Java 1

Lecture 07

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A problem we can't solve

- Consider the following program (input underlined):

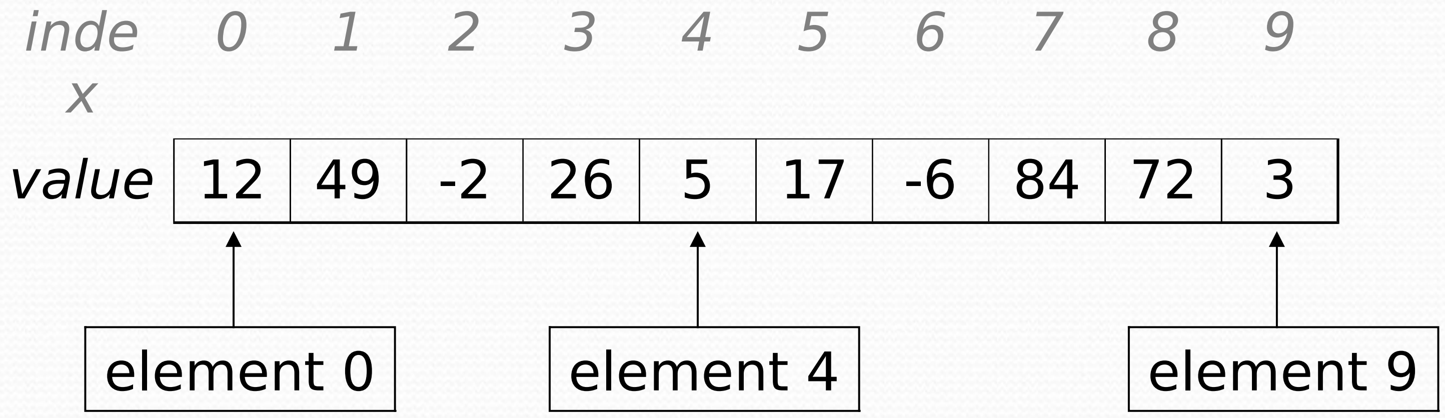
```
How many days' temperatures? 7
Day 1's high temp: 45
Day 2's high temp: 44
Day 3's high temp: 39
Day 4's high temp: 48
Day 5's high temp: 37
Day 6's high temp: 46
Day 7's high temp: 53
Average temp = 44.6
4 days were above average.
```

Why the problem is tough

- We need each input value twice:
  - to compute the average (a cumulative sum)
  - to count how many were above average
- We could read each value into a variable... but we:
  - don't know how many days are needed until the program runs
  - don't know how many variables to declare
- We need a way to declare many variables in one step.

Arrays

- **array**: object that stores many values of the same type.
  - **element**: One value in an array.
  - **index**: A 0-based integer to access an element from an array.



Array declaration

type[] **name** = new **type**[**length**];

- Example:

```
int[] numbers = new int[10];
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	0	0	0	0	0	0	0	0	0	0

Array declaration, cont.

- The length can be any integer expression.

```
int x = 2 * 3 + 1;
int[] data = new int[x % 5 + 2];
```

- Each element initially gets a "zero-equivalent" value.

Type	**Default value**
`int`	`0`
`double`	`0.0`
`boolean`	`false`
`String` or other object	`null` (means, "no object")

Accessing elements

```
name[index]                  // access
name[index] = value;         // modify
```

- Example:

```
numbers[0] = 27;
numbers[3] = -6;

System.out.println(numbers[0]);
if (numbers[3] < 0) {
    System.out.println("Element 3 is negative.");
}
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	**27**	0	0	**-6**	0	0	0	0	0	0

Arrays of other types

```
double[] results = new double[5];
results[2] = 3.4;
results[4] = -0.5;
```

index	*0*	*1*	*2*	*3*	*4*
value	0.0	0.0	**3.4**	0.0	**-0.5**

```
boolean[] tests = new boolean[6];
tests[3] = true;
```

index	*0*	*1*	*2*	*3*	*4*	*5*
value	false	false	false	**true**	false	false

Out-of-bounds

- Legal indexes: between **0** and the **array's length - 1**.
  - Reading or writing any index outside this range will throw an `ArrayIndexOutOfBoundsException`.
- Example:

```
int[] data = new int[10];
System.out.println(data[0]);        // okay
System.out.println(data[9]);        // okay
System.out.println(data[-1]);       // exception
System.out.println(data[10]);       // exception
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	0	0	0	0	0	0	0	0	0	0

Accessing array elements

```
int[] numbers = new int[8];
numbers[1] = 3;
numbers[4] = 99;
numbers[6] = 2;

int x = numbers[1];
numbers[x] = 42;
numbers[numbers[6]] = 11; // use numbers[6] as index
```

x	3

	index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
numbers	*value*	0	4	11	42	99	0	2	0	0	0

Arrays and for loops

- It is common to use for loops to access array elements.

```
for (int i = 0; i < 8; i++) {
    System.out.print(numbers[i] + " ");
}
System.out.println();  // output: 0 4 11 0 44 0 0 2
```

- Sometimes we assign each element a value in a loop.

```
for (int i = 0; i < 8; i++) {
    numbers[i] = 2 * i;
}
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*
value	0	2	4	6	8	10	12	14

The `length` field

- An array's `length` field stores its number of elements.

```
name.length

for (int i = 0; i < numbers.length; i++) {
    System.out.print(numbers[i] + " ");
}
// output: 0 2 4 6 8 10 12 14
```

  - It does not use parentheses like a String's `.length()`.

- What expressions refer to:
  - The last element of any array?
  - The middle element?

Weather question

- Use an array to solve the weather problem:

```
How many days' temperatures? 7
Day 1's high temp: 45
Day 2's high temp: 44
Day 3's high temp: 39
Day 4's high temp: 48
Day 5's high temp: 37
Day 6's high temp: 46
Day 7's high temp: 53
Average temp = 44.6
4 days were above average.
```

Weather answer

```
// Reads temperatures from the user, computes average and # days above average.
import java.util.*;

public class Weather {
    public static void main(String[] args) {
        Scanner console = new Scanner(System.in);
        System.out.print("How many days' temperatures? ");
        int days = console.nextInt();

        int[] temperatures = new int[days];  // array to store days' temperatures
        int sum = 0;

        for (int i = 0; i < days; i++) {     // read/store each day's temperature
            System.out.print("Day " + (i + 1) + "'s high temp: ");
            temperatures[i] = console.nextInt();
            sum += temperatures[i];
        }
        double average = (double) sum / days;

        int count = 0;                       // see if each day is above average
        for (int i = 0; i < days; i++) {
            if (temperatures[i] > average) {
                count++;
            }
        }

        // report results
        System.out.printf("Average temp = %.1f\n", average);
        System.out.println(count + " days above average");
    }
}
```

Arrays for counting and tallying

A multi-counter problem

- Problem: Examine a large integer and count the number of occurrences of every digit from 0 through 9.
  - Example: The number 229231007 contains:

    two 0s, one 1, three 2s, one 7, and one 9.

- We could declare 10 counter variables for this...

```
int counter0, counter1, counter2, counter3, counter4,
    counter5, counter6, counter7, counter8, counter9;
```

  - Yuck!

A multi-counter problem

- A better solution is to use an array of size 10.
  - The element at index *i* will store the counter for digit value *i*.
  - for integer value 229231007, our array should store:

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	2	1	3	0	0	0	0	1	0	1

- The index at which a value is stored has meaning.
  - Sometimes it doesn't matter.
  - What about the weather case?

Creating an array of tallies

```
int num = 229231007;
int[] counts = new int[10];
while (num > 0) {
    // pluck off a digit and add to proper counter
    int digit = num % 10;
    counts[digit]++;
    num = num / 10;
}
```

index	*0*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
value	2	1	3	0	0	0	0	1	0	1

Array histogram question

- Given a file of integer exam scores, such as:

```
82
66
79
63
83
```

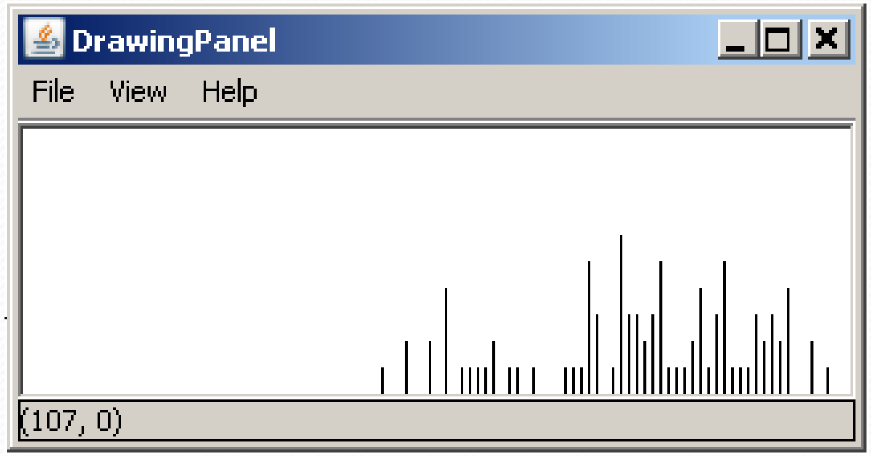
Write a program that will print a histogram of stars indicating the number of students who earned each unique exam score.

```
85: *****
86: ************
87: ***
88: *
91: ****
```

Histogram variations

- Curve the scores; add a fixed number to each score. (But don't allow a curved score to exceed the max of 101.)

- Chart the data with a `DrawingPanel`.
  - window is 100px tall
  - 2px between each bar
  - 10px tall bar for each student who earned that score



Array histogram answer

```
// Reads an input file of test scores (integers) and displays a
// graphical histogram of the score distribution.
import java.awt.*;
import java.io.*;
import java.util.*;

public class Histogram {
    public static final int CURVE = 5;   // adjustment to each exam score

    public static void main(String[] args) throws FileNotFoundException {
        Scanner input = new Scanner(new File("midterm.txt"));
        int[] counts = new int[101];     // counters of test scores 0 - 100

        while (input.hasNextInt()) {     // read file into counts array
            int score = input.nextInt();
            score = Math.min(score + CURVE, 100);    // curve the exam score
            counts[score]++;             // if score is 87, then counts[87]++
        }

        for (int i = 0; i < counts.length; i++) {    // print star histogram
            if (counts[i] > 0) {
                System.out.print(i + ": ");
                for (int j = 0; j < counts[i]; j++) {
                    System.out.print("*");
                }
                System.out.println();
            }
        }

        ...
```

Array histogram solution 2

```
        ...

        // use a DrawingPanel to draw the histogram
        DrawingPanel p = new DrawingPanel(counts.length * 3 + 6, 200);
        Graphics g = p.getGraphics();
        g.setColor(Color.BLACK);
        for (int i = 0; i < counts.length; i++) {
            g.drawLine(i * 3 + 3, 175, i * 3 + 3, 175 - 5 * counts[i]);
        }
    }
}
```

ArrayList

Exercise

- Write a program that reads a file and displays the words of that file as a list.
  - First display all words.
  - Then display them with all plurals (ending in "s") capitalized.
  - Then display them in reverse order.
  - Then display them with all plural words removed.

- Should we solve this problem using an array?
  - Why or why not?

Naive solution

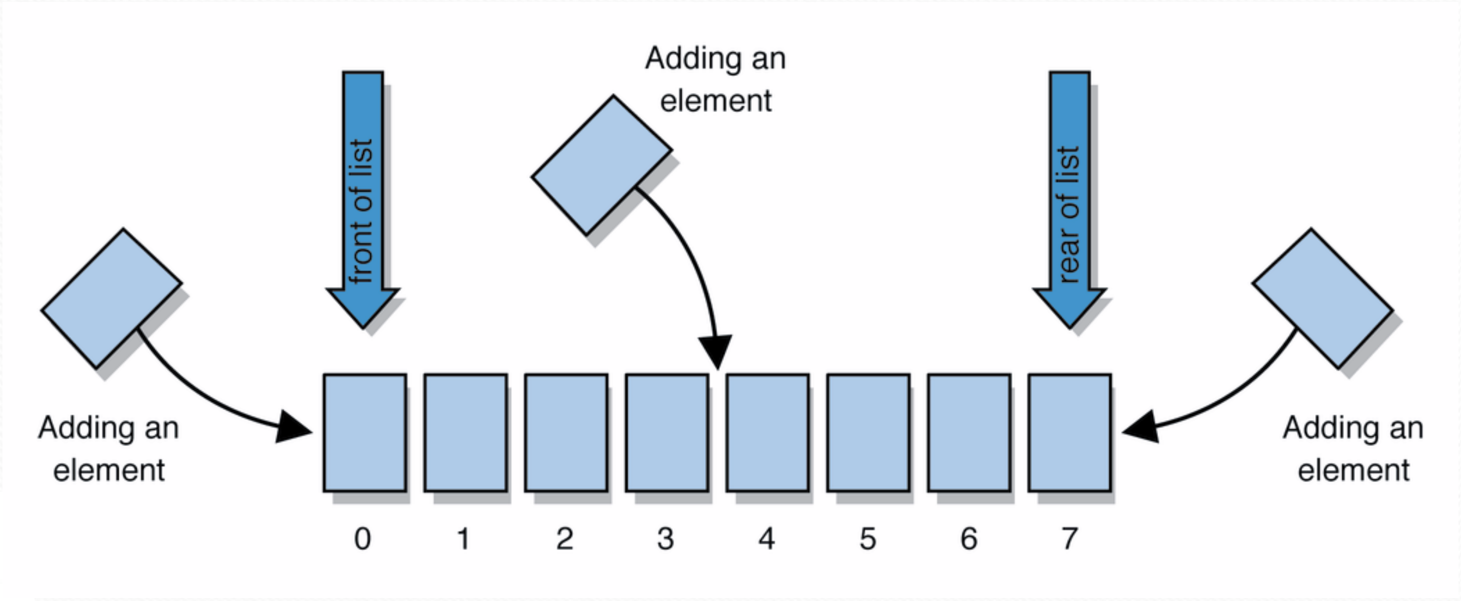
```
String[] allWords = new String[1000];
int wordCount = 0;

Scanner input = new Scanner(new File("data.txt"));
while (input.hasNext()) {
    String word = input.next();
    allWords[wordCount] = word;
    wordCount++;
}
```

- Problem: You don't know how many words the file will have.
  - Hard to create an array of the appropriate size.
  - Later parts of the problem are more difficult to solve.
- Luckily, there are other ways to store data besides in an array.

Lists

- **list**: a collection storing an ordered sequence of elements
  - each element is accessible by a 0-based **index**
  - a list has a **size** (number of elements that have been added)
  - elements can be added to the front, back, or elsewhere
  - in Java, a list can be represented as an **`ArrayList`** object



Idea of a list

- Rather than creating an array of boxes, create an object that represents a "list" of items. (initially an empty list.)

```
[]
```

- You can add items to the list.
  - The default behavior is to add to the end of the list.

```
[hello, ABC, goodbye, okay]
```

- The list object keeps track of the element values that have been added to it, their order, indexes, and its total size.
  - Think of an "array list" as an automatically resizing array object.
  - Internally, the list is implemented using an array and a size field.

ArrayList methods (10.1)

`add(`**`value`**`)`	appends value at end of list
`add(`**`index`**`, `**`value`**`)`	inserts given value just before the given index, shifting subsequent values to the right
`clear()`	removes all elements of the list
`indexOf(`**`value`**`)`	returns first index where given value is found in list (-1 if not found)
`get(`**`index`**`)`	returns the value at given index
`remove(`**`index`**`)`	removes/returns value at given index, shifting subsequent values to the left
`set(`**`index`**`, `**`value`**`)`	replaces value at given index with given

Type Parameters (Generics)

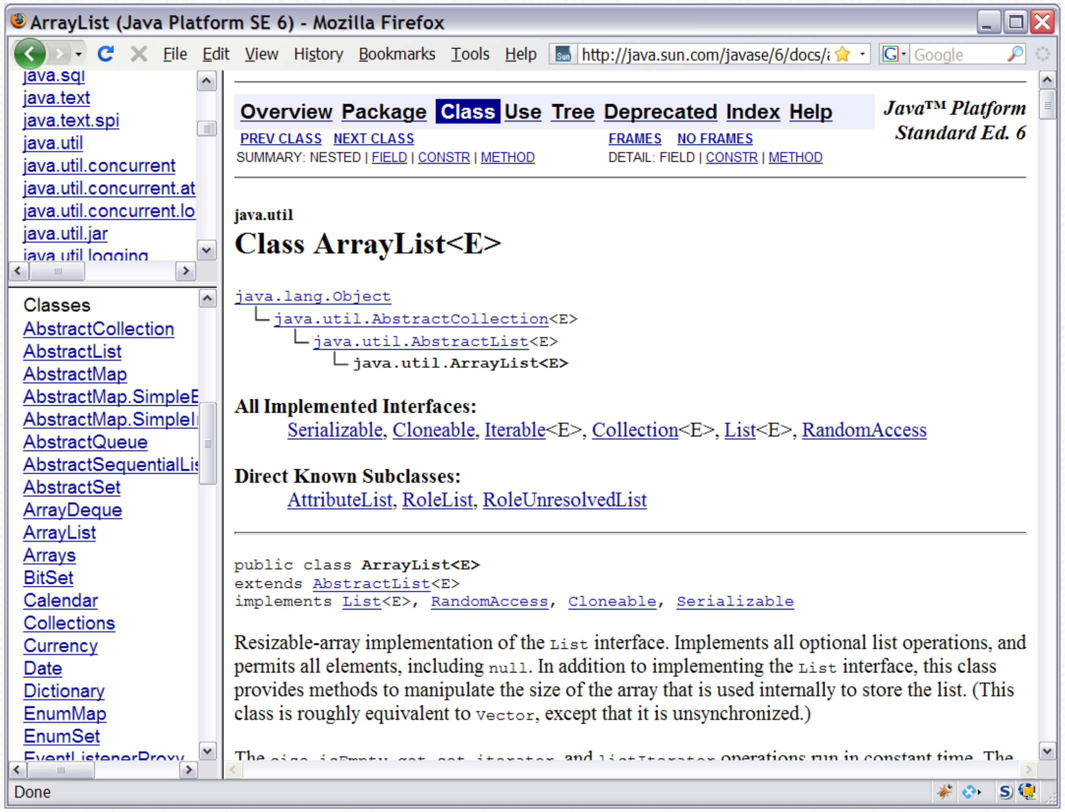
```
ArrayList<Type> name = new ArrayList<Type>();
```

- When constructing an `ArrayList`, you must specify the type of elements it will contain between < and >.
  - This is called a *type parameter* or a *generic* class.
  - Allows the same `ArrayList` class to store lists of different types.

```
ArrayList<String> names = new ArrayList<String>();
names.add("Marty Stepp");
names.add("Stuart Reges");
```

Learning about classes

- The Java API Specification is a huge web page containing documentation about every Java class and its methods.
  - The link to the API Specs is on the course web site.



ArrayList (Java Platform SE 6) - Mozilla Firefox
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http://java.sun.com/javase/6/docs/
Google
Done

java.sql
java.text
java.text.spi
java.util
java.util.concurrent
java.util.concurrent.at
java.util.concurrent.lo
java.util.jar
java.util.logging

Classes
AbstractCollection
AbstractList
AbstractMap
AbstractMap.SimpleE
AbstractMap.SimpleI
AbstractQueue
AbstractSequentialLis
AbstractSet
ArrayDeque
ArrayList
Arrays
BitSet
Calendar
Collections
Currency
Date
Dictionary
EnumMap
EnumSet
EventListenerProxy

Overview Package **Class** Use Tree Deprecated Index Help

Java™ Platform Standard Ed. 6

PREV CLASS NEXT CLASS FRAMES NO FRAMES
SUMMARY: NESTED | FIELD | CONSTR | METHOD DETAIL: FIELD | CONSTR | METHOD

java.util
Class ArrayList<E>

```
java.lang.Object
  └java.util.AbstractCollection<E>
      └java.util.AbstractList<E>
          └java.util.ArrayList<E>
```

All Implemented Interfaces:
Serializable, Cloneable, Iterable<E>, Collection<E>, List<E>, RandomAccess

Direct Known Subclasses:
AttributeList, RoleList, RoleUnresolvedList

```
public class ArrayList<E>
extends AbstractList<E>
implements List<E>, RandomAccess, Cloneable, Serializable
```

Resizable-array implementation of the `List` interface. Implements all optional list operations, and permits all elements, including `null`. In addition to implementing the `List` interface, this class provides methods to manipulate the size of the array that is used internally to store the list. (This class is roughly equivalent to `Vector`, except that it is unsynchronized.)

The size, isEmpty, get, set, iterator, and listIterator operations run in constant time. The

ArrayList vs. array

- construction

```
String[] names = new String[5];
ArrayList<String> list = new ArrayList<String>();
```

- storing a value

```
names[0] = "Jessica";
list.add("Jessica");
```

- retrieving a value

```
String s = names[0];
String s = list.get(0);
```

ArrayList vs. array 2

- doing something to each value that starts with "B"

```
for (int i = 0; i < names.length; i++) {
    if (names[i].startsWith("B")) { ... }
}
```

`for (int i = 0; i < list.size(); i++) {`
`    if (list.get(i).startsWith("B")) { ... }`
`}`

- seeing whether the value "Benson" is found

```
for (int i = 0; i < names.length; i++) {
    if (names[i].equals("Benson")) { ... }
}
```

`if (list.contains("Benson")) { ... }`

Exercise, revisited

- Write a program that reads a file and displays the words of that file as a list.
  - First display all words.
  - Then display them in reverse order.
  - Then display them with all plurals (ending in "s") capitalized.
  - Then display them with all plural words removed.

Exercise solution (partial)

```
ArrayList<String> allWords = new ArrayList<String>();
Scanner input = new Scanner(new File("words.txt"));
while (input.hasNext()) {
    String word = input.next();
    allWords.add(word);
}
System.out.println(allWords);

// remove all plural words
for (int i = 0; i < allWords.size(); i++) {
    String word = allWords.get(i);
    if (word.endsWith("s")) {
        allWords.remove(i);
        i--;
    }
}
```

ArrayList as parameter

```
public static void name(ArrayList<Type> name) {
```

- Example:

```
// Removes all plural words from the given list.
public static void removePlural(ArrayList<String> list)
  {
    for (int i = 0; i < list.size(); i++) {
        String str = list.get(i);
        if (str.endsWith("s")) {
            list.remove(i);
            i--;
        }
    }
}
```

- You can also return a list:

```
public static ArrayList<Type> methodName(params)
```

ArrayList of primitives?

- The type you specify when creating an `ArrayList` must be an object type; it cannot be a primitive type.

```
// illegal -- int cannot be a type parameter
ArrayList<int> list = new ArrayList<int>();
```

- But we can still use `ArrayList` with primitive types by using special classes called *wrapper* classes in their place.

```
// creates a list of ints
ArrayList<Integer> list = new ArrayList<Integer>();
```

Wrapper classes

Primitive Type	Wrapper Type
`int`	`Integer`
`double`	`Double`
`char`	`Character`
`boolean`	`Boolean`

- A wrapper is an object whose sole purpose is to hold a primitive value.
- Once you construct the list, use it with primitives as normal:

```
ArrayList<Double> grades = new ArrayList<Double>();
grades.add(3.2);
grades.add(2.7);
...
double myGrade = grades.get(0);
```

Exercise

- Write a program that reads a file full of numbers and displays all the numbers as a list, then:
  - Prints the average of the numbers.
  - Prints the highest and lowest number.
  - Filters out all of the even numbers (ones divisible by 2).

Exercise solution (partial)

```
ArrayList<Integer> numbers = new ArrayList<Integer>();
Scanner input = new Scanner(new File("numbers.txt"));
while (input.hasNextInt()) {
    int n = input.nextInt();
    numbers.add(n);
}
System.out.println(numbers);
filterEvens(numbers);
System.out.println(numbers);
...

// Removes all elements with even values from the given list.
public static void filterEvens(ArrayList<Integer> list) {
    for (int i = list.size() - 1; i >= 0; i--) {
        int n = list.get(i);
        if (n % 2 == 0) {
            list.remove(i);
        }
    }
}
```

Other Exercises

- Write a method `reverse` that reverses the order of the elements in an `ArrayList` of strings.
- Write a method `capitalizePlurals` that accepts an `ArrayList` of strings and replaces every word ending with an "s" with its uppercased version.
- Write a method `removePlurals` that accepts an `ArrayList` of strings and removes every word in the list ending with an "s", case-insensitively.

Out-of-bounds

- Legal indexes are between **0** and the **list's size() - 1**.
  - Reading or writing any index outside this range will cause an `IndexOutOfBoundsException`.

```
ArrayList<String> names = new ArrayList<String>();
names.add("Marty");    names.add("Kevin");
names.add("Vicki");    names.add("Larry");
System.out.println(names.get(0));        // okay
System.out.println(names.get(3));        // okay
System.out.println(names.get(-1));       // exception
names.add(9, "Aimee");                   // exception
```

index	*0*	*1*	*2*	*3*
value	Marty	Kevin	Vicki	Larry

ArrayList "mystery"

```
ArrayList<Integer> list = new ArrayList<Integer>();
for (int i = 1; i <= 10; i++) {
    list.add(10 * i);   // [10, 20, 30, 40, ..., 100]
}
```

- What is the output of the following code?

```
for (int i = 0; i < list.size(); i++) {
    list.remove(i);
}
System.out.println(list);
```

- Answer:

```
[20, 40, 60, 80, 100]
```

ArrayList "mystery" 2

```
ArrayList<Integer> list = new ArrayList<Integer>();
for (int i = 1; i <= 5; i++) {
    list.add(2 * i);   // [2, 4, 6, 8, 10]
}
```

- What is the output of the following code?

```
int size = list.size();
for (int i = 0; i < size; i++) {
    list.add(i, 42);   // add 42 at index i
}
System.out.println(list);
```

- Answer:

```
[42, 42, 42, 42, 42, 2, 4, 6, 8, 10]
```

Exercise

- Write a method `addStars` that accepts an array list of strings as a parameter and places a `*` after each element.
  - Example: if an array list named `list` initially stores:
    `[the, quick, brown, fox]`
  - Then the call of `addStars(list);` makes it store:
    `[the, *, quick, *, brown, *, fox, *]`

- Write a method `removeStars` that accepts an array list of strings, assuming that every other element is a `*`, and removes the stars (undoing what was done by `addStars` above).

Exercise solution

```
public static void addStars(ArrayList<String> list) {
    for (int i = 0; i < list.size(); i += 2) {
        list.add(i, "*");
    }
}


public static void removeStars(ArrayList<String> list) {
    for (int i = 0; i < list.size(); i++) {
        list.remove(i);
    }
}
```

Exercise

- Write a method `intersect` that accepts two sorted array lists of integers as parameters and returns a new list that contains only the elements that are found in both lists.
  - Example: if lists named `list1` and `list2` initially store:

    `[1, `**`4`**`, 8, 9, `**`11`**`, 15, 17, `**`28`**`, 41, `**`59`**`]`

    `[`**`4`**`, 7, `**`11`**`, `**`17`**`, 19, 20, 23, `**`28`**`, 37, `**`59`**`, 81]`

  - Then the call of `intersect(list1, list2)` returns the list:

    `[4, 11, 17, 28, 59]`

Other Exercises

- Write a method `reverse` that reverses the order of the elements in an `ArrayList` of strings.

- Write a method `capitalizePlurals` that accepts an `ArrayList` of strings and replaces every word ending with an "s" with its uppercased version.

- Write a method `removePlurals` that accepts an `ArrayList` of strings and removes every word in the list ending with an "s", case-insensitively.