Arrays

CPT204 Advanced Object-oriented Programming

Lecture 1.1 OOP Review 1

1

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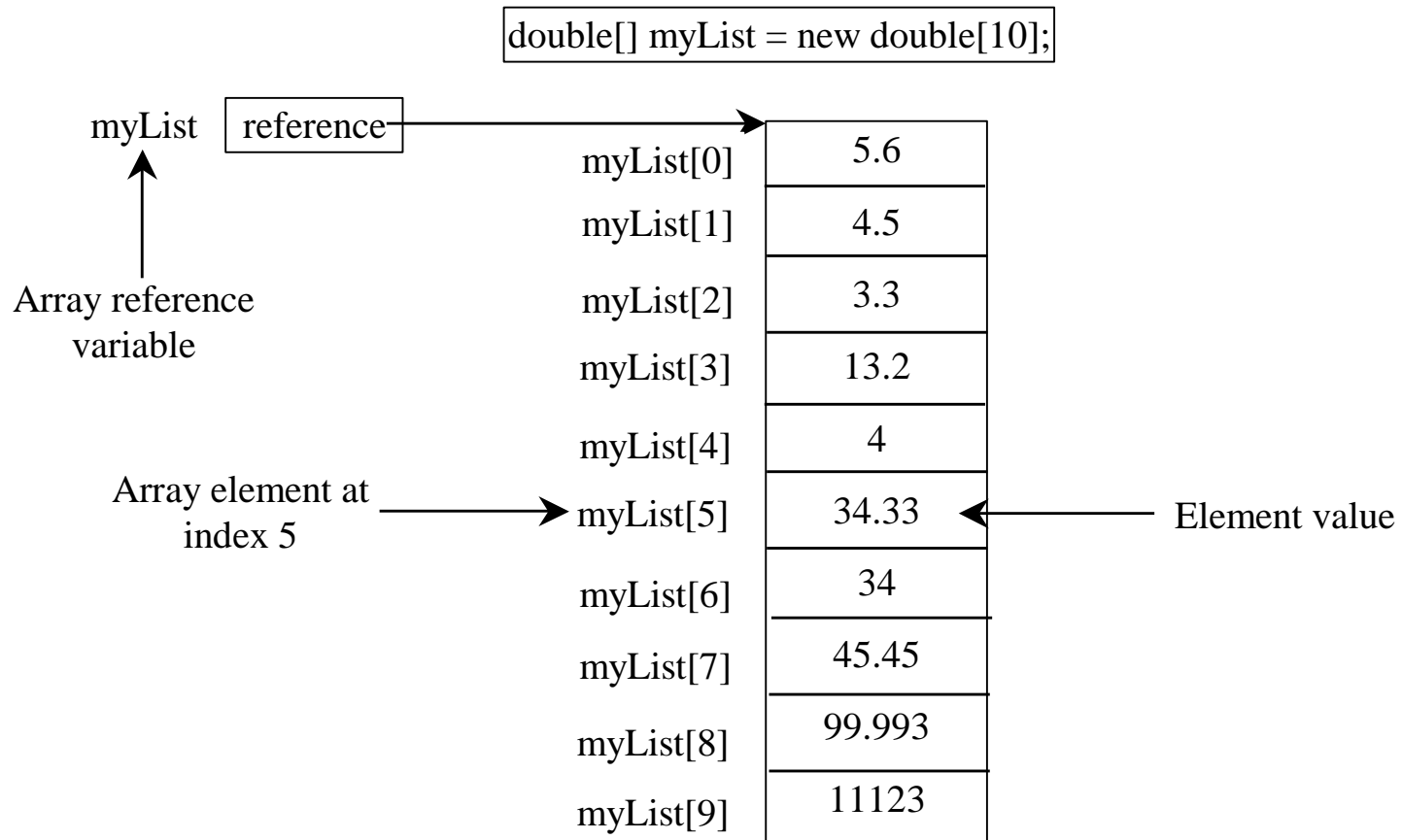- Sorting Arrays: Selection Sort and Insertion Sort

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

Array element at index 5

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

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 <u>char</u> types, and

  false for <u>boolean</u> 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];
```

In-Class Quiz 1: Array Initialization

- Which of the following is a valid way to initialize an array in Java?

  - ```
    int[] arr = new int {1, 2, 3, 4, 5};
    ```
  - ```
    int arr[5] = {1, 2, 3, 4, 5};
    ```
  - ```
    int[] arr = {1, 2, 3, 4, 5};
    ```
  - ```
    int[5] arr = {1, 2, 3, 4, 5};
    ```

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

```java
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

```java
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

```java
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

```java
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

```java
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)

```java
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

```java
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];
  }
}
```
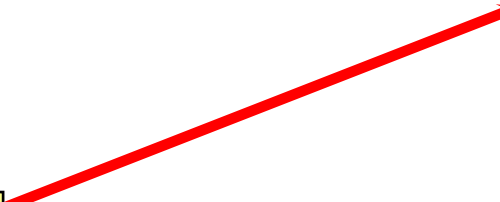
After the fourth iteration

0	0
1	1
2	3
3	6
4	10

Trace Program with Arrays

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

```java
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];
  }
}
```
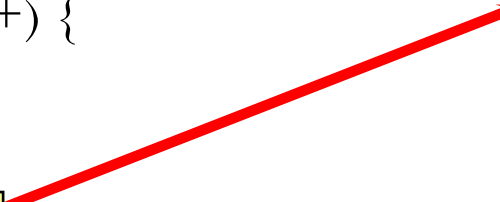
0	11
1	1
2	3
3	6
4	10

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

```java
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;
}
```
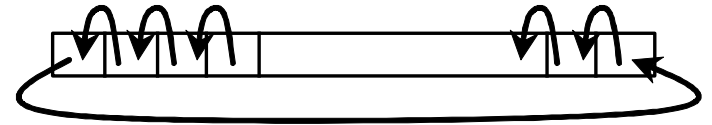
myList

i ⟶ [0]

[1]

.

.

.

swap

[j]

A random index
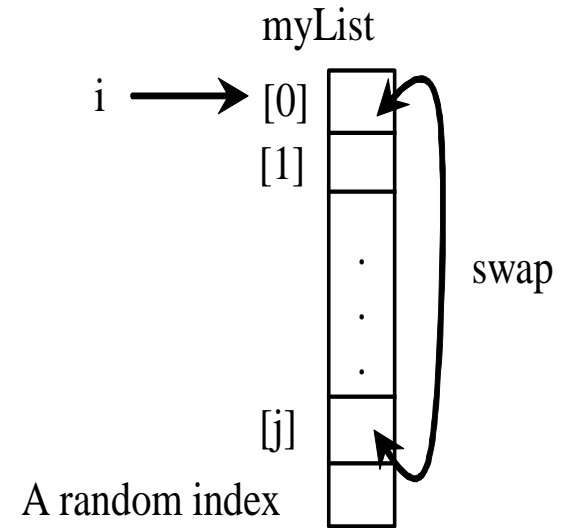
Shifting Left

```
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;
```

myList

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 <u>for</u> 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 <u>for</u> 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 <u>for</u> 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 + " ");
}
```
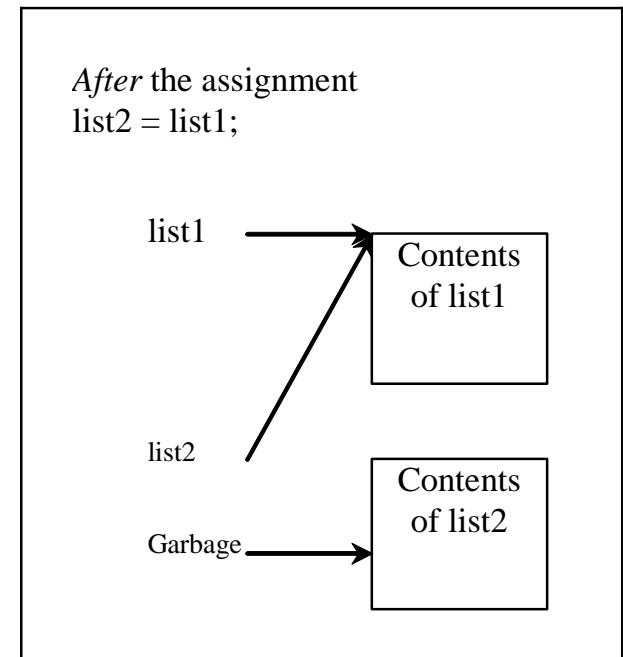
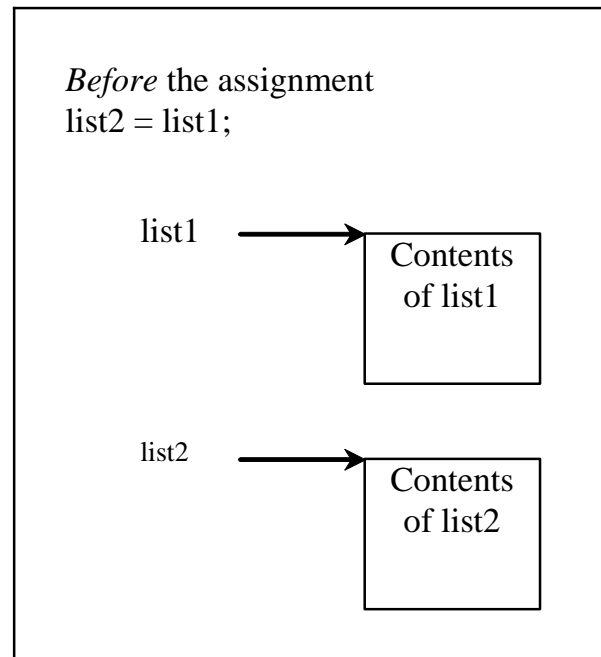# In-Class Quiz 2: Enhanced For-Loop

- What is the output of the following code:

```
int[] numbers = {1, 2, 3, 4, 5};
for (int num : numbers) {
    num *= 2;
}
System.out.println(numbers[2]);
```

○ 2

○ 3

○ 4

○ 6

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 "=" !**

Before the assignment
list2 = list1;

list1 → Contents of list1

list2 → Contents of list2

After the assignment
list2 = list1;

list1 → Contents of list1

list2 ↗ Contents of list1

Garbage → Contents of list2

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.

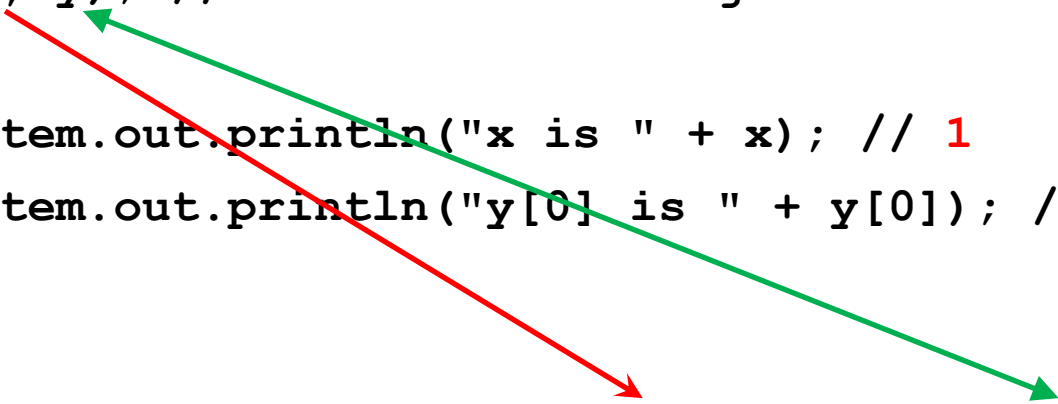Such array is called an *anonymous array*.

Pass By Value

Java uses ***pass by value*** to pass arguments to a method.
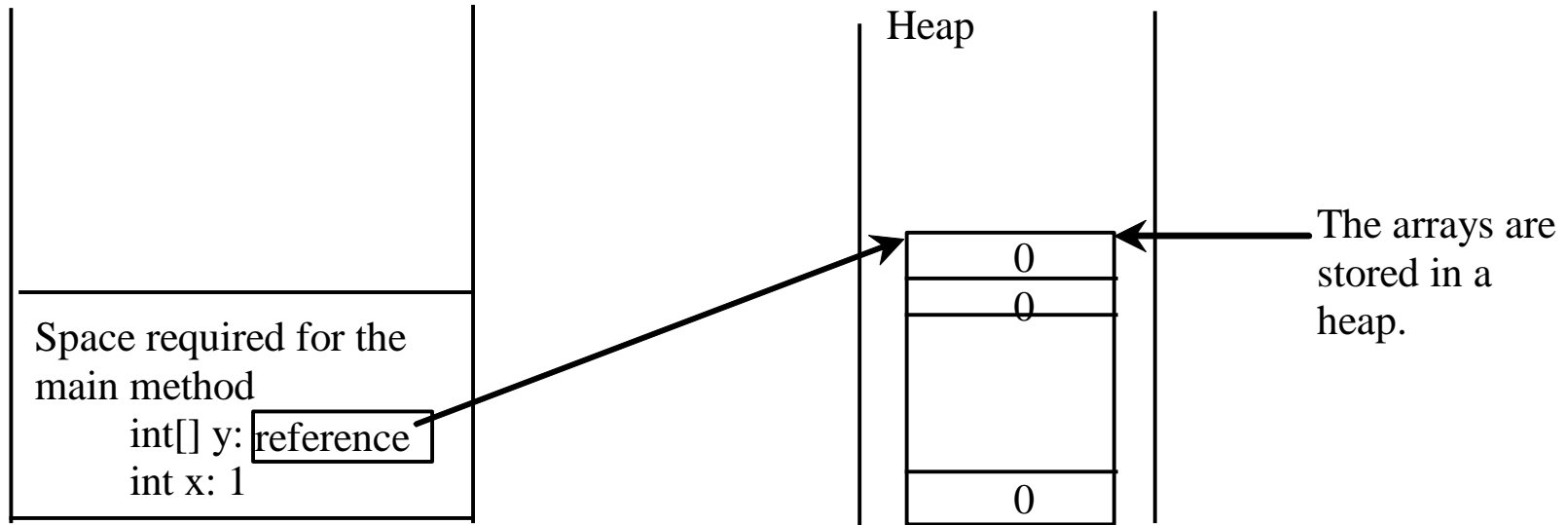
- For a parameter of an array type, the value of the parameter contains a reference to an array; this reference is passed to the method.
  - Any changes to the array that occur inside the method body will affect the original array that was passed as the argument.
- Different from a parameter of a primitive 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

```java
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]
  }
}
```

50

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
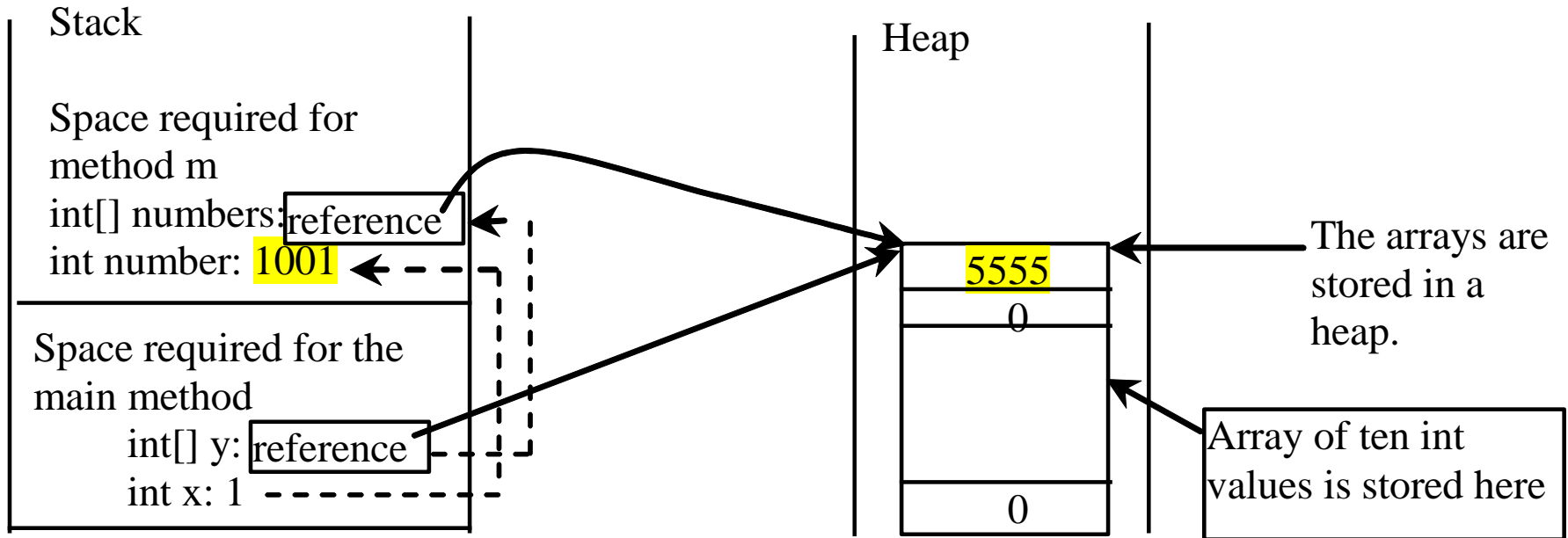heap.

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 <u>m(x, y)</u>, the values of <u>x</u> and <u>y</u> are passed to <u>number</u> and <u>numbers</u>. Since <u>y</u> contains the reference value to the array, <u>numbers</u> 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;
}
```

list

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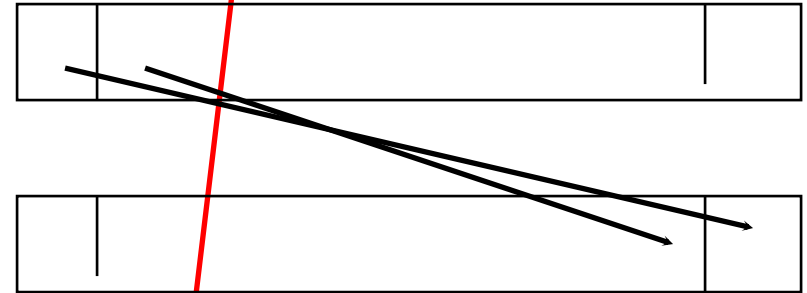
```
int[] list1 = new int[]{1, 2, 3, 4, 5, 6};
int[] list2 = reverse(list1);
```

Trace the reverse Method

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


  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;
  }
```

Declare result and create array

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

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

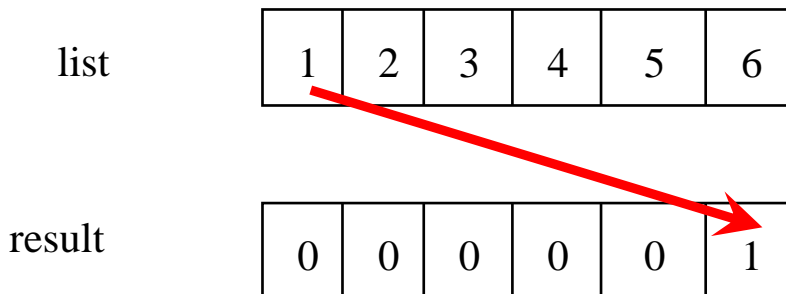| 0	0	0	0	0	1

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.

```java
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

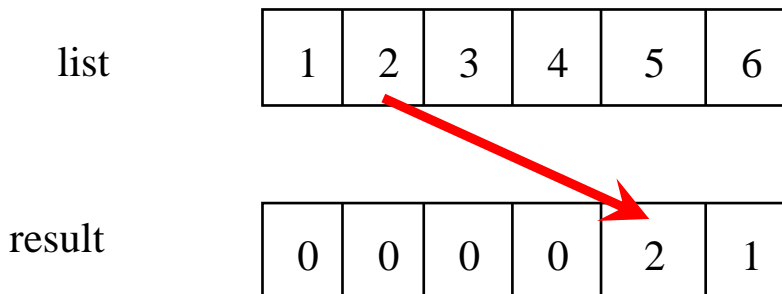| 1	2	3	4	5	6

result

0	0	0	0	0	1

Trace the reverse Method, cont.

```java
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 and j = 4
Assign list[1] to result[4]

list

1	2	3	4	5	6

result

0	0	0	0	2	1

```
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

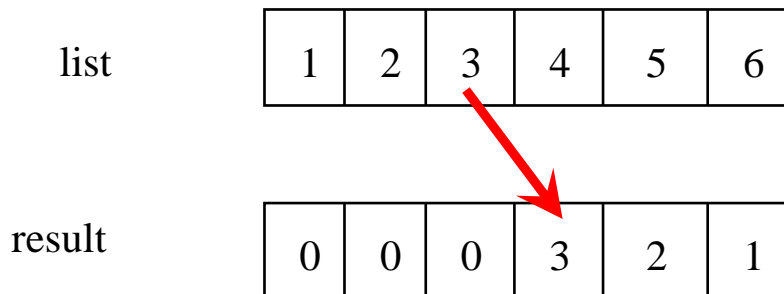| 1	2	3	4	5	6

result

0	0	0	3	2	1

Trace the reverse Method, cont.

```java
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 3 and j becomes 2

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) is still less than 6

list	1	2	3	4	5	6

result	0	0	0	3	2	1

Trace the reverse Method, cont.

```java
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

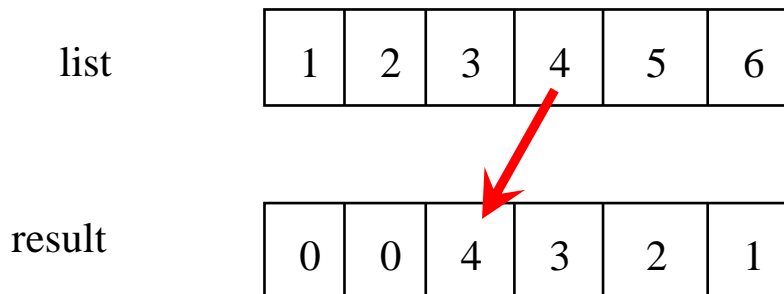| 1	2	3	4	5	6

result

0	0	4	3	2	1

Trace the reverse Method, cont.

```java
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.

```java
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

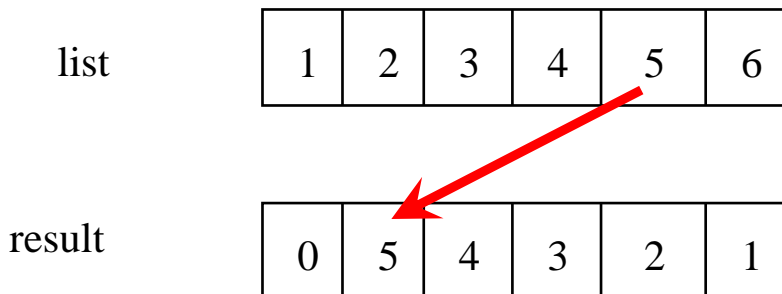| list	1	2	3	4	5	6

result	0	0	4	3	2	1

```java
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.

```java
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 5 and j becomes 0

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.

```java
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

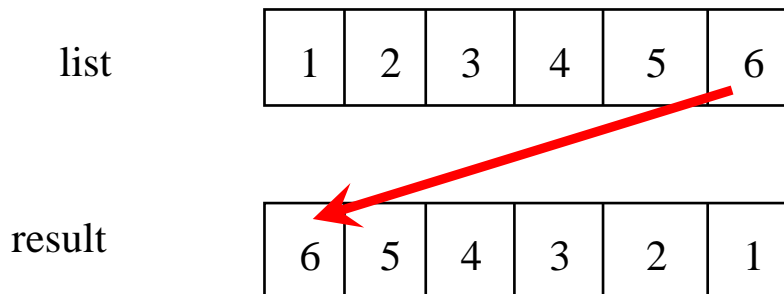| 1	2	3	4	5	6

result

6	5	4	3	2	1

Trace the reverse Method, cont.

```java
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 6 and j becomes -1

list

1	2	3	4	5	6

result

6	5	4	3	2	1

Trace the reverse Method, cont.

```java
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

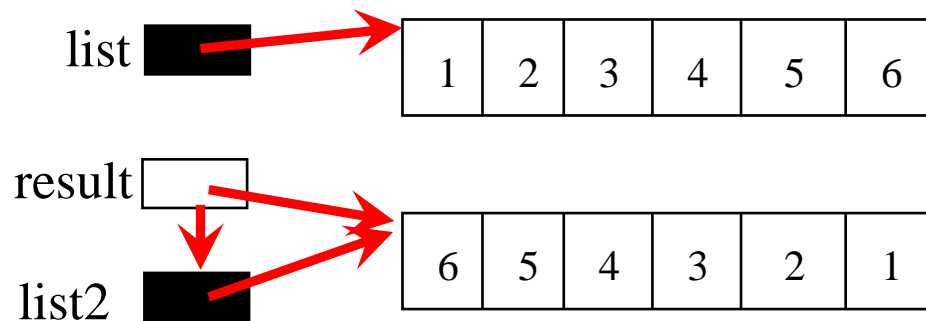| 1	2	3	4	5	6

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);


  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;
  }
```

Return result

| list | | 1 | 2 | 3 | 4 | 5 | 6 |

| result | | | 6 | 5 | 4 | 3 | 2 | 1 |

| list2 | |

# Use the same Array in a method

```java
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)
```

```
        [0] [1] [2] …
list   [  |  |  |        |  |  ]
key    Compare key with list[i] for i = 0, 1, …
```
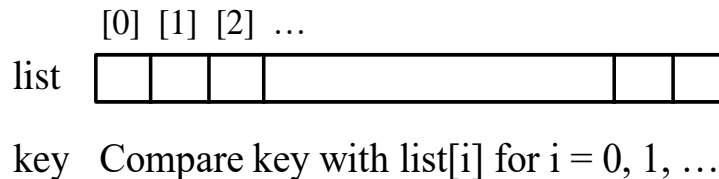
- return the index of the first occurrence of the key in list
- if not found, return -1

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 |

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From Idea to Solution

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

```java
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 <u>middle</u> of the array.

Binary Search

Consider the following three cases:

- If the key is <u>less than the middle element</u>, 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 |

82

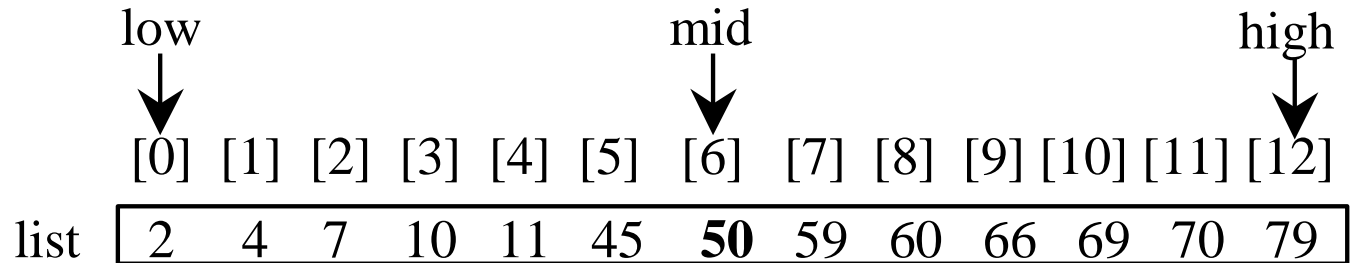# From Idea to Solution

```java
/** 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 (high >= low) {
    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

low   mid   high

key > 50

[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 |

85
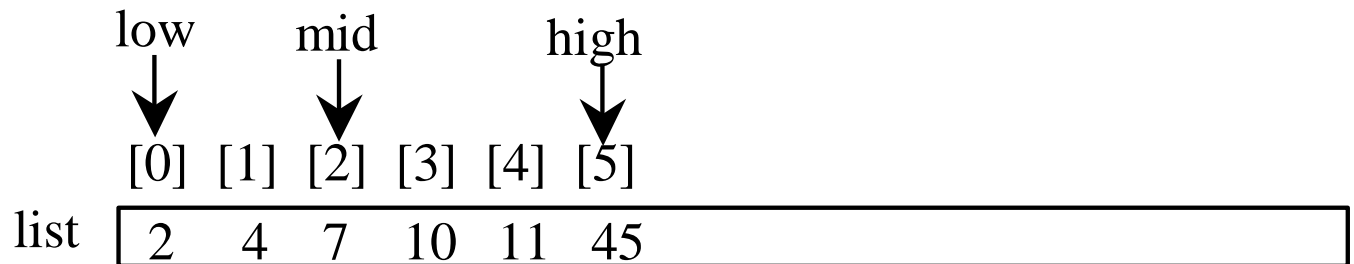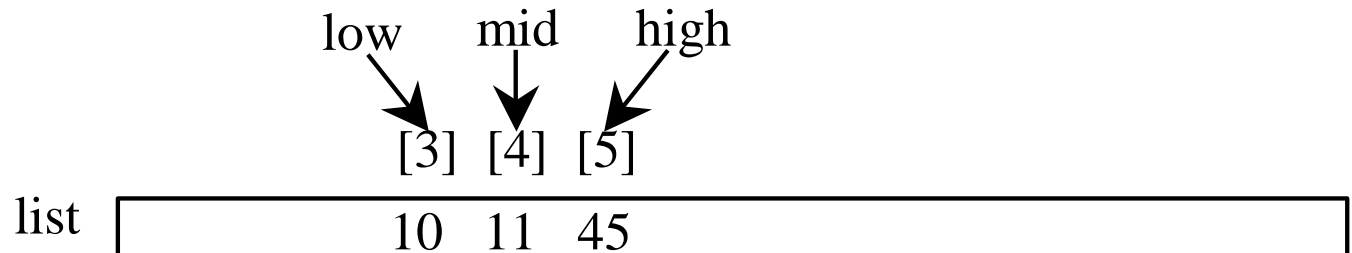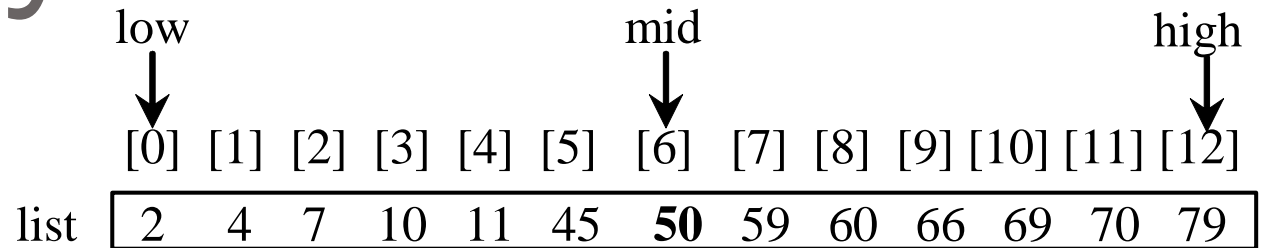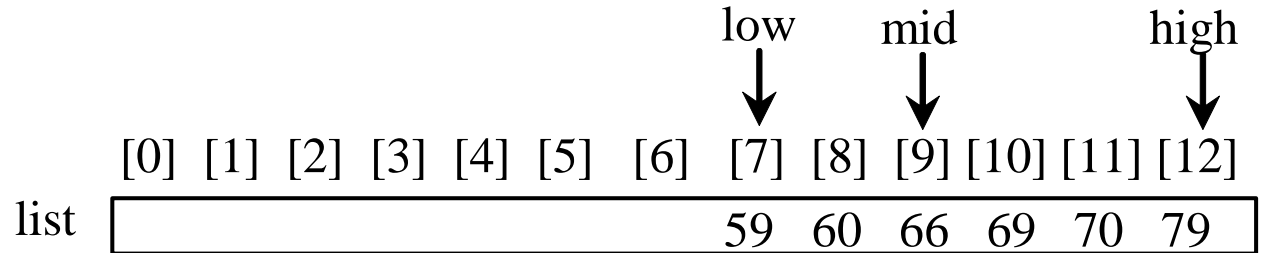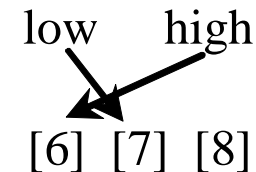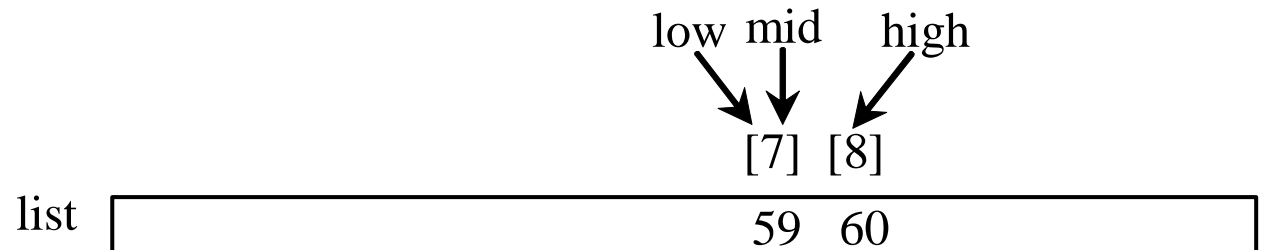
In-Class Quiz 3: Binary Search

- What is the worst-case time complexity of binary search?

    - O(1)

    - O(log n)

    - O(n)

    - O(n log n)

    - O(n^2)

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:
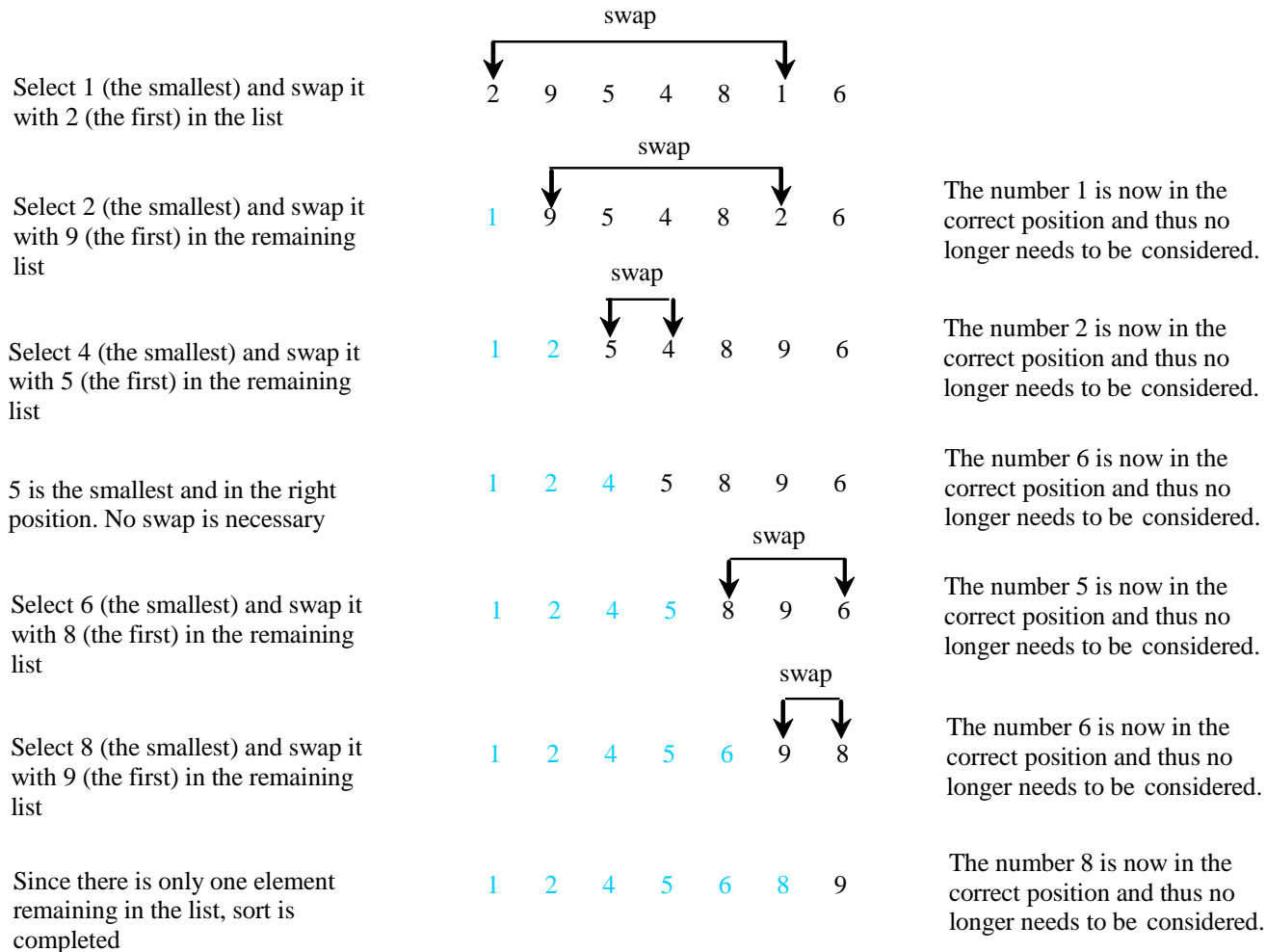
swap

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

2   9   5   4   8   1   6

swap

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.

swap

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.

swap

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.

swap

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.

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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

```java
/** A selectionSort method for sorting numbers */
public static void selectionSort(double[] list) {
    for (int i = 0; i < list.length; 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

The insertion sort algorithm sorts a list of values by repeatedly inserting an unsorted element into a sorted sublist until the whole list is sorted.
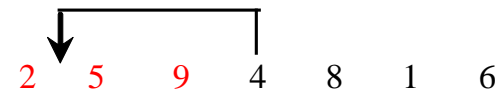
Step 1: Initially, the sorted sublist contains the first element in the list. Insert 9 to the sublist.
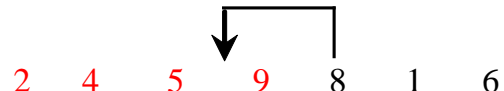
2 9 5 4 8 1 6

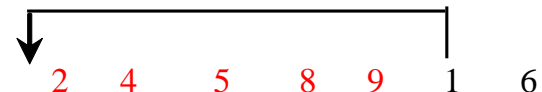Step 2: The sorted sublist is {2, 9}. Insert 5 to the sublist.

2 9 5 4 8 1 6

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

2 5 9 4 8 1 6

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

2 4 5 9 8 1 6

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

2 4 5 8 9 1 6

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

1 2 4 5 8 9 6

Step 7: The entire list is now sorted

1 2 4 5 6 8 9

How to Insert?

The insertion sort algorithm sorts a list of values by repeatedly inserting an unsorted element into a sorted sublist until the whole list is sorted.

```
        [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

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

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);
```