14 Summary - Introduction

- Java vs. C/C++
  - ◆ no preprocessor, strongly typed, no pointer arithmetic, no procedures, ...
- Abstraction and Encapsulation
- Objects - Classes - Methods - Variables
- Constructors
- Packages: package, import
- Encapsulation: private, protected, public
- Applets and Applications

15 Overview of todays tutorial

- Overloading
- Inheritance
- Overriding
- static
- final
- abstract classes
- interfaces

16 Overloading

- The same method name can be used with different parameters
- Example:

```
class Date {
    ...
    void print(PrintStream stream) { stream.println(...); }
    void print() { print(System.out); }
}
```

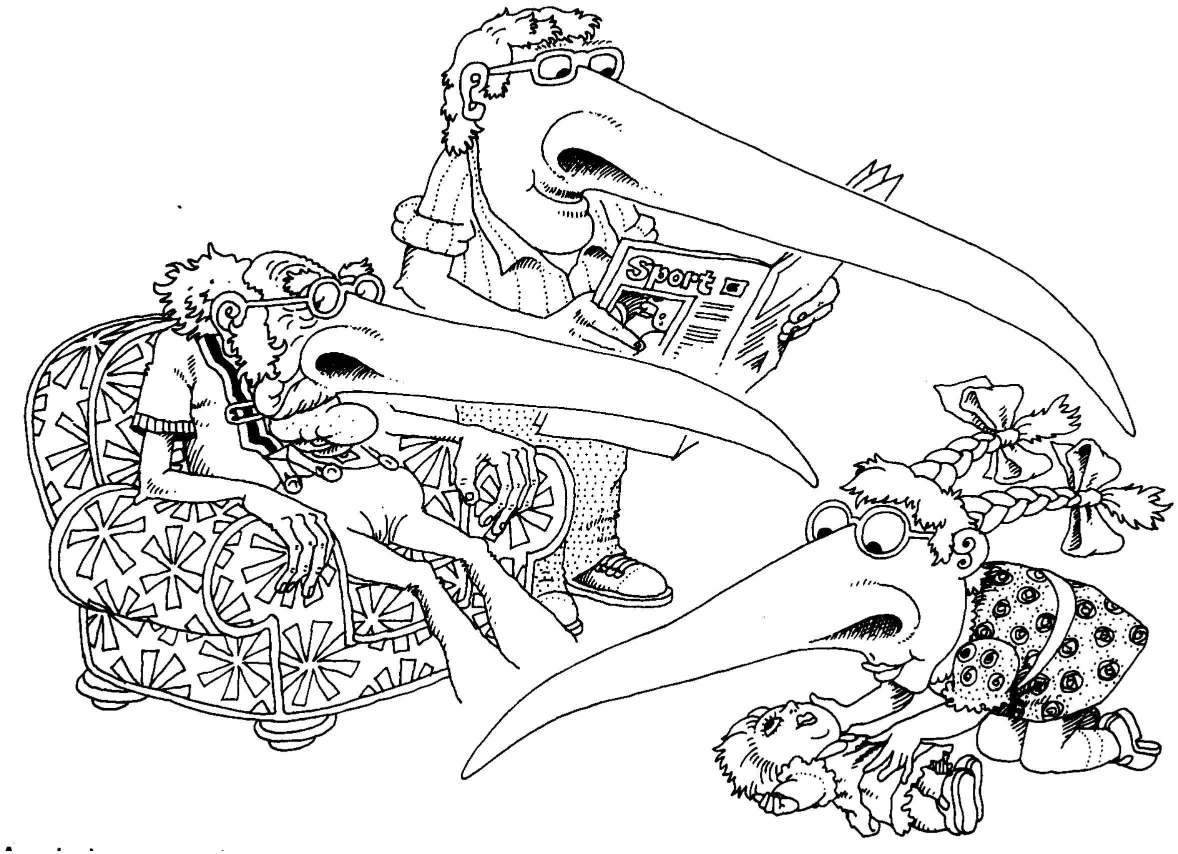
- Notice: Overloading works only with parameters not return types

```
class Income {
    ...
    int computeIncome() { ... }
    float computeIncome() { ... } // Error !!
}
```

Inheritance

- Define objects by referring to other objects
  - Example:
    - Definition of an animal: A thing that breathes and eats.
    - Definition of a cow: An animal that makes "muuuu" and gives milk.
    - Cow *inherits* the properties "breathes" and "eats" from animal.

17.1 Inheritance in the Real World



17.2 Inheritance in Java

- Inheritance: Definition of a new object based on a specialized definition of an existing object.
- New classes can be derived from existing classes.
- Example: A customer is a person.

```
class Customer extends Person {
    int number;
    ...
}
```

- **`Customer` is a *subclass* of `Person`**

17.3 Subclasses

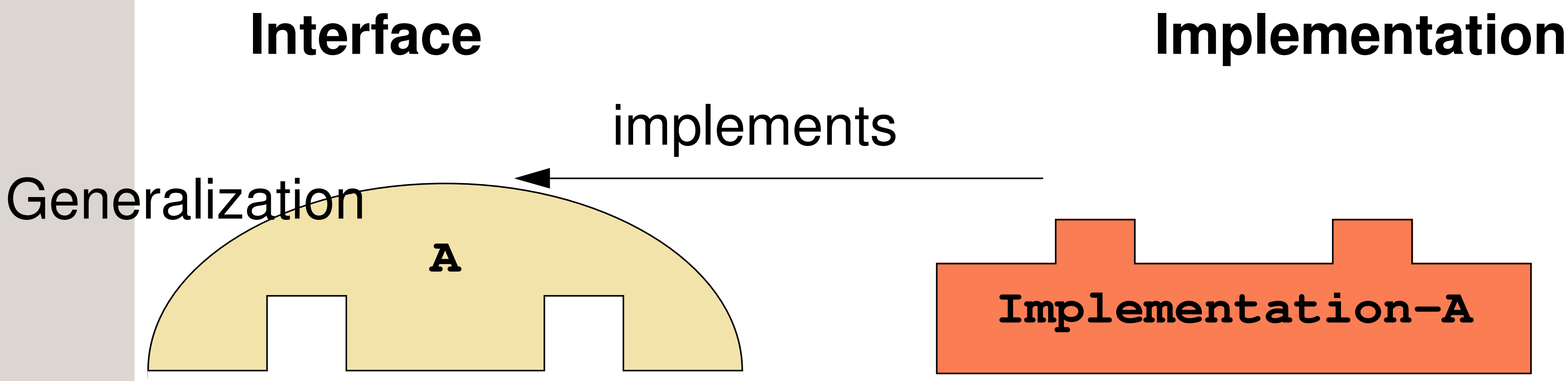
- Subclass inherits
  - State (instance variables) and
  - Behavior (methods) from superclass
- Subclass can
  - add new instance variables
  - add new methods
  - override inherited methods
  - shadow inherited instance variables (be careful!)

17.4 The Substitutability Principle

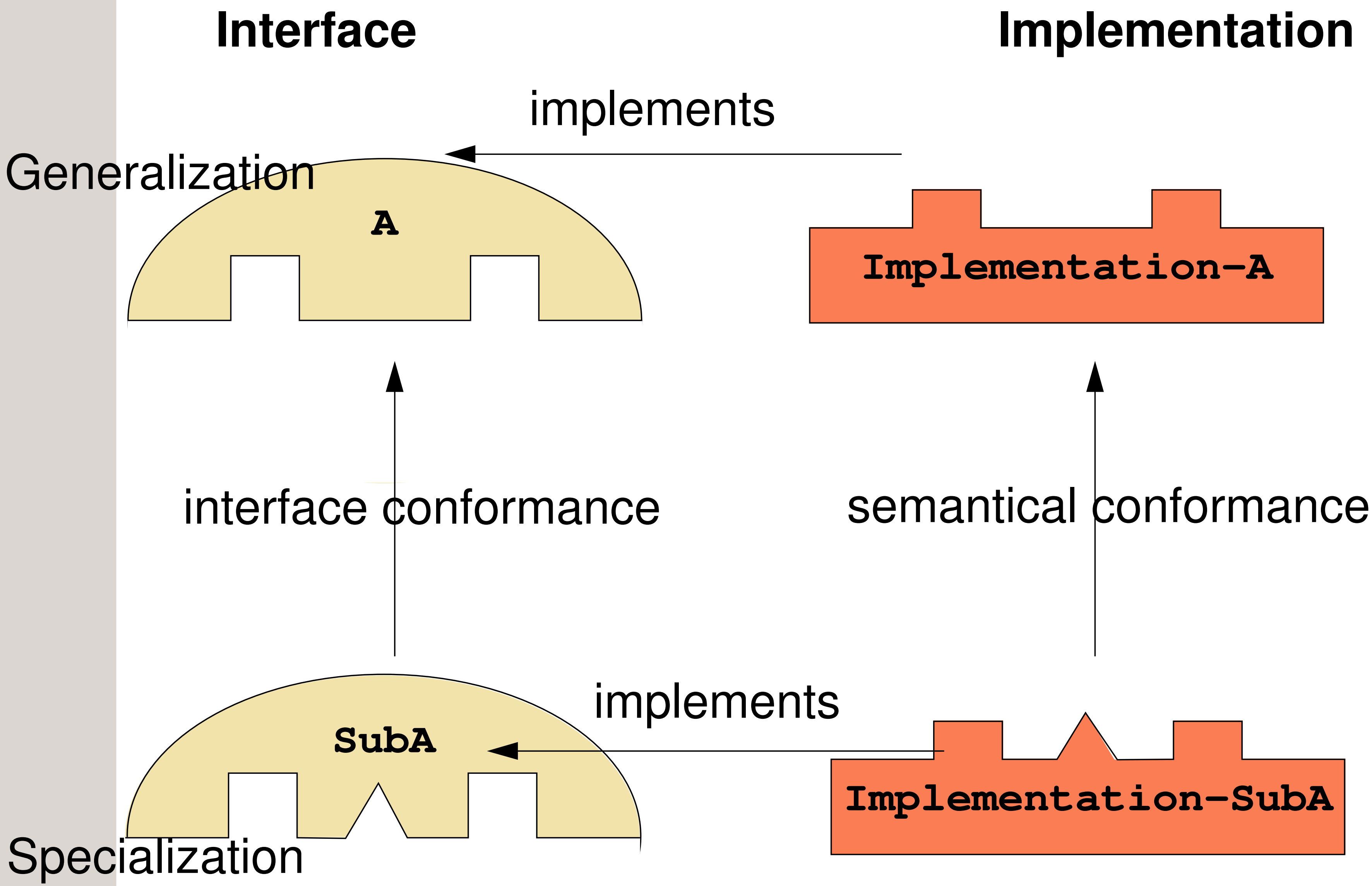
- An object of a subclass can be used wherever an object of the superclass is expected.
  - most important kind of polymorphism
- Inheritance is specialization ("is-a" relation, "kind-of" relation)
- Everything that holds for the generalization must also be true for the specialization.
  - The specialization fulfills all promises of the generalization.

→ Abstraction

17.5 Inheritance is Specialization

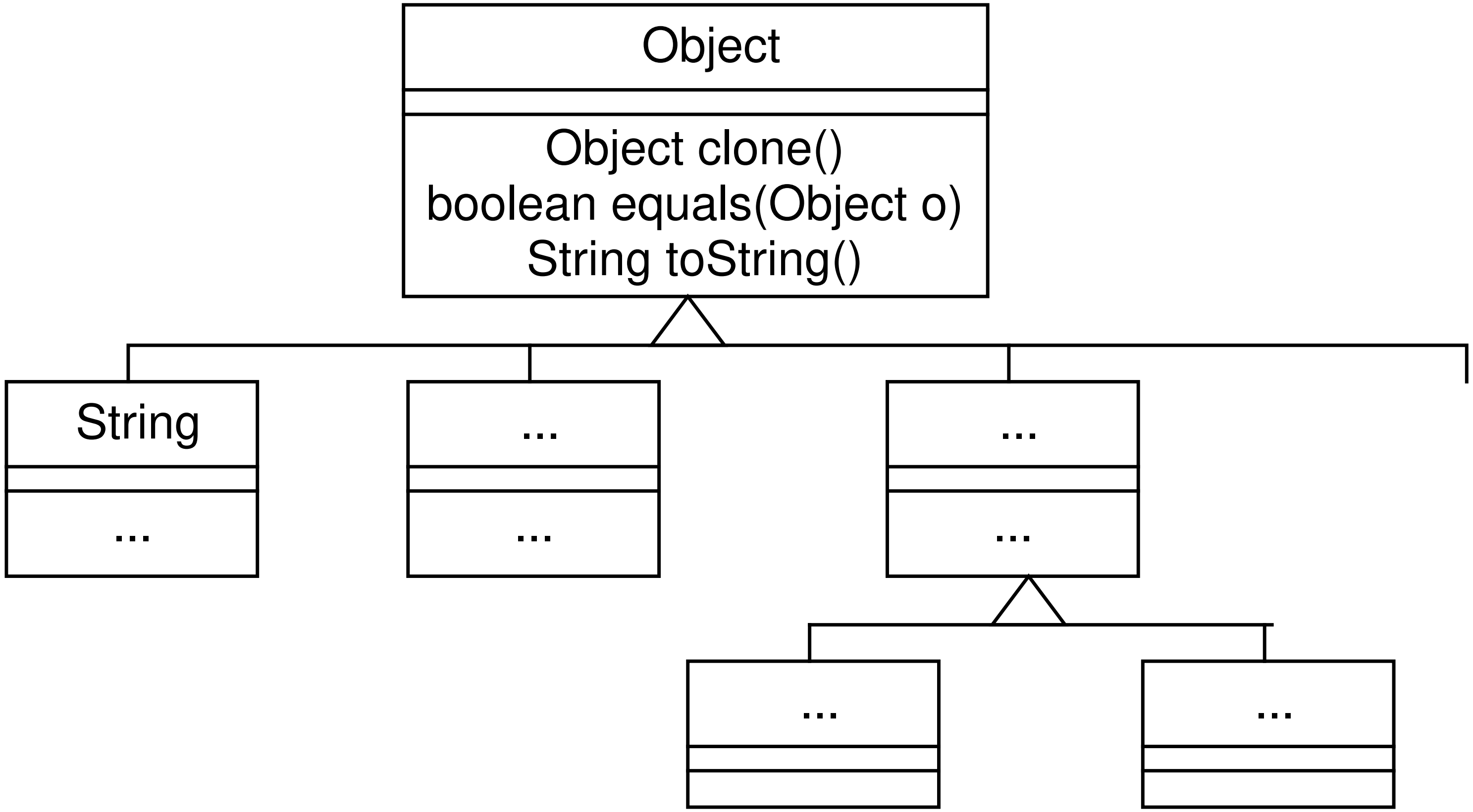


17.5 Inheritance is Specialization



17.6 Inheritance in Java

- Classes with single inheritance
- Tree hierarchy with class **`Object`** as base class of all other classes



- primitive types (**`int`**,**`float`**,...) are outside the class tree

17.7 Object

- Class **`Object`**: Base class of all classes

```
class Person extends Object {... }
```

- ◆ **`extends Object`** can be omitted

```
class Person {... }
```

- Supplies some base functionality, for example:
  - ◆ **`boolean equals(Object o)`** // test for equality
    - default implementation compares references
    - you should provide your own implementation
  - ◆ **`String toString()`** // represent object as String
    - contains class name and object ID
    - you should provide your own implementation

17.8 Overriding

- Subclasses can provide a new implementation for an inherited method
- The new implementation *overrides* the inherited implementation.

```
class Person {
    String name;
    ...
    void print() {
        System.out.println("Person: " + name);
    }
}
class Customer extends Person {
    int number;
    ...
    void print() {
        System.out.println("Person: " + name);
        System.out.println("Customer number: " + number);
    }
}
```

17.9 Overriding

- Invoke super class implementation with **`super.`*`method`*`()`**

```
class Customer extends Person {
    int number;
    ...
    void print() {
        super.print();
        System.out.println("Customer number: " + number);
    }
}
```

17.10 Overloading vs. Overriding

- To override a method the parameter and return types must be identical (*no-variance*) otherwise the method is overloaded
- To fulfill the substitutability principle it would be sufficient that the parameters of the overriding method be supertypes (*contra-variance*) and return types are subtypes (*co-variance*) -- this is not supported by Java
- Frequent mistake:

```
class Object {
    boolean equals(Object o) { ... }
     ...
}

class Customer {
     int number;
     boolean equals(Customer c) { return number == c.number;}
     ...
}
```

does not *override equals of Object*

17.11 Dynamic Binding

- Method code is not linked until method invocation
- *Dynamic type*: type/class of the referenced object (class used with **`new`**)
- *Static type*: type of the reference
- The static type determines what methods can be invoked.
- The dynamic type is used to select the method.

```
Customer c = new Customer("Max", 1234);
Person p = c;  // dynamic type of p is Customer,
               // static type is Person

c.print();
p.print(); // although the reference p is of type Person,
           // the print() method of Customer is used
```

17.12 Visibility and Inheritance

- The visibility of methods must not be restraint in subclasses (substitutability).

```
class Person {
    public String getName() { ... }
}
class Customer extends Person {
    private String getName() { ... }
}
```

Error

17.13 Constructors and Inheritance

- Constructors are **not** inherited
- Invocation of the super-class constructor with **`super(...)`**
- **`super(...)`** must be the first statement in a constructor
- if first statement is not **`super(...)`**, the compiler automatically inserts a **`super()`** statement
- Default constructor
  - created by the compiler, if *no* constructor is defined
  - consists of **`super()`** - call

17.13 Constructors and Inheritance

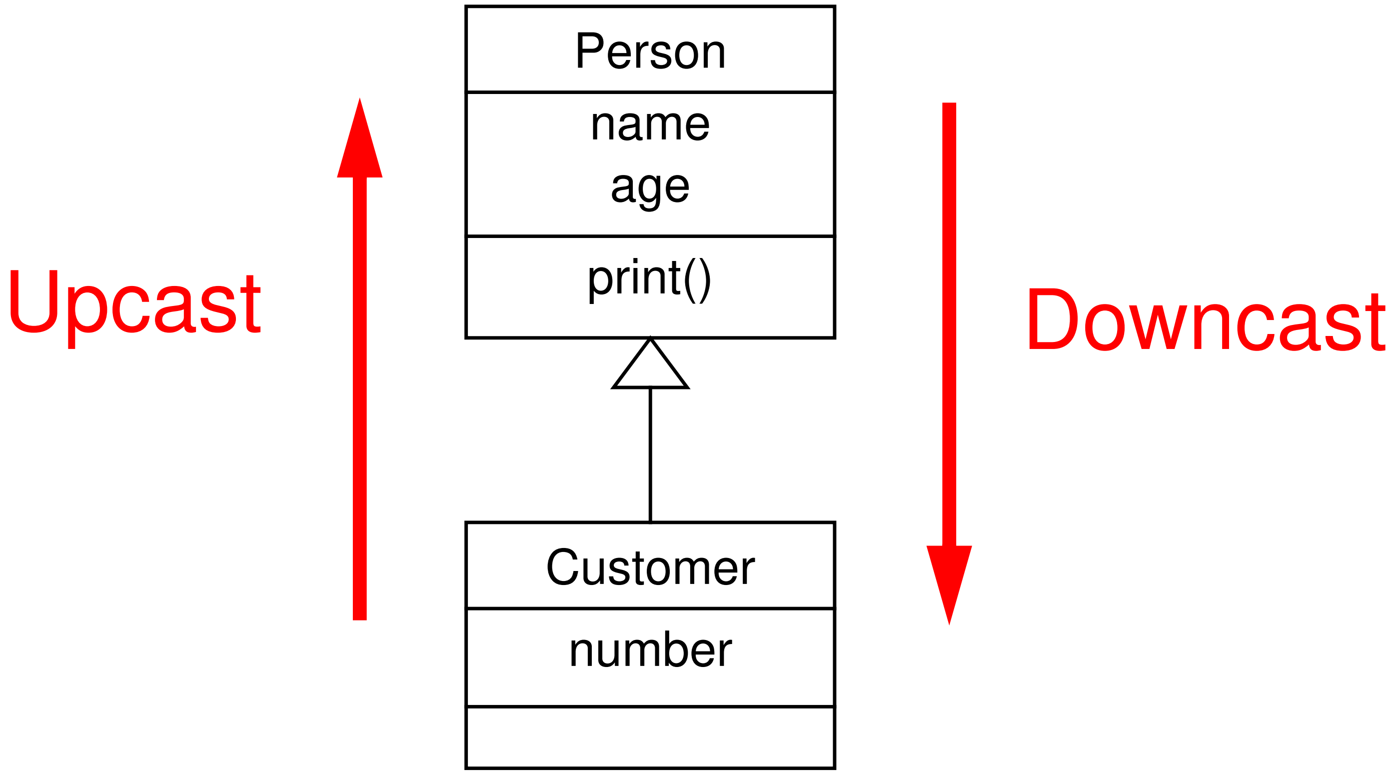
- Example

```
class Customer extends Person {
    int number;
    Customer(String name, int number) {
        super(name);
        this.number = number;
    }
    ...
}
```

17.14 Type Conversions: Upcast & Downcast

- Type conversion from subclass to superclass (*upcast*) is done automatically

```
Person p = new Customer(...);
```



17.15 Downcast

- Type conversion from superclass to subclass (*downcast*) must be done with the cast operator

```
Customer c = new Customer(...)
Person p = c; // implicit type conversion
Customer c2 = (Customer) p;//explicit type conversion
```

- A **`ClassCastException`** is generated if object and variable are not type conform

```
Customer c = new Customer(...)
Person p = c; // implicit type conversion
Employee e = (Employee) p;
                    // generates a ClassCastException at run time
```

17.16 Type Deduction

- **`instanceof`** operator

```
Customer c = new Customer(...)
Person person = c; // upcast
if (person instanceof Employee) {
    Employee employee = (Employee) person;
    ...
} else if (person instanceof Customer) {
    Customer customer = (Customer) person;
    ...
}
```

- **`instanceof`** may be used with a superclass of the dynamic type

```
person instanceof Person
```

... would give **`true`** in the example

17.17 Class

- Class `Class`: The class of all classes.
- A Class object represents one class or interface
- Can be used to create new instances

```
Customer c = new Customer();
...
Class aClass = c.getClass();
System.out.println("Class of c is:"+aClass);

Object o = aClass.newInstance();  // now we have a new Customer
                                   // object
Person p = (Person) o;
```

- A class object can be created from a class name

```
Class aClass = Class.forName("Employee");
```

17.18 Class Literals

- since Java 1.1 there are class literals
- better than `Class.forName(...)`

```
Class aClass = Employee.class;
...

Object o = aClass.newInstance();
Person p = (Person) o;
```

18 Other Language Features

- Class Methods/Variables
- Class Constructors
- Constants
- Final Methods
- Final Classes

18.1 Class Variables and Class Methods

- Classes can contain variables and methods: static variables and methods
- they can be used without an object
- Example:

```
class Test {
    private static int counter = 0;
    public Test() { counter++; }
    public static int howMany() { return counter; }
}
Test t = new Test();
System.out.println("No. of Test objects: " + Test.howMany());
```

- Example:
  - **`System.out`** is a static variable of the **`System`** class
  - **`System.out`** is of type **`PrintStream`**, **`PrintStream`** objects have **`println`** method

18.2 Class Constructors

- Classes are stateful (**`static`** variables) and must be initialized with a class constructor
- Example:

```
class Test {
    static int counter;
    static {
        counter = 9;
    }
}
```

18.3 Constants

- Variables can be constant (*final*):
  - They must be initialized during declaration (JDK 1.0) or later (JDK 1.1: *blank finals*)
  - This initial value can not be changed.

```
class Test {
    public static final int x=5; // constant class variable
    private final int t=10;      // constant instance variable
}
```

18.4 Constants

- since Java 1.1 method parameters and local variables can be constant

```
class Test {
    String name;
    void setName(final String name) {
        final int i = 42;
        this.name = name;
    }
}
```

18.5 Final Methods

- If methods are declared **`final`** they cannot be overridden
  - Security
  - Efficiency (makes inlining possible)

```
class Test {
    final void hello() {...}
}

class Test2 extends Test {
    void hello() { ... } // Error!! hello is final in Test
}
```

18.6 Final Classes

- If classes are declared **`final`** you cannot derive subclasses from them.
- Example:

```
public final class Test {
     ...
}
```

19 Abstract Classes

- Problem:
  - drawing editor with geometrical shapes (circle, rectangle,line)
  - Drawing sheet **`Sheet`** should only cope with **`Shape`**
  - **`Sheet`** must call **`draw()`** at **`Shape`**
  - **`Shape`** cannot provide a useful implementation of **`draw()`**
- **`Shape`** is an *abstract* class

19.1 Abstract Classes

- used to distill common properties of classes
- can **not** be used to create objects
- abstract classes contain not implemented methods (*abstract methods*)
- abstract classes and methods are declared with the **`abstract`** keyword

```
abstract class Shape {
    public abstract void draw();
}
```

- if a concrete class extends an abstract class it must implement all abstract methods

```
class Circle extends Shape {
    public void draw() { ... }
}
```

20 Interfaces

- Java separates the class concept from the type concept
- Interfaces represent types
- Interfaces contain
  - method names and signatures
  - constants (**`static final`**)
- all methods are (implicitly) abstract
- classes can be compatible to interfaces (keyword **`implements`**)
- These classes must implement all methods of the interface.
- Definition of interfaces with the keyword **`interface`**

20.1 Example

1. Definition of an interface

```
public interface Printable {
    public void print();
}
```

2. Definition of classes that implement the interface

```
public class Account implements Printable {
    ...
    public void print() {
        System.out.println("balance="+balance());
    }
}
public class Person implements Printable { ... }
```

20.1 Example

3. Using the interface

```
public class PrintQueue {
    public void add(Printable p ) { ... }
}
....
PrintQueue queue = new PrintQueue();
Printable p=new Person(...);
queue.add(p);
Account account = new Account(...);
queue.add(account);
```

20.2 Inheritance of Interfaces

- Interface can *inherit* multiple interfaces,
  classes can *implement* multiple interfaces

- Example:

```
interface Streamable extends FileIO, Printable {
    // additional methods
}

class Test implements Streamable, TestInterface {
    ...
}

class Test1 extends Test {
    ...
}
// Test1 is compatible to FileIO, Printable, Streamable,
// TestInterface and the class Test
```

Abstract Classes vs. Interfaces

- Abstract classes can provide a "partial" implementation of an abstraction.
- Abstract classes can contain instance variables.
- An abstract class should be used when only some parts of the implementation are "left open".
- An interface is suitable to represent certain properties (Printable, Clonable,...)

22 Inner Classes

- **local inner class**: only usable from enclosing class
- **inner class with method scope**: only usable in method
- **anonymous inner class**: only usable when defined
- **static inner class**: globally usable

22.1 Local Inner Classes

- Inner class can access instance variables of enclosing class

```
class Test {
  private String array[] = { "hans", "otto", "max"};
  class Inner {
    String method(int i) { return "Name:+" + array[i]; }
  }
}
```

- visibility modifiers like methods and instance variables (**private**,default,**protected**,**public**)

```
class Test {
  private String array[] = { "hans", "otto", "max"};
  private class MyEnum implements Enumeration {
    private int counter = 0;
    public Object nextElement() { return [counter++]; }
    public boolean hasMoreElements() { return counter<array.length; }
  }
  public Enumeration enumerate() { return new MyEnum(); }
}
```

22.2 Inner Classes with Method Scope

- class only needed in one method

```
class Test {
  private String array[] = { "hans", "otto", "max"};
  public Enumeration enumerate() {
    class MyEnum implements Enumeration {
      private int counter = 0;
      public Object nextElement() { return [counter++]; }
      public boolean hasMoreElements() { return counter<array.length; }
    }
    return new MyEnum();
  }
}
```

22.2 Inner Classes with Method Scope

- Can access **`final`** parameters and **`final`** local variables of the enclosing method
- Access to **`this`** of the enclosing class **`X`** with **`X.this`**

```
class Test {
  public void test(final String msg) {
     class Inner {
      public void output(String hello) { System.out.println(hello+msg);}
     }
     ...
  }
}
```

22.3 Anonymous Classes

- Class name **`MyEnum`** in previous example contains no information ➜ Use an anonymous inner class

```
class Test {
  private String array[] = { "hans", "otto", "max"};

  Enumeration enumerate() {
    return new Enumeration() {
      int counter = 0;
      public boolean hasMoreElements() {
        return counter < array.length; }
      public Object nextElement() {
        return array[counter++]; }
    };
  }
}
                                  concludes return statement
```

22.4 Static Inner Classes

- Static classes can only access static variables and methods of the enclosing class

```
class Test {
  private static String array[] = { "hans", "otto", "max"};

   static class E implements Enumeration() {
     int count = 0;
     public boolean hasMoreElements() {
       return count < array.length; }
     public Object nextElement() {
       return array[count++]; }
   }
}
...
Enumeration e = new Test.E();
System.out.println(e.nextElement());
```