APIT - Java recap etc

Dr. Simon Rogers

29/12/2018

Overview

- Introduction
- Objects, interfaces etc
- Immutable objects
- Call by reference / value
- Final
- Testing
- Documenting
- Tools

Programming

Compiling and running Java from the command line

- I will do this in class
- In simplest case, it involves two steps:
  - Compiling: `javac MyClass.java`
  - Running: `java MyClass`
- We will see some more complex examples throughout the course
- Feel free to use Eclipse if you prefer
- Also, Visual Studio Code...

Organising projects

- All the programs in this course involve small numbers of classes
- For larger projects, it is important to organise all your files in a standard manner
  - Eclipse does this automatically
- If you want to do it manually, good description is available here

Classes

- Classes define objects
- `Pet` is a simple class used by `PetTest`
- Classes allow us to neatly combine related attributes and methods

Inheritance

- One of the big strengths of OOP is *inheritance*
  - Creating classes that *inherit* everything of another class and add more
  - e.g. `Dog`, `Goldfish`, `PetInheritanceTest`
- In this example we also see `overridden` methods
  - `Dog` and `Goldfish` override the `description` method
  - The loop does not care which subclass the objects belong to.
  - This is very useful in many applications - *polymorphism*

Abstract Classes

- Standard classes can be *instantiated*
  - i.e. we can create objects of their type (e.g. `Pet`, `Dog`, etc)
- Java allows you to define classes that cannot be instantiated: **Abstract classes**
- Abstract classes can only be sub-classed
  - e.g. `AbstractPet`, `Cat` and `AbstractPetTest`
- There is no situation where you would *have* to use an abstract class but many where it's neater
- Note that sub-classes have to implement all abstract methods or be abstract themselves

Interfaces

- Interfaces are similar to abstract classes but:
  - Cannot have fields (unless they are `static` and `final`)
- See `InterfacePet`, `Parrot` and `TestInterfacePet`
- Interfaces are like contracts: they just specify the methods a class must implement
  - Note that methods in interfaces are abstract by default
- Note:
  - Classes can only sub-class one class...
  - ...but can implement many interfaces

Some odds and ends

`public`, `private` and `protected`

- Fields/attributes and methods are either public, private, or protected
  - Public: anything can access
  - Private: only objects of this type can access
    - e.g. `provideBone` method in `Dog`
  - Protected: only objects of this type, sub-classes (and other things within the same package)
    - e.g. `name` and `age` in `Pet` and `AbstractPet`
- In general, be as restrictive as possible.

`static`

- Fields and methods can also be declared `static`
- This means that they are accessible without an object being instantiated
- Useful for storing generic methods and constants
- e.g. `MyMath` and `MyMathTest`
  - `areaOfCircle` is used without creating a `MyMath` object
  - Another static thing is used here - what is it?

`static` attributes

- Static attributes within an object are *shared* by all instances
- Change the value in one, and it will change in all of the others...
  - Useful, but not always the neatest solution

Memory in Java

- Most data in Java is stored in Objects
- Objects are stored in an area of memory called the *heap*
  - There is one heap for the whole program
- Each thread has its own stack
  - All programs have at least one thread
  - In your programmes so far, there is one thread

The Stack

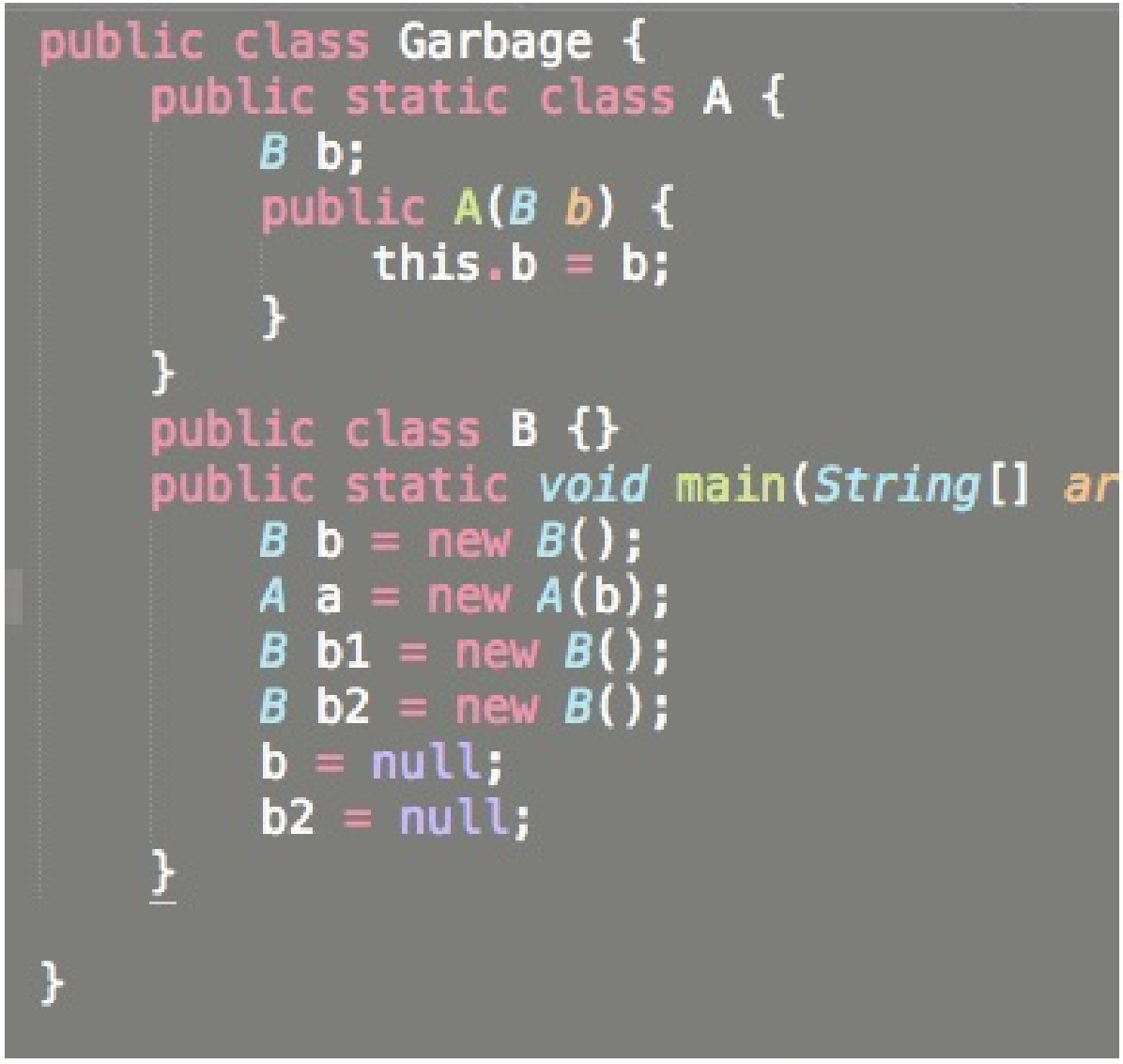
- The stack is used for three purposes:
  - Evaluating expressions
  - Storage of local variables (variables in the current *scope*)
  - Management of method calls
- Think of it as a stack of paper.
  - Pieces of paper are put on (pushed), and taken off (popped), the top of the pile
  - LIFO: Last In First Out

The Heap

- The heap is an area of memory used to store objects in Java
- Objects in the heap are accessible from any part of the program that has a local reference to the object
- Threads share a single heap
  - i.e. each thread can access objects in the heap
  - Useful, but causes all of the multi-threading problems we wil see
- In Java, objects are stored in the heap, references to objects are stored in the stack
  - This is very important, and we will come back to it later. . .

Garbage collection

- Java periodically deletes objects when they are not needed
- An object is not needed if it is *unreachable*
  - i.e. no references to it exist



```
public class Garbage {
    public static class A {
        B b;
        public A(B b) {
            this.b = b;
        }
    }
    public class B {}
    public static void main(String[] ar
        B b = new B();
        A a = new A(b);
        B b1 = new B();
        B b2 = new B();
        b = null;
        b2 = null;
    }

}
```

Figure 1: Example program

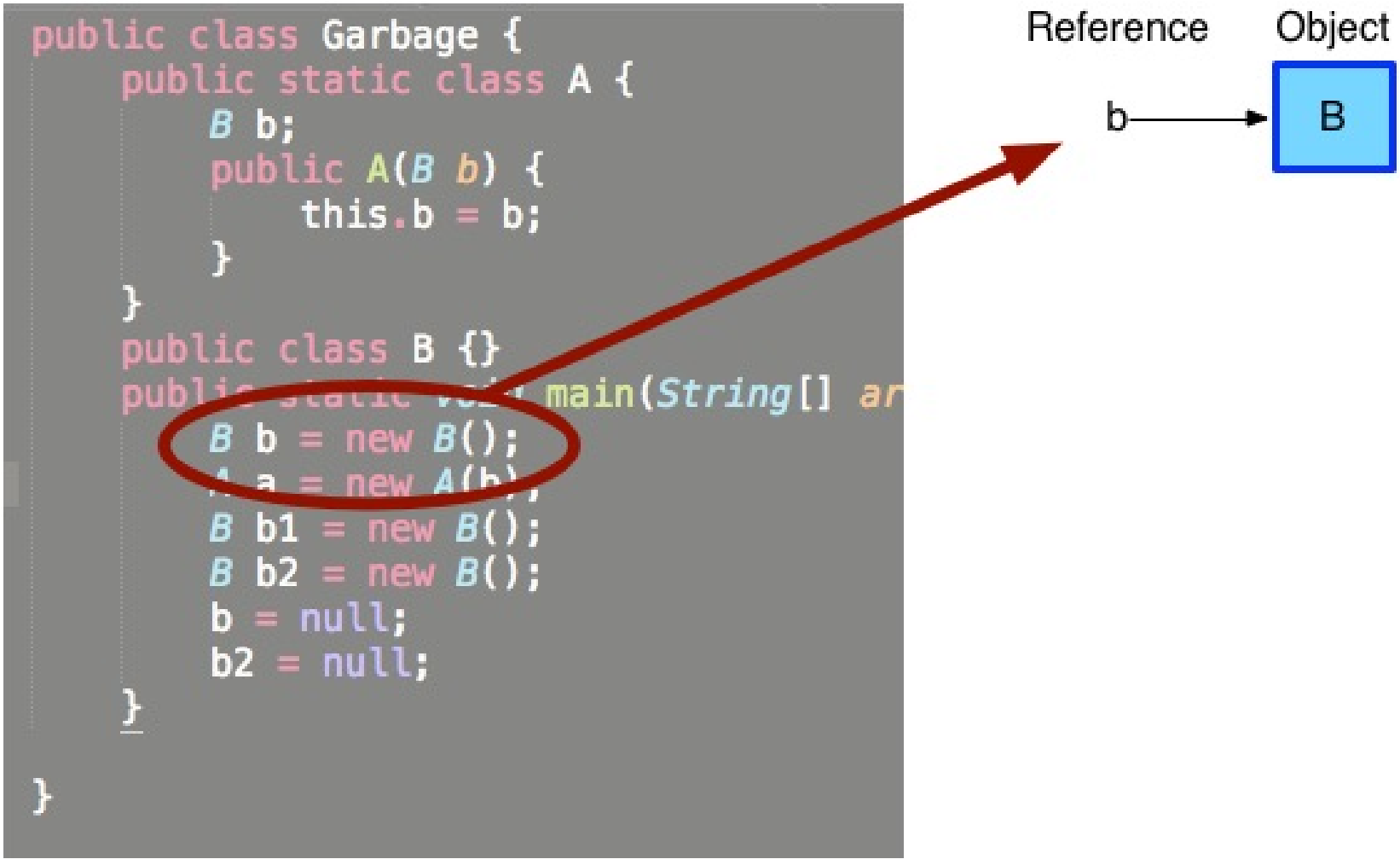


Figure 2: Object (B) and reference (b) created

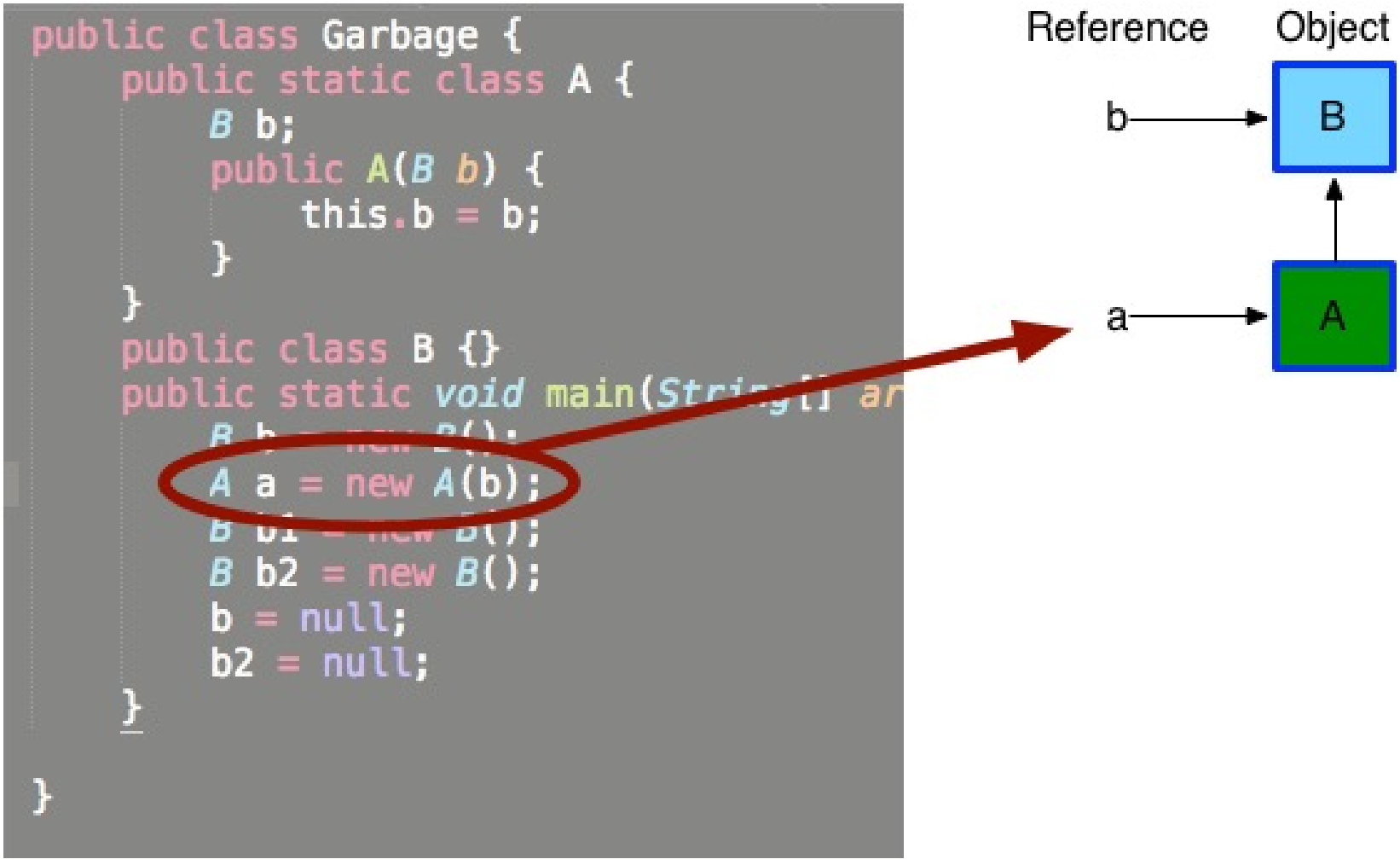


Figure 3: object (A) and reference (a) created. Note that A includes a reference to B)

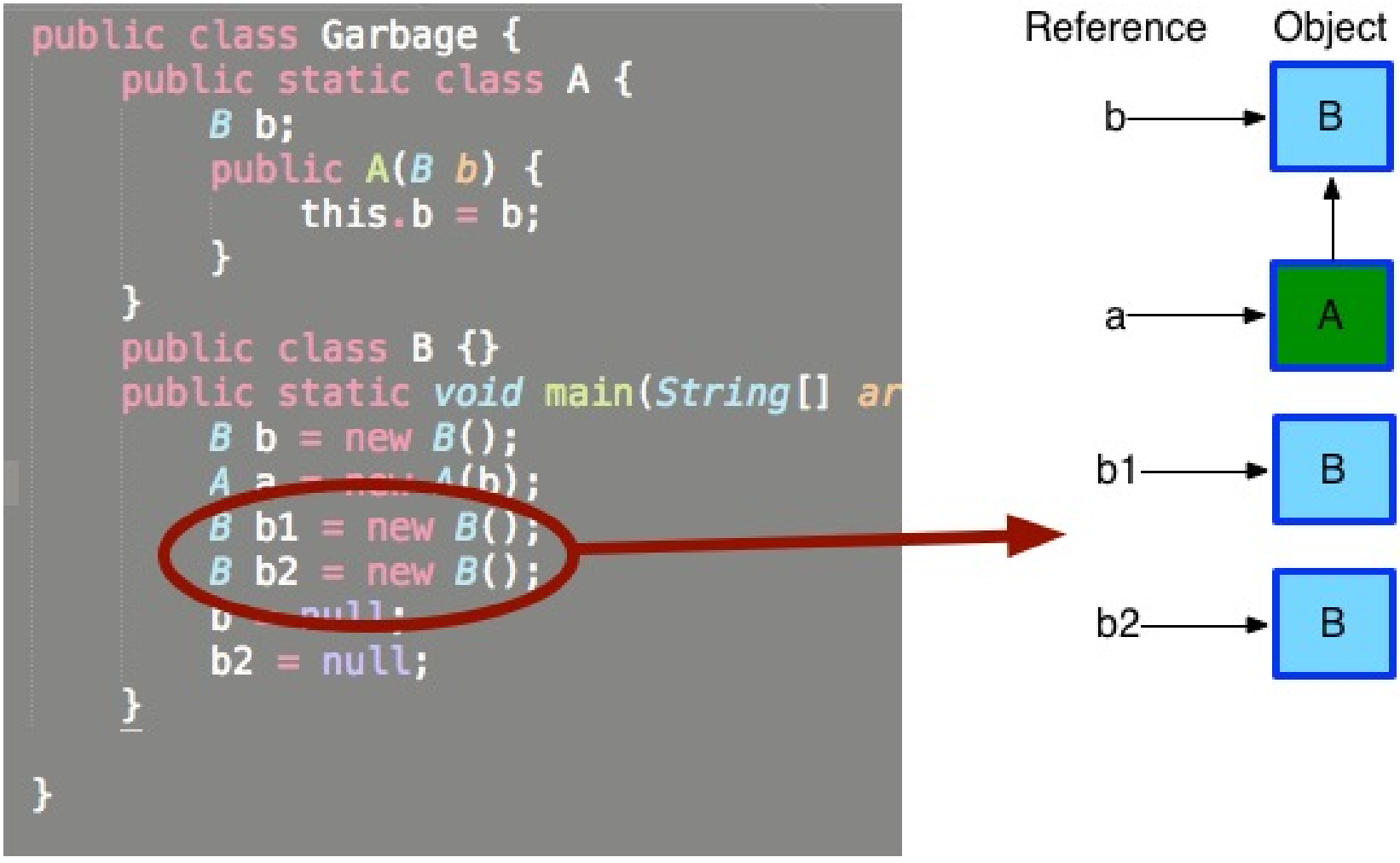


Figure 4: Two more B objects and references created

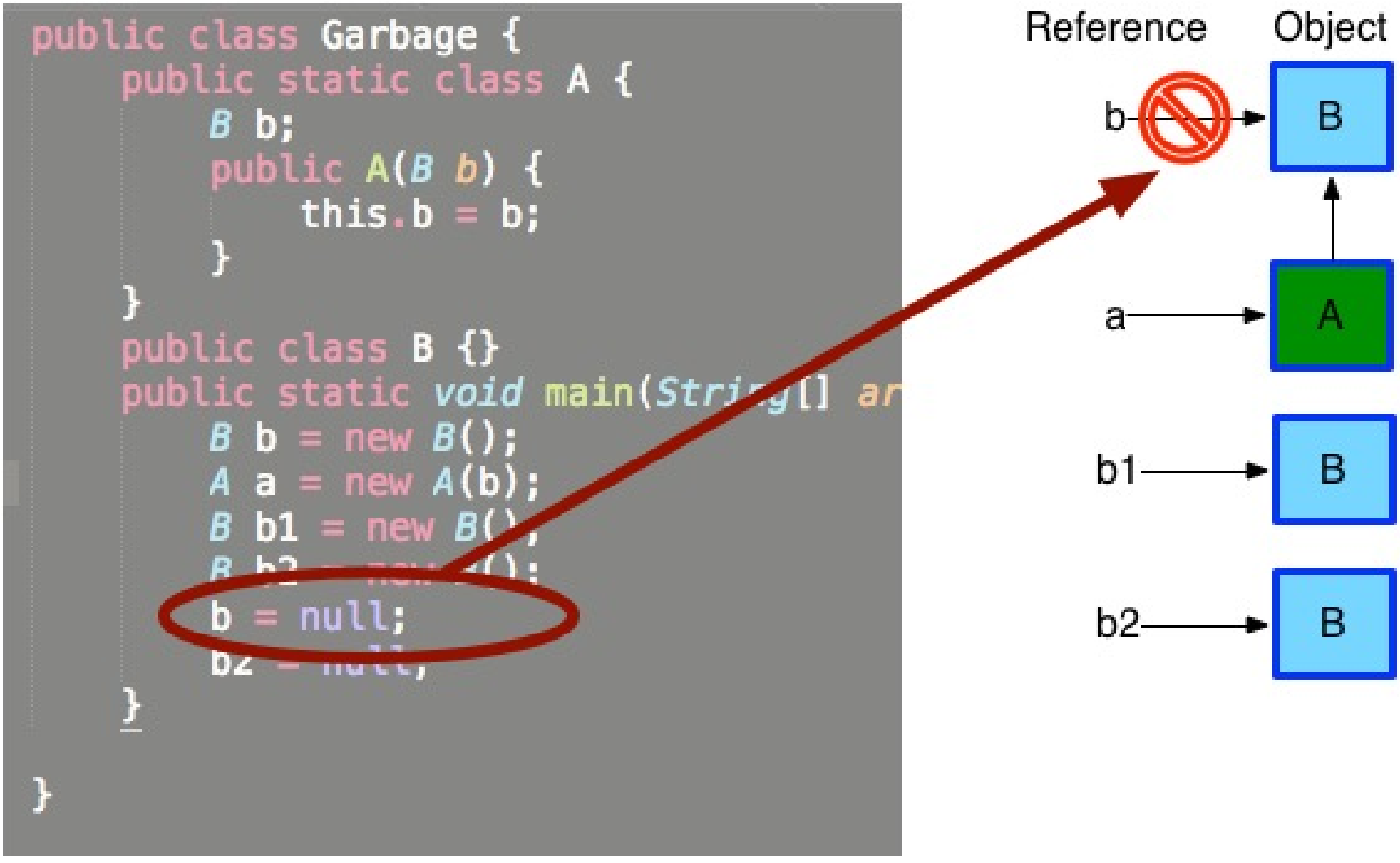


Figure 5: Reference b deleted

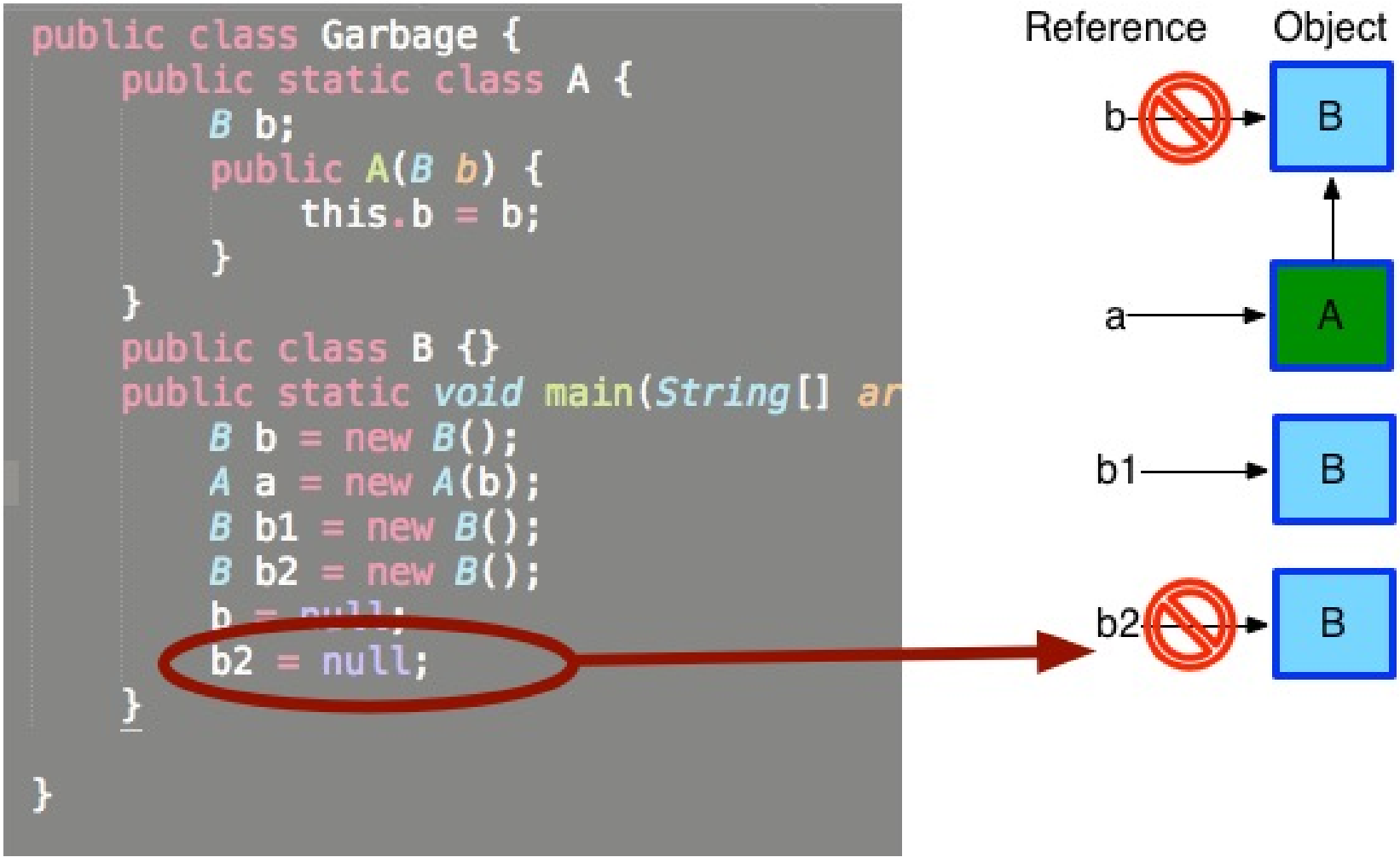


Figure 6: Reference b2 deleted

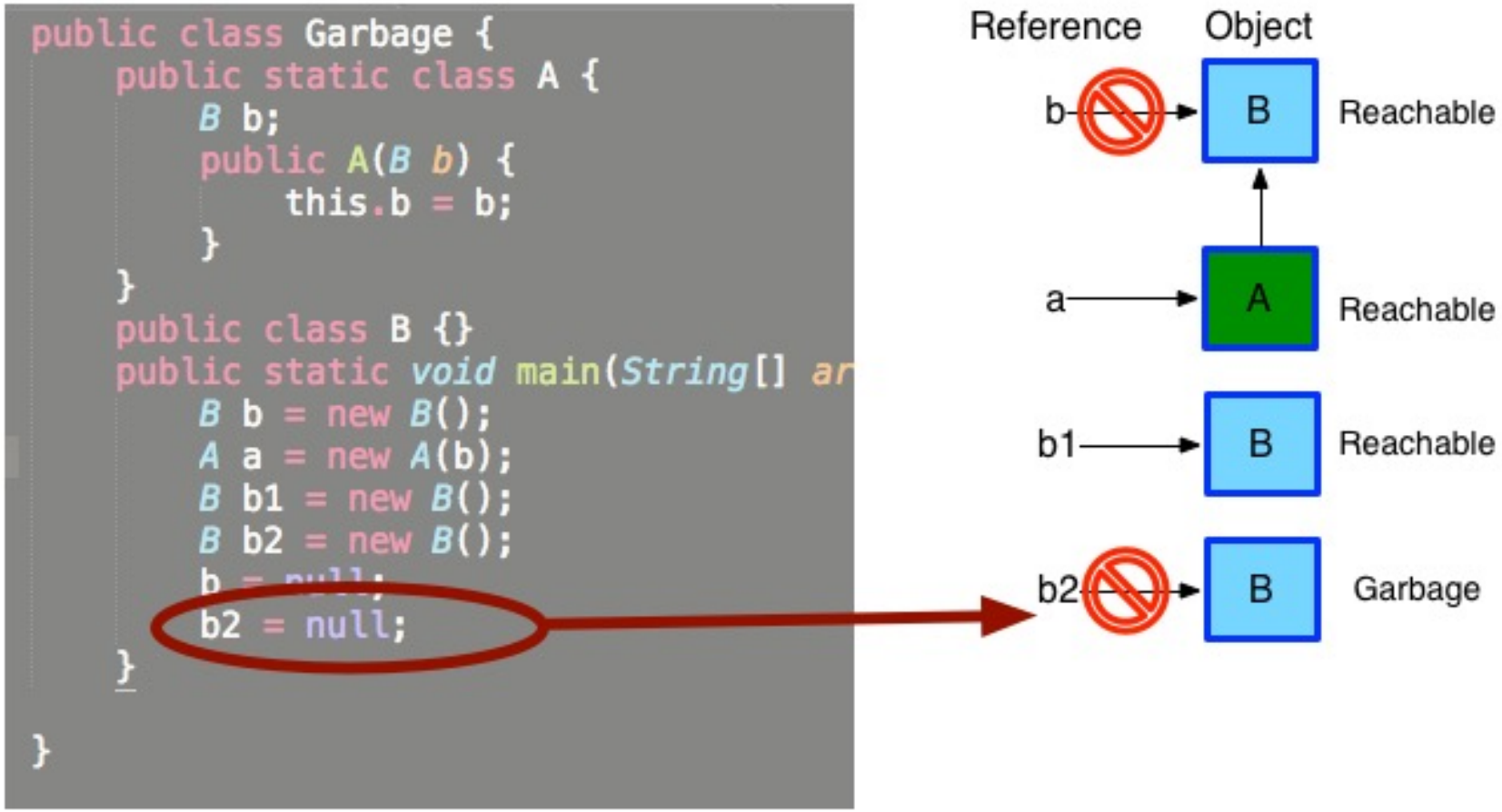


Figure 7: Objects with no reference are garbage. Note that the first B is still referenced from A so isn't garbage even though its original reference has been deleted

Immutable objects

- Some native Java objects are *immutable*
- Once they are created they cannot be changed
  - e.g. String, Double, Float, Integer, etc
- It looks like we can change them?

```
String a = "hello";
a+=" simon";
```

- But, Java is creating a new object and storing the reference in `a`
  - Objects in heap, references in stack...
- See `StringExample`

Call by value and call by reference

- Call by value
  - Value of a variable is passed to a method
  - Changes to the local copy are not reflected in the calling space
- Call by reference (e.g. C++)
  - Object references are passed to method
  - Actual object can be modified

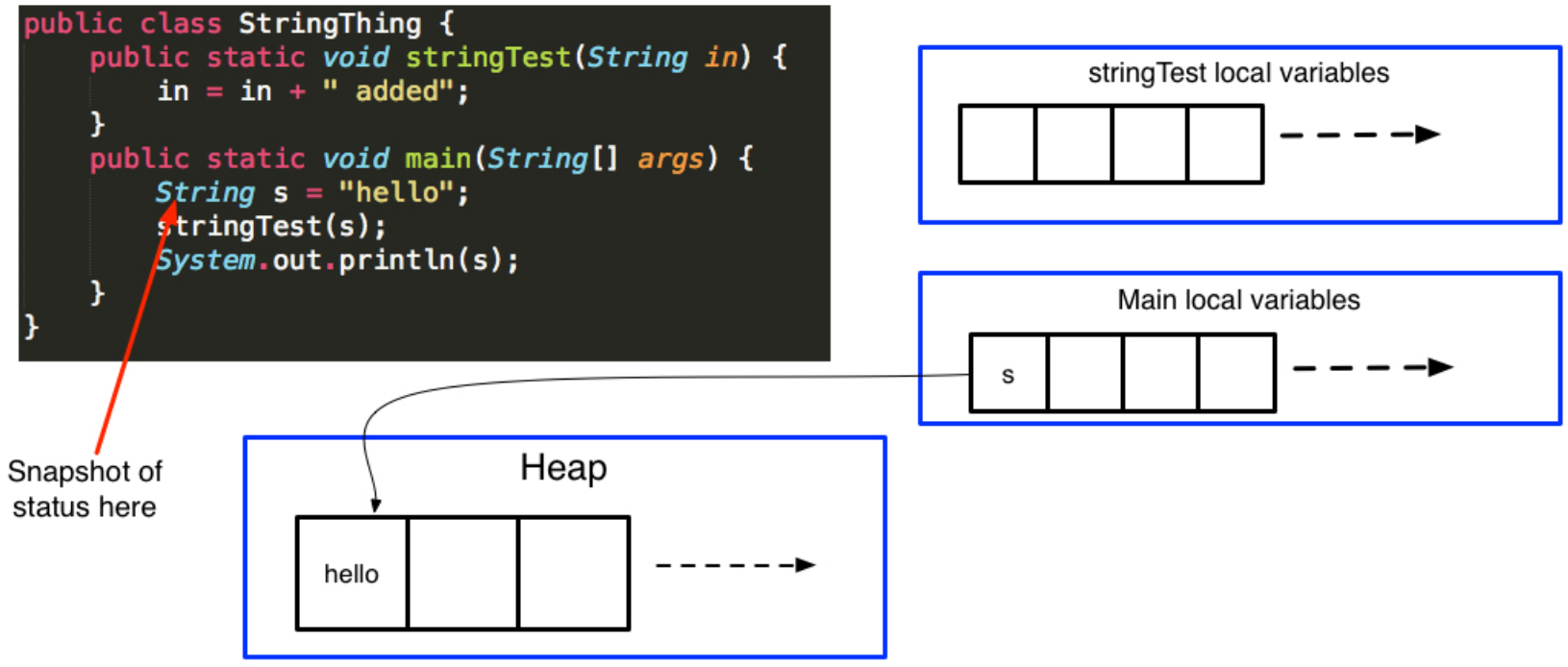

public class StringThing {
public static void stringTest(String in) {
in = in + " added";
}
public static void main(String[] args) {
String s = "hello";
stringTest(s);
System.out.println(s);
}
}
stringTest local variables
Main local variables
s
Heap
hello
Snapshot of
status here

Figure 8:

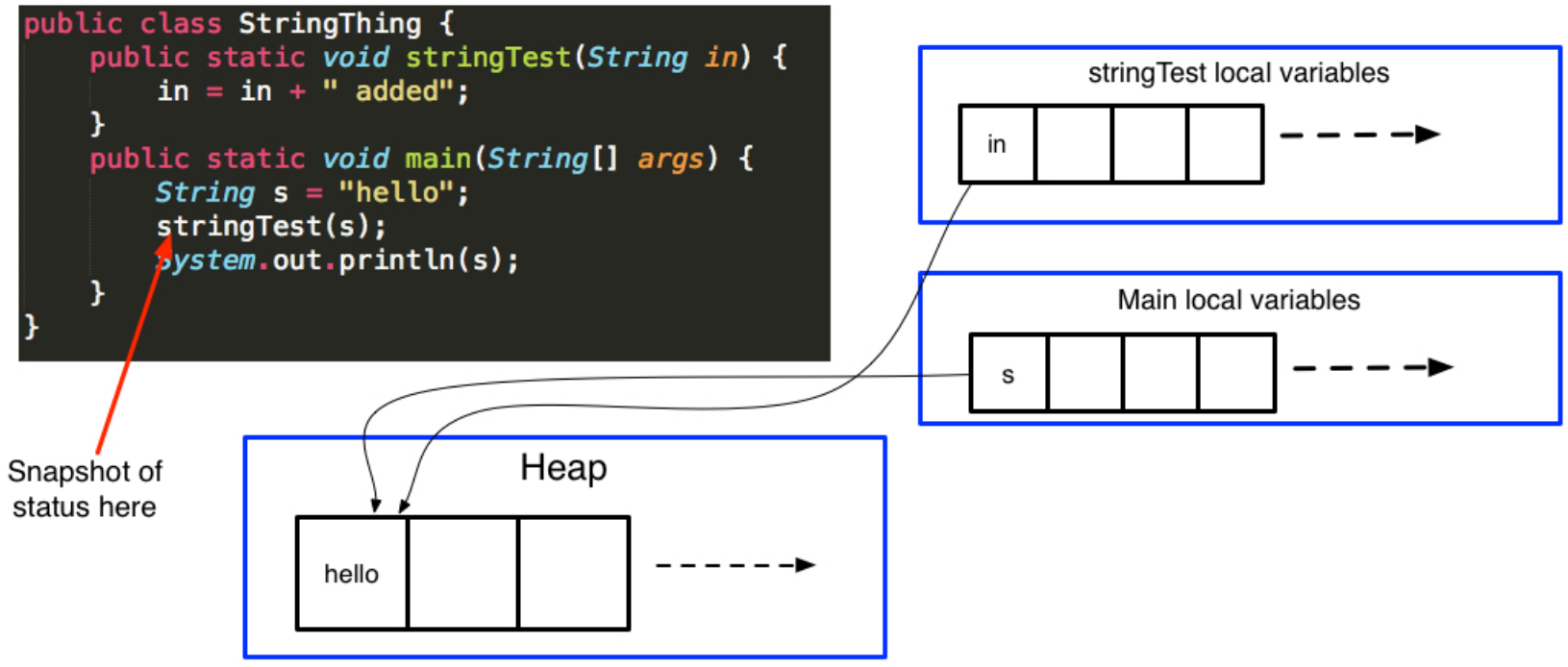

public class StringThing {
public static void stringTest(String in) {
in = in + " added";
}
public static void main(String[] args) {
String s = "hello";
stringTest(s);
System.out.println(s);
}
}
Snapshot of status here
stringTest local variables
in
Main local variables
s
Heap
hello

Figure 9:

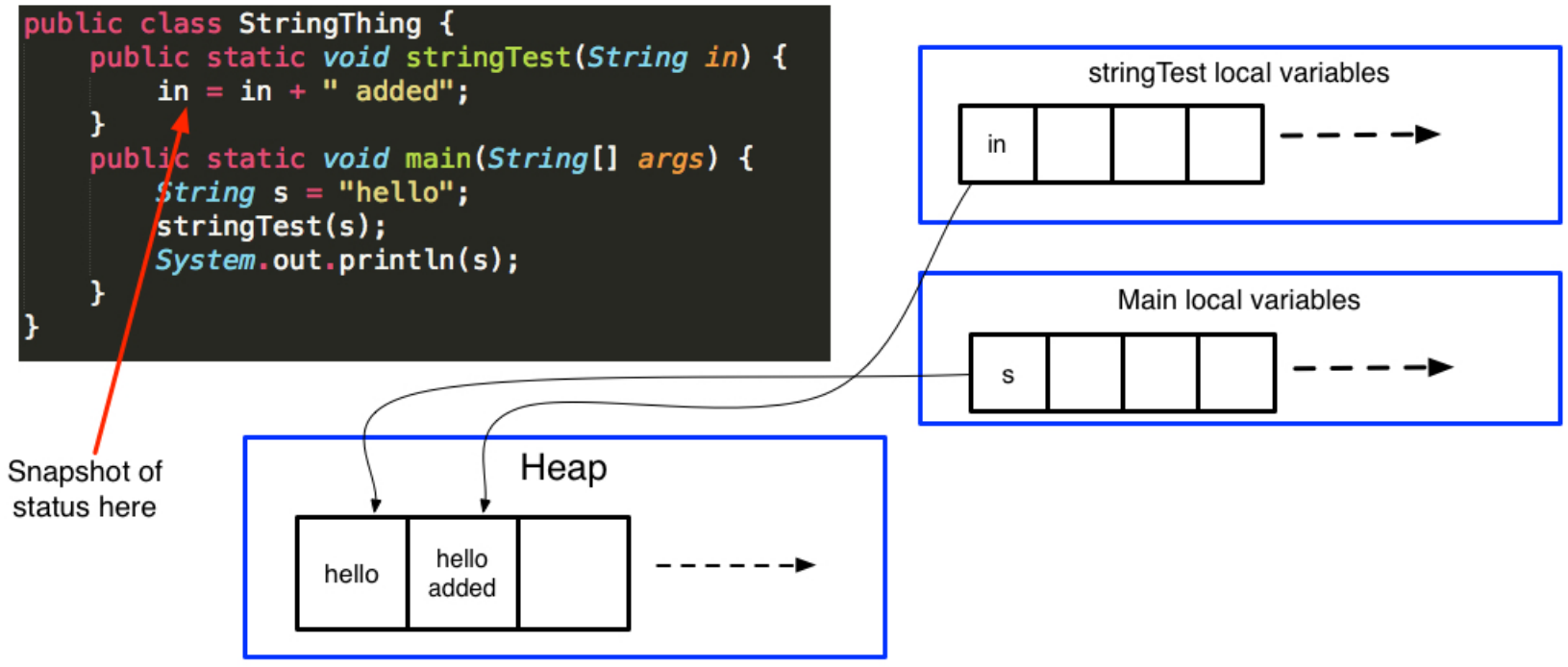

public class StringThing {
public static void stringTest(String in) {
in = in + " added";
}
public static void main(String[] args) {
String s = "hello";
stringTest(s);
System.out.println(s);
}
}
Snapshot of status here
stringTest local variables
in
Main local variables
s
Heap
hello
hello added

Figure 10:

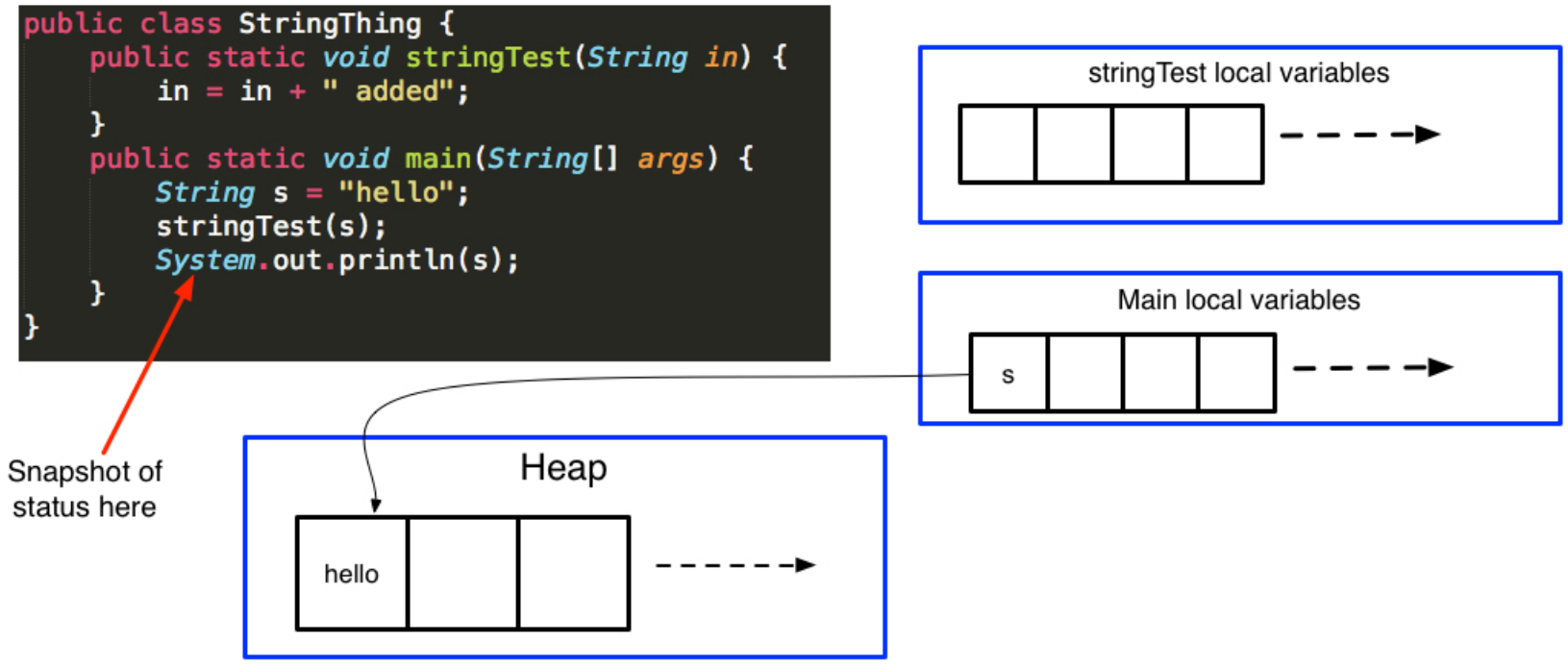

public class StringThing {
public static void stringTest(String in) {
in = in + " added";
}
public static void main(String[] args) {
String s = "hello";
stringTest(s);
System.out.println(s);
}
}
stringTest local variables
Main local variables
s
Heap
hello
Snapshot of
status here

Figure 11:

```
public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }
    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}
```

Snapshot of status here

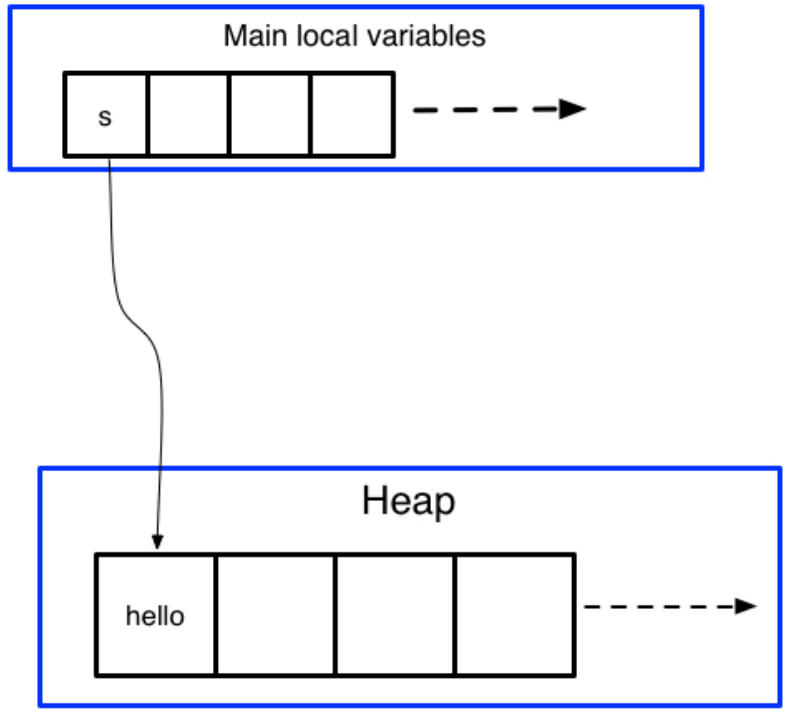


Figure 12:

```
public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }
    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}
```

Snapshot of status here

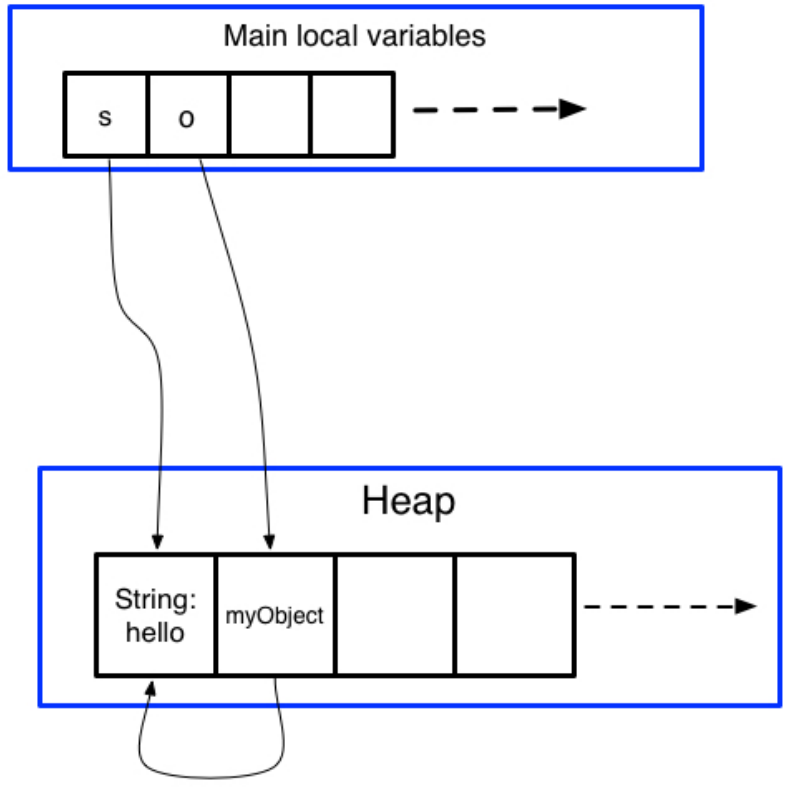


Figure 13:

```
public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }
    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}
```

Snapshot of status here

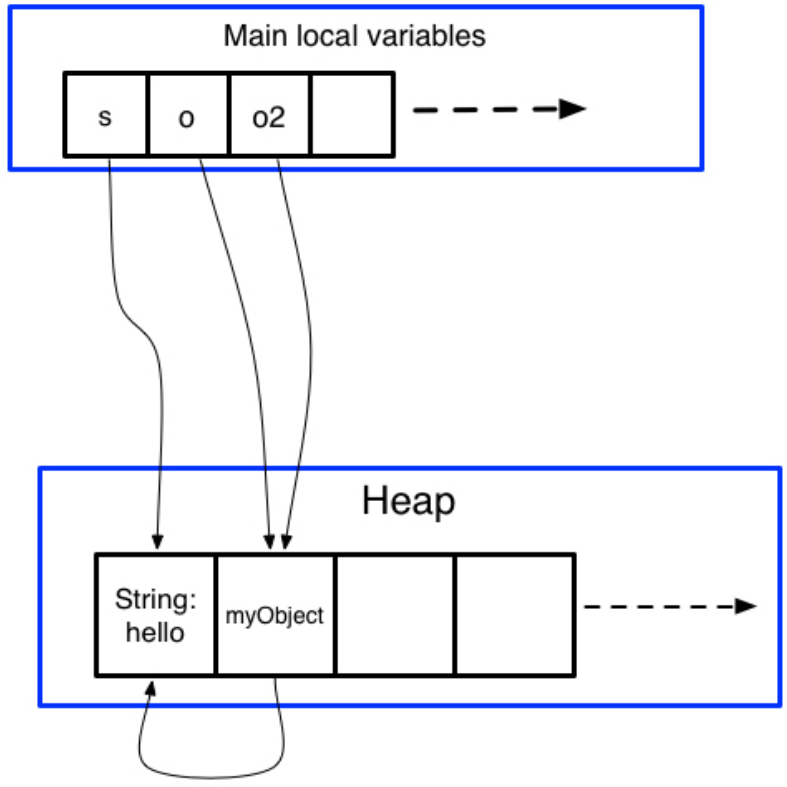


Figure 14:

```
public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }
    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}
```

Snapshot of status here

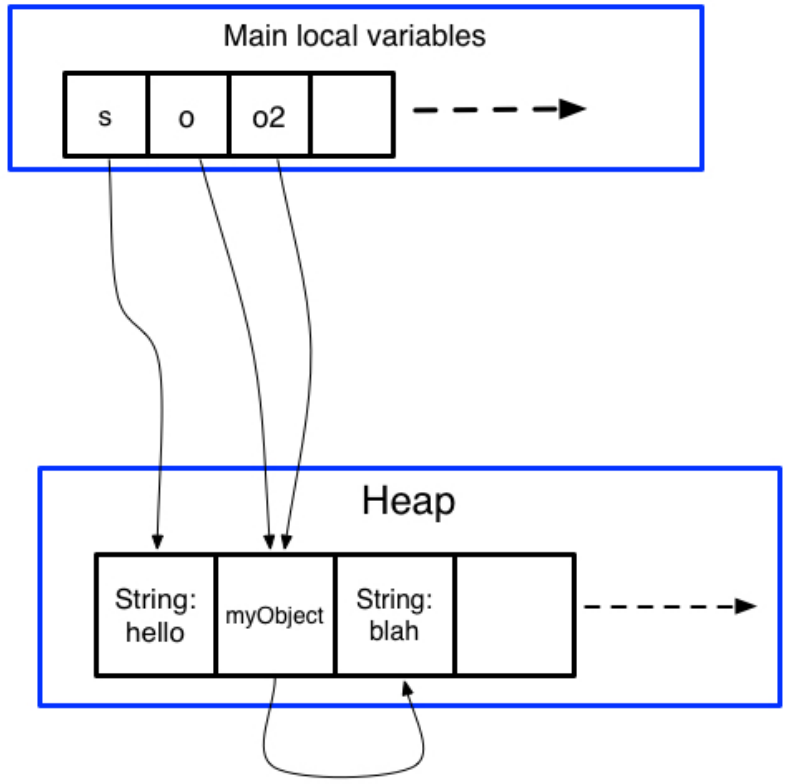


Figure 15:

- In Java, numbers and object references are call by value. Note that there is a difference between:
  - Objects are passed by reference
  - Object references are passed by value
- Objects passed to a method can be modified, but creating new ones will not be reflected in the calling scope (the reference cannot change)
  - `CallExamples`
- Objects are stored in the heap, references to objects are stored in the stack

Reference (main) Object Reference (stringTest)

```
public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}
```

Figure 16: Example program

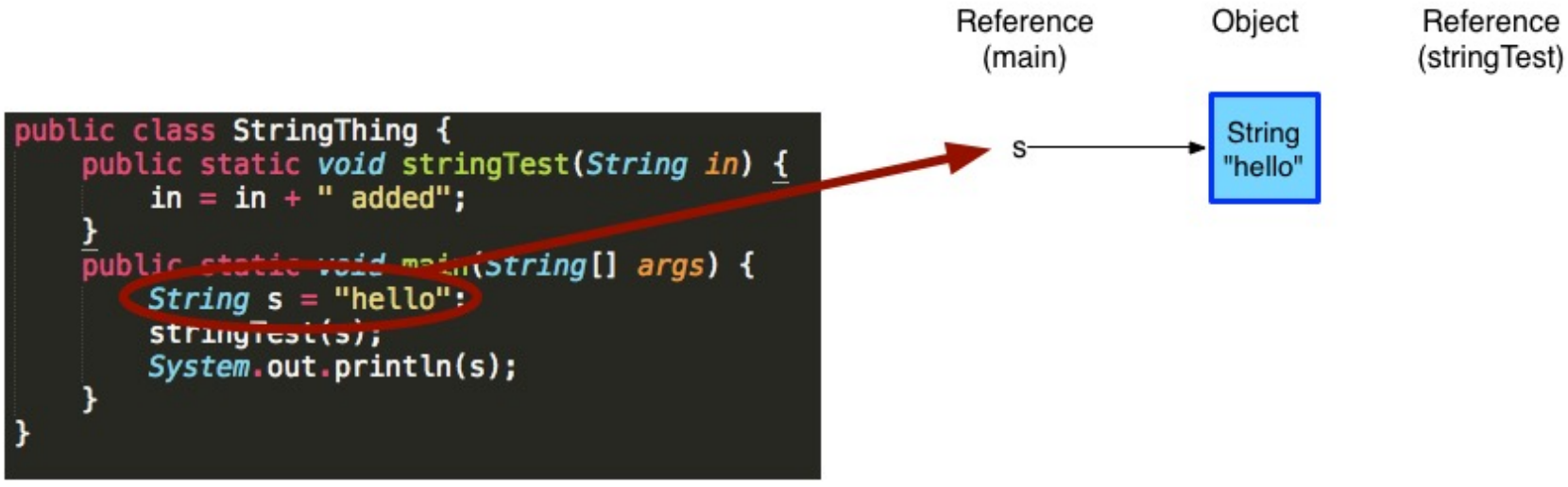


Figure 17: Main makes a String object and a reference (s)

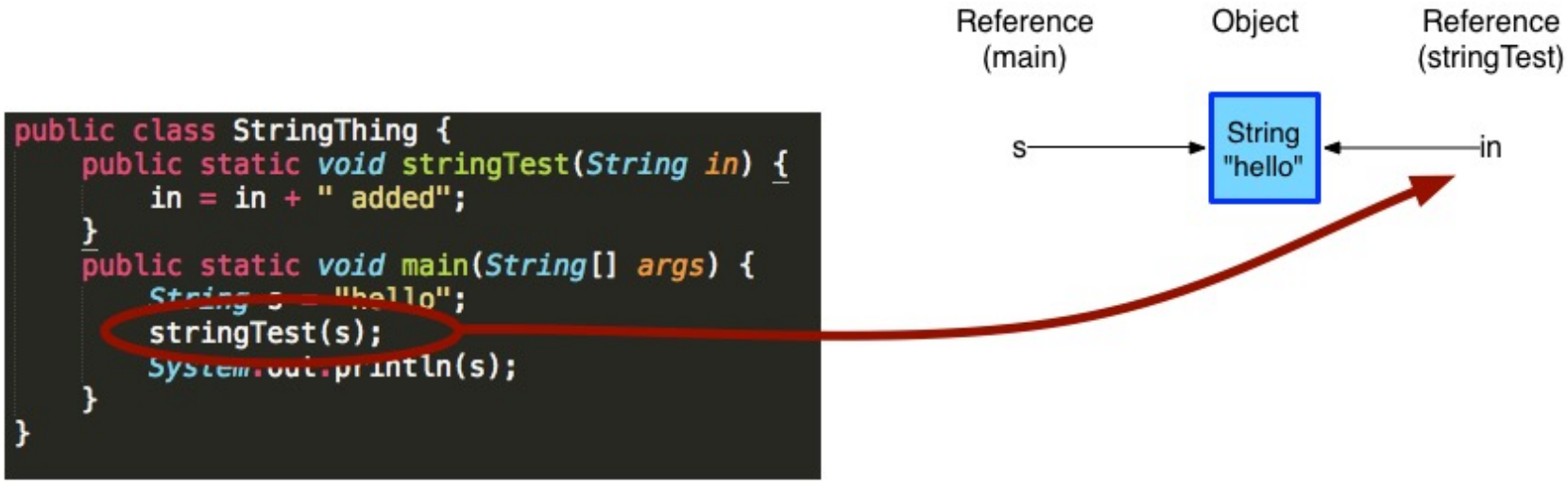


Figure 18: stringTest makes its own reference to the String object (in)

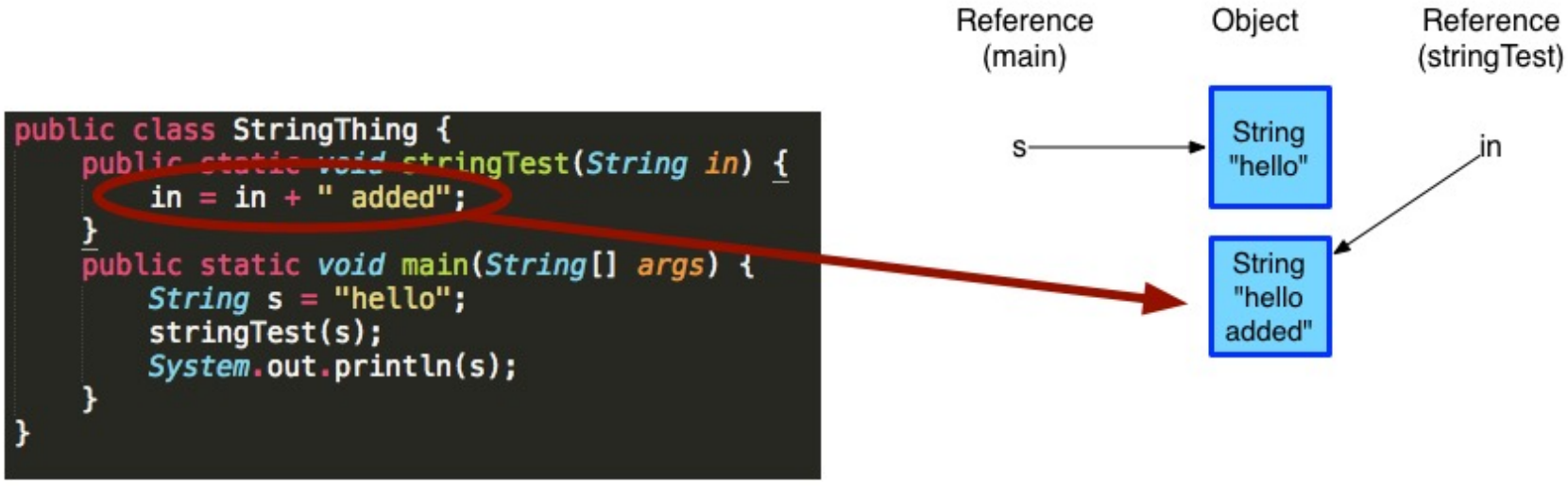


Figure 19: String is an immutable type so when we change it, a new String is made

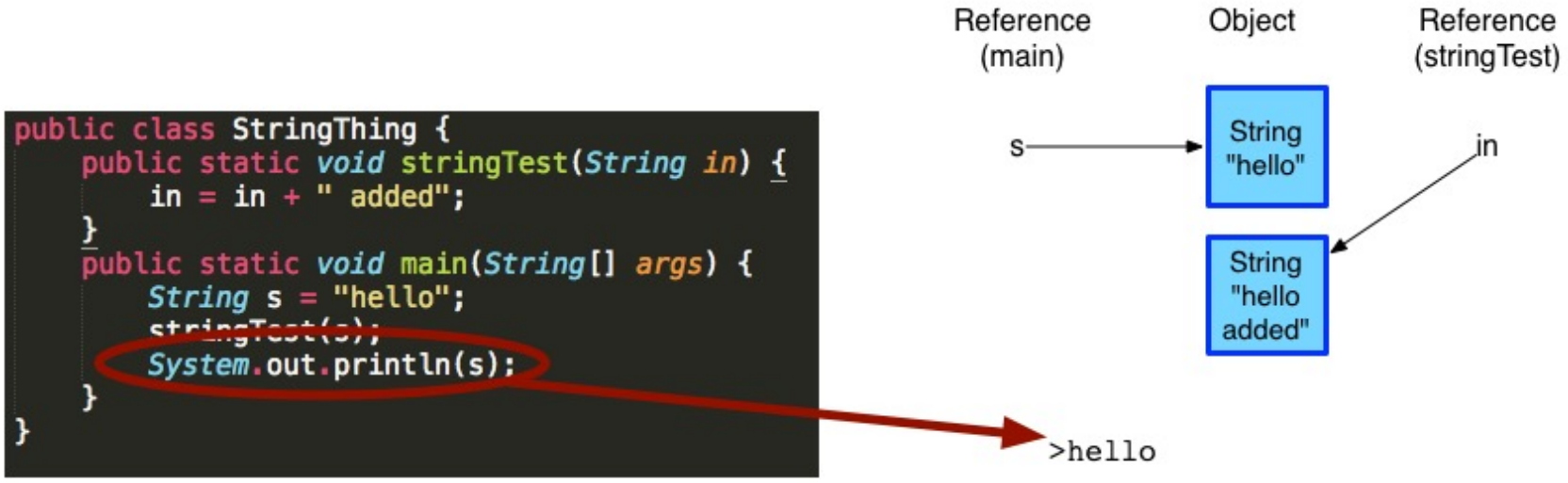


Figure 20: Back in main, s is still a reference to the original object. What happens to the "hello added" string when we return to main?

Mutable objects

- In `StringExample` the main method created a new String object `s+=" simon"`
- The original one remained unchanged
  - This is because `String` is *immutable*
- What about a mutable object?
- `MutableNastiness`
- Returning mutable objects is bad practice
- `MutableNastinessFixed` fixes it by returning a new object

Final

- It is good practice to make as many things `final` as possible
- Make as many attributes `final` as possible
- Stops other people doing bad things to your code
  - `final` classes can not be sub-classed
  - `final` methods can not be overloaded
  - `final` variables cannot be modified once declared
- `final` is not the same as `immutable`
- `FinalTest` and `FinalTestFixed`

Some useful Java objects

ArrayList

- Java arrays are of fixed length
- `ArrayList` gives you an object that can handle arrays of any object that change length

```
ArrayList<Integer> a = new ArrayList();
a.add(3);
a.add(5);
System.out.println(a.contains(4)); // Checks is 4 is in a
```

HashSet

- Useful way of keeping a set of objects together (not ordered)

```
HashSet<String> h = new HashSet<String>();
h.add("hello");
h.add("simon");
h.add("hello"); // Wont add as already in there
h.contains("hello"); // returns true
h.remove("simon"); // removes this one
```

- Very fast for checking if an item is in the set

HashMap

- Useful way of storing key,value pairs

```
HashMap<String,Double> h = new HashMap<String,Double>()
h.put("banana",3.0);
h.put("apple",2.0);
System.out.println(h.get("apple")); //print 2
h.keySet(); // Returns a set of the keys
```

- Very fast for obtaining items for a particular key

Hashing

- Hashing solves the problem of *efficiently* finding items in some collection
- We'll use the example of storing a phonebook. E.g. we want to store the following:
  - Simon, 0777777777
  - Jennifer, 0666677889
  - Ravi, 056782776
  - Ken, 0447838827
  - Hannah, 066848382

- The simplest solution would be to create two arrays (forget the problem of parallel arrays for now)
- Then, to find the number for a particular person, we loop through the array of names
- `PhoneBook1.java`

- In general looping over all entries will be slow (if lots of entries)
- A solution:
  - Assume no name longer than 15 characters
  - Create two arrays as before
  - Store the name and number in the nth position, where n = length of the name
  - `PhoneBook2.java`
- This is much quicker as we can jump directly to the correct array position.
- It is a simple example of *hashing*
- In general, hashing is a way of mapping an object to a position in an array that enables finding it quickly
- A *hash function* is the function used to map from the object to the position
- In this example, the object is a `String` and the function simply computes its length

Collisions

- What will happen if we have two names of the same length?
- A *collision*, and our simple program will fail
- Solution: maintain a list at each array position
- `PhoneBook3.java`
- Final problem is what to do if a name is longer than 15?
- Solution:
  - Fix the max length of array (e.g. 6)
  - Store entries in the position length % 6
  - `PhoneBook4.java`
- This is the basics of hashing
- Length isn't a great hash function
  - Want something that will spread the objects fairly evenly over the array

`hashCode()`

- All objects have a `hashCode()` method
- Here's equivalent code to Java's `String` hashCode function:

```
public int hashCode() {
  int hash = 0;
  for (int i = 0; i < length(); i++) {
    hash = hash * 31 + charAt(i);
  }
  return hash;
}
```

- You can overwrite `hashCode()` for your own objects
- By default the hashCode returns (roughly) the memory location of the object
- Note:
  - Two objects that are `equal` *must* have the same hash.
  - I.e. if `obj1.equals(obj2)` then `obj1.hashCode()` must equal `obj2.hashCode()`
  - Why? Think about our hashing examples...

Generics

ArrayList

- What is the `<Double>` for in `ArrayList`?
- It is a `generic`
- i.e. `ArrayList` can work with any type (specified when you create it)
- You can make classes with generics too...

Creating generic objects

```
public class MyClass<T> {
    private T t;
    public MyClass(T t) {
        this.t = t;
    }
}
```

- In the code above `T` can be any class
- Can also have multiple types in the definition (`<A,B,C,D>`)
- See `Dictionary.java`

Testing

Unit testing

- Testing individual components (e.g. classes, methods) to see if they are fit for use
- Design a suite of tests that can be run every time objects are changed
- Separates testing from the classes themselves

JUnit

- `JUnit` is a popular Java unit test framework
- A *test class* is created for each normal class
- We can then run `JUnit` and it will automatically perform the tests
- Easiest to do this directly in Eclipse

Pointless.java

```
public class Pointless {
    public int myInt;
    public Pointless(int n) {
        myInt = n;
    }
    public void increment() {
        myInt++;
    }
    public int getMyInt() {
        return myInt;
    }
}
```

Assertions

- Unit testing is done at compile time
- We might also want *runtime* checks
  - to catch runtime errors (e.g. based on input that is unknown at compile time)
- The naive way is through the use of `if` statements

```
public class AssertionExample {
    private int myInt;
    public AssertionExample(int n) {
        myInt = n;
    }
    public void decrement(int d) {
        if(d>myInt) {
            // Cannot decrement!
            System.out.println("Can't decrement!!");
        }else {
            myInt = myInt - d;
        }
    }
    public static void main(String[] args) {
        new AssertionExample(5).decrement(10);
    }
}
```

- Assertions are a neater way to achieve this
  - Cause the program to exit if the condition is not met
  - Can be switched on or off at runtime
    - e.g. switch between runtime and debugging

```
public class AssertionExample2 {
    private int myInt;
    public AssertionExample2(int n) {
        myInt = n;
    }
    public void decrement(int d) {
        assert myInt >= d;
        myInt = myInt - d;
    }
    public static void main(String[] args) {
        new AssertionExample2(5).decrement(10);
    }
}
```

- Running:

```
java -enableassertions AssertionExample2
```

- can also use `-ea`
- Try running with and without
- An alternative is to explicitly throw exceptions but..
  - Takes longer to write
  - Exceptions cannot be switched off at runtime (slows things down)

JavaDoc

- It's very important to properly document your code
- Standard comments // /* are good
- Javadoc is better!
- [This]{http://agile.csc.ncsu.edu/SEMaterials/tutorials/javadoc/} is quite a good tutorial

Things we are not covering here

Testing

- We have only touched upon testing. It's very important! Those of you doing SE will cover it more there.
- Much software engineering is now done in a *test driven* manner.
  - First write test cases and then write code.
  - Stop coding when the test cases are finished.
  - Writing a good set of test cases is hard!

Data structures

- We make use of Java objects (e.g. `ArrayList`) but we don't worry about how Java implements this
- We also don't worry too much about the efficiency of different data structures and algorithms
- Those of you in ADS will do lots of this

Build systems

- Compiling from the command line is fine for simple projects
- But..when you have a more complex project with lots of *dependencies* things get very complex
- Systems exist to help you with this
- Examples:
  - Maven (the current standard for Java)
  - ANT (older but still popular)
- See Tim Storer's ANT guide on Moodle

Software Engineering

- Programming is only a small part of building software
- Engineering large software projects is hard (evidenced by the number of times they end badly)
- Youll get lots of SE in, erm, SE