Data Structures and Object-Oriented Design V

Spring 2014
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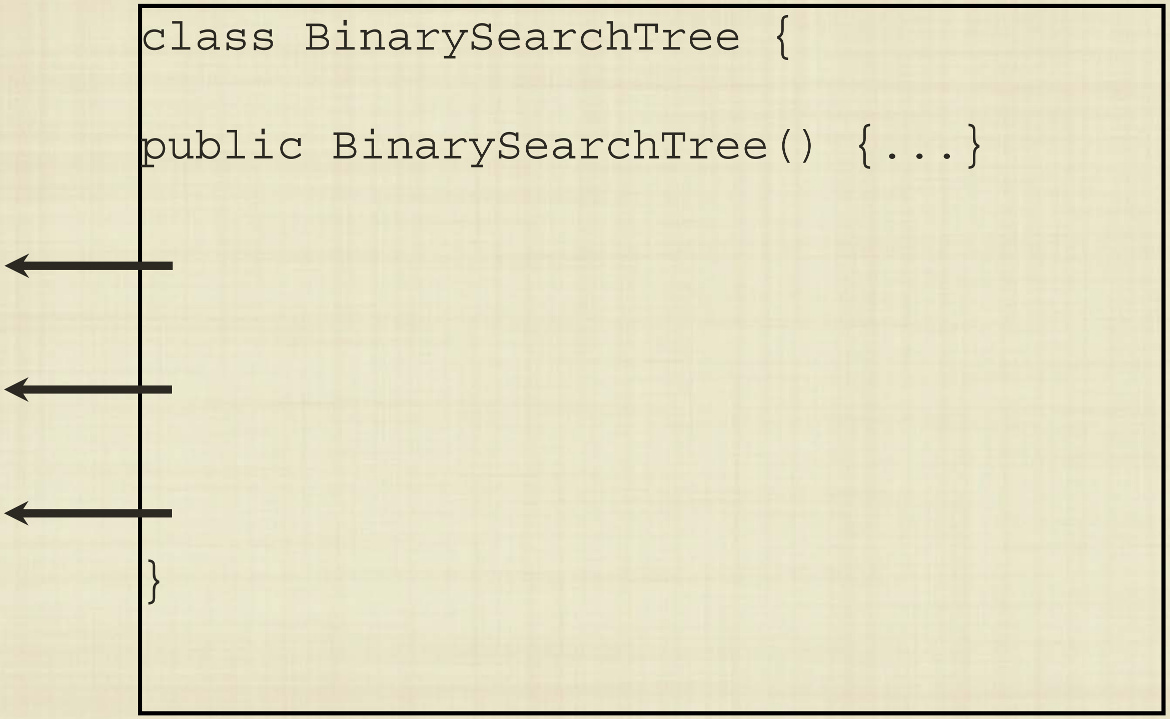
Other Data Types/Structures

- We’ve seen that the actual implementation of the data type only matters in the overall performance (and possibly functionality).



```
class BinarySearchTree {

public BinarySearchTree() {...}



}
```

What operations did binary search trees offer us, and how did it differ in implementation or functionality?

Other Data Types/Structures

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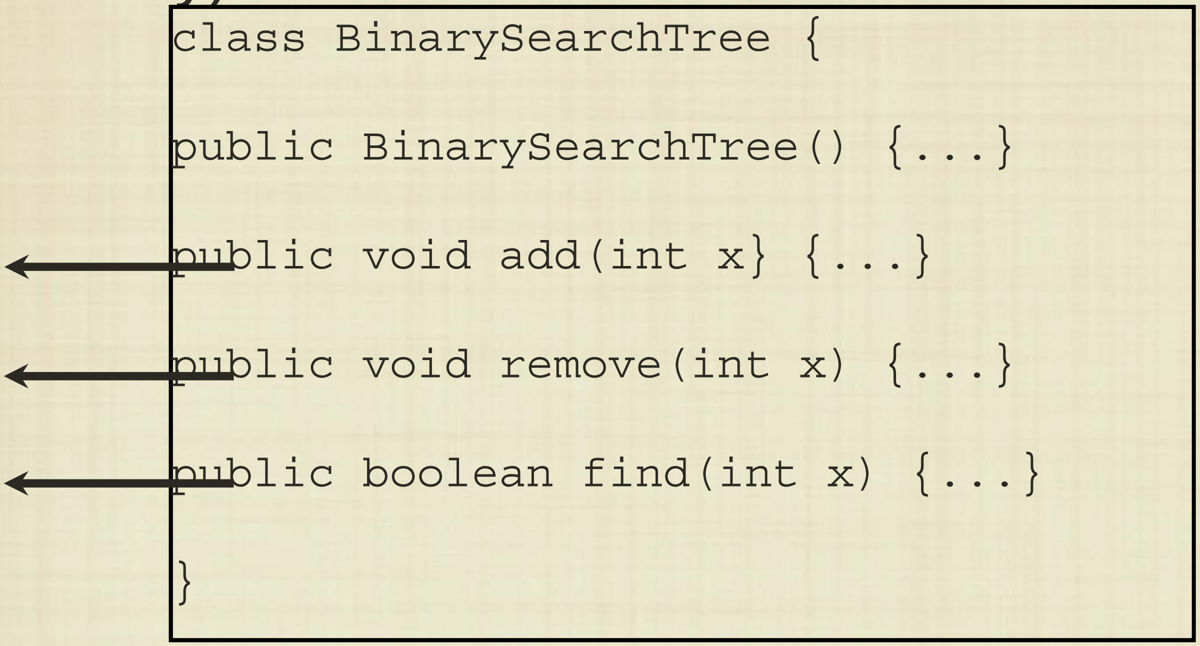
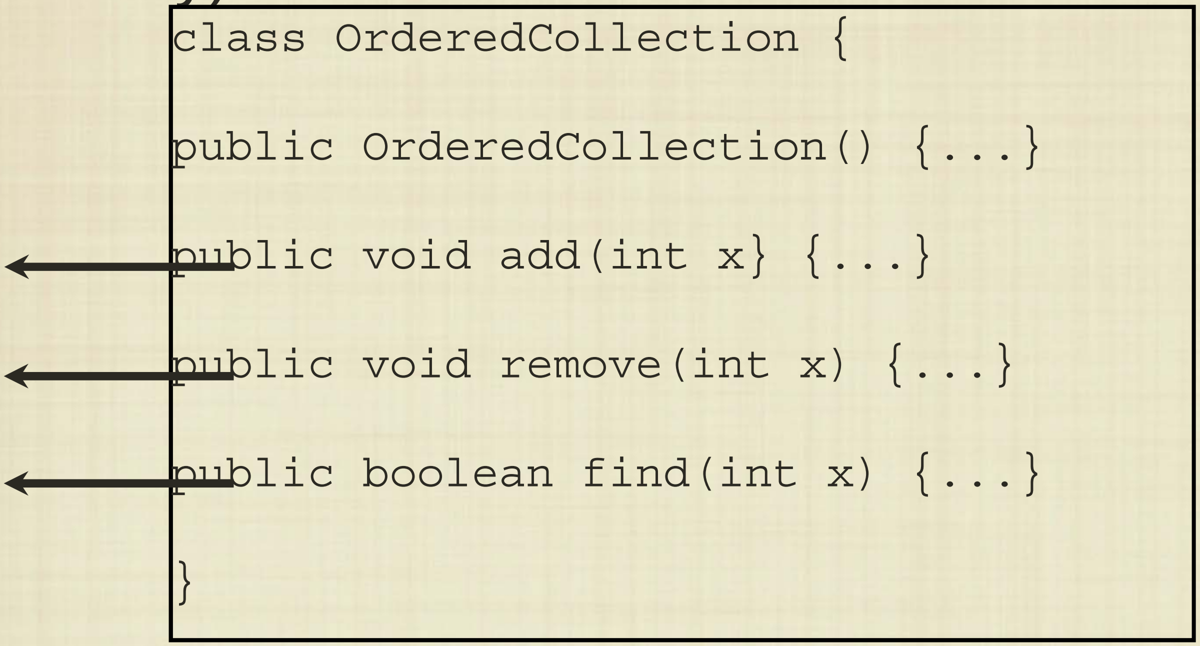


```
class BinarySearchTree {

public BinarySearchTree() {...}

public void add(int x} {...}

public void remove(int x) {...}

public boolean find(int x) {...}

}
```

Do we even need to name this class to refer to its data structure?

Other Data Types/Structures

- We’ve seen that the actual implementation of the data type only matters in the overall performance (and possibly functionality).



```
class OrderedCollection {

public OrderedCollection() {...}

public void add(int x} {...}

public void remove(int x) {...}

public boolean find(int x) {...}

}
```

Do we even need to name this class to refer to its data structure? Not really - the user doesn’t need to know how the data is organized.

What about Type Compatibility?

- So far, our class definitions have been defined to manipulate a single type (usually `int`).

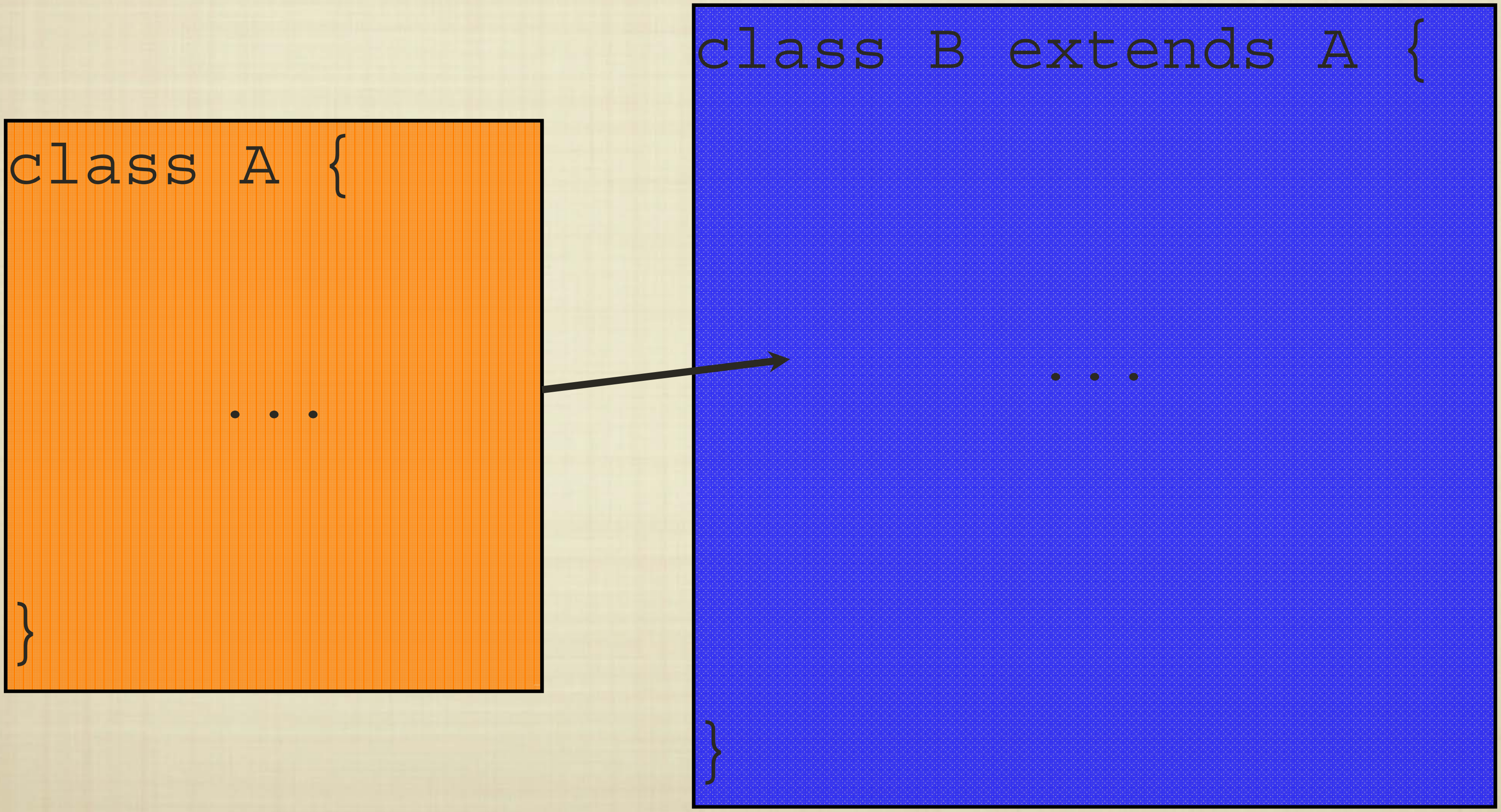
- Do we really have to define a different class for a stack of strings? Can we define a general-purpose stack?

```
class intStack {

private int[] S = null;
private int top;

public Stack(int capacity) {
     S = new int[capacity];
     top = capacity;
}

public int pop() {
     return S[top++];
}

public void push(int x) {
     S[--top] = x;
}
```

```
class StringStack {

private String[] S = null;
private int top;

public Stack(int capacity) {
     S = new String[capacity];
     top = capacity;
}

public String pop() {
     return S[top++];
}

public void push(String x) {
     S[--top] = x;
}
```

Object-Oriented Design

- In Java, “everything is an object” and different classes can be defined to be compatible according to functionality.

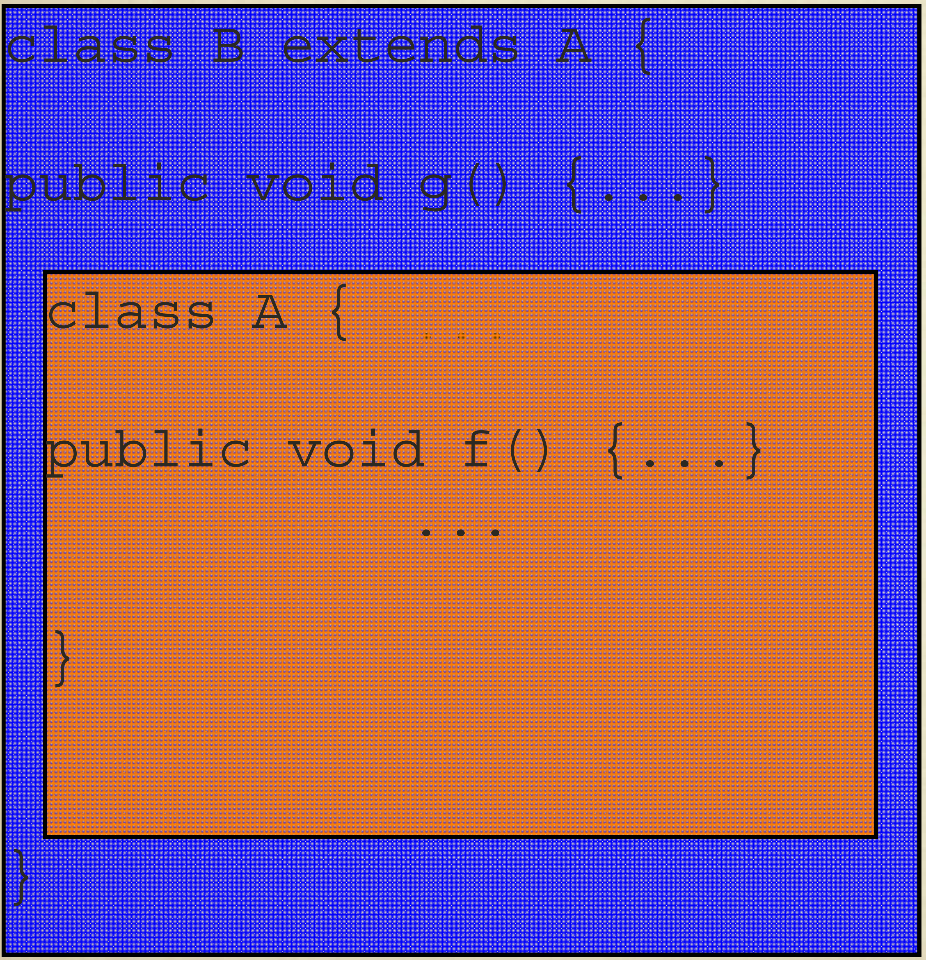


```
class A {

        ...

}
```

```
class B extends A {

            ...

}
```

Object-Oriented Design

The best way to think of type compatibility is that it is always acceptable to extend functionality, but never ok to remove it.

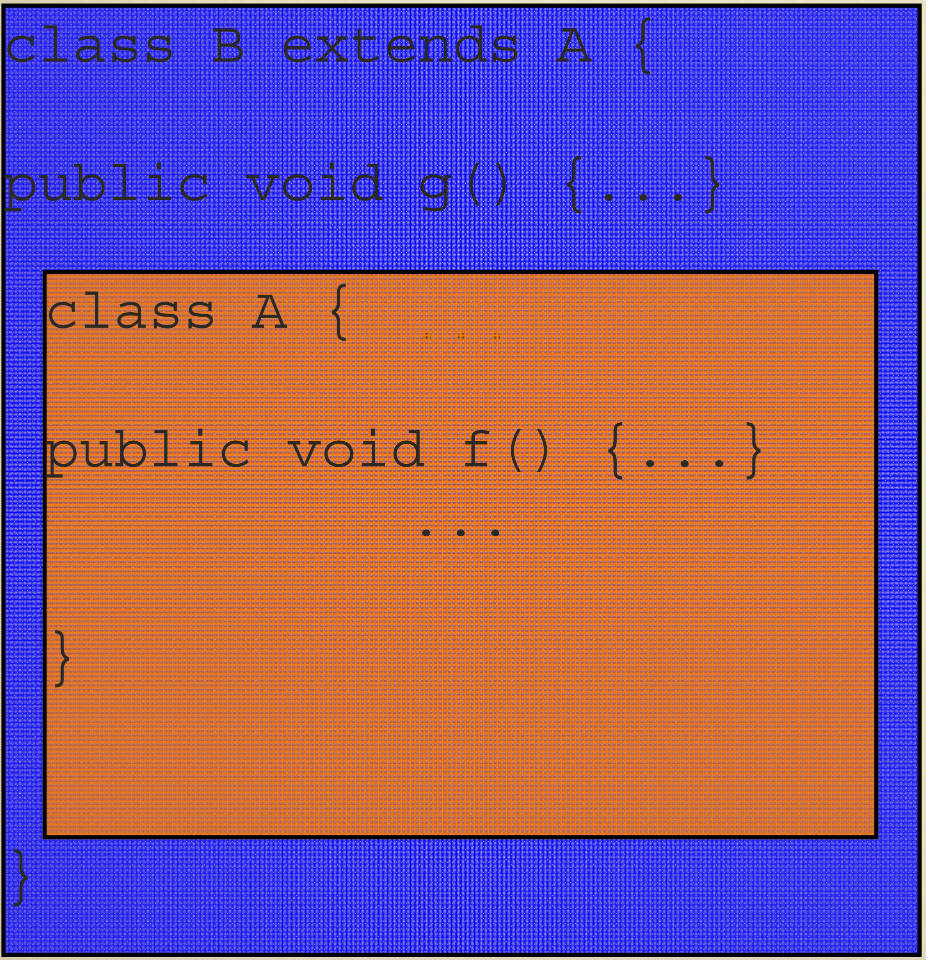


```
class B extends A {

public void g() {...}

  class A {  ...

  public void f() {...}
            ...

  }

}
```

```
...

A x = new A();
B y = new B();

x.f();
y.f();

y.g();
x = new B();
// not allowed!
x.g();
x.f();
```

Object-Oriented Design

Java's type checking is simple: a reference must "hold" at least as much functionality as it was declared to (more is ok).



```
class B extends A {

public void g() {...}

  class A {  ...

  public void f() {...}
           ...

  }

}
```

```
...

A x = new A();
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```

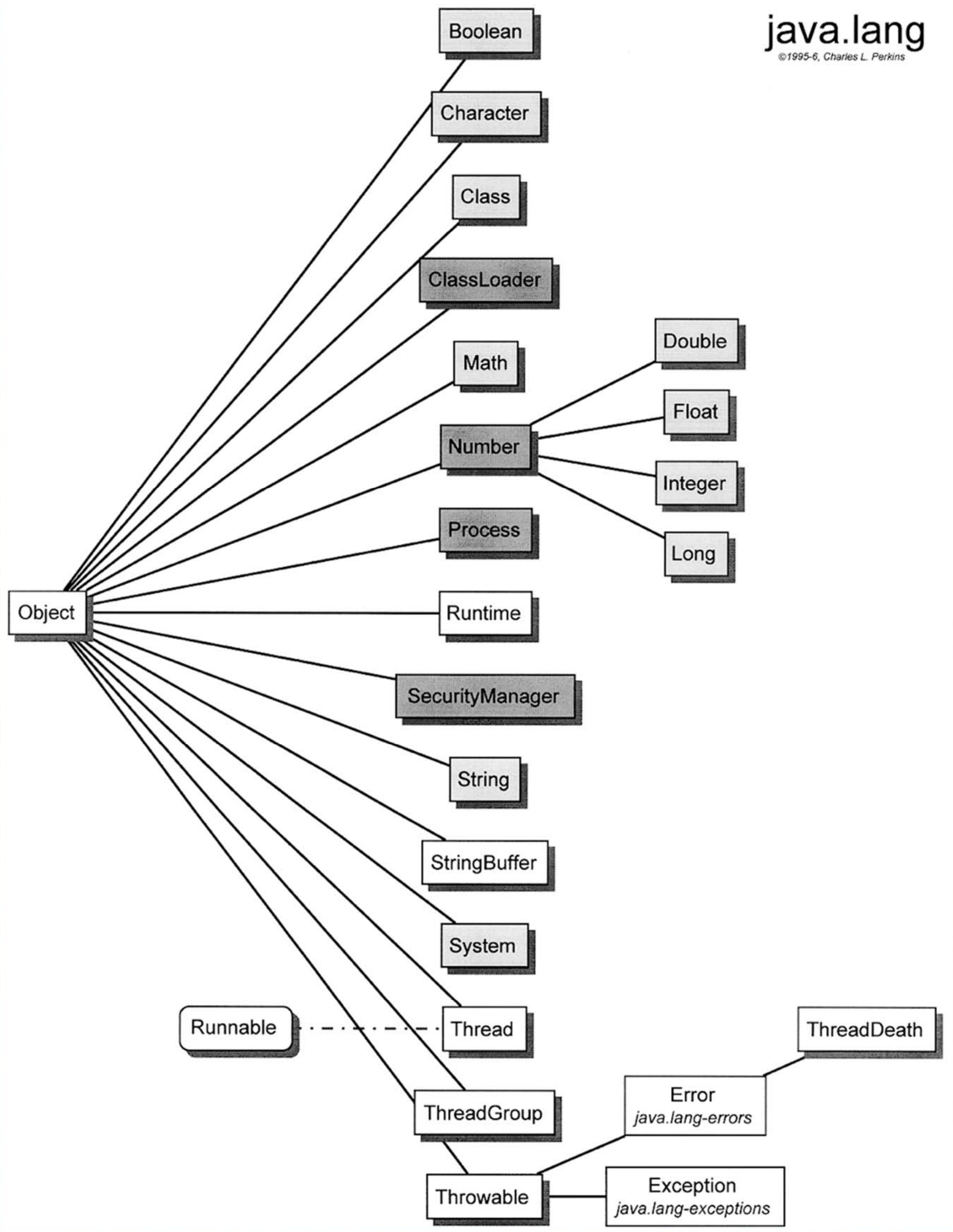

java.lang

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Object

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java.lang-errors

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java.lang-exceptions

Rules of Inheritance

```
class A {

public void f(int x) {
    System.out.println(x);
}
             ...

}
```

```
class B extends A {

public void f(int x) {
    super.f(x)
}

public void g() {...}

             ...

}
```

- The class extending functionality is called a <u>subclass</u>, and the class being extended is called the <u>superclass</u>. We can access inherited attributes using the `super` keyword.

Rules of Inheritance

```
class A {

public void f(int x) {
    System.out.println(x);
}
             ...

}
```

```
class B extends A {

public void f(int x) {
    super.f(2*x)
}

public void g() {...}

             ...

}
```

- The class extending functionality is called a subclass, and the class being extended is called the superclass. We can access inherited attributes using the `super` keyword.

Rules of Inheritance

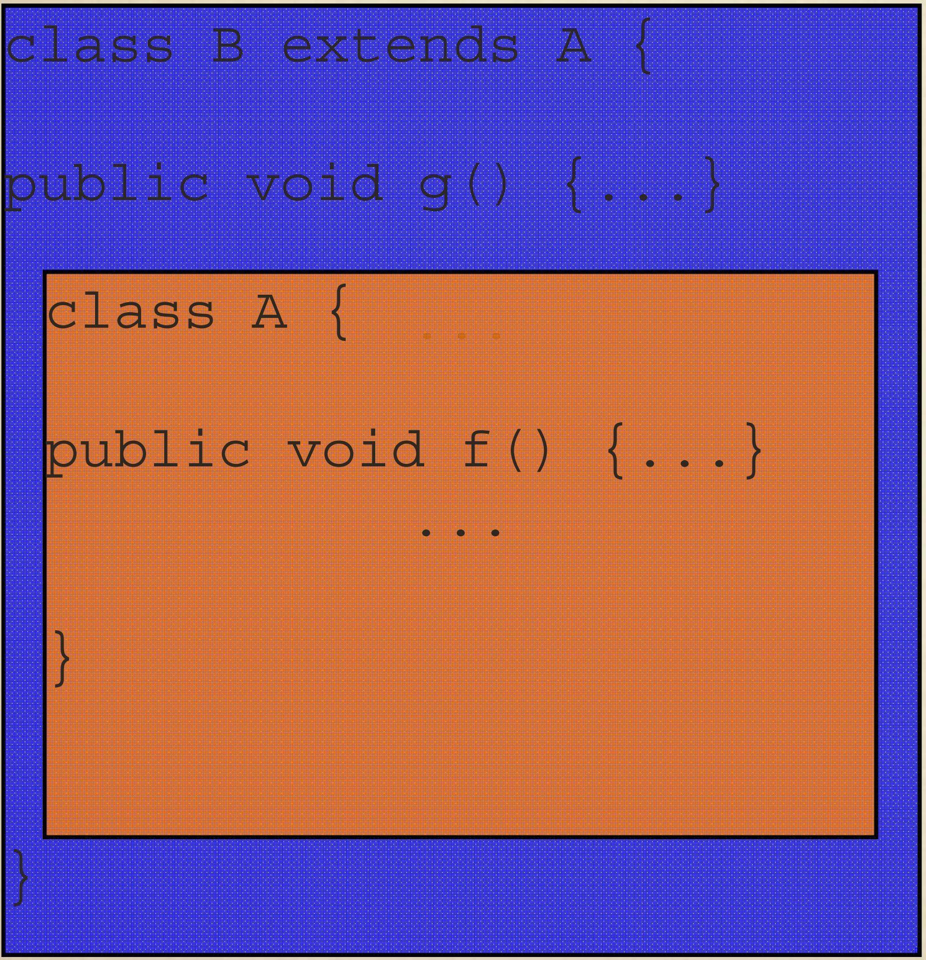
```
class A {

protected int a;

public A(int x) { a = x; }

public void f(int x) {
    System.out.println(x);
}
                ...

}
```

```
class B extends A {

private double b;

public B(int x, double y) {
    super(x); b = y;
}

public void f(int x) {
    super.f(2*x);
}

public void g() {...}

                ...
}
```

- The class extending functionality is called a <u>subclass</u>, and the class being extended is called the <u>superclass</u>. We can access inherited attributes using the `super` keyword.

Object-Oriented Design

The fancy name for how references in Java work is type polymorphism.

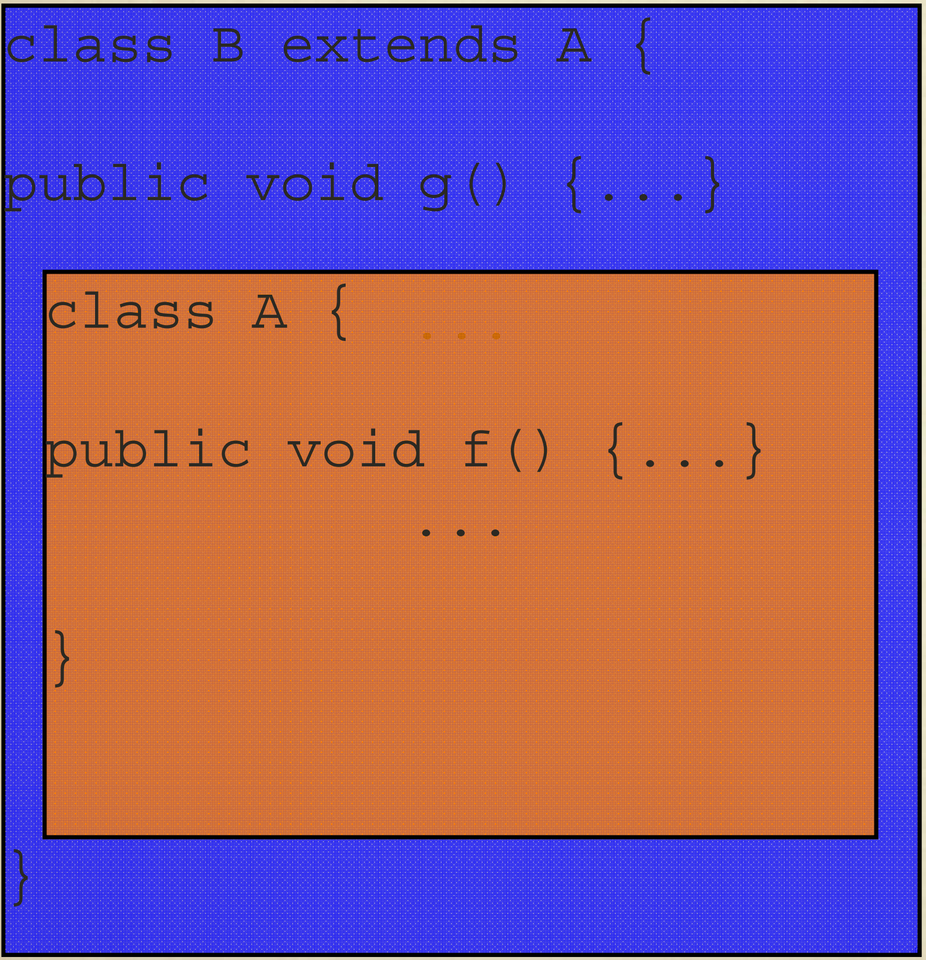


```
class B extends A {

public void g() {...}

  class A {  ...

  public void f() {...}
            ...

  }
}
```

```
...

A x = new A(1);
B y = new B(1, 2.0);

x.f(1);
y.f(1);

y.g();
x = new B();
x.g();
x.f();
```

Object-Oriented Design

These restrictions on references allow us to check for type violations at compile-time - why is this important?

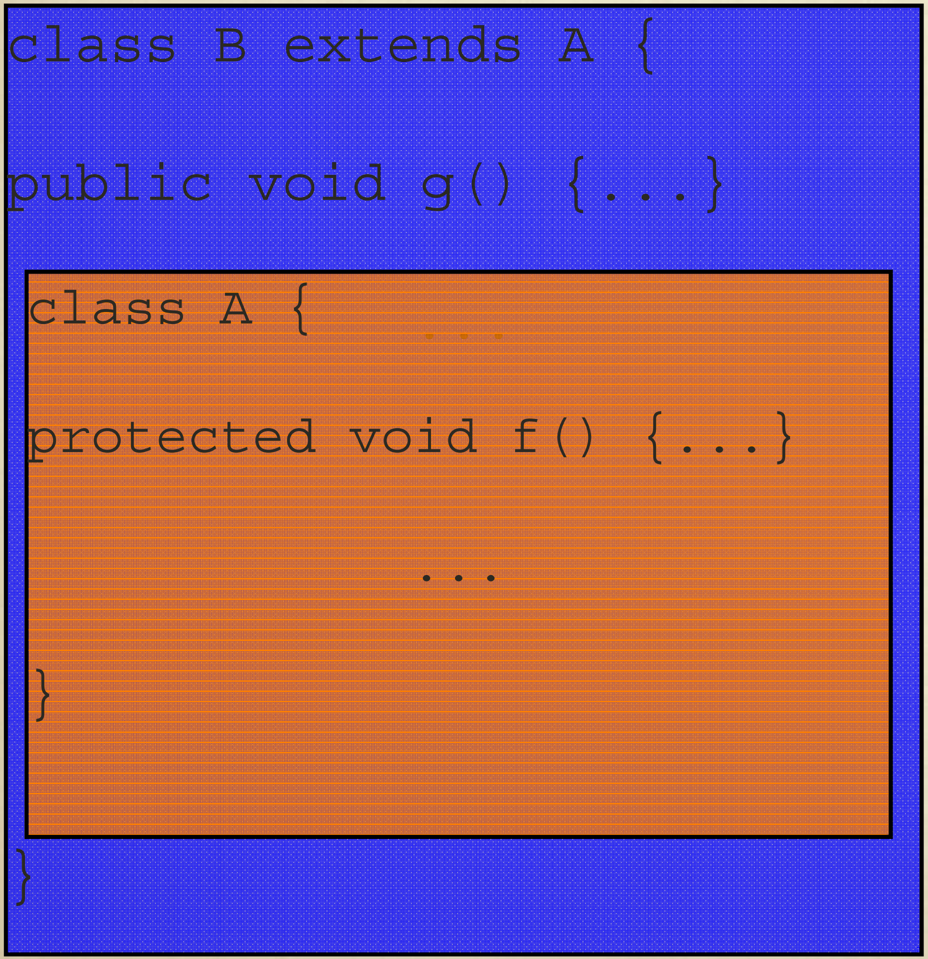


```
class B extends A {

public void g() {...}

  class A {   ...

  public void f() {...}
             ...

  }

}
```

```
...

A x = new A(1);
B y = new B(1, 2.0);

x.f(1);
y.f(1);

y.g();
x = new B();
x.g();
x.f();
```

`protected` access

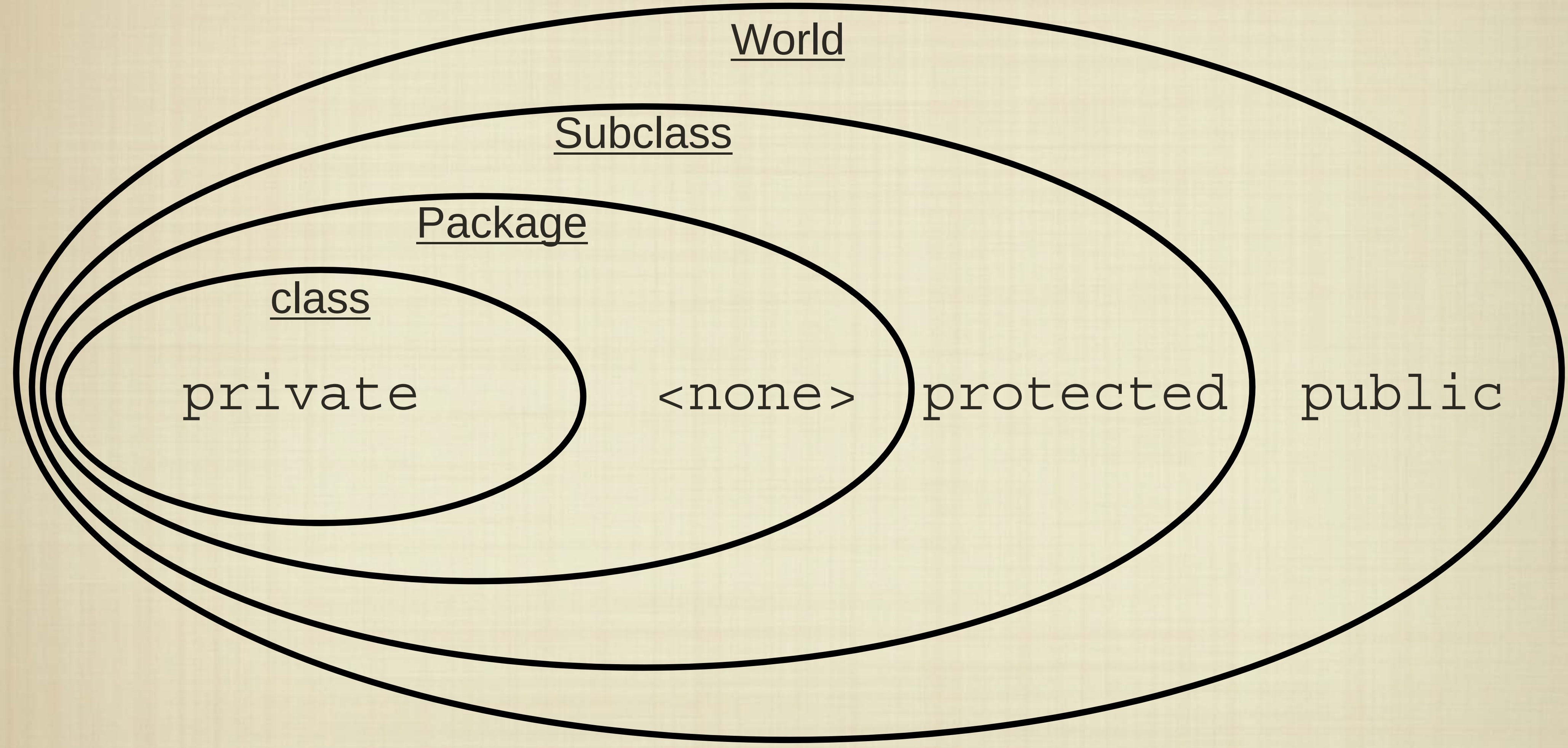
- Any attributes that are declared `protected` are accessible by subclasses, but not the "outside world."



```
class B extends A {

public void g() {...}

class A {        ...

protected void f() {...}

            ...

}
}
```

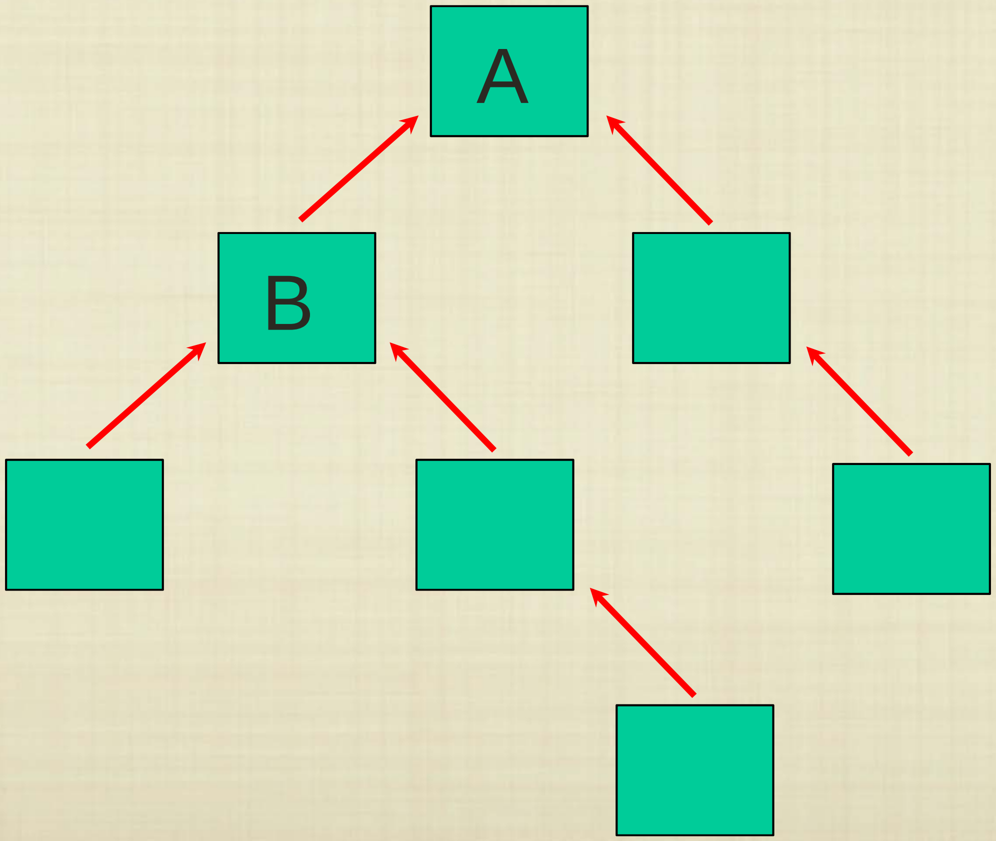
```
...

A x = new A();
B y = new B();

x.f();
// not allowed!
y.f();

y.g();
x = new B();
x.g();
```

Java Access Rules



Big Picture

We can be flexible about how we assign objects, as long as these assignments respect the defined hierarchy of compatibility:



Big Picture

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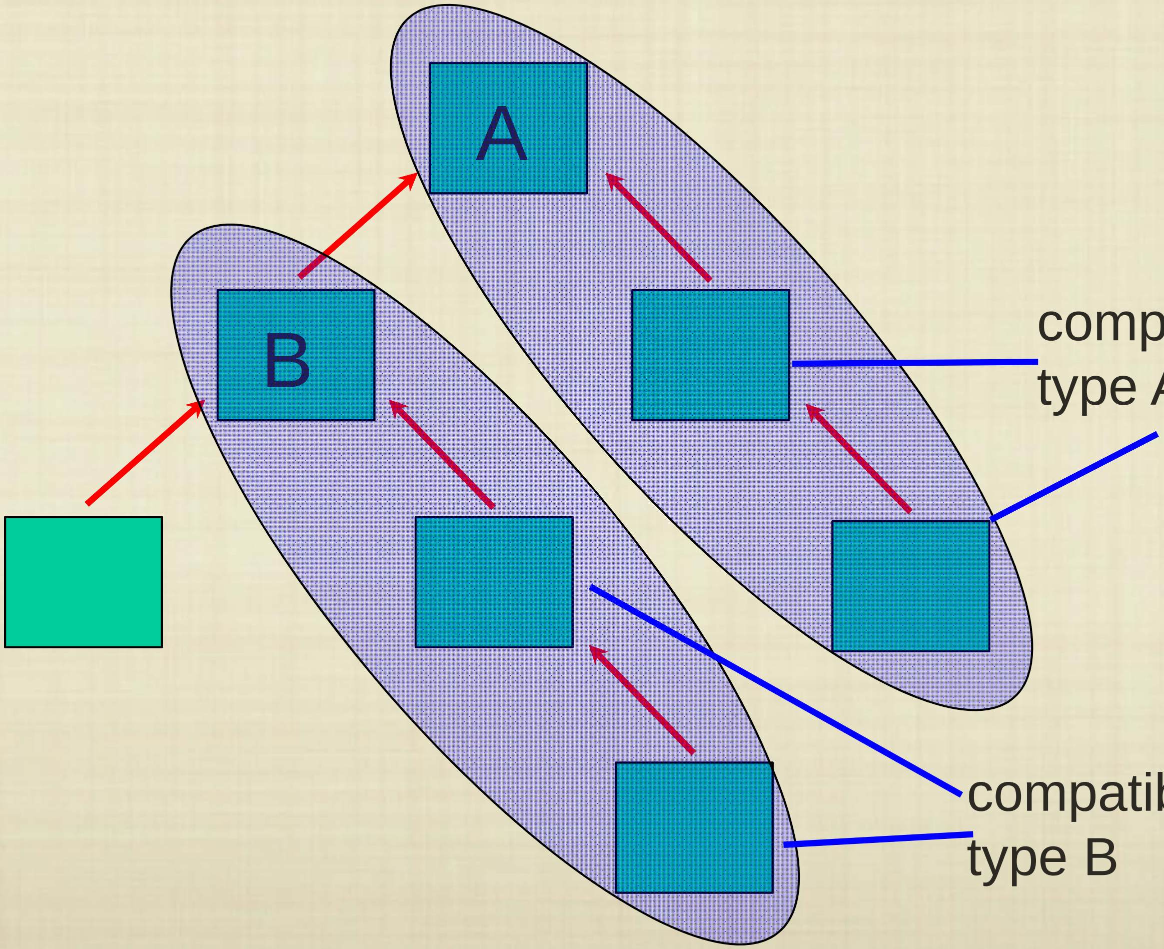
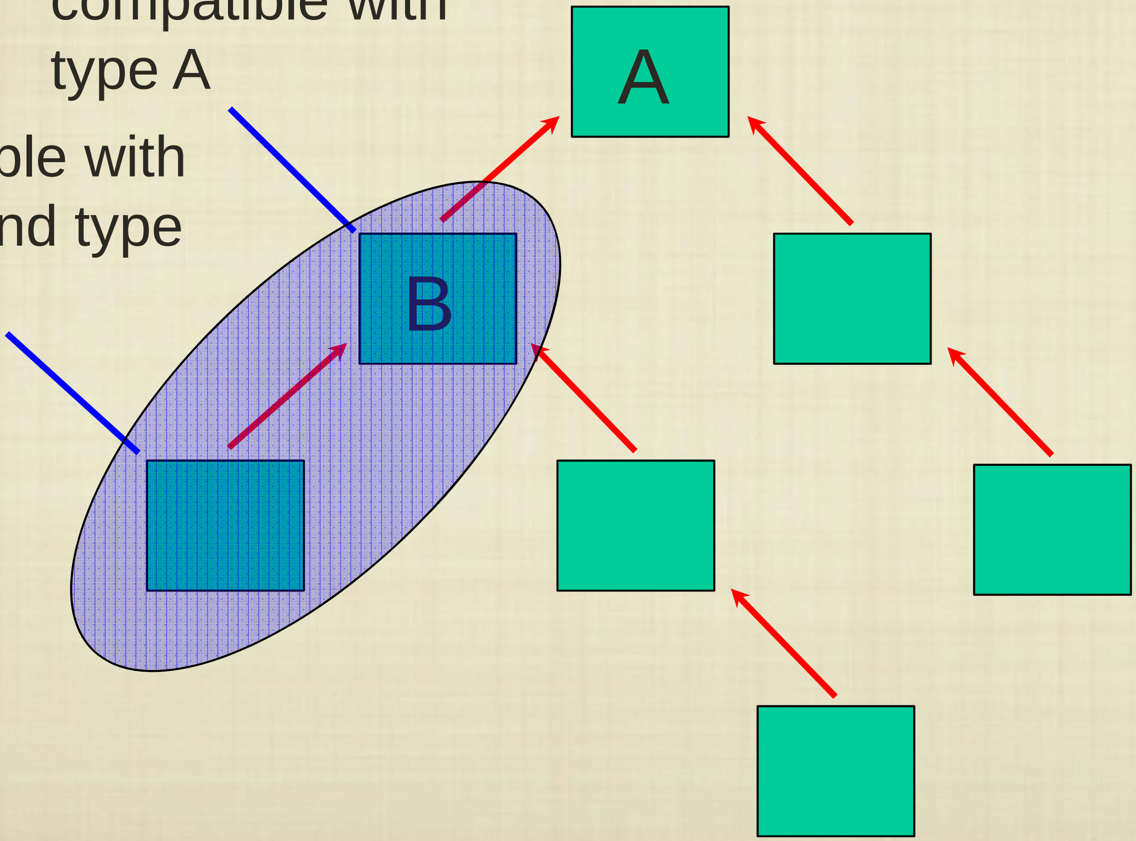


compatible with type A

compatible with type B

Big Picture

We can be flexible about how we assign objects, as long as these assignments respect the defined hierarchy of compatibility:



compatible with type A

compatible with type A and type B

java.lang

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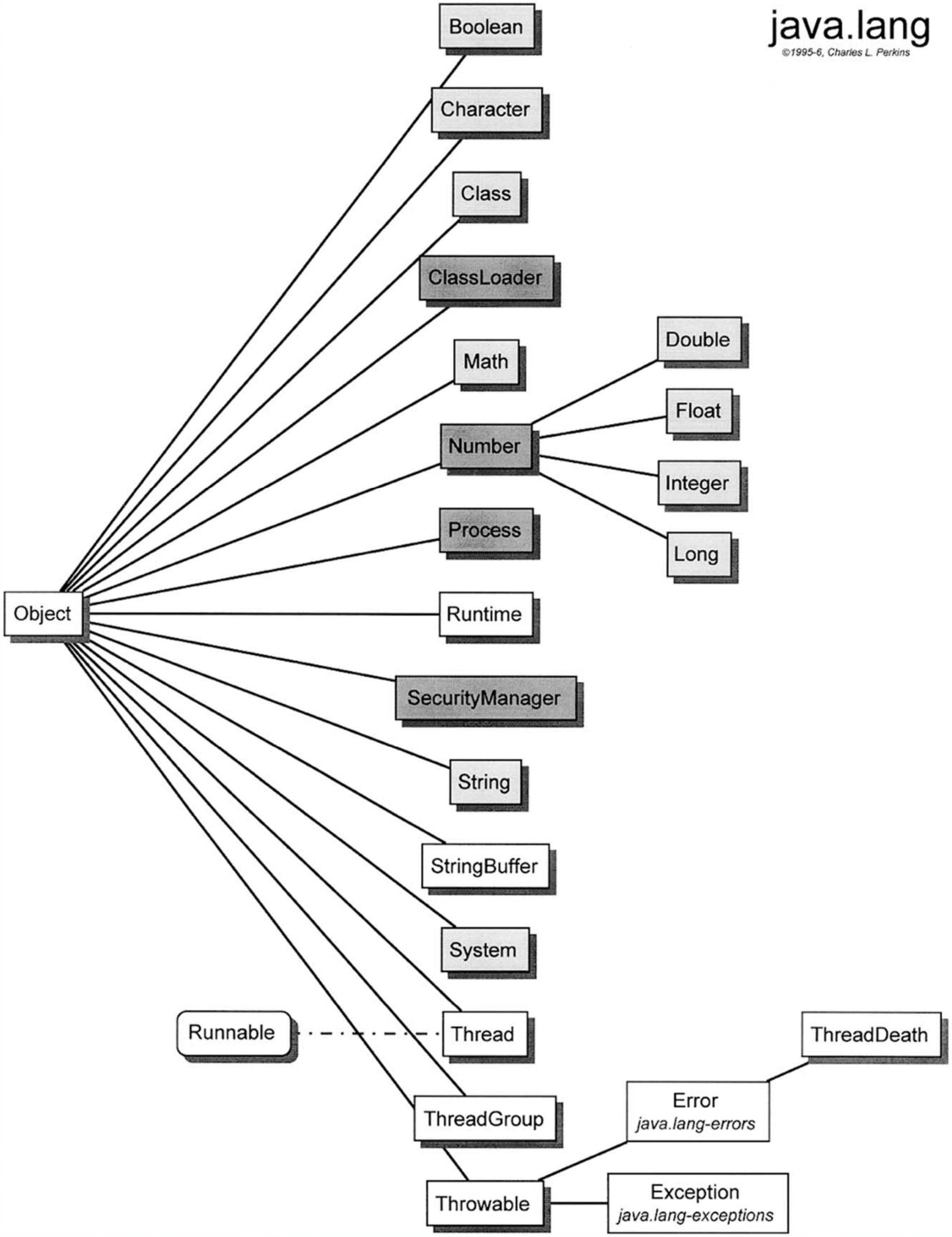

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Using Inheritance

- Note that references are essentially “unidirectional.”

- How general-purpose can we make types using Java’s object model?

```
class Stack {

private Object[] S = null;
private int top;

public Stack(int capacity) {
     S = new Object[capacity];
     top = capacity;
}

public Object pop() {
     return S[top++];
}

public void push(Object x) {
     S[--top] = x;
}
```

Limitations

- Inheritance is useful for extending functionality, but it can’t do everything.
- By defining `Stack` to hold `Object`s, we “lose” functionality when we remove things from the stack:

```
...

Stack S = new Stack(10);
S.push(new Integer(15));
S.push(new String(“foo”));


// this is the only legal way to
// retrieve items - why?
Object a = S.pop();
Object b = S.pop();

// what are the types of a and b?
```

Type Casting

- Java actually allows us to regain functionality by “casting” the returned `Object` into the “correct” type.

- This helps us use one class declaration to create different kinds of `Stack`s, but does not allow a heterogeneous `Stack`.

```
...

Stack S = new Stack(10);
S.push(new Integer(15));
S.push(new String(“foo”));


// this is the only legal way to
// retrieve items - why?
Integer a = (Integer) S.pop();
String b = (String) S.pop();

// what are the types of a and b?
```

Java Generics

- Java also provides a mechanism to make classes generic, which avoids the need for casting:

```
class MyClass<T> {

private T member_variable;

public T foo(T x) {
     ...
}

}
```

- This way, we can use the same class definition for multiple types (without losing functionality), and errors in type usage can still be caught at compile-time.

Java Generics

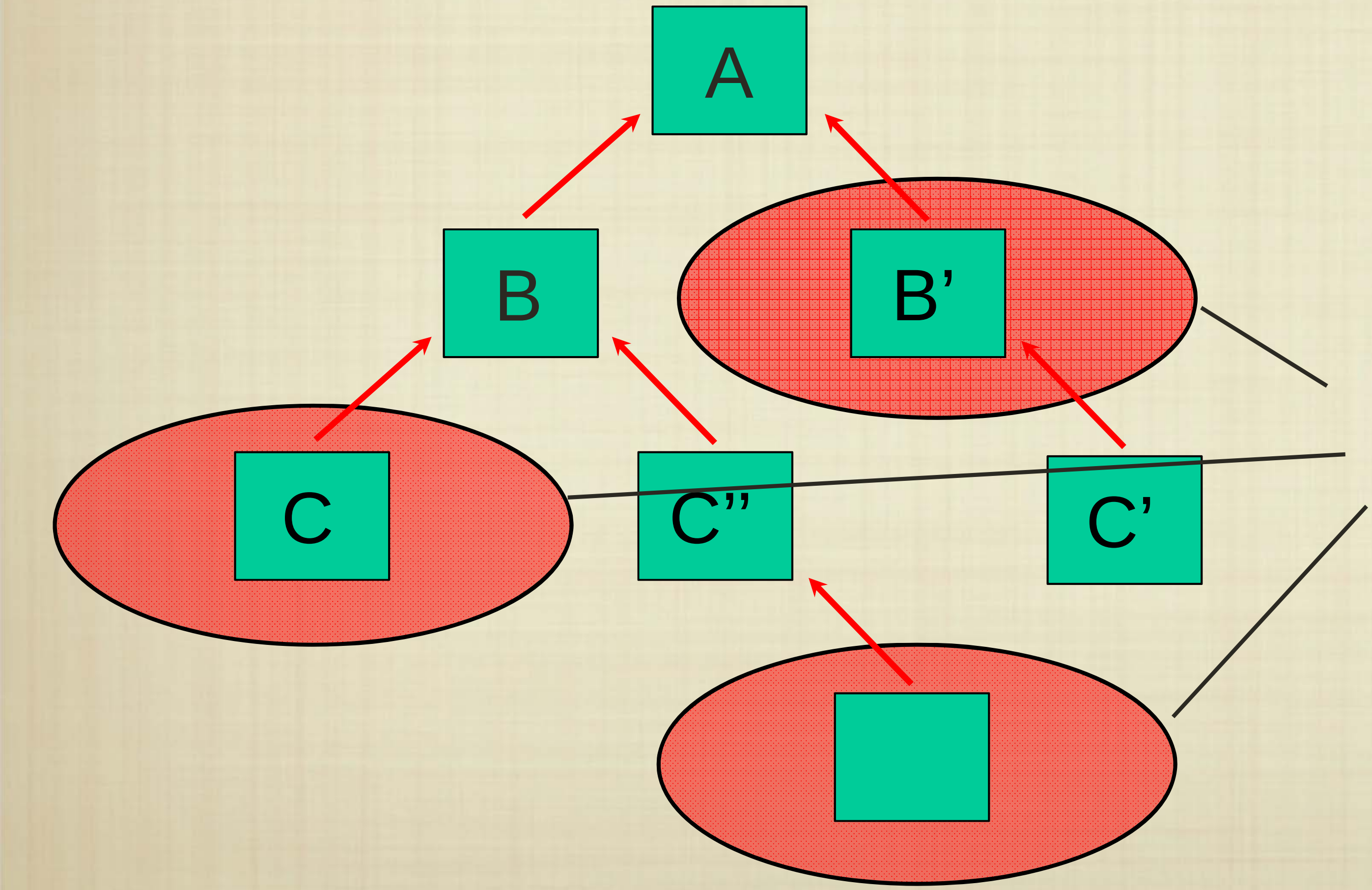
- Java also provides a mechanism to make classes generic, which avoids the need for casting:

```
class MyClass<T> {

private T member_variable;

public T foo(T x) {
     ...
}

}
```

- Given the way Java expects us to declare everything up front - is there a potential problem with using generic types?

Another Problem

Specialized classes can implement similar functionality - but our rules (so far) for references don’t allow us to refer to such instances interchangeably.



What if these classes implement some similar functionality?

Java Interfaces

- We can specify that a Java class implements a particular kind of functionality defined as an `interface`.

```
interface Collection {

  boolean add(Object o);
  boolean remove(Object o);
  boolean contains(Object o);
  boolean equals(Object o);
}
```

```
class Foo implements Collection {
                ...
}

class Bar implements Collection {
                ...
}
```

```
Foo X = new Foo();
Bar Y = new Bar();

Collection C;

C = X;
C = Y;
```

Interfaces in Java can be extended like classes, and follow the same inheritance rules.

Recap: Object-Oriented Design

- In Java, everything is an “Object” - what does this mean?
- What are the rules of inheritance for class attributes?
- What are the rules for declaring and using references to class instances?
- What are the differences between generic types and polymorphic types?
- What gap in the object-oriented paradigm do interfaces help address?