THE COMPOSITE PATTERN

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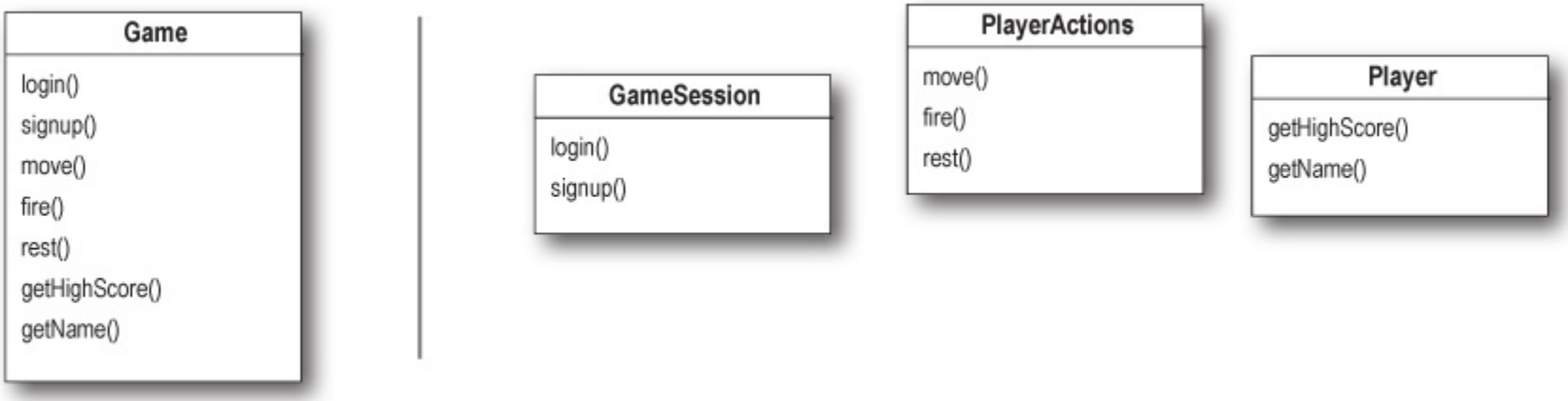
Week 7-2

Today …

Single Responsibility

How to treat a part and the whole uniformly?

Low or high cohesion?



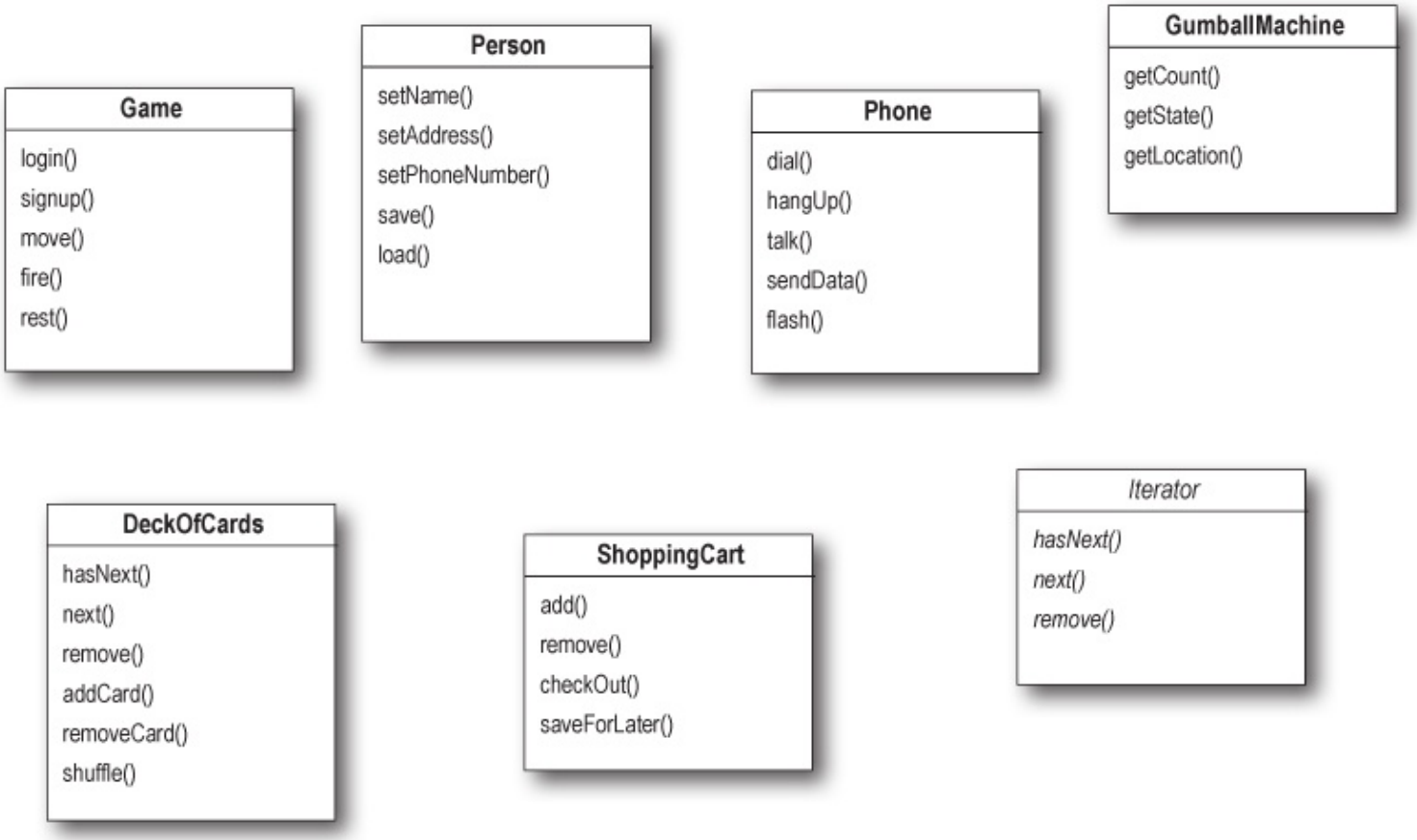
Single Responsibility

Why having aggregate implement the collection related methods as well as iteration related method a bad idea?

It can change if the collection changes in some way, and it can change if the way we iterate changes.

A class should have only one reason to change.

Which one have multiple responsibilities?



Q1

New Merger with Objectville Cafe

Taking a look at the Café Menu

CafeMenu doesn't implement our new Menu interface, but this is easily fixed.

The café is storing their menu items in a HashMap. Does that support Iterator? We'll see shortly...

```
public class CafeMenu {
    HashMap<String, MenuItem> menuItems = new HashMap<String, MenuItem>();

    public CafeMenu() {
        addItem("Veggie Burger and Air Fries",
            "Veggie burger on a whole wheat bun, lettuce, tomato, and fries",
            true, 3.99);
        addItem("Soup of the day",
            "A cup of the soup of the day, with a side salad",
            false, 3.69);
        addItem("Burrito",
            "A large burrito, with whole pinto beans, salsa, guacamole",
            true, 4.29);
    }

    public void addItem(String name, String description,
                        boolean vegetarian, double price)
    {
        MenuItem menuItem = new MenuItem(name, description, vegetarian, price);
        menuItems.put(menuItem.getName(), menuItem);
    }

    public Map<String, MenuItem> getItems() {
        return menuItems;
    }
}
```

Like the other Menus, the menu items are initialized in the constructor.

Here's where we create a new MenuItem and add it to the menuItems hashtable.

The key is the item name.

The value is the menuItem object.

We're not going to need this anymore.

Reworking the Café Menu

CafeMenu implements the Menu interface, so the Waitress can use it just like the other two Menus.

```
public class CafeMenu implements Menu {
    HashMap<String, MenuItem> menuItems = new HashMap<String, MenuItem>();

    public CafeMenu() {
        // constructor code here
    }

    public void addItem(String name, String description,
                        boolean vegetarian, double price)
    {
        MenuItem menuItem = new MenuItem(name, description, vegetarian, price);
        menuItems.put(menuItem.getName(), menuItem);
    }

    public Map<String, MenuItem> getItems() {
        return menuItems;
    }

    public Iterator<MenuItem> createIterator() {
        return menuItems.values().iterator();
    }
}
```

We're using HashMap because it's a common data structure for storing value.

Just like before, we can get rid of getItems() so we don't expose the implementation of menuItems to the Waitress.

And here's where we implement the createIterator() method. Notice that we're not getting an Iterator for the whole HashMap, just for the values.

Adding the Café Menu to the Waitress

```
public class Waitress {
    Menu pancakeHouseMenu;
    Menu dinerMenu;
    Menu cafeMenu;

    public Waitress(Menu pancakeHouseMenu, Menu dinerMenu, Menu cafeMenu) {
        this.pancakeHouseMenu = pancakeHouseMenu;
        this.dinerMenu = dinerMenu;
        this.cafeMenu = cafeMenu;
    }

    public void printMenu() {
        Iterator<MenuItem> pancakeIterator = pancakeHouseMenu.createIterator();
        Iterator<MenuItem> dinerIterator = dinerMenu.createIterator();
        Iterator<MenuItem> cafeIterator = cafeMenu.createIterator();

        System.out.println("MENU\n----\nBREAKFAST");
        printMenu(pancakeIterator);
        System.out.println("\nLUNCH");
        printMenu(dinerIterator);
        System.out.println("\nDINNER");
        printMenu(cafeIterator);
    }

    private void printMenu(Iterator iterator) {
        while (iterator.hasNext()) {
            MenuItem menuItem = iterator.next();
            System.out.print(menuItem.getName() + ", ");
            System.out.print(menuItem.getPrice() + " -- ");
            System.out.println(menuItem.getDescription());
        }
    }
}
```

The café menu is passed into the Waitress in the constructor with the other menus, and we stash it in an instance variable.

We're using the café's menu for our dinner menu. All we have to do to print it is create the iterator, and pass it to printMenu(). That's it!

Nothing changes here.

Breakfast, lunch, and dinner

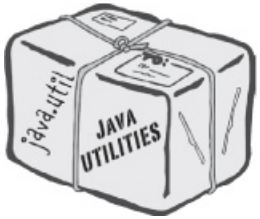
```
public class MenuTestDrive {
    public static void main(String args[]) {
        PancakeHouseMenu pancakeHouseMenu = new PancakeHouseMenu();
        DinerMenu dinerMenu = new DinerMenu();
        CafeMenu cafeMenu = new CafeMenu();

        Waitress waitress = new Waitress(pancakeHouseMenu, dinerMenu, cafeMenu);

        waitress.printMenu();
}
```

Create a CafeMenu...

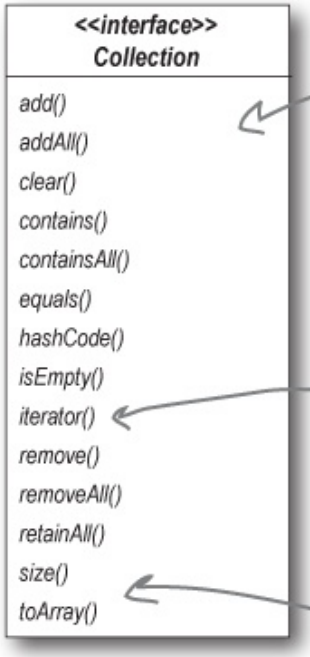
... and pass it to the waitress.

Now, when we print we should see all three menus.

Iterators and Collections



Java Collections Framework is just a set of classes and interfaces, including ArrayList, which we've been using, and many others like Vector, LinkedList, Stack, and PriorityQueue.



As you can see, there's all kinds of good stuff here. You can add and remove elements from your collection without even knowing how it's implemented.

Here's our old friend, the iterator() method. With this method, you can get an Iterator for any class that implements the Collection interface.

Other handy methods include size(), to get the number of elements, and toArray() to turn your collection into an array.

The nice thing about Collections and Iterator is that each Collection object knows how to create its own Iterator. Calling iterator() on an ArrayList returns a concrete Iterator made for ArrayLists, but you never need to see or worry about the concrete class it uses; you just use the Iterator interface.

Let's further improve the Waitress

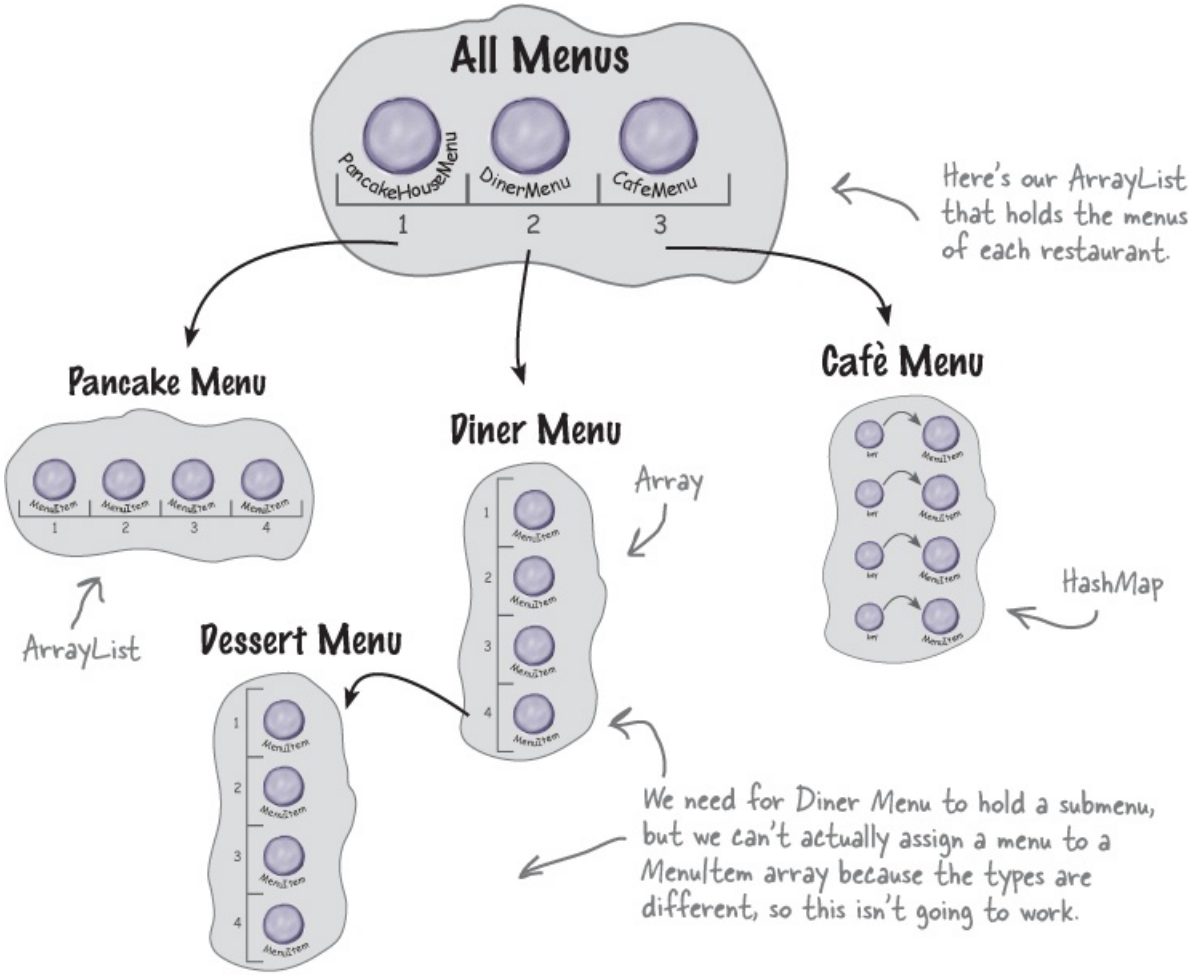
```
public class Waitress {
    ArrayList<Menu> menus;

    public Waitress(ArrayList<Menu> menus) {
        this.menus = menus;
    }

    public void printMenu() {
        Iterator<Menu> menuIterator = menus.iterator();
        while(menuIterator.hasNext()) {
            Menu menu = menuIterator.next();
            printMenu(menu.createIterator());
        }
    }

    void printMenu(Iterator<Menu> iterator) {
        while (iterator.hasNext()) {
            MenuItem menuItem = iterator.next();
            System.out.print(menuItem.getName() + ", ");
            System.out.print(menuItem.getPrice() + " -- ");
            System.out.println(menuItem.getDescription());
        }
    }
}
```

Now we just take an ArrayList of menus.

And we iterate through the menus, passing each menu's iterator to the overloaded printMenu() method.

No code changes here.

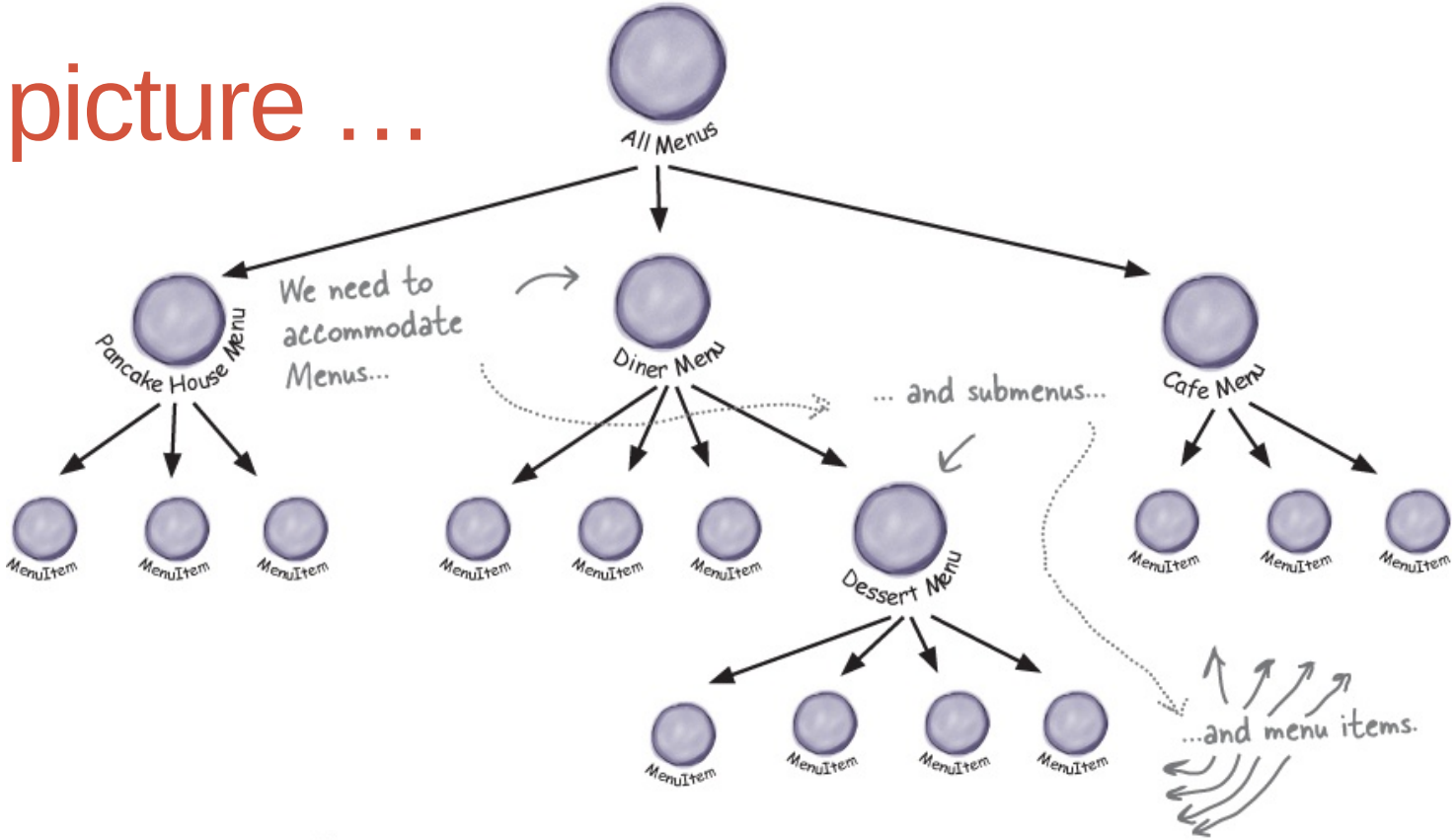
Just when we thought we were done ...



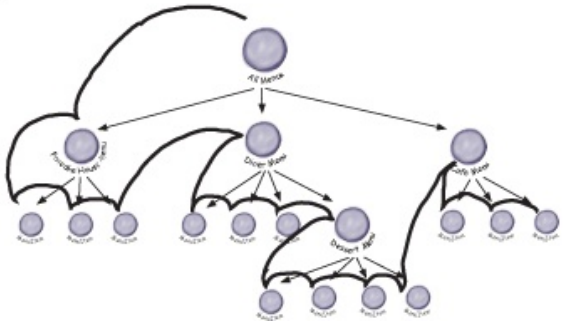
But this won't work!

Q3

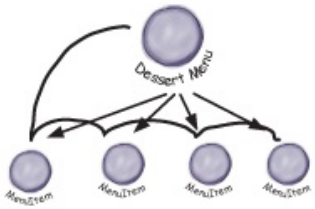
The big picture …



We still need to be able to traverse all the items in the tree.

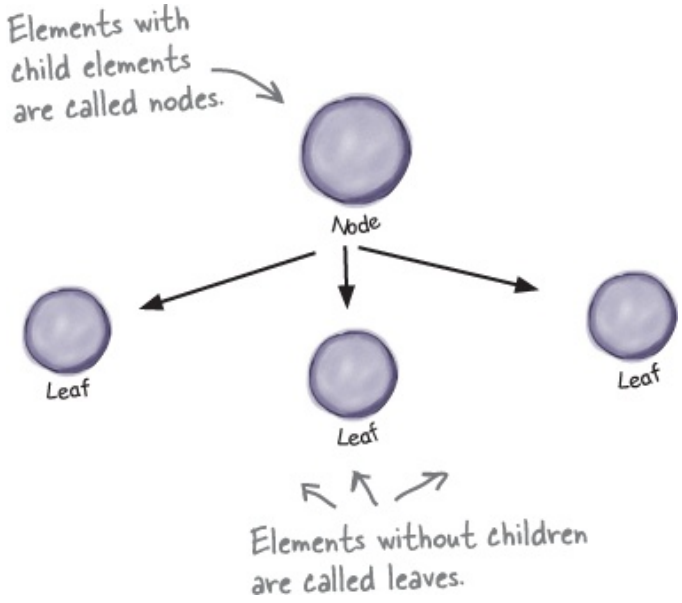


We also need to be able to traverse more flexibly, for instance over one menu.

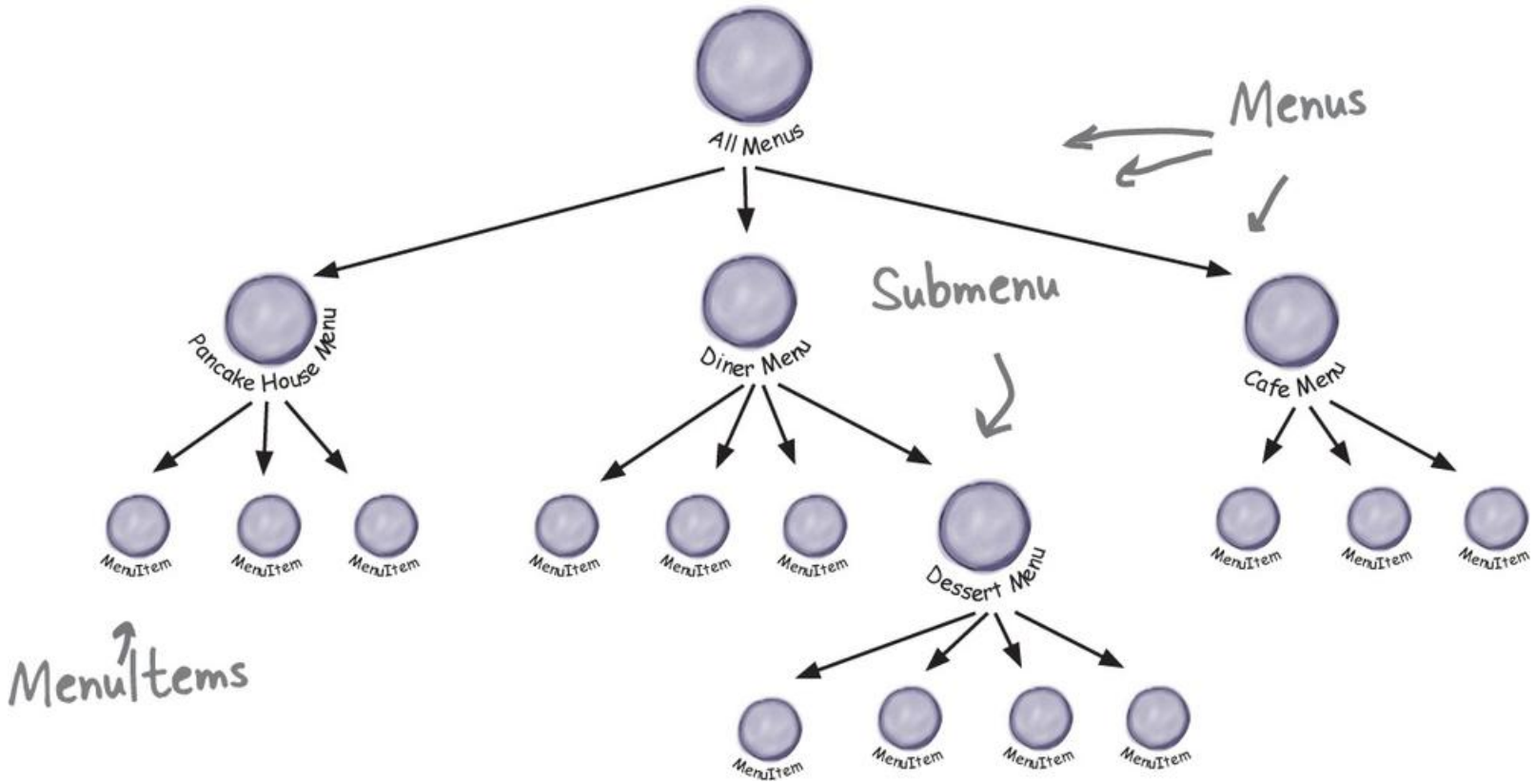


The Composite Pattern defined

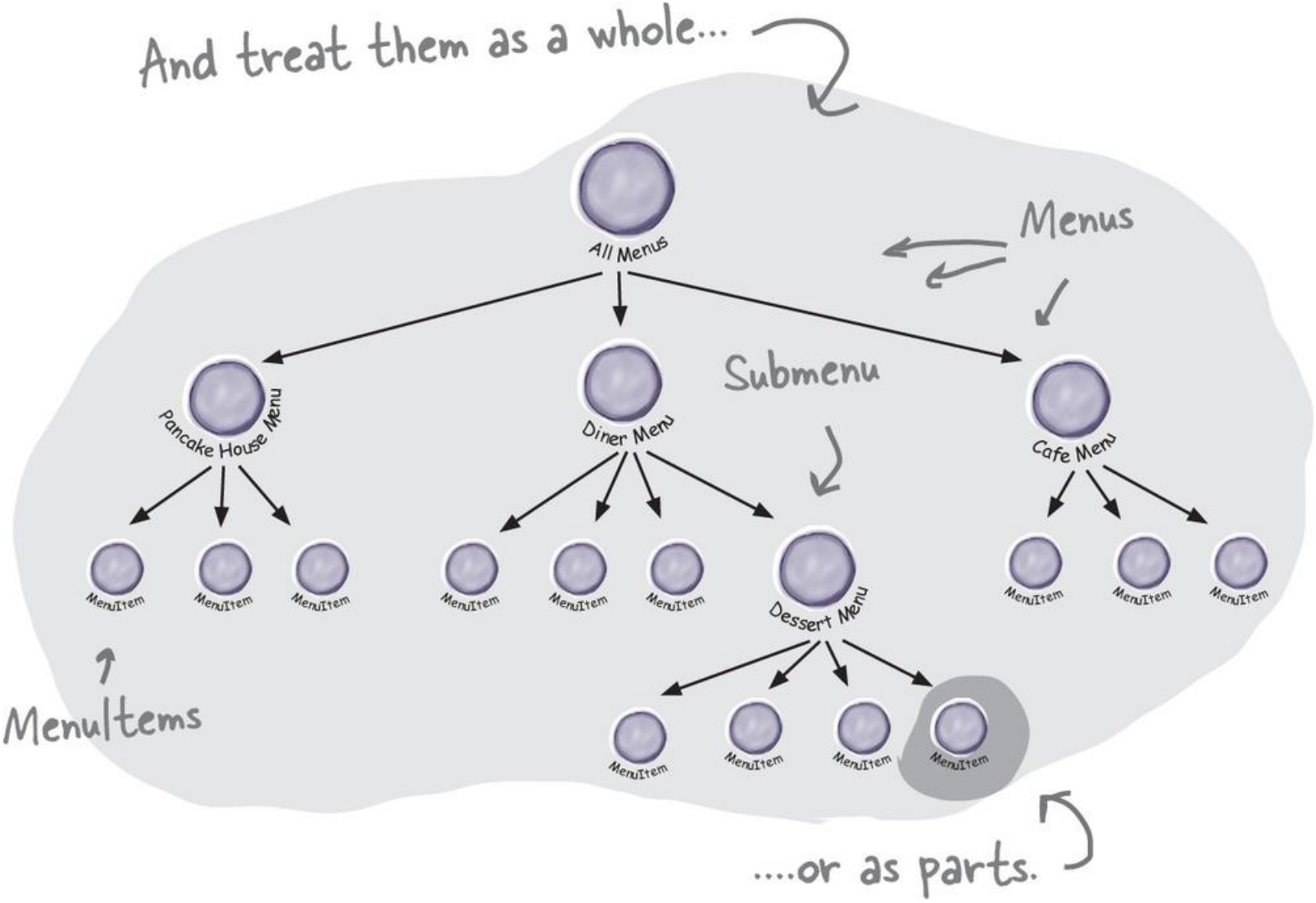
The Composite Pattern allows you to compose objects into tree structures to represent part-whole hierarchies. Composite lets clients treat individual objects and compositions of objects uniformly.



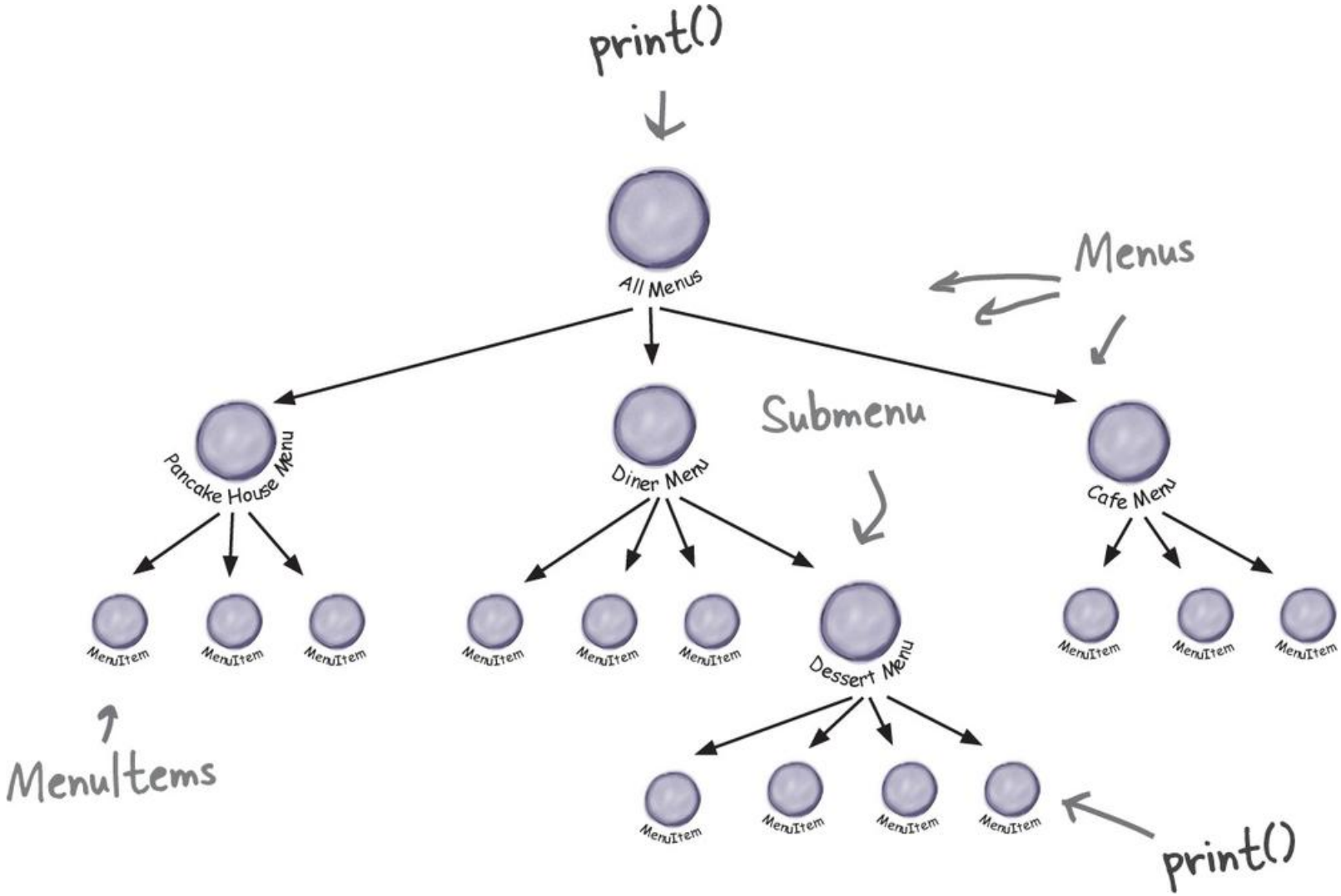
Arbitrarily complex trees with Composite



And …


And treat them as a whole…
All Menus
Menus
Submenu
Pancake House Menu
Diner Menu
Cafe Menu
Dessert Menu
MenuItem
MenuItems
….or as parts.

Operations on both the whole or the parts

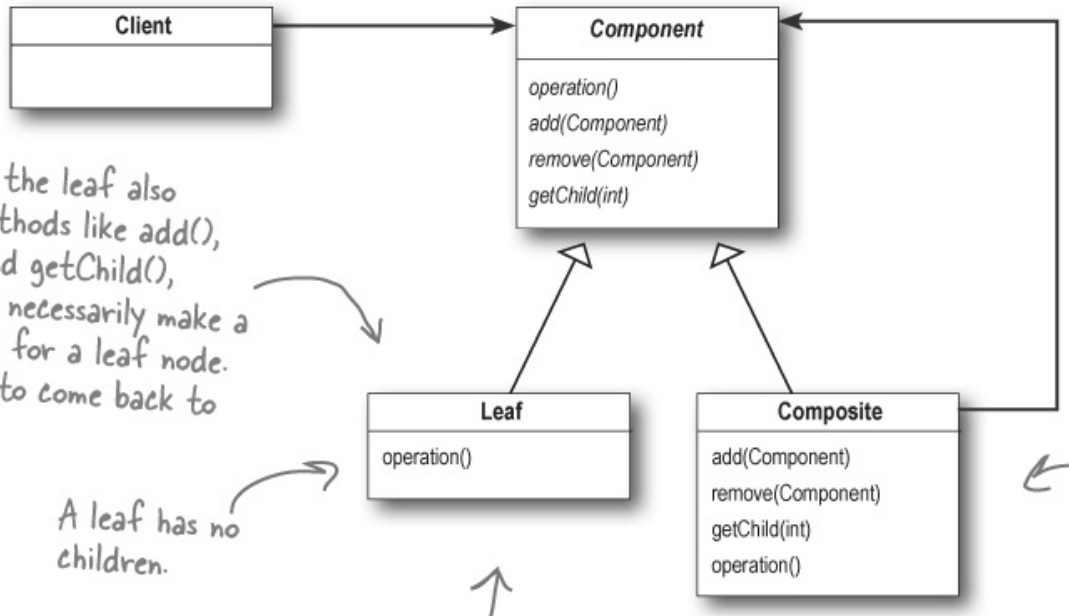


The Pattern

The Client uses the Component interface to manipulate the objects in the composition.

The Component defines an interface for all objects in the composition: both the composite and the leaf nodes.

The Component may implement a default behavior for add(), remove(), getChild() and its operations.



Note that the leaf also inherits methods like add(), remove() and getChild(), which don't necessarily make a lot of sense for a leaf node. We're going to come back to this issue.

A leaf has no children.

A leaf defines the behavior for the elements in the composition. It does this by implementing the operations the Composite supports.

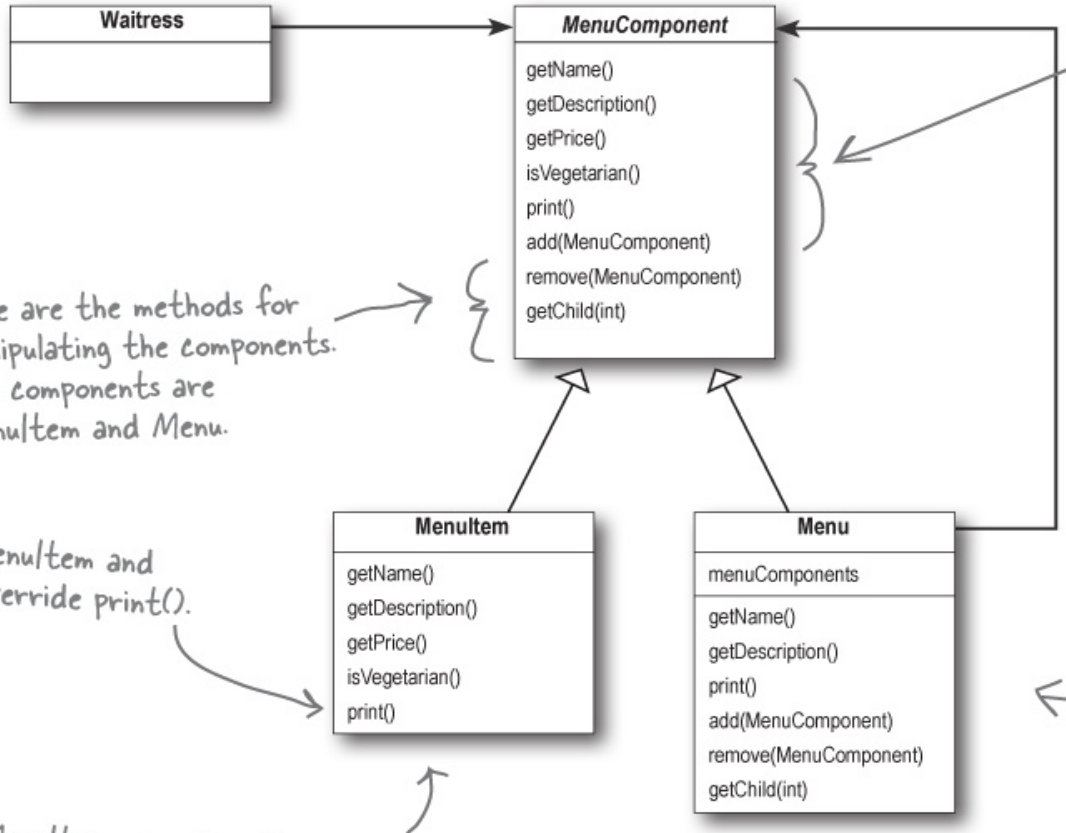
The Composite's role is to define behavior of the components having children and to store child components.

The Composite also implements the Leaf-related operations. Note that some of these may not make sense on a Composite, so in that case an exception might be generated.

New Design

The Waitress is going to use the MenuComponent interface to access both Menus and MenuItems.

MenuComponent represents the interface for both MenuItem and Menu. We've used an abstract class here because we want to provide default implementations for these methods.



We have some of the same methods you'll remember from our previous versions of MenuItem and Menu, and we've added print(), add(), remove() and getChild(). We'll describe these soon, when we implement our new Menu and MenuItem classes.

Here are the methods for manipulating the components. The components are MenuItem and Menu.

Both MenuItem and Menus override print().

MenuItem overrides the methods that make sense, and uses the default implementations in MenuComponent for those that don't make sense (like add() – it doesn't make sense to add a component to a MenuItem... we can only add components to a Menu).

Menu also overrides the methods that make sense, like a way to add and remove menu items (or other menus!) from its menuComponents. In addition, we'll use the getName() and getDescription() methods to return the name and description of the menu.

Implementing the Menu Component

MenuComponent provides default implementations for every method.

```
public abstract class MenuComponent {

    public void add(MenuComponent menuComponent) {
        throw new UnsupportedOperationException();
    }
    public void remove(MenuComponent menuComponent) {
        throw new UnsupportedOperationException();
    }
    public MenuComponent getChild(int i) {
        throw new UnsupportedOperationException();
    }

    public String getName() {
        throw new UnsupportedOperationException();
    }
    public String getDescription() {
        throw new UnsupportedOperationException();
    }
    public double getPrice() {
        throw new UnsupportedOperationException();
    }
    public boolean isVegetarian() {
        throw new UnsupportedOperationException();
    }

    public void print() {
        throw new UnsupportedOperationException();
    }
}
```

We've grouped together the "composite" methods – that is, methods to add, remove and get MenuComponents.

Here are the "operation" methods; these are used by the MenuItems. It turns out we can also use a couple of them in Menu too, as you'll see in a couple of pages when we show the Menu code.

print() is an "operation" method that both our Menus and MenuItems will implement, but we provide a default operation here.

Implementing the Menu Item

```
public class MenuItem extends MenuComponent {
    String name;
    String description;
    boolean vegetarian;
    double price;

    public MenuItem(String name,
                    String description,
                    boolean vegetarian,
                    double price)
    {
        this.name = name;
        this.description = description;
        this.vegetarian = vegetarian;
        this.price = price;
    }

    public String getName() {
        return name;
    }

    public String getDescription() {
        return description;
    }

    public double getPrice() {
        return price;
    }

    public boolean isVegetarian() {
        return vegetarian;
    }

    public void print() {
        System.out.print("  " + getName());
        if (isVegetarian()) {
            System.out.print("(v)");
        }
        System.out.println(", " + getPrice());
        System.out.println("     -- " + getDescription());
    }
```

First we need to extend the MenuComponent interface.

The constructor just takes the name, description, etc. and keeps a reference to them all. This is pretty much like our old menu item implementation.

Here's our getter methods – just like our previous implementation.

This is different from the previous implementation. Here we're overriding the print() method in the MenuComponent class. For MenuItem this method prints the complete menu entry: name, description, price and whether or not it's veggie.

Implementing the Composite Menu

Menu is also a MenuComponent, just like MenuItem.

Menu can have any number of children of type MenuComponent. We'll use an internal ArrayList to hold these.

```
public class Menu extends MenuComponent {
    ArrayList<MenuComponent> menuComponents = new ArrayList<MenuComponent>();
    String name;
    String description;

    public Menu(String name, String description) {
        this.name = name;
        this.description = description;
    }

    public void add(MenuComponent menuComponent) {
        menuComponents.add(menuComponent);
    }

    public void remove(MenuComponent menuComponent) {
        menuComponents.remove(menuComponent);
    }

    public MenuComponent getChild(int i) {
        returnmenuComponents.get(i);
    }

    public String getName() {
        return name;
    }

    public String getDescription() {
        return description;
    }

    public void print() {
        System.out.print("\n" + getName());
        System.out.println(", " + getDescription());
        System.out.println("---------------------");
    }
}
```

This is different than our old implementation: we're going to give each Menu a name and a description. Before, we just relied on having different classes for each menu.

Here's how you add MenuItems or other Menus to a Menu. Because both MenuItems and Menus are MenuComponents, we just need one method to do both.

You can also remove a MenuComponent or get a MenuComponent.

Here are the getter methods for getting the name and description.

Notice, we aren't overriding getPrice() or isVegetarian() because those methods don't make sense for a Menu (although you could argue that isVegetarian() might make sense). If someone tries to call those methods on a Menu, they'll get an UnsupportedOperationException.

To print the Menu, we print the Menu's name and description.

The print() method?

Wait a sec, I don't understand the implementation of print(). I thought I was supposed to be able to apply the same operations to a composite that I could to a leaf. If I apply print() to a composite with this implementation, all I get is a simple menu name and description. I don't get a printout of the COMPOSITE.

```
public class Menu extends MenuComponent {
    ArrayList<MenuComponent> menuComponents = new ArrayList<MenuComponent>();
    String name;
    String description;

    // constructor code here

    // other methods here

    public void print() {
        System.out.print("\n" + getName());
        System.out.println(", " + getDescription());
        System.out.println("---------------------");

        Iterator<MenuComponent> iterator = menuComponents.iterator();
        while (iterator.hasNext()) {
            MenuComponent menuComponent =
                                iterator.next();
            menuComponent.print();
        }
    }
}
```

All we need to do is change the print() method to make it print not only the information about this Menu, but all of this Menu's components: other Menus and MenuItems.

Look! We get to use an Iterator. We use it to iterate through all the Menu's components... those could be other Menus, or they could be MenuItems.

Since both Menus and MenuItems implement print(), we just call print() and the rest is up to them.

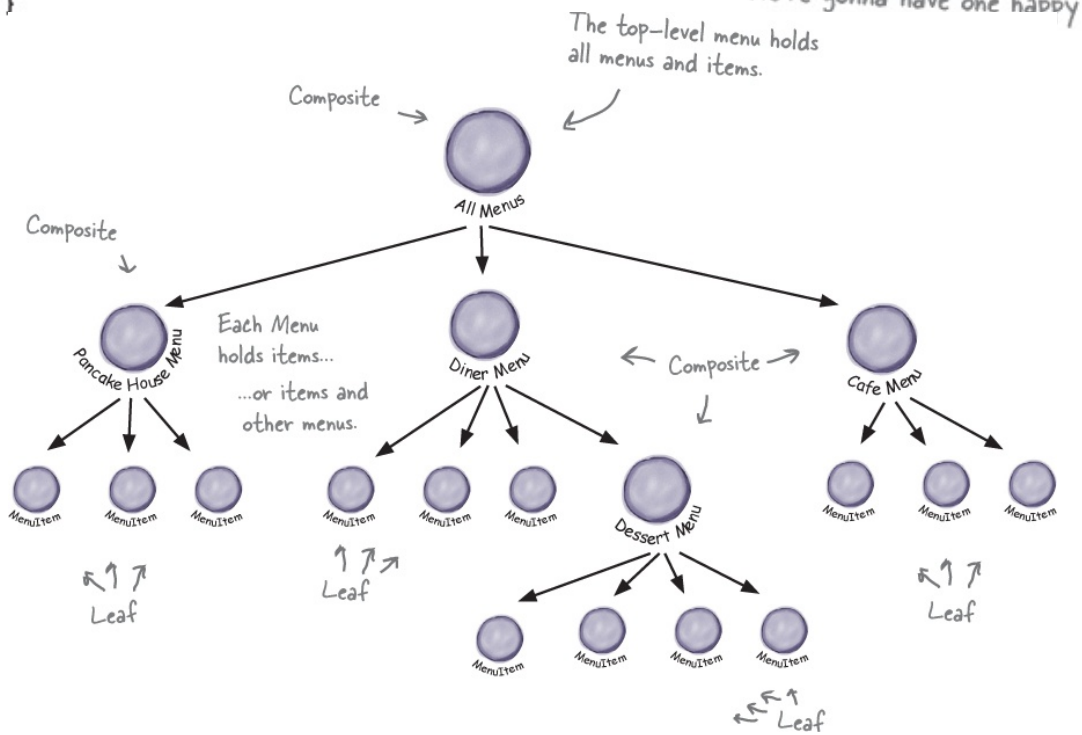
Getting ready for a test drive...

```
public class Waitress {
    MenuComponent allMenus;

    public Waitress(MenuComponent allMenus) {
        this.allMenus = allMenus;
    }

    public void printMenu() {
        allMenus.print();
    }
}
```

Yup! The Waitress code really is this simple. Now we just hand her the top-level menu component, the one that contains all the other menus. We've called that allMenus.

All she has to do to print the entire menu hierarchy – all the menus, and all the menu items – is call print() on the top level menu.

We're gonna have one happy Waitress.



The Test Drive

```
public class MenuTestDrive {
    public static void main(String args[]) {
        MenuComponent pancakeHouseMenu =
            new Menu("PANCAKE HOUSE MENU", "Breakfast");
        MenuComponent dinerMenu =
            new Menu("DINER MENU", "Lunch");
        MenuComponent cafeMenu =
            new Menu("CAFE MENU", "Dinner");
        MenuComponent dessertMenu =
            new Menu("DESSERT MENU", "Dessert of course!");

        MenuComponent allMenus = new Menu("ALL MENUS", "All menus combined");

        allMenus.add(pancakeHouseMenu);
        allMenus.add(dinerMenu);
        allMenus.add(cafeMenu);

        // add menu items here

        dinerMenu.add(new MenuItem(
            "Pasta",
            "Spaghetti with Marinara Sauce, and a slice of sourdough bread",
            true,
            3.89));

        dinerMenu.add(dessertMenu);

        dessertMenu.add(new MenuItem(
            "Apple Pie",
            "Apple pie with a flakey crust, topped with vanilla icecream",
            true,
            1.59));

        // add more menu items here

        Waitress waitress = new Waitress(allMenus);

        waitress.printMenu();
    }
}
```

Let's first create all the menu objects.

We also need a top-level menu that we'll name allMenus.

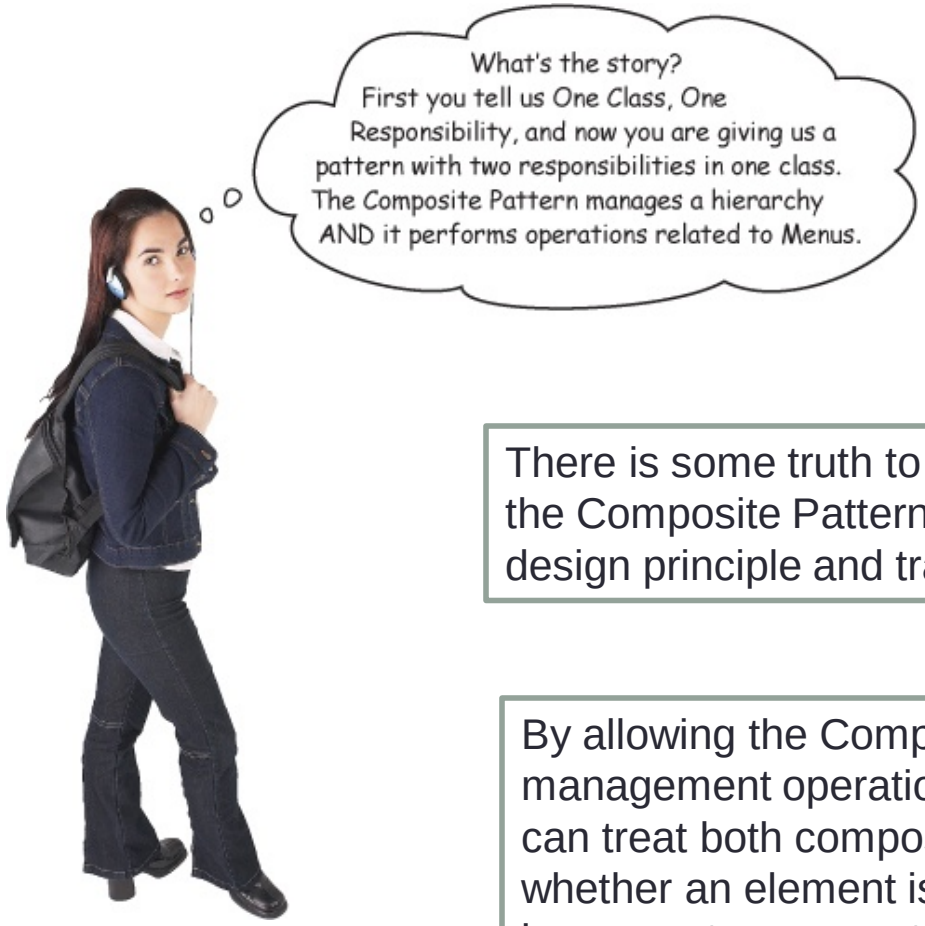
We're using the Composite add() method to add each menu to the top-level menu, allMenus.

Now we need to add all the menu items. Here's one example; for the rest, look at the complete source code.

And we're also adding a menu to a menu. All dinerMenu cares about is that everything it holds, whether it's a menu item or a menu, is a MenuComponent.

Add some apple pie to the dessert menu...

Once we've constructed our entire menu hierarchy, we hand the whole thing to the Waitress, and as you've seen, it's as easy as apple pie for her to print it out.



Observations

There is some truth to that observation. We could say that the Composite Pattern takes the Single Responsibility design principle and trades it for **transparency**.

By allowing the Component interface to contain the child management operations *and* the leaf operations, a client can treat both composites and leaf nodes uniformly; so whether an element is a composite or leaf node becomes transparent to the client.

Flashback to Iterator

What if our Waitress wants to go through the entire menu and pull out vegetarian items?

MenuComponent

- getName()
- getDescription()
- getPrice()
- isVegetarian()
- print()
- add(Component)
- remove(Component)
- getChild(int)
- *createIterator()*

We've added a createIterator() method to the MenuComponent. This means that each Menu and MenuItem will need to implement this method. It also means that calling createIterator() on a composite should apply to all children of the composite.

```
public class Menu extends MenuComponent {
    Iterator<MenuComponent> iterator = null;
    // other code here doesn't change

    public Iterator<MenuComponent> createIterator() {
        if (iterator == null) {
            iterator = new CompositeIterator(menuComponents.iterator());
        }
        return iterator;
    }
}
public class MenuItem extends MenuComponent {
    // other code here doesn't change

    public Iterator<MenuComponent> createIterator() {
        return new NullIterator();
    }
}
```

Here we're using a new iterator called CompositeIterator. It knows how to iterate over any composite. We pass it the current composite's iterator.

Now for the MenuItem...

Whoa! What's this NullIterator? You'll see in two pages.

The Composite Iterator

```
import java.util.*;

public class CompositeIterator implements Iterator {
    Stack<Iterator<MenuComponent>> stack = new Stack<Iterator<MenuComponent>>();

    public CompositeIterator(Iterator iterator) {
        stack.push(iterator);
    }

    public Object next() {
        if (hasNext()) {
            Iterator<MenuComponent> iterator = stack.peek();
            MenuComponent component = iterator.next();

            stack.push(component.createIterator());

            return component;
        } else {
            return null;
        }
    }

    public boolean hasNext() {
        if (stack.empty()) {
            return false;
        } else {
            Iterator<MenuComponent> iterator = stack.peek();
            if (!iterator.hasNext()) {
                stack.pop();
                return hasNext();
            } else {
                return true;
            }
        }
    }
}
```

Like all iterators, we're implementing the java.util.Iterator interface.

The iterator of the top-level composite we're going to iterate over is passed in. We throw that in a stack data structure.

Okay, when the client wants to get the next element we first make sure there is one by calling hasNext()...

If there is a next element, we get the current iterator off the stack and get its next element.

We then throw that component's iterator on the stack. If the component is a Menu, it will iterate over all its items. If the component is a MenuItem, we get the NullIterator, and no iteration happens. Then we return the component.

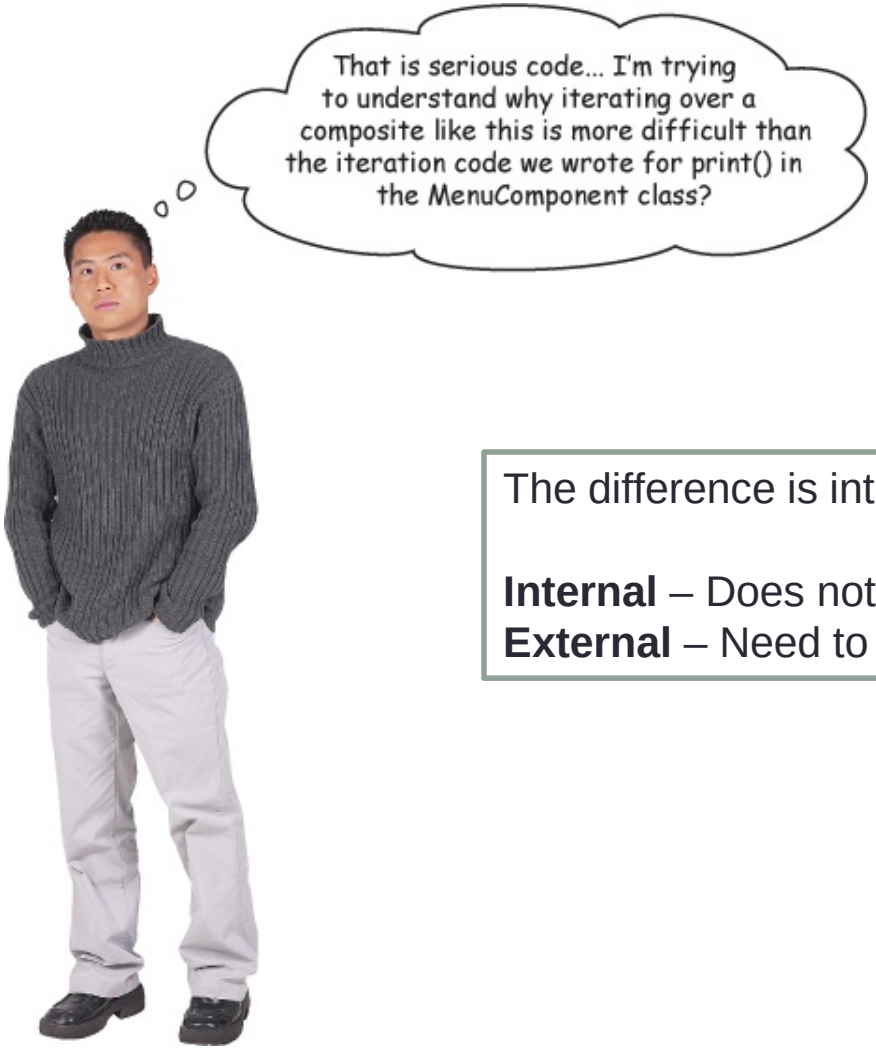
To see if there is a next element, we check to see if the stack is empty; if so, there isn't.

Otherwise, we get the iterator off the top of the stack and see if it has a next element. If it doesn't we pop it off the stack and call hasNext() recursively.

Otherwise there is a next element and we return true.

We're not supporting remove, so we don't implement it and leave it up to the default behavior in java.util.Iterator.

That is serious code …



The difference is internal vs external iterator!

Internal – Does not need to keep track of tree depth
External – Need to keep track of tree depth using Stack

The Null Iterator

```
import java.util.Iterator;

public class NullIterator implements <MenuComponent> {

    public Object next() {
        return null;
    }

    public boolean hasNext() {
        return false;
    }

    public void remove() {
        throw new UnsupportedOperationException();
    }
}
```

This is the laziest Iterator you've ever seen. At every step of the way it punts.

When next() is called, we return null.

Most importantly when hasNext() is called we always return false.

And the NullIterator wouldn't think of supporting remove. We don't need to implement this; we could leave it off and let the default java.util.Iterator remove handle it.

Give me the vegetarian menu

```
public class Waitress {
    MenuComponent allMenus;

    public Waitress(MenuComponent allMenus) {
        this.allMenus = allMenus;
    }

    public void printMenu() {
        allMenus.print();
    }

    public void printVegetarianMenu() {
        Iterator<MenuComponent> iterator = allMenus.createIterator();

        System.out.println("\nVEGETARIAN MENU\n----");
        while (iterator.hasNext()) {
            MenuComponent menuComponent = iterator.next();
            try {
                if (menuComponent.isVegetarian()) {
                    menuComponent.print();
                }
            } catch (UnsupportedOperationException e) {}
        }
    }
}
```

The printVegetarianMenu() method takes the allMenu's composite and gets its iterator. That will be our CompositeIterator.

Iterate through every element of the composite.

Call each element's isVegetarian() method and if true, we call its print() method.

print() is only called on MenuItems, never composites. Can you see why?

We implemented isVegetarian() on the Menus to always throw an exception. If that happens we catch the exception, but continue with our iteration.

Recap

We should strive to assign only **one responsibility** to each class.

The Composite Pattern allows clients to **treat** composites and individual objects **uniformly**.

There are many design tradeoffs in implementing Composite. You need to **balance transparency and safety** with your needs.