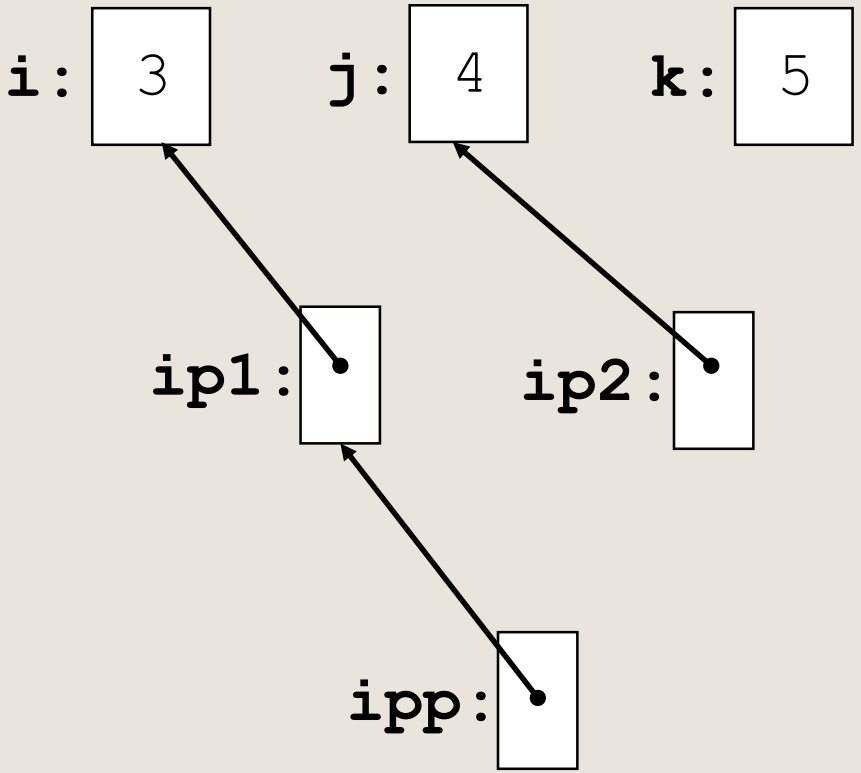
Pointers to pointers & multi-dimensional arrays

Pointers to pointers

```
int i=3;
int j=4;
int k=5;


int *ip1 = &i;
int *ip2 = &j;
int **ipp = &ip1;
```



Pointers to pointers

```
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int k=5;


int *ip1 = &i;
int *ip2 = &j;
int **ipp = &ip1;
ipp = &ip2;
```
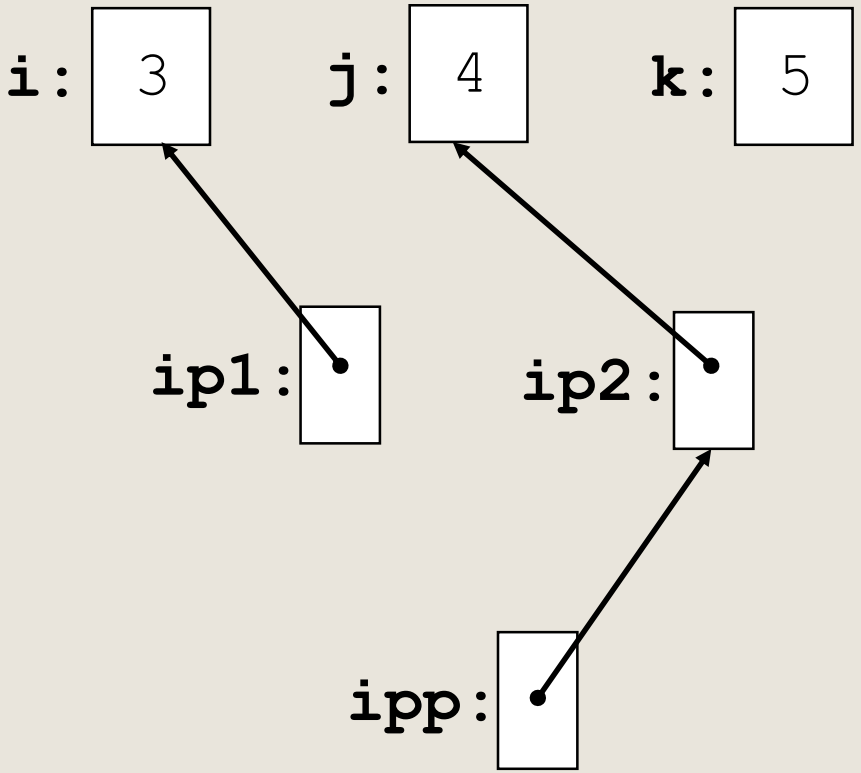
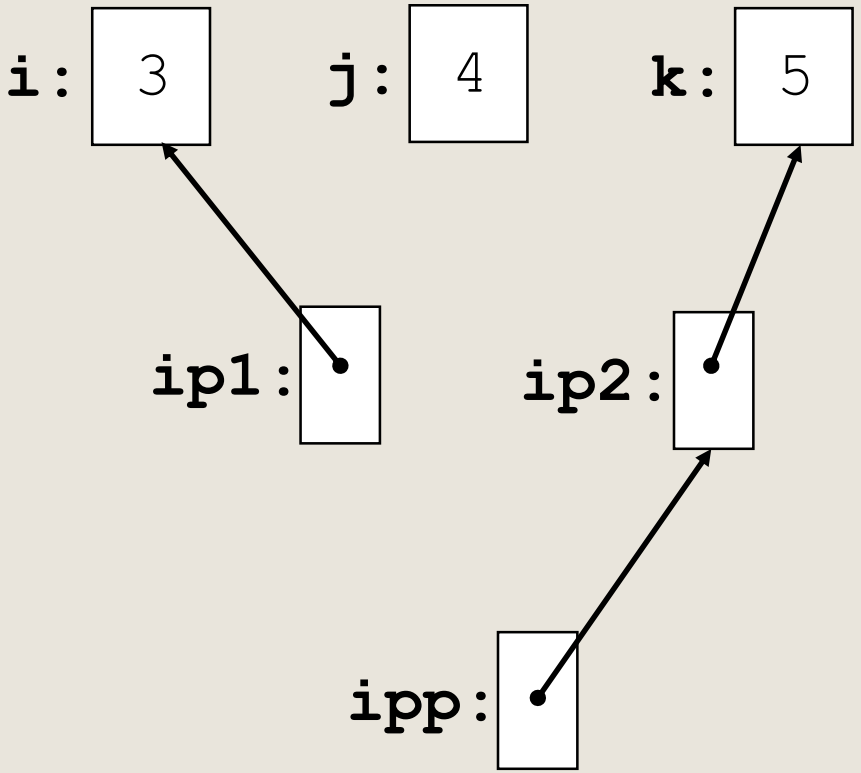



Pointers to pointers

```
int i=3;
int j=4;
int k=5;


int *ip1 = &i;
int *ip2 = &j;
int **ipp = &ip1;
ipp = &ip2;
*ipp = &k;
```



Reminder – the swap function

Does nothing

```
void swap(int a, int b)
{
   int temp = a;
   a = b;
   b = temp;
}
int main()
{
   int x, y;
   x = 3; y = 7;
   swap(x, y);
   // now x==3, y==7
}
```

Works

```
void swap(int *pa, int *pb)
{
   int temp = *pa;
   *pa = *pb;
   *pb = temp;
}
int main()
{
   int x, y;
   x = 3; y = 7;
   swap(&x, &y);
   // x == 7, y == 3
}
```

Pointers to pointers: example

```
//put pointer to an allocated string in pp
int allocString( size_t len, char ** pp)
{
    char *str = (char*)malloc(len + 1);
    if (str==NULL)
    {
        return 1;
    }
    *pp = str;
    return 0;
}
```

Pointers to pointers: example

```
// copy a string using "allocString"
void main()
{
    char *s = "example";
    char *copy;
    allocString( strlen(s), &copy );
    strcpy( copy, s);
    free (copy);
}
```

Multi-dimensional arrays

Multi-dimensional arrays

Can be created in few ways:

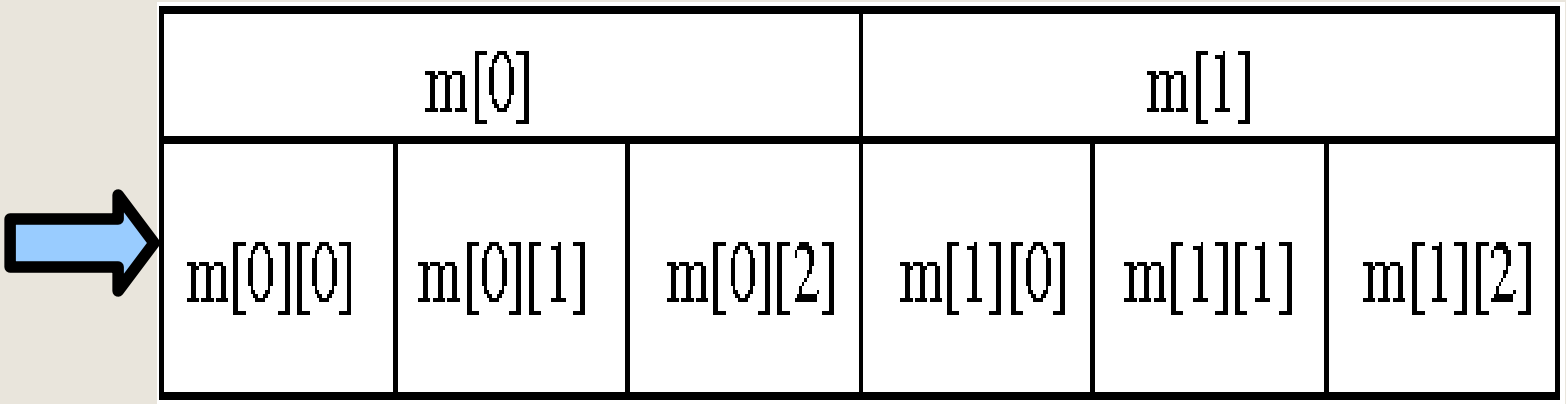
1. Automatically:

```
int m[2][3]; // 2 rows, 3 columns
```

- continuous memory (divided to 2 blocks)
- access: m[row][col] = 0;

Automatic multi-dimensional arrays

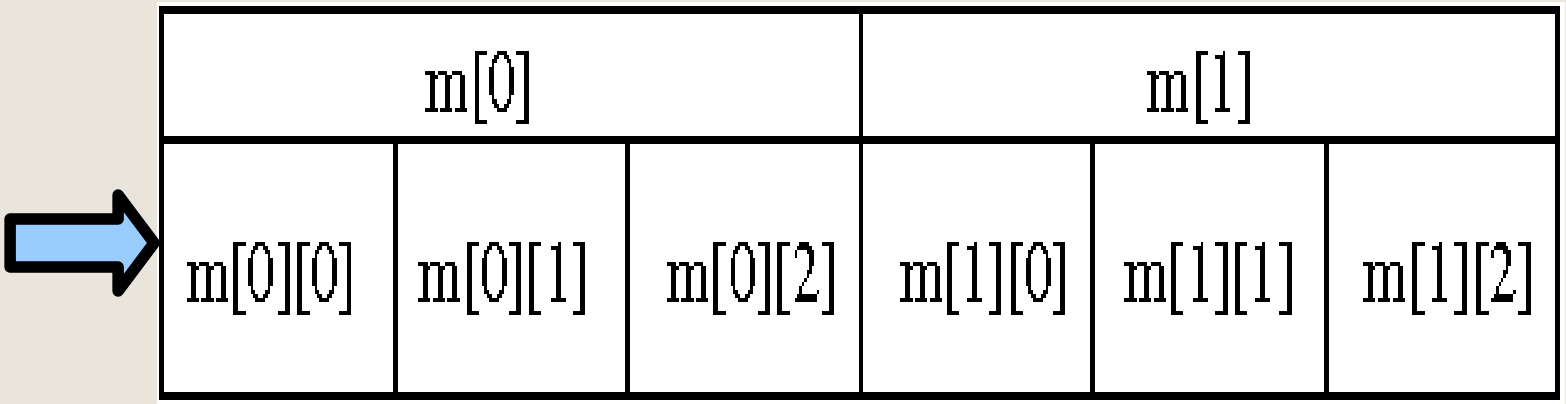
```
#define R 2
#define C 3
int m[R][C];
```




```
int* m_ptr= &(m[0][0]);
size_t i;
for (i=0; i<R*C; ++i) {
  printf("%d\n", *(m_ptr++) );
}
```

Automatic multi-dimensional arrays

```
#define R 2
#define C 3
int m[R][C];
```




```
int* m_ptr;
for (m_ptr= &(m[0][0]);
     m_ptr<=&(m[R-1][C-1]);
     ++m_ptr) {
  printf("%d\n", *m_ptr );
}
```

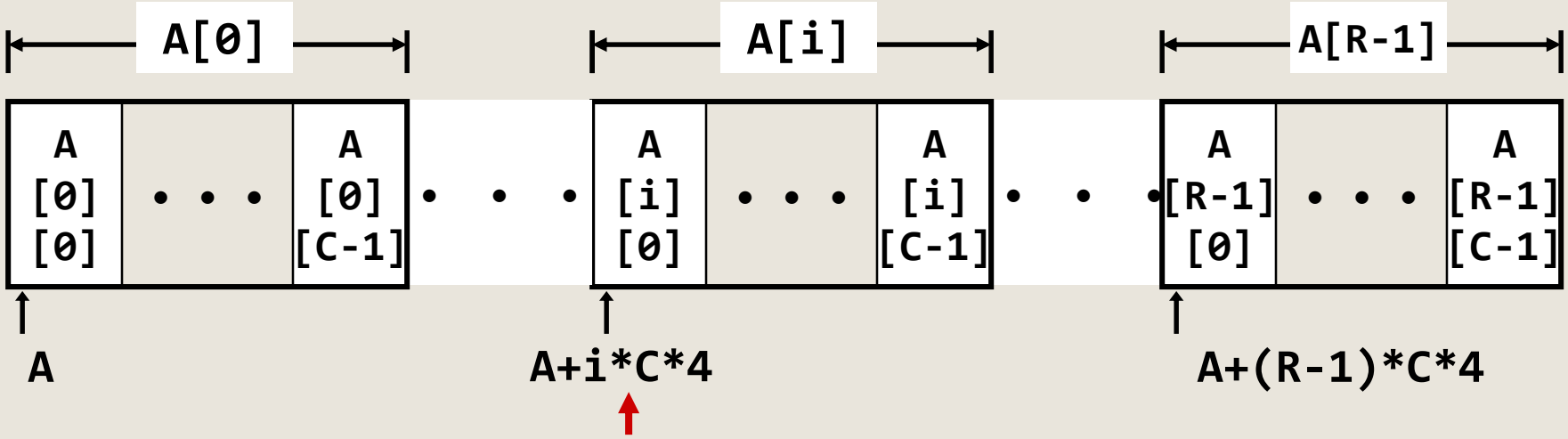
Automatic multi-dimensional arrays

```
int A[R][C];
```

Like a matrix →

A[0][0]	A[0][1]	…	A[0][c-1]
…	…	…	…
A[i][0]	A[i][1]	…	A[i][c-1]
…	…	…	…
A[R-1][0]	A[R-1][1]	…	A[R-1][C-1]

Row-major ordering →



Semi-dynamic multi-dimensional arrays

2. Semi-dynamic:

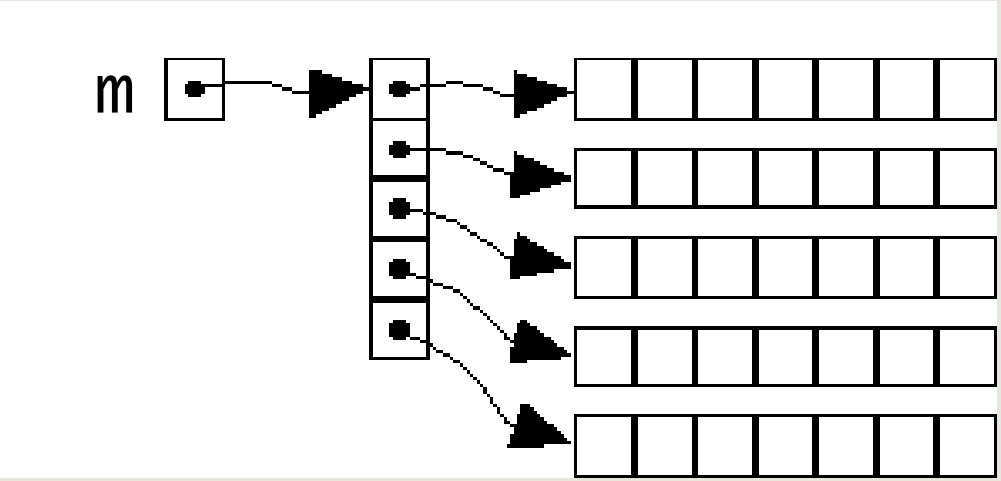
Define an array of pointers:

```
int* m[5]; // allocates memory for 5 pointers
for (i=0; i<5; ++i)
{
   m[i] = (int*) malloc( 7*sizeof(int) );
   // m[i] now points to a memory for 7 ints
}
```

Dynamic multi-dimensional arrays

3. Dynamically:

```
int ** m;
m = (int**) malloc( 5*sizeof(int*) );
for (i=0; i<5; ++i)
{
    m[i] = (int*)malloc( 7*sizeof(int) );
}
```



Semi/Dynamic multi-dimensional arrays

Memory not continuous

- Each pointer can be with different size
- Access: `m[ i ][ j ]`
- Don’t forget to free all the memory:

```
for (i=0; i<nrows; i++ )
{
   free( m[i] );
}
free( m ); // only for dynamic
```

Dynamic arrays – more efficient way

```
int* A= (int*) malloc(R*C*sizeof(int));
```

1-D array R=3 C=2 →

0,0	0,1	0,2	1,0	1,1	1,2

- **Access:** `A[ i*C + j ] // A [i][j]`
  - One access to memory vs. two in previous semi/dynamic representations.
  - Easier (& more efficient) implementation of iterators
- But:
  - Less readable code (can hide with macro or **much** better, inline functions)

Pointers to pointers to …

We also have pointers to pointers to pointers, etc.:

```
double ** mat1 = getMatrix();
double ** mat2 = getMatrix();
//allocate an array of matrices
double *** matrices =
(double***) malloc(n*sizeof(double**));
matrices[0] = mat1;
matrices[1] = mat2;
```

Automatic multi-dimensional arrays as arguments to functions

```
int x[5][7]; // 5 rows, 7 columns
```

When sending ‘x’ as an argument to a function, only the 1st index can be omitted:

- `void func( int x[5][7] ) //ok`
- `void func( int x[][7] ) //ok`
- `void func( int x[][] ) //does not compile`
- `void func( int * x[] ) //something else`
- `void func( int ** x ) //something else`

Why ?

Pointers to arrays (of size X):

```
int foo (char m[][20]);
```

`m` is a pointer to an array of 20 chars.

Therefore:

```
sizeof (m) = sizeof (void*);
sizeof (*m) = 20*sizeof (char);
```

Pointers to arrays (of size X):

Explicit declaration:

```
char (*arr_2d)[20];
                // arr_2d is a pointer
               // not initialized
```

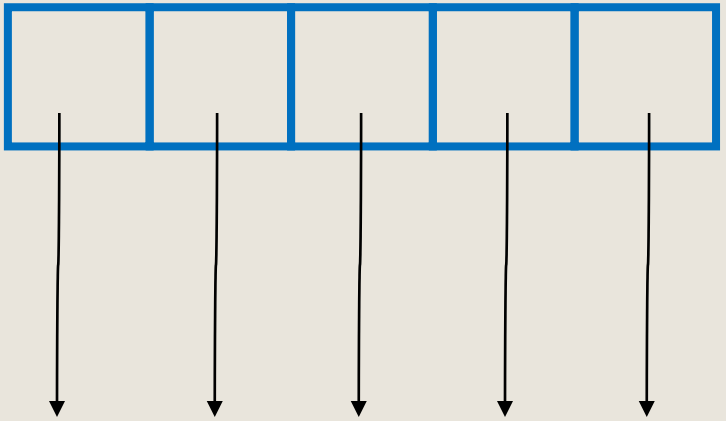
Using `typedef`:

```
typdef char arr_2d_20[20];
arr_2d_20 *p_arr_2d;
```

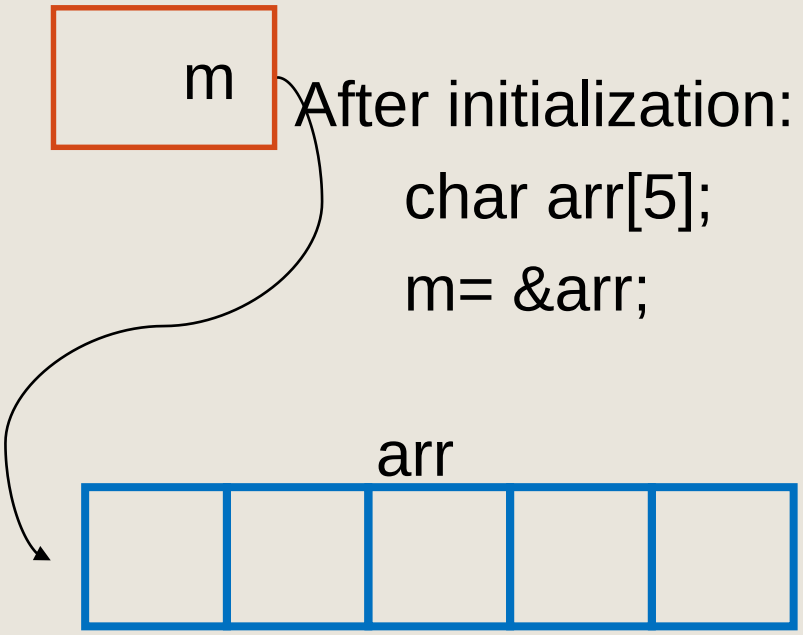
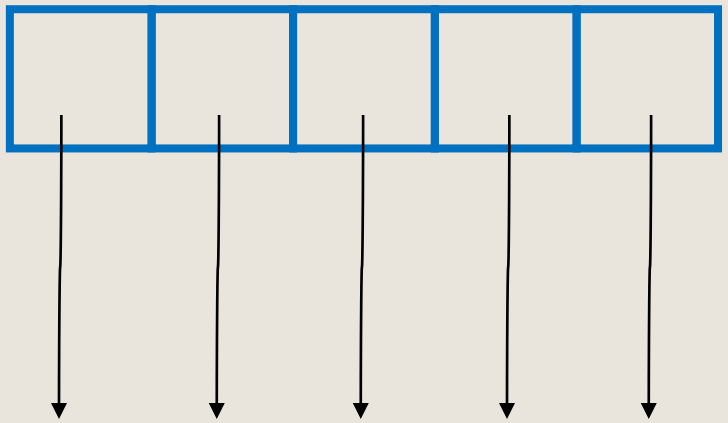
But:

```
typdef char arr_2d[][]; // comp. error
```

Pointers to arrays (of size X):

`char (*m)[5];`	`char *m[5];`
	

Pointers to arrays (of size X):

`char (*m)[5];`	`char *m[5];`
	

Pointers to arrays (of size X):

`char (*m)[5];`	`char *m[5];`

`sizeof (m) =`
`  sizeof(void*)`
 	
`sizeof (*m) =`
`  5*sizeof(char)`
	`sizeof (m) =`
	`5*sizeof (char*) =`
	`5*sizeof (void*)`
	
	`sizeof (*m) =`
	`  sizeof (char*)=`
	`  sizeof (void*)`

Multi-dimensional arrays as arguments to functions

Multi-dimensional arrays as arguments to functions

```
void foo( int matrix[ROWS_NUM][COLS_NUM] ) {
```

Multi-dimensional arrays as arguments to functions

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void foo( int matrix[ROWS_NUM][COLS_NUM] ) {
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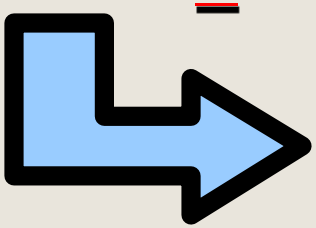


What is really sent?

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {
```

pointer to an array of COLS_NUM ints!

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {

    ...
    ...         matrix[r][c]
```

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {

    ...
    ...        matrix[r][c]
    ...    (*(matrix+r))[c]
```

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {

    ...
    ...        matrix[r][c]
    ...    (*(matrix+r))[c]
```

matrix is a pointer to int[COLS_NUM].

addition is done in this units.

This is why COLS_NUM is needed!

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {

    ...
    ...        matrix[r][c]
    ...    (*(matrix+r))[c]
    ... *((*(matrix+r)) + c)
```

Multi-dimensional arrays as arguments to functions

```
void foo( int (*matrix)[COLS_NUM] ) {

    ...
    ...        matrix[r][c]
    ...     (*(matrix+r))[c]
    ... *((*(matrix+r)) + c) == *(matrix+r*COLS_NUM+c)
```

The compiler is probably optimizing the internal computation to this.

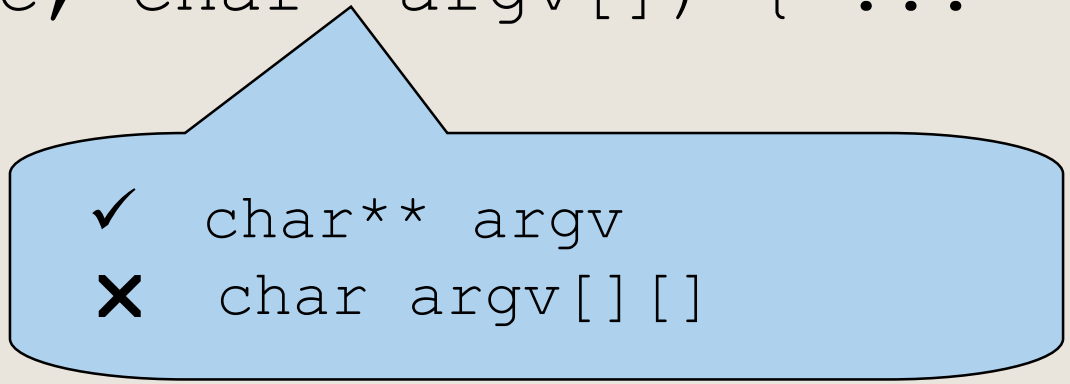
Example of dynamic multidimensional array: argv, argc

We want to pass parameters to the program running via the shell

argv, argc

- To pass command line arguments to our program we should use the following **`main`** declaration:

```
main(int argc, char* argv[]) { ...
```



- Compare to `main(String[] args)` in Java

- Unlike Java the **first argument** is the **name of the program** itself.

argv & argc: example

- **`$ prog1 -u danny -p 1234`**

  `argc == 5`
  `argv[0] == "prog1"`
  `argv[1] == "-u"`
  `...`
  `argv[4] == "1234"`

Always: `argv[argc] == NULL`

(redundant since we are also given argc)