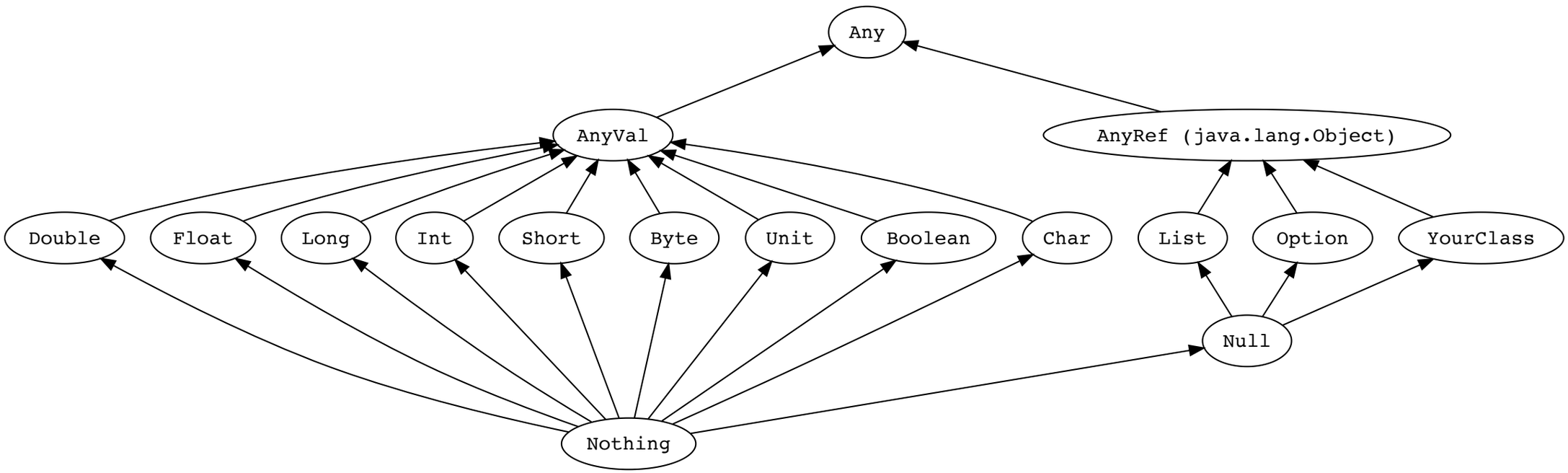
# Inheritance

# Lecture Question

**Question**: in a package named "oop.electronics", implement the following. This functionality is similar to the last lecture question

- class Battery with
    - A constructor that takes a variable named "charge" of type Int
- abstract class Electronic with
    - A constructor that takes no parameters
    - A state variable named "battery" of type Battery
    - A method named "use" that takes no parameters and returns Unit (This can be abstract)
    - A method named "replaceBattery" that takes a Battery as a parameter and returns a Battery
        - This method swaps the input Battery with the Battery currently stored in this Electronic's state variable
        - The returned Battery is the one that was in the state variable when the method is called
- class Flashlight that extends Electronic
    - A constructor that takes no parameters
        - When a new Flashlight is created, assign the inherited state variable named "battery" to a new Battery with 5 charge (ie. Batteries included)
    - Override the "use" method to reduce the charge of the battery in the state variable by 1 if its charge is 1 or greater
- class BoomBox that extends Electronic
    - A constructor that takes a variable of type Battery and assigns it to the inherited state variable named "battery"
        - Your BoomBox constructor parameter should have a different name than the state variable
    - Override the "use" method to reduce the charge of the battery in the state variable by 3 if its charge is 3 or greater

# 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**

# 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
    - Each player has a set health and strength
    - Players can pick up and throw balls
    - If a player gets hit with a ball, 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
  - Ball
  - HealthPotion

# Objects Review

| Player | | |
|---|---|---|
| State | location: PhysicsVector | (2.0, -2.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 2.0) |
| | velocity: PhysicsVector | (0.0, -1.0, 0.0) |
| | orientation: PhysicsVector | (0.5, -0.5, 0.0) |
| | health: Int | 17 |
| | maxHealth: Int | 20 |
| | strength: Int | 25 |
| Behavior | useBall(ball: Ball): Unit | |
| | useHealthPotion(potion: HealthPotion): Unit | |

```
object Player {
  var location: PhysicsVector = new PhysicsVector(2.0, -2.0, 2.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 2.0)
  var velocity: PhysicsVector = new PhysicsVector(0.0, -1.0, 0.0)
  var orientation: PhysicsVector = new PhysicsVector(0.5, -0.5, 0.0)

  val maxHealth: Int = 20
  val strength: Int = 25

  var health: Int = 17

  def useBall(ball: Ball): Unit = {
    ball.use(this)
  }

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

# Objects Review

| Ball | | |
|---|---|---|
| State | location: PhysicsVector | (1.0, 5.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (1.0, 1.0, 10.0) |
| | mass: Double | 5.0 |
| Behavior | used(player: Player): Unit | |

```
object Ball {
  var location: PhysicsVector = new PhysicsVector(1.0, 5.0, 2.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 1.0)
  var velocity: PhysicsVector = new PhysicsVector(1.0, 1.0, 10.0)
  val mass: Double = 5.0

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

# Objects Review

| HealthPotion | | |
|---|---|---|
| State | location: PhysicsVector | (5.0, 7.0, 0.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (0.0, 0.0, 0.0) |
| | volume: Int | 3 |
| Behavior | use(player: Player): Unit | |

```
object HealthPotion {
  var location: PhysicsVector = new PhysicsVector(5.0, 7.0, 0.0)
  var dimensions: PhysicsVector = new PhysicsVector(1.0, 1.0, 1.0)
  var velocity: PhysicsVector = new PhysicsVector(0.0, 0.0, 0.0)
  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 Ball, one HealthPotion, and on Player
- Can play, but not very fun

| Player | | |
|---|---|---|
| State | location: PhysicsVector | (2.0, -2.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 2.0) |
| | velocity: PhysicsVector | (0.0, -1.0, 0.0) |
| | orientation: PhysicsVector | (0.5, -0.5, 0.0) |
| | health: Int | 17 |
| | maxHealth: Int | 20 |
| | strength: Int | 25 |
| Behavior | useBall(ball: Ball): Unit | |
| | useHealthPotion(potion: HealthPotion): Unit | |

| Ball | | |
|---|---|---|
| State | location: PhysicsVector | (1.0, 5.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (1.0, 1.0, 10.0) |
| | mass: Double | 5.0 |
| Behavior | used(player: Player): Unit | |

| HealthPotion | | |
|---|---|---|
| State | location: PhysicsVector | (5.0, 7.0, 0.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (0.0, 0.0, 0.0) |
| | volume: Int | 3 |
| Behavior | use(player: Player): Unit | |

# Classes Review

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

| Player | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | orientation: PhysicsVector |
| | health: Int |
| | maxHealth: Int |
| | strength: Int |
| **Behavior** | useBall(ball: Ball): Unit |
| | useHealthPotion(potion: HealthPotion): Unit |

| Ball | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | mass: Double |
| **Behavior** | use(player: Player): Unit |

| HealthPotion | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | volume: Int |
| **Behavior** | use(player: Player): Unit |

# Classes Review

| Player | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | orientation: PhysicsVector |
| | health: Int |
| | maxHealth: Int |
| | strength: Int |
| **Behavior** | useBall(ball: Ball): Unit |
| | useHealthPotion(potion: HealthPotion): Unit |

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

  var health: Int = maxHealth

  def useBall(ball: Ball): Unit = {
    ball.use(this)
  }

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

# Classes Review

| Ball | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | mass: Double |
| **Behavior** | use(player: Player): Unit |

```
class Ball(var location: PhysicsVector,
           var dimensions: 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,
      player.strength
    )
  }

}
```

# Classes Review

| HealthPotion | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | volume: Int |
| **Behavior** | use(player: Player): Unit |

```
class HealthPotion(var location: PhysicsVector,
                   var dimensions: PhysicsVector,
                   var velocity: 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

| Ball | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | mass: Double |
| **Behavior** | use(player: Player): Unit |

```
var ball1: Ball = new Ball(
  new PhysicsVector(1.0, 5.0, 2.0),
  new PhysicsVector(1.0, 1.0, 1.0),
  new PhysicsVector(1.0, 1.0, 10.0),
  5.0
)
// ball1 stores 54224


var ball2: Ball = new Ball(
  new PhysicsVector(6.0, -3.0, 2.0),
  new PhysicsVector(1.0, 1.0, 1.0),
  new PhysicsVector(0.0, 4.5, 4.5),
  10.0
)
// ball2 stores 21374
```

| Ball@54224 | | |
|---|---|---|
| State | location: PhysicsVector | (1.0, 5.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (1.0, 1.0, 10.0) |
| | mass: Double | 5.0 |
| Behavior | use(player: Player): Unit | |

| Ball@21374 | | |
|---|---|---|
| State | location: PhysicsVector | (6.0, -3.0, 2.0) |
| | dimensions: PhysicsVector | (1.0, 1.0, 1.0) |
| | velocity: PhysicsVector | (0.0, 4.5, 4.5) |
| | mass: Double | 10.0 |
| Behavior | use(player: Player): Unit | |

# Inheritance

- Use inheritance to create classes with different behavior
- Observe: Ball and HealthPotion have a lot in common

| Ball | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | mass: Double |
| **Behavior** | use(player: Player): Unit |

| HealthPotion | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | volume: Int |
| **Behavior** | use(player: Player): Unit |

# Inheritance

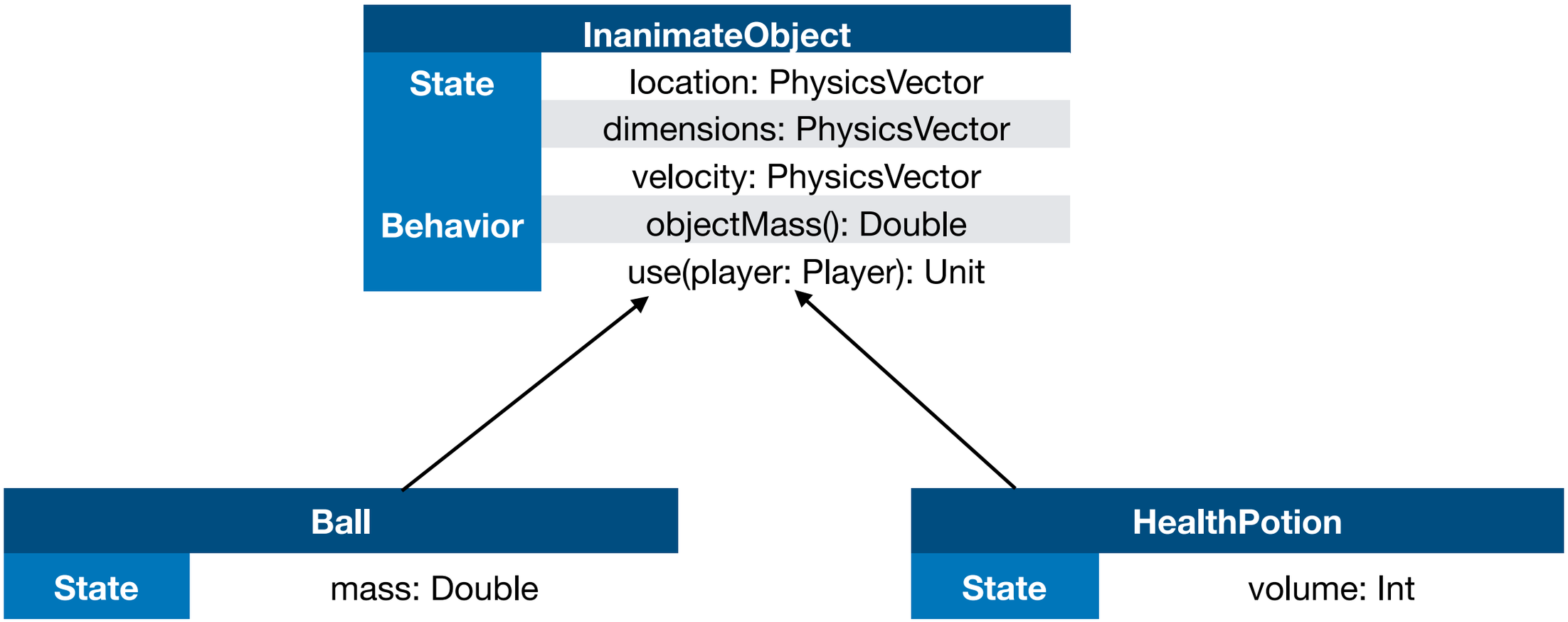
- Can add much more common functionality (that doesn't fit on a slide)
  - Compute mass of a potion based on volume
  - Compute momentum of both types based on mass * velocity
  - Method defining behavior when either hits the ground (bounce or shatter)

| Ball | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | mass: Double |
| **Behavior** | use(player: Player): Unit |

| HealthPotion | |
|---|---|
| **State** | location: PhysicsVector |
| | dimensions: PhysicsVector |
| | velocity: PhysicsVector |
| | volume: Int |
| **Behavior** | use(player: Player): Unit |

# Inheritance

- Factor out common state and behavior into a new class
- Ball and HealthPotion classes **inherent** the state and behavior of InanimateObject
- Ball 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 InanimateObject(var location: PhysicsVector, var dimensions:
PhysicsVector, var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

# Inheritance

- Use the extends keyword to inherent another class
  - Extend the definition of InanimateObject
  - We call InanimateObject the superclass of Ball

```
abstract class InanimateObject(
         var location: PhysicsVector,
         var dimensions: PhysicsVector,
         var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class Ball(location: PhysicsVector,
           dimensions: PhysicsVector,
           velocity: PhysicsVector,
           mass: Double)
  extends InanimateObject(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
    this.velocity.z = player.strength
  }

}
```

# Inheritance

- Ball has it's own constructor
- Ball must call InanimateObject's constructor
- var/val declared in concrete class to make these public

```
abstract class InanimateObject(
          var location: PhysicsVector,
          var dimensions: PhysicsVector,
          var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class Ball(location: PhysicsVector,
           dimensions: PhysicsVector,
           velocity: PhysicsVector,
           mass: Double)
  extends InanimateObject(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
    this.velocity.z = 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 InanimateObject(
         var location: PhysicsVector,
         var dimensions: PhysicsVector,
         var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class Ball(location: PhysicsVector,
           dimensions: PhysicsVector,
           velocity: PhysicsVector,
           mass: Double)
  extends InanimateObject(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
    this.velocity.z = player.strength
  }

}
```

# Inheritance

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

```
abstract class InanimateObject(
          var location: PhysicsVector,
          var dimensions: PhysicsVector,
          var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

}
```

```
class HealthPotion(location: PhysicsVector,
                   dimensions: PhysicsVector,
                   velocity: PhysicsVector,
                   val volume: Int)
  extends InanimateObject(location, dimensions,
velocity) {


  override def objectMass(): Double = {
    val massPerVolume: Double = 7.0
    volume * massPerVolume
  }
  override def use(player: Player): Unit = {
    player.health = (player.health +
                this.volume).min(player.maxHealth)
  }
}
```

```
class Ball(location: PhysicsVector,
           dimensions: PhysicsVector,
           velocity: PhysicsVector,
           mass: Double)
  extends InanimateObject(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
    this.velocity.z = player.strength
  }

}
```

# Inheritance

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

```
abstract class InanimateObject(var location: PhysicsVector, var dimensions: PhysicsVector,
var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Double = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

# Inheritance

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

```
abstract class InanimateObject(var location: PhysicsVector, var dimensions: PhysicsVector,
var velocity: PhysicsVector) {

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Double = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

# Inheritance

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

```
abstract class InanimateObject(location: PhysicsVector, dimensions: PhysicsVector,
inputVelocity: PhysicsVector) extends DynamicObject(location, dimensions) {

  this.velocity = inputVelocity

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Double = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

# Inheritance

- If we want Ball, HealthPotion, and all other InanimateObjects to work with our physics engine
  - Extend DynamicObject!

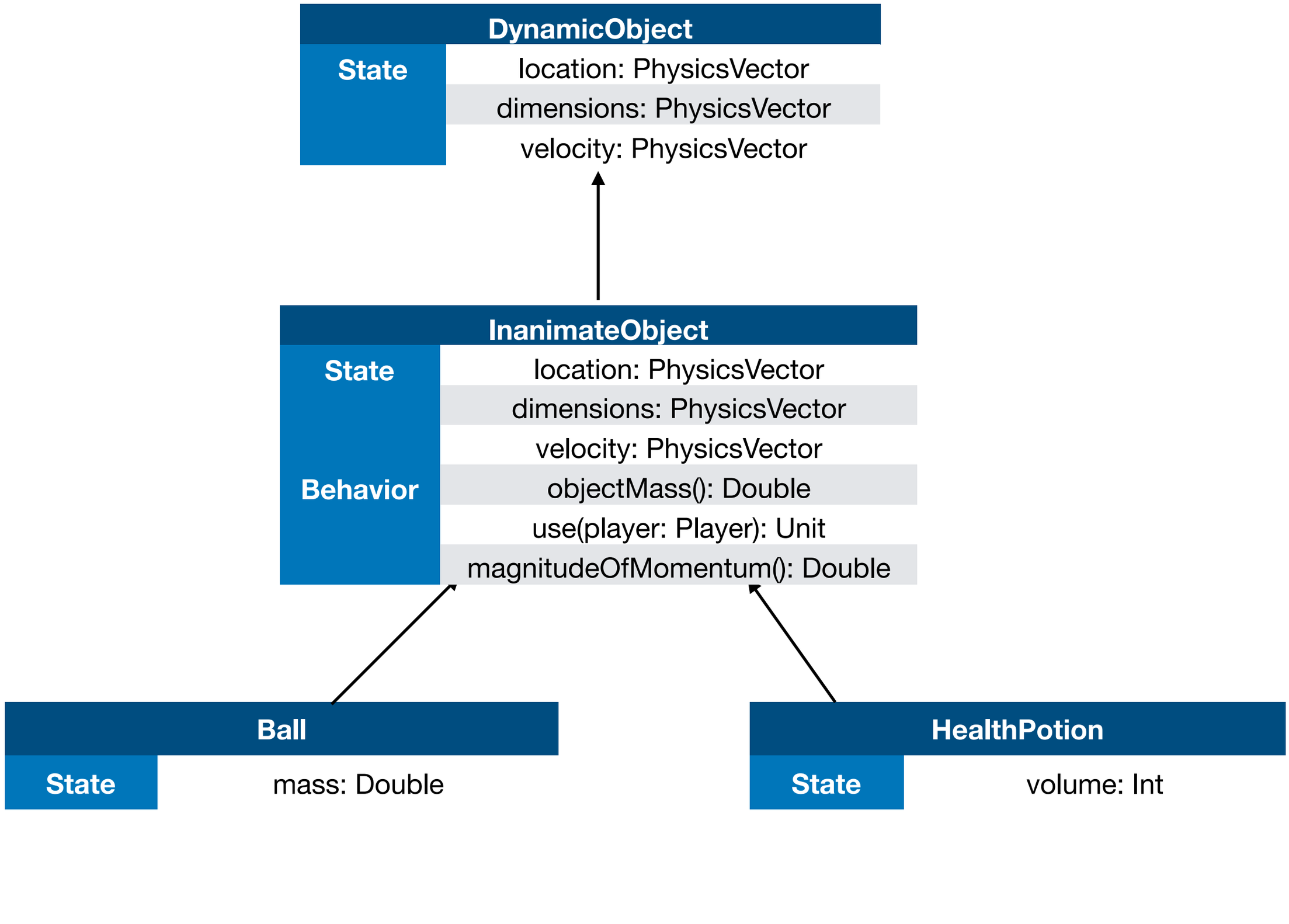
```
abstract class InanimateObject(location: PhysicsVector, dimensions: PhysicsVector,
inputVelocity: PhysicsVector) extends DynamicObject(location, dimensions) {

  this.velocity = inputVelocity

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Double = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

# Inheritance

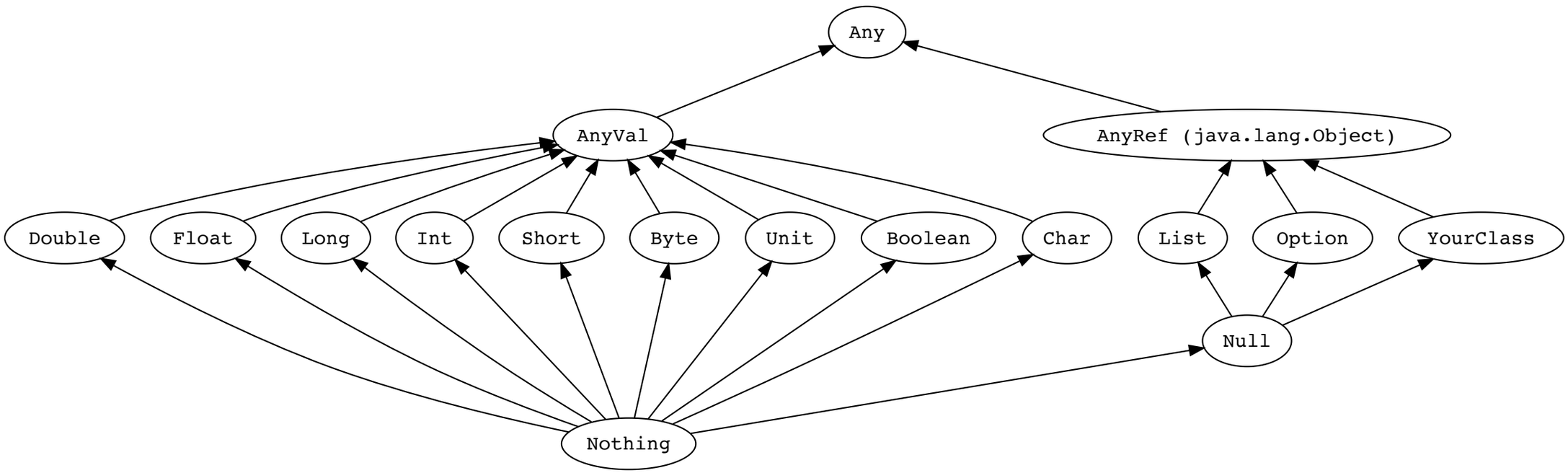
- Note that the velocity is inherited
- The velocity parameter in the constructor must have a different name that the inherited variable
  - Allows us to assign its value to the state variable
  - They would both be referred to with **this** causing a name conflict
- No name conflict with multiple location/dimension since they are only in the header

```
abstract class InanimateObject(location: PhysicsVector, dimensions: PhysicsVector,
inputVelocity: PhysicsVector) extends DynamicObject(location, dimensions) {

  this.velocity = inputVelocity

  def objectMass(): Double

  def use(player: Player): Unit

  def magnitudeOfMomentum(): Double = {
    val magnitudeOfVelocity = Math.sqrt(
      Math.pow(this.velocity.x, 2.0) +
        Math.pow(this.velocity.y, 2.0) +
        Math.pow(this.velocity.z, 2.0)
    )
    magnitudeOfVelocity * this.objectMass()
  }

}
```

# Inheritance



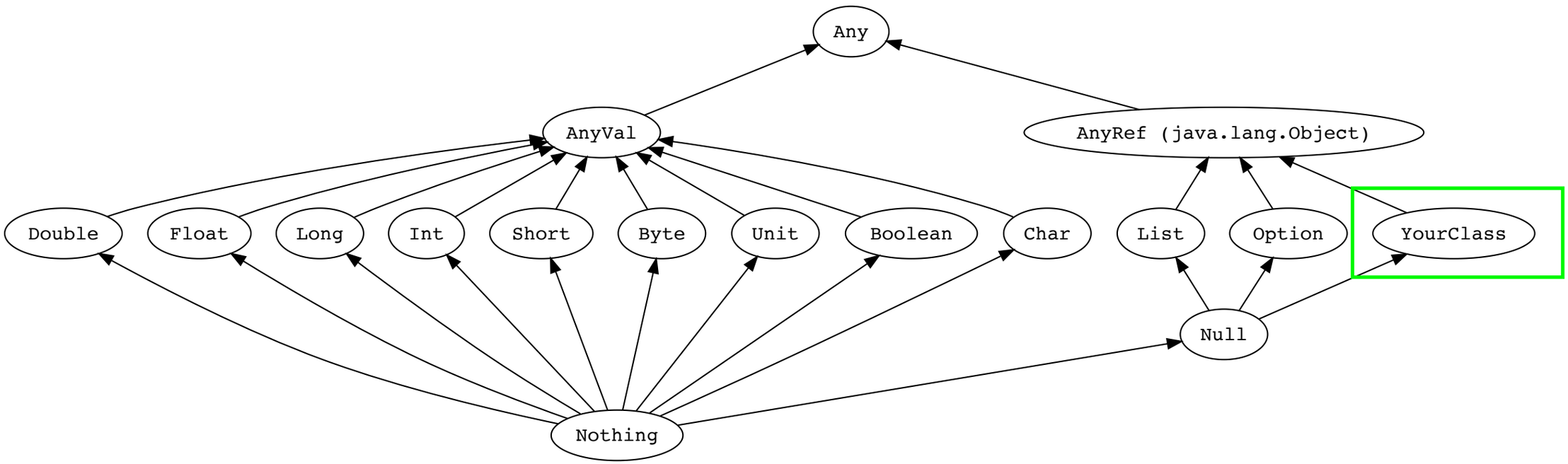
# Scala Type Hierarchy




- 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 6 different types

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion3: DynamicObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion4: GameObject = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion5: AnyRef = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
val potion6: Any = new HealthPotion(new PhysicsVector(), new PhysicsVector(), new PhysicsVector(), 6)
```

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

# Lecture Question

**Question**: in a package named "oop.electronics", implement the following. This functionality is similar to the last lecture question

- class Battery with
    - A constructor that takes a variable named "charge" of type Int
- abstract class Electronic with
    - A constructor that takes no parameters
    - A state variable named "battery" of type Battery
    - A method named "use" that takes no parameters and returns Unit (This can be abstract)
    - A method named "replaceBattery" that takes a Battery as a parameter and returns a Battery
        - This method swaps the input Battery with the Battery currently stored in this Electronic's state variable
        - The returned Battery is the one that was in the state variable when the method is called
- class Flashlight that extends Electronic
    - A constructor that takes no parameters
        - When a new Flashlight is created, assign the inherited state variable named "battery" to a new Battery with 5 charge (ie. Batteries included)
    - Override the "use" method to reduce the charge of the battery in the state variable by 1 if its charge is 1 or greater
- class BoomBox that extends Electronic
    - A constructor that takes a variable of type Battery and assigns it to the inherited state variable named "battery"
        - Your BoomBox constructor parameter should have a different name than the state variable
    - Override the "use" method to reduce the charge of the battery in the state variable by 3 if its charge is 3 or greater

# Lecture Question

The code is in a different package so it doesn't interfere with your code from the previous question. Be sure you check that this import works from a different package in your project

```
import oop.electronics.{Battery, BoomBox, Flashlight, Electronic}
```

Your Flashlight and BoomBox classes must inherit Electronic. This will be checked by storing them in variables of type Electronic

```
val flashlight1: Electronic = new Flashlight()
val boomBox1: Electronic = new BoomBox(new Battery(10))
```