Software Development (CS2500)

Lecture 25: Inheritance (Continued)

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Outline

- We continue studying inheritance.
- Study some class-design tests that help:
  - Determining sub- and superclass relationship;
  - Determining what attributes to use.
- Continue our study of abstract classes.
- Decide class membership with `instanceof`.
- Learn how to override some common methods:
  - `toString( );`
  - `equals( );`
- Learn how to *control* inheritance.

A Test for Inheritance

- Designing a class hierarchy is an art, more than a science.
- It may be difficult to get things right from the start.
  - What classes should you use?
  - Which class should go to top, middle, and bottom?
- The *is-a test* provides some help to catch early mistakes.
- If 'every *A* *is-a* *B*' then *A* can be a subclass of *B*.

Examples

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- Every `Cat` is-a `Feline`? ($\surd$)
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The ‘extends test’ is not so robust:

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- `Conservatory` (`Sunroom`) extends `House`.

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- `Feline` extends `Cat`.
  - No, so `Feline` cannot be a subclass of `Cat`.
- `Conservatory` (`Sunroom`) extends `House`.
  - Yes, but `Conservatory` cannot be a subclass of `House`.
  - For example:
    - If `Conservatory` extends `House` then it inherits all `House` methods:
    - `Conservatory.ringDoorBell( )`????
    - `Conservatory.lightFireplace( )`????

An Association Test

- The `House` uses/requires/has access to the `Conservatory`.
- Still `Conservatory` cannot extend `House`.
- However, it makes sense if `House` class has `Conservatory` attribute.

Java

```
public class House {
    private Bell doorBell;
    private Window[] groundfloorWindows;
    private Window[] firstFloorWindows;
    private Conservatory conservatory;
    …
}
```

An Association Test (Continued)

- `MouseCursor` cannot be a subclass of `Window`.
- But, makes sense if `Window` class has `MouseCursor` attribute.

Java

```
public class Window {
    private Position currentPosition;
    private Point lowerLeft;
    private Point upperRight;
    private MouseCursor cursor;
    …
}
```

An Association Test (Continued)

- If a class *A* has a class-*B* attribute then class *A* *uses* *B*.
  - `Window` uses a `MouseCursor`.
  - `House` uses a `Conservatory`.
- The *has-a* test determines when a class uses another class.
- If '*A* has-a *B*' then *A* can have a class-*B* attribute.

Examples

- Every `House` has-a `Conservatory` (possibly `null`).

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- Every `Animal` has-a `Cat`.

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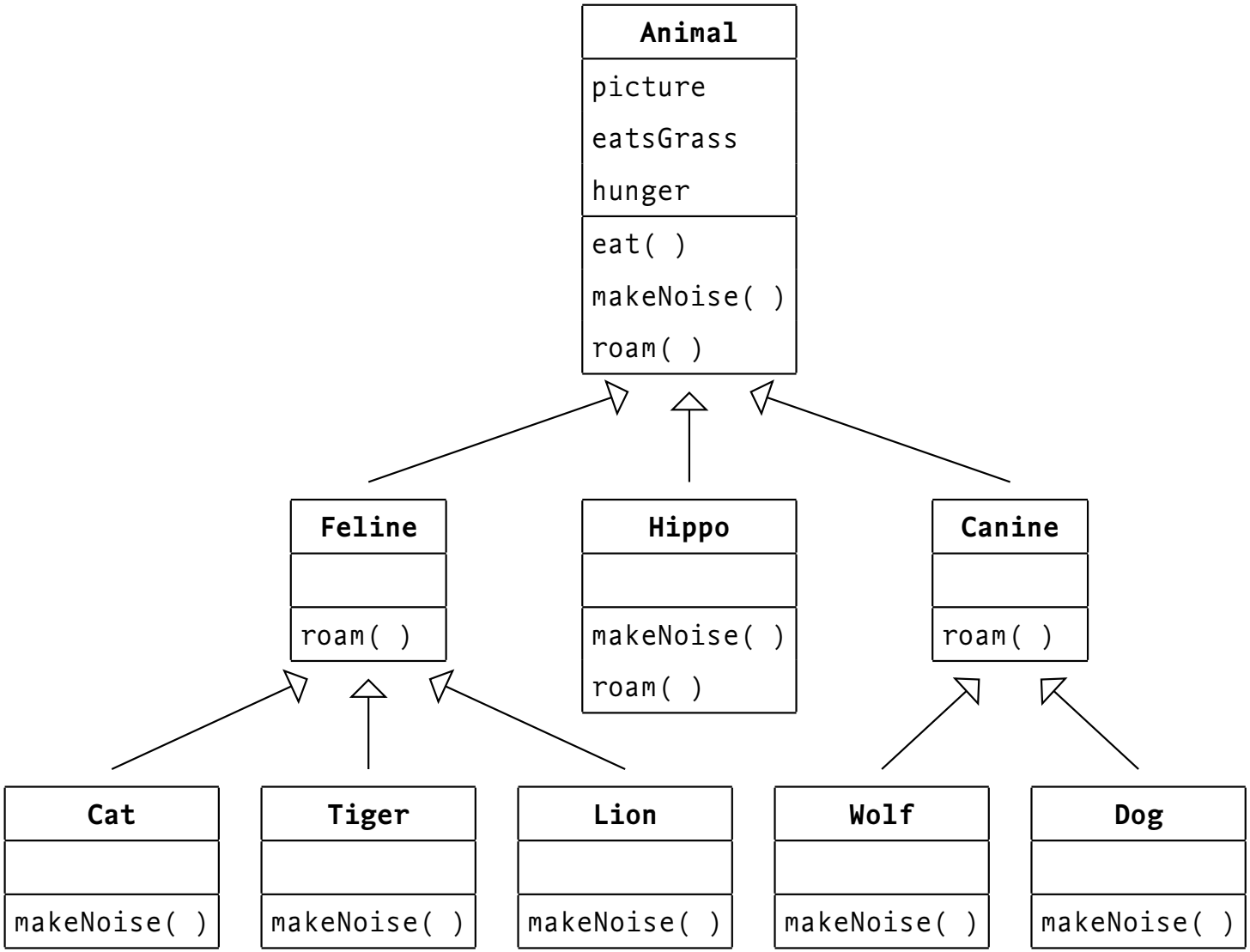
Abstract Classes



Abstract Classes

```
Hippo hippo = new Hippo( )
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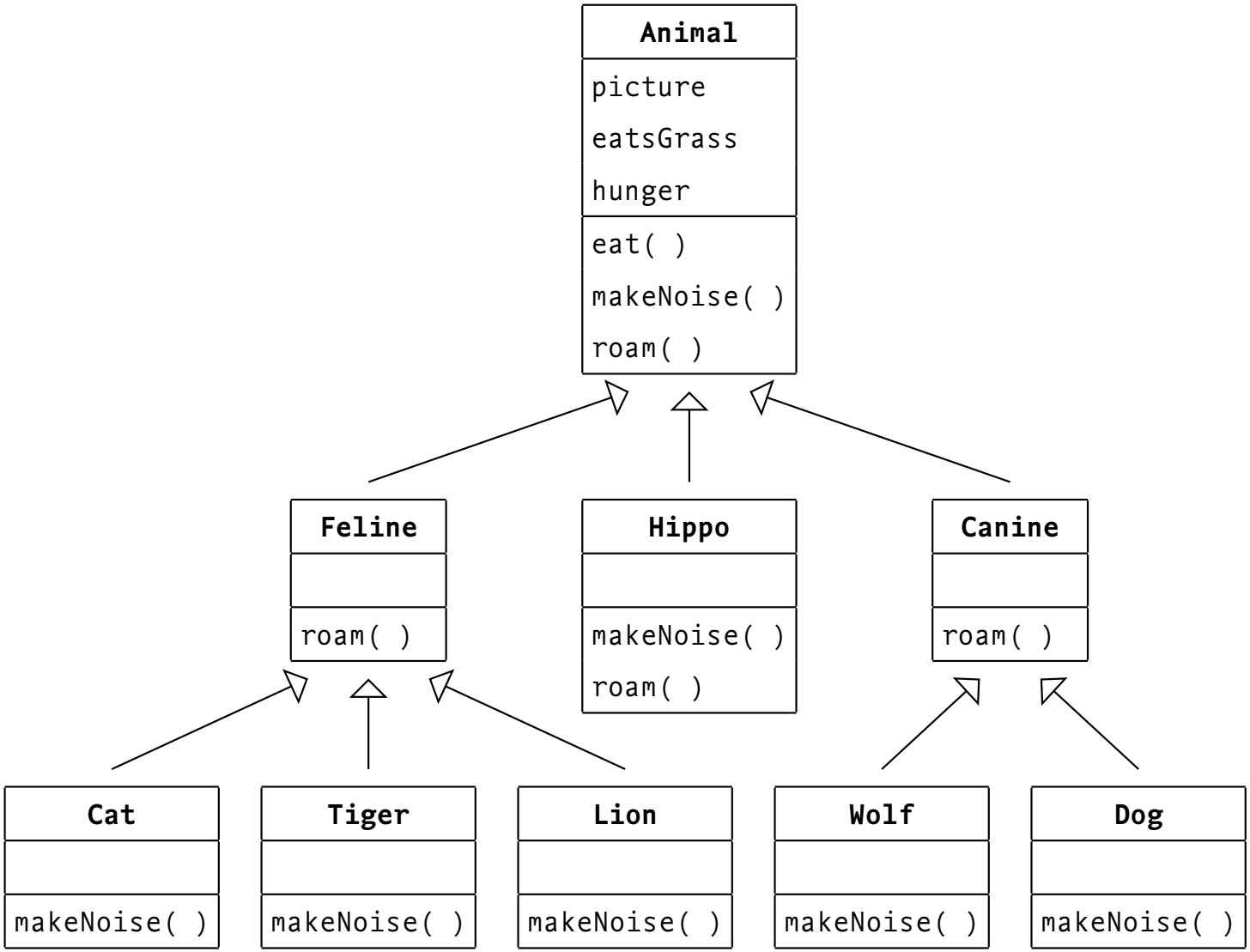

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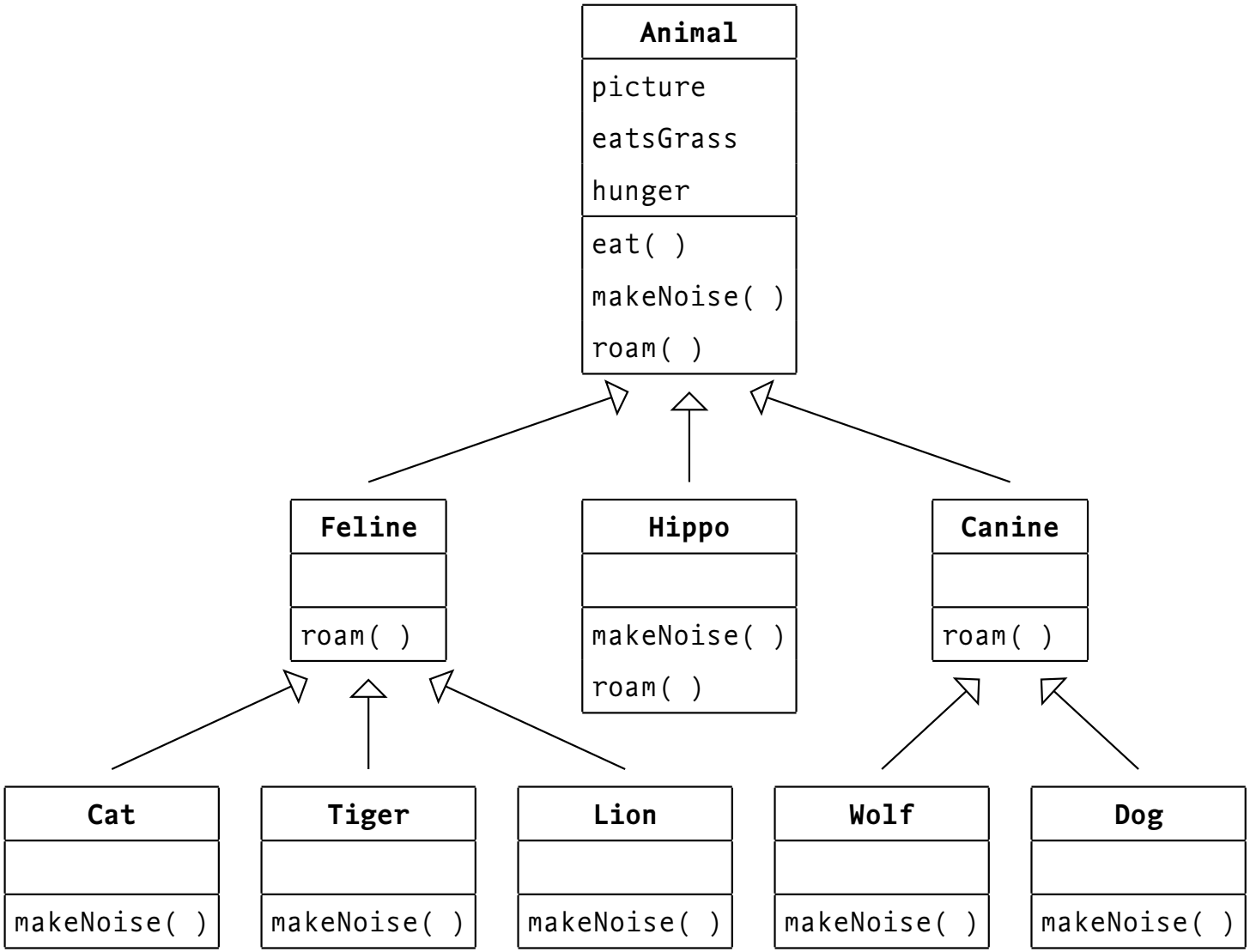

Abstract Classes

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Cat cat = new Cat( )
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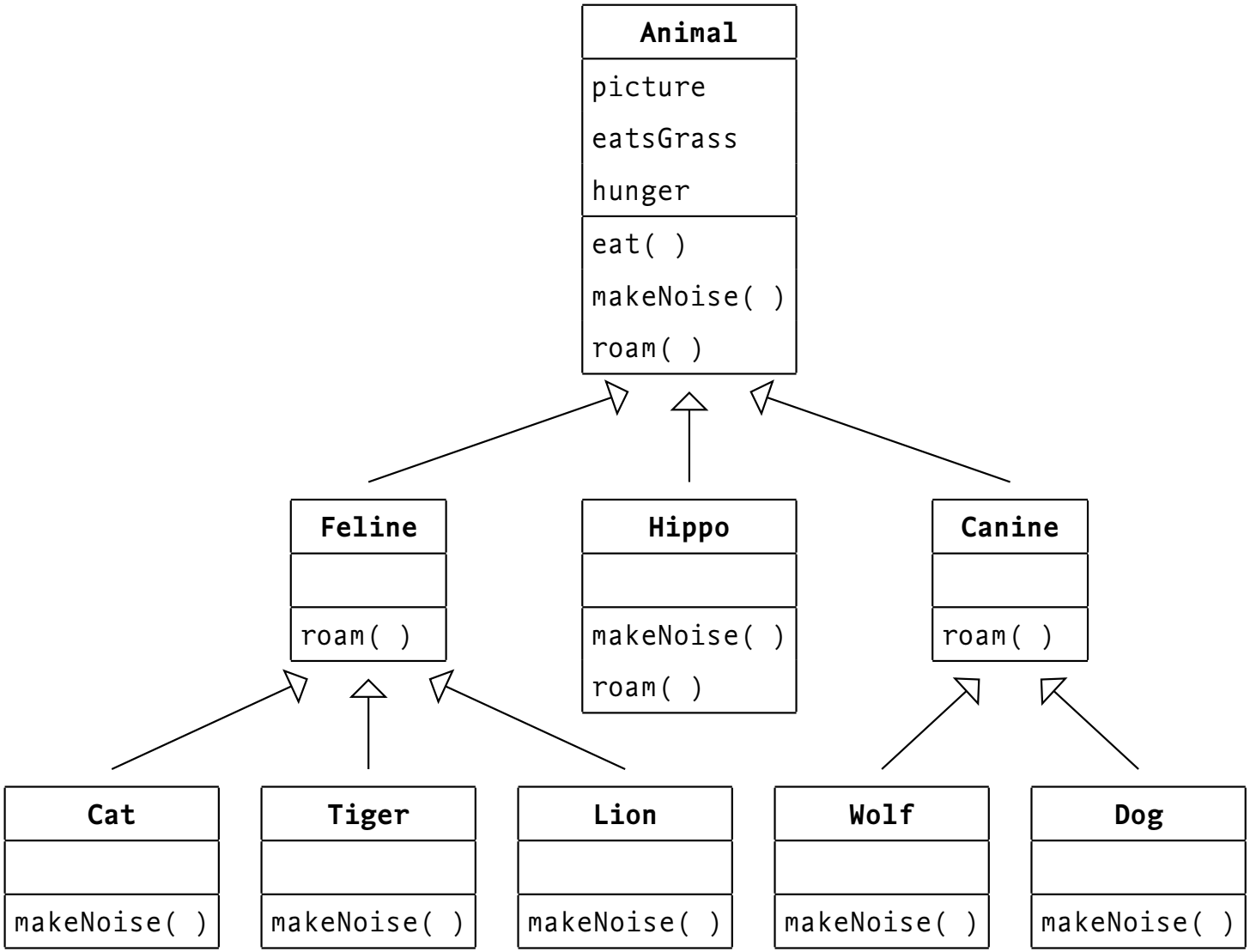

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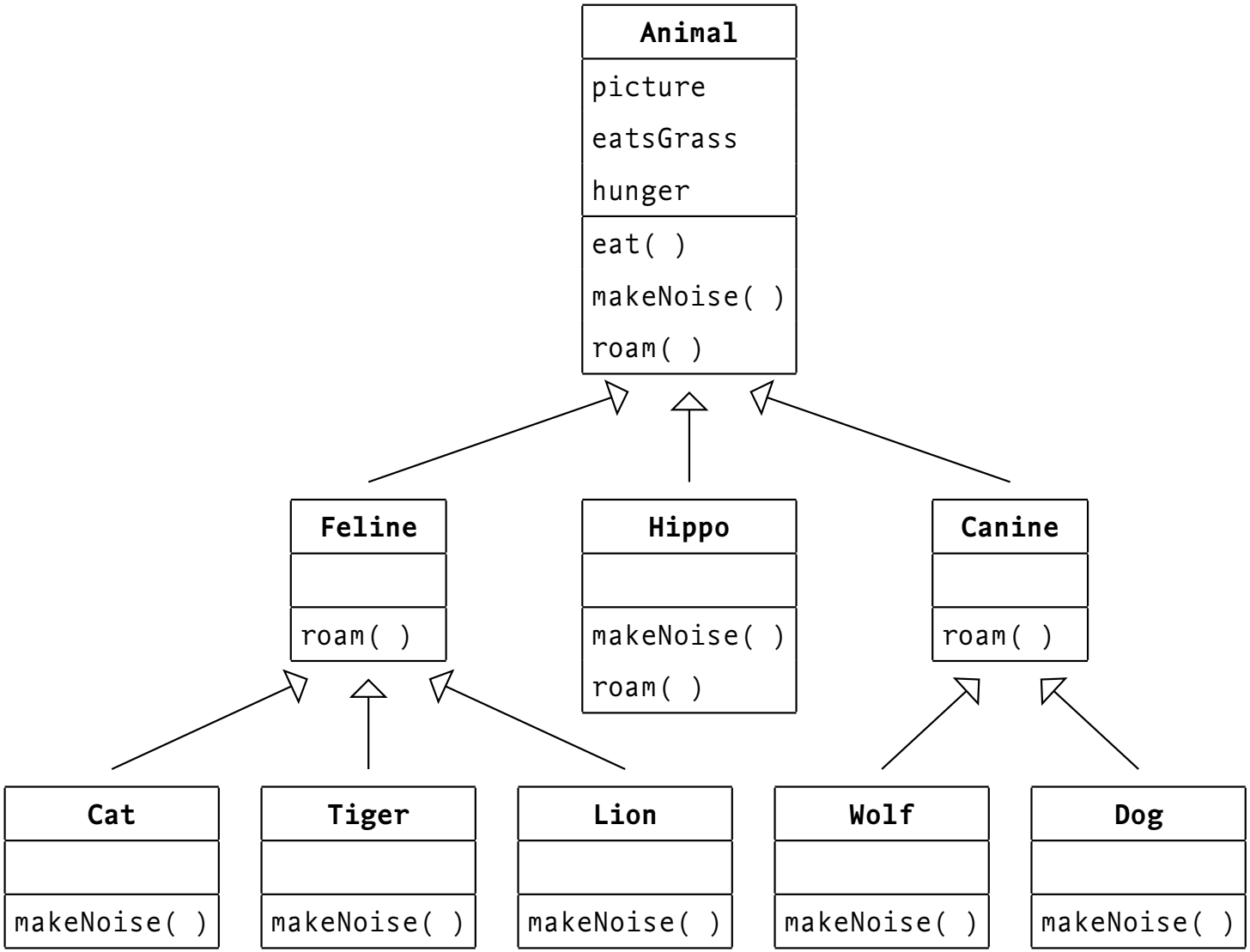

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Animal cat = new Cat( )
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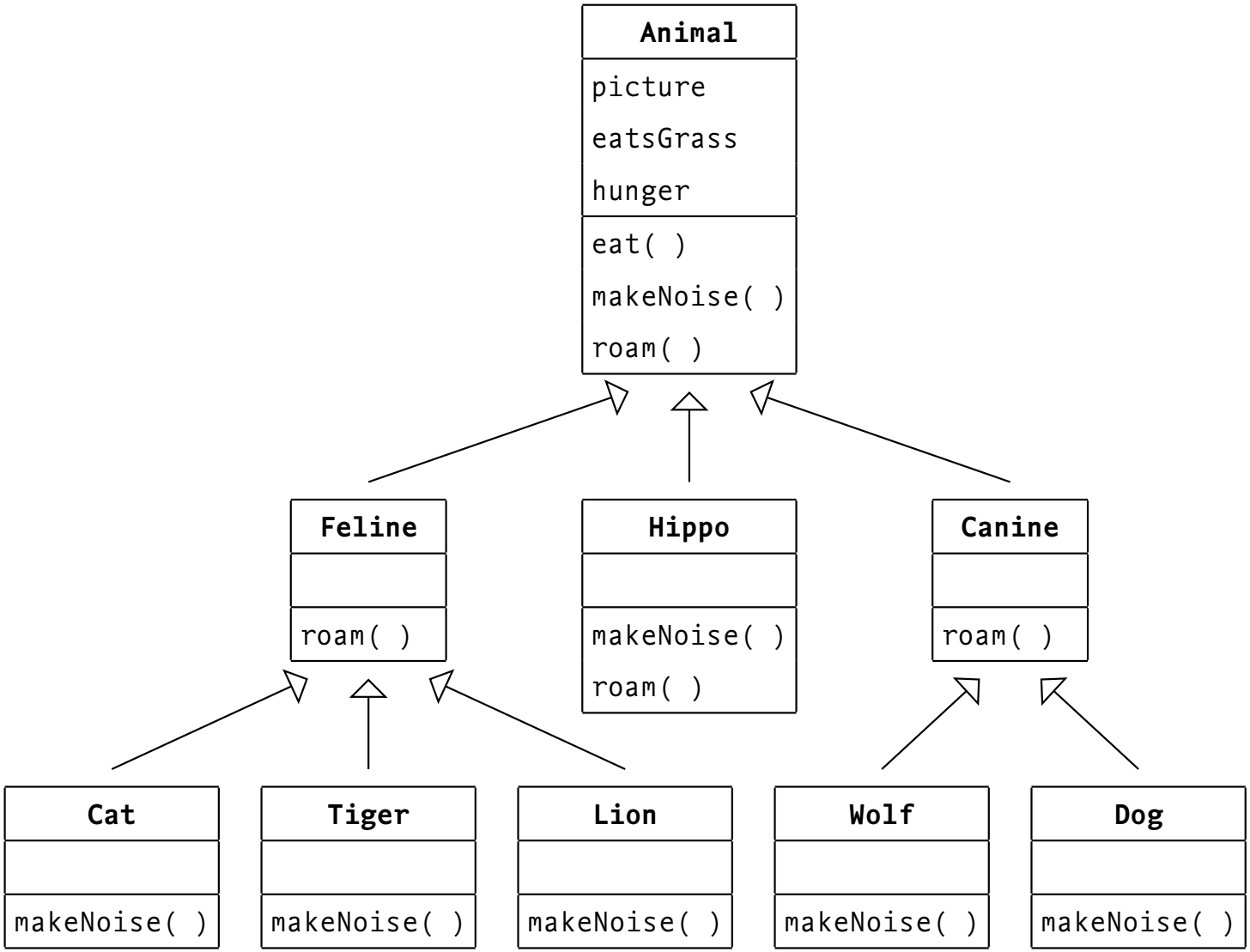

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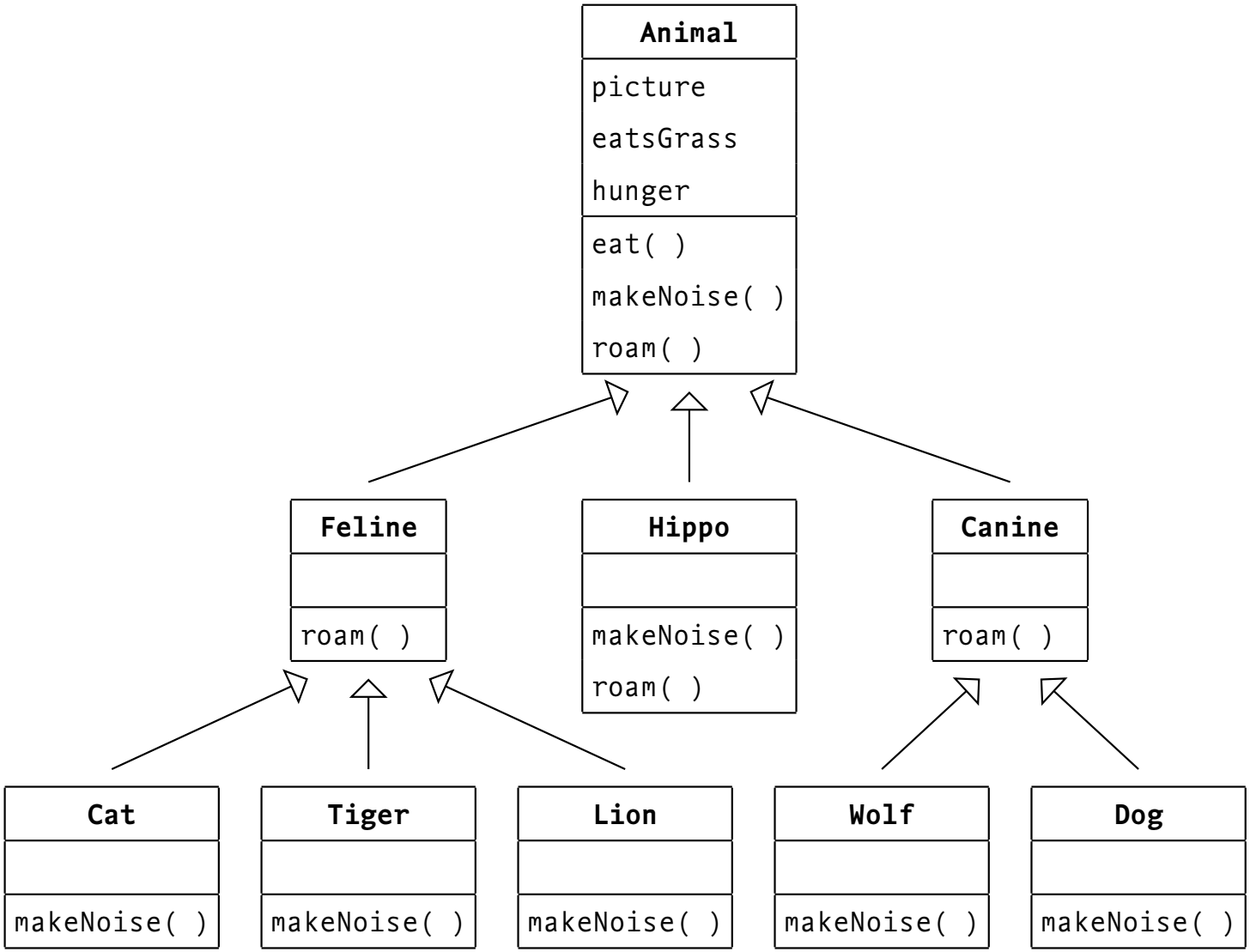

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Animal animal = new Animal( )
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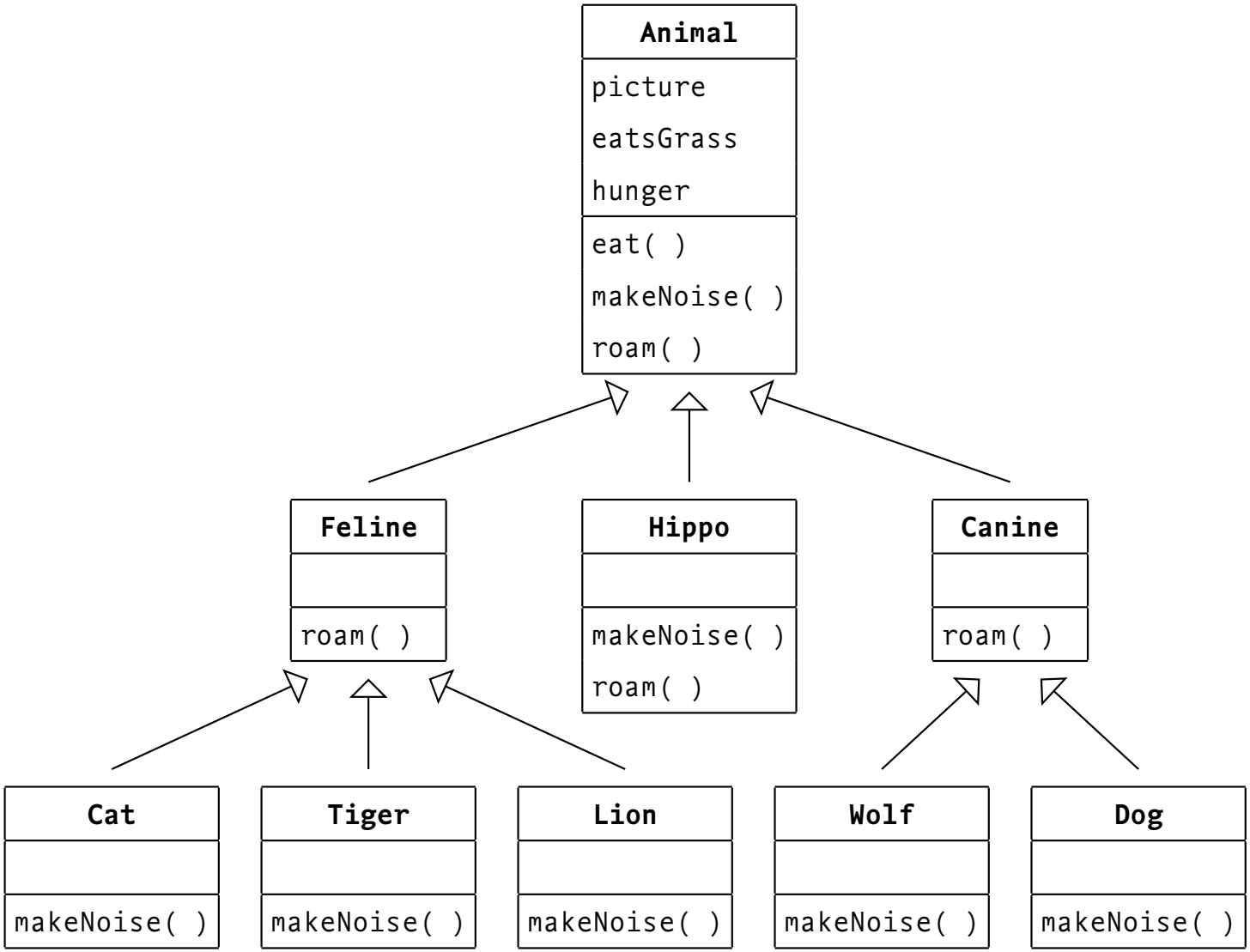

Abstract Classes

```
Animal animal = new Animal( )???
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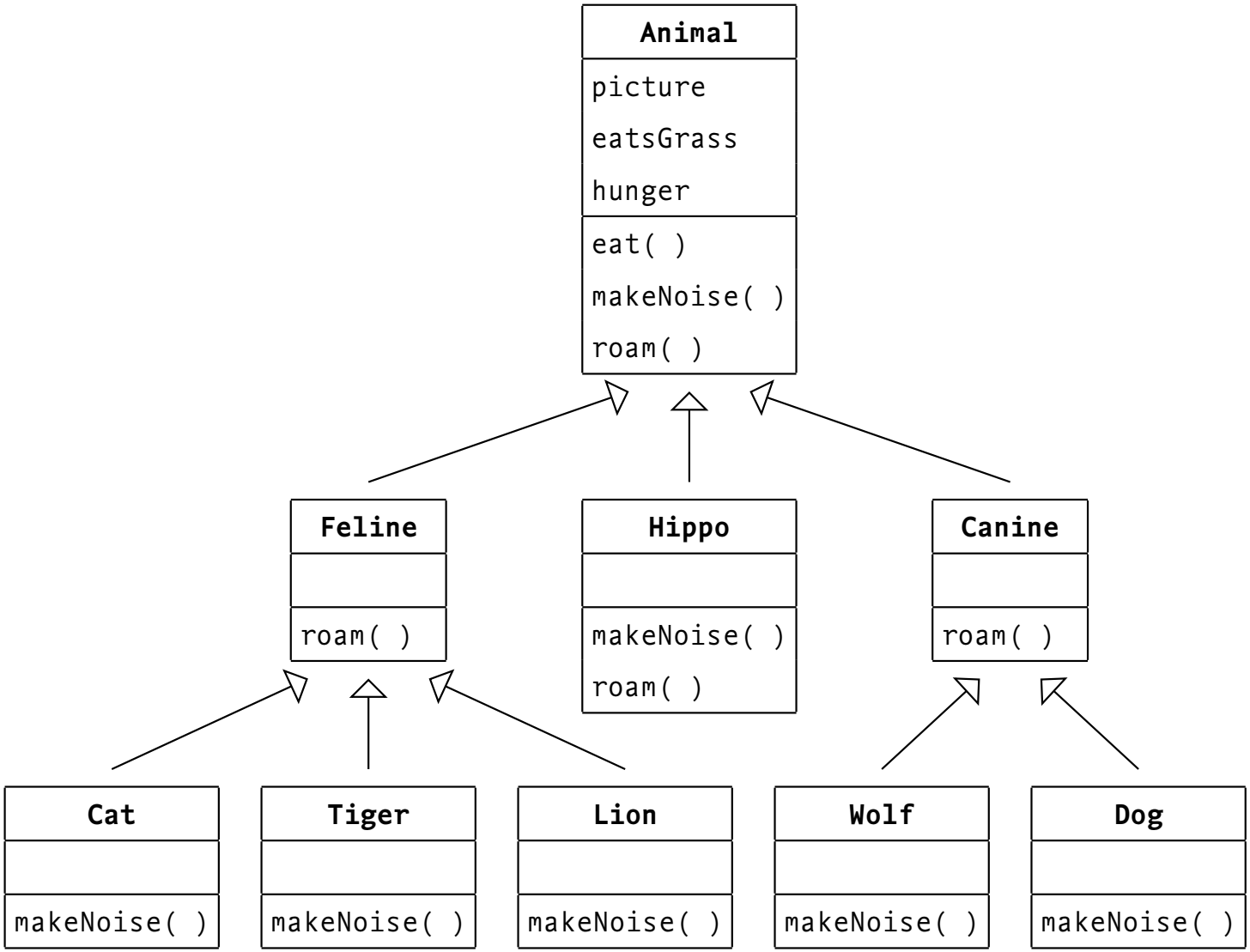

Why do we Need the `Animal` Class?

- We need it for inheritance, so we can:
  - Share common code, and
  - Define a common protocol for `Animals`.
- We need it for polymorphism, so we can:
  - Write code that will still work if we add subclasses.

Some Classes Should Never be Instantiated

- We never intended the `Animal` class to be instantiated.
- We want `Cat` and `Dog` objects, but not `Animal` objects.
- The spell `abstract` prevents classes from being instantiated.

Java

```
public abstract class Animal {
    ...
}
```

- Now `javac` won't let you instantiate abstract classes:

Don't Try This at Home

```
Animal animal = new Animal( );
```

Subclasses can be Abstract Too

Java

```
public abstract class Canine extends Animal {
    ...
}
```

Abstract and Concrete Classes

- A class is *abstract* if it's defined with the keyword `abstract`.
- Otherwise it is *concrete*.

Abstract and Concrete Classes (Continued)

- You can still use abstract polymorphic reference variables.

Java

```
Dog dog = new Dog( );
Cat cat = new Cat( );
Animal animal = dog;
animal = cat;
```

- But, you can only instantiate concrete classes.

Java

```
Cat cat = new Cat( );
Animal dog = new Dog( );
```

- Instantiating an abstract base class *array* is also allowed.

Java

```
Animal[] animals = new Animal[ 3 ];
```

Abstract Methods

- `Java` also has *abstract methods*.
  - They are defined in abstract classes,
  - They are defined with the keyword `abstract`, and
  - They have no body.

Java

```
public abstract void roam( );
```

Why Have Abstract Methods

- Abstract classes *must* be *extended*.
- Abstract methods *must* be *overridden*.
  - They define the nature of the common protocol.
  - They don't require a default implementation.
  - Saves you from fogetting to implement proper behaviour.

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Implementing Abstract Methods

- Abstract methods have no body.
  - They only occur in abstract classes.
  - They have no default behaviour.
- Each concrete subclass needs the behaviour for its API.
- Therefore, you *have to* implement the abstract method.
- You implement an abstract method by providing a body.
  - This may be done in any class on the shortest path from concrete class to the abstract class that defines the abstract method.
  - So, implementing in abstract subclasses is allowed.
  - Of course, a method may be overridden, and overridden, ...

How does this Work?

Implementing the Method

Java

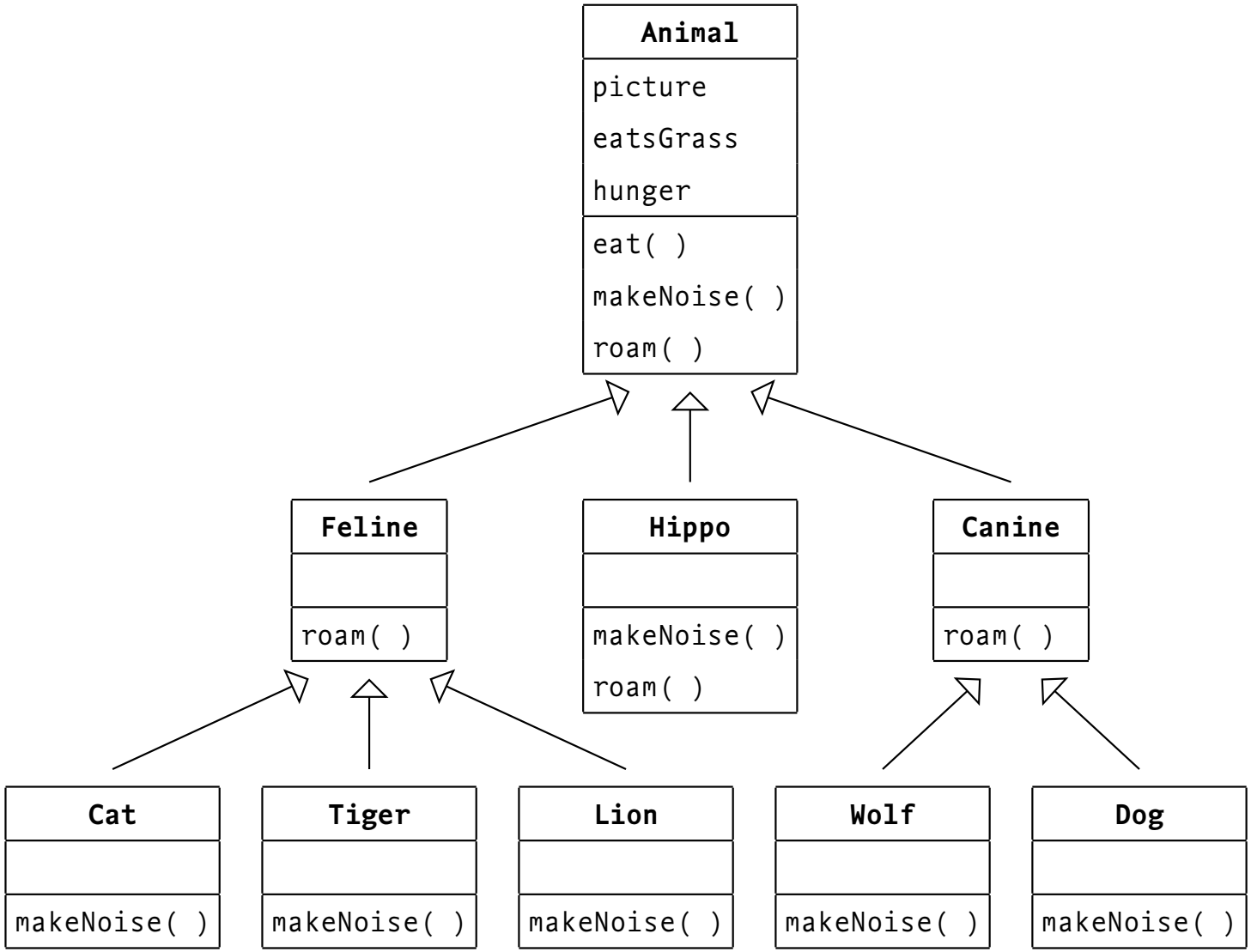
```
public abstract class Animal {
    public abstract void makeNoise( );
}
```

Java

```
public class Dog extends Animal {
    @Override
    public void makeNoise( ) { ... }
}
```

How does this Work?

Implementing the Method for all Relevant Classes



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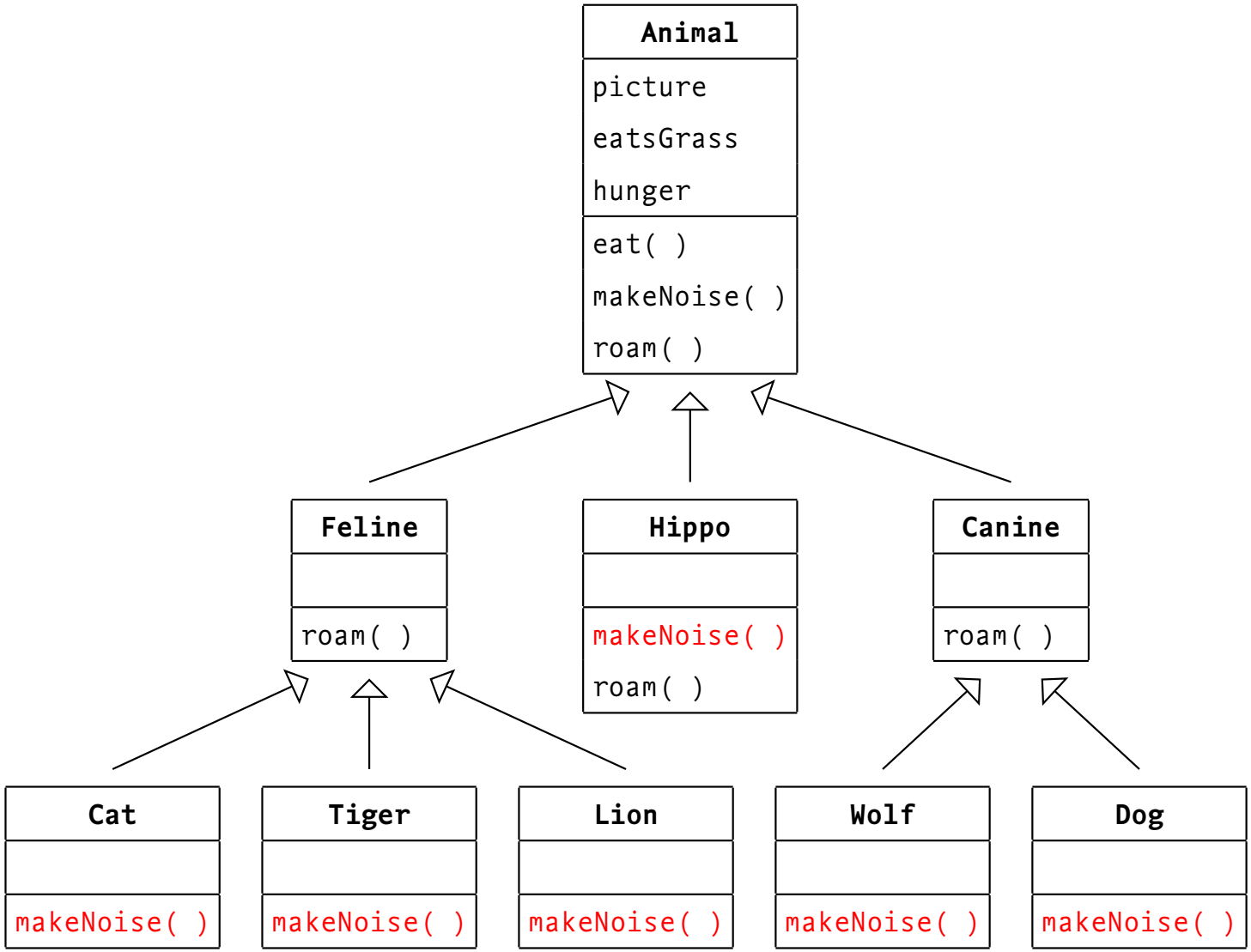

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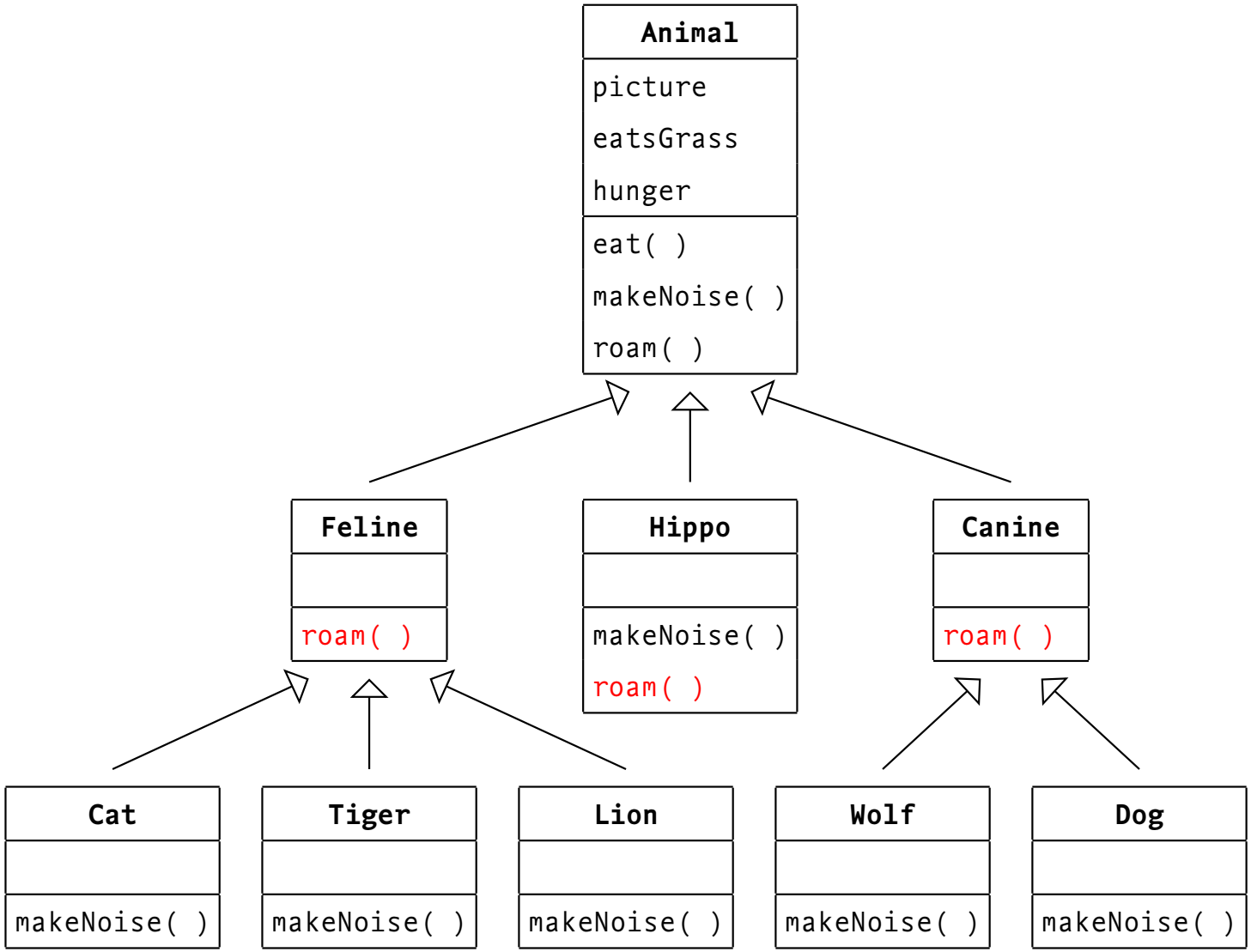

The Barber of Seville

- A barber is somebody that shaves people that don't shave themselves.

The Barber of Seville

- A barber is somebody that shaves people that don't shave themselves.
- Who shaves the barber?

Deciding Class Membership

- Sometimes you need to decide class/interface membership.
- For example, when a polymorphic variable's type is too loose.

Java

```
public class Person {
    public static void main( String[] args ) {
        final Barber barber = Barber.orderBarber( );
        final Person person = new Person( );
        person.shave( );
        barber.shave( );
    }

    public void shave( ) {
        final Person person = this;
        if (/* person is a Barber */) {
            final Barber barber = (Barber)person;
            barber.shaveMyself( );
        } else {
            final Barber barber = Barber.orderBarber( );
            barber.shave( person );
        }
    }
}
```

- More important applications a few slides further on.

Deciding Class Membership

- Sometimes you need to decide class/interface membership.
- For example, when a polymorphic variable's type is too loose.

Java

```
public class Barber extends Person {
    private Barber( ) { }

    public static Barber orderBarber( ) {
        return new Barber( );
    }

    public void shaveMyself( ) {
        System.out.println( "Shaving myself" );
    }

    public void shave( final Person person ) {
        System.out.println( "Shaving person" );
    }
}
```

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    public void shave( ) {
        final Person person = this;
        if (person instanceof Barber) {
            final Barber barber = (Barber)person;
            barber.shaveMyself( );
        } else {
            final Barber barber = Barber.orderBarber( );
            barber.shave( person );
        }
    }
}
```

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Deciding Subclass Membership

- The text `reference instanceof Clazz` tests for class membership of `Clazz`.
- It returns:
  - `true` if `reference` is an instance of `Clazz`;
  - `true` if `reference` is an instance of a subclass of `Clazz`;
  - `false` otherwise.
- The test also works for interfaces.

Java

```
final String bomb = "blast";
if (bomb instanceof Comparable) {
    System.out.println( bomb );
}
```

Overriding `toString( )`

- The `Object` class defines instance method `public String toString( );`
- It should return a “meaningful” representation of its instance.
- Arguably most classes should override the method.
- It’s especially useful when testing.

How?

Depends on the Class

Java

```
public class Person {
    private final String firstName;
    private final String surname;

    ...

    @Override
    public String toString( ) {
        return firstName + " " + surname;
    }
}
```

How?

Depends on the Class

Java

```
public class Dice {
    private final Random generator; // not printed
    private int faceValue;
    ...

    @Override
    public String toString( ) {
        return Integer.toString( faceValue );
    }
}
```

How?

Depends on the Class

Java

```
public class DataBaseConnection {
    private final Database db;
    private final long id;
    private final URL url;
    ...

    // Not sure what to do really.
    @Override
    public String toString( ) {
        return "DatabaseConnection[ id = " + id
                                + ", db = " + db // ????
                                + ", url = " + url
                                + ... // all attributes
                                + " ]";
    }
}
```

How?

Depends on the Class

Java

```
public interface Testable {
    public String testOutput( );
}

public class URL implements Testable { ... }
public class Database implements Testable { ... }

public class DataBaseConnection implements Testable {
    private final Database db;
    private final long id;
    private final URL url;
    ...

    // Better!
    @Override
    public String testOutput( ) {
        return "DatabaseConnection[ id = " + id
                                + ", db = " + db.testOutput( )
                                + ", url = " + url.testOutput( )
                                + ... // all attributes
                                + " ]"l
    }
}
```

Overriding `equals( )`

- `public boolean equals( Object object ):`
  - Defined in `Object` class.
- Method is supposed to test for deep equality.
- Easy if you know the base class of `object`:

Java

```
public class Person {
    private final String firstName;
    private final String surname;

    ...

    @Override
    public boolean equals( Object object ) {
        final Person that = (Person)object;
        return this.firstName.equals( that.firstName )
                  && this.surname.equals( that.surname );
    }
}
```

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        return this.firstName.equals( that.firstName )
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    }
}
```

- But what if you don't know the base class?

Overriding equals( )

If You're Not Sure About Base Class

Java

```
public class Person {
    private final String firstName;
    private final String surname;

    ...

    @Override
    public boolean equals( Object object ) {
        final boolean result;

        if (object instanceof Person) {
            final Person that = (Person)object;
            result = this.firstName.equals( that.firstName )
                        && this.surname.equals( that.surname );
        } else {
            result = false;
        }

        return result;
    }
}
```

Controlling Inheritance

- In `Java` a subclass inherits all `public` methods and attributes.
- This is useful but public methods may lead to problems.
  - E.g. what if a malicious subclass overrides a method?
- It's clear that more control is needed.
- In `Java` you can restrict inheritance and method overriding:
  1. Make the class `final`:
     - By making a class `final` the class cannot be extended.
  2. Make a method `final`:
     - By making a method `final` the method cannot be overridden.

Making the Class Final

Java

```
public final class LastWord {
    // You cannot extend this class.
    …
    @Override
    public void word( ) {
        System.out.println( "Oh yes it is." );
    }
}
```

Why Make a Class Final?

Why Make a Class Final?

Inheritance Violates Encapsulation

- With method overriding, client classes may change behaviour.
- Almost as bad as providing them direct attribute access.
- Here methods, not attributes, are exposed to modification.

Security: Make sure the class does what it should do.

- An overridden method may misbehave.
- Makes it impossible to enforce invariants.
- A `String` should behave as a `String`.

Maintenance: Clients may rely on own overridden behaviour.

Making the Method Final

Java

```
public class Example {
    // You aren't allowed to override this method.
    public final void finalMethod( ) { … }
    // You can override this method.
    public void overridableMethod( ) { … }
}
```

For Friday

- Study [Horstmann 2013, Sections 9.3–9.4].

Acknowledgements

- This lecture corresponds to [Horstmann 2013, Sections 9.3–9.4].
- Some material is based on [Sierra, and Bates 2004].

About this Document

- This document was created with `pdflatex`.
- The LaTeX document class is `beamer`.