Principles of Software Construction: Objects, Design, and Concurrency

Inheritance (continued), type-checking, and behavioral contracts

Spring 2014

Charlie Garrod Christian Kästner

School of Computer Science
institute for SOFTWARE RESEARCH

Administrivia

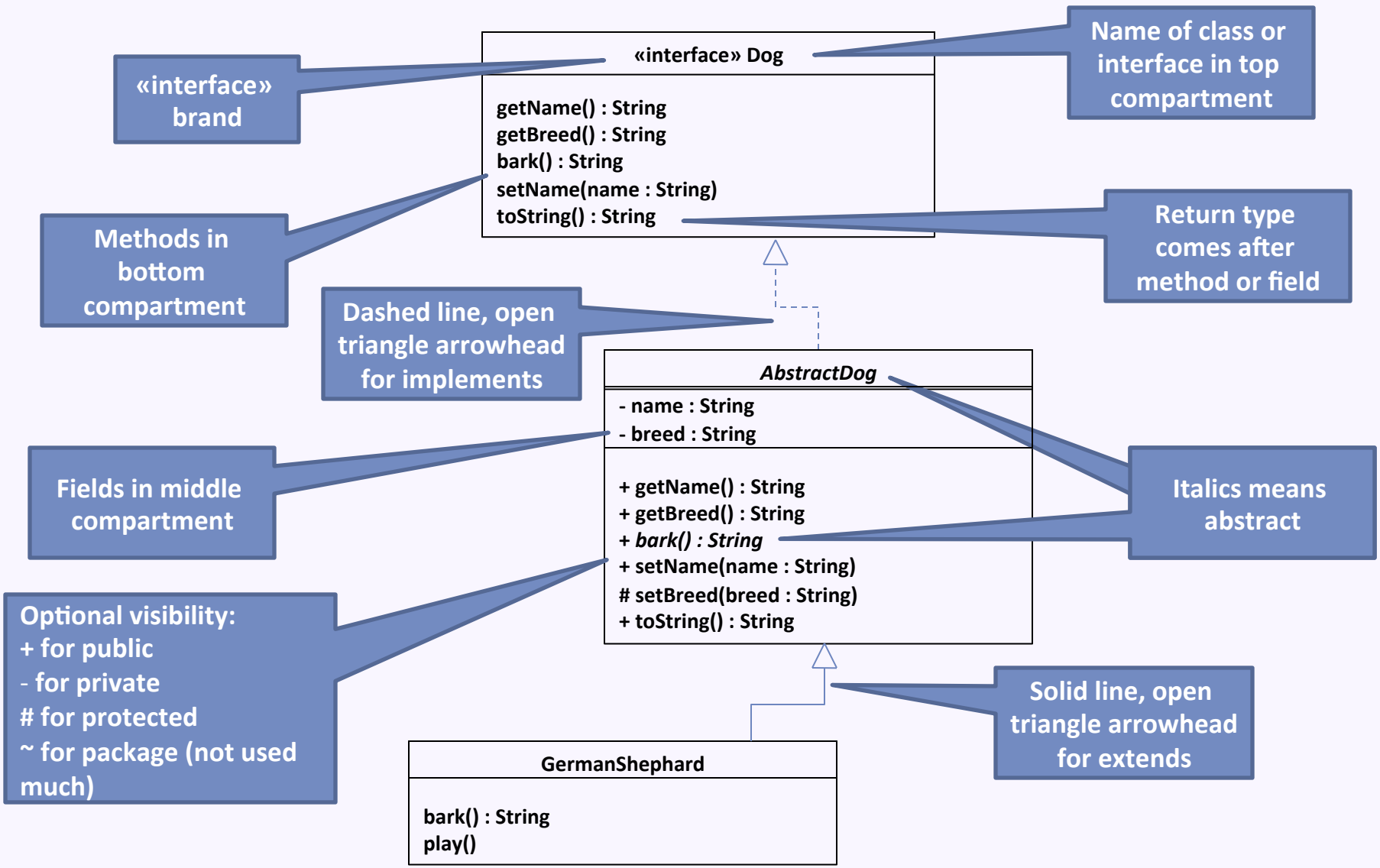
- Homework 1 due next Tuesday

Key concepts from Tuesday

Key concepts from Tuesday

- Module systems
- The key encapsulation principle
- Inheritance
  - For code reuse
  - Abstract classes
  - Some design principles
    - Hierarchical modeling

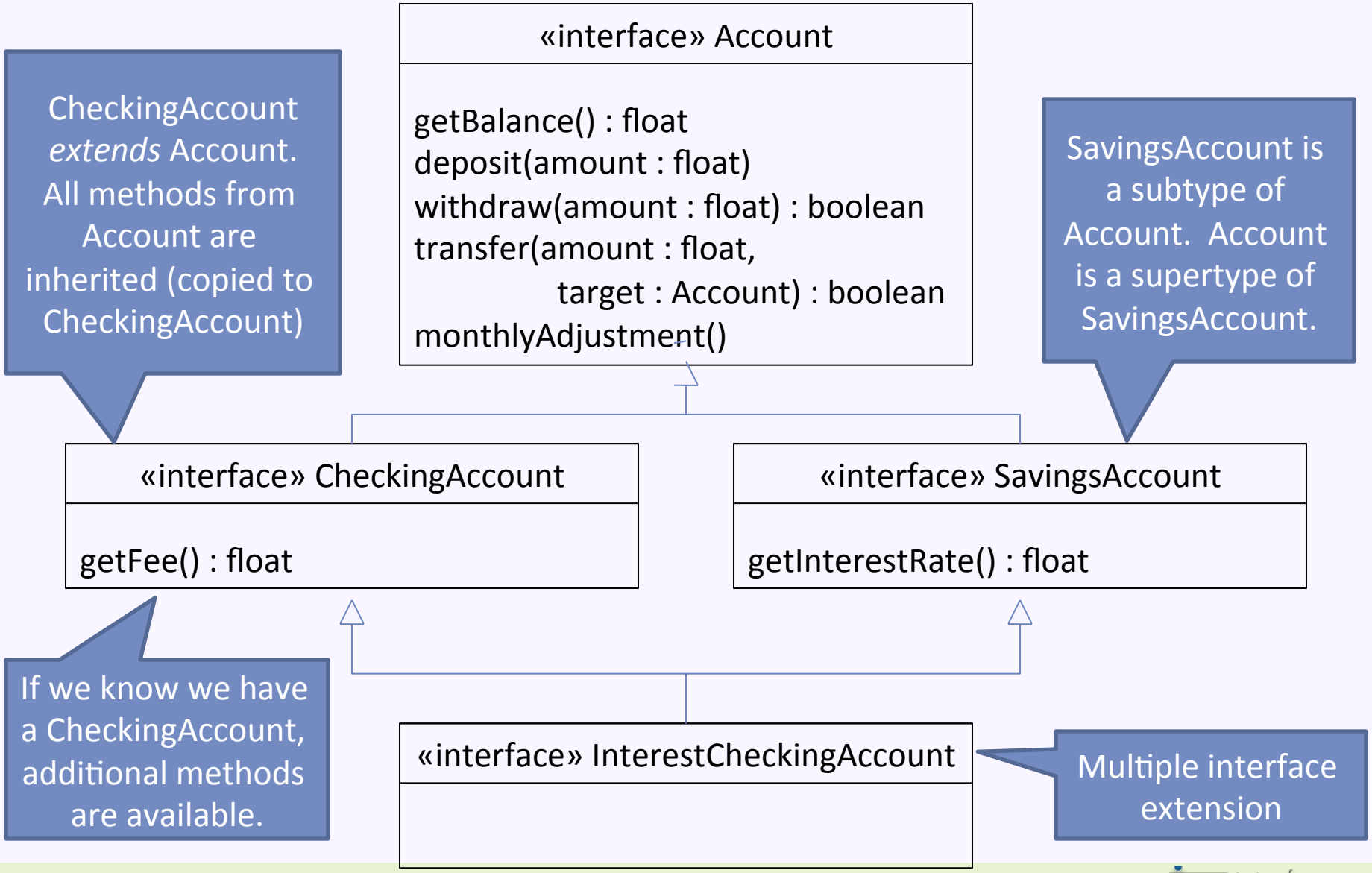
Aside: UML class diagram notation



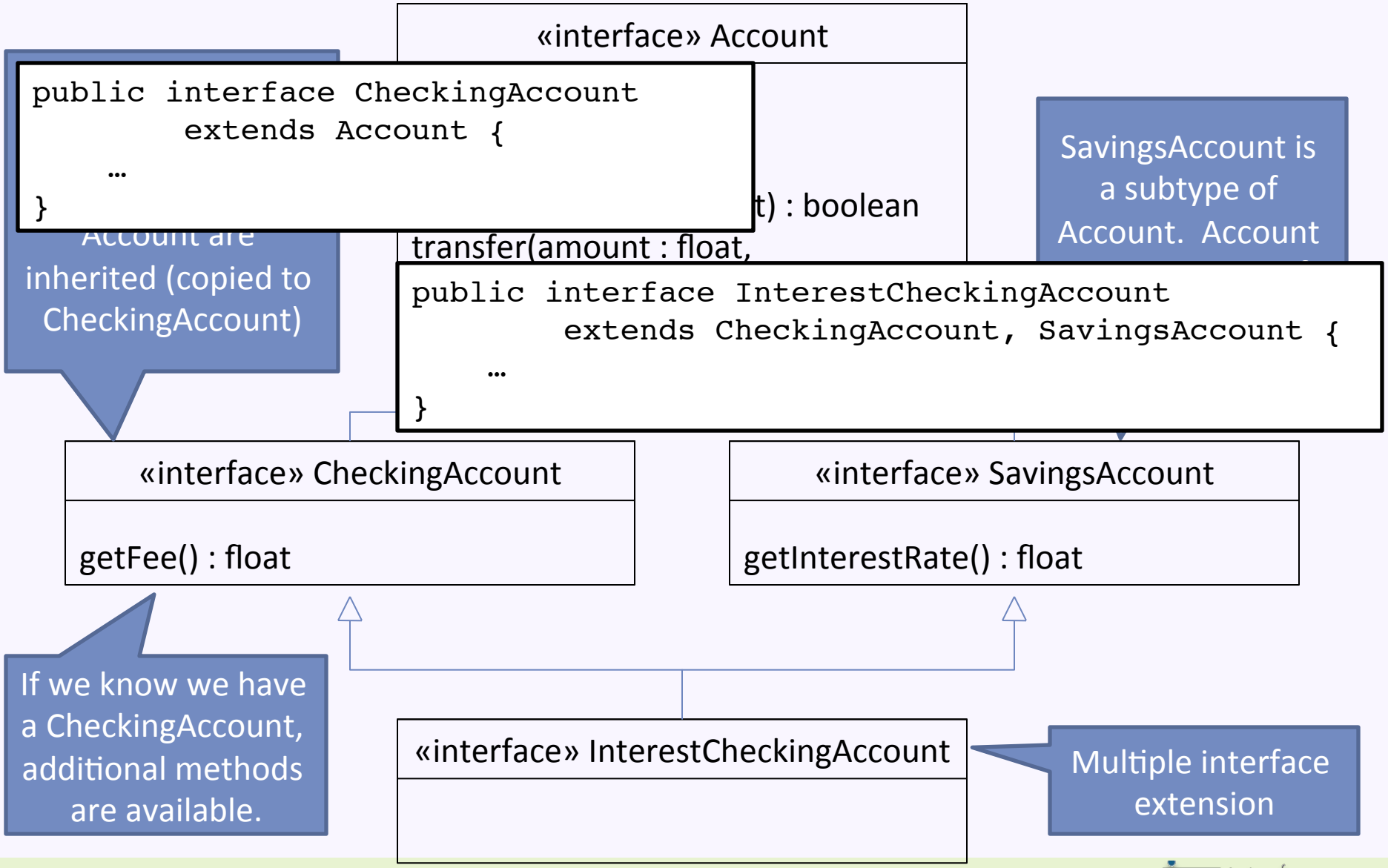
Today:

- Inheritance and polymorphism (continued)
  - For maximal code re-use
  - Diagrams to show the relationships between classes
  - Inheritance and its alternatives
  - Java details related to inheritance
- Type checking and its limitations
  - The subtype relation
  - Behavioral contracts
    - The `java.lang.Object`

A better design: An account type hierarchy



A better design: An account type hierarchy



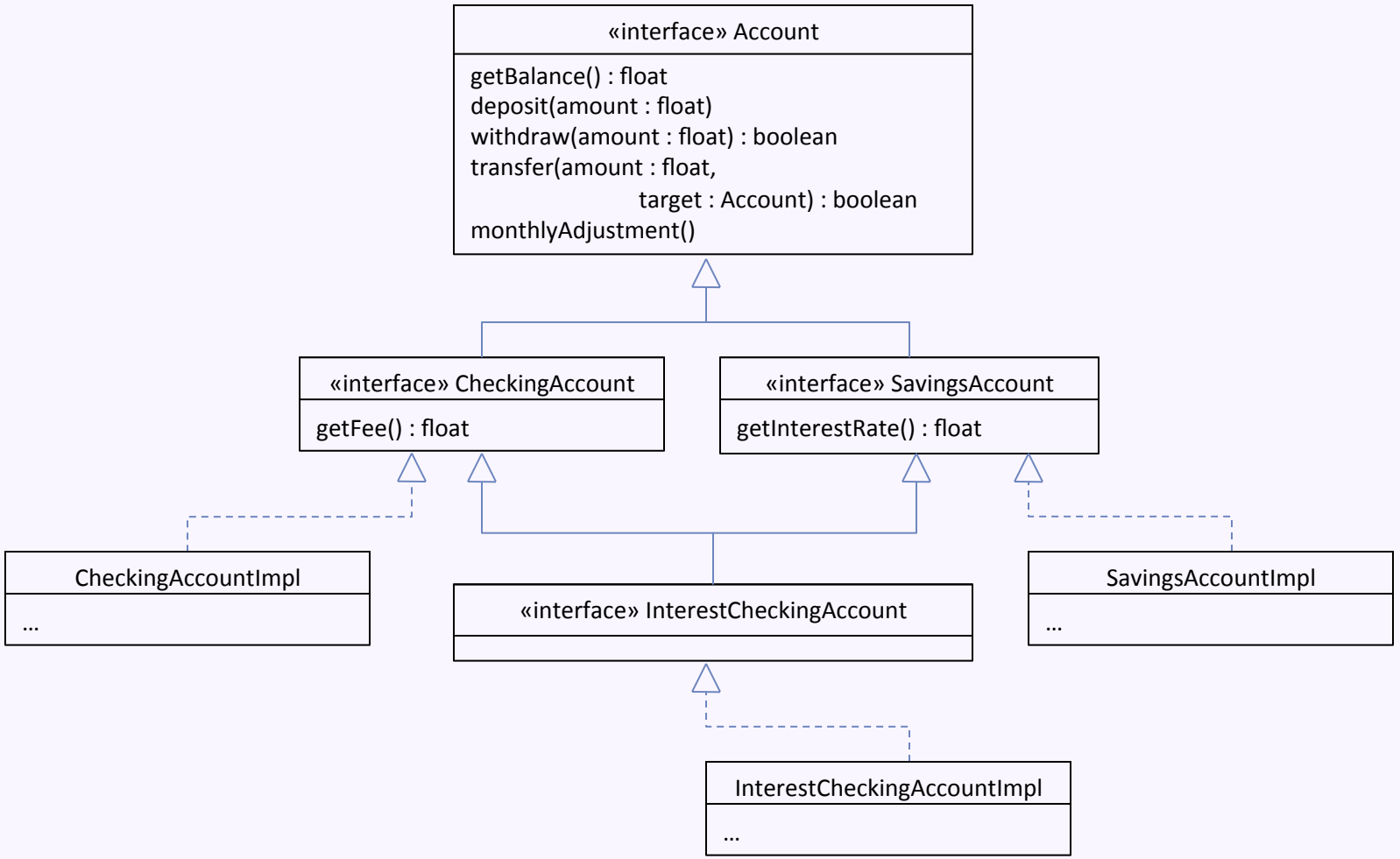
The power of object-oriented interfaces

- Polymorphism
  - Different kinds of objects can be treated uniformly by client code
    - e.g., a list of all accounts
  - Each object behaves according to its type
    - If you add new kind of account, client code does not change
  - Consider this pseudocode:

```
If today is the last day of the month:
   For each acct in allAccounts:
      acct.monthlyAdjustment();
```

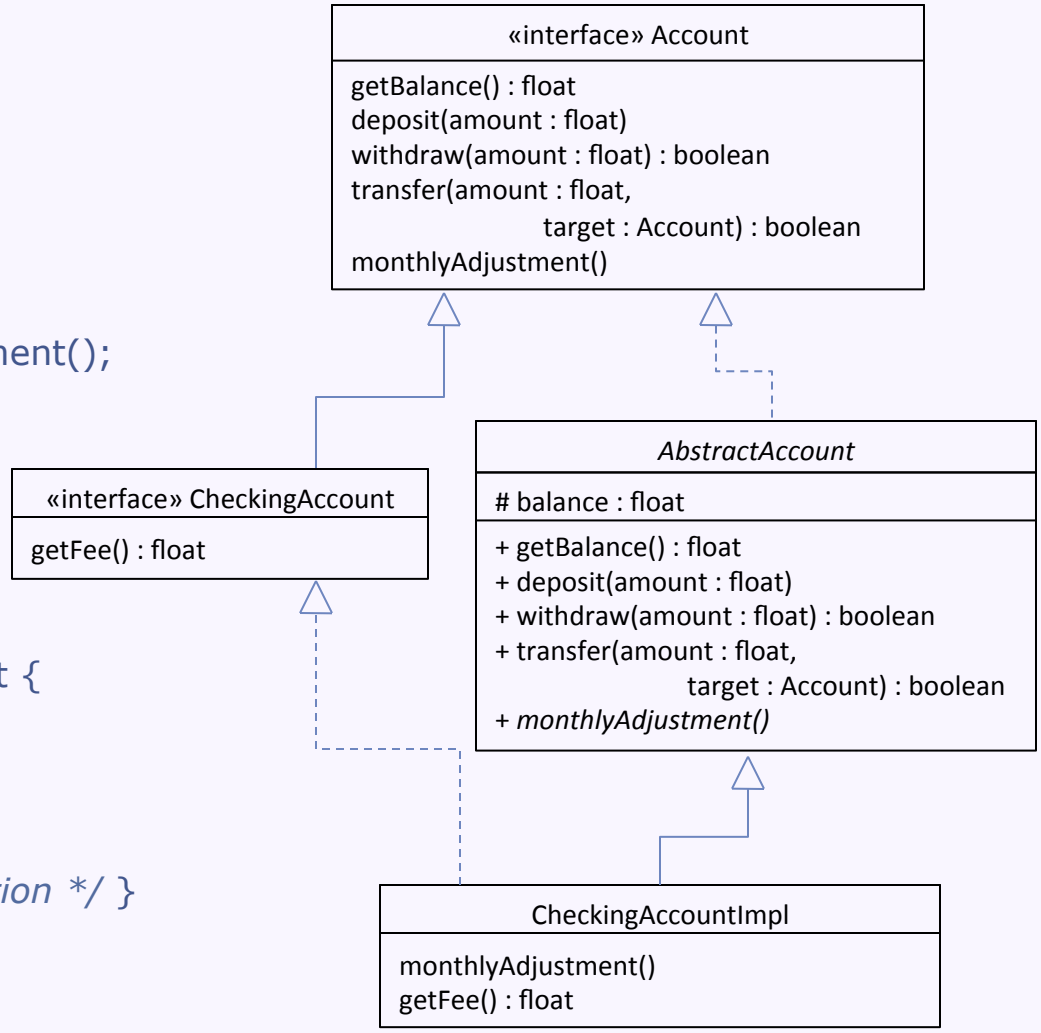
  - See the DogWalker example

One implementation: Just use interface inheritance



Better: Reuse abstract account code

```
public abstract class AbstractAccount
                implements Account {
    protected float balance = 0.0;
    public float getBalance() {
                return balance;
    }
    abstract public void monthlyAdjustment();
    // other methods…
}

public class CheckingAccountImpl
                extends AbstractAcount
                implements CheckingAccount {
    public void monthlyAdjustment() {
                balance -= getFee();
    }
    public float getFee() { /* fee calculation */ }
}
```



Better: Reuse abstract account code

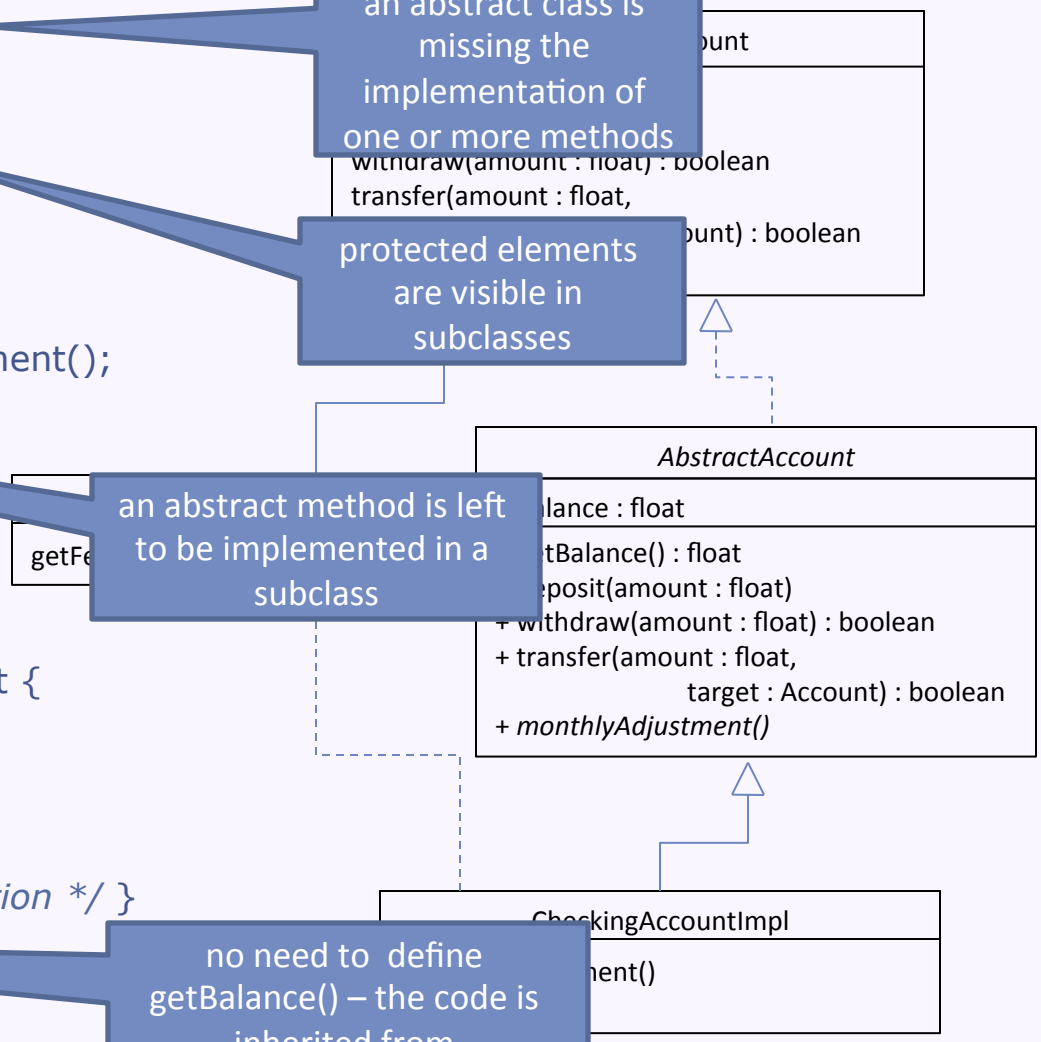
```
public abstract class AbstractAccount
            implements Account {
    protected float balance = 0.0;
    public float getBalance() {
            return balance;
    }
    abstract public void monthlyAdjustment();
    // other methods…
}

public class CheckingAccountImpl
            extends AbstractAcount
            implements CheckingAccount {
    public void monthlyAdjustment() {
            balance -= getFee();
    }
    public float getFee() { /* fee calculation */ }
}
```

an abstract class is missing the implementation of one or more methods

protected elements are visible in subclasses

an abstract method is left to be implemented in a subclass

no need to define getBalance() – the code is inherited from AbstractAccount



Inheritance and subtyping

- Inheritance is for code reuse
  - Write code once and only once
  - Superclass features implicitly available in subclass

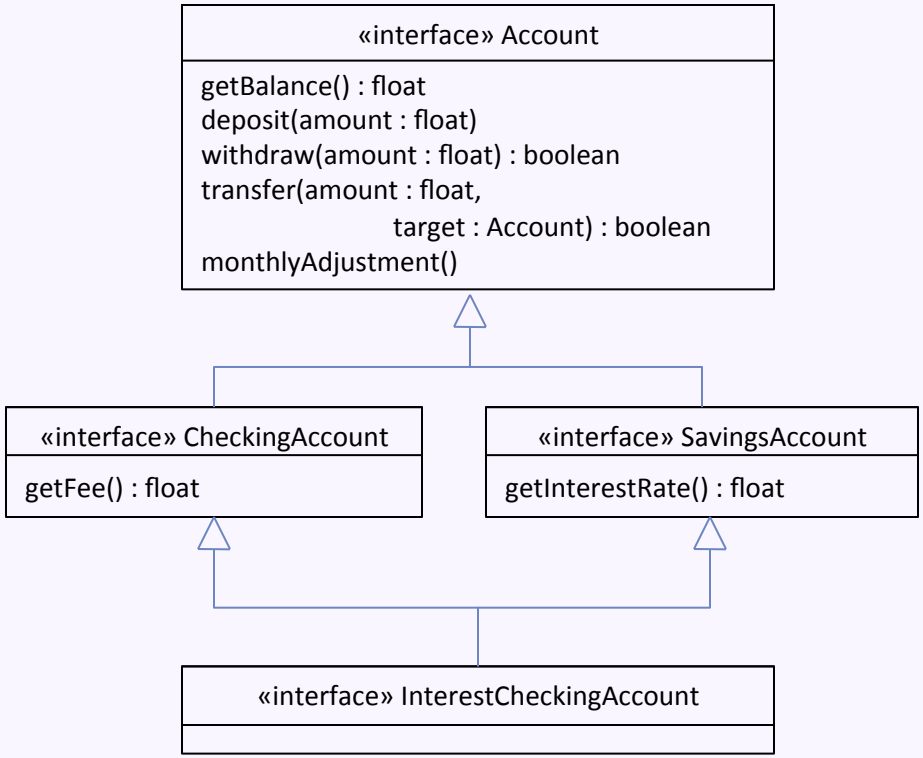
```
class A extends B
```

- Subtyping is for polymorphism
  - Accessing objects the same way, but getting different behavior
  - Subtype is substitutable for supertype

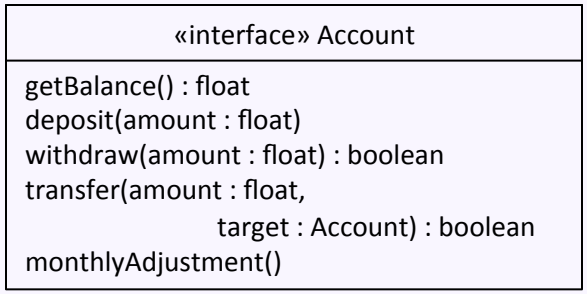
```
class A implements I
class A extends B
```

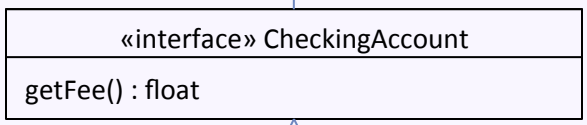
Challenge: Is inheritance necessary?

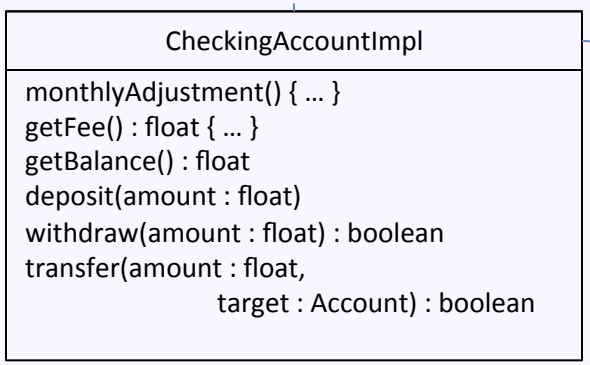
- Can we get the same amount of code reuse without inheritance?



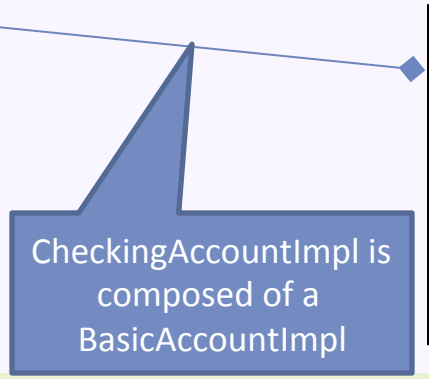
Reuse via *composition* and *delegation*

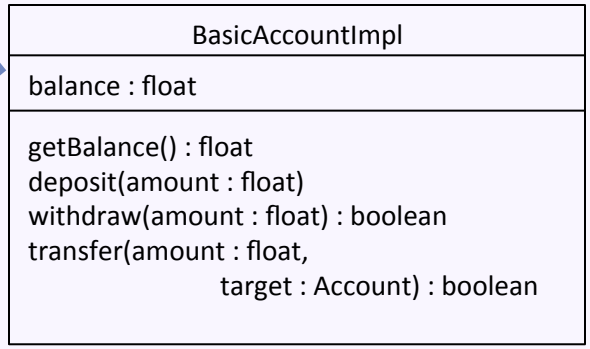







```
public class CheckingAccountImpl
        implements CheckingAccount {
    BasicAccountImpl basicAcct = new(…);
    public float getBalance() {
        return basicAcct.getBalance();
    }
    // …
```





Java details: extended re-use with `super`

```
public abstract class AbstractAccount implements Account {
  protected float balance = 0.0;
  public boolean withdraw(float amount) {
      // withdraws money from account (code not shown)
  }
}

public class ExpensiveCheckingAccountImpl
      extends AbstractAcount implements CheckingAccount {
  public boolean withdraw(float amount) {
      balance -= HUGE_ATM_FEE;
      boolean success = super.withdraw(amount)
      if (!success)
         balance += HUGE_ATM_FEE;
      return success;
  }
}
```

Overrides `withdraw` but also uses the superclass `withdraw` method

Java details: constructors with `this` and `super`

```
public class CheckingAccountImpl
      extends AbstractAcount implements CheckingAccount {

  private float fee;

  public CheckingAccountImpl(float initialBalance, float fee) {
      super(initialBalance);
      this.fee = fee;
  }

  public CheckingAccountImpl(float initialBalance) {
      this(initialBalance, 5.00);
  }
  /* other methods… */ }
```

Invokes a constructor of the superclass. Must be the first statement of the constructor.

Invokes another constructor in this same class

Java details: `final`

- A final class: prevents extending the class
  - e.g., `public final class CheckingAccountImpl { …`
- A final method: prevents overriding the method
- A final field: prevents assignment to the field
  - (except to initialize it)

- Why might you want to use final in each of the above cases?

Recall: type-casting in Java

- Sometimes you want a different type than you have
  - e.g.,
```
float pi = 3.14;
int indianaPi = (int) pi;
```
- Useful if you know you have a more specific subtype:
  - e.g.,
```
Account acct = …;
CheckingAccount checkingAcct =
                        (CheckingAccount) acct;
float fee = checkingAcct.getFee();
```
  - Will get a `ClassCastException` if types are incompatible
- Advice: avoid downcasting types

Recall: `instanceof`

- Operator that tests whether an object is of a given class

```
public void doSomething(Account acct) {
    float adj = 0.0;
    if (acct instanceof CheckingAccount) {
        checkingAcct = (CheckingAccount) acct;
        adj = checkingAcct.getFee();
    } else if (acct instanceof SavingsAccount) {
        savingsAcct = (SavingsAccount) acct;
        adj = savingsAcct.getInterest();
    }
    …
}
```

- Advice: avoid `instanceof` if possible

Avoiding `instanceof` with the Template Method pattern

```
public interface Account {
    …
    public float getMonthlyAdjustment();
}

public class CheckingAccount implements Account {
    …
    public float getMonthlyAdjustment() {
        return getFee();
    }
}

public class SavingsAccount implements Account {
    …
    public float getMonthlyAdjustment() {
        return getInterest();
    }
}
```

Avoiding `instanceof` with the Template Method pattern

```
float adj = 0.0;
if (acct instanceof CheckingAccount) {
    checkingAcct = (CheckingAccount) acct;
    adj = checkingAcct.getFee();
} else if (acct instanceof SavingsAccount) {
    savingsAcct = (SavingsAccount) acct;
    adj = savingsAcct.getInterest();
}
```

Instead:

```
float adj = acct.getMonthlyAdjustment();
```

Today:

- Inheritance and polymorphism (continued)
  - For maximal code re-use
  - Diagrams to show the relationships between classes
  - Inheritance and its alternatives
  - Java details related to inheritance
- Type checking and its limitations
  - The subtype relation
  - Behavioral contracts
    - The `java.lang.Object`

Typechecking

- The key idea: Analyze a program to determine whether each operation is applicable to the types it is invoked on
- Benefits:
  - Finds errors early
    - e.g., `int h = "hi" / 2;`
  - Helps document program code
    - e.g.,
```
baz(frob) { /* what am I supposed to do
             with a frob? */ }
void baz(Car frob) { /* oh, look,
                      I can drive it! */ }
```

Value flow and subtyping

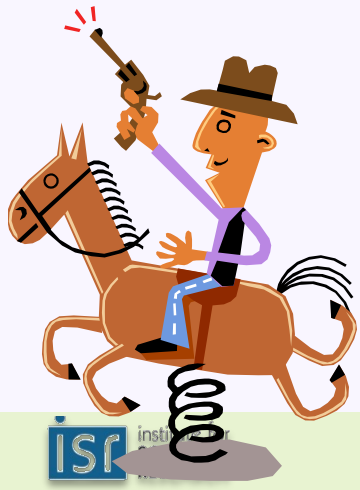
- Value flow: assignments, passing parameters
  - e.g., `Foo f = expression;`
  - Determine the type T_{source} of the source expression
  - Determine the type T_{dest} of the destination variable `f`
  - Check that T_{source} is a subtype of T_{dest}
- Aside: The subtype relation *A* <: *B*
  - Base cases:
    - *A* <: B if *A* extends *B* or *A* implements *B*
    - *A* <: *A* (reflexivity)
  - Inductive case:
    - If *A* <: *B* and *B* <: *C* then *A* <: *C* (transitivity)

Typechecking expressions in Java

- Base cases:
  - variables and fields
    - the type is explicitly declared
  - Expressions using `new ...()`
    - the type is the class being created
  - Type-casting
    - the type is the type forced by the cast
- For method calls, e.g., e1.m(e2)
  1. Determine the type *T1* of the receiver expression e1
  2. Determine the type *T2* of the argument expression e2
  3. Find the method declaration m in type *T1* (or supertypes), using dispatch rules
  4. The type is the return type of the method declaration identified in step 3

Subtyping rules

- If a concrete class B extends type A
  - B inherits all concrete methods declared in A
    - B can override non-final inherited methods
  - B must override abstract or undefined interface methods
- If B overrides a method declared in type A
  - The argument types must be the same as in A
  - The result type must be subtype of result type from A
- Behavioral subtyping
  - If B overrides a method declared in A, it should conform to the *specification* from A
  - If `Cowboy.draw()` overrides `Circle.draw()` somebody gets hurt!



The `java.lang.Object`

- All Java objects inherit from `java.lang.Object`
- Commonly-used/overridden public methods:

```
String    toString()
boolean   equals(Object obj)
int       hashCode()
Object    clone()
```

Overriding `java.lang.Object`'s `.equals`

- The default `.equals`:

```
public class Object {
    public boolean equals(Object obj) {
        return this == obj;
    }
}
```

- An aside: Do you like:

```
public class CheckingAccountImpl
        implements CheckingAccount {
    @Override
    public boolean equals(Object obj) {
        return false;
    }
}
```

Recall the `.equals(Object obj)` contract

- An equivalence relation
  - Reflexive: ∀`x` `x.equals(x)`
  - Symmetric: ∀`x,y` `x.equals(y)` if and only if `y.equals(x)`
  - Transitive: ∀`x,y,z` `x.equals(y)` and `y.equals(z)` implies `x.equals(z)`
- Consistent
  - Invoking `x.equals(y)` repeatedly returns the same value unless `x` or `y` is modified
- `x.equals(null)` is always false
- `.equals()` always terminates and is side-effect free

The `.hashCode()` contract

- Consistent
  - Invoking `x.hashCode()` repeatedly returns same value unless `x` is modified
- `x.equals(y)` implies `x.hashCode() == y.hashCode()`
  - The reverse implication is not necessarily true:
    - `x.hashCode() == y.hashCode()` does not imply `x.equals(y)`
- Advice: Override `.equals()` if and only if you override `.hashCode()`

The `.clone()` contract

- Returns a *deep copy* of an object
- Generally (but not required!):
  - `x.clone() != x`
  - `x.clone().equals(x)`

Conforming to behavioral contracts

- Complete to support object equality checks:

```
public class Person {
    private String firstName;
    private String lastName;
    public Person(String name) {
        this.firstName = name.split(" ")[0];
        this.lastName = name.split(" ")[1];
    }

}
```

Next week

- Exceptional control flow
- Type polymorphism (and Java Generics)
- Introduction to specification and testing