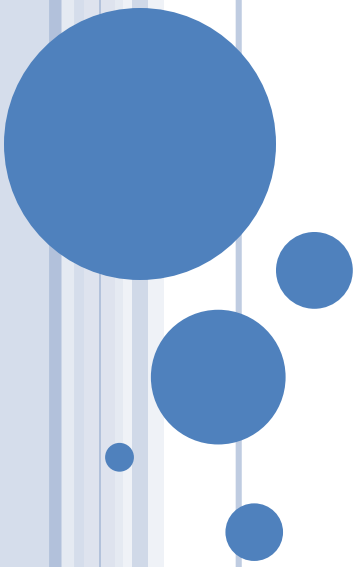


Comp 401
Dynamic Dispatch and Virtual and Abstract Methods

Instructor: Prasun Dewan

Prerequisites

- Inheritance
- Abstract Classes

A PointHistory Implementation

```
public class APointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {return size == MAX_SIZE;}
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = new ACartesianPoint(x, y);
      contents[size] = p;
      size++;
    }
  }
}
```

A PolarPointHistory Implementation

```
public class APolarPointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int
    return contents[index];
  }
  protected boolean isFull() {return size == MAX_SIZE;}
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = new APolarPoint(x, y);
      contents[size] = p;
      size++;
    }
  }
}
```

Reducing code duplication?

A PolarPointHistory Implementation

```
public class APolarPointHistoryWithAddMethod
                        extends APointHistory {
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = new APolarPoint(x, y);
      contents[size] = p;
      size++;
    }
  }
}
```

Only line changed, still code duplication

A PointHistory Implementation

```
public class ACartesianPointHistoryWithDynamicallyDispatchedMethod
                  implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
  protected Point createPoint(int x, int y) {
     return new ACartesianPoint(x, y);
  }
}
```

Overriding Method

```
public class APolarPointHistoryWithDynamicallyDispatchedMethod
        extends ACartesianPointHistoryWithDynamicallyDispatchedMethod {
  protected Point createPoint(int x, int y) {
    return new ACartesianPoint(x, y);
  }
}
```

```
public static void main (String[] args) {
  PointHistory pointHistory =
    new APolarPointHistoryWithDynamicallyDispatchedMethod();
  pointHistory.addElement(50, 100);
}
```

A PointHistory Implementation

```
public  class ACartesianPointHistoryWithDynamicallyDispatchedMethod
                implements PointHistory {
```

```
public class APolarPointHistoryWithDynamicallyDispatchedMethod
        extends ACartesianPointHistoryWithDynamicallyDispatchedMethod {
  protected Point createPoint(int x, int y) {
    return new ACartesianPoint(x, y);
  }
}
```

Static dispatching: call most specific method known when caller method was compiled

```
PointHistory pointHistory =
    new APolarPointHistoryWithDynamicallyDispatchedMethod();
  pointHistory.addElement(50, 100);
```

```
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full histor
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
  protected Point createPoint(int x, int y) {
     return new ACartesianPoint(x, y);
  }
}
```

Dynamic dispatching: call most specific method for the calling object

Virtual vs. Regular Method and Different Languages

Virtual method: Call to it is dynamically dispatched

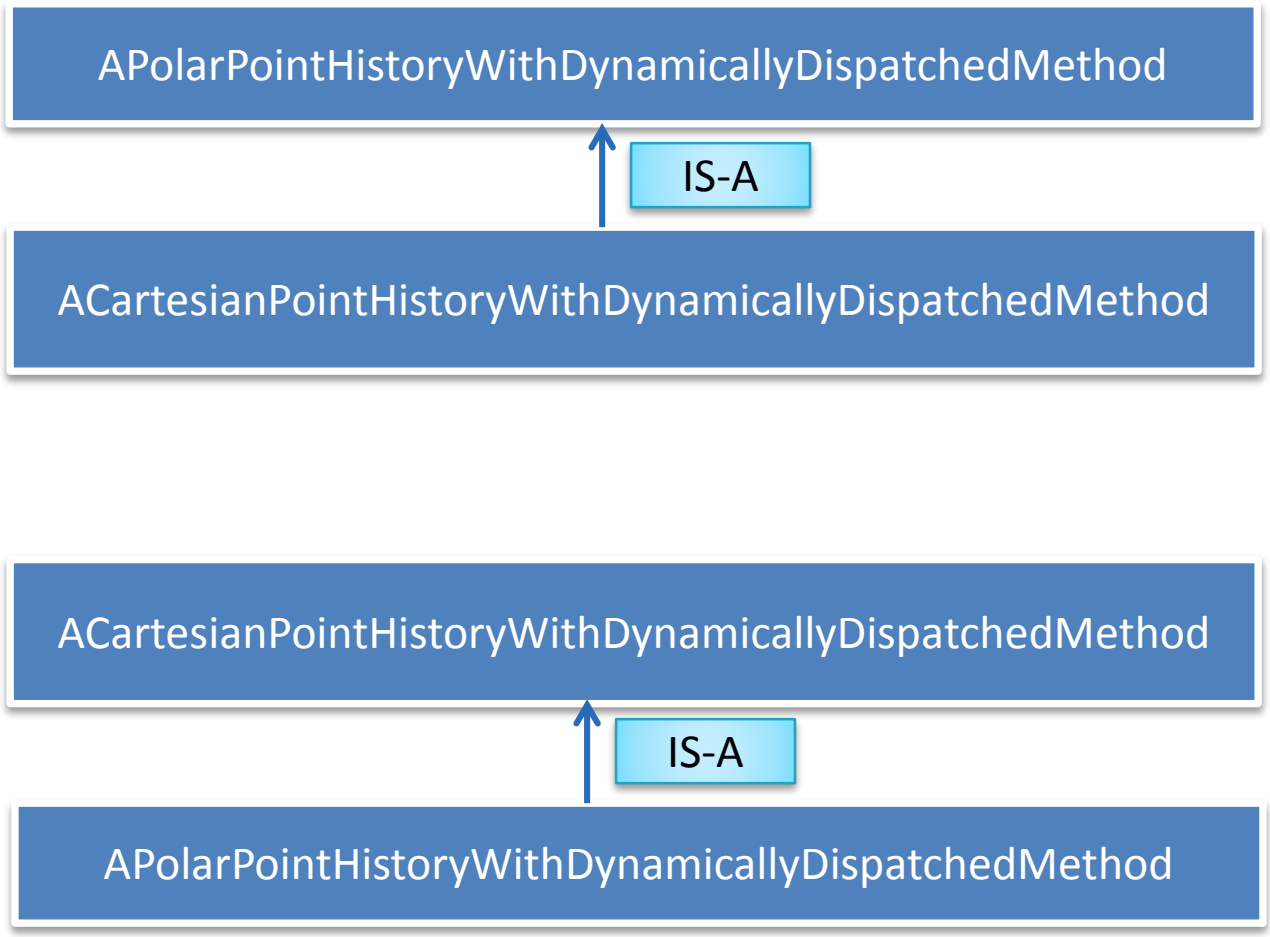
Regular method: Call to it is statically dispatched

Java: All instance methods are virtual methods and all class (static)methods are regular methods

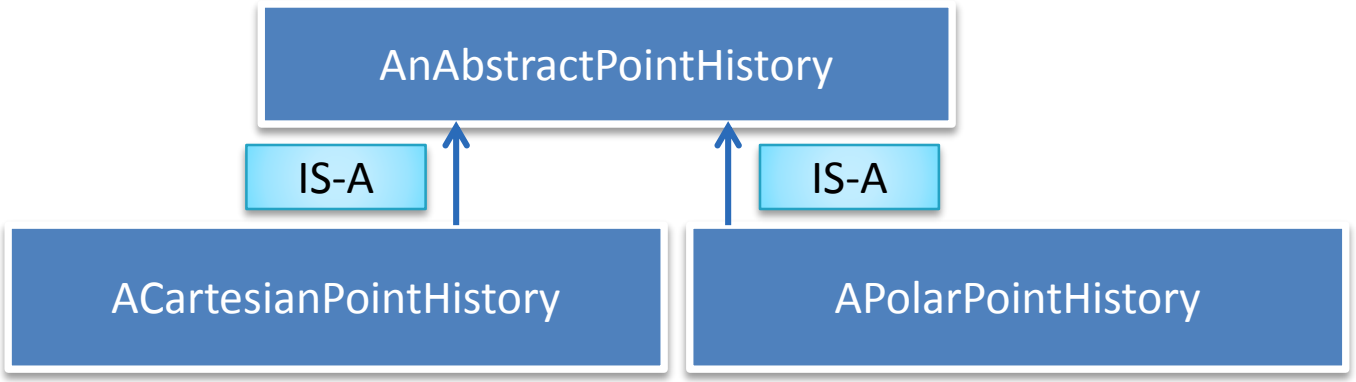
C++: Instance methods can be declared to be regular or virtual and all class (static)methods are regular methods

Smalltalk: All methods are virtual

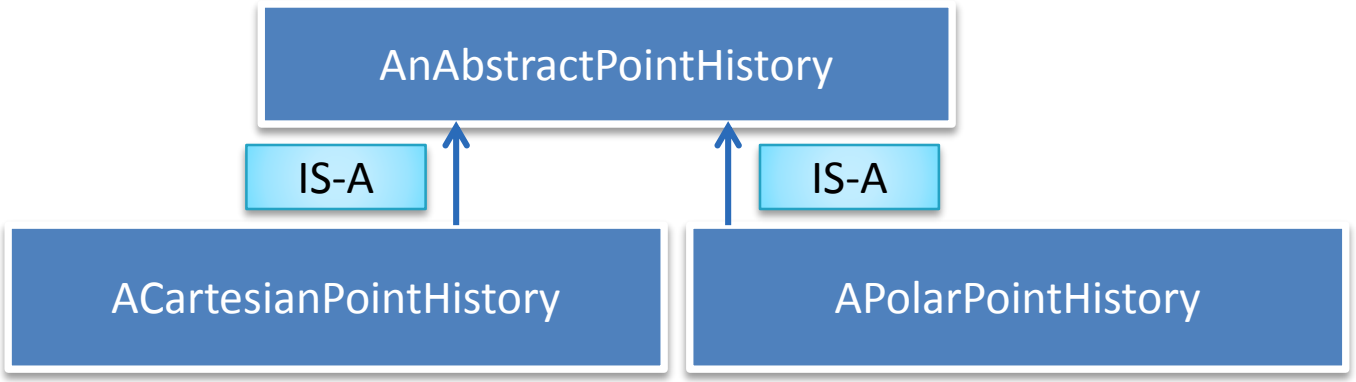
Inheritance Relationships?



Correct Inheritance



Correct Inheritance



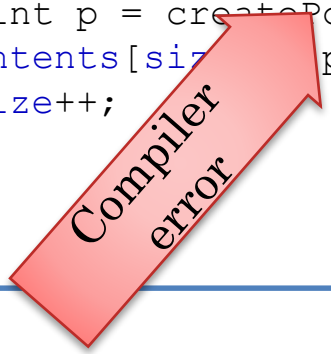
A Catersian History Implementation

```
public class ACartesianPointHistoryWithDynamicallyDispatchedMethod
                implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
  protected Point createPoint(int x, int y) {
     return new ACartesianPoint(x, y);
  }
}
```

Changed how?

Removing createPoint

```
public abstract class AnAbstractPointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[si    p;
       size++;
     }
  }
}
```



Null Overridden Method

```
public abstract class AnAbstractPointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
  protected Point createPoint(int x, int y) {}
}
```

Overriding Dynamically Dispatched Method

```
public class ACartesianPointHistory
                extends AnAbstractPointHistory{
  protected Point createPoint(int x, int y) {
    return new ACartesianPoint(x, y);
  }
}
```

Erroneous Implementation with No Errors

```
public class ACartesianPointHistory extends AnAbstractPointHistory{

}
```

Abstract Method

```
public abstract class AnAbstractPointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
   protected abstract Point createPoint(int x, int y);
}
```

Only header of method provided as in interface

Erroneous Implementation

```
public class ACartesianPointHistory extends AnAbstractPointHistory{

}
```

Java complains abstract method not implemented in concrete class

Null vs. Abstract Methods

Null methods could replace abstract methods.

Abstract method force overriding implementations in subclasses.

Provide better documentation, indicating to programmer that subclass will implement them.

Abstract method

- Declared only in abstract classes
- Keyword: **abstract**
- No body
- Each (direct or indirect) subclass must implement abstract methods defined by an abstract class.
- Much like each class must implement the methods defined by its interface(s).

Abstract class vs. methods

- Abstract method => containing class abstract
  - Cannot have an unimplemented method in an instance
- Abstract class may not contain abstract method

A Course with Abstract Method

```
public abstract class ACourse {
        String title, dept;
        public ACourse (String theTitle, String theDept) {
                super();
                title = theTitle;
                dept = theDept;
        }
        public String getTitle() {
                return title;
        }
        public String getDepartment() {
                return dept;
        }
        abstract public int getNumber();

        public String toString() {
                return "Title:" + title + " Dept:" + dept +
                        " Number: " + getNumber();
}
```

Abstract Method

Equivalent with Interface

```
public abstract class ACourse implements Course {
        String title, dept;
        public ACourse (String theTitle, String theDept) {
                super();
                title = theTitle;
                dept = theDept;
        }
        public String getTitle() {
                return title;
        }
        public String getDepartment() {
                return dept;
        }
        public String toString() {
                return "Title:" + title + " Dept:" + dept +
                        " Number: " + getNumber();
```

An abstract class can implement any interface

This means all sub classes implement the interface

Interface implementation check is made for concrete classes

Another Course

```
package courses;
public abstract class ACourse  implements Course {
        String title, dept;
        public ACourse (String theTitle, String theDept) {
                super();
                title = theTitle;
                dept = theDept;
        }
        public String getTitle() {
                return title;
        }
        public String getDepartment() {
                return dept;
        }
public String toString() {
                return "Title:" + title + " Dept:" + dept + " Number: " +
getNumber();
```

An abstract class can implement any interface

This means all sub classes implement the interface

Interface implementation check is made for concrete classes

Alternative ARegularCourse

```
public class ARegularCourse extends ACourse {
        int courseNum;
        public ARegularCourse (String theTitle, String theDept, int
theCourseNum) {
                super (theTitle, theDept);
                courseNum = theCourseNum;
        }
        public int getNumber() {
                return courseNum;
        }
}
```

Saying ARegularCourse implements Course is redundant

Alternative AFreshmanSeminar

```
public class AFreshmanSeminar extends ACourse {
        public AFreshmanSeminar (String theTitle, String theDept) {
                super (theTitle, theDept);
        }
        public int getNumber() {
                return SEMINAR_NUMBER;
        }
}
```

No need for implementation clause

When Abstract Method Required

```
public abstract class AnAbstractPointHistory implements PointHistory {
  public final int MAX_SIZE = 50;
  protected Point[] contents = new Point[MAX_SIZE];
  protected int size = 0;
  public int size() {
    return size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
  protected abstract Point createPoint(int x, int y);
}
```

Not public

Adding createPoint to Interface

```
public interface PointHistoryWithExtraPublicMethod {
  public Point createPoint(int x, int y);
}
```

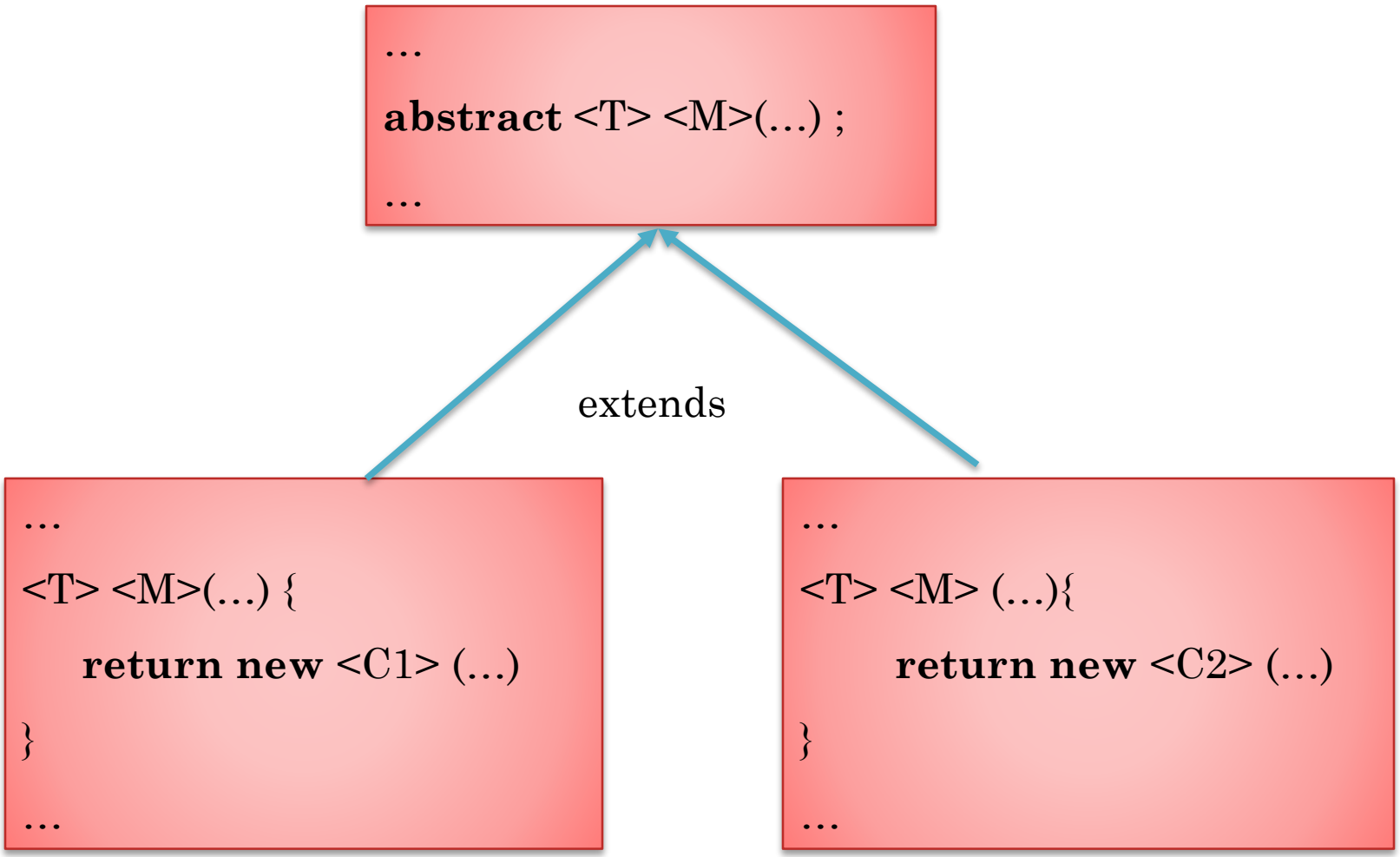
Factory method

```
public ab      ass AnAbstractPointHistoryWithExtraPublicMethod
                mplements PointHistoryWithExtraPublicMethod {
  publ         nt MAX_SIZE = 50;
  pr           int[] contents = new Point[MAX_SIZE];
               nt size = 0;
               t size() {
               n size;
  }
  public Point elementAt (int index) {
    return contents[index];
  }
  protected boolean isFull() {
    return size == MAX_SIZE;
  }
  public void addElement(int x, int y) {
    if (isFull())
      System.out.println("Adding item to a full history");
    else {
      Point p = createPoint(x, y);
      contents[size] = p;
       size++;
     }
  }
}
```

Concrete class guaranteed to implement it

Least privilege violated

Factory Abstract Method



Abstract method that returns an instance of some type T – like a factory, it creates and initializes an object.

Abstract methods vs. Interfaces

- Unimplemented methods become abstract methods to be implemented by concrete subclasses. Do not need explicit implements clause in subclass if no additional public methods implemented,
  - **public class** ARegularCourse **extends** ACourse {
    ....
    }
- A class with only abstract methods simulates interfaces.
- No multiple inheritance in Java
- Separation of abstract and concrete methods with interfaces.
- A class implements but does not inherit a specification!

Abstract methods vs. Interfaces

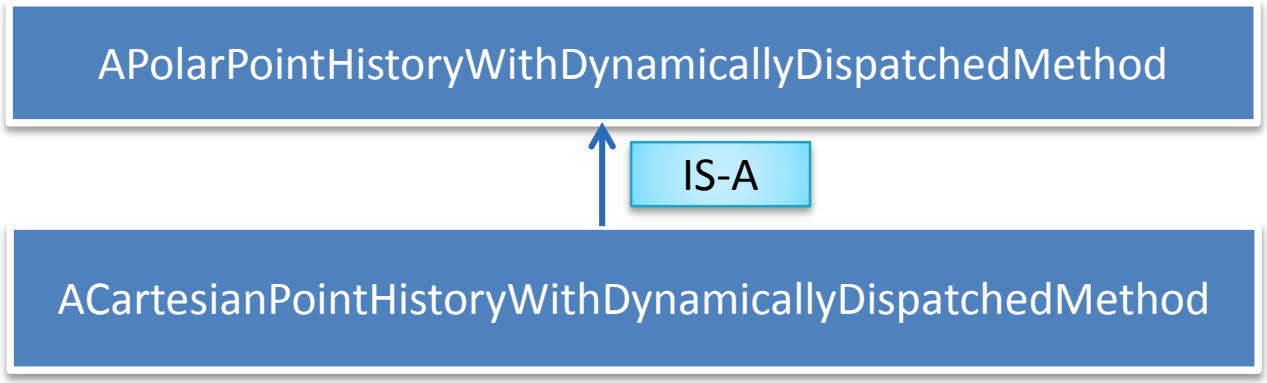
- Non-public abstract methods relevant even in Java
- All interface methods must be public.
- May want non public abstract methods.E.g.
  - **abstract boolean** isFull() ;

Abstract methods vs. Virtual Methods

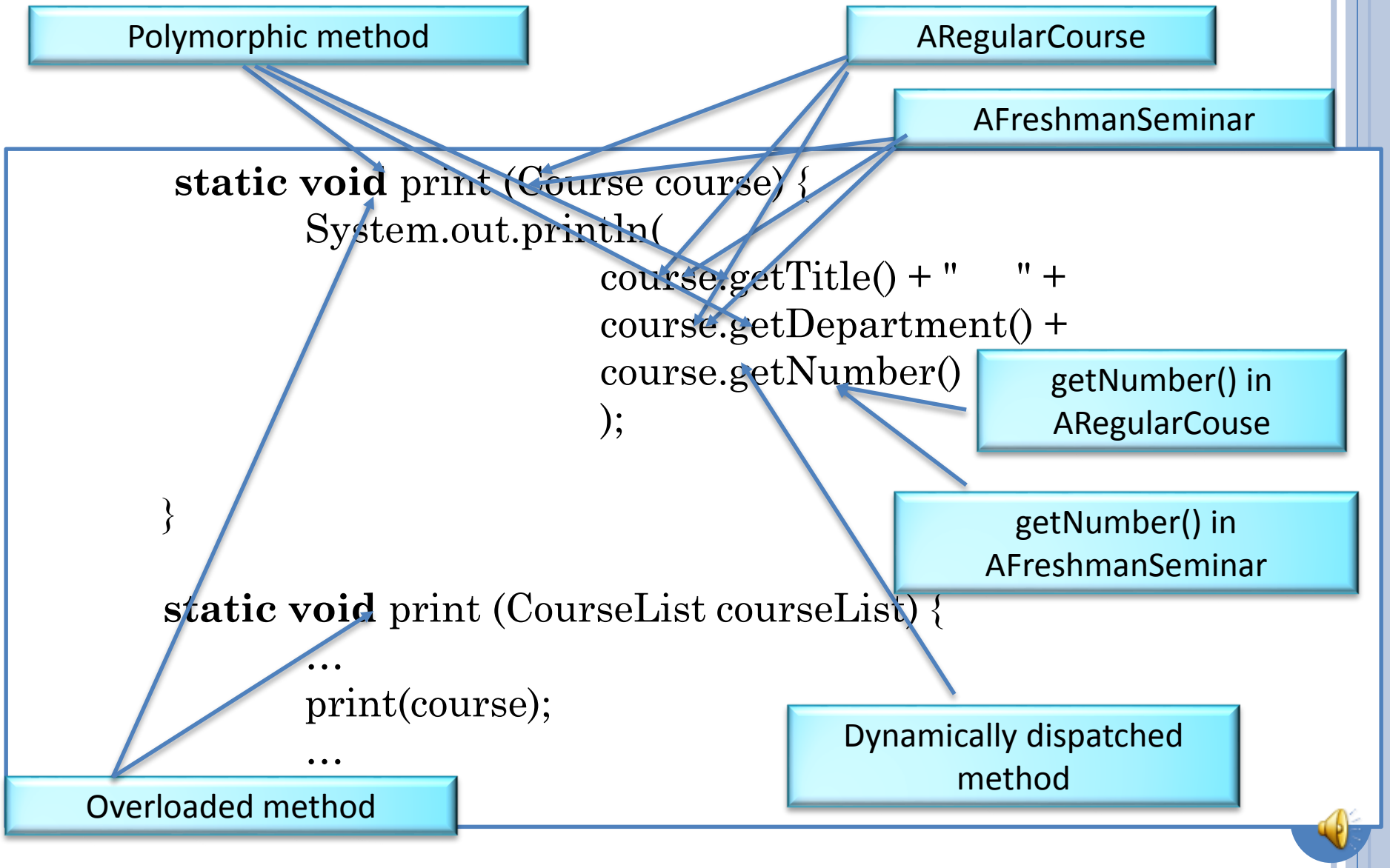
- Abstract methods must be virtual methods.
- Virtual methods need not be abstract methods

Factory methods vs. Abstract Methods

- Some abstract methods may be factory methods
- Factory methods may not be abstract methods but often this means bad programming practice



Overloading, Polymorphism, and Dynamic dispatch



Overloading, Polymorphism, and Dynamic dispatch

- Same method name works on different types.
- Overloading
  - Multiple (static or instance) methods with same name but different parameter types.
  - Resolved at compile time based on parameter types
- Polymorphism
  - Same method implementation works on multiple object types.
- Dynamic dispatch (or virtual methods)
  - Multiple instance methods with same name in different classes
  - Resolved at execution time based on type of target object

Polymorphism vs. Overloading and Dynamic Dispatch

- Polymorphism vs. Overloading
  - Polymorphism: single `print (Course course)`
  - Overloading: `print (ARegularCourse course)` and `print (AFreshmanSeminar course)` with same implementation.
- Polymorphism vs. Dynamic Dispatch
  - Polymorphism: single `getTitle()` in `ACourse`
  - Dynamic dispatch: `getTitle()` in `AFreshmanSeminar()` and `getTitle()` in `ARegularCourse()` with same implementation.
- Create polymorphic code when you can
  - In overloading and dynamic dispatch, multiple implementations associated with each method name.
  - In polymorphic case, single implementation.
    - Use interfaces rather than classes as types of parameters
    - Use supertypes rather than subtypes as types of parameters

Polymorphism vs. Overloading and Dynamic Dispatch

- Cannot always create polymorphic method.
  - `getNumber()` for `ARegularCourse` and `AFreshmanSeminar` do different things.
  - `print(Course course)` and `print (CourseList courseList)` do different things.
- When polymorphism not possible try overloading and dynamic dispatch.

Manual instead of Dynamic Dispatch

```
static void print (Course course) {
    if (course instanceof ARegularCourse)
        number = ((ARegularCourse)course).
                    getCourseNumberRegularCourse ();
    else if (course instanceof AFreshmanSeminar)
        number = ((AFreshmanSeminar)course).
                    getCourseNumberFreshmanSeminar ();
    System.out.println(
        course.getTitle() + "          " +
        course.getDepartment() +
        number );
}
```

More Work

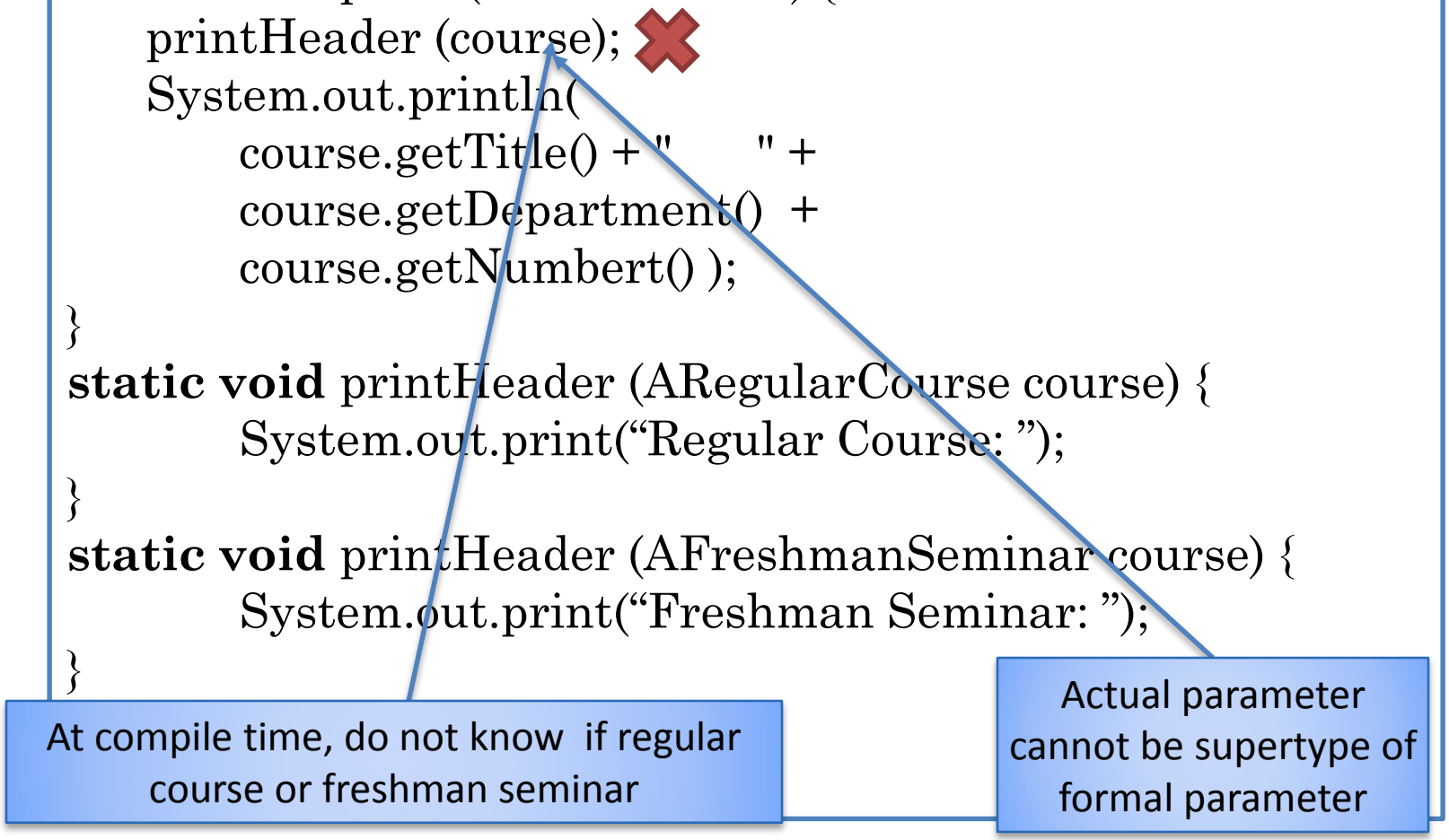
Must update code as subtypes added

Can we get rid of manual dispatch/instanceof?

```
static void print (Course course) {
    if (course instanceof RegularCourse)
        System.out.print("Regular Course: ");
    else if (course instanceof AFreshmanSeminar)
        System.out.println("Freshman Seminar");
    System.out.println(
        course.getTitle() + "      " +
        course.getDepartment()  +
        course.getNumber() );
}
```

Cannot always get rid of manual dispatch/instancof

```
static void print (Course course) {
    printHeader (course);
    System.out.println(
        course.getTitle() + "      " +
        course.getDepartment()  +
        course.getNumbert() );
}
static void printHeader (ARegularCourse course) {
        System.out.print("Regular Course: ");
}
static void printHeader (AFreshmanSeminar course) {
        System.out.print("Freshman Seminar: ");
}
```



At compile time, do not know if regular course or freshman seminar

Actual parameter cannot be supertype of formal parameter

printHeader() in ARegularCourse

```
package courses;
public class ARegularCourse extends ACourse implements Course {
        ...
        public void printHeader () {
            System.out.print ("Regular Course: ")
        }
}
```

printHeader() in AFreshmanSeminar

```
package courses;
public class AFreshmanSeminar extends ACourse implements
FreshmanSeminar {
        ...
        public void printHeader () {
            System.out.print ("Freshman Seminar: ")
    }
}
```

SHOULD NOT ALWAYS GET RID OF MANUAL DISPATCH/INSTANCOF

```
static void print (Course course) {
      printHeader (course);
      System.out.println(
            course.getTitle() + "      " +
            course.getDepartment()  +
            course.getNumbert() );
}
static void printHeader (ARegularCourse course) {
            System.out.print("Regular Course: ");
}
static void printHeader (AFreshmanSeminar course) {
```

Should not put printHeader() in ARegularCourse or AFreshmanSeminar as it is UI code.

Hence need to use instanceof

Used in parsers