DESIGN PATTERNS II

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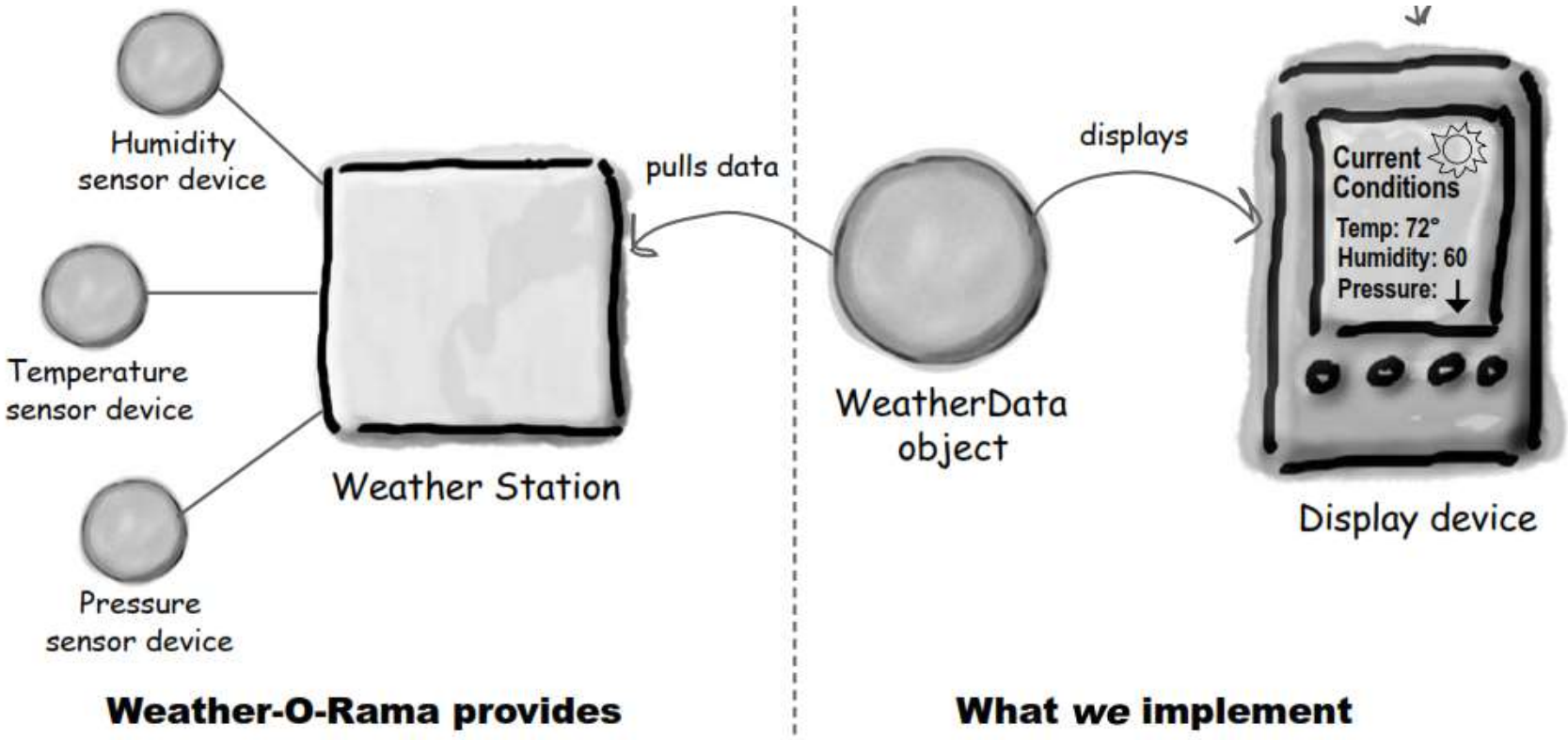
CS304

Figures from Head First Design Patterns

THE OBSERVER PATTERN

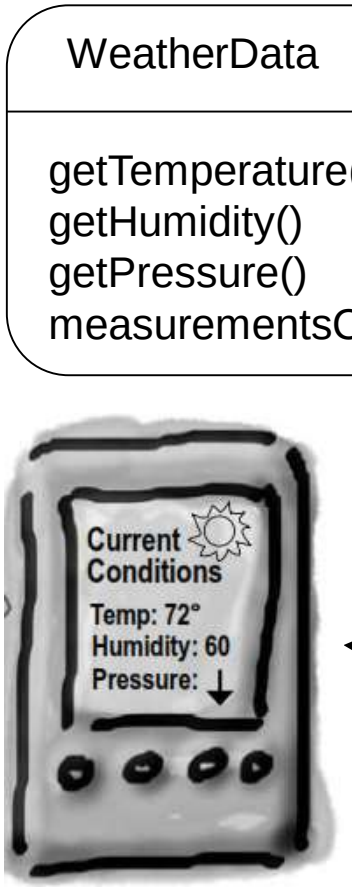
A Weather Monitoring Application



Create an app that uses the WeatherData object to update three different displays:

- “current conditions”
- “weather stats”
- “forecast”

What Needs to be Done?




```
/*
* Call this method
* whenever measurements are
* Updated
*/
public void measurementsChanged(){
  // your code goes here
}
```


Update three different displays

Problem Specification

- The `WeatherData` class has getters and setters for temperature, humidity, and pressure
- The `measurementsChanged()` method is called anytime new weather data is available
  - We don't know *or care* how.
- We need to implement three different display elements that use the weather data
- The system must be expandable, in case others want to add other display elements later

A First Try

```
public class WeatherData {

  //instance variable declarations

  public void measurementsChanged(){
         float temp = getTemperature();
         float humidity = getHumidity();
         float pressure = getPressure();

         currentConditionsDisplay.update(temp, humidity, pressure);
         statisticsDisplay.update(temp, humidity, pressure);
         forecastDisplay.update(temp, humidity, pressure);
  }
  // other methods
}
```

What's Wrong?

A First Try

```
public class WeatherData {

  //instance variable declarations

  public void measurementsChanged(){
                                    mperature();
                                    etHumidity();
                                    etPressure();

      currentConditionsDisplay.update(temp, humidity, pressure);
      statisticsDisplay.update(temp, humidity, pressure);
      forecastDisplay.update(temp, humidity, pressure);
  }
  // other methods
}
```

Coding to implementations: adding displays requires changing the program

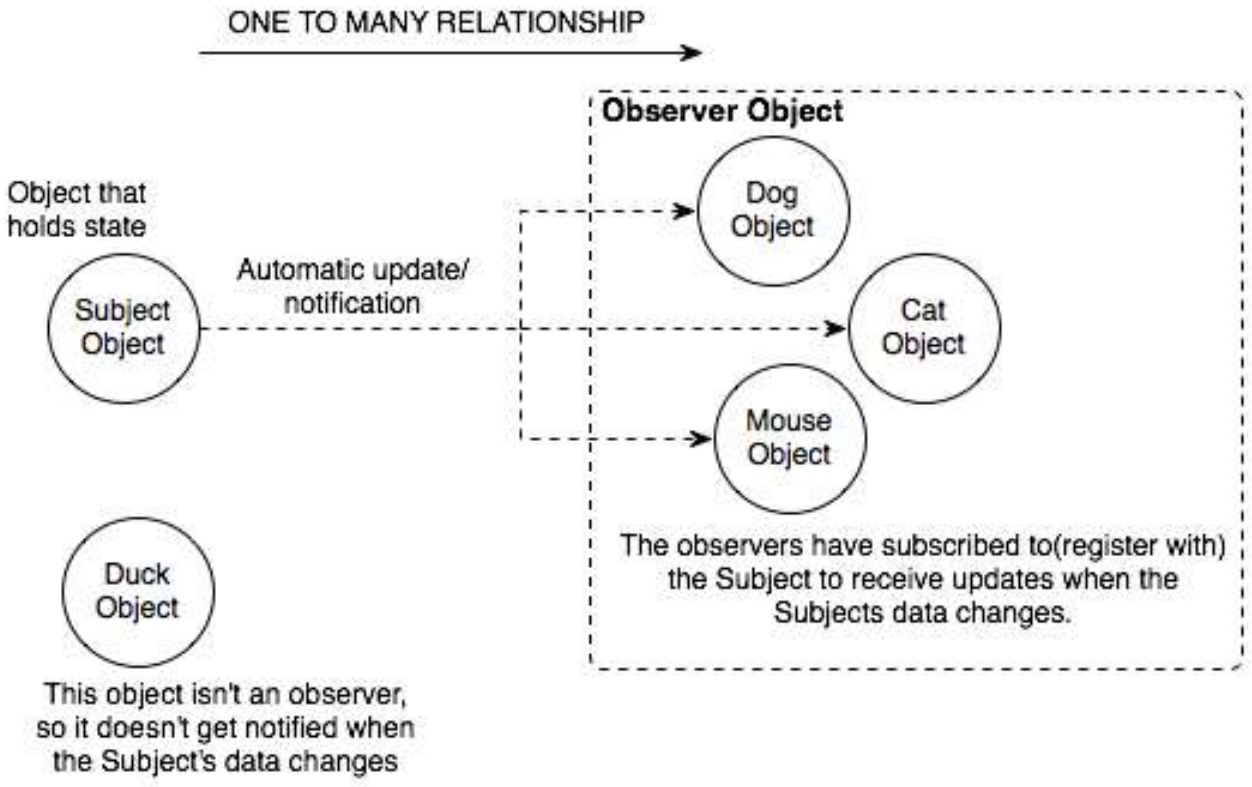
Not so bad: here's a common interface!

Encapsulate stuff that changes!

What's Wrong?

Publish/Subscribe

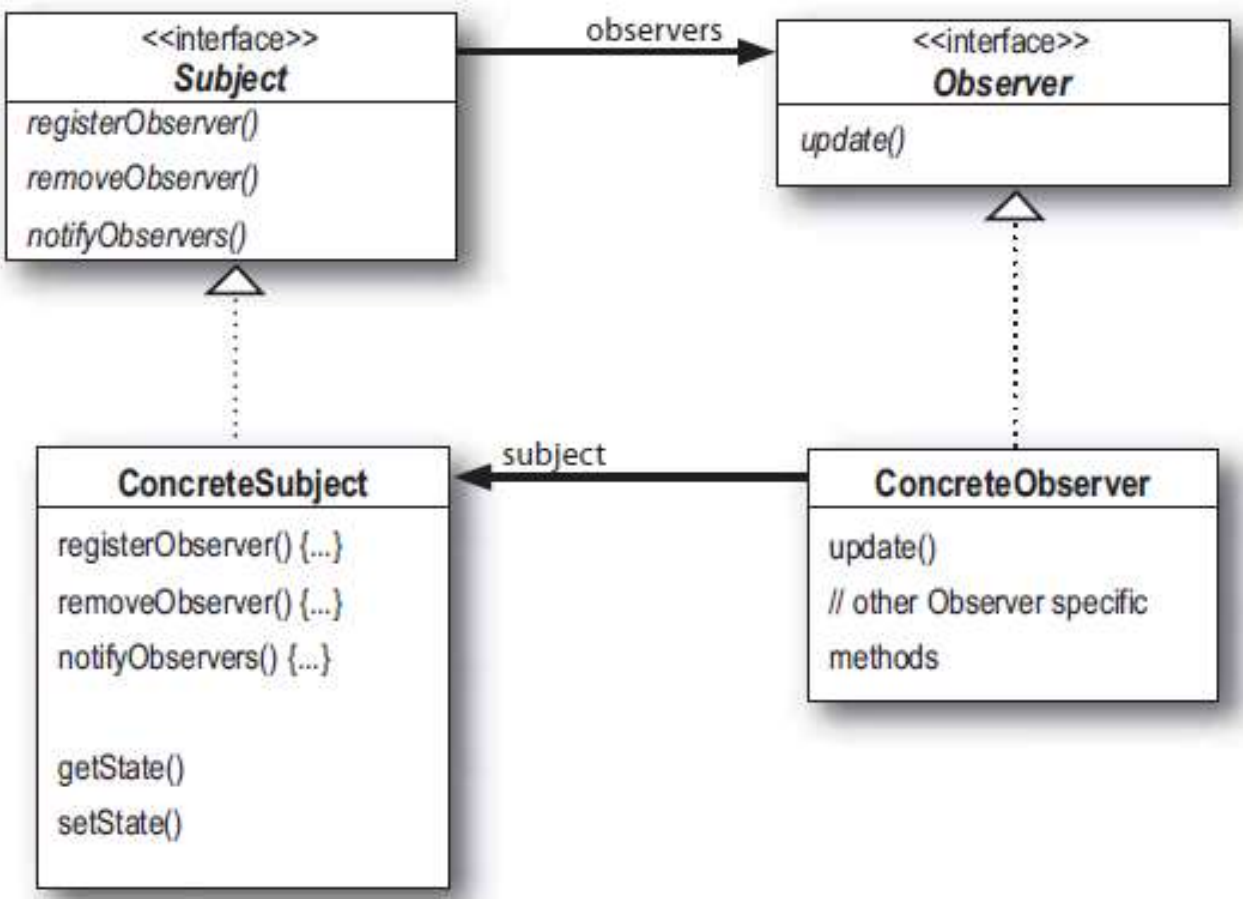
- Just like newspapers and magazines
  - You subscribe and receive any new additions
  - You unsubscribe and stop receiving anything



The Observer Pattern

The Observer Pattern defines a one-to-many dependency between objects so that when one object changes state, all its dependences are notified and updated automatically.

The Observer Pattern

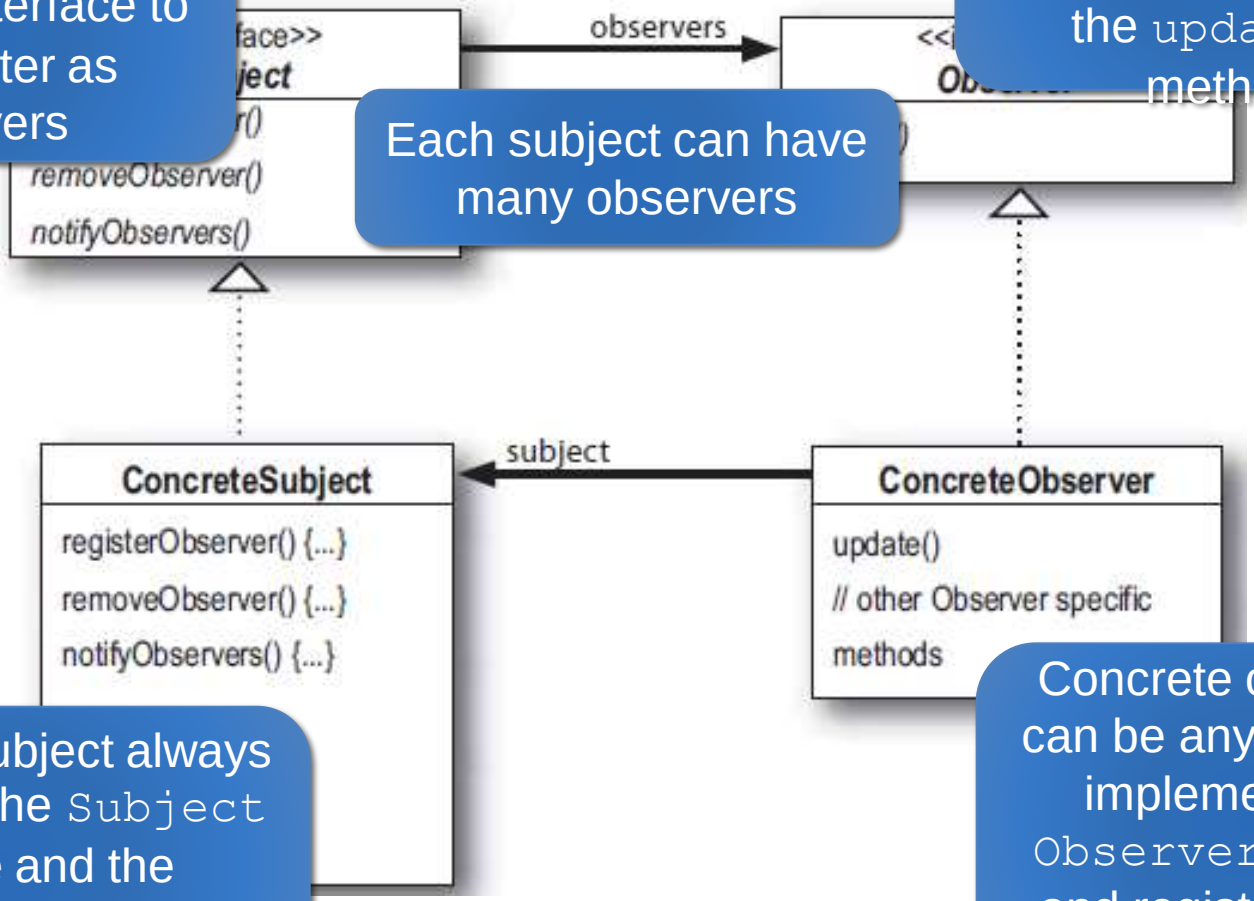


The Observer Pattern

Objects use the `Subject` interface to (de)register as observers

All potential observers need to implement the `Observer` interface and provide the `update()` method

Each subject can have many observers



A concrete subject always implements the `Subject` interface and the `notifyObservers()` method

Concrete observers can be any class that implements the `Observer` interface and registers with a concrete subject

The Power of Loose Coupling

- The only thing a subject knows about an observer is that it implements a given interface
- We can add new observers at any time
- We never need to modify the subject to add new types of observers
- We can reuse subjects or observers independently of each other
- Cha affect eac

Loosely coupled designs allow us to build flexible OO systems that can handle change because they minimize the interdependencies between objects.

Exercise

- Draw the class diagram for the weather data app

Weather Data Interfaces

```
public interface Subject {
  public void registerObserver(Observer o);
  public void removeObserver(Observer o);
  public void notifyObservers();
}
```

```
public interface Observer {
  public void update(float temp, float humidity, float pressure);
}
```

```
public interface DisplayElement {
  public void display();
}
```

Weather Data Interfaces

```
public interface Subject {
  public void registerObserver(Observer o);
  public void removeObserver(Observer o);
  public void notifyObservers();
}

public interface Observer {
  public void update(float temp, float humidity, float pressure);
}

public interface DisplayElement {
  public void display();
}
```

These first two methods take an `Observer` as an argument

This method is called to notify all observers when the `Subject`'s state has changed

The `Observer` interface is implemented by all observers, giving them the `update()` method

We added in a `DisplayElement` interface since all of the display types share the need to `display()`

Implementing the Subject Interface

```
public class WeatherData implements Subject {
  private ArrayList observers;
  private float temperature;
  private float humidity;
  private float pressure;

  public WeatherData() {
    observers = new ArrayList();
  }

  public void registerObserver(Observer o) {
    observers.add(o);
  }

  public void removeObserver(Observer o) {
    int i = observers.indexOf(o);
    if (i >= 0) {
      observers.remove(i);
    }
  }
```

Implementing the Subject Interface

```
public class WeatherData implements Subject {
  private ArrayList observers;
  private float temperature;
  private float humidity;
  private float pressure;

  public WeatherData() {
    observers = new ArrayList();
  }

  public void registerObserver(Observer o) {
    observers.add(o);
  }

  public void removeObserver(Observer o) {
    int i = observers.indexOf(o);
    if (i >= 0) {
      observers.remove(i);
    }
  }
```

This `ArrayList` holds our observers, and we'll have to maintain it…

These methods were required by the `Subject` interface.

Notify Methods

```
public void notifyObservers() {
  for (int i = 0; i < observers.size(); i++) {
    Observer observer = (Observer)observers.get(i);
    observer.update(temperature, humidity, pressure);
  }
}


public void measurementsChanged() {
  notifyObservers();
}

public void setMeasurements(float temperature, float
  humidity, float pressure){
  this.temperature = tempreature;
  this.humidity = humidity;
  this.pressure = pressure;
  meassurementChanged();
}
```

Notify Methods

```
public void notifyObservers() {
  for (int i = 0; i < observers.size(); i++) {
    Observer observer = (Observer)observers.get(i);
    observer.update(temperature, humidity, pressure);
  }
}
```

This one was required by the `Subject` interface, too.

```
public void measurementsChanged() {
  notifyObservers();
}
```

We notify the observers when we get updated measurements fro the weather station

```
public void setMeasure                                    float
  humidity, float press
  this.temperature = tempreature;
  this.humidity = humidity;
  this.pressure = pressure;
  meassurementChanged();
}
```

A Display Element

```
public class CurrentConditionsDisplay implements Observer, DisplayElement {
  private float temperature;
  private float humidity;
  private Subject weatherData;

  public CurrentConditionsDisplay(Subject weatherData) {
    this.weatherData = weatherData;
    weatherData.registerObserver(this);
  }

  public void update(float temperature, float humidity, float pressure) {
    this.temperature = temperature;
    this.humidity = humidity;
    display();
  }

  public void display() {
    System.out.println("Current conditions: " + temperature
                       + "F degrees and " + humidity + "% humidity");
  }
}
```

A Display Element

This display element is an `Observer` so it can get changes from the `WeatherData` object

```
public class CurrentConditionsDisplay implements Observer, DisplayElement {
  private float temperature;
  private float humidity;
  private Subject weatherData;

  public CurrentConditionsDisplay(Subject wea
    this.weatherData = weatherData;
    weatherData.registerObserver(this);
  }

  public void update(float temperature, float humidity, float pressure) {
    this.temperature = temperature;
    this.humidity = humidity;
    display();
  }

  public void display() {
    System.out.println("Current conditions: " + temperature
                       + "F degrees and " + humidity + "% humidity");
  }
}
```

The constructor is passed the `Subject`, and we use it to register as an observer

When `update()` is called, we save the measurements and call `display()`

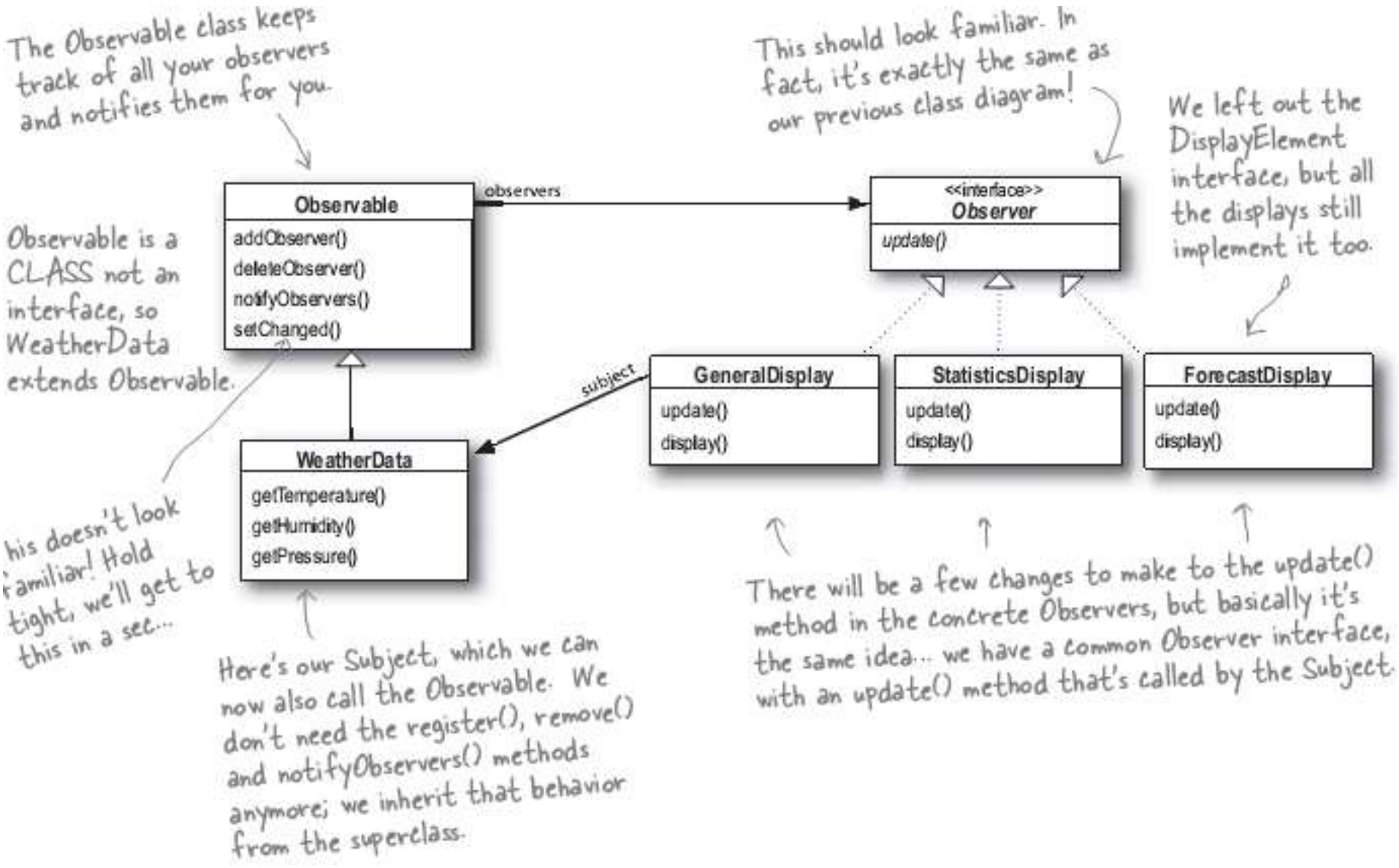
Client Test

```
public class WeatherData {
      public static void main (String[] args) {
            WeatherData weatherdate = new WeatherData();

            CurrentConditionsDisplay currentDisplay = new
CurrentConditionsDisplay(weatherData);
            StatisticsDisplay statisticsDisplay = new
StatisticsDisplay(weatherData);
            ForecastDisplay forecastDisplay = new
ForecastDisplay(weatherData);

            weatherData.setMeasurement(80, 65, 30.4f);
            weatherData.setMeasurement(82, 70, 29.2f);
            weatherData.setMeasurement(78, 90, 29.2f);
      }
}
```

The Observer Pattern in Java

- Java provides the `Observer` interface and the `Observable` class in the package `java.util`
  - Similar to `Subject` and `Observer`
- Enable both push and pull style interactions (as opposed to only push as before)

Another Design…



The Java Observer Pattern

- For an object to become an observer
  - Just implement the `Observer` interface (as before)
- For the observable to send notifications
  - Become observable by *extending* the `java.util.Observable` superclass
  - Call the `setChanged()` method to signify that the state of the object has changed
  - Call one of two notification methods:
    - `notifyObservers()`
    - `notifyObservers(Object arg)`

Notification Revisited

- For an observer to receive notifications
  - Provides a definition of the update method:

```
update(Observable o, Object arg)
```

The subject that sent the notification

The data object passed through `notifyObservers(arg)` (or `null`)

- To *push* data
  - Pass the data as a data object through the `notifyObservers(arg)` method
- To have the Observer *pull* data
  - The Observer must use the `Observable` object passed to it using the object's getters and setters

How to pull

```
import java.util.Observable;
import java.util.Observer;

public class WeatherData extends Observable{
    ...;
    public weatherData() {}
    public void measurementChanged(){
        setChanged();
        notifyObservers();
    }
    ...;
    public float getTempeature(){
        return temperature;
    }
    ...;
}
```

how to pull (pseudo)

```
setChanged(){
    changed = true
}

notifyObservers(Object arg){
    if (changed){
       for every obsrver on the list {
            call update (this, arg)
       }
    changed = false
}

notifyObservers(){
    notifyObservers(null);
}
```

Rebuilding CurrentConditionsDisplay

```
public class CurrentConditionsDisplay implements Observer,
DisplayElement{
    Observable observable;
    ...;
    public CurrentConditionsDisplay(Observable observable){
        this.observable = observable;
        obserable.addObservable(this);
    }

    public void update (Observable obs, Object arg){
        if (obs instanceof WeatherData){
            WeatherData weatherData = (WeatherData) obs;
            this.temperature = weatherData.getTemperature();
            this.humidity = weatherData.getHumidity();
            display();
        }
    ...;
}
```

The Dark Side of Java Observables

- Observable is a class, not an interface
  - You have to *subclass* it, so you can't add the Observable behavior onto a class that already extends something else
    - Limits reuse potential
  - Because there's no Observable interface, you cannot create your own implementations of Observables
- Observable protects crucial methods
  - E.g., setChanged() can only be called by subclasses
    - Limits flexibilty; you cannot favor composition over inheritance

Observers are Everywhere

- Especially in Java Swing
  - E.g., JButton and associated listeners
- Etc.

THE FACTORY PATTERN

Creating Objects

- …it's more than just `new`

- A key tenet
  - Constructor usages often lead to unintended *coupling*

- Remember the note in the Strategy pattern?
  - When we say "`new`" to create a new object by calling a constructor, we're directly programming to an implementation
  - E.g., `Duck duck = new MallardDuck()`

We really WANT to use the interface…

But we're forced to create an instance of a concrete class!

It's More Complicated than That

```
Duck duck;
if (picnic){
  duck = new MallardDuck();
} else if (hunting) {
  duck = new DecoyDuck();
} else if (inBathTub) {
  duck = new RubberDuck();
}
```

- … especially when you think about the fact that things might change
  - E.g., you add a new type of duck and have to figure out when/how to instantiate it
  - And you make new kinds of Ducks in all different parts of your code

“Open for Extension, Closed for Modification”

- A key design goal:
  - Allow classes to be easily extended to incorporate new behavior
  - Without modifying existing code
    - Because everytime you modify it, you risk introducing new bugs
- This results in designs that are resilient to change but also flexible enough to accept new functionality to meet changing requirements

Back to Identifying Things that Change

```
Pizza orderPizza(String type) {
  Pizza pizza = new Pizza();

  if (type.equals("cheese")) {
    pizza = new CheesePizza();
  } else if (type.equals("greek")) {
    pizza = new GreekPizza();
  } else if (type.equals("pepperoni") {
    pizza = new PepperoniPizza();
  }

  pizza.prepare();
  pizza.bake();
  pizza.cut();
  pizza.box();
  return pizza;
}
```

It'd really be nice to use an abstract class here, but, alas, one cannot instantiate an abstract class

These methods can now be specific to a particular type of pizza (i.e., the pizza type knows how to prepare itself) or generic to all pizza types

Change… it's Coming

- The pizza business is a trendy one
  - Greek pizza is so yesterday…
  - But with all of the people moving in from CA, we've got increasing demands for Veggie pizza. And some weirdos who want clam pizza
- What to do?

- The `orderPizza` method is not **closed for modification**

- What varies? What stays the same?
  - The choices of pizza types change over time
  - The process (algorithm) for filling an order stays the same

Information Hiding?

- What is it we're supposed to do with the stuff that changes?
- Encapsulate it!
- Practically, since the thing that's changing is **object creation**, we need an object that encapsulates object creation
- This object is called a **factory**
  - Then the `orderPizza` method is a **client** of the factory
    - Anytime it needs a pizza, it goes to the factory to request that one is created

The Pizza Factory

```
public class SimplePizzaFactory {
  public Pizza createPizza(String type) {
    Pizza pizza = null;
    if (type.equals("cheese")) {
      pizza = new CheesePizza();
    } else if (type.equals("pepperoni") {
      pizza = new PepperoniPizza();
    } else if (type.equals("clam") {
      pizza = new ClamPizza();
    } else if (type.equals("veggie") {
      pizza = new VeggiePizza();
    }
    return pizza;
  }
}
```

Wait, what?

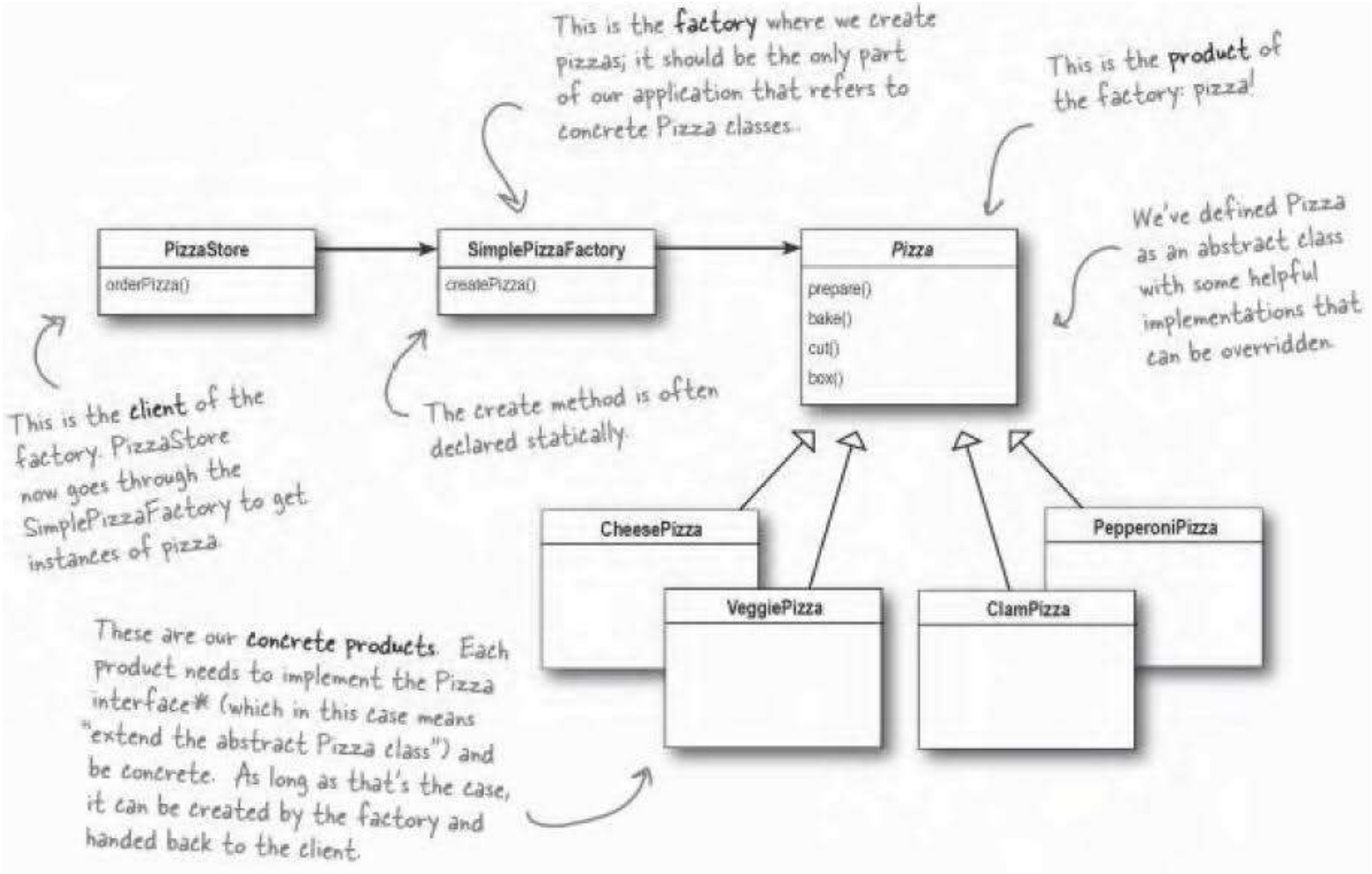
- Well, that seems silly. All we did is copy the code out of the `orderPizza` method, but it still has all of the same problems…
- Does it?
- The `SimplePizzaFactory` might have lots of clients (not just the `orderPizza` method)
  - That was why we want to encapsulate the thing that changes!
- Also, the `orderPizza` method no longer needs to know anything at all about concrete `Pizza`s!

Rebuilding PizzaStore

```
public class PizzaStore {
    SimplePizzaFactory factory;

    public PizzaStore(SimplePizzaFactory factory){
        this.factory = factory;
    }

    public Pizza orderPizza(String type){
        Pizza pizza;

        pizza = factory.createPizza(type);

        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();
        return pizza;
     }
...;
}
```

Simple Factory: Not Quite a Pattern

- But it is a **programming idiom**, and it's commonly used



Franchising the Pizza Store

- Now you want to spread your successful business
  - We want to localize the pizza making activities to the `PizzaStore` class
    - For quality control
  - But we want to give regional franchises the liberty to have their own pizza styles
- General framework:
  - Make the `PizzaStore` abstract
  - Put the `createPizza` method back in `PizzaStore`, but make it abstract
  - Create a `PizzaStore` subclass for every regional type of pizza

The Abstract Method

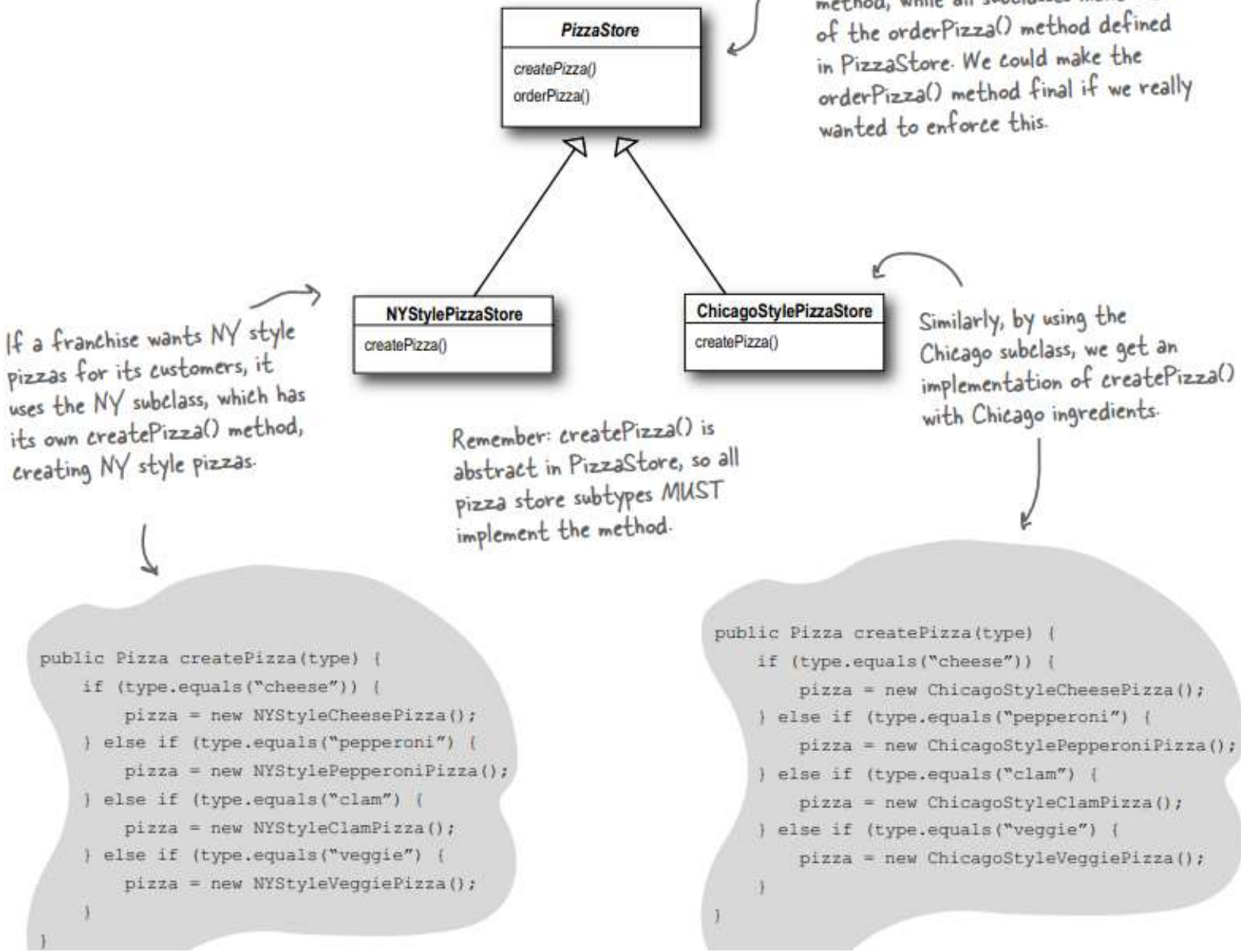
```
public abstract class PizzaStore {
  public Pizza orderPizza(String type) {
    Pizza pizza;
    pizza = createPizza(type);
    pizza.prepare();
    pizza.bake();
    pizza.cut();
    pizza.box();
    return pizza;
  }
  abstract Pizza createPizza(String type);
}
```

This is the “factory method”

Delegating to the Subclasses

- We've perfected the pizza ordering method, and it stays the same across all of the subclasses
- But now the regional franchises can differ in the style of pizza they make
  - E.g., thin crust in New York, thick crust in Chicago
- While the `orderPizza` method *looks* like it's defined in the `PizzaStore` class, this class is abstract
  - It can't *actually* do anything
  - So when it is executed, it is actually executing in the context of a concrete subclass
  - This context gets determined when the (abstract) method `createPizza` gets called

Delegating to the Subclasses (cont.)

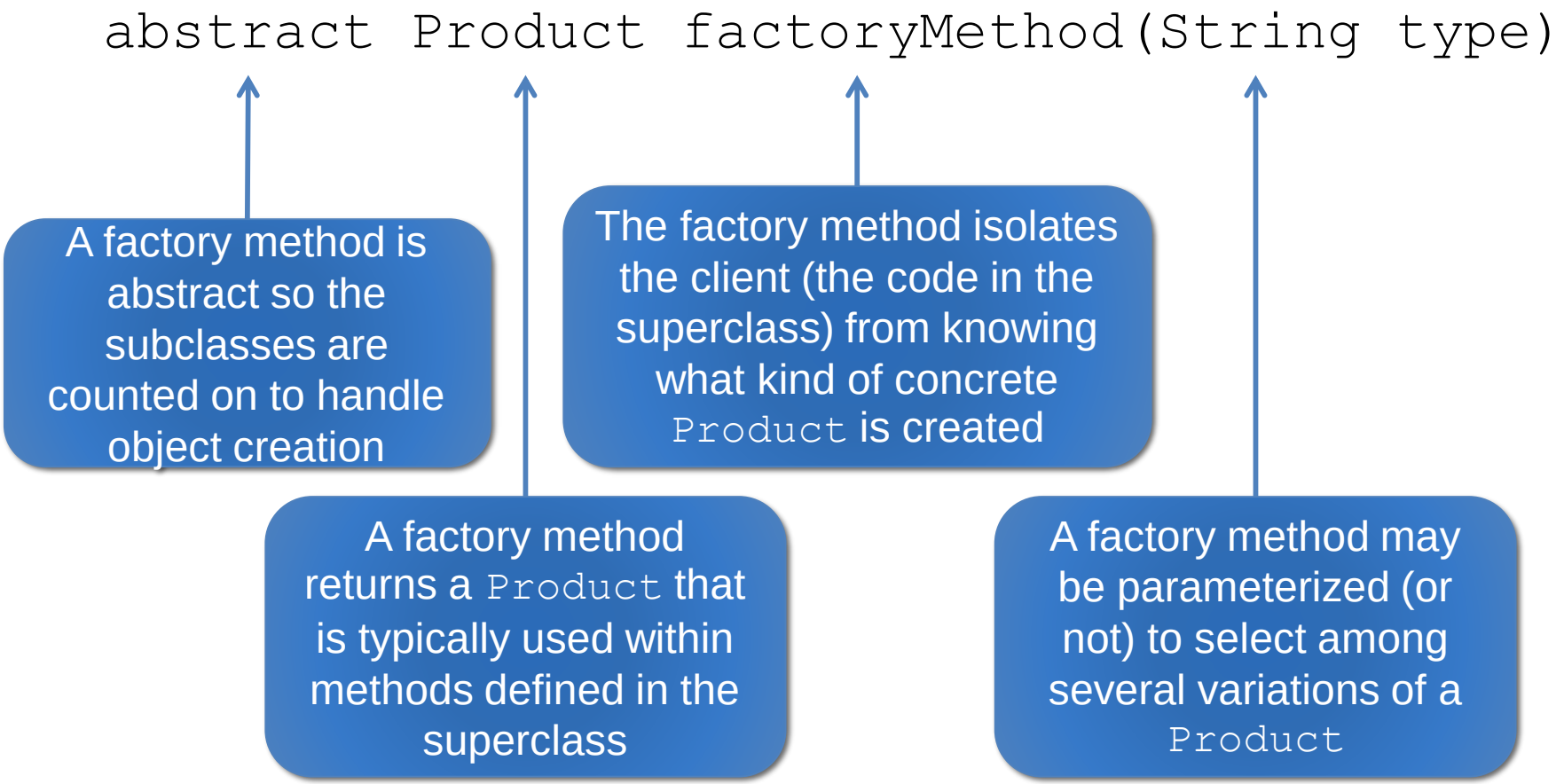


What does a Franchise Look Like?

- Bonus. The franchises get all of the benefits of the perfected PizzaStore ordering process
- All they have to do is define how to create pizzas!

```
public class NYPizzaStore extends PizzaStore {
  Pizza createPizza(String item) {
    if (type.equals("cheese")) {
      return new NYStyleCheesePizza();
    } else if (type.equals("pepperoni") {
      return new NYStylePepperoniPizza();
    } else if (type.equals("clam") {
      return new NYStyleClamPizza();
    } else if (type.equals("veggie") {
      return new NYStyleVeggiePizza();
    } else return null;
  }
}
```

A Generic Factory Method



Ordering a Pizza

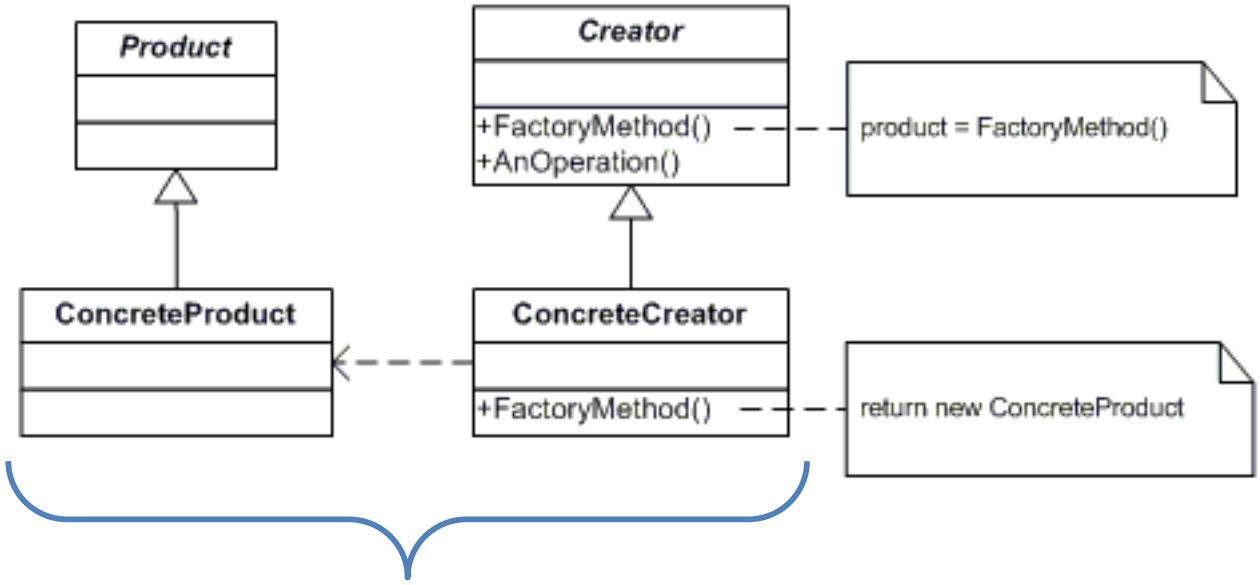
- What happens when a customer wants to order a pizza?
  - Write down the sequence of steps involved in a customer ordering a NY style (thin crust) cheese pizza.

Solution

1. First, the customer needs to get a NY PizzaStore:
   - `PizzaStore nyPizzaStore = new NYPizzaStore();`
2. Now the pizza store can accept our order
   - `nyPizzaStore.orderPizza("cheese");`
3. The `orderPizza` method calls the `createPizza` method
   - `Pizza pizza = createPizza("cheese");`
     - Remember the `createPizza` method is implemented in the subclass, so we're automagically getting a NY style cheese pizza here
4. The `orderPizza` method finishes preparing our pizza
   - `pizza.prepare();pizza.bake();pizza.cut();pizza.box();`
     - These methods are defined in the abstract `PizzaStore` class, which doesn't need to know which kind of pizza it is in order to follow the steps

The Entire Solution

- The whole thing requires some pizzas to tie everything together; you can check out the sample source code to see how it all fits



Parallel Class Hierarchies

The Factory Method Pattern

The Factory Method Pattern defines an interface for creating an object but lets subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses

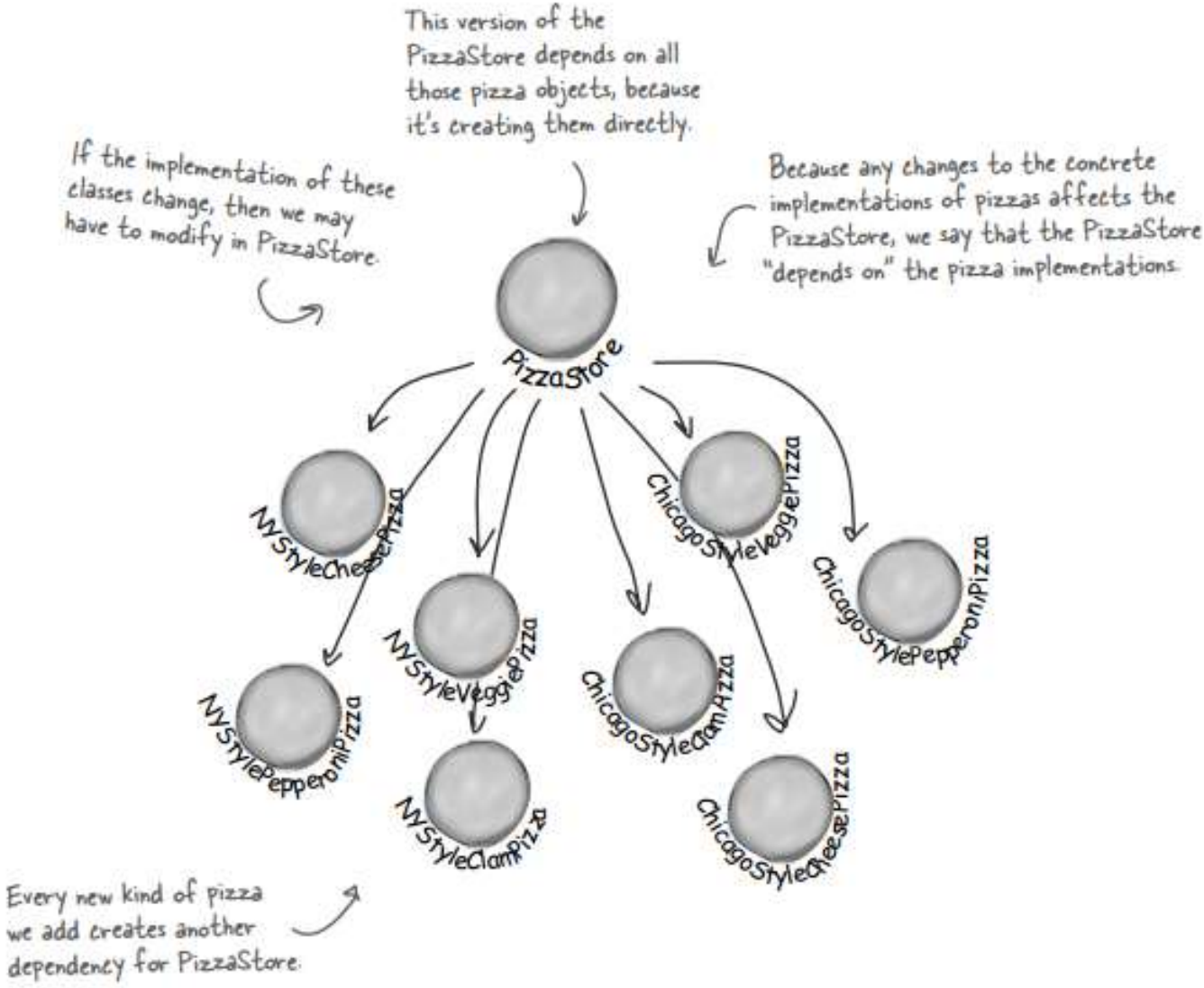
Our “Dumb” Pizza Store Revisited

- Imagine going back to the beginning and creating a PizzaStore that amassed all of the decision making
  - Inside the createPizza method of this pizza store, I would just have a huge, nested set of if statements to determine which *style* of pizza and then which *type* of pizza to create

The intuitive way of design

```
public class DependentPizzaStore{
    public Pizza createPizza (String style, String type){
        Pizza pizza = null;
        if (style.euqals("NY")){
            if (type.equals("cheese")){
                pizza = new NYStyleCheesePizza();
            } else if (type.equals("veggie")){
                pizza = new NYStyleVeggiePizza();
            } else if (type.equals("clam")){
                pizza = new NYStyleClamPizza();
            } else if (type.equals("pepperoni")){
                pizza = new NYStylePepperoniPizza();
            }
        } else if (style.equals("Chicago")){
            ...;
        }
        pizza.prepare();
        pizza.bake();
        ...;
        return pizza;
    }
}
```

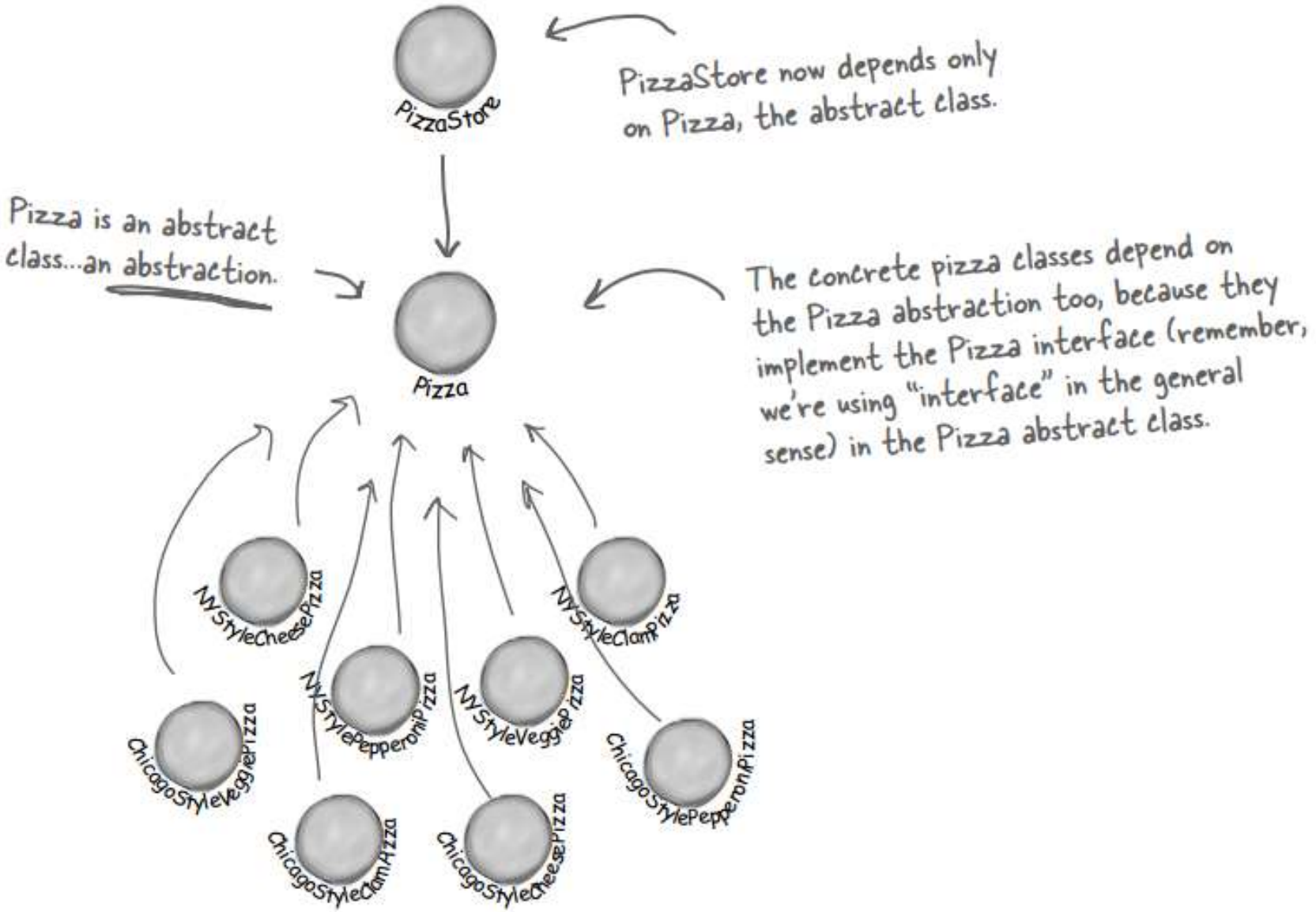
What does this Look Like?



Another Design Principle

- This seems like a bad idea. We're definitely not encapsulating for change.
- If we change any of the concrete pizza classes, we have to change the PizzaStore because it **depends** on them
- Instead we should **depend upon abstractions. Do not depend upon concrete classes**
  - High level components should not depend on low-level components; instead, both should depend on abstractions
  - For example, in the previous pizza store, the store depended on all of the pizza types
  - Instead, the pizza store should depend on the abstract notion of Pizza, and the concrete pizza types should too
    - This is exactly what the Factory Method pattern we applied did!

Dependency Inversion



Guidelines that Help

- **NOT RULES TO FOLLOW**
- No variable should hold a reference to a concrete class
  - If you use new, you'll be holding a reference to a concrete class
  - Use a factory to get around that!
- No class should derive from a concrete class
  - If you do, you're depending on the concrete class
  - Instead, derive from an abstraction (like an interface or an abstract class)
- No method should override an implemented method of any of its base classes
  - If you do, then your base class wasn't really an abstraction
  - The methods implemented in the base class are meant to be shared by the derived classes

THE ABSTRACT FACTORY

Controlling Pizza Quality

- Some of your franchises have gone rogue and are substituting inferior ingredients to increase their per-pizza profit
- Time to enter the pizza ingredient business
  - You'll make all the ingredients yourself and ship them to your franchises
  - But this is not so easy…
- You have the same product families (e.g., dough, sauce, cheese, veggies, meats, etc.) but different implementations (e.g., thin vs. thick or mozzarella vs. reggiano) based on region

The Ingredient Factory Interface

```
public interface PizzaIngredientFactory {
   public Dough createDough();
   public Sauce createSuace();
   public Cheese createCheese();
   public Veggies[] createVeggies();
   public Pepperoni createPepperoni();
   public Clams createClams();
}
```

Then What?

1. For each region, create a subclass of the `PizzaIngredientFactory` that implements the concrete methods
2. Implement a set of ingredients to be used with the factory (e.g., `ReggianoCheese`, `RedPeppers`, `ThickCrustDough`)
   - These can be shared among regions if appropriate
3. Integrate these new ingredient factories into the `PizzaStore` code

The New York Ingredient Factory

```
public class NYPizzaIngredientFactory implements PizzaIngredientFactory {
  public Dough createDough() {
    return new ThinCrustDough();
  }
  public Sauce createSauce() {
    return new MarinaraSauce();
  }
  public Cheese createCheese() {
    return new ReggianoCheese();
  }
  public Veggies[] createVeggies() {
    Veggies veggies[] = {new Garlic(), new Onion(), new Mushroom(), new RedPepper()};
    return veggies;
  }
  public Pepperoni createPepperoni() {
    return new SlicedPepperoni();
  }
  public Clams createClam() {
    return new FreshClams();
  }
}
```

Connecting to the Pizzas

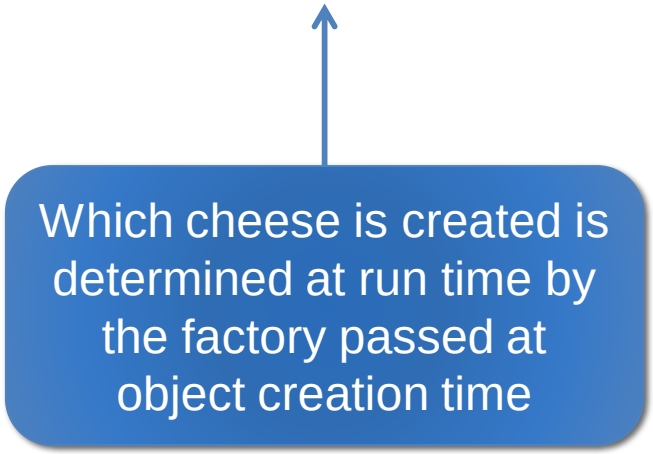
- Now, we need to force our franchise owners to only use factory produced ingredients
- Before, the abstract `Pizza` class just had `String`s to name its ingredients
  - It implemented the `prepare()` method (and `bake()`, `cut()`, and `box()`)
  - The concrete `Pizza` classes just defined the constructor which, in some cases, specialized the ingredients (and sometimes cut corners) and maybe overwrote other methods
- Now, the abstract `Pizza` class has actual ingredient objects
  - And the `prepare()` method is abstract
  - The concrete pizza classes will collect the ingredients from the factories to prepare the pizza

Concrete Pizzas

- Now, we only need one CheesePizza class (before we had a ChicagoCheesePizza and a NYCheesePizza)
- When we create a CheesePizza, we pass it an IngredientFactory, which will provide the (regional) ingredients

An Example Pizza

```
public class CheesePizza extends Pizza {
  PizzaIngredientFactory ingredientFactory;
  public CheesePizza(PizzaIngredientFactory ingredientFactory){
    this.ingredientFactory = ingredientFactory;
  }
  void prepare() {
    System.out.println("Preparing " + name);
    dough = ingredientFactory.createDough();
    sauce = ingredientFactory.createSauce();
    cheese = ingredientFactory.createCheese();
  }
}
```



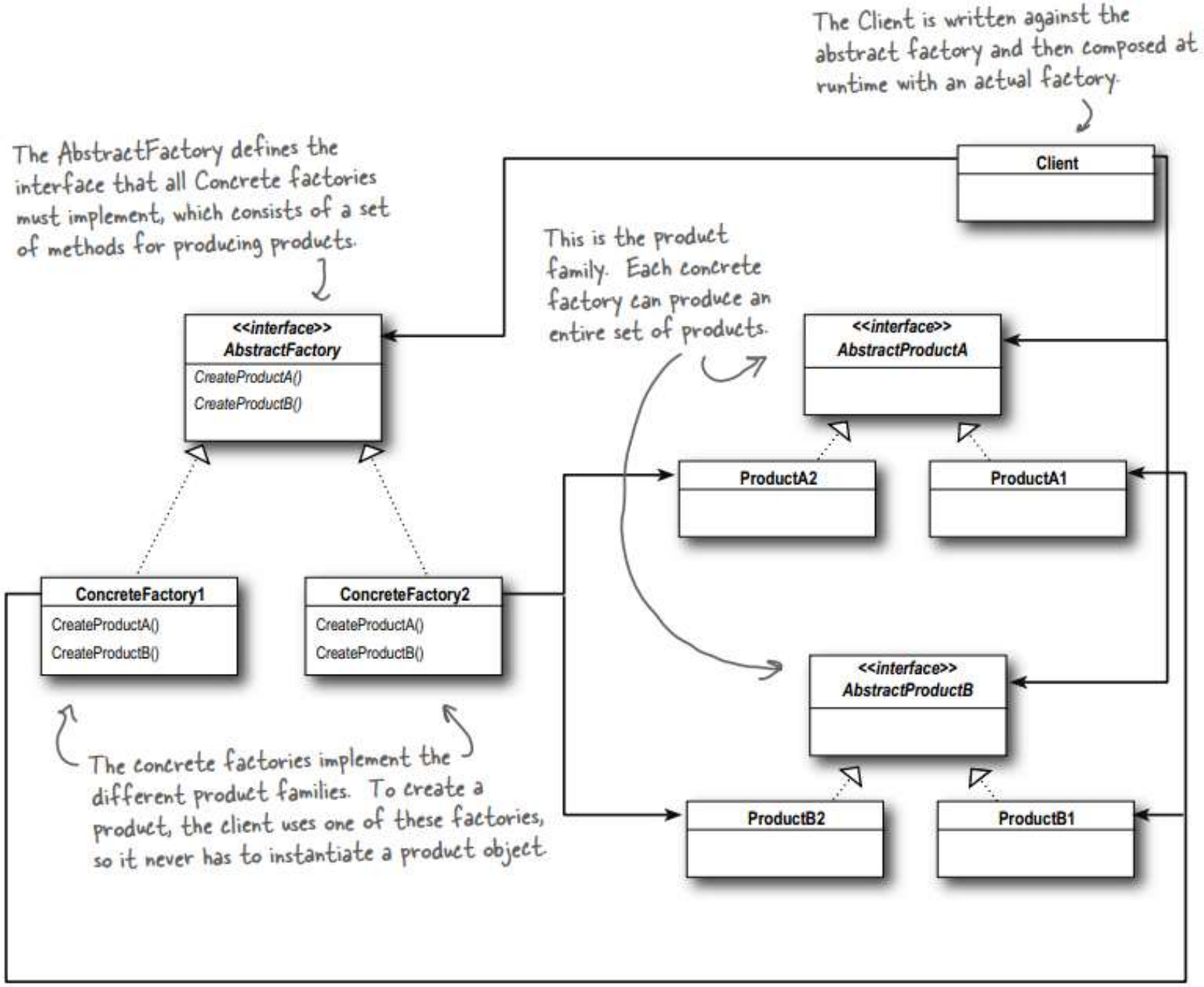
Fixing the Pizza Stores

```
public class NYPizzaStore extends PizzaStore {
  protected Pizza createPizza(String item) {
    Pizza pizza = null;
    PizzaIngredientFactory ingredientFactory = new NYPizzaIngredientFactory();
    if (item.equals("cheese")) {
      pizza = new CheesePizza(ingredientFactory);
      pizza.setName("New York Style Cheese Pizza");
    } else if (item.equals("veggie")) {
      pizza = new VeggiePizza(ingredientFactory);
      pizza.setName("New York Style Veggie Pizza");
    } // more of the same…
    return pizza;
  }
}
```

For each type of pizza, we instantiate a new pizza and give it the factory it needs to get its ingredients

Whew. Recap.

- We provided a means of creating a family of ingredients for pizzas by introducing a new type of factory: the **abstract factory**
- An abstract factory provides an interface for creating a family of products
  - Decouples code from the actual factory that creates the products
  - Makes it easy to implement a variety of factories that produce products for different contexts (we used regions, but it could just as easily be different operating systems, or different “look and feels”)
- We can substitute different factories to get different behaviors


The Client is written against the abstract factory and then composed at runtime with an actual factory.
The AbstractFactory defines the interface that all Concrete factories must implement, which consists of a set of methods for producing products.
This is the product family. Each concrete factory can produce an entire set of products.
Client
<<interface>>
AbstractFactory
CreateProductA()
CreateProductB()
<<interface>>
AbstractProductA
ProductA2
ProductA1
ConcreteFactory1
CreateProductA()
CreateProductB()
ConcreteFactory2
CreateProductA()
CreateProductB()
<<interface>>
AbstractProductB
ProductB2
ProductB1
The concrete factories implement the different product families. To create a product, the client uses one of these factories, so it never has to instantiate a product object.

The Abstract Factory Pattern

The Abstract Factory Pattern provides an interface for creating families of related or dependent objects without specifying their concrete classes.

Factory Method vs. Abstract Factory

- Decouples applications from specific implementations
- Creates objects through inheritance
  - Create objects by extending a class and overriding a factory method
- Useful if you don’t know ahead of time what concrete classes will be needed

- Decouples applications from specific implementations
- Creates objects through object composition
  - Create objects by providing an abstract type for a family of products
  - Subclasses define how products are produced
- Interface must change if new products are added

QUESTIONS?