Generics

IRS W-9 Form
Generics

Generic class and methods.
BNF notation
Syntax

Non-parametrized class:

```
<class declaration> ::= 
  "class" <identifier> 
  ["extends" <type>] 
  ["implements" <type list>] 
  
  
  
  "{" <class body> "}"
```

Generic class

```
<class declaration> ::= 
  "class" <identifier> [<type parameter list>] 
  ["extends" <type>] 
  ["implements" <type list>] 
  
  "{" <class body> "}"
```
Non-parametrized method

```
<method declaration> ::= 
    <type> <identifier>
    "(" [<formal parameters list>] ")"
    ["throws" <qualified identifier list>]
    "{" <method body> "}"
```

Generic method

```
<method declaration> ::= 
    [/<type parameter list>] <type> <identifier>
    "(" [<formal parameters list>] ")"
    ["throws" <qualified identifier list>]
    "{" <method body> "}"
```
Syntax

Generic type parameters

```plaintext
<type parameter list> ::= 
    "<" <type parameter> {"," <type parameter>} ">"
<type parameter> ::= 
    <identifier> [ "extends" <bound> ]
<bound> ::= <type> { "&" <type> }

<type argument list> ::= 
    "<" <type argument> {"," <type argument>} ">"
<type argument> ::= <type>
    | "?" ["extends" <type>]
    | "?" ["super" <type>]
```
Syntax

\[
\text{<type> ::= <identifier> [<type argument list>]}
\]
\[
{"." <identifier> [<type argument list>]}
\]
\[
{"[" "]"}
\]
\[
/ <primitive type>
\]
Consider building a class to hold two values.

class Pair {
    int first, second;
}

Not very flexible. So we try using subtype polymorphism (object-oriented programming). We take advantage of the fact that every object is a subclass of `Object`.

```java
class Pair {
    Object first, second;
    void setFirst (Object first) { this.first=first; }
    Object getFirst () { return first; }
}

Pair p = new Pair();
p.setFirst (new Object());
p.setFirst ("hello");
p.setFirst (new Integer (5));
System.out.println (p.getFirst());
```
Subtype polymorphism here is unsafe. The type of the objects is “laundered.” We can put it in; but we can’t take it out as the same type of thing we put in.

class Pair {
    Object first, second;
    void setFirst (Object first) { this.first=first; }
    Object getFirst () { return first; }
}

Pair p = new Pair();
p.setFirst (new Integer (5));
Integer i = (Integer) p.getFirst();  // narrowing
Generic classes (universal polymorphism) is the perfect solution.

```java
class Pair <T> {
    public final T first, second;
    Pair (T first, T second) {
        this.first=first; this.second=second;
    }
    T getFirst () { return first; }
}
```

Pair<Integer> p =
    new Pair<Integer>(new Integer(5), new Integer(8))
Integer i = p.getFirst();
Pair<String> q =
    new Pair<String>("abc","xyz");
String s = q.getFirst();

**Autoboxing and unboxing of primitive types.**

Pair<Integer> p = new Pair<Integer>(5, 8)
int i = p.getFirst();
```java
class Pair <T,U> {
    public final T first;
    public final U second;
    Pair (T first, U second) {
        this.first=first; this.second=second;
    }
    T getFirst () { return first; }
    U getSecond() { return second; }
}

Autoboxing and unboxing.
Pair<Integer,String> p =
    new Pair<Integer,String>(5, "hello");
int i = p.getFirst();
String s = p.getSecond();
```
A method can be generic even if the class it is in is not generic.

```java
generic <T> T pick (T... choices) {
    if (choices.length == 0) return null;
    final int i = new Random().nextInt(choices.length);
    return choices[i];
}
```
Generic method

This does not work:

```java
public <T> T max (T t1, T t2) {
    if (t1 < t2) {
        return t1;
    } else {
        return t2;
    }
}
```
Generic method

This does not work:

```java
public <T> T max (T t1, T t2) {
    if (t1 < t2) {
        return t1;
    } else {
        return t2;
    }
}
```

```java
public <T extends Comparable<T>> T max (T t1, T t2) {
    if (t1.compareTo(t2) > 0) {
        return t1;
    } else {
        return t2;
    }
}
```
Three important Java generic interfaces:

1. Iterator
2. Comparable
3. Comparator

are often used in conjunction with Java collections.
Iterator

The interface java.lang.Iterator<E> has methods (i.a.):

boolean hasNext()
E next()

The interface java.util.Collection has method (i.a.):

Iterator<E> iterator()

```java
public static void main (String[] args) {
    final List<Integer> list = new ArrayList<Integer>();
    final Iterator<Integer> it = list.iterator();
    while (it.hasNext()) {
        // NB. auto unboxing, no narrowing
        final int x = it.next();
        // Do something with "x"
    }
}
```
I tend to use the for loop.

```java
public static void main (String[] args) {
    final List<Integer> list=new ArrayList<Integer>();
    for (Iterator<Integer> it=list.iterator();
         it.hasNext();
         /* */) {
        final int x = it.next();
        // Do something with "x"
    }
}
```
The “for each” loop is better:

```java
public static void main (String[] args) {
    final List<Integer> list = new ArrayList<Integer>();
    for (Integer x : list) {
        // Do something with "x"
    }
}
```

No narrowing necessary, and static type checking possible!
Comparable

The interface `java.lang.Comparable<T>` has just one method.

```java
interface Comparable <T> {
    int compareTo (T other);
}
```

The interface is used to give a class a “natural” ordering — an ordering the Java API’s (especially the collection API’s) uses by default. It *should* be a total ordering consistent with equals: for every `e1` and `e2` of the class `T`, `e1.compareTo(e2)==0` iff `e1.equals(e2)`. 
// Give X a "natural" ordering

class X implements Comparable<X> {
    /* ... */
    int compareTo (X other) {
        /* compare 'this' and 'other' */
        if (/* 'this' is greater than 'other' */) {
            return +1;
        } else if (/* 'this' is less than 'other' */) {
            return -1;
        } else {
            return 0;
        }
    }
}
For example:

```java
abstract static class Coin implements Comparable<Coin> {
    abstract int value ();
    public int compareTo (final Coin other) {
        final int v=value (), w=other.value ();
        if (v<w) return -1;
        else if (v>w) return +1;
        else return 0;
    }
}
```
The interface `java.util.Comparator<T>` has two methods.

```java
interface Comparator <T> {
    int compare (T o1, T o2)
    boolean equals (Object obj);  // equal comparing
}
```

(We rarely create more than one instance of a particular comparator, so `equals` is hardly ever overridden.)

A comparator allows us to describe an ordering of objects without a natural ordering, or with a completely different ordering. This ordering is completely independent from the class.
Comparator

An example program which compares 2D points in two ways.
interface/Main.java
Comparator

The generic procedure `reserveOrder()` has some really advanced code ultimately relying on a unsafe cast to do the work. The code is something like this:

```java
class Collections {
    // ...
    private static final class RevComp<T> implements Comparator<T> {
        private static final RevComp<Object> INSTANCE = new RevComp<Object>();

        public int compare (Comparable<Object> o1, T o2) {
            Comparable<T> c2 = (Comparable<T>) o2;
            return c2.compare(o1);
        }
    }

    public static <T> Comparator<T> reverseOrder () {
        return (Comparator<T>) RevComp.INSTANCE;
    }
}
```
End of interfaces. Next Arrays and Collections classes??
The class `java.util.Arrays` has methods (i.a.):

```java
static void sort (int[] a)
static void sort (double[] a)
static void sort (Object[] a)
```

class Main {
    public static void main (String[] args) {
        Coin[] xs;
        Arrays.sort (xs);
    }
}

[Notice that arrays are co-variant in Java so that this sort of call works. This leads to the problem of `ArrayStoreException`.]

Many predefined classes in Java are generic. Generics make these classes useful in more situations. The Java package `java.util` is filled with generic, “utility” classes — classes that are used to solve a wide variety of problems types.

Many of these classes are container or collection classes — classes that hold many individual sub-pieces (like arrays do). These classes are organized in a rich system known as the collection classes.

Collections classes share two important characteristics:

1. the individual items have arbitrary type
2. it is common to iterate over all the individual items of the collection
What is a list?
A list is an ordered collection of elements, like a chain.

There is a first element, a second element, and so on. There is a last element as well. Sometimes this structure is called a sequence. The same value may occur more than once (unlike a set).
The advantage of an array is that it is fairly cheap to allocate a big fixed amount of storage at once. But it wastes storage if a lot of requested, but little is needed. Also, removing an element in the middle of an array is expensive because one has to move a lot of elements.

A list allocates exactly what is needed as it is needed—no space is wasted. Removing an element in the middle can be cheaper than with an array. On the other hand, random access to all elements is lost and more bookkeeping is required. Access to the first and last elements of a list may be cheap.

ArrayList in an attempted compromise. How does it handle changes in the number of elements?
The Java API has already implemented the LinkedList class. Let us implement our own simple version.

Implementing our own lists:
list/IntList.java
list/GenericList.java

But first a mental picture of the approach:
Linked List

Linked list represented by instances of two-part nodes
Linked List

Linked list with elements allocated in the heap
Abstract representation of a linked list
Let us implement our own simple version of a linked list:
list/IntList.java
list/GenericList.java

The Java API has already implemented the LinkedList class, which like the ArrayList class, implements the generic List interface.
interface java.util.List<E> implements Collection<E>

E get (int index)
E set (int index, E element) returns previous element
void add (int index, E element)
E remove (int index)

int size() number of elements in the list
void clear() removes all the elements

boolean contains (Object o) search
int indexOf (Object o) index of the first occurrence

Iterator<E> iterator ()
List Interface in the Collection Classes

The Java API has two implementations of the list interface with different performance characteristics.
ArrayList in the Collection Classes

java.util.ArrayList<E> implements List<E>

ArrayList()
ArrayList (int initialCapacity)

void ensureCapacity (int minCapacity)
void trimToSize ()
LinkedList in the Collection Classes

java.util.LinkedList<E> implements List<E>, Dequeue<E>

LinkedList()

E      getFirst()   same as element()
E      getLast()
void   addFirst()   same as push()
void   addLast()
E      removeFirst() same as pop(), remove()
E      removeLast()
Lists

If you have to save space, then use a linked list. If you have to have fast access (set/get) to random elements, then use a list implemented as an array. If you have remove and add elements in the middle of the list, use a linked list. See the Josephus problem.
Collection Classes

Not be be confused with the generic interface Collection\<T\> is the utility class

```java
java.util.Collections

static <T> int binarySearch(List<...> list, T key)
static <T> List<T> emptyList()
static <T> List<T> singletonList(T o)
static <T ...> T max (Collection<? extends T> coll)
static <T ...> T min (Collection<? extends T> coll)
static int frequency (Collection<??> coll, Object o)
static void shuffle (List<?> list)
static <T> List<T> sort (List<T> list)
static <T> List<T> synchronizedList (List<T> list)
static <T> List<T> unmodifiableList (List<T> list)
```
Also Useful

Also in `java.util.Arrays`

```java
static <T> List<T> asList (T... a)
```

```java
List<Integer> list = Arrays.asList (1,2,3,4,5,6);
```

I never can remember where this very useful static method is found.
Avoid

Do not use `StringBuffer`, `Stack`, `Vector`, or `Hashtable`, unless you need synchronization.
Use `StringBuilder`, `ArrayDeque`, `ArrayList`, or `HashMap`, instead.
The class `java.util.Collections` has methods (i.a.):

```java
static void sort (List list);
static void sort (List list, Comparator c);
```

Notice the use of the interface `List`.

class Main {
   // For some class X implementing Comparable<X>
   public static void main (String[] args) {
      final List<X> list = new ArrayList<X> ();
      add (new X());
      add (new X());
      Collections.sort (list);
      Collections.sort (list, Collections.<X>.reverseOrder ());
   }
}`
Stack, Queue, Deque

stack (LIFO): addFirst or push, removeFirst or pop
queue (FIFO): addLast (enqueue), removeFirst
deque: addFirst, addLast, removeFirst, removeLast
Enqueue

Dequeue
If you want a stack, a queue, or a deque in Java.

```java
Deque<Integer> stack = new ArrayDeque<Integer> ();
Deque<String> queue = new ArrayDeque<String> ();
Deque<Integer> deque = new ArrayDeque<Integer> ();
```

The LinkedList class also implements the interface Deque. It is preferred only when it that data is treated as an ordered sequence in which it is necessary to insert elements.