# Inheritance and Polymorphism

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# Topics

Java Inheritance

Class hierarchy - An example

## Visibility

I can see what you can't

Constructors and inheritance

Polymorphism

# Known

- Between objects, relationships exist

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- An association represents a *Has*-relationship
  - A human being has two legs
  - A chair has 4 chair legs
  - A car has 4 wheels

# Known

- Between objects, relationships exist
- An association represents a *Has*-relationship
  - A human being has two legs
  - A chair has 4 chair legs
  - A car has 4 wheels
- Beside, a *Is-a*-relationship exists
  - Apples and pears are fruit species
  - Students and lecturers are humans
  - The type defines characteristics for its elements
    - Each human being has an eye color
    - Each human being has a hair color
    - Each human being has a size
  - Java represents this relationship by inheritance
  - *Parents* give their *Childs* characteristics

# Java Inheritance

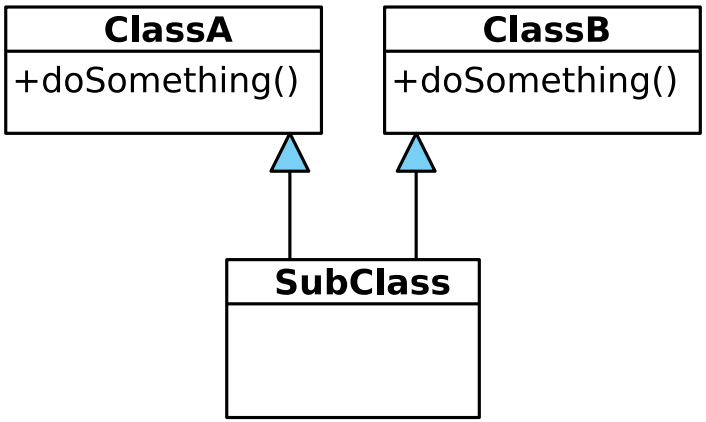
- Java defines classes in hierarchical relationships
- Therefore, classes have a *Is-a*-relationship with their parent class
- The keyword `extends` shows that a class is derived from another class
- Therefore, a class becomes a sub class
- The parent class is the super class
- The sub class inherits all **visible** characteristics of the super class

# The implicit base class `Object`

- Classes without the `extends`-keyword automatically inherit from `Object`
- Object is an implicit super class
- Each class inherits either directly or indirectly from `java.lang.Object`
- All visible attributes and methods, like toString(), are inherited

# No Multiple inheritance in Java

- Java only allows single inheritance
- Behind the `extends`-keyword, only *one* super class is allowed
- ao C++, Python and Perl allow Multiple Inheritance. Why does java not?




- `new SubClass().doSomething();` **Do what???**

# Example *Person*

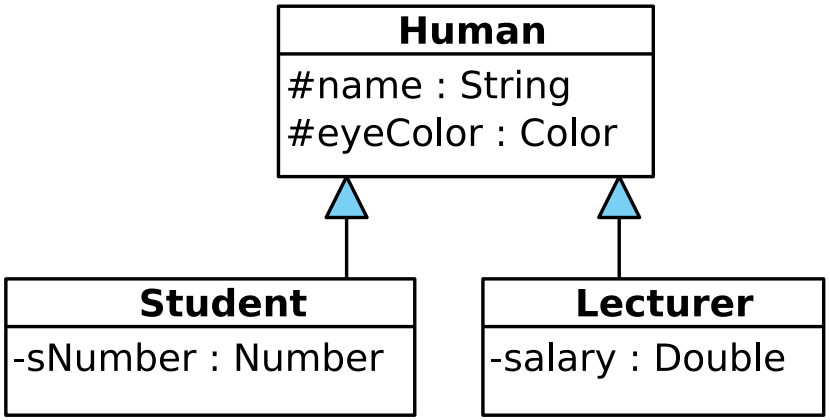



Figure: A class hierarchy for our school

- Students and Lecturers are Humans
- with ao a name and an eye color
- `TeamLeader` could have been a sub class of Lecturer

# Example *Human*

```java
package nl.fontys.pro2.week1;

import java.awt.Color;

public class Human {
    protected String name;
    protected Color eyeColor;
}
```

```java
package nl.fontys.pro2.week1;

public class Student extends Human {
    private Number number;
}
```

# Example *Human*

```
public static void main(String[] args) {
    Student theStud = new Student();
    theStud.name = "Richard Stallman";
}
```

- Class Student can use the inherited attributes `name` and `eyeColor`
- Changes in a super class are automatically represented in sub classes
- Therefore, a sub class has a very strong coupling to its super class
- Super classes *don't know* their sub classes

# peekabo:I can see what you can't

# Visibility

- Sub classes inherit all **visible** characteristics from their super class
- `public`: visible for all classes
- package-private: visible for all classes in the same package
- `private`: only visible within class (including contained inner class)
- In addition: `protected`:
  - protected attributes and methods are inherited by all sub classes
  - are visible for all classes in the same package
- `public` ➜ `protected` ➜ *package-private* ➜ `private`
- `Protected` -protection is weaker than package-private!

# Visibility table

Table: Normalized visibility table.

| Modifier | Class | Package | Subclass | World |
|---|---|---|---|---|
| public | y | y | y | y |
| protected | y | y | y | - |
| (default) | y | y | - | - |
| private | y | - | - | - |

# Usage of constructors with inheritance

- In contrast to methods, constructors are not inherited
- Sub classes need a constructor to enable objects to be created
- Within the constructor, Java automatically invokes the super class constructor
- When no constructor has explicitly been defined, the implicit default constructor is used

# A super constructor

- `super()` invokes the super constructor explicitly
- The default constructor is always invoked implicitly
- `super` can invoke parameterized constructors
- Mandatory, if super class does not have default constructor

```
public class Student extends Human {
    public Student(Number number){ ... }
}
```

```
public class StudAssistant extends Student {
    public StudAssistant(Number sNumber){
        super(sNumber);
    }
}
```

# Summary constructors and methods

- Constructors
  - can't be `abstract`, `final`, `native`, `static` or `synchronized`
  - don't have a return value, even not void
  - are not inherited
  - Can have all visibility attributes
  - `this(...)` refers to another constructor in the same class
  - `super(...)` invokes a constructor of super class
- Methods
  - can be public, protected, package-private, private, abstract, final, native, static or synchronized
  - can have return values, or void
  - Visible methods are inherited
  - Inherited visibility cannot be changed
  - `this` is a reference to the current instance of the class
  - With `super`, overridden methods of the superclass can be invoked

# Static and dynamic types

- Seemingly trivial relationships
  - A Student is a Human
  - A Lecturer is a Human
  - A Human is an Object
  - A Student is a Student
- In Java:

```
Human   studentIsHuman   = new Student();
Human   lecturerIsHuman  = new Lecturer();
Object  humanIsObject    = new Human();
Student studentIsStudent = new Student();
```

# Static and Dynamic types

- The declared type is the so-called **static type**
- The initialised type is the **dynamic type**
- The declared type or L-Value is configured with their static type. An object knows its dynamic type.
- Variables are treated as being of a static type

```
Human studHum = new Student();
System.out.println(studHum.getName());
// The following will not work:
System.out.println(studHum.getSNumber());
```

# Static and dynamic types

- Variables can not simply be initialised with *lesser*[1] types.
- In case of the correct dynamic type, a typecast helps
- `instanceof` verifies dynamic types

```
Human stud = new Student();
// next line will not work:
Student stud2 = stud;
// This one will:
Student stud3 = (Student) stud;
// Because stud has the dynamic type  Student
if(stud instanceof Student){
    // instanceof tests the dynamic Typ
}
```

[1] less specific

# Override a method

- Methods of Super classes are overwritten when
  - The name **and**
  - the list of parameters (number of params and their type, not their name)
  - **and** return type
  - **exactly** match that of the super classes method
- The annotation `@Override` lets the compiler also check whether a method is actually and correctly overwritten
- The method of the superclass is then ruled out, right?
- Example: override the `toString()` method of `Object`

# Override a method

- makes calling overridden methods possible
- You can only reach one level higher with super: Chaining of `super` keywording at a deeper inheritance hierarchy is not possible
- `Super` methods are not accessible from the outside. A call to a `super....` method can only be made on `this`, inside the defining class, not any other object.

```
public class Student extends Human {
...
    @Override
    public void setName(String name) {
        if(isNiceName(name)){
            super.setName(name);
        }
    }
}
```

# prohibit method override

- The keyword `final` prohibits overriding.
  - In classes, thereby prohibiting extension
    - example `final class Integer`
  - for methods, thereby prohibiting that they can be overridden
    - example: `public final wait()`[2]
- Quiz: could you come up with a use for a `protected final` method?

[2] Defined in this way in `java.lang.Object`

# Not all understood? For next time read:

- Introduction to Java Programming: Chapter 11

## Questions?

Questions or remarks?

# Polymorphism, abstract classes and interfaces
# Part II

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# Topics

- Polymorphism
- Abstract classes and methods
- Interfaces

## Java8 interfaces: default and static

## multiple inheritance of implementation

- Example: Parents
- Example: Child interfaces

# Polymorphism

Polymorphism is the ability to provide a single interface to entities of different types

- Visible methods of super classes also exist in sub classes
- Super classes can predefine implementations, which can be overwritten, if required
- We can however be sure the methods exist

# Polymorphism - Example

```
public class Human extends Object {
...
  @Override
  public String toString(){
    return "[Human:...";
  }
}
```

```
public class Student extends Human {
...
  @Override
  public String toString(){
    return "[Student:...";
  }
}
```

# Polymorphism - Example

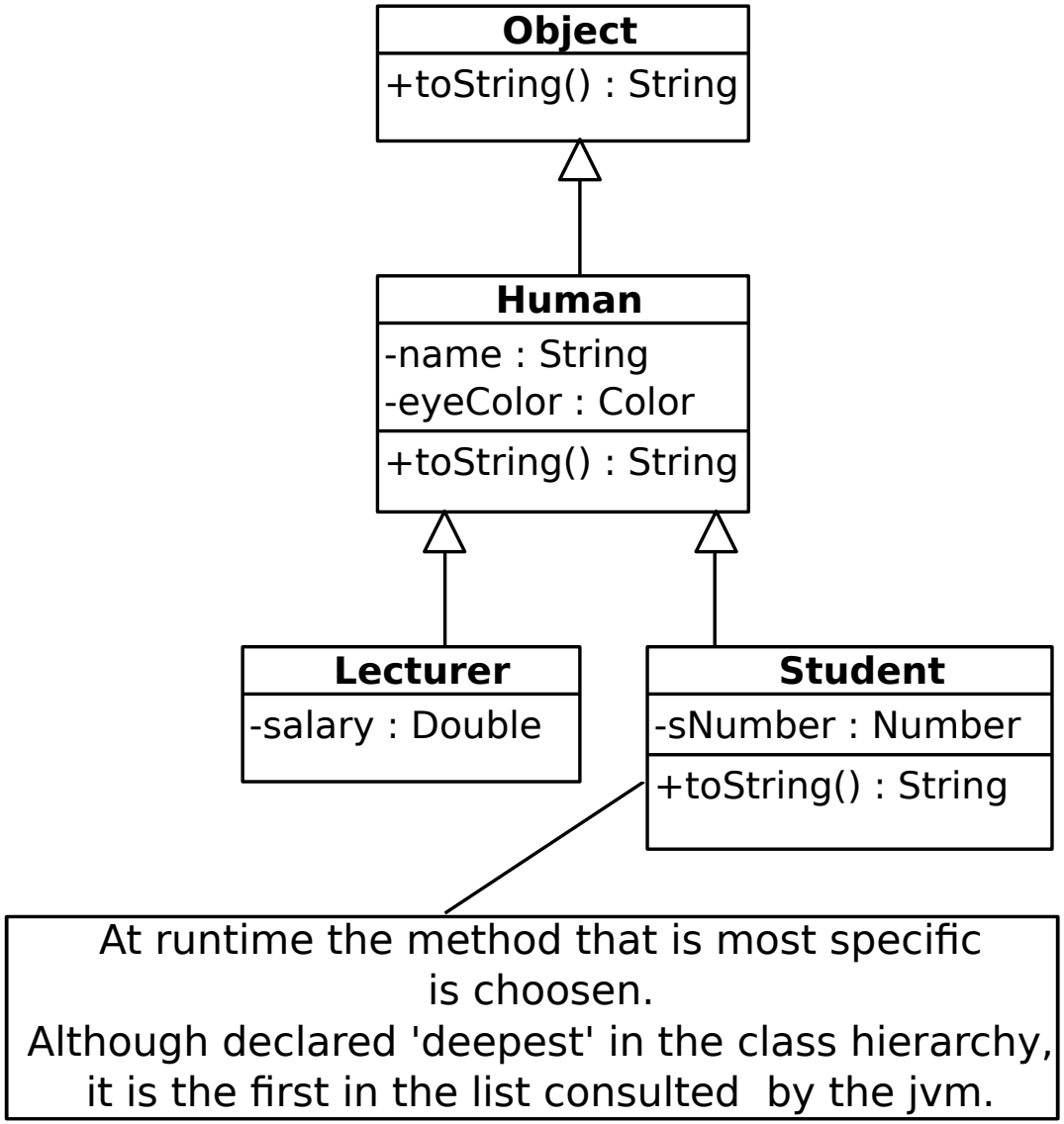
```
Student student = new Student();
System.out.println(student);

Human human = new Student();
System.out.println(human);

Object object = new Student();
System.out.println(object);
```

What will the output look like?

# Polymorphism - Example

- During runtime, the method `toString()` from `Student` will always be used
- In contrast to the compiler, the runtime environment knows the dynamic type
- This is called **dynamic binding**, because the actual type of an object is only determined at runtime
- The method that is the deepest one in the class hierarchy is chosen

# Polymorphism - Example



# Exceptions on polymorphism

- Not all methods are dynamically bound
  - Only **overridden** methods participate
  - Methods which can't be overridden will bound statically
  - `private`, `static` and `final` methods fall in this category.

# Abstract classes

- Abstract classes can't be instantiated
- An abstract class can be used as a static (or declaration) type.
- Useful, for example for classes which are only used as super class, to provide signatures for sub classes
- The keyword `abstract` identifies abstract classes
- Abstract classes are the opposite of concrete classes

```
public abstract class Human{
...
}
```

# Abstract classes

- Abstract classes are often used in inheritance
- They behave like concrete classes
- A subclass can extend an abstract class and can be abstract itself again

```
Human stud1 = new Student();
Human[] humans = new Human[] {new Student(), new ↩
    Lecturer() };
```

Where could abstract classes be used for as well?

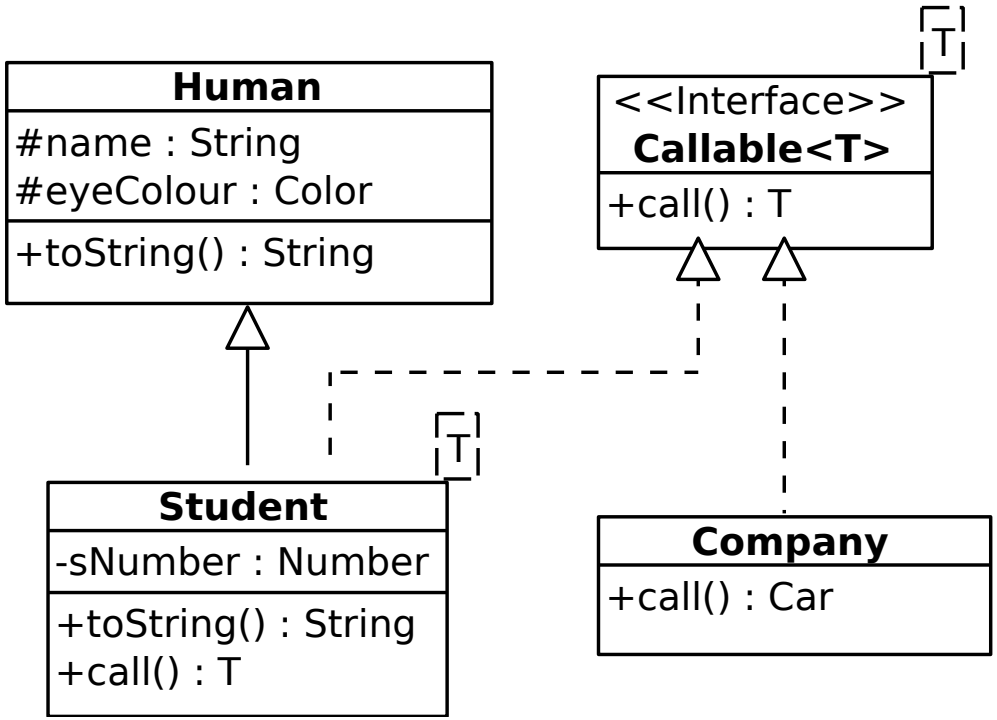
# Abstract methods

- Methods in abstract classes *could* also be abstract
- They only define a method signature for the sub class
- *Concrete* sub classess have to implement these

```
public abstract class Human extends Object {
...
    protected abstract void dress();
}
```

# Interfaces

- It's difficult to give classes multiple types by using inheritance
- Inheritance is always done in order, Human inherits from Object, Students inherits from Human, etc.
- Sometimes, classes need to have types from different hierarchies



# Interfaces

- Instead of `class`, `interface` is used
- Methods in interfaces don't have a body
- All methods are automatically `abstract` and `public`
- Constructors are useless and therefore not allowed
- Instance variables are not allowed either, `static`-variables however are allowed (automatically `final`)

```
public interface Callable<T> {

    T call();

}
```

# Interfaces

```
public class Student extends Human
                    implements Callable{
    //...
    public void call() {...}
}
```

```
public class Student extends Human
    implements Callable, Annoyable{
    //...

    public void call() {...}

    public StressLevel annoy(double degree) {...}
}
```

# Interfaces

```
public class Student extends Human
                    implements Callable{
    //...
    public void call() {...}
}
```

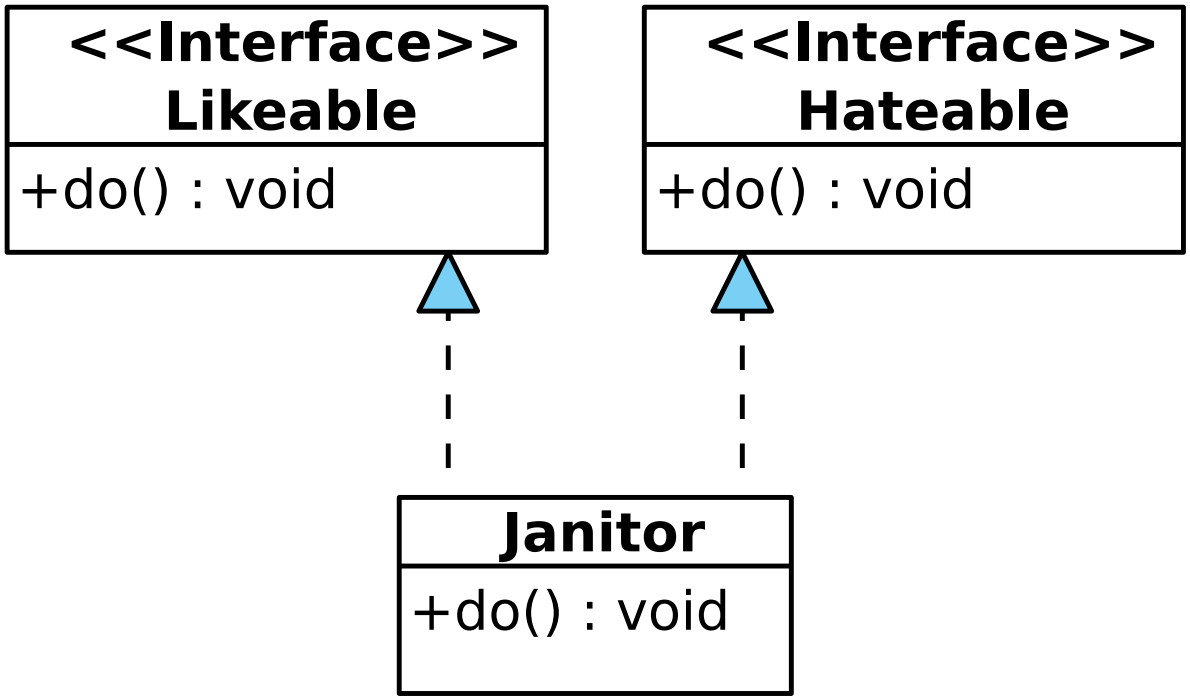
```
public class Student extends Human
    implements Callable, Annoyable{
    //...

    public void call() {...}

    public StressLevel annoy(double degree) {...}
}
```

# Interfaces

- Classes can implement multiple interfaces
- Interfaces can extend zero, one or **multiple** other interfaces
- They allow objects to act in different roles
- A powerful object can be reduced to a single method
- Usage analogous to usage of abstract classes

```
Callable callable = new Student();
Human human = (Student) callable;
```

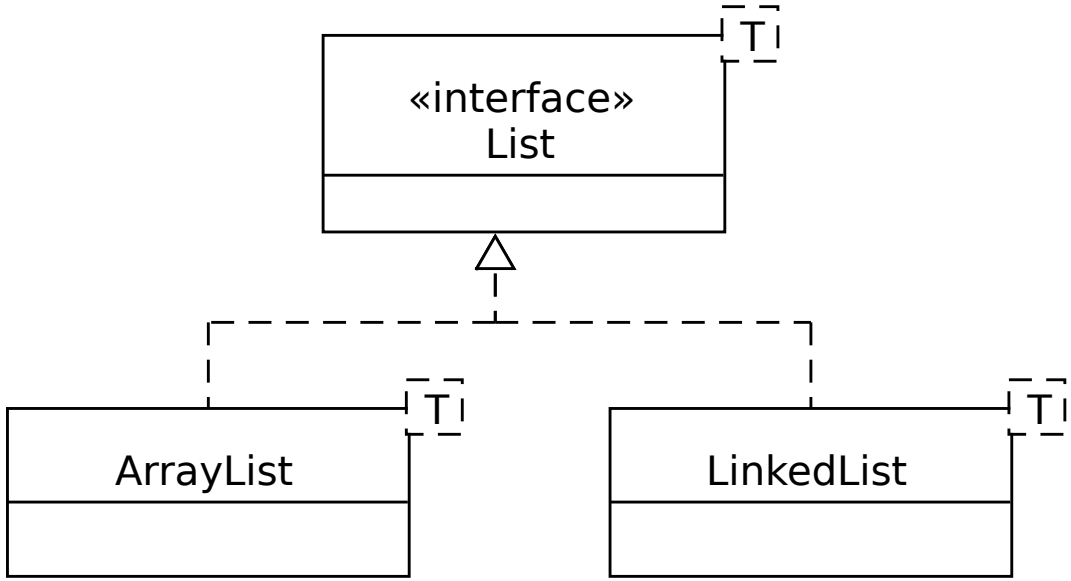
# Interfaces




What will happen now?

# Interfaces as specification

- Separation of functionality and implementation
- Clients communicate implementation-independent
- Alternative implementations can be used



# Interfaces vs. Abstract classes

```
public interface Callable<T> {

    T call();

}
```

```
public abstract class Callable<T> {

    abstract T call();

}
```

# Java8 interfaces: default and static methods

To be able to extend of the framework without breaking existing interfaces and implementing classes, Java 8 introduces a few new concepts.

- `static` methods (implementations) in `interface`s.
- `default` method (implementations!) in `interface`s.
- It allows the extension of interfaces without breaking existing implementing classes.
- The static methods are typically helpers for the default methods.
- It also implies multiple inheritance for said default methods.
- If a conflict is possible, the implementation programmer must help the compiler by specifying which default variant method is to be taken.
- The first use case of this extension is the stream framework, introduced in Java 8, in combination with $\lambda$ expression.

# Multiple inheritance example, parents

```
interface AnInterface {

    default String getName() {
        return "An";
    }
}

interface BnInterface {

    default String getName() {
        return "Bn";
    }
}
```

# Multiple inheritance example, child

```
interface CnInterface extends AnInterface,
                              BnInterface {

    // resolve which super to use.
    // also works in implementing classes
    @Override
    default String getName() {
        return AnInterface.super.getName();
    }

}
```

**Note** that a class implementing two interfaces-methods with the same signature must also specify which variant to select, using the same construction as above.
See **DEMO**

# Any open issues?

Not all understood? For next time read:

- Introduction to Java Programming: Chapter 11
- Java 8 tutorial on default methods
  `http://docs.oracle.com/javase/tutorial/java/IandI/defaultmethods.html`

## Questions?

Questions or remarks?