2D Arrays

Two-Dimensional Arrays

- It often happens that you want to store collections of values that have a two-dimensional layout.

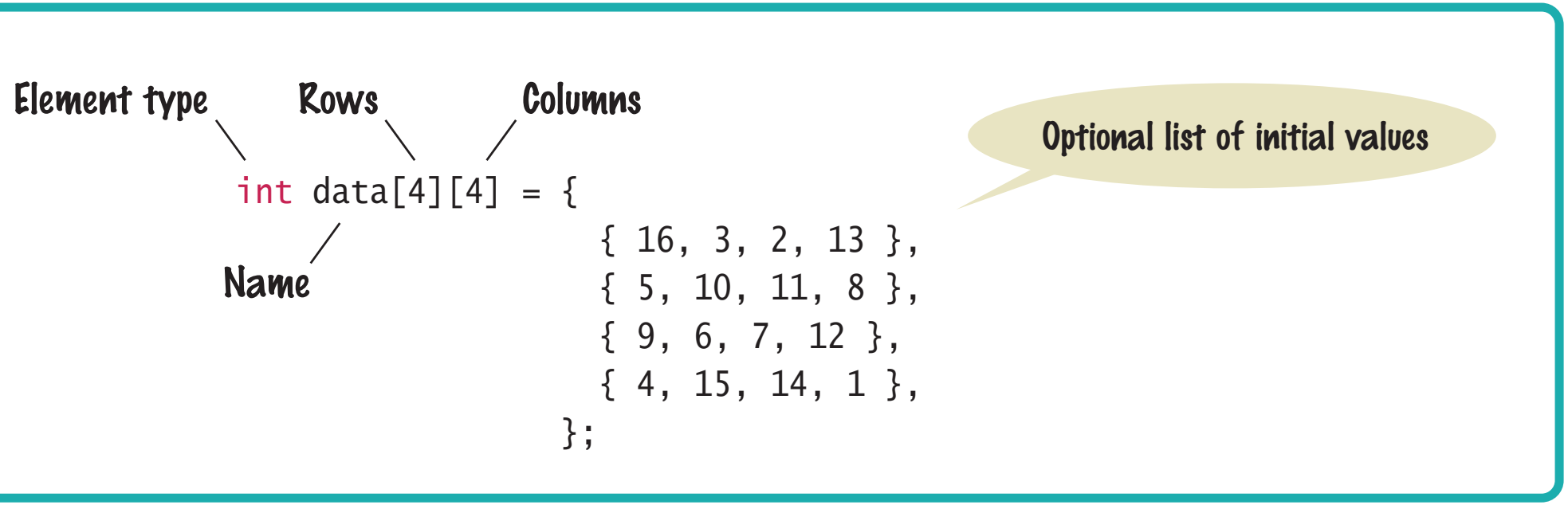
- Such data sets commonly occur in financial and scientific applications.

- An arrangement consisting of *tabular data (rows and columns* of values) is called:

a ***two-dimensional array***, or a ***matrix***

Defining 2D arrays

Two-Dimensional Array Definition

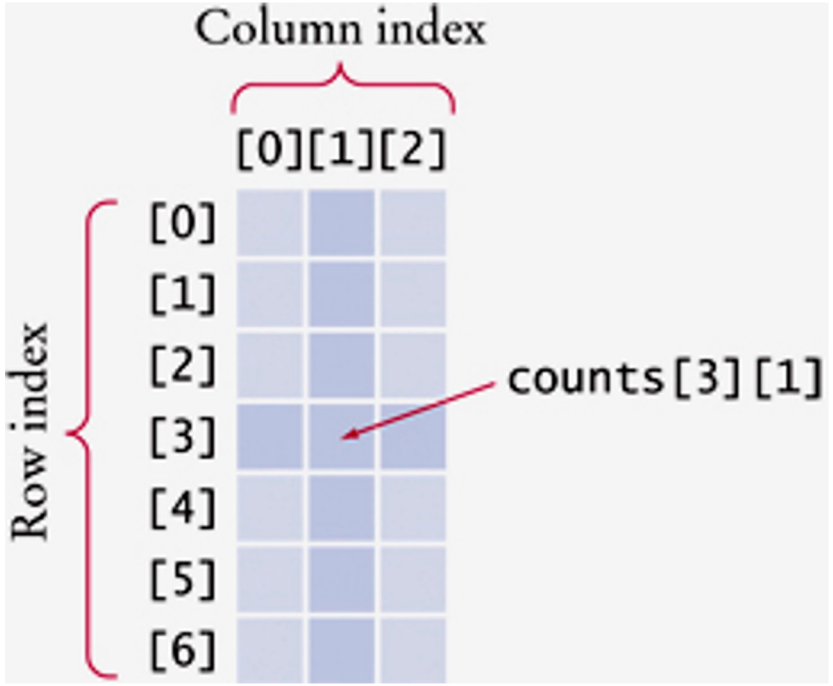


Two-Dimensional Arrays – Accessing Elements

```
// copy to num what is currently
// stored in the array at [3][1]

int num = counts[3][1];


// Then set that position in the
array to 8
counts[3][1] = 8;
```



Two-Dimensional Array Example

Consider the sales data from 2018 - 2021

	2018	2019	2020	2021
January	57	47.2	61	32
February	68.1	34	46	54
March	43	58	38.6	67.5
April	82.4	43.2	57	29
May	27	34.5	42.4	35
June	34.8	18	31	80
July	55	21	47.1	115
August	61.6	71.7	67	98
September	107	91.4	87.3	100
October	86	51	54.1	65
November	142	112	173.5	210.5
December	74	83	107.2	140

Defining Two-Dimensional Arrays

C++ uses an array with *two* subscripts to store a *2D* array.

```
const int MONTHS = 12;
const int YEARS = 4;
int sales[MONTHS][YEARS];
```

An array with 12 rows and 4 columns is suitable for storing our sales data.

- 2D arrays are built up as an array of 1D arrays!
- Each row is a 1D array

Defining Two-Dimensional Arrays – Initializing

Just as with one-dimensional arrays, you *cannot* change the size of a two-dimensional array once it has been defined.

You can initialize them.

```
double sales[MONTHS][YEARS] ={ {57, 47.2, 61, 32},
                               {68.1, 34, 46, 54},
                               {43, 58, 38.6, 67.5},
                               {82.4, 43.2, 57, 29},
                               {27, 34.5, 42.4, 35},
                               {34.8, 18, 31, 80},
                               {55, 21, 47.1, 115},
                               {61.6, 71.7, 67, 98},
                               {107, 91.4, 87.3, 100},
                               {86, 51, 54.1, 65},
                               {142, 112, 173.5, 210.5},
                               {74, 83, 107.2, 140}};
```

Print 1st row elements in a 2D Array

	2018	2019	2020	2021
January	57	47.2	61	32
February	68.1	34	46	54
March	43	58	38.6	67.5
April	82.4	43.2	57	29
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December	74	83	107.2	140

```
[0][0], [0][1], [0][2], [0][3]
// Print the 1st row:
cout << setw(8) << sales[0][0];
cout << setw(8) << sales[0][1];
cout << setw(8) << sales[0][2];
cout << setw(8) << sales[0][3];
```

Print 1st row elements in a 2D Array

	2018	2019	2020	2021
January	57	47.2	61	32
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December	74	83	107.2	140

```
[0][0], [0][1], [0][2], [0][3]
// Process the 1st row:
for (int j = 0; j < YEARS; j++)
{
    cout << setw(8) << sales[0][j];
}
```

Print all elements in a 2D Array

	2018	2019	2020	2021
January	57	47.2	61	32
February	68.1	34	46	54
March	43	58	38.6	67.5
April	82.4	43.2	57	29
May	27	34.5	42.4	35
June	34.8	18	31	80
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October	86	51	54.1	65
November	142	112	173.5	210.5
December	74	83	107.2	140

```
[0][0], [0][1], [0][2], [0][3]
[1][0], [1][1], [1][2], [1][3]
[2][0], [2][1], [2][2], [2][3]
for (int j = 0; j < YEARS; j++)
{
    cout << setw(8) << sales[i][j];
}
```

Print all elements in a 2D Array

```
for (int i = 0; i < MONTHS; i++)
{
    // Process the ith row
    for (int j = 0; j < YEARS; j++)
    {
        // Process the jth column in the ith row
        cout << setw(8) << sales[i][j];
    }
    // Start a new line at the end of the row
    cout << endl;
}
```

In order to print each element, we need two for loops:

- one to loop over all rows,
- and another to loop over all columns.

Computing Row and Column Totals

- We must be careful to get the right indices.
- For each row **i**, we must use the column indices:

```
0, 1, … (YEARS -1)
```

Computing Column Totals: Code Example

Column totals:

Let `j` be the 2021 column:

	2018	2019	2020	2021
January	57	47.2	61	32
February	68.1	34	46	54
March	43	58	38.6	67.5
April	82.4	43.2	57	29
May	27	34.5	42.4	35
June	34.8	18	31	80
July	55	21	47.1	115
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```
int total = 0; //loop to sum down the rows
int j = 3;
for (int i = 0; i < MONTHS; i++)
{
   total = total + sales[i][j];
}
```

Multidimensional Array Parameters

- Similar to one-dimensional array
  - 1st dimension size not given (Provided as second parameter)
  - 2nd dimension size IS given
- Example:

```
void DisplayPage(const char p[][100], int sizeDimension1)
{
	for (int index1=0; index1<sizeDimension1; index1++)
	{
		for (int index2=0; index2 < 100; index2++)
			cout << p[index1][index2];
		cout << endl;
	}
}
```

Two-Dimensional Array Parameters

- When passing a two-dimensional array to a function, you must specify the number of columns *as a constant* when you write the parameter type, so the compiler can pre-calculate the memory addresses of individual elements.
- This function computes the total of a given row.

```
const int COLUMNS = 3;
int rowTotal(int table[][COLUMNS], int row)
{
   int total = 0;
   for (int j = 0; j < COLUMNS; j++)
   {
      total = total + table[row][j];
   }
   return total;
}
```

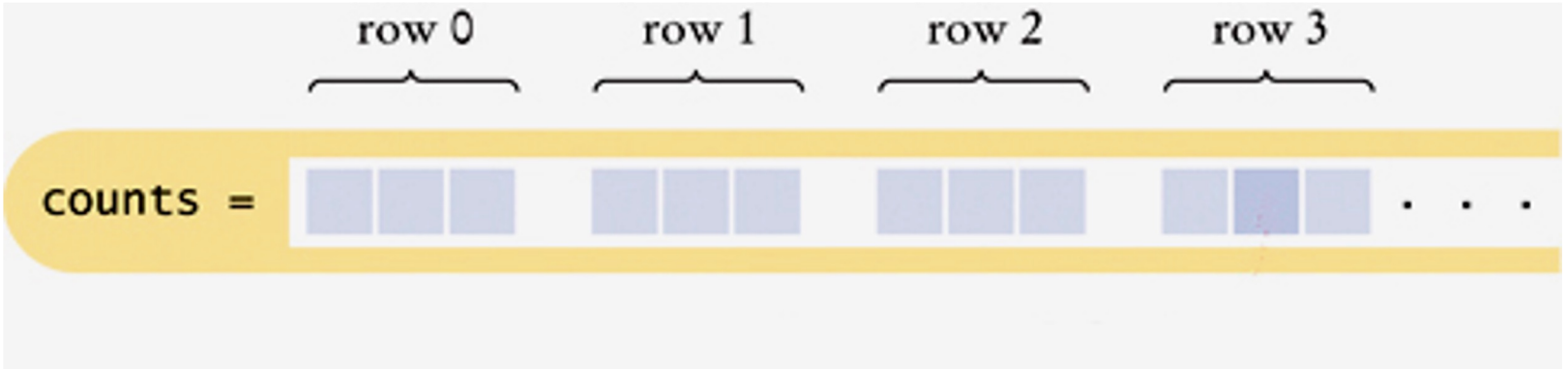
Two-Dimensional Array Parameter Columns Hardwired

That function works for only arrays of 3 columns.

If you need to process an array with a different number of columns, like 4, you would have to write ***a different function*** that has 4 as the parameter.

Two-Dimensional Array Storage

What's the reason behind this?



Although the array appears to be two-dimensional, the elements are still stored as a linear sequence.

`counts` is stored as a sequence of rows, each 3 long.

So where is **`counts[3][1]`**?

The offset (calculated by the compiler) from the start of the array is

`3 x number of columns + 1`

Two-Dimensional Array Parameters: Rows

The **`rowTotal`** function did not need to know the number of rows of the array.

If the number of rows is required, pass it in:

```
int columnTotal(int table[][COLUMNS], int rows, int col)
{
   int total = 0;
   for (int i = 0; i < rows; i++)
   {
      total = total + table[i][col];
   }
   return total;
}
```

Arrays -- fixed size can be a drawback

The size of an array cannot be changed after it is created.

- You have to get the size right before you define an array
- The compiler needs to know the size in order to build the array, and functions need to be told number of elements in array, and possibly its capacity (and arrays can’t hold more than their initial capacity)

- In a few weeks, we’ll talk about vectors, which can have variable size and some other nice flexible features that arrays don’t have.

Multidimensional Arrays

- 2D array
- 3D array
- 4D array