Inheritance

Lecture Task

- Point of Sale: Lecture Task 3 -

Functionality: Add the following to the store.model.items package.

An **abstract** class named Modifier with no constructor parameters and:

- A method named “updatePrice” that takes a price as a Double and returns a new price as a Double that is the input price with this modifier applied
- A method named “computeTax” that takes a price as a Double and returns a the tax to be charged on that price, according to this modifier, as a Double

Modify the Sale class by having it **inherit** the Modifier abstract class

- Make any necessary changes to the Sale class without changing its functionality
- The tax returned by a sale should be 0.0

A class named SalesTax that **inherits** the Modifier abstract class with:

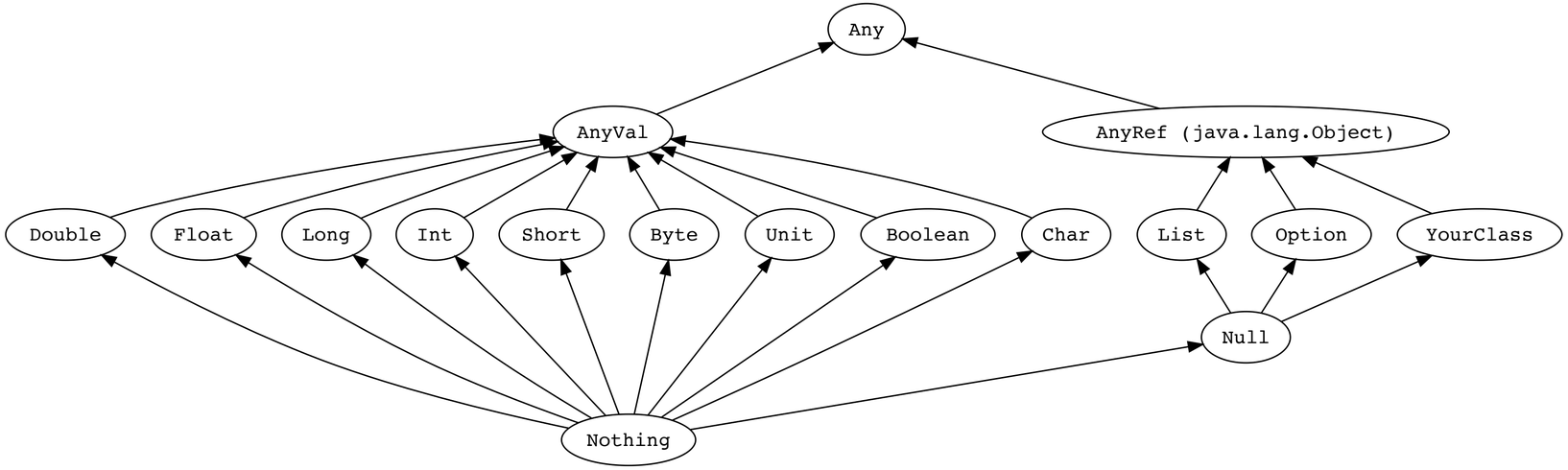
- A constructor that takes a Double representing the percentage of the sales tax
- Implement the updatePrice method to return the price unmodified (Tax does not change the price of an item)
- Implement the computeTax method to return the amount of sales tax that should be charged based on the price of the item
    - This price will be the final price of the item after all sales

A class named BottleDeposit that **inherits** the Modifier abstract class with:

- A constructor that takes a Double representing the total amount of the deposit to be charged
- Implement updatePrice to return the price unmodified
- Implement the computeTax method to return the deposit amount from the constructor
    - The amount of the deposit does not depend on the price of the item

Testing: In the tests package, create a test suite named LectureTask3 that tests this functionality.

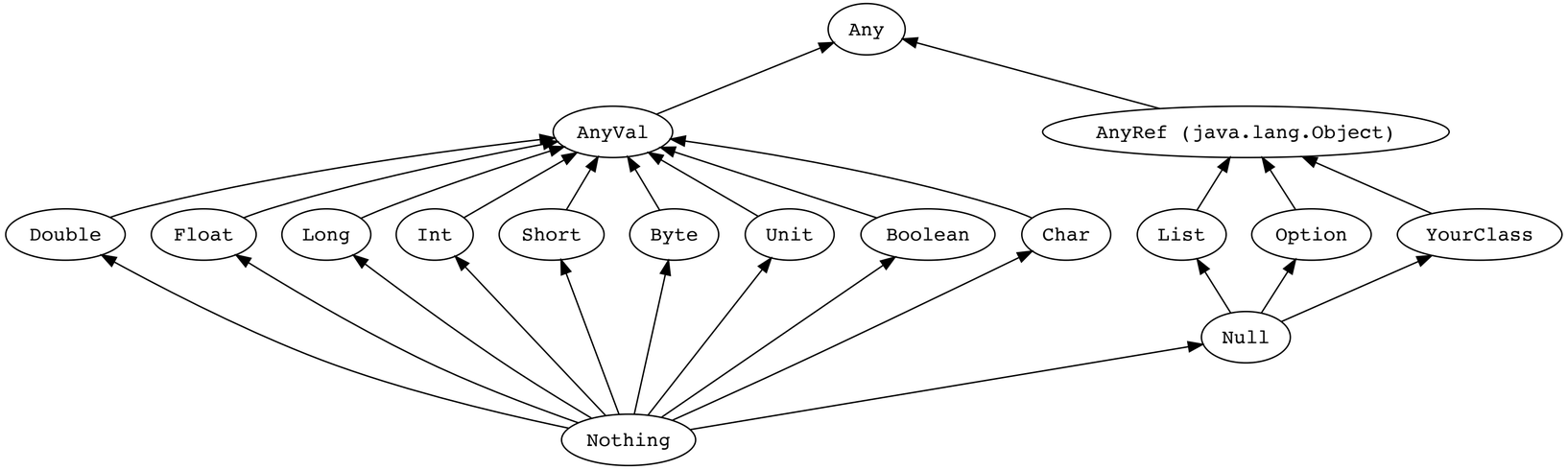
Scala Type Hierarchy



- All objects share Any as their base types
- Classes extending **AnyVal** will be stored on the **stack**
- Classes extending **AnyRef** will be stored on the **heap**

https://docs.scala-lang.org/tour/unified-types.html

Scala Type Hierarchy



- But what does it mean for a class to **extend** another class?
- This is **inheritance**

- Let's explore this concept through an example

https://docs.scala-lang.org/tour/unified-types.html

Overview

- Let's do some world building

- If we're making a game, we'll want various objects that will interact with each other
- We'll setup a simple game where
  - Players can move in a 2d top-down space
  - Each player has a set health and strength
  - Players can pick up and throw DodgeBalls
  - If a player gets hit with a DodgeBall, they lose health
  - Players can collect health potions to regain health
- Note: We might not build this full game, but we will build some of the game mechanics

Objects Review

- We'll need different objects for this game
  - Player
  - DodgeBall
  - HealthPotion

Objects Review

Player		
State	location: PhysicsVector	(2.0, -2.0)
	orientation: PhysicsVector	(0.5, -0.5)
	health: Int	17
	maxHealth: Int	20
	strength: Int	25
Behavior	useDodgeBall(DodgeBall: DodgeBall): Unit	
	useHealthPotion(potion: HealthPotion): Unit	

```
object Player {
  var location: PhysicsVector = new PhysicsVector(2.0, -2.0)
  var orientation: PhysicsVector = new PhysicsVector(0.5, -0.5)

  var health: Int = 17
  val maxHealth: Int = 20

  val strength: Int = 25


  def useDodgeBall(dodgeBall: DodgeBall): Unit = {
    dodgeBall.use(this)
  }

  def useHealthPotion(potion: HealthPotion): Unit = {
    potion.use(this)
  }
}
```

Objects Review

DodgeBall		
State	location: PhysicsVector	(1.0, 5.0)
	velocity: PhysicsVector	(0.0, 0.0)
	mass: Double	5.0
Behavior	used(player: Player): Unit	

```
object DodgeBall {
  var location: PhysicsVector = new PhysicsVector(1.0, 5.0)
  var velocity: PhysicsVector = new PhysicsVector(0.0, 0.0)
  val mass: Double = 5.0

  def use(player: Player): Unit = {
    this.velocity = new PhysicsVector(
      player.orientation.x * player.strength,
      player.orientation.y * player.strength
    )
  }
}
```

Objects Review

HealthPotion		
State	location: PhysicsVector	(5.0, 7.0)
	volume: Int	3
Behavior	use(player: Player): Unit	

```
object HealthPotion {
  var location: PhysicsVector = new PhysicsVector(5.0, 7.0)
  val volume: Int = 3

  def use(player: Player): Unit = {
    player.health = (player.health + this.volume).min(player.maxHealth)
  }
}
```

Objects Review

- But this is restrictive
- Game can only have one DodgeBall, one HealthPotion, and on Player
- Can play, but not very fun

Player		
State	location: PhysicsVector	(2.0, -2.0)
	orientation: PhysicsVector	(0.5, -0.5)
	health: Int	17
	maxHealth: Int	20
	strength: Int	25
Behavior	useBall(ball: Ball): Unit	
	useHealthPotion(potion: HealthPotion): Unit	

DodgeBall		
State	location: PhysicsVector	(1.0, 5.0)
	velocity: PhysicsVector	(1.0, 1.0)
	mass: Double	5.0
Behavior	used(player: Player): Unit	

HealthPotion		
State	location: PhysicsVector	(5.0, 7.0)
	volume: Int	3
Behavior	use(player: Player): Unit	

Classes Review

- **This is why we use classes**
- Classes let us create multiple objects of type DodgeBall, HealthPotion, and Player

Player	
State	location: PhysicsVector
	orientation: PhysicsVector
	health: Int
	maxHealth: Int
	strength: Int
Behavior	useDodgeBall(DodgeBall: DodgeBall): Unit
	useHealthPotion(potion: HealthPotion): Unit

DodgeBall	
State	location: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Classes Review

Player	
State	location: PhysicsVector
	orientation: PhysicsVector
	health: Int
	maxHealth: Int
	strength: Int
Behavior	useDodgeBall(DodgeBall: DodgeBall): Unit
	useHealthPotion(potion: HealthPotion): Unit

```
class Player(var location: PhysicsVector,
             var orientation: PhysicsVector,
             val maxHealth: Int,
             val strength: Int) {

  var health: Int = maxHealth

  def useDodgeBall(DodgeBall: DodgeBall): Unit = {
    DodgeBall.use(this)
  }

  def useHealthPotion(potion: HealthPotion): Unit = {
    potion.use(this)
  }
}
```

Classes Review

DodgeBall	
State	location: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

```
class DodgeBall(var location: PhysicsVector,
                var velocity: PhysicsVector,
                val mass: Double) {

  def use(player: Player): Unit = {
    this.velocity = new PhysicsVector(
      player.orientation.x * player.strength,
      player.orientation.y * player.strength
    )
  }

}
```

Classes Review

HealthPotion	
State	location: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

```
class HealthPotion(var location: PhysicsVector,
                   val volume: Int) {

  def use(player: Player): Unit = {
    player.health = (player.health + this.volume).min(player.maxHealth)
  }

}
```

Classes Review

- Use the class to create multiple objects with different states

DodgeBall	
State	location: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

```
var DodgeBall1: DodgeBall = new DodgeBall(
  new PhysicsVector(1.0, 5.0),
  new PhysicsVector(1.0, 1.0),
  5.0
)
// DodgeBall1 stores the reference @54224
```

DodgeBall@54224		
State	location: PhysicsVector	(1.0, 5.0)
	velocity: PhysicsVector	(1.0, 1.0)
	mass: Double	5.0
Behavior	use(player: Player): Unit	

```
var DodgeBall2: DodgeBall = new DodgeBall(
  new PhysicsVector(6.0, -3.0),
  new PhysicsVector(0.0, 4.5),
  10.0
)
// DodgeBall2 stores the reference @21374
```

DodgeBall@21374		
State	location: PhysicsVector	(6.0, -3.0)
	velocity: PhysicsVector	(0.0, 4.5)
	mass: Double	10.0
Behavior	use(player: Player): Unit	

Inheritance

Inheritance

- Use inheritance to create classes with similar state and behavior
- Observe: DodgeBall and HealthPotion have a lot in common

DodgeBall	
State	location: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Inheritance

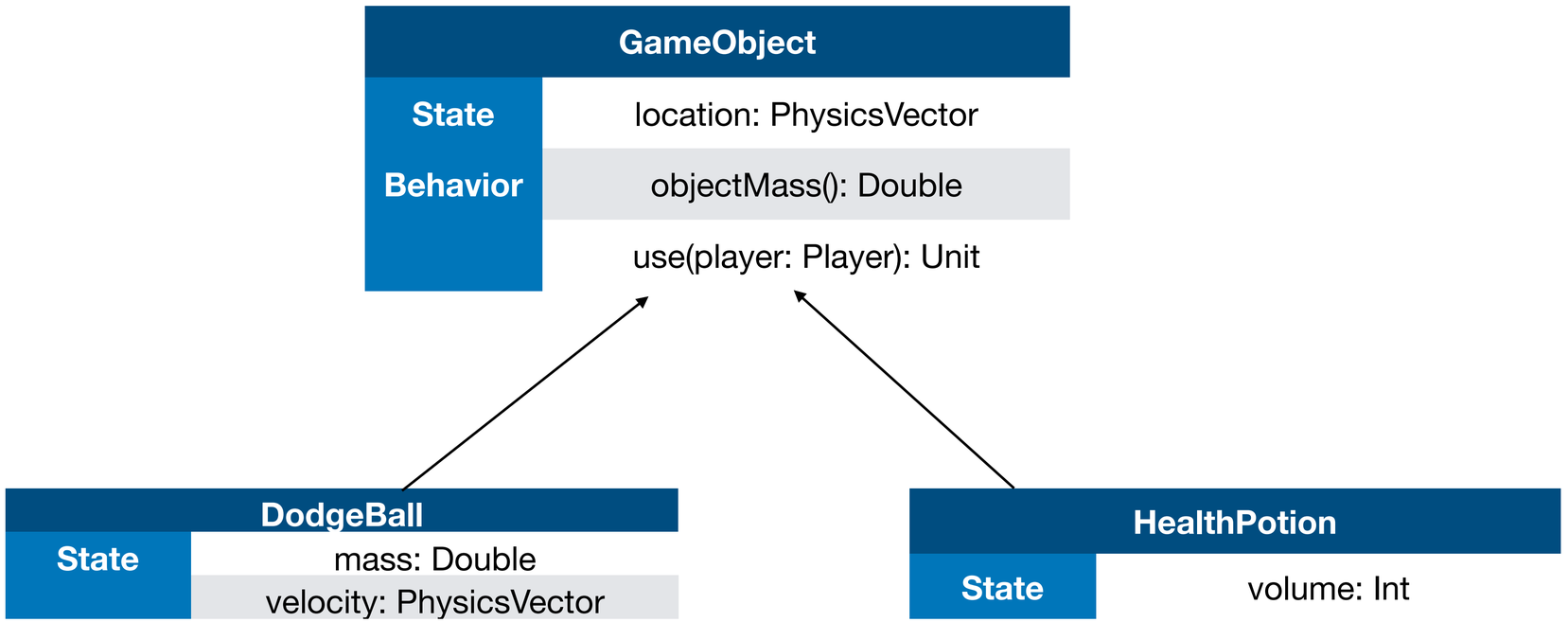
- Can add much more common functionality (that doesn't fit on a slide)
  - Compute mass of a potion based on volume
  - Compute momentum of both types based on mass * velocity
  - Method defining behavior when either hits the ground (bounce or shatter)

DodgeBall	
State	location: PhysicsVector
	velocity: PhysicsVector
	mass: Double
Behavior	use(player: Player): Unit

HealthPotion	
State	location: PhysicsVector
	volume: Int
Behavior	use(player: Player): Unit

Inheritance

- Factor out common state and behavior into a new class
- DodgeBall and HealthPotion classes **inherent** the state and behavior of GameObject
- DodgeBall and HealthPotion add their specific state and behavior



Inheritance

- New class defines what every inheriting class must define
- Any behavior that is to be defined by inheriting classes is declared **abstract**
  - We call this an abstract class
  - Cannot create objects of abstract types
- Inheriting classes will define all abstract behavior
  - We call these concrete classes

```
abstract class GameObject(var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

Inheritance

- Abstract methods have no definitions
  - No body
- These methods must be defined by the inheriting classes

```
abstract class GameObject(var location: PhysicsVector) {
  def objectMass(): Double
  def use(player: Player): Unit
}
```

Inheritance

- Use the extends keyword to inherent another class
  - Extend the definition of GameObject
  - DodgeBall "inherits" all of the state and behavior from GameObject

```
abstract class GameObject(
         var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class DodgeBall(location: PhysicsVector,
           velocity: PhysicsVector,
           mass: Double)
  extends GameObject(location) {

  override def objectMass(): Double = {
    this.mass
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
  }

}
```

Inheritance

- DodgeBall has its own constructor
- DodgeBall must call GameObject's constructor
- var/val declared in concrete class to make these public
- If reusing variable names, only one can be declared with val/var (ie. Cannot have both locations as vars)

```
abstract class GameObject(
          var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class DodgeBall(location: PhysicsVector,
            var velocity: PhysicsVector,
            mass: Double)
  extends GameObject(location) {

  override def objectMass(): Double = {
    this.mass
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
 }

}
```

Inheritance

- Implement all abstract behavior
- Use the **override** keyword when overwriting behavior from the superclass
- Override all abstract methods with behavior for this class

```
abstract class GameObject(
         var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class DodgeBall(location: PhysicsVector,
           var velocity: PhysicsVector,
           mass: Double)
  extends GameObject(location) {

  override def objectMass(): Double = {
    this.mass
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
 }

}
```

Inheritance

- Define different behavior for each base class
- Define similar types with some differences

```
class HealthPotion(location: PhysicsVector,
                   val volume: Int)
  extends GameObject(location) {


  override def objectMass(): Double = {
    val massPerVolume: Double = 7.0
    this.volume * massPerVolume
  }

  override def use(player: Player): Unit = {
    player.health = (player.health +
                this.volume).min(player.maxHealth)
  }

}
```

```
abstract class GameObject(
         var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class DodgeBall(location: PhysicsVector,
           var velocity: PhysicsVector,
           mass: Double)
  extends GameObject(location, dimensions, velocity) {

  override def objectMass(): Double = {
    this.mass
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
 }

}
```

Inheritance

- Example: Calling objectMass() will have different behaviour depending on the type of the object

```
class HealthPotion(location: PhysicsVector,
                   val volume: Int)
  extends GameObject(location) {


  override def objectMass(): Double = {
    val massPerVolume: Double = 7.0
    this.volume * massPerVolume
  }

  override def use(player: Player): Unit = {
    player.health = (player.health +
                this.volume).min(player.maxHealth)
  }

}
```

```
abstract class GameObject(
         var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class DodgeBall(location: PhysicsVector,
           var velocity: PhysicsVector,
           mass: Double)
  extends GameObject(location, dimensions, velocity) {

  override def objectMass(): Double = {
    this.mass
  }

  override def use(player: Player): Unit = {
    this.velocity.x = player.orientation.x * player.strength
    this.velocity.y = player.orientation.y * player.strength
 }

}
```

Inheritance

- OK, BUT Y THO?
- Add behavior to GameObject
- Behavior is added to ALL inheriting classes

```
abstract class GameObject(var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

  def closeToPlayer(player: Player): Boolean = {
    val distanceToPlayer = Math.sqrt(
      Math.pow(this.location.x - player.location.x, 2.0) +
        Math.pow(this.location.y - player.location.y, 2.0)
    )
    val threshold: Double = 0.5
    distanceToPlayer < threshold
  }

}
```

Inheritance

- We may want many, many more subtypes of GameObjects in our game
- Any common functionality added to GameObject
  - Easy to add functionality to ALL subtypes will very little effort

```
abstract class GameObject(var location: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

  def closeToPlayer(player: Player): Boolean = {
    val distanceToPlayer = Math.sqrt(
      Math.pow(this.location.x - player.location.x, 2.0) +
        Math.pow(this.location.y - player.location.y, 2.0)
    )
    val threshold: Double = 0.5
    distanceToPlayer < threshold
  }

}
```

Inheritance

- **But wait!**
  - **There's more**

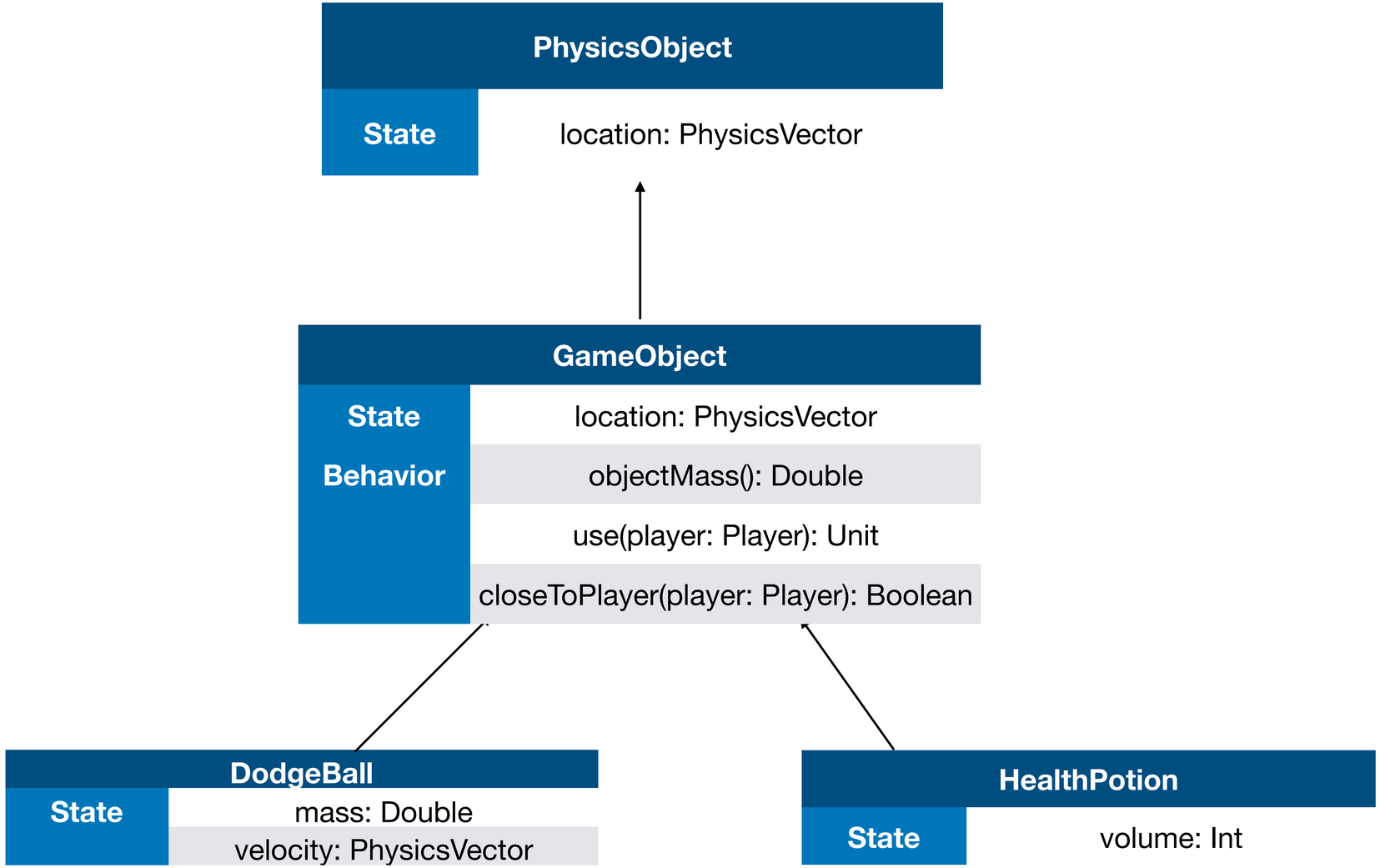
```
abstract class GameObject(location: PhysicsVector) extends PhysicsObject(location) {

  def objectMass(): Double

  def use(player: Player): Unit

  def closeToPlayer(player: Player): Boolean = {
    val distanceToPlayer = Math.sqrt(
      Math.pow(this.location.x - player.location.x, 2.0) +
        Math.pow(this.location.y - player.location.y, 2.0)
    )
    val threshold: Double = 0.5
    distanceToPlayer < threshold
  }

}
```

Inheritance

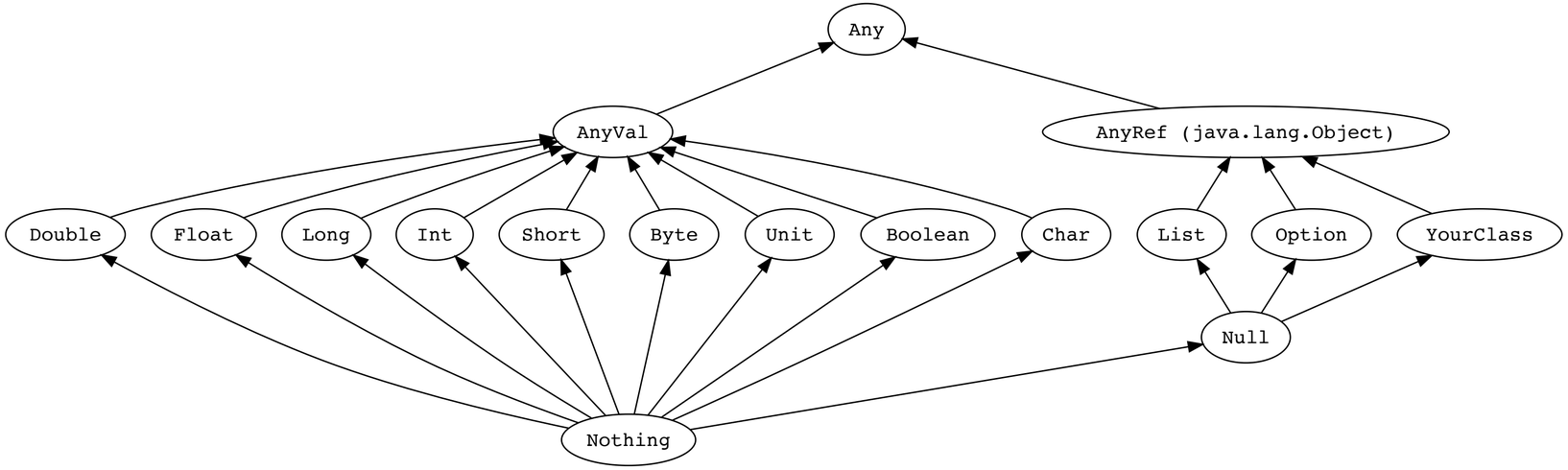
- Suppose we have a physics engine that apply physics to objects of type PhysicsObject
- We want to use this physics engine to control the movement of DodgeBalls and HealthPotions
- Solution: Have GameObject extend PhysicsObject!

```
abstract class GameObject(location: PhysicsVector) extends PhysicsObject(location) {

  def objectMass(): Double

  def use(player: Player): Unit

  def closeToPlayer(player: Player): Boolean = {
    val distanceToPlayer = Math.sqrt(
      Math.pow(this.location.x - player.location.x, 2.0) +
        Math.pow(this.location.y - player.location.y, 2.0)
    )
    val threshold: Double = 0.5
    distanceToPlayer < threshold
  }

}
```

Inheritance



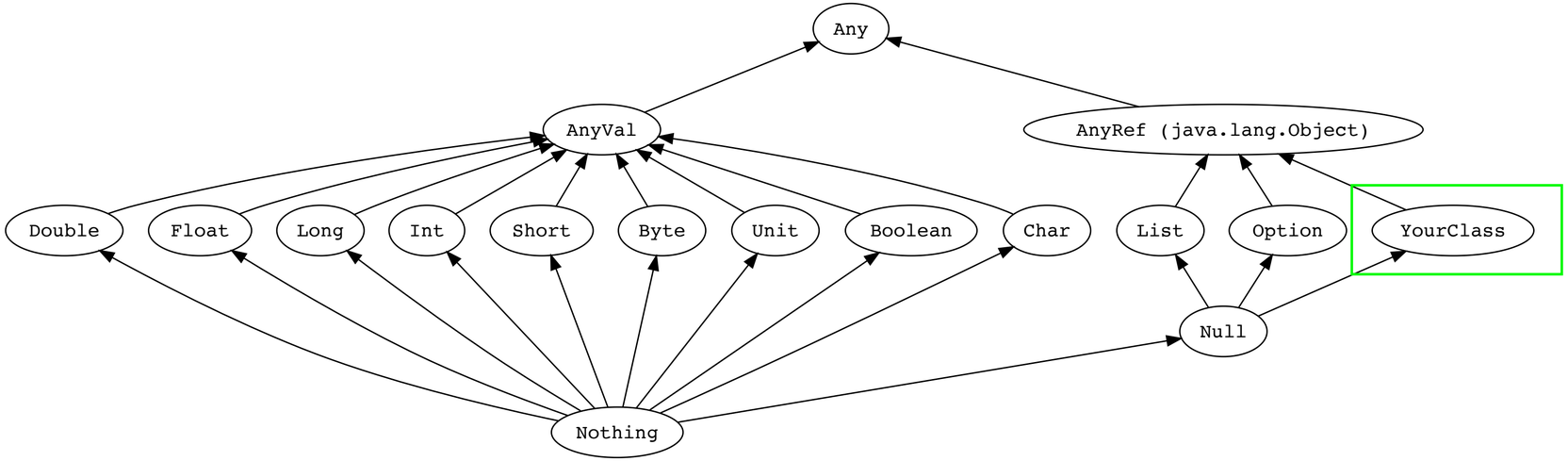
Scala Type Hierarchy



- All objects share Any as their base types
- Classes extending **AnyVal** will be stored on the **stack**
- Classes extending **AnyRef** will be stored on the **heap**

https://docs.scala-lang.org/tour/unified-types.html

Scala Type Hierarchy



- Classes you define extend AnyRef by default
- HealthPotion has 5 different types

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0.0, 0.0), 6)
val potion2: GameObject = new HealthPotion(new PhysicsVector(0.0, 0.0), 6)
val potion3: PhysicsObject = new HealthPotion(new PhysicsVector(0.0, 0.0), 6)
val potion4: AnyRef = new HealthPotion(new PhysicsVector(0.0, 0.0), 6)
val potion5: Any = new HealthPotion(new PhysicsVector(0.0, 0.0), 6)
```

https://docs.scala-lang.org/tour/unified-types.html

Lecture Task

- Point of Sale: Lecture Task 3 -

Functionality: Add the following to the store.model.items package.

An **abstract** class named Modifier with no constructor parameters and:

- A method named “updatePrice” that takes a price as a Double and returns a new price as a Double that is the input price with this modifier applied
- A method named “computeTax” that takes a price as a Double and returns a the tax to be charged on that price, according to this modifier, as a Double

Modify the Sale class by having it **inherit** the Modifier abstract class

- Make any necessary changes to the Sale class without changing its functionality
- The tax returned by a sale should be 0.0

A class named SalesTax that **inherits** the Modifier abstract class with:

- A constructor that takes a Double representing the percentage of the sales tax
- Implement the updatePrice method to return the price unmodified (Tax does not change the price of an item)
- Implement the computeTax method to return the amount of sales tax that should be charged based on the price of the item
    - This price will be the final price of the item after all sales

A class named BottleDeposit that **inherits** the Modifier abstract class with:

- A constructor that takes a Double representing the total amount of the deposit to be charged
- Implement updatePrice to return the price unmodified
- Implement the computeTax method to return the deposit amount from the constructor
    - The amount of the deposit does not depend on the price of the item

Testing: In the tests package, create a test suite named LectureTask3 that tests this functionality.

Lecture Question

Your Sale, SalesTax, and BottleDeposit classes must inherit Modifier. This will be checked by storing objects of these types in variables of type Modifier

```
val sale: Modifier = new Sale(20.0)
val salesTax: Modifier = new SalesTax(8.75)
val deposit: Modifier = new BottleDeposit(0.05)
```

You can test the functionality of your classes by calling updatePrice and computeTax on these objects with different inputs and checking the outputs