CS 320

Introduction to Software Engineering
Spring 2017

March 06, 2017

Recap: types of Polymorphism

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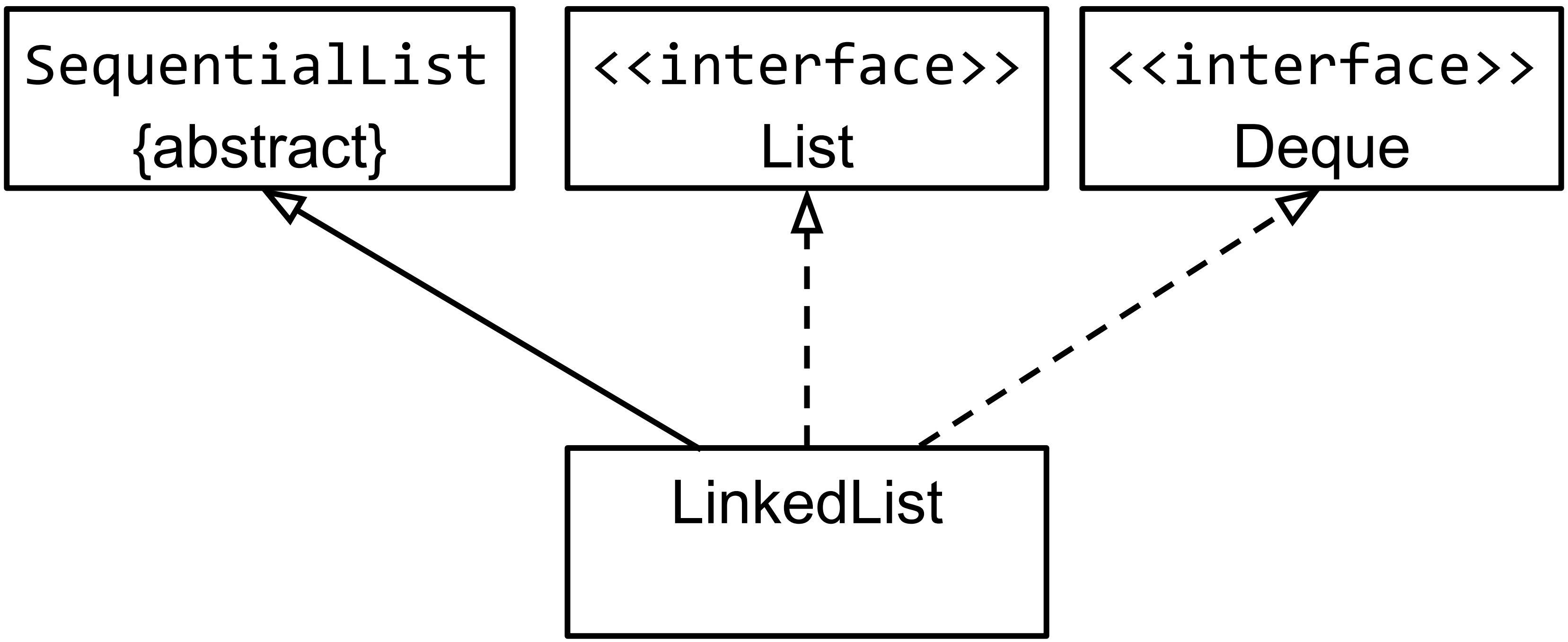
- Ad-hoc polymorphism (e.g., operator overloading)
  - `a + b` ⇒ String vs. int, double, etc.

- Subtype polymorphism (e.g., method overriding)
  - ```
    Object obj = ...;
    obj.toString();
    ```
    ⇒ toString() can be overridden in subclasses and therefore provide a different behavior.

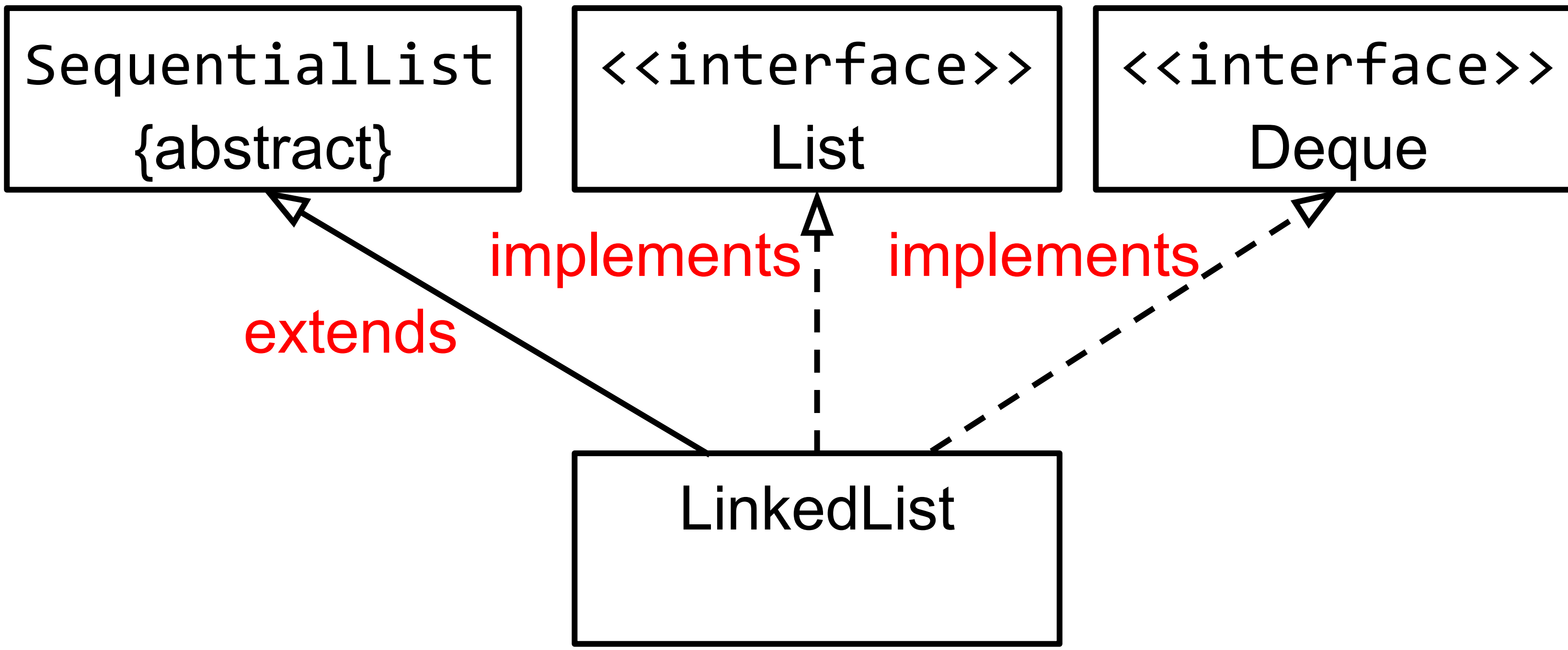
- Parametric polymorphism (e.g., Java generics)
  - ```
    class LinkedList<E> {
      void add(E) {...}
      E get(int index) {...}
    ```
    ⇒ A LinkedList can store elements regardless of their type but still provide full type safety.

Recap: inheritance of classes and interfaces

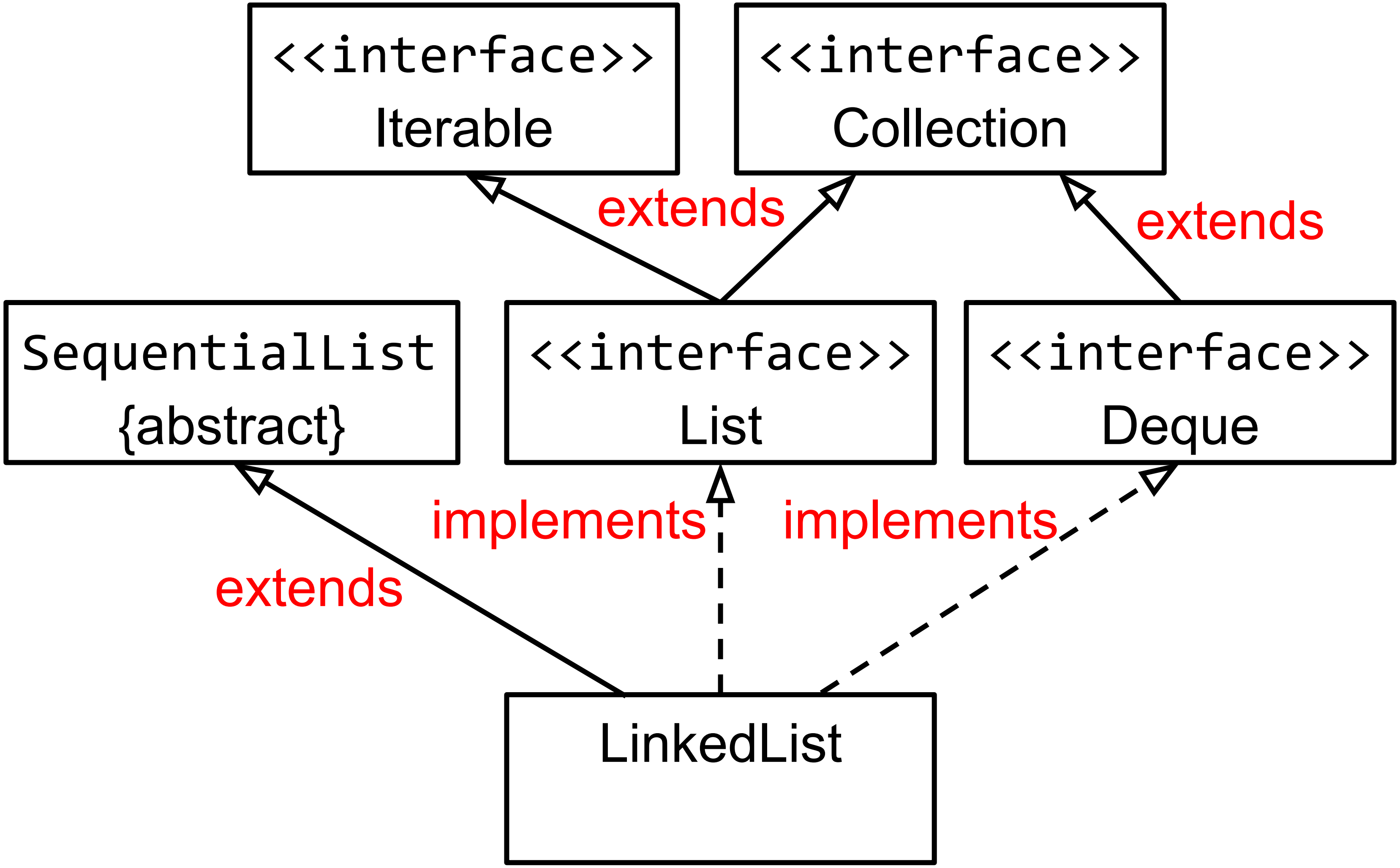


Recap: inheritance of classes and interfaces

LinkedList extends SequentialList implements List, Deque



Recap: inheritance of classes and interfaces



Today

Software design principles

- The diamond of death
- Composition/aggregation over inheritance
- Information hiding (and encapsulation)
- Open/closed principle
- Liskov substitution principle

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Software design principles

- **The diamond of death**
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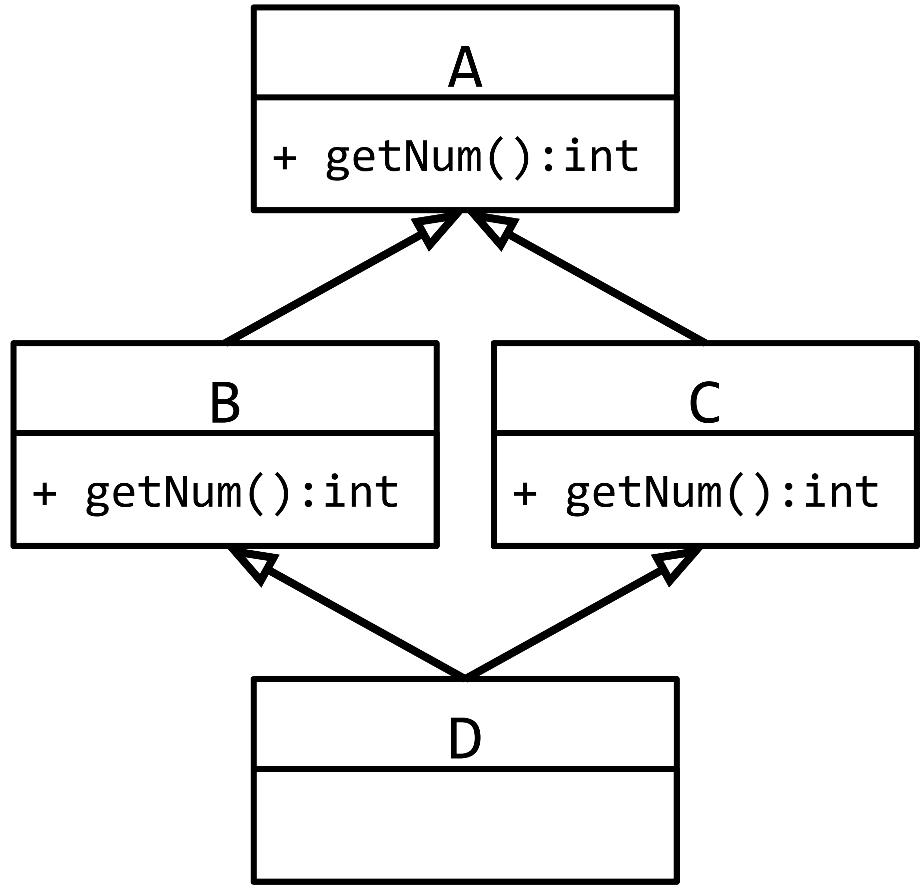
The “diamond of death”

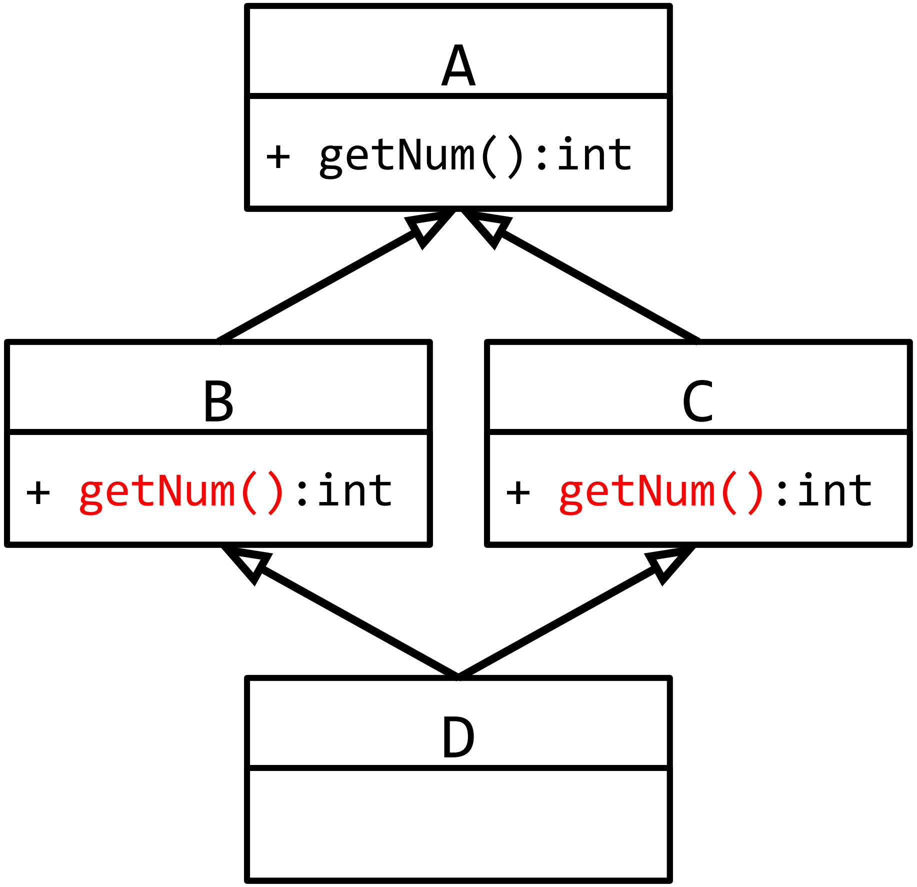
```
...
A a = new D();
int num = a.getNum();
...
```



The “diamond of death”

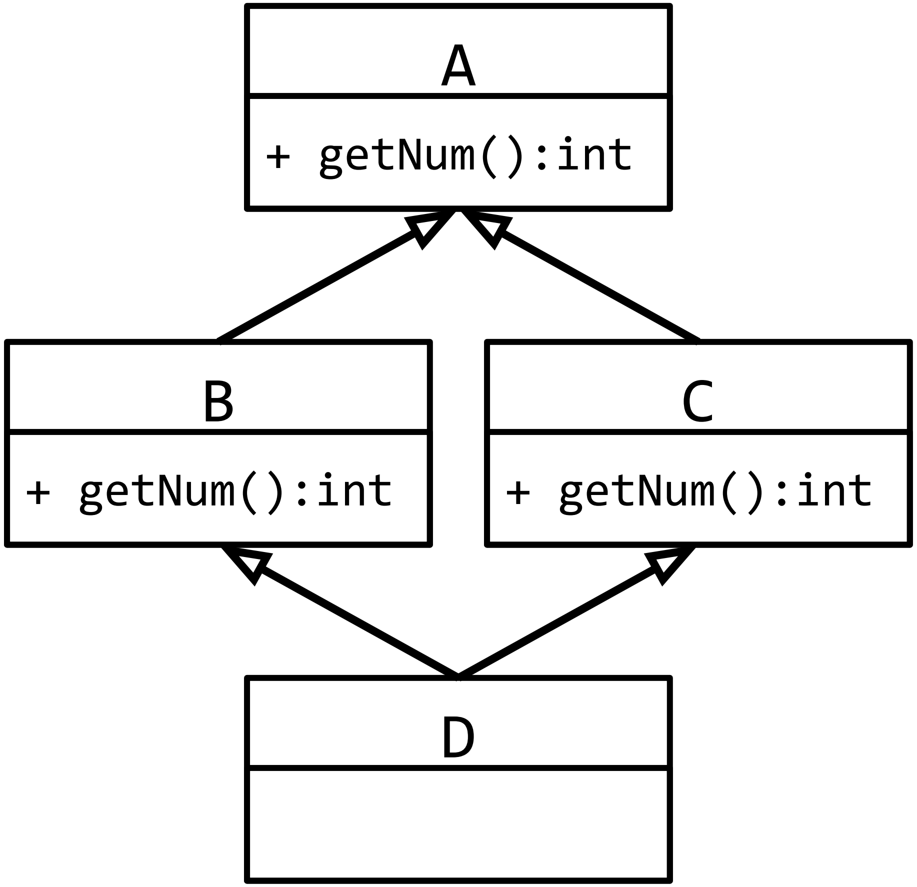
```
...
A a = new D();
int num = a.getNum();
...
```

What version of getNum() to call?



The “diamond of death”

```
...
A a = new D();
int num = a.getNum();
...
```



Can you think of a particular method in Java for which this problem could arise (if Java would allow multiple inheritance)?

Classes, abstract classes, and interfaces

MyClass	MyAbstractClass {abstract}	<<interface>> MyInterface

```java
public class MyClass {


  public void op() {
    ...
  }

  public int op2() {
    ...
  }
}
```

```java
public abstract class
    MyAbstractClass {

  public abstract void op();



  public int op2() {
    ...
  }
}
```

```java
public interface
    MyInterface {

  public void op();



  public int op2();


}
```

Recall how default methods (Java 8) fit into this spectrum?

Classes, abstract classes, and interfaces

MyClass	MyAbstractClass {abstract}	<<interface>> MyInterface

```
public class MyClass {

  public void op() {
    ...
  }

  public int op2() {
    ...
  }
}
```

```
public abstract class
     MyAbstractClass {

  public abstract void op();

  public int op2() {
    ...
  }
}
```

```
public interface
     MyInterface {

  public void op();

  public default int op2() {
    ...
  }
}
```

So, how does an interface with default methods differ from an abstract class?

Coding example: cs320/ArrayList.java (v1,v2)

Why does Java 8 allow default methods?

- Compile all files in *cs320* → what do you observe?
- Fix the compilation issue.

Source code is available on the course web site.

Coding example: cs320/ArrayList.java (v3)

Why does Java 8 allow default methods?

- Compile all files in *cs320* → what do you observe?
- Fix the compilation issue.

- Pretend 10 years have passed...
- Add a new method to the List interface (*List.java*):
  - *public int getNumElems()*
- Compile all files in *cs320* → what do you observe?

Source code is available on the course web site.

Coding example: cs320/ArrayList.java (v4)

Why does Java 8 allow default methods?

- Compile all files in *cs320* → what do you observe?
- Fix the compilation issue.

- Pretend 10 years have passed...
- Add a new method to the List interface (*List.java*):
  - *public int getNumElems()*
- Compile all files in *cs320* → what do you observe?

- Make *getNumElems* a default method in *List.java*
  - *public default int getNumElems() {...}*
- Compile all files in *cs320* → what do you observe?

Source code is available on the course web site.

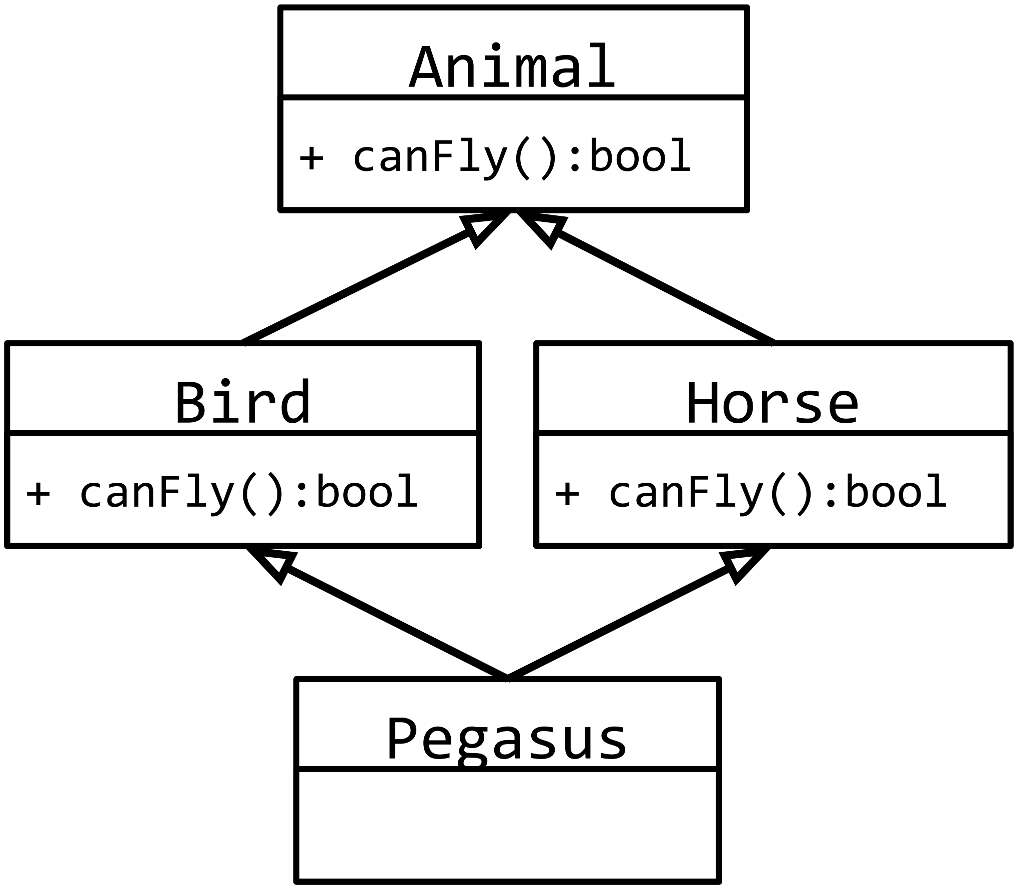
Coding example: inheritance/Pegasus.java

Default methods in Java can cause the diamond of death!

- Remove the *canFly()* method in *Pegasus.java*
- Compile the code → what do you observe?

Source code is available on the course web site.

Coding example: inheritance/Pegasus.java



Coding example: inheritance/Pegasus.java

Default methods in Java can cause the diamond of death!

- Remove the *canFly()* method in *Pegasus.java*
- Compile the code → what do you observe?

```
public class Pegasus implements Horse, Bird {
    public boolean canFly() {
        return true;
    }
}
```

How can you resolve the conflict without hard-coding the return value in the *canFly* method?

Coding example: inheritance/Pegasus.java

Default methods in Java can cause the diamond of death!

- Remove the *canFly()* method in *Pegasus.java*
- Compile the code → what do you observe?

```
public class Pegasus implements Horse, Bird {
    public boolean canFly() {
        return Bird.super.canFly();
    }
}
```

Today

Software design principles

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- **Composition/aggregation over inheritance**
- Information hiding (and encapsulation)
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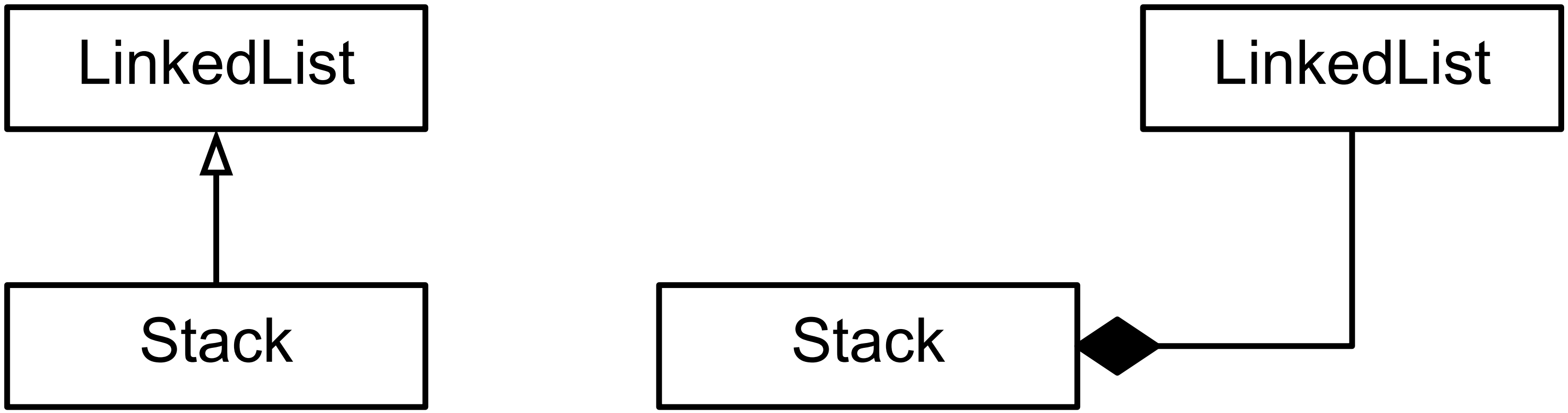
- Liskov substitution principle

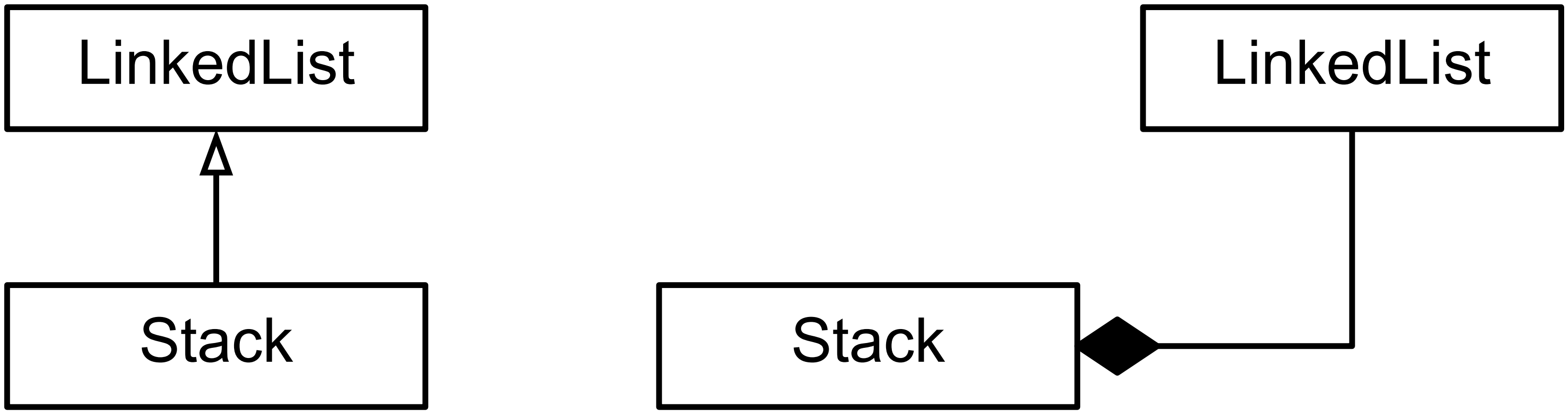
Design choice: inheritance or composition?




```
public class Stack<E>
     extends LinkedList<E> {
  ...
}
```

```
public class Stack<E> {
  private List<E> l = new LinkedList<>();
  ...
}
```

Design choice: inheritance or composition?

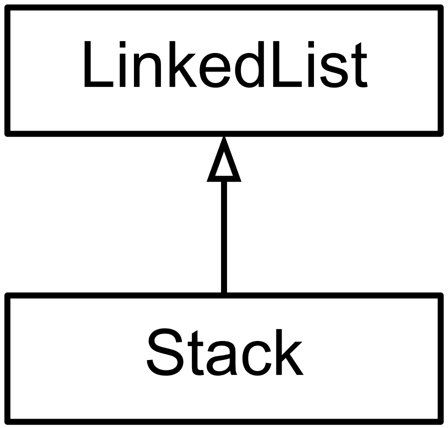


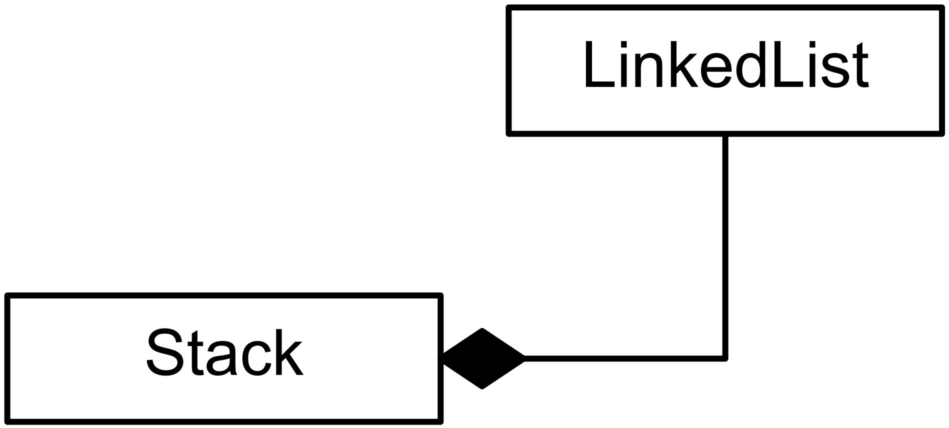

```
public class Stack<E>
     extends LinkedList<E> {
  ...
}
```

```
public class Stack<E> {
  private List<E> l = new LinkedList<>();
  ...
}
```

Hmm, both designs seem valid -- what are pros and cons?

Design choice: inheritance or composition?





Pros
- No delegation methods required.
- Reuse of common state and behavior.

Cons
- Exposure of all inherited methods (a client might rely on this particular superclass -> can't change it later).
- Changes in superclass are likely to break subclasses.

Pros
- Highly flexible and configurable.
- No additional subclasses required for different has-a relationships.

Cons
- All interface methods need to be implemented -> delegation methods required, even for code reuse.

Composition/aggregation over inheritance allows more flexibility.

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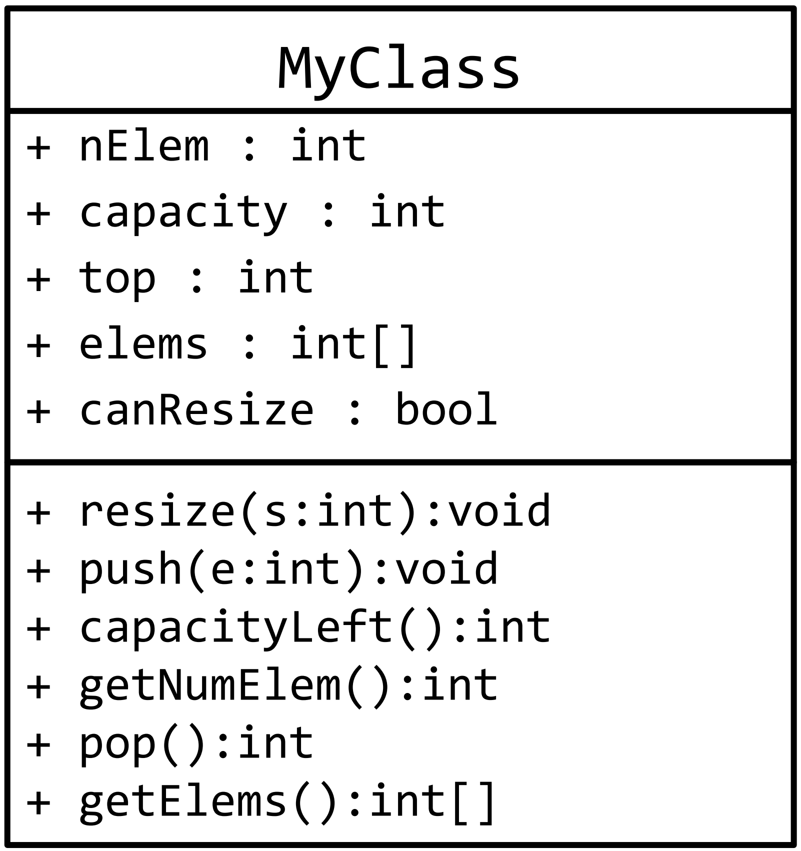
Information hiding



Information hiding

MyClass
+ nElem : int + capacity : int + top : int + elems : int[] + canResize : bool
+ resize(s:int):void + push(e:int):void + capacityLeft():int + getNumElem():int + pop():int + getElems():int[]

```
public class MyClass {
  public int nElem;
  public int capacity;
  public int top;
  public int[] elems;
  public boolean canResize;
  ...
  public void resize(int s){...}
  public void push(int e){...}
  public int capacityLeft(){...}
  public int getNumElem(){...}
  public int pop(){...}
  public int[] getElems(){...}
}
```

Information hiding

```
MyClass
-----------------------------
+ nElem : int
+ capacity : int
+ top : int
+ elems : int[]
+ canResize : bool
-----------------------------
+ resize(s:int):void
+ push(e:int):void
+ capacityLeft():int
+ getNumElem():int
+ pop():int
+ getElems():int[]
```

```java
public class MyClass {
  public int nElem;
  public int capacity;
  public int top;
  public int[] elems;
  public boolean canResize;
  ...
  public void resize(int s){...}
  public void push(int e){...}
  public int capacityLeft(){...}
  public int getNumElem(){...}
  public int pop(){...}
  public int[] getElems(){...}
}
```

What does MyClass do?

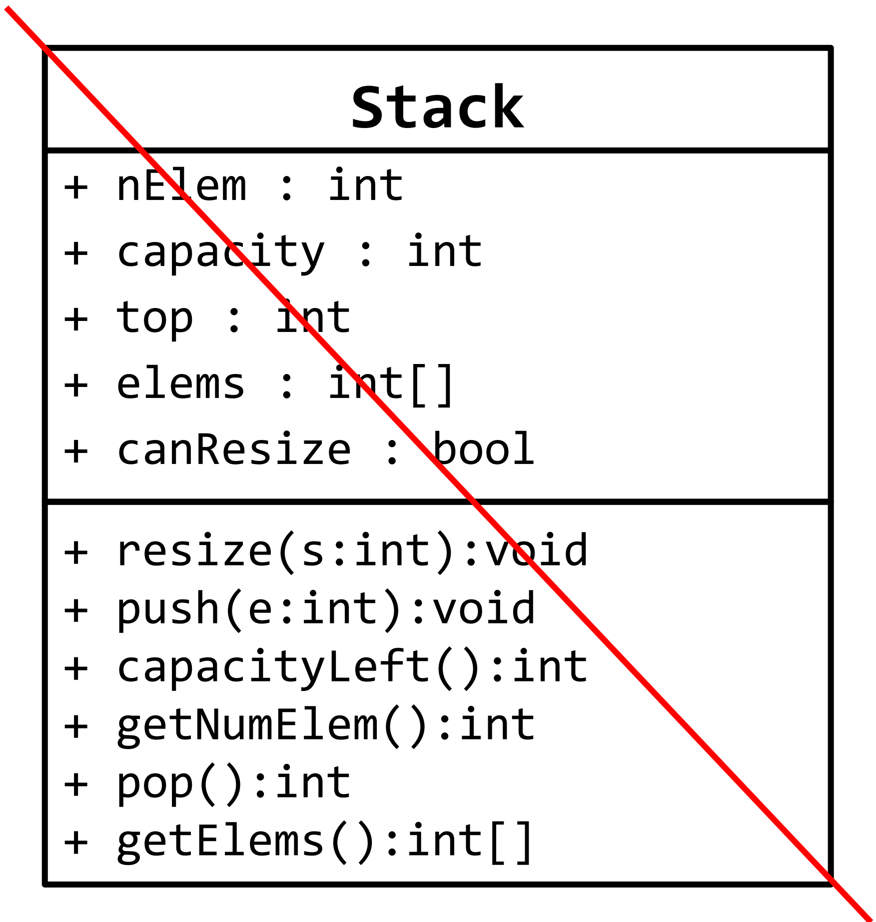
Information hiding

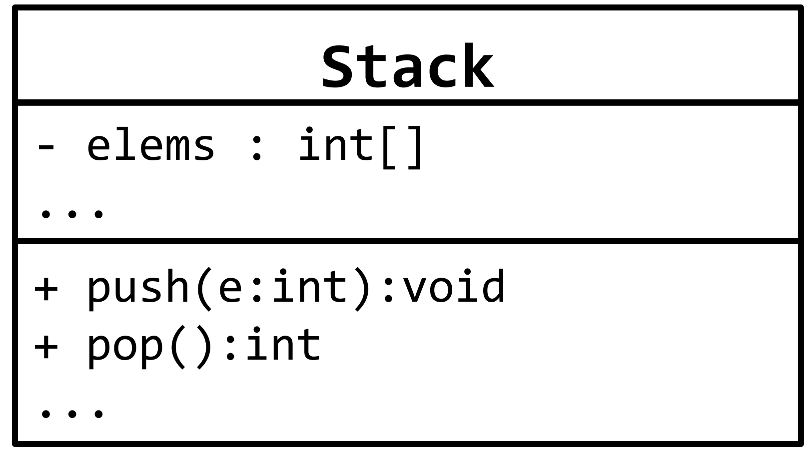
```
Stack
--------------------------
+ nElem : int
+ capacity : int
+ top : int
+ elems : int[]
+ canResize : bool
--------------------------
+ resize(s:int):void
+ push(e:int):void
+ capacityLeft():int
+ getNumElem():int
+ pop():int
+ getElems():int[]
```

```java
public class Stack {
  public int nElem;
  public int capacity;
  public int top;
  public int[] elems;
  public boolean canResize;

  ...

  public void resize(int s){...}
  public void push(int e){...}
  public int capacityLeft(){...}
  public int getNumElem(){...}
  public int pop(){...}
  public int[] getElems(){...}
}
```

Anything that could be improved in this implementation?

Information hiding

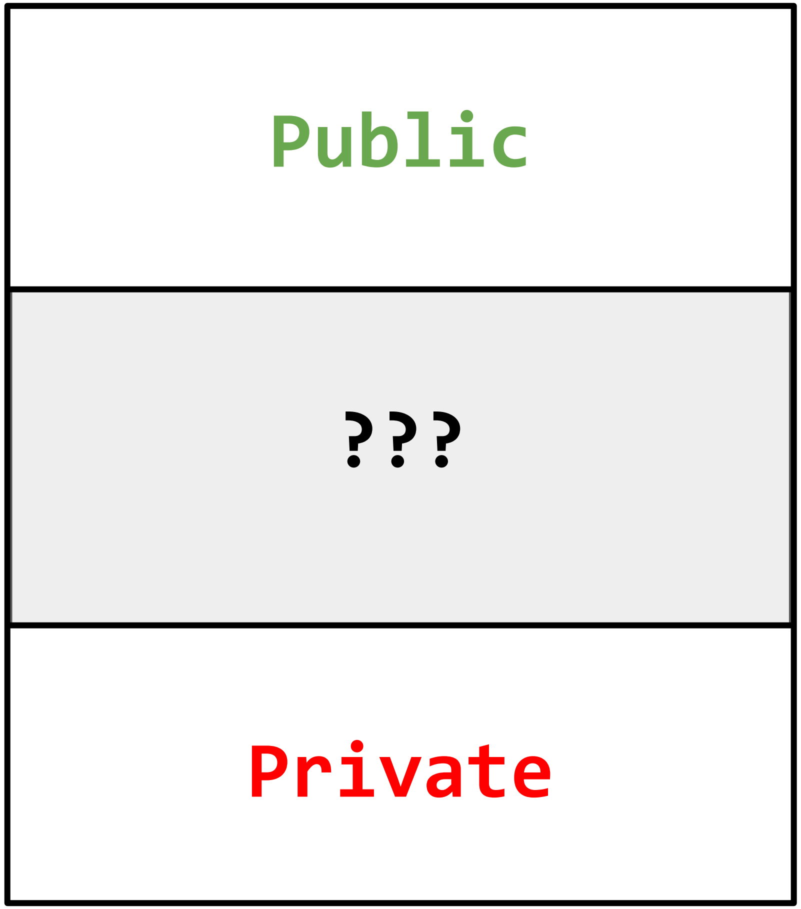




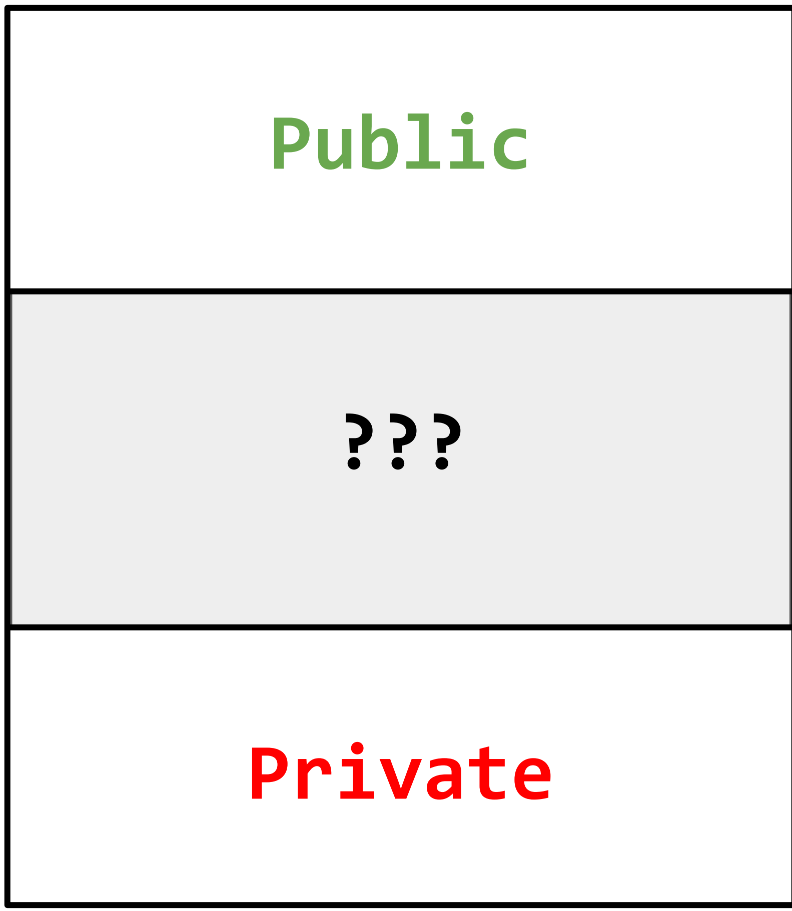
Information hiding:

- Reveal as little information about internals as possible.
- Segregate public interface and implementation details.
- Reduces complexity.

Information hiding vs. visibility



Information hiding vs. visibility



- Protected, package-private, or friend-accessible (C++).
- Not part of the public API.
- Implementation detail that a subclass/friend may rely on.

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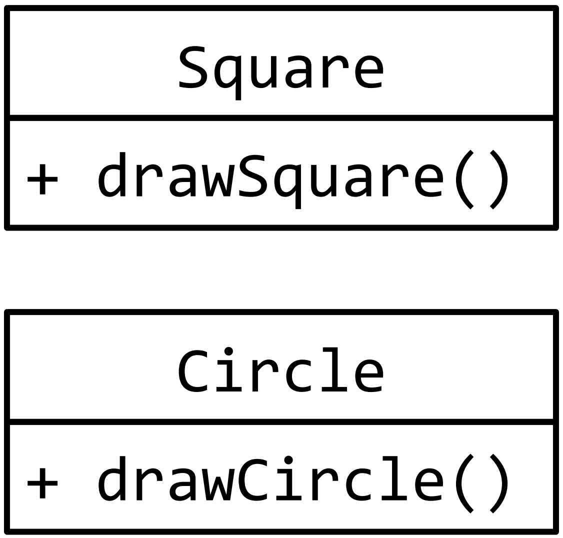
- **Open/closed principle**
- Liskov substitution principle

Design principles: open/closed principle

Software entities (classes, components, etc.) should be:

- **open** for extensions
- **closed** for modifications

```
public static void draw(Object f) {
  if (f instanceof Square) {
    drawSquare((Square) f)
  } else if (f instanceof Circle) {
    drawCircle((Circle) f);
  } else {
    ...
  }
}
```



Good or bad design?

Design principles: open/closed principle

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```
public static void draw(Object f) {
  if (f instanceof Square) {
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    ...
  }
}
```
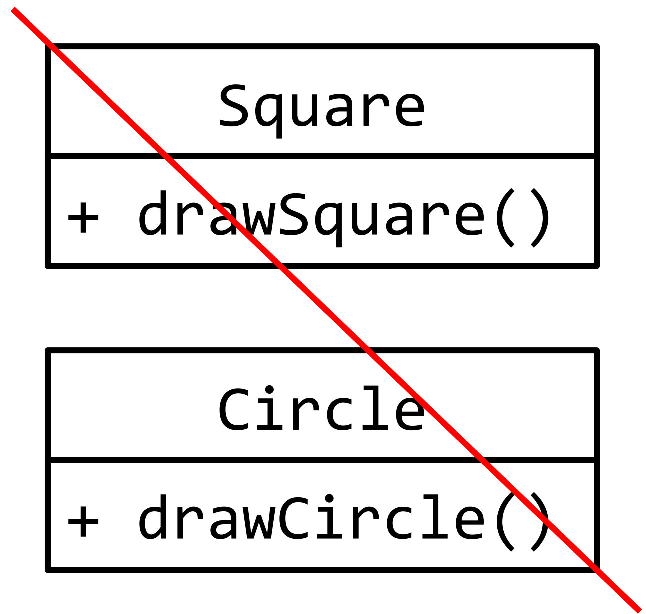



Violates the open/closed principle!

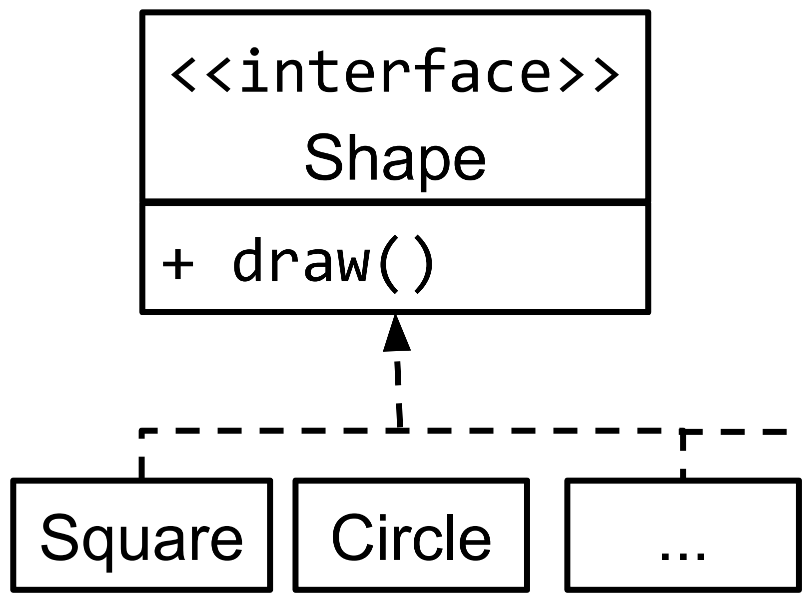
Design principles: open/closed principle

Software entities (classes, components, etc.) should be:

- **open** for extensions
- **closed** for modifications

```
public static void draw(Object f) {
  if (f instanceof Figure) {
     f.draw();
  } else {
     …
  }
}
```

```
public static void draw(Figure f) {
  f.draw();
}
```



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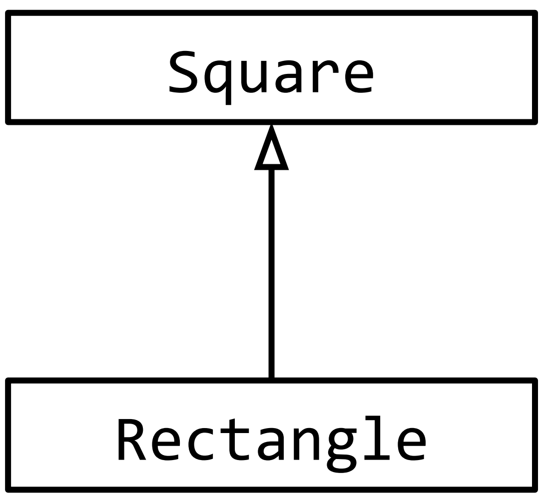
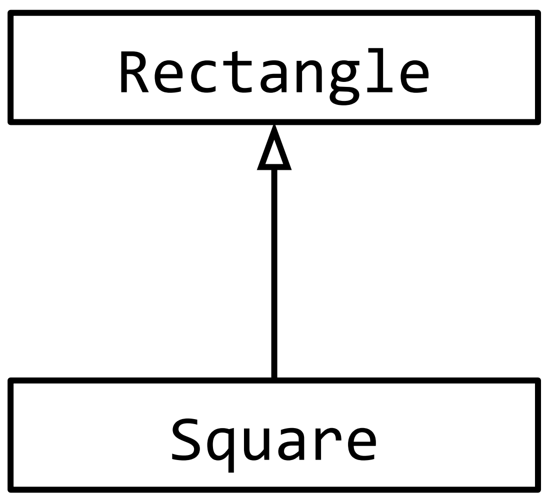
Design principles: Liskov substitution principle

Motivating example

We know that a square is a special kind of a rectangle. So, which of the following OO designs makes sense?

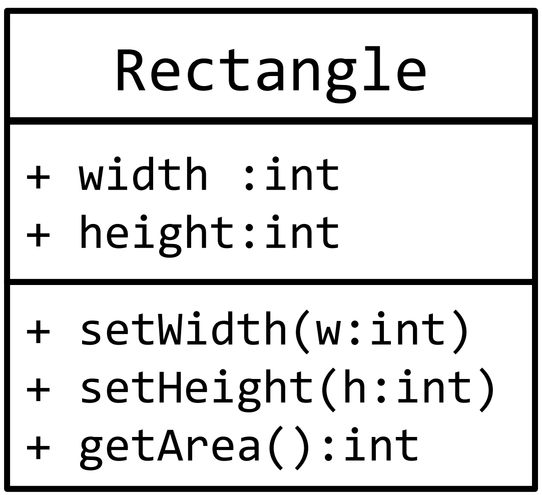


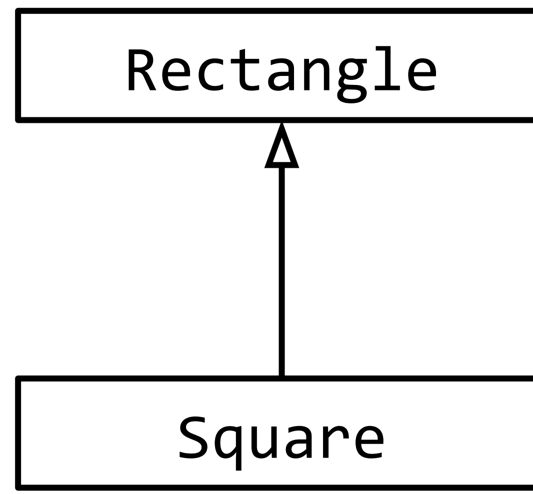


Design principles: Liskov substitution principle

Subtype requirement

Let object x be of type T1 and object y be of type T2. Further, let T2 be a subtype of T1 (T2 <: T1). Any provable property about objects of type T1 should be true for objects of type T2.





Is the subtype requirement fulfilled?

Design principles: Liskov substitution principle

Subtype requirement

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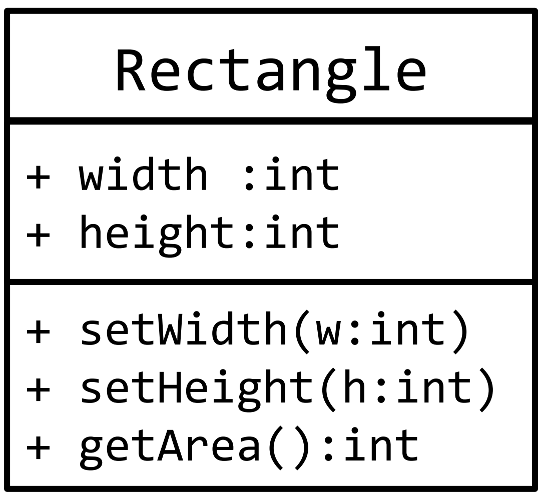
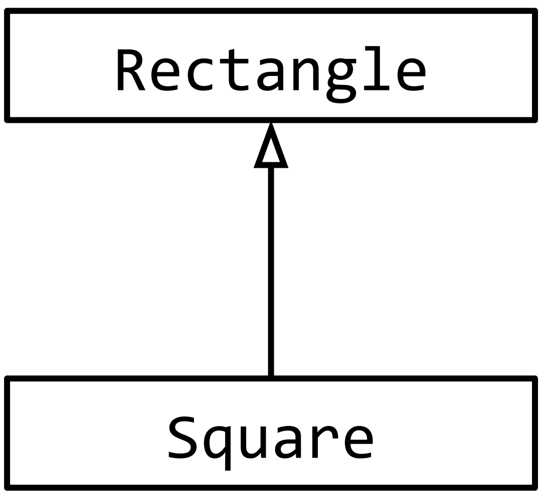



```
Rectangle r =
  new Rectangle(2,2);


int A = r.getArea();
int w = r.getWidth();
r.setWidth(w * 2);

assertEquals(A * 2,
    r.getArea());
```



Design principles: Liskov substitution principle

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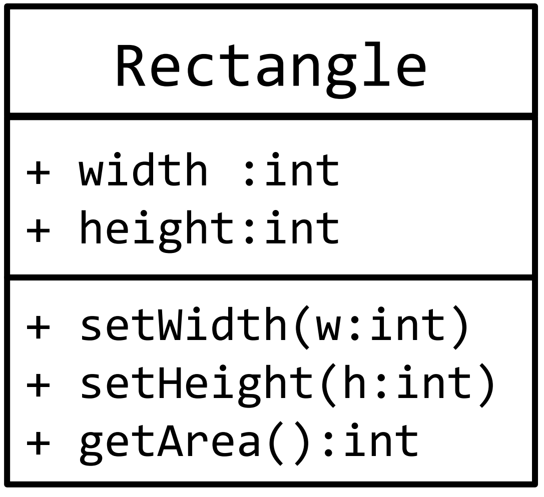
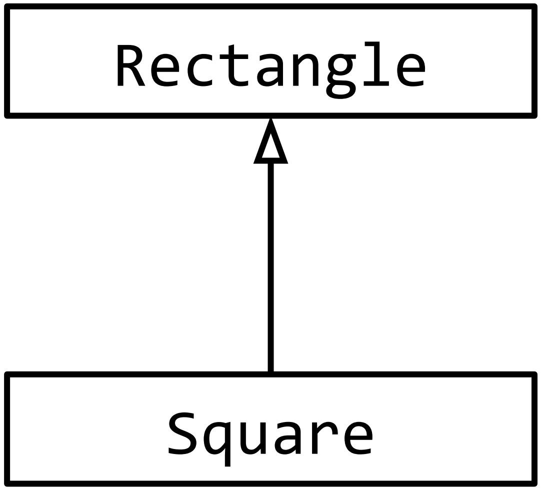



```
Rectangle r =
  new Rectangle(2,2);
  new Square(2);

int A = r.getArea();
int w = r.getWidth();
r.setWidth(w * 2);

assertEquals(A * 2,
    r.getArea());
```



Design principles: Liskov substitution principle

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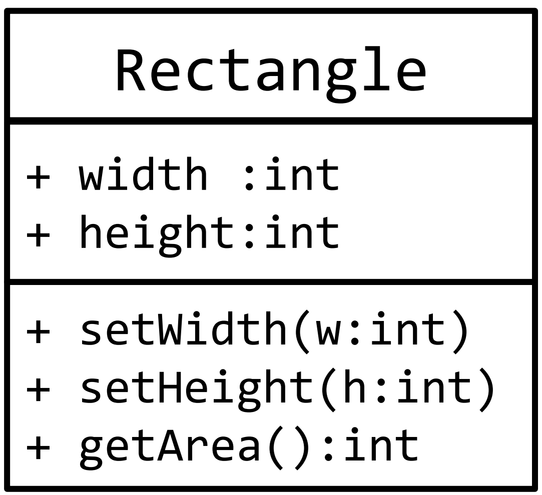


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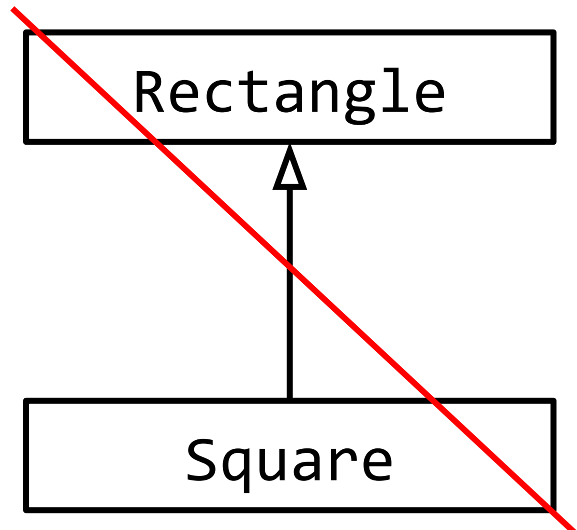

Violates the Liskov substitution principle!

Design principles: Liskov substitution principle

Subtype requirement

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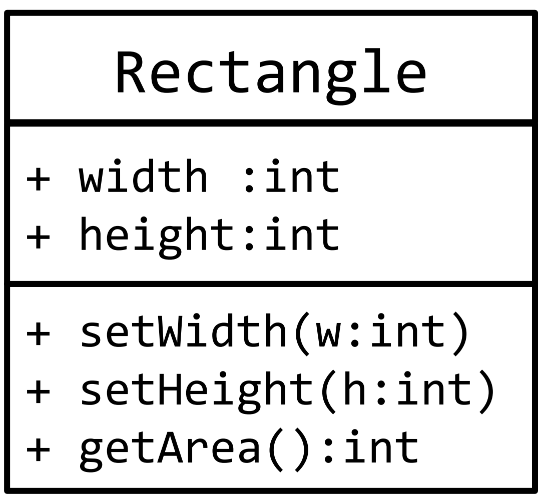

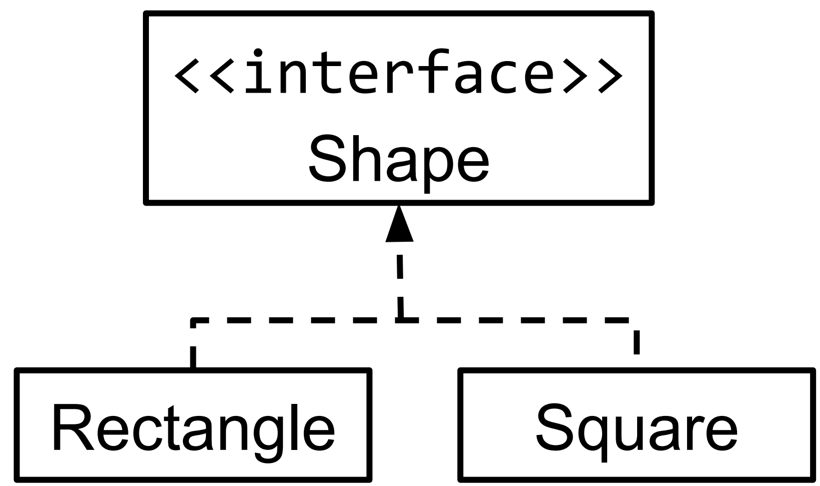

Summary

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- Open/closed principle
- Liskov substitution principle