Chapter 10
Classes and Objects:
A Deeper Look (Ⅱ)

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Objectives

- To use `static` variables and methods
- To organize classes in packages to promote reuse
- Class member access levels
- Declare constants with the `final` keyword
- Enumerations
- Stack and heap memory

`static` Class Members

- Recall that every object of a class has its own copy of all the instance variables of the class.
  - Instance variables represent concepts that are unique per instance, e.g., `name` in class `Employee`.
- In certain cases, only one copy of a particular variable should be shared by all objects of a class (e.g., a counter that keeps track of every object created for memory management).
  - A `static` field—called a class variable—is used in such cases.

static Class Members

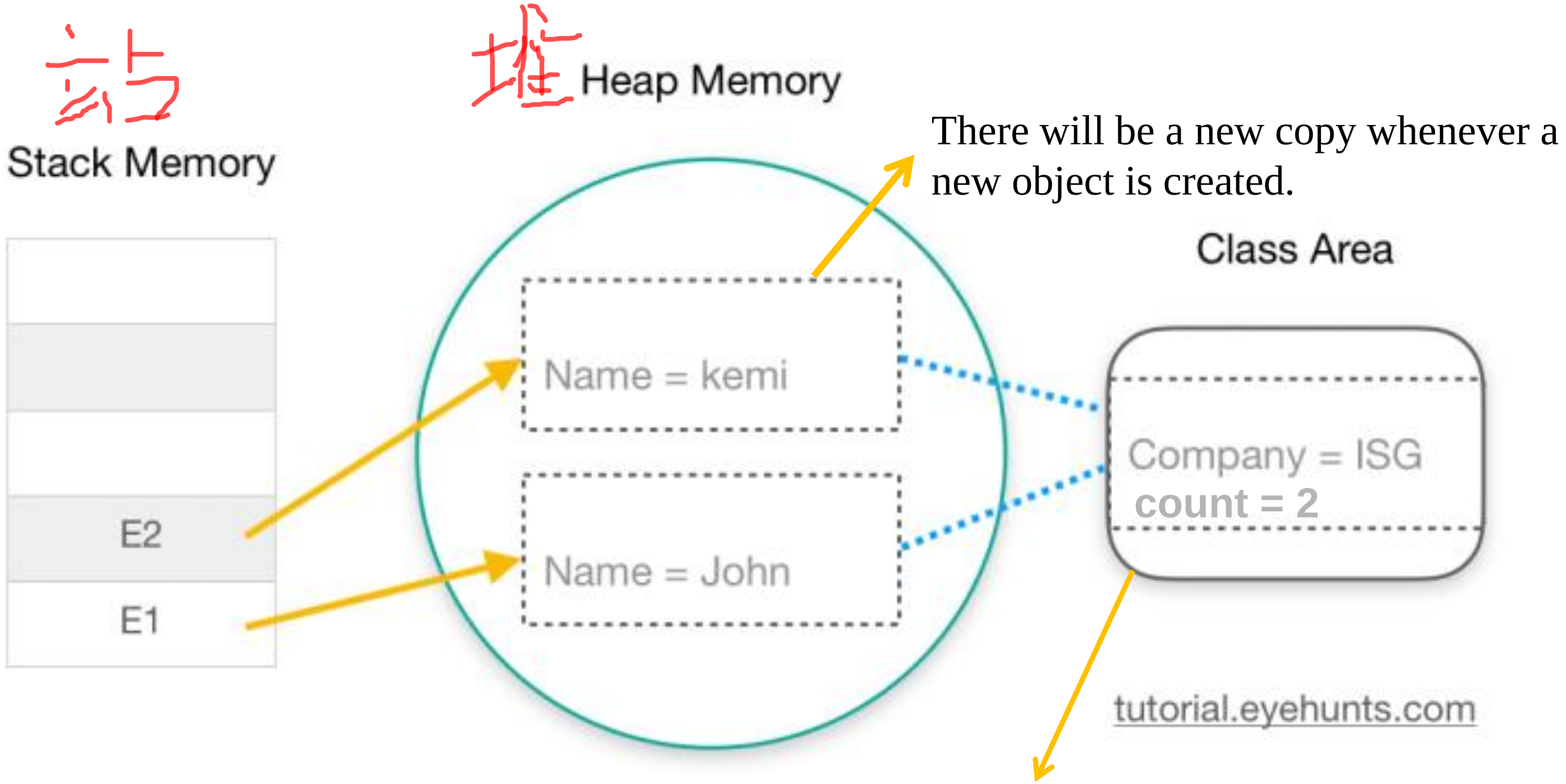
- A static variable represents class-wide information. All objects of the class share the same piece of data.

```
public class Employee {

    private String name;

    private static int count; // number of employees created

}
```

There will be a new copy whenever a new object is created.

There is only one copy for each static variable. Make a variable static when all objects of the class must use the same copy of the variable.

static Class Members



There will be a new copy whenever a new object is created.

There is only one copy for each static variable. Make a variable `static` when all objects of the class must use the same copy of the variable.

Example

```
public class Employee {
    private String firstName;
    private String lastName;
    private static int count; // number of employees created
    public Employee(String first, String last) {
        firstName = first;
        lastName = last;
        ++count;
        System.out.printf("Employee constructor: %s %s; count = %d\n",
                         firstName, lastName, count);
    }
    public String getFirstName() {  return firstName;  }
    public String getLastName() {  return lastName;  }
    public static int getCount() {  return count;  }
}
```

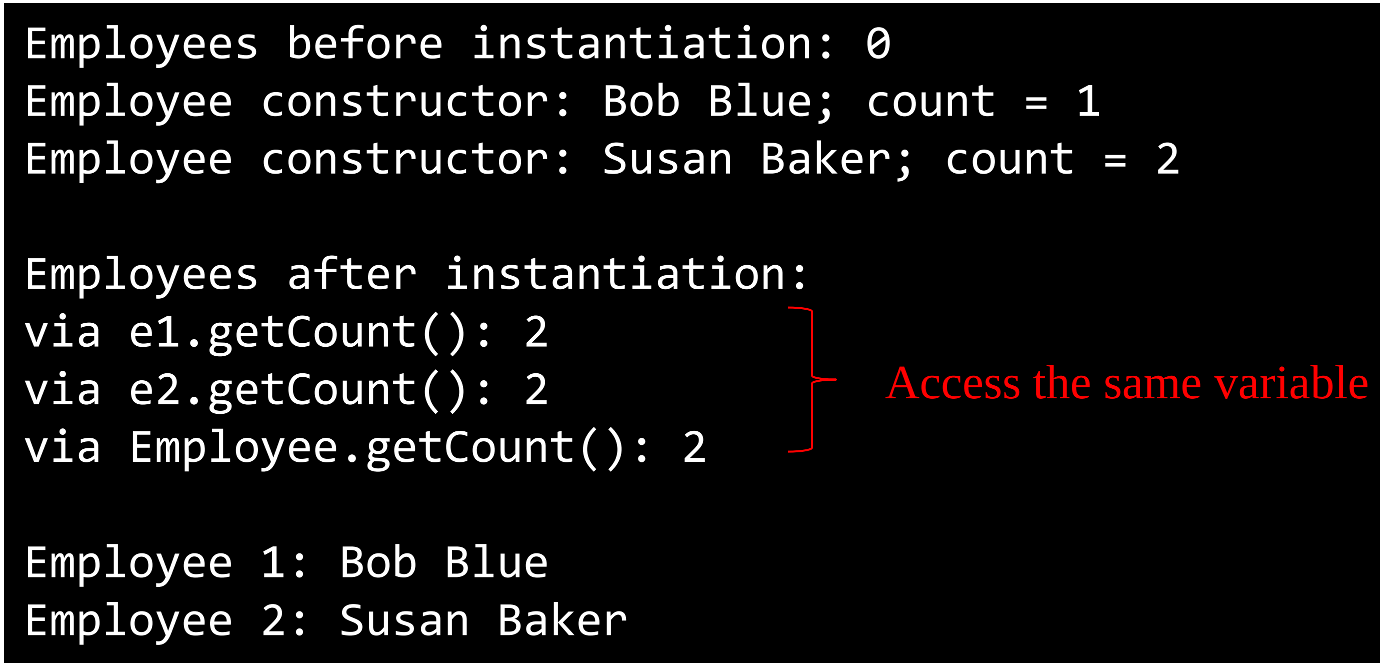
Example

```
public class EmployeeTest {
  public static void main(String[] args) {
    System.out.printf("Employees before instantiation: %d\n",
                       Employee.getCount());
    Employee e1 = new Employee("Bob", "Blue");
    Employee e2 = new Employee("Susan", "Baker");
    System.out.println("\nEmployees after instantiation:");
    System.out.printf("via e1.getCount(): %d\n", e1.getCount());
    System.out.printf("via e2.getCount(): %d\n", e2.getCount());
    System.out.printf("via Employee.getCount(): %d\n", Employee.getCount());
    System.out.printf("\nEmployee 1: %s %s\nEmployee 2: %s %s\n",
                      e1.getFirstName(), e1.getLastName(),
                      e2.getFirstName(), e2.getLastName());
  }
}
```

The only way to access private static variables at this stage

More choices when there are objects

Example



```
Employees before instantiation: 0
Employee constructor: Bob Blue; count = 1
Employee constructor: Susan Baker; count = 2

Employees after instantiation:
via e1.getCount(): 2
via e2.getCount(): 2
via Employee.getCount(): 2

Employee 1: Bob Blue
Employee 2: Susan Baker
```

Access the same variable

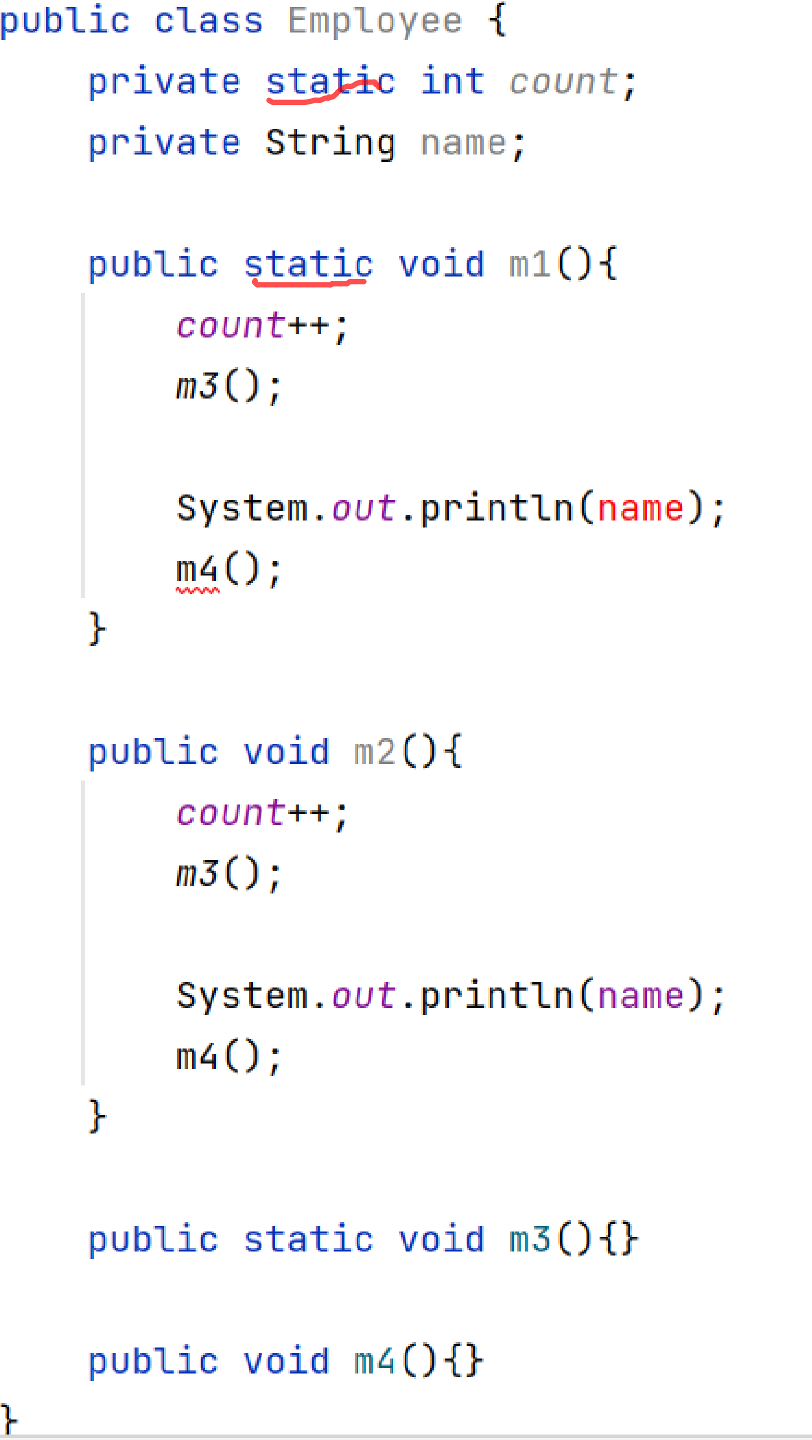
static Class Members

- getCount() is a static method
- getCount() accesses a static variable count

```
public class Employee {
    private String name;
    private static int count; // number of employees created
    public static int getCount() {  return count;   }
}
```

Can getCount() access the instance variable name?

Can we make getCount() an instance method?



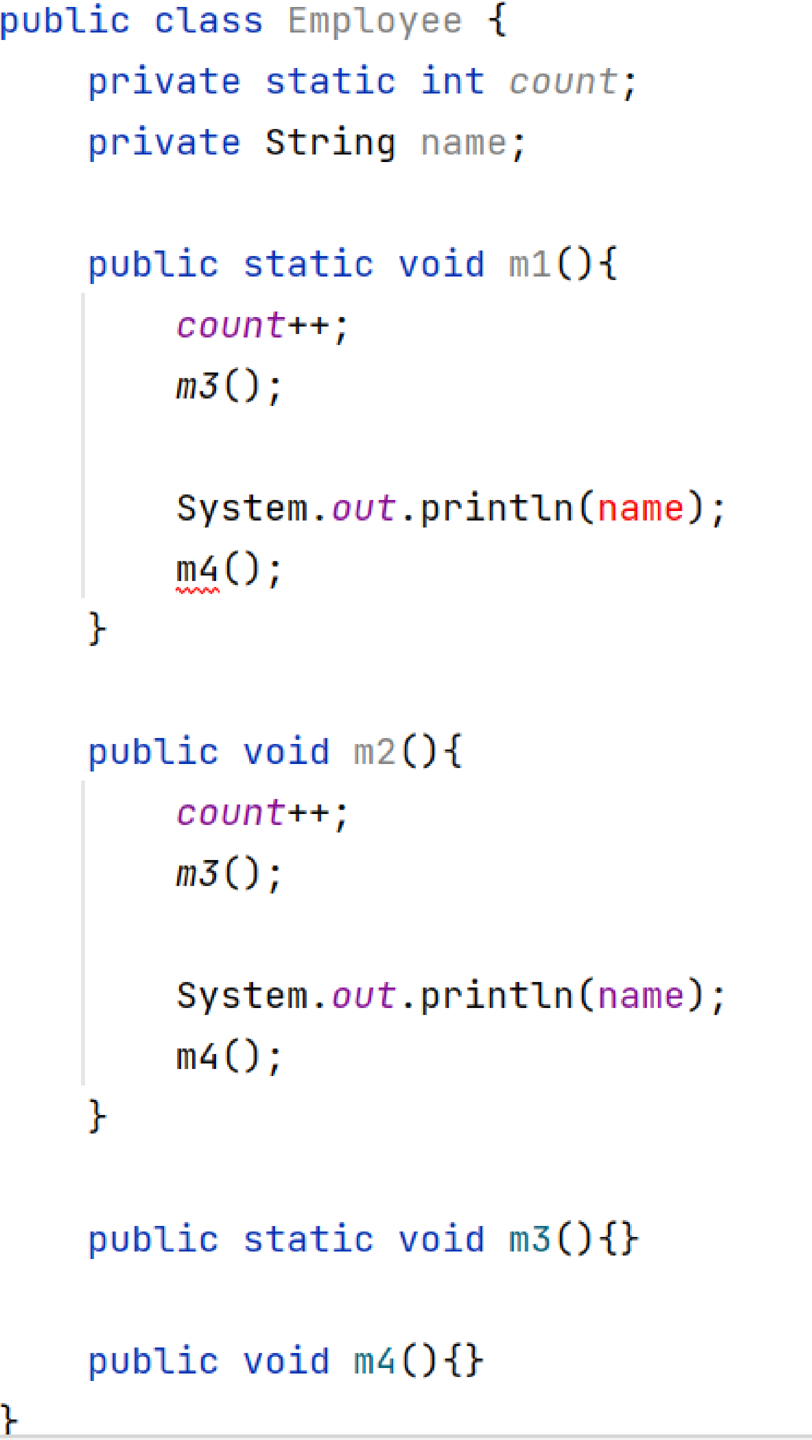
```
public class Employee {
    private static int count;
    private String name;

    public static void m1(){
        count++;
        m3();

        System.out.println(name);
        m4();
    }

    public void m2(){
        count++;
        m3();

        System.out.println(name);
        m4();
    }

    public static void m3(){}

    public void m4(){}
}
```

- count is static/class variable
- name is instance variable

Static method m1

- can access static variable count and static method m3
- CANNOT access instance variable name and instance method m4

- `static` class members are available as soon as the class is loaded into memory at execution time (objects may not exist yet)
- A `static` method CANNOT access non-static class members (instance variables, instance methods), because a static method can be called even when no objects of the class have been instantiated.
- For the same reason, the `this` reference cannot be used in a `static` method.

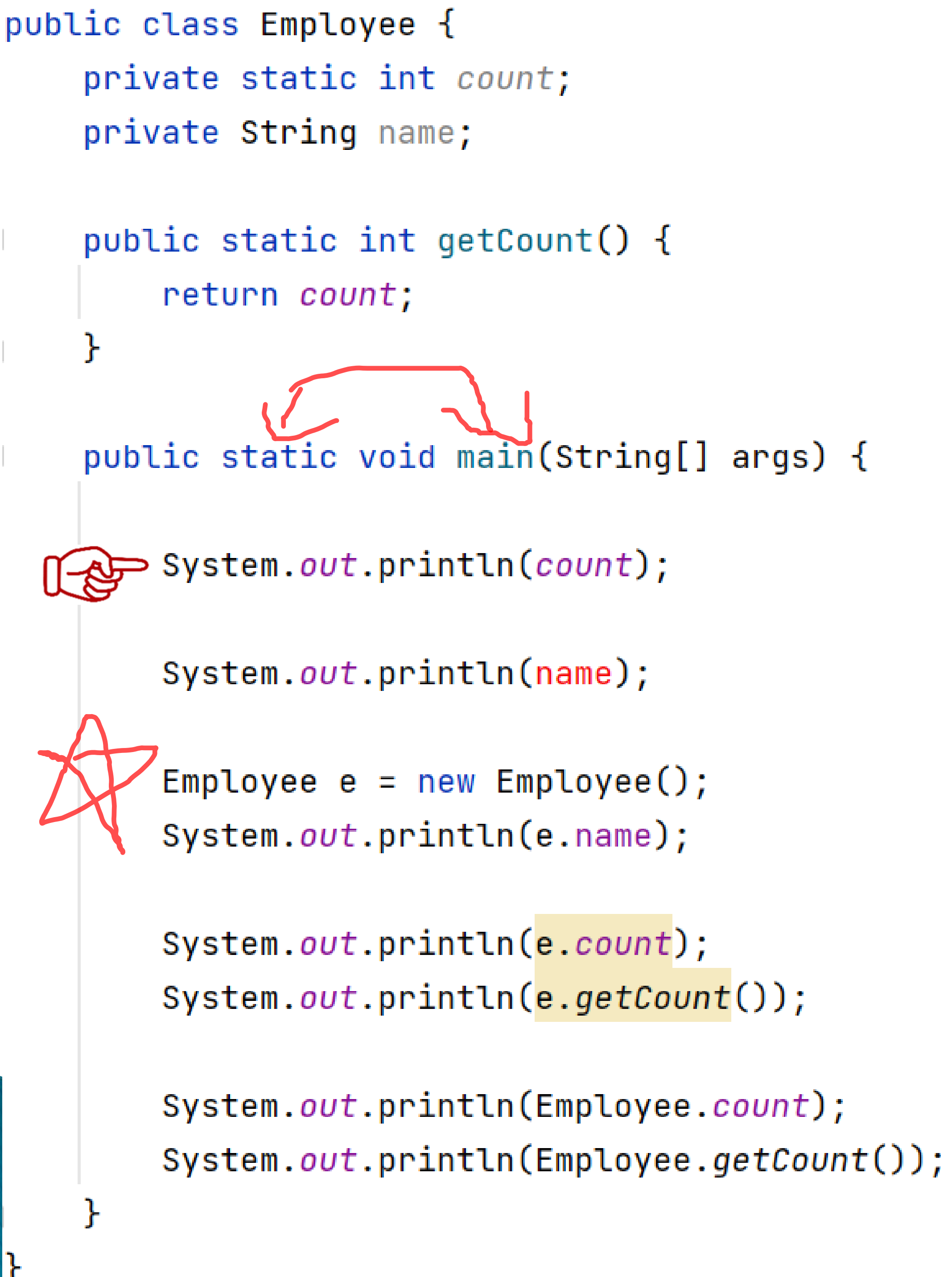


```
public class Employee {
    private static int count;
    private String name;

    public static void m1(){
        count++;
        m3();

        System.out.println(name);
        m4();
    }

    public void m2(){
        count++;
        m3();

        System.out.println(name);
        m4();
    }

    public static void m3(){}

    public void m4(){}
}
```

- count is static/class variable
- name is instance variable

Instance method m2

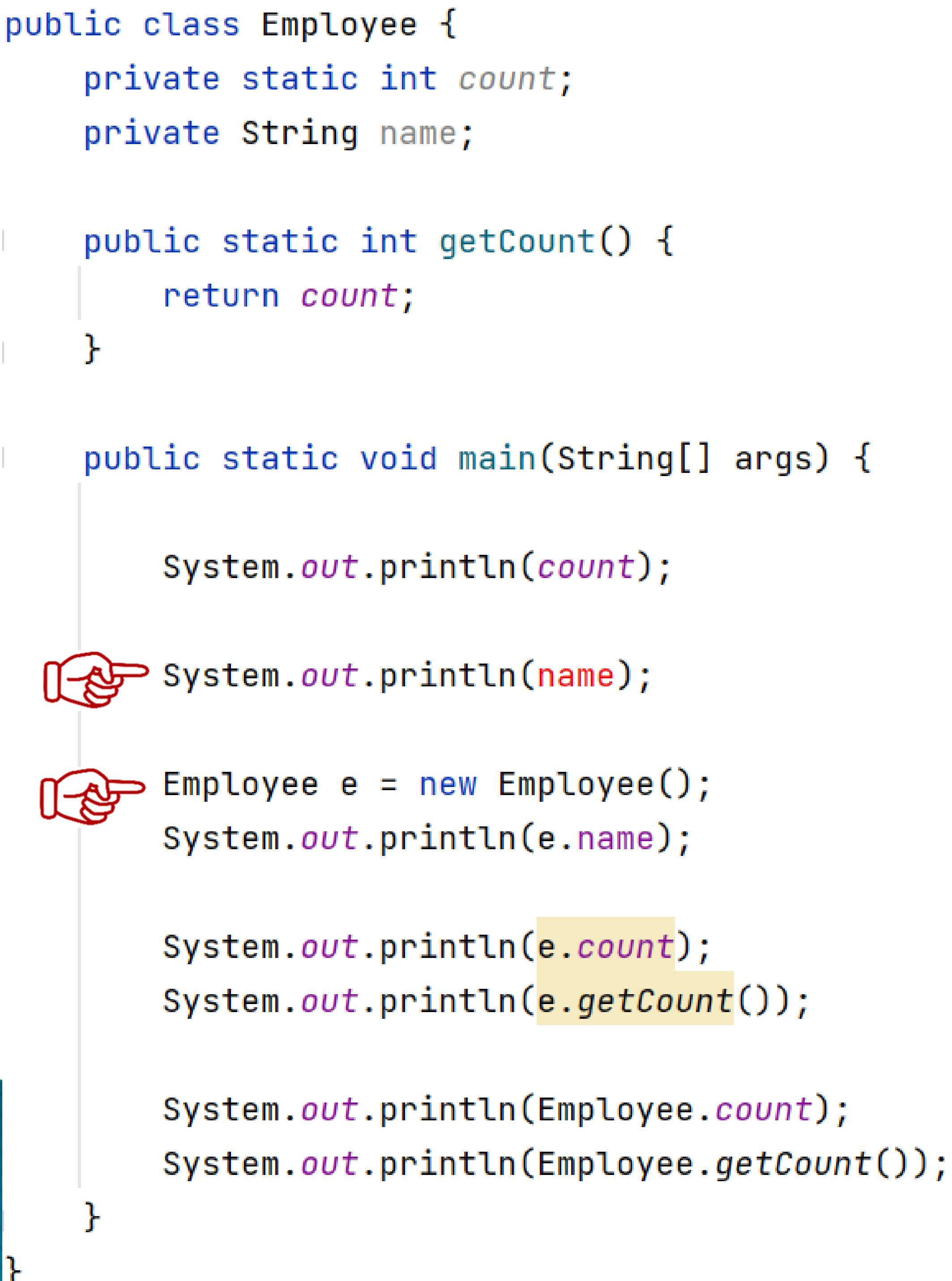
- can access static variable count and static method m3
- can access instance variable name and instance method m4



```java
public class Employee {
    private static int count;
    private String name;

    public static int getCount() {
        return count;
    }

    public static void main(String[] args) {

        System.out.println(count);

        System.out.println(name);

        Employee e = new Employee();
        System.out.println(e.name);

        System.out.println(e.count);
        System.out.println(e.getCount());

        System.out.println(Employee.count);
        System.out.println(Employee.getCount());
    }
}
```

main(String[] args) is also a static method

OK. A static method can access a static variable.
If a `static` variable is not initialized, the compiler assigns it a default value (e.g., 0 for `int`)

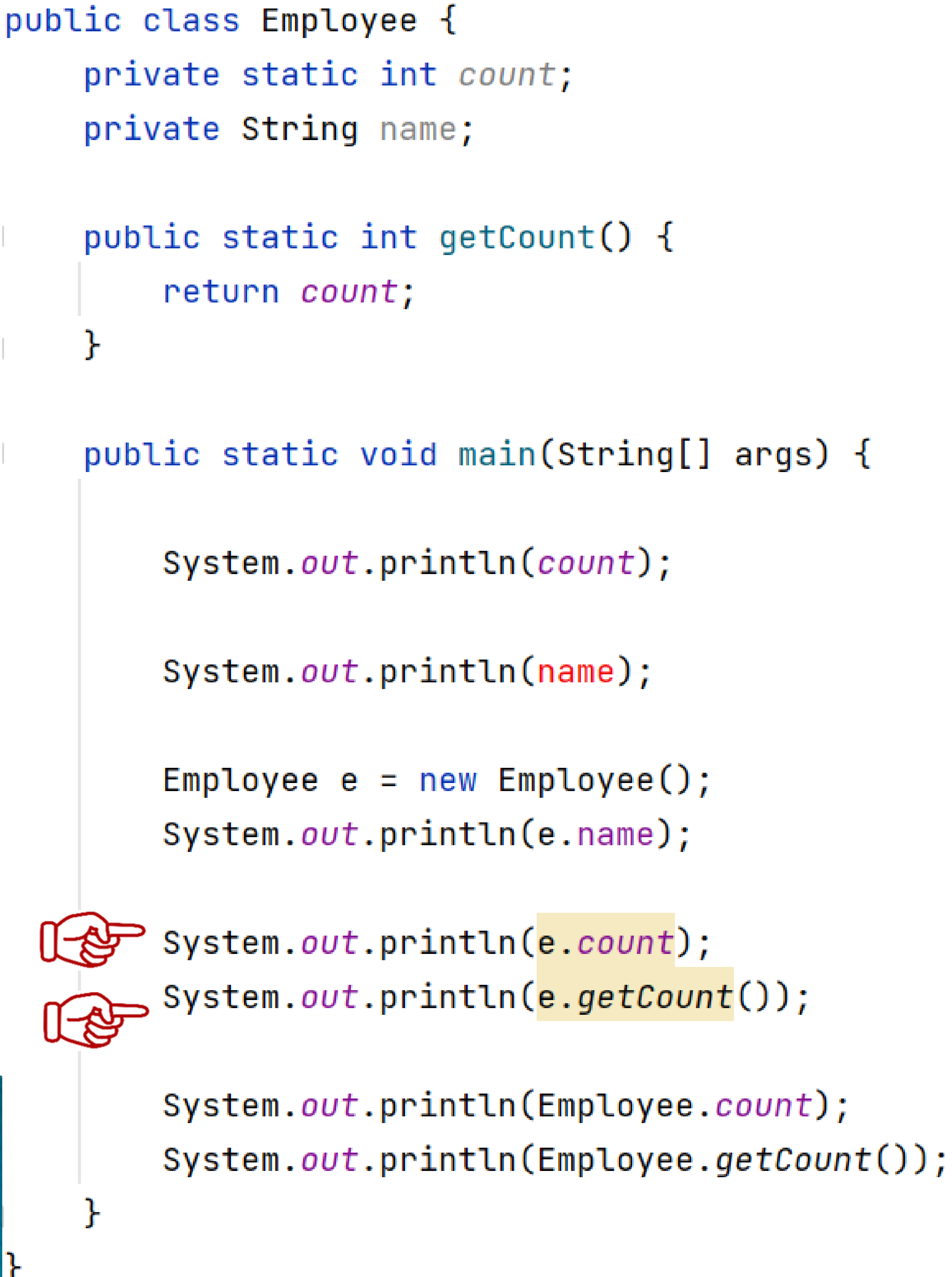


```
public class Employee {
    private static int count;
    private String name;

    public static int getCount() {
        return count;
    }

    public static void main(String[] args) {

        System.out.println(count);

        System.out.println(name);

        Employee e = new Employee();
        System.out.println(e.name);

        System.out.println(e.count);
        System.out.println(e.getCount());

        System.out.println(Employee.count);
        System.out.println(Employee.getCount());
    }
}
```

main(String[] args) is also a static method

NO. A static method CANNOT access an instance variable.

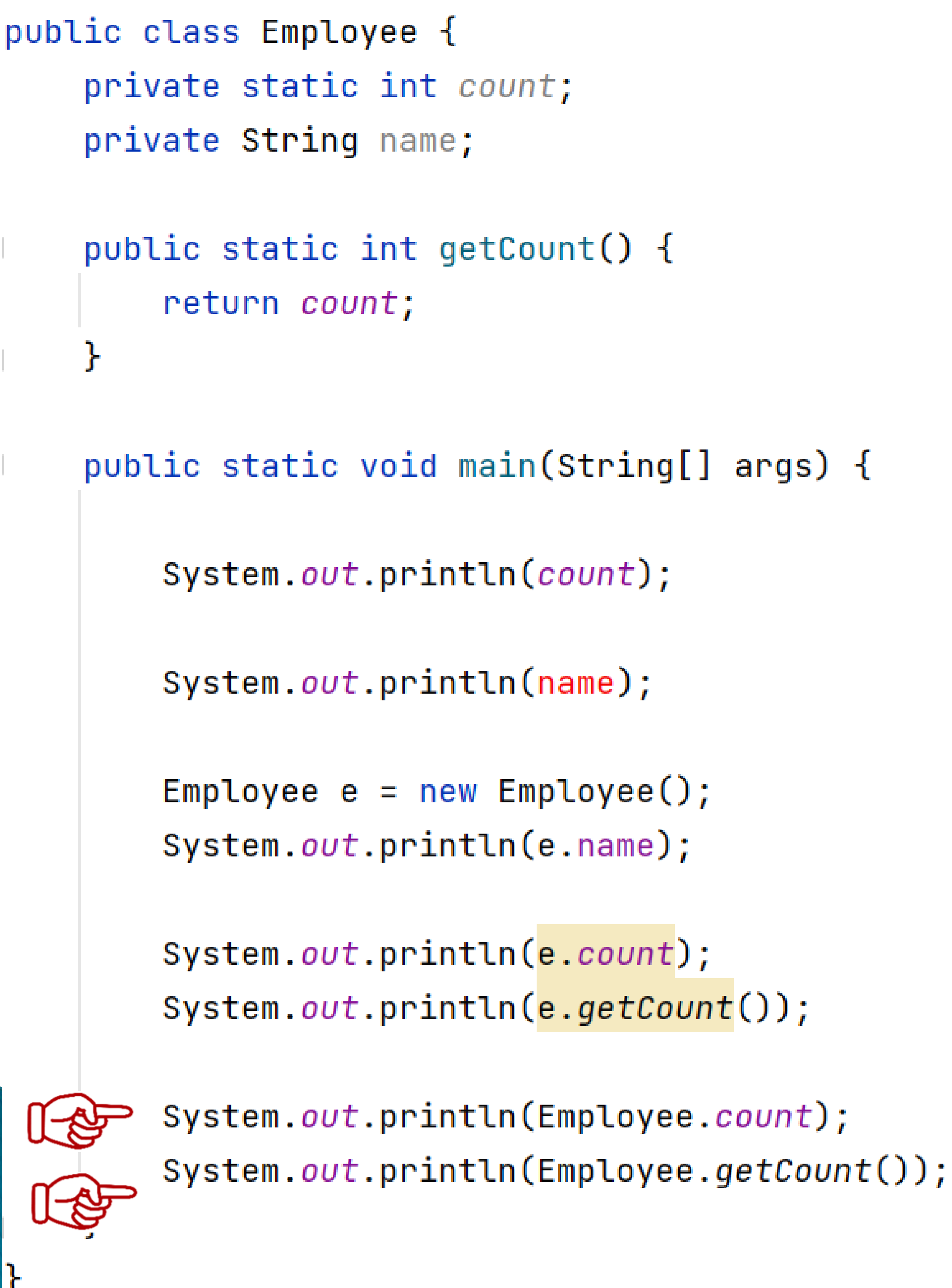
We need to create an instance first before accessing name.



```java
public class Employee {
    private static int count;
    private String name;

    public static int getCount() {
        return count;
    }

    public static void main(String[] args) {

        System.out.println(count);

        System.out.println(name);

        Employee e = new Employee();
        System.out.println(e.name);

        System.out.println(e.count);
        System.out.println(e.getCount());

        System.out.println(Employee.count);
        System.out.println(Employee.getCount());
    }
}
```

main(String[] args) is also a static method

OK. A class’s `static` member can be accessed through a reference to any object of the class. But this is NOT recommended.



```
public class Employee {
    private static int count;
    private String name;

    public static int getCount() {
        return count;
    }

    public static void main(String[] args) {

        System.out.println(count);

        System.out.println(name);

        Employee e = new Employee();
        System.out.println(e.name);

        System.out.println(e.count);
        System.out.println(e.getCount());

        System.out.println(Employee.count);
        System.out.println(Employee.getCount());
    }
}
```

main(String[] args) is also a static method

OK and recommended. A class’s `static` member can be accessed by qualifying the member name with the class name and a dot (.), e.g., `Math.PI`

Objectives

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Creating Packages

- Each class in the Java API belongs to a package that contains a group of related classes.
- Packages help programmers organize application components (logically related classes can be put into the same package (e.g., java.io)).
- Packages facilitate software reuse by enabling programs to import classes from other packages, rather than copying the classes into each program that uses them.

Declaring a reusable class

- **Step 1:** Declare a `public` class (to be reusable)
- **Step 2:** Choose a package name and add a `package` declaration to the source file for the reusable class declaration.
  - In each Java source file there can be only one `package` declaration, and it must precede all other declarations and statements.

☞

```
package sustech.cs102a;

public class Time {
    private int hour; // 0 - 23
    private int minute; // 0 - 59
    private int second; // 0 - 59
    //...
}
```

A .java file must have the following order:

a `package` declaration (if any)

`import` declarations (if any)

class declarations

Creating Packages (Cont.)

- A Java package structure is like a directory structure. Its a tree of packages, subpackages and classes inside these classes. A Java package structure is indeed organized as directories on your hard drive, or as directories inside a zip file (JAR files)

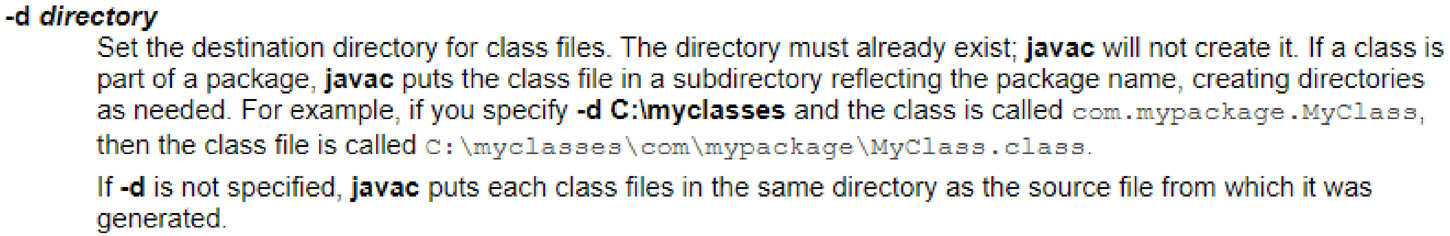
- The class `Time` should be placed in the directory

```
sustech

    cs102a
```

```java
package sustech.cs102a;

public class Time {
    private int hour; // 0 - 23
    private int minute; // 0 - 59
    private int second; // 0 - 59
    //...
}
```

Creating Packages (Cont.)

- `javac` command-line option `-d` causes the compiler to create appropriate directories based on the class's `package` declaration.



-d *directory*

Set the destination directory for class files. The directory must already exist; **javac** will not create it. If a class is part of a package, **javac** puts the class file in a subdirectory reflecting the package name, creating directories as needed. For example, if you specify **-d C:\myclasses** and the class is called `com.mypackage.MyClass`, then the class file is called `C:\myclasses\com\mypackage\MyClass.class`.

If **-d** is not specified, **javac** puts each class files in the same directory as the source file from which it was generated.

- Example command: `javac -d . Time.java`
  - specifies that the first directory in our package name should be placed in the current directory (`.`)
  - The compiled classes are placed into the directory that is named last in the `package` declaration
  - `Time.class` will appear in the diretroy `./sustech/cs102a/`

Creating Packages (Cont.)

- `package` name is part of the fully qualified name of a class
  - `sustech.cs102a.Time`
- We can use the fully qualified name in programs, or `import` the class and use its simple name (e.g., `Time`).
- If another package contains a class of the same name, the fully qualified class names can be used to distinguish between the classes in the program and prevent a name conflict

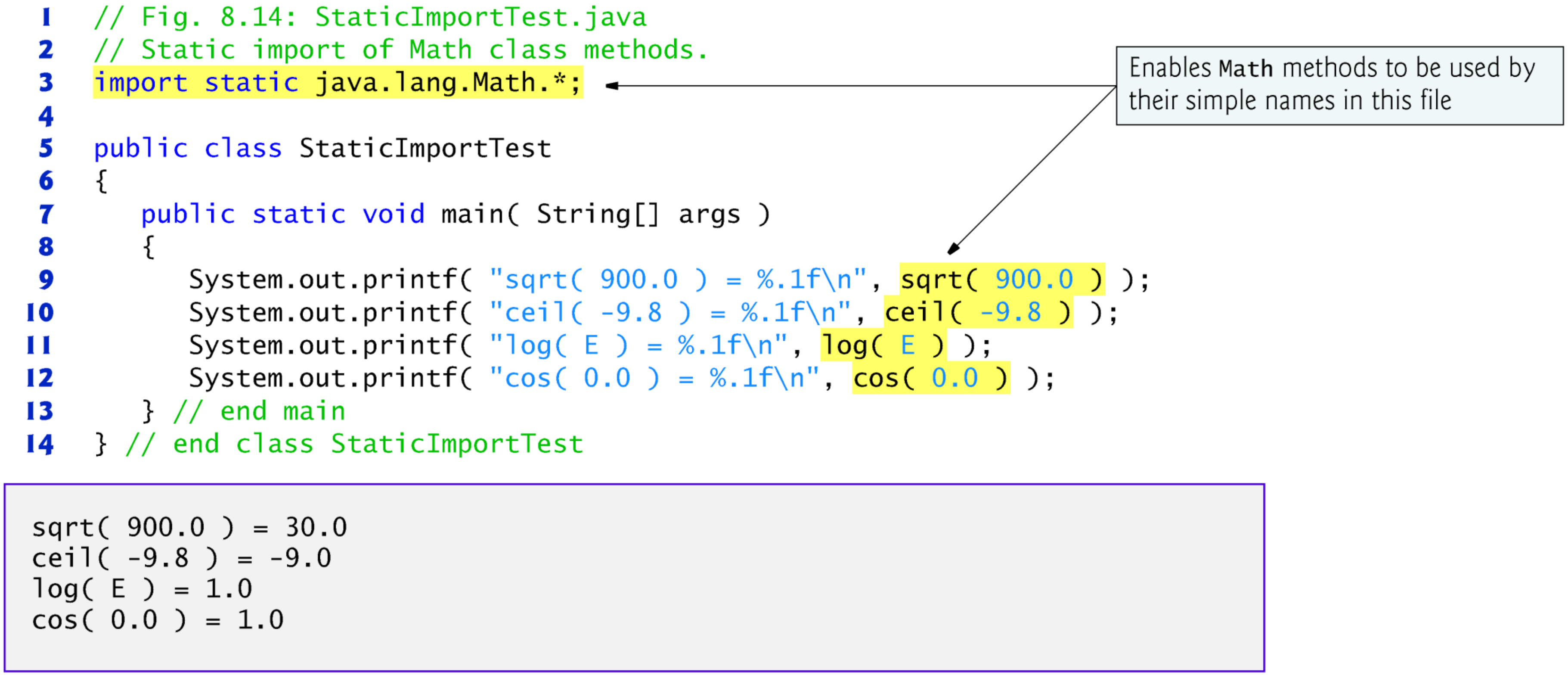
Importing a class

- A single-type-import declaration specifies one class to import
  - `import java.util.Scanner;`
- When your program uses multiple classes from the same package, you can import them with a type-import-on-demand declaration.
  - `import java.util.*; // import java.util classes`
- The wild card * informs the compiler that all `public` classes from the `java.util` package are available for use in the program.

static Import

- Normal import declarations import classes from packages, allowing them to be used without package qualification
- A static import declaration enables you to import the static members (fields or methods) of a class so you can access them via their unqualified names, i.e., without including class name and a dot (.)
  - Math.sqrt(4.0) → sqrt(4.0)

Example



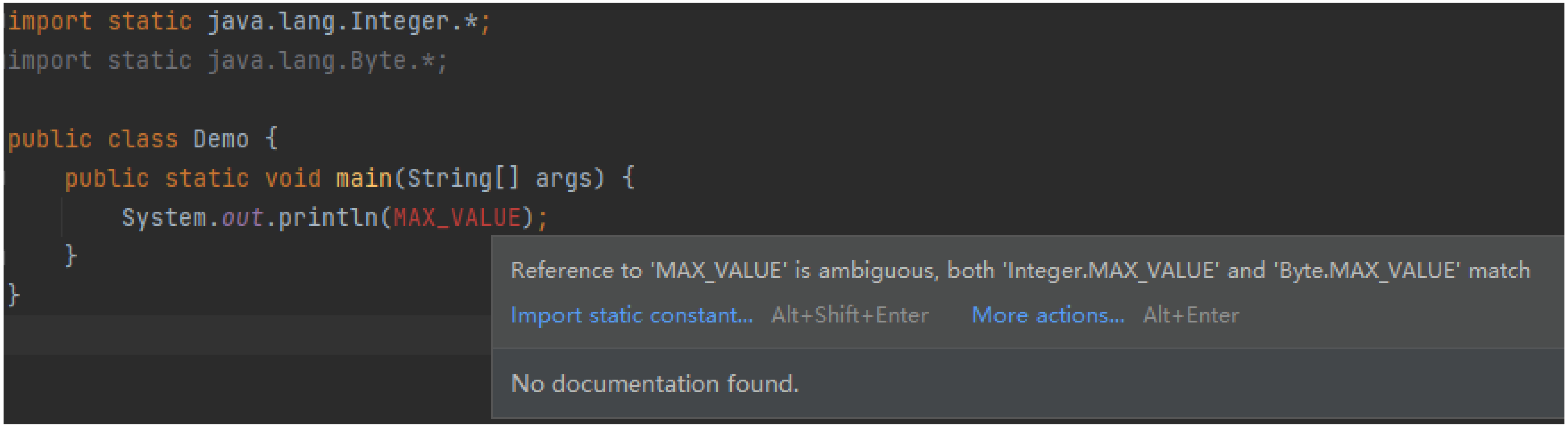
```java
// Fig. 8.14: StaticImportTest.java
// Static import of Math class methods.
import static java.lang.Math.*;

public class StaticImportTest
{
   public static void main( String[] args )
   {
      System.out.printf( "sqrt( 900.0 ) = %.1f\n", sqrt( 900.0 ) );
      System.out.printf( "ceil( -9.8 ) = %.1f\n", ceil( -9.8 ) );
      System.out.printf( "log( E ) = %.1f\n", log( E ) );
      System.out.printf( "cos( 0.0 ) = %.1f\n", cos( 0.0 ) );
   } // end main
} // end class StaticImportTest
```

Enables `Math` methods to be used by their simple names in this file

```
sqrt( 900.0 ) = 30.0
ceil( -9.8 ) = -9.0
log( E ) = 1.0
cos( 0.0 ) = 1.0
```

Ambiguity in static import

- If two static members of the same name are imported from multiple different classes, the compiler will throw an error, as it will not be able to determine which member to use in the absence of class name qualification.



```
import static java.lang.Integer.*;
import static java.lang.Byte.*;

public class Demo {
    public static void main(String[] args) {
        System.out.println(MAX_VALUE);
    }
}
```

Reference to 'MAX_VALUE' is ambiguous, both 'Integer.MAX_VALUE' and 'Byte.MAX_VALUE' match

Import static constant... Alt+Shift+Enter
More actions... Alt+Enter

No documentation found.

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Package Access for Class Members

- If no access modifier is specified for a class member when it’s declared in a class, it is considered to have package access.

```
public class Time1 {
        int hour;
        int minute;
        int second;
        void setTime(int h, int m, int s) {...}
}
```

No modifier

The variables and method are package-private, visible only to classes of the same package

Access Level Modifiers (So Far)

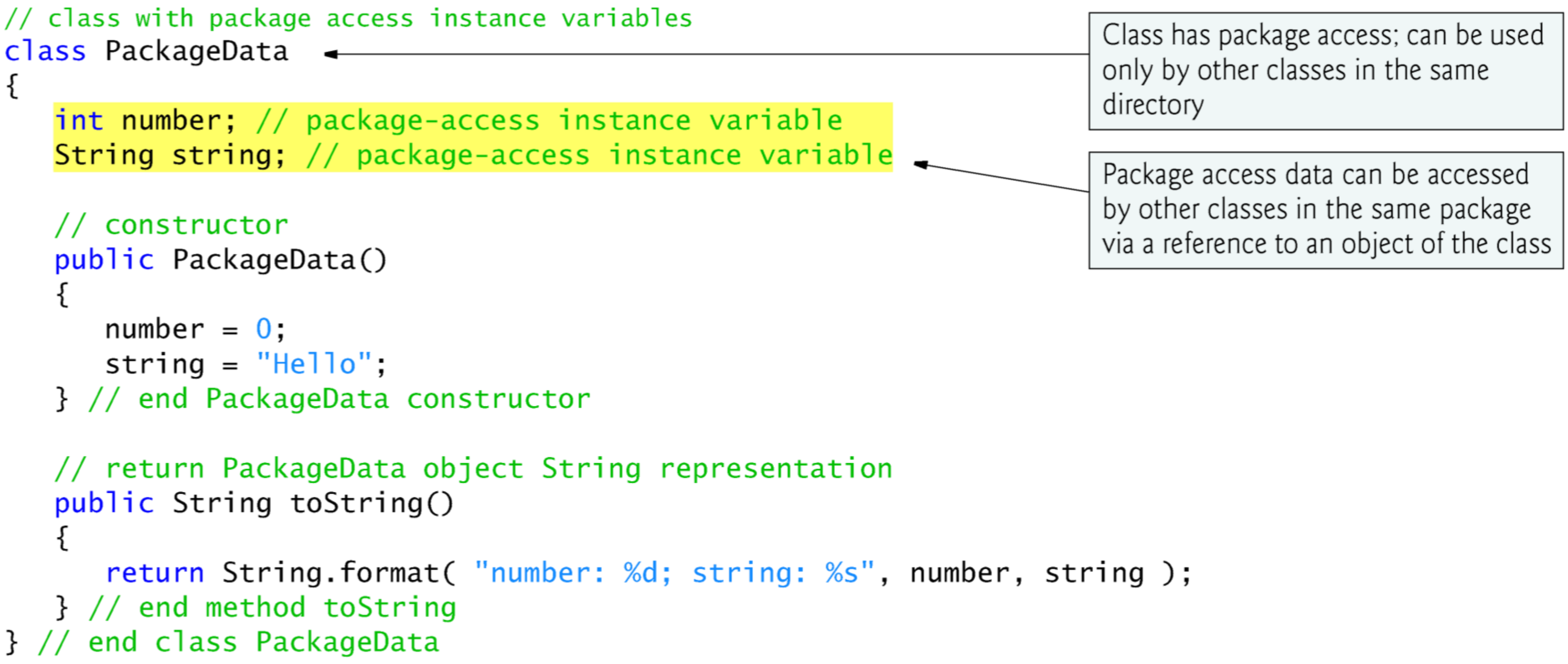
Modifier	Class	Package	World
public	Y	Y	Y
no modifier	Y	Y	N
private	Y	N	N

Note that this table is for controlling access to class members. At the top level, a class can only be declared as `public` or package-private (no explicit modifier)

Access Modifiers for Classes

- We can declare multiple classes in one `.java` file
  - Only one of the class declarations in a `.java` file can be `public`.
  - Other classes in the file must not have public access modifiers, and can be used only by the other classes in the package (package-private).
- Think: Can classes be declared as private?

Example: Package Access



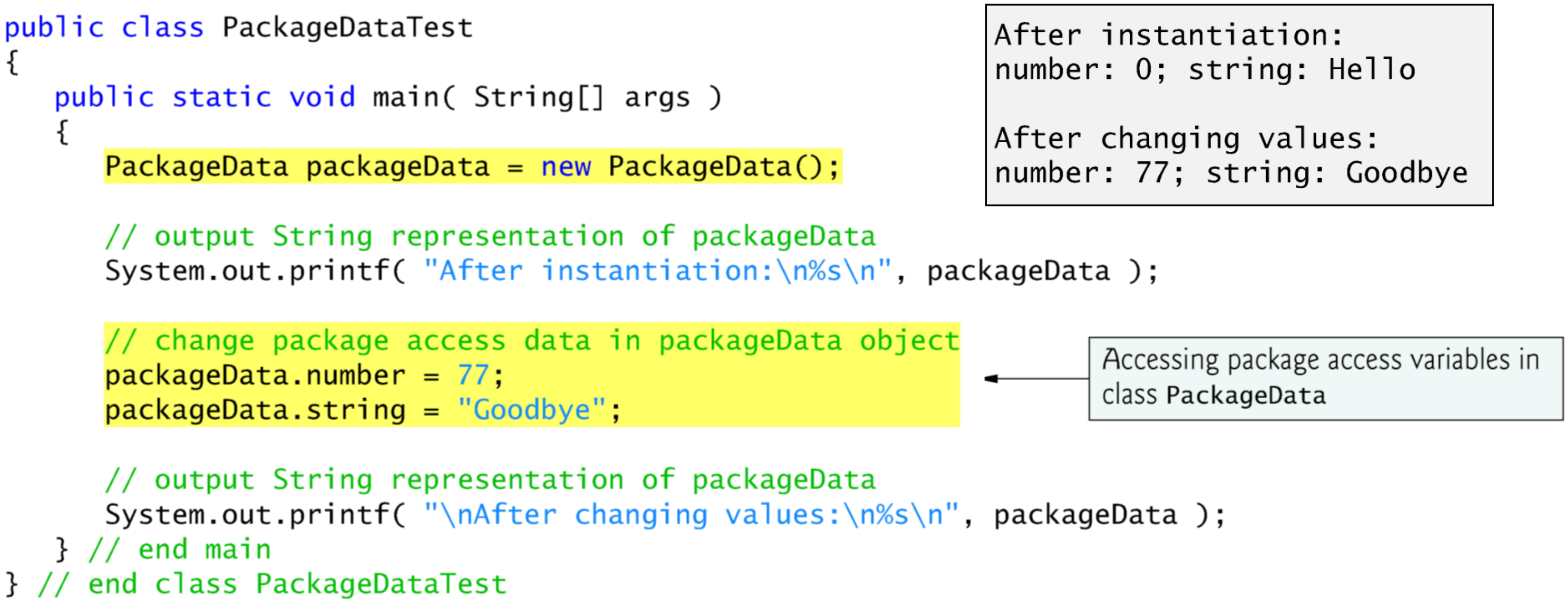
```java
// class with package access instance variables
class PackageData
{
   int number; // package-access instance variable
   String string; // package-access instance variable

   // constructor
   public PackageData()
   {
      number = 0;
      string = "Hello";
   } // end PackageData constructor

   // return PackageData object String representation
   public String toString()
   {
      return String.format( "number: %d; string: %s", number, string );
   } // end method toString
} // end class PackageData
```

Class has package access; can be used only by other classes in the same directory

Package access data can be accessed by other classes in the same package via a reference to an object of the class

Example: Package Access

PackageData and PackageDataTest can be in the same .java file, or in two separate .java files within the same package



```java
public class PackageDataTest
{
   public static void main( String[] args )
   {
      PackageData packageData = new PackageData();

      // output String representation of packageData
      System.out.printf( "After instantiation:\n%s\n", packageData );

      // change package access data in packageData object
      packageData.number = 77;
      packageData.string = "Goodbye";

      // output String representation of packageData
      System.out.printf( "\nAfter changing values:\n%s\n", packageData );
   } // end main
} // end class PackageDataTest
```

```
After instantiation:
number: 0; string: Hello

After changing values:
number: 77; string: Goodbye
```

Accessing package access variables in class PackageData

Package access is rarely used in practice.

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final Instance Variables

- The principle of least privilege (PoLP, 最小特权原则) is fundamental to good software engineering
  - Code should be granted only the amount of privilege and access that it needs to accomplish its designated task, but no more (any user, program, or process should have only the bare minimum privileges necessary to perform its function).
  - Makes your programs more robust by preventing code from accidentally (or maliciously) modifying variable values and calling methods that should not be accessible.

`final` Instance Variables

- The keyword `final` specifies that a variable is not modifiable (i.e., constant) and any attempt to modify leads to an error (cannot compile)

```
private final int INCREMENT;
```

- Generally, every field in an object or class is initialized to a zero-like value during the allocation of memory (primitive types start out with zero values, object types start out as null, and Boolean types start out false).
- However, there is an exception to this behavior for `final` fields, which are required to be explicitly initialized. If this is not done, the code will fail to compile.

`final` Instance Variables

- Two ways to initialize a final variable
  - `final` variables can be initialized when they are declared.

    ```
    public static final double PI = 3.14159265358979323846;
    ```

  - If they are not, they must be initialized in every constructor of the class (Initializing `final` variables in constructors enables each object of the class to have a different value for the constant)
- If a `final` variable is not initialized when it is declared or in every constructor, the program will not compile.

Enumerations (枚举)

- There are cases when a variable can only take one of a small set of predefined constant values, e.g., compass direction (N, S, E, W) and the days of a week (MON, TUE, etc.)
- In such cases, you should use an `enum` type to define a set of constants represented as unique identifiers

```
public enum Direction {
    NORTH, SOUTH, EAST, WEST
}
```

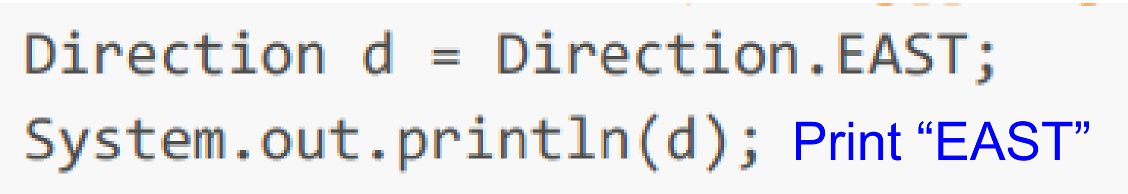
Enumerations

- `Direction` is a type called an **enumeration**, which is a special kind of class introduced by the keyword `enum` and a type name
- Inside the braces {} is a comma-separated list of enumeration constants, each representing a unique value (you don't need to care about the underlying implementation or the exact values)
- The identifiers in an `enum` must be unique

```
public enum Direction {
    NORTH, SOUTH, EAST, WEST
}
```

Enumerations

- Variables of the type `Direction` can be assigned only the four constants declared in the enumeration (other values are illegal, won’t compile)



```
Direction d = Direction.EAST;
System.out.println(d);
```

Print “EAST”

- The last statement is equivalent to System.out.println(d.toString()).
- When an enum constant is converted to a String using toString(), the constant’s identifier is used as the String representation.

- Like classes, all `enum` types are reference types

```
public enum Direction {
    NORTH, SOUTH, EAST, WEST
}
```

Enumerations under the hood

- Each `enum` declaration declares an `enum` class with the following restrictions:
  - `enum` declarations contain two parts: (1) the `enum` constants, (2) the other members such as overloaded constructor, fields and methods (optional)
  - `enum` constants are implicitly `final` (constants that shouldn't be modified)
  - `enum` constants are implicitly `static` (no objects need to access them)
  - An enum constructor cannot be public; Any attempt to create an object of an `enum` type with operator `new` results in a compilation error

Example

enum constants (objects in this example) initialized with constructor calls

```
public enum Book {
    JHTP("Java How to Program", "2012"),
    CHTP("C How to Program", "2007"),
    IW3HTP("Internet & World Wide Web How to Program", "2008"),
    CPPHTP("C++ How to Program", "2012"),
    VBHTP("Visual Basic 2010 How to Program", "2011"),
    CSHARPHTP("Visual C# 2010 How to Program", "2011");

    private final String title;
    private final String copyrightYear;
    private Book(String bookTitle, String year) {
        title = bookTitle;
        copyrightYear = year;
    }
    public String getTitle() {  return title;  }
    public String getCopyrightYear() {  return copyrightYear;  }
}
```

Just like normal classes, defining public methods for clients to use the enum type

Only six Book objects will be created, constants such as Book.JHTP store the references.

Example

```
import java.util.EnumSet;
    public class EnumTest {
    public static void main(String[] args) {
        System.out.println("All books:\n");

        for(Book book : Book.values())
            System.out.printf("%-10s%-45s%s\n", book,
                   book.getTitle(), book.getCopyrightYear());

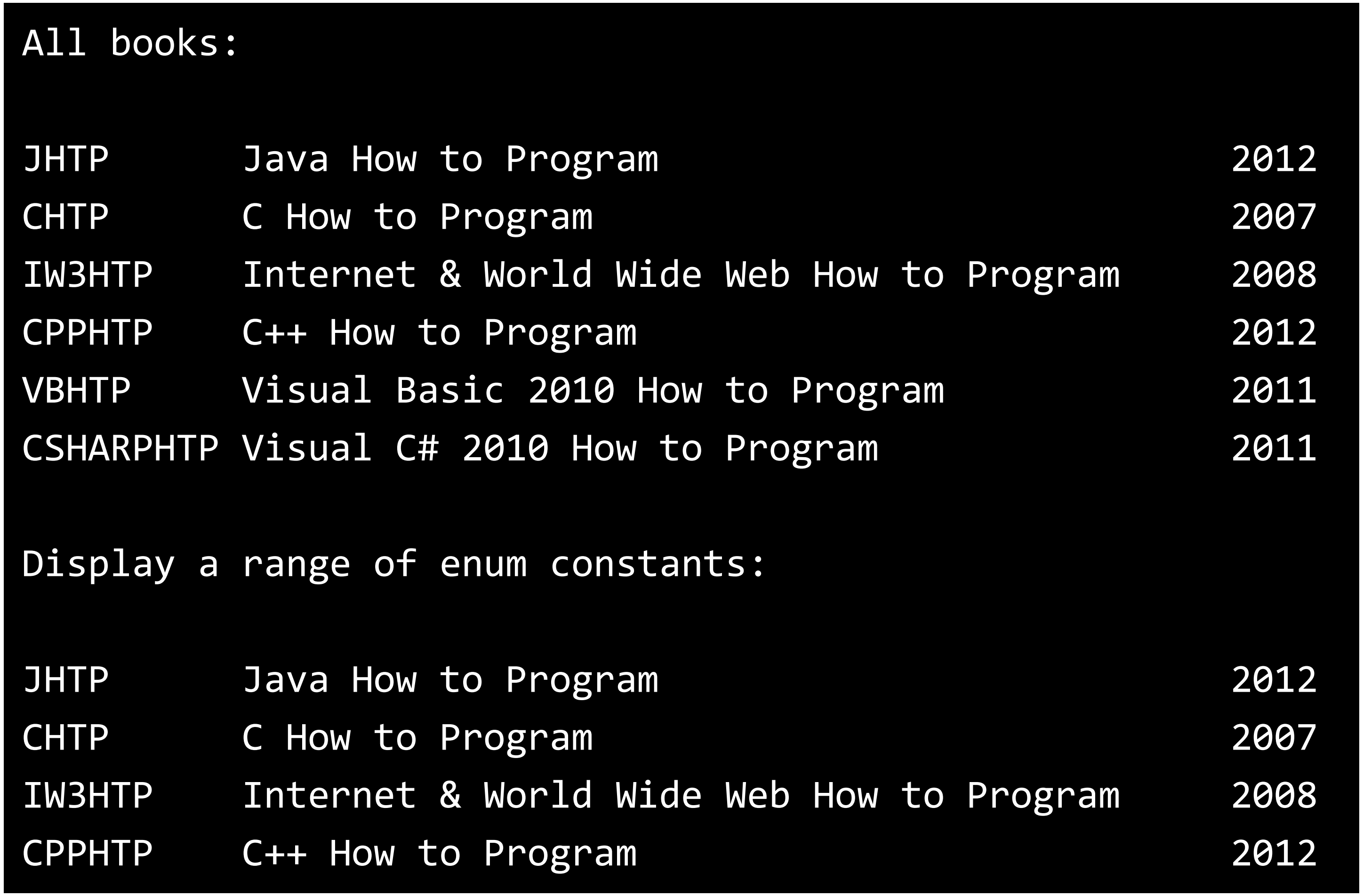
        System.out.println("\nDisplay a range of enum constants:\n");

        for(Book book : EnumSet.range(Book.JHTP, Book.CPPHTP))
            System.out.printf("%-10s%-45s%s\n", book,
                   book.getTitle(), book.getCopyrightYear());
    }
}
```

`Values()` returns an array of the `enum`’s constants

`EnumSet`’s method `range()` returns a collection of the `enum` constants in the specified range of constants

Example



```
All books:

JHTP      Java How to Program                          2012
CHTP      C How to Program                             2007
IW3HTP    Internet & World Wide Web How to Program     2008
CPPHTP    C++ How to Program                           2012
VBHTP     Visual Basic 2010 How to Program             2011
CSHARPHTP Visual C# 2010 How to Program                2011

Display a range of enum constants:

JHTP      Java How to Program                          2012
CHTP      C How to Program                             2007
IW3HTP    Internet & World Wide Web How to Program     2008
CPPHTP    C++ How to Program                           2012
```

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Java Heap Memory

- The heap space is used by Java runtime to allocate memory to Objects. Whenever we create an object (including arrays), it’s created in the heap space.
- Any object created in the heap space has global access and can be referenced from anywhere of the application (as long as you have a reference)
- Garbage Collection runs on the heap memory to free the memory used by objects that doesn’t have any reference.

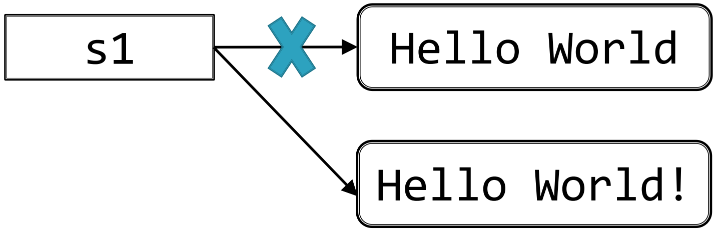
https://www.journaldev.com/4098/java-heap-space-vs-stack-memory

Garbage Collection

- Every object uses system resources, such as memory
- We need a disciplined way to give resources back to the system when they’re no longer needed; otherwise, resource leaks may occur.
- The JVM performs automatic garbage collection to reclaim the memory occupied by objects that are no longer used (no references to them).

```
String s1 = "Hello World";

s1 = s1.concat("!");
```



Becomes garbage
if not referenced

Java Stack Memory

- Stack memory stores information for execution of methods in a thread:
  - Method specific values (short-lived)
  - References to other objects in the heap (getting referred from the methods)
- Stack memory is always referenced in LIFO order. Whenever a method is invoked, a new block is created in the stack memory for the method to hold local primitive values and references to other objects.
- As soon as a method ends, the block will be erased and become available for next method. Therefore, stack memory size is very less compared to heap memory (storing long-lived objects).

https://www.journaldev.com/4098/java-heap-space-vs-stack-memory

Memory Allocation Example

```
public class Memory {

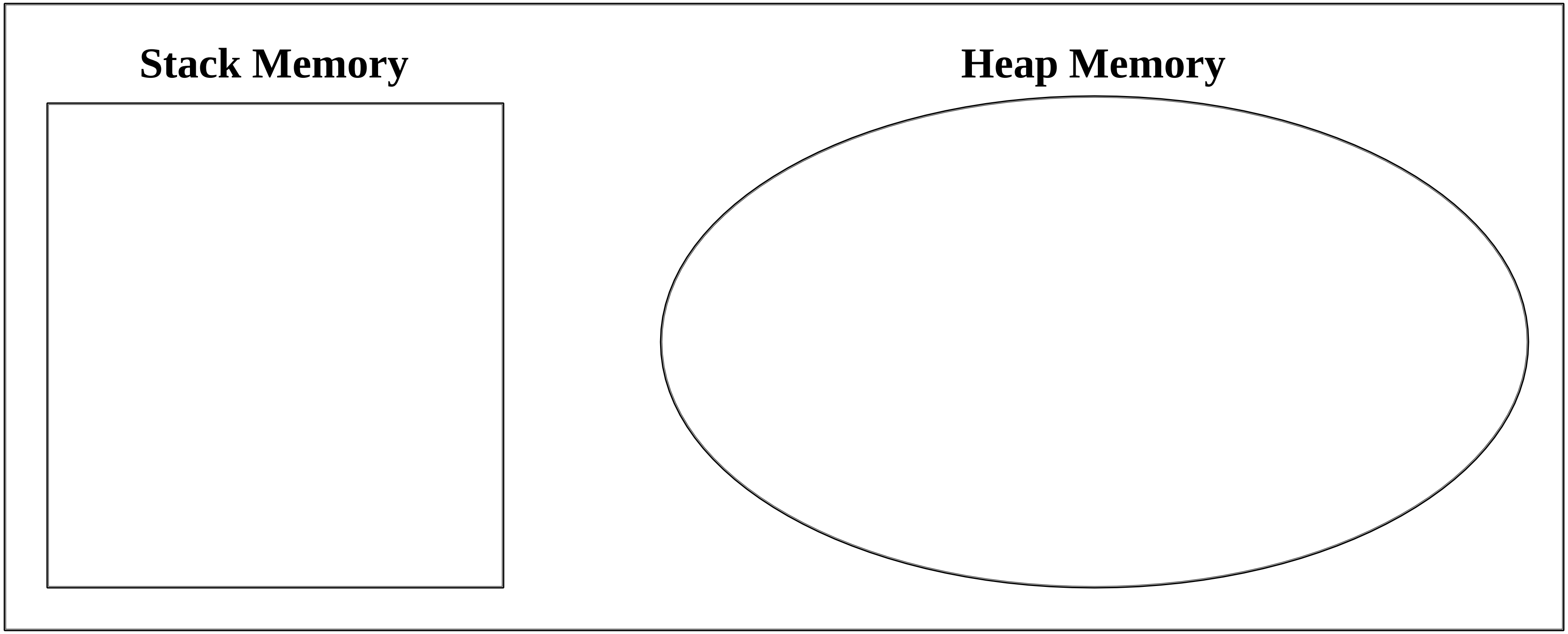
    public static void main(String[] args) {
        int i = 1;
        Object obj = new Object();
        Memory mem = new Memory();
        mem.foo(obj);
    }

    private void foo(Object param) {
        String str = param.toString();
        System.out.println(str);
    }

}
```

```
public static void main(String[] args) {
    int i = 1;
    Object obj = new Object();
    Memory mem = new Memory();
    mem.foo(obj);
}
```

```
private void foo(Object param) {
    String str = param.toString();
    System.out.println(str);
}
```



Java Runtime Memory

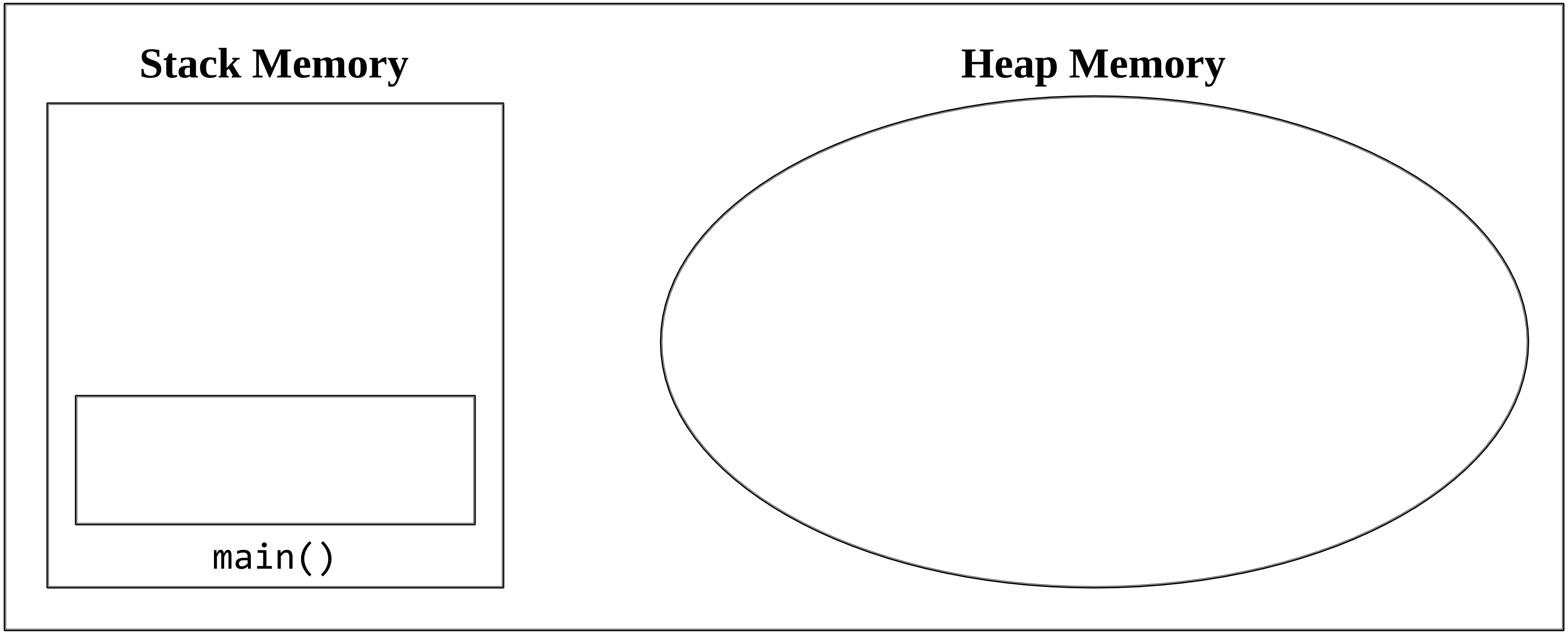
```
public static void main(String[] args) {
    int i = 1;
    Object obj = new Object();
    Memory mem = new Memory();
    mem.foo(obj);
}
```

```
private void foo(Object param) {

    String str = param.toString();

    System.out.println(str);

}
```



Java Runtime Memory

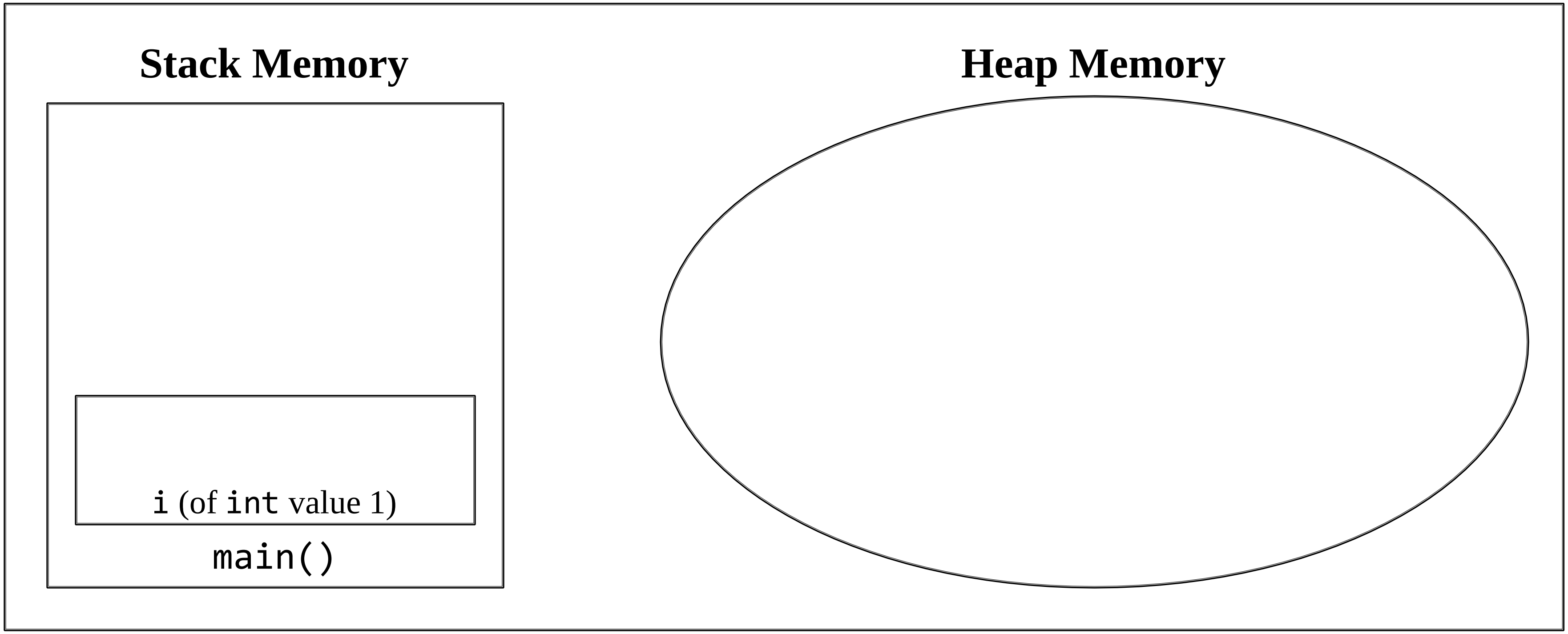
```
public static void main(String[] args) {
→   int i = 1;
    Object obj = new Object();
    Memory mem = new Memory();
    mem.foo(obj);
}
```

```
private void foo(Object param) {

    String str = param.toString();

    System.out.println(str);

}
```



Java Runtime Memory

```
public static void main(String[] args) {
    int i = 1;
→   Object obj = new Object();
    Memory mem = new Memory();
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private void foo(Object param) {

    String str = param.toString();

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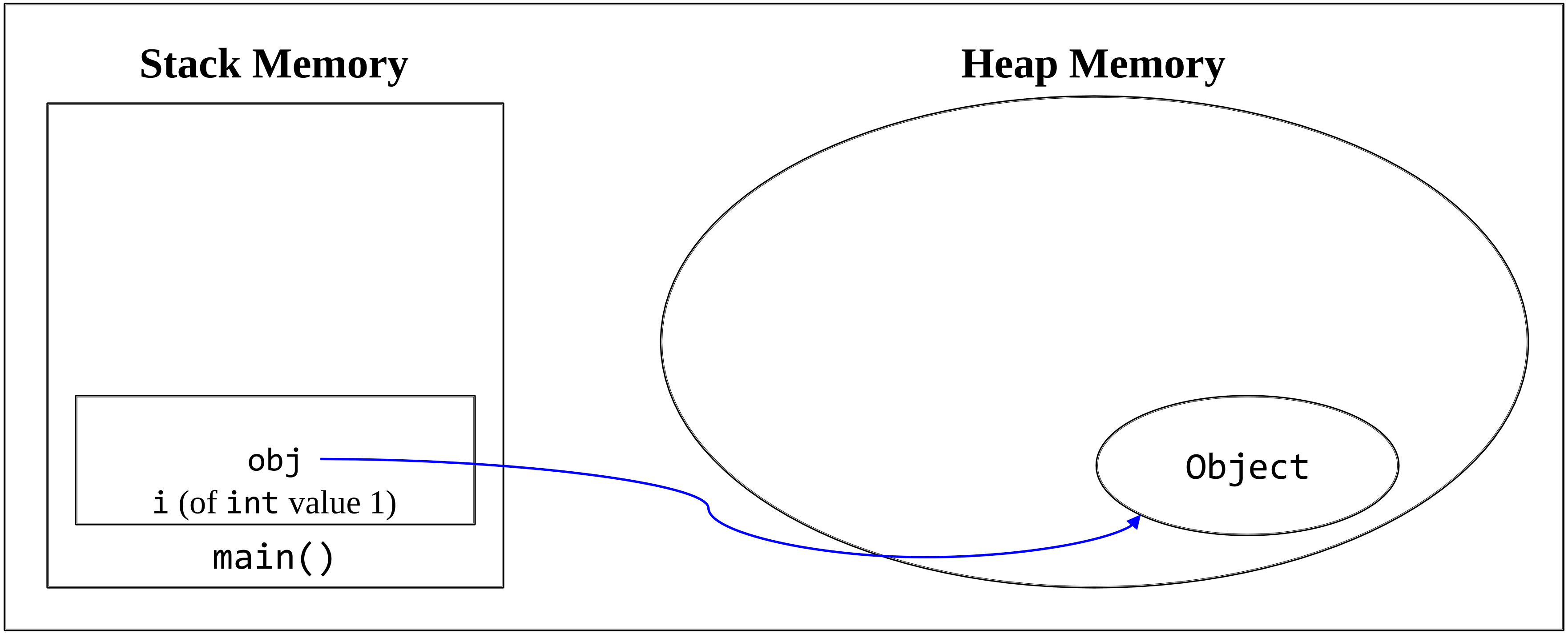

Java Runtime Memory

```
public static void main(String[] args) {
    int i = 1;
    Object obj = new Object();
→   Memory mem = new Memory();
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private void foo(Object param) {

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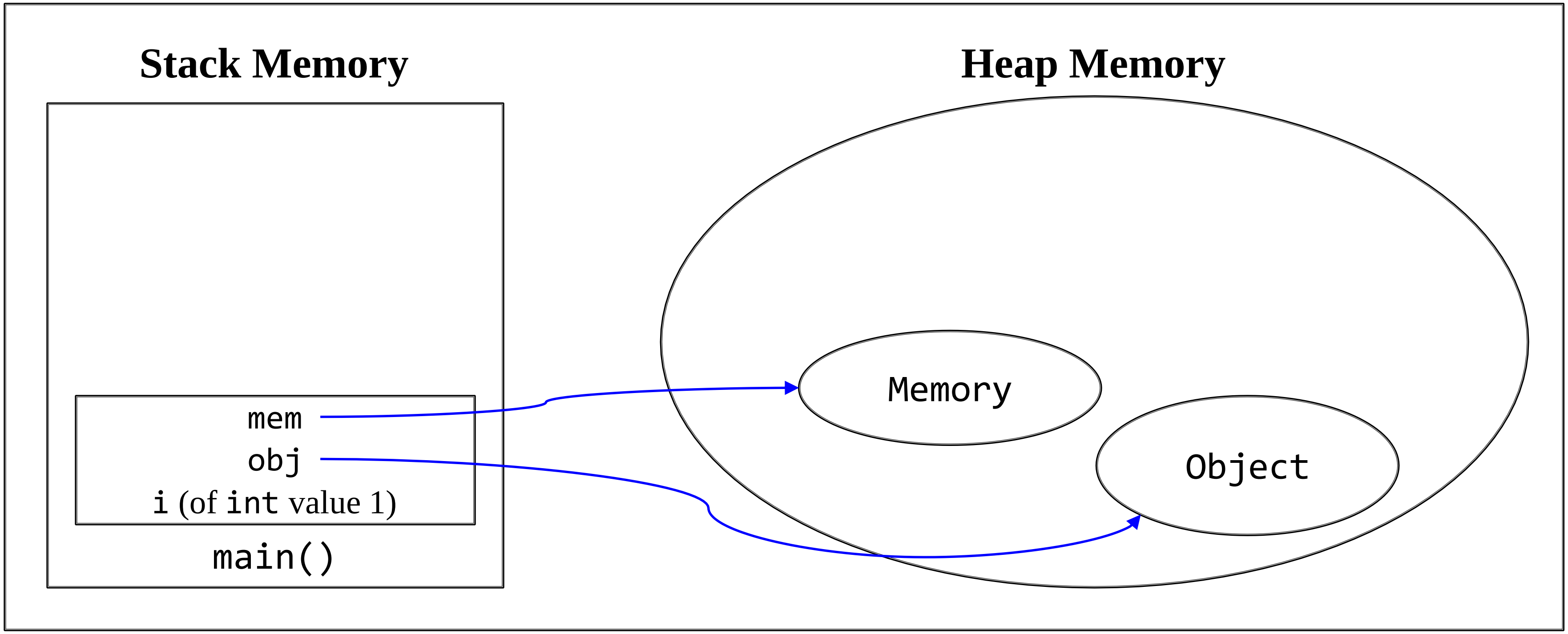

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    Object obj = new Object();
    Memory mem = new Memory();
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private void foo(Object param) {

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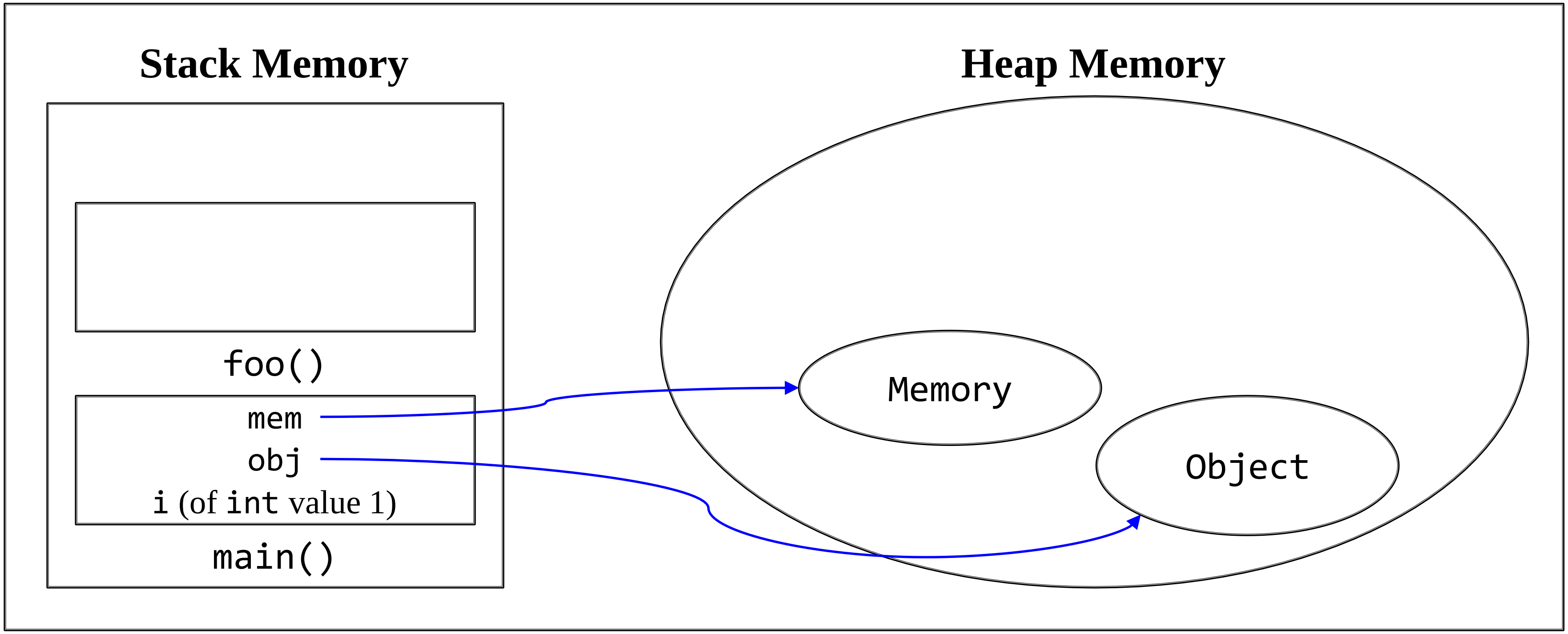

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}
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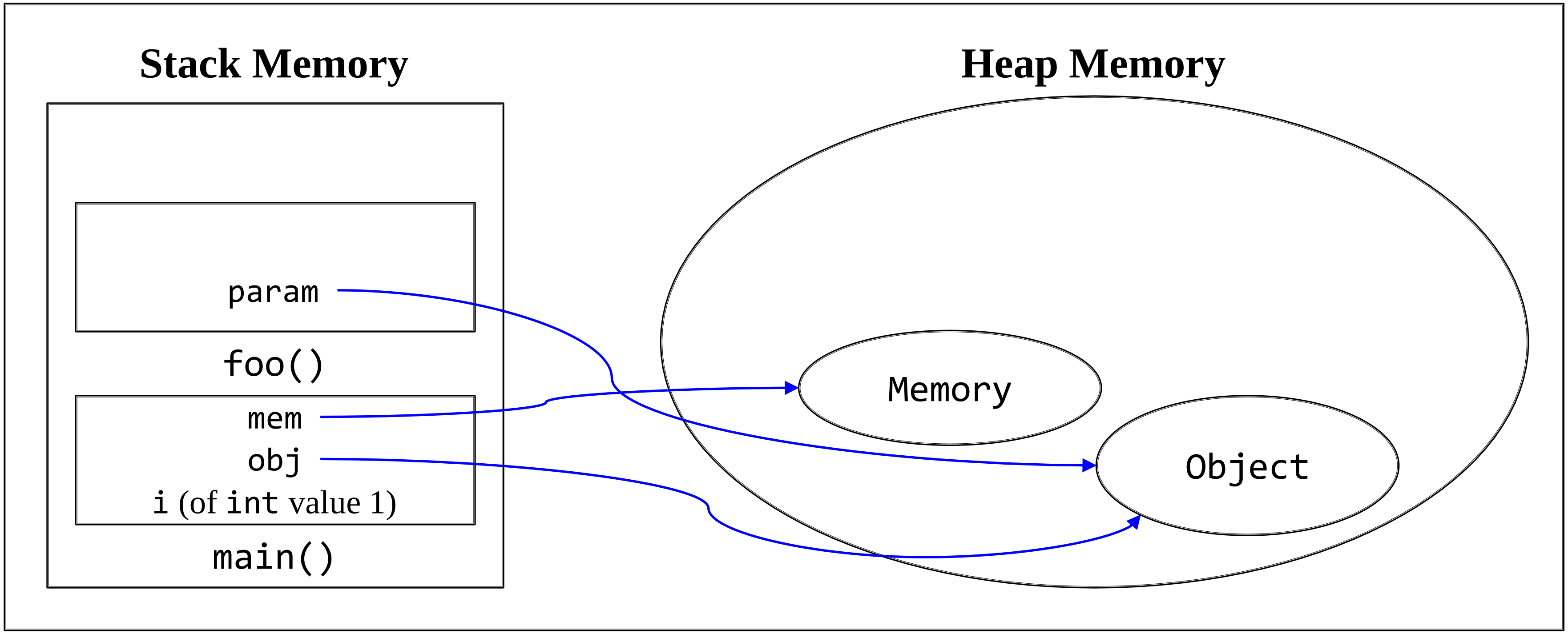

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private void foo(Object param) {
  → String str = param.toString();
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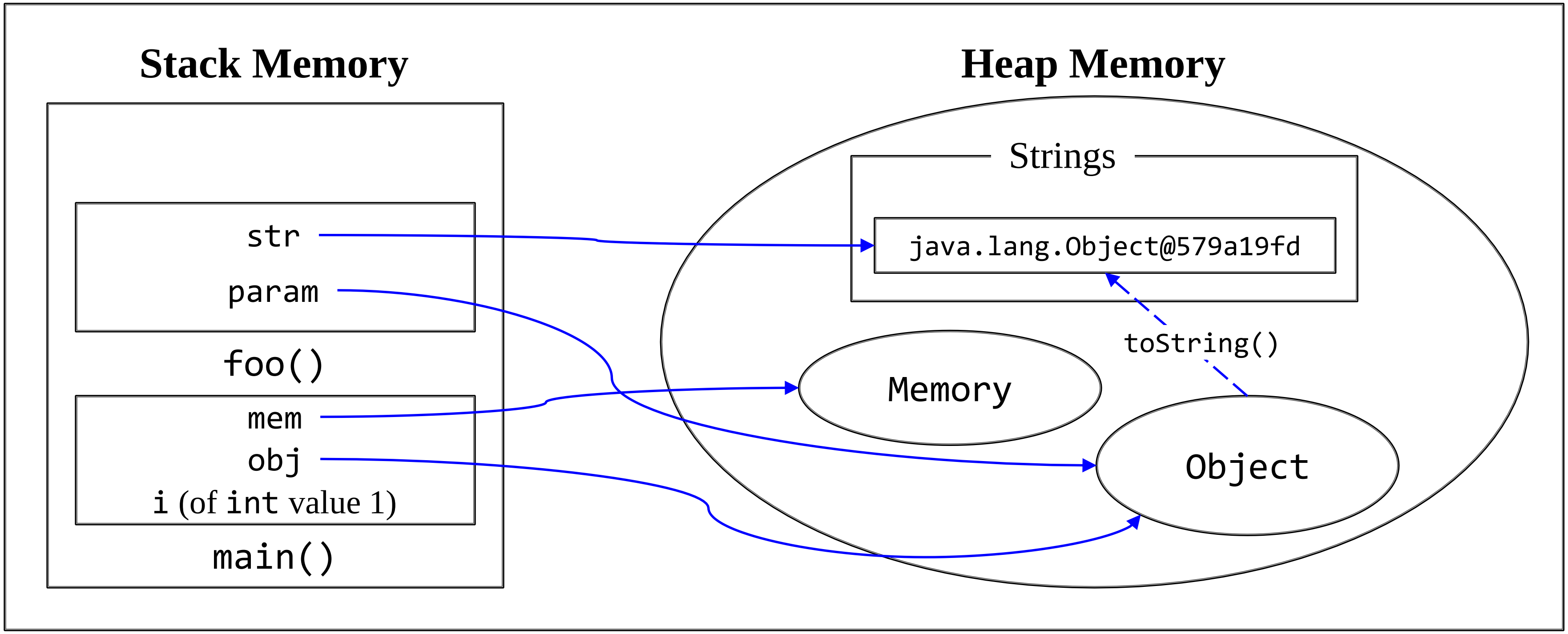
```



Java Runtime Memory

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    Memory mem = new Memory();
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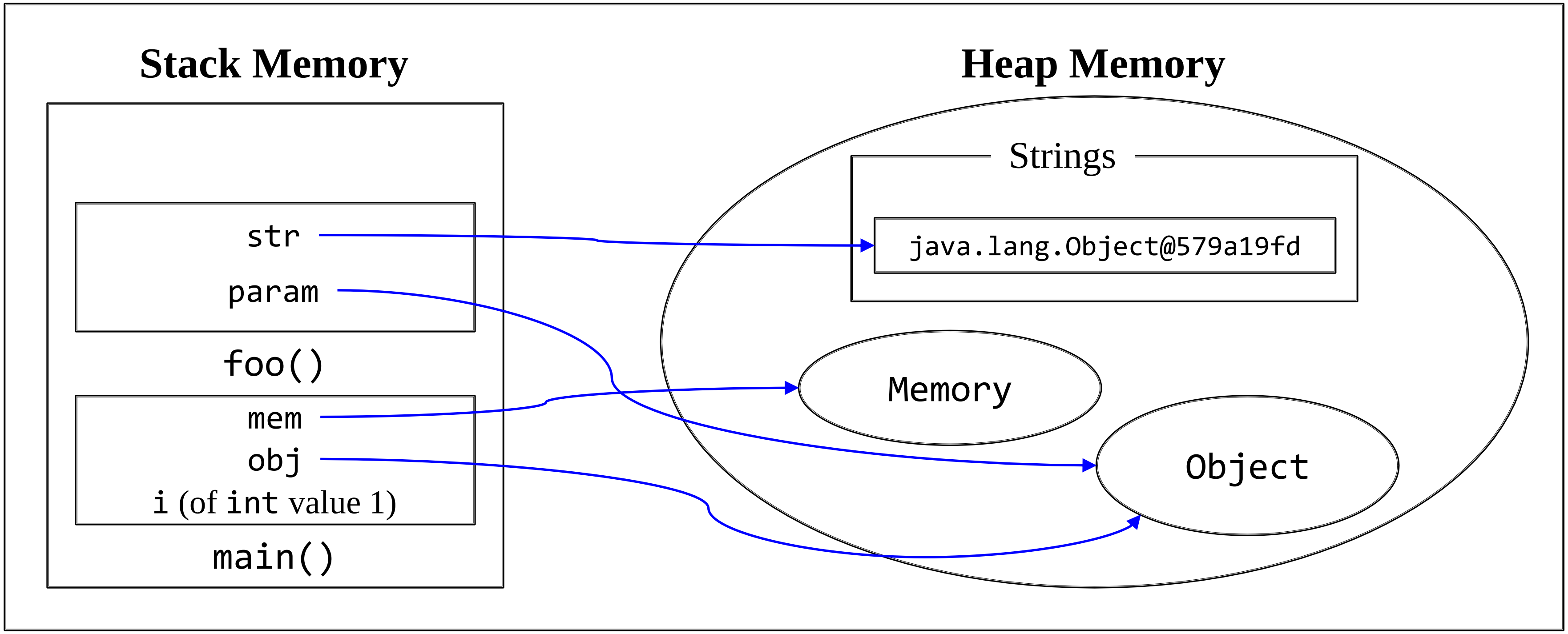

Java Runtime Memory

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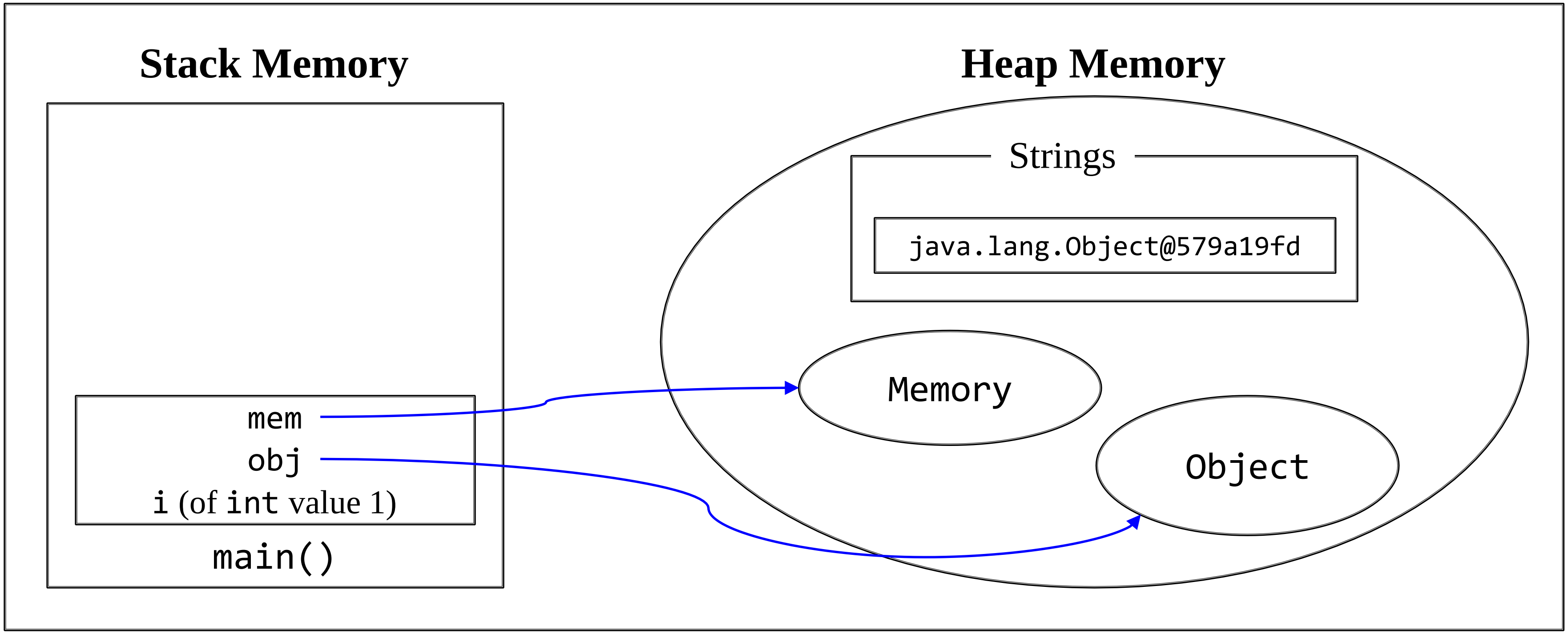

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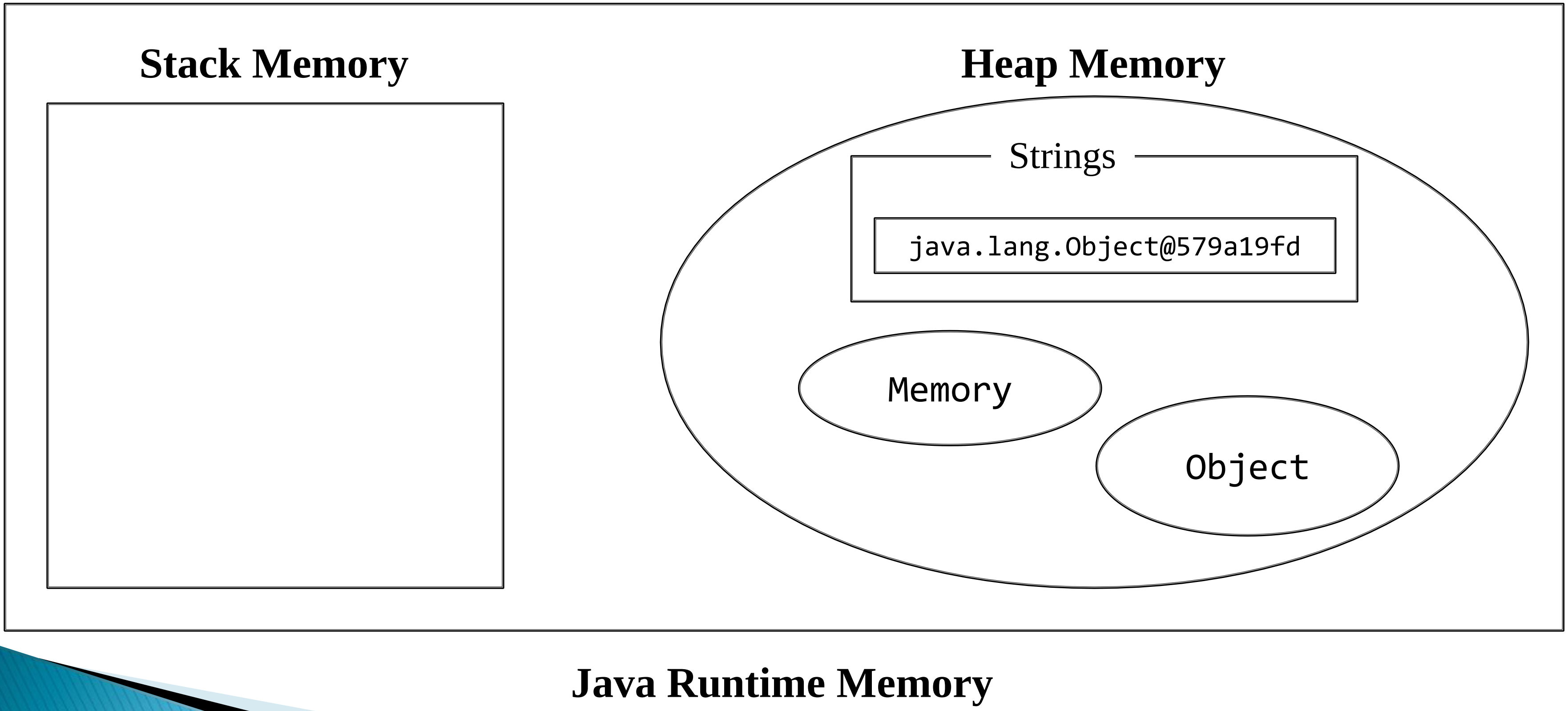

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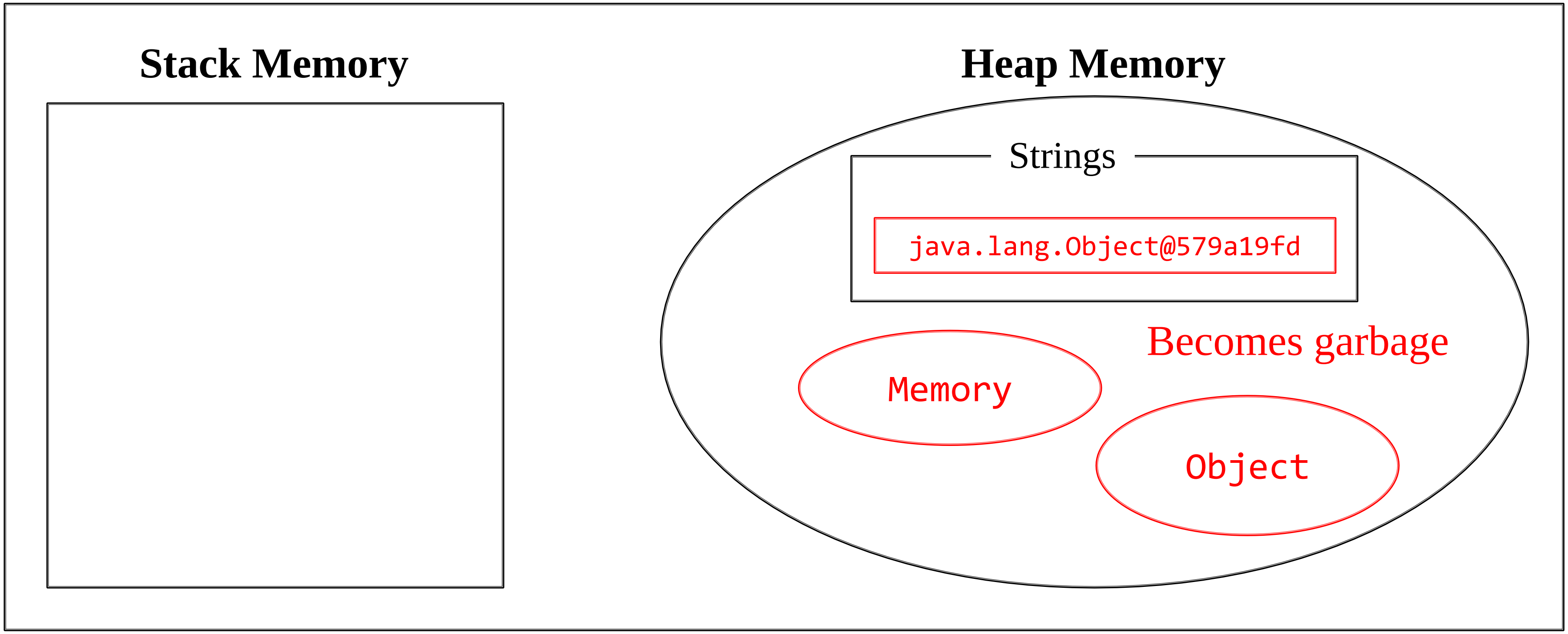

Java Runtime Memory