CS 520

Theory and Practice of Software Engineering
Spring 2021

Object Oriented (OO) Design Principles

February 11, 2021

Recap: Some best programming practices

- Decomposition into modules/packages, classes, and methods
- Encapsulation of methods and fields
- Pre- and post-conditions for methods (e.g., defensive programming techniques, run-time assertions)
- Type safety for methods (e.g., enum types instead of ints)
- Readability/Understandability:
    - Naming conventions
    - Documentation (e.g., internal comments, README files)

Triangle class snippet

```
public class Triangle extends Shape {
        public int b;
        public int h;

        public Triangle(int b, int h) {
                super();
                this.b = b;
                this.h = h;
        }

        public int getB() { return this.b; }


        …
}
```

Code review

Satisfies best practices:	Violates best practices:

Code review

Satisfies best practices:

- Decomposition
- Naming conventions

Violates best practices:

- Encapsulation
- Pre- and post-conditions
- Documentation

Today

- OO design principles
  - Information hiding (and encapsulation)
  - Polymorphism
  - Open/closed principle
  - Inheritance in Java
  - The diamond of death
  - Liskov substitution principle
  - Composition/aggregation over inheritance

OO design principles

- **Information hiding (and encapsulation)**
- Polymorphism
- Open/closed principle
- Inheritance in Java
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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(){...}
}
```

Information hiding

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

```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?

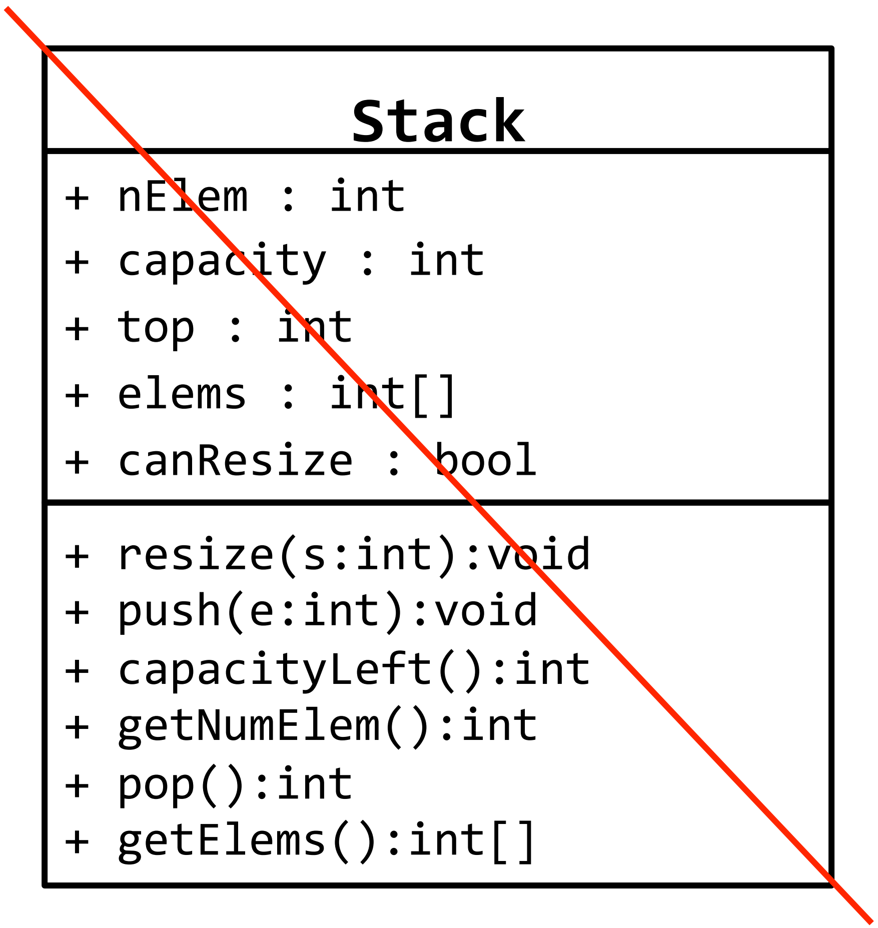
Information hiding

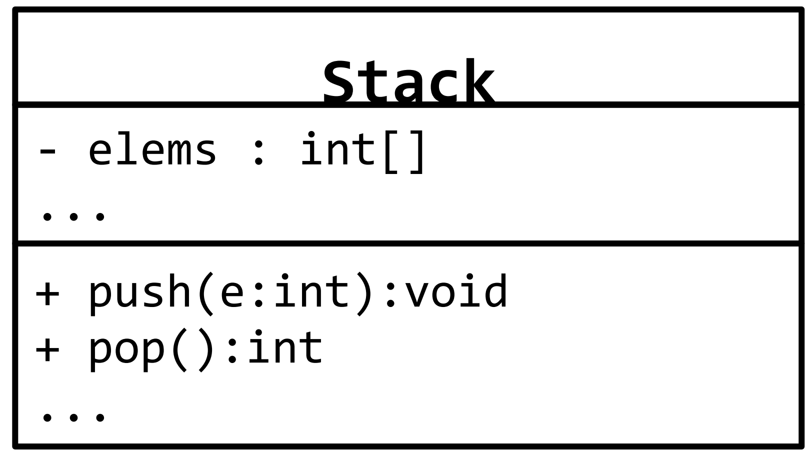
Stack
+ nElem : int + capacity : int + top : int + elems : int[] + canResize : bool
+ resize(s:int):void + push(e:int):void + capacityLeft():int + getNumElem():int + pop():int + getElems():int[]

```
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

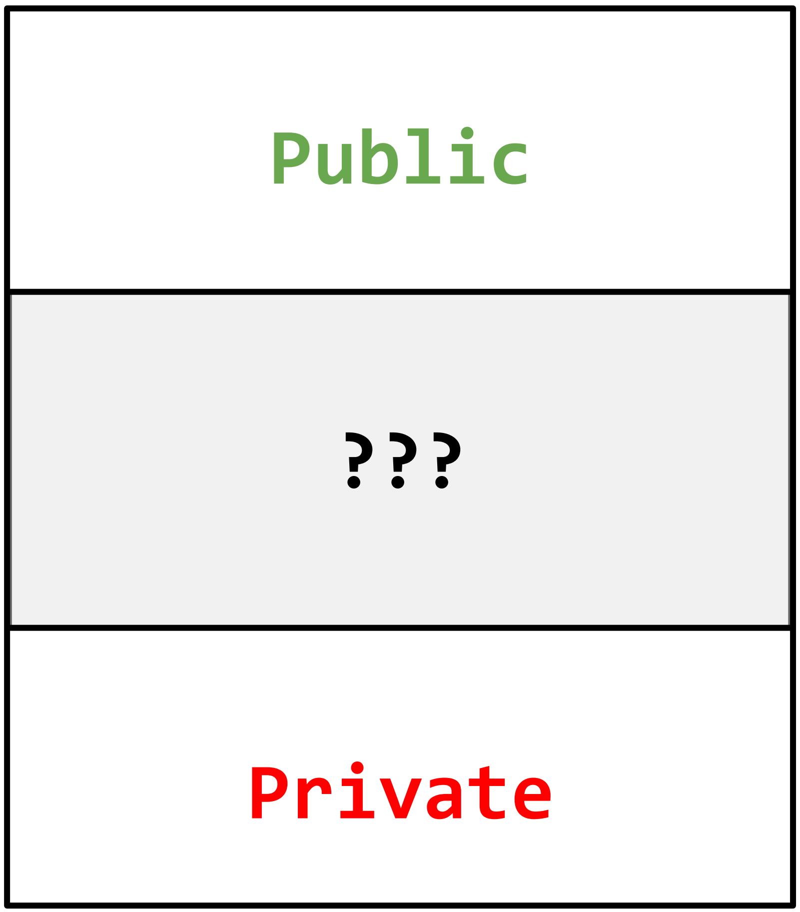




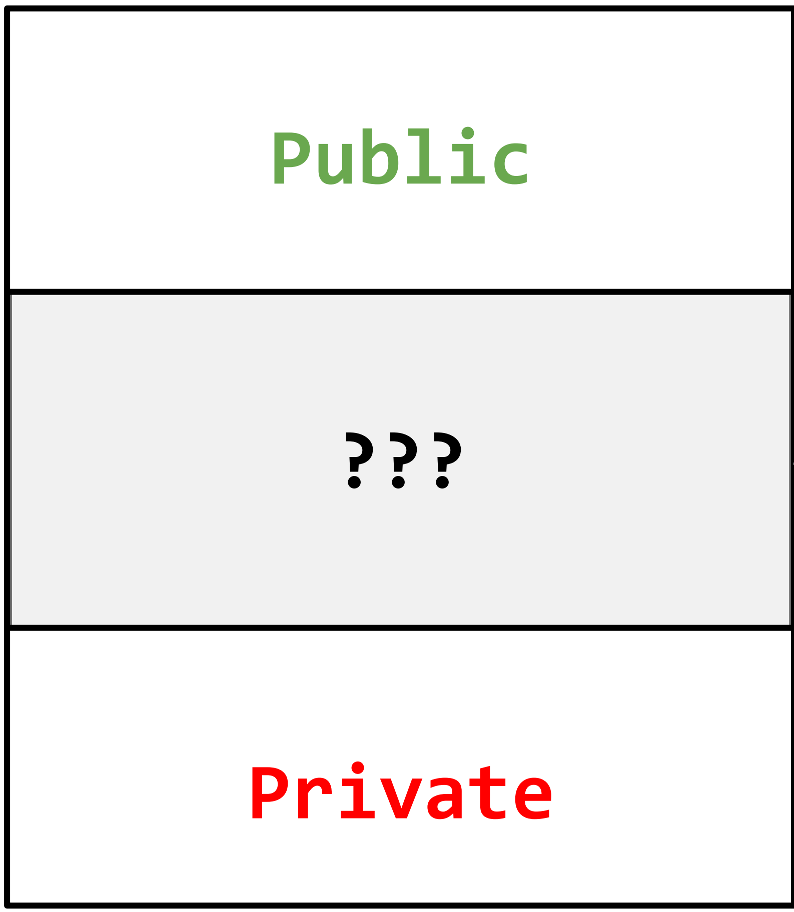
Information hiding:

- Reveal as little information about internals as possible.
- Separate public interface from implementation details.
- Reduce 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.

OO design principles

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

A little refresher: what is Polymorphism?

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An object's ability to provide different behaviors.

Types of polymorphism

- 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.

https://www.destroyallsoftware.com/talks/wat

A little refresher: what is Polymorphism?

An object's ability to provide different behaviors.

Types of polymorphism

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

Subtype polymorphism is essential to many OO design principles.

OO design principles

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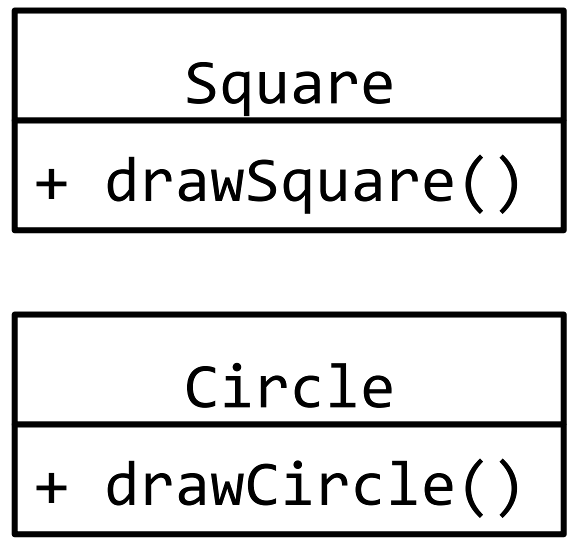
Open/closed principle

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

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

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



Good or bad design?

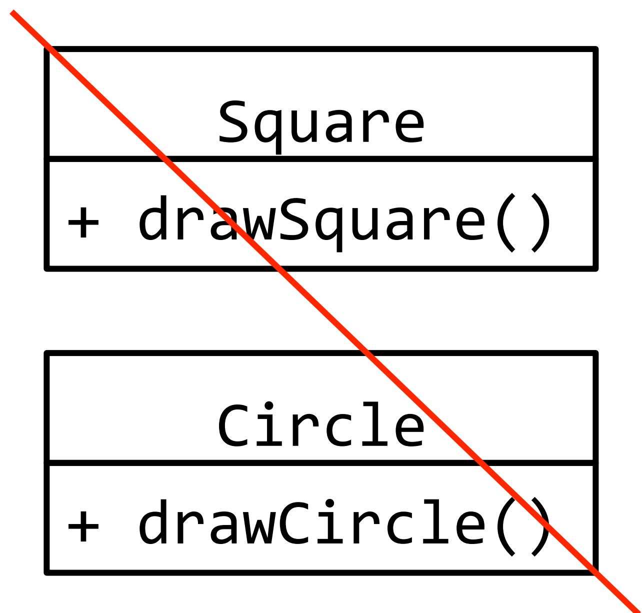
Open/closed principle

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

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

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

Violates the open/closed principle!



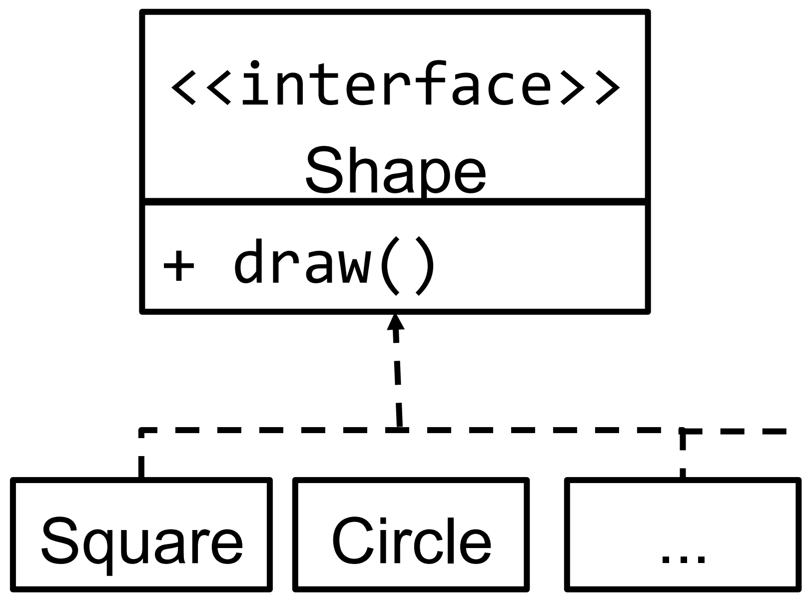
Open/closed principle

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

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

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

```
public static void draw(Shape s) {
  s.draw();
}
```



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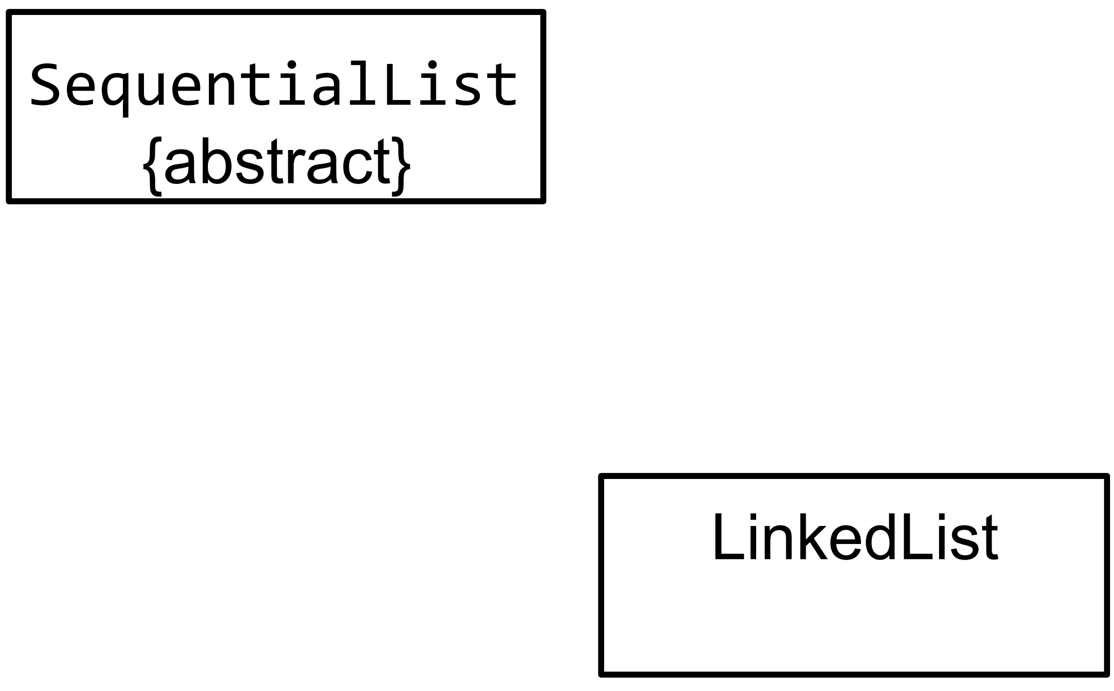
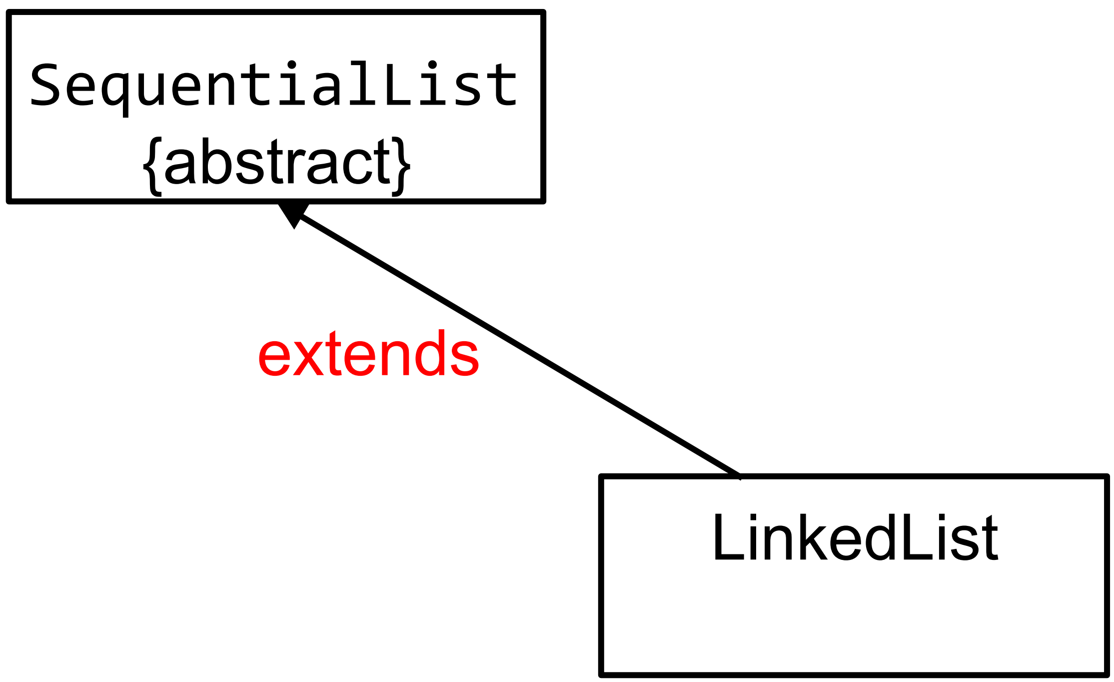
Inheritance: (abstract) classes and interfaces



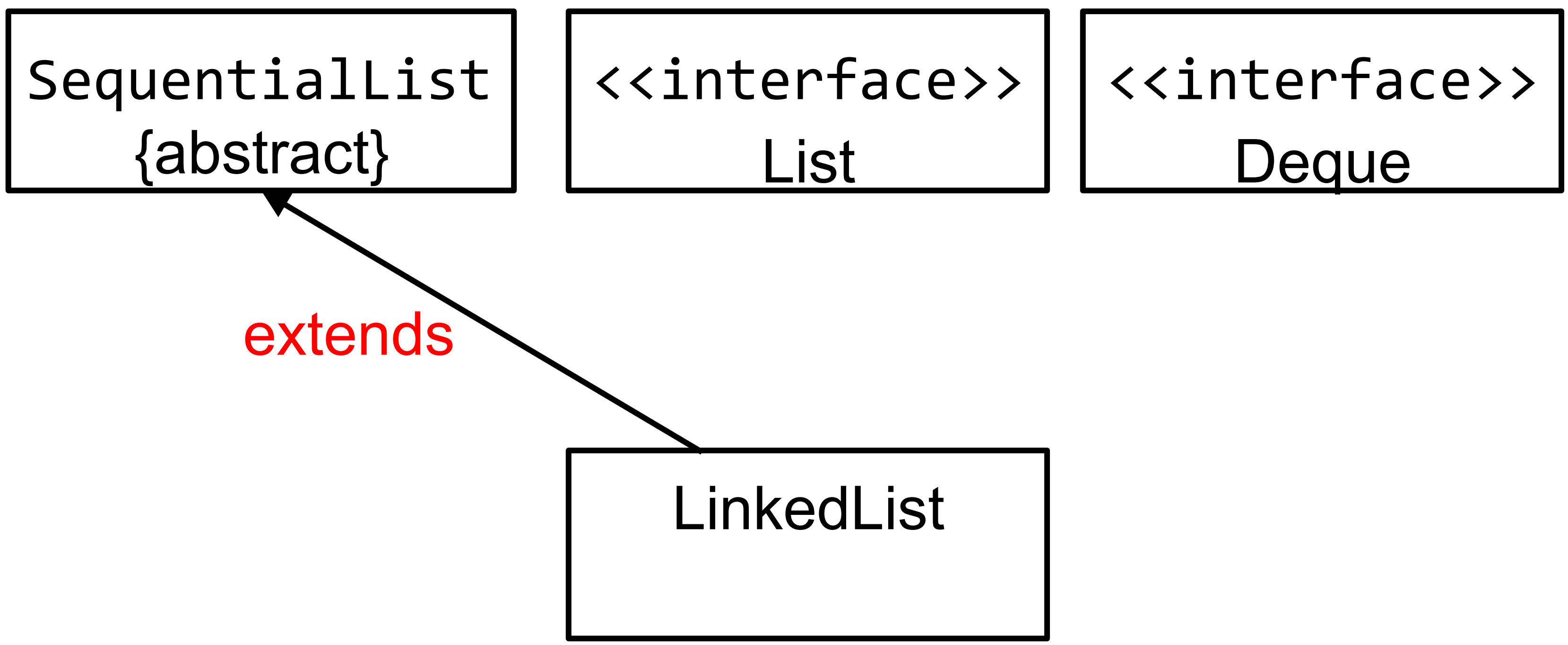
Inheritance: (abstract) classes and interfaces

LinkedList extends SequentialList



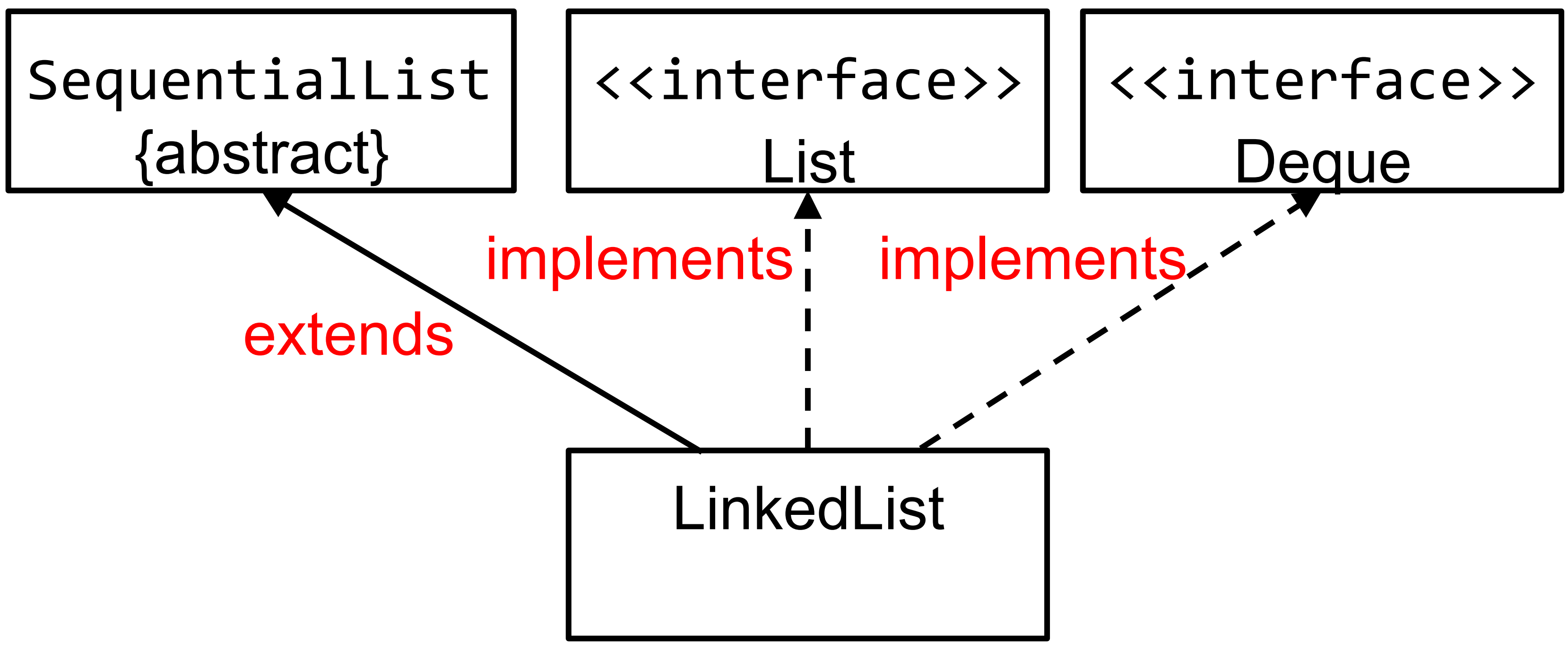
Inheritance: (abstract) classes and interfaces

LinkedList extends SequentialList

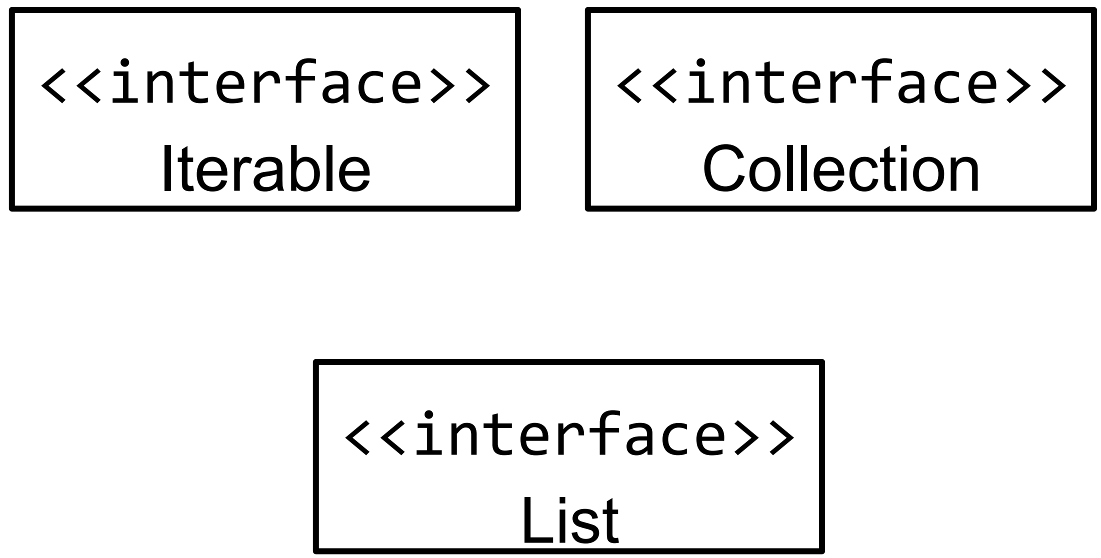


Inheritance: (abstract) classes and interfaces

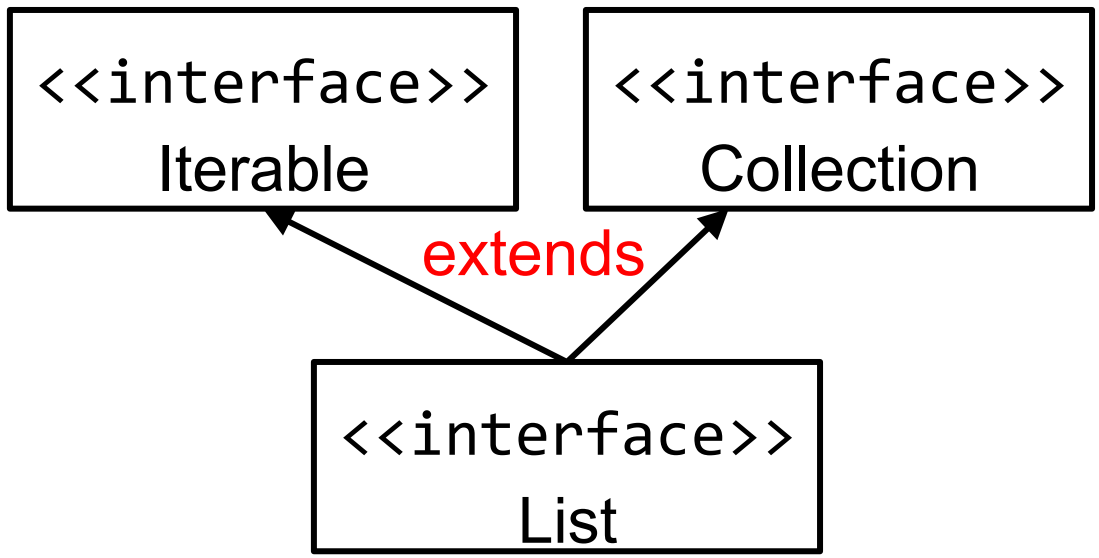
LinkedList extends SequentialList implements List, Deque



Inheritance: (abstract) classes and interfaces

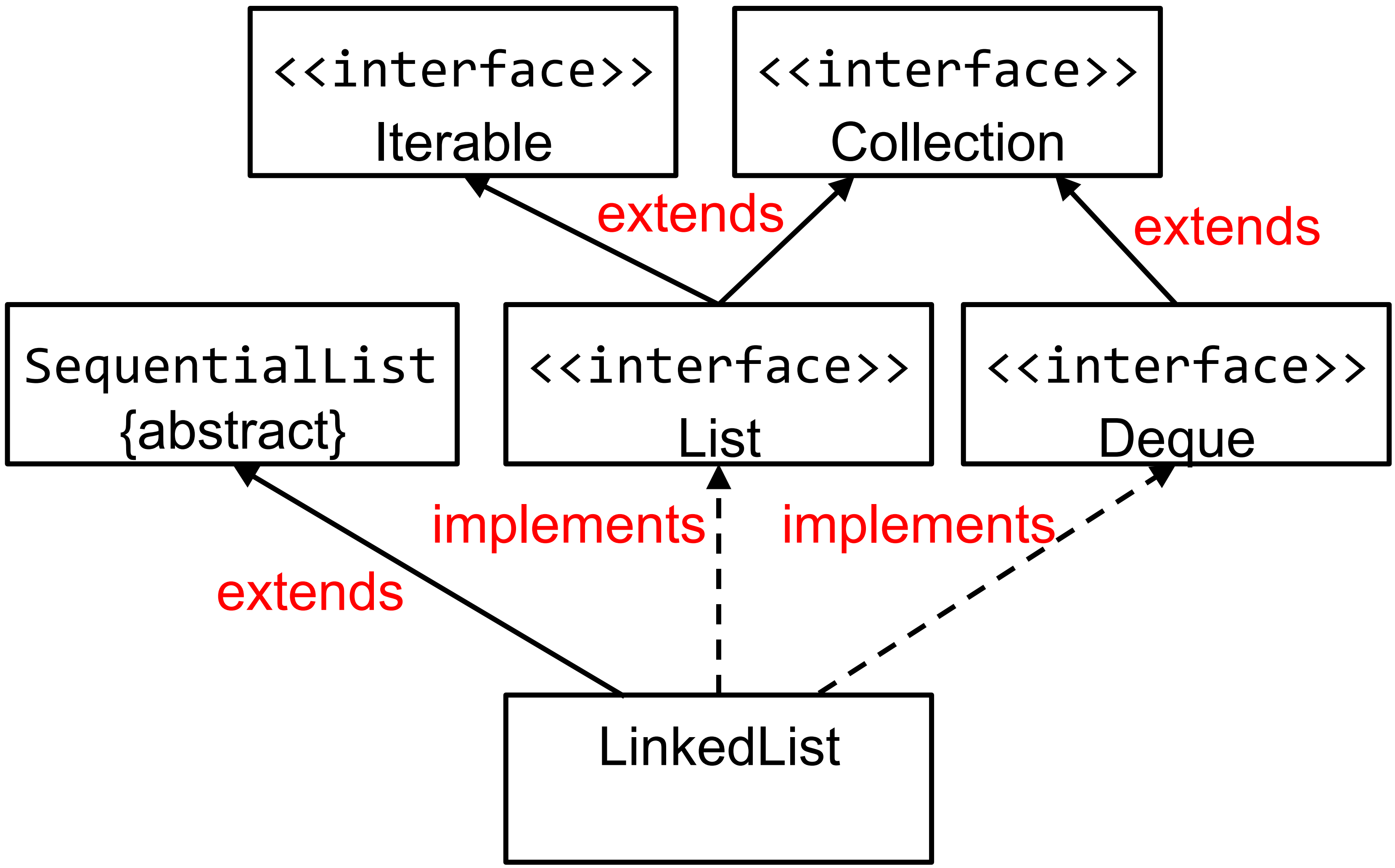


Inheritance: (abstract) classes and interfaces



List extends Iterable, Collection

Inheritance: (abstract) classes and interfaces



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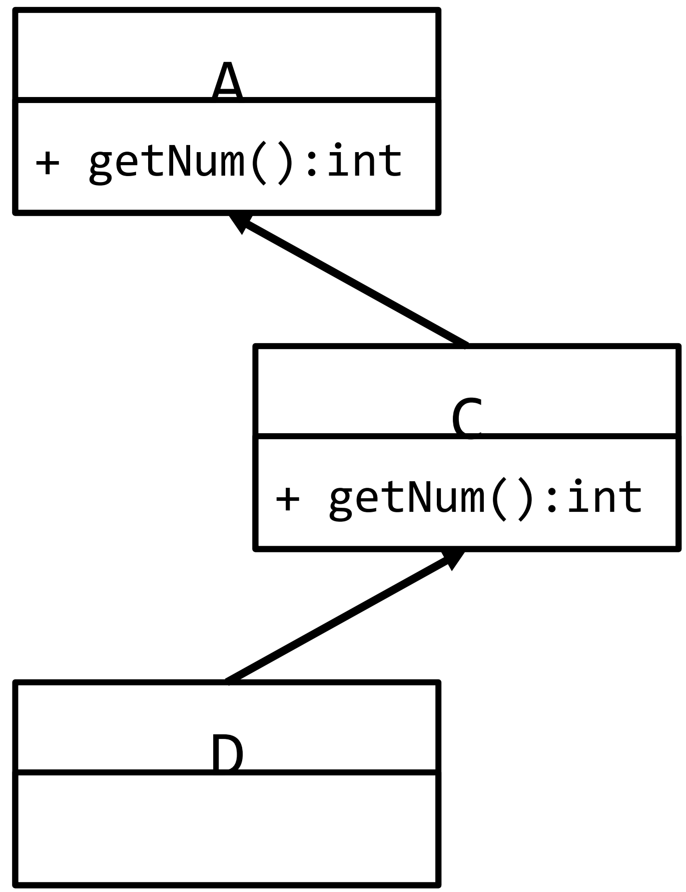
The “diamond of death”: the problem

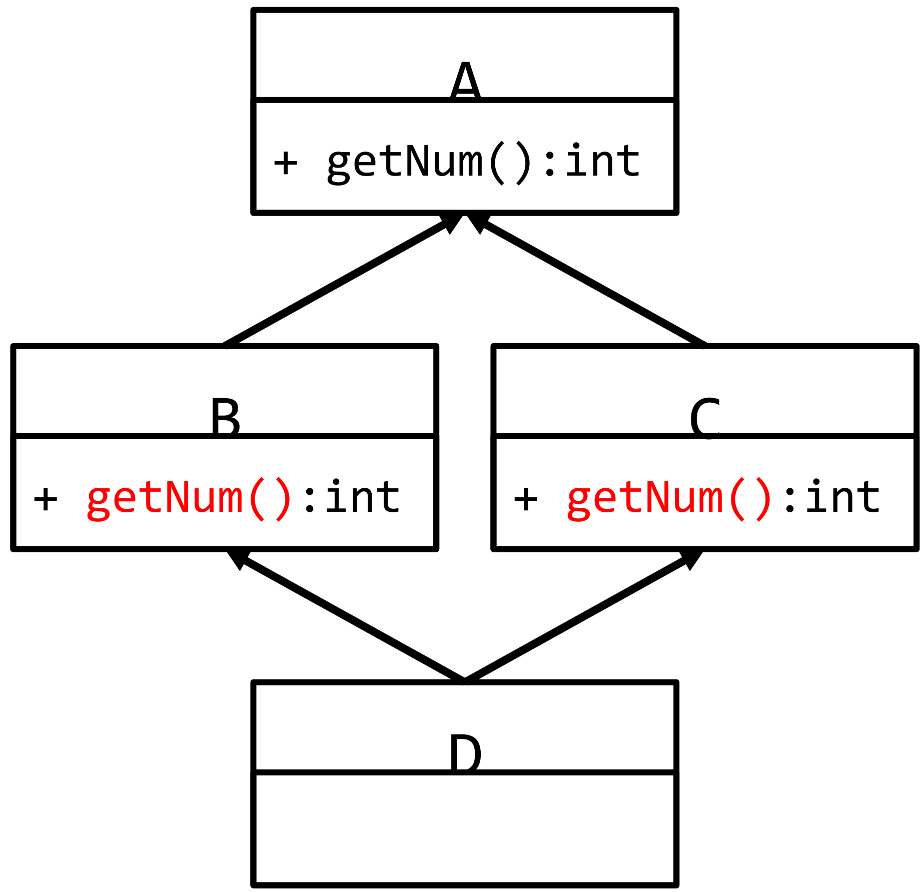
```
...
A a = new D();
int num = a.getNum();
...
```



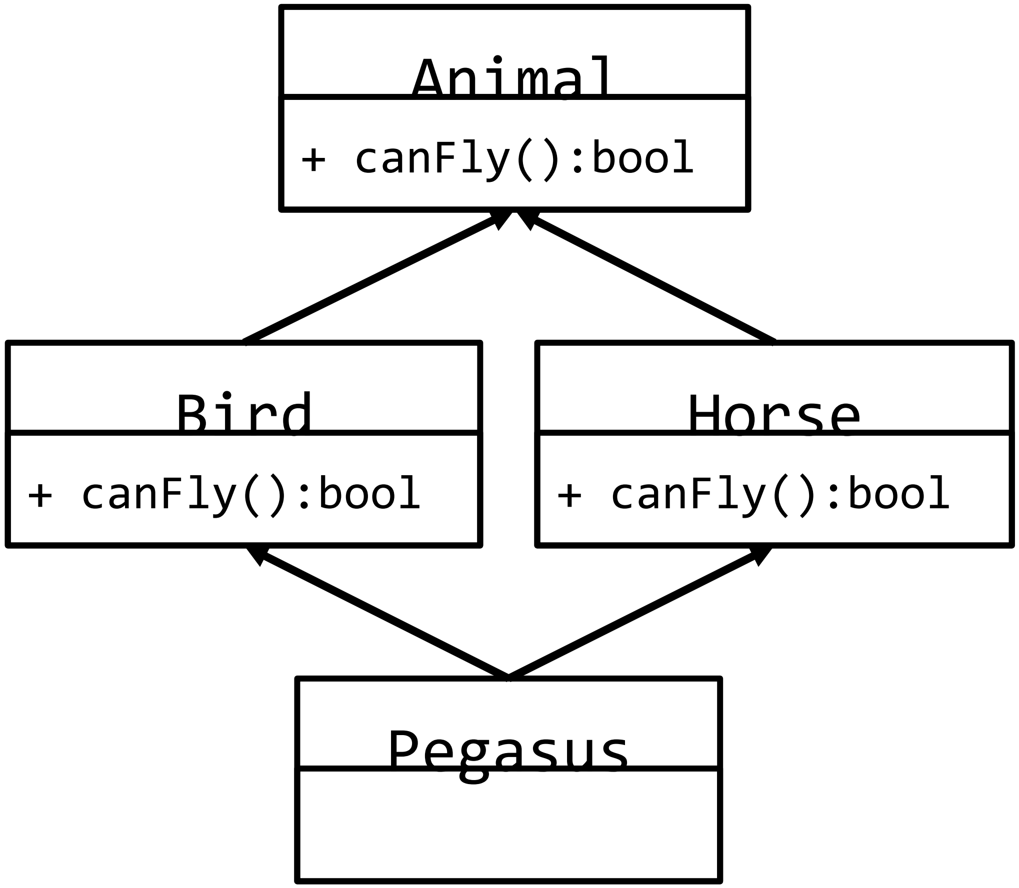
The “diamond of death”: the problem

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

Which getNum() method should be called?



The “diamond of death”: concrete example



Can this happen in Java? Yes, with default methods in Java 8.

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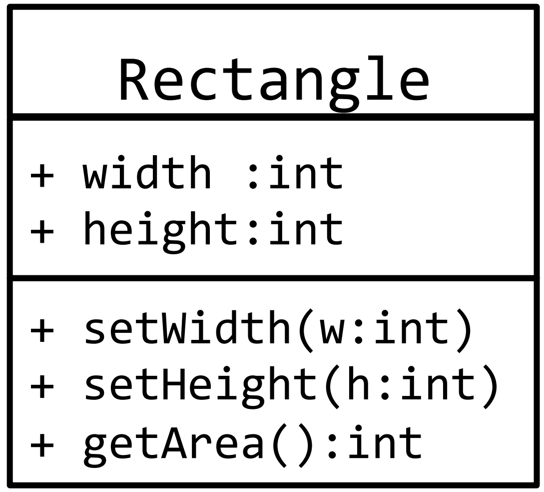
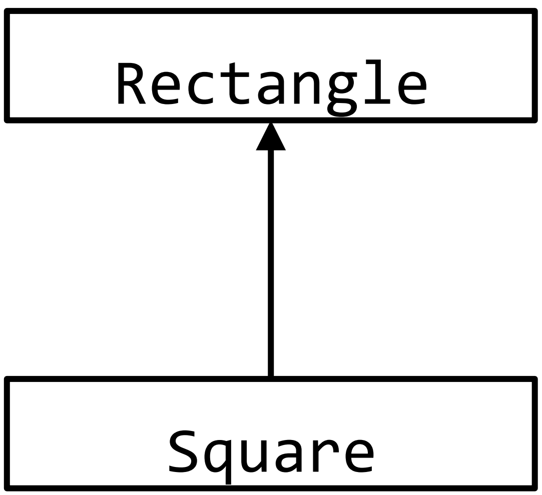
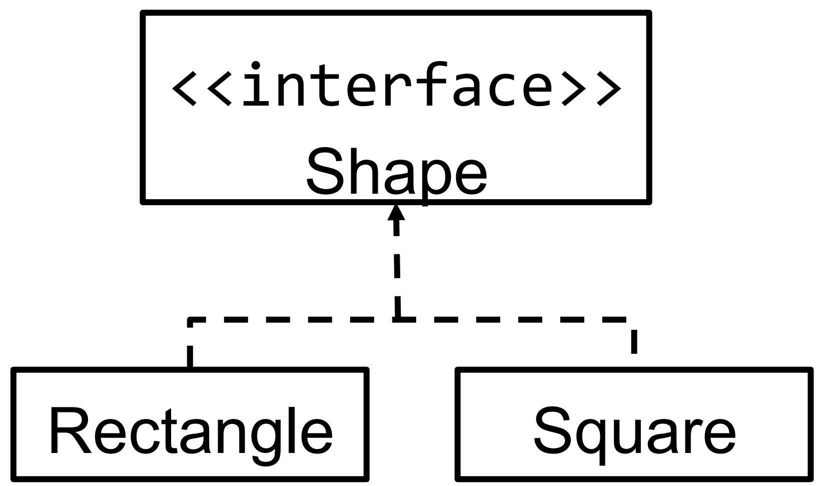
Design principles: Liskov substitution principle

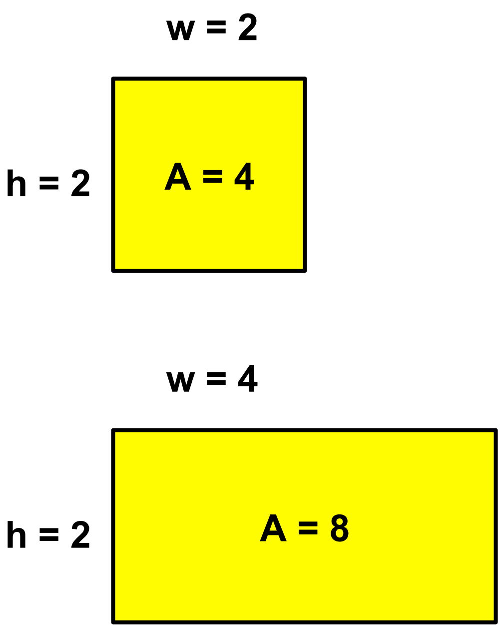


Which design below should be used?





Design principles: Liskov substitution principle

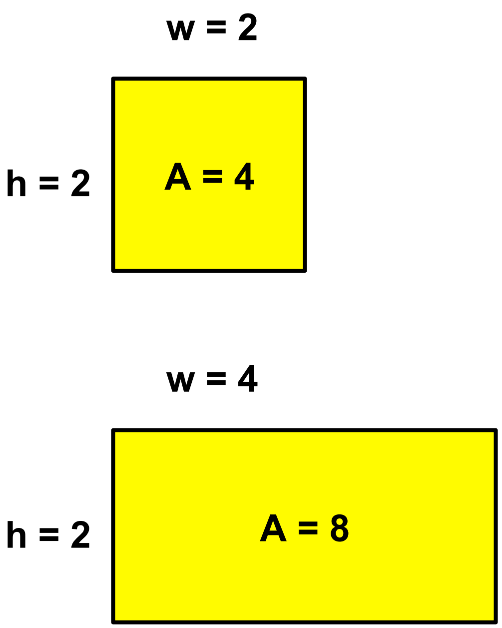



```
Rectangle r =
  new Rectangle(2,2);


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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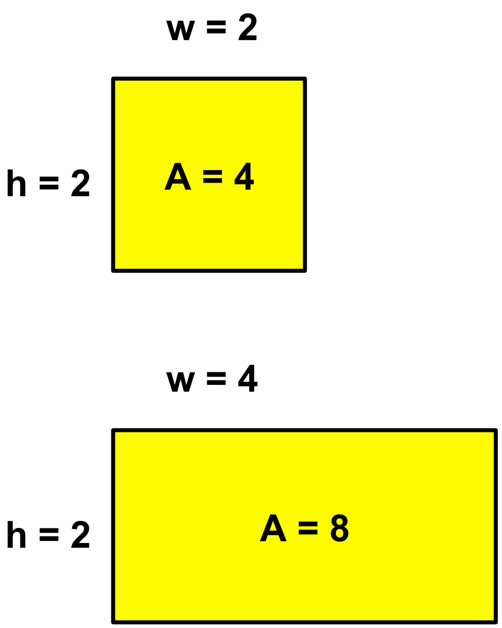
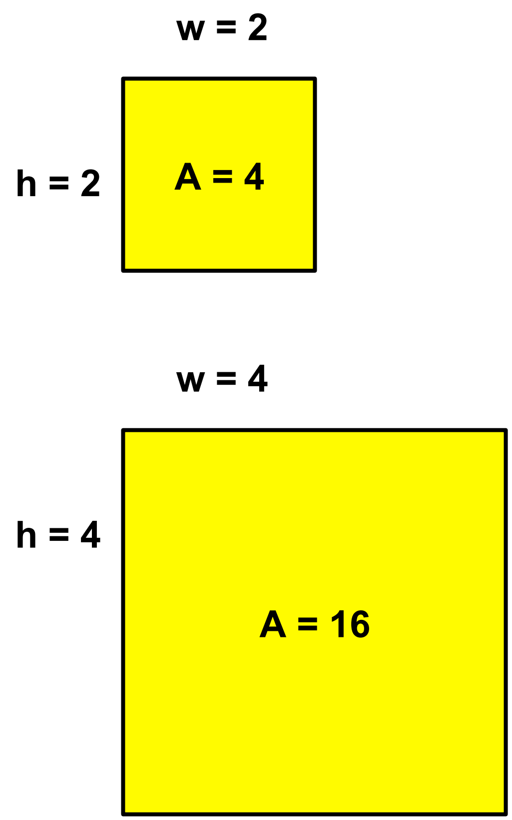
Design principles: Liskov substitution principle



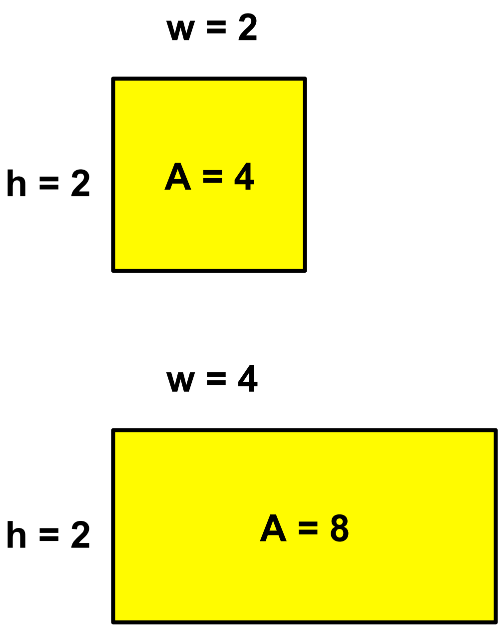

```
Rectangle r =
  new Rectangle(2,2);
  new Square(2);

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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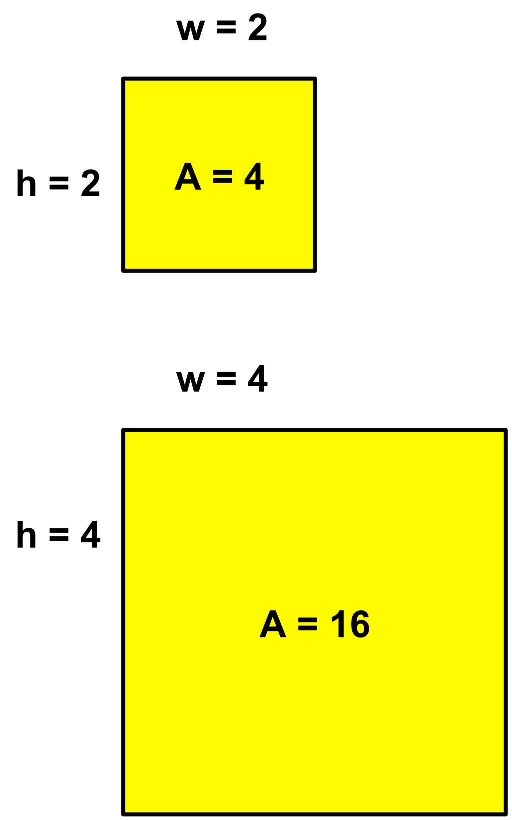
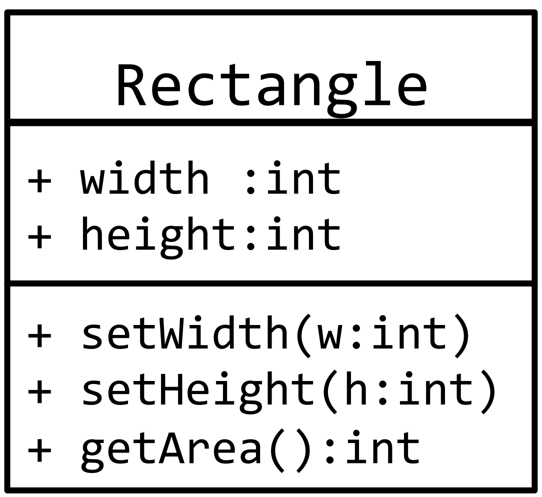


Design principles: Liskov substitution principle

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.

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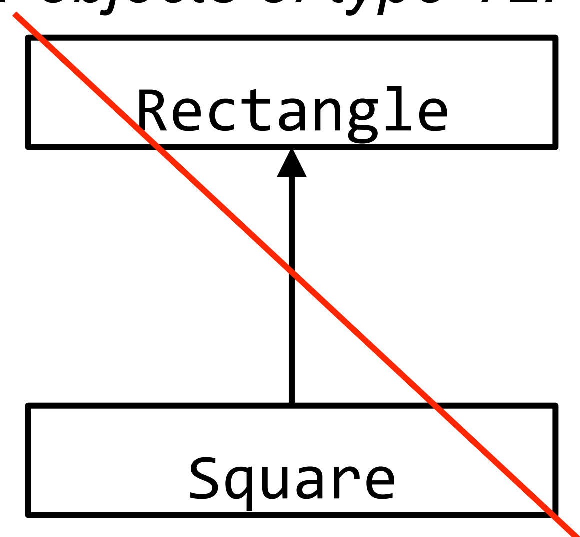

Violates the Liskov substitution principle!

Design principles: Liskov substitution principle

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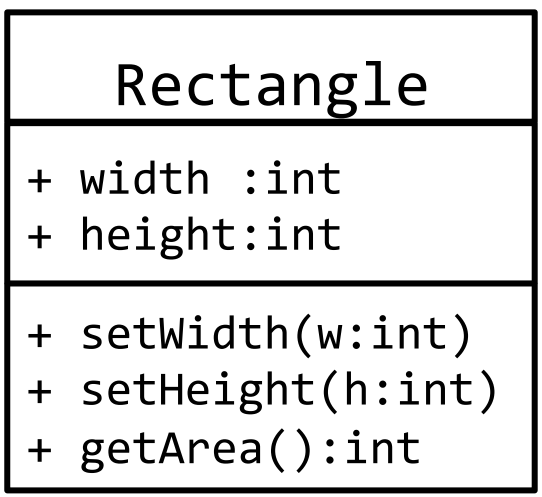

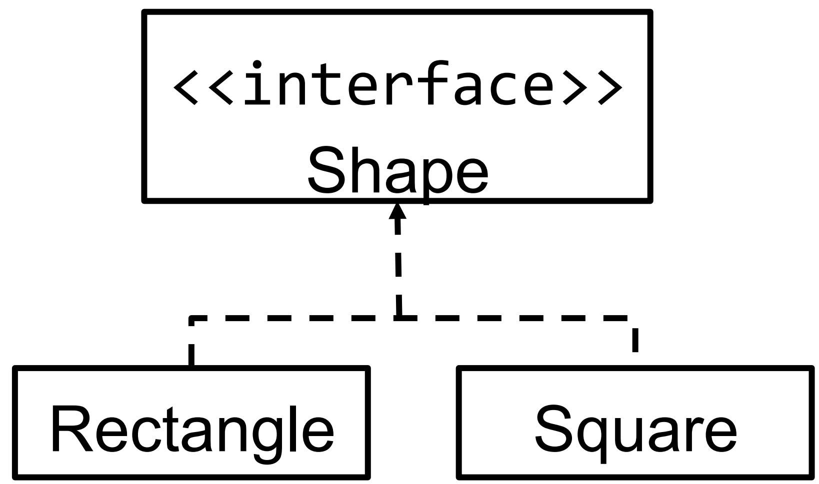

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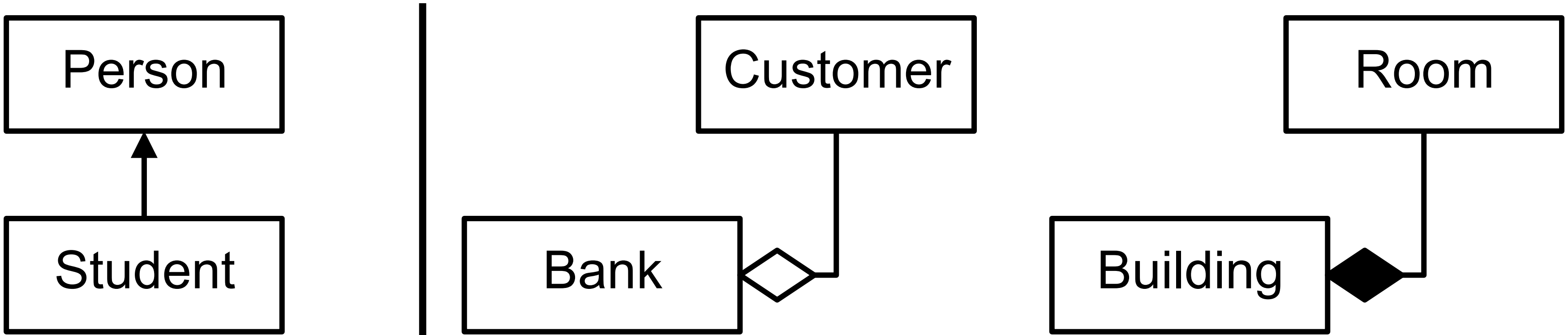
Inheritance vs. (Aggregation vs. *Composition*)




```
public class Student
    extends Person{
 public Student(){
 }

 ...
}
```

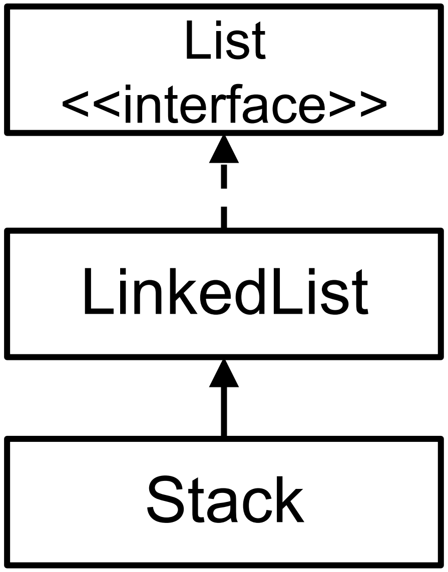
```
public class Bank {
 Customer c;
 public Bank(Customer c){
  this.c = c;
 }
 ...
}
```

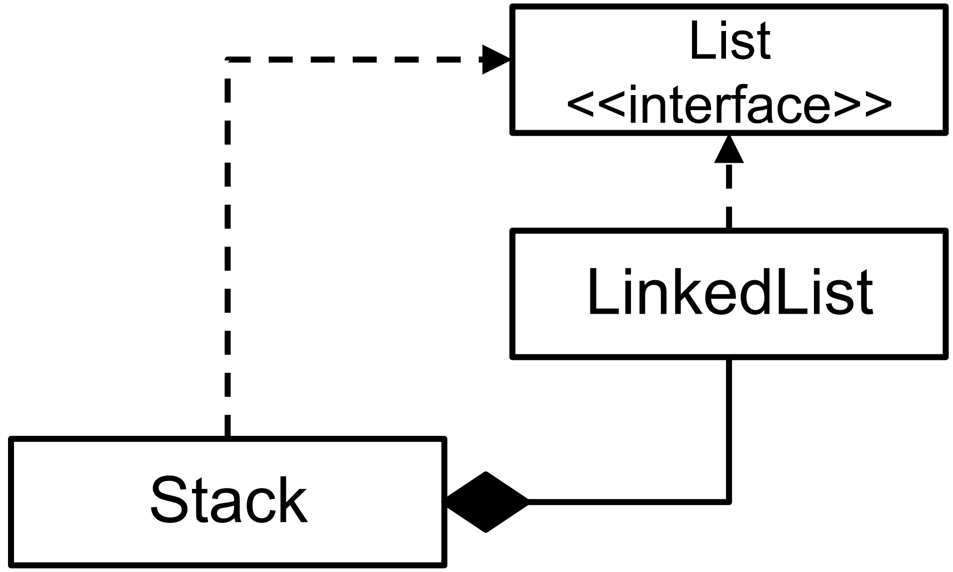
```
public class Building {
 Room r;
 public Building(){
  this.r = new Room();
 }
 ...
}
```

is-a relationship

has-a relationship

Design choice: inheritance or composition?



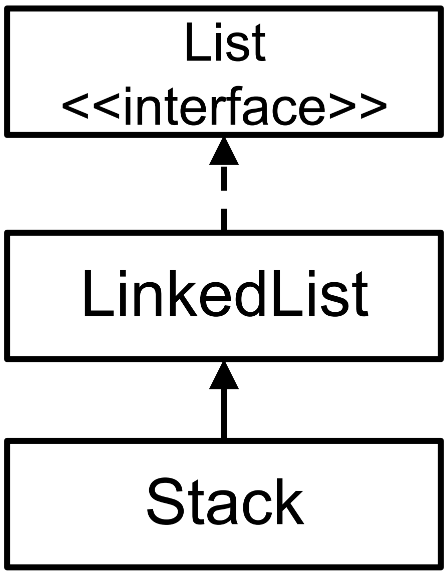


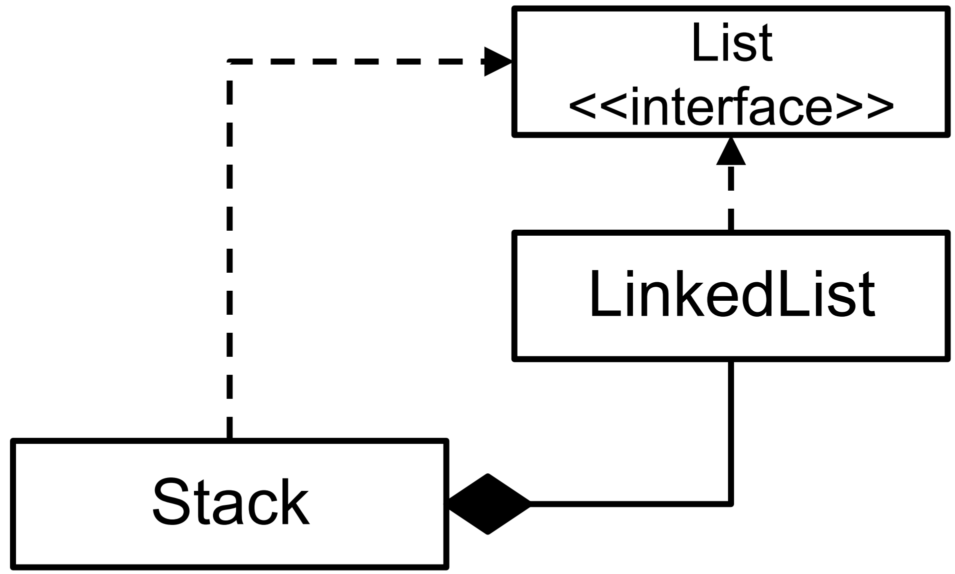

```
public class Stack<E>
     extends LinkedList<E> {
  ...
}
```

```
public class Stack<E> implements List<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 compositions.

Cons

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

Composition/aggregation over inheritance allows more flexibility.

OO design principles: summary

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