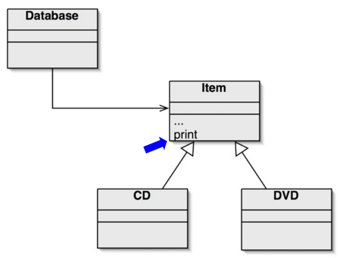
8 More about inheritance

Polymorphism

Main concepts to be covered

- method polymorphism
- static and dynamic type
- overriding
- dynamic method lookup
- protected access

The inheritance hierarchy



Print method in Item

```
public class Item
{
    ...

    public void print()
    {
        System.out.print("title: " + title +
            " (" + playingTime + " mins)");
        if(gotIt) {
            System.out.println("*");
        } else {
            System.out.println();
        }
        System.out.println("    " + comment);
    }
    ...
}
```

Conflicting output

What we want

```
CD: A Swingin' Affair (64 mins)*
    Frank Sinatra
    tracks: 16
    my favourite Sinatra album

DVD: O Brother, Where Art Thou? (106 mins)
     Joel & Ethan Coen
     The Coen brothers' best movie!
```

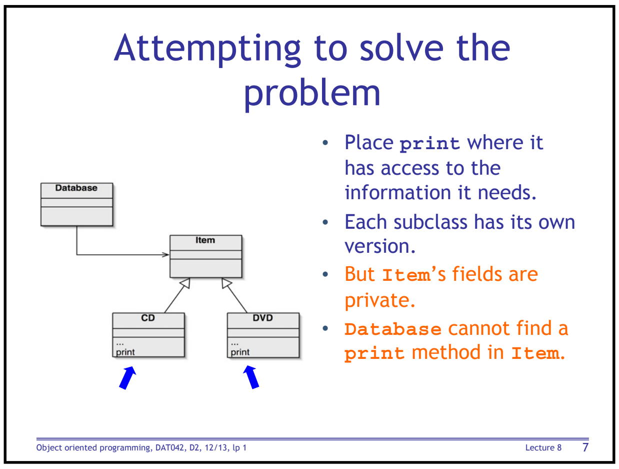
What we have

```
title: A Swingin' Affair (64 mins)*
       my favourite Sinatra album

title: O Brother, Where Art Thou? (106 mins)
       The Coen brothers' best movie!
```

The problem

- The `print` method in `Item` only prints the common fields.
- Inheritance is a one-way street:
  - A subclass inherits the superclass fields.
  - The superclass knows nothing about its subclass's fields.



Attempting to solve the problem

Database
Item
CD
...
print
DVD
...
print

- Place `print` where it has access to the information it needs.
- Each subclass has its own version.
- But `Item`'s fields are private.
- `Database` cannot find a `print` method in `Item`.

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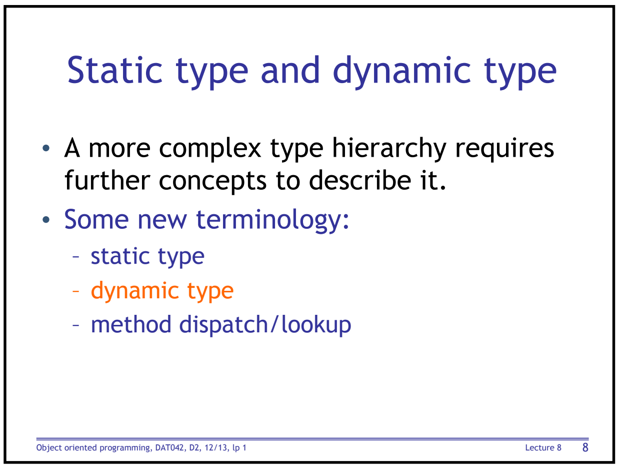

Static type and dynamic type

- A more complex type hierarchy requires further concepts to describe it.
- Some new terminology:
  - static type
  - dynamic type
  - method dispatch/lookup

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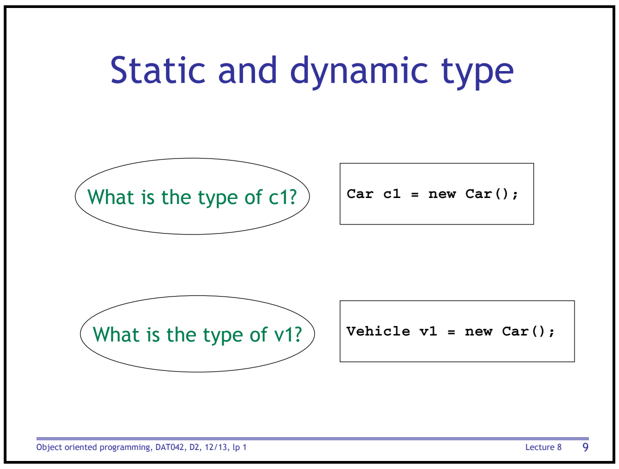

Static and dynamic type

What is the type of c1?

```
Car c1 = new Car();
```

What is the type of v1?

```
Vehicle v1 = new Car();
```

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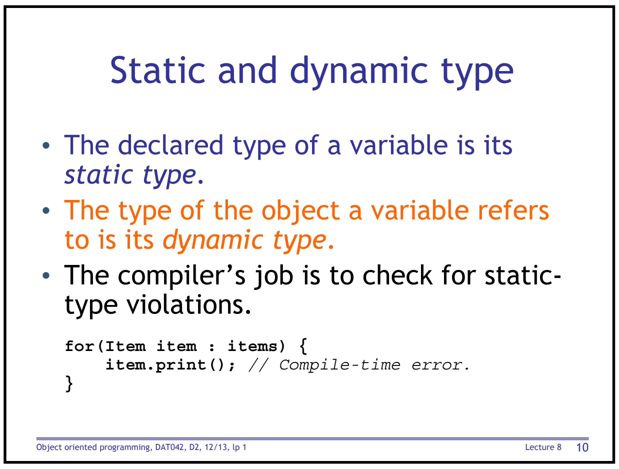

Static and dynamic type

- The declared type of a variable is its *static type*.
- The type of the object a variable refers to is its *dynamic type*.
- The compiler's job is to check for static-type violations.

```
for(Item item : items) {
    item.print(); // Compile-time error.
}
```

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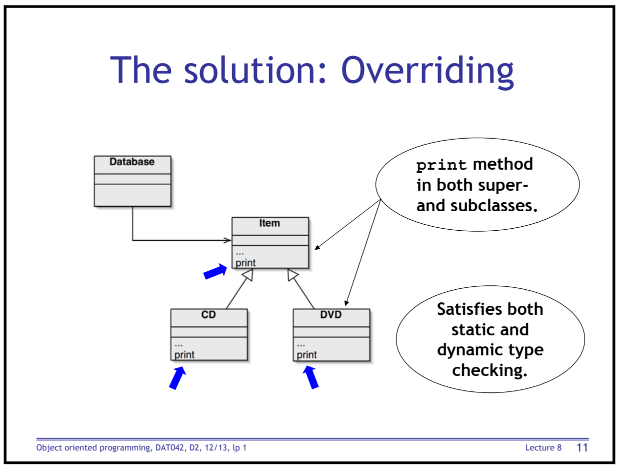

The solution: Overriding

Database
Item
...
print
CD
...
print
DVD
...
print
print method in both super- and subclasses.
Satisfies both static and dynamic type checking.

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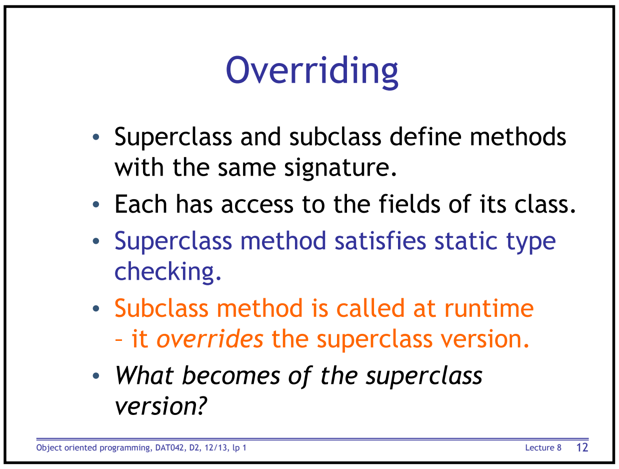

Overriding

- Superclass and subclass define methods with the same signature.
- Each has access to the fields of its class.
- Superclass method satisfies static type checking.
- Subclass method is called at runtime – it *overrides* the superclass version.
- *What becomes of the superclass version?*

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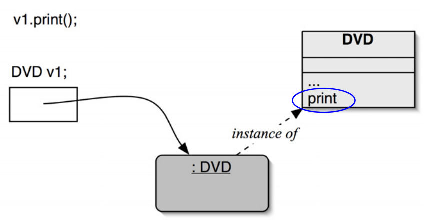
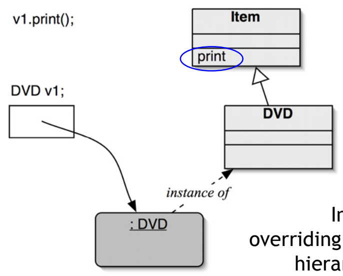
Method lookup



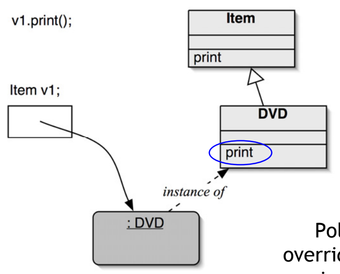
No inheritance or polymorphism. The obvious method is selected.

Method lookup



Inheritance but no overriding. The inheritance hierarchy is ascended, searching for a match.

Method lookup



Polymorphism and overriding. The 'first' version found is used.

Method lookup summary

- The variable is accessed.
- The object stored in the variable is found.
- The class of the object is found.
- The class is searched for a method match.
- If no match is found, the superclass is searched.
- This is repeated until a match is found, or the class hierarchy is exhausted.
- Overriding methods take precedence.

Super call in methods

- Overridden methods are hidden ...
- ... but we often still want to be able to call them.
- An overridden method *can* be called from the method that overrides it.
  - `super.method(...)`
  - Compare with the use of `super` in constructors.

Calling an overridden method

```
public class CD extends Item
{
    ...
    public void print()
    {
        super.print();
        System.out.println("    " + artist);
        System.out.println("    tracks: " +
                                numberOfTracks);
    }
    ...
}
```

Method polymorphism

- We have been discussing *polymorphic method dispatch*.
- A polymorphic variable can store objects of varying types.
- Method calls are polymorphic.
  - The actual method called depends on the dynamic object type.

The Object class's methods

- Methods in `Object` are inherited by all classes.
- Any of these may be overridden.
- The `toString` method is commonly overridden:
  - `public String toString()`
  - Returns a string representation of the object.

Overriding toString

- Explicit `print` methods can often be omitted from a class:
  - `System.out.println(item.toString());`
- Calls to `println` with just an object automatically result in `toString` being called:

```
for(Item item : items) {
    System.out.println(item);
}
```

Overriding toString in Item

```
public class Item
{
    ...

    public String toString()
    {
        String line1 = title +
                       " (" + playingTime + " mins)");
        if(gotIt) {
            return line1 + "*\n" + "    " +
                   comment + "\n");
        } else {
            return line1 + "\n" + "    " +
                   comment + "\n");
        }
    }
    ...
}
```

Overriding toString in CD

```
public class CD extends Item
{
    ...

    public String toString()
    {
        return
            super.toString() + "\n" +
            "    " + artist + "\n" +
            "    tracks: " + numberOfTracks + "\n";
    }
    ...
}
```

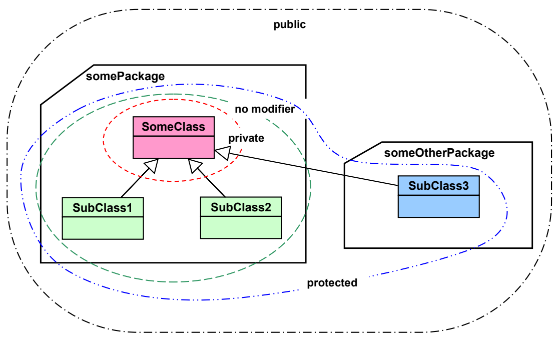
Protected access

- Private access in the superclass may be too restrictive for a subclass.
- The closer inheritance relationship is supported by *protected access*.
- Protected access is more restricted than public access.
- We still recommend keeping fields private.
  - Define protected accessors and mutators.

Visibility for class members

Modifier	Class	Package	Subclass	World
`public`	Yes	Yes	Yes	Yes
`protected`	Yes	Yes	Yes	No
no modifier (package private)	Yes	Yes	No	No
`private`	Yes	No	No	No

Access levels



Access levels

Example

A class member (method, constructor, variable) which is declared in `SomeClass` with access level

`private`
is only visible in `SomeClass`

no modifier (package private)
is visible in `SomeClass`, `SubClass1`, `SubClass2`

`protected`
is visible in `SomeClass`, `SubClass1`, `SubClass2`, `SubClass3`

`public`
is visible everywhere

Access levels and overriding

- An overriding method in a sub class must be at least as visible as the overridden method in its base class.

Visibility in base class	Allowed visibility in sub class
`public`	`public`
`protected`	`protected` `public`
package private	package private `protected` `public`

Overriding and Covariant Return Types

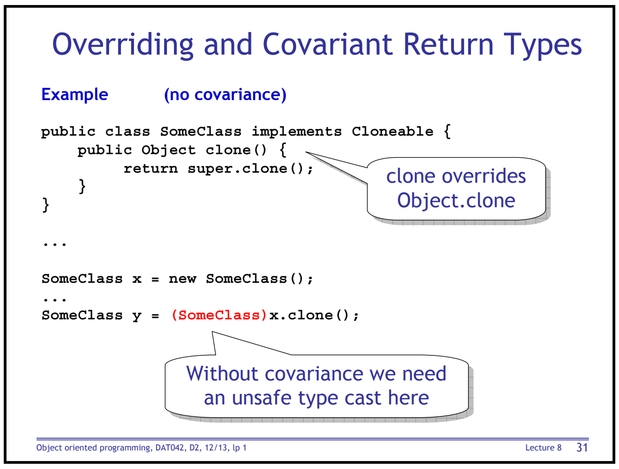
- In Java, the return type of an overriding method is allowed to be a subtype of the return type of the overridden method.
- This is called *covariance*.
- The benefit is type safety
  - Less need for unsafe type casts when calling overridden methods.

Overriding and Covariant Return Types

```
public class A {}
public class B extends A {}

public class Base {
    public A f() { return new A(); }
    public Base g() { return new Base(); }
}

public class Sub extends Base {
    public A f() { return new A(); }
    public A f() { return new B(); }
    public B f() { return new B(); }

    // In particular, covariance can be
    // applied to the class itself:
    public Base g() { return new Base(); }
    public Base g() { return new Sub(); }
    public Sub g() { return new Sub(); }
}
```

Any of these is a correct overriding of f

Any of these is a correct overriding of g



Overriding and Covariant Return Types

Example (no covariance)

```
public class SomeClass implements Cloneable {
    public Object clone() {
        return super.clone();
    }
}

...

SomeClass x = new SomeClass();
...
SomeClass y = (SomeClass)x.clone();
```

clone overrides Object.clone

Without covariance we need an unsafe type cast here

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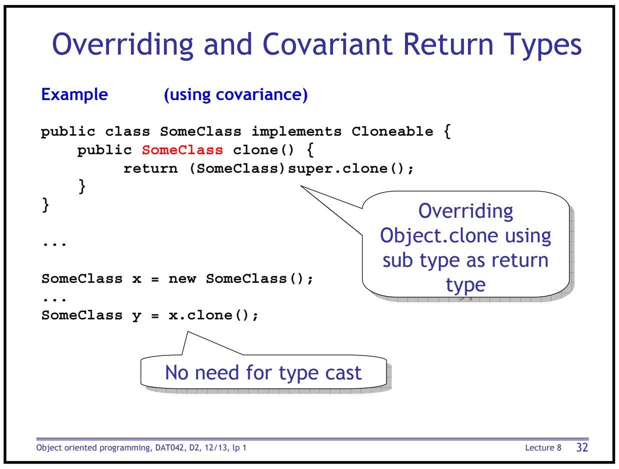

Overriding and Covariant Return Types

Example (using covariance)

```
public class SomeClass implements Cloneable {
    public SomeClass clone() {
        return (SomeClass)super.clone();
    }
}

...

SomeClass x = new SomeClass();
...
SomeClass y = x.clone();
```

Overriding Object.clone using sub type as return type

No need for type cast

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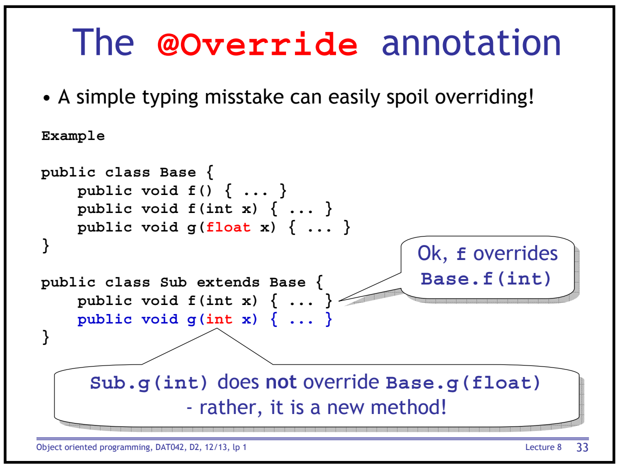

The `@Override` annotation

- A simple typing misstake can easily spoil overriding!

```
Example

public class Base {
    public void f() { ... }
    public void f(int x) { ... }
    public void g(float x) { ... }
}

public class Sub extends Base {
    public void f(int x) { ... }
    public void g(int x) { ... }
}
```

Ok, `f` overrides `Base.f(int)`

`Sub.g(int)` does not override `Base.g(float)` - rather, it is a new method!

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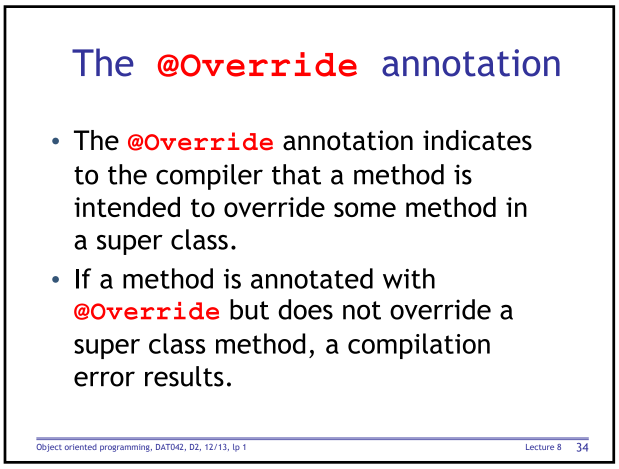

The `@Override` annotation

- The `@Override` annotation indicates to the compiler that a method is intended to override some method in a super class.
- If a method is annotated with `@Override` but does not override a super class method, a compilation error results.

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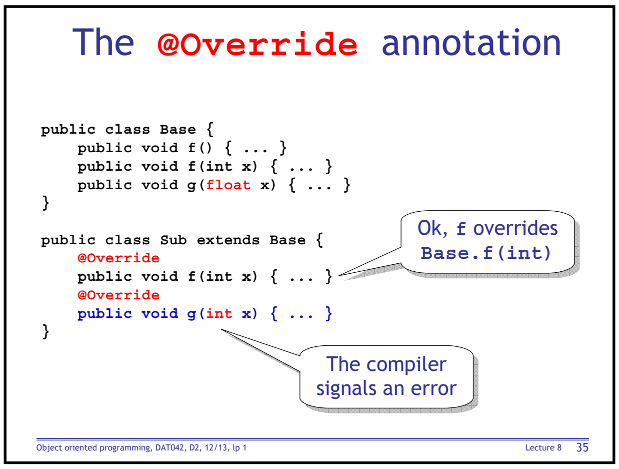

The `@Override` annotation

```
public class Base {
    public void f() { ... }
    public void f(int x) { ... }
    public void g(float x) { ... }
}

public class Sub extends Base {
    @Override
    public void f(int x) { ... }
    @Override
    public void g(int x) { ... }
}
```

Ok, `f` overrides `Base.f(int)`

The compiler signals an error

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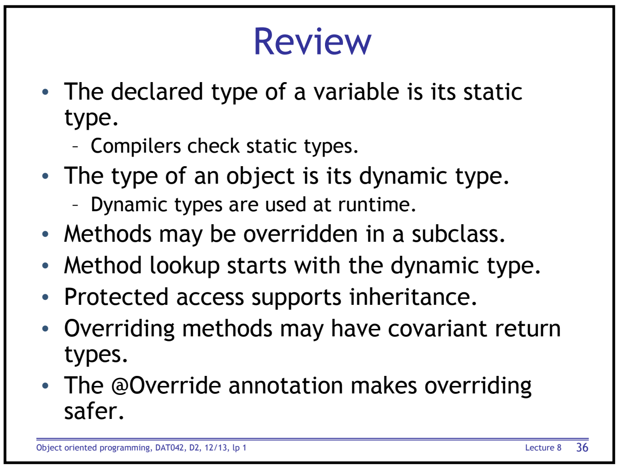

Review

- The declared type of a variable is its static type.
  - Compilers check static types.
- The type of an object is its dynamic type.
  - Dynamic types are used at runtime.
- Methods may be overridden in a subclass.
- Method lookup starts with the dynamic type.
- Protected access supports inheritance.
- Overriding methods may have covariant return types.
- The @Override annotation makes overriding safer.

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