Arrays

CSE160: Computer Science A: Honors

Paul Fodor

Stony Brook University

http://www.cs.stonybrook.edu/~cse160

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Opening Problem

- Read one hundred numbers (e.g., temperatures, units sold), compute their average, and find out how many numbers are above the average
  - Problems:

    - you need to read all the numbers before you can compute the average and compare them

    - storing 100 numbers

    - variables with one number each?

      NO.
  - Solution:

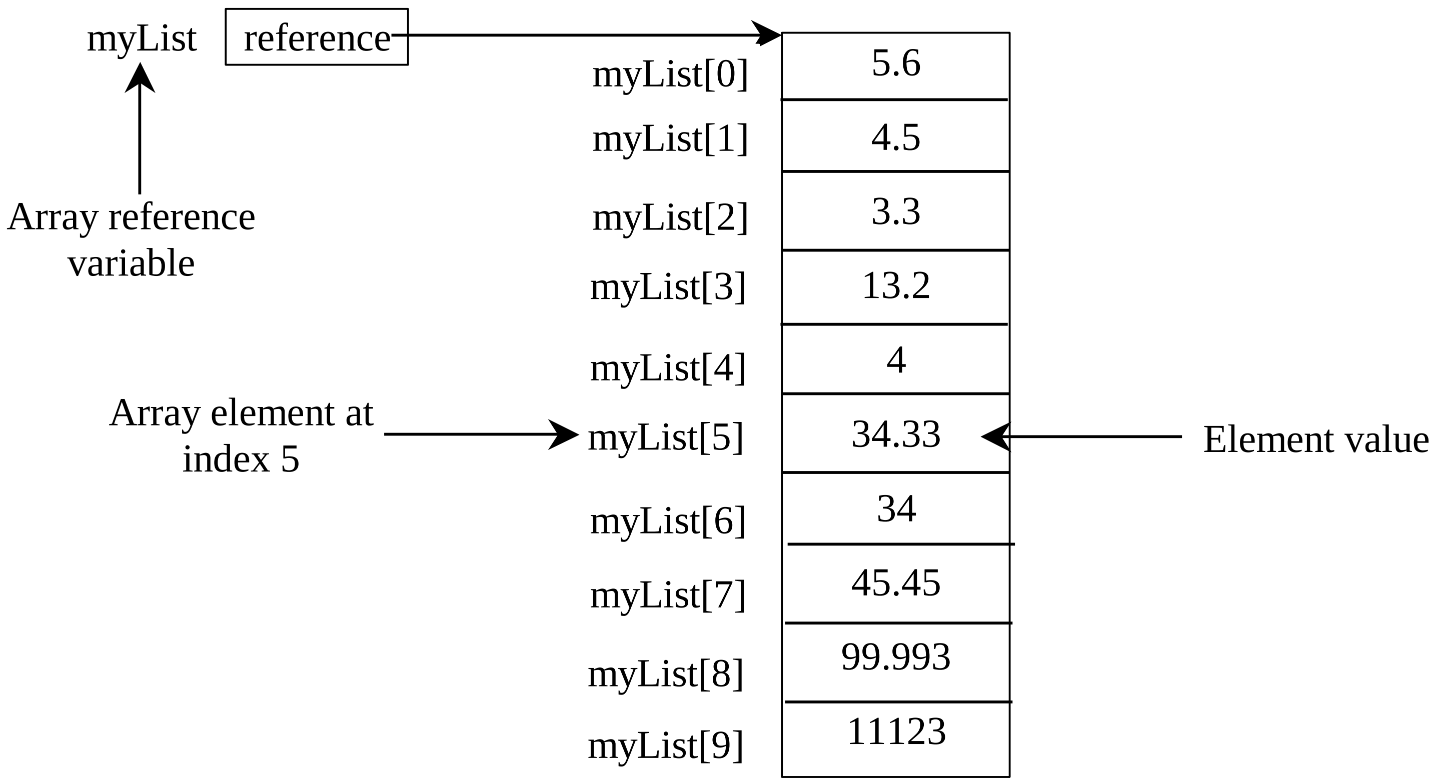
    - arrays: one variable for all 100 numbers

```java
import java.util.Scanner;
public class Test {
  public static void main(String[] args) {
    double[] myList;
    int n = 100;
    myList = new double[n];
    Scanner input = new Scanner(System.in);
    System.out.print("Enter "+myList.length+" doubles: ");
    double sum = 0;
    for (int i = 0; i < myList.length; i++) {
      myList[i] = input.nextDouble();
      sum += myList[i];
    }
    double avg = sum / myList.length;
    int counter = 0;
    for (double v : myList)
      if (v > avg)
        counter++;
    System.out.println(counter
      +" are greater than the average "+avg);
  }
}
```

Introducing Arrays

An *array* is a data structure that represents a collection of the same type of data.

```
double[] myList = new double[10];
```



myList reference

Array reference variable

myList[0] 5.6
myList[1] 4.5
myList[2] 3.3
myList[3] 13.2
myList[4] 4
myList[5] 34.33
myList[6] 34
myList[7] 45.45
myList[8] 99.993
myList[9] 11123

Array element at index 5

Element value

Declaring Array Variables

- `elementDatatype[] arrayRefVar;`

  Example:

  ```
  double[] myList;
  ```

- `elementDatatype arrayRefVar[];`

  // This style is allowed in Java, but **NOT** preferred

  Example:

  ```
  double myList[];
  ```

Creating Arrays

```
arrayRefVar = new elementDatatype[arraySize];
```

- Examples:

```
myList = new double[10];


int size = 10;
double[] myList2 = new double[size];
```

Declaring and Creating in One Step

- `elementDatatype[] arrayRefVar =`
  `new elementDatatype[arraySize];`

  - Example:

```
double[] myList = new double[10];
```

Old syntax:

```
double myList[] = new double[10];
```

The Length of an Array

- Once an array is created, its size is fixed.
    - It cannot be changed.
- You can find the array size using:

```
arrayRefVar.length
```

- Example:

`myList.length` returns 10

Default Values

- When an array is created, its elements are assigned the default value of

  `0` for the numeric primitive data types,

  `'\u0000'` for char types, and

  `false` for boolean types, and

  `null` for reference types

Indexed Variables

- The array elements are accessed through the index.
  - The array indices are ***0-based***, i.e., it starts from `0` to `arrayRefVar.length - 1`.
  - Each element in the array is represented using the following syntax, known as an *indexed variable*:

```
arrayRefVar[index]
```

Using Indexed Variables

After an array is created, an indexed variable can be used in the same way as a regular variable.

`myList[0]` references the first element in the array

`myList[9]` references the last element in the array

Examples:

```
  myList[0] = 1;
  myList[1] = 2;
  myList[2]= myList[0] + myList[1];
```

Array Initializers

- Declaring, creating, initializing in one step:

```
double[] myList = {1.9, 2.9, 3.4, 3.5};
```

  - This shorthand syntax must be in one statement!

This shorthand notation is equivalent to the following statements:

```
double[] myList = new double[4];
myList[0] = 1.9;
myList[1] = 2.9;
myList[2] = 3.4;
myList[3] = 3.5;
```

Array Initializers

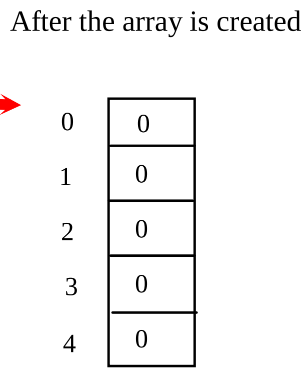
- Another syntax:

```
double[] myList = new double[]
           {1.9, 2.9, 3.4, 3.5};



double[] myList2;
myList2 = new double[]{1.9, 2.9, 3.4, 3.5}
```

Trace Program with Arrays

Declare array variable values, create an array, and assign its reference to values

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```



After the array is created

0	0
1	0
2	0
3	0
4	0

Trace Program with Arrays

i becomes 1

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the array is created

0	0
1	0
2	0
3	0
4	0

Trace Program with Arrays

i (=1) is less than 5

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the array is created

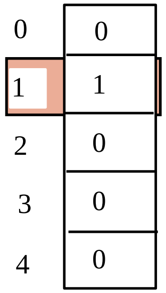
0	0
1	0
2	0
3	0
4	0

Trace Program with Arrays

After this line is executed, value[1] is 1

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the first iteration



0	0
1	1
2	0
3	0
4	0

Trace Program with Arrays

After i++, i becomes 2

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the first iteration

0	0
1	1
2	0
3	0
4	0

Trace Program with Arrays

i (= 2) is less than 5

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the first iteration

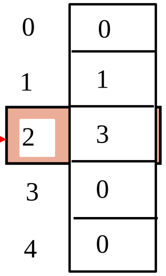
0	0
1	1
2	0
3	0
4	0

Trace Program with Arrays

After this line is executed, values[2] is 3 (2 + 1)

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the second iteration



0	0
1	1
2	3
3	0
4	0

Trace Program with Arrays

After this, i becomes 3.

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the second iteration

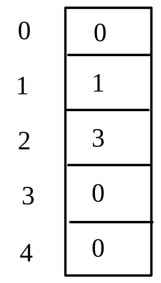
0	0
1	1
2	3
3	0
4	0

Trace Program with Arrays

i (=3) is still less than 5.

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the second iteration



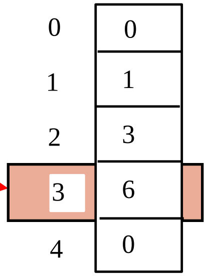
0	0
1	1
2	3
3	0
4	0

Trace Program with Arrays

After this line, values[3] becomes 6 (3 + 3)

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the third iteration



0	0
1	1
2	3
3	6
4	0

Trace Program with Arrays

After this, i becomes 4

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the third iteration

0	0
1	1
2	3
3	6
4	0

Trace Program with Arrays

i (=4) is still less than 5

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the third iteration

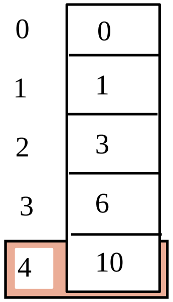
0	0
1	1
2	3
3	6
4	0

Trace Program with Arrays

After this, values[4] becomes 10 (4 + 6)

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the fourth iteration



0	0
1	1
2	3
3	6
4	10

Trace Program with Arrays

After i++, i becomes 5

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the fourth iteration

0	0
1	1
2	3
3	6
4	10

Trace Program with Arrays

i (=5) < 5 is false. Exit the loop

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

After the fourth iteration

0	0
1	1
2	3
3	6
4	10

Trace Program with Arrays

After this line, values[0] is 11 (1 + 10)

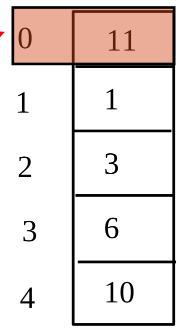
```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < 5; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```

0	11
1	1
2	3
3	6
4	10

Trace Program with Arrays

After this line, values[0] is 11 (1 + 10)

```
public class Test {
  public static void main(String[] args) {
    int[] values = new int[5];
    for (int i = 1; i < values.length; i++) {
      values[i] = i + values[i-1];
    }
    values[0] = values[1] + values[4];
  }
}
```



0	11
1	1
2	3
3	6
4	10

Initializing arrays with input values

```
double[] myList = new double[10];
Scanner input = new Scanner(System.in);
System.out.print("Enter " + myList.length
   + " values: ");
for (int i = 0; i < myList.length; i++)
  myList[i] = input.nextDouble();
```

Initializing arrays with random values

```
double[] myList = new double[10];
for(int i = 0; i < myList.length; i++)
   myList[i] = Math.random() * 100;
```

Printing arrays

```
double[] myList = new double[10];
...
for(int i = 0; i < myList.length; i++)
   System.out.print(myList[i] + " ");
```

Summing all elements

```
double[] myList = new double[10];
...
double total = 0;
for(int i = 0; i < myList.length; i++)
   total += myList[i];
```

Finding the largest element

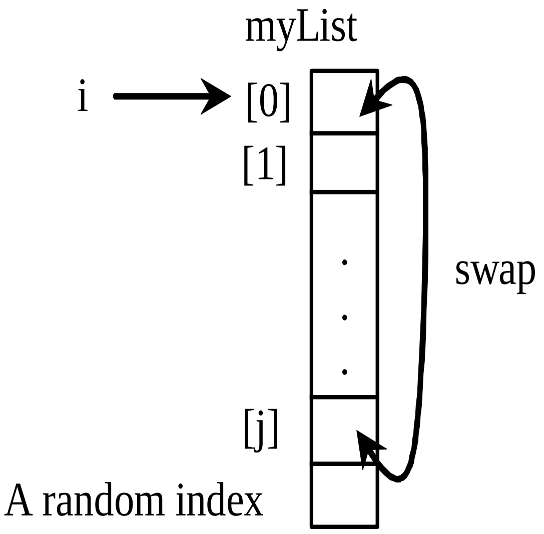
```
double max = myList[0];
for(int i = 1; i < myList.length; i++)
  if (myList[i] > max)
        max = myList[i];
```

Finding the smallest element

```
double min = myList[0];
for(int i = 1; i < myList.length; i++)
   if (myList[i] < min)
         min = myList[i];
```

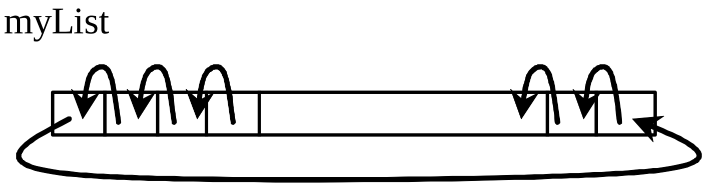
Random shuffling

```
for (int i = 0; i < myList.length; i++) {
  // Generate an index j randomly
  int j = (int)(Math.random()
    * myList.length);

  // Swap myList[i] with myList[j]
  double temp = myList[i];
  myList[i] = myList[j];
  myList[j] = temp;
}
```



Shifting Left

```
double temp = myList[0]; // Retain the first element

// Shift elements left
for (int i = 1; i < myList.length; i++) {
  myList[i - 1] = myList[i];
}

// Move the first element to fill in the last position
myList[myList.length - 1] = temp;
```



Shifting Right

```
double temp = myList[myList.length - 1];
for(int i=myList.length-1; i>0; i--)
    myList[i] = myList[i-1];
myList[0] = temp;
```

Enhanced for Loop (for-each loop)

JDK 1.5 introduced a new **`for-`**loop that enables you to traverse the complete array sequentially without using an index variable.

- For example, the following code displays all elements in the array myList:

```
for (double value: myList)
  System.out.println(value);
```

In general, the syntax is

```
for (elementType value: arrayRefVar) {
  // Process the value
}
```

Note: You still have to use an index variable if you wish to traverse the array in a different order or change the elements in the array.

Enhanced for Loop (for-each loop)

for loop

```
double total = 0.;
for (int i = 0; i <
  myList.length; i++) {
   total += myList[i];
}
```

for-each loop

```
double total=0;
for (double d : myList) {
    total += d;
}
```

The for-each loop is much more general (you can use it with any Java Collection)

Enhanced for Loop (for-each loop)

- Printing arrays

for loop

```
for (int i = 0; i < myList.length; i++) {
  System.out.print(myList[i] + " ");
}
```

for-each loop

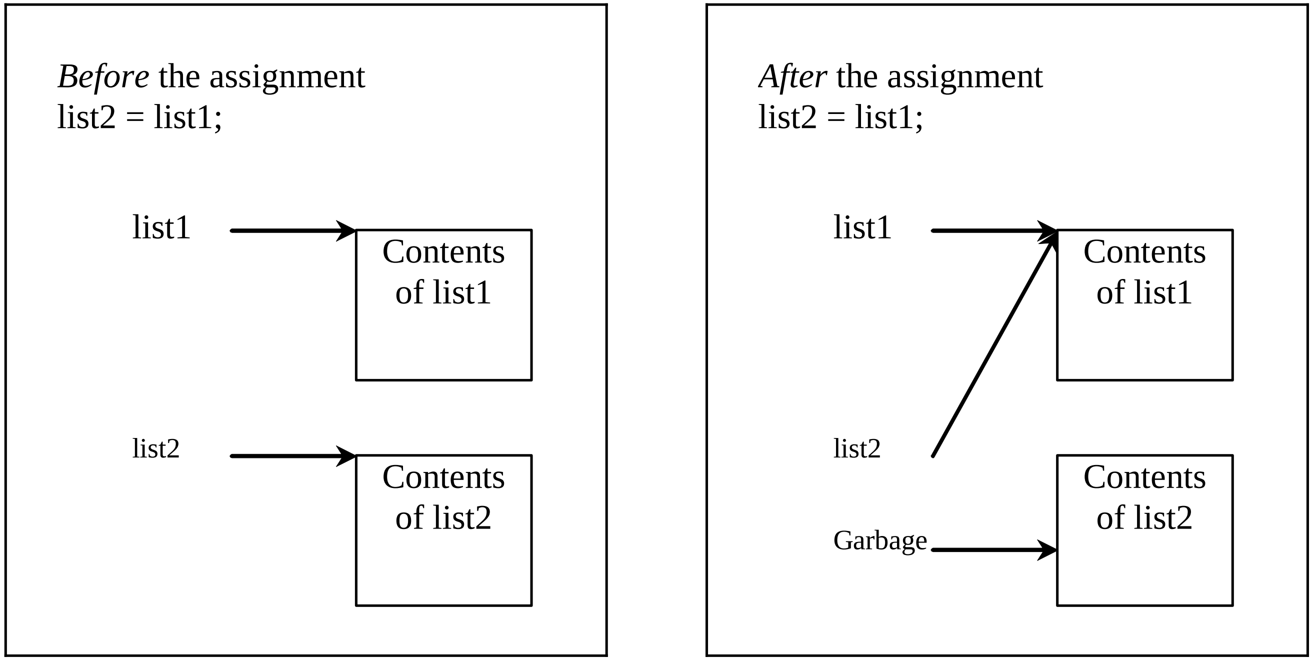
```
for (double d: myList) {
  System.out.print(d + " ");
}
```

Copying Arrays

- Often, in a program, you need to duplicate an array or a part of an array.
- **Using the assignment statement (=), you re-direct the pointer:**

list2 = list1;

- **You don't copy with "=" !**



Copying Arrays

- Using a loop:

```
int[] sourceArray={2, 3, 1, 5, 10};
int[] targetArray=new int[sourceArray.length];
for (int i = 0; i < sourceArray.length; i++)
    targetArray[i] = sourceArray[i];
```

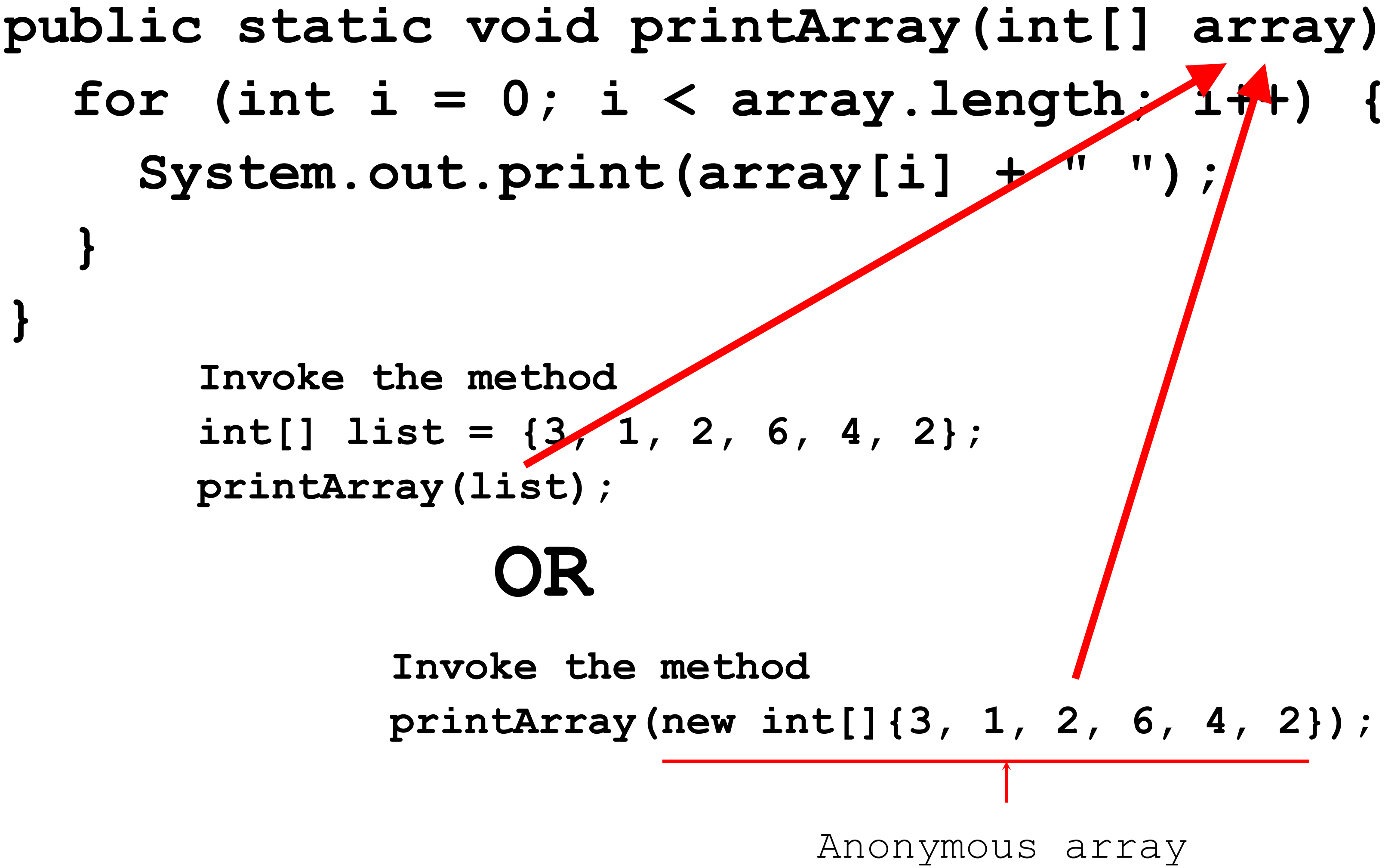
The `arraycopy` Utility

```
System.arraycopy(sourceArray,
  src_pos, targetArray, tar_pos,
  length);
```

Example:

```
int[] sourceArray={2, 3, 1, 5, 10};
int[] targetArray=new int[sourceArray.length];
System.arraycopy(sourceArray, 0,
  targetArray, 0, sourceArray.length);
```

Passing Arrays to Methods



```
public static void printArray(int[] array) {
  for (int i = 0; i < array.length; i++) {
    System.out.print(array[i] + " ");
  }
}
```

```
Invoke the method
int[] list = {3, 1, 2, 6, 4, 2};
printArray(list);
```

OR

```
Invoke the method
printArray(new int[]{3, 1, 2, 6, 4, 2});
```

Anonymous array

Anonymous Array

The statement

```
printArray(new int[]{3, 1, 2, 6, 4, 2});
```

creates an array using the following syntax:

```
new dataType[]{literal_0, literal_1, ..., literal_k}
```

There is no explicit reference variable for the array.

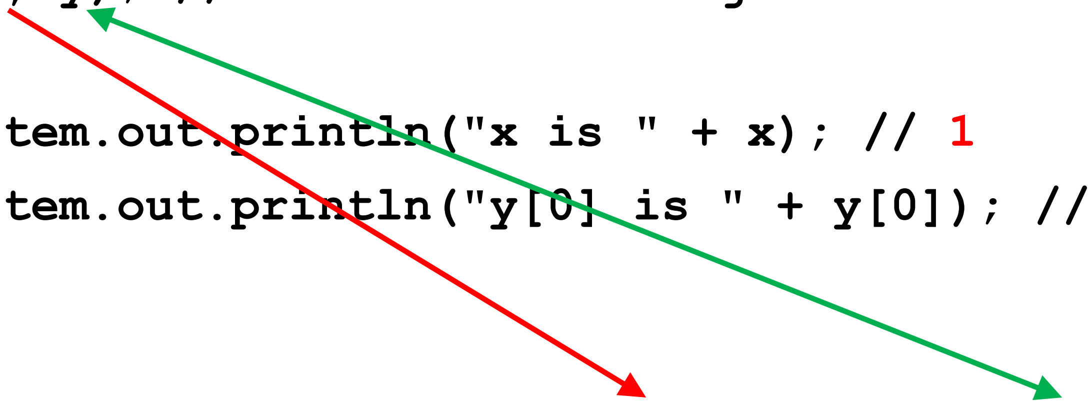
Such array is called an ***anonymous array***.

Pass By Value

Java uses ***pass by value*** to pass arguments to a method.

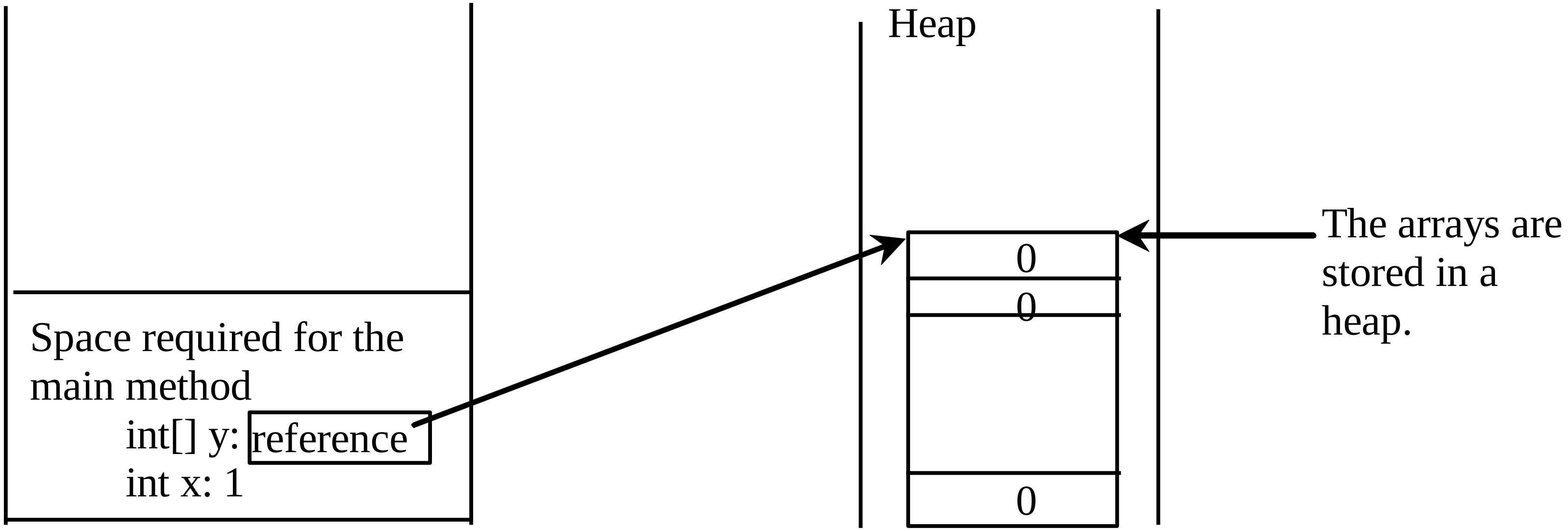
- For a parameter of an array type, the value of the parameter contains a reference to an array; this reference is passed to the method.
  - Any changes to the array that occur inside the method body will affect the original array that was passed as the argument.
- Different from a parameter of a primitive type value where the actual value is passed.
  - Changing the value of the local parameter inside the method does not affect the value of the variable outside the method.

Simple Example



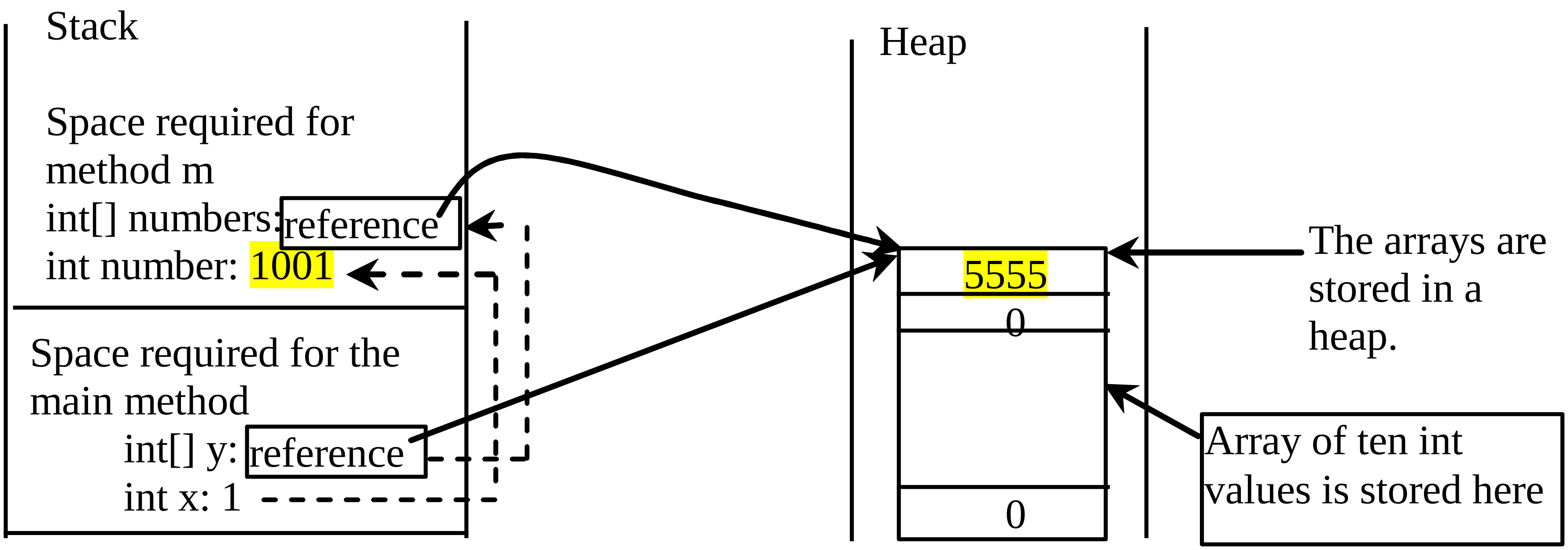
```
public class Test {
  public static void main(String[] args) {
    int x = 1; // x represents an int value
    int[] y = new int[10]; // y represents an array of int values

    m(x, y); // Invoke m with arguments x and y

    System.out.println("x is " + x); // 1
    System.out.println("y[0] is " + y[0]); // 5555
  }

  public static void m(int number, int[] numbers) {
    number = 1001; // Assign a new value to number
    numbers[0] = 5555; // Assign a new value to numbers[0]
  }
}
```

The Heap Segment


Heap
Space required for the main method
int[] y: reference
int x: 1
0
0
0
The arrays are stored in a heap.

The JVM stores arrays and objects in an area of memory, called *heap*, which is used for dynamic memory allocation where blocks of memory are allocated and freed in an arbitrary order.

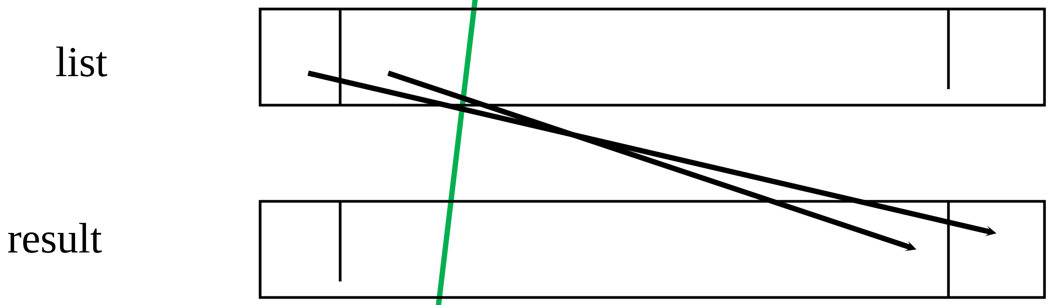
The Call Stack Memory


Stack
Space required for method m
int[] numbers: reference
int number: 1001
Space required for the main method
int[] y: reference
int x: 1
Heap
5555
0
0
The arrays are stored in a heap.
Array of ten int values is stored here

When invoking m(x, y), the values of x and y are passed to number and numbers. Since y contains the reference value to the array, numbers now contains the same reference value to the same array.

Returning an Array from a Method

```
public static int[] reverse(int[] list) {
  int[] result = new int[list.length];

  for (int i = 0, j = result.length - 1;
       i < list.length; i++, j--)
    result[j] = list[i];

  return result;
}
```



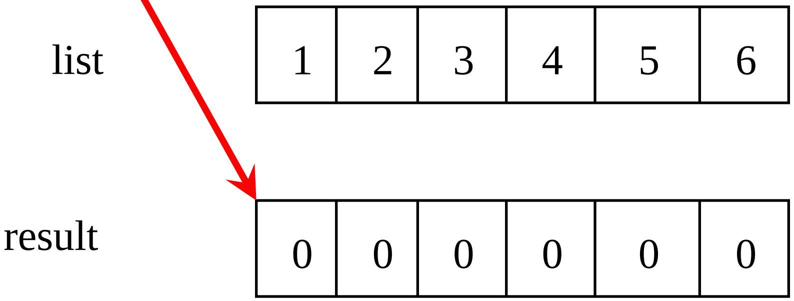
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

Trace the reverse Method

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

Declare result and create array

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```



list	1	2	3	4	5	6
result	0	0	0	0	0	0

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

i = 0 and j = 5

```
public static int[] reverse(int[] list) {
  int[] result = new int[list.length];

  for (int i = 0, j = result.length - 1;
       i < list.length; i++, j--) {
    result[j] = list[i];
  }

  return result;
}
```

list	1	2	3	4	5	6
result	0	0	0	0	0	0

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Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

i (= 0) is less than 6

```
public static int[] reverse(int[] list) {
  int[] result = new int[list.length];

  for (int i = 0, j = result.length - 1;
       i < list.length; i++, j--) {
    result[j] = list[i];
  }

  return result;
}
```

list	1	2	3	4	5	6
result	0	0	0	0	0	0

Trace the reverse Method, cont.

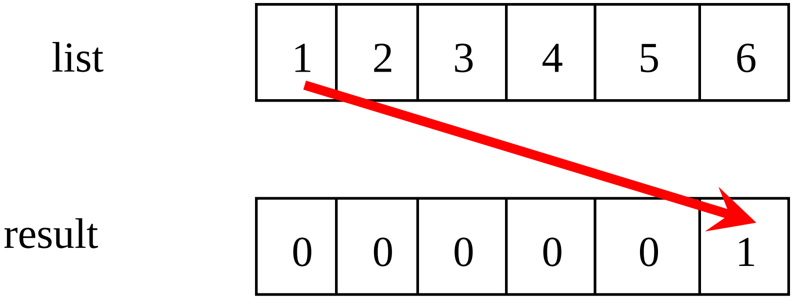
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i = 0 and j = 5
Assign list[0] to result[5]



list	1	2	3	4	5	6
result	0	0	0	0	0	1

Trace the reverse Method, cont.

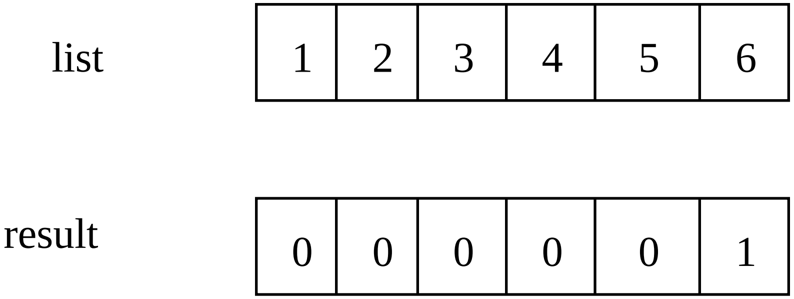
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

After this, i becomes 1 and j becomes 4



list

1	2	3	4	5	6

result

0	0	0	0	0	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i (=1) is less than 6

list	1	2	3	4	5	6
result	0	0	0	0	0	1

Trace the reverse Method, cont.

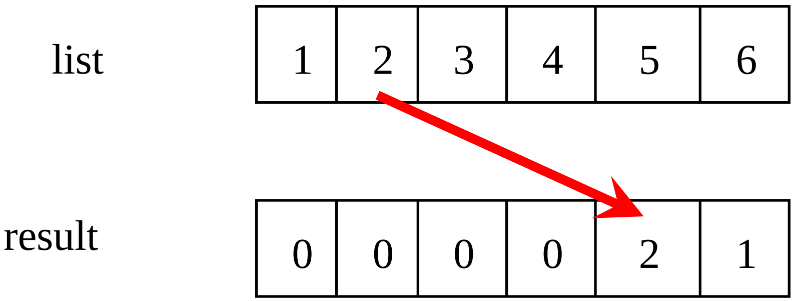
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

i = 1 and j = 4
Assign list[1] to result[4]

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```



list	1	2	3	4	5	6
result	0	0	0	0	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

After this, i becomes 2 and j becomes 3

list	1	2	3	4	5	6
result	0	0	0	0	2	1

Trace the reverse Method, cont.

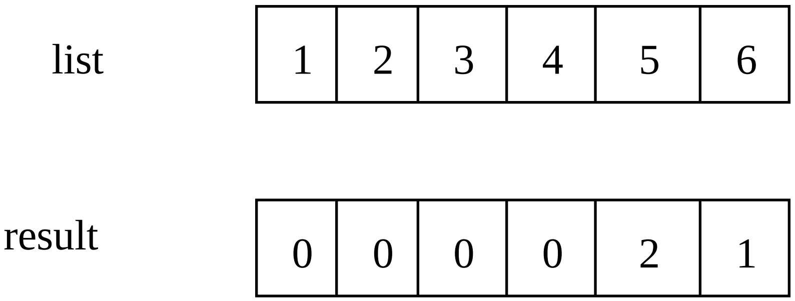
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i (=2) is still less than 6



list	1	2	3	4	5	6
result	0	0	0	0	2	1

Trace the reverse Method, cont.

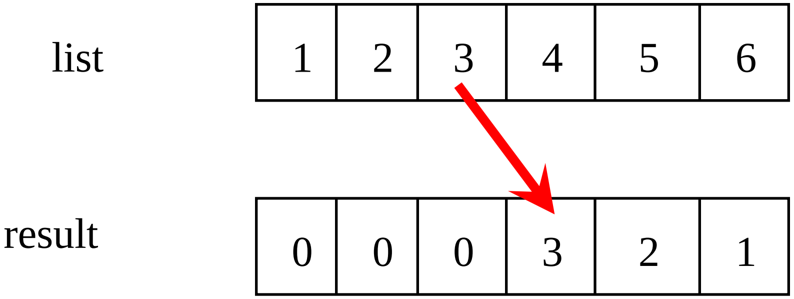
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i = 2 and j = 3
Assign list[i] to result[j]



list	1	2	3	4	5	6
result	0	0	0	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

After this, i becomes 3 and j becomes 2

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

list	1	2	3	4	5	6
result	0	0	0	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

i (=3) is still less than 6

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

list	1	2	3	4	5	6
result	0	0	0	3	2	1

Trace the reverse Method, cont.

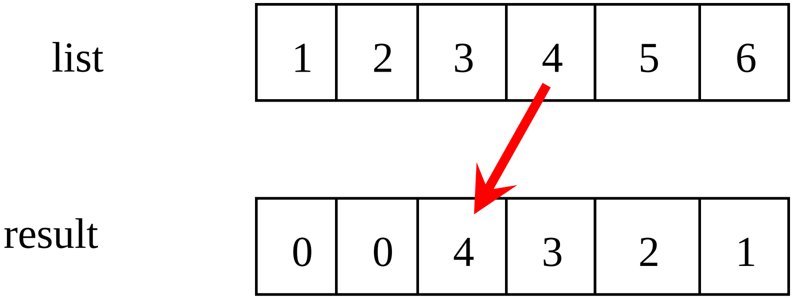
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i = 3 and j = 2
Assign list[i] to result[j]



list	1	2	3	4	5	6
result	0	0	4	3	2	1

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Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

After this, i becomes 4 and j becomes 1

list	1	2	3	4	5	6
result	0	0	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

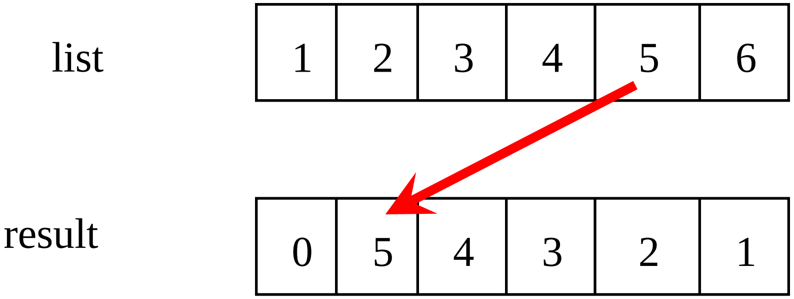
i (=4) is still less than 6

list	1	2	3	4	5	6
result	0	0	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i = 4 and j = 1
Assign list[i] to result[j]



list	1	2	3	4	5	6
result	0	5	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

After this, i becomes 5 and j becomes 0

```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

list	1	2	3	4	5	6
result	0	5	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i (=5) is still less than 6

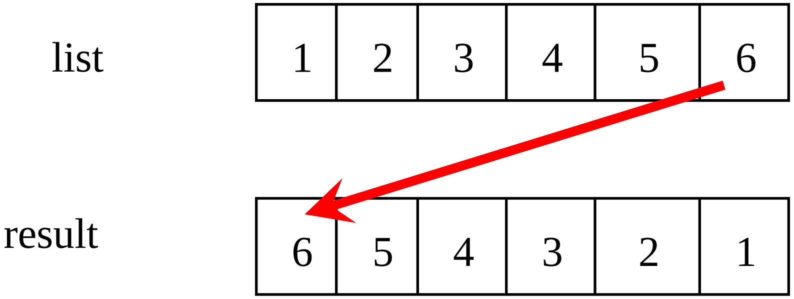
list	1	2	3	4	5	6

result	0	5	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i = 5 and j = 0
Assign list[i] to result[j]



list	1	2	3	4	5	6
result	6	5	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

After this, i becomes 6 and j becomes -1

```
public static int[] reverse(int[] list) {
  int[] result = new int[list.length];

  for (int i = 0, j = result.length - 1;
       i < list.length; i++, j--) {
    result[j] = list[i];
  }

  return result;
}
```

list	1	2	3	4	5	6
result	6	5	4	3	2	1

Trace the reverse Method, cont.

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);


  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
         i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```

i (=6) < 6 is false. So exit the loop.

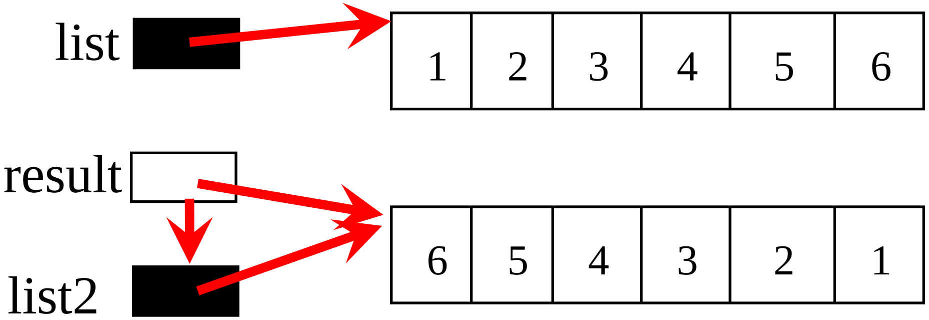
list	1	2	3	4	5	6
result	6	5	4	3	2	1

Returning an Array from a Method

```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

Return result

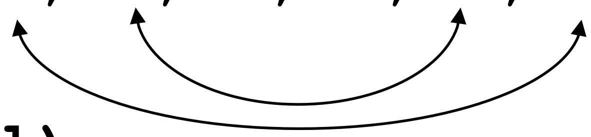
```
  public static int[] reverse(int[] list) {
    int[] result = new int[list.length];

    for (int i = 0, j = result.length - 1;
        i < list.length; i++, j--) {
      result[j] = list[i];
    }

    return result;
  }
```



Use the same Array in a method

```
public static void reverse(int[] list) {
   int temp;
   for (int i = 0, j = list.length - 1;
         i < list.length/2; i++, j--) {
      temp = list[j];
      list[j] = list[i];
      list[i] = temp;
   }
}
```

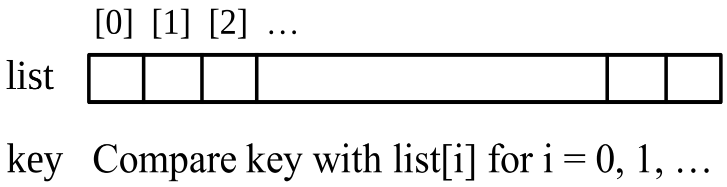
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
reverse(list1);
System.out.print(list1[0]);
```



Searching Arrays

- Searching is the process of looking for a specific element in an array

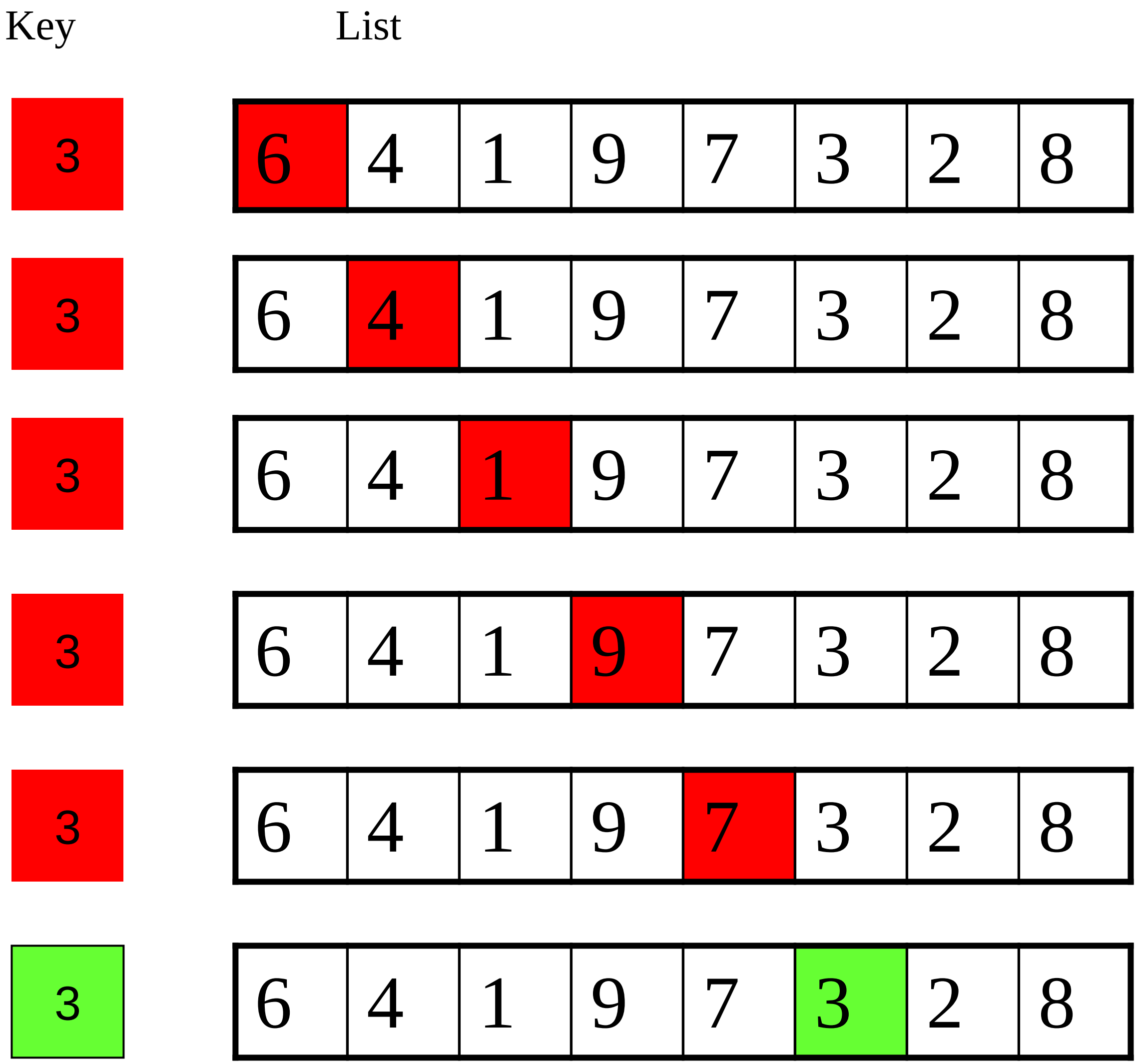
```
public static int linearSearch(int[] list, int key)
```



Compare key with list[i] for i = 0, 1, …

- return the index of the first occurrence of the key in list
- if not found, return -1

Linear Search Example



Key	List							
3	6	4	1	9	7	3	2	8
3	6	4	1	9	7	3	2	8
3	6	4	1	9	7	3	2	8
3	6	4	1	9	7	3	2	8
3	6	4	1	9	7	3	2	8
3	6	4	1	9	7	3	2	8

From Idea to Solution

```
public static int linearSearch(int[] list, int key) {
  for(int i = 0; i < list.length; i++)
    if (key == list[i])
      return i;
  return -1;
}
```

```
int[] list = {6,4,1,9,7,3,2,8};
int i = linearSearch(list, 3);  // returns 5
int j = linearSearch(list, -4); // returns -1
int k = linearSearch(list, 4); // returns 1
```

Binary Search

- If an array is already ordered, then it is cheaper to find an element
  - Assume that the array is in ascending order. e.g., 1, 2, 3, 4, 6, 7, 8, 9

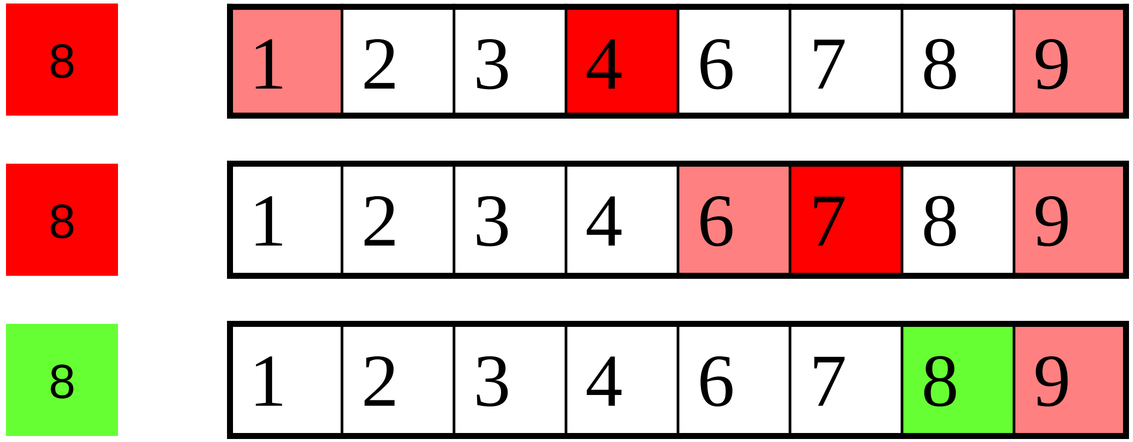
The binary search first compares the key (e.g., 8) with the element in the middle of the array.

Binary Search

Consider the following three cases:

- If the key is less than the middle element, you only need to search the key in the **first half** of the array.
- If the key is equal to the middle element, the search ends with a match.
- If the key is greater than the middle element, you only need to search the key in the second half of the array.

Binary Search

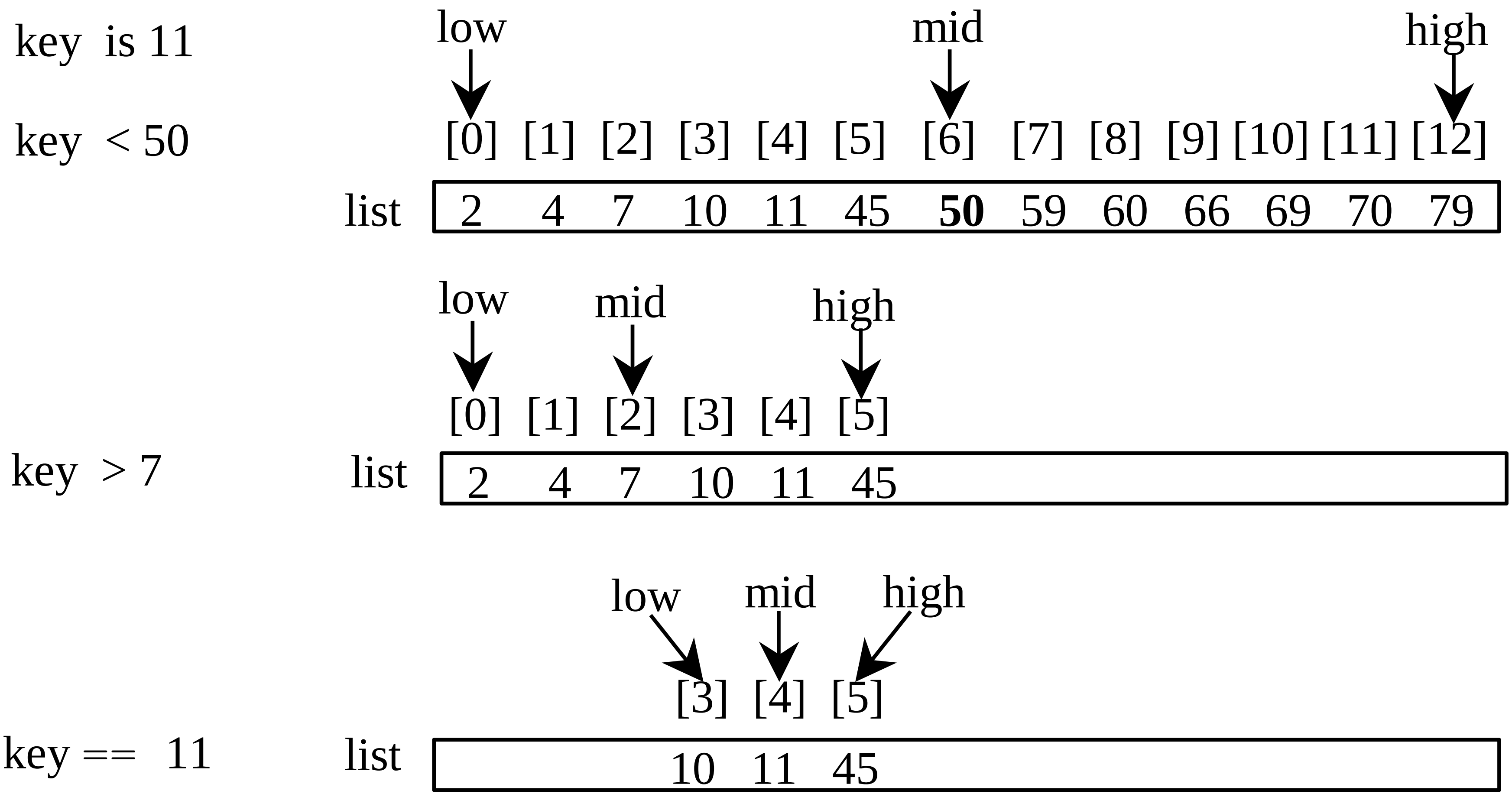


Key	List							
8	1	2	3	4	6	7	8	9
8	1	2	3	4	6	7	8	9
8	1	2	3	4	6	7	8	9

From Idea to Solution

```
/** Use binary search to find the key in the list */
public static int binarySearch(int[] list, int key) {
  int low = 0;
  int high = list.length - 1;
  int mid;
  while(low <= high) {
    mid = (low + high) / 2;
    if (key < list[mid])
      high = mid - 1;
    else if (key == list[mid])
      return mid;
    else
      low = mid + 1;
  }
  return -1 - low;
}
```

Binary Search



key is 11

key < 50

low mid high

[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]

list 2 4 7 10 11 45 **50** 59 60 66 69 70 79

low mid high

[0] [1] [2] [3] [4] [5]

key > 7

list 2 4 7 10 11 45

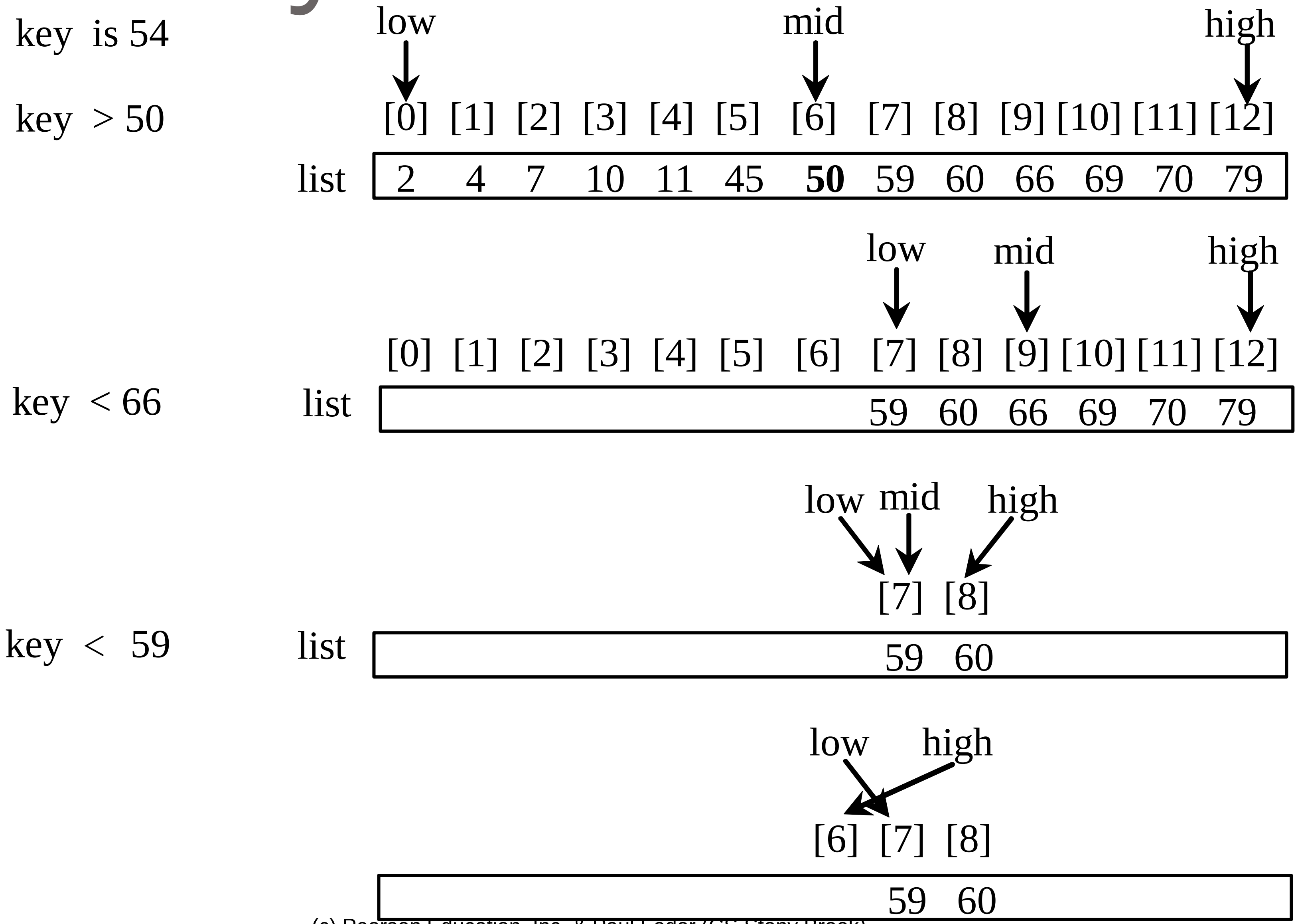
low mid high

[3] [4] [5]

key == 11

list 10 11 45

Binary Search



key is 54

key > 50

low mid high

[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]

list 2 4 7 10 11 45 **50** 59 60 66 69 70 79

low mid high

[0] [1] [2] [3] [4] [5] [6] [7] [8] [9] [10] [11] [12]

key < 66

list 59 60 66 69 70 79

low mid high

[7] [8]

key < 59

list 59 60

low high

[6] [7] [8]

59 60

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The Arrays.binarySearch Method

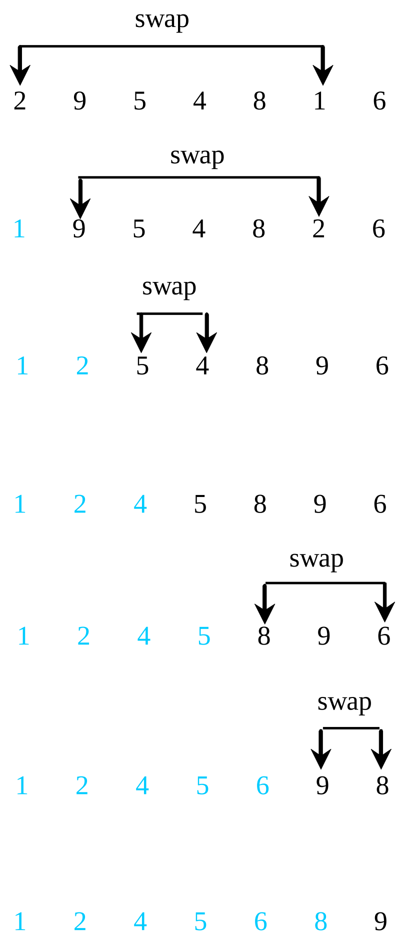
- Java provides several overloaded binarySearch methods for searching a key in an array of int, double, char, short, long, and float in the java.util.Arrays class.

```
int[] list = {1, 2, 3, 4, 6, 7, 8, 9};
System.out.println("Index is " +
  java.util.Arrays.binarySearch(list, 6));
```

Return is 4

Selection Sort

Selection sort finds the smallest number in the list and places it first. It then finds the smallest number in the remaining list and places it second, and so on until the list contains only a single number. Sort the list {2, 9, 5, 4, 8, 1, 6} using selection sort would be:



Select 1 (the smallest) and swap it with 2 (the first) in the list

2 9 5 4 8 1 6

Select 2 (the smallest) and swap it with 9 (the first) in the remaining list

1 9 5 4 8 2 6

The number 1 is now in the correct position and thus no longer needs to be considered.

Select 4 (the smallest) and swap it with 5 (the first) in the remaining list

1 2 5 4 8 9 6

The number 2 is now in the correct position and thus no longer needs to be considered.

5 is the smallest and in the right position. No swap is necessary

1 2 4 5 8 9 6

The number 6 is now in the correct position and thus no longer needs to be considered.

Select 6 (the smallest) and swap it with 8 (the first) in the remaining list

1 2 4 5 8 9 6

The number 5 is now in the correct position and thus no longer needs to be considered.

Select 8 (the smallest) and swap it with 9 (the first) in the remaining list

1 2 4 5 6 9 8

The number 6 is now in the correct position and thus no longer needs to be considered.

Since there is only one element remaining in the list, sort is completed

1 2 4 5 6 8 9

The number 8 is now in the correct position and thus no longer needs to be considered.

From Idea to Solution

```
for (int i = 0; i < list.length; i++) {
  select the smallest element in list[i..listSize-1];
  swap the smallest with list[i], if necessary;
  // list[i] is in its correct position.
  // The next iteration apply on list[i+1..listSize-1]
}
```

From Idea to Solution

```
for (int i = 0; i < list.length; i++) {
  select the smallest element in list[i..listSize-1];
  swap the smallest with list[i], if necessary;
  // list[i] is in its correct position.
  // The next iteration apply on list[i+1..listSize-1]
}
```

Expand

```
   double currentMin = list[i];
   int currentMinIndex = i;
   for (int j = i+1; j < list.length; j++) {
     if (currentMin > list[j]) {
       currentMin = list[j];
       currentMinIndex = j;
     }
   }
```

Wrap it in a Method

```
/** A selectionSort method for sorting numbers */
public static void selectionSort(double[] list) {
    for(int i = 0; i < list.length - 1; i++) {
      // Find the minimum in the list[i..list.length-1]
      double currentMin = list[i];
      int currentMinIndex = i;
      for (int j = i + 1; j < list.length; j++)
        if (currentMin > list[j]) {
          currentMin = list[j];
          currentMinIndex = j;
        }
      // Swap list[i] with list[currentMinIndex] if necessary;
      if (currentMinIndex != i) {
        list[currentMinIndex] = list[i];
        list[i] = currentMin;
      }
    }
  }
```

Insertion Sort

int[] myList = {2, 9, 5, 4, 8, 1, 6}; // Unsorted

From index 1 on, the prefix is sorted and we want to insert the current element in its right sorted place (by starting from the position and comparing the elements with temp, for every element greater than temp, shift it right.

Step 1: Initially, the sorted sublist contains the first element in the list. Insert 9 to the sublist.

Step2: The sorted sublist is {2, 9}. Insert 5 to the sublist.

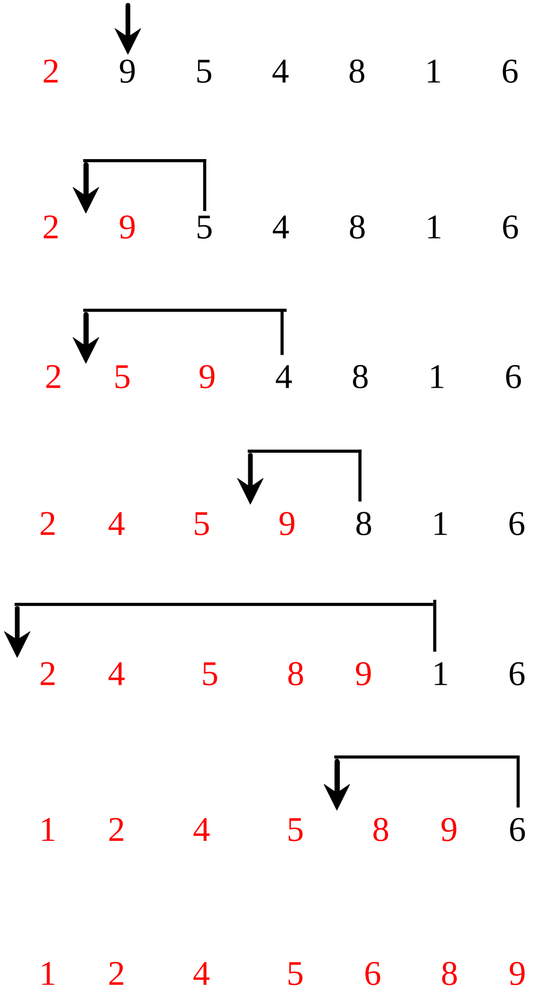
Step 3: The sorted sublist is {2, 5, 9}. Insert 4 to the sublist.

Step 4: The sorted sublist is {2, 4, 5, 9}. Insert 8 to the sublist.

Step 5: The sorted sublist is {2, 4, 5, 8, 9}. Insert 1 to the sublist.

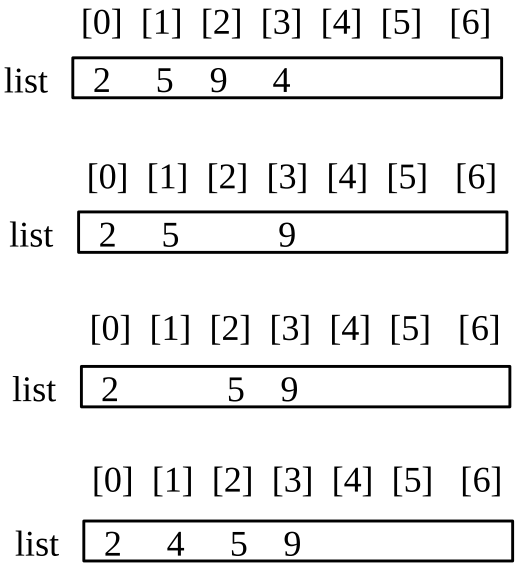
Step 6: The sorted sublist is {1, 2, 4, 5, 8, 9}. Insert 6 to the sublist.

Step 7: The entire list is now sorted



How to Insert?

One iteration:



	[0]	[1]	[2]	[3]	[4]	[5]	[6]
list	2	5	9	4			

Step 1: Save 4 to a temporary variable currentElement

	[0]	[1]	[2]	[3]	[4]	[5]	[6]
list	2	5		9			

Step 2: Move list[2] to list[3]

	[0]	[1]	[2]	[3]	[4]	[5]	[6]
list	2		5	9			

Step 3: Move list[1] to list[2]

	[0]	[1]	[2]	[3]	[4]	[5]	[6]
list	2	4	5	9			

Step 4: Assign currentElement to list[1]

From Idea to Solution

```
public static void insertionSort(double[] a){
  for(int i=1; i < a.length - 1; i++){
    double temp = a[i];
    int j;
    for(j = i-1; j >= 0; j--)
      if(temp < a[j])
        a[j+1] = a[j];
      else
        break;
    a[j+1] = temp;
  }
}
```

```
public class Test {
  public static void insertionSort(double[] a) {
    for (int i = 1; i < a.length - 1; i++) {
      double temp = a[i];
      int j;
      for (j = i - 1; j >= 0; j--)
        if (temp < a[j])
          a[j + 1] = a[j];
        else
          break;
      a[j + 1] = temp;
    }
  }
  public static void main(String[] args) {
    double[] a = { 5.0, 4.0, 3.0, 2.0, 1.0 };
    insertionSort(a);
    for (double v : a)
      System.out.print(v + " ");
  }
}
```

```
1.0 2.0 3.0 4.0 5.0
```

The Arrays.sort Method

- Since sorting is frequently used in programming, Java provides several overloaded sort methods for sorting an array of int, double, char, short, long, and float in the **`java.util.Arrays`** class.
  - For example, the following code sorts an array of numbers and an array of characters:

```
double[] numbers = {6.0, 4.4, 1.9, 2.9, 3.4, 3.5};
java.util.Arrays.sort(numbers);

char[] chars = {'a', 'A', '4', 'F', 'D', 'P'};
java.util.Arrays.sort(chars);
```