Generics and Collections

Intro: Generics

With generics, we can define a class that takes a **type as a parameter**

Ex: List <Integer>, Map<String>

Motivation: make Collections safer to use

```
public class MyListOfStuff<T> {
        // The T can be any type
        public void add(T val) {
                ...
        }
}
```

Demo

Type erasure

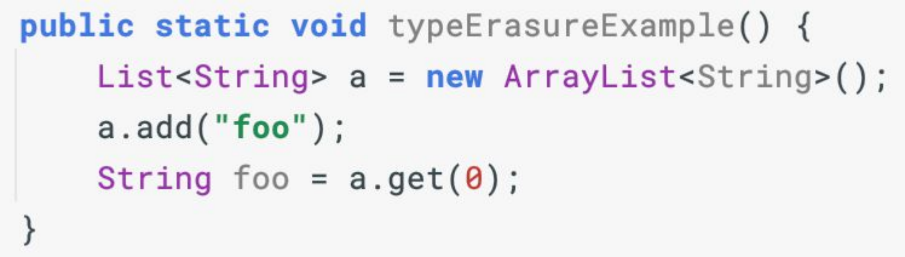
Once your code is compiled, the generic types are **erased.**

Limitations:

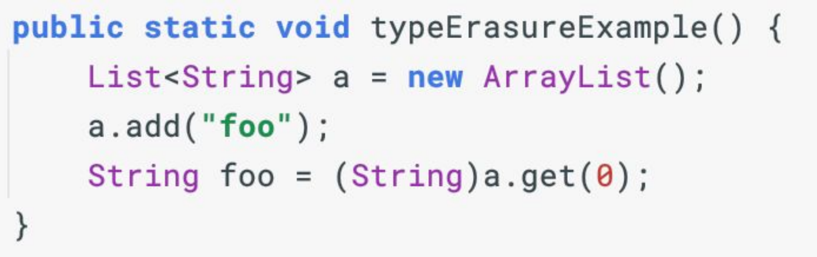
- Constructing a new instance of T
- Creating an array of type T

Can't do these things -- At run time, T is not known!

Pre-compilation vs post compilation



```
public static void typeErasureExample() {
    List<String> a = new ArrayList<String>();
    a.add("foo");
    String foo = a.get(0);
}
```



```
public static void typeErasureExample() {
    List<String> a = new ArrayList();
    a.add("foo");
    String foo = (String)a.get(0);
}
```

Arrays of Generics

```
class Example {
        public static T[] makeArray(int length) {
                return new T[length];              //Illegal!
        }
}
```

Solutions

```
class Example {
        public static <T> T[] makeArray(int length) {
                return (T[]) (new Object [length]);            //Legal, but not always safe
        }
}
```

This array can never be assigned to a variable with a concrete (non-generic) type.

Solutions

```
class Example<T> {
        public static <T> T[] makeArray(int length) {
                return (T[]) (new Object [length]);
        }

        public static String[] makeStringArray(int length) {
                String[] s = Example.<String>makeArray(length);     //Not ok
                return s;
        }

        public static <T> void printLength(int length) {
                T[] s = <T>makeArray(length);       //OK!
                System.out.println(s.length);
        }
}
```

Solutions

Use a Collection instead of an array!

Wildcards

List<String> is **not** a subtype of List<Object>, even though String **is** a subtype of Object.

Note: if List<> **<:** Collection<>, then List<String> **<:** Collection<String>. Just can't state these relations if they involve <T> itself

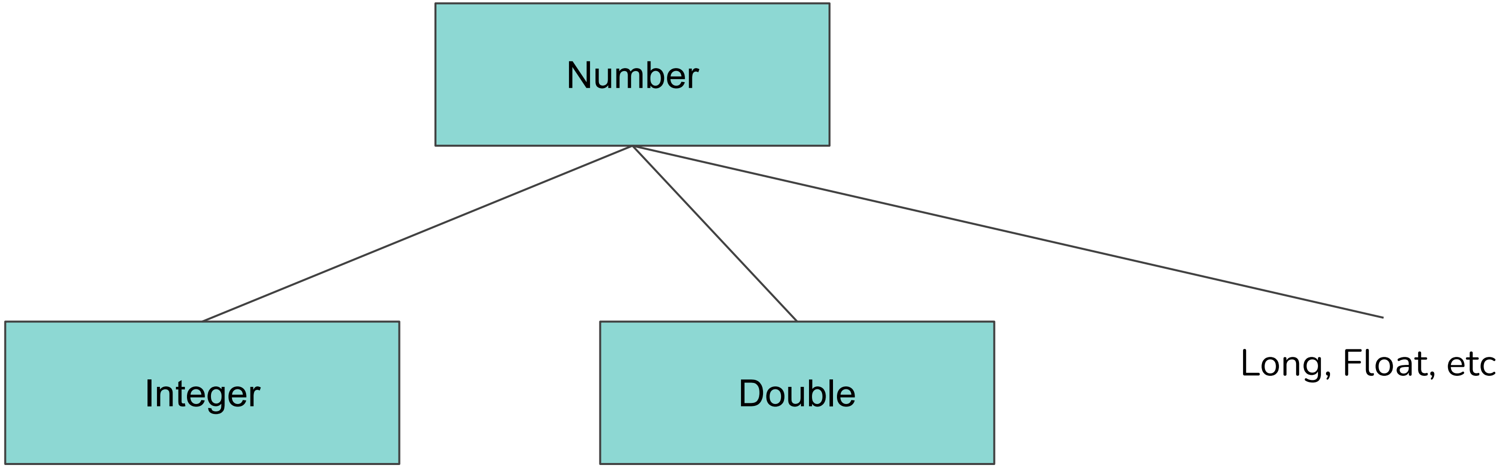
How do we program for cases covering related types?

Wildcards

There are three wildcard operators we can use to represent groups of types in generics.

- List <?>
  - A List of any type
- List <? extends A>
  - A List of any subtype of A
  - Upper Bound
- List <? super A>
  - A List of any supertype of A
  - Lower Bound

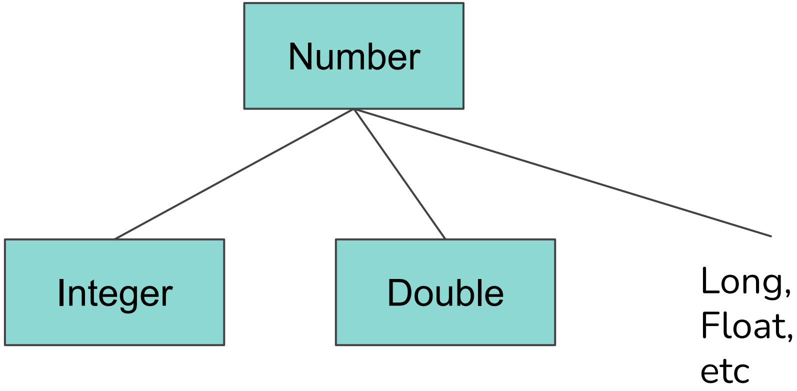
Type Hierarchy of Number, Integer, Double



Wildcards

```
List<?> unbound = new ArrayList<>();
List<? extends Number> ext = new ArrayList<>();
List<? super Number> sup = new ArrayList<>();

unbound.add(0);             //Illegal
ext.add(0);                 //Illegal
sup.add(0);                 //Legal
```

Why this works the way it does



Number

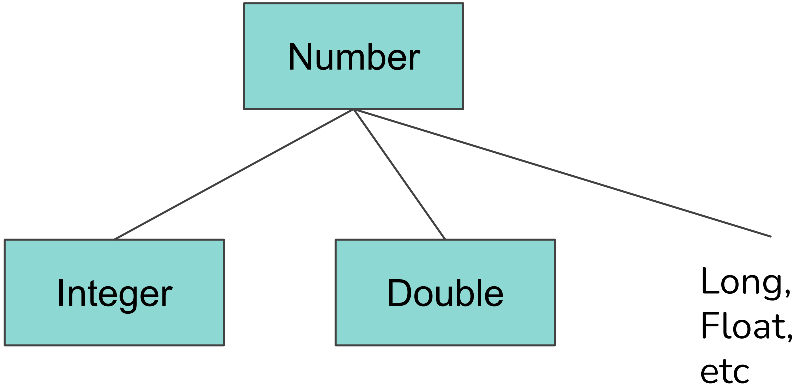
Integer

Double

Long,
Float,
etc

```
List<String> strList = new ArrayList<>();
strList.add(“hello”);
List<?> unbound = strList;
Integer zero = 0;

unbound.add(zero);    //Next slide
```

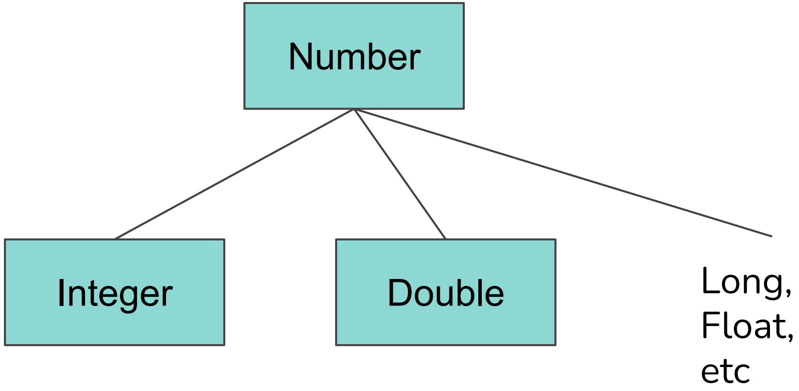
Why this works the way it does



```
List<String> strList = new ArrayList<>();
strList.add(“hello”);
List<?> unbound = strList;
Integer zero = 0;

unbound.add(zero);    //Illegal! This would be adding an Integer to a String list
```

Why this works the way it does

```
List<Double> dbList = new ArrayList<>();
dbList.add(2.112);
List<? extends Number> ext = dbList;
Integer zero = 0;

ext.add(zero);    //Next slide
```



Number

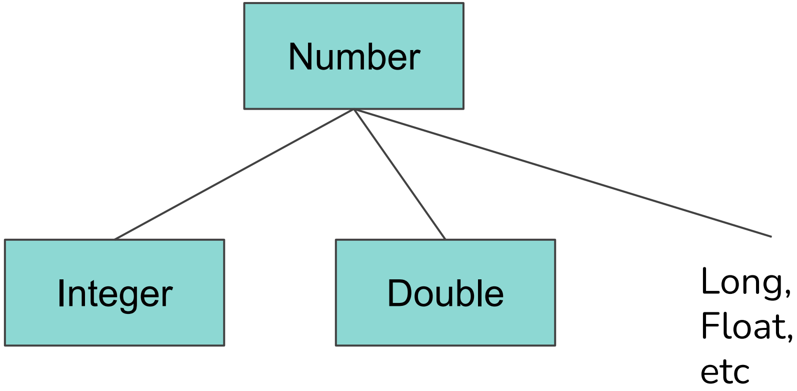
Integer

Double

Long,
Float,
etc

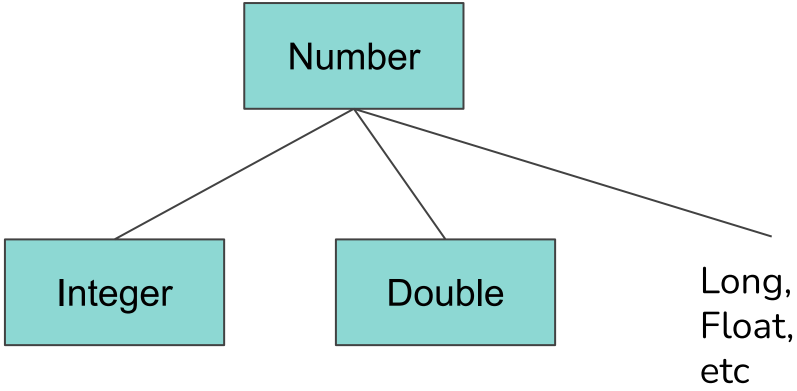
Why this works the way it does

```
List<Double> dbList = new ArrayList<>();
dbList.add(2.112);
List<? extends Number> ext = dbList;
Integer zero = 0;

ext.add(zero);    //Illegal! This would be adding an Integer to a Double list
```



Why this works the way it does

```
List<Object> oList = new ArrayList<>();
oList.add(“hello”);
List<? super Number> sup = oList;
Integer zero = 0;

sup.add(zero);    //Next slide
```



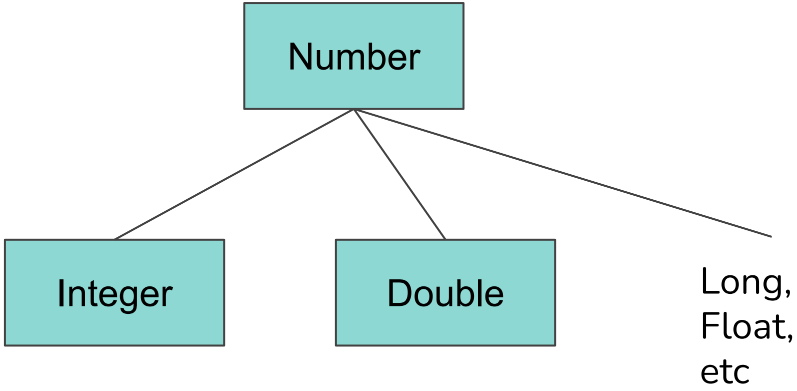
Number

Integer

Double

Long,
Float,
etc

Why this works the way it does



```
List<Object> oList = new ArrayList<>();
oList.add(“hello”);
List<? super Number> sup = oList;
Integer zero = 0;

sup.add(zero);    //Legal zero is still an Object, which is a super class of Number
```

Wildcards

```
List<Integer> original= new ArrayList<>();
original.add(0);

List<?> unbound = original;
List<? extends Integer> ext = original;
List<? super Integer> sup = original;


Integer i = unbound.get(0);   //Illegal
Integer i = ext.get(0);       //Legal
Integer i = sup.get(0);       //Illegal
```

Wildcards

```
List<Integer> original= new ArrayList<>();
original.add(0);

List<?> unbound = original;

Integer i = unbound.get(0);        //Illegal, we have no clue what type is inside of unbound
```

Wildcards

```
List<Integer> original= new ArrayList<>();
original.add(0);

List<? extends Integer> ext = original;

Integer i = ext.get(0);        //Legal, regardless of the type of the list, we know it is a subtype
                               // of Integer!
```

Wildcards

```
List<Number> original= new ArrayList<>();
original.add(2.112);

List<? super Integer> sup = original;

Integer i = sup.get(0);         //Illegal, we only know that the list is a super type of Integer. It
                                //could be a Number list or even an Object list.
```

Raw Types

You don’t actually have to specify a type!

```
List a = new ArrayList<>();     //this is dangerous, java will warn you
a.add(2112);                    //Legal
a.add(“hello”);                 //Legal
a.add(true);                    //Legal
a.add(null);                    //Legal
```

Only available to maintain backwards compatibility with older versions of Java

Solutions

```
import java.lang.reflect.Array;
class Example <T> {
        public static <T> T[] makeArray(Class<T> clazz, int length) {
                return (T[]) Array.newInstance(clazz, length);          //Legal and safe, but gross.
        }
}
```

Unless you have an extremely good reason, please do not do this. You may lose points on your A3 and future assignments.

Collection

Interface that describes collections of items.

Ex: ArrayList, LinkedList, HashSet

Maps act similarly to Collections although they are not a subtype, so people often refer to Map as part of the “Collections Framework”

Useful Methods in Collection

boolean add(E e) - adds an element of type E, returns whether the collection added the element

boolean contains(Object o) - returns true if o is in the collection

boolean remove(Object o) -removes the element equal to o if it is present, returns whether something was actually removed

int size() - returns the number of elements in the collection

Iterating

You can also iterate through elements of a collection with a foreach loop

Ex:

```
ArrayList<Integer> nums = ....;

for (Integer i : nums) {
        //do stuff
}
```

Array of Collection

This is probably the only case in which you would want to use a raw type!

```
ArrayList<Integer>[] arrListArr = new ArrayList<Integer>[10];        // Illegal
ArrayList<Integer>[] arrListArr2 = new ArrayList[10];                // Legal
```

Is this Legal?

```
Set<?> setOfUnknownType = new LinkedHashSet<String>();
setOfUnknownType = new LinkedHashSet<Integer>();
```

Is this Legal?

```
Set<?> setOfUnknownType = new LinkedHashSet<String>();
setOfUnknownType = new LinkedHashSet<Integer>(); // Legal
```

Is this Legal?

```
Set<String> setOfString = new HashSet<String>();
Set<Object> setOfObject = new HashSet<String>();
```

Is this Legal?

```
Set<String> setOfString = new HashSet<String>();
Set<Object> setOfObject = new HashSet<String>(); // Illegal
```

Is this Legal?

```
Set<? extends Number> set = new HashSet<Integer>();
set = new HashSet<Float>();
```

Is this Legal?

```
Set<? extends Number> set = new HashSet<Integer>();
set = new HashSet<Float>(); // Legal
```

Will this Compile?

```
public static void print(List<? extends Number> list) {
        for (Number n : list) {
                System.out.print(n + " ");
        }
        System.out.println();
}
```