When we program we start developing from the main class and its main method

Java Basic Features

Object Oriented Programming

http://softeng.polito.it/courses/09CBI

SoftEng http://softeng.polito.it

Version 2.3.0

Comments

- C-style comments (multi-lines)

```
/* this comment is so long
   that it needs two lines */
```

- Comments on a single line

```
// comment on one line
```

Code blocks and Scope

- Java code blocks are the same as in C
- Each block is enclosed by braces `{ }` and starts a new scope for the variables
- Variables can be declared both at the beginning and in the middle of a block

```
for (int i=0; i<10; i++){
    int x = 12;
    ...
    int y;
    ...
}
```

Control statements

- Similar to C
  - if-else
  - switch,
  - while
  - do-while
  - for
  - break
  - continue

Switch statements with strings

- Strings can be used as cases values
  - Since Java 7

```
switch(season){
case “summer”:
case “spring”: temp = “hot”;
               break;
}
```

  - Compiler generates more efficient bytecode from switch using String objects than from chained if-then-else statements.

Boolean

- Java has an explicit type (**`boolean`**) to represent logical values (**`true`**, **`false`**)
- Conditional constructs require boolean conditions
  - Illegal to evaluate integer condition

    ```
    int x = 7; if(x){…} //NO
    ```
  - Use relational operators **`if (x != 0)`**
  - Avoids common mistakes, e.g. **`if(x=0)`**

Passing parameters

- Parameters are always passed by value
- ...they can be primitive types or object references

In Java everything is passed by value!
(except primitive variables)

  - Note: only the object reference is copied not the whole object

Elements in a OO program

Structural elements
(types)
(compile time)

- Class
- Primitive type

Dynamic elements
(instances)
(run time)

- Reference
- Variable

Classes and primitive types

Type

- Class

```
class Exam {}
```

- type primitive

```
int, char,
  float
```

Instance

- Variable of type reference

```
Exam e;
e = new Exam();
```

- Variable of type primitive

```
int i;
```

PRIMITIVE TYPES

Primitive type

- Defined in the language:
  - int, double, boolean, etc.
- Instance declaration:
  - Declares instance name
  - Declares the type
  - Allocates memory space for the value

```
int i;
```

0

Primitive types

Type	Size	Encoding
`boolean`	1 bit	–
`char`	16 bits	Unicode UTF16
`byte`	8 bits	Signed integer 2C
`short`	16 bits	Signed integer 2C
`int`	32 bits	Signed integer 2C
`long`	64 bits	Signed integer 2C
`float`	32 bits	IEEE 754 sp
`double`	64 bits	IEEE 754 dp
`void`	–	

Logical size != memory occupation

Literals

- Literals of type int, float, char, strings follow C syntax
  - **`123  256789L  0xff34  123.75  0.12375e+3`**
  - **`'a'  '%'  '\n' "prova" "prova\n"`**
- Boolean literals (do not exist in C) are
  - **`true`**, **`false`**

Operators (integer and f.p.)

- Operators follow C syntax:
  - arithmetical `+` `-` `*` `/` `%`
  - relational `==` `!=` `>` `<` `>=` `<=`
  - bitwise (int) `&` `|` `^` `<<` `>>` `~`
  - Assignment `=` `+=` `-=` `*=` `/=` `%=` `&=` `|=` `^=`
  - Increment `++` `--`
- Chars are considered like integers (e.g. switch)

Logical operators

- Logical operators follows C syntax:

  `&&   ||   !   ^`

- Warning: logical operators work ONLY on **`boolean`** operands
  - Type **`int`** is NOT treated like a boolean: this is different from C
  - Relational operators return **`boolean`** values

Classes and Objects

Class

In Java, local variables (variables declared inside a method or block) are not automatically initialized to null. They must be explicitly initialized before they can be used. If you try to use an uninitialized local variable, you will get a compile-time error.
On the other hand, instance variables (also known as class-level variables) are automatically initialized to null if they are not explicitly initialized. This means that if you define a class with instance variables but do not assign any initial values to them, they will be initialized to null when an instance of the class is created.

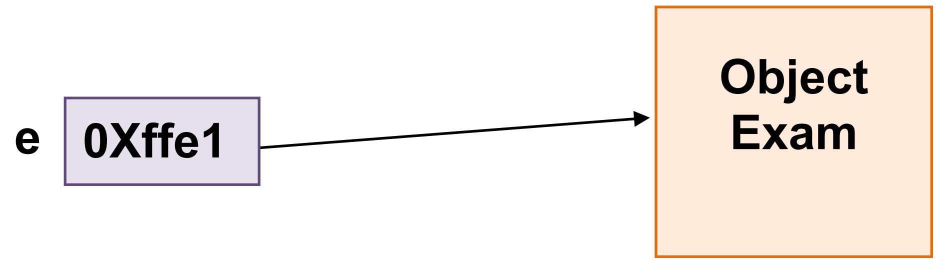
- Defined by developer (e.g., **`Exam`**) or in the Java runtime libraries (e.g., **`String`**)
- The declaration

```
Exam e;
```

e | null

- allocates memory for the *reference* (‘pointer’)
  …and *sometimes* it initializes it with null
- Allocation and initialization of the *object* value are made later by its constructor

```
e = new Exam();
```



Class

- Object descriptor
  - Defines the common structure of a set of objects
- Consists of a set of members
  - Attributes
  - Methods
  - Constructors

With . we separate attributes and methods from classes

Methods, differently than attributes, require a parenthesis since the may require arguments

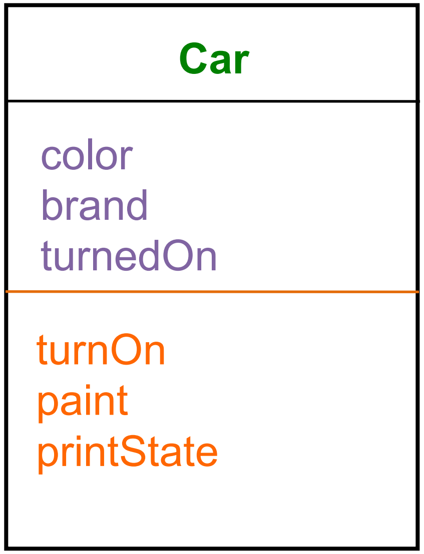
Class – definition

```
public class Car {
   String color;
   String brand;
   boolean turnedOn;
   void turnOn() {
      turnedOn = true;
   }
   void paint (String newCol) {
      color = newCol;
   }
   void printState () {
      System.out.println(“Car “ + brand + “ “ + color);
      System.out.println(“the engine is”
         +(turnedOn?”on”:”off”));
   }
}
```

Name

Attributes

Methods



Attributes

Attributes are like variables but they are defined inside classes

- Attributes describe the data that can be stored within objects
- They are like variables, defined by:
  - Type
  - Name
- Each object has its own copy of the attributes

Methods

- Methods represent the messages that an object can accept
  - **`turnOn`**
  - **`paint`**
  - **`printState`**
- Methods may accept arguments
  - **`paint(String )`**

Objects

An object is an instance of a class
Every object is passed via reference with the exception of primitive variables

- An object is identified by:
  - Class, which defines its structure (in terms of attributes and methods)
  - State (values of attributes)
  - Internal unique identifier
- An object can be accessed through a reference
  - Any object can be pointed to by one or more references
    - Aliasing

Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```

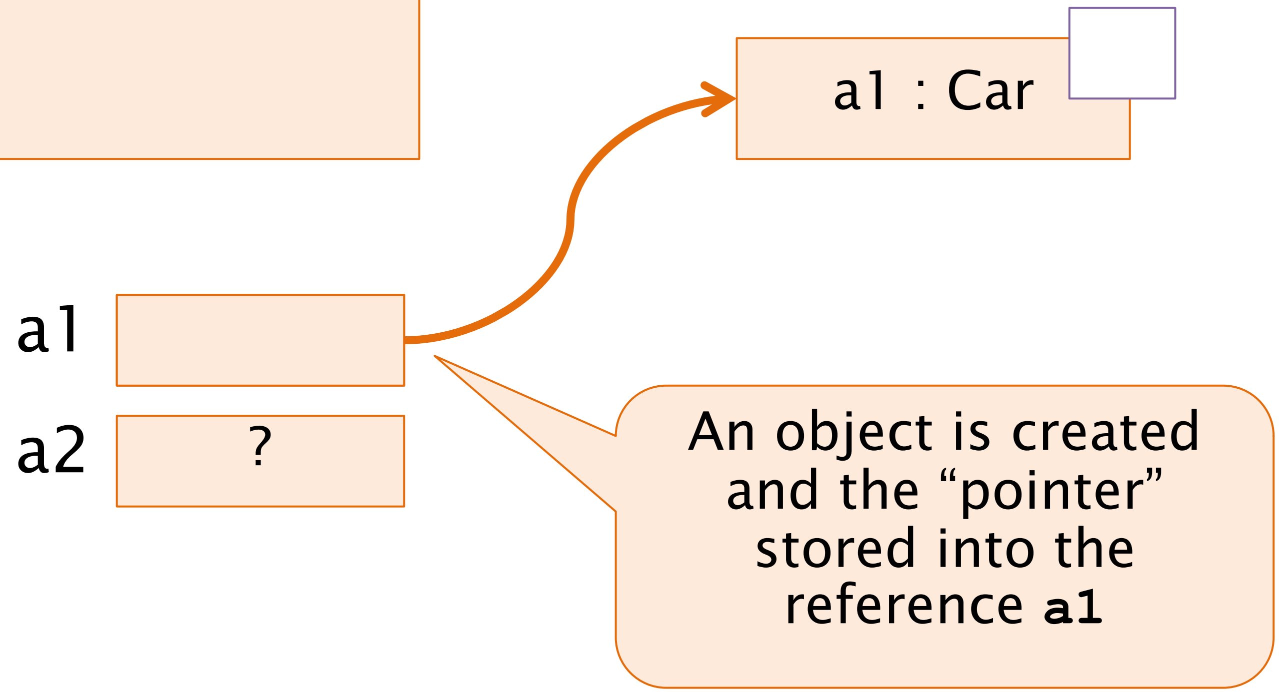
a1 ?

a2 ?

Two uninitialized references are created, they can't be used in any way.
A reference **is not** an object

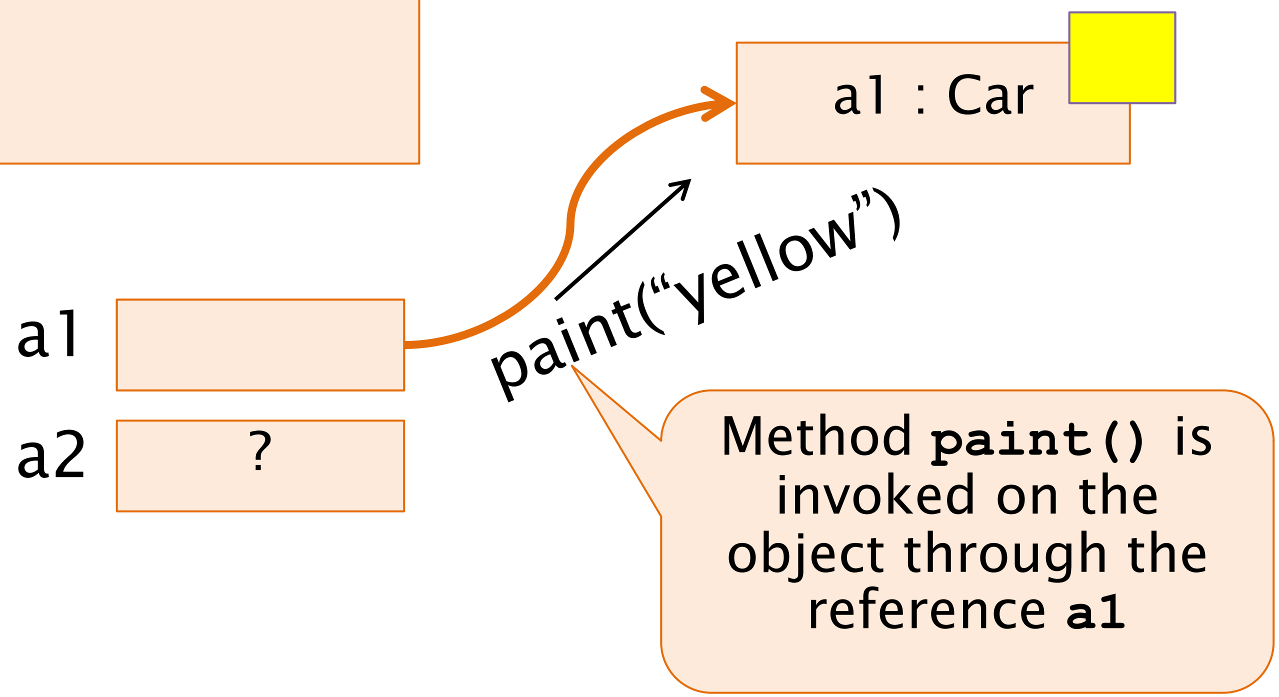
Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



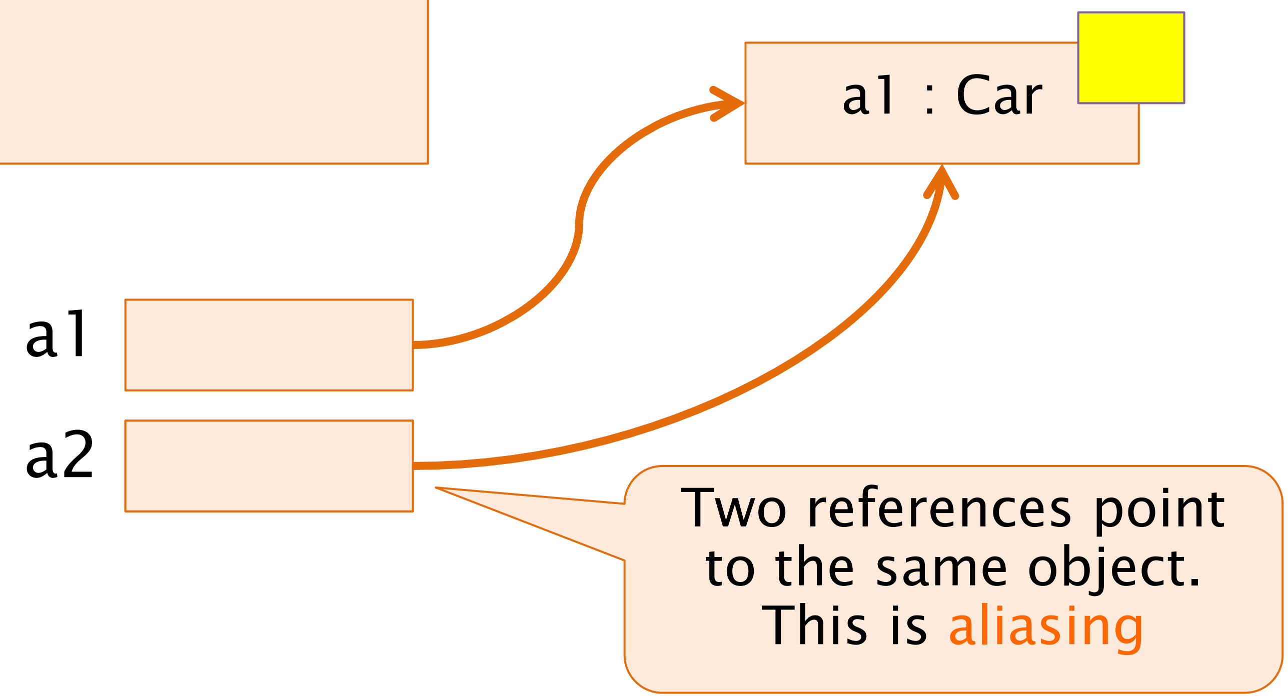
Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



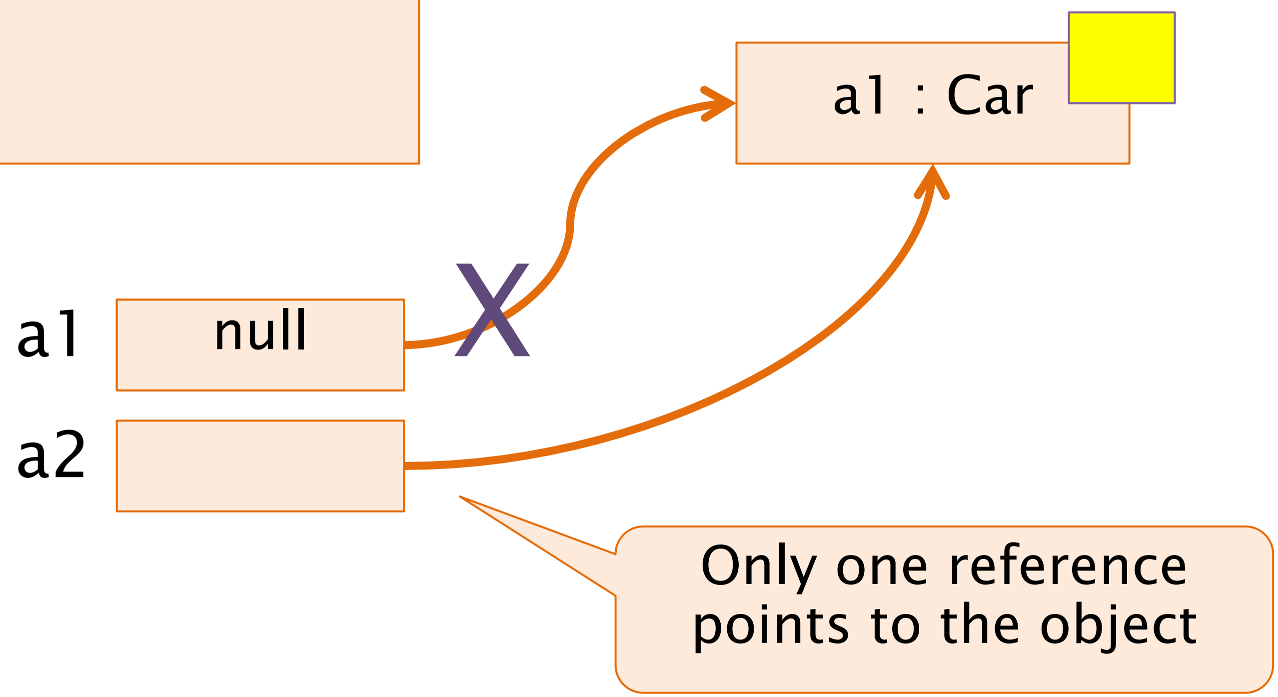
Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



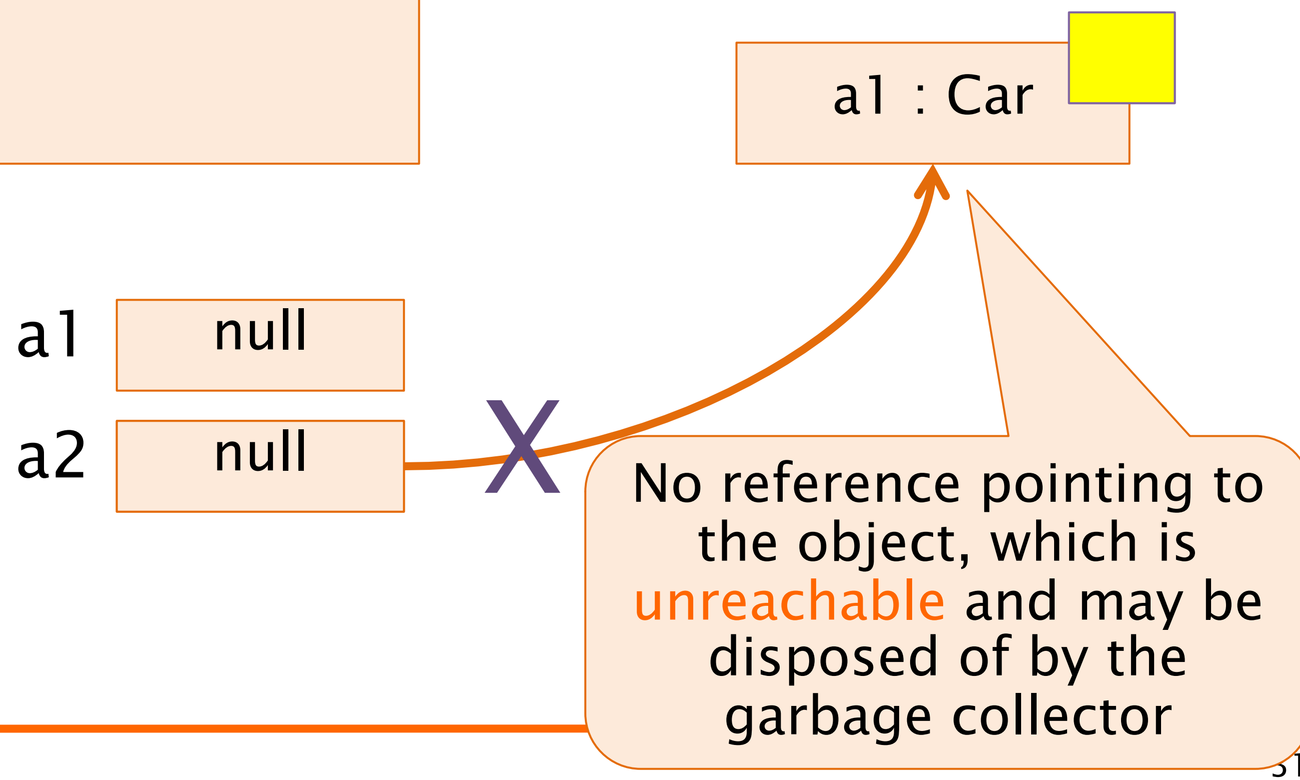
Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



Objects and references

```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



Objects Creation

- Creation of an object is performed using the keyword **`new`**
- It returns a reference to the area of memory containing the newly created object

```
Car m = new Car();
```

The keyword **`new`**

- Creates a new instance of the specific class
- Allocates the required memory in the heap
- Calls the constructor of the object
  - a special method without return type and named like the class
- Returns a reference to the new object
- Constructor may have parameters, e.g.
  - **`String s = new String("ABC");`**

Heap

- A part of the memory used by an executing program to store data dynamically created at run-time

- C: **`malloc`**, **`calloc`** and **`free`**
  - Instances of types in static memory or in heap

- Java: **`new`**
  - Instances (Objects) are always in the heap

Constructor (1)

- Constructor is a special method containing the operations (e.g. initialization of attributes) to be executed on each object as soon as it is created
- Attributes are always initialized
- If no constructor at all is declared, a default one (with no arguments) is provided
- Overloading of constructors is often used

The constructor is a method called upon abject construction (new)

In Customer c=new Customer(name,surname); c contains a reference to a Customer object

Every class has a default constructor which, as soon as a constructor is defined, it disappears.

Constructor (2)

- Attributes are always initialized before any possible constructor
  - Attributes are initialized with default values
    - Numeric: `0` (zero)
    - Boolean: **`false`**
    - Reference: **`null`**
- Return type must not be declared for constructors
  - If present, constructor is considered a method and it is not invoked upon instantiation

Current object – a.k.a `this`

- During the execution of a method it is possible to refer to the current object using the keyword `this`
  - The object upon which the method has been invoked
- This makes no sense within methods that have not been invoked on an object
  - E.g. the `main` method

Method invocation

- A method is invoked using dotted notation

```
objectReference.method(parameters)
```

- Example:

```
Car a = new Car();
a.turnOn();
a.paint("Blue");
```

Note

- If a method is invoked from within another method of the same object dotted notation is not mandatory

```
class Book {
   int pages;
   void readPage(int n) { … }
   void readAll() {
         for(int i=0; i<pages; i++){
            readPage(i);
         }
   }
}
```

Note (cont'd)

- In such cases **this** is implied
- It is not mandatory

```
class Book {
  int pages;
  void readPage(int n){…}
  void readAll() {
    for(…){
      readPage(i);
  } }
}
```

equivalent

```
  void readAll() {
    for(…){
      this.readPage(i);
  } }
```

Access to attributes

- Dotted notation

  objectReference.attribute

  - A reference is used like a normal variable

```
Car a = new Car();
a.color = "Blue"; //what's wrong here?
boolean x = a.turnedOn;
```

Access to attributes

- Methods accessing attributes of the same object do not need to use the object reference

```
class Car {
  String color;
  …
  void paint(){
    color = "green";
    // color refers to current obj
  }
}
```

Using “`this`” for attributes

- The use of this is not mandatory
- It can be useful in methods to disambiguate object attributes from local variables

```
class Car{
   String color;
   ...
   void paint (String color) {
      this.color = color;
   }
}
```

Chaining dotted notations

- Dotted notations can be combined in a single expression

```
System.out.println("Hello world!");
```

- **`System`** is a Class in package java.lang
- **`out`** is a (static) attribute of System referencing an object of type **`PrintStream`** (representing the standard output)
- **`println()`** is a method of **`PrintStream`** which prints a text line followed by a new-line

Method Chaining

```
public class Counter {
   private int value;
   public Counter reset(){
      value=0; return this;
   }
   public Counter increment(int by){
      this.value+=by; return this;
   }
   public Counter print(){
      System.out.println(value);
      return this;
   }
}
```

```
Counter cnt = new Counter();
cnt.reset().print()
    .increment(10).print()
    .decrement(7).print();
```

Operations on references

- Only the comparison operators `==` and `!=` are defined
  - Note well: the equality condition is evaluated on the values of the references and NOT on the objects themselves!
  - The relational operators tells whether the references points to the same object in memory
- Dotted notation is applicable to object references
- There is NO pointer arithmetic

Overloading

Methods must have different signature! So could have the same name (as long as different signature, i.e. if the name is the same a different ordered list of argument types)

- Several methods in a class can share the same name
- They must have have distinct signature
- A signature consists of:
  - Method name
  - Ordered list of argument types

Overloading: disambiguation

- Invocation of an overloaded method is potentially ambiguous
- Disambiguation is performed by the compiler based on actual parameters
  - The method definition whose argument types list matches the actual parameters, is selected

Overloading

```
class Car {
   String color;
   void paint(){
      color = "white";
   }
   void paint(int i){ … }
   void paint(String newCol){
      color = newCol;
   }
}
```

Constructors with overloading

```
class Car { // …
//   Default constructor, creates a red Ferrari
  public Car(){
     color = "red";
     brand = "Ferrari";
  }
// Constructor accepting the brand only
  public Car(String carBrand){
     color = "white”;
      brand = carBrand;
  }
// Constructor accepting the brand and the color
  public Car(String carBrand, String carColor){
     color = carColor;
     brand = carBrand;
  }
}
```

Destruction of objects

- Memory release, in Java, is no longer a programmer's concern
  - Managed memory language
- Before the object is really destroyed the method **`finalize`**, if defined, is invoked:

```
public void finalize()
```

SCOPE AND ENCAPSULATION

Scope and Syntax

- Visibility modifiers
  - Applicable to members of a class
- **`private`**
  - Member is visible and accessible from instances of the same class only
- **`public`**
  - Member is visible and accessible from everywhere

Info hiding

```
class Car {
  public String color;
}
```

```
Car a = new Car();
a.color="white"; // ok
```

better

```
class Car {
  private String color;
  public void paint(String color)
    {this.color = color;}
}
```

```
Car a = new Car();
a.color = "white";   // error
a.paint("green");    // ok
```

Info hiding

```
class Car{
      private String color;
      public void paint();
}
```

no

```
class B {
   public void f1(){
      ...
   };
}
```

yes

Access

	Method in the same class	Method in another class
Private (attribute / method)	yes	no
Public (attribute / method)	yes	yes

Getters and setters

Use shortcuts!
Like for this:
Source->Generate Getters and Setters
but also others like:
Source->Generate Constructor using Fields

- Methods used to read/write a private attribute
- Allow to better control in a single point each write access to a private field

```
public String getColor() {
    return color;
}
public void setColor(String newColor) {
    color = newColor;
}
```

Example without getter/setter

```
public class Student {
   public String first;
   public String last;
   public int id;
   public Student(…){…}
}
```

```
public class Exam {
   public int grade;
   public Student student;
   public Exam(…){…}
}
```

Example without getter/setter

```
class StudentExample {
  public static void main(String[] args) {
     // defines a student and her exams
     // lists all student's exams
     Student s=new Student("Alice","Green",1234);
     Exam e = new Exam(30);
     e.student = s;
     // print vote
     System.out.println(e.grade);
     // print student
     System.out.println(e.student.last);
  }
}
```

Example with getter/setter

```
class StudentExample {
  public static void main(String[] args) {
    Student s = new Student("Alice", "Green",
                             1234);
    Exam e = new Exam(30);

    e.setStudent(s);
    // prints its values and asks students to
    // print their data
    e.print();
  }
}
```

Example with getter/setter

```
public class Student {

  private String first;
  private String last;
  private int id;

  public String toString() {
   return first + " " +
              last  + " " +
              id;
  }
}
```

Example with getter/setter

```
public class Exam {
    private int grade;
    private Student student;

    public void print() {
    System.out.println("Student " +
        student.toString() + "got " + grade);
    }

    public void setStudent(Student s) {
    this.student =s;
    }
}
```

Getters & setters vs. public fields

- Getter
  - Allow changing the internal representation without affecting
    - E.g. can perform type conversion
- Setter
  - Allow performing checks before modifying the attribute
    - E.g. Validity of values, authorization

Modifier / Query methods

- Modifiers
  - Change the state of the object but do not return a value
    - e.g. getters

the examples are exchanged:
an example of modifiers are setters
and of query are getters

- Query
  - Return a result and do not change the state of the object
  - No side-effects
    - e.g. setters

Modifier / Query Separation

- Invocations to
  - queries can be added, removed, and swapped without affecting the overall behavior
  - modifiers cannot be touched without affecting the behavior
- Important to clearly separate them:
  - Queries return a value
  - Modifiers return `void`

See: https://www.martinfowler.com/bliki/CommandQuerySeparation.html
Original concepts in: B.Meyer, Object-Oriented Software Construction, Prentice-Hall, 1997

Packages

- Class is a better mechanism of modularization than a procedure
- But it is still small, when compared to the size of an application
- For the purpose of code organization and structuring Java provides the package feature

Package

analogous to libraries in C/Python

- A package is a logic set of class definitions
- These classes consist in several files, all stored in the same folder
- Each package defines a new scope (i.e., it puts bounds to visibility of names)
- It is therefore possible to use same class names in different package without name–conflicts

Package name

- A package is identified by a name with a hierarchic structure (*fully qualified name*)
  - E.g. **java.lang** (String, System, …)

- Conventions to create unique names
  - Internet name in reverse order
  - **`it.polito.myPackage`**

Examples

- **`java.awt`**
  - **`Window`**
  - **`Button`**
  - **`Menu`**

- **`java.awt.event`** (sub-package)
  - **`MouseEvent`**
  - **`KeyEvent`**

Creation and usage

- Declaration:
  - Package statement at the beginning of each class file

```
package packageName;
```

- Usage:
  - Import statement at the beginning of class file (where needed)

```
import packageName.className;
```

Import single class (class name is in scope)

```
import java.awt.*;
```

Import all classes but not the sub packages

Access to a class in a package

- Referring to a method/class of a package

```
int i = myPackage.Console.readInt()
```

- If two packages define a class with the same name, they cannot be both imported
- If you need both classes you have to use one of them with its fully-qualified name:

```
import java.sql.Date;
Date d1; // java.sql.Date
java.util.Date d2 = new java.util.Date();
```

Default package

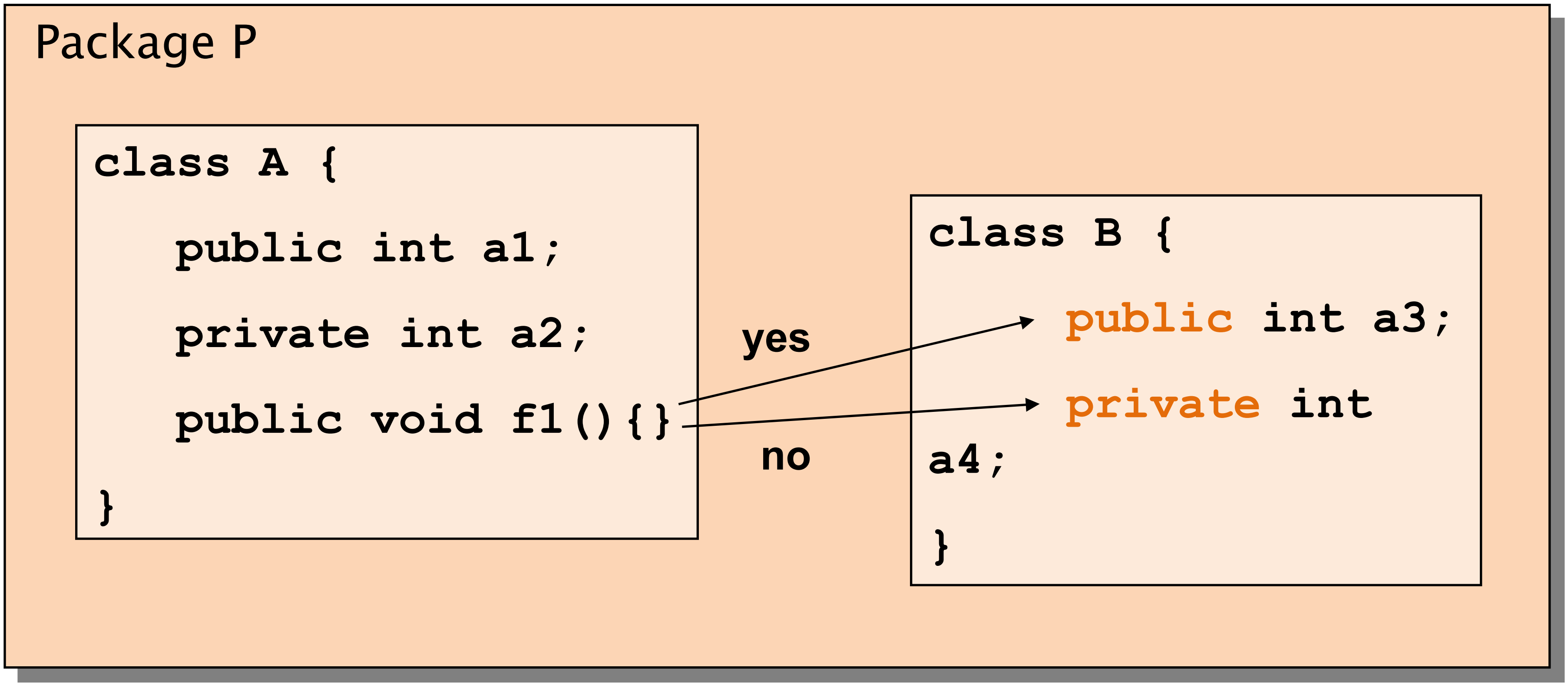
- When no package is specified, the class belongs to the default package
  - The default package has no name
- Classes in the default package cannot be accessed by classes residing in other packages
- Usage of default package is a bad practice and is discouraged

Package and scope

- Scope rules also apply to packages
- The “interface” of a package is the set of public classes contained in the package

- Hints
  - Consider a package as an entity of modularization
  - Minimize the number of classes, attributes, methods visible outside the package

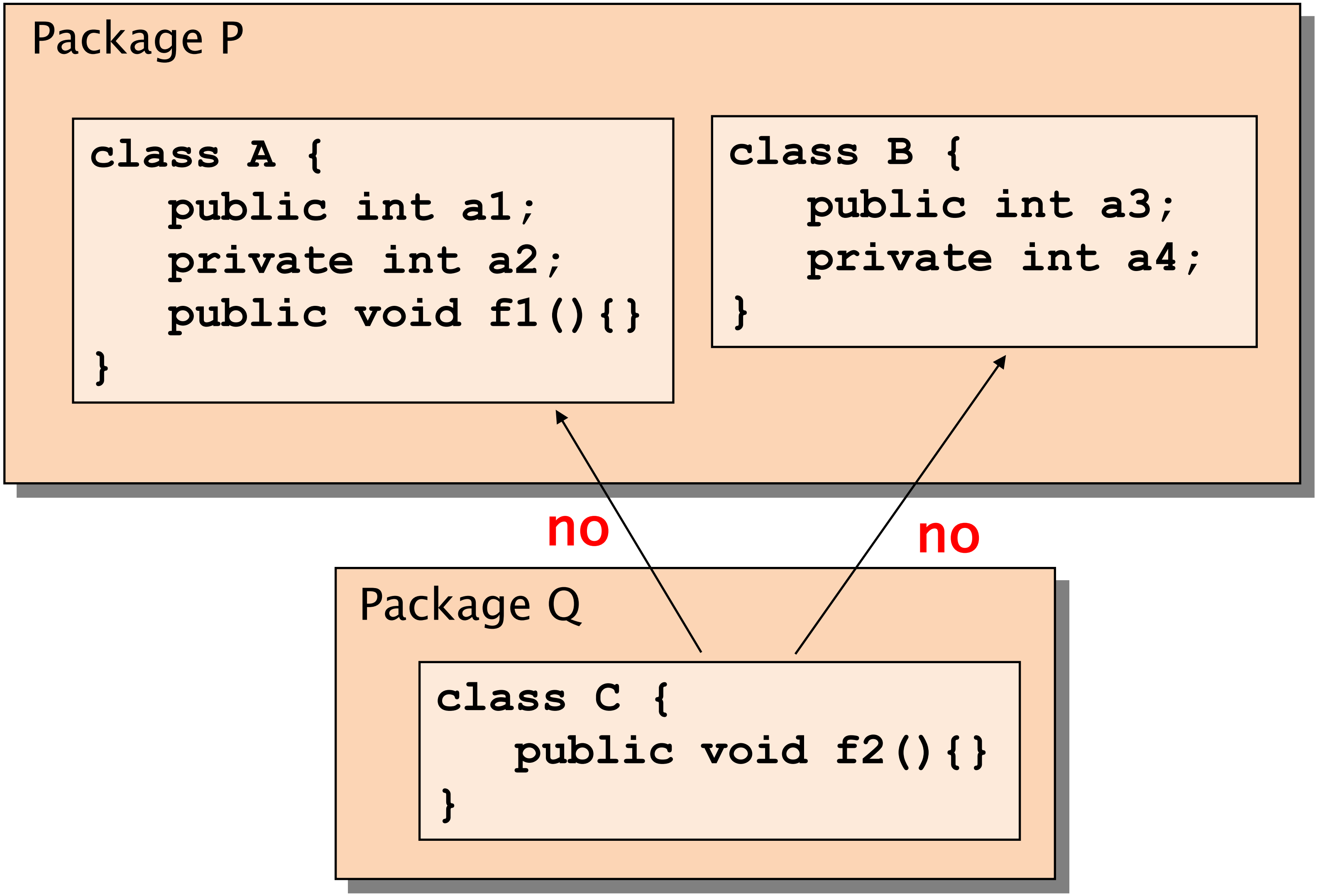
Package visibility



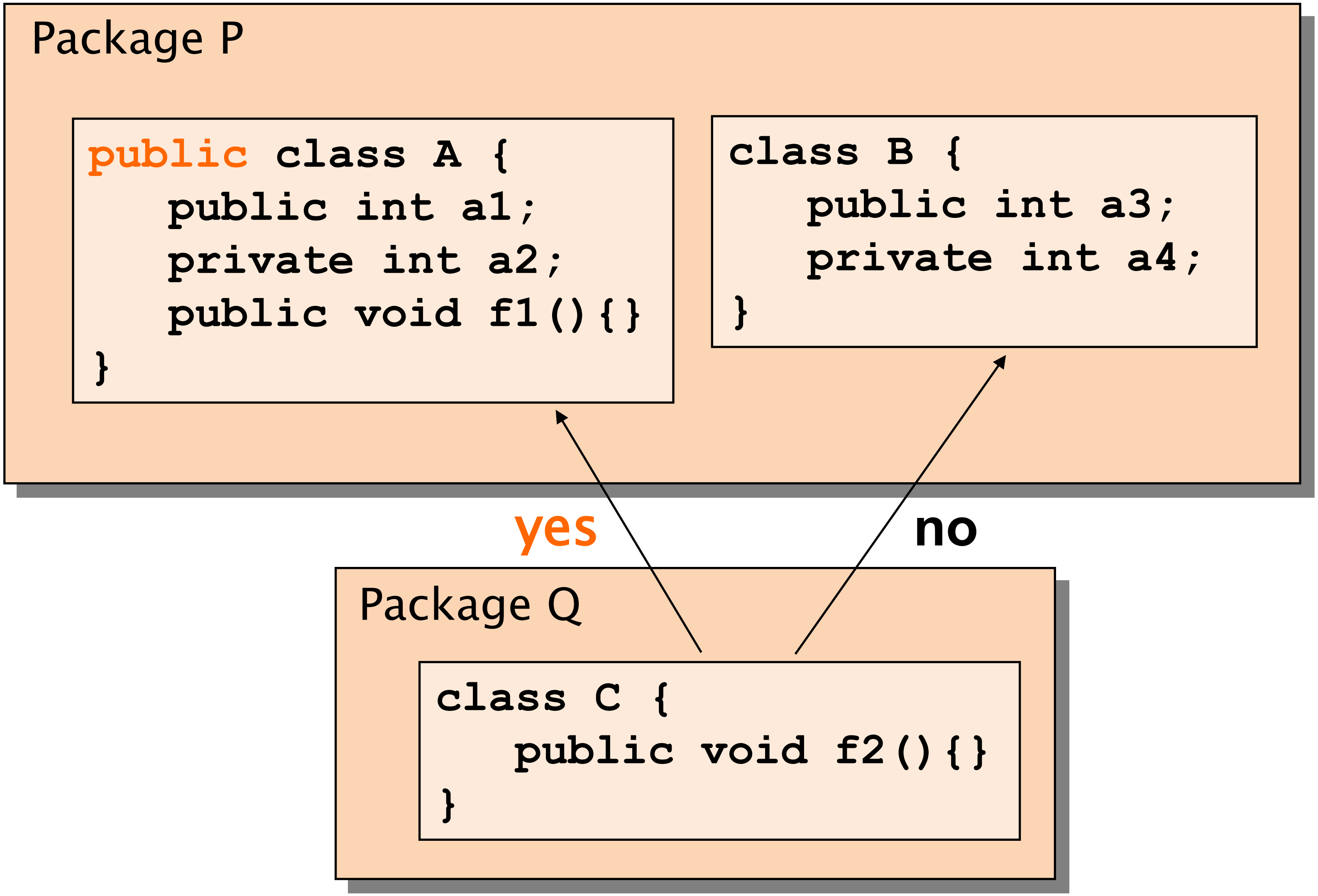
Visibility w/ multiple packages

- `public class A { }`
  - Class and public members of A are visible from outside the package
- `class B { }`
  - Package visibility
  - Class and any members of B are not visible from outside the package
  - but visible to the package
- `private class A { }`
  - Illegal: why?
  - The class and its members would be visible to themselves only

Multiple packages



Multiple packages



Access rules

	Method of the same class	Method of other class in the same package	Method of other class in other package
Private member	Yes	No	No
Package member	Yes	Yes	No
Public member in package class	Yes	Yes	No
Public member in public class	Yes	Yes	Yes

Wrapper Classes

"transforming primitive data types into classes to keep coherance with the purely object-oriented nature"

String

- No primitive type to represent string
- String literal is a quoted text
- C
  - **`char s[] = “literal”`**
  - Equivalence between string and char arrays
- Java
  - **`char[] != String`**
  - String class in **`java.lang`** package

The string cannot change a value

See slide deck “Java Characters and Strings”

Motivation

- In an ideal OO world, there are only classes and objects
- For the sake of efficiency, Java use primitive types (int, float, etc.)

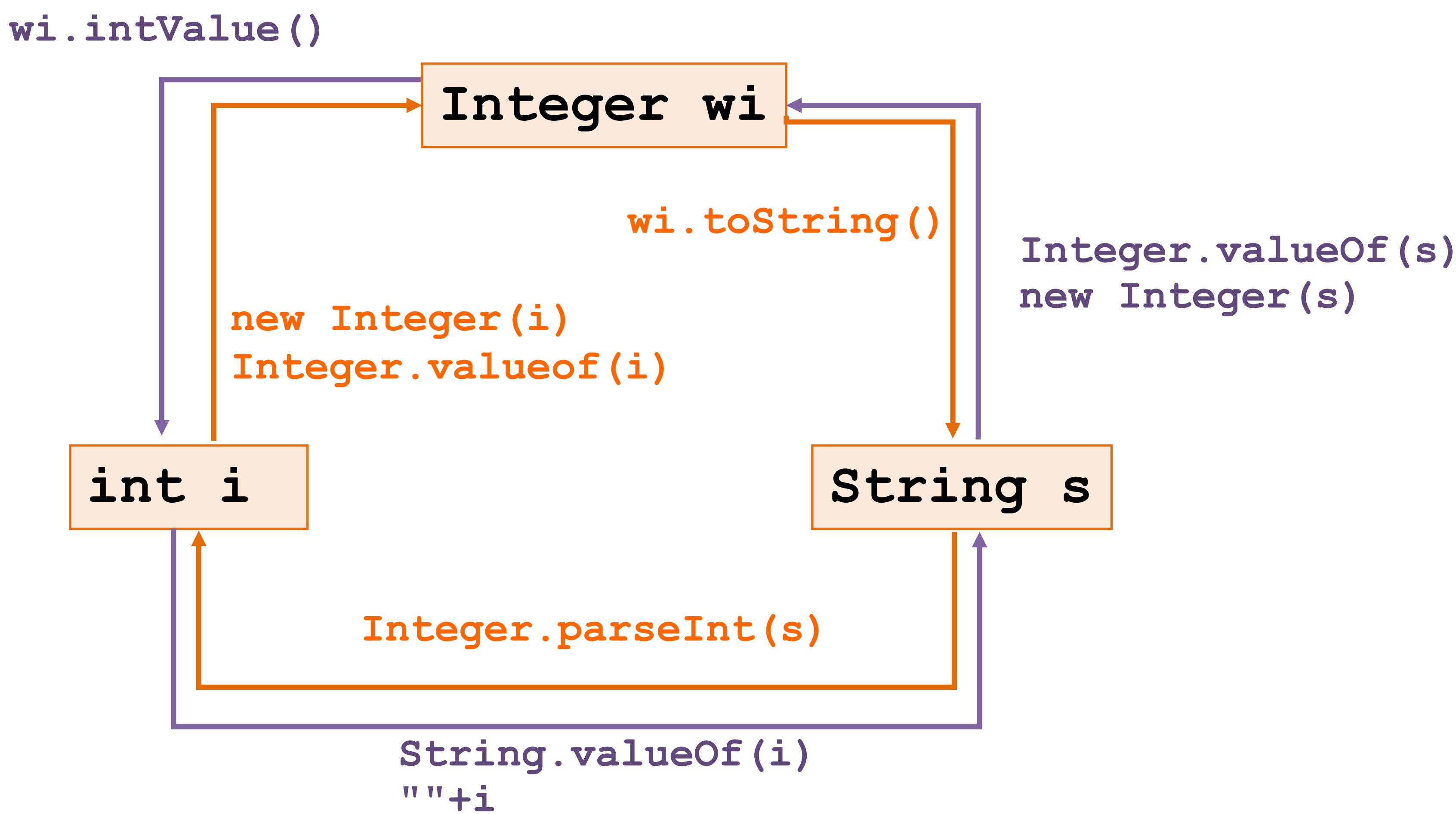
- Wrapper classes are object versions of the primitive types
- They define conversion operations between different types

Wrapper Classes

Defined in `java.lang` package

Primitive type	Wrapper Class
`boolean`	`Boolean`
`char`	`Character`
`byte`	`Byte`
`short`	`Short`
`int`	`Integer`
`long`	`Long`
`float`	`Float`
`double`	`Double`
`void`	`Void`

Conversions



Example

```
Integer obj = new Integer(88);
String s = obj.toString();
int i = obj.intValue();

int j = Integer.parseInt("99");
int k=(new Integer(99)).intValue();
```

Using `Scanner`

- Scanner can be initialized with a string

```
Scanner s = new Scanner("123");
```

- then values can be parsed

```
int i = s.nextInt();
```

- In addition a scanner is able to parse several numbers in the same string

Autoboxing

- Since Java 5, the conversion between primitive types and wrapper classes is performed automatically (*autoboxing*)

```
Integer i= new Integer(2); int j;
j = i + 5;
  //instead of:
j = i.intValue()+5;
i = j + 2;
   //instead of:
i = new Integer(j+2);
```

Character

- Utility methods on the kind of char
  - **`isLetter(), isDigit(), isSpaceChar()`**
- Utility methods for conversions
  - **`toUpper(), toLower()`**

Arrays

Array

- An array is an ordered sequence of variables of the same type which are accessed through an index
- Can contain both primitive types or object references (but no object values)
- Array dimension can be defined at run-time, during object creation (cannot change afterwards)

Array declaration

- An array reference can be declared with one of these equivalent syntaxes

```
int[] a;
int a[];
```

- In Java an array is an Object and it is stored in the heap
- Array declaration allocates memory space for a reference, whose default value is null

a null

Array creation

- Using the new operator…

Size of the array is defined in the new , the number can be an integer or a constant. This is because it is treated as an object

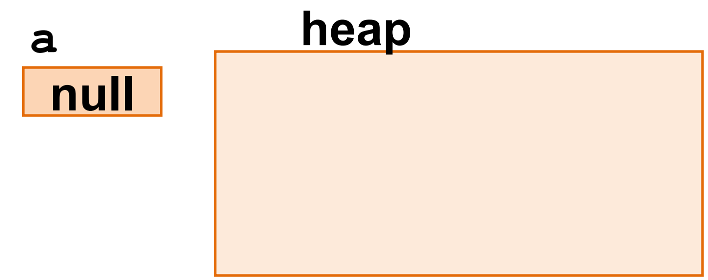
```
int[] a;
a = new int[10];
String[] s = new String[5];
```

- …or using static initialization, filling the array with values

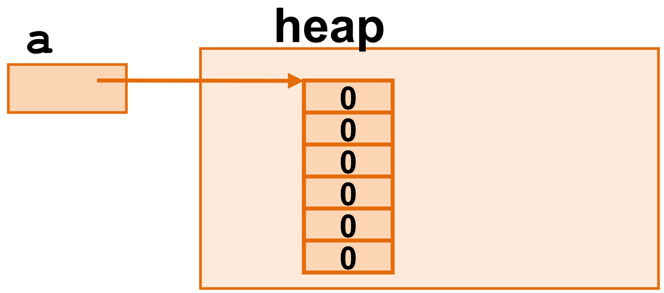
```
int[] primes = {2,3,5,7,11,13};
Person[] p = { new Person(“John”),
           new Person(“Susan”) };
```

Example – primitive types

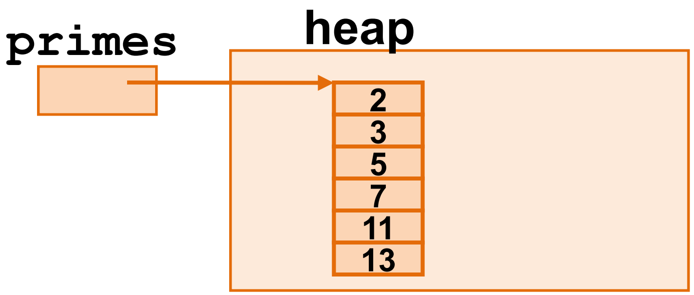
```
int[] a;
```




```
a = new int[6];
```

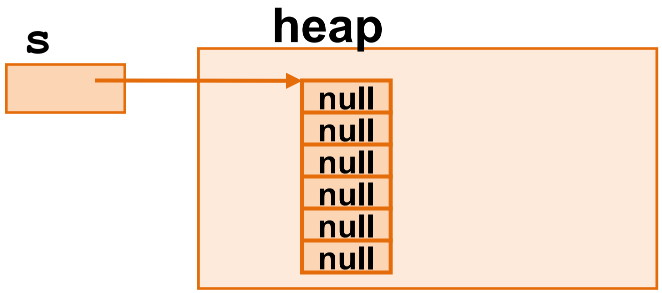



```
int[] primes =
  {2,3,5,7,11,13};
```

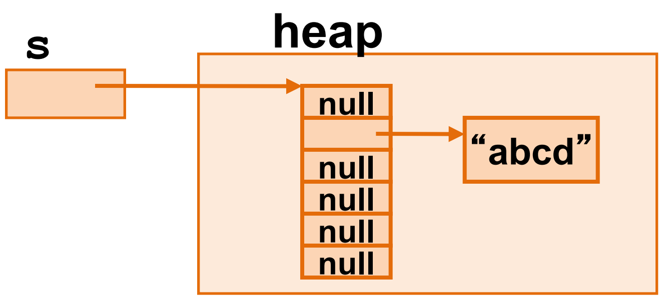


Example – object references

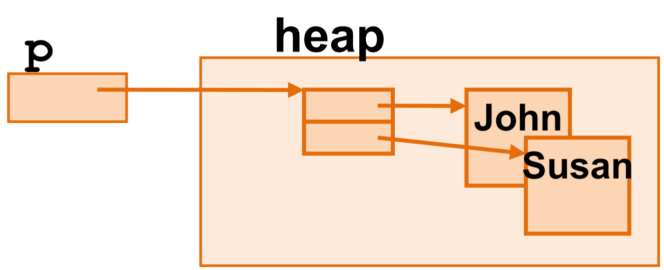
```
String[] s = new
  String[6];
```




```
s[1] = new
  String("abcd");
```




```
Person[] p =
{new Person("John") ,
 new Person("Susan")};
```



Operations on arrays

- Elements are selected with brackets [ ] (C-like)
  - But Java makes **bounds checking**

- Array length (number of elements) is given by attribute length

```
for (int i=0; i < a.length; i++)
    a[i] = i;
```

Operations on arrays

- An array reference is not a pointer to the first element of the array
- It is a pointer to the array object

- Arithmetic on pointers does not exist in Java

For each

- New loop construct:

  `for( Type var : set_expression )`

  - Very compact notation
  - *set_expression* can be
    - either an array
    - a class implementing `Iterable`
  - The compiler can generate automatically the loop with correct indexes
    - Less error prone

For each – example

- Example:

```
for(String arg : args){
   //...                  but you will loose the index information
}
```

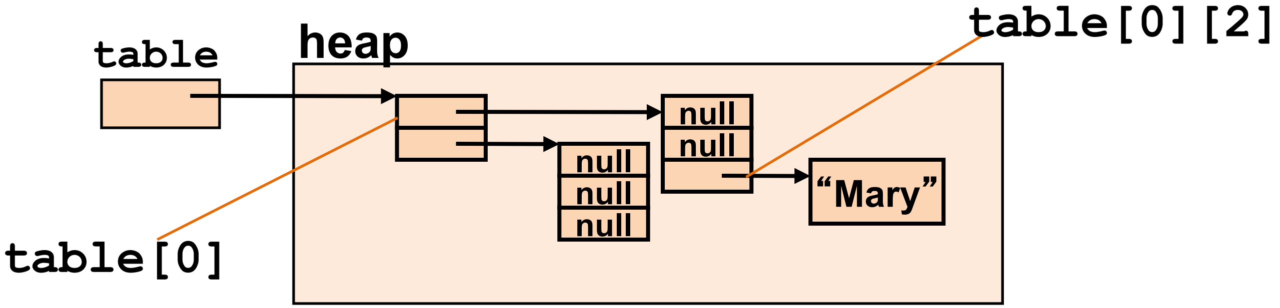
  - is equivalent to

```
for(int i=0; i<args.length;++i){
   String arg= args[i];
   //...
}
```

Multidimensional array

- Implemented as array of arrays

```
Person[][] table = new Person[2][3];
table[0][2] = new Person("Mary");
```



Rows and columns

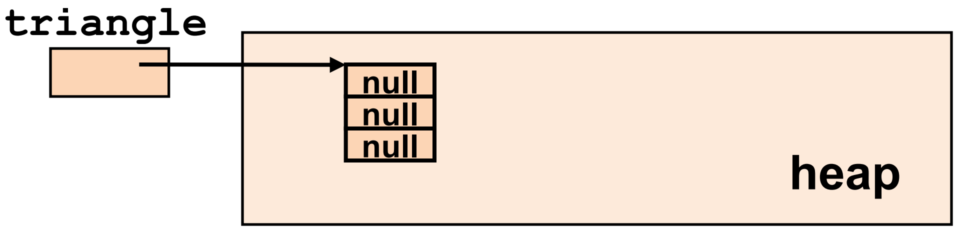
- Since rows are not stored in adjacent positions in memory they can be easily exchanged

```
double[][] balance = new double[5][6];
...
double[] temp = balance[i];
balance[i] = balance[j];
balance[j] = temp;
```

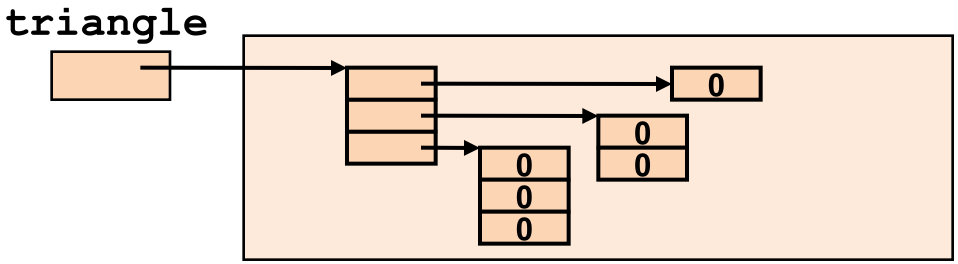
Rows with different length

- A matrix (bidimensional array) is indeed an array of arrays

```
int[][] triangle = new int[3][]
```




```
for (int i=0; i< triangle.length; i++)
    triangle[i] = new int[i+1];
```



Static Attributes and Methods

Static attributes

- Represent properties which are common to all instances of a class
  - A single copy of a static attribute is shared by all instances of the class
  - Sometimes called class attributes as opposed to instance attributes
  - Static attributes exists before any object is created
  - A change performed by any object is visible to all instances at once
- They are defined with the **`static`** modifier

so they are properties of a class, not of an object

Static attributes: why

- Used to keep a shared property
  - A count of created instances
  - A pool of all instances
- Keep a common constant value

```
class Car {
   static int countBuiltCars = 0;
   public Car(){
      countBuiltCars++;
   }
}
```

Static methods

Do not overuse them, but keep it object-oriented

- Static methods are not related to any instance
- They are defined with the `static` modifier
- Used to implement functions

```
public class HelloWorld {
  public static void main (String args[]) {
     System.out.println("Hello World!");
  }
}
```

```
public class Utility {
  public static int inverse(double n){
     return 1 / n;
  }
}
```

Static members access

- The name of the class is used to access the member:

```
Car.countCountBuiltCars
Utility.inverse(10);
```

- It is possible to import all static items:

```
import static package.Utility.*;
```

  - Then all static members are accessible without specifying the class name
    - Note: Impossible if class in default package

Static methods: why

- Implement *functions*
  - Avoid creating an object just to invoke the method (see e.g., **`main()`**)
  - Collected in utility classes
- Provide ideal factory method
  - Method to create an instance

Function method

- A "*function*" is a method whose return value depends only on the arguments
  - Typically defined as **`static`**
- Often collected within a utility class
  - Class containing **`static`** function methods only
- Wrapper types include several *function* methods for conversion purposes

Utility classes

- **`System`**
  - Interact with the operating system
- **`Math`**
  - Mathematical functions
- **`Arrays`**
  - Functions to operate on arrays
- **`Objects`**
  - Functions to operate on object

Class `Math`

- Defines several math-related function methods
  - Trigonometric functions
  - Min-max
  - Exponential and logarithms
  - Truncations
  - Random number generation

Class **`Arrays`**

- Arrays utility functions
  - Binary search (**`binarySearch()`**)
  - Copy (**`copyOf()`**, **`copyOfRange()`**)
  - Equality (**`equals()`**, **`deepEquals()`**)
  - Fill-in (**`fill()`**)
  - Sorting (**`sort()`**)
  - String representation (**`toString()`**)

Class `System`

- General purpose utilities
  - `static long currentTimeMillis()`
    - Current system time in milliseconds
  - `static void exit(int code)`
    - Terminates the execution of the JVM
  - `static final PrintStream out`
    - Standard output stream,
    - Also `err` for standard error

Factory method

- A method used to create an object
  - Encapsulates an explicit object creation with the **`new`** operator
- Can be used to:
  - Return objects from a pool
    - Requires immutable objects
    - Either pre-allocated or cached
  - Simplify creation
  - Maintain a collection of created objects
  - Control new objects allocation
    - See e.g., Singleton pattern

Factory methods: `Integer`

- `valueOf(int)`
  - Replaces new Integer(int)
  - Cache values in the range -128 to 127
- `valueOf(String)`
  - Returns the integer corresponding to the parsed string
  - Same as:
    `new Integer(Integer.parseInt(s))`

Final Attributes

- An attribute declared as **`final`**:
  - cannot be changed after object construction
  - can be initialized inline or by the constructor

```
class Student {
  final int years=3;
  final String id;
  public Student(String id){
    this.id = id;
  }
}
```

Final variables / parameters

- Final parameters cannot be changed
  - Non final parameters are treated as local variables (initialized by the caller)
- Final variables
  - Cannot be modified after initialization
  - Initialization can occur at declaration or later

Constants

- Use `final static` modifiers
  - `final` implies not modifiable
  - `static` implies non redundant

```
final static float PI = 3.14;
…
PI = 16.0;          // ERROR, no changes
final static int SIZE; // missing init
```

- All uppercase (coding conventions)

Static initialization block

- Block of code preceded by **`static`**
- Executed at class loading time

```
public final static double 2PI;
static {
  2PI = Math.acos(-1);
}
```

Example: Global directory (a)

- Manages a global name directory

```
class Directory {
  public final static Directory root;
  static {
    root = new Directory();
  }
  // …
}
```

What if not always useful and expensive creation?

Example: Global directory (b)

- Manages a global directory

```
class Directory {
  private static Directory root;
  public static Directory getInstance(){
    if(root==null){
      root = new Directory();
    }
    return root;
  }
  // …
}
```

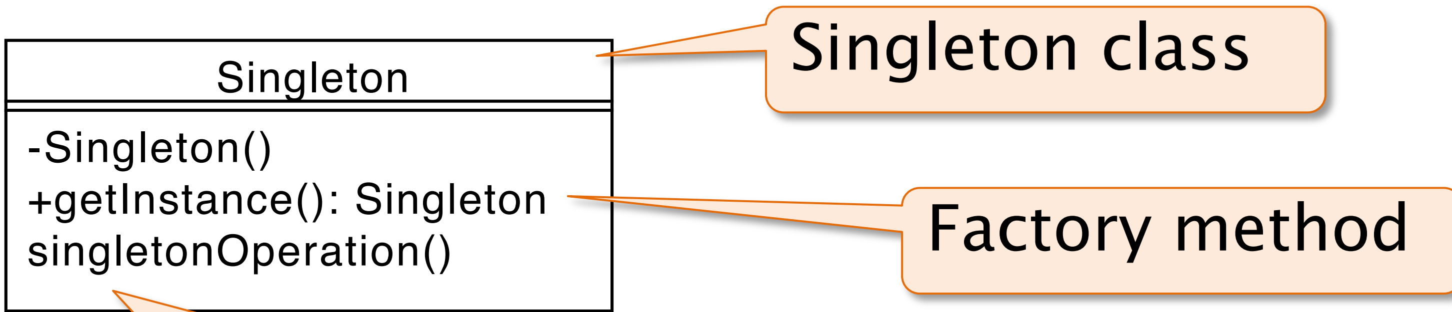
Created on-demand at first usage

Singleton Pattern

- Context:
  - A class represents a concept that requires a single instance
- Problem:
  - Clients could use this class in an inappropriate way

See slide deck on design patterns

Singleton Pattern




```
private Singleton() { }
private static Singleton instance;
public static Singleton getInstance(){
   if(instance==null)
        instance = new Singleton();
   return instance;
}
```

Fluent Interfaces

- Method to design OO API based on extensive use of method chaining
- The goal is to improve readability
  - Code looks like prose
  - Often used to build complex objects
- Create a sort of Domain Specific Language (DSL) leveraging the syntax of the host language

See: https://www.martinfowler.com/bliki/FluentInterface.html

Example

- Usual non–fluent

$$10.40\ kg \cdot m^2 \cdot s^{-3}$$

```
Measure power = new Measure(10.4);
power.addUnit("kg", 1);
power.addUnit("m", 2);
power.addUnit("s", -3);
power.setPrecision(2);
```

- Fluent

```
Measure power = Measure.value(10.4).
     is("kg").by("m").squared().by("s").to(-3).
     withPrecision(2).done();
```

Measure

```
public class Measure {
  private double value;
  private Unit unit;
  private int precision;
  public Measure(double value) {
    this.value = value;
  }
  public void setPrecision(int precision) {
    this.precision = precision;
  }
  public void addUnit(String name, double exp){
    unit = new Unit(name,exp,unit);
  }
}
```

Fluent Builder

```
public static
Builder value(double v){
  return new Builder(v);
}
```

```
public static class Builder{
  private Measure object;
  private String unitName;
  public Builder(double v){object = new Measure(v);}
  public Builder is(String name) {
    unitName = name;  return this;
  }
  public Builder by(String name) {
    if(unitName!=null) {
      object.addUnit(unitName, 1);
    }
    unitName = name;  return this;
  }
```

Fluent Builder

```
  public Builder squared() {
    object.addUnit(unitName, 2);
    unitName = null; return this;
  }
  public Builder to(double exponent) {
    object.addUnit(unitName, exponent);
    unitName = null;  return this;
  }
  public Measure done() { return object; }
  public Builder withPrecision(int precision) {
    object.setPrecision(precision);
    return this;
  }
}
```

OTHER FEATURES

Variable arguments

- It is possible to pass a variable number of arguments to a method using the varargs notation

```
method( type ... args )
```

- The compiler assembles an array that can be used to scan the actual arguments
  - Type can be primitive or class

Variable arguments– example

```
static int min(int... values){
      int res = Integer.MAX_VALUE;
      for(int v : values){
         if(v < res) res=v;
      }
      return res;
}
public static void main(String[] args) {
   int m = min(9,3,5,7,2,8);
   System.out.println("min=" + m);
}
```

Enum

- Defines an enumerative type

```
public enum Suits {
    SPADES, HEARTS, DIAMONDS, CLUBS
}
```

- Variables of enum types can assume only one of the enumerated values

```
Suits card = Suits.HEARTS;
```

  - They allow much stricter static checking compared to integer constants (e.g. in C)

Enum

- Enum can are similar to a class that automatically instantiates the values

```
class Suits {
   public static final Suits HEARTS=
                             new Suits ("HEARTS",0);
   public static final Suits DIAMONDS=
                             new Suits("DIAMONDS",1);
   public static final Suits CLUBS=
                             new Suits ("CLUBS", 2);
   public static final Suits SPADES=
                             new Suits ("SPADES", 3);
   private Suits (String enumName, int  index)
  {…}
 }
```

NESTED CLASSES

Nested class types

- Static nested class
  - Within the container name space
- Inner class
  - As above + contains a link to the creator container object
- Local inner class
  - As above + may access (final) local variables
- Anonymous inner class
  - As above + no explicit name

(Static) Nested class

- A class declared inside another class

```
package pkg;
class Outer {
   static class Nested {
   }
}
```

- Similar to regular classes
  - Subject to usual member visibility rules
  - Fully qualified name includes the outer class:
    - `pkg.Outer.Inner`

(Static) Nested class – Usage

- Static nested classes can be used to hide classes that are used only within another class
  - Reduce namespace pollution
  - Encapsulate internal details
  - Nested class lies within the scope of the outer class

(Static) Nested class – Example

```
public class StackOfInt{
  private static class Element {
    int value;
    Element next;
  }
  private Element head
  public void push(int v){ … }
  public int void pop(){ … }
}
```

Inner Class

- Linked to an instance
  - A.k.a. non-static nested class

```
package pkg;
class Outer {
   class Inner{
   }
}
```

- It is linked to instances of enclosing outer classes (i.e. it is non static)

Inner Class

- Any inner class instance is associated with the instance of its enclosing class that instantiated it
- Cannot be instantiated from
  - a static method
  - Other classes
- Has direct access to that enclosing object methods and fields

Inner Class (example)

```
public class Counter {
   int i;      default value of i is zero
   public class Incrementer {
      private int step=1;
      public void doIncrement(){ i+=step; }
      Incrementer(int step){ this.step=step; }
   }
   public Incrementer buildIncrementer(int step){
      return new Incrementer(step);
   }
  public int getValue(){
    return i;
  }
}
```

inner instance is linked to **this** outer object

```
Counter c = new Counter()
Incrementer byOne = c.buildIncrementer(1);
Incrementer byFour = c.buildIncrementer(4);
byOne.doIncrement();
byFour.doIncrement();
c.getValue(); // -> 5
```

Local Inner Class

- Declared inside a method

```
public void m(){
   int j=1;
   class X {
      int plus(){ return j + 1; }
   }

   X x = new X();
   System.out.println(x.plus());
}
```

- References to local variables are allowed
  - Replaced with "current" value
  - Set of such local variables is called closure

Local Inner Class

- Declared inside a method

```
public void m(){
   int j=1;
   class X {
      int plus(){ return j + 1; }
   }
   j++;
   X x = new X();
   System.out.println(x.plus());
}
```

What result should we expect?

- Local variable cannot be changed after being referred to by an inner class

Local Inner Class

- Declared inside a method

```
public void m(){
   final int j=1;
   class X {
      int plus(){ return j + 1; }
   }
   j++;
   X x = new X();
   System.out.println(x.plus());
}
```

- Local variables used in local inner classes should be declared final
  - Or be effectively final

Anonymous Inner Class

- Local class without a name
- Only possible with inheritance
  - Implement an interface, or
  - Extend a class

- See: inheritance

Memory Management

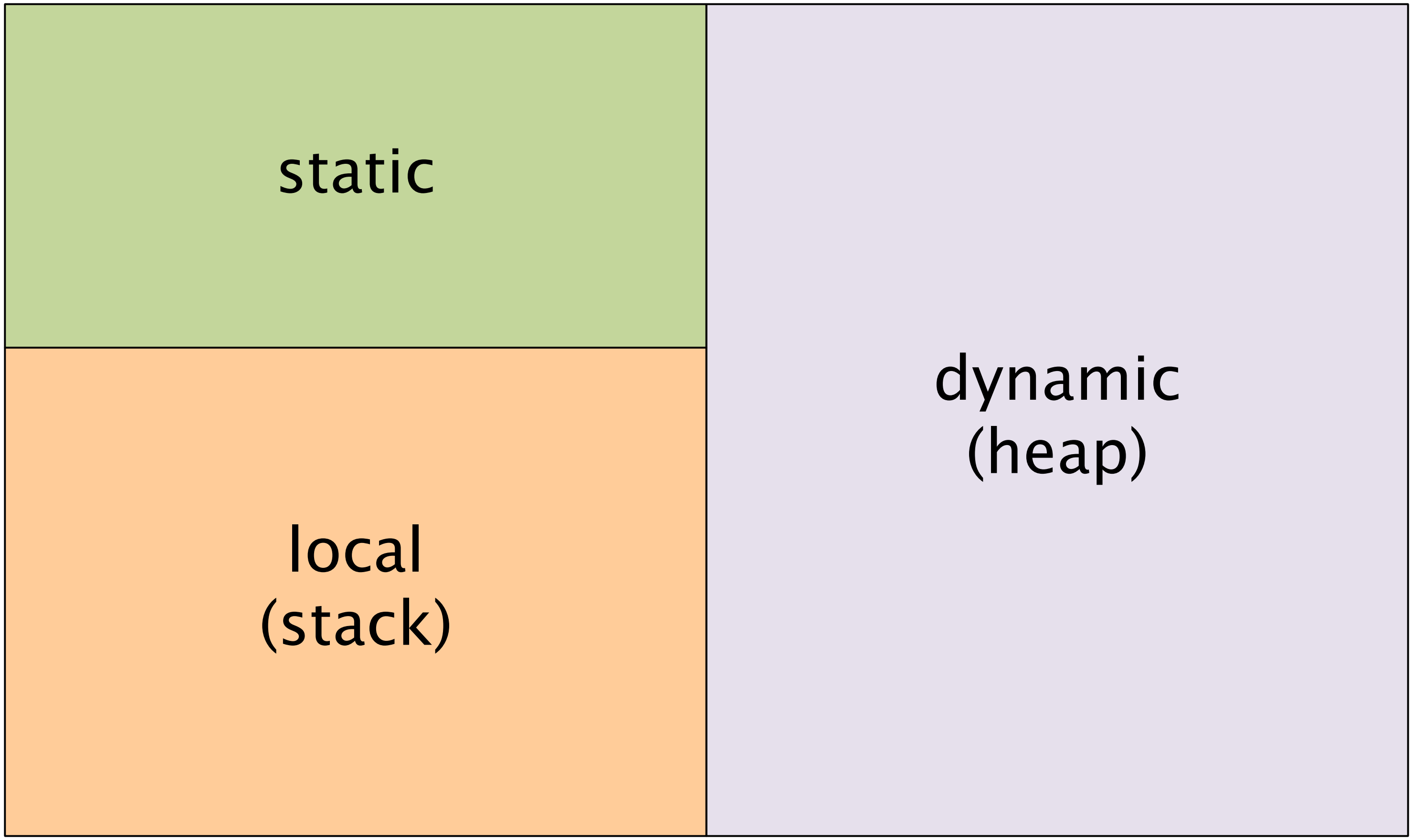
Memory types

Depending on the kind of elements they include:

- Static memory
  - elements living for all the execution of a program (class definitions, static variables)
- Heap (dynamic memory)
  - elements created at run-time (with 'new')
- Stack
  - elements created in a code block (local variables and method parameters)

Memory types

Memoria est omnis divisa in partes tres...

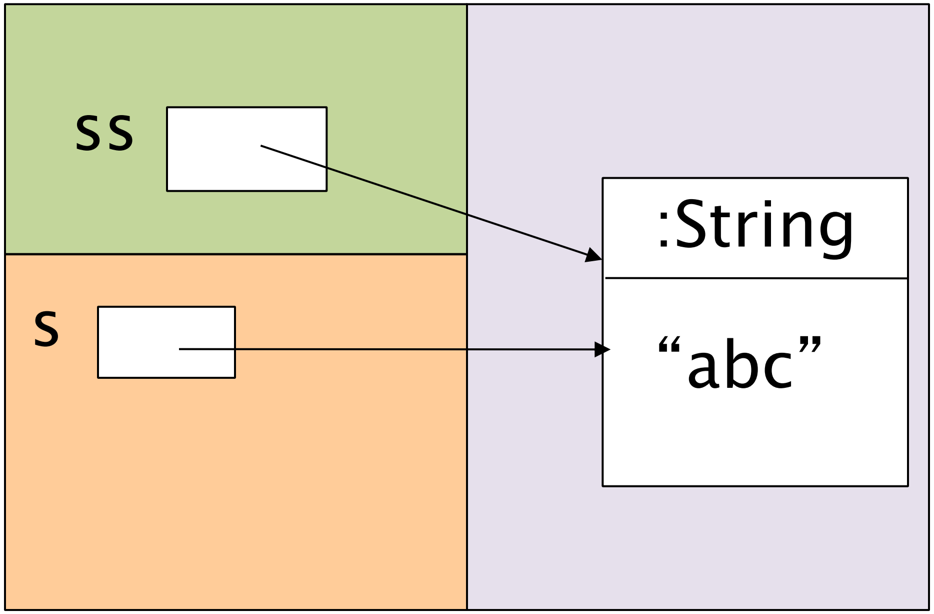


Example

```
static String ss;
.. main(){
  String s;

  s=new String("abc");

  ss = s;
}
```



Types of variables

- **Instance variables**
  - Stored within objects (in the heap)
  - A.k.a. fields or attributes
- **Local Variables**
  - Stored in the Stack
- **Static Variables**
  - Stored in static memory

Garbage collector

- Component of the JVM that cleans the heap memory from '*dead*' objects
- Periodically it analyzes references and objects in memory
- ...and then it releases the memory for objects with no active references
- No predefined timing
  - **`System.gc()`** can be used to *suggest* GC to run as soon as possible

Object destruction

- It' s not made explicitly but it is made by the JVM garbage collector when releasing the object's memory
  - Method **`finalize()`** is invoked upon release
- Warning: there is no guarantee an object will be ever explicitly released

Finalization and garbage collection

```
class Item {
  public void finalize(){
    System.out.println("Finalizing”);
  }
}
```

```
public static void main(String args[]){
  Item i = new Item();
  i = null;
  System.gc(); // probably will finalize object
}
```

Wrap-up

- Java syntax is very similar to that of C
- New primitive type: **`boolean`**
- Objects are accessed through references
  - References are disguised pointers!
- Reference definition and object creation are separate operations
- Different scopes and visibility levels
- Arrays are objects
- Wrapper types encapsulate primitive types