MODERN C++ DESIGN PATTERNS

Multi-Dimensional Arrays

by Prasanna Ghali

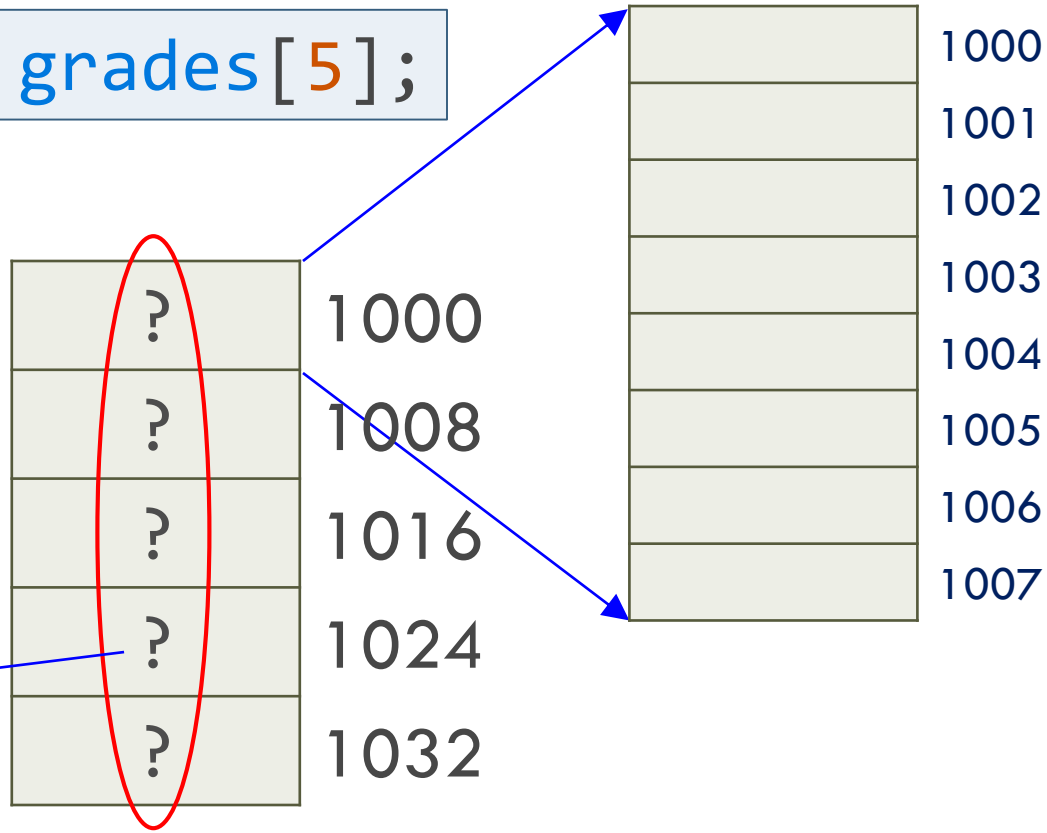
Arrays: Memory Storage (1/2)

- Arrays have linear structure - elements are given contiguous memory storage

```
double grades[5];
```

Memory block is 40 bytes which is equivalent to `sizeof(double)*5`

No initializers during definition; thus, memory contents are garbage!!!



Arrays: Memory Storage (2/2)


```
double grades[5] = {11.1, 22.2, 33.3, 44.4, 55.5};
```

1) *Base type* `double` means each element is 8 bytes
2) Size 5 means contiguous memory block is 40 bytes
3) Compiler will fix *base address* for array, say 1000
4) From compiler's perspective, name `grades` means base address 1000

11.1	1000
22.2	1008
33.3	1016
44.4	1024
55.5	1032

sizeof Operator

- For array names, `sizeof` returns number of bytes of storage for <u>all</u> array elements
- Type of value returned by `sizeof`: `size_t`
  - `size_t` is *largest unsigned integral type* – most implementations use `unsigned long int`

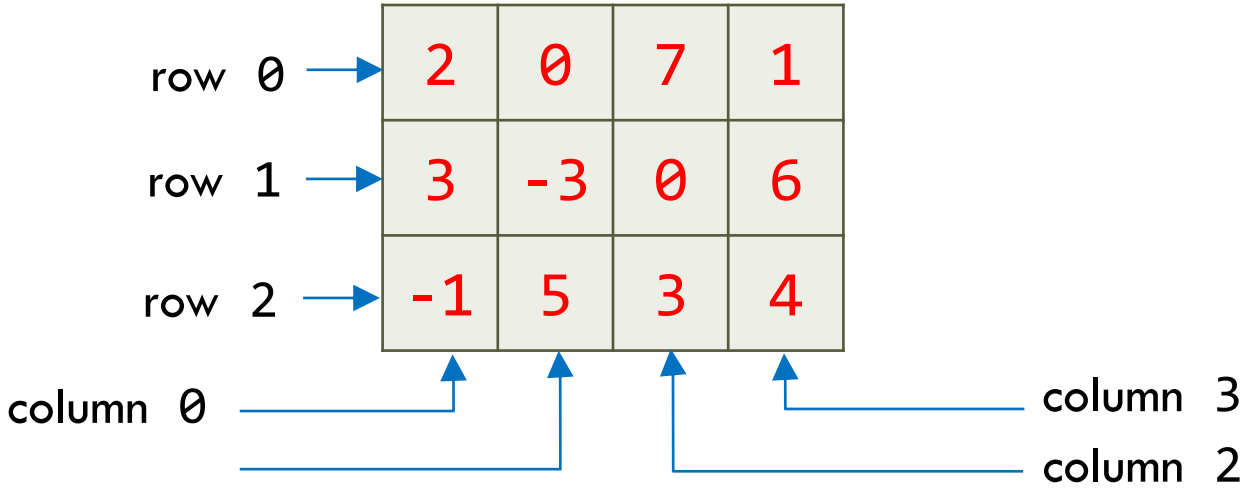
```
int    racers[5];
double prizes[10];
char   inits[1000];

printf("sizeof(racers): %lu\n", sizeof(racers));
printf("sizeof(prizes): %lu\n", sizeof(prizes));
printf("sizeof(inits):  %lu\n", sizeof(inits));
```

Notice that array name is operand to `sizeof` operator

Two-dimensional arrays: Introduction (1/3)

- One-dimensional arrays keep track of data values visualized as row or column
- Many examples (digital images, board games) exist where data is best visualized using grid or table having both rows and columns



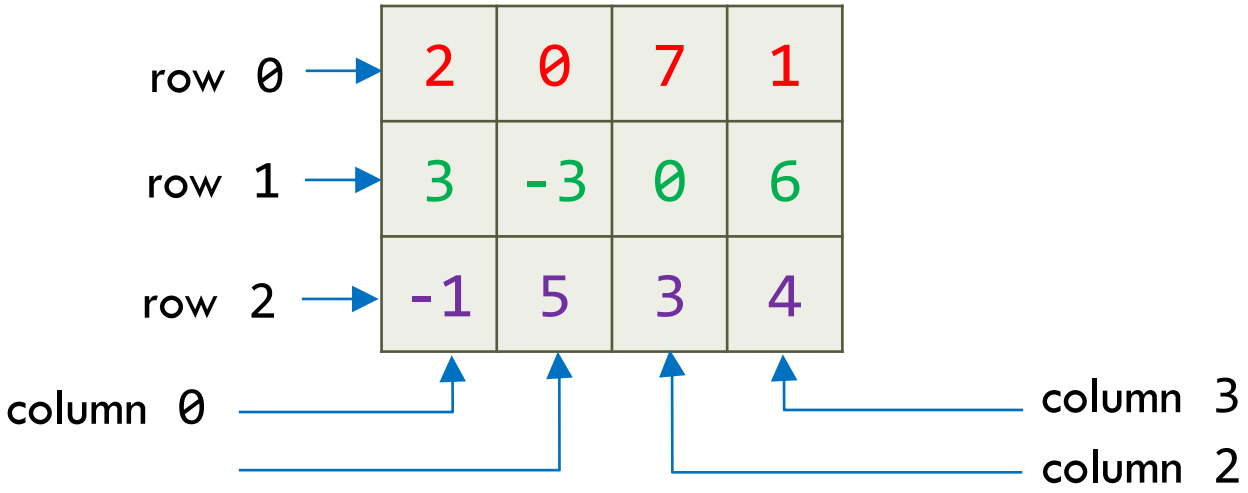
Two-dimensional arrays: Introduction (2/3)

2
0
7
1
3
-3
0
6
-1
5
3
4

in memory

In C/C++, table or matrix represented as two-dimensional array: `int carrot[3][4];`

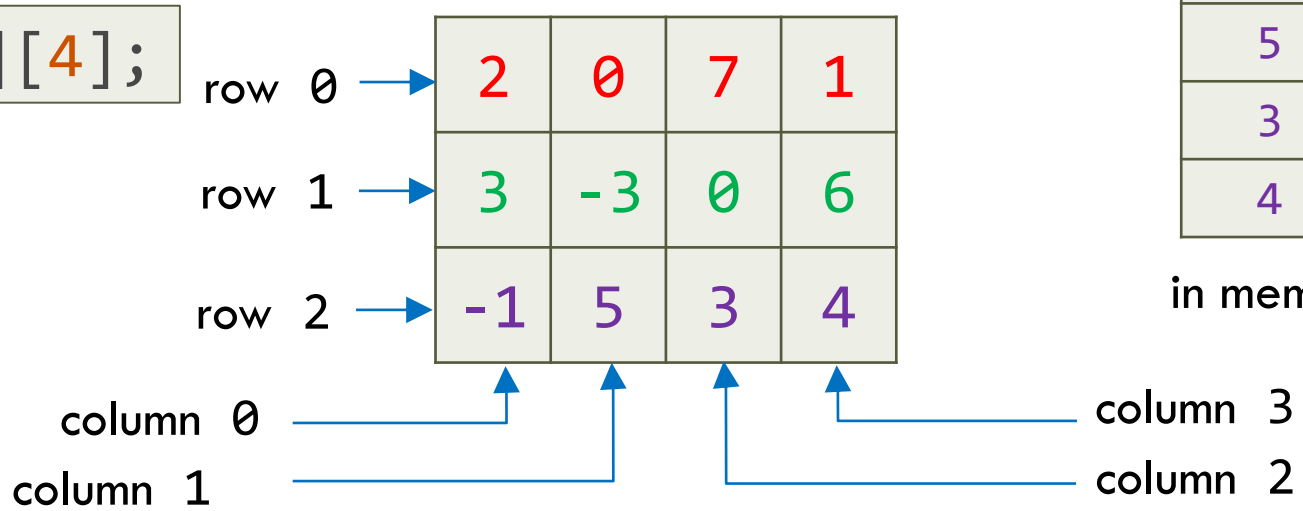
- `carrot` has 12 elements – each of type `int` – divided into 3 rows with each row having 4 columns

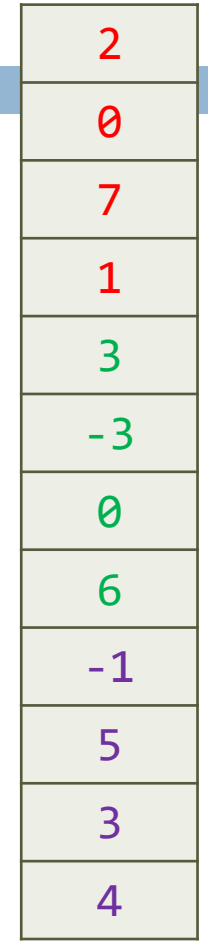


Two-dimensional arrays: Introduction (3/3)

- Each element in `carrot` accessed using two subscripts – a *row* subscript and a *column* subscript
  - As usual, subscripts begin at zero
  - `carrot[1][2]` evaluates to `int` value 0

```
int carrot[3][4];
```



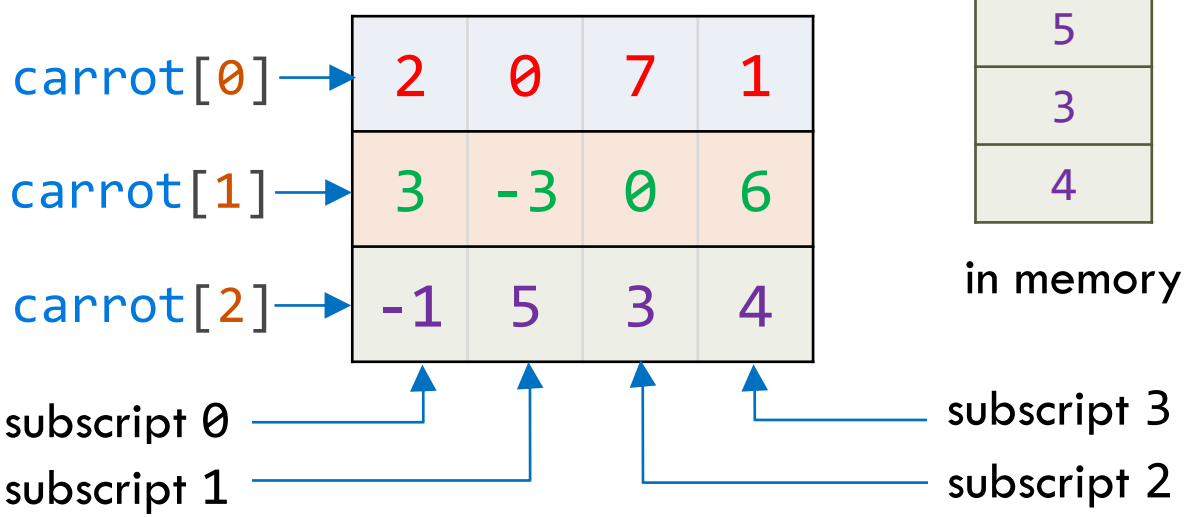


in memory

Array of arrays (1/3)

- Internally, multi-dimensional arrays are considered as *array of arrays*
- Two-dimensional array is one-dimensional array with each element being one-dimensional array

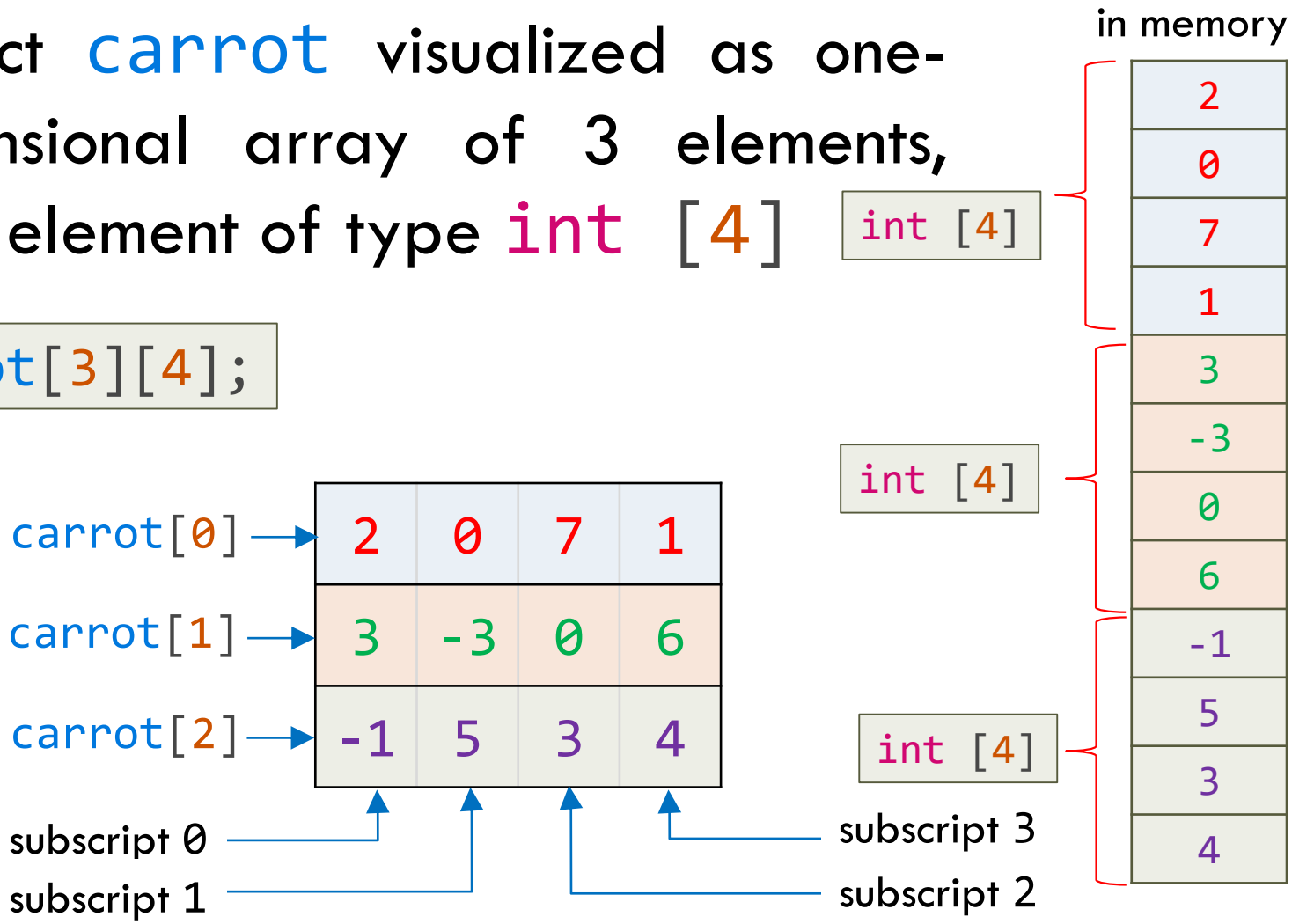
```
int carrot[3][4];
```



Array of arrays (2/3)

- Object `carrot` visualized as one-dimensional array of 3 elements, each element of type `int [4]`

```
int carrot[3][4];
```

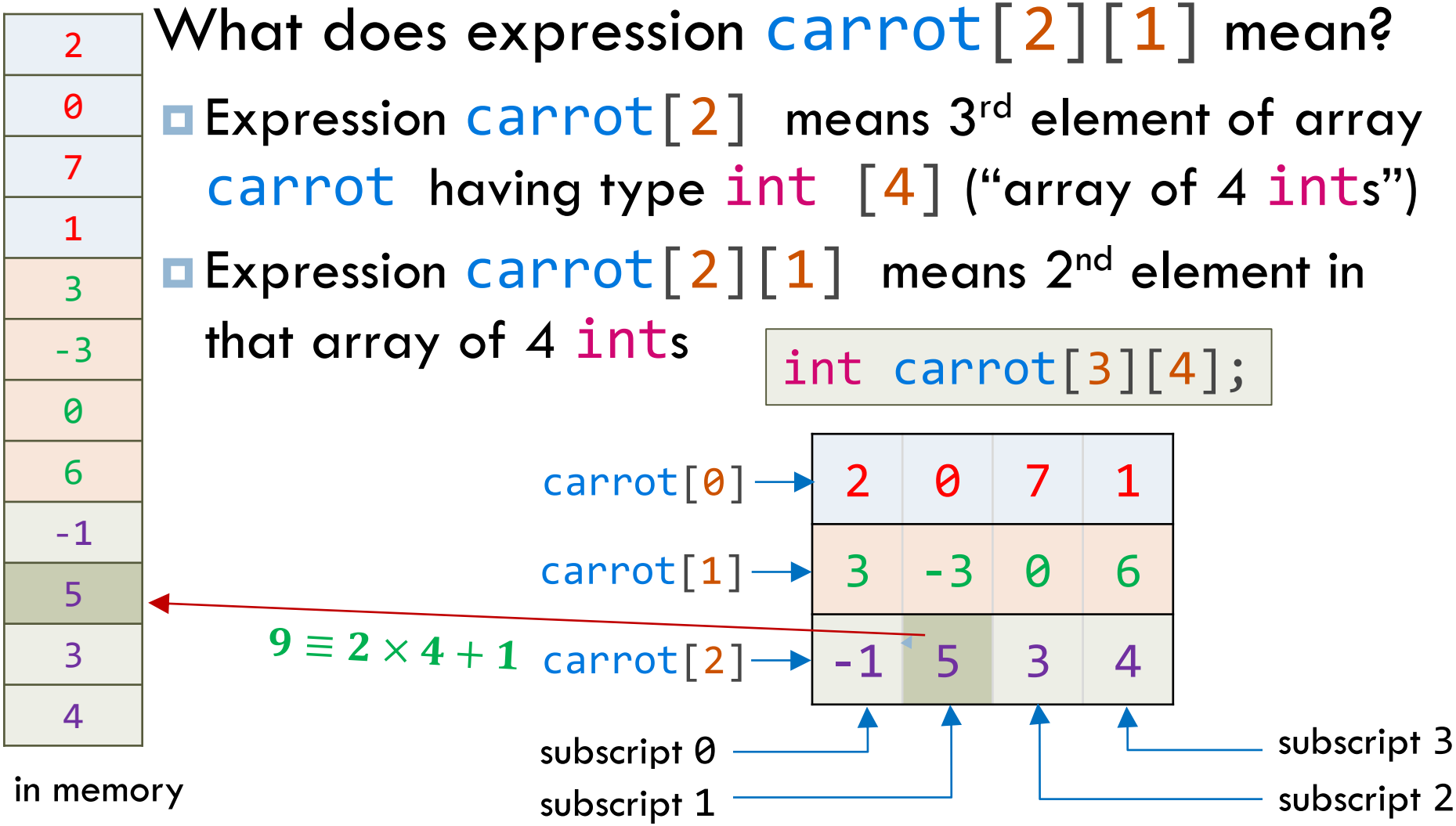


Array of arrays (3/3)

What does expression `carrot[2][1]` mean?

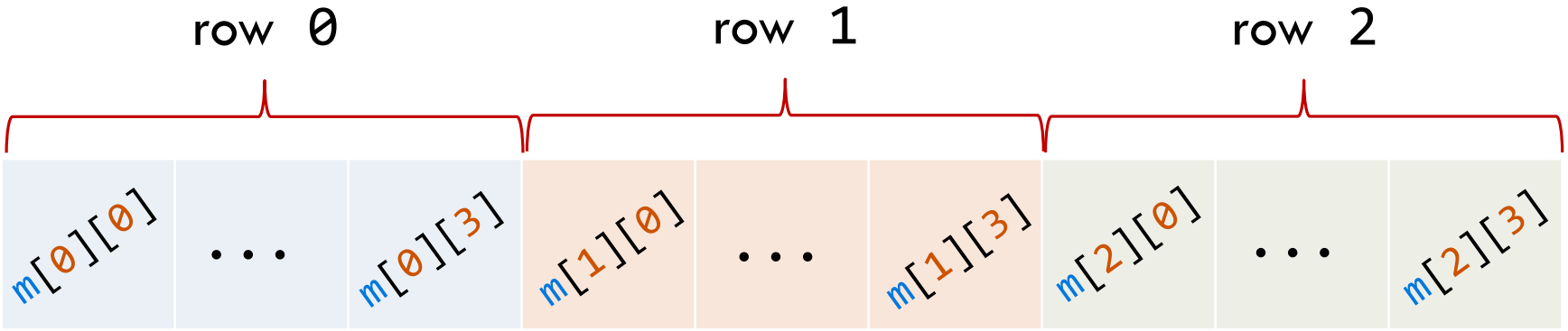
- Expression `carrot[2]` means 3rd element of array `carrot` having type `int [4]` ("array of 4 `int`s")
- Expression `carrot[2][1]` means 2nd element in that array of 4 `int`s

```
int carrot[3][4];
```



Row-major storage

- Consider two-dimensional array `int m[3][4];`
  - 12 `int` elements of two-dimensional array `m` are contiguously stored in memory
  - Since `m` is array of arrays, 4 elements of 1st row `m[0]` are given contiguous storage, followed by 4 elements of 2nd row `m[1]`, and so on



"Array of Array"-ish Declaration (1/2)

- C/C++ can be used to define a 3-by-4 multidimensional arrays of `int`s like this:

```
int carrot[3][4];
```

- Or in a way that is more "array of array"-ish like this:

```
using vegetable = int [4];
vegetable carrot[3];
```

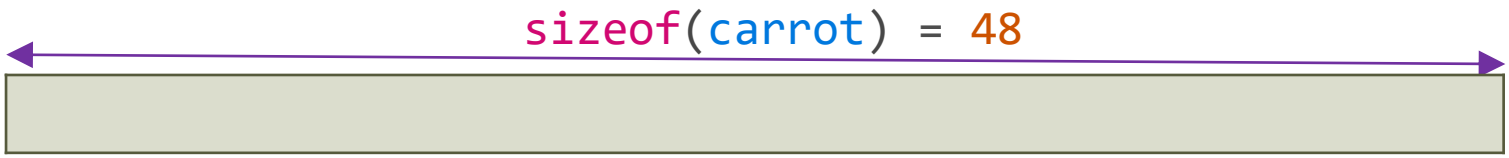
- In either case, individual element is accessed by `carrot[i][j]`
- At compile time, compiler will resolve that to

```
*(*(carrot+i)+j)
```

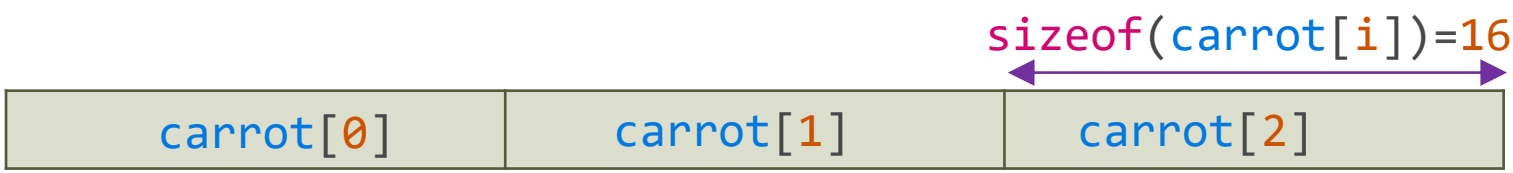
“Array of Array”-ish Declaration (2/2)

- Whenever you see “array” in C/C++, think “vector”, that is, a one-dimensional array of *something*, possibly another array

Multidimensional Array Storage: `int carrot[3][4];`




```
int (*p)[4] = carrot
```




```
int *r = carrot[i]
```


```
int t = carrot[i][j]
```

Multidimensional Array Storage:

```
int apricot[2][3][4];
```