Topic 12
ADTS, Data Structures, Java Collections and Generic Data Structures

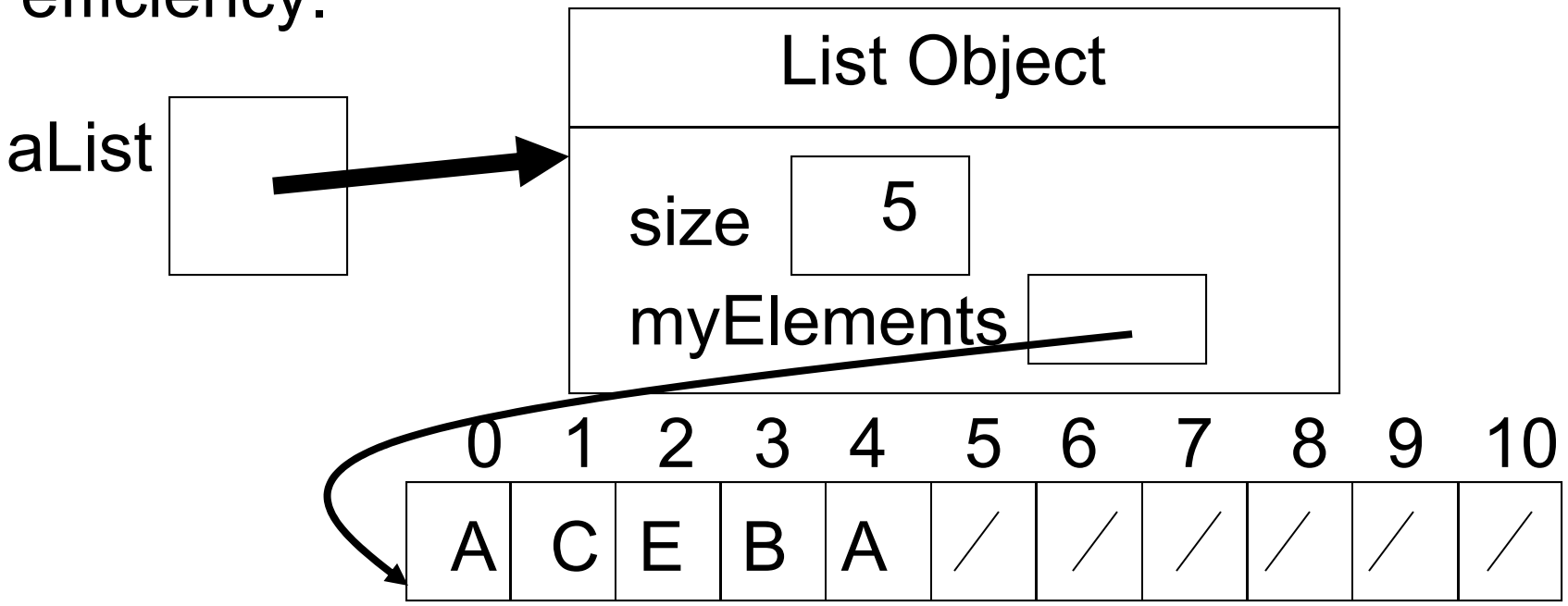
"Get your data structures correct first, and the rest of the program will write itself."
- *David Jones*

Abstract Data Types

- Abstract Data Types (aka ADTs) are descriptions of how a data type will work without implementation details
- Example, Stack at NIST DADS
  - http://xw2k.nist.gov/dads/HTML/stack.html
- Description can be a formal, mathematical description
- Java interfaces are a form of ADTs
  - some implementation details start to creep in

Data Structures

- A *Data Structure* is:
  - an implementation of an abstract data type *and*
  - "An organization of information, usually in computer memory", for better algorithm efficiency."



Data Structure Concepts

- Data Structures are containers:
  - they hold other data
  - arrays are a data structure
  - ... so are lists
- Other types of data structures:
  - stack, queue, tree,
    binary search tree, hash table,
    dictionary or map, set, and on and on
  - www.nist.gov/dads/
  - en.wikipedia.org/wiki/List_of_data_structures
- Different types of data structures are optimized for certain types of operations

Core Operations

- Data Structures will have 3 core operations
  - a way to add things
  - a way to remove things
  - a way to access things
- Details of these operations depend on the data structure
  - Example: List, add at the end, access by location, remove by location
- More operations added depending on what data structure is designed to do

ADTs and Data Structures in Programming Languages

- Modern programming languages usually have a library of data structures
  - Java collections framework
  - C++ standard template library
  - .Net framework (small portion of VERY large library)
  - Python lists and tuples
  - Lisp lists

Data Structures in Java

- Part of the Java Standard Library is the *Collections Framework*
  - In class we will create our own data structures and discuss the data structures that exist in Java
- A library of data structures
- Built on two interfaces
  - Collection
  - Iterator
- http://java.sun.com/j2se/1.5.0/docs/guide/collections/index.html

The Java Collection interface

- A generic collection
- Can hold any object data type
- Which type a particular collection will hold is specified when declaring an instance of a class that implements the Collection interface
- Helps guarantee *type safety* at compile time

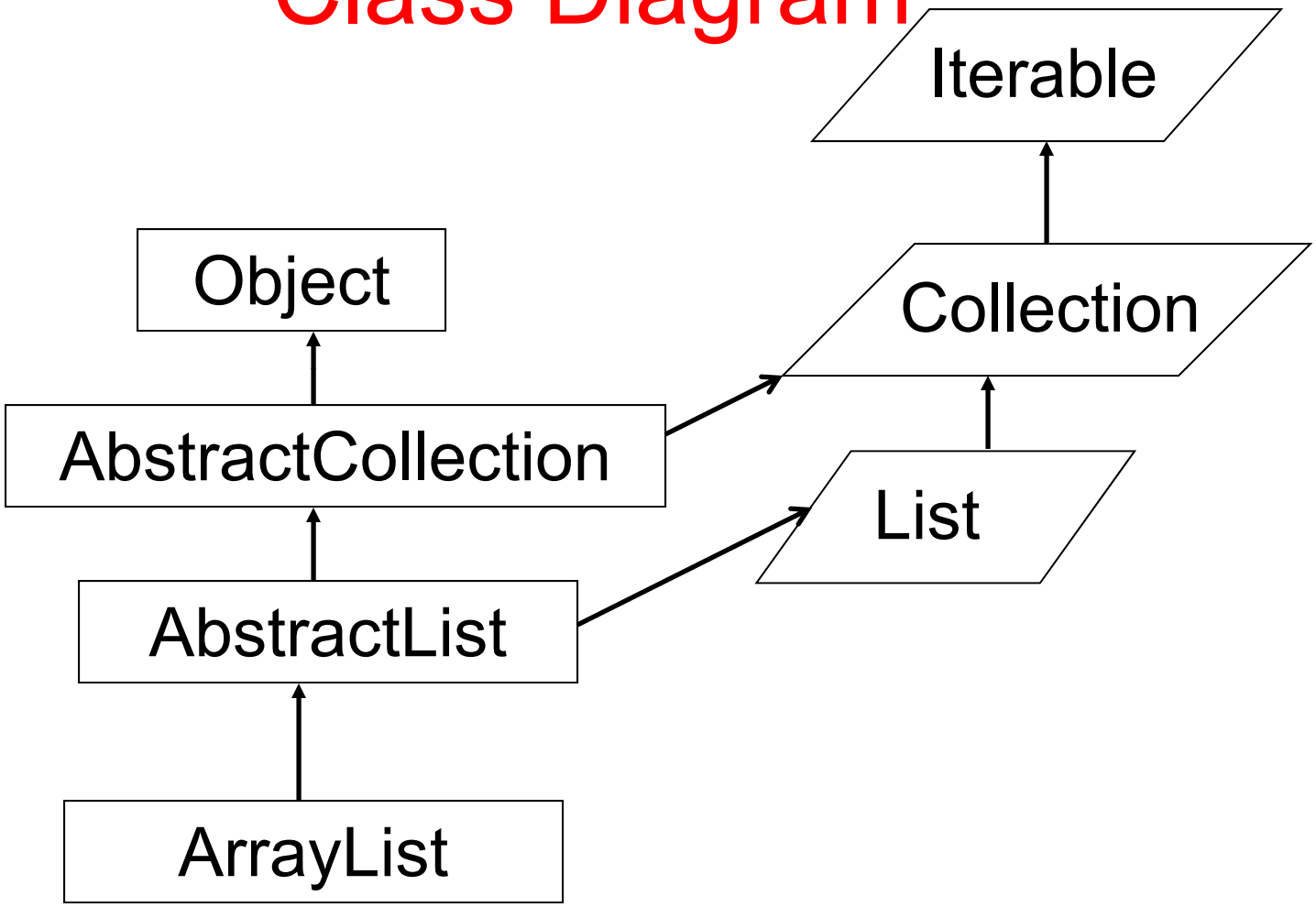
Methods in the Collection interface

```
public interface Collection<E>
{     public boolean add(E o)
      public boolean addAll(Collection<? extends E> c)
      public void clear()
      public boolean contains(Object o)
      public boolean containsAll(Collection<?> c)
      public boolean equals(Object o)
      public int hashCode()
      public boolean isEmpty()
      public Iterator<E> iterator()
      public boolean remove(Object o)
      public boolean removeAll(Collection<?> c)
      public boolean retainAll(Collection<?> c)
      public int size()
      public Object[] toArray()
      public <T> T[] toArray(T[] a)
}
```

The Java ArrayList Class

- Implements the List interface and uses an array as its *internal storage container*
- It is a list, not an array
- The array that actual stores the elements of the list is hidden, not visible outside of the ArrayList class
- all actions on ArrayList objects are via the methods
- ArrayLists are generic.
  - They can hold objects of any type!

ArrayList's (Partial) Class Diagram



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 `Object`s 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 point at 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 straight forward
- Using these generic containers leads to some difficulties
  - Casting
  - Type checking
- Code examples on the following slides

Attendance Question 1

- What is output by the following code?

```
ArrayList list = new ArrayList();
String name = "Olivia";
list.add(name);
System.out.print( list.get(0).charAt(2) );
```

A. `i`

B. `O`

C. `l`

D. No output due to syntax error.

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?

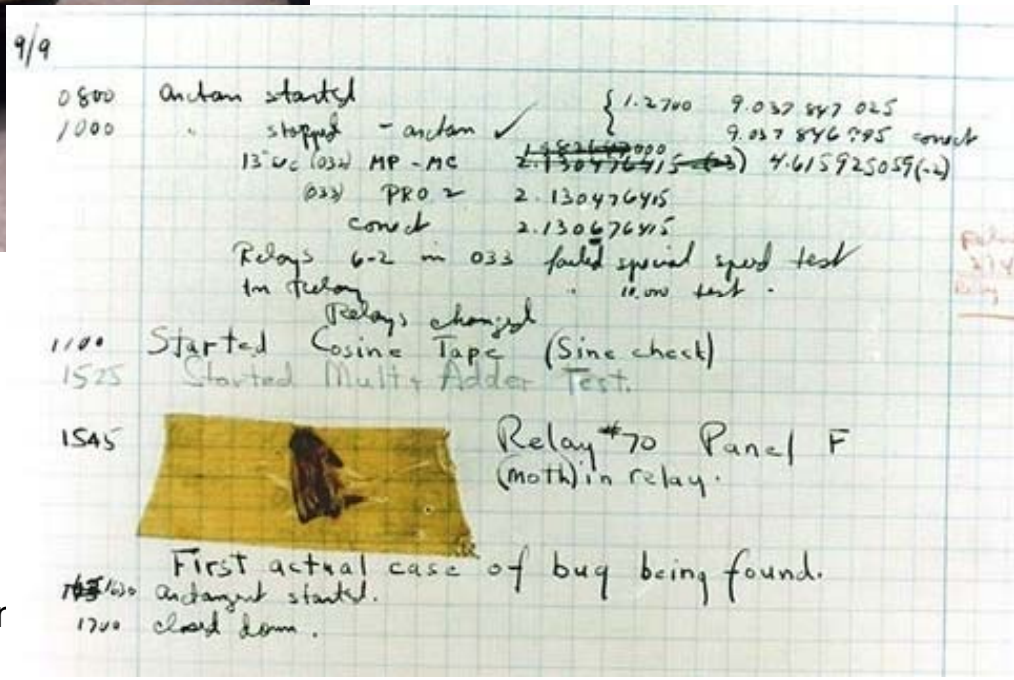
- Does the compiler allow this?

```
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

```
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

Making our Array List Generic

- Data type variables declared in class header

```
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`

```
GenericList<String> li =
                    new GenericList<String>();
```

Modifications to GenericList

- instance variable

```
private E[] myCon;
```

- Parameters on
  - add, insert, remove, insertAll
- Return type on
  - get
- Changes to creation of internal storage container

```
myCon = (E[])new Object[DEFAULT_SIZE];
```

- Constructor header does not change

Using Generic Types

- Back to Java's ArrayList

```
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

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

- `list5` can store `ClosedShape`s and any descendants of `ClosedShape`