

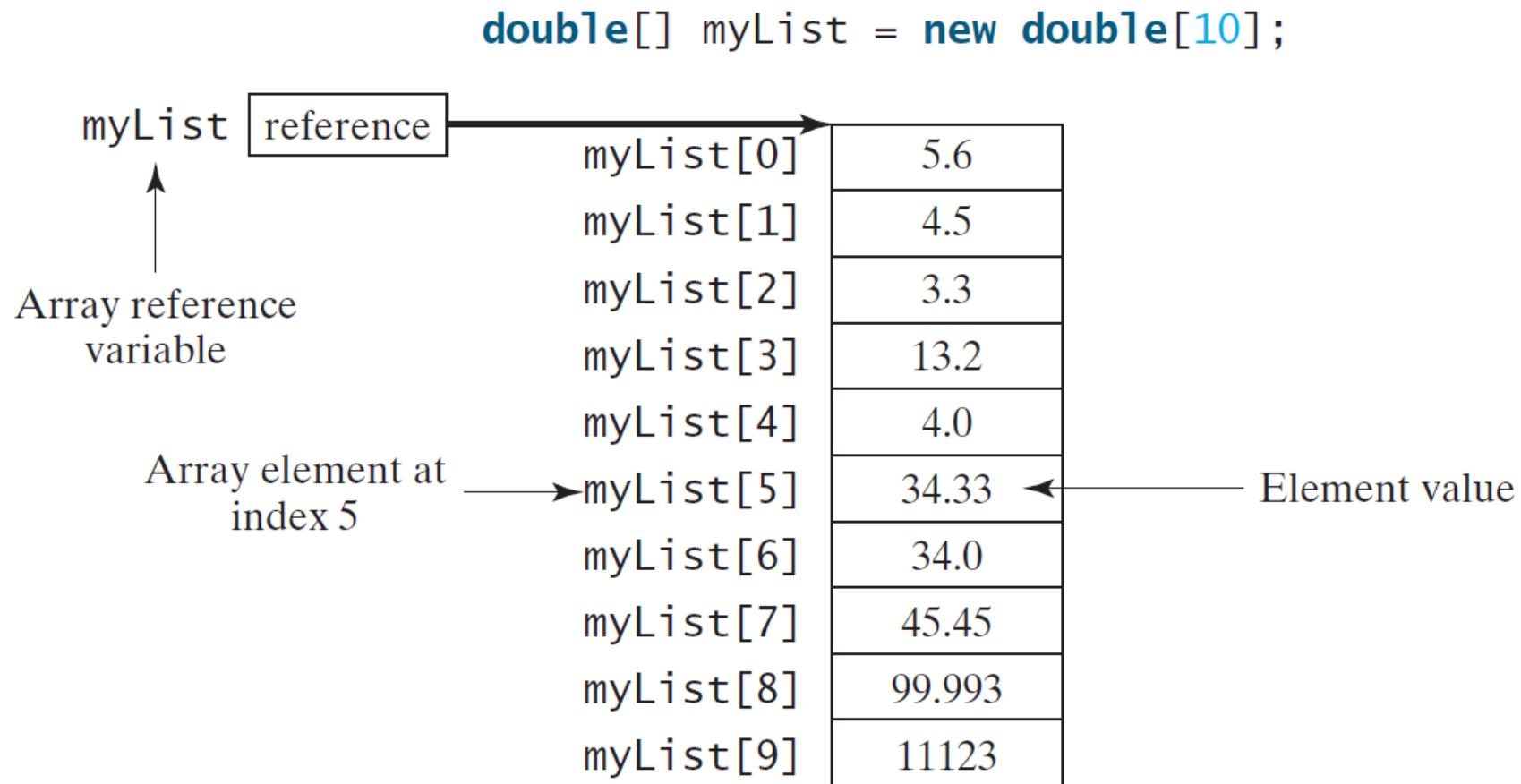


Lecture 5

Arrays



- Array is a data structure that represents a collection of the same types of data.





- `datatype[] arrayRefVar;`
- **Example:**
- `double[] myList;`

- `datatype arrayRefVar[];`
 // This style is allowed, but not preferred
- **Example:**
- `double myList[];`



- `arrayRefVar = new datatype[arraySize];`
- **Example:**
- `myList = new double[10];`
- `myList[0]` references the first element in the array.
- `myList[9]` references the last element in the array.



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

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

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

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



- Once an array is created, its size is fixed.
- It cannot be changed.
- You can find its size using
`arrayRefVar.length`
- For example:
`myList.length` returns 10



- When an array is created, its elements are assigned the default value:
 - 0 for the **numeric primitive data types**,
 - '\u0000' for **char** types, and
 - **false** for **boolean** types.



- The array elements are accessed through the index.
- The array indices are 0-based
 - The index starts from 0 to `arrayRefVar.length-1`.
 - In the example `myList` holds ten double values and the indices are from 0 to 9.
- Each element in the array is represented using the following syntax, known as an indexed variable:
 - `arrayRefVar[index]`;



- After an array is created, an indexed variable can be used in the same way as a regular variable.
- Example: add the value in `myList[0]` and `myList[1]` to `myList[2]`.
 - `myList[2] = myList[0] + myList[1];`



- Declaring, creating, initializing in one step:

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

- This shorthand syntax must be in one statement.



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



- Using the shorthand notation, you have to
 - Declare
 - Create
 - Initialize
- the array all in one statement.
- Splitting it would cause a syntax error.
- Example (wrong):

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



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];  
    }  
}
```

0	0
1	0
2	0
3	0
4	0



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];  
    }  
}
```

0	0
1	0
2	0
3	0
4	0



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];  
    }  
}
```

0	0
1	0
2	0
3	0
4	0



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];  
    }  
}
```

0	0
1	1
2	0
3	0
4	0



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];  
    }  
}
```

0	0
1	1
2	0
3	0
4	0



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];  
    }  
}
```

0	0
1	1
2	0
3	0
4	0



After this line is executed,
value[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];  
    }  
}
```

0	0
1	1
2	3
3	0
4	0



After `i++`, `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];  
    }  
}
```

0	0
1	1
2	3
3	0
4	0



i (=3) 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];  
    }  
}
```

0	0
1	1
2	3
3	0
4	0



After this line is executed,
value[3] is $6 = (3 + 3)$

```
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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	0



After `i++`, `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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	0



i (=4) 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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	0



After this line is executed,
value[4] is $10 = (4 + 6)$

```
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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	10



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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	10



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];  
    }  
}
```

0	0
1	1
2	3
3	6
4	10



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



- Initializing arrays with input values
 - Initializing arrays with random values
-
- Printing arrays
 - Summing all elements
-
- Finding the largest element
 - Finding the smallest index of the largest element
-
- Random shuffling
 - Shifting elements



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



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



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



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

```
...
```

```
double total = 0;
```

```
for (int i = 0; i < myList.length; i++)
```

```
{
```

```
    total += myList[i];
```

```
}
```



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



```
double[] myList = new double[n];  
  
for (int i = 0; i < myList.length - 1; 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;  
}
```



```
double[] myList = new double[n];  
  
//retain the first element  
double temp = myList[0];  
  
//Shift elements left  
for (int i = 1; i < myList.length; i++)  
{  
    myList[i-1] = myList[i];  
}  
myList[myList.length - 1] = temp;
```



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

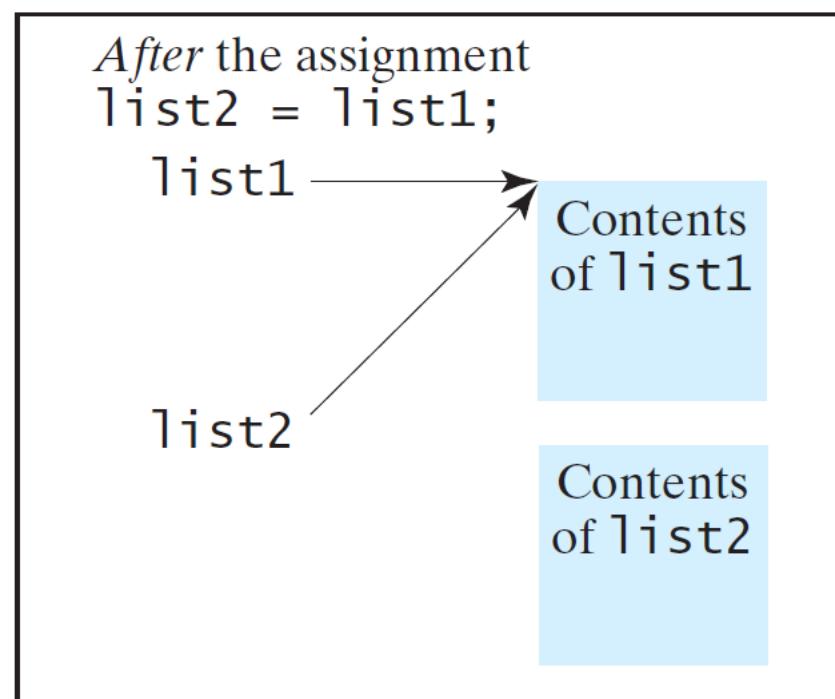
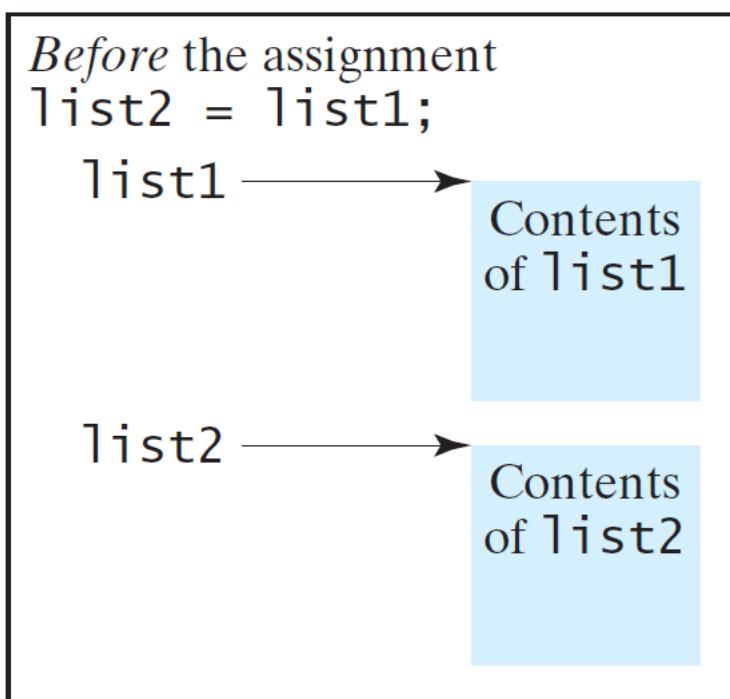
```
for (double value: myList)
    System.out.println(value);
```

- In general, the syntax is
- ```
for (elementType value: arrayRefVar) {
 // Process the value
}
```
- 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.



- Often, in a program, you need to duplicate an array or a part of an array. In such cases you could attempt to use the assignment statement (=)

- `list2 = list1;`





- 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];
```



- `arraycopy(sourceArray, src_pos,  
targetArray, tar_pos, length);`
- Example
  - `System.arraycopy(sourceArray, 0,  
targetArray, 0, sourceArray.length);`



```
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);
```

- Invoke the method

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



- The statement
  - `printArray(new int[] {3, 1, 2, 6, 4, 2});`
- creates an array using the following syntax:
  - `new dataType[] {literal0, literal1, ..., literalk};`
- There is no explicit reference variable for the array.
- Such array is called an anonymous array.



- Java uses pass by value to pass arguments to a method.
- There are important differences between passing a value of variables of **primitive data types** and passing **arrays**.
- For a parameter of a **primitive type value**, 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.
- 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.



```
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

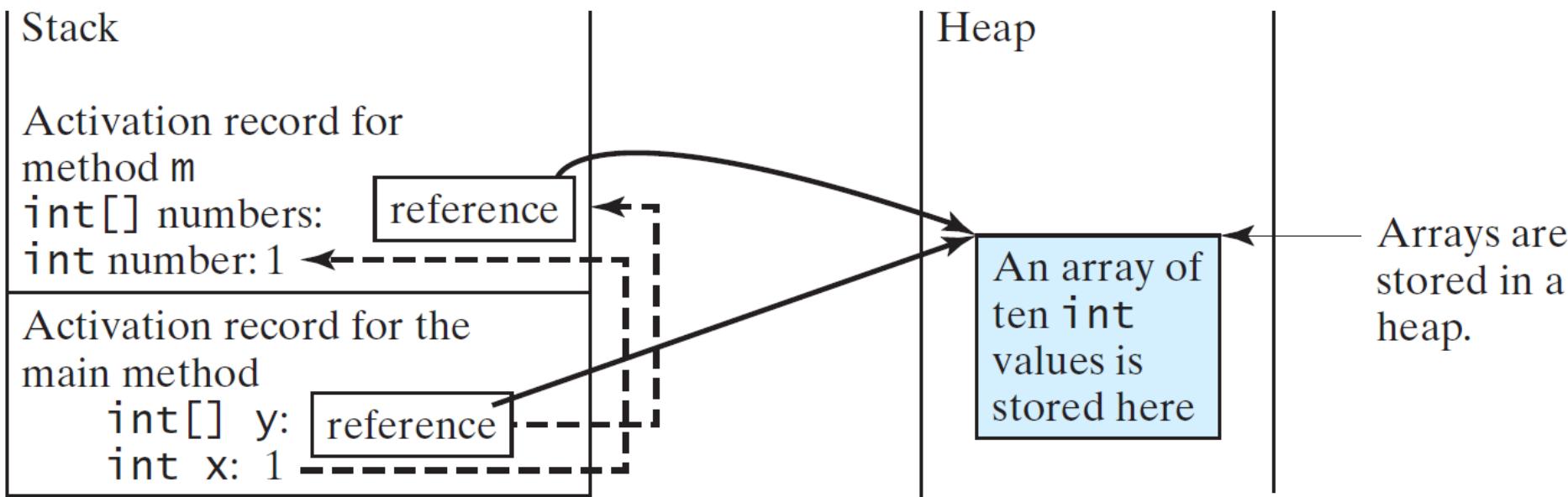
 m(x, y); // Invoke m with arguments x and y

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

 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]
 }
}
```

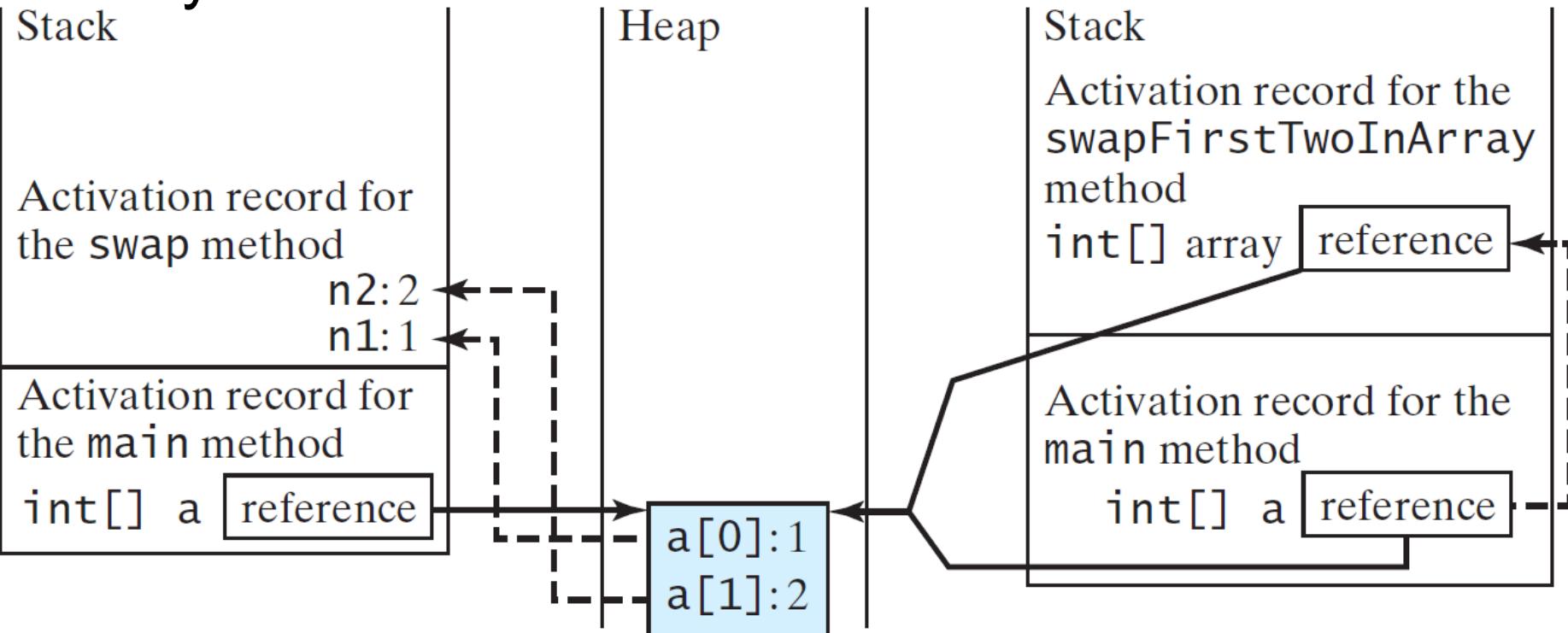


- When invoking `m(x, y)`, the values of `x` and `y` are passed to **number** and **numbers**. Since `y` contains the reference value to the array, `numbers` now contains the same reference value to the same array.



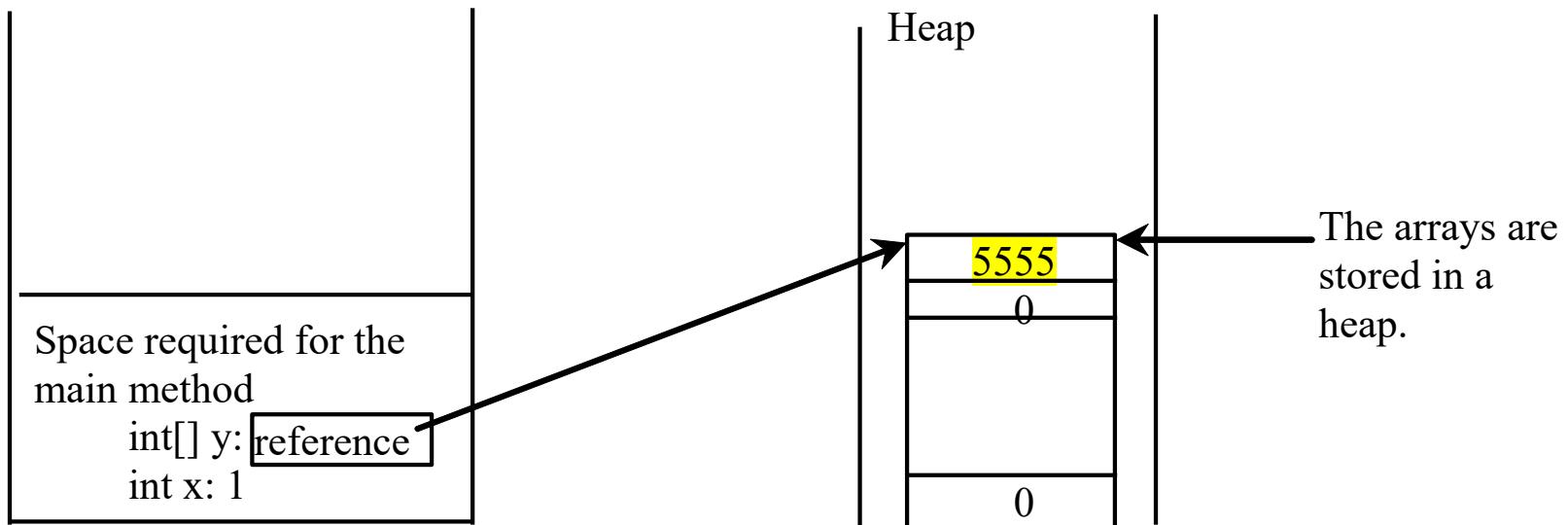


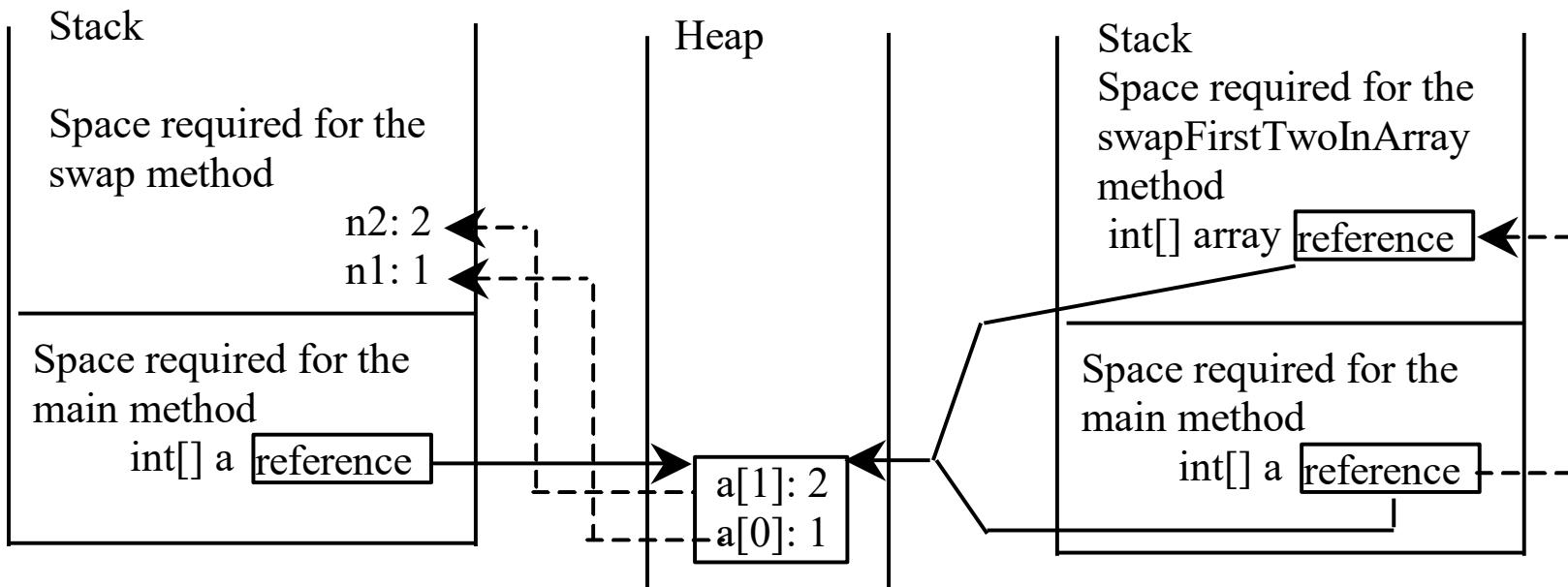
- When invoking `m(x, y)`, the values of `x` and `y` are passed to **number** and **numbers**. Since `y` contains the reference value to the array, `numbers` now contains the same reference value to the same array.





- The JVM stores the array 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.





Invoke `swap(int n1, int n2)`.  
The primitive type values in `a[0]` and `a[1]` are passed to the swap method.

The arrays are stored in a heap.

Invoke `swapFirstTwoInArray(int[] array)`.  
The reference value in `a` is passed to the `swapFirstTwoInArray` method.



- You can pass a variable number of arguments of the same type to a method by using an array.
- Example:

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

 return average / numbers.length;
}
```



```
int[] list1 = {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;
```

```
}
```

```
list1
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

Array is declared and created



```
int[] list1 = {1, 2, 3, 4, 5, 6};
```

```
int[] list2 = reverse(list1);
```

The **reference** of list1 is passed to the method reverse

```
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;
```

```
}
```

list1

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|

Declare result and  
create array



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|

i = 0 and j = 5



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|

i (= 0) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
|---|---|---|---|---|---|

After this, i becomes  
1 and j becomes 4



```
int[] list1 = {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;
```

```
}
```

```
list == list1
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 1 |
|---|---|---|---|---|---|

i (= 1) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 2 | 1 |
|---|---|---|---|---|---|

After this, i becomes  
2 and j becomes 3



```
int[] list1 = {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;
```

```
}
```

```
list == list1
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 2 | 1 |
|---|---|---|---|---|---|

i (= 2) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 3 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 3 | 2 | 1 |
|---|---|---|---|---|---|

After this, i becomes  
3 and j becomes 2



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 3 | 2 | 1 |
|---|---|---|---|---|---|

i (= 3) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

After this, i becomes  
4 and j becomes 1



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 0 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

i (= 4) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

After this, i becomes 5 and j becomes 0



```
int[] list1 = {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;
```

```
}
```

```
list == list1
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 0 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

i (= 5) is less than 6



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

After this, i becomes  
6 and j becomes -1



```
int[] list1 = {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;
```

```
}
```

```
list *= list1"
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

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



```
int[] list1 = {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;
```

```
}
```

```
list == list1
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

```
result
```

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|

Return result



```
int[] list1 = {1, 2, 3, 4, 5, 6};
```

```
int[] list2 = reverse(list1);
```

The reference of  
“result” is copied to  
list2

```
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;
```

```
}
```

list1

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|

list2 = “result”

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|



- Searching is the process of looking for a specific element in an array
- Example:
  - discovering whether a certain score is included in a list of scores.
- Searching is a common task in computer programming.
- There are many algorithms and data structures devoted to searching.



- The linear search approach compares the key element, key, sequentially with each element in the array list.
- The method continues to do so until the key matches an element in the list or the list is exhausted without a match being found.
- If a match is made, the linear search returns the index of the element in the array that matches the key. If no match is found, the search returns -1.



```
public class LinearSearch {
 /** The method for finding
 * a key in the list */
 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 = {1, 4, 4, 2, 5, -3, 6, 2};
 int i = linearSearch(list, 4); // returns 1
 int j = linearSearch(list, -4); // returns -1
 int k = linearSearch(list, -3); // returns 5
```



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 |
|---|---|---|---|---|---|---|---|



```
public class LinearSearch {
 /** The method for finding
 * a key in the list */
 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 = {1, 4, 4, 2, 5, -3, 6, 2};
 int i = linearSearch(list, 4); // returns 1
 int j = linearSearch(list, -4); // returns -1
 int k = linearSearch(list, -3); // returns 5
```



- For binary search to work, the elements in the array must already be ordered.
- Without loss of generality, assume that the array is in ascending order.
  - Example: 2 4 7 10 11 45 50 59 60 66 69 70 79
- The binary search first compares the key with the element in the middle of the array.

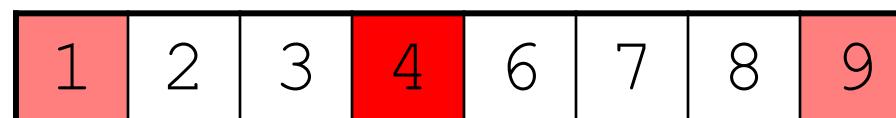
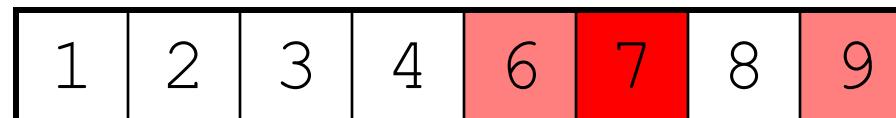


- Consider the following three cases:
  1. If the key is **less than the middle** element, you only need to search the key in the first half of the array.
  2. If the key is **equal to the middle** element, the search ends with a match.
  3. If the key is **greater than the middle element**, you only need to search the key in the second half of the array.



Key

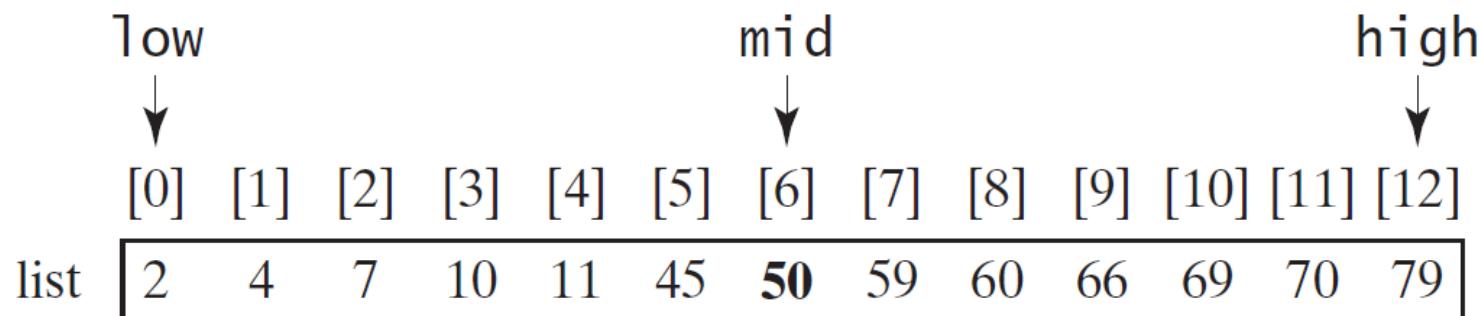
List

**8****8****8**

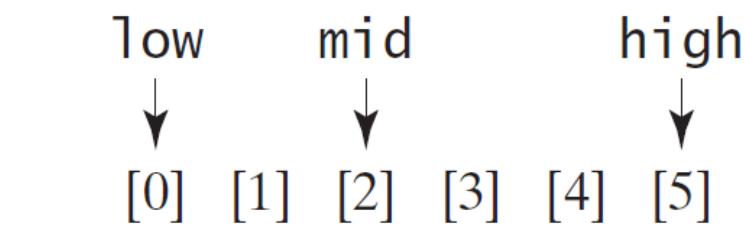


key is 11

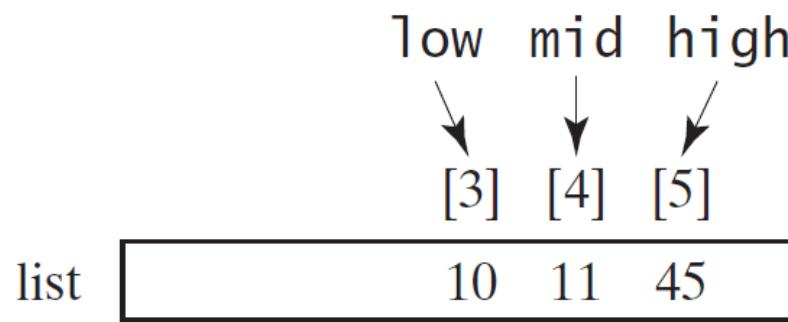
key < 50



key > 7



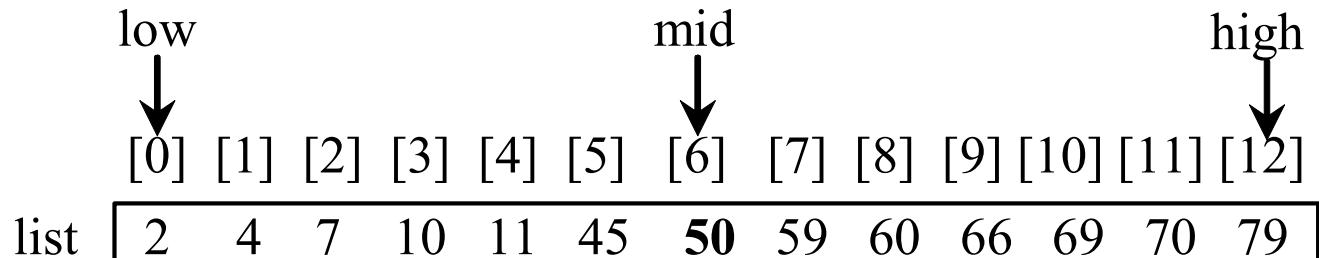
key == 11



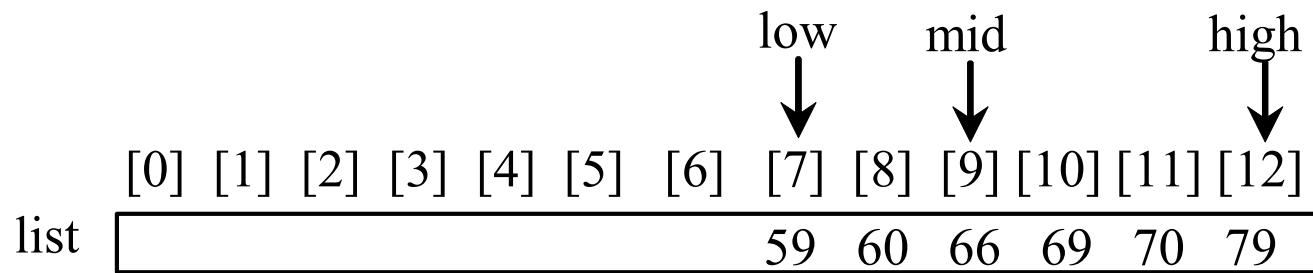


key is 54

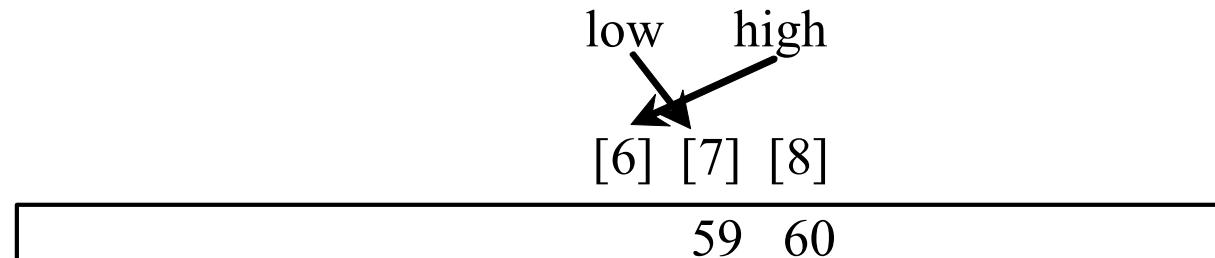
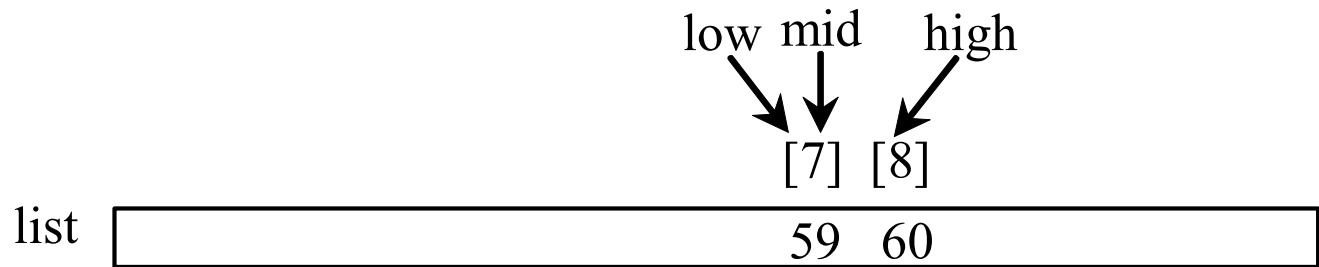
key > 50



key < 66



key < 59





- The `binarySearch` method returns the index of the element in the list that matches the search key if it is contained in the list.
- Otherwise, it returns -**insertion point - 1**.
- The **insertion point** is the point at which the key would be inserted into the list.



```
/** 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;

 while (high >= low) {
 int 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 is frequently used in programming
- Java provides several overloaded `binarySearch` methods for searching a key in an array of `int`, `double`, `char`, `short`, `long`, and `float` in `java.util.Arrays`.
- Example:

```
int[] list = {2, 4, 7, 10, 11, 45, 50, 59, 60, 66, 69, 70, 79};
System.out.println("Index is " +
 java.util.Arrays.binarySearch(list, 11));

char[] chars = {'a', 'c', 'g', 'x', 'y', 'z'};
System.out.println("Index is " +
 java.util.Arrays.binarySearch(chars, 't'));
```

- For the `binarySearch` method to work, the **array must be pre-sorted in increasing order**.



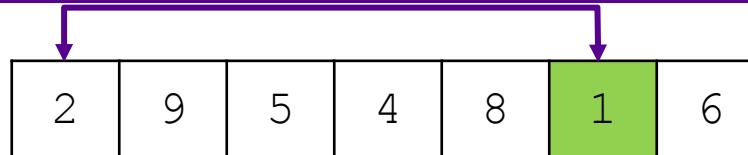
- Sorting, like searching, is also a common task in computer programming.
- Many different algorithms have been developed for sorting.
  - Insertion sort
  - **Selection sort**
  - Merge sort
  - Quicksort
  - Bubble sort
  - Counting sort
  - ...



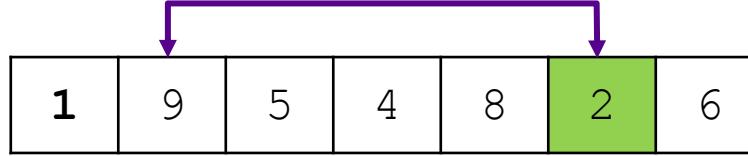
- Selection sort finds the smallest number in the list and places it first.
- It then finds the smallest number remaining and places it second, and so on until the list contains only a single number.



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

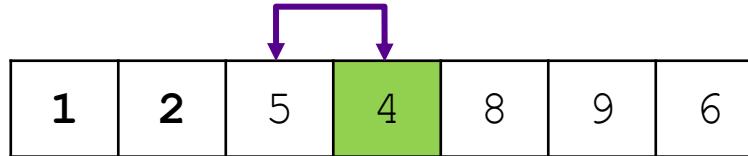


1 is in the correct position, and it is not considered



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

2 is in the correct position, and it is not considered



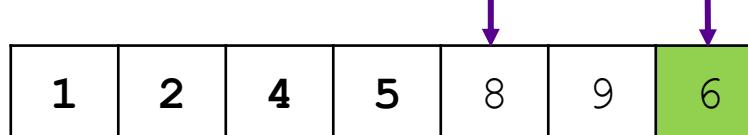
Select 4 (the smallest) and swap it with 5 (the first)

4 is in the correct position, and it is not considered



5 is the smallest and in the correct position. No swap

5 is in the correct position, and it is not considered



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

6 is in the correct position, and it is not considered



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

8 is in the correct position, and it is not considered



Only one element left. The sort is completed



```
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]
}
```

|         |         |         |         |     |          |
|---------|---------|---------|---------|-----|----------|
| list[0] | list[1] | list[2] | list[3] | ... | list[10] |
| list[0] | list[1] | list[2] | list[3] | ... | list[10] |
| list[0] | list[1] | list[2] | list[3] | ... | list[10] |
| list[0] | list[1] | list[2] | list[3] | ... | list[10] |
|         |         |         |         |     | ...      |
| list[0] | list[1] | list[2] | list[3] | ... | list[10] |



```
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]
}
```

```
double currentMin = list[i];

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

 }
}
```



```
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]
}
```

```
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;
 }
}
```



```
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]
}
```

```
if (currentMinIndex != i) {
 list[currentMinIndex] = list[i];
 list[i] = currentMin;
}
```



```
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;
 }
 }
}
```



- 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.
- Example:

```
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);
```

- Java 8 now provides `Arrays.parallelSort(list)` that utilizes the multicore for fast sorting.



- The `Arrays.toString(list)` method can be used to return a string representation for the list.
- Example:

```
double[] numbers = {6.0, 4.4, 1.9, 2.9, 3.4, 3.5};
String s = java.util.Arrays.toString(numbers);
System.out.println(s);
```



- You can call a regular method by passing actual parameters.
  - Can you pass arguments to main?
  - Of course, yes.
- 
- Example:
    - the main method in class B is invoked by a method in A

```
public class A {
 public static void main(String[] args) {
 String[] strings = {"New York",
 "Boston", "Atlanta"};
 B.main(strings);
 }
}
```

```
class B {
 public static void main(String[] args) {
 for (int i = 0; i < args.length; i++)
 System.out.println(args[i]);
 }
}
```



```
class TestMain {
 public static void main(String[] args) {
 ...
 }
}
```

Java TestMain arg0 arg1 arg2 ... argn

- The main method, gets the arguments from args[0], args[1], ..., args[n], which corresponds to arg0, arg1, ..., argn in the command line.