal and
        //  vertical scrollbars
        Window decoratedWindow =
                new HorizontalScrollBarDecorator(
                new VerticalScrollBarDecorator(
                new SimpleWindow()));
        // Print the Window's description
        System.out.println(decoratedWindow.getDescription());
    }
}
```

The output of this program is "simple window, including vertical scrollbars, including horizontal scrollbars" (each decorator decorates the window description with a suffix).

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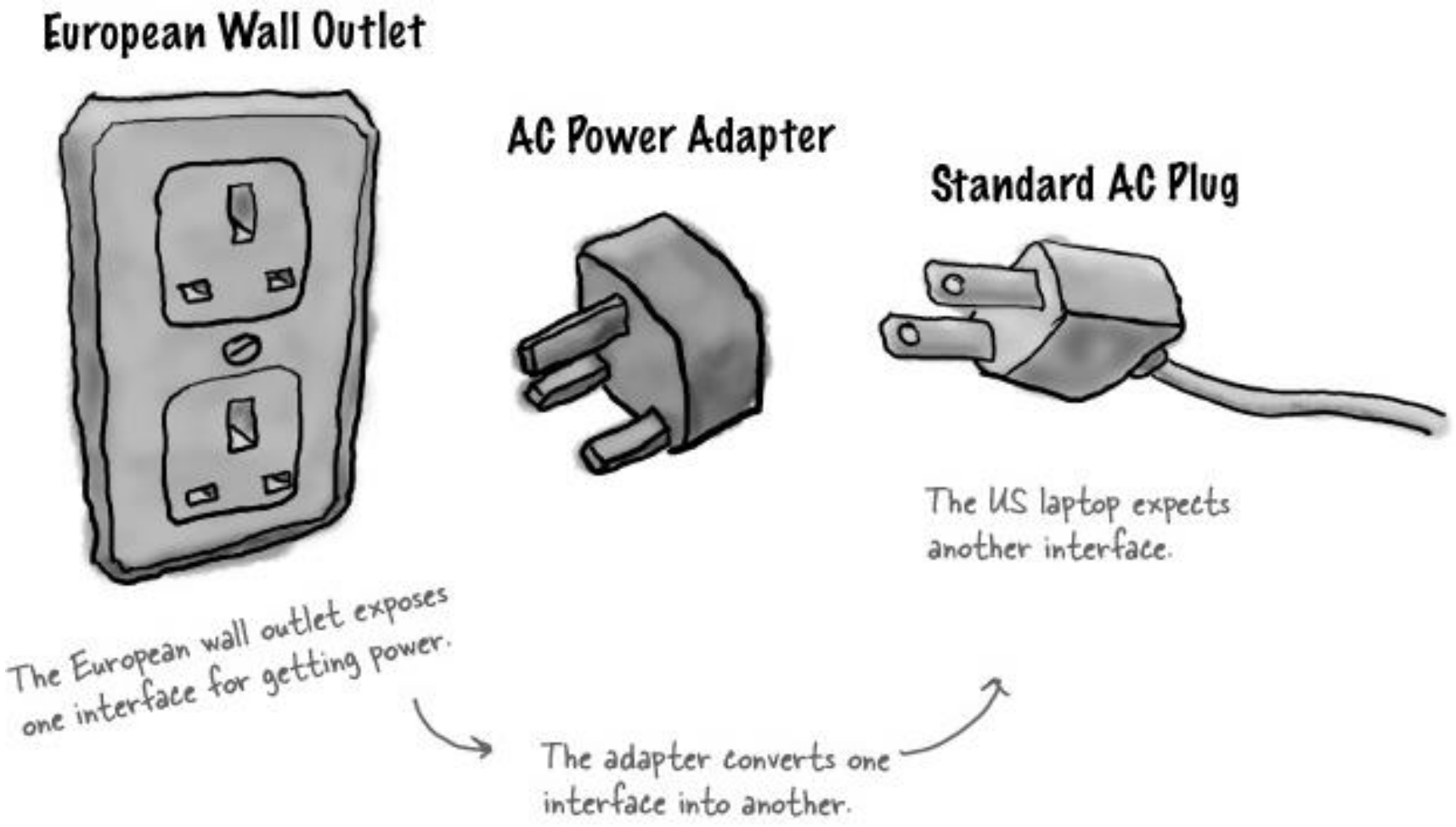
Textbook: Head First Design Patterns

Ever been to Europe, Asia or Australia?

- You need adaptors (sometimes transformers:)



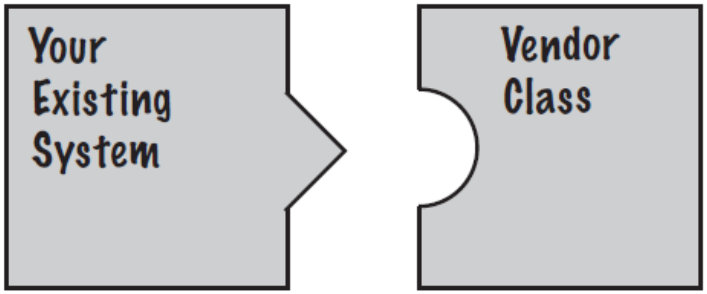
The Adapter Pattern

- Converts the interface of a class into another interface a client expects
- Adapter lets classes work together that couldn't otherwise because of incompatible interfaces
- Do you know what a driver is?

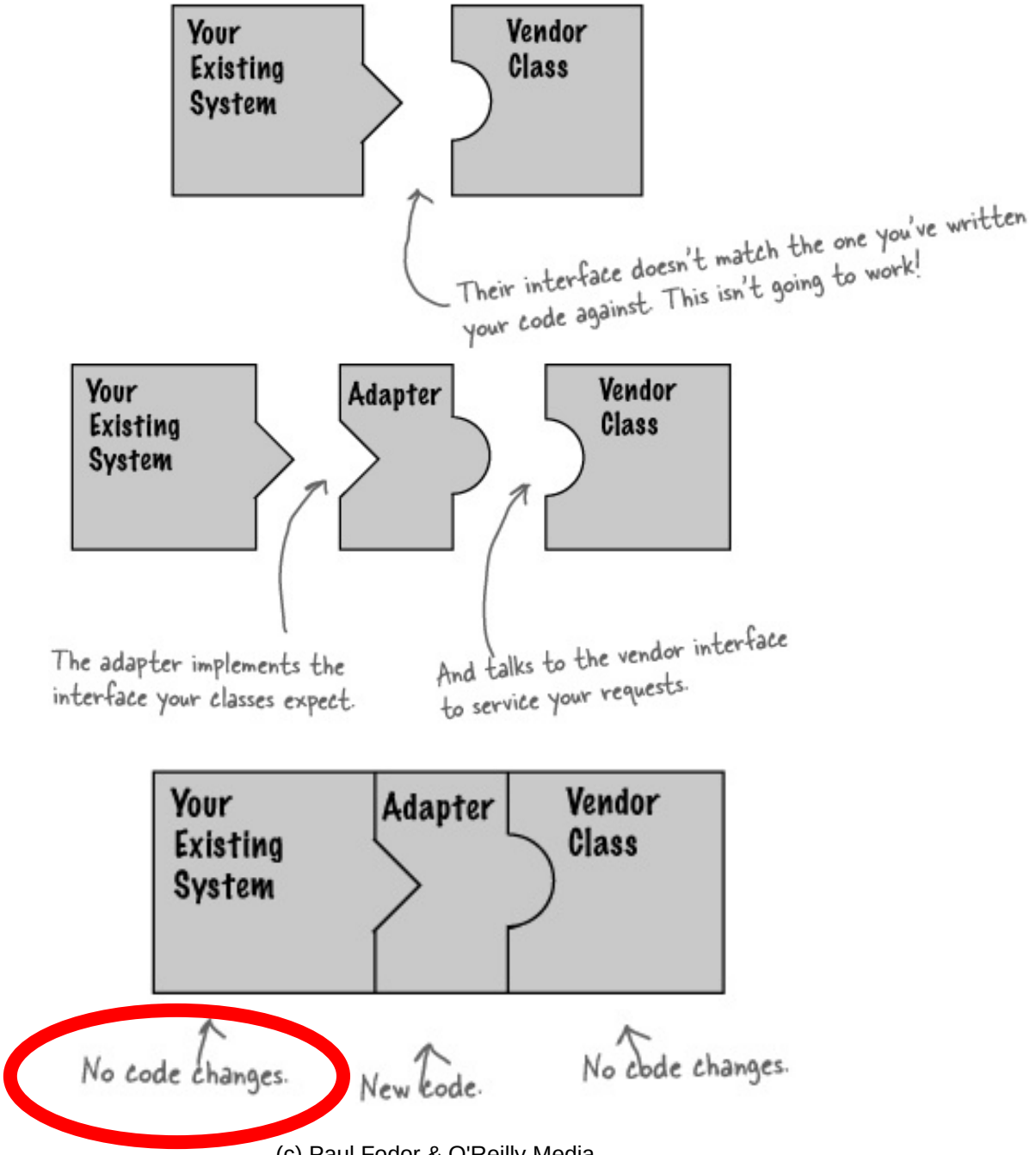
Device drivers.

Object oriented adapters

- **You have an existing system**
- You need to work a vendor library into the system
- The new vendor interface is different from the last vendor



- You really don't want to and **should not** change your existing system
- Solution: Make a class that **adapts** the new vendor interface into what the system uses.



How do we do it?

- Example: Driver
  - Existing system uses a driver via an interface
  - New hardware uses a different interface
  - Adapter can adapt differences
- Existing system HAS-A **`OldInterface`**
- Adapter implements **`OldInterface`** and HAS-A **`NewInterface`**
- Existing system calls **`OldInterface`** methods on adapter, adapter forwards them to **`NewInterface`** implementations

What's good about this?

- Decouple the client from the implemented interface
- If we expect the interface to change over time, the adapter encapsulates that change so that the client doesn't have to be modified each time it needs to operate against a different interface.

```
public interface Duck {                                    // old class
        void quack();
        void walk();
}
public class MallardDuck implements Duck {
        @Override
        public void quack() {
                System.out.println("Quack... quack...");
        }
        @Override
        public void walk() {
                System.out.println("Walking duck ...");
        }
}
public class Main {
        public static void main(String[] args) {
                System.out.println("Duck: ");
                Duck duck = new MallardDuck();
                test(duck);
        }

        static void test(Duck duck) {
                duck.quack();
                duck.walk();
        }
}
```

```
public class Turkey {
        public void walk() {                                    // A new class
                System.out.println("Walking turkey ...");
        }
        public void gobble() {
                System.out.println("Gobble ... gobble ...");
        }
}
public class TurkeyAdapter implements Duck {
        private Turkey turkey;
        public TurkeyAdapter(Turkey turkey) {
                this.turkey = turkey;
        }
        @Override
        public void quack() {
                turkey.gobble();
        }
        @Override
        public void walk() {
                turkey.walk();
        }
}
public class Main {
        public static void main(String[] args) {
                System.out.println("Fake duck (i.e., turkey): ");
                Duck x = new TurkeyAdapter(new Turkey());
                test(x);
        }
        static void test(Duck duck) {
                duck.quack();     duck.walk();
        }
}
```

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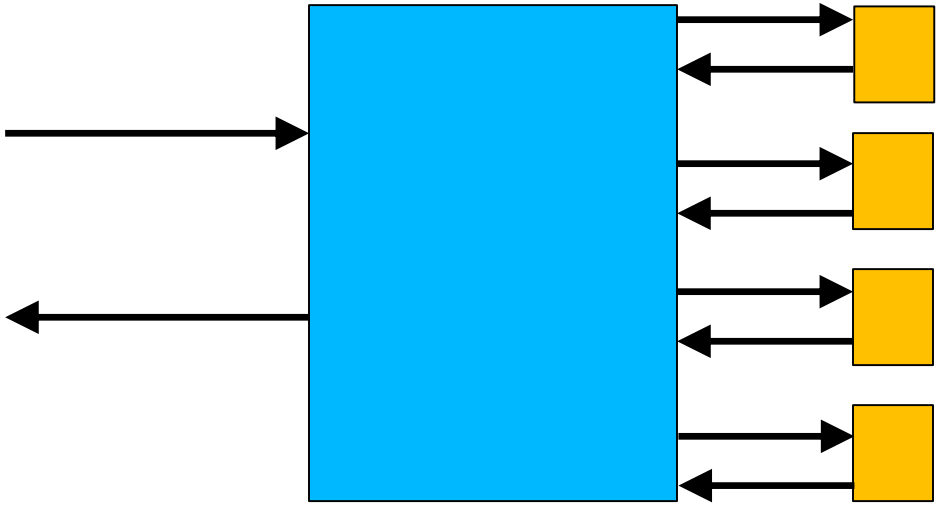
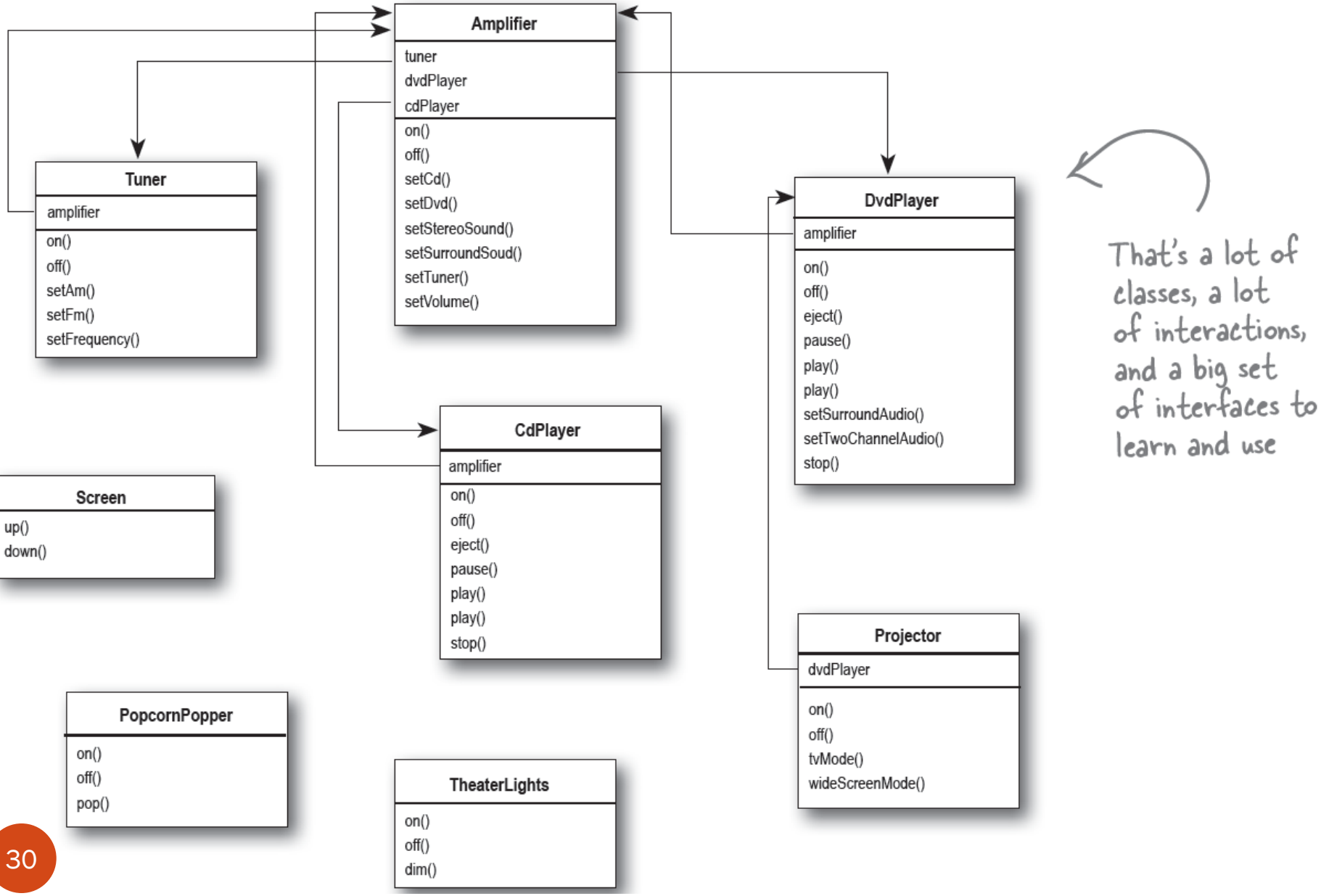
The Facade Pattern

- Provides a **unified interface** to a set of interfaces in a subsystem.
- The facade defines a higher-level interface that **makes the subsystem easier to use**
- Employs the principle of "*least knowledge*"



Home Sweet Home Theater

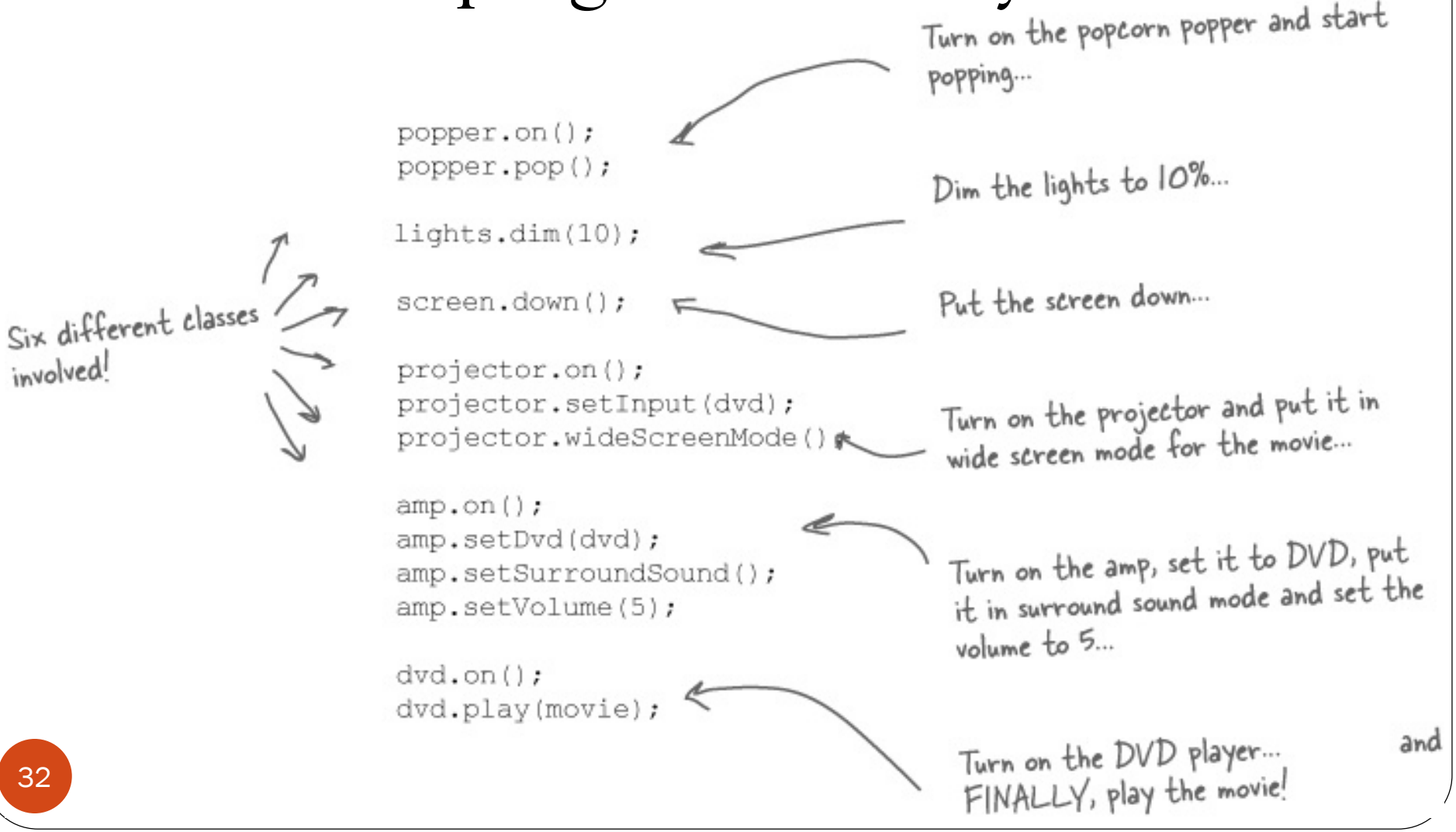


Scenario: Watching a movie

- Steps (very complicated):
  1. Put the screen down
  2. Turn the projector on
  3. Set the projector input to DVD
  4. Put the projector on wide-screen mode
  5. Turn the sound amplifier on
  6. Set the amplifier to DVD input
  7. Set the amplifier to surround sound
  8. Set the amplifier volume to medium (5)
  9. Turn the DVD Player on
  10. Start the DVD Player playing
  11. Turn on the popcorn popper
  12. Start the popper popping
  13. Dim the lights

Scenario: Watching a movie

- Let's do it programmatically:



The Facade Pattern

- When the movie is over, how do you turn everything off ?
  - Wouldn't you have to do all of this over again, in reverse?
- If you decide to upgrade your system, you're probably going to have to learn a different procedure.

The Façade Pattern

Abstract everything in a few methods:

`watchMovie()`
`endMovie()`

`watchMovie()`
`endMovie()`

This client only has one friend; the HomeTheaterFacade. In OO programming, having only one friend is a GOOD thing!

Client

The HomeTheaterFacade manages all those subsystem components for the client. It keeps the client simple and flexible.

HomeTheaterFacade
watchMovie()
endMovie()
listenToCd()
endCd()
listenToRadio()
endRadio()

We can upgrade the home theater components without affecting the client.

Amplifier
Tuner
DvdPlayer
CdPlayer
Screen
Projector
PopcornPopper
TheaterLights

We try to keep subsystems adhering to the Principle of Least Knowledge as well. If this gets too complex and too many friends are intermingling, we can introduce additional facades to form layers of subsystems.

```
public class HomeTheaterFacade {
  Amplifier amp;
  Tuner tuner;
  DvdPlayer dvd;
  CdPlayer cd;
  Projector projector;
  TheaterLights lights;
  Screen screen;
  ...
  public HomeTheaterFacade(Amplifier amp, Tuner tuner, DvdPlayer
    dvd, CdPlayer cd, Projector projector, Screen screen,
    TheaterLights lights, ...) { ... }
  public void watchMovie(String movie) {
    lights.dim(10);
    screen.down();
    projector.on();
    projector.wideScreenMode();
    amp.on();
    amp.setDvd(dvd);
    amp.setSurroundSound();
    amp.setVolume(5);
    dvd.on();
    dvd.play(movie);
  }
  public void endMovie() {
    lights.on();
    screen.up();
    projector.off();
    amp.off();
    dvd.stop();
    dvd.eject(); ...}
```

```
public class Main {
  public static void main(String[] args) {
        HomeTheaterFacade facade = new HomeTheaterFacade(
                        new Amplifier(),
                        new Tuner(),
                        new DvdPlayer(),
                        new CdPlayer(),
                        new Projector(),
                        new Screen(),
                        new TheaterLights(),...);
                facade.watchMovie("Action in Space");
                facade.endMovie();
        }
}
```

```
// Computers are complicated
class CPU {
    public void freeze() { ... }
    public void jump(long position) { ... }
    public void execute() { ... }
}
class Memory {
    public void load(long position, byte[] data) { ... }
}

class HardDrive {
    public byte[] read(long lba, int size) { ... }
}
/* Facade */
class ComputerFacade {
    private CPU processor;
    private Memory ram;
    private HardDrive hd;

    public ComputerFacade() {
        this.processor = new CPU();
        this.ram = new Memory();
        this.hd = new HardDrive();
    }
    public void start() {
        processor.freeze();
        ram.load(BOOT_ADDRESS, hd.read(BOOT_SECTOR, SECTOR_SIZE));
        processor.jump(BOOT_ADDRESS);
        processor.execute();
    }…
}
```

```
public static void main(String[] args) {
    ComputerFacade computer =
            new ComputerFacade();
    computer.start();
}
```

Quiz: Which is which?

- Converts one interface to another
- Makes an interface simpler
- Doesn't alter the interface, but adds responsibility

A) Decorator

B) Adapter

C) Facade

Quiz: Which is which?

- Converts one interface to another B
- Makes an interface simpler C
- Doesn't alter the interface, but adds responsibility A

A) Decorator

B) Adapter

C) Facade

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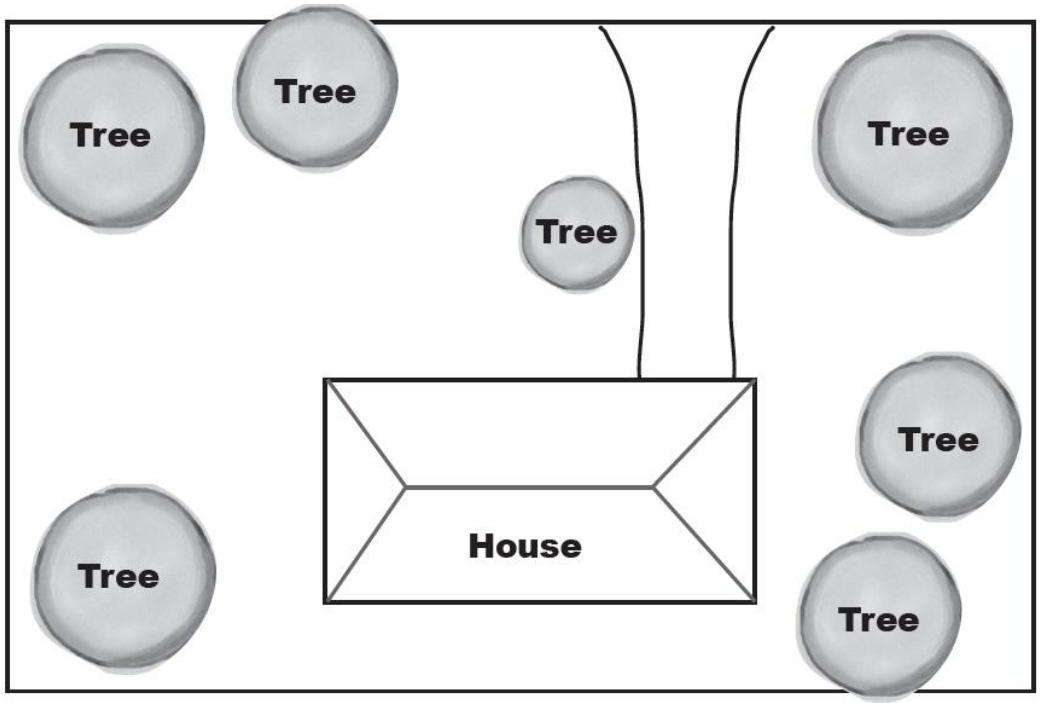
Flyweight scenario

- You develop a landscape design application for Stony Brook:

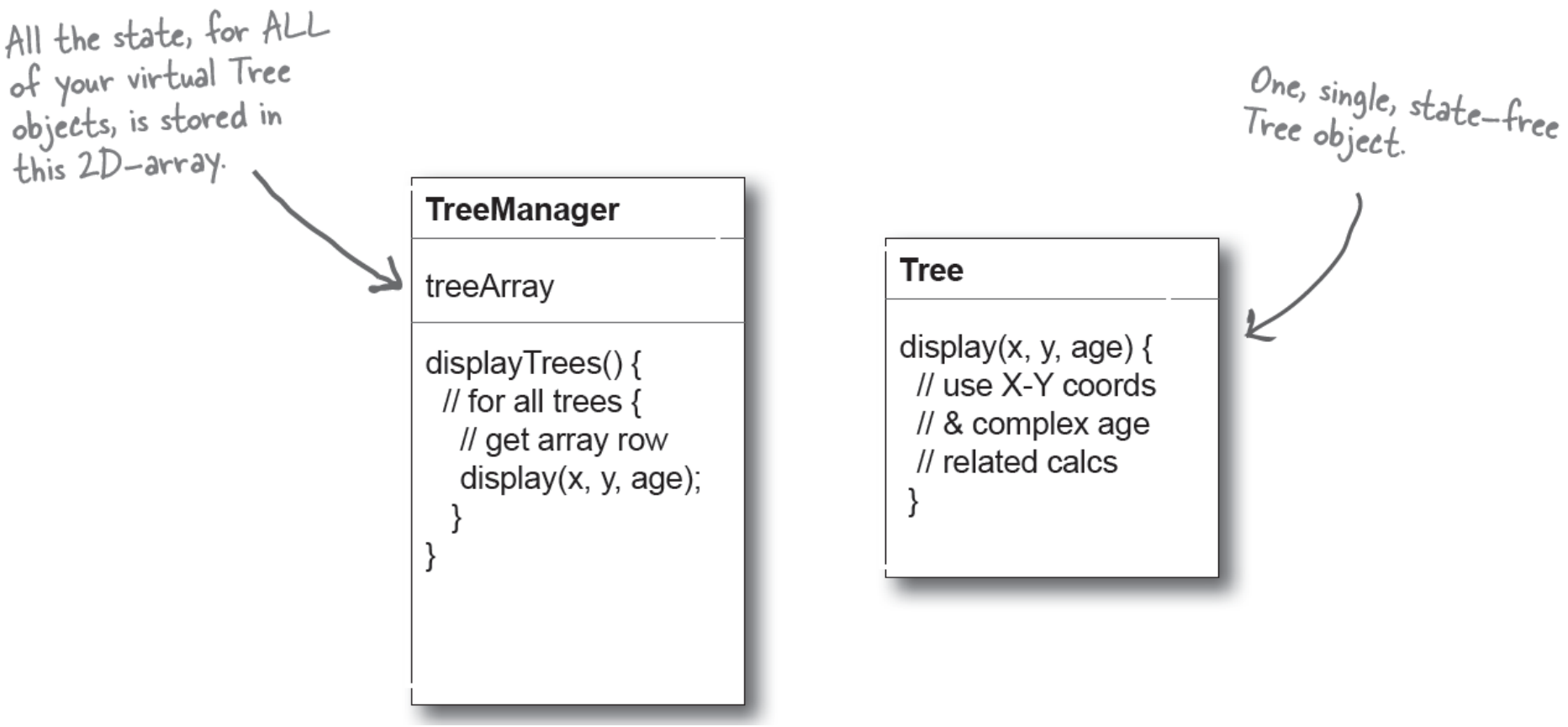


Tree
xCoord yCoord age
display() {

- After using your software for a week, your client is complaining that when they create large groves of trees, the app starts getting sluggish.

Flyweight scenario

- Flyweight: only one instance of Tree, and a client object that maintains the state of ALL the trees.



The Flyweight Pattern

- A "neat hack"
- Allows one object to be used to represent many identical instances
  - The Flyweight is used when a class has many instances, and they can all be controlled identically.
- Flyweight Benefits:
  - Reduces the number of object instances at runtime, saving memory.
  - Centralizes state for many "virtual" objects into a single location.
- Flyweight Uses and Drawbacks:
  - Once you've implemented it, single, logical instances of the class will not be able to behave independently from the other instances.

The Flyweight Pattern

- Flyweights must be immutable.
- Flyweights depend on an associated table
  - maps identical instances to the single object that represents all of them
- Used in processing many large documents
  - search engines
  - a document as an array of immutable **`String`**s
  - repeated words would share objects
  - just one object referenced all over the place
    - use static **`Hashtable`** to store mappings

You have a coffee shop

```
import java.util.ArrayList;
import java.util.HashMap;
import java.util.List;
import java.util.Map;
// Instances of CoffeeFlavour will be the Flyweights
class CoffeeFlavour {
  private final String name;
  CoffeeFlavour(String newFlavor) {
    this.name = newFlavor;
  }
  @Override
  public String toString() {
    return name;
  }
}
// Menu acts as a factory and cache for CoffeeFlavour flyweight objects
class Menu {
  private Map<String, CoffeeFlavour> flavours =
                new HashMap<String,CoffeeFlavour>();
  CoffeeFlavour lookup(String flavorName) {
    if (!flavours.containsKey(flavorName))
      flavours.put(flavorName, new CoffeeFlavour(flavorName));
    return flavours.get(flavorName);
  }
  int totalCoffeeFlavoursMade() {
    return flavours.size();
  }
}
```

```
class Order {
  private final int tableNumber;
  private final CoffeeFlavour flavour;
  Order(int tableNumber, CoffeeFlavour flavor) {
    this.tableNumber = tableNumber;
    this.flavour = flavor;
  }
  void serve() {
    System.out.println("Serving " + flavour + " to table " + tableNumber)
  }
}
public class CoffeeShop {
  private final List<Order> orders = new ArrayList<Order>();
  private final Menu menu = new Menu();
  void takeOrder(String flavourName, int table) {
    CoffeeFlavour flavour = menu.lookup(flavourName);
    Order order = new Order(table, flavour);
    orders.add(order);
  }
  void service() {
    for (Order order : orders)
      order.serve();
  }
  String report() {
    return "\ntotal CoffeeFlavour objects made: "
        + menu.totalCoffeeFlavoursMade();
  }
```

```
  public static void main(String[] args) {
    CoffeeShop shop = new CoffeeShop();
    shop.takeOrder("Cappuccino", 2);
    shop.takeOrder("Frappe", 1);
    shop.takeOrder("Espresso", 1);
    shop.takeOrder("Frappe", 897);
    shop.takeOrder("Cappuccino", 97);
    shop.takeOrder("Frappe", 3);
    shop.takeOrder("Espresso", 3);
    shop.takeOrder("Cappuccino", 3);
    shop.takeOrder("Espresso", 96);
    shop.takeOrder("Frappe", 552);
    shop.takeOrder("Cappuccino", 121);
    shop.takeOrder("Espresso", 121);
    shop.service();
    System.out.println(shop.report());
  }
Output:
 Serving Cappuccino to table 2
 Serving Frappe to table 1
 Serving Espresso to table 1
 Serving Frappe to table 897
 Serving Cappuccino to table 97
 Serving Frappe to table 3
 Serving Espresso to table 3
 Serving Cappuccino to table 3 ...
```

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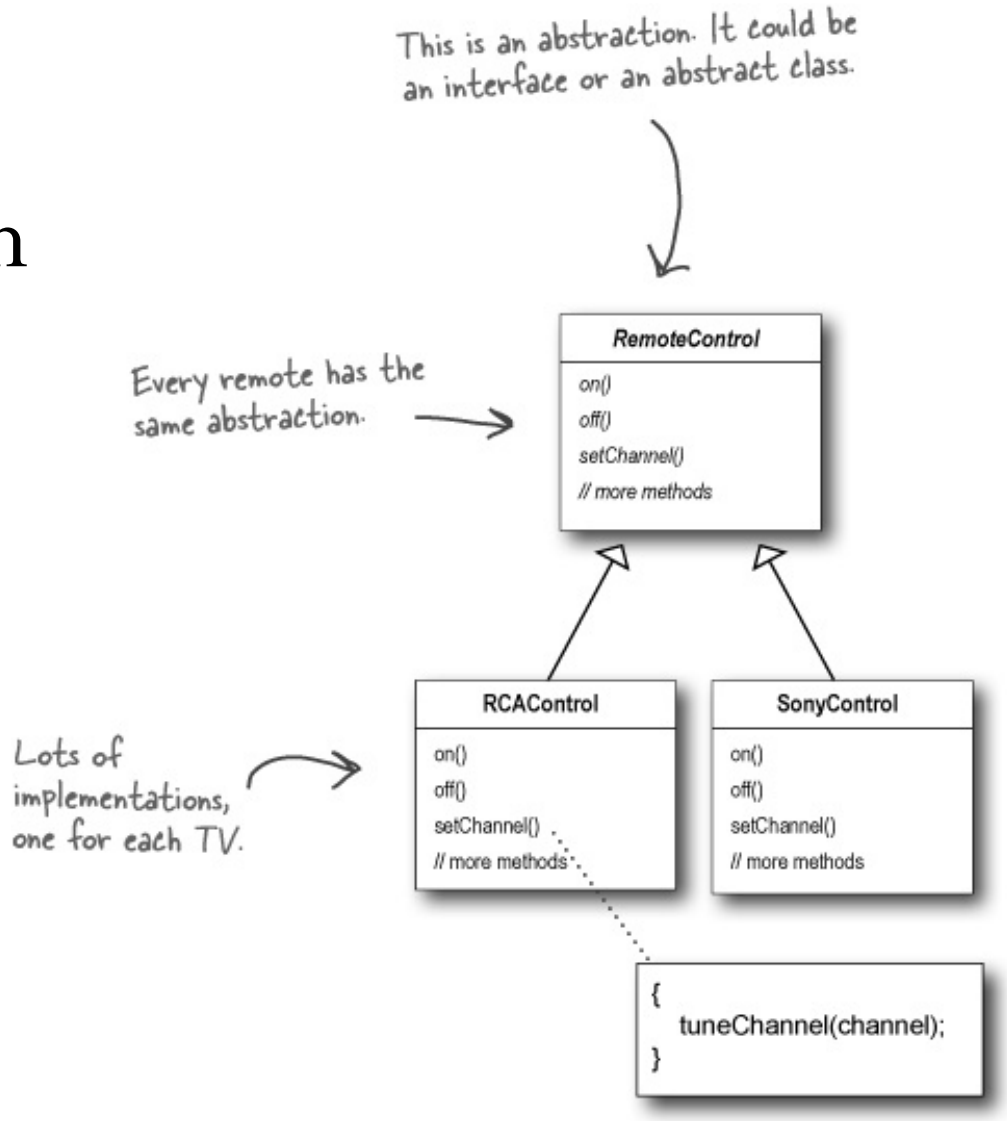
The Bridge Pattern

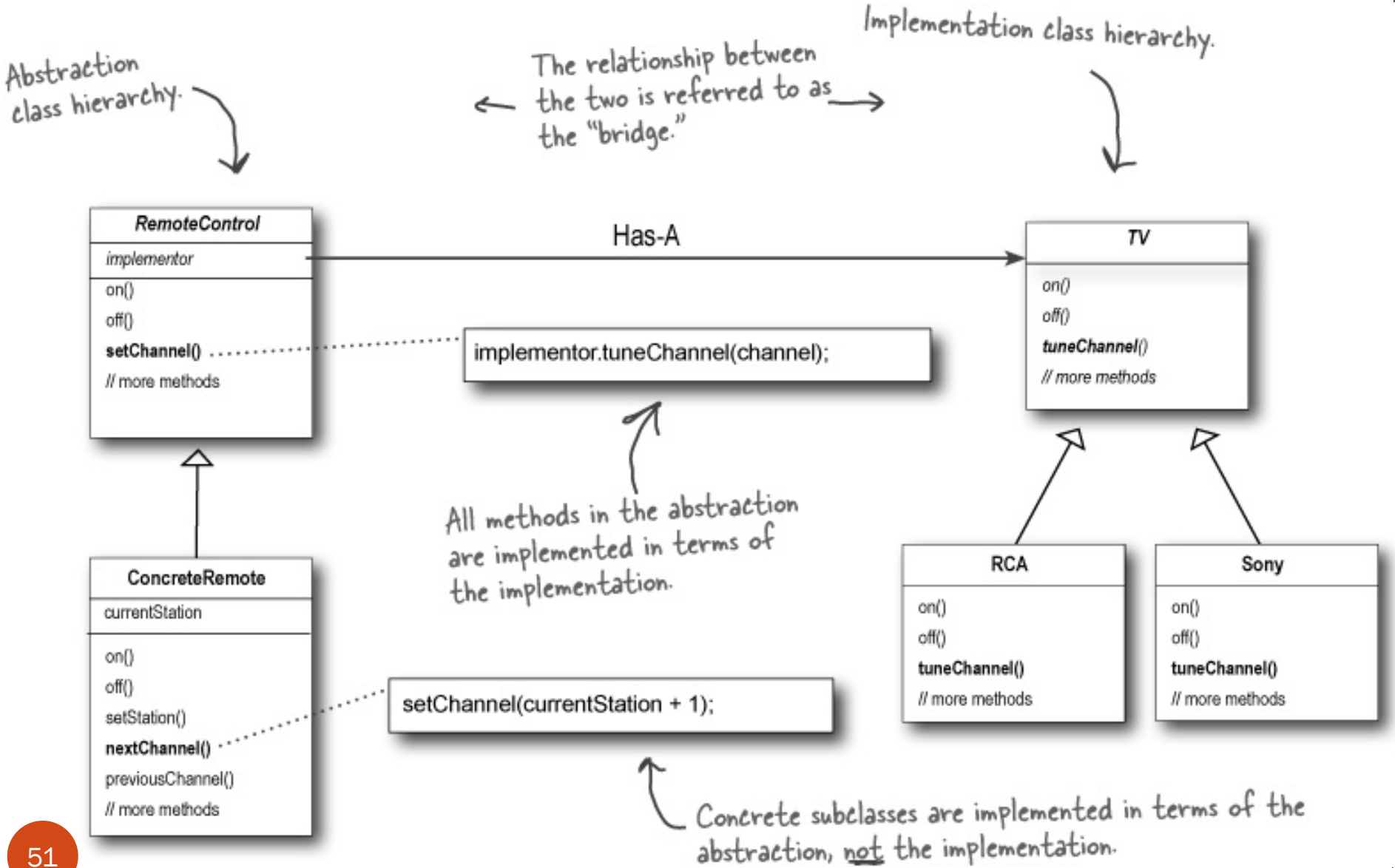
- Used to vary not only your implementations, but also your abstractions!
- Scenario:
  - you're writing the code for a new ergonomic and user-friendly remote control for TVs
  - there will be **lots of implementations** – one for each model of TV –> use an abstraction (interface)
  - you know there will be many changes over time to the specification – needs to accommodate changes
  - Solution? **Abstract the abstraction**!

Scenario

- A bridge-less design
- Won't easily accommodate change



This is better



The Bridge Pattern

- Bridge Benefits
  - Decouples an implementation so that it is not bound permanently to an interface.
  - **Abstraction and implementation can be extended independently.**
  - Useful in graphics and windowing systems that need to run over multiple platforms.
  - Useful any time you need to vary an interface and an implementation in different ways.
- Bridge Drawback:
  - Increases complexity.

```
/** "Abstraction" */
abstract class Shape {
    protected DrawingAPI drawingAPI;
    protected Shape(DrawingAPI drawingAPI){
        this.drawingAPI = drawingAPI;
    }
    public abstract void draw();                                  // low-level
    public abstract void resizeByPercentage(double pct);   // high-level
}
/** "Refined Abstraction" */
class CircleShape extends Shape {
    private double x, y, radius;
    public CircleShape(double x, double y, double radius,
                DrawingAPI drawingAPI) {
        super(drawingAPI);
        this.x = x;  this.y = y;  this.radius = radius;
    }
    // low-level i.e. Implementation specific
    public void draw() {
        drawingAPI.drawCircle(x, y, radius);
    }
    // high-level i.e. Abstraction specific
    public void resizeByPercentage(double pct) {
        radius *= pct;
    }
}
```

```
/** "Implementor" */
interface DrawingAPI {
    public void drawCircle(double x, double y, double radius);
}
/** "ConcreteImplementor"  1 */
class DrawingAPI1 implements DrawingAPI {
    public void drawCircle(double x, double y, double radius) {
     System.out.printf("API1.circle at %f:%f radius %f\n", x, y, radius);
    }
}
/** "ConcreteImplementor" 2 */
class DrawingAPI2 implements DrawingAPI {
    public void drawCircle(double x, double y, double radius) {
        System.out.printf("API2.circle at %f:%f radius %f\n",x,y,radius);
    }
}
/** "Client" */
public class BridgePattern {
    public static void main(String[] args) {
        Shape[] shapes = new Shape[] {
            new CircleShape(1, 2, 3, new DrawingAPI1()),
            new CircleShape(5, 7, 11, new DrawingAPI2()),
        };
        for (Shape shape : shapes) {
            shape.resizeByPercentage(2.5);
            shape.draw();
        }}}
```

Output:
API1.circle at 1.0:2.0 radius 7.5
API2.circle at 5.0:7.0 radius 27.5