"Get your data structures correct first, and the rest of the program will write itself."
- David Jones
Back to our Array Based List

- Started with a list of ints
- Don't want to have to write a new list class for every data type we want to store in lists
- Moved to an array of Objects to store the elements of the list

    // from array based list
    private Object[] myCon;
Using Object

- In Java, all classes inherit from exactly one other class except Object which is at the top of the class hierarchy
- Object variables can refer to objects of their declared type and any descendants
  - polymorphism
- Thus, if the internal storage container is of type Object it can hold anything
  - primitives handled by *wrapping* them in objects.
    - int – Integer, char - Character
Difficulties with Object

- Creating generic containers using the Object data type and polymorphism is relatively straightforward

Using these generic containers leads to some difficulties
  - Casting
  - Type checking

- Code examples on the following slides
Clicker Question 1

What is output by the following code?

```java
GenericList list = new GenericList(); // 1
String name = "Olivia";
list.add(name); // 2
System.out.println( list.get(0).charAt(2) ); // 3
```

A. i
B. No output due to syntax error at line // 1
C. No output due to syntax error at line // 2
D. No output due to syntax error at line // 3
E. No output due to runtime error.
Code Example - Casting

Assume a list class

ArrayList li = new ArrayList();
li.add("Hi");
System.out.println(li.get(0).charAt(0));
// previous line has syntax error
// return type of get is Object
// Object does not have a charAt method
// compiler relies on declared type
System.out.println(
    ((String)li.get(0)).charAt(0));
// must cast to a String
Code Example – type checking

//pre: all elements of li are Strings
public void printFirstChar(ArrayList li) {
    String temp;
    for(int i = 0; i < li.size(); i++) {
        temp = (String)li.get(i);
        if( temp.length() > 0 )
            System.out.println(
                temp.charAt(0) );
    }
}

// what happens if pre condition not met?
Too Generic?

Does the compiler allow this?

```java
ArrayList list = new ArrayList();
list.add( "Olivia" );
list.add( new Integer(12) );
list.add( new Rectangle() );
list.add( new ArrayList() );
```

A. Yes
B. No
Is this a bug or a feature?
"Fixing" the Method

//pre: all elements of li are Strings
public void printFirstChar(ArrayList li) {
    String temp;
    for(int i = 0; i < li.size(); i++) {
        if( li.get(i) instanceof String ){
            temp = (String)li.get(i);
            if( temp.length() > 0 )
                System.out.println(
                    temp.charAt(0) );
        }
    }
}
Generic Types

- Java has syntax for *parameterized data types*
- Referred to as *Generic Types* in most of the literature
- A traditional parameter *has* a data type and can store various values just like a variable
  
  ```java
  public void foo(int x)
  ```
- Generic Types are like parameters, but the data type for the parameter is *data type*
  - like a variable that stores a data type
  - this is an abstraction. Actually, all data type info is erased at compile time
Making our Array List Generic

- Data type variables declared in class header

```java
public class GenericList<E> {

- The <E> is the declaration of a data type parameter for the class
  - any legal identifier: Foo, AnyType, Element, DataTypeThisListStores
  - Sun style guide recommends terse identifiers

- The value E stores will be filled in whenever a programmer creates a new
  GenericList<String> li = new GenericList<String>();
```
Modifications to GenericList

- instance variable
  ```java
  private E[] myCon;
  ```
- Parameters on
  - add, insert, remove, insertAll
- Return type on
  - get
- Changes to creation of internal storage container
  ```java
  myCon = (E[]) new Object[DEFAULT_SIZE];
  ```
- Constructor header does not change
Modifications to GenericList

- Careful with the equals method
- Recall type information is actually erased
- use of wildcard
- rely on the elements equals methods
Using Generic Types

- Back to Java's ArrayList

```java
ArrayList list1 = new ArrayList();
- still allowed, a "raw" ArrayList
- works just like our first pass at GenericList
- casting, lack of type safety
```
Using Generic Types

ArrayList<String> list2 =
    new ArrayList<String>();

    for list2 E stores String

list2.add( "Isabelle" );

System.out.println(
    list2.get(0).charAt(2) ); //ok

list2.add( new Rectangle() );

// syntax error
Parameters and Generic Types

‡ Old version
//pre: all elements of li are Strings
public void printFirstChar(ArrayList li){

‡ New version
//pre: none
public void printFirstChar(ArrayList<String> li){

‡ Elsewhere
ArrayList<String> list3 = new ArrayList<String>();
printFirstChar( list3 ); // ok
ArrayList<Integer> list4 = new ArrayList<Integer>();
printFirstChar( list4 ); // syntax error
Generic Types and Subclasses

```java
ArrayList<Shape> list5 =
    new ArrayList<Shape>();
list5.add( new Rectangle() );
list5.add( new Square() );
list5.add( new Circle() );
// all okay
```

- `list5` can store `Shape` objects and any descendants of `Shape`