Introduction to Inheritance

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These slides cover only the basics of inheritance.

For deeper understanding, see the textbook and study the programming assignments.

What is Inheritance?

One class incorporates all the attributes and behavior from another class -- it *inherits* these attributes and behavior.

- ❑ A subclass inherits **all** the attributes and behavior of the superclass.

- ❑ It can directly access the public & protected members of the superclass.

- ❑ Subclass can *redefine* some inherited behavior, or add new attributes and behavior.

```
SuperClass
 more
 general
```

is a

```
SubClass
 more
 specialized
```
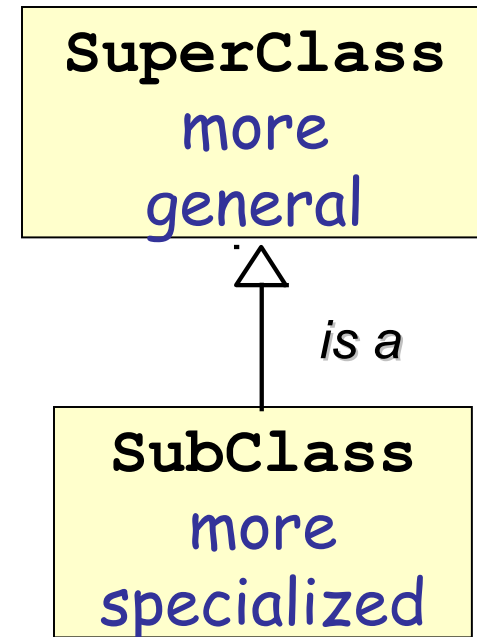
UML for inheritance

Terminology

Different names are used for inheritance relationships.

They mean *the same thing*.

Actor	Animal
parent class	child class
superclass	subclass
base class	derived class

superclass

subclass

subclass
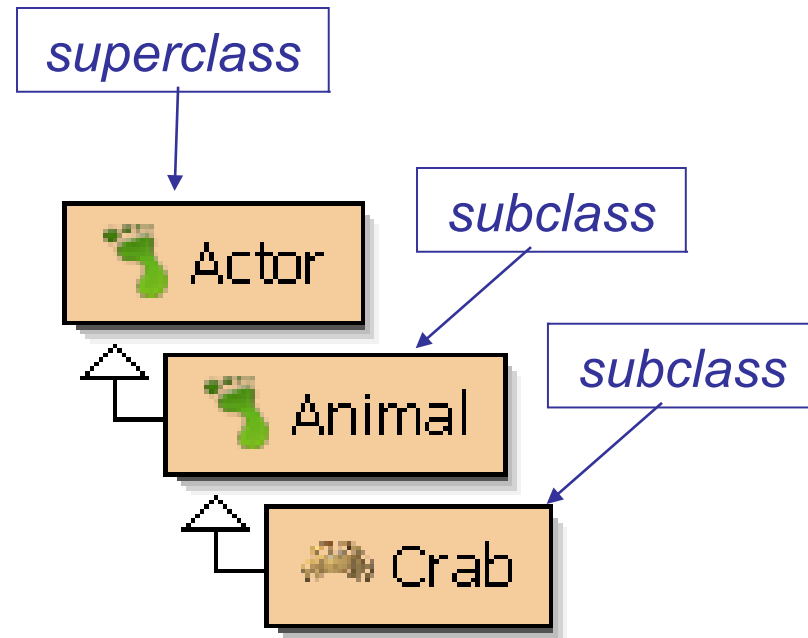
Inheritance in Greenfoot.

"Specializing" or "Extending" a Type

Car
start( )
stop( )
accelerate( )

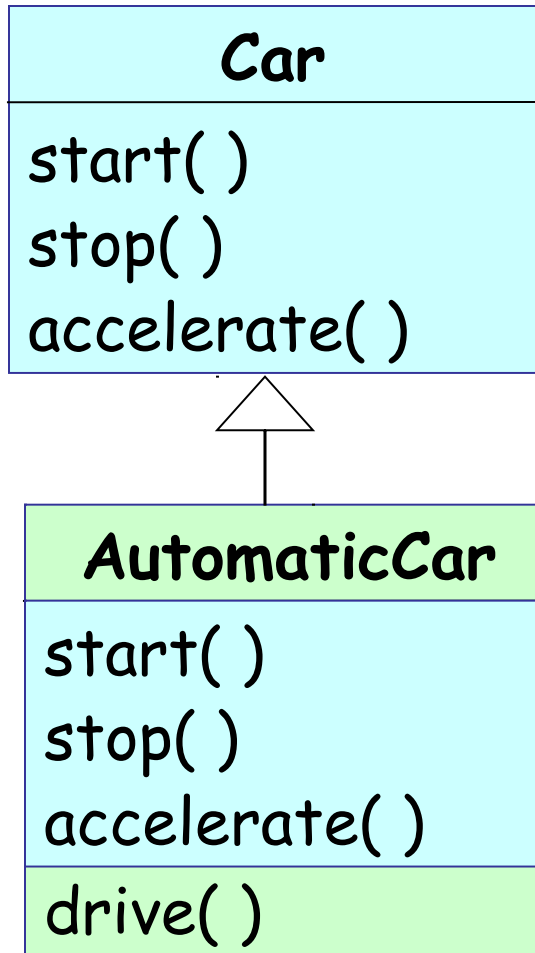| **AutomaticCar** |
|---|
| start( ) |
| stop( ) |
| accelerate( ) |
| drive( ) |
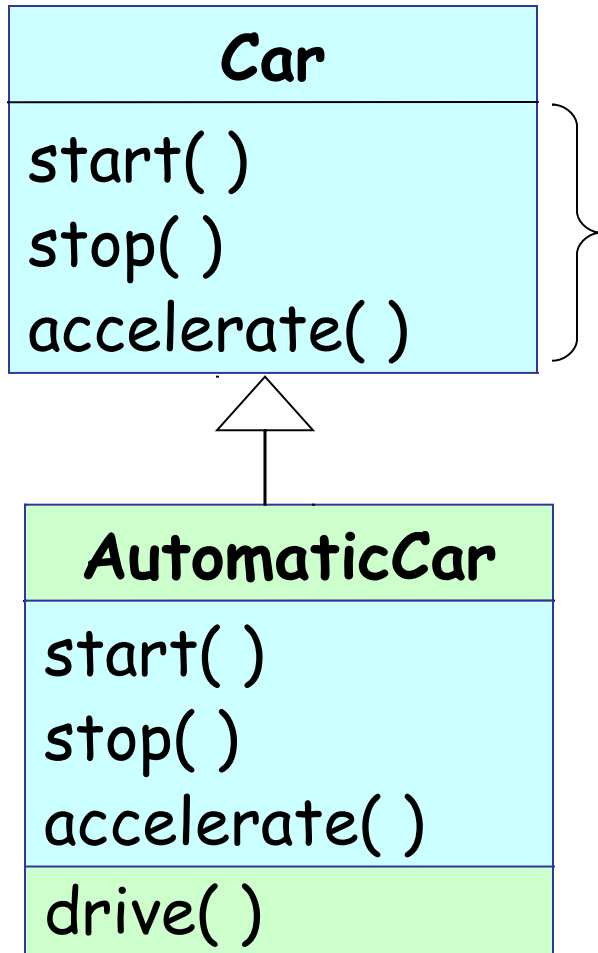
Consider a basic Car.

What is the behavior of a Car?

An AutomaticCar is a *special kind* of Car with automatic transmission.

AutomaticCar can do anything a Car can do.

It also adds *extra behavior*.

Benefit of Extending a Type

Car
start( )
stop( )
accelerate( )

AutomaticCar
start( )
stop( )
accelerate( )
drive( )

Extension has some big benefits:

Benefit to Car Driver

If you can drive a basic Car, you can drive an Automatic Car. It works (almost) the same.

Benefit to Car Producer

You can *reuse* the design and behavior from Car to create AutomaticCar. Just add automatic "drive".
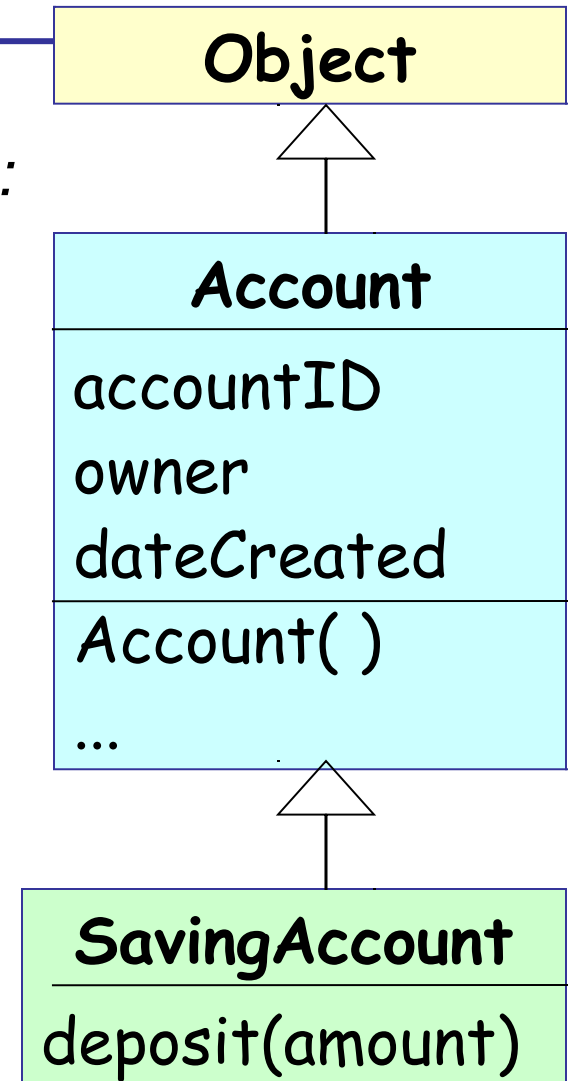
What do you *inherit*?

A subclass *inherits* from its *parent classes:*

- ✓ attributes

- ✓ methods - even <u>private</u> ones.

- ✓ cannot *access* "**private**" members of parent

In Java, **Object** is a superclass of all classes.

Any method that Object has, every class has.

Object

Account

accountID
owner
dateCreated

Account( )

...

SavingAccount

deposit(amount)

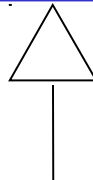# What you don't inherit

A subclass does not inherit

✓   constructors

✓   static members

  ✓   subclass can invoke parent's static members through superclass

Notation for Inheritance

```
class SuperClass {
 ...
}
```

```
class SubClass extends SuperClass {
 ...
}
```

Use "extends" and the parent class name.

Interpretation of Inheritance (1)

Superclass defines basic
   behavior and attributes.

Account
- accountName
- accountID
balance
+ deposit(Money) : void
+ withdraw(Money) : void
+ toString( ) : String

Interpretation of Inheritance (2)

A subclass can...

- □ **add new** behavior and attributes (extension)

- □ **redefine** existing behavior (specialize)

Subclass can override methods to specialize its own behavior.

SavingAccount overrides withdraw and toString.

SavingAccount

> **Account**
>
> - accountName
> - accountId
> # balance
> + deposit(Money) : void
> + withdraw(Money) : void
> + toString( ) : String

+getInterest(): double
+withdraw(Money) : void
+toString( ) : String

Using Inheritance: attributes

Subclass can access:

1) public and protected attributes of parent

2) for private attributes must use an *accessor method (provided by the parent class)*

```
class SavingAccount extends Account  {
   public String toString( ) {
     m = balance;        ←——— protected member of Account
     id = getAccountId( );
```

use accessor method to get private accountId value of Account

Object: the Universal Superclass

- All Java classes are subclasses of Object.

- You don't write "`... extends Object`".

- `Object` defines basic methods for all classes:

java.lang.Object
#clone()   : Object
+equals(Object): bool
+finalize() : void
+getClass() : Class
+hashCode() : int
+toString() : String
+wait()   : void

Every class is guaranteed to have these methods.

Either:

(1) inherit them

(2) override in subclass

Specializing from Object

- Most classes want to define their own **equals** and **toString** methods.

- This lets them *specialize* the behavior for their type.

- Java automatically calls the class's own method (polymorphism).

```
                Object
```

```
                 Coin


+equals(Object): bool

+hashCode()  : int

+toString()  : String
```
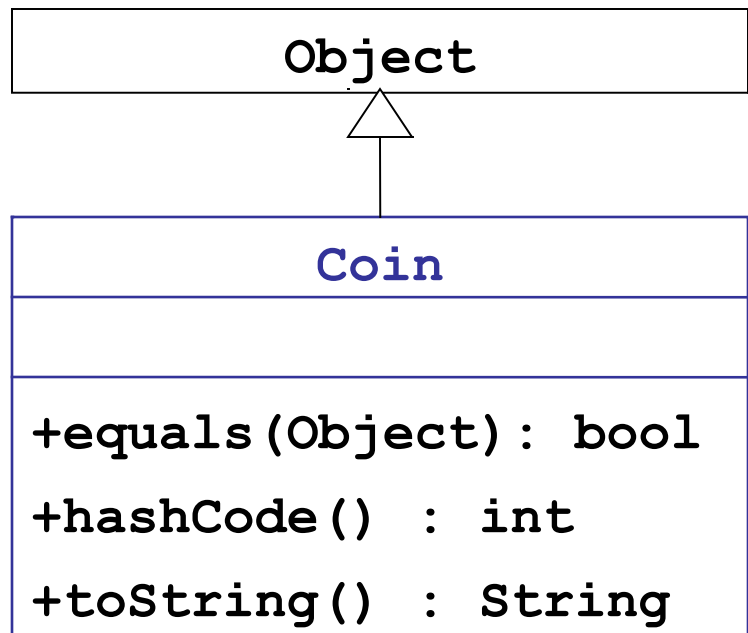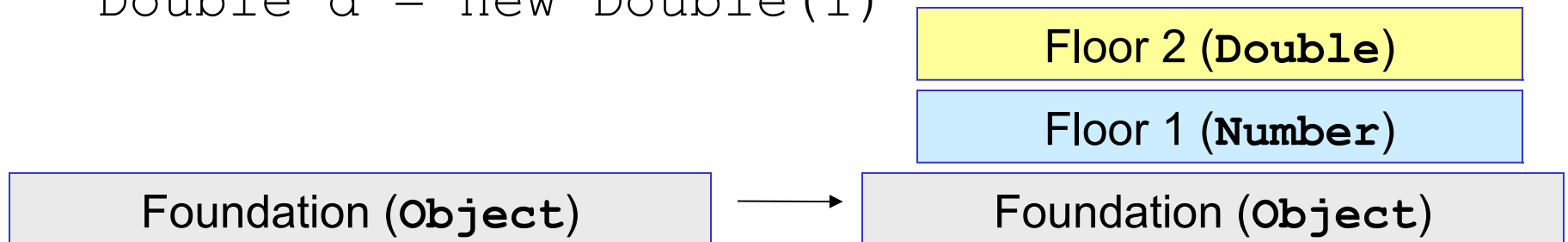
Coin overrides these methods for Coin objects.

Constructors and Inheritance

To **build** a building...

- first you must build the foundation

- then build the first floor

- then build the second floor

- *etc*... until you build all the floors

Example: Double is subclass of Number

```
Double d = new Double(1)
```

Floor 2 (`Double`)

Floor 1 (`Number`)

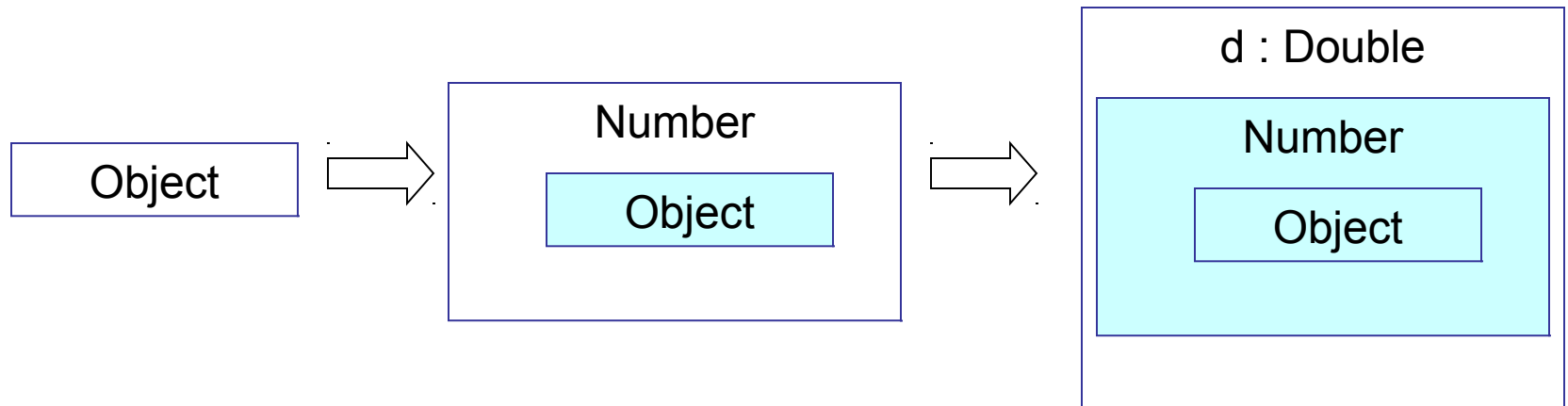| Foundation (`Object`)	→	Foundation (`Object`)

Constructors and Inheritance

To *construct* an object of the `Double` class...

- first you have to build the foundation class (`Object`)

- then build the 1st subclass of Object (`Number`)

- then build the next subclass (`Double`)
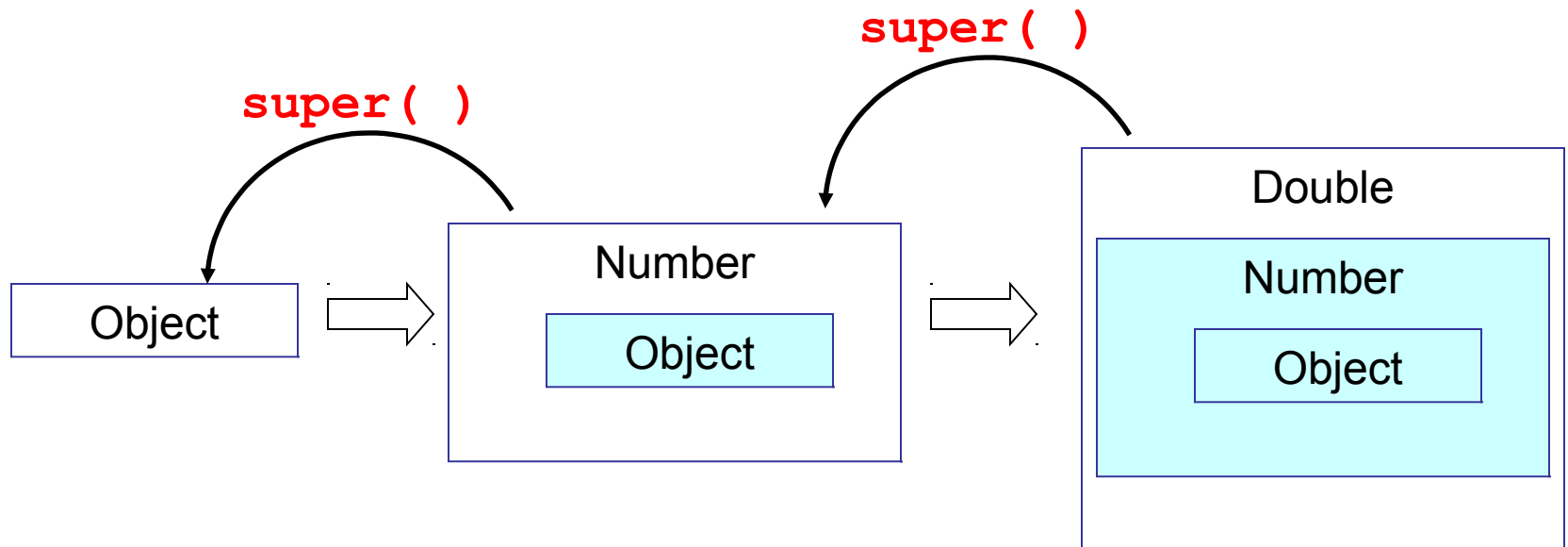
Example:

```
Double d = new Double( 1.0 );
```

Calling a Superclass Constructor

Each subclass must invoke its subclass constructor to "build" the superclass object.

2 ways to do this:

- explicitly write super( ) to invoke super constructor

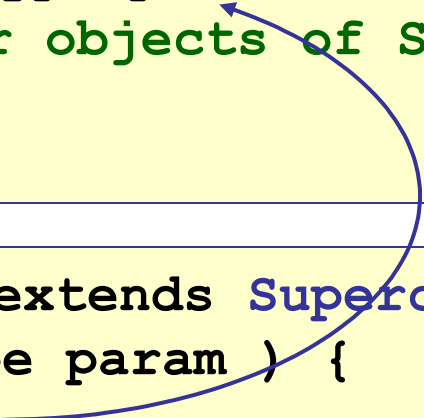- *implicitly* (by Java compiler) invoke the superclass *default* constructor

super( )

super( )

| Object |

Number
| Object |

Double

Number
| Object |

Explicitly Call Superclass Constructor

□ A subclass can call a superclass constructor using the reserved name: **super(...)**

□ **super** must be the first statement in the constructor.

```
public class Superclass  {
   public Superclass( Type param ) {
      // constructor for objects of Superclass
   }
}
```

```
public class Subclass extends Superclass  {
   public Subclass( Type param ) {
      super( param );
   }
}
```

Implicit Call to Superclass Constructor

❑ If a class does not explicitly call a "super" constructor, then Java will <u>automatically</u> insert a call to **super( )**

❑ Java always calls the superclass *default constructor*

```
public class Object  {
   public Object( ) { /* constructor for Object class */ }
```

```
public class Superclass extends Object {
   public Superclass( ) { /* default constructor */ }
}
```

super( )

```
public class Subclass  extends Superclass {
   public Subclass( Type1 arg1, Type2 arg2 )
   {  this.property1 = arg1;
      this.property2 = arg2;
   }
```

super( )

Error in Implicit call to super( )

□ If superclass does not have a default constructor, you will get an error from compiler. In SavingAccount:

```
public class SavingAccount extends Account {
  public SavingAccount(String name) {
      <--  implicit call to super( )

    // initialize SavingAccount attributes
    overDraftLimit = 0;
    ...
}
```

The Java compiler issues an error message:

```
Implicit super constructor Account( ) is
undefined.
```

Why the Error?

- `Account` doesn't have a default constructor, so we get an error.

- This error is good!

 It reminds us that we must invoke the right constructor of `Account`.

Lesson:

- If superclass does not have a default constructor, then subclasses must *explicitly* write super(something).

A Class has only One Parent Class

A class can directly extend only one other class.

A class cannot have two parent classes.

Parent

AnotherParent

Subclass
+ equals(Object): bool + toString( ) : String

X
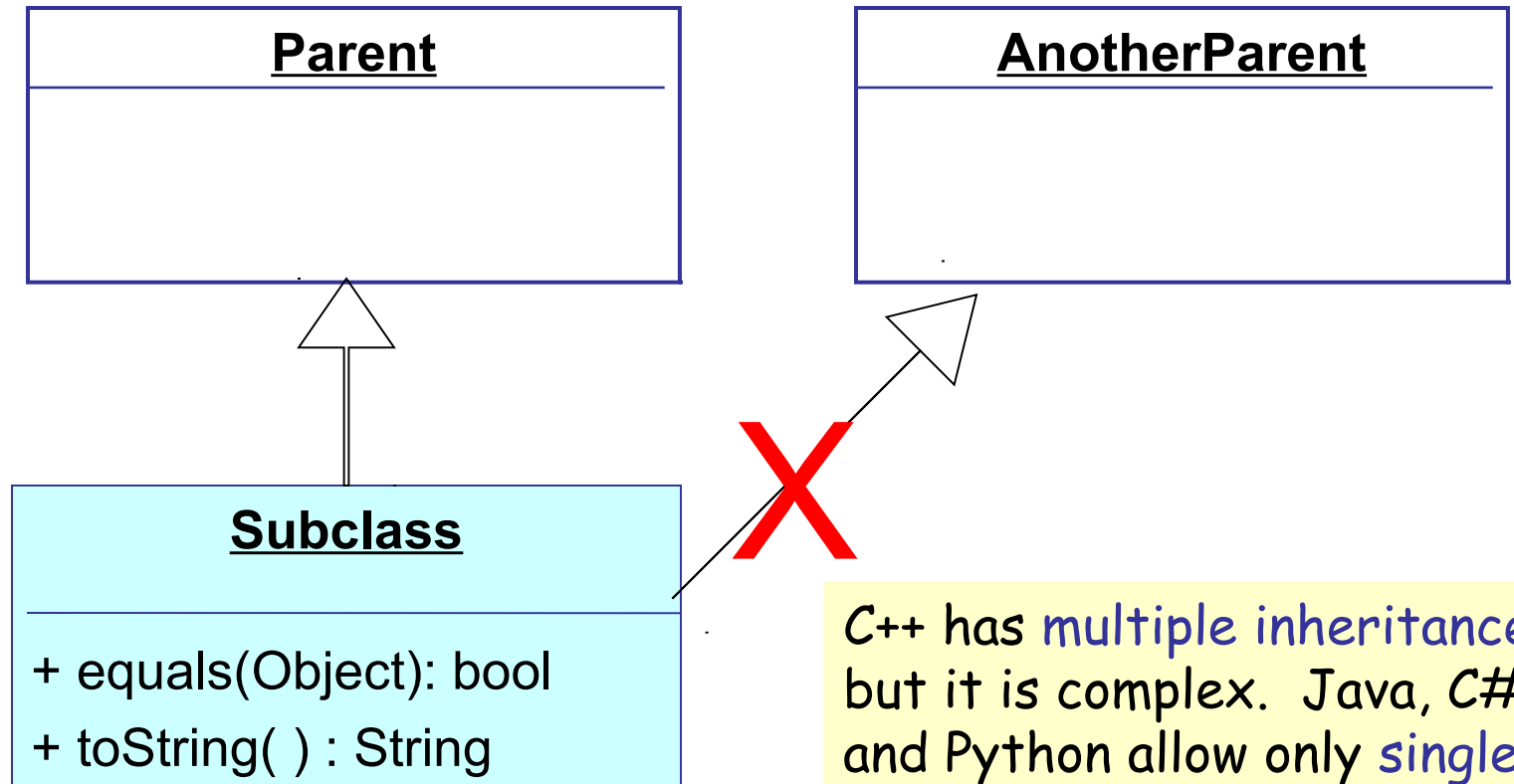
C++ has multiple inheritance, but it is complex. Java, C#, and Python allow only single inheritance.

Number: parent of numeric classes

- Another prodigious parent class is **Number**.
- **Number** defines methods that all numeric classes *must* have, but does not implement them (abstract methods).

```
Object
```

```
Number
shortValue()
intValue()
longValue()
floatValue()
doubleValue()
```

These methods are *abstract* in Number. This means the subclasses are required to implement them

```
Short    Integer    Long    Float    Double
```

```
BigInteger              BigDecimal
```
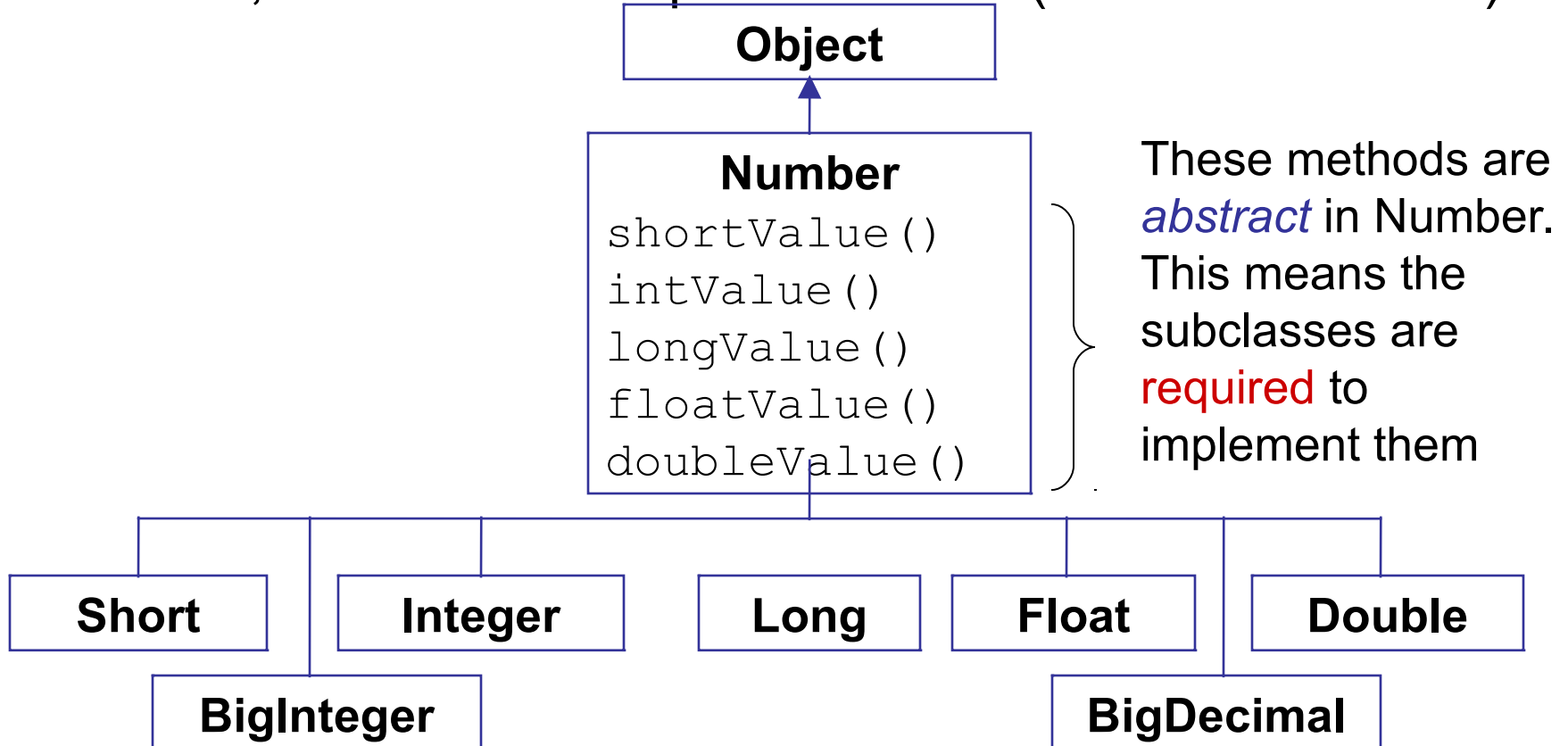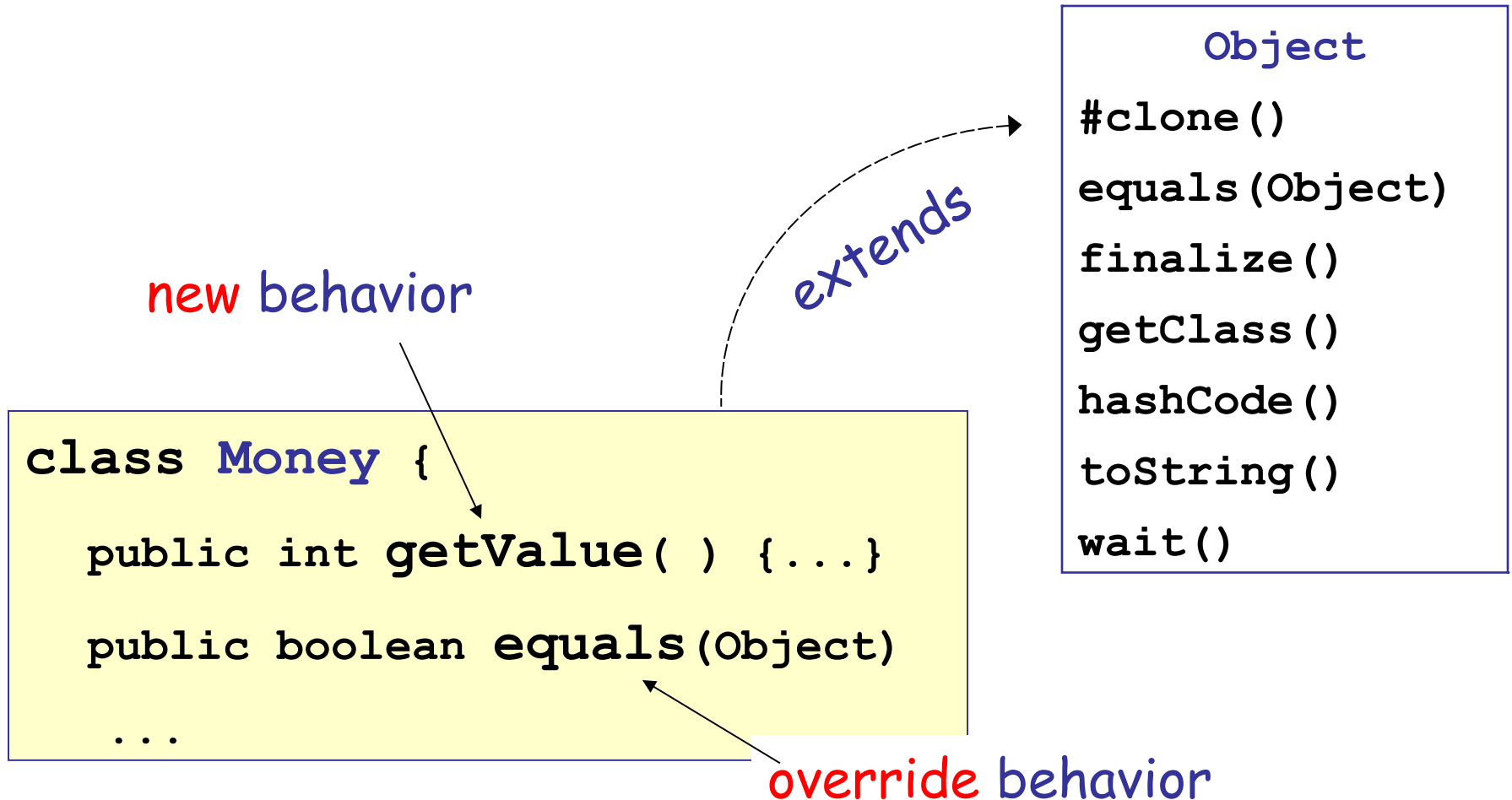
Polymorphism using Number

```
public void display(Number num) {
  System.out.println("The value is "+num.intValue() );
}


display( new Integer( 10 ) );
display( new BigDecimal( 3.14159 ) );
```

```
The value is 10

The value is 3
```
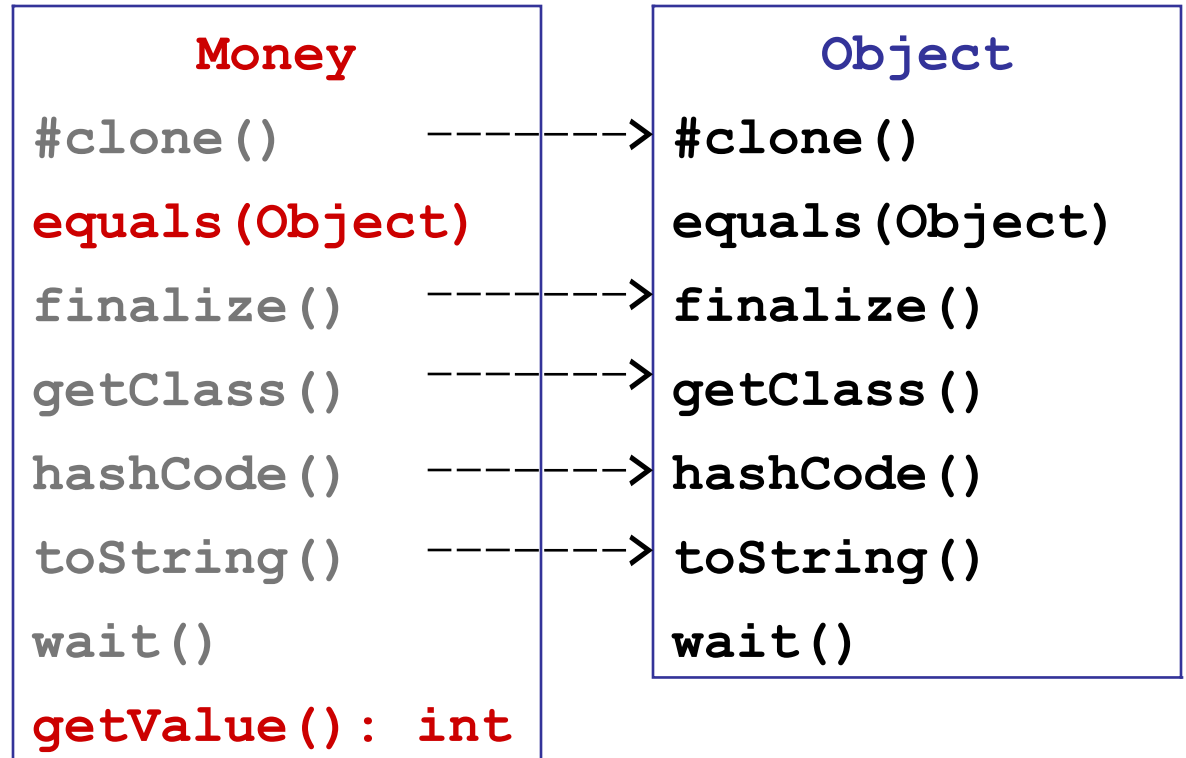
Question: What O-O fundamental enables display to accept a parameter of type Integer or BigDecimal?

Inherited Methods

Object

#clone()

equals(Object)

finalize()

getClass()

hashCode()

toString()

wait()

extends

new behavior

```
class Money {

   public int getValue( ) {...}

   public boolean equals(Object)

   ...
```

override behavior

Inherited Methods

Money	Object
#clone() ------>	**#clone()**
equals(Object)	**equals(Object)**
finalize() ------>	**finalize()**
getClass() ------>	**getClass()**
hashCode() ------>	**hashCode()**
toString() ------>	**toString()**
wait()	**wait()**
getValue(): int	

Summary: Override vs New Method

Override method must match the *signature* of the superclass method:

```
public class Money {
    public int compareTo( Money other )
}
public class Coin extends Money {
    public int compareTo( Money other )
}
```
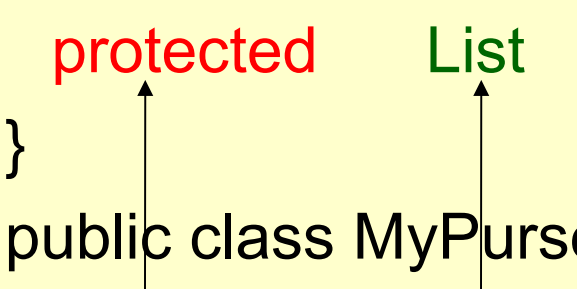
What Can Override Methods Change

Override method can change 2 things in the signature:

(1) can be *more visible* than parent method

(2) return type can be a *subtype* of parent's return type

```
public class Purse {
    protected    List    withdraw( double amount )
}
public class MyPurse extends Purse {
    public       ArrayList withdraw( double amount )
}
```

New Method, not Override

Any other change in the method signature defines a new method, not an override of parent method.

```
public class Money {
   public int compareTo( Money other )
    @Override
   public boolean equals( Object other )
}
public class Coin  extends Money {
    public int compareTo( Coin other ) // new method
    public int compareTo( Coin a, Coin b ) // new method
    public boolean equals( Coin other ) // new method
```

Why write @Override ?

Enables compiler to detect accidental misspelling, etc.

```
public class Money {

    @Override // Compile-time ERROR: invalid "override"

    public boolean equals( Money other ) {

        return this.value == other.value;

    }



    // Typing error, but not detected by compiler

    public String tostring(  ) {

        return "Money, money";

    }
```

Compiler will warn you of misspelled "toString" if you write @Override

Two uses of @Override

1. In Java 5, @Override always meant "override a method"

```java
public class Money {

    @Override

    public String toString( ) {

        return "some money";

    }
```

2. In Java 6+, @Override can also mean "implements"

```java
public class Money implements Comparable<Money> {

    @Override

    public int compareTo(Money other) {

        . . .

    }
```

Cannot Override

- ✓ Constructors

- ✓ static methods
- ✓ private methods

Subclass method creates a <u>new</u> method for these -- having the same name.

- ✓ final methods

Redefining final methods is forbidden. Compile-time error.

Preventing Inheritance: *final class*

A "final" class cannot have any subclasses.

All "enum" types are final.

String, Double, Float, Integer, ... classes are final.

```
public final class String {
   ...
}
```

Prevent Overriding: *final* methods

- A "final" method cannot be overridden by a subclass.
- final is used for important logic that should not be changed.

```java
public class Account {

    // don't let subclasses change deposit method

    public final void deposit(Money amount) {

    ...

    }
```

final method

```
public class Money {



    public final double getValue( ) { return value; }
}
```

```
public class Coin extends Money {
    // ERROR
    public double getValue( ) { ... }
```

Question: Does `Object` have any final methods?

Inheritance of Attributes

1. subclass object inherits all attributes of the parent class (even the private ones).

- subclass cannot directly access private attributes of the parent -- but they are still part of the object's memory!

2. subclass can *shadow* attributes of the parent by defining a new attribute with the same name.

- shadow creates a *new attribute having same name as parent's attribute,* but the parent's attributes are still there (just hidden or "shadowed").

- this is rarely used -- not good design.

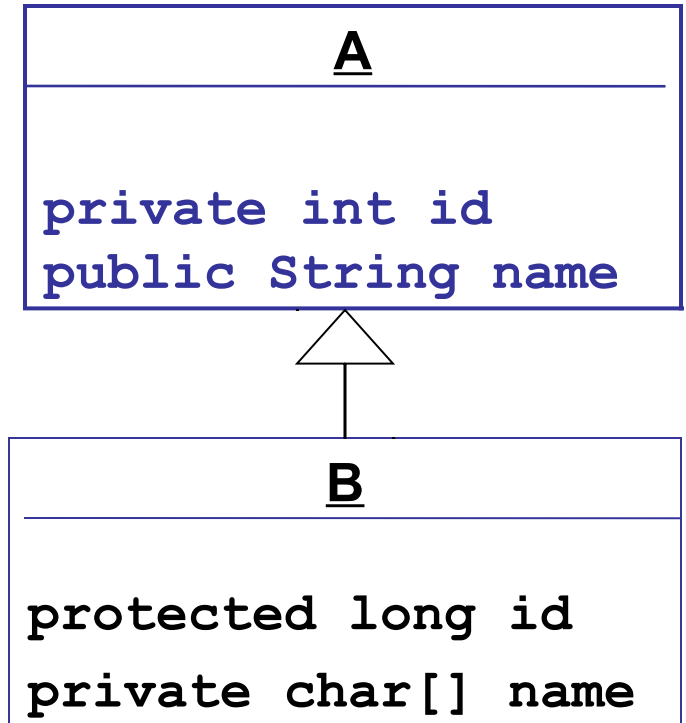# Inheritance of Attributes

B b1 = new B(12345, "baby")

In memory...

b1: B

long id = 1234567890

char [] name = { 'b','a','b','y' }

(hidden) int id = 0

(hidden) String name = "unknown"

A

`private int id`
`public String name`

B

`protected long id`
`private char[] name`

Inheritance and Polymorphism

How inheritance and run-time "binding" of method names to method code enable polymorphism

Binding of Methods to References

□ Java determines which *instance method* should be called for a method name at run-time.

□ This is called dynamic binding or late binding.

□ This means that you can't tell which actual method will be called from only the variable type.

```
Object obj = "What am I?";   // obj -> String
if (Math.random() > 0.5)
        obj = new Date( );

// which toString will be used?
obj.toString( );
```

Binding a method name to code

Compile Time Binding

Compiler "binds" a method name to code using the declared class of the variable

❑ most efficient
❑ no polymorphism

When is this used?

❑ "final" methods
❑ "final" class
❑ private methods
❑ static methods
❑ constructors
❑ "value" types (C#: struct)

Runtime Binding

Method is invoked using the actual type of the object.

❑ slower
❑ enables polymorphism

When is this used?

❑ Java: all methods except "`final`", "`static`", or "`private`"
❑ C#: only for virtual methods

Overriding Methods and access

Q: Can a subclass change the visibility of a method that it overrides?

A: a subclass can *increase the visibility* of method it overrides, but it cannot *decrease* the visibility.

Method in Superclass	**Method in Subclass**
`public`	`public`
`protected`	`public protected`
`package (default)`	`public protected package`
`private`	`anything`

Overriding Methods (1): visibility

```
class BankAccount {
  public boolean withdraw( double amount ) {
     ....
   }
}
class CheckingAccount extends BankAccount {
    ???   boolean withdraw( double amount ) {
     ....
   }
```

The Test: does polymorphism work?

```
BankAccount b = new BankAccount( "Mine" );
BankAccount c = new CheckingAccount( "Yours" );
b.withdraw( 100 );  // if this is OK
c.withdraw( 100 );  // then will this be OK?
```

Overriding Methods (2): visibility

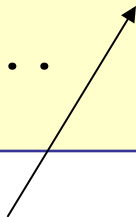**Q**: Can a subclass change the visibility (access privilege) of a method that it overrides?

□ change access from "`public`" to "`protected`":

```java
class CheckingAccount extends BankAccount {
  protected void withdraw( double amount ) {
    if ( amount > balance + overDraftLimit ) {
      System.out.printf(
      "Error: you can withdraw at most %f Baht\n",
        balance+overDraftLimit );
      return /*false*/; // cannot withdraw
    }
```

This method is "**public**" in the BankAccount class.

Overriding Methods (3): return type

```
class BankAccount {
 public boolean withdraw( double amount ) {
    ....
   }
}
class CheckingAccount extends BankAccount {
  public void withdraw( double amount ) {
    ....
   }
```

Can a subclass change the return type of overridden method?

The Test: does polymorphism work?

Overriding Methods (4): parameters

Q: Can a subclass change the type of a <u>parameter</u> of an overridden method?

Example: change **amount** from "`double`" to "`long`":

```
class BankAccount {
  public boolean withdraw( double amount ) {...}
    ....
   }
}
class CheckingAccount extends BankAccount { /**
  withdraw method for checking account */
  public boolean withdraw( long amount ) { ... }
```

Overriding Methods: parameters

Answer: Yes, but then you aren't overriding the method!

If the parameter type is different then you are creating a new method with the same name
(called "method overloading").

```
/** test the withdraw method */
public void testWithdraw( ) {
  CheckingAccount ca = new CheckingAccount("...");
  ca.withdraw( 50000 );
    // this calls CheckingAccount.withdraw()
  ca.withdraw( 25000.0 );
    // calls BankAccount.withdraw()
```

Overriding Methods (5): using **super**

Q: Can we access the method of the superclass, even though it has been overridden?

❑ invoke withdraw of BankAccount using "super".

```
class CheckingAccount extends BankAccount {
 public boolean withdraw( long amount ) {
    if ( overDraftLimit == 0 )
      super.withdraw(amount); // parent's method
    else if ( amount > balance + overDraftLimit )
      System.out.printf("Error: ...");
    else
      balance = balance - amount;
```

Overriding Methods (6): using **super**

Consider a **Person** superclass and **Student** subclass.

- (Person) p.compareTo( ) compares people by name
- (Student) s.compareTo( ) compares by student ID first and then name.

```java
public class Student extends Person {
    private String studentID;
    public int compareTo(Object other) {
        ... // test for null and Student type
        Student s = (Student) other;
        int comp = studentID.compareTo(s.studentID);
        if ( comp != 0 )return comp;
        // if studentID is same, compare by name
        return super.compareTo(other);
```

Redefining Attributes

A subclass can declar an attribute with the same name as in the superclass.

The subclass attribute *hides* the attribute from parent class, but it still inherits it!

You can see this in BlueJ by "inspecting" an object.
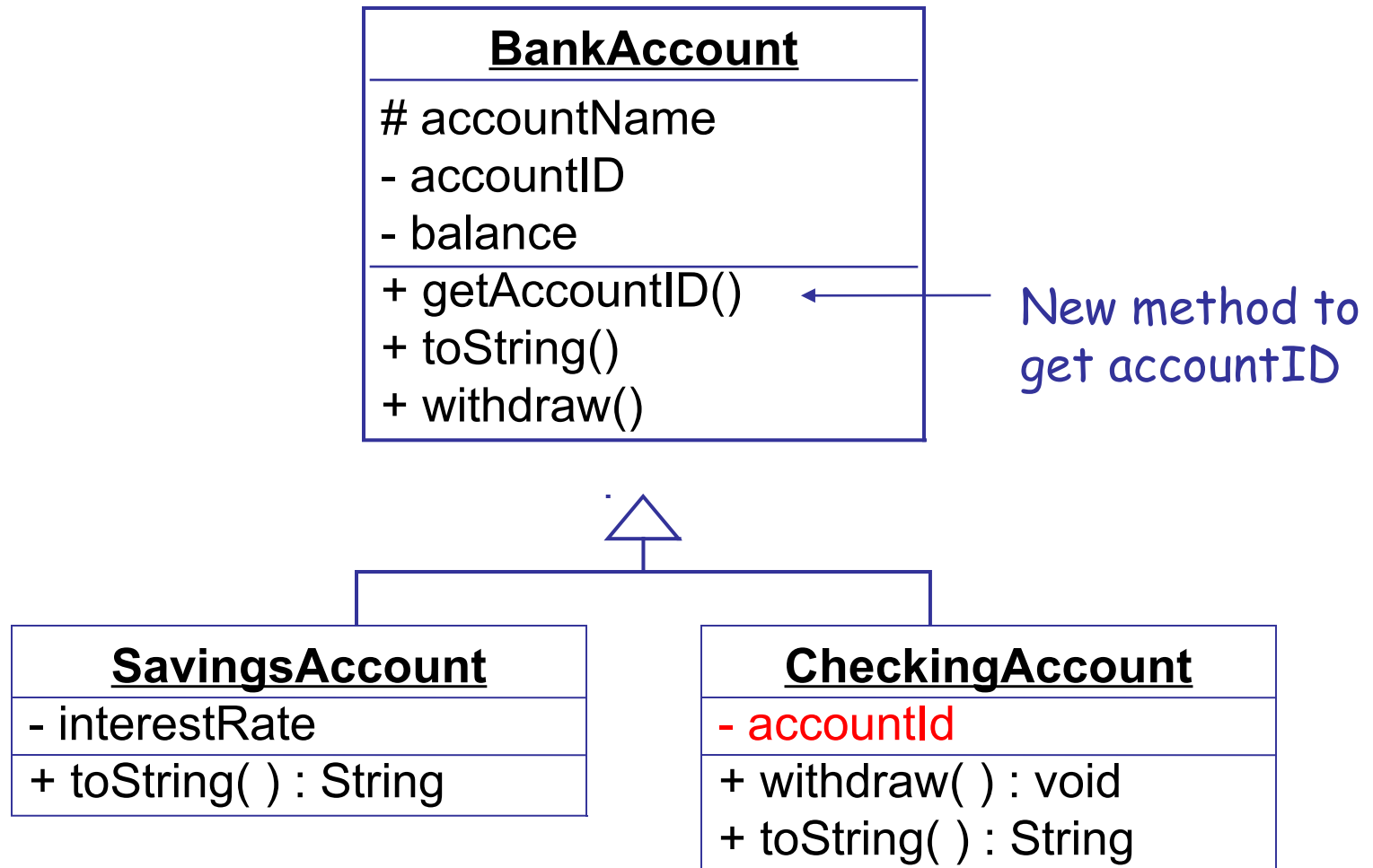
```
public class BankAccount {
   private long accountId;
}
```

```
public class SavingAccount
        extends BankAccount {
  private String accountId;
}
```

SavingAccount has 2 id attributes. The parent attribute is private (not accessible) and hidden by its own attribute.

Redefining Attributes

The new BankAccount hierarchy is:

BankAccount

accountName
- accountID
- balance

+ getAccountID()
+ toString()
+ withdraw()

New method to get accountID

SavingsAccount

- interestRate

+ toString( ) : String

CheckingAccount

- accountId

+ withdraw( ) : void
+ toString( ) : String

Questions About Redefined Attributes

If a subclass redefines an attribute of the superclass...

- can the subclass still access the superclass attribute?
- can the subclass change the visibility of the attribute?

  Example: in CheckingAccount can we declare:

  ```
  private long accountID;
  ```

- can the subclass change the datatype of the attribute?

  Example: in CheckingAccount can we declare:

  ```
  protected String accountID;
  ```

Review Questions

Object References

Q1: Which of these assignments is legal?

```
/* 1 */
BankAccount b = new CheckingAccount("Nok");
/* 2 */
CheckingAccount c = new BankAccount("Noi");
/* 3 */
Object o = new BankAccount("Maew");
/* 4 */
BankAccount b = new Object( );
```

Object References

Q2: What is the effect of this reassignment?

```
BankAccount ba;
CheckingAccount ca = new CheckingAccount("Noi");
ca.deposit( 100000 );
// assign to a BankAccount object
ba = ca;
```

What happens when "`ba = ca`" is executed?

1. It converts CheckingAccount object to a BankAccount object. Any extra attributes of CheckingAccount are lost!

2. It converts CheckingAccount object to a BankAccount object. Any extra attributes of CheckingAccount are hidden until it is cast back to a CheckingAccount object.

3. Has no effect on the object.

4. This statement is illegal.

I Want My Checking Account!

Q3: Suppose a BankAccount *reference* refers to a CheckingAccount *object*. How can you assign it to a CheckingAccount?

```
BankAccount ba = new CheckingAccount("Jim");
CheckingAccount ca;
if ( ba instanceof CheckingAccount ) {
  // this is a checking account.
  ca = ??? ;   // make it look like a checking acct
  how can you assign the bank account(ba) to ca ?
```

1. `ca = ba;`
2. `ca = new CheckingAccount( ba );`
3. `ca = ba.clone( );`
4. `ca = (CheckingAccount) ba;`
5. `none of the above.`

Overriding equals( )

- The Object class contains a public `equals()` method.

Q1: Does BankAccount `equals( )` override the Object `equals()` method?

```
/** compare two BankAccounts using ID */
public boolean equals( BankAccount other ) {
  if ( other == null ) return false;
  return accountID == other.accountID;
}
```

```
Object a = new Object( );
BankAccount b = new BankAccount( "Joe" );
if ( b.equals( a ) )
    System.out.println("Same");
```

Overriding equals( )

□ The Object class contains a public `equals()` method.

Q2: CheckingAccount does not have an equals method. Which equals will be called here?

```
/** compare two Checking Accounts */
CheckingAccount ca1 = new CheckingAccount(...);
CheckingAccount ca2 = new CheckingAccount(...);
...
if ( ca1.equals(ca2) ) /* accounts are same */
```
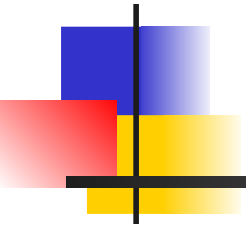
1. `(BankAccount)equals`

2. `(Object)equals`

3. neither. Its an error because CheckingAccount doesn't have equals.

Homework: Binding of Methods

There are at least 3 situations where Java "binds" a method name to an actual method at **compile time** (for more efficient for execution).

> What are these situations?

> Give an example of each.

Summary of Important Concepts

Subclass has all behavior of the parent

- A subclass inherits the attributes of the superclass.

- A subclass inherits behavior of the superclass.

- Example:

  `Number` has a `longValue`( ) method.

  `Double` and `Fraction` are subclasses of `Number` .

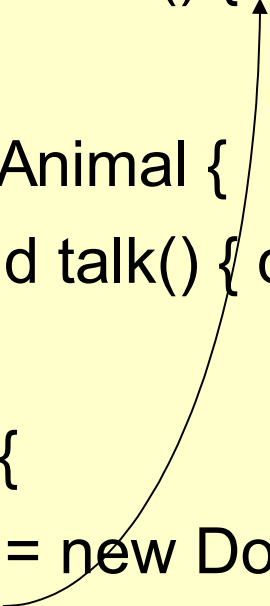 Therefore, `Double` and `Fraction` also have `longValue`()

Java

```
class Animal {
    void talk() { console.print("grrrrr"); }
}
class Dog extends Animal {
    void talk() { console.print("woof"); }
}
void main() {
    Animal a = new Dog();
    a.talk( );   <--- which talk method is invoked?
}
```

C#

```
class Animal {
    public void talk() { console.write("grrrrr"); }
}
class Dog : Animal {
    public void talk() { console.write("woof"); }
}
void main() {
    Animal a = new Dog();
    a.talk( );   <--- which talk method is invoked?
}
```

Polymorphism in C#

```
class Animal {
    virtual void talk() { console.write("grrrrr"); }
}
class Dog : Animal {
    override void talk() { console.write("woof"); }
}
void main() {
    Animal a = new Dog();
    a.talk( );   <--- which talk method is invoked?
}
```