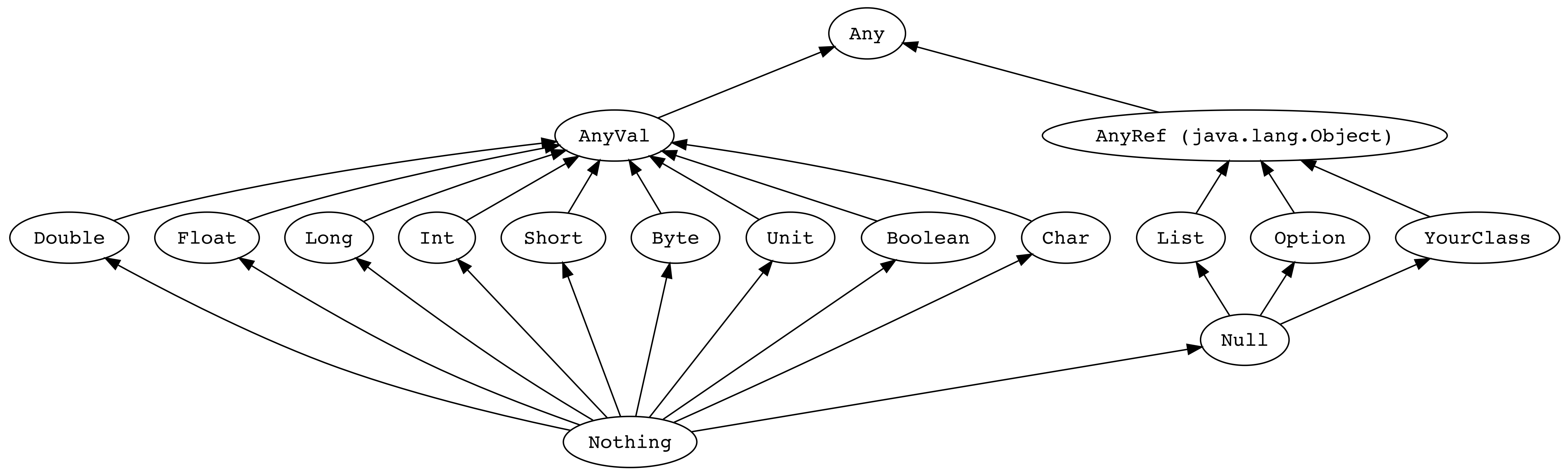
Polymorphism

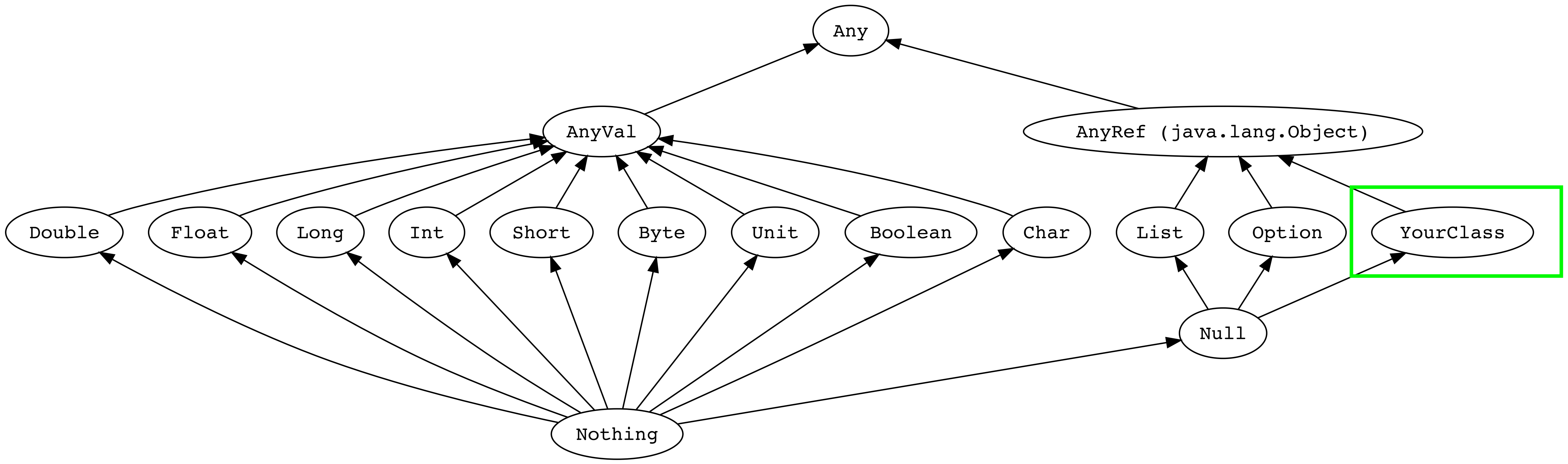
Scala Type Hierarchy



- 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), new PhysicsVector(0,0,0), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion3: PhysicalObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion4: AnyRef = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion5: Any = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
```

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

Polymorphism

- HealthPotion has 5 different types
- Polymorphism
  - Poly -> Many
  - Morph -> Forms
  - Polymorphism -> Many Forms
- Can store values in variables of any of their types

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion3: PhysicalObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion4: AnyRef = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion5: Any = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
```

Polymorphism

- Can only access state and behavior defined in variable type
- Defined magnitudeOfMomentum in InanimateObject
- HealthPotion inherited magnitudeOfMomentum when it extended InanimateObject
- PhysicalObject has no such method
  - Even when potion3 stores a reference to a HealthPotion object it cannot access magnitudeOfMomentum

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion2: InanimateObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion3: PhysicalObject = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion4: AnyRef = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)
val potion5: Any = new HealthPotion(new PhysicsVector(0,0,0), new PhysicsVector(0,0,0), 6)


potion1.magnitudeOfMomentum()
potion2.magnitudeOfMomentum()
potion3.magnitudeOfMomentum() // Does not compile
```

Polymorphism

- Why polymorphism if restricts use?
    - Simplify other classes
- Player has 2 methods
    - One to use a ball
    - One to use a potion
- Each item the Player can use will need another method in the Player class
- Tedious to expand game

```scala
class Player(val location: PhysicsVector,
             val 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)
  }
}
```

Polymorphism

- Write function using the common base type
- The use method is part of InanimateObject
- Can't access any Ball or HeathPotion specific functionality
    - Any state/behavior needed by Player must be in the InanimateObject class

```scala
class Player(val location: PhysicsVector,
             val 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)
  }
}
```

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

  var health: Int = maxHealth

  def useItem(item: InanimateObject): Unit = {
    item.use(this)
  }

}
```

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

  def objectMass(): Double

  def use(player: Player): Unit

}
```

Polymorphism

- Even better, we can mix types in data structures
    - Something we took for granted in Python/JavaScript
- Physics.updateWorld does not care about the types in world.object
    - As long as they all have PhysicalObject as a superclass

```
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(-8.27, -3.583, 5.3459),
  new PhysicsVector(-9.0, 7.17, -9.441), 6)

val potion2: HealthPotion = new HealthPotion(new PhysicsVector(-8.046, -2.128, 5.5179),
  new PhysicsVector(6.24, -3.18, -4.021), 6)

val ball1: Ball = new Ball(new PhysicsVector(-2.28, 4.88, 5.1689),
  new PhysicsVector(-0.24, 8.59, -6.711), 2)

val ball2: Ball = new Ball(new PhysicsVector(10.325, -2.14, 0.0),
  new PhysicsVector(3.65, -9.0, -7.051), 5)

val ball3: Ball = new Ball(new PhysicsVector(-6.988, 1.83, 2.5419),
  new PhysicsVector(-3.08, 5.4, 7.019), 10)

val gameObjects: List[PhysicalObject] = List(potion1, potion2, ball1, ball2, ball3)

val world: World = new World(15)
world.objects = gameObjects

Physics.updateWorld(world, 0.0167)
```

Override

- Functionality is inherited from Any and AnyRef
- println calls an inherited .toString method
    - Converts object to a String with <object_type>@<reference>
- == calls the inherited .equals method
    - returns true only if the two variables refer to the same object in memory

```scala
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion2: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion3 = potion1

println(potion1)
println(potion2)
println(potion3)
println(potion1 == potion2)
println(potion1 == potion3)
```

```
oop_physics.with_oop.HealthPotion@1d251891
oop_physics.with_oop.HealthPotion@48140564
oop_physics.with_oop.HealthPotion@1d251891
false
true
```

Override

- We can override this default functionality
- Override toString to return a different string

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

...

  override def toString: String = {
    "location: " + this.location + "; velocity: " + this.velocity + "; volume: " + volume
  }

}
```

```scala
class PhysicsVector(var x: Double, var y: Double, var z: Double) {

  override def toString: String = {
    "(" + x + ", " + y + ", " + z + ")"
  }

}
```

Override

- Override equals to change the definition of equality
- Takes Any as a parameter
- Use match and case to behave differently on different types
- The _ wildcard covers all types not explicitly mentioned
- This method return true when compared to another potion with the same volume, false otherwise

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

...

  override def equals(obj: Any): Boolean = {
    obj match {
      case hp: HealthPotion => this.volume == hp.volume
      case _ => false
    }
  }

}
```

Override

- With our overridden methods this code gives a very different output

```scala
val potion1: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion2: HealthPotion = new HealthPotion(new PhysicsVector(0,0,0),
  new PhysicsVector(0,0,0), 4)
val potion3 = potion1

println(potion1)
println(potion2)
println(potion3)
println(potion1 == potion2)
println(potion1 == potion3)
```

```
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
location: (0.0, 0.0, 0.0); velocity: (0.0, 0.0, 0.0); volume: 4
true
true
```

Lecture Question

Objective: Apply polymorphism and method overrides in Scala

Question: [Scala] In a package named "inheritance" create an abstract class named "Animal" and concrete classes named "Cat" and "Dog". **Create an object named "Park"**:

Animal: A constructor that takes a String called name (Do not use either val or var. It will be declared in the base classes); An abstract method named sound that takes no parameters and returns a String

- **Override toString to return the name of this Animal**

Cat: Inherent Animal; A constructor that take a String called name as a value (use val to declare name); Override sound() to return "meow"

Dog: Inherent Animal; A constructor that take a String called name as a value (use val to declare name); Override sound() to return "woof"

Park:

- **A method named "animals" that take no parameters and returns a list of animals containing**
  - **2 dogs with names "Snoopy" and "Finn"**
  - **2 cats with names "Garfield" and "Morris"**
- **A method named "makeSomeNoise" that takes a list of animals as a parameter and returns a list of strings containing the noises from each animal in the input list**

* This question will be open until midnight

Lecture Question

```scala
package tests

import inheritance._
import org.scalatest._

class TestPolymorphism extends FunSuite {

  test("test animal names") {

    val animals: List[Animal] = Park.animals()

    val names: List[String] = animals.map(animal => animal.toString).sorted
    val expectedNames: List[String] = List("Garfield", "Morris", "Snoopy", "Finn").sorted

    assert(names == expectedNames)
  }


  test("test animal noises") {

    val sounds: List[String] = Park.makeSomeNoise(Park.animals()).sorted
    val expectedSounds: List[String] = List("meow", "meow", "woof", "woof").sorted

    assert(sounds == expectedSounds)
  }

}
```