Objects and Classes

Objects

Objects have State and Behavior

Objects

- State / Variables
  - Objects store their state in variables
- Behavior / Functions
  - Objects contain functions that can depend on its state
  - [Vocab] When a function is part of an object it's called a **method**

Object With State

```
object ObjectWithState {

  // State of the object
  var x: Int = 10
  var y: Int = 7

  // Behavior of the object
  def doubleX(): Unit = {
    this.x *= 2
  }

}
```

- Any variable outside of all methods is part of the state of the object
- Keyword **this** stores a *reference* to the enclosing object
- Use this.<variable_name> to access state from within the object

Object With State

```
object ObjectWithState {

  // State of the object
  var x: Int = 10
  var y: Int = 7

  // Behavior of the object
  def doubleX(): Unit = {
    this.x *= 2
  }

}
```

- The variables defining the state of an object have many different names
  - Instance variables
  - Member variables
  - Fields
  - State variables <-- I'll use this one in CSE116

Object With State

```
object ObjectWithState {

  // State of the object
  var x: Int = 10
  var y: Int = 7

  // Behavior of the object
  def doubleX(): Unit = {
    this.x *= 2
  }

}
```

```
object ObjectMain {

  def main(args: Array[String]): Unit = {
    ObjectWithState.doubleX()
    println(ObjectWithState.x)
  }

}
```

- Any code with access to an object can also access its state/behavior with the dot notation
- Example: This syntax is used to call methods in the Math object

Object With State

```
object ObjectWithState {

  // State of the object
  var x: Int = 10
  var y: Int = 7

  // Behavior of the object
  def doubleX(): Unit = {
    this.x *= 2
  }

}
```

```
object ObjectMain {

  def main(args: Array[String]): Unit = {
    ObjectWithState.doubleX()
    println(ObjectWithState.x)
  }

}
```

- The state of an object can be changed
- We called a method that changed the value of a state variable

Every **value** in Scala is an **object**

Objects

- Every value in Scala is an object
  - You can use the . dot operator to access the state and behaviour of any value
  - Example: Calling methods from a String object (length, split, contains, toLowerCase)
  - Example: Accessing the PI value from the Math object
  - Example: Calling aboveAverageCities from your PaleBlueDot object

Classes

Classes are used to create **objects**

Classes

- Classes are templates used to create objects
  - Objects are **instantiated** from classes using the keyword **new**
- Classes define a type
  - Used to create many objects of the same type
  - Each object can have a different state
  - Each object has its own copies of the state variables

Classes

- Let's create a Player class with
  - A location on an x/y coordinate system
  - A fixed max hit points
  - Current hit points
  - The ability to damage other players

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damageDealt)
  }

  def conscious(): Boolean = {
    this.hp > 0
  }

  def move(dx: Double, dy: Double): Unit = {
    this.xLocation += dx
    this.yLocation += dy
  }
}
```

```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
val player2: Player = new Player(7.0, -4.0, 10)

player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- Define a class to represent a player in a game
- We'll analyze this code piece by piece

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
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  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damageDealt)
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  }
}
```

```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
val player2: Player = new Player(7.0, -4.0, 10)

player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- This class defines several state variables
- Each object of type Player will contain its own copies of each of these variables

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
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}
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```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
val player2: Player = new Player(7.0, -4.0, 10)

player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- This class has several methods that define its behaviour
- These methods can be called on each object of type Player

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
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    this.hp > 0
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  def move(dx: Double, dy: Double): Unit = {
    this.xLocation += dx
    this.yLocation += dy
  }
}
```

```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
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player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- Classes contain a method called a constructor
- This method is called when a new object is created using this class
- Any code calling the constructor can use its parameters to set the initial state of the created object

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
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  def move(dx: Double, dy: Double): Unit = {
    this.xLocation += dx
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  }
}
```

```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
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player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- [In Scala] All constructor parameters become state variables
- The constructor parameters can be declared with either val or var
  - If neither val nor var is used, the parameter is a val **and** it cannot be accessed from outside the class

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
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// ...

val player1: Player = new Player(0.0, 0.0, 10)
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player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- The keyword "this" is a reference to the calling object
- It is used to access the state and behavior of the object through which the method was called

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
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  def attack(otherPlayer: Player): Unit ={
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}
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```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
val player2: Player = new Player(7.0, -4.0, 10)

player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- When you write a class, you define a new **type**
- This type can be used like any other type
  - Variable of this type, methods that take this type as a parameter, etc.

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damageDealt)
  }

  def conscious(): Boolean = {
    this.hp > 0
  }

  def move(dx: Double, dy: Double): Unit = {
    this.xLocation += dx
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}
```

```
// ...

val player1: Player = new Player(0.0, 0.0, 10)
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player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- Use the keyword **new** to call the constructor method
- The constructor creates a new object of this type
- The constructor returns a *reference* to the new object

Classes

```
class Player(var xLocation: Double, var yLocation: Double, val maxHitPoints: Int) {

  var hp: Int = this.maxHitPoints
  val damageDealt: Int = 4

  def takeDamage(damage: Int): Unit = {
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player2.move(-6.5, 3.4)

player2.attack(player1)
player2.attack(player1)

assert(player1.hp == 2)

// ...
```

- Use the references to these objects to access their state and behavior
- Each object has its own copy of all the state variables
  - Allows player1 and player2 to move independently and have different hp

Classes

- Int, Double, Boolean, List, Array, Map
  - Are all classes
  - We use these classes to create objects

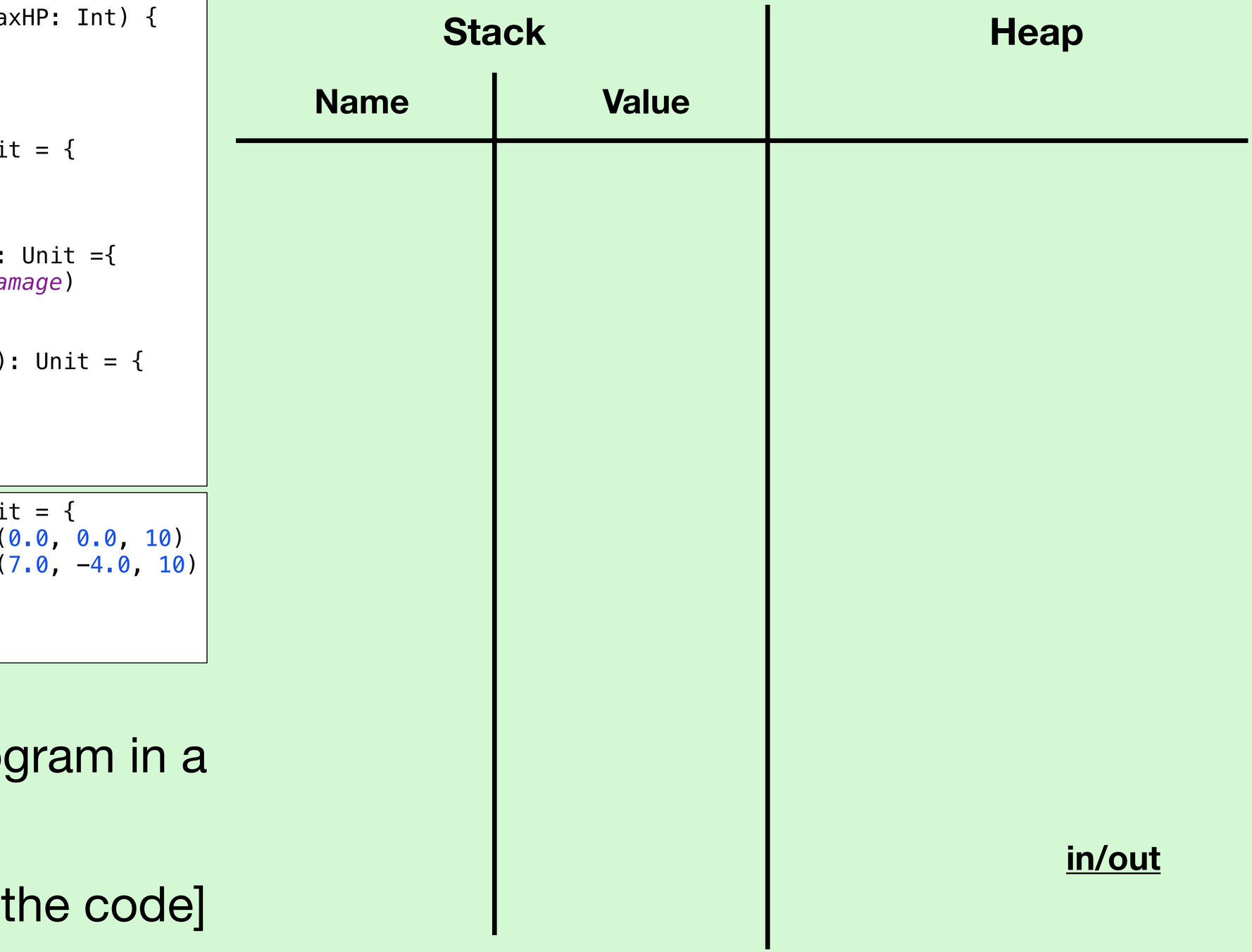
```
var list: List[Int] = List(2, 3, 4)
```

- Create objects by calling the constructor for that class
- List is setup in a way that we don't use **new**
- For our classes we will use the **new** keyword

```scala
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
  val damage: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damage)
  }

  def move(dx: Double, dy: Double): Unit = {
    this.x += dx
    this.y += dy
  }
}
```

```scala
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```

- Let's trace this program in a memory diagram
- [Slight changes to the code]



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             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
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```
def main(args: Array[String]): Unit = {
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 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```
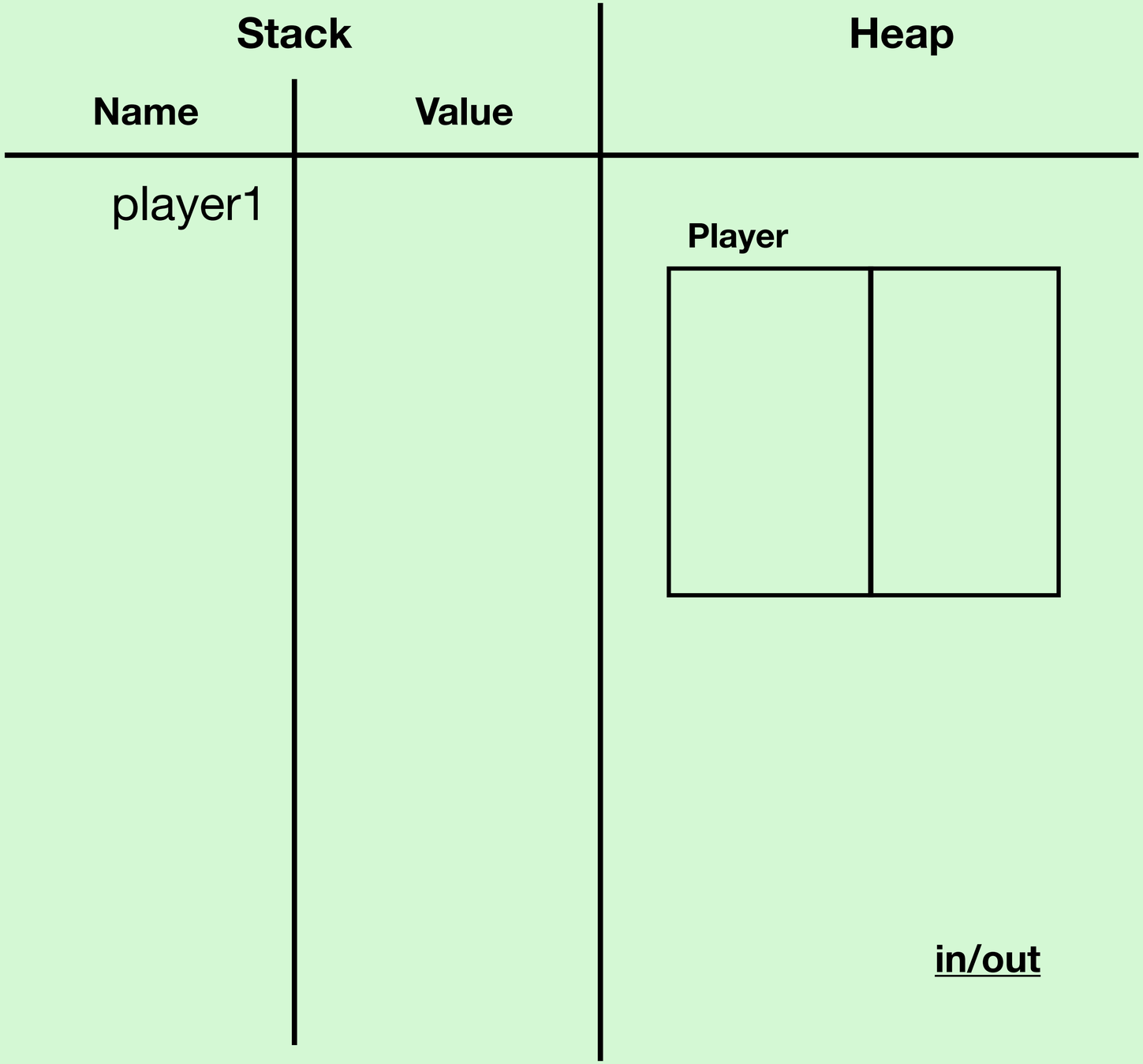

- Every time you see the keyword "new" something is being added to the heap
- Create a new object of type Player



in/out

```
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
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  def takeDamage(damage: Int): Unit = {
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  def attack(otherPlayer: Player): Unit ={
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  }

  def move(dx: Double, dy: Double): Unit = {
    this.x += dx
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  }
}
```
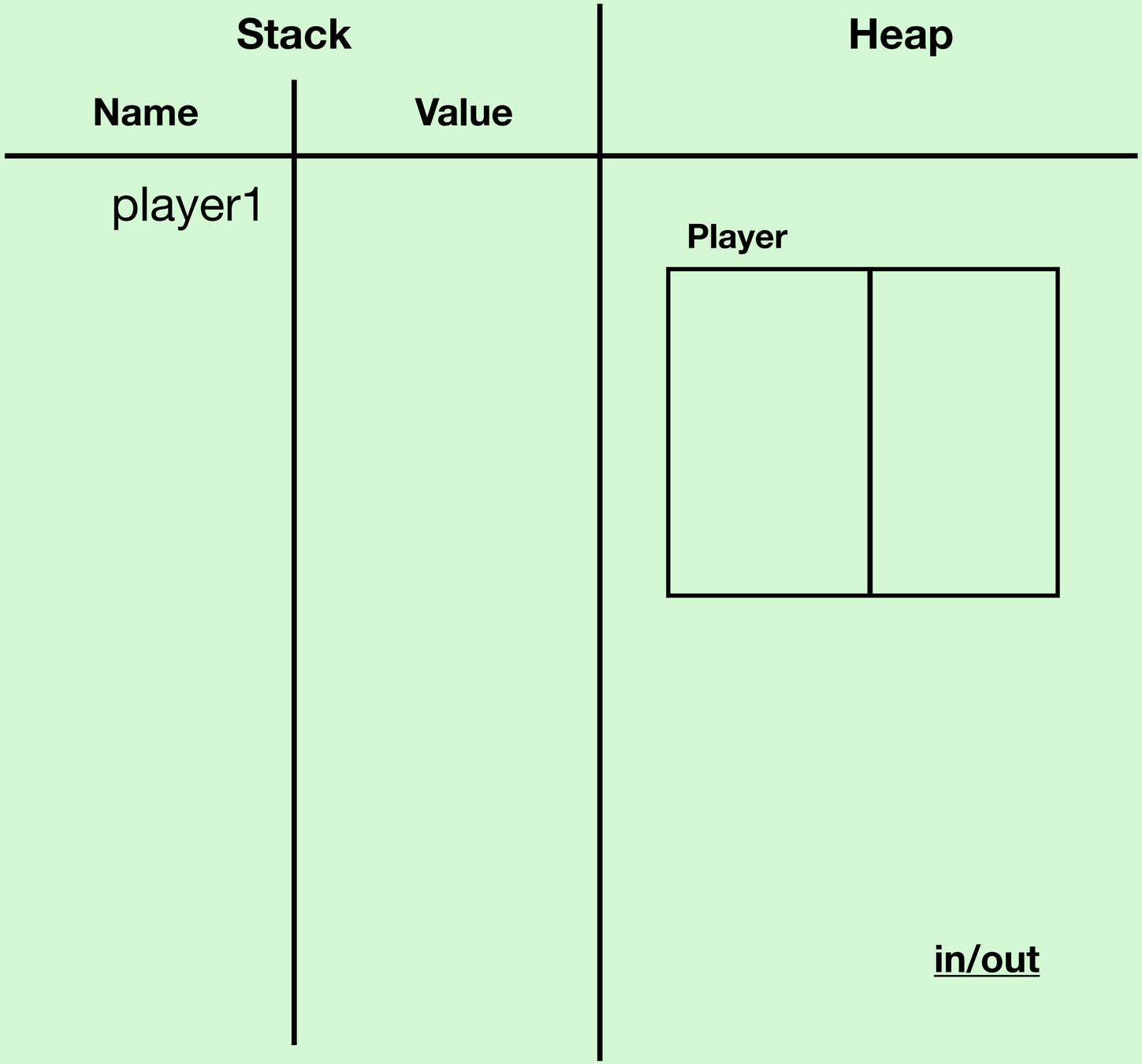

```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```

- We draw a box that will contain all of the state variables of the new object
- Write the type of the object



```
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
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  def takeDamage(damage: Int): Unit = {
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    this.x += dx
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```
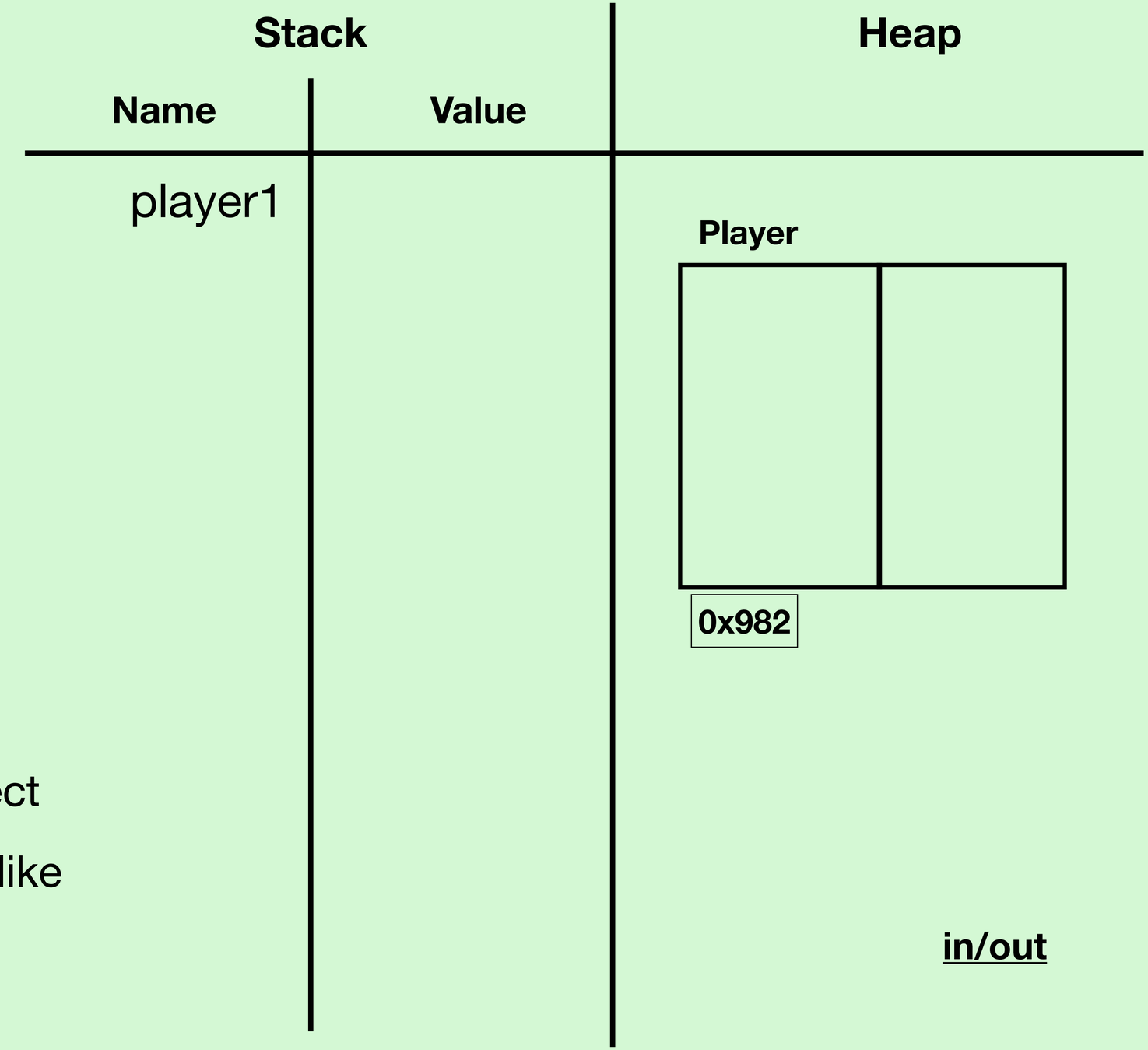

```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```

- Add a reference number for the object
- You may choose any number you'd like
- This number represents the object's location in memory



```
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  var hp: Int = this.maxHP
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    this.x += dx
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```
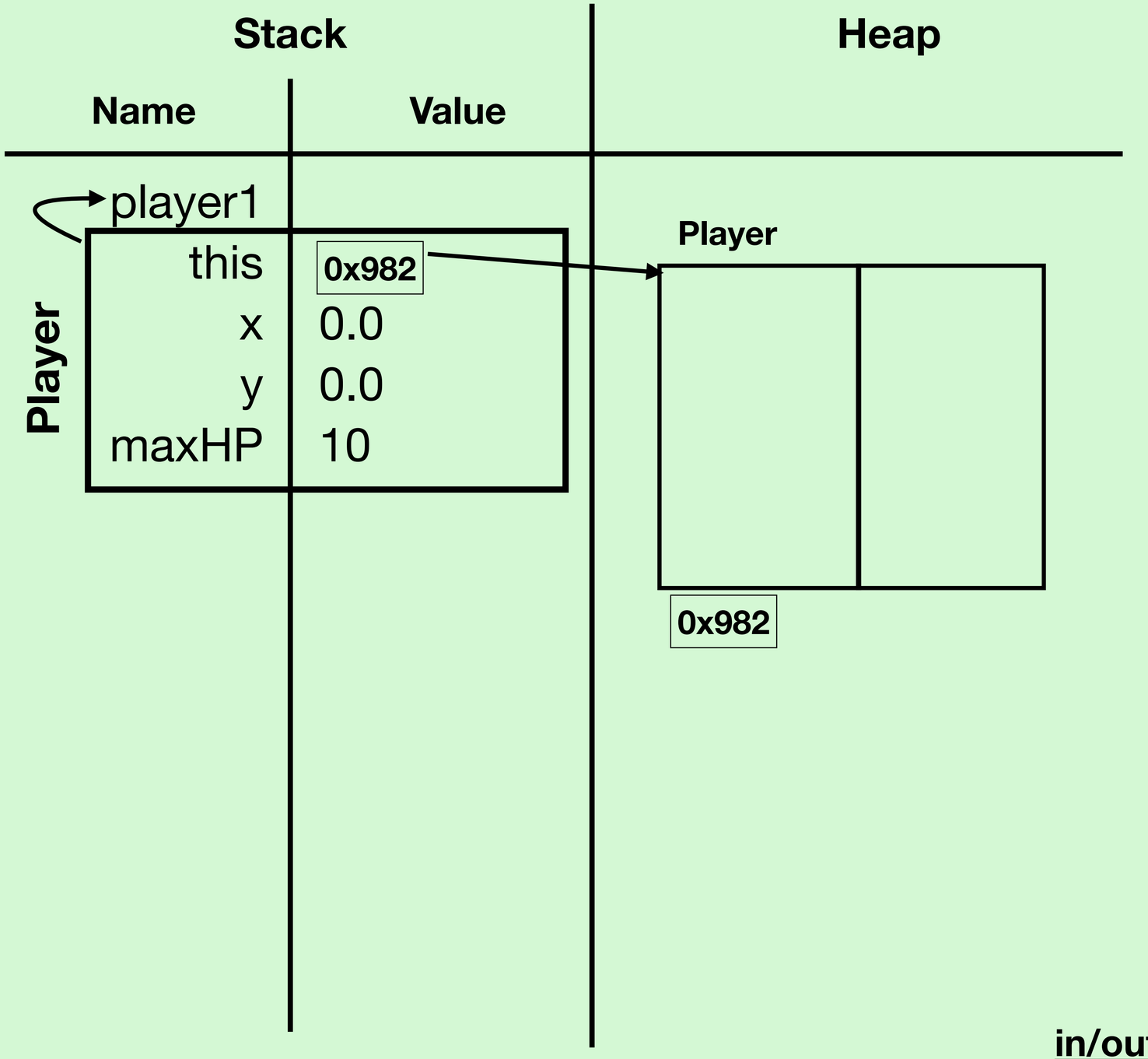

```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```

- Constructors are methods!
- Add a stack frame for the constructor call



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```

```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
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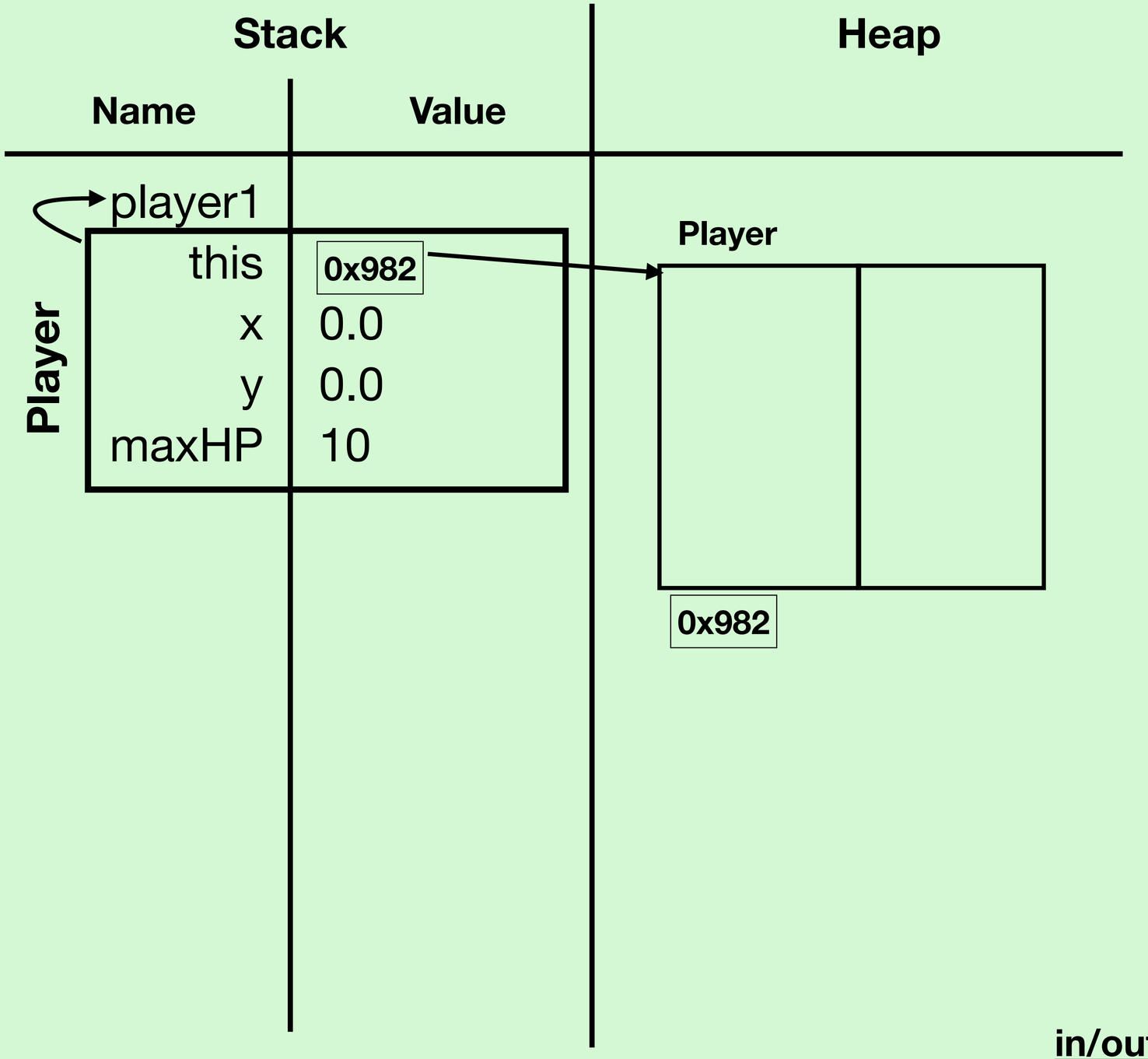
 val player3: Player = player1
 player2.attack(player1)
}
```



- When calling a method we have an implicit parameter of "this"
- "this" stores a reference to the calling object (Object being created when the method is a constructor)

in/out

```
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
  val damage: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damage)
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```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
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 player2.attack(player1)
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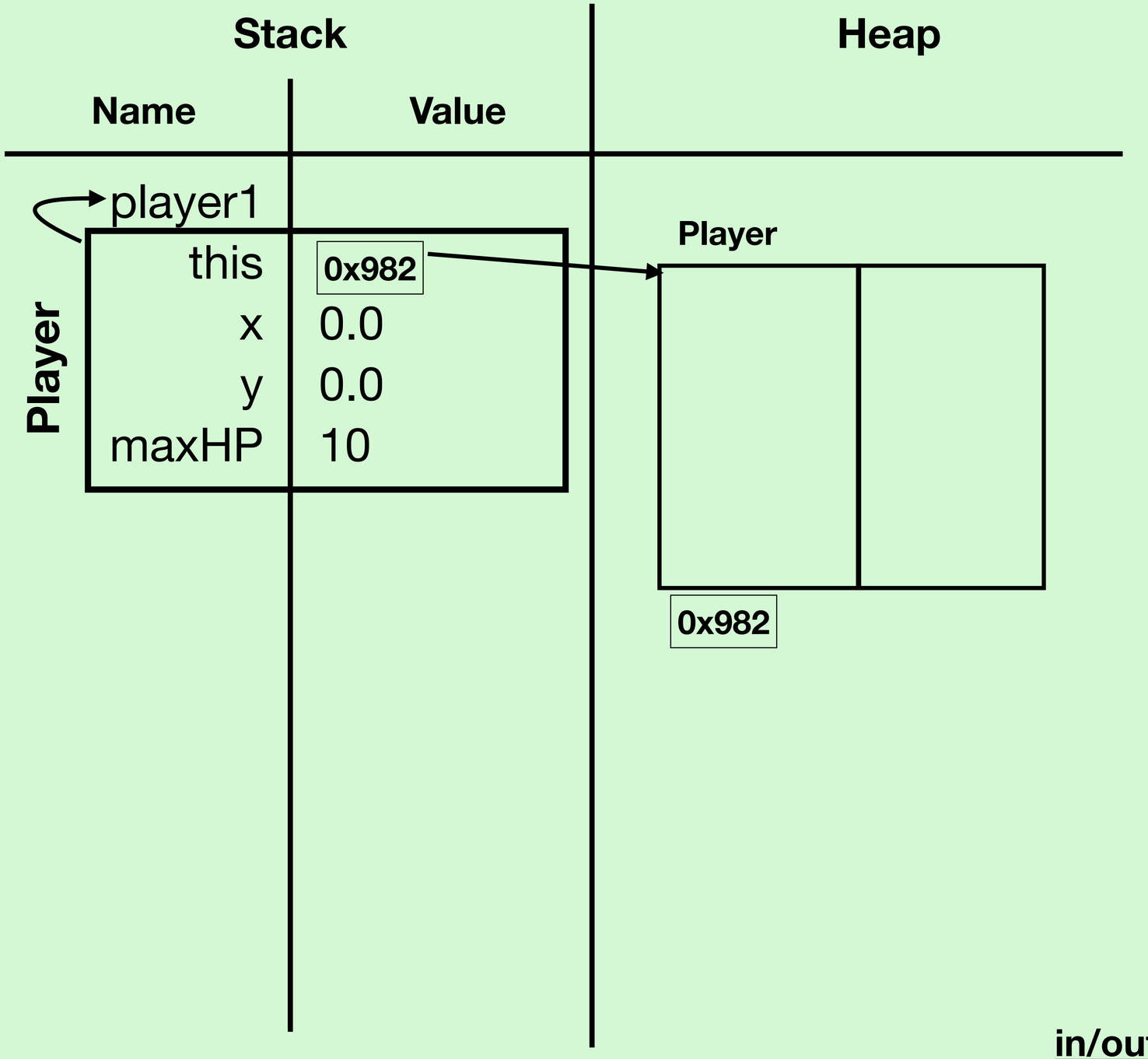

- When we have a variable that stores a reference, draw an arrow from the reference to the object that it refers to

```
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

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  def takeDamage(damage: Int): Unit = {
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def main(args: Array[String]): Unit = {
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 val player2: Player = new Player(7.0, -4.0, 10)
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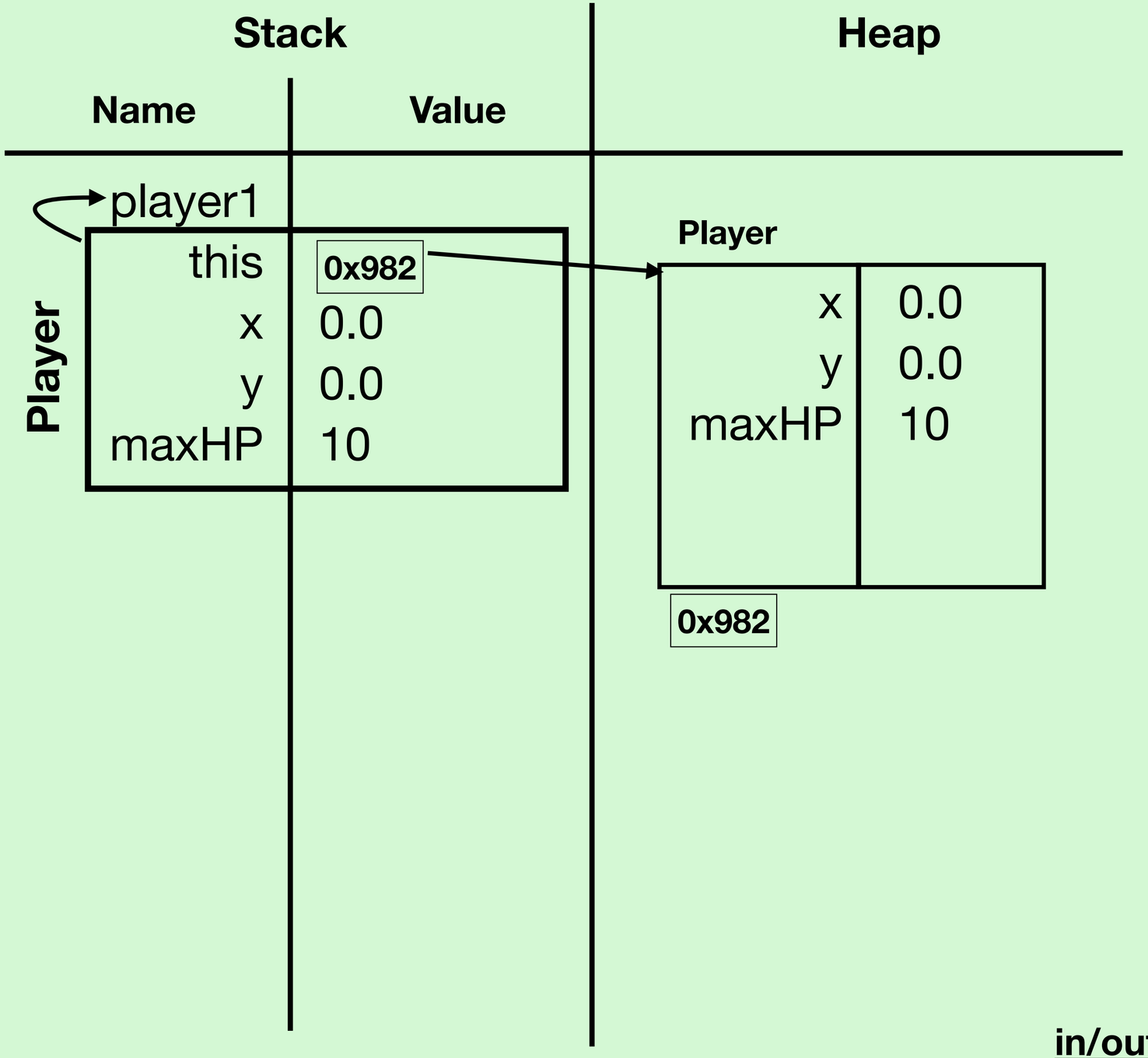
 player2.attack(player1)
}
```

- Constructor parameters become state variables in the object
- Write all state variables and their values in the object



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def main(args: Array[String]): Unit = {
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 player2.attack(player1)
}
```
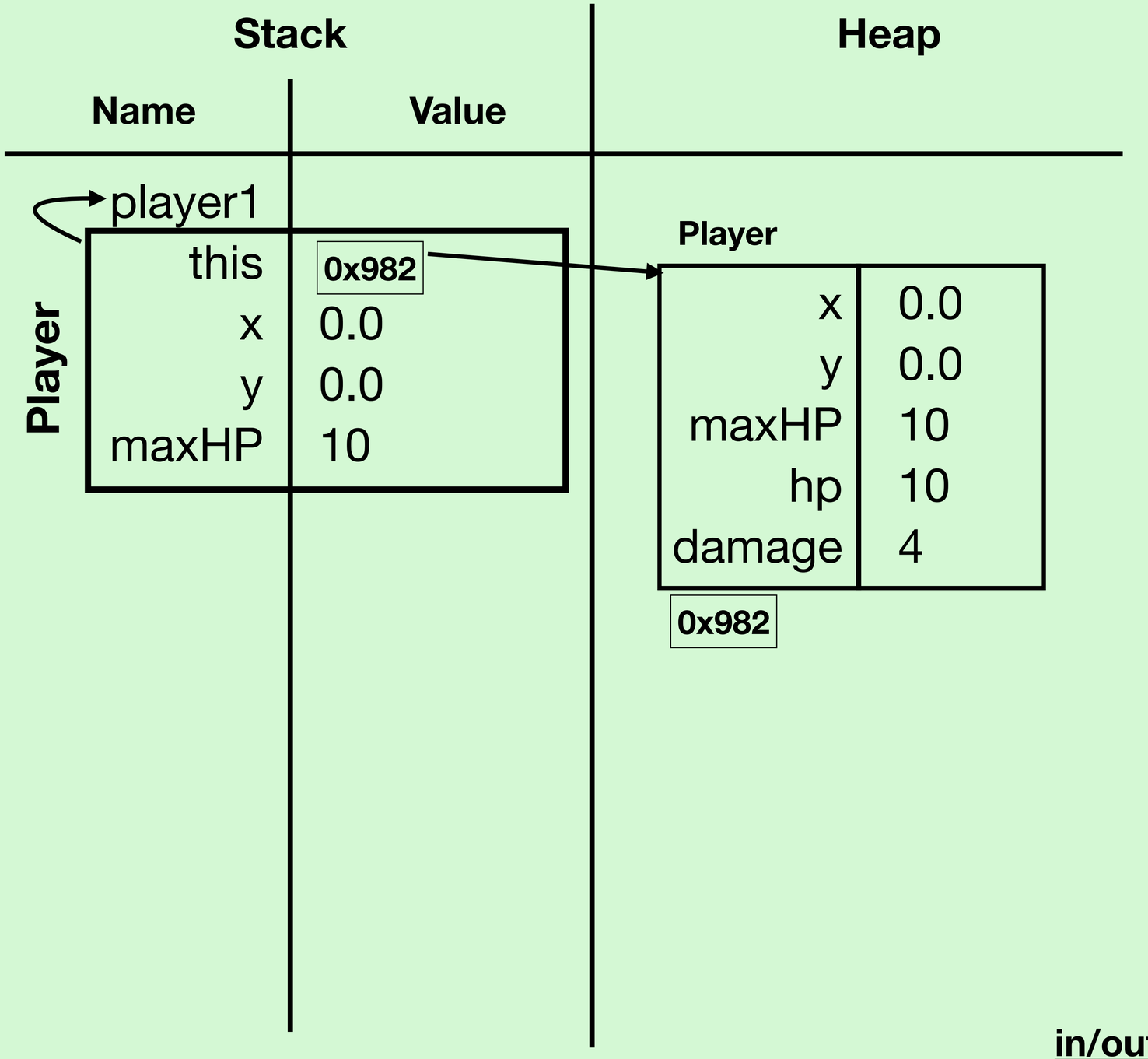

- Run all code that's outside of methods when the constructor is called
- Any variables declared become state variables in the object



```
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def main(args: Array[String]): Unit = {
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 val player3: Player = player1
 player2.attack(player1)
}
```
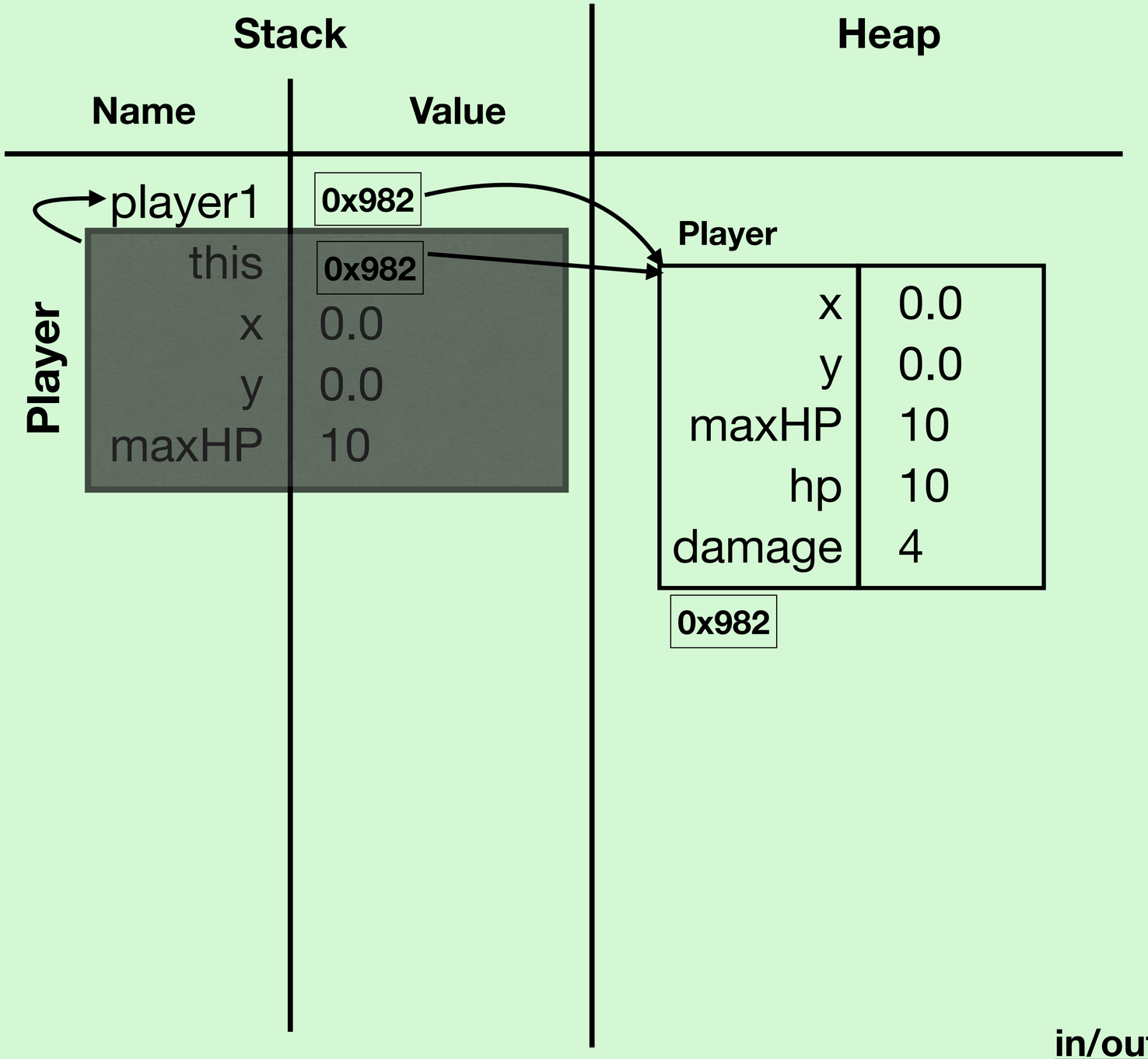

- Constructor ends and returns a **reference** to the object that was created



```
class Player(var x: Double,
             var y: Double, val maxHP: Int) {

  var hp: Int = this.maxHP
  val damage: Int = 4

  def takeDamage(damage: Int): Unit = {
    this.hp -= damage
  }

  def attack(otherPlayer: Player): Unit ={
    otherPlayer.takeDamage(this.damage)
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  def move(dx: Double, dy: Double): Unit = {
    this.x += dx
    this.y += dy
  }
}
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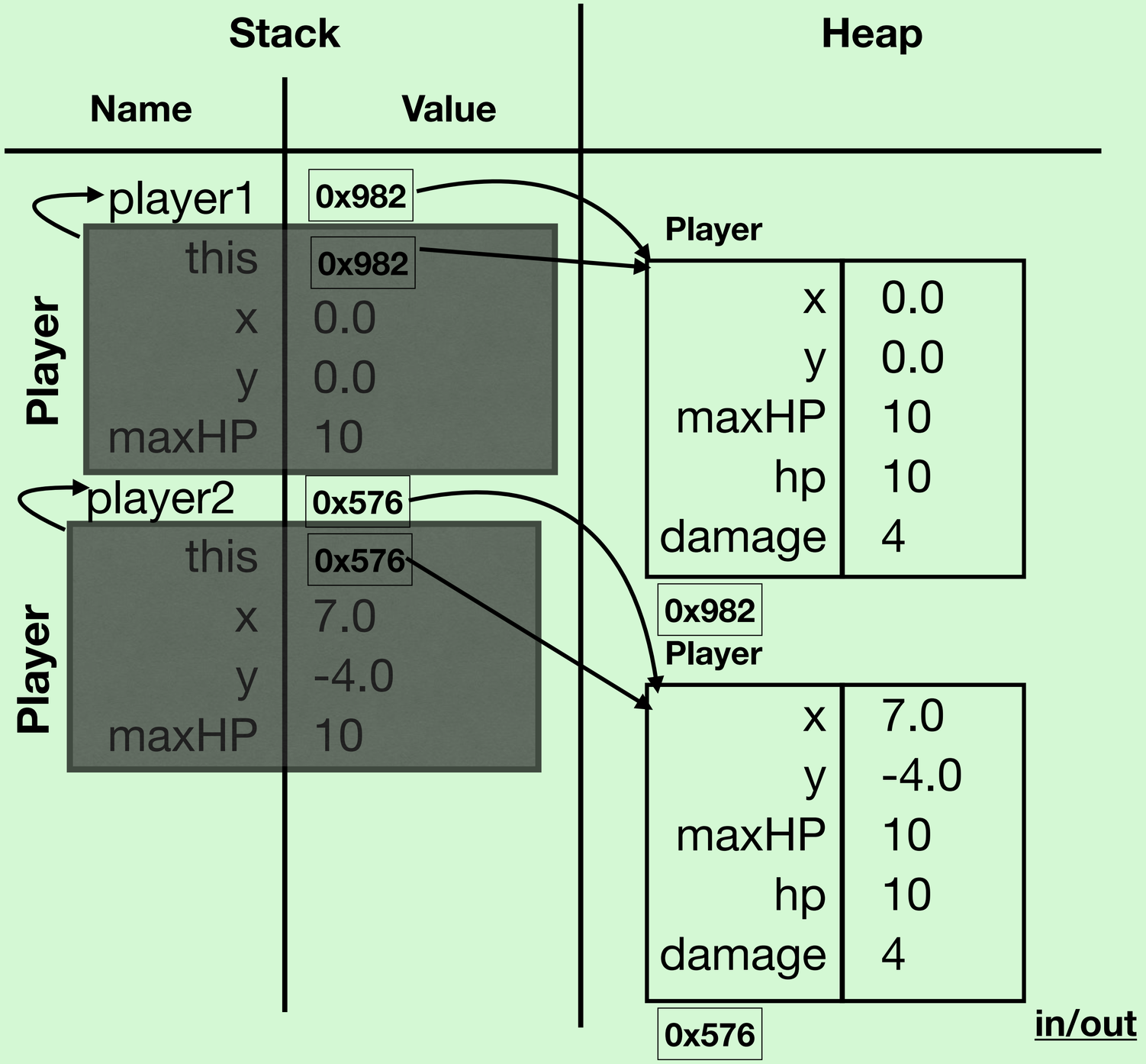
```
def main(args: Array[String]): Unit = {
 val player1: Player = new Player(0.0, 0.0, 10)
 val player2: Player = new Player(7.0, -4.0, 10)
 val player3: Player = player1
 player2.attack(player1)
}
```

- Repeat the process for player2



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}
```
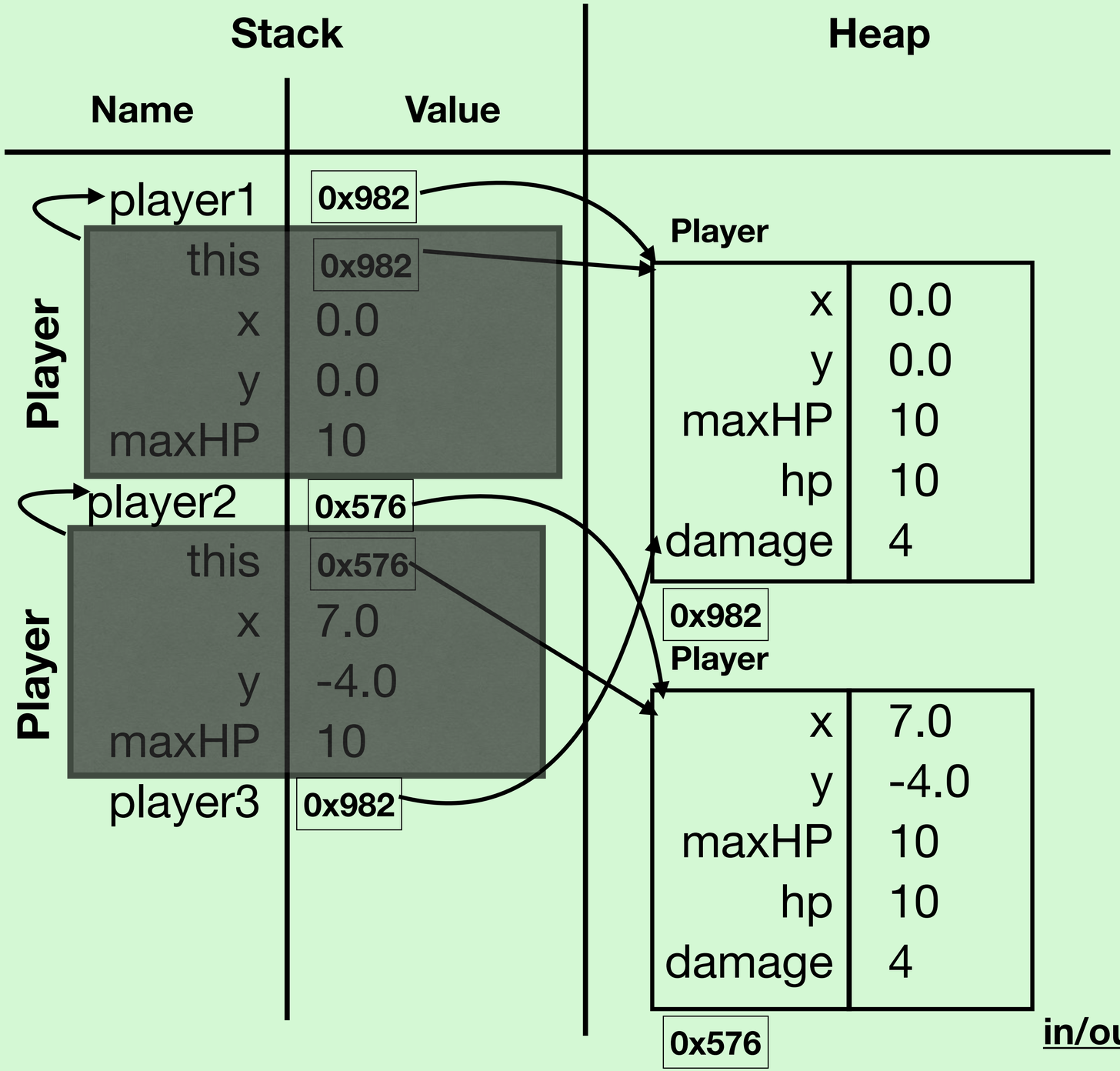

- player3 is assigned the value of player1
- player1's value is a **reference**!!



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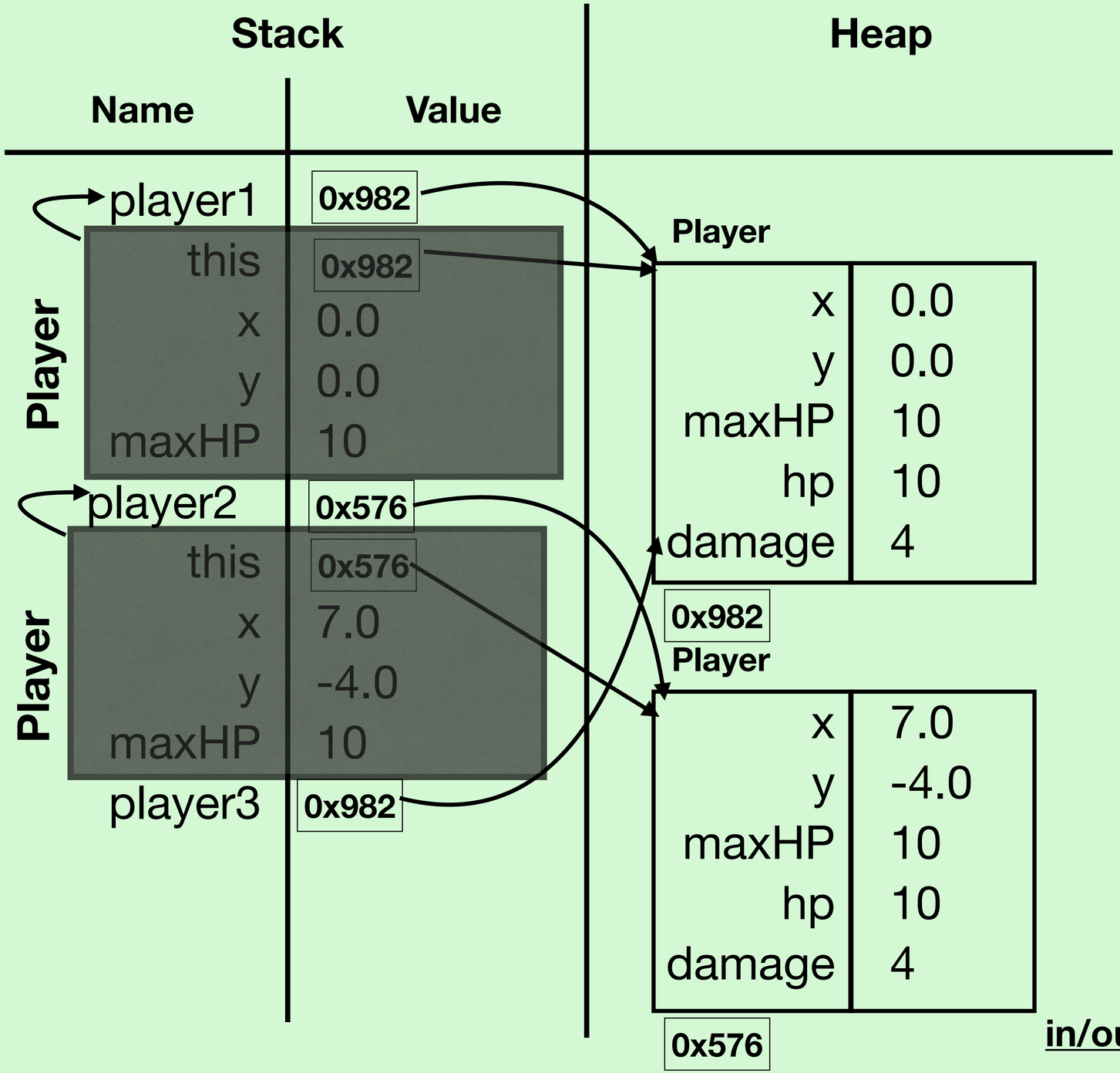
}
```

- player3 and player1 refer to the same object!
- No new object was created for player3



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 val player3: Player = player1
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}
```
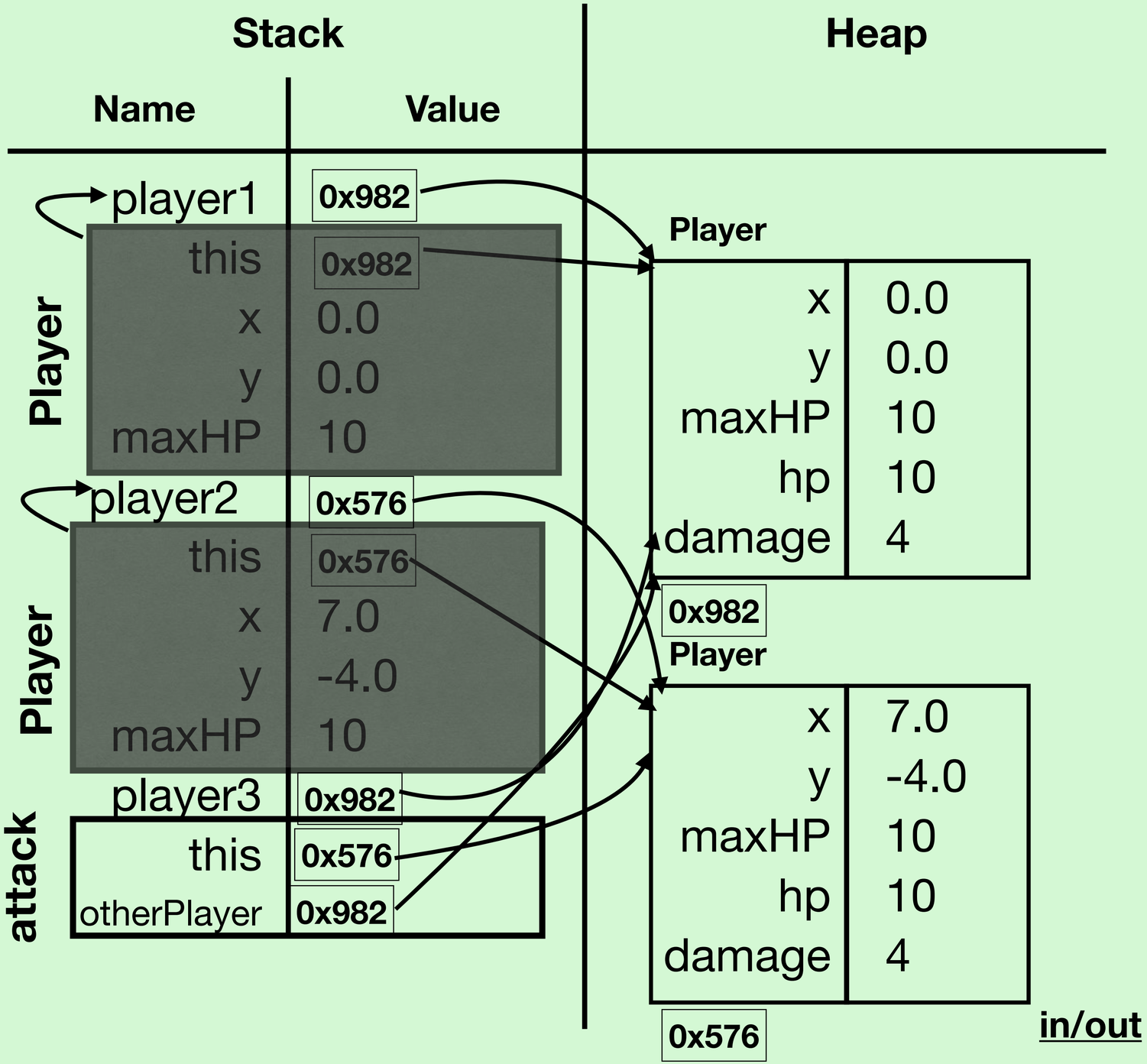

- player2 attacks player1!
- New stack frame
- implicit parameter of this with the reference stored in player2



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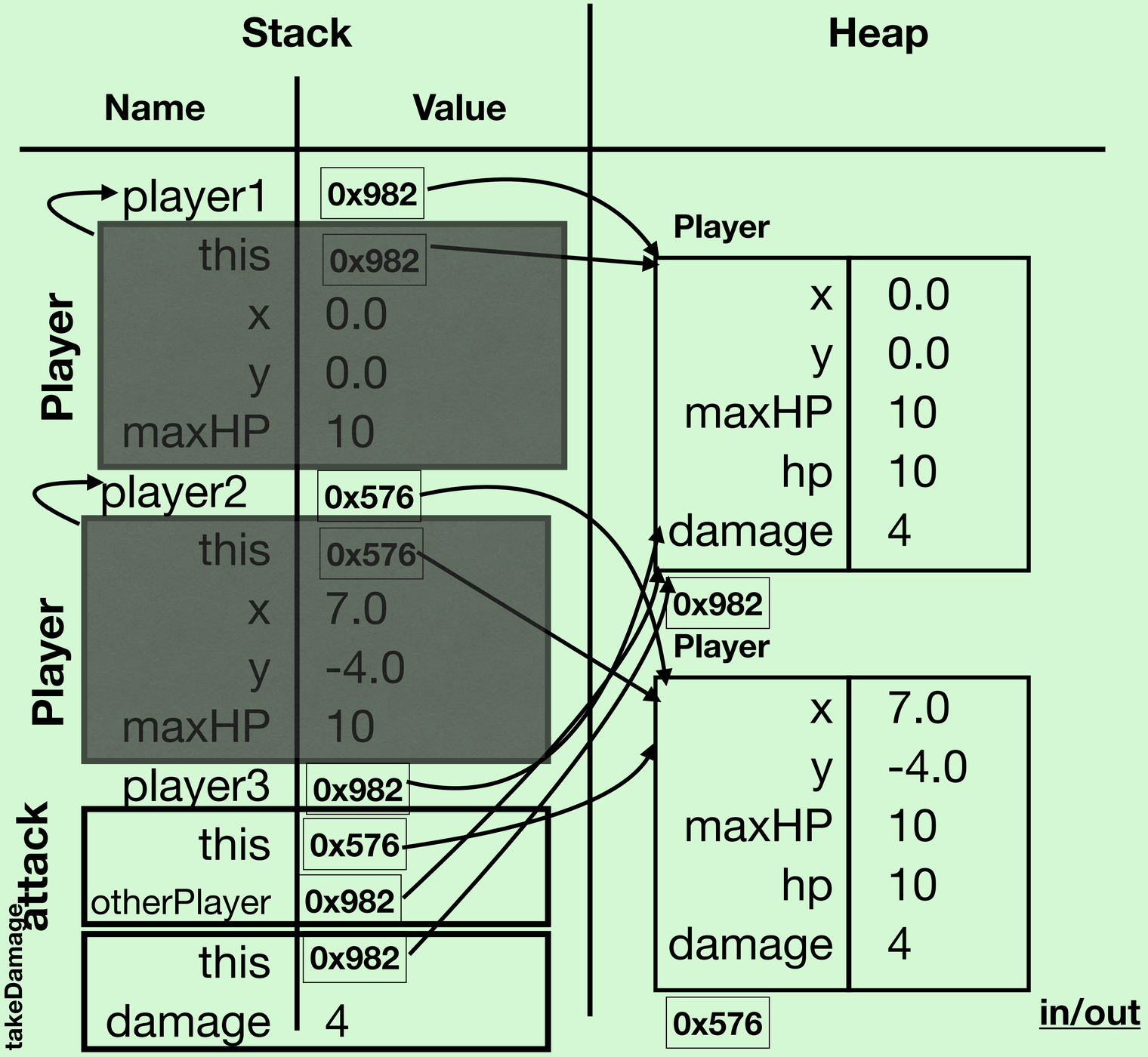
}
```

- Call takeDamage
- this stores a reference to the object that called the method



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 val player3: Player = player1
 player2.attack(player1)
}
```

- Decrement hp and return
- player1 and player3 **both** see the damage!!!