Structs, malloc, 2D arrays

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What we have learnt

- Pointers
- Pointers and arrays
- Characters and strings

Today

- Finish string leftovers
- structs, malloc, 2D array

A different way of initializing string …

```
char s1[3] = {‘h’,‘i’,‘\0’};
//equivalent to
//char s1[3] = “hi”;
char *s2 = “bye”;
s1[0] = ‘H’;
```

OK

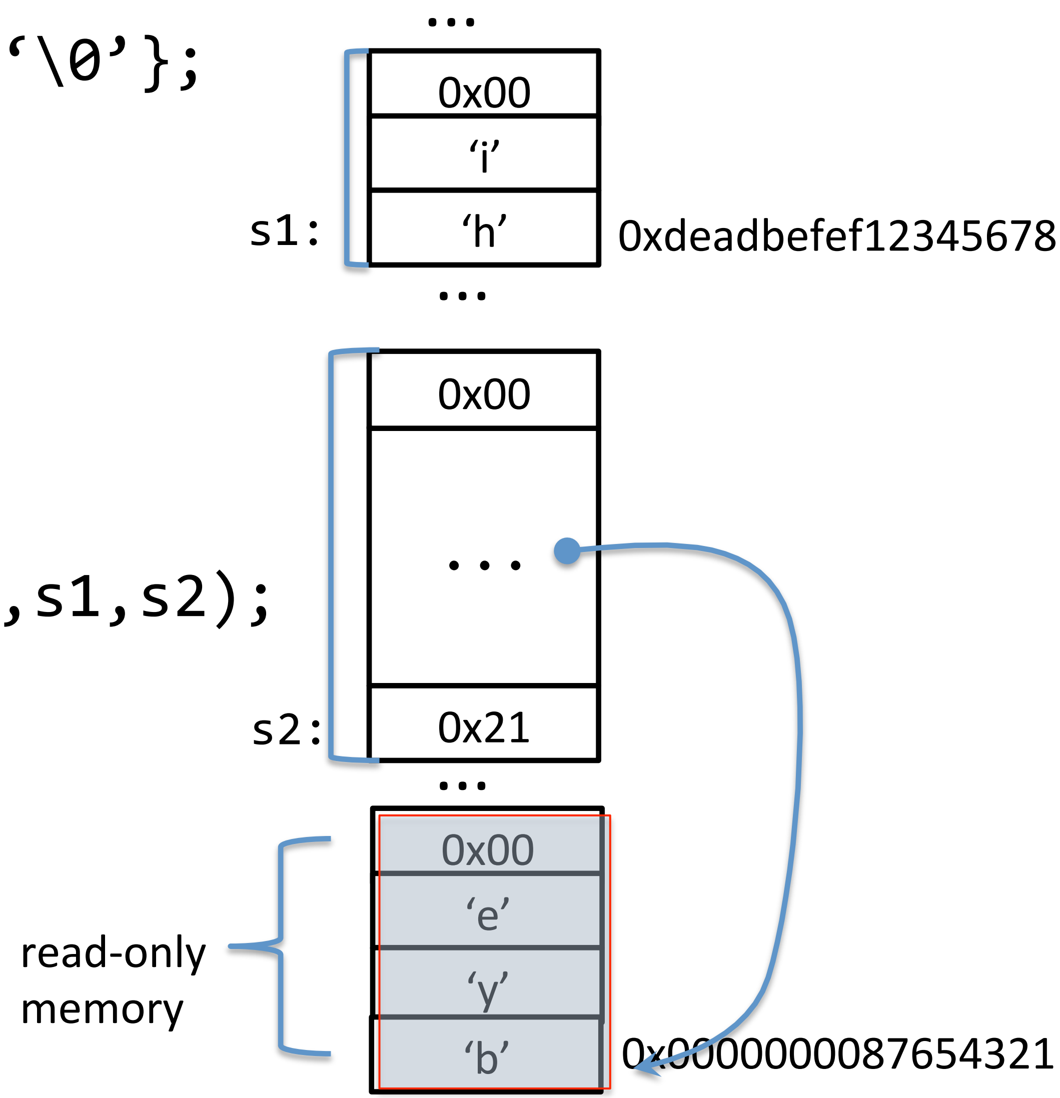
```
s2[0] = ‘B’;
```

Segmentation fault (bus error)

```
printf(“s1=%s s2=%s\n”,s1,s2);
```

A different way of initializing string

```
char s1[3] = {‘h’,‘i’,‘\0’};
//equivalent to
//char s1[3] = “hi”;
char *s2 = “bye”;
s1[0] = ‘H’;
s2[0] = ‘B’;

printf(“s1=%s s2=%s\n”,s1,s2);
```

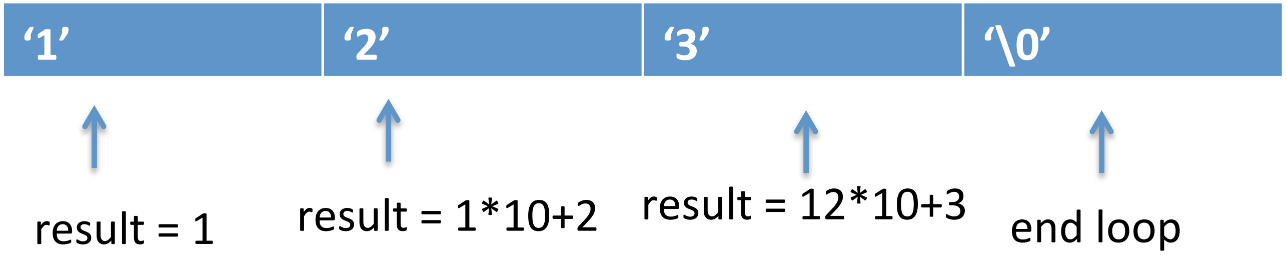


The Atoi function

```
// atoi returns the integer
// corresponding to the string of digits
int atoi(char *s)
{

}

int main()
{
   char *s= “123”;
   printf(“integer is %d\n”, atoi(s));
}
```

The Atoi function

```
// atoi returns the integer
// corresponding to the string of digits
int atoi(char *s) {
    int result = 0;
    int i = 0;
    while (s[i] >= '0' && s[i] <= '9') {
            result = result * 10 + (s[i] -'0');
            i++;
     }
     return result;
}
```

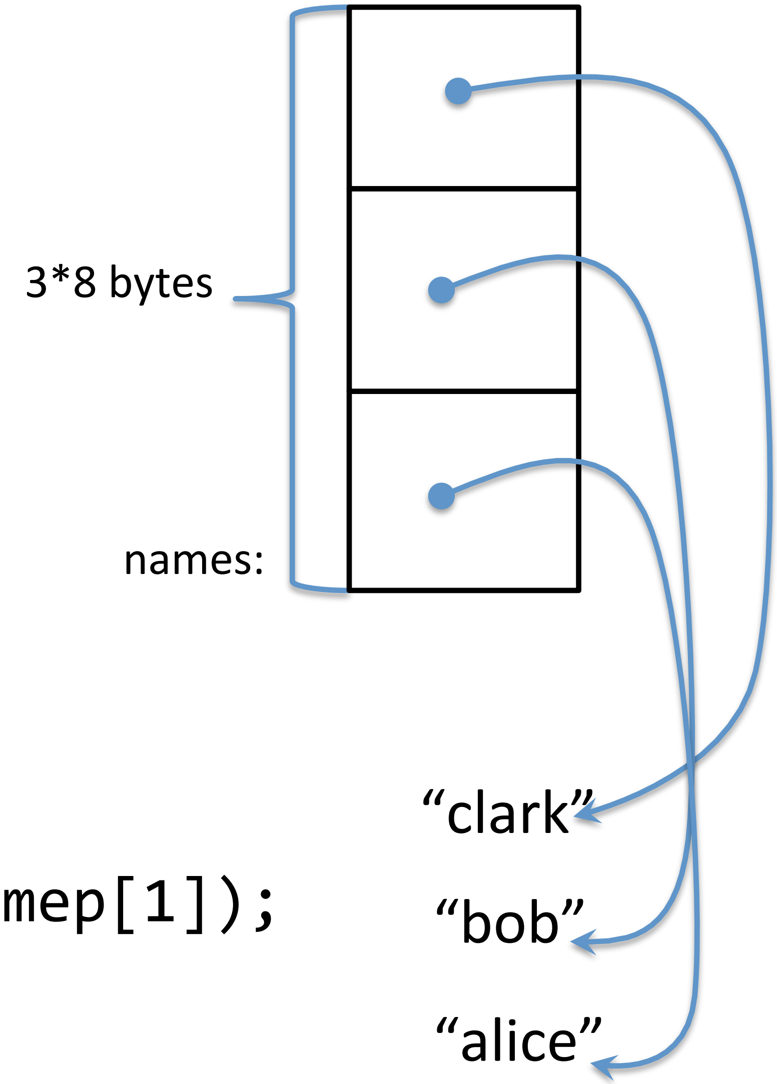


‘1’	‘2’	‘3’	‘\0’
result = 1	result = 1*10+2	result = 12*10+3	end loop

Array of pointers

```
char* names[3] = {
   “alice”,
   “bob”,
   “clark”
};
```

```
char **namep;
namep = names;

printf(“name is %s”, namep[1]);
```



The most commonly used array of pointers: argv

```
int main(int argc, char **argv)
{
   for (int i = 0; i < argc; i++) {
      printf(“%s\n”, argv[i]);
   }
}
```

```
$ ./a.out 1 2 3
./a.out 1 2 3
```

argv[0] is the name of the executable

Structs

Struct stores fields of different types contiguously in memory

C has no class/object.
Struct is like a class without associated methods

Struct

- Array: a block of n consecutive elements of the same type.
- Struct: a collection of elements of diffferent types.

Structure

```
struct student {
    int id;
    char *name;
};
```

Fields of a struct are allocated next to each other, but there may be gaps (padding) between them.

Structure

```
struct student {
    int id;
    char *name;
};

struct student t;
```

define variable t with type “struct student”

Structure

```
struct student {
    int id;
    char *name;
};

struct student t;

t.id = 1024;
t.name = “alice”;
```

Access the fields of this struct

Typedef

```
typedef struct {
    int id;
    char *name;
} student;
```

~~struct~~ student t;

Pointer to struct

```
typedef struct {
    int id;
    char *name;
} student;

student t = {1024, “alice”};
student *p = &t;

p->id = 1023;
p->name = “bob”;
printf(“%d %s\n”, t.id, t.name);
```

Mallocs

Allocates a chunk of memory dynamically

Recall memory allocation for global and local variables

- Global variables are allocated space before program execution.

- Local variables are allocated when entering a function and de-allocated upon its exit.

Malloc

Allocate space dynamically and flexibly:

- malloc: allocate storage of a given size
- free: de-allocate previously malloc-ed storage

```
void *malloc(size_t size);
```

A void pointer is a pointer that has no associated data type with it. A void pointer can hold address of any type and can be casted to any type.

```
void free(void *ptr);
```

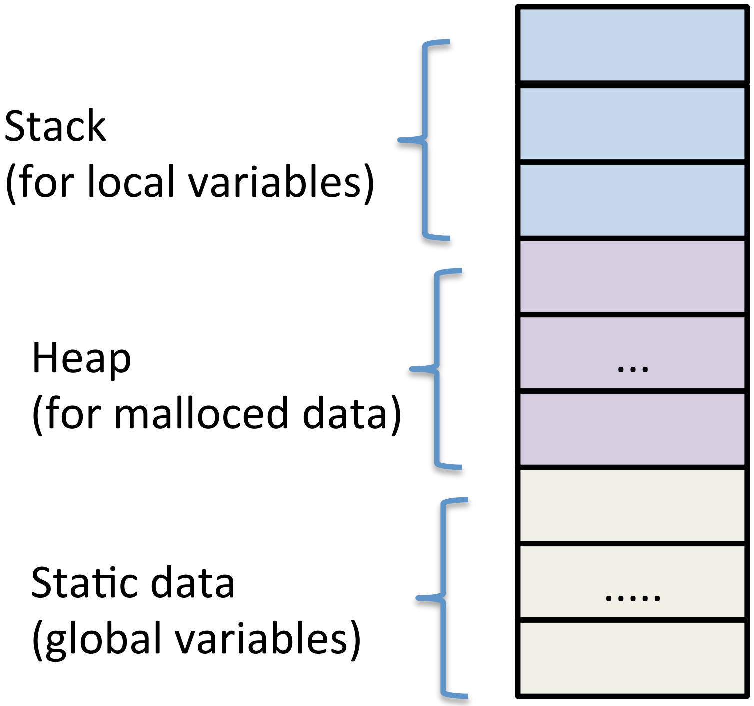
Malloc

Malloc is implemented as a C library

```
#include <stdlib.h>

int *newArray(int n) {
   int *p;
   p = (int*)malloc(sizeof(int) * n);
   return p;
}
```

Conceptual view of a C program’s memory at runtime

- Separate memory regions for global, local, and malloc-ed.



Stack
(for local variables)

Heap
(for malloced data)

...

Static data
(global variables)

.....

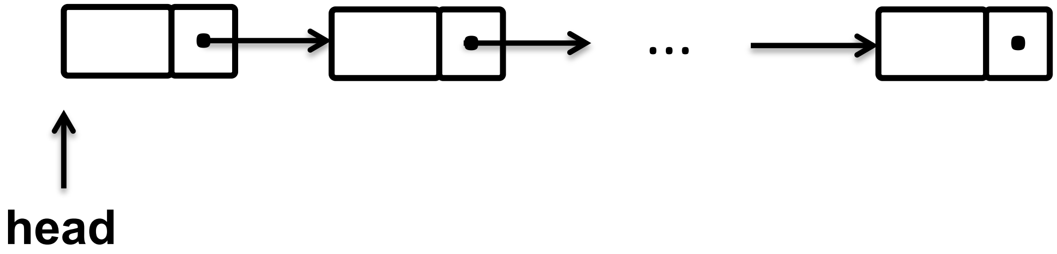
We will refine this simple view in later lectures

Linked list in C: insertion

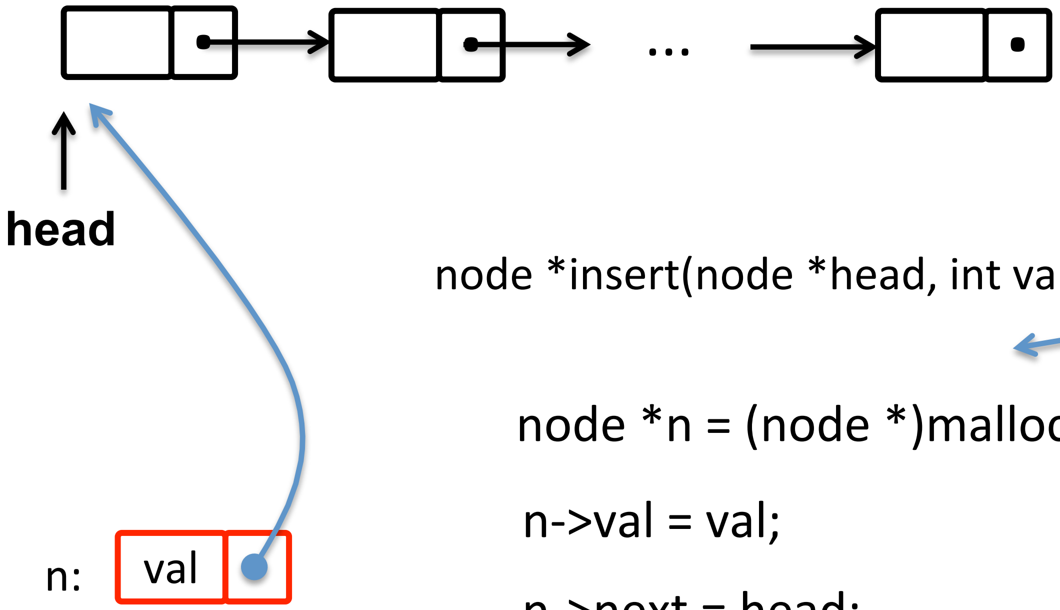
```
typedef struct {
     int val;
     struct node *next;
 }node;

// insert val into linked list to the head
// of the linked list and return the new
// head of the list.
node*
insert(node *head, int val) {

}

int main() {
    node *head = NULL;
    for (int i = 0; i < 3; i++)
       head = insert(head, i);
}
```

* this linked list implementation is different from Lab1

Inserting into a linked list



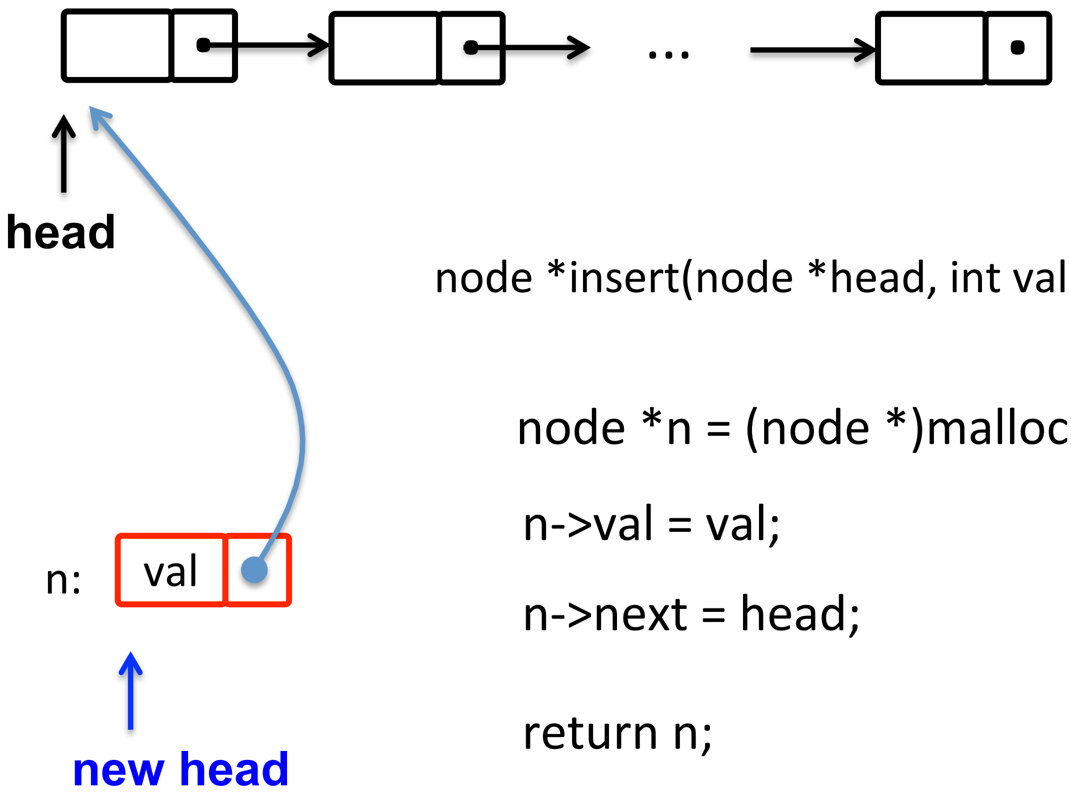
Inserting into a linked list



```
node *insert(node *head, int val) {

    node *n = (node *)malloc(sizeof(node));

    n->val = val;

    n->next = head;



}
```

```
node nn;
node *n = &nn;
```

Inserting into a linked list



```
node *insert(node *head, int val) {

    node *n = (node *)malloc(sizeof(node));
    n->val = val;
    n->next = head;

    return n;

}
```

2D Arrray

2D arrays are stored contiguously in memory in row-major format

Multi-dimensional arrays

Declare a `k` dimensional array

`int arr`$[n_1][n_2][n_3]\ldots[n_{k-1}][n_k]$

n_i is the length of the `i`th dimension

Multi-dimensional arrays

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Example: 2D array

int matrix[2][3]

Multi-dimensional arrays

Declare a k dimensional array

int arr$[n_1][n_2][n_3]\ldots[n_{k-1}][n_k]$

n_i is the length of the ith dimension

Example: 2D array

int matrix[2][3]

	Col 0	Col 1	Col 2
Row 0			
Row 1			

Multi-dimensional arrays

Declare a k dimensional array

int arr[n_1][n_2][n_3]…[n_{k-1}][n_k]

n_i is the length of the ith dimension

Example: 2D array

int matrix[2][3] = {{1, 2, 3}, {4, 5, 6}};

	Col 0	Col 1	Col 2
Row 0	1	2	3
Row 1	4	5	6

Multi-dimensional arrays

Declare a k dimensional array

int arr[n_1][n_2][n_3]…[n_{k-1}][n_k]

n_i is the length of the ith dimension

Example: 2D array

int matrix[2][3] = {{1, 2, 3}, {4, 5, 6}};

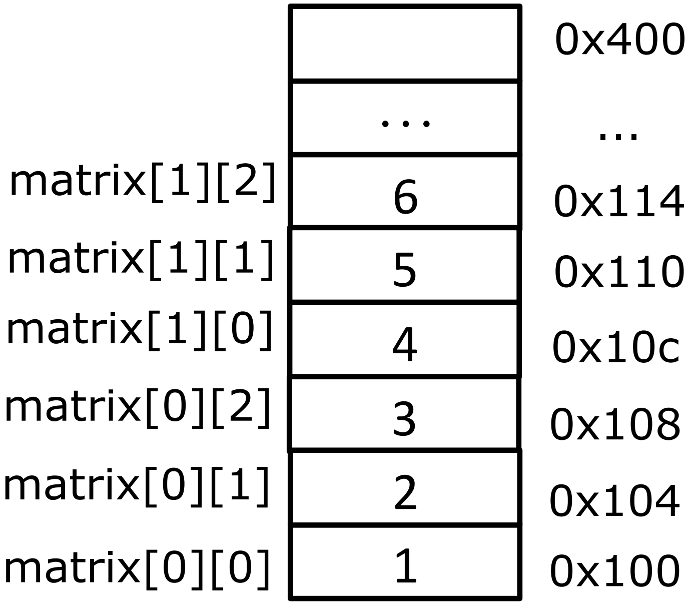
Access an element at second row and third column

matrix[1][2] = 10

Memory layout

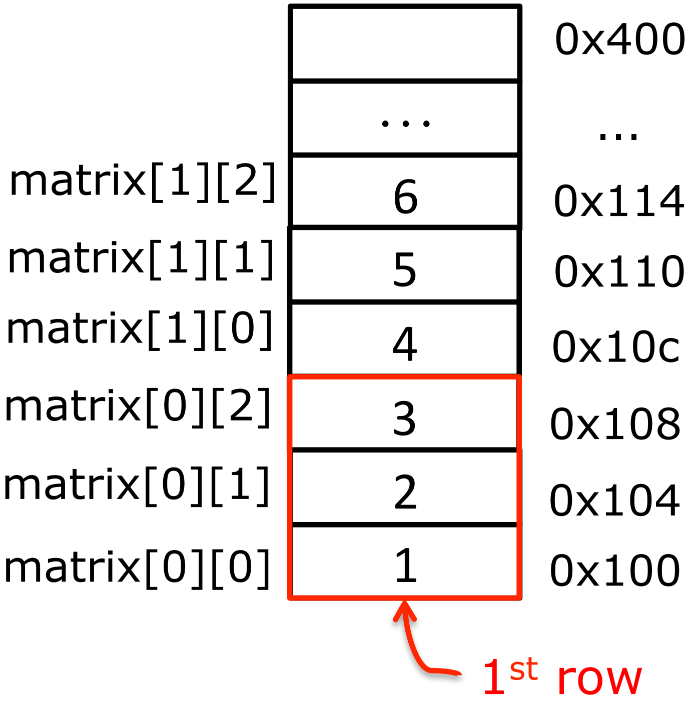
```
int matrix[2][3] = {{1, 2, 3}, {4, 5, 6}};

for (int i = 0; i < 2; i++) {

    for (int j = 0; j < 3; j++) {

        printf(“%p\n”,&matrix[i][j]);

    }
}
```

Memory layout



		0x400
	...	...
matrix[1][2]	6	0x114
matrix[1][1]	5	0x110
matrix[1][0]	4	0x10c
matrix[0][2]	3	0x108
matrix[0][1]	2	0x104
matrix[0][0]	1	0x100

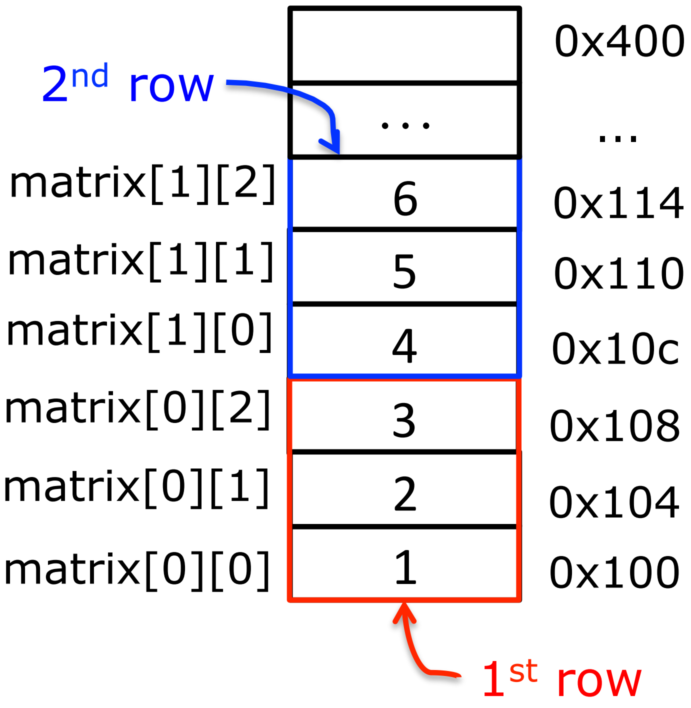
Memory layout



		0x400
	. . .	...
matrix[1][2]	6	0x114
matrix[1][1]	5	0x110
matrix[1][0]	4	0x10c
matrix[0][2]	3	0x108
matrix[0][1]	2	0x104
matrix[0][0]	1	0x100

1st row

Memory layout

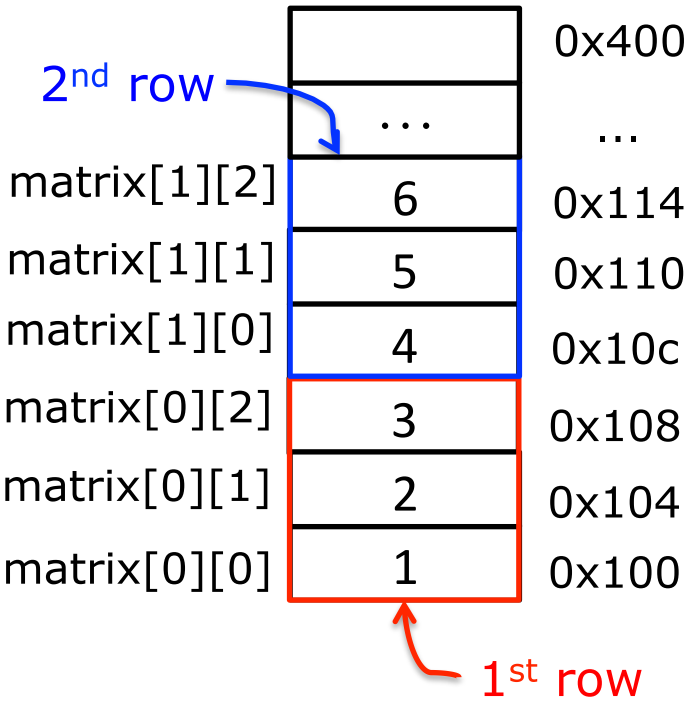


		0x400
	. . .	...
matrix[1][2]	6	0x114
matrix[1][1]	5	0x110
matrix[1][0]	4	0x10c
matrix[0][2]	3	0x108
matrix[0][1]	2	0x104
matrix[0][0]	1	0x100

2nd row

1st row

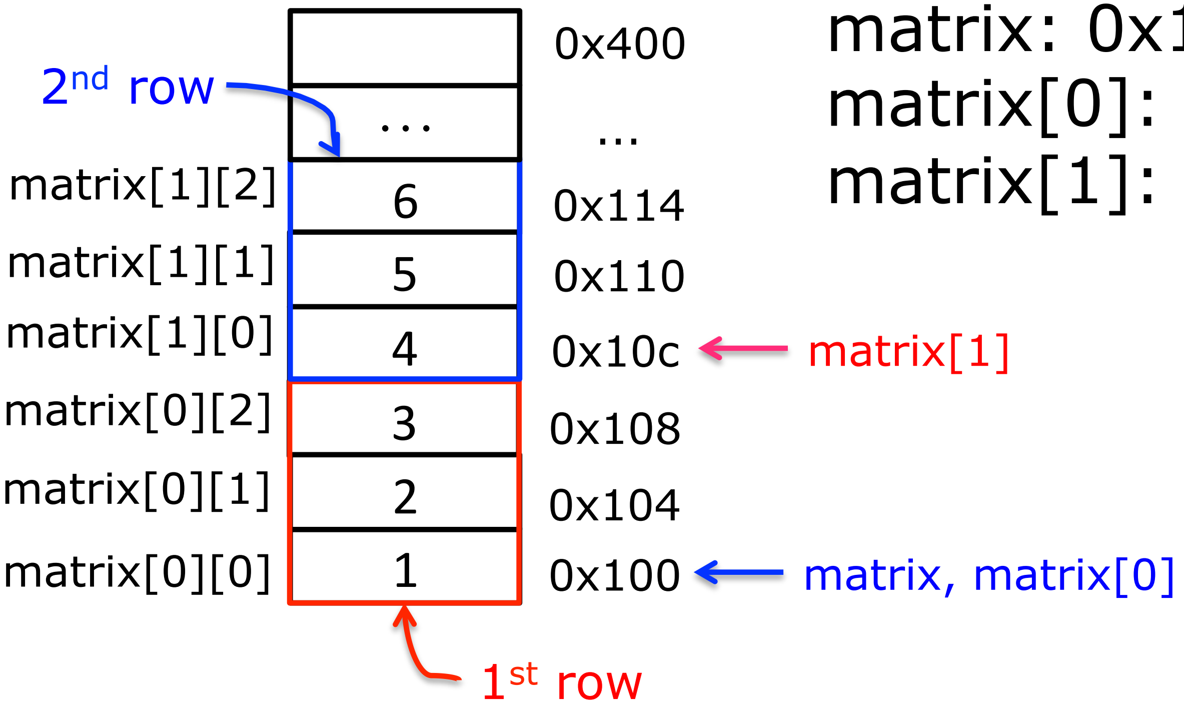
Pointers



What are the values of matrix, matrix[0] and matrix[1]?

```
int *p1, *p2, *p3;
p1 = (int *)matrix;
p2 = matrix[0];
p3 = matrix[1];

printf(“matrix:%p matrix[0]:%p\
matrix[1]:%p\n”, p1, p2, p3);
```

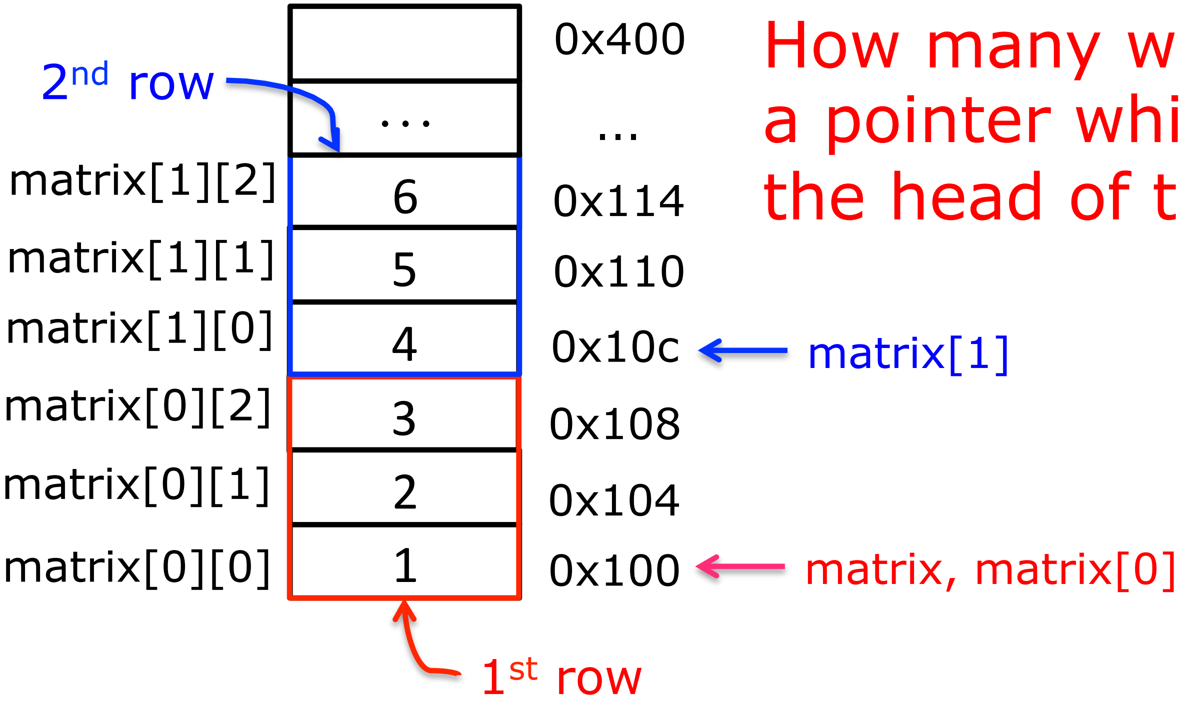
Pointers



matrix: 0x100
matrix[0]: 0x100
matrix[1]: 0x10c

Pointers

How many ways to define a pointer which points to the head of the array?



2nd row

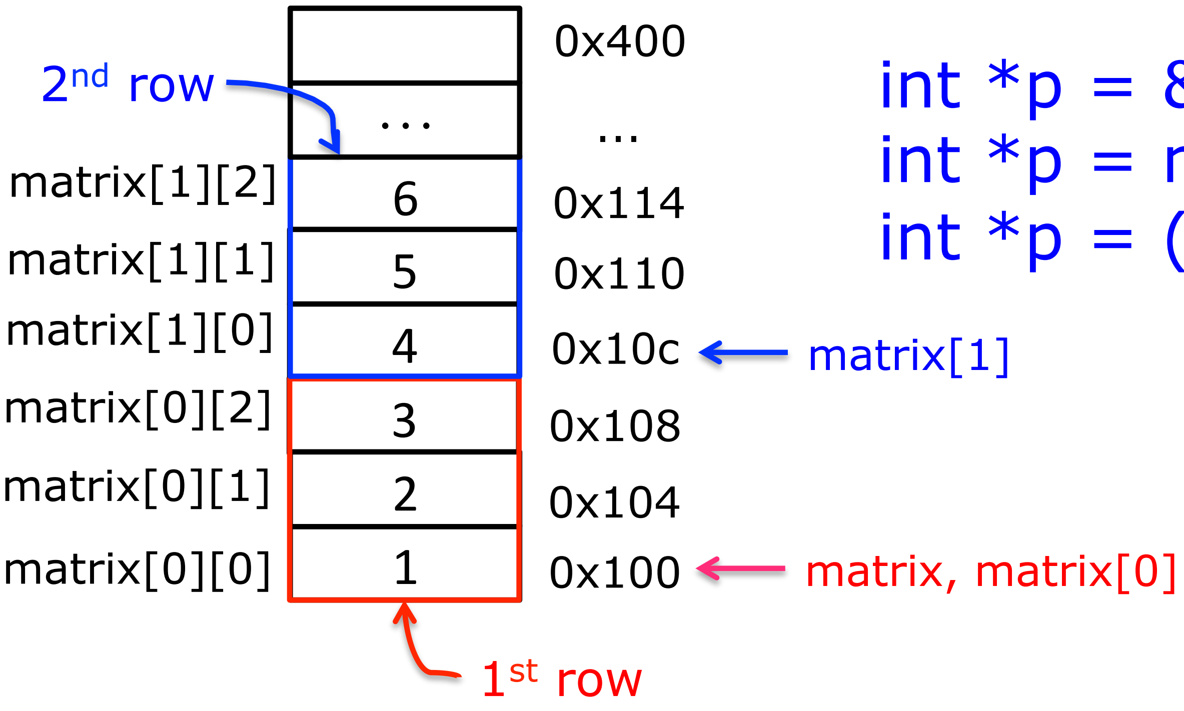
		0x400
	…	…
matrix[1][2]	6	0x114
matrix[1][1]	5	0x110
matrix[1][0]	4	0x10c
matrix[0][2]	3	0x108
matrix[0][1]	2	0x104
matrix[0][0]	1	0x100

matrix[1]

matrix, matrix[0]

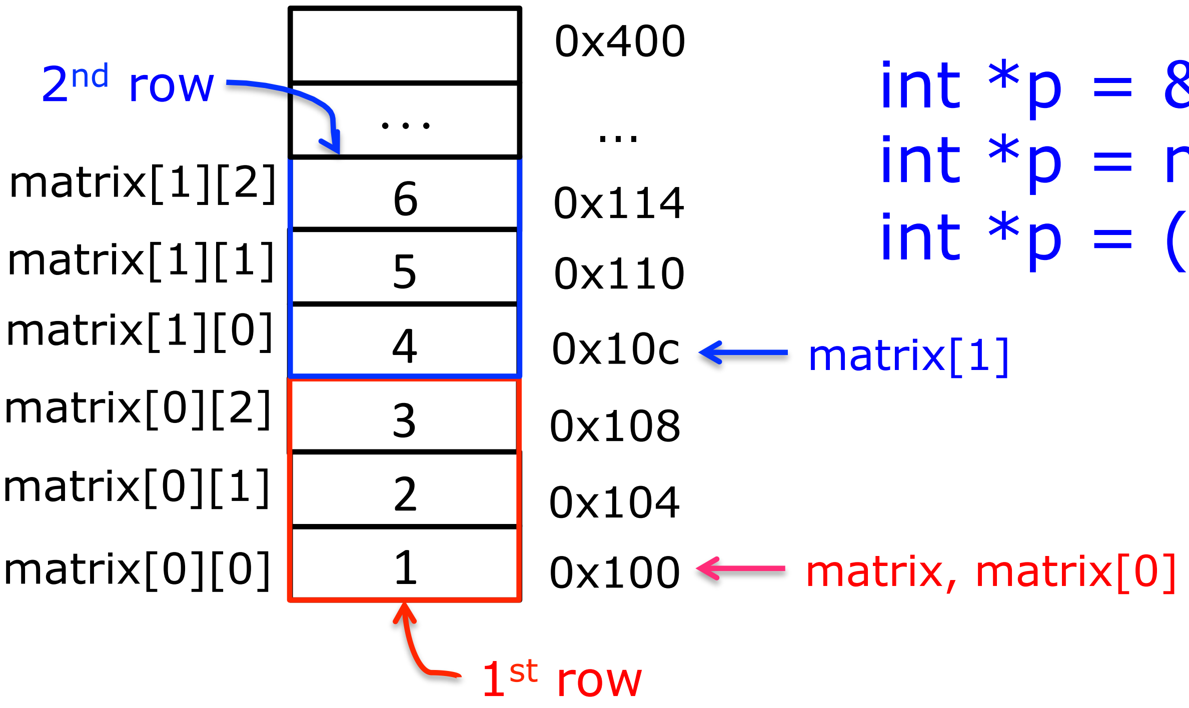
1st row

Pointers



```
int *p = &matrix[0][0];
int *p = matrix[0];
int *p = (int *)matrix;
```

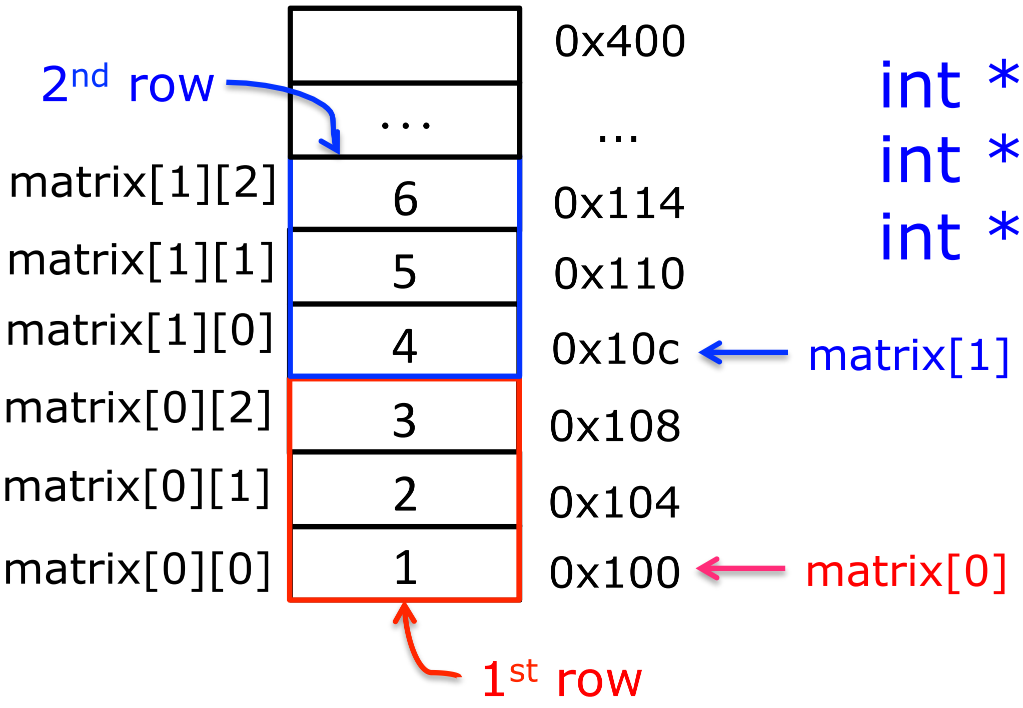
Pointers



```
int *p = &matrix[0][0];
int *p = matrix[0];
int *p = (int *)matrix;
```

How to access matrix[1][0] with p?

Pointers



```
int *p = &matrix[0][0];
int *p = matrix[0];
int *p = (int *)matrix;
```

```
matrix[1][0]: *(p + 3)
              p[3]
```

A general question

Given a 2D array matrix[m][n] and a pointer p which points to matrix[0][0], how to use p to access matrix[i][j]?

A general question

Given a 2D array matrix[m][n] and a pointer p which points to matrix[0][0], how to use p to access matrix[i][j]?

address of matrix[i][j]: p + i * n + j

Accessing 2D array using pointer

```
int matrix[2][3] = {{1, 2, 3}, {4, 5, 6}};
```

```
for (int i = 0; i < 2; i++) {
    for (int j = 0; j < 3; j++) {
        printf(“%d\n”, matrix[i][j]);
    }
}
```

OR

```
int *p = matrix[0]; // or int *p = (int *)matrix;
for (int i = 0; i < 2*3; i++) {
    printf(“%d\n”, p[i]);
}
```