As we've seen, an array type is written as the element type followed by a pair of square brackets. An array of `char` is `char[]`, and an array of arrays of `char` is `char[][]`. When the elements of an array are themselves arrays, we say that the array is *multidimensional*. In order to work with multidimensional arrays, you need to understand a few additional details.

Imagine that you want to use a multidimensional array to represent a multiplication table:

```
int[][] products;      // A multiplication table
```

Each of the pairs of square brackets represents one dimension, so this is a two-dimensional array. To access a single `int` element of this two-dimensional array, you must specify two index values, one for each dimension. Assuming that this array was actually initialized as a multiplication table, the `int` value stored at any given element would be the product of the two indexes. That is, `products[2][4]` would be 8, and `products[3][7]` would be 21.

To create a new multidimensional array, use the `new` keyword and specify the size of both dimensions of the array. For example:

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

In some languages, an array like this would be created as a single block of 100 `int` values. Java does not work this way. This line of code does three things:

- Declares a variable named `products` to hold an array of arrays of `int`.
- Creates a 10-element array to hold 10 arrays of `int`.
- Creates 10 more arrays, each of which is a 10-element array of `int`. It assigns each of these 10 new arrays to the elements of the initial array. The default value of every `int` element of each of these 10 new arrays is 0.

To put this another way, the previous single line of code is equivalent to the following code:

```
int[][] products = new int[10][]; // An array to hold 10 int[] values
for(int i = 0; i < 10; i++)       // Loop 10 times...
    products[i] = new int[10];    // ...and create 10 arrays
```

The `new` keyword performs this additional initialization automatically for you. It works with arrays with more than two dimensions as well:

```
float[][][] globalTemperatureData = new float[360][180][100];
```



When using `new` with multidimensional arrays, you do not have to specify a size for all dimensions of the array, only the leftmost dimension or dimensions. For example, the following two lines are legal:

```
float[][][] globalTemperatureData = new float[360][][];
float[][][] globalTemperatureData = new float[360][180][];
```

The first line creates a single-dimensional array, where each element of the array can hold a `float[][]`. The second line creates a two-dimensional array, where each element of the array is a `float[]`. If you specify a size for only some of the dimensions of an array, however, those dimensions must be the leftmost ones. The following lines are not legal:

```
float[][][] globalTemperatureData = new float[360][][100];  // Error!
float[][][] globalTemperatureData = new float[][180][100];  // Error!
```

Like a one-dimensional array, a multidimensional array can be initialized using an array initializer. Simply use nested sets of curly braces to nest arrays within arrays. For example, we can declare, create, and initialize a 5 × 5 multiplication table like this:

```
int[][] products = { {0, 0, 0, 0, 0},
                     {0, 1, 2, 3, 4},
                     {0, 2, 4, 6, 8},
                     {0, 3, 6, 9, 12},
                     {0, 4, 8, 12, 16} };
```

Or, if you want to use a multidimensional array without declaring a variable, you can use the anonymous initializer syntax:

```
boolean response = bilingualQuestion(question, new String[][] {
                                                  { "Yes", "No" },
                                                  { "Oui", "Non" }});
```

When you create a multidimensional array using the `new` keyword, it is usually good practice to only use *rectangular* arrays: one in which all the array values for a given dimension have the same size.

Excerpts from Flanagan, D. (2019). *Java in a Nutshell*. Sebastopol, CA. O'Reilly.

Reference types and objects differ substantially from primitive types and their primitive values:

- Eight primitive types are defined by the Java language, and the programmer cannot define new primitive types. Reference types are user-defined, so there is an unlimited number of them. For example, a program might define a class named `Point` and use objects of this newly defined type to store and manipulate *x,y* points in a Cartesian coordinate system.
- Primitive types represent single values. Reference types are aggregate types that hold zero or more primitive values or objects. Our hypothetical `Point` class, for example, might hold two `double` values to represent the *x* and *y* coordinates of the points. The `char[]` and `Point[]` array types are aggregate types because they hold a sequence of primitive `char` values or `Point` objects.
- Primitive types require between one and eight bytes of memory. When a primitive value is stored in a variable or passed to a method, the computer makes a copy of the bytes that hold the value. Objects, on the other hand, may require substantially more memory. Memory to store an object is dynamically allocated on the heap when the object is created and this memory is automatically "garbage collected" when the object is no longer needed.

When an object is assigned to a variable or passed to a method, the memory that represents the object is not copied. Instead, only a reference to that memory is stored in the variable or passed to the method.

Excerpts from Flanagan, D. (2019). *Java in a Nutshell*. Sebastopol, CA. O'Reilly.



We've seen that primitive types and reference types differ significantly in the way they are assigned to variables, passed to methods, and copied. The types also differ in the way they are compared for equality. When used with primitive values, the equality operator (==) simply tests whether two values are identical (i.e., whether they have exactly the same bits). With reference types, however, == compares references, not actual objects. In other words, == tests whether two references refer to the same object; it does not test whether two objects have the same content. Here's an example:

```
String letter = "o";
String s = "hello";              // These two String objects
String t = "hell" + letter;      // contain exactly the same text.
if (s == t) System.out.println("equal"); // But they are not equal!

byte[] a = { 1, 2, 3 };
// A copy with identical content.
byte[] b = (byte[]) a.clone();
if (a == b) System.out.println("equal"); // But they are not equal!
```

When working with reference types, keep in mind there are two kinds of equality: equality of reference and equality of object. It is important to distinguish between these two kinds of equality. One way to do this is to use the word "identical" when talking about equality of references and the word "equal" when talking about two distinct objects that have the same content. To test two nonidentical objects for equality, pass one of them to the `equals()` method of the other:

```
String letter = "o";
String s = "hello";              // These two String objects
String t = "hell" + letter;      // contain exactly the same text.
if (s.equals(t)) {               // And the equals() method
    System.out.println("equal"); // tells us so.
}
```

All objects inherit an `equals()` method (from `Object`), but the default implementation simply uses == to test for identity of references, not equality of content. A class that wants to allow objects to be compared for equality can define its own version of the `equals()` method. Our `Point` class does not do this, but the `String` class does, as indicated in the code example. You can call the `equals()` method on an array, but it is the same as using the == operator, because arrays always inherit the default `equals()` method that compares references rather than array content. You can compare arrays for equality with the `java.util.Arrays.equals()` convenience method.