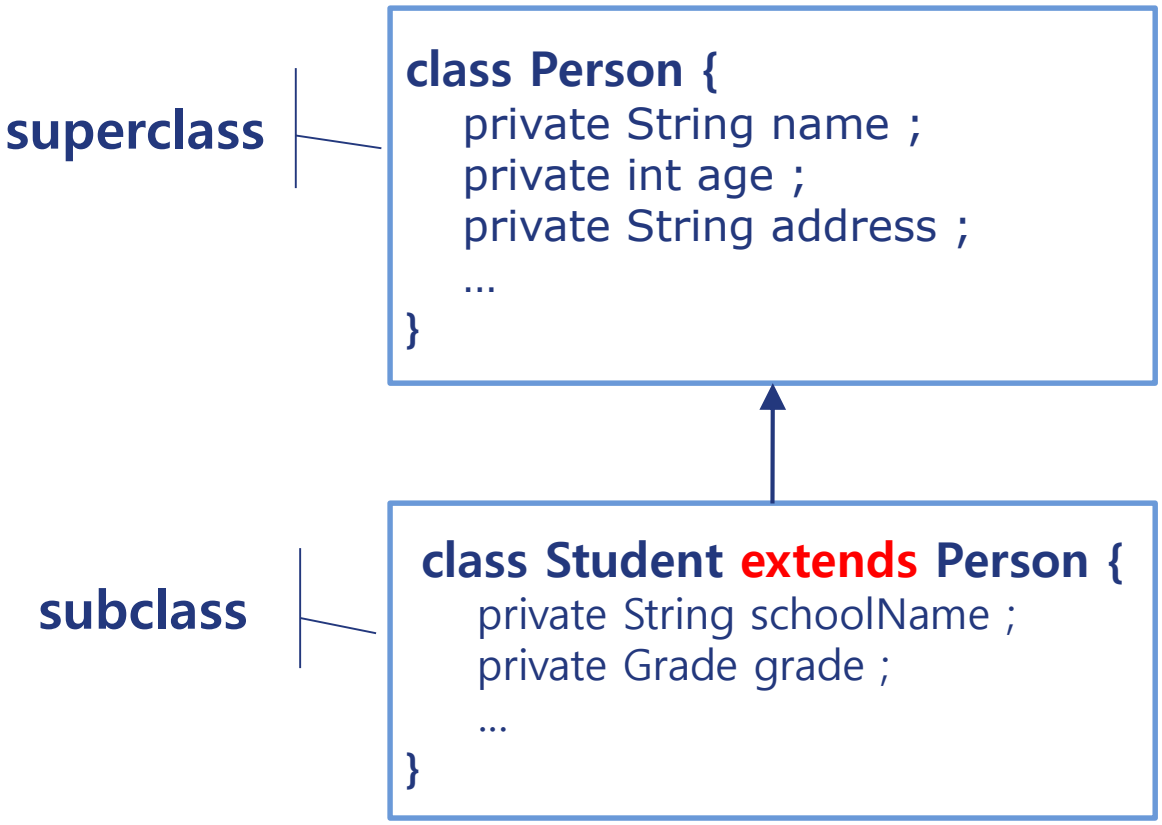
Inheritance

- Inheritance – concept
- super keyword
- Protected members
- Constructions of subclass
- polymorphism
- Abstract classes and abstract methods
- Final classes and final methods
- Reflection

Inheritance

- A **subclass** inherits all the members of the **superclass**.



class Person

```
class Person {
    private String name ;
    private int age ;
    private String address ;

    public Person(String name, int age, String address) {
        this.name = name ; this.age = age ; this.address = address ;
    }
    public String getName() { return name ; }
    public void rename(String name) { this.name = name ; }
    public int getAge() { return age ; }
    public void increaseAge() { age ++ ; }
    public String getAddress() { return address ; }
    public void moveTo(String address) { this.address = address ; }
    @Override
    public String toString() {
        return String.format("%s, %d, %s", name, age, address) ;
    }
    // override hashCode() and equals()
}
```

class Student

```
public class Student extends Person {
    private String schoolName ;
    private Grade grade = new Grade();

    public Student(String name, int age, String address, String schoolName) {
        super(name, age, address) ;
        this.schoolName = schoolName ;
    }
    public String getSchoolName() { return schoolName ; }
    public void setSchoolName(String schoolName) {
        this.schoolName = schoolName ;
    }
    public Grade getGrade() { return grade ; }
    public void upGrade() { grade.upGrade() ; }
    @Override
    public String toString() {
        return String.format("%s, %d, %s, %s, %s",
            getName(), getAge(), getAddress(), schoolName, grade) ;
    }
    // override hashCode() and equals()
}
```

class Grade

```
public class Grade {
    public static final int FRESH = 1 ;
    public static final int SOPHOMORE = 2 ;
    public static final int JUNIOR = 3 ;
    public static final int SENIOR = 4 ;

    private int grade ;
    public Grade() { this.grade = FRESH ; }
    public Grade(int grade) { this.grade = grade ; }

    public int getGrade() { return grade ; }
    public void upGrade() { if ( grade != SENIOR ) grade ++ ; }
    @Override
    public String toString() { return String.valueOf(grade); }
    // override hashCode() and equals()
}
```

Inheritance

- Clients of a class can access the **inherited public members** in addition to its public members.

```
public class StudentTest {
    public static void main(String[] args) {
        Student s1 = new Student("Ford", 19, "Kimhae", "PNU") ;
        System.out.println(s1) ;
        s1.setSchoolName("한국대학교") ;
        s1.upGrade() ;
        System.out.println(s1) ;

        Student s2 = new Student("Porter", 20, "Ulsan", "PNU") ;
        System.out.println(s2) ;
        s2.rename("Harrison") ;
        s2.increaseAge() ;
        System.out.println(s2) ;
    }
}
```

```
Ford, 19, Kimhae, PNU, 1
Ford, 19, Kimhae, 한국대학교, 2
Porter, 20, Ulsan, PNU, 1
Harrison, 21, Ulsan, PNU, 1
```

Access to the inherited members

- A subclass itself can access the **inherited public members**

```
class Person {
    private String name ;
    private int age ;
    private String address ;

    public String getName() { return name ; }
    public int getAge() { return age ; }
    public String getAddress() { return address ; }
}
```

```
class Student extends Person {
   private String schoolName ;
   private Grade grade = new Grade();
   ...
   public String toString() {
      return String.format("%s, %d, %s, %s, %s",
          getName(), getAge(), getAddress(), schoolName, grade) ;
          // name, age, and address can not be accessed because they are private
   }
}
```

protected member

- **Protected members** can be directly accessed from subclass.

```
class Person {
    protected String name ;
    protected int age ;
    protected String address ;
    ...
```

```
class Student extends Person {
  private String schoolName ;
  private Grade grade = new Grade();

    ...

  public String toString() {
    return String.format("%s, %d, %s, %s, %s",
        name, age, address, schoolName, grade) ;
        // name, age, address can be accessed
        // now that they are protected!
  }
}
```

- **The use of protected members should be limited** because they can cause poor maintainability.

Access to the inherited members

- You can use the keyword "**super**" to indicate the members of the superclass

```
class Person {
    protected String name ;
    protected int age ;
    protected String address ;
    …
```

However, we should consider different names for different concepts

```
class Student extends Person {
   private String name ;
   private Grade grade = new Grade();

      …

   public String toString() {
      return String.format("%s, %d, %s, %s, %s",
          super.name, age, address, name, grade) ;
   }
}
```

Add new members to subclasses

- A subclass can add new members for its own purpose.

```
class Student extends Person {
    private String schoolName ;
    private Grade grade = new Grade();

    public Student(String name, int age, String address, String schoolName) {
        super(name, age, address) ;
        this.schoolName = schoolName ;
    }
    public String getSchoolName() { return schoolName ; }
    public void setSchoolName(String schoolName) {
        this.schoolName = schoolName ;
    }
    public Grade getGrade() { return grade ; }
    public void upGrade() { grade.upGrade() ; }
    @Override
    public String toString() {
        return String.format("%s, %d, %s, %s, %s",
            getName(), getAge(), getAddress(), schoolName, grade) ;
    }
    // override hashCode() and equals()
}
```

Inheritance and Overloading

- Overloading is applied for inherited member functions.

```
class Person {
    …
    private int age ;
    …

    public int getAge() { return age ; }
    protected void setAge(int age) {
        this.age = age ;
    }
   public void increaseAge() { age ++ ; }
}
```

```
class Student extends Person {

   …
   public void increaseAge(int delta) {
     setAge(getAge()+delta) ;
   }
   …
}
```

```
Student s1 = new Student("Ford", 19,
                         "Kimhae", "PNU") ;

s1.increaseAge() ;
s1.increaseAge(2) ;
```

Constructors of subclasses

- A constructor of a subclass can initialize for members of a superclass through the constructor of its superclass.

```
class Person {
    private String name ;
    private int age ;
    private String address ;

    public Person(String name, int age, String address) {
        this.name = name ; this.age = age ; this.address = address ;
    }
...
```

```
class Student extends Person {
    private String schoolName ;
    private Grade grade = new Grade();

    public Student(String name, int age, String address, String schoolName) {
        super(name, age, address) ;
        this.schoolName = schoolName ;
    }
    ...
```

super(..) should be the **first** statement

class Object

- Object is the implicit superclass of every class when the class does not specify its superclass.

```
class Person {
    private String name ;
    private int age ;
    private String address ;
    …
}
```

=

```
class Person extends Object {
    private String name ;
    private int age ;
    private String address ;
    …
}
```

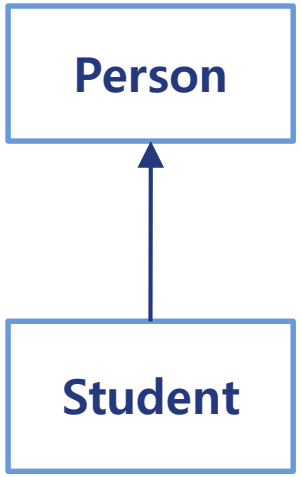
class Object

Method Summary	
protected Object	**clone**() Creates and returns a copy of this object.
boolean	**equals**(Object obj) Indicates whether some other object is "equal to" this one.
protected void	**finalize**() Called by the garbage collector on an object when garbage collection determines that there are no more references to the object.
Class<? extends Object>	**getClass**() Returns the runtime class of an object.
int	**hashCode**() Returns a hash code value for the object.
String	**toString**() Returns a string representation of the object.

Polymorphism

- Superclass variable can point to any descent objects.

```
...
Person brown = new Person("Brown", 19, "Busan") ;
Student ford = new Student("Ford", 19, "Kimhae", "PNU") ;

Person p ; // r can point to Person and Person's descents.

p = brown ;  // OK
p = ford ; // OK

Student s ;
s = brown ;  // Type mismatch: cannot convert from Person to Student

s = ford ;  // OK
s = (Student) brown ; // OK, but not recommended !
```



Polymorphism

```
public class PolymorphismTest {
  public static void main(String[] args) {
    Person p1 = new Person("Brown", 19, "Busan") ;
    Person p2 = new Person("James", 20, "Masan") ;

    Student s1 = new Student("Ford", 19, "Kimhae", "PNU") ;
    Student s2 = new Student("Porter", 20, "Ulsan", "PNU") ;

    Person[] list = {p1, p2, s1, s2} ;

    for ( Person p: list) {
      System.out.printf("%s, %d%n", p.getName(), p.getAge()) ;
      // Note: p.getSchoolName() not allowed
      // because p is a type of Person, not Student
      // The method getSchoolName() is undefined for the type Person
    }
  }
}
```

```
Brown, 19, Busan
James, 20, Masan
Ford, 19, Kimhae
Porter, 20, Ulsan
```

Polymorphism

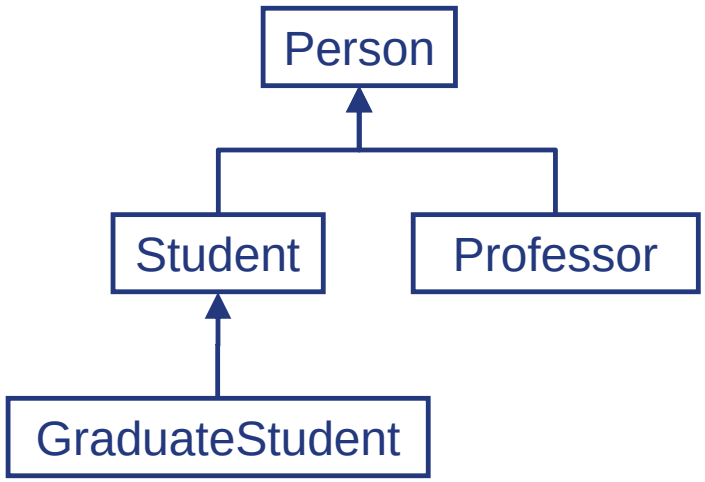
- **instanceof** operator can to used to determine the class of an object

```
public class InstanceOfTest {
   public static void main(String[] args) {
       Person p1 = new Person("Brown", 19, "Busan") ;
       Person p2 = new Person("James", 20, "Masan") ;
       Student s1 = new Student("Ford", 19, "Kimhae", "PNU") ;
       Student s2 = new Student("Porter", 20, "Ulsan", "PNU") ;

       Person[] list = {p1, p2, s1, s2} ;

       for ( Person p: list) {
           System.out.printf("%s, %d, %s%n", p.getName(), p.getAge(), p.getAddress()) ;
           if ( p instanceof Student ) {
               Student s = (Student) p ;
               System.out.printf(" School: %s, %s%n", s.getSchoolName(), s.getGrade()) ;
           }
       }
   }
}
```

```
Brown, 19, Busan
James, 20, Masan
Ford, 19, Kimhae
 School: PNU, 1
Porter, 20, Ulsan
 School: PNU, 1
```

Inheritance Hierarchy

- A set of related classes comprises an hierarchy.




```
class Food { … }
class Person {
    …
    public void sleep() { … }
    public void eat(Food food) { … }
}
class Course { … }
class Student exnteds Person {
    …
    public void transferTo(School school) {…}
    public void takeCourse(Course course) { … }
    public void takeExam(Course course) { … }
}
class GraduateStudent extends Student {
    …
    public void writeThesis() { … }
    public void participateIn(Project project) { … }
    public void assignAdvisor(Professor professor) { … }
}
class Professor extends Person {
    …
    public void teach(Course course) { … }
    public void lead(Project project) { … }
}
```

Abstract method

- A method is abstract if you cannot define its implementation

We know that shapes can be drawn and erased.
However, we cannot implement them.

```
public class Shape {
    private int lineColor ;

    public int getLineColor() { return lineColor ; }
    public void setLineColor(int color) { lineColor = color ; }

    public abstract void draw() ;
    public abstract void erase() ;
    public abstract void copyToClipboard() ;
    public abstract void pasteFromClipboard() ;
}
```

Abstract class

- An abstract class cannot be used to create objects

```
public abstract class AbstractClass {
    …
}
```

```
public class ConcreteClass extends AbstractClass {
    …
}
```

```
…
AbstractClass a1 = new AbstractClass() ; // Cannot instantiate the type Shape
ConcreteClass c = new ConcreteClass() ; // OK


AbstractClass a2 = new ConcreateClass() ; // OK
```

Abstract class

- A class should be abstract if it has abstract methods

Without abstract, Shape should be abstract to define abstract methods

```
public abstract class Shape {
    private int lineColor ;

    public int getLineColor() { return lineColor ; }
    public void setLineColor(int color) { lineColor = color ; }

    public abstract void draw() ;
    public abstract void erase() ;
    public abstract void copyToClipboard() ;
    public abstract void pasteFromClipboard() ;
}
```

Abstract class

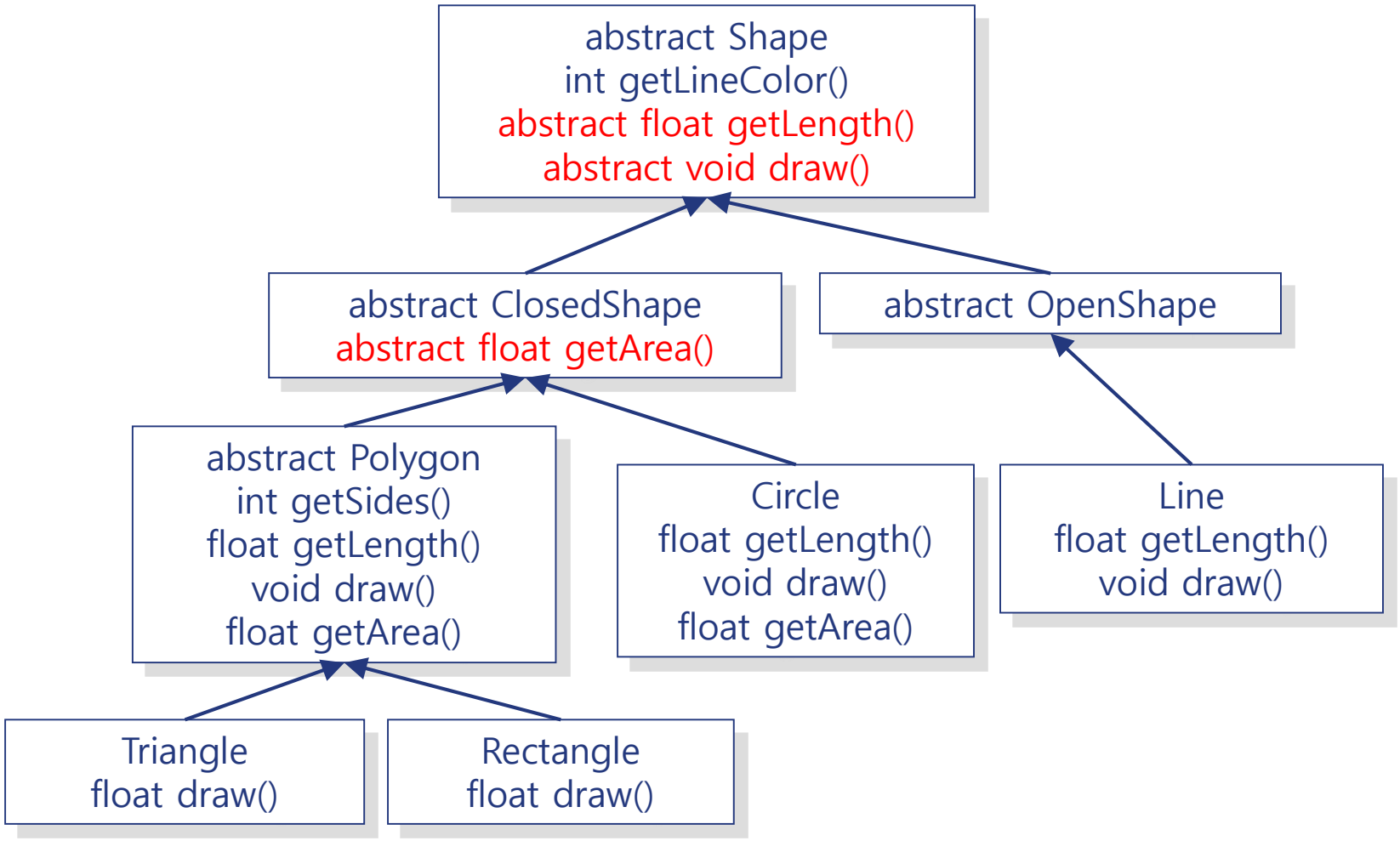
- A class with no abstract methods can be abstract

```
public abstract class Person {
    private String name ;
    private int age ;
    private String address ;

    public String getName() { return name ; }
    public int getAge() { return age ; }
    public String getAddress() { return address ; }
}
```

```
Person p = new Person() ;
// cannot instantiate Person, because Person is abstract
```

- This kind of classes are only used to define subclasses, not create objects.

Inheritance Hierarchy for Shape: Revised with Abstract Class



Shape, ClosedShape, OpenShape

```
public abstract class Shape {
    private int lineColor ;

    public int getLineColor() { return lineColor ; }
    public void setLineColor(int color) { lineColor = color ; }

    public abstract void draw() ;
    public float getLength();
}
```

```
public abstract class ClosedShape extends Shape {
    public abstract float getArea() ;
}
```

```
public abstract class OpenShape extends Shape {
}
```

Polygon

```
public abstract class Polygon extends ClosedShape {
    private List<Point> points = new ArrayList<>() ;

     protected void addPoint(float x, float y) {
          Point p = new Point(x, y) ;
          points.add(p) ;
     }
    @Override
     public float getLength() { float length = 0 ; return length ; }
    @Override
     public float getArea() { float area = 0 ; return area ; }
    @Override
     public void draw() {
          for ( Point p : points) System.out.print(p) ;
          System.out.println() ;
     }
 }
```

Triangle, Rectangle

```
public class Triangle extends Polygon {
     public Triangle(float x1, float y1, float x2, float y2, float x3, float y3) {
         addPoint(x1, y1) ; addPoint(x2, y2) ; addPoint(x3, y3) ;
     }
     @Override
     public void draw() {
         System.out.println("Triangle") ;
         super.draw();
     }
 }
```

```
public class Rectangle extends Polygon {
     public Rectangle(float x1, float y1, float x2, float y2,
             float x3, float y3, float x4, float y4) {
         addPoint(x1, y1) ; addPoint(x2, y2) ; addPoint(x3, y3) ; addPoint(x4, y4) ;
     }
     @Override
     public void draw() {
         System.out.println("Rectangle") ;
         super.draw();
     }
 }
```

Circle

```
public class Circle extends ClosedShape {
    private Point center ;
    private float radius ;

    public Circle(float x, float y, float radius) {
        center = new Point(x, y) ;
        this.radius = radius ;
    }
    @Override
    public float getLength() { return (float) (2 * Math.PI * radius) ; }
    @Override
    public float getArea() { return (float) (Math.PI * radius * radius) ; }
    @Override
    public void draw() {
        System.out.println("Circle") ;
        System.out.printf("Center: %s, Radius: %6.2f%n", center, radius) ;
    }
}
```

Line

```
public class Line extends OpenShape {
    private Point start, end ;

    public Line(float x1, float y1, float x2, float y2) {
        start = new Point(x1, y1) ; end = new Point(x2, y2) ;
    }
   @Override
    public float getLength() {
        return (float) (Math.sqrt( (end.getX() - start.getX()) *
           (end.getX() - start.getX()) + (end.getY() - start.getY()) *
           (end.getY() - start.getY()) ) ) ;
   }
   @Override
    public void draw() {
        System.out.println("Line") ;
        System.out.printf("\tStart: %s, End: %s%n", start, end) ;
    }
}
```

ShapeHierarchyTest

```
public class ShapeHierarchy {
   public static void main(String[] args) {
      Circle c1 = new Circle(0F, 5.5F, 10F) ;
      c1.draw() ;
      Triangle t1 = new Triangle(0F, 0F, 10F, 0F, 20F, 20F) ;
      t1.draw() ;
      Rectangle r1 = new Rectangle(0F, 0F, 10F, 0F, 10F, 10F, 0F, 10F) ;
      r1.draw() ;
      Line l1 = new Line(10F, 10F, 15F, 10F) ;
      l1.draw() ;
   }
}
```

```
Circle
Center: [     0.00,      5.50], Radius:  10.00
Triangle
[     0.00,      0.00][    10.00,      0.00][    20.00,     20.00]
Rectangle
[     0.00,      0.00][    10.00,      0.00][    10.00,     10.00][     0.00,     10.00]
Line
                Start: [    10.00,     10.00], End: [    15.00,     10.00]
```

Generic Shape List

- ArrayList of Shape can support any descents of Shape

```
public class ShapeListTest {
    public static void main(String[] args) {
        List<Shape> shapes = new ArrayList<>() ;

        Circle c1 = new Circle(0F, 5.5F, 10F) ;
        Triangle t1 = new Triangle(0F, 0F, 10F, 0F, 20F, 20F) ;
        Rectangle r1 = new Rectangle(0F, 0F, 10F, 0F, 10F, 10F, 0F, 10F) ;

        shapes.add(c1) ;
        shapes.add(t1) ;
        shapes.add(r1) ;

       for ( Shape s : shapes ) s.draw() ; // polymorphic invocation of draw()
    }
}
```

Abstract vs. Interface

- Polymorphism is also possible by Interface.
- 클래스, 추상 클래스/인터페이스의 비교

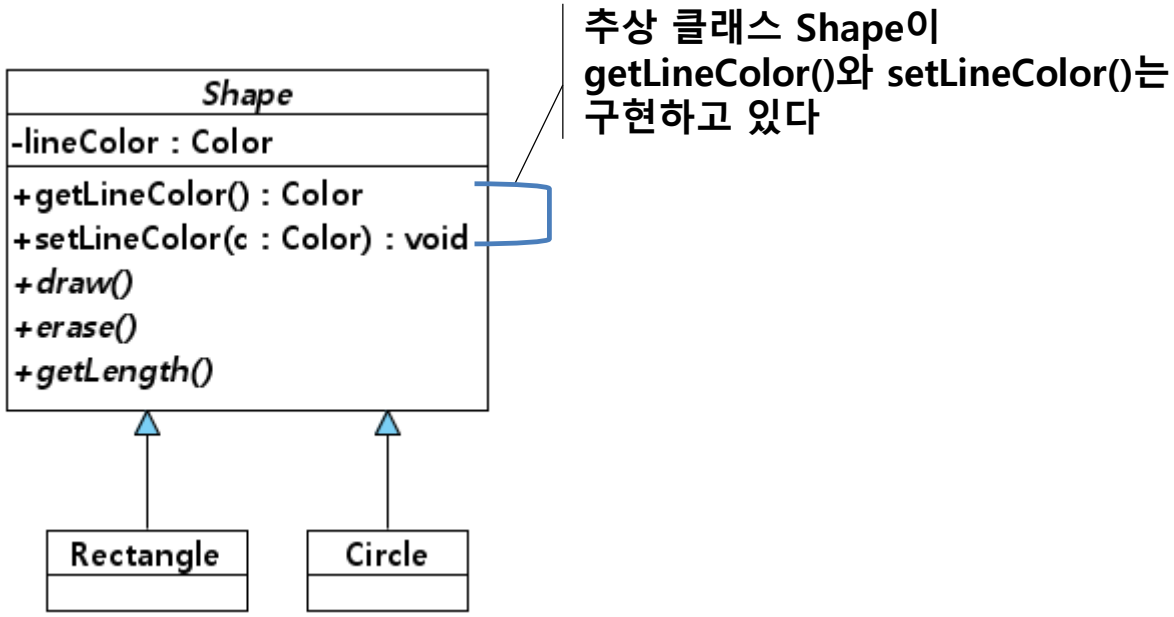
	구체 클래스	추상 클래스	인터페이스
객체의 생성	가능	불가능	
용도	기능의 구현	기능의 명세	

- 추상 클래스와 인터페이스의 비교

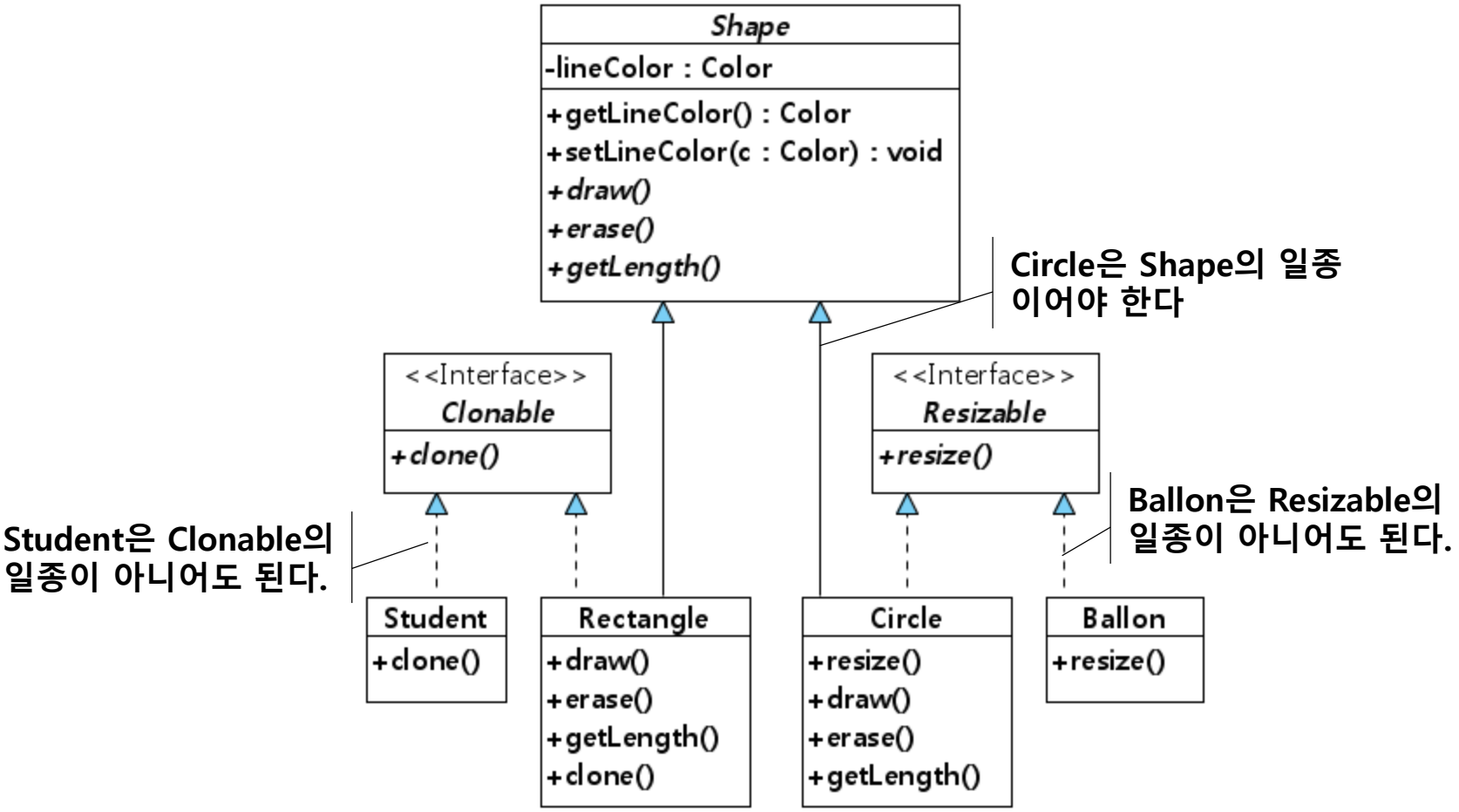
	추상 클래스	인터페이스
구현의 포함 여부	일부 가능	불가능
명세의 영향 대상	자식 클래스 (Is-A 관계 준수)	임의의 구현 클래스

Abstract class vs. Interface

- Some of the methods in abstract class can be implemented



Abstract class vs. Interface



final class

- Classes declared with **final** cannot be extended!

```
class Person {
    …
}
class Student extends Person {      // OK
    …
}
class Undergraduate extends Student {      // OK
    …
}
final class Teacher extends Person {      // OK
    …
}

class HomeroomTeacher extends Teacher {
    // ERROR; final class Teacher cannot be extended!
    …
}
```

final method

- Methods declared with **final** cannot be overridden!

```
class Person {
   public toStrign() { … }
   public final String getName() { … }
}
class Student extends Person {
   public String toStrig() { … }      // OK
   public String getName() {…}   // ERROR; Cannot override the final method!
}
```

Reflection

- With reflection, you can analyze the capabilities of classes from their byte codes.

```
Enter class name (e.g. java.util.Date):
Person
class Person
{
   public Person(java.lang.String, int, java.lang.String);

   public int getAge();
   public void increaseAge();
   public java.lang.String getAddress();
   public java.lang.String toString();
   public java.lang.String getName();
   public void rename(java.lang.String);
   public void moveTo(java.lang.String);

   private java.lang.String name;
   private int age;
   private java.lang.String address;
}
```

```
import java.util.*;
import java.lang.reflect.*;
public class ReflectionTest {
   public static void main(String[] args) {
      String name;
      if (args.length > 0) name = args[0];
      else  {
         Scanner scanner = new Scanner(System.in);
         System.out.println("Enter class name (e.g. java.util.Date): ");
         name = scanner.next();
         scanner.close();
      }
      try {
         // print class name and superclass name
         Class<?> cl = Class.forName(name); // java.lang.Class
         Class<?> supercl = cl.getSuperclass();
         System.out.print("class " + name);
         if (supercl != null && supercl != Object.class)
              System.out.print(" extends " + supercl.getName());

         System.out.print("₩n{₩n");
         printConstructors(cl);
         System.out.println();
         printMethods(cl);
         System.out.println();
         printFields(cl);
         System.out.println("}");
      }
      catch(ClassNotFoundException e) { e.printStackTrace(); }
   }
```

```
public static void printConstructors(Class<?> cl) {
   // java.lang.reflect.Constructor
    Constructor<?>[] constructors = cl.getDeclaredConstructors();

    for (Constructor<?> c : constructors) {
       System.out.print("    " + Modifier.toString(c.getModifiers()));
       System.out.print(" " + c.getName() + "(");

       // print parameter types
       Class<?>[] paramTypes = c.getParameterTypes();
       for (int j = 0; j < paramTypes.length; j++) {
          if (j > 0) System.out.print(", ");
          System.out.print(paramTypes[j].getName());
       }
       System.out.println(");");
    }
}
```

```
public static void printMethods(Class<?> cl) {
   Method[] methods = cl.getDeclaredMethods();
   for (Method m : methods) {
      Class<?> retType = m.getReturnType();

      // print modifiers, return type and method name
      System.out.print("   " + Modifier.toString(m.getModifiers()));
      System.out.print(" " + retType.getName() + " " + m.getName() + "(");

      // print parameter types
      Class<?>[] paramTypes = m.getParameterTypes();
      for (int j = 0; j < paramTypes.length; j++) {
         if (j > 0) System.out.print(", ");
         System.out.print(paramTypes[j].getName());
      }
      System.out.println(");");
   }
}
```

```
    public static void printFields(Class<?> cl) {
        Field[] fields = cl.getDeclaredFields();

        for (Field f : fields) {
            Class<?> type = f.getType();
            System.out.print("    " + Modifier.toString(f.getModifiers()));
            System.out.println(" " + type.getName() + " " + f.getName() + ";");
        }
    }
}
```