Java Basic Features

Object Oriented Programming

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Learning objectives

- Learn the syntax of the Java language
- Understand the primitive types
- Understand how classes are defined and objects used
- Understand how modularization and scoping work
- Learn about wrapper types
- Understand how arrays work
- Learn about static members
- Understand nested classes

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
  - 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

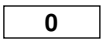
```
int i;
```


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;
```



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

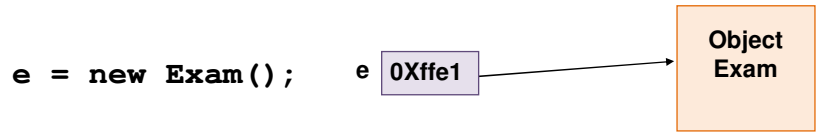
- Defined by developer (e.g., **`Exam`**) or in the Java runtime libraries (e.g., **`String`**)
- The declaration

```
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();
```

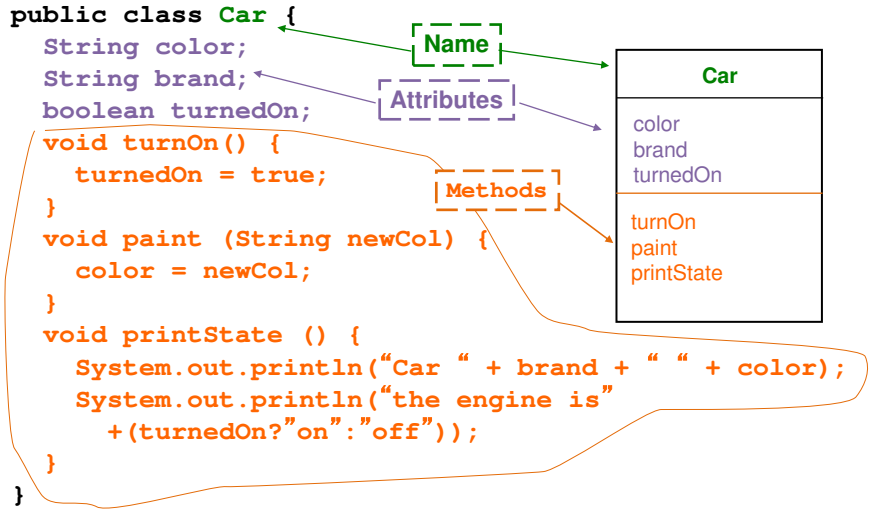


Class

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

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"));
  }
}
```



Attributes

- 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

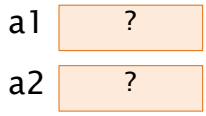
- Methods represent the messages that an object can accept
  - `turnOn`
  - `paint`
  - `printState`
- Methods may accept arguments
  - `paint(String )`

Objects

- An object is 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

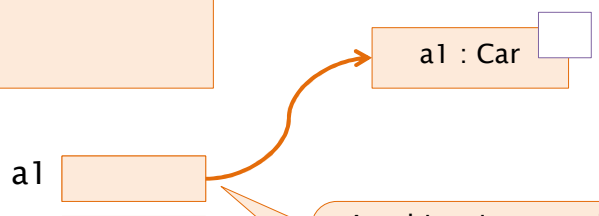
```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



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

Objects and references

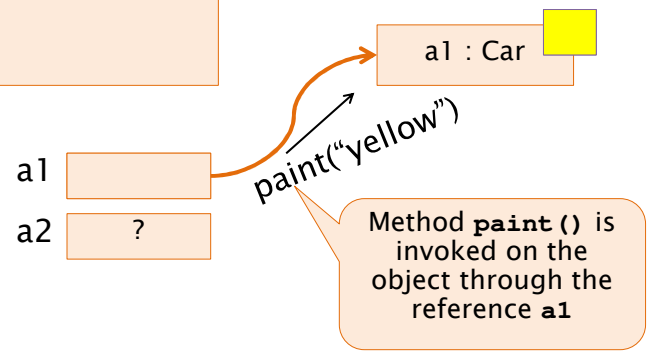
```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



An object is created and the "pointer" stored into the reference **a1**

Objects and references

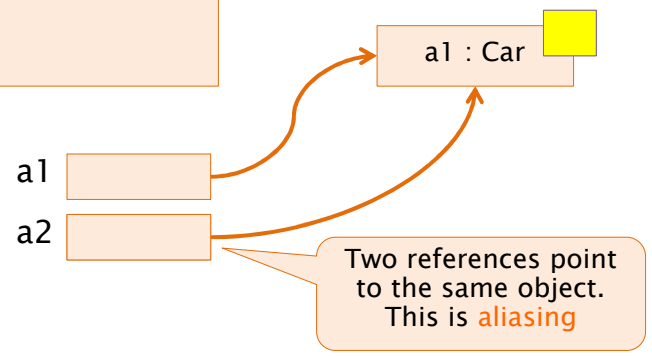
```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



Method **paint()** is invoked on the object through the reference **a1**

Objects and references

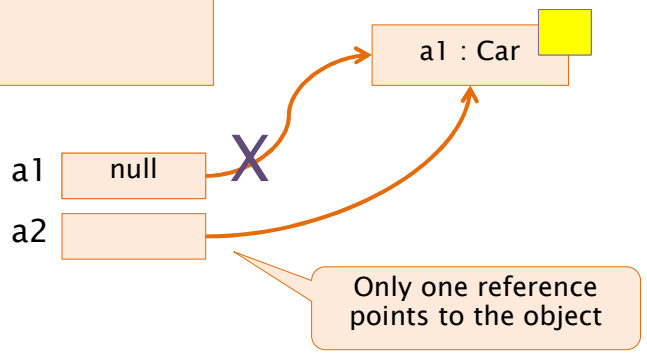
```
Car a1, a2;
a1 = new Car();
a1.paint("yellow");
a2 = a1;
a1 = null;
a2 = null;
```



Two references point to the same object. This is aliasing

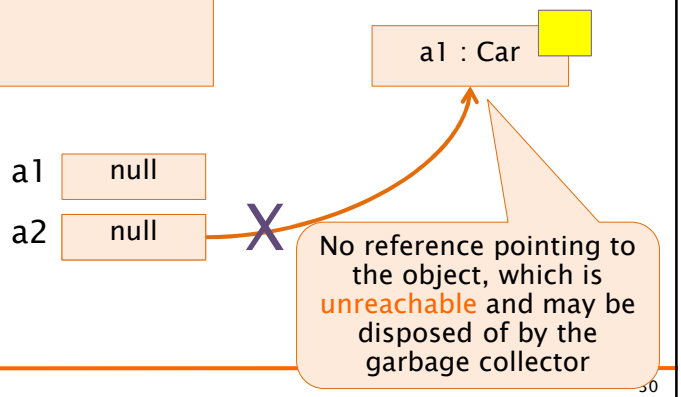
Objects and references

```
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

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

Constructor example

```
public class Car {
   String color;
   String brand;
   boolean turnedOn;
   public Car(){
      color = "white";
   }
}
```

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 used to disambiguate attributes vs. local variables in methods

```
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

Operation chaining idiom

- Often you need to perform several operations on the same object
- That requires repeating many times `reference.`
- It is possible to avoid such repetition by adding at the end of the methods a `return this;`
  - Methods return references to the initial object enabling invocations of other methods
  - Works if operations do return void

Operation chaining idiom

```
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 decrement(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

- 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;
  }
}
```

Overloading

```
public class Foo{
  public void doIt(int x, long c){
    System.out.println("a"); }
  public void doIt(long x, int c){
    System.out.println("b"); }
  public static void main(String args[]){
    Foo f = new Foo();
    f.doIt(       5 , 7 );
    f.doIt(       5 , 7L); // "a"
    f.doIt( (long)5 , 7 ); // "b"
    f.doIt(       5L, 7 ); // "b"
  }
}
```

Error: ambiguous invocation

Overloading constructors

```
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 not a programmer's concern
  - Managed memory language
- Before the object is really destroyed the method **`finalize`** – if defined – is invoked:

```
public void finalize()
```


Object life cycle

```
class ExLifeCycle(){
  public static void main(String[] args){
    // declare reference
    Car c;

    // create object
    c = new Car();

    // use object
    c.paint("yellow");

  }  // reference is lost
}  // sooner or later JVM will free memory
```

Object Oriented Programming

SCOPE AND ENCAPSULATION

Scope and Syntax

- Member visibility modifiers
  - **`private`**
    - Member is visible and accessible from instances of the same class only
  - **`public`**
    - Member is visible and accessible from everywhere
- Beware: modifiers work at class level not at object level!
  - Therefore two objects of the same class can see each other attributes

Information 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 rules

Access.. / ..from:	Method in the same class	Method in other class
Private member	Yes	No
Public member	Yes	Yes

Getters and setters

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

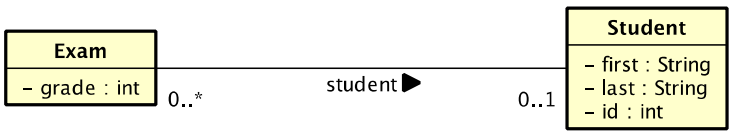
```
public String getColor() {
    return color;
}
public void setColor(String newColor) {
    color = newColor;
}
```

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(…){…}
}
```

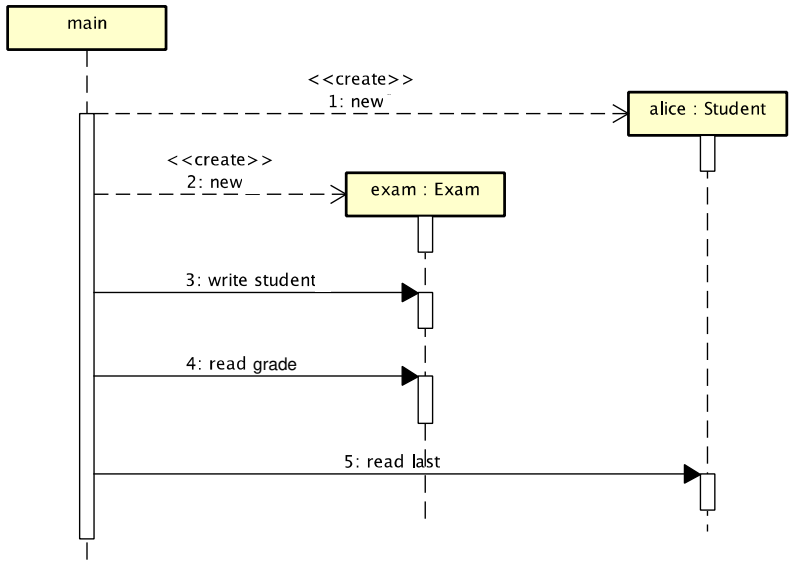

Example without getter/setter



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);
  }
}
```


Sequence without getter/setter

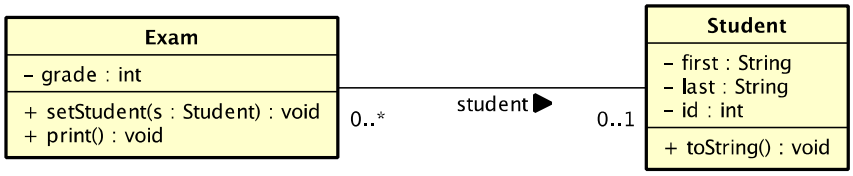


Example with getter/setter

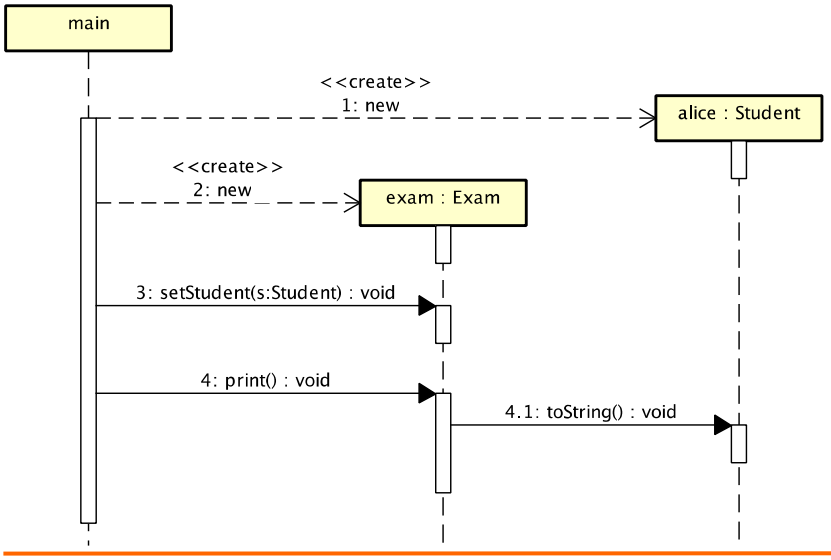
```
class StudentExample {
  public static void main(String[] args) {
     Student s = new Student("Alice", "Green",
                             1234);
     Exam e = new Exam(30);

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


Classes with getters/setters



Sequence with getter/setter



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;
    }
}
```

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 getters/setters

- Obeys principle of encapsulation
  - Client does not have to know internals
    - Implementation details of classes may vary without affecting their clients
  - Makes use of delegation
    - Single point of change
      - E.g., `Student.toString()`
  - More readable and understandable
    - Method names describe the operation
      - `setStudent()` vs. `println(e.student.last)`

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

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

- 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 hierarchical structure (*fully qualified name*)
  - E.g. **java.lang** (String, System, …)
- Convention 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`**

Definition 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 java.awt.*;
```

Import single class (class name is in scope)

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

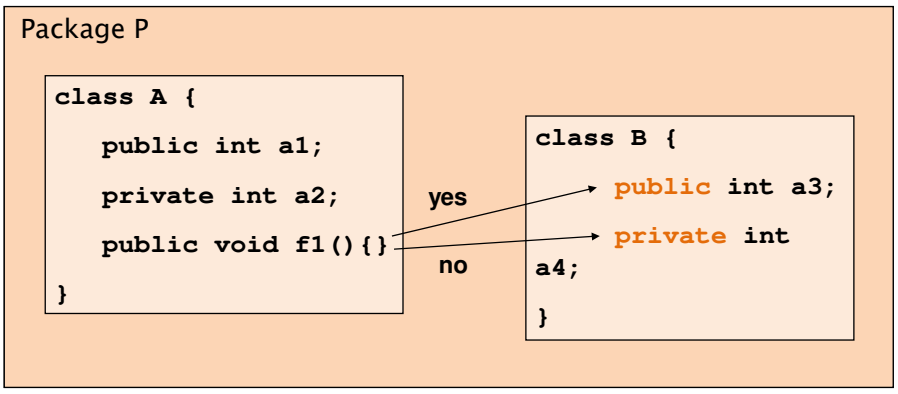
- When no package is specified, the class belongs to the default package
  - The default package has no name
- Classes in the default package cannot be accessed by classes residing in other packages
  - Cannot be imported since it is unnamed!
- Usage of default package is a bad practice and thus it is 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

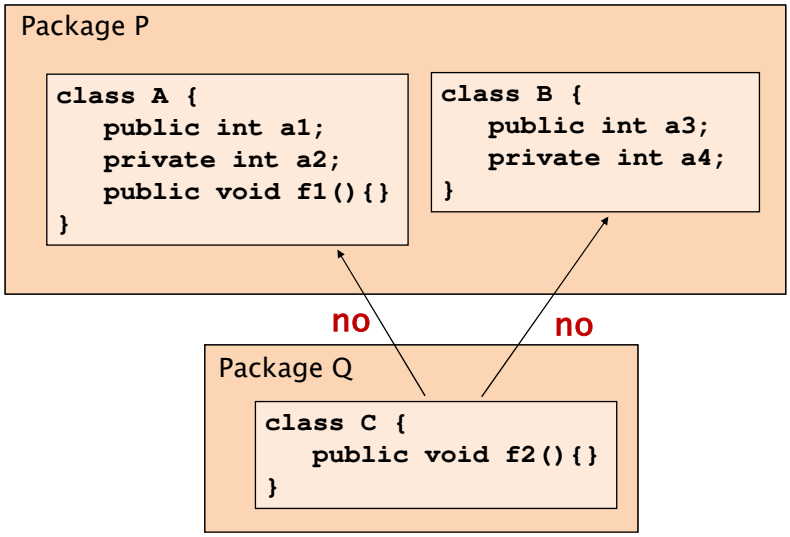
- **`public class A { }`**
  - Class and public members of A are visible from outside the package
- **`class B { }`**
  - Class and any members of B are not visible from outside the package

Package visibility

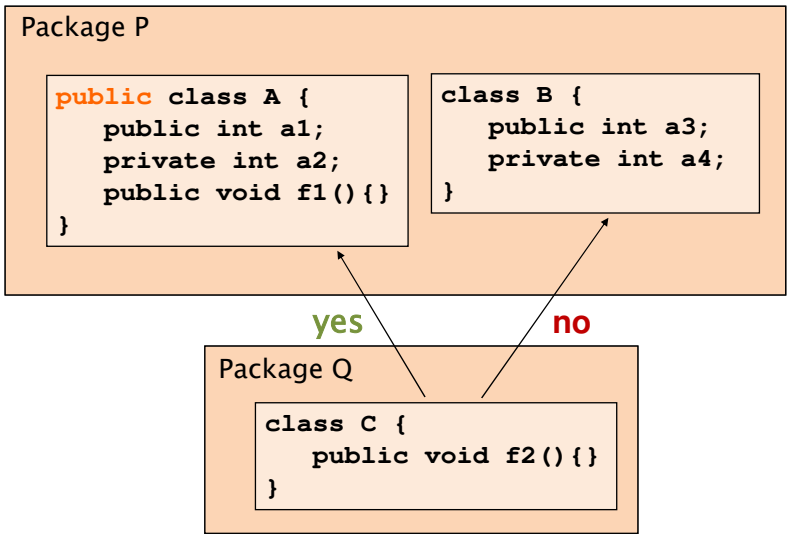
- **`private class A { }`**
  - Illegal: why?

The class and its members would be visible to themselves only

Multiple packages



Multiple packages



Access rules

Access.. ..from:	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

Object Oriented Programming

WRAPPER CLASSES

Motivation

- Ideal OO has only classes and objects
- For the sake of efficiency, Java use primitive types (**`int`**, **`float`**, etc.)
- Wrapper classes are the object versions of the primitive types
  - Encapsulate a value of the corresponding primitive type
  - Define conversion operations between different types
  - They are immutable

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`

String

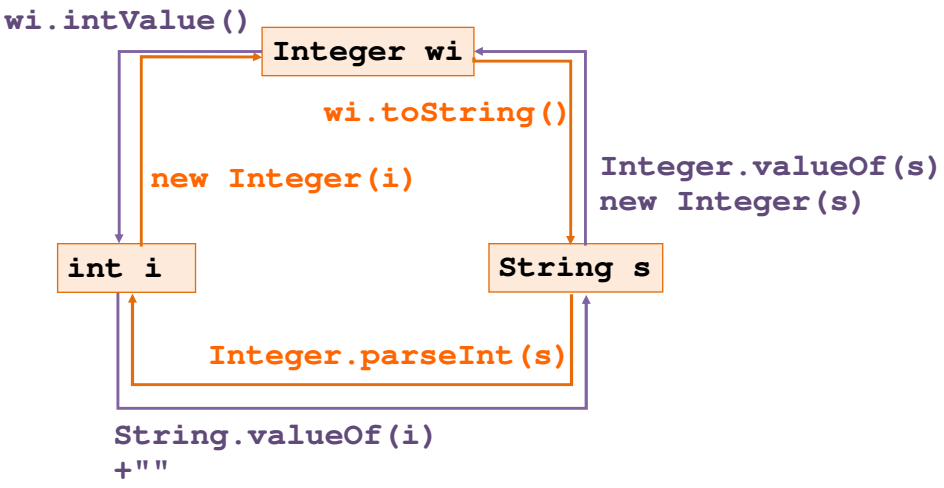
- No primitive type to represent string
- String literal is a quoted text
- C
  - **`char s[] = "literal"`**
  - Equivalence between string and char arrays
- Java
  - **`char[] != String`**
  - String class in **`java.lang`** package

See slide deck "Java Characters and Strings"

Numeric wrappers

- Wrap numeric primitive types
  - **`Integer`**, **`Long`**, **`Double`**, **`Float`**
- They provide conversion methods:
  - **`.xxxxValue()`** extracts primitive value
  - **`.toString()`** converts to String
  - **`Xxxx.valueOf(…)`** parses a String

Conversions (example)



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();
```


Conversion 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 can 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()`

Object Oriented Programming

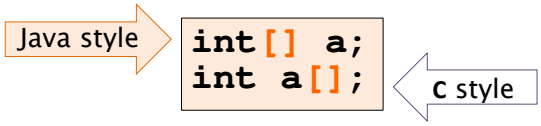
ARRAYS

Array

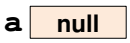
- An array is an ordered sequence of variables of the same type which are accessed through an index
- Can contain both primitive types or object references
  - But no directly object values
- Array dimension can be defined at run-time, when array object is created
  - Size cannot change afterwards

Array declaration

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



- 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



Array creation

- Using the new operator…

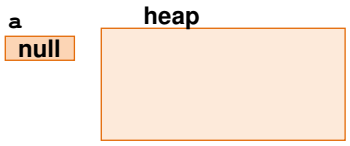
```
int[] a;
a = new int[10];
String[] s = new String[5];
```

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

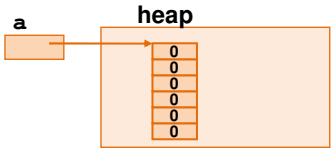
```
int[] primes = {2,3,5,7,11,13};
Person[] p = { new Person("John"),
        new Person("Susan") };
```

Example – primitive types

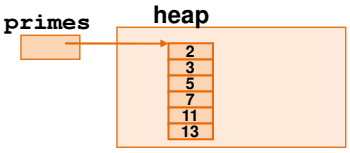
```
int[] a;
```




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

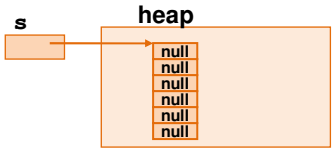



```
int[] primes =
  {2,3,5,7,11,13};
```

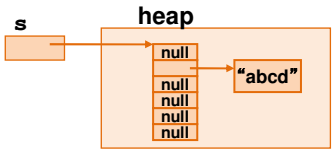


Example – object references

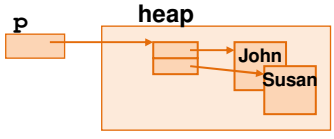
```
String[] s = new
  String[6];
```




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




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



Operations on arrays

- Brackets `[ ]` access to selected element (C-like)
  - Java performs run-time bounds checks
- 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 reference 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 automatically generates the loop with correct indexes
  - Less error prone

For each – example

- Example:

```
for(String arg : args){
  //...
}
```

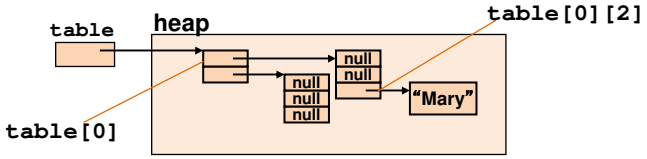
  - is equivalent to

```
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

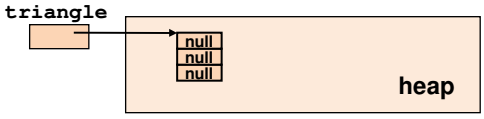
- Since rows are not stored in adjacent positions in memory they can be easily exchanged

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

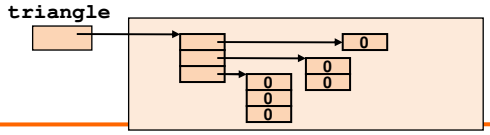
Rows with different length

- There is no constraint on rows having the same length

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




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



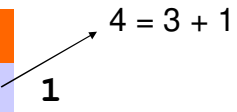
Exercise

- Create an object representing an ordered list of integer numbers (at most 100)
- **`print()`**
  - prints current list
- **`add(int)`** and **`add(int[])`**
  - Adds the new number(s) to the list

Tartaglia's triangle

- Write an application printing out the following Tartaglia's triangle

```
1
1   1
1   2   1
1   3   3   1
1   4   6   4   1
1   5  10  10   5   1
1   6  15  20  15   6   1
```



Object Oriented Programming

Final Modifier and Static Members

Final Attributes

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

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


Final arguments and variables

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

Final is not transitive

```
class Person {
  public String first;
  public String last;
}
```

```
final Person p = new Person();
p = new Person(); // not ok
p.first = "John"; // ok
```

Il riferimento **p** è **final** ma non lo è l'oggetto puntato

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 exist since when class is loaded, before any object is instantiated
  - Any change to static attributes by an object is visible to all other instances at once
- They are defined with the **`static`** modifier

Static attributes: why

- Used to keep a shared value, e.g.
  - A count of created instances
  - A pool of all instances
  - A common constant value

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


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 methods

- 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

System class

- Provides several utility functions and objects e.g.
  - **`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

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;
  }
  // …
}
```

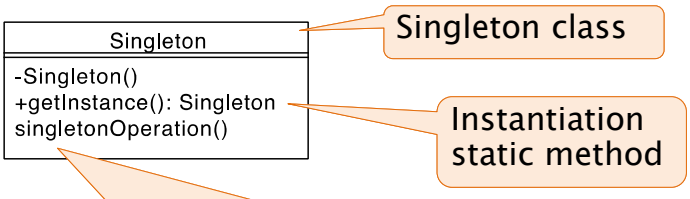
Created on-demand at first usage

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;
}
```

Factory method

- Method used to create a new instance
  - Encapsulates the invocation of **`new`**
  - Often **`static`**
  - May perform additional operations or checks, e.g.,
    - Return a single instance (Singleton)
    - Return an object from a pool
    - Create an intermediate builder object

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);  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;
  }
}
```

Object Oriented Programming

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 classes

- Are classes whose declaration is nested within another class
- A nested class is a special member of the outer class
  - Its methods have complete access to the outer class members
    - Just like outer class's methods

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 top;
  public void push(int v){ … }
  public int pop(){ … }
}
```

Visible only from within container

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
- Has direct access to that enclosing object methods and fields
- Cannot be instantiated from
  - other classes
  - a static method of the same class

Inner Class (example)

```
public class Counter {
   private int v;


   public increment(int by){
      v += by
   }



   public int getValue(){
     return v;
   }
}
```

Inner Class (example)

```
public class Counter {
   private int v;
   public class Incrementer {
      private int by;
      Incrementer(int by){ this.by=by; }
      public void doIncrement(){ v+=by; }
   }
   public Incrementer buildIncrem(int by){
      return new Incrementer(by);
   }
   public int getValue(){
     return v;
   }
}
```

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

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

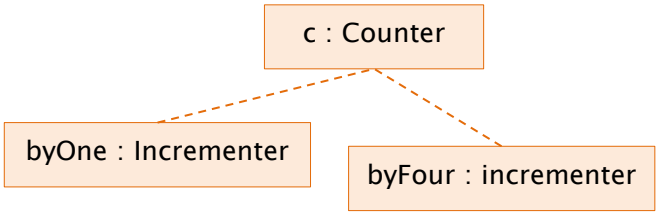

Inner Class (example)

This is like the compiler would translate it

```
public class Counter {
   private int v;
   public class Incrementer {
      private int by;
      Counter outer;
      Incrementer(Counter outer, int by){
        this.by=by;
        this.outer=outer;
      }
      public void doIncrement(){ outer.v+=by; }
   }
   public Incrementer buildIncrem(int by){
      return new Incrementer(this,by);
   }
   public int getValue(){
     return v;
   }
}
```

Inner Class (example)

```
Counter c = new Counter();
Incrementer byOne = c.buildIncrem(1);
Incrementer byFour = c.buildIncrem(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());
}
```

1

  - 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());
}
```

1

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

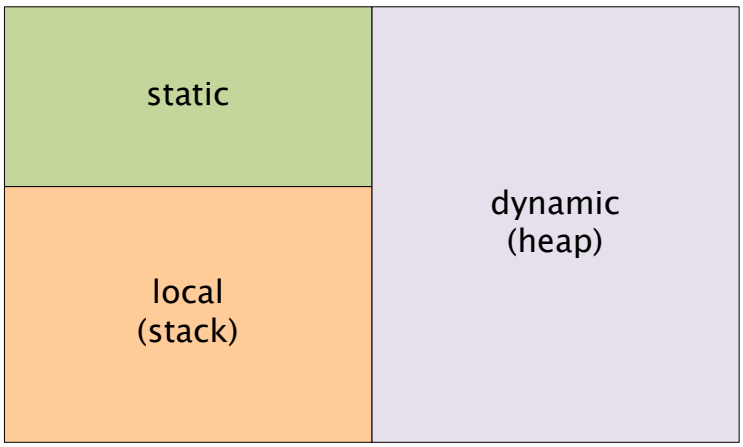
Memory types

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...

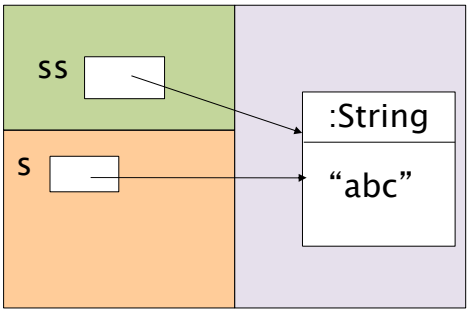


Example

```
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