Chapter 3 Javascript Multiple Values: Part 1: Arrays

1 Lesson Objectives

A multiple-value variable is a variable (or the object) that can store more than one value.

This part discusses arrays, a type of multiple-value variable in JavaScript.

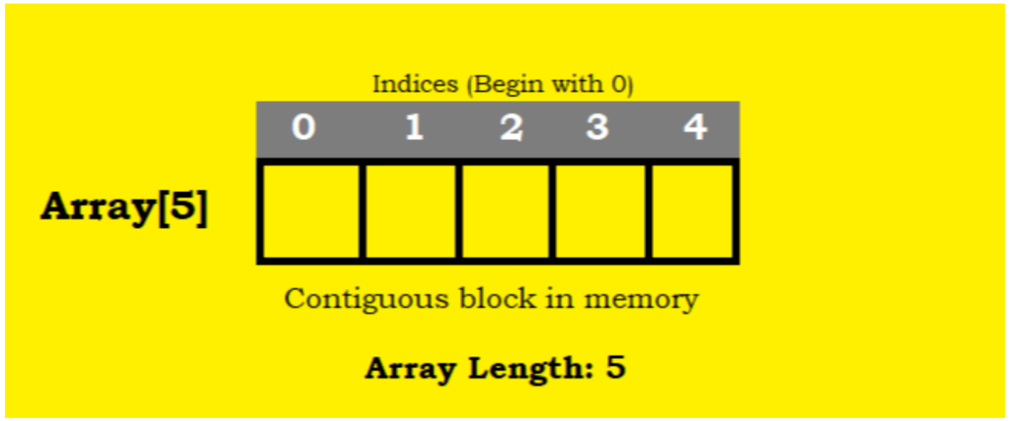
The following topics are covered in this chapter:

- Arrays and their properties
- Basic operations on arrays
  - Creating an array, Accessing array elements, Iterating an array
- Array methods
  - Add and replace elements, Concatenate arrays, Sorting, Find elements

2 Arrays and their properties

An array is an object that saves a list of values in the memory.

- Values are stored in the contiguous memory locations
- The values are indexed; the index starts from 0



Source: JavaScript Arrays: A Beginner's Guide – TecAdmin

3 Basic operations on arrays

Basic operations on arrays include:

- Creating an array
- Accessing array elements
- Modifying array elements (adding, deleting, and updating)
- Get the length of an array
- Iterating through an array

4 Creating an array

Array Literal, Array Constructor, Array.of(), Array.from()

Array Literal

Use the array literal `[]` to create an array.

- Often used when creating an empty array or an array with a list of values known in advance.

```
let colors = [];   // create an empty array
let colors = ['red', 'green', 'blue'];  // create an array with three elements
```

Array constructor

- Limitation of the Array literal
  - Be convenient to create an empty array or an array with a list of values.
- What if we want to create an array dynamically?
  - e.g., create an array of length n with all elements `undefined.`
- Array constructor `Array(n)` is the right choice.

Example: Create an array of length 5 with empty slots.

```
// let emptyArray = Array(5);  // the new keyword is optional
let emptyArray = new Array(5);
console.log(emptyArray);  // [ <5 undefined items> ]
```

Initialize an array with the array constructor

Pass a list of arguments to the array constructor to create an array with the elements.

```
let basicColors = new Array('red', 'green', 'blue');
console.log(basicColors);  // ['red', 'green', 'blue']
```

The trap of the array constructor

However, be careful about the trap of the array constructor:

- Cannot create an array containing a single integer value.
- If only one argument is passed and it is an integer, the array constructor creates an array of length `n` with empty slots.

For example, we want to create the array `[5]` and use the following code:

```javascript
let numbers = new Array(5);  // create an array of length 5
console.log(numbers);  // [ <5 empty items> ]
```

The first statement creates an array of length 5 with empty slots, not `[5]`.

Array.of() method: Create an array from a list of values

If you want to avoid the trap of the array constructor, use the `Array.of()` method when creating an array with a list of values.

- This shows your intent clearly.

```
let numbers = Array.of(5);  // create an array with one element 5
console.log(numbers);  // [5]
let basicColors = Array.of('red', 'green', 'blue');
```

See more about the `Array.of()` method in the MDN web docs: Array.of() - JavaScript | MDN

Array.from() method: Convert an array-like object or an iterable object to an array

This method creates a new array by iterating an **array-like object** or an **iterable object**.

Example 5: Convert an array-like object to an array.

```
let arrayLike = {0: 'red', 1: 'green', 2: 'blue', length: 3};
let colors = Array.from(arrayLike);
console.log(colors);  // ['red', 'green', 'blue']
```

See more about the `Array.from()` method in the MDN web docs: Array.from() - JavaScript | MDN

Concept: Array-like object

An array-like object is an object that has the **length property** and **indexed elements**.

- It behaves like an array but does not have all the array methods.

Example 6: An array-like object `arrayLike` with the `length` property and indexed elements.

```
let arrayLike = {
  0: 'red',
  1: 'green',
  2: 'blue',
  length: 3
};
```

Other examples of the array-like object:

- NodeList and HTMLCollection objects in DOM.
- The `arguments` object in a function.

See more in Array - JavaScript | MDN

Concept: Iterable Object

An iterable object in JavaScript is an object that can be iterated over using a `for...of` loop.

Common Iterable Objects:

- Arrays, Strings, Maps, Sets, NodeLists (from DOM queries)

Example: Iterating over an array using the `for...of` loop.

```
let iterable = "Javascript"

for (let value of iterable) {
  console.log(value);
}
// outputs: J a v a s c r i p t
```

Convert the string to a character array using the `Array.from()` method.

```
let iterable = "Javascript"
let charArray = Array.from(iterable);
console.log(charArray);  // ['J', 'a', 'v', 'a', 's', 'c', 'r', 'i', 'p', 't']
```

Quick Practice

- Create an array of length 100 with all elements are `undefined`.
- Create an array with the elements: `['apple', 'banana', 'orange', 'grape']`

5 Accessing array elements

Access by index: the square brackets `[ ]`

Use the square brackets `[n]` where `n` is the index of the element after the array name to access the elements of an array

- n is an integer starting from 0
- return undefined if the index is out of the range of the array

Example: Accessing the first element of the `basicColors` array.

```
let basicColors = ['red', 'green', 'blue'];
console.log(basicColors[0]);  // red
console.log(basicColors[-1]);  // undefined
console.log(basicColors[4]);  // undefined
```

No out-of-bound error

- When you try to query a nonexistent property of any object, you don’t get an error;
    - you get **undefined**

Indexes other than non-negative integers

- The index of an array must be a non-negative integer.
- The non-negative integer becomes the **property** of the array object.
    - the square brackets `[property_name]` is used to access the property of an object, the same case as assessing an array element.

Example: Accessing the property of an array object.

```
let basicColors = ['red', 'green', 'blue'];
basicColor[-1] = 'Negative Value';
console.log(basicColors[-1]);  // Negative Value
```

Quick summary for using the square brackets `[ ]`

- array[n]: access the n-th element of the array when n is a non-negative integer.
- array[property_name]: access the property of the array object when the property name is not a non-negative integer.
  - the non-negative integer will be converted to a number string.
  - It is equivalent to `array.property_name` when the property name is a valid identifier.

```
let basicColors = ['red', 'green', 'blue'];
basicColors[-1] = 'yellow';  // add the property "-1" to the basicColors array
console.log(basicColors[-1]);  // yellow
console.log(basicColors['-1']);  // the same as basicColors[-1]
```

6 Add, delete, and update array elements

Add elements

- Use the assignment operator `=` to add elements to an array with an index that is out of the range of the array.
- Javascript will automatically expand the array to accommodate the new element.
- Empty slots are created between the last element and the new element.

Example: Add an element

```
let basicColors = ['red', 'green', 'blue'];
basicColors[5] = 'yellow';   // auto expand the array to accommodate the new element
console.log(basicColors);  // ['red', 'green', 'blue', <2 empty items>, 'yellow']
```

Note: there are two empty slots between the last element, `green`, and the new element, `yellow.`

Non-negative integer index becomes a property

Recall that using values other than non-negative integers as the index will add the property, not the element, to the array object.

Example: use index values other than non-negative integers.

```
let basicColors = ['red', 'green', 'blue'];
basicColors[-1] = 'yellow';
console.log(basicColors);  // ['red', 'green', 'blue', '-1': 'yellow']
```

Append elements to the end of the array

Example: Add an element to the end of the array

To append an element to the end of the array, we:

- first, get the length of the array, and
- then use the length value as the index to add the element.

```
let basicColors = ['red', 'green', 'blue'];
basicColors[basicColors.length] = 'yellow';  // append 'yellow' to the end of the array
console.log(basicColors);  // ['red', 'green', 'blue', 'yellow']
```

Use the `push()` method to append elements

A more concise way to do this is to use the `push()` method.

- don't need to know the length of the array.

The above code can be rewritten as follows:

```
let basicColors = ['red', 'green', 'blue'];
basicColors.push('yellow');  // append 'yellow' to the end of the array
console.log(basicColors);  // ['red', 'green', 'blue', 'yellow']
```

Syntax of push()

```
push()
push(element1)
push(element1, element2)
push(element1, element2, /* …, */ elementN)
```

Delete elements

- Use the `delete` operator to delete an element from an array.
- The `delete` operator sets the element's value to `undefined`
  - does not change the length of the array.

Example: Delete the second element from the `basicColors` array.

```
let basicColors = ['red', 'green', 'blue'];
delete basicColors[1];  // delete the second element
console.log(basicColors);  // ['red', <1 empty item>, 'blue']
```

The side effect of the `delete` operator

The `delete` operator will make the array sparse because it does not alter its length.

If you want to remove an element and its memory space, use the `splice()` method.

- avoiding the array becoming sparse.

The `splice()` method is a general method for inserting, updating, and deleting elements in an array.

- `splice` means joining or connecting.

See MDN web docs: Array.prototype.splice() - JavaScript | MDN

Update elements

Assign a new value to an existing element to update it.

Example: Update the second element of the `basicColors` array.

```
let basicColors = ['red', 'green', 'blue'];
basicColors[1] = 'yellow';  // update the second element
console.log(basicColors);  // ['red', 'yellow', 'blue']
```

Quick Practice

- Create an empty array of `dc_heroes`.
- Add the following heroes to the array: superman, batman, wonderwoman, aquaman, the flash, king shark
- delete the last two heroes from the array.
- Update the second hero to be `green lantern`.
- Print the array.

▶ Referenced Answer

7 Iterating array

Ways to iterate an array

Ways to visit each element of an array:

- `for` loop: the old way to iterate an array.
- `for/of` loop: a more concise way to iterate an array.
- `forEach()` method: a functional way to iterate an array.

for loop

Iterating an array means visiting each element of the array one by one.

- A common operation on an array.

The old way to iterate an array is to use the `for` loop with the index.

- Programmers are responsible for managing the index.
- The `for` loop is verbose and error-prone.

```
let colors = ['red', 'green', 'blue'];
for (let i = 0; i < colors.length; i++) {
    console.log(colors[i]);
}
```

for/of loop

The `for/of` loop (ES6) is a more concise way to iterate an array.

- JavaScript engine manages the iteration.
- The index is hidden and managed by the JavaScript engine.

Rewrite the above code using the `for/of` loop.

```
let colors = ['red', 'green', 'blue'];
for (let color of colors) {
    // Task to do with each element
    console.log(color);
}
```

the current index and value while iterating an array using the `for/of` loop

The variable before the `of` keyword is the returned value of each visit.

What if you want to use the index in the `for/of` loop?

- use the `entries()` method of the array object to return each element's index and value in an array.

```
let colors = ['red', 'green', 'blue'];
for( let [idx, color] of colors.entires()) {
    console.log(`${idx}: ${color}`);
}
```

Sample outputs:

```
0: red
1: green
2: blue
```

Quick Practice

Given the following array, log the index and value of each element in the array.

```
let revengers = ['ironman', 'thor', 'hulk', 'black widow', 'hawk eye'];
```

You must use the `for/of` loop to iterate the array.

forEach() method of the array object

Using the view of functional programming can lead to a more concise way to iterate an array.

Think of the `for/of` loop body block as a function that processes each array element.

So, instead of the body block, we can pass a function applied to each visited element in the array.

```
let colors = ['red', 'green', 'blue'];

for( let [idx, color] of colors.entires())
{   // body block
    console.log(`${idx}: ${color}`);
}
```

```
let colors = ['red', 'green', 'blue'];

colors.forEach(
// Replace the for/of body block with a function:
(color, idx) => {
    console.log(`${idx}: ${color}`);
});
```

The `forEach()` method of an array object is a method that applies a function to each element of the array.

- It takes a function as an argument.
- The passed function can take three arguments: 1)the current element, 2)the index, and 3)the array itself.
- In most cases, we only need the current element

Example: Rewrite the above code using the `forEach()` method.

```
let colors = ['red', 'green', 'blue'];
colors.forEach((color, idx) => {
    console.log(`${idx}: ${color}`);
});
```

Quick Practice

Given the following arrays, print their elements in uppercase:

```
let colors = ['red', 'green', 'blue'];
let fruits = ['apple', 'banana', 'orange'];
```

Use the `forEach()` method to complete the task.

Hints:

- First, define a function that takes an element as an argument and prints the element in uppercase.
    - Use the `String` object's `toUpperCase()` method to convert the element to uppercase.
- Then, use the `forEach()` method to apply the function to each element of the arrays.

▶ Referenced Answer

Review questions for the array iteration

1. When iterating an array, which way may require you to know the array's length?
2. If you already have a function and want to apply it to each array element, which way should you use it?

8 Array methods

Some common methods for operating on arrays include:

- Add and replacing elements: `push()`, `unshift()`, `splice()`
- Remove elements: `pop()`, `shift()`, `splice()`
- Concatenate arrays: `concat()`
- Find elements: `indexOf()`, `find()`
- Reverse order: `reverse()`
- Sorting: `sort()`

`push()` and `pop()` methods

Scenario: Insert and remove elements from the end of the array.

- `push(val1,...valN)` : append one or more elements to the end of the array
  - return the new length of the array.
  - the array is modified.
- `pop()` : remove and return the last element from the array
  - return the removed element.

```
[1,2,3,4,5].push(6);  // [1,2,3,4,5,6]
let val = [1,2,3,4,5].pop();  // [1,2,3,4]
console.log(val);  // 5
```

`shift()` and `unshift()` methods

Scenario: Insert and remove elements from the beginning of the array.

- `shift()` : remove the first element from the array (shift all elements to the left).
  - return the removed element.
- `unshift(val)` : insert an element to the beginning of the array (shift all elements to the right and put the new element at the beginning).
  - return the new length of the array.

```
[1,2,3,4,5].unshift(0);  // [0,1,2,3,4,5]
const val = [1,2,3,4,5].shift();  // [2,3,4,5]
console.log(val);  // 1
```

Quick Practice

1. There are three people, Jack, Tom, and Mary, standing in line to buy tickets. Describe this using an array.
2. Jack has finished buying his ticket. Remove him from the queue and print his name. Update the order of the queue.
3. Emily arrives. Add her to the end of the queue.
4. Sophia arrives and is a VIP. Add her to the front of the queue.
5. Print the order of the queue.

`splice()` method

A general array method to add, remove, and replace elements in an array from an arbitrary position.

What the `splice()` method does on the array:

1. Remove `deleteCount` elements starting from the `start` index when `deleteCount` > 0.
2. Insert the `item1, item2, ...` elements at the `start` index
    - Original elements after the `start` index are shifted to the right.
3. Update the element at the `start` index with `deleteCount` = 1 (delete the element and insert a new element).

The `splice()` method modifies the original array and returns the removed elements as a new array.

Function signature for the `splice()` method

Function signature: `arrayObject.splice(start, deleteCount, item1, item2, ...)`

- `start`: the index to start changing the array (inclusive).
- `deleteCount`: the number of elements to remove from the array from the `start` index (inclusive).
    - Set it to 0 if you want to insert elements.
- `item1, item2, ...`: the elements to add to the array.

Effect:

- Modify the original array.

Return:

- An array containing the deleted elements.

Insert elements

Scenario: Insert multiple elements at the `start` index.

```
// Insert Feb after Jan => Insert an element at index 1
let months = ['Jan', 'March', 'April', 'June'];
months.splice(1,0,'Feb');
console.log(months); // ['Jan', 'Feb', 'March', 'April', 'June']
```

Update elements

- No direct update.
- Delete then insert.

Scenario: Update two elements from the `start` index.

Ex. Update the `Feb` and `Mar` to `February` and `March`.

```
let months = ['Jan', 'Feb', 'Mar', 'Apr'];
let delElements = months.splice(1, 2, 'February', 'March');
console.log(months); // ['Jan', 'February', 'March', 'Apr']
console.log(delElements); // ['Feb', 'Mar']
```

Delete elements

Delete multiple elements:

Scenario: Delete two elements from the `start` index.

```
let months = ['Jan', 'Feb', 'Mar', 'Apr', 'Jun'];
// Delete the first two months
delElements = months.splice(0, 2);
console.log(months); // ['Mar', 'Apr', 'Jun']
console.log(delElements); // ['Jan', 'Feb']
```

See the full code in the ex_03_splice.js file.

Quick Practice

Given the following array: ['A', 'B', 'C'], insert values '1', '2' to the array so that you get ['A', '1', '2', 'B', 'C'].

▶ Referenced Answer

Concatenate arrays: `concat()` method

Concatenate two or more arrays and return a new array.

```
const array1 = [1,2,3].concat([4,5,6]);
console.log(array1);  // [1,2,3,4,5,6]
array1.concat([7,8,9]);
```

Concatenate arrays: the spread operator `...` (ES6)

Use the spread operator `...` to add elements from another array in the array literal.

The spread operator `...` can spread the array of elements into a list of elements.

- Convert the array into a list of elements.

Use the spread operator in:

- the array literal to create a new array.
- the function call to pass the array elements as arguments.

Scenario: Use the spread operator in the array literal

- You have an array and want to extend it with other elements from another array.

Example: Extend the `moreColors` array with the `basicColors` array.

```
let basicColors = ['red', 'green', 'blue'];

// Equivalent to let moreColors = ['yellow', 'purple', 'red', 'green', 'blue'];
let moreColors = ['yellow', 'purple', ...basicColors];

// ['yellow', 'purple', 'red', 'green', 'blue']
console.log(moreColors);
```

The Array's `concat()` method can also achieve the same result.

Scenario: Use the spread operator in the function call

- You have an array and want to insert it with other elements from another array into it.

Example: Insert the `basicColors` array into the `moreColors` array at index 1.

Use the splice():

```
let basicColors = ['red', 'green', 'blue'];
let moreColors = ['yellow', 'purple'];
moreColors.splice(1, 0, ...basicColors);
console.log(moreColors);  // ['yellow', 'red', 'green', 'blue', 'purple']
```

`

Characteristics of the spread operator `...`

- Copy: A Copy of the elements of the original array when spreading.
- Shallow copy: Only copy scalar or reference values of the array elements.
  - That means the nested objects are shared between the original and the new array.

Example 2: Shallow copy of the `basicColors` array.

```
let basicColors = ['red', 'green', 'blue'];

// ...basicCopy shallowly copy of the basicColors array
let moreColors = ['yellow', 'purple', ...basicColors];

// Modify the original array
basicColors[0] = 'black';
console.log(basicColors);  // ['black', 'green', 'blue']
// The new array is not affected
console.log(moreColors);  // ['yellow', 'purple', 'red', 'green', 'blue']
```

Quick Practice

Given the following arrays, use three different ways to concatenate them into a new array:

```
let fruits = ['apple', 'banana'];
let vegetables = ['carrot', 'potato'];
```

The new array `food` should be: `['apple', 'banana', 'carrot', 'potato']`, an **independent** copy of the two arrays.

▶ Referenced Answer

Find elements: `find()` method

The `find()` method returns **the first element** in the provided array that satisfies the provided testing function.

- Pass a function returning a boolean value to the `find()` method.

Example: Find the values greater than 5 in the array.

```
const array1 = [5, 12, 8, 130, 44];
const firstFound = array1.find(element => element > 5);
console.log(found);  // 12
```

See more about the `find()` method in the MDN web docs: Array.prototype.find() - JavaScript | MDN

Note to the expression: `element => element > 5`

- It is a lambda function that returns a boolean value.
- A lambda function (anonymous function) is a function without a name.
- The syntax of a lambda function
    - Single parameter with one expression: `parameter => expression`
        - the function returns the value of the expression.
    - Multiple parameters with multiple statements: `(parameter1, parameter2, ...) => { statements; return expression; }`
        - The return statement is mandatory when using multiple statements.

See more about the lambda function in the MDN web docs: Arrow function expressions - JavaScript | MDN

Sorting: `sort()`

The `sort()` method sorts the elements of an array in place and returns the sorted array.

- elements are converted to strings and compared in UTF-16 code unit order.
- the default sort order is ascending.

Ex. Sorting an array of numbers.

what is the result?

```
let numbers = [4, 41, 2, 21, 10];
numbers.sort();
console.log(numbers);
```

The result is: `[10, 2, 21, 4, 41]`

Control the sort order: define a compare function

- To control the sort order, you can pass a compare function to the `sort()` method.
- The compare function takes two arguments (`a` and `b`)
    - `a` is the first and `b` is the second parameter.
    - Sort `a` after `b` if the function returns a positive value.
    - Sort `a` before `b` if the function returns a negative value.
    - Keep the original order if the function returns 0.

Order control and test expressions:

- a, b, c in ascending order: a < b < c
  - first is less than or equal to second -> `return a - b`
- a, b, c in descending order: a > b > c
  - second is less than or equal first -> `return -(a - b)`
  - a - b > 0 ==> Sort `a` after `b`. Add a negative sign to alter the order.

See more about the `sort()` method in the MDN web docs: Array.prototype.sort() - JavaScript | MDN and the `reverse()` method in the MDN web docs: Array.prototype.reverse() - JavaScript | MDN

Ex. Sorting an array of numbers in ascending order.

Ascending order: a < b < c

- return a - b

```
let numbers = [4, 41, 2, 21, 10];
numbers.sort((a, b) => a - b);
console.log(numbers);  // [2, 4, 10, 21, 41]
```

Ex. Sorting an array of numbers in descending order.

Descending order: a > b > c

- return -(a - b) or b - a

```
let numbers = [4, 41, 2, 21, 10];
numbers.sort((a, b) => b - a);
console.log(numbers);  // [41, 21, 10, 4, 2]
```

Quick Practice

Given the following array, sort it in descending order:

```
let numbers = [67, 87, 123, 32, 55]
```

▶ Referenced Answer

Reverse order `reverse()`

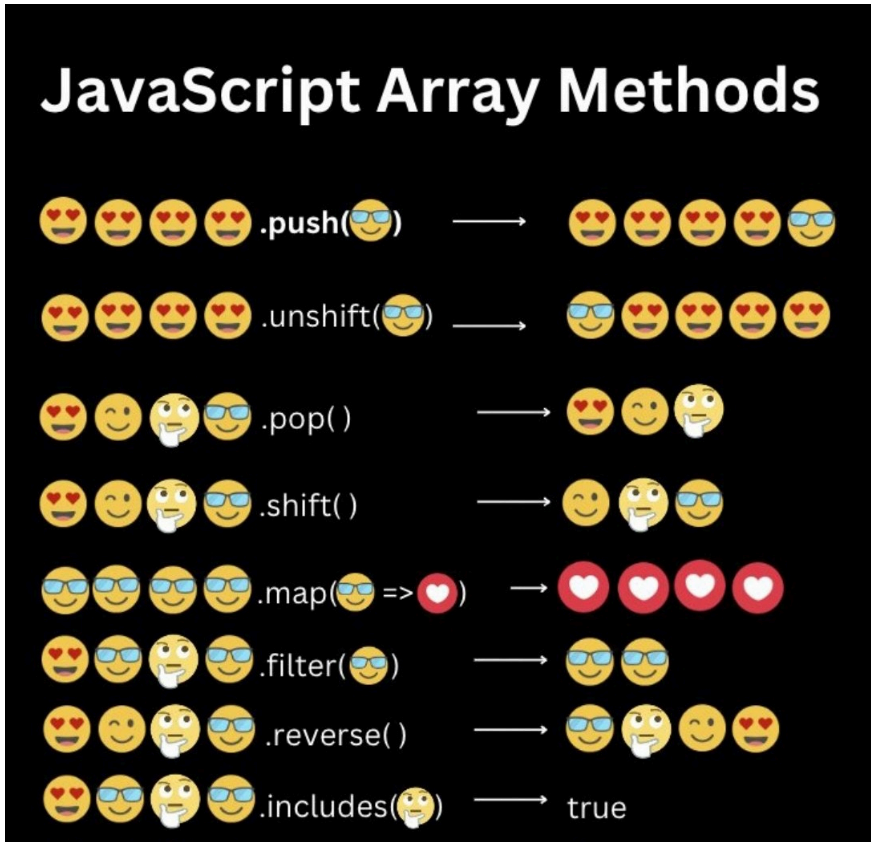
The `reverse()` method reverses the elements of an array in place and returns a reference to the reversed array.

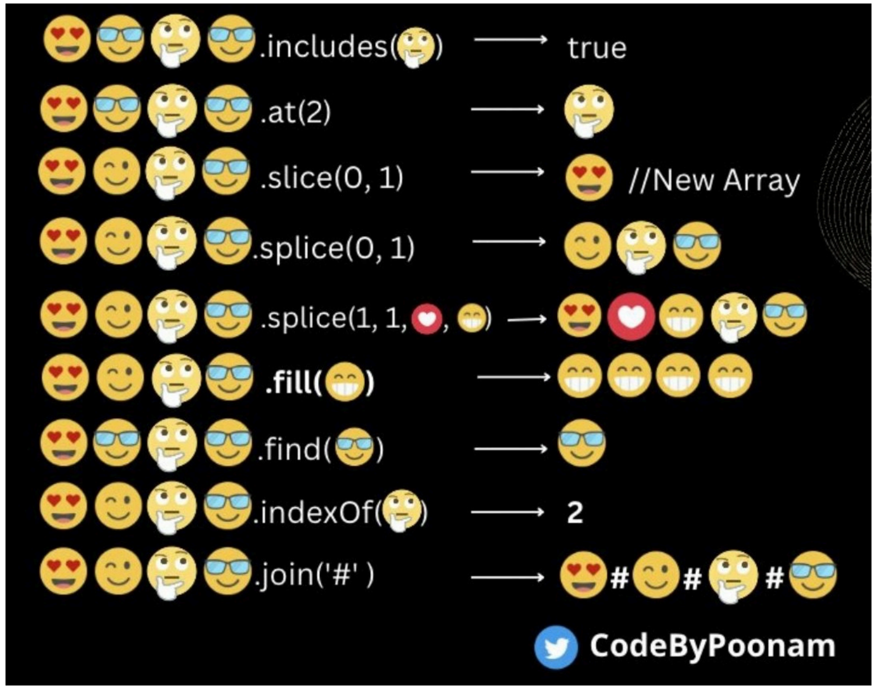
- Note: it modifies the original array.

Leave it as the reading assignment.

Cheat Sheet

Use the following cheat sheet to remember the usage of the array methods.





Source: Poonam Soni@CodeByPoonam

Summary of the array methods

Add and replace elements:

- `push()` : append an element to the end of the array.
- `unshift()` : insert an element to the beginning of the array.
- `splice()` : add, remove, and replace elements in an array.

Remove elements:

- `pop()` : remove and return the last element from the array.
- `shift()` : remove and return the first element from the array.
- `splice()` : add, remove, and replace elements in an array.

Concatenate arrays:

- `concat()` : concatenate two or more arrays and return a new array.

Find elements:

- Find with the test function:
    - `find()`: find the first element in the array that satisfies the provided testing function.
    - `findIndex()`: find the index of the first element in the array that satisfies the provided testing function.
- Find the index:
    - `indexOf()`: find the index of the first occurrence of the element in the array.
    - `lastIndexOf()`: find the index of the last occurrence of the element in the array.
    - `findIndex()`
- Membership test:
    - `includes()`: check if the array contains the element.

Sorting:

- `sort()`: sort the elements of the array.

Change the order:

- `reverse()`: reverse the order of the elements in the array.

9 Summary

We have learned:

- Data types that can store multiple values: Arrays and Objects.
- Ways to create an array: array literal, array constructor, `Array.of()` method, and `Array.from()` method.
- Methods to operate on arrays: `push()`, `pop()`, `shift()`, `unshift()`, `splice()`, `concat()`, `find()`, `sort()`, and `reverse()`.
- Ways to iterate an array: `for/of` loop, `forEach()` method, and `entries()` method.

10 References

[1] Eric T. Freeman and Elisabeth Robson, 2014. Head First JavaScript Programming: A Brain-Friendly Guide, O'Reilly Media