Garbage Collection

covering

** Objects and Variables: Heap *versus* Stack

** (Overloaded) Constructors, **`this()`**, **`super()`**

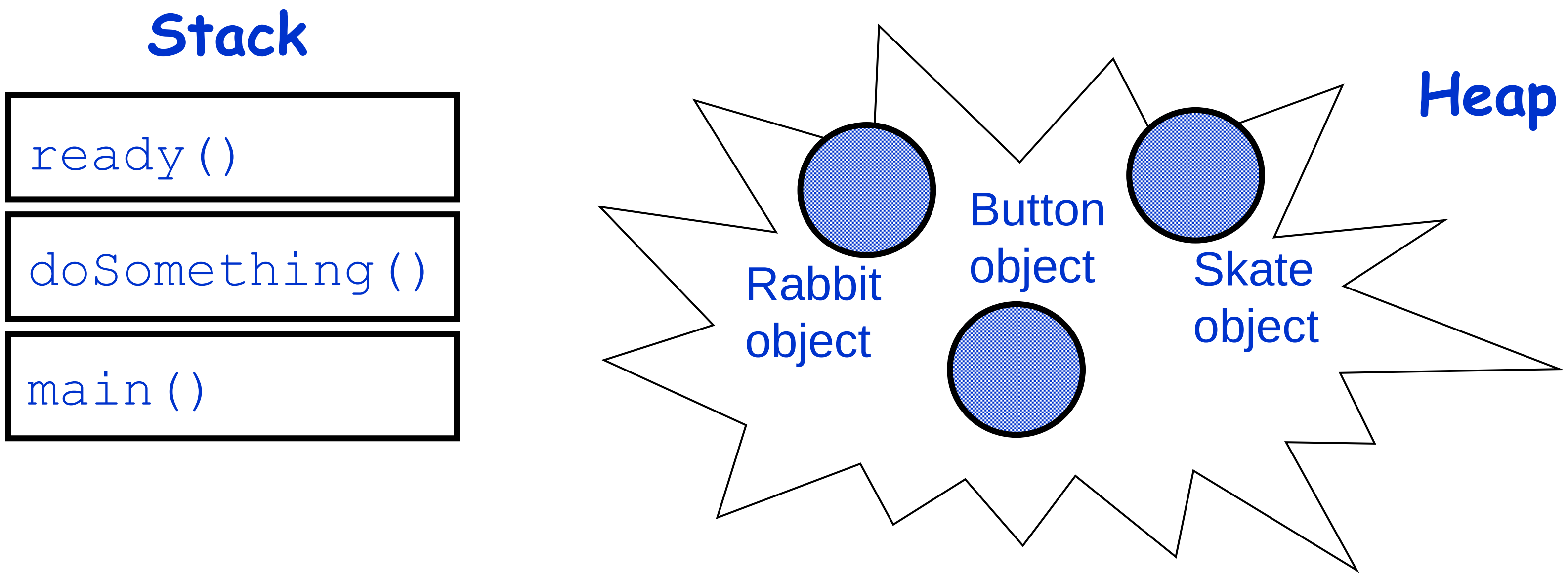
** Life of an Object // Scope of a Variable

** Garbage Collector // **`null`** References

Chapters 4+5, (sections 4.3, 4.6, 5.1) – “Big Java” book
Chapter 9 – “Head First Java” book
Chapters 5, 8, 10 (sections 5.9, 8.4-8.5, 10.3-10.4) – “Introduction to Java Programming” book
Chapter 6 – “Java in a Nutshell” book

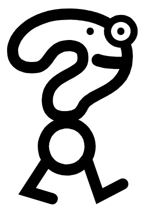
Heap *versus* Stack

- **Running a Java program**:
  - Memory is obtained by the JVM, from the OS being used.
- **Two main areas of memory in Java**:
  - (Garbage-collectible) Heap (where **objects** live);
  - Stack (where **local variables** and **methods,** when called, live).



Local Variables & Instance Variables

- **Main types of variables we care about**:
  - Local (*also known as* stack) variables
    - Variables declared in a method and method parameters.
    - Temporary variables, alive only when the method they belong to is on the *Stack*.
  - Instance variables
    - Variables declared in a class (**not** inside of a method).
    - Live inside the object they belong to.



So where do instance variables live?

Example: Local *versus* Instance Variables

```
public class Dog {
   int size;
   String name;

   private int maxDistanceRun(int timeRun) {
      int maxSpeed = 10;
      int maxDistance = maxSpeed * timeRun;
      return maxDistance;
   }
}
```

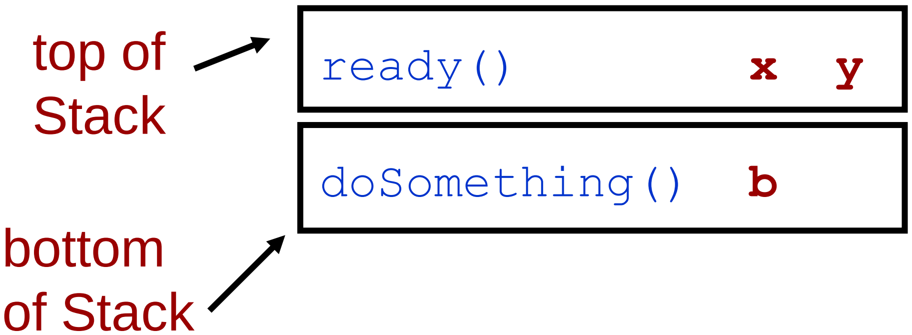
instance variables; every Dog has a “size” and “name”

local variables

What is the difference between instance and class variables?

Methods and the Stack

- Method goes on top of the *Stack* when it is called and stays in the *Stack* until it's done (closing curly brace).
- **Stack frame**:
  - What actually is pushed onto the *Stack*.
  - Contains the state of the method (which line of code is executing and values of all local variables).
- Method at top of the *Stack* is <u>always</u> the method being executed.
- **Example**:




```java
public void doSomething() {
  boolean b = true;
  ready(10);
}
public void ready(int x) {
  int y = x * 24;
  // more code here
}
```

Object References & Where Variables Live

- Object reference **(***aka* non-primitive**)** variables:
  - Hold a reference to an object, not the actual object.
  - A local variable that is a reference to an object goes on the *Stack* (the object it refers to still goes on the *Heap*).
- **Where variables** (primitive and non-primitive types) **live**:
  - Local variables (on the *Stack*)
  - Instance variables (on the *Heap*)

Why learn about the *Stack* and *Heap*?

- **Required in order to understand**,
  - variable scope;
  - issues with creating objects;
  - memory management (*);
  - threads (**);
  - exception handling (*).

(*) Later in the course!
(**) Covered in advanced course!

- **Heap and Stack**:
  - Not necessary to know how they're implemented on a given JVM or platform!

Initialising Object State

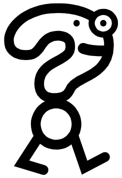
- **Using a constructor to initialise object state** (i.e. instance variables):
  - Most common use of constructors.
  - Constructors: the best place to put initialisation code.
  - Programmers should always write a “no arguments” constructor (to build an object with default values): makes things easier for the program’s users.
  - **Example**:

instance variable

constructor

mutator/setter method

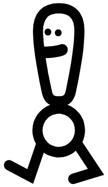
```
public class Dog {
  private String name;
  public Dog() {
    System.out.println("Woof, Woof!");
  }
  public void setName(String newName) {
    this.name = newName;
  }
}
public class UseADog {
  public static void main (String[] args) {
    Dog myDog = new Dog();
    myDog.setName("Rover");
  }
}
```



Is this OK?

Example: Two Constructors for an Object

```
public class Dog {
  private int weight;
  public Dog() {
    // Use a default weight (in Kg).
    this.weight = 30;
  }
  public Dog(int dogWeight) {
    // Use the dogWeight parameter.
    this.weight = dogWeight;
  }
}
```



There is a *special name* for this type of constructors.

- Making a **Dog** in two different ways:

```
Dog myDog = new Dog(15);
Dog anotherDog = new Dog();
```

if you know the dog's weight

if you don't know the dog's weight

Overloaded Constructors

- When you have more than one constructor in a class.
- Must have different argument lists (it's the variable type and order that matters);
- There may be cases where a no-arguments constructor makes no sense (e.g. making a **`Color`** object).
- **Example**:

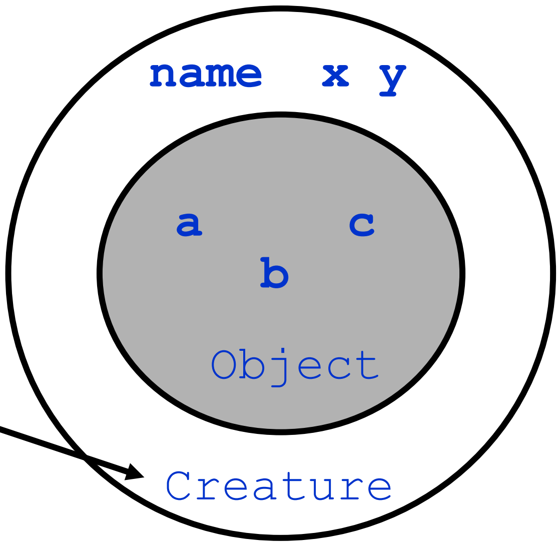
no-arguments constructor, when you just want to create an `Account`

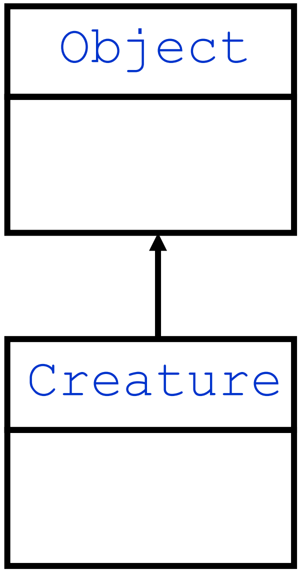
```
public class Account {
  public Account() {}
  public Account(int balance) {}
  public Account(boolean giveOverdraft) {}
  public Account(int balance, boolean giveOverdraft) {}
  public Account(boolean junior, int balance) {}
}
```

Superclasses, Inheritance & Constructors

- **How they relate**:
  - Every object holds both its own declared instance variables and everything from its superclasses.
  - When an object is created, that object will have “layers” of itself representing each superclass.
  - Remember: Every class in Java extends class **`Object`** (it’s the mother of all classes!).
  - **Example**:

a `Creature` object on the *Heap*





As a consequence, we have Constructor Chaining

- **Superclass constructors** (or constructor chaining):
  - When a new object is created, all the constructors in its inheritance tree must be run.
  - Saying **`new`** triggers a ‘chain reaction’ of constructors being run implicitly.
  - An object is only completely formed when all the superclass parts of itself are formed.

Example (to demonstrate): Constructor Chaining

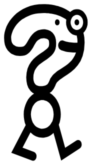
```
public class BigCat {
  public BigCat() {
    System.out.println("Making a BigCat");
  }
}

public class Tiger extends BigCat {
  public Tiger() {
    System.out.println("Making a Tiger");
  }
}

public class TestTiger {
  public static void main(String[] args) {
    System.out.println("Starting ...");
    Tiger myTiger = new Tiger();
  }
}
```

Output is …

```
% java TestTiger
Starting ...
Making a BigCat
Making a Tiger
```

Calling and Making Constructors

- Calling a superclass constructor:
  - using **super()** calls the super constructor;
  - using **super()** in your constructor puts the superclass on the top of the stack.



What does this trigger?

It is usually only used when we don't want to call the parent's no-args constructor (which means that we usually use **super()** with arguments).

  - **Example**:

```
public class Tiger extends BigCat {
  private int size;
  public Tiger(int newSize) {
    super();
    size = newSize;
    System.out.println("Making a Tiger");
  }
}
```

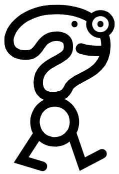
- **Compiler and making constructors**:
  - if no constructor is provided, the compiler adds one that looks like:

    `public ClassName() { super(); }`

  - if you provide a constructor but do not add a call to **super()**, the compiler puts such a call in each of your overloaded constructors.

Using `super()` (1/2)

- The call to **`super()`** must be the first statement in a constructor.



Are all these constructors OK?

```
public Dog() {
  super();
}
```

```
public Dog(int dogWeight) {
  weight = dogWeight;
  super();
}
```

```
public Dog() {}
```

```
public Dog(int dogWeight) {
  weight = dogWeight;
}
```

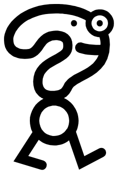
Using `super()` (2/2)

- You can pass arguments into a call to `super()`.

```
public class Creature {
  private String name;
  public String getName() {
    return this.name;
  }
  public Creature(String aName) {
    this.name = aName;
  }
}
public class Rabbit extends Creature {
  public Rabbit(String name) {
    super(name);
  }
}
```

Output is …

```
% java TestRabbit
Bunny
```



What does this statement do here?

```
public class TestRabbit {
  public static void main(String[] args) {
    Rabbit aRabbit = new Rabbit("Bunny");
    System.out.println(aRabbit.getName());
  }
}
```

Overloaded constructors, `super()` and `this()`

- To call a constructor from another overloaded one in the same class, use **`this()`** – must be the first statement in the constructor.
- A constructor can have a call to either **`super()`** or **`this()`** but not to both!

```
public class Tiger extends BigCat {
  private int speed;

  public Tiger() {
    this(5);
  }
  public Tiger(int newSpeed) {
    super("Tiger");
    this.speed = newSpeed;
    // maybe more initialisation
  }
```

cont.

```
  public Tiger(String newName) {
    this(5);
    super(newName);
  }
}
```

```
% javac Tiger.java
Tiger.java:14: call to
super must be first
statement in constructor
            super();
                 ^
```

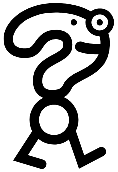
Output is …

Life of Objects and Variables (1/2)

- Life of an object: depends only on the life of reference variables referring to it.
  - Object is ***alive*** (or ***dead***) if its reference is ***alive*** (or ***dead***).
- Variable lifetime:
  - same for primitive and reference variables;
  - different for local and instance variables.

```
public class ExampleGoneWrong {
  public void method1() {
    int x = 10;
    method2();
  }
  public void method2() {
    x = 20;
  }
}
```

local variable **x** is *out of scope* here



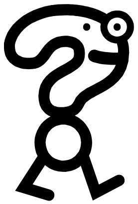
Is x *alive* here?

… and things for you to try out!

Life of Objects and Variables (2/2)

- Life duration:
  - **local variables**: live only within the method that declared it (also referred to as ***being in scope***);
  - **instance variables**: live for as long as object they belong to lives.

```
public class Dog {
  private String name;
  // name can be used throughout the class.
  public void setName(String dogName) {
    this.name = dogName;
    // dogName disappears at the end of the method.
  }
  public void sleep() {
    int x = 10;
  }
}
```



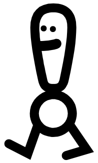
What about the *scope* of variable **`x`**?

Local Variables: Life *versus* Scope

- **Local Variable**:
  - Is **alive** as long as its *Stack* frame is on the *Stack*, i.e. until the method it belongs to completes.
  - Is **in scope** only within the method where it was declared.
  - Is alive (and maintains its state) but is not in scope when its own method calls another.
  - A (reference) variable can only be used when it is in scope.

`go()`	**c**	
`ready()`	**x**	**y**
`doSomething()`	**b**	

Stack

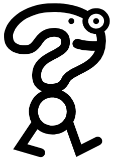


All 3 methods not always on the *Stack*!

```
public void doSomething() {
   boolean b = true;
   ready(10);
}
public void ready(int x) {
   int y = x * 24;
   go();
}
public void go() {
   char c = 'T';
}
```

Practice Exercise 1

- Show the contents of the stack before **`max()`** is invoked, just entering **`max()`**, just before **`max()`** is exited, and after **`max()`** is exited.



What is the output of the program?

```
public class Test {
  public static void main(String[] args) {
    Test myTest = new Test();
    int max = 0;
    myTest.max(1, 2, max);
    System.out.println(max);
  }
  public void max(int value1, int value2, int max) {
    if (value1 > value2) { max = value1; }
    else { max = value2; }
  }
}
```

Answer: Practice Exercise 1 *[to be completed in class …]*

Space required for
the **main()** method

args: null
max: 0

just before
invoking **`max()`**

just entering
`max()`

just before exiting
from **`max()`**

just after
exiting **`max()`**

Life of an Object (again) & GC (1/2)

- Objects in Java are *dynamically* allocated and created *on demand*:
  - memory space for an object is allocated at *runtime*, not at *compile time*;
  - the **`new`** statement causes the memory for an object to be allocated (similar to the **C `malloc()`** function).
- As a consequence, the memory taken up by a program will grow (and shrink) as the program executes.
- **Example**:

```
for (long i = 0; i < 10000000; i++) {
    Date d = new Date();
}
```

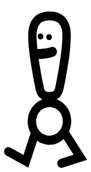
What happens here?

- Once a **reference to an object is lost**, it can never be regained!
  - The object is still taking up memory, but cannot be used by the program.
- **Memory Leak**:
  - In C, this is a classic reason for program failure.
  - In Java, we don't need to worry about this: it handles *garbage collection* for us.

Life of an Object (again) & GC (2/2)

- An **object is alive as long as there are live references to it**.
  - If an object has only one reference to it and the *Stack* frame holding it gets popped off the *Stack*, then the object is now abandoned in the *Heap*.
    - In this case, the object becomes eligible for Garbage Collection (GC).

- **Objects eligible for GC**:
  - **Programmers** don't need to reclaim their used memory, but they need to make sure objects are abandoned, when appropriate.
  - If a **program gets low on memory**, the GC will destroy as many eligible objects as possible, to avoid the program running out of RAM.



This is not full proof!

Making an Object Eligible for GC

- Ways to get rid of an object's references:
  - (1) The reference goes out of scope, permanently.
  - (2) The reference is assigned to another object.
  - (3) The reference is explicitly set to **`null`**.

```
public void doSomething() {
  Car myCar = new Car();    (1)
}
```

```
Car myCar = new Car();
myCar = new Car();          (2)
```

```
Car myCar = new Car();
myCar = null;               (3)
```

- **Note**: The opposite of a Java constructor is a finalizer; it can sometimes be used for the *cleanup* of an object.

`null` References

- **Setting a reference variable to `null`** (it means ***no object***).
  - If you use the dot operator on a null reference, you will get a **`NullPointerException`** error at runtime.
  - Unless initialised/assigned to, instance reference variables have a default value of **`null`**.

```
public class Student {
   String name;
   int age;
   boolean isMScStudent;
   char gender;

   public static void main(String[] args) {
      Student aStudent = null;
      System.out.println("Student name? " + aStudent.name);
   }
}
```

`name` not initialised so has default value of **`null`**

default values are: 0; **`false`**; **`'\u0000'`**

this will cause a **`NullPointerException`** runtime error

Practice Exercise 2

- What is wrong with the code below?

```
public class Foo {
  public void method1() {
    Circle c = null;
    System.out.println("What is radius " +
                                                c.getRadius());
    c = new Circle();
  }
}
```

Assumption: **`Circle`** is a class we have defined somewhere else.

… and things for you to try out!