Java Generics

Arrays Class

Provides, among other things, static methods for sorting primitive arrays of different types (byte, char, int, double)

Arrays Class

Problems with this?

- Separate implementation for each type
- Each new type needs a new implementation

Solutions?

Arrays Class

Solutions?

- Could provide a static method that sorts an array of Objects

Arrays Class

Could provide a static method that sorts an array of Objects

- But - what does it mean to compare two arbitrary Objects so that we can establish an ordering between them?
  - For example a String and an Integer?

- We really need a way of talking generically about a homogeneous array of Objects

Java Generics

- A type becomes a parameter to a class and/or a method:

```
public class ClassName<T>{
    :
}
```

- T is the variable type that is assigned when we use the class
- Within the class definition, we can “pretend” that it is a real type (parameters, variable declarations and return types)

GenericStack example …

Standard Generic Type Names

Generic type symbols are arbitrary, but we tend to use a few:

- E - Element (used extensively by the Java Collections Framework)
- K - Key
- N - Number
- T - Type
- V – Value

Advantages of Generics

- Code reuse
  - ArrayList, Java Collections Framework
- Specific types are checked at compile time (as opposed to everything having to be an Object)
  - Reduces runtime errors
- Easier to read and understand code when we can be very explicit about types

Notes

- Primitive types cannot be used as generic types
    - Must use the wrapper classes
- Type erasure: generics are checked at compile time, not at runtime
    - This decision was made to maintain backward compatibility
    - Not a serious issue most of the time

Implications of Type Erasure

- Cannot construct objects of type E

```
E myData = new E();  // illegal code
```

- Cannot construct arrays of type E

```
E[] elements = new E[capacity]; // illegal
```

  - Solution to the latter: create an array of objects and then cast to array of E

```
E[] elements = (E[]) new Object[capacity]; // Legal
```

Implications of Type Erasure

- instanceof() cannot distinguish same class with different generic type, because it is done at run time
    - ArrayList<Integer> and ArrayList<String> are the same type according to instanceof
- Exception classes cannot be generic
- Static data cannot be of a generic type

Inheritance and Generics

- In many situations, we might have more than one generic type as part of a class or method definition
- These could be arbitrary types or we might want them to have some specific relationship
  - For example: we might want T1 to be a superclass of T2

Administrivia

- Lab 5 grades: coming
- Project 1 grades: posted
- Exam 1 grades & returned exams: posted and emailed
- Lab 7 coming soon

Generics

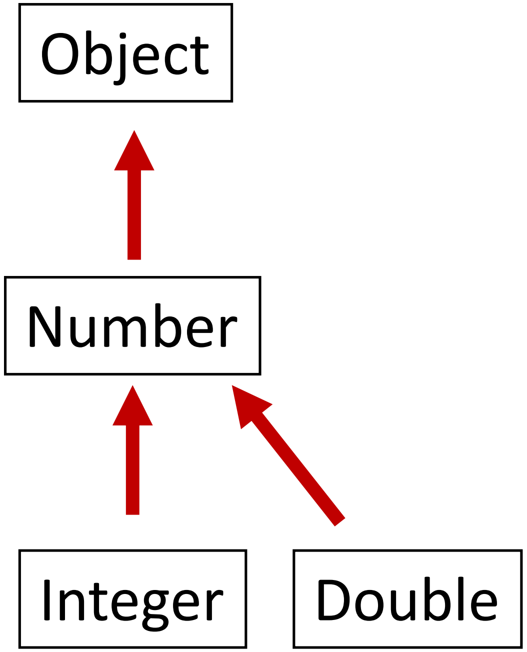
A type becomes a parameter of another type definition

For example: GenericStack<Person>

- Code reuse
- Standard interfaces
- Type checking at compile time

- Type erasure: generic types are lost at run time

Class Hierarchies



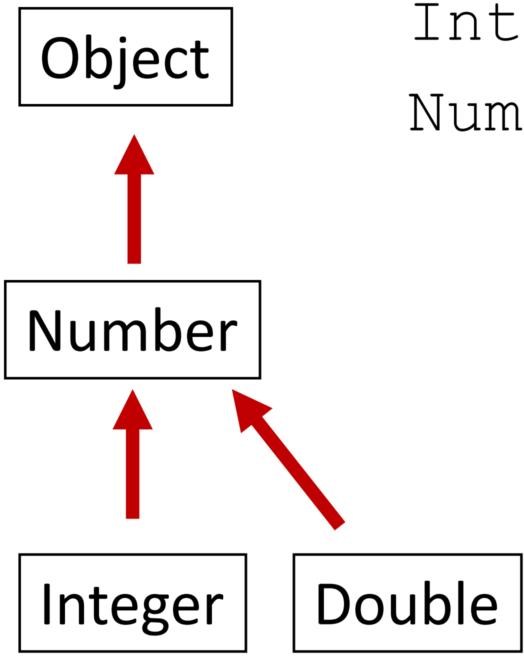
Object

Number

Integer

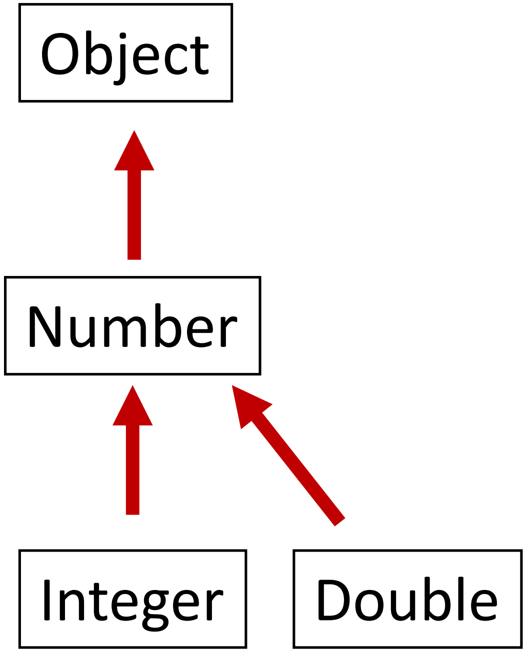
Double

Class Hierarchies



```
Integer i = new Integer(42);
Number n = new Integer(1138);
```

Class Hierarchies



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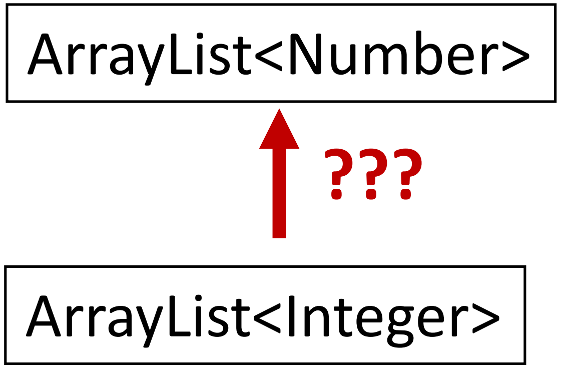
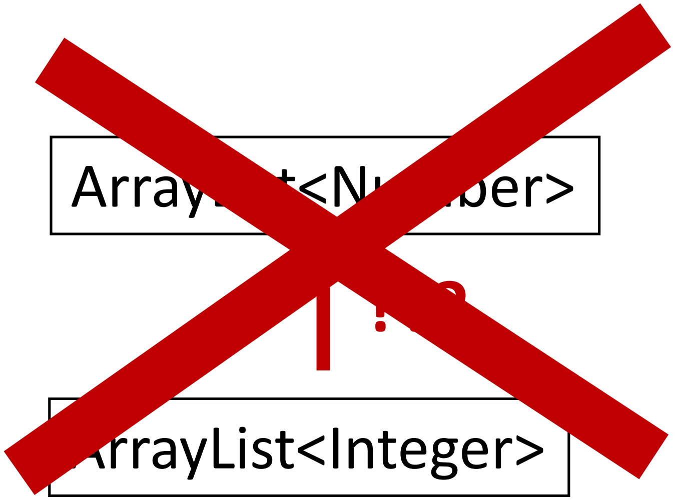


ArrayList<Number>

???

ArrayList<Integer>

Class Hierarchies

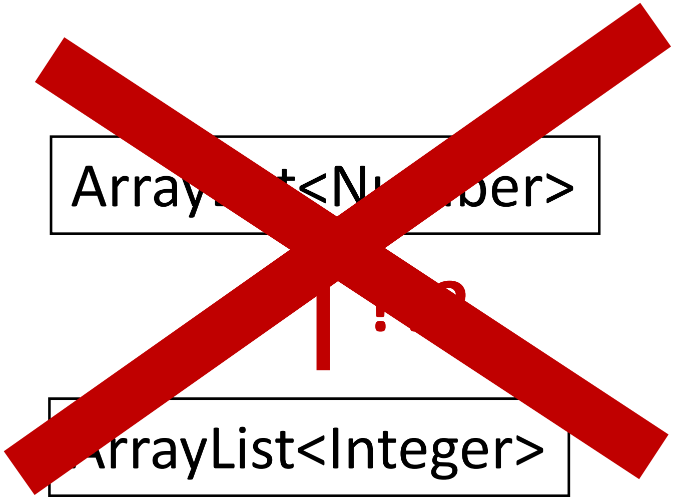


ArrayList<Number>

!?

ArrayList<Integer>

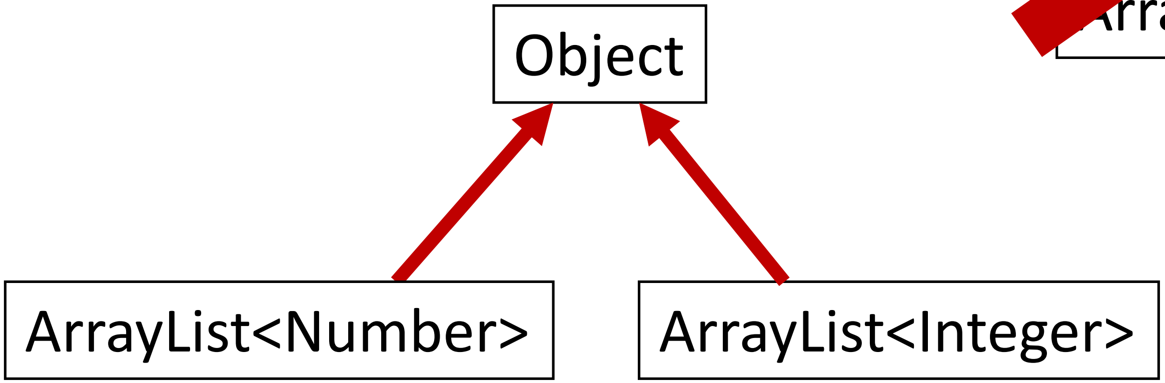
Class Hierarchies



ArrayList<Number>

!?

ArrayList<Integer>



Object

ArrayList<Number>

ArrayList<Integer>

The only common (specific) ancestor is Object…

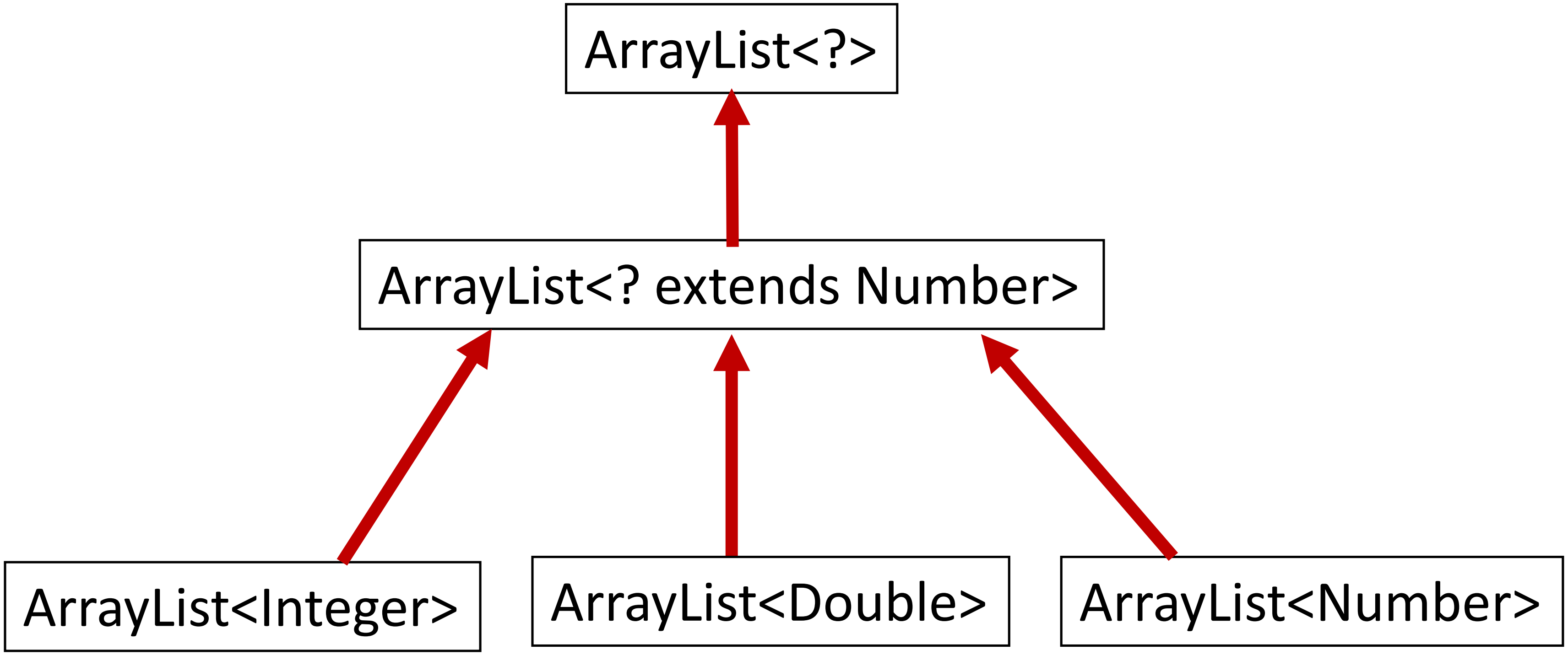
GenericTest example

Wildcards

- We still want a way of saying that we will accept any type as input to a generic
- Or – we want to put constraints on the type

Wildcards

There is a class hierarchy that we can use…



ArrayList<?>

ArrayList<? extends Number>

ArrayList<Integer>

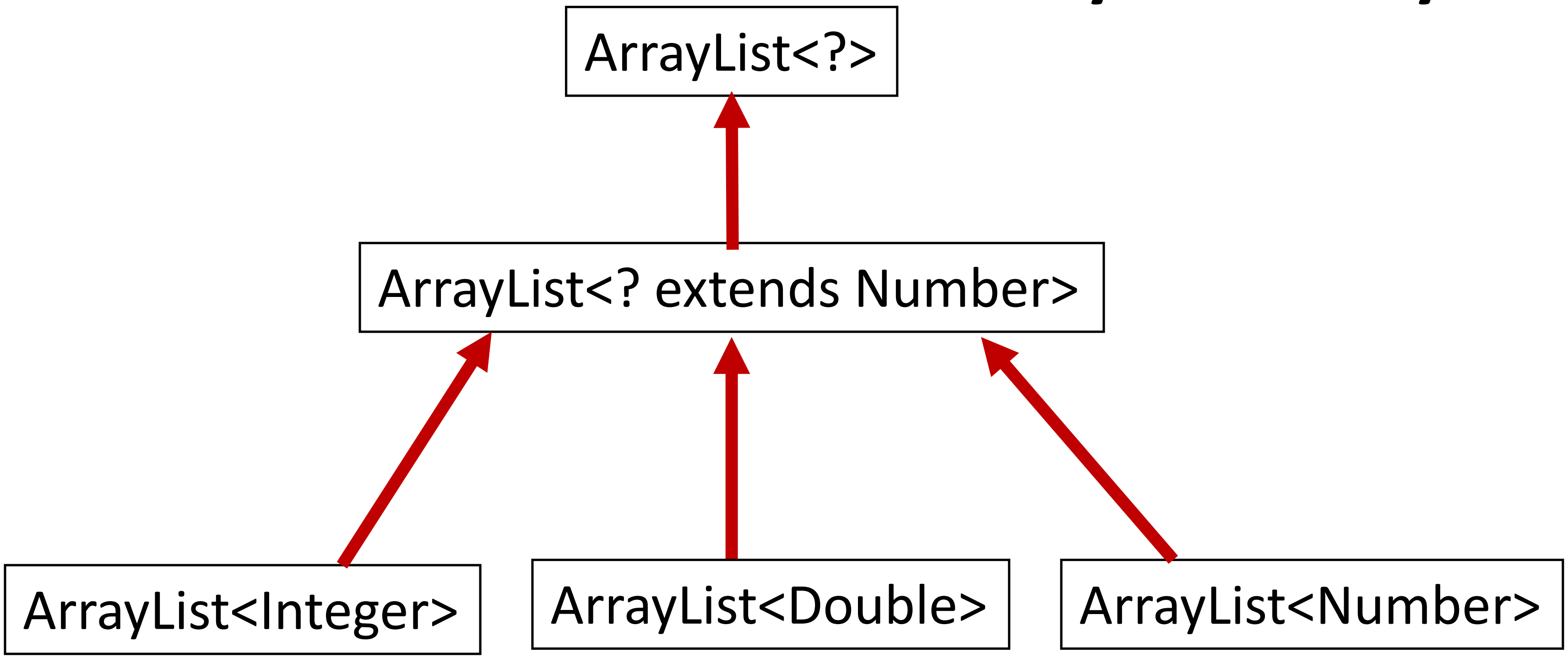
ArrayList<Double>

ArrayList<Number>

Wildcards

But, there is a hierarchy that we can use…

"ArrayList of anything"



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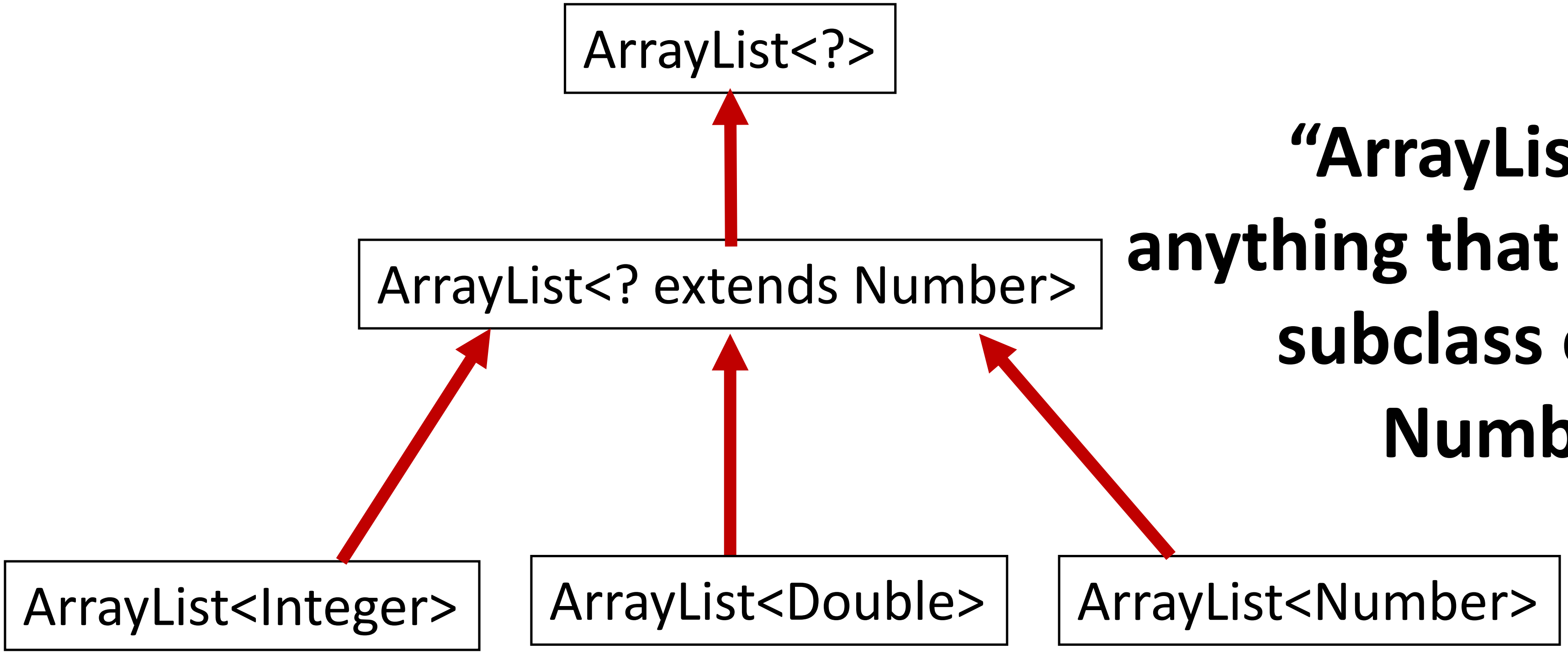
Wildcards

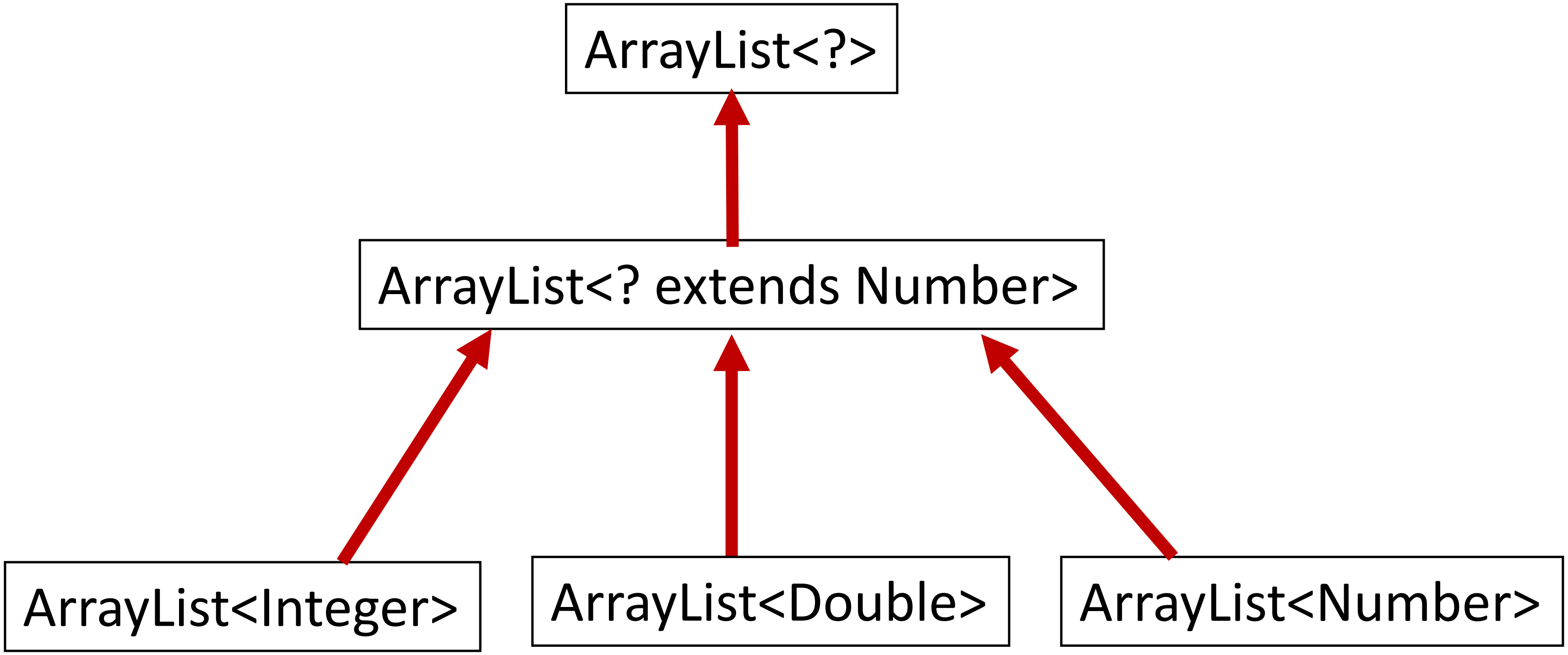
But, there is a hierarchy that we can use…



"ArrayList of anything that is a subclass of a Number"

Wildcards

```
ArrayList<Integer> list1 = new ArrayList<Integer>();
ArrayList<? extends Number> list2 = list1;   // Legal
```



ArrayList<?>

ArrayList<? extends Number>

ArrayList<Integer>

ArrayList<Double>

ArrayList<Number>

Example: sum a stack of Numbers

Binary Search

Search for a key in an array and return it’s index

- One possible implementation:

```
public static int <T>
    binarySearch(T[] a, T key, Comparator<T> c)
```

- The Comparator allows us to compare the key against the elements of the array
- The generic implementation doesn’t require knowledge of the specific object types

Binary Search

Could we be more general about what Comparators are acceptable?

- Suppose T = Double

Binary Search

Could we be more general about what Comparators are acceptable?

- Suppose T = Double

- Could a Comparator<Number> work?
  - Yes! Number allows access to the doubleValue

  - public static int compare(Number d1, Number d2)
  - If(d1.doubleValue() < d2.doubleValue()) return -1;
  - …

Wildcard Example I

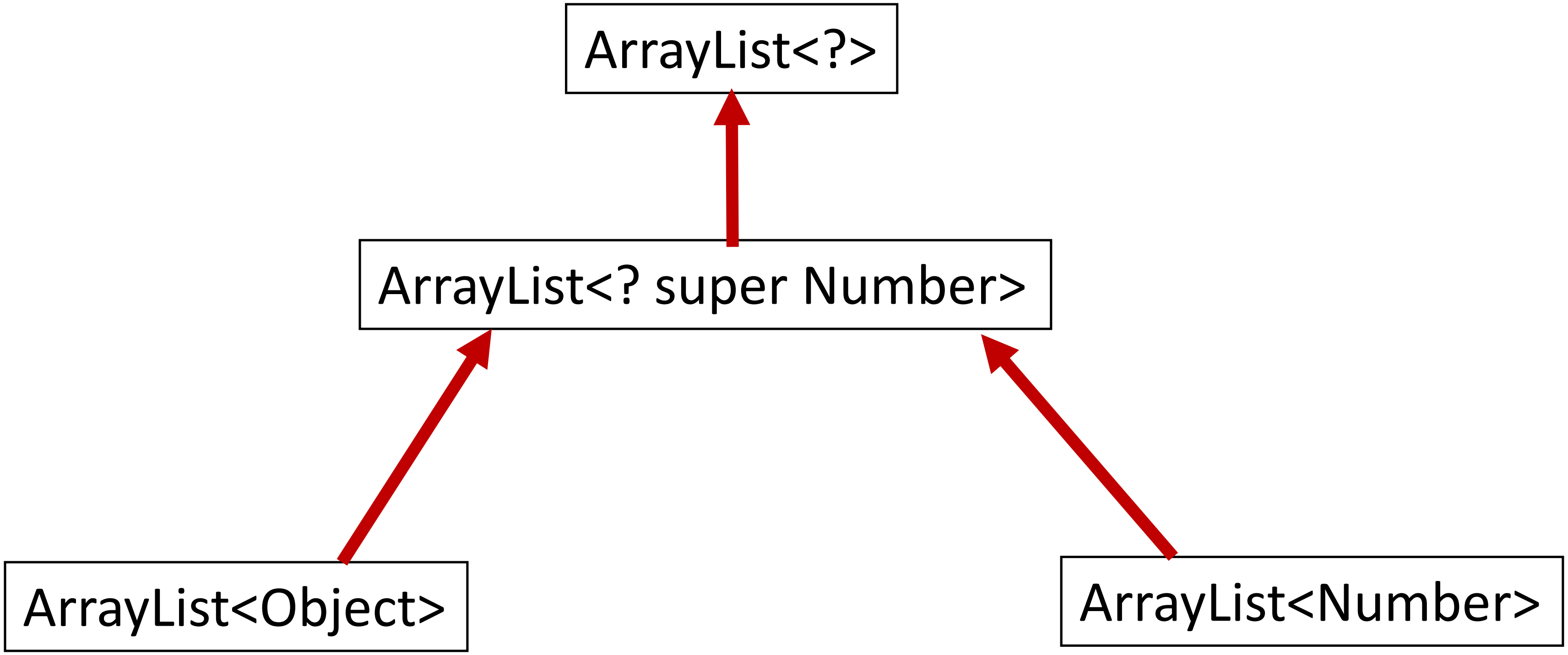
Arrays in Java API (actual implementation):

```
binarySearch(T[] a, T key, Comparator<? super T> c)
```

- The class that is passed as the third parameter must implement the Comparator interface for type T or a superclass of type T

Wildcards

The complement…



ArrayList<?>

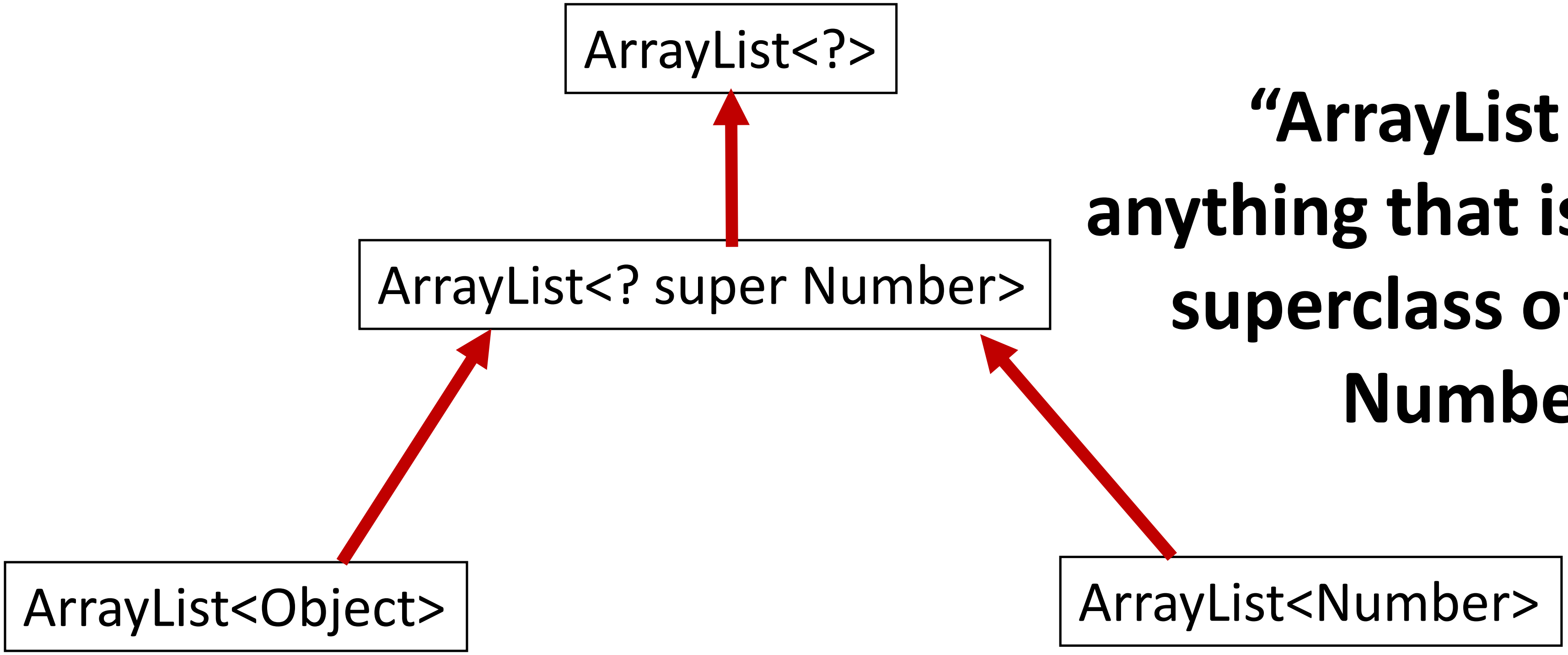
ArrayList<? super Number>

ArrayList<Object>

ArrayList<Number>

Wildcards

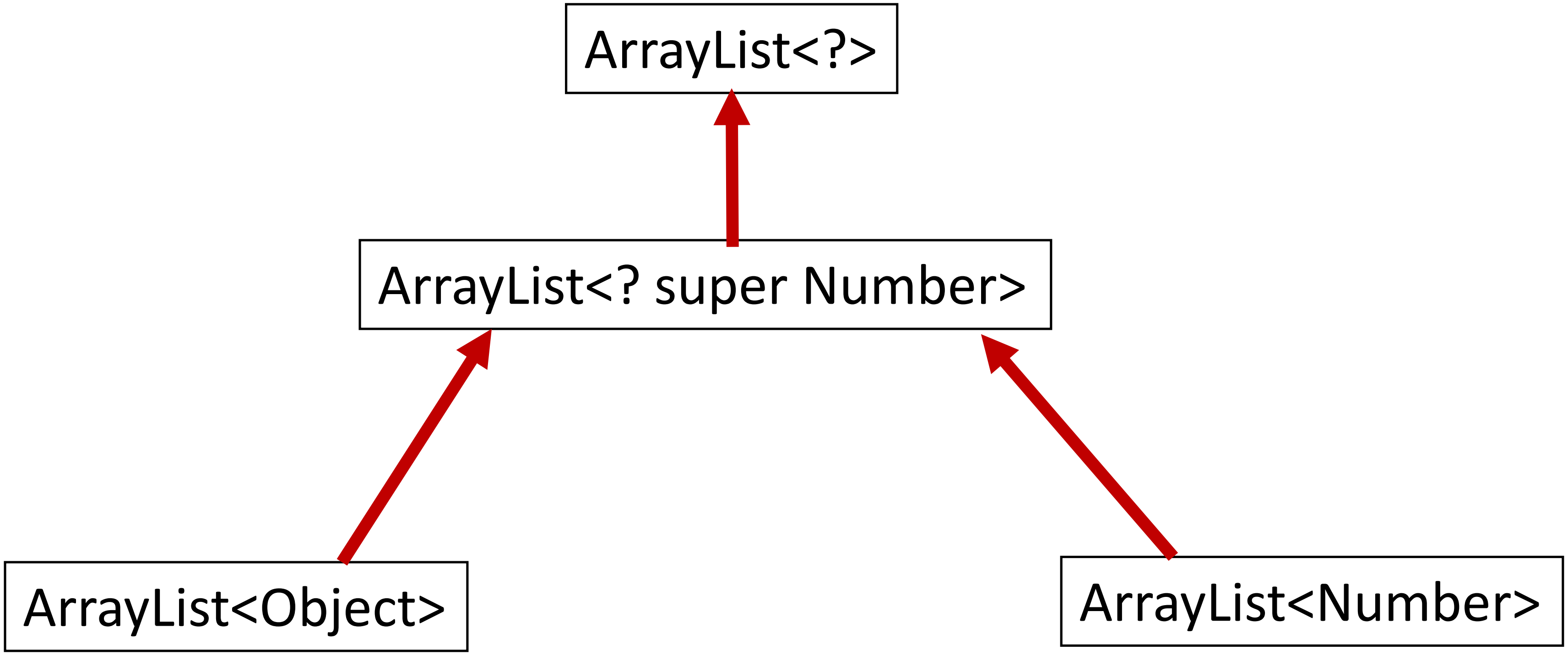
The complement…



“ArrayList of anything that is a superclass of a Number”

Wildcards

```
ArrayList<Object> list1 = new ArrayList<Object>();
ArrayList<? super Number> list2 = list1;    // Legal
```



Wildcard Example II

Example: Copy from one GenericStack to another

```
public static<T> void
     copy (GenericStack<? super T> dest,
            GenericStack<? extends T> src)
```

- The <T> before the method name determines the base type
- The source must be a class that is or extends T
- The destination must be a class that is or is a superclass of T

Wildcards and Generic Types

- Give us a tremendous amount of flexibility
- Wildcard types are defined and checked at compile time
    - Reduce runtime errors!

- Lab 7: we will define:
    - Generic notion of a Card<T>
    - Generic notion of a Deck<T, E extends Card<T>>