Class hierarchy

- Subclasses inherit attributes from parent class
- Subclasses can add functionality
  - A subclass is more specific than its parent
  - Subclasses can be used in place of the parent class
- ```
  class Employee {...}

  class Manager extends Employee{
       private String secretary;
       public boolean setSecretary(name s){ ... }
       public String getSecretary(){ ... }
  }

  Employee e = new Manager()
  ```
  ```

Overriding and dynamic dispatch

- Subclass can override parent class method
  - Function name and signature must both match
  - `public equals(Date d)` does not override `public equals (Object o)`
- Dynamic dispatch allows each object to "know" which method to use.

```
class Employee { ... public double bonus(double p) ...}

class Manager extends Employee{
   ...  public double bonus(double p) ...
}

Employee e = new Manager();
...
print(e.bonus(x));
```

Java class hierarchy

- No multiple inheritance — tree-like
- Universal superclass `Object`
- Useful methods defined in `Object`

```
boolean equals(Object o)  // defaults to pointer equality

String toString()         // converts the values of the
                          // instance variable to String
```

- To print `o`, use `System.out.println(o+"");`

Subclasses, subtyping and inheritance

- Class hierarchy provides both subtyping and inheritance
- Subtyping
  - Compatibility of interfaces.
  - `B` is a subtype of `A` if every function that can be invoked on an object of type `A` can also be invoked on an object of type `B`.
- Inheritance
  - Reuse of implementations.
  - `B` inherits from `A` if some functions for `B` are written in terms of functions of `A`.

Subtyping vs inheritance

Consider the following classes

- `queue`, with methods `insert-rear`, `delete-front`
- `stack`, with methods `insert-front`, `delete-front`
- `deque`, with methods `insert-front`, `delete-front`, `insert-rear`, `delete-rear`

Subtyping vs inheritance

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What are the subtype and inheritance relationships between these classes?

Subtyping vs inheritance

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Subtyping

- `deque` has more functionality than `queue` or `stack`
- `deque` is a subtype of both these types

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Subtyping

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Inheritance

- Can suppress two functions in a `deque` and use it as a `queue` or `stack`
- Both `queue` and `stack` inherit from `deque`

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Using one idea (hierarchical classes) to implement both concepts blurs the distinction between the two

Abstract classes

- Collect together classes under a common heading
- Classes `Circle`, `Square` and `Rectangle` are all shapes
- Create a class `Shape` so that `Circle`, `Square` and `Rectangle` extend `Shape`

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- We want to force every shape to define a function

  `public double perimeter()`
  - Define a function in `Shape` that returns an absurd value

    `public double perimeter() { return -1.0; }`
  - Rely on the subclass to redefine this function

Abstract classes . . .

- A better solution
  - Provide an abstract definition in `Shape`

    ```
    public abstract double perimeter();
    ```

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Abstract classes . . .

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- Forces subclasses to provide a concrete implementation
- Cannot create objects from a class that has abstract functions
- `Shape` must itself be declared to be `abstract`

```
abstract class Shape{
  ...
  public abstract double perimeter();
  ...
}
```

Abstract classes . . .

- Can still declare variables whose type is an abstract class

```
Shape sarr[] = new Shape[3];

Circle c = new Circle(...);    sarr[0] = c;
Square s = new Square(...);    sarr[1] = s;
Rectangle r = new Rectangle(...);  sarr[2] = r;

for (i = 0; i < 2; i++){
  size = sarr[i].perimeter();
     // each sarr[i] calls the appropriate method
  ...
}
```

Generic functions

- Use abstract classes to specify generic properties

```
abstract class Comparable{
  public abstract int cmp(Comparable s);
    // return -1 if this < s, 0 if this == 0,
    //         +1 if this > s
}
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Generic functions

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abstract class Comparable{
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```

- Now we can sort any array of objects that extend `Comparable`

```
class Sortfunctions{
  public static void quicksort(Comparable[] a){
    ...
    // Usual code for quicksort, except that
    // to compare a[i] and a[j] we use a[i].cmp(a[j])
  }
}
```

Generic functions . . .

- ```
  class Sortfunctions{
    public static void quicksort(Comparable[] a){
      ...
    }
  }
  ```
- To use this definition of `quicksort`, we write

```
class Myclass extends Comparable{
  double size;   // quantity used for comparison
  ...
  public int cmp(Comparable s){
    if (s instanceof Myclass){
      // compare this.size and ((Myclass) s).size
      // Note the cast to access s.size
      ...
    }
  }
}
```
```

Mutiple inheritance

- How do can we sort `Circle` objects?
  - `Circle` already extends `Shape`
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- A class that extends an interface is said to "implement" it:

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class Circle extends Shape implements Comparable{
  public double perimeter(){...}
  public int cmp(Comparable s){...}
    ...
}
```

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- Can implement multiple interfaces