Chapter 4. The Factory Pattern: Baking with OO Goodness

Get ready to bake some loosely coupled OO designs. There is more to making objects than just using the **new** operator. You'll learn that instantiation is an activity that shouldn't always be done in public and can often lead to *coupling problems*. And you don't want *that*, do you? Find out how Factory Patterns can help save you from embarrassing dependencies.

When you see "new", think "concrete".

Yes, when you use **new** you are certainly instantiating a concrete class, so that's definitely an implementation, not an interface. And it's a good question; you've learned that tying your code to a concrete class can make it more fragile and less flexible.

```
Duck duck = new MallardDuck();
```

We want to use interfaces to keep code flexible.

But we have to create an instance of a concrete class!

When you have a whole set of related concrete classes, often you're forced to write code like this:

```
Duck duck;

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

We have a bunch of different duck classes, and we don't know until runtime which one we need to instantiate.

Here we've got several concrete classes being instantiated, and the decision of which to instantiate is made at runtime depending on some set of conditions.

When you see code like this, you know that when it comes time for changes or extensions, you'll have to reopen this code and examine what needs to be added (or deleted). Often this kind of code ends up in several parts of the application making maintenance and updates more difficult and error-prone.

What's wrong with "new"?

Technically there's nothing wrong with **new**, after all, it's a fundamental part of Java. The real culprit is our old friend CHANGE and how change impacts our use of **new**.

By coding to an interface, you know you can insulate yourself from a lot of changes that might happen to a system down the road. Why? If your code is written to an interface, then it will work with any new classes implementing that interface through polymorphism. However, when you have code that makes use of lots of concrete classes, you're looking for trouble because that code may have to be changed as new concrete classes are added. So, in other words, your code will not be "closed for modification." To extend it with new concrete types, you'll have to reopen it.

NOTE

Remember that designs should be "open for extension but closed for modification" - see Chapter 3 for a review.

So what can you do? It's times like these that you can fall back on OO Design Principles to look for clues. Remember, our first principle deals with change and guides us to *identify the aspects that vary and separate them from what stays the same.*

BRAIN POWER

How might you take all the parts of your application that instantiate concrete classes and separate or encapsulate them from the rest of your application?

Identifying the aspects that vary

Let's say you have a pizza shop, and as a cutting-edge pizza store owner in Objectville you might end up writing some code like this:

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

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

For flexibility, we really want this to be an abstract class or interface, but we can't directly instantiate either of those.

But you need more than one type of pizza...

So then you'd add some code that *determines* the appropriate type of pizza and then goes about *making* the pizza:

```
Pizza orderPizza(String type) {
       Pizza 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;
}
```

We're now passing in the type of pizza to orderPizza.

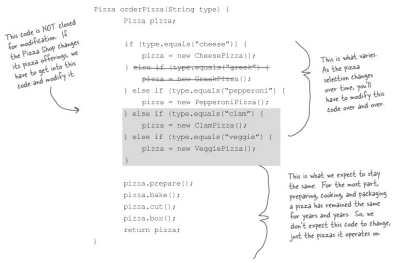
Based on the type of pizza, we instantiate the correct concrete class and assign it to the pizza instance variable. Note that each pizza here has to implement the Pizza interface.

Once we have a Pizza, we prepare it (you know, roll the dough, put on the sauce and add the toppings & cheese), then we bake it, cut it and box it!

Each Pizza subtype (CheesePizza, VeggiePizza, etc.) knows how to prepare itself.

But the pressure is on to add more pizza types

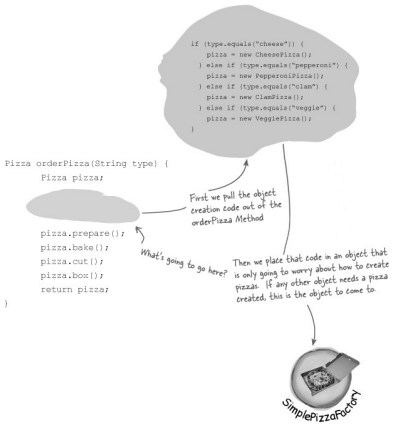
You realize that all of your competitors have added a couple of trendy pizzas to their menus: the Clam Pizza and the Veggie Pizza. Obviously you need to keep up with the competition, so you'll add these items to your menu. And you haven't been selling many Greek Pizzas lately, so you decide to take that off the menu:



Clearly, dealing with *which* concrete class is instantiated is really messing up our orderPizza() method and preventing it from being closed for modification. But now that we know what is varying and what isn't, it's probably time to encapsulate it.

Encapsulating object creation

So now we know we'd be better off moving the object creation out of the orderPizza() method. But how? Well, what we're going to do is take the creation code and move it out into another object that is only going to be concerned with creating pizzas.



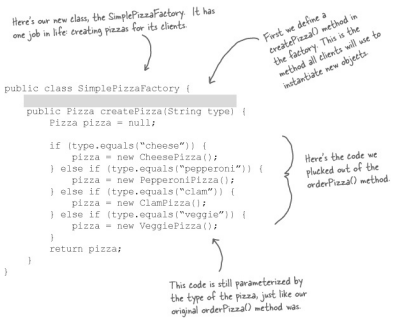
We've got a name for this new object: we call it a Factory.

Factories handle the details of object creation. Once we have a SimplePizzaFactory, our orderPizza() method just becomes a client of that object. Any time it needs a pizza it asks the pizza factory to make one. Gone are the days when the orderPizza() method needs to know about Greek versus Clam pizzas. Now the orderPizza() method just cares that it gets a pizza, which implements the Pizza interface so that it can call prepare(), bake(), cut(), and box().

We've still got a few details to fill in here; for instance, what does the orderPizza() method replace its creation code with? Let's implement a simple factory for the pizza store and find out...

Building a simple pizza factory

We'll start with the factory itself. What we're going to do is define a class that encapsulates the object creation for all pizzas. Here it is...



THERE ARE NO DUMB QUESTIONS

Q: **Q: What's the advantage of this? It looks like we are just pushing the problem off to another object.**

A: **A:** *One thing to remember is that the SimplePizzaFactory may have many clients. We've only seen the orderPizza() method; however, there may be a PizzaShopMenu class that uses the factory to get pizzas for their current description and price. We might also have a HomeDelivery class that handles pizzas in a different way than our PizzaShop class but is also a client of the factory.*

So, by encapsulating the pizza creating in one class, we now have only one place to make modifications when the implementation changes.

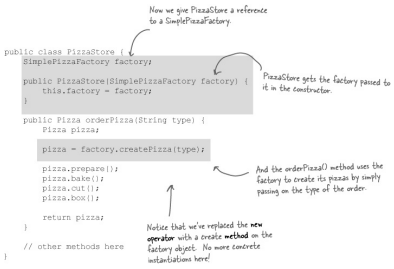
Don't forget, we are also just about to remove the concrete instantiations from our client code!

Q: **Q: I've seen a similar design where a factory like this is defined as a static method. What is the difference?**

A: **A:** *Defining a simple factory as a static method is a common technique and is often called a static factory. Why use a static method? Because you don't need to instantiate an object to make use of the create method. But remember it also has the disadvantage that you can't subclass and change the behavior of the create method.*

Reworking the PizzaStore class

Now it's time to fix up our client code. What we want to do is rely on the factory to create the pizzas for us. Here are the changes:




```
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;
    }

    // other methods here
}
```

BRAIN POWER

Q: *We know that object composition allows us to change behavior dynamically at runtime (among other things) because we can swap in and out implementations. How might we be able to use that in the PizzaStore? What factory implementations might we be able to swap in and out?*

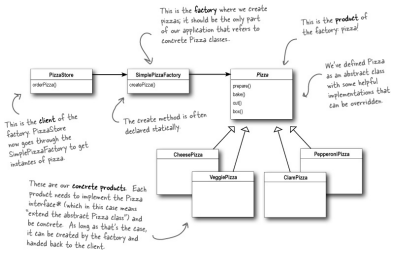
A: *We don't know about you, but we're thinking New York, Chicago, and California style pizza factories (let's not forget New Haven, too)*

The Simple Factory defined

Pattern Honorable Mention

The Simple Factory isn't actually a Design Pattern; it's more of a programming idiom. But it is commonly used, so we'll give it a Head First Pattern Honorable Mention. Some developers do mistake this idiom for the "Factory Pattern," so the next time there is an awkward silence between you and another developer, you've got a nice topic to break the ice.

Just because Simple Factory isn't a REAL pattern doesn't mean we shouldn't check out how it's put together. Let's take a look at the class diagram of our new Pizza Store:



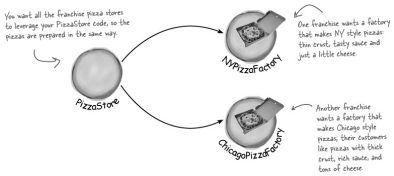
*Just another reminder: in design patterns, the phrase "implement an interface" does NOT always mean "write a class that implements a Java interface, by using the "implements" keyword in the class declaration." In the general use of the phrase, a concrete class implementing a method from a supertype (which could be a class OR interface) is still considered to be "implementing the interface" of that supertype.

Think of Simple Factory as a warm up. Next, we'll explore two heavy duty patterns that are both factories. But don't worry, there's more pizza to come!

Franchising the pizza store

Your Objectville PizzaStore has done so well that you've trounced the competition and now everyone wants a PizzaStore in their own neighborhood. As the franchiser, you want to ensure the quality of the franchise operations and so you want them to use your time-tested code.

But what about regional differences? Each franchise might want to offer different styles of pizzas (New York, Chicago, and California, to name a few), depending on where the franchise store is located and the tastes of the local pizza connoisseurs.



We've seen one approach...

If we take out SimplePizzaFactory and create three different factories, NYPizzaFactory, ChicagoPizzaFactory and CaliforniaPizzaFactory, then we can just compose the PizzaStore with the appropriate factory and a franchise is good to go. That's one approach.

Let's see what that would look like...

```
NYPizzaFactory nyFactory = new NYPizzaFactory();
PizzaStore nyStore = new PizzaStore(nyFactory);
nyStore.orderPizza("Veggie");
```

Here we create a factory for making NY style pizzas.

Then we create a PizzaStore and pass it a reference to the NY factory.

...and when we make pizzas, we get NY-styled pizzas.

```
ChicagoPizzaFactory chicagoFactory = new ChicagoPizzaFactory();
PizzaStore chicagoStore = new PizzaStore(chicagoFactory);
chicagoStore.orderPizza("Veggie");
```

Likewise for the Chicago pizza stores: we create a factory for Chicago pizzas and create a store that is composed with a Chicago factory. When we make pizzas, we get the Chicago flavored ones

But you'd like a little more quality control...

So you test marketed the SimpleFactory idea, and what you found was that the franchises were using your factory to create pizzas, but starting to employ their own home grown procedures for the rest of the process: they'd bake things a little differently, they'd forget to cut the pizza and they'd use third-party boxes.

Rethinking the problem a bit, you see that what you'd really like to do is create a framework that ties the store and the pizza creation together, yet still allows things to remain flexible.

In our early code, before the SimplePizzaFactory, we had the pizza-making code tied to the PizzaStore, but it wasn't flexible. So, how can we have our pizza and eat it too?

A framework for the pizza store

There *is* a way to localize all the pizza making activities to the PizzaStore class, and yet give the franchises freedom to have their own regional style.

What we're going to do is put the createPizza() method back into PizzaStore, but this time as an **abstract method**, and then create a PizzaStore subclass for each regional style.

First, let's look at the changes to the PizzaStore:

PizzaStore is now abstract (see why below).

```
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);
}
```

Now createPizza is back to being a call to a method in the PizzaStore rather than on a factory object.

All this looks just the same...

Now we've moved our factory object to this method.

Our "factory method" is now abstract in PizzaStore.

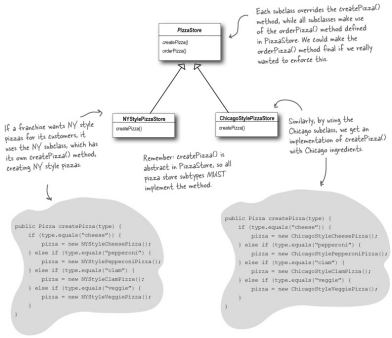
Now we've got a store waiting for subclasses; we're going to have a subclass for each regional type (NYPizzaStore, ChicagoPizzaStore, CaliforniaPizzaStore) and each subclass is going to make the decision about what makes up a pizza. Let's take a look at how this is going to work.

Allowing the subclasses to decide

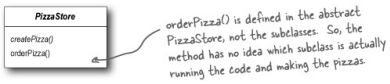
Remember, the PizzaStore already has a well-honed order system in the orderPizza() method and you want to ensure that it's consistent across all franchises.

What varies among the regional PizzaStores is the style of pizzas they make – New York Pizza has thin crust, Chicago Pizza has thick, and so on – and we are going to push all these variations into the createPizza() method and make it responsible for creating the right kind of pizza. The way we do this is by

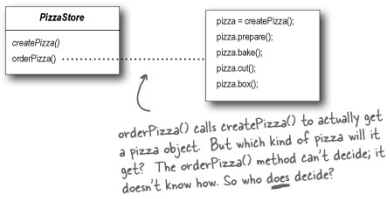
letting each subclass of PizzaStore define what the createPizza() method looks like. So, we will have a number of concrete subclasses of PizzaStore, each with its own pizza variations, all fitting within the PizzaStore framework and still making use of the well-tuned orderPizza() method.



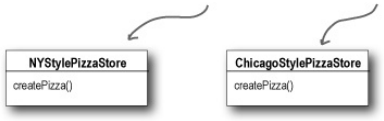
Well, think about it from the point of view of the PizzaStore's orderPizza() method: it is defined in the abstract PizzaStore, but concrete types are only created in the subclasses.



Now, to take this a little further, the orderPizza() method does a lot of things with a Pizza object (like prepare, bake, cut, box), but because Pizza is abstract, orderPizza() has no idea what real concrete classes are involved. In other words, it's decoupled!



When orderPizza() calls createPizza(), one of your subclasses will be called into action to create a pizza. Which kind of pizza will be made? Well, that's decided by the choice of pizza store you order from, NYStylePizzaStore or ChicagoStylePizzaStore.

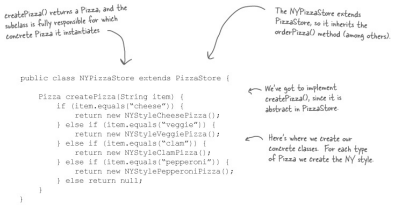


So, is there a real-time decision that subclasses make? No, but from the perspective of orderPizza(), if you chose a NYStylePizzaStore, that subclass gets to determine which pizza is made. So the subclasses aren't really "deciding" – it was *you* who decided by choosing which store you wanted – but they do determine which kind of pizza gets made.

Let's make a PizzaStore

Being a franchise has its benefits. You get all the PizzaStore functionality for free. All the regional stores need to do is subclass PizzaStore and supply a createPizza() method that implements their style of Pizza. We'll take care of the big three pizza styles for the franchisees.

Here's the New York regional style:



NOTE

* Note that the orderPizza() method in the superclass has no clue which Pizza we are creating; it just knows it can prepare, bake, cut, and box it!

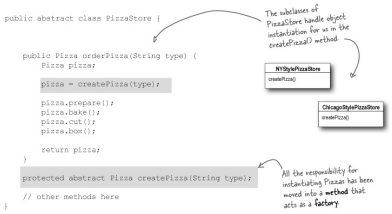
Once we've got our PizzaStore subclasses built, it will be time to see about ordering up a pizza or two. But before we do that, why don't you take a crack at building the Chicago Style and California Style pizza stores on the next page.

SHARPEN YOUR PENCIL

We've knocked out the NYPizzaStore, just two more to go and we'll be ready to franchise! Write the Chicago and California PizzaStore implementations here:

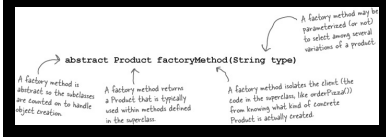
Declaring a factory method

With just a couple of transformations to the PizzaStore we've gone from having an object handle the instantiation of our concrete classes to a set of subclasses that are now taking on that responsibility. Let's take a closer look:



CODE UP CLOSE

A factory method handles object creation and encapsulates it in a subclass. This decouples the client code in the superclass from the object creation code in the subclass.



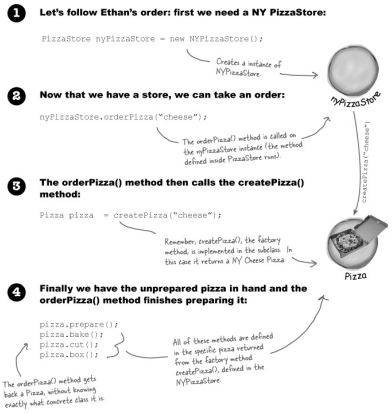
Let's see how it works: ordering pizzas with the pizza factory method

So how do they order?

1. First, Joel and Ethan need an instance of a PizzaStore. Joel needs to instantiate a ChicagoPizzaStore and Ethan needs a NYPizzaStore.
2. With a PizzaStore in hand, both Ethan and Joel call the orderPizza() method and pass in the type of pizza they want (cheese, veggie, and so on).
3. To create the pizzas, the createPizza() method is called, which is defined in the two subclasses NYPizzaStore and ChicagoPizzaStore. As we defined them, the NYPizzaStore instantiates a NY style pizza, and the ChicagoPizzaStore instantiates Chicago style pizza. In either case, the Pizza is returned to the orderPizza() method.
4. The orderPizza() method has no idea what kind of pizza was created, but it knows it is a pizza and it prepares, bakes, cuts, and boxes it for Ethan and Joel.

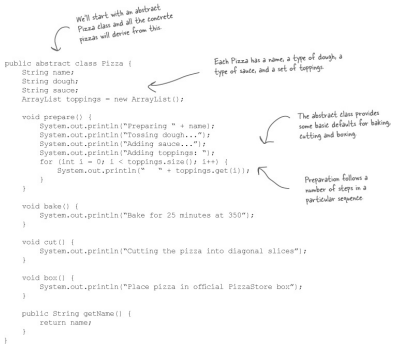
Let's check out how these pizzas are really made to order...

Behind the Scenes



We're just missing one thing: PIZZA!

Our PizzaStore isn't going to be very popular without some pizzas, so let's implement them

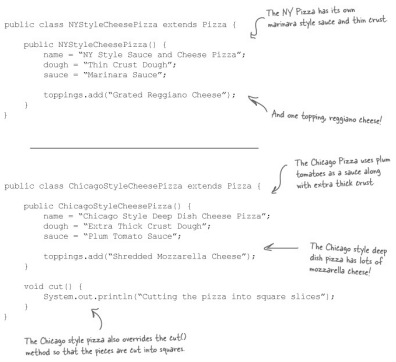



```
public abstract class Pizza {
    String name;
    String dough;
    String sauce;
    ArrayList toppings = new ArrayList();

    void prepare() {
        System.out.println("Preparing " + name);
        System.out.println("Tossing dough...");
        System.out.println("Adding sauce...");
        System.out.println("Adding toppings: ");
        for (int i = 0; i < toppings.size(); i++) {
            System.out.println("   " + toppings.get(i));
        }
    }

    void bake() {
        System.out.println("Bake for 25 minutes at 350");
    }

    void cut() {
        System.out.println("Cutting the pizza into diagonal slices");
    }

    void box() {
        System.out.println("Place pizza in official PizzaStore box");
    }

    public String getName() {
        return name;
    }
}
```

NOTE

REMEMBER: we don't provide import and package statements in the code listings. Get the complete source code from the wickedlysmart web site. You'll find the URL on Read Me in the intro.

Now we just need some concrete subclasses... how about defining New York and Chicago style cheese pizzas?




```
public class NYStyleCheesePizza extends Pizza {

    public NYStyleCheesePizza() {
        name = "NY Style Sauce and Cheese Pizza";
        dough = "Thin Crust Dough";
        sauce = "Marinara Sauce";

        toppings.add("Grated Reggiano Cheese");
    }
}
```

```
public class ChicagoStyleCheesePizza extends Pizza {

    public ChicagoStyleCheesePizza() {
        name = "Chicago Style Deep Dish Cheese Pizza";
        dough = "Extra Thick Crust Dough";
        sauce = "Plum Tomato Sauce";

        toppings.add("Shredded Mozzarella Cheese");
    }

    void cut() {
        System.out.println("Cutting the pizza into square slices");
    }
}
```

You've waited long enough, time for some pizzas!


```
public class PizzaTestDrive {

    public static void main(String[] args) {
        PizzaStore nyStore = new NYPizzaStore();
        PizzaStore chicagoStore = new ChicagoPizzaStore();

        Pizza pizza = nyStore.orderPizza("cheese");
        System.out.println("Ethan ordered a " + pizza.getName() + "\n");

        pizza = chicagoStore.orderPizza("cheese");
        System.out.println("Joel ordered a " + pizza.getName() + "\n");
    }
}
```

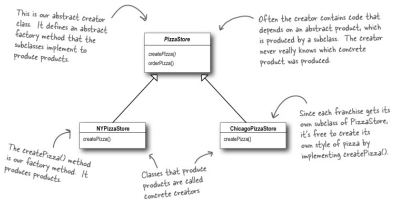
```
File Edit Window Help YouWantMoodsOnThatPizza?
%java PizzaTestDrive

Preparing NY Style Sauce and Cheese Pizza
Tossing dough...
Adding sauce...
Adding toppings:
   Grated Reggiano cheese
Bake for 25 minutes at 350
Cutting the pizza into diagonal slices
Place pizza in official PizzaStore box
Ethan ordered a NY Style Sauce and Cheese Pizza

Preparing Chicago Style Deep Dish Cheese Pizza
Tossing dough...
Adding sauce...
Adding toppings:
   Shredded Mozzarella Cheese
Bake for 25 minutes at 350
Cutting the pizza into square slices
Place pizza in official PizzaStore box
Joel ordered a Chicago Style Deep Dish Cheese Pizza
```

Both pizzas get prepared, the toppings added, and the pizzas baked, cut and boxed. Our superclass never had to know the details, the subclass handled all that just by instantiating the right pizza.

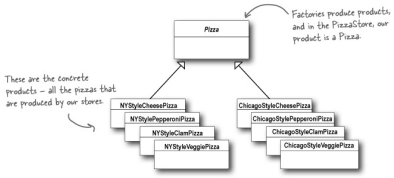
It's finally time to meet the Factory Method Pattern

All factory patterns encapsulate object creation. The Factory Method Pattern encapsulates object creation by letting subclasses decide what objects to create. Let's check out these class diagrams to see who the players are in this pattern:

The Creator classes



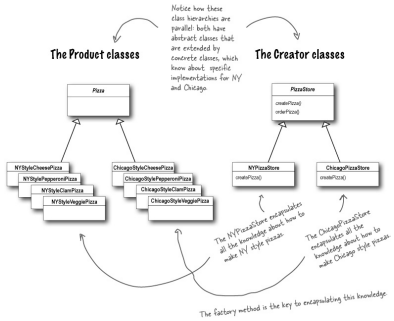
The Product classes



Another perspective: parallel class hierarchies

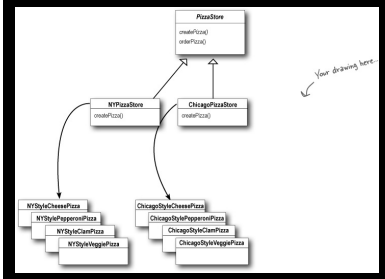
We've seen that the factory method provides a framework by supplying an orderPizza() method that is combined with a factory method. Another way to look at this pattern as a framework is in the way it encapsulates product knowledge into each creator.

Let's look at the two parallel class hierarchies and see how they relate:



DESIGN PUZZLE

We need another kind of pizza for those crazy Californians (crazy in a *good* way of course). Draw another parallel set of classes that you'd need to add a new California region to our PizzaStore.



Okay, now write the five *most bizarre* things you can think of to put on a pizza. Then, you'll be ready to go into business making pizza in California!

Factory Method Pattern defined

It's time to roll out the official definition of the Factory Method Pattern:

NOTE

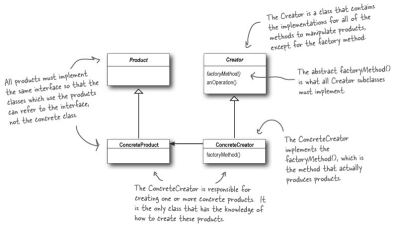
The Factory Method Pattern defines an interface for creating an object, but lets subclasses decide which class to instantiate. Factory Method lets a class defer instantiation to subclasses.

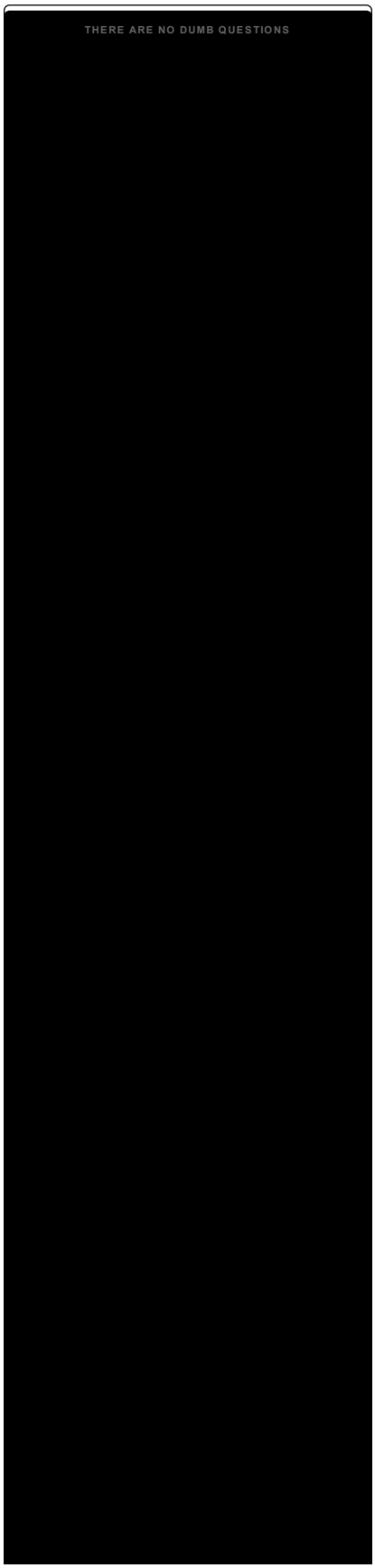
As with every factory, the Factory Method Pattern gives us a way to encapsulate the instantiations of concrete types. Looking at the class diagram below, you can see that the abstract Creator gives you an interface with a method for creating objects, also known as the "factory method." Any other methods implemented in the abstract Creator are written to operate on products produced by the factory method. Only subclasses actually implement the factory method and create products.

As in the official definition, you'll often hear developers say that the Factory Method lets subclasses decide which class to instantiate. They say "decide" not because the pattern allows subclasses themselves to decide at runtime, but because the creator class is written without knowledge of the actual products that will be created, which is decided purely by the choice of the subclass that is used.

NOTE

You could ask them what "decides" means, but we bet you now understand this better than they do!




THERE ARE NO DUMB QUESTIONS

Q: **Q: What's the advantage of the Factory Method Pattern when you only have one ConcreteCreator?**

A: **A:** *The Factory Method Pattern is useful if you've only got one concrete creator because you are decoupling the implementation of the product from its use. If you add additional products or change a product's implementation, it will not affect your Creator (because the Creator is not tightly coupled to any ConcreteProduct).*

Q: **Q: Would it be correct to say that our NY and Chicago stores are implemented using Simple Factory? They look just like it.**

A: **A:** *They're similar, but used in different ways. Even though the implementation of each concrete store looks a lot like the SimplePizzaFactory, remember that the concrete stores are extending a class which has defined createPizza() as an abstract method. It is up to each store to define the behavior of the createPizza() method. In Simple Factory, the factory is another object that is composed with the PizzaStore.*

Q: **Q: Are the factory method and the Creator always abstract?**

A: **A:** *No, you can define a default factory method to produce some concrete product. Then you always have a means of creating products even if there are no subclasses of the Creator.*

Q: **Q: Each store can make four different kinds of pizzas based on the type passed in. Do all concrete creators make multiple products, or do they sometimes just make one?**

A: **A:** *We implemented what is known as the parameterized factory method. It can make more than one object based on a parameter passed in, as you noticed. Often, however, a factory just produces one object and is not parameterized. Both are valid forms of the pattern.*

Q: **Q: Your parameterized types don't seem "type-safe." I'm just passing in a String! What if I asked for a "CalmPizza"?**

A: **A:** *You are certainly correct and that would cause, what we call in the business, a "runtime error." There are several other more sophisticated techniques that can be used to make parameters more "type safe", or, in other words, to ensure errors in parameters can be caught at compile time. For instance, you can create objects that represent the parameter types, use static constants, or, in Java 5, you can use enums.*

Q: **Q: I'm still a bit confused about the difference between Simple Factory and Factory Method. They look very similar, except that in Factory Method, the class that returns the pizza is a subclass. Can you explain?**

A: **A:** *You're right that the subclasses do look a lot like Simple Factory, however think of Simple Factory as a one shot deal, while with Factory Method you are creating a framework that lets the subclasses decide which implementation will be used. For example, the orderPizza() method in the Factory Method provides a general framework for creating pizzas that relies on a factory method to actually create the concrete classes that go into making a pizza. By subclassing the PizzaStore class, you decide what concrete products go into making the pizza that orderPizza() returns. Compare that with SimpleFactory, which gives you a way to encapsulate object creation, but doesn't give you the flexibility of the Factory Method because there is no way to vary the products you're creating.*

MASTER AND STUDENT...

Master: *Grasshopper, tell me how your training is going?*

Student: *Master, I have taken my study of "encapsulate what varies" further.*

Master: *Go on...*

Student: *I have learned that one can encapsulate the code that creates objects. When you have code that instantiates concrete classes, this is an area of frequent change. I've learned a technique called "factories" that allows you to encapsulate this behavior of instantiation.*

Master: *And these "factories," of what benefit are they?*

Student: *There are many. By placing all my creation code in one object or method, I avoid duplication in my code and provide one place to perform maintenance. That also means clients depend only upon interfaces rather than the concrete classes required to instantiate objects. As I have learned in my studies, this allows me to program to an interface, not an implementation, and that makes my code more flexible and extensible in the future.*

Master: *Yes Grasshopper, your OO instincts are growing. Do you have any questions for your master today?*

Student: *Master, I know that by encapsulating object creation I am coding to abstractions and decoupling my client code from actual implementations. But my factory code must still use concrete classes to instantiate real objects. Am I not pulling the wool over my own eyes?*

Master: *Grasshopper, object creation is a reality of life; we must create objects or we will never create a single Java program. But, with knowledge of this reality, we can design our code so that we have corralled this creation code like the sheep whose wool you would pull over your eyes. Once corralled, we can protect and care for the creation code. If we let our creation code run wild, then we will never collect its "wool."*

Student: *Master, I see the truth in this.*

Master: *As I knew you would. Now, please go and meditate on object dependencies.*

A very dependent PizzaStore

SHARPEN YOUR PENCIL

Let's pretend you've never heard of an OO factory. Here's a version of the PizzaStore that doesn't use a factory; make a count of the number of concrete pizza objects this class is dependent on. If you added California style pizzas to this PizzaStore, how many objects would it be dependent on then?

```
public class DependentPizzaStore {

    public Pizza createPizza(String style, String type) {
        Pizza pizza = null;
        if (style.equals("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")) {
            if (type.equals("cheese")) {
                pizza = new ChicagoStyleCheesePizza();
            } else if (type.equals("veggie")) {
                pizza = new ChicagoStyleVeggiePizza();
            } else if (type.equals("clam")) {
                pizza = new ChicagoStyleClamPizza();
            } else if (type.equals("pepperoni")) {
                pizza = new ChicagoStylePepperoniPizza();
            }
        } else {
            System.out.println("Error: invalid type of pizza");
            return null;
        }
        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();
        return pizza;
    }
}
```

Handles all the NY style pizzas

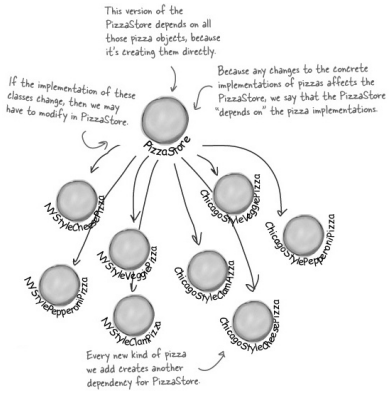
Handles all the Chicago style pizzas

You can write your answers here: number number with California too

Looking at object dependencies

When you directly instantiate an object, you are depending on its concrete class. Take a look at our very dependent PizzaStore one page back. It creates all the pizza objects right in the PizzaStore class instead of delegating to a factory.

If we draw a diagram representing that version of the PizzaStore and all the objects it depends on, here's what it looks like:



The Dependency Inversion Principle

It should be pretty clear that reducing dependencies to concrete classes in our code is a "good thing." In fact, we've got an OO design principle that formalizes this notion; it even has a big, formal name: *Dependency Inversion Principle*.

> NOTE
>
> Yet another phrase you can use to impress the execs in the room! Your raise will more than offset the cost of this book, and you'll gain the admiration of your fellow developers.

Here's the general principle:

> NOTE
>
> ***Design Principle***
>
> *Depend upon abstractions. Do not depend upon concrete classes.*

At first, this principle sounds a lot like "Program to an interface, not an implementation," right? It is similar; however, the Dependency Inversion Principle makes an even stronger statement about abstraction. It suggests that our high-level components should not depend on our low-level components; rather, they should *both* depend on abstractions.

> NOTE
>
> A "high-level" component is a class with behavior defined in terms of other, "low level" components. For example, PizzaStore is a high-level component because its behavior is defined in terms of pizzas - it creates all the different pizza objects, prepares, bakes, cuts, and boxes them, while the pizzas it uses are low-level components.

But what the heck does that mean?

Well, let's start by looking again at the pizza store diagram on the previous page. PizzaStore is our "high-level component" and the pizza implementations are our "low-level components," and clearly the PizzaStore is dependent on the concrete pizza classes.

Now, this principle tells us we should instead write our code so that we are depending on abstractions, not concrete classes. That goes for both our high level modules and our low-level modules.

But how do we do this? Let's think about how we'd apply this principle to our Very Dependent PizzaStore implementation...

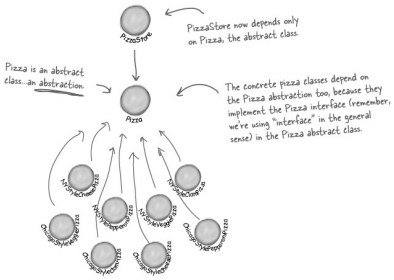
Applying the Principle

Now, the main problem with the Very Dependent PizzaStore is that it depends on every type of pizza because it actually instantiates concrete types in its orderPizza() method.

While we've created an abstraction, Pizza, we're nevertheless creating concrete Pizzas in this code, so we don't get a lot of leverage out of this abstraction.

How can we get those instantiations out of the orderPizza() method? Well, as we know, the Factory Method allows us to do just that.

So, after we've applied the Factory Method, our diagram looks like this:



After applying the Factory Method, you'll notice that our high-level component, the PizzaStore, and our low-level components, the pizzas, both depend on Pizza, the abstraction. Factory Method is not the only technique for adhering to the Dependency Inversion Principle, but it is one of the more powerful ones.

Where's the "inversion" in Dependency Inversion Principle?

The "inversion" in the name Dependency Inversion Principle is there because it inverts the way you typically might think about your OO design. Look at the diagram on the previous page, notice that the low-level components now depend on a higher level abstraction. Likewise, the high-level component is also tied to the same abstraction. So, the top-to-bottom dependency chart we drew a couple of pages back has inverted itself, with both high-level and low-level modules now depending on the abstraction.

Let's also walk through the thinking behind the typical design process and see how introducing the principle can invert the way we think about the design...

Inverting your thinking...

	Okay, so you need to implement a PizzaStore. What's the first thought that pops into your head? Right, you start at top and follow things down to the concrete classes. But, as you've seen, you don't want your store to know about the concrete pizza types, because then it'll be dependent on all those concrete classes!
	Now, let's "invert" your thinking... instead of starting at the top, start at the Pizzas and think about what you can abstract.
	Right! You are thinking about the abstraction *Pizza*. So now, go back and think about the design of the Pizza Store again. Close. But to do that you'll have to rely on a factory to get those concrete classes out of your Pizza Store. Once you've done that, your different concrete pizza types depend only on an abstraction and so does your store. We've taken a design where the store depended on concrete classes and inverted those dependencies (along with your thinking).

A few guidelines to help you follow the Principle...

The following guidelines can help you avoid OO designs that violate the Dependency Inversion Principle:

- No variable should hold a reference to a concrete class.

  NOTE

  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.

  NOTE

  If you derive from a concrete class, you're depending on a concrete class. Derive from an abstraction, like an interface or an abstract class.

- No method should override an implemented method of any of its base classes.

  NOTE

  If you override an implemented method, then your base class wasn't really an abstraction to start with. Those methods implemented in the base class are meant to be shared by all your subclasses.

You're exactly right! Like many of our principles, this is a guideline you should strive for, rather than a rule you should follow all the time. Clearly, every single Java program ever written violates these guidelines!

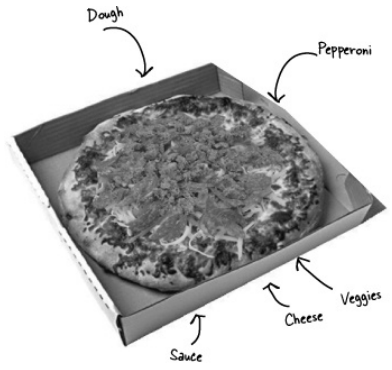
But, if you internalize these guidelines and have them in the back of your mind when you design, you'll know when you are violating the principle and you'll have a good reason for doing so. For instance, if you have a class that isn't likely to change, and you know it, then it's not the end of the world if you instantiate a concrete class in your code. Think about it; we instantiate String objects all the time without thinking twice. Does that violate the principle? Yes. Is that okay? Yes. Why? Because String is very unlikely to change.

If, on the other hand, a class you write is likely to change, you have some good techniques like Factory Method to encapsulate that change.

Meanwhile, back at the PizzaStore...

The design for the PizzaStore is really shaping up: it's got a flexible framework and it does a good job of adhering to design principles.

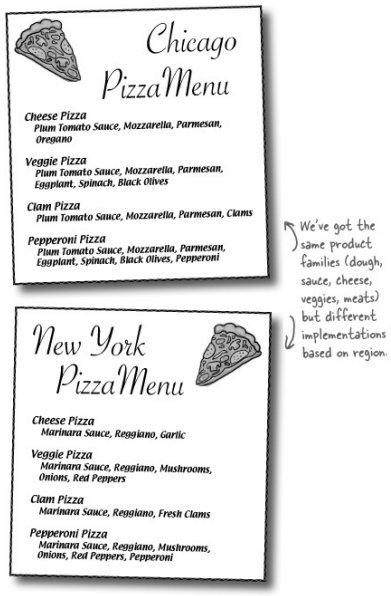
Now, the key to Objectville Pizza's success has always been fresh, quality ingredients, and what you've discovered is that with the new framework your franchises have been following your *procedures*, but a few franchises have been substituting inferior ingredients in their pies to lower costs and increase their margins. You know you've got to do something, because in the long term this is going to hurt the Objectville brand!



Ensuring consistency in your ingredients

So how are you going to ensure each franchise is using quality ingredients? You're going to build a factory that produces them and ships them to your franchises!

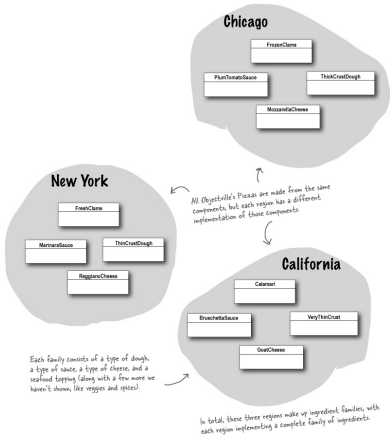
Now there is only one problem with this plan: the franchises are located in different regions and what is red sauce in New York is not red sauce in Chicago. So, you have one set of ingredients that needs to be shipped to New York and a *different* set that needs to be shipped to Chicago. Let's take a closer look:



Families of ingredients...

New York uses one set of ingredients and Chicago another. Given the popularity of Objectville Pizza it won't be long before you also need to ship another set of regional ingredients to California, and what's next? Seattle?

For this to work, you are going to have to figure out how to handle families of ingredients.



Building the ingredient factories

Now we're going to build a factory to create our ingredients; the factory will be responsible for creating each ingredient in the ingredient family. In other words, the factory will need to create dough, sauce, cheese, and so on... You'll see how we are going to handle the regional differences shortly.

Let's start by defining an interface for the factory that is going to create all our ingredients:

```
public interface PizzaIngredientFactory {

    public Dough createDough();
    public Sauce createSauce();
    public Cheese createCheese();
    public Veggies[] createVeggies();
    public Pepperoni createPepperoni();
    public Clams createClam();

}
```

For each ingredient we define a create method in our interface.

Lots of new classes here, one per ingredient

NOTE

If we'd had some common "machinery" to implement in each instance of factory, we could have made this an abstract class instead...

Here's what we're going to do:

1. Build a factory for each region. To do this, you'll create a subclass of PizzaIngredientFactory that implements each create method

2. Implement a set of ingredient classes to be used with the factory, like ReggianoCheese, RedPeppers, and ThickCrustDough. These classes can be shared among regions where appropriate.

3. Then we still need to hook all this up by working our new ingredient factories into our old PizzaStore code.

Building the New York ingredient factory

Okay, here's the implementation for the New York ingredient factory. This factory specializes in Marinara sauce, Reggiano Cheese, Fresh Clams...

The NY ingredient factory implements the interface for all ingredient factories

```
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();
    }
}
```

For each ingredient in the ingredient family we create the New York version.

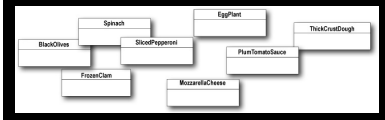
For veggies, we return an array of Veggies. Here we've hardcoded the veggies. We could make this more sophisticated, but that doesn't really add anything to learning the factory pattern, so we'll keep it simple.

The best sliced pepperoni. This is shared between New York and Chicago. Make sure you use it on the next page when you get to implement the Chicago factory yourself.

New York is on the coast; it gets fresh clams. Chicago has to settle for frozen.

SHARPEN YOUR PENCIL

Write the ChicagoPizzaIngredientFactory. You can reference the classes below in your implementation:



Reworking the pizzas...

We've got our factories all fired up and ready to produce quality ingredients; now we just need to rework our Pizzas so they only use factory-produced ingredients. We'll start with our abstract Pizza class:

```
public abstract class Pizza {
    String name;

    Dough dough;
    Sauce sauce;
    Veggies veggies[];
    Cheese cheese;
    Pepperoni pepperoni;
    Clams clam;

    abstract void prepare();

    void bake() {
        System.out.println("Bake for 25 minutes at 350");
    }

    void cut() {
        System.out.println("Cutting the pizza into diagonal slices");
    }

    void box() {
        System.out.println("Place pizza in official PizzaStore box");
    }

    void setName(String name) {
        this.name = name;
    }

    String getName() {
        return name;
    }

    public String toString() {
        // code to print pizza here
    }
}
```

Each pizza holds a set of ingredients that are used in its preparation.

We've now made the prepare method abstract. This is where we are going to collect the ingredients needed for the pizza, which of course will come from the ingredient factory.

Our other methods remain the same, with the exception of the prepare method.

Now that you've got an abstract Pizza to work from, it's time to create the New York and Chicago style Pizzas – only this time around they will get their ingredients straight from the factory. The franchisees' days of skimping on ingredients are over!

When we wrote the Factory Method code, we had a NYCheesePizza and a

ChicagoCheesePizza class. If you look at the two classes, the only thing that differs is the use of regional ingredients. The pizzas are made just the same (dough + sauce + cheese). The same goes for the other pizzas: Veggie, Clam, and so on. They all follow the same preparation steps; they just have different ingredients.

So, what you'll see is that we really don't need two classes for each pizza; the ingredient factory is going to handle the regional differences for us. Here's the Cheese 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();
    }
}
```

To make a pizza now, we need a factory to provide the ingredients. So each Pizza class gets a factory passed into its constructor, and it's stored in an instance variable.

Here's where the magic happens!

The prepare() method steps through creating a cheese pizza, and each time it needs an ingredient, it asks the factory to produce it.

CODE UP CLOSE

The Pizza code uses the factory it has been composed with to produce the ingredients used in the pizza. The ingredients produced depend on which factory we're using. The Pizza class doesn't care; it knows how to make pizzas. Now, it's decoupled from the differences in regional ingredients and can be easily reused when there are factories for the Rockies, the Pacific Northwest, and beyond.

```
sauce = ingredientFactory.createSauce();
```

We're setting the Pizza instance variable to refer to the specific sauce used in this pizza.

This is our ingredient factory. The Pizza doesn't care which factory is used, as long as it is an ingredient factory.

The createSauce() method returns the sauce that is used in its region. If this is a NY ingredient factory, then we get marinara sauce.

Let's check out the ClamPizza as well:

```
public class ClamPizza extends Pizza {
    PizzaIngredientFactory ingredientFactory;

    public ClamPizza(PizzaIngredientFactory ingredientFactory) {
        this.ingredientFactory = ingredientFactory;
    }

    void prepare() {
        System.out.println("Preparing" + name);
        dough = ingredientFactory.createDough();
        sauce = ingredientFactory.createSauce();
        cheese = ingredientFactory.createCheese();
        clam = ingredientFactory.createClam();
    }
}
```

ClamPizza also stashes an ingredient factory.

To make a clam pizza, the prepare method collects the right ingredients from its local factory.

If it's a New York factory, the clams will be fresh, if it's Chicago, they'll be frozen.

Revisiting our pizza stores

We're almost there; we just need to make a quick trip to our franchise stores to make sure they are using the correct Pizzas. We also need to give them a reference to their local ingredient factories:

```
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");

        } else if (item.equals("clam")) {

            pizza = new ClamPizza(ingredientFactory);
            pizza.setName("New York Style Clam Pizza");

        } else if (item.equals("pepperoni")) {

            pizza = new PepperoniPizza(ingredientFactory);
            pizza.setName("New York Style Pepperoni Pizza");

        }
        return pizza;
    }
}
```

The NY Store is composed with a NY pizza ingredient factory. This will be used to produce the ingredients for all NY style pizzas.

We now pass each pizza the factory that should be used to produce its ingredients.

Look back one page and make sure you understand how the pizza and the factory work together!

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

BRAIN POWER

Compare this version of the createPizza() method to the one in the Factory Method implementation earlier in the chapter.

What have we done?

That was quite a series of code changes; what exactly did we do?

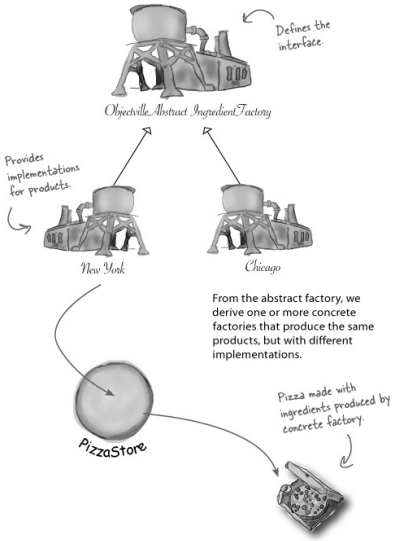
We provided a means of creating a family of ingredients for pizzas by introducing a new type of factory called an Abstract Factory.

An Abstract Factory gives us an interface for creating a family of products. By writing code that uses this interface, we decouple our code from the actual

factory that creates the products. That allows us to implement a variety of factories that produce products meant for different contexts – such as different regions, different operating systems, or different look and feels.

Because our code is decoupled from the actual products, we can substitute different factories to get different behaviors (like getting marinara instead of plum tomatoes).

An Abstract Factory provides an interface for a family of products. What's a family? In our case it's all the things we need to make a pizza: dough, sauce, cheese, meats and veggies.



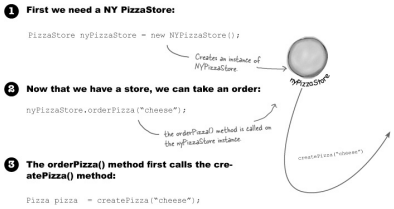
We then write our code so that it uses the factory to create products. By passing in a variety of factories, we get a variety of implementations of those products. But our client code stays the same.

More pizza for Ethan and Joel...

Behind the Scenes

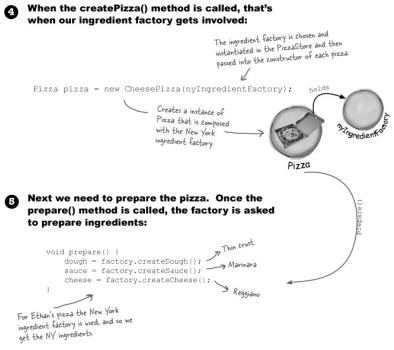
Ethan and Joel can't get enough Objectville Pizza! What they don't know is that now their orders are making use of the new ingredient factories. So now when they order...

The first part of the order process hasn't changed at all. Let's follow Ethan's order again:



From here things change, because we are using an ingredient factory

Behind the Scenes

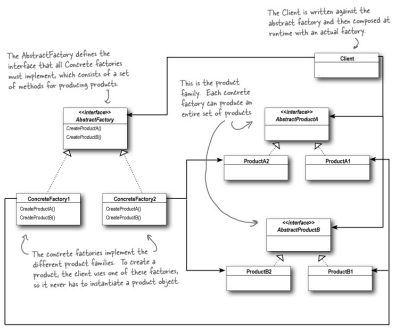


Abstract Factory Pattern defined

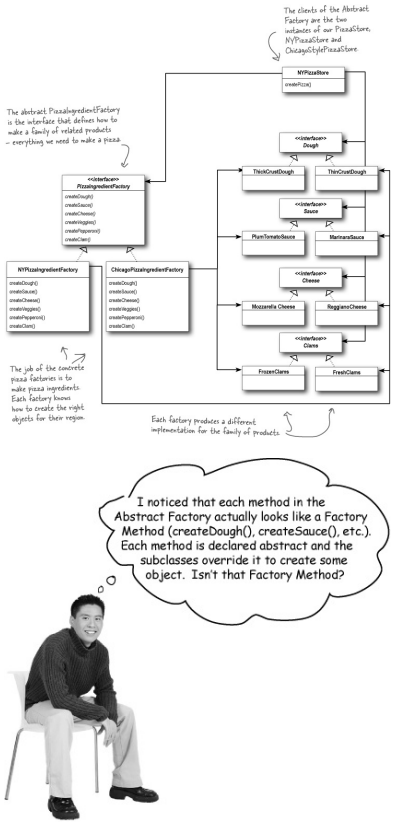
We're adding yet another factory pattern to our pattern family, one that lets us create families of products. Let's check out the official definition for this pattern:

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

We've certainly seen that Abstract Factory allows a client to use an abstract interface to create a set of related products without knowing (or caring) about the concrete products that are actually produced. In this way, the client is decoupled from any of the specifics of the concrete products. Let's look at the class diagram to see how this all holds together:



That's a fairly complicated class diagram; let's look at it all in terms of our PizzaStore:



Is that a Factory Method lurking inside the Abstract Factory?

Good catch! Yes, often the methods of an Abstract Factory are implemented as factory methods. It makes sense, right? The job of an Abstract Factory is to define an interface for creating a set of products. Each method in that interface is responsible for creating a concrete product, and we implement a subclass of the Abstract Factory to supply those implementations. So, factory methods are a natural way to implement your product methods in your abstract factories.

PATTERNS EXPOSED

This week's interview: Factory Method and Abstract Factory, on each other

HeadFirst: Wow, an interview with two patterns at once! This is a first for us.

Factory Method: Yeah, I'm not so sure I like being lumped in with Abstract Factory, you know. Just because we're both factory patterns doesn't mean we shouldn't get our own interviews.

HeadFirst: Don't be miffed, we wanted to interview you together so we could help clear up any confusion about who's who for the readers. You do have similarities, and I've heard that people sometimes get you confused.

Abstract Factory: It is true, there have been times I've been mistaken for Factory Method, and I know you've had similar issues, Factory Method. We're both really good at decoupling applications from specific implementations; we just do it in different ways. So I can see why people might sometimes get us confused.

Factory Method: Well, it still ticks me off. After all, I use classes to create and you use objects; that's totally different!

HeadFirst: Can you explain more about that, Factory Method?

Factory Method: Sure. Both Abstract Factory and I create objects – that's our jobs. But I do it through inheritance...

Abstract Factory: ...and I do it through object composition.

Factory Method: Right. So that means, to create objects using Factory Method, you need to extend a class and override a factory method.

HeadFirst: And that factory method does what?

Factory Method: It creates objects, of course! I mean, the whole point of the Factory Method Pattern is that you're using a subclass to do your creation for you. In that way, clients only need to know the abstract type they are using, the subclass worries about the concrete type. So, in other words, I keep clients decoupled from the concrete types.

Abstract Factory: And I do too, only I do it in a different way.

HeadFirst: Go on, Abstract Factory... you said something about object composition?

Abstract Factory: I provide an abstract type for creating a family of products. Subclasses of this type define how those products are produced. To use the factory, you instantiate one and pass it into some code that is written against the abstract type. So, like Factory Method, my clients are decoupled from the actual concrete products they use.

HeadFirst: Oh, I see, so another advantage is that you group together a set of related products.

Abstract Factory: That's right.

HeadFirst: What happens if you need to extend that set of related products, to say add another one? Doesn't that require changing your interface?

Abstract Factory: That's true; my interface has to change if new products are added, which I know people don't like to do....

Factory Method: <snicker>

Abstract Factory: What are you snickering at, Factory Method?

Factory Method: Oh, come on, that's a big deal! Changing your interface means you have to go in and change the interface of every subclass! That sounds like a lot of work.

Abstract Factory: Yeah, but I need a big interface because I am used to creating entire families of products. You're only creating one product, so you don't really need a big interface, you just need one method.

HeadFirst: Abstract Factory, I heard that you often use factory methods to implement your concrete factories?

Abstract Factory: Yes, I'll admit it, my concrete factories often implement a factory method to create their products. In my case, they are used purely to create products...

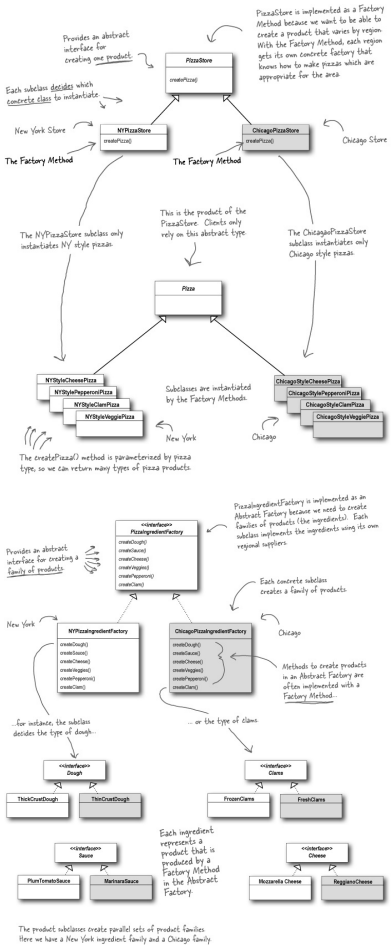
Factory Method: ...while in my case I usually implement code in the abstract creator that makes use of the concrete types the subclasses create.

HeadFirst: It sounds like you both are good at what you do. I'm sure people like having a choice; after all, factories are so useful, they'll want to use them in all kinds of different situations. You both encapsulate object creation to keep applications loosely coupled and less dependent on implementations, which is really great, whether you're using Factory Method or Abstract Factory. May I allow you each a parting word?

Abstract Factory: Thanks. Remember me, Abstract Factory, and use me whenever you have families of products you need to create and you want to make sure your clients create products that belong together.

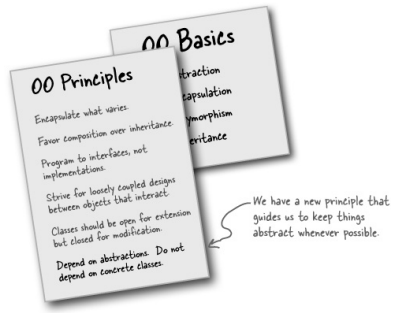
Factory Method: And I'm Factory Method; use me to decouple your client code from the concrete classes you need to instantiate, or if you don't know ahead of time all the concrete classes you are going to need. To use me, just subclass me and implement my factory method!

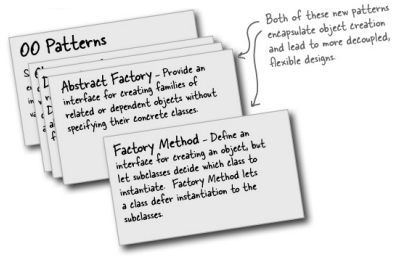
Factory Method and Abstract Factory compared



Tools for your Design Toolbox

In this chapter, we added two more tools to your toolbox: Factory Method and Abstract Factory. Both patterns encapsulate object creation and allow you to decouple your code from concrete types.

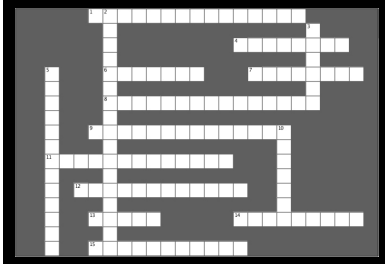




BULLET POINTS

- All factories encapsulate object creation.
- Simple Factory, while not a bona fide design pattern, is a simple way to decouple your clients from concrete classes.
- Factory Method relies on inheritance: object creation is delegated to subclasses which implement the factory method to create objects.
- Abstract Factory relies on object composition: object creation is implemented in methods exposed in the factory interface.
- All factory patterns promote loose coupling by reducing the dependency of your application on concrete classes.
- The intent of Factory Method is to allow a class to defer instantiation to its subclasses.
- The intent of Abstract Factory is to create families of related objects without having to depend on their concrete classes.
- The Dependency Inversion Principle guides us to avoid dependencies on concrete types and to strive for abstractions.
- Factories are a powerful technique for coding to abstractions, not concrete classes

It's been a long chapter. Grab a slice of Pizza and relax while doing this crossword; all of the solution words are from this chapter.



Across

1. In Factory Method, each franchise is a _____

4. In Factory Method, who decides which class to instantiate?

6. Role of PizzaStore in Factory Method Pattern

7. All New York Style Pizzas use this kind of cheese

8. In Abstract Factory, each ingredient factory is a _____

9. When you use new, you are programming to an _____

11. createPizza() is a _____ (two words)

12. Joel likes this kind of pizza

13. In Factory Method, the PizzaStore and the concrete Pizzas all depend on this abstraction

14. When a class instantiates an object from a concrete class, it's _____ on that object

15. All factory patterns allow us to _____ object creation

Down

2. We used _____ in Simple Factory and Abstract Factory and inheritance in Factory Method

3. Abstract Factory creates a _____ of products

5. Not a REAL factory pattern, but handy nonetheless

10. Ethan likes this kind of pizza

Exercise Solutions

SHARPEN YOUR PENCIL

We've knocked out the NYPizzaStore; just two more to go and we'll be ready to franchise! Write the Chicago and California PizzaStore implementations here:

Both of these stores are almost exactly like the New York store... they just create different kinds of pizzas

```
public class ChicagoPizzaStore extends PizzaStore {
    protected Pizza createPizza(String item) {
        if (item.equals("cheese")) {
            return new ChicagoStyleCheesePizza();
        } else if (item.equals("veggie")) {
            return new ChicagoStyleVeggiePizza();
        } else if (item.equals("clam")) {
            return new ChicagoStyleClamPizza();
        } else if (item.equals("pepperoni")) {
            return new ChicagoStylePepperoniPizza();
        } else return null;
    }
}
```

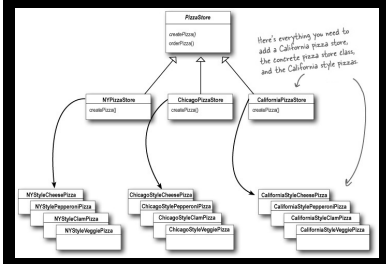
For the Chicago pizza store, we just have to make sure we create Chicago style pizzas...

```
public class CaliforniaPizzaStore extends PizzaStore {
    protected Pizza createPizza(String item) {
        if (item.equals("cheese")) {
            return new CaliforniaStyleCheesePizza();
        } else if (item.equals("veggie")) {
            return new CaliforniaStyleVeggiePizza();
        } else if (item.equals("clam")) {
            return new CaliforniaStyleClamPizza();
        } else if (item.equals("pepperoni")) {
            return new CaliforniaStylePepperoniPizza();
        } else return null;
    }
}
```

And for the California pizza store, we create California style pizzas.

DESIGN PUZZLE SOLUTION

We need another kind of pizza for those crazy Californians (crazy in a GOOD way of course). Draw another parallel set of classes that you'd need to add a new California region to our PizzaStore.



Okay, now write the five silliest things you can think of to put on a pizza. Then, you'll be ready to go into business making pizza in California!

Here are our suggestions...

Mashed Potatoes with Roasted Garlic

BBQ Sauce

Artichoke Hearts

M&M's

Peanuts

A very dependent PizzaStore

SHARPEN YOUR PENCIL

Let's pretend you've never heard of an OO factory. Here's a version of the PizzaStore that doesn't use a factory; make a count of the number of concrete pizza objects this class is dependent on. If you added California style pizzas to this PizzaStore, how many objects would it be dependent on then?

```
public class DependentPizzaStore {

    public Pizza createPizza(String style, String type) {
        Pizza pizza = null;
        if (style.equals("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")) {
            if (type.equals("cheese")) {
                pizza = new ChicagoStyleCheesePizza();
            } else if (type.equals("veggie")) {
                pizza = new ChicagoStyleVeggiePizza();
            } else if (type.equals("clam")) {
                pizza = new ChicagoStyleClamPizza();
            } else if (type.equals("pepperoni")) {
                pizza = new ChicagoStylePepperoniPizza();
            }
        } else {
            System.out.println("Error: invalid type of pizza");
            return null;
        }
        pizza.prepare();
        pizza.bake();
        pizza.cut();
        pizza.box();
        return pizza;
    }
}
```

Handles all the NY style pizzas

Handles all the Chicago style pizzas

You can write your answers here

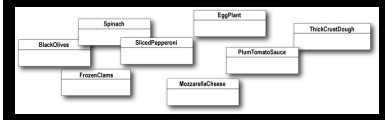
0 number

12. number with California types

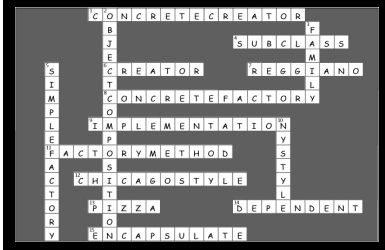
SHARPEN YOUR PENCIL

Go ahead and write the ChicagoPizzaIngredientFactory; you can reference the classes below in your implementation:

```
public class ChicagoPizzaIngredientFactory
    implements PizzaIngredientFactory
{

    public Dough createDough() {
        return new ThickCrustDough();
    }

    public Sauce createSauce() {
        return new PlumTomatoSauce();
    }

    public Cheese createCheese() {
        return new MozzarellaCheese();
    }

    public Veggies[] createVeggies() {
        Veggies veggies[] = { new BlackOlives(),
                              new Spinach(),
                              new Eggplant() };
        return veggies;
    }

    public Pepperoni createPepperoni() {
        return new SlicedPepperoni();
    }

    public Clams createClam() {
        return new FrozenClams();
    }
}
```



PUZZLE SOLUTION



PREV
3. The Decorator Pattern: Decorating Objects

NEXT
5. The Singleton Pattern: One of a Kind Objects