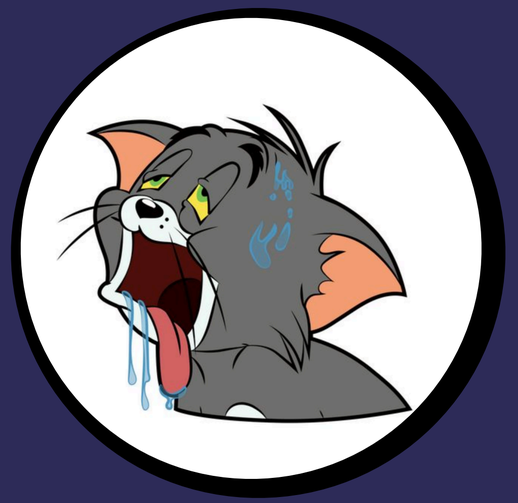
Generics



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What do we win with generics?

- no need for ~~explicit casting~~
- type checking in **compile time** ~~(ClassCastException)~~
- (enabling programmers to implement **generic algorithms**)

Introduction

- introduced by *JDK 5*
- new syntactic elements (`?`, `<>`)
- rewrite core Java classes, methods, etc.
- can be ***class***, ***interface***, ***method***, ***constructor***

1. Class

`A class is generic if it declares one or more type variables. These type variables are known as the type parameters.`

`syntax: class class-name<type-param-list> {…}`

`type parameter scope: inside class definition block`

- **type erasure:**

  To implement generics and to also preserve backward compatibility *javac* applies type erasure.

  - replaces all type parameters with their bounds or with `Object` if the parameter is unbounded
  - inserts type casts if necessary
  - generates bridge methods to preserve polymorphism

```java
class Gen<T> {

    private T ob;

    public Gen(T o) {
        ob = o;
    }

    public T getOb() {
        return ob;
    }

    public void setOb(T o) {
        this.ob = o;
    }
}
```

type erasure

```java
class Gen {

    private Object ob;

    public Gen(Object o) {
        ob = o;
    }

    public Object getOb() {
        return ob;
    }

    public void setOb(Object o){
      this.ob = o;
    }
}
```

Raw types

- support for generics did not exist prior to *JDK 5*
- it was necessary to provide a transition path which enables pre-generics code to remain functional while at the same time being compatible with generics.
- to handle the transition to generics, Java allows a generic class to be used without any type arguments, resulting in ***raw type***
- **disadvantage:**
  type safety of generics is lost

```
{
    List myList = new ArrayList();

    myList.add("one");

    for(int i=0; i<myList.size(); i++){
        //explicit type cast needed
        String str = (String) myList.get(i);
        System.out.println("The "+i+"th element is: "+str);
    }
}
```

Type parameter

- scope depends on where it is declared
- needs to be declared inside <>
- no special significance to the name T
- naming conventions:
  - E: Element (mainly used by *Collection Framework*)
  - K: Key
  - N: Number
  - T: Type
  - V: Value
  - S, U, etc.

```
1 class Gen<T> {
2
3     private T ob;
4
5     public Gen(T o) {
6         ob = o;
7     }
8
9     public T getOb() {
10        return ob;
11    }
12
13    public void setOb(T o) {
14        this.ob = o;
15    }
16 }
```

Type parameter

- *JDK 10*: cannot be ~~var~~
- arguments can only be reference types
  eg.: `Integer,List<Integer>, int[]`
- more than one type parameter in a comma-separated list

```
1 class Gen<T, V> {
2
3     T obT;
4     V obV;
5 }
6
7 {
8 //        T        V                              T       V
9     Gen<Integer, String> genReference = new Gen<Integer, String>(69, "is awesome!");
10    Gen<String, String> x = new Gen<String, String>("69", "is awesome");
11 }
```

Type parameter - Bounding

We can use inheritance in order **to limit** the types that can be substituted.

`syntax: <T extends superclass>`

This specifies that T can only be replaced by superclass, or subclasses of superclass, thus superclass defines an inclusive, upper limit.

- limit can be an *interface* or a *class*
- only *upper* bound
- only specified types can be extended, else you have to specify it by listing it as a type parameter

```
1 //valid
2 class Box<U extends Number> {}
3
4 //invalid
5 class Box<U extends V> {}
6
7 //valid
8 class Box<U extends V, V> {}
```

Type parameter - Bounding

- a type parameter can have multiple bounds
  - **&** operator
  - only 1 class
  - class has to come first
- if the superclass is generic, and it doesn't have a specified argument, than it's type has to be listed in the parameter list

```
1  Class A {}
2
3  interface B {}
4
5  interface C {}
6
7  //valid
8  class D <T extends A & B & C> {}
9
10 //invalid
11 class D <T extends B & A & C> {}
12
13
14 //valid
15 class A<T extends B<String>> {}
16
17 //valid
18 class A<T extends B<T>> {}
19
20 //invalid
21 class A<T extends B<U>> {}
22
23 //valid
24 class A<T extends B<U>, U> {}
```

Wildcard argument

In generic code, the question mark (**?**), called the **wildcard**, represents an **unknown type**.

- **can** use a generic type with a wildcard:
  - as a parameter in a method
  - as a field
  - as a local variable
- **can't** use a generic type with a wildcard:
  - as a type argument for a generic method invocation
  - at generic class instance creation
  - as a supertype

```
1  class A {
2      //valid
3      private List<?> list;
4
5      //valid
6      public List<?> getList(){
7          return this.list;
8      }
9
10     public void setList(List<?> list){
11         //valid
12         List<?> myListCopy = list;
13         this.list = list;
14     }
15 }
16
17 {
18     //invalid
19     Arrays.<?>asList(6, 9, "=69");
20
21     //invalid
22     List<String> list = new ArrayList<?>();
23
24     //invalid
25     class MyList implements List<?> {}
26 }
```

Wildcard argument - Bounding

We can use inheritance in order **to limit** the types that can be substituted.

- limit can be an *interface* or a *class*
- works only with specified types
- no multiple bounds
- upper bound ***and*** lower bound

```
{
    //invalid
    List<? extends A & B> foobar;
    A & B item = foobar.get(0)
}
```

Wildcard argument - Bounding

- *Upper:* `syntax: <? extends superclass>`
  This specifies, that **?** can only be superclass type, or a type that is a subclass of the superclass, thus superclass defines an inclusive, upper limit.

- Lower: `syntax: <? super subclass>`
  This specifies, that **?** can only be subclass type, or a type that is a superclass of the subclass, thus subclass defines an inclusive, lower limit.

```
1 {
2  /*
3  * Suppose we want to accept lists, which can contain any Number type
4  * eg.: List<Integer>, List<Double>...etc.
5  */
6   public void printList(List<Number> list){} //not OK
7   public void printList(List<? extends Number> list){} //OK
8
9   /*
10 * Suppose we want to accept lists, which can contain Integer type
11 * eg.: List<Integer>, List<Number>, List<Object>...etc.
12 */
13  public void printList(List<Integer> list){} //not OK
14  public void printList(List<? super Integer> list){} //OK
15 }
```

2. Method

A method is generic if it declares one or more type variables.
These type variables are known as the formal type parameters of the method.

/Generic methods are methods that introduce their own type parameters./

syntax: <formal-type-param-list > ret-type meth-name (param-list) {…}

formal type parameter scope: inside method definition block

- same type parameter rules apply
- can be declared in generic and in non-generic class or interface
- you can explicitly specify the type argument if needed on calling:

```
StringLengthChecker.
<Integer, String>compareStringLength(69, "ok")
```

```
1 class StringLengthChecker {
2     public static <K, V> int compareStringLength(K ob1,V ob2){
3         Integer ob1Length=ob1.toString().length();
4         Integer ob2Length=ob2.toString().length();
5         return ob1Length.compareTo(ob2Length);
6     }
7 }
```

3. Constructor

A constructor is generic if it declares one or more type variables.
These type variables are known as the formal type parameters of the constructor.

/Generic constructors are constructors that introduce their own type parameters./

syntax: <formal-type-param-list > constructor-name (param-list) {…}

formal type parameter scope: inside constructor definition block

- same type parameter rules apply
- can be declared in generic and in non-generic class
- you cannot explicitly specify the type argument on calling

```
1 class A {
2
3     private double val;
4
5     <T extends Number> A(T arg) {
6         val = arg.doubleValue();
7     }
8
9     void showVal() {
10        System.out.println("val: " + val);
11    }
12 }
```

Inheritance

In a generic hierarchy, any type arguments needed by a generic superclass or interface must be passed up the hierarchy by all subclasses.

- only the not specified type arguments have to be passed!
- if the needed type argument is a bounded type, then the inheritor has to define its bound.
  Once this bound has been established, its not allowed to specify it again!

```
1  class Gen<T> {}
2
3  interface GenI<T> {}
4
5  class Gen2<U, V> extends Gen<U> implements GenI<V> {}
6
7  class Gen3 extends Gen<String> {}
8
9
10 interface GenI<T extends Number> {}
11
12 //valid
13 class Gen<U extends Number> implements GenI<U> {}
14
15 //valid
16 class Gen2<U extends Integer> implements GenI<U> {}
17
18 //invalid
19 class Gen3<U extends Integer> implements GenI<U extends Integer> {}
```

4. Interface

An interface is generic if it declares one or more type variables. These type variables are known as the type parameters of the interface.

syntax: interface interface-name<type-param-list> {…}

type parameter scope: inside interface definition block

- same type parameter rules apply

```
1 public interface List<E> extends Collection<E> {}
```

Type inference

`Type inference is the ability of the Java compiler to infer datatypes based on corresponding declarations.`

- *JDK 7* introduced the diamond operator `<>`
  - prior to JDK 7: `class-name<type-arg-list> var-name = new class-name <same-type-arg-list>(cons-arg-list);`
  - after JDK 7: `class-name<type-arg-list > var-name = new class-name <>(cons-arg-list);`
- *JDK 10* introduced the `var` keyword
  - after JDK 10: `var var-name = new class-name <type-arg-list>(cons-arg-list);`

```
1 {
2  Map<Integer, String> myMap=new HashMap<Integer, String>();
3  Map<Integer, String> myMap=new HashMap<>();
4  var myMap=new HashMap<Integer, String>();
5 }
```

Ambiguity error

`Ambiguity errors occur when erasure causes two seemingly distinct generic declarations to resolve to the same erased type, causing a conflict, resulting a compile time error.`

- mainly happens on **overloading**
  (same name, same class or interface, different signature)

```java
class MyGenClass<T, V> {

  T ob1;
  V ob2;

  // These two overloaded methods are ambiguous
  // and will not compile.
  void set(T o) {
      ob1 = o;
  }

  void set(V o) {
      ob2 = o;
  }
}
```

type erasure

= compile-time error!

```java
class MyGenClass {

  Object ob1;
  Object ob2;

  void set(Object o) {
      ob1 = o;
  }

  void set(Object o) {
      ob2 = o;
  }
}
```

Some restrictions

- cannot instantiate a **type parameter**

```
1 class Gen<T> {
2     T ob;
3     Gen() {
4         //invalid
5         ob = new T();
6     }
7 }
```

- cannot instantiate an **array** whose element type is a *type parameter*

```
1 class Gen<T> {
2     T[] vals;
3     Gen() {
4         //invalid
5         vals = new T[10];
6     }
7 }
```

- cannot create an **array** of *type-specific generic references*

```
1 //invalid
2 List<String>[] myStringListArray = new List<>[10];
3 //valid
4 List<?>[] myStringListArray = new List<?>[10];
```

Some restrictions

- **no static member** can use a *type parameter* declared by the enclosing class

```
1 class Gen<T> {
2
3     //invalid
4     static T ob;
5
6     //invalid
7     static T getOb() {
8         return ob;
9     }
10 }
```

- a generic class cannot extend **Throwable**, meaning you cannot create generic exception classes

```
1 //invalid
2 class Gen<T> extends Throwable {}
```

Summary

introduced by JDK 5, no explicit type-casting, type check at compile-time, can be class | interface | method | constructor, type erasure, raw types, type parameter and it's rules, type parameter bounding, wildcard argument (`?`), wildcard argument and it's bounding, inheritance between generics, type inference (`<>` JDK7, `var` JDK10), ambiguity compile time error, some restrictions

- *further reading: bridge methods*

The End