561B Lecture #25: Java Generics

The Old Days

types such as List didn't used to be parameterized. All
ists of Objects.

e things like this:

```
 = 0; i < L.size(); i += 1)
g s = (String) L.get(i); ... }
```

t explicitly cast result of L.get(i) to let the compiler
 is.

alling L.add(x), was no check that you put only Strings

 with 1.5, the designers tried to alleviate these per-
ems by introducing *parameterized types*, like List<String>.

ly, it is not as simple as one might think.

Basic Parameterization

finitions of ArrayList and Map in java.util:

```
ss ArrayList<Item> implements List<Item> {
Item get(int i) { ... }
boolean add(Item x) { ... }


erface Map<Key, Value> {
et(Key x);
```

occurrences of Item, Key, and Value introduce formal
ters, whose "values" (which are reference types) get
for all the other occurrences of Item, Key, or Value
List or Map is "called" (as in ArrayList<String>, or
nt[]>, or Map<String, List<Particle>>).

rences of Item, Key, and Value are uses of the formal
ke uses of a formal parameter in the body of a function.

Type Instantiation

g a generic type is analogous to calling a function.

in

```
lass ArrayList<Item> implements List<Item> {
: Item get(int i) { ... }
: boolean add(Item x) { ... }
```

ite ArrayList<String>, we get, in effect, a new type,
e

```
tring_ArrayList implements List<String> {
: String get(int i) { ... }
: boolean add(String x) { ... }
```

ewise, List<String> refers to a new interface type as

Parameters on Methods

ethods) may also be parameterized by type. Example of
a.util.Collections:

```
-only list containing just ITEM. */
 List<T> singleton(T item) { ... }
odifiable empty list. */
 List<T> emptyList() { ... }
```

figures out T in the expression singleton(x) by look-
pe of x. This is a simple example of *type inference*.

```
g> empty = Collections.emptyList();
```

ers obviously don't suffice, but the compiler deduces
er T from context: it must be assignable to List<T>.

Wildcards

e definition of something that counts the number of
hing occurs in a collection of items. Could write this

```
 of items in C that are equal to X. */
 int frequency(Collection<T> c, Object x) {
 n = 0;
 y : c) {
 (x.equals(y))
  n += 1;

 n;
```

really care what T is; we don't need to declare anything
the body, because we could write instead

```
bject y : c) {
```

pe parameters say that you don't care what a type pa-
.e., it's any subtype of Object):

```
 frequency(Collection<?> c, Object x) {...}
```

Subtyping (I)

e relationships between the types

```
ring>,  List<Object>, ArrayList<String>, ArrayList<Object>?
```

at ArrayList ⪯ List and String ⪯ Object (using ⪯
type of")...

:<String> ⪯ List<Object>?

Subtyping (II)

s fragment:

```
ng> LS = new ArrayList<String>();
ct> LObj = LS;      // OK??
 { 1, 2 };
(A);                // Legal, since A is an Object
 = LS.get(0);       // OOPS! A.get(0) is NOT a String,
                    // but spec of List<String>.get
                    // says that it is.
```

st<String> ⪯ List<Object> would violate *type safety:*
 is wrong about the type of a value.

l for T1<X> ⪯ T2<Y>, must have X = Y.

ut T1 and T2?

Subtyping (III)

r

```
<String> ALS = new ArrayList<String>();
ng> LS = ALS;      // OK??
```

everything's fine:

t's dynamic type is ArrayList<String>.

e, the methods expected for LS must be a subset of
ALS.

the type parameters are the same, the signatures of
hods will be the same.

e, all the legal calls on methods of LS (according to the
will be valid for the actual object pointed to by LS.

1<X> ⪯ T2<X> if T1 ⪯ T2.

A Java Inconsistency: Arrays

guage design is not entirely consistent when it comes to

reason that ArrayList<String> ⋠ ArrayList<Object>,
pect that String[] ⋠ Object[].

a *does* make String[] ⪯ Object[].

explained above, one gets into trouble with

```
S = new String[3];
bj = AS;
ew int[] { 1, 2 };  // Bad
```

he Bad line causes an ArrayStoreException.

is way? Basically, because otherwise there'd be no way
, e.g., ArrayList.

Type Bounds (I)

your program needs to ensure that a particular type pa-
eplaced only by a subtype (or supertype) of a particular
 like specifying the "type of a type.").

```
ricSet<T extends Number> extends HashSet<T> {
 minimal element */
 { ... }
```

t all type parameters to NumbericSet must be subtypes
he "type bound"). T can either extend or implement the
ropriate.

Type Bounds (II)

mple:

```
l elements of L to X. */
 void fill(List<? super T> L, T x) { ... }
```

 can be a List<Q> for any Q as long as T is a subtype of
implements) Q.

he library designers just define this as

```
l elements of L to X. */
 void fill(List<T> L, T x) { ... }
```

Type Bounds (II)

mple:

```
l elements of L to X. */
 void fill(List<? super T> L, T x) { ... }
```

. can be a List<Q> for any Q as long as T is a subtype of implements) Q.

he library designers just define this as

```
l elements of L to X. */
 void fill(List<T> L, T x) { ... }
```

```
oid blankIt(List<Object> L) {
(L, " ");
```

e illegal if L were forced to be a List<String>.

Type Bounds (III)

e:

```
 sorted list L for KEY, returning either its position (if
t), or k-1, where k is where KEY should be inserted.  */
 int binarySearch(List<? extends Comparable<? super T>> L,
                  T key)
```

ems of L have to have a type that is comparable to T's upertype of T.

to be able to contain the value key?

is make sense?

Type Bounds (III)

e:

```
 sorted list L for KEY, returning either its position (if
t), or k-1, where k is where KEY should be inserted.  */
 int binarySearch(List<? extends Comparable<? super T>> L,
                  T key)
```

ems of L have to have a type that is comparable to T's upertype of T.

to be able to contain the value key?

is make sense?

ght have

```
it findX(List<Object> L) {
 binarySearch(L, "X");
```


Dirty Secrets Behind the Scenes

n for parameterized types was constrained by a desire d compatibility.

en you write

```
T> {                                Foo<Integer> q = new Foo<Integer>();
fy(T y) { ... }                     Integer r = q.mogrify(s);
```

ives you

```
{
x;                                  Foo q = new Foo();
mogrify(Object y) { ... }           Integer r =
                                        (Integer) q.mogrify((Integer) s);
```

upplies the casts automatically, and also throws in some ecks. If it can't guarantee that all those casts will work, arning about "unsafe" constructs.

Limitations

a's design choices, there are some limitations to generic

ds of Foo or List are really the same,

ceof List<String> will be true when L is a List<Integer>.

g., class Foo, you cannot write new T(), new T[], or x of T.

es are not allowed as type parameters.

: ArrayList<int>, just ArrayList<Integer>.

ly, automatic boxing and unboxing makes this substitu-

```
(ArrayList<Integer> L) {
 N;  N = 0;
 (int x : L) { N += x; }
urn N;
```

ately, boxing and unboxing have significant costs.