ECE 220

Lecture x0010 - 03/19/24
Dynamic Memory Allocation

Slides based on material originally by: Yuting Chen & Thomas Moon

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Announcements

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  - Deadline is **03/22**

Recap

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    - Streams, buffers, queue (FIFO)

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  - Examples

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  A. write struct to file

  B. load struct from file

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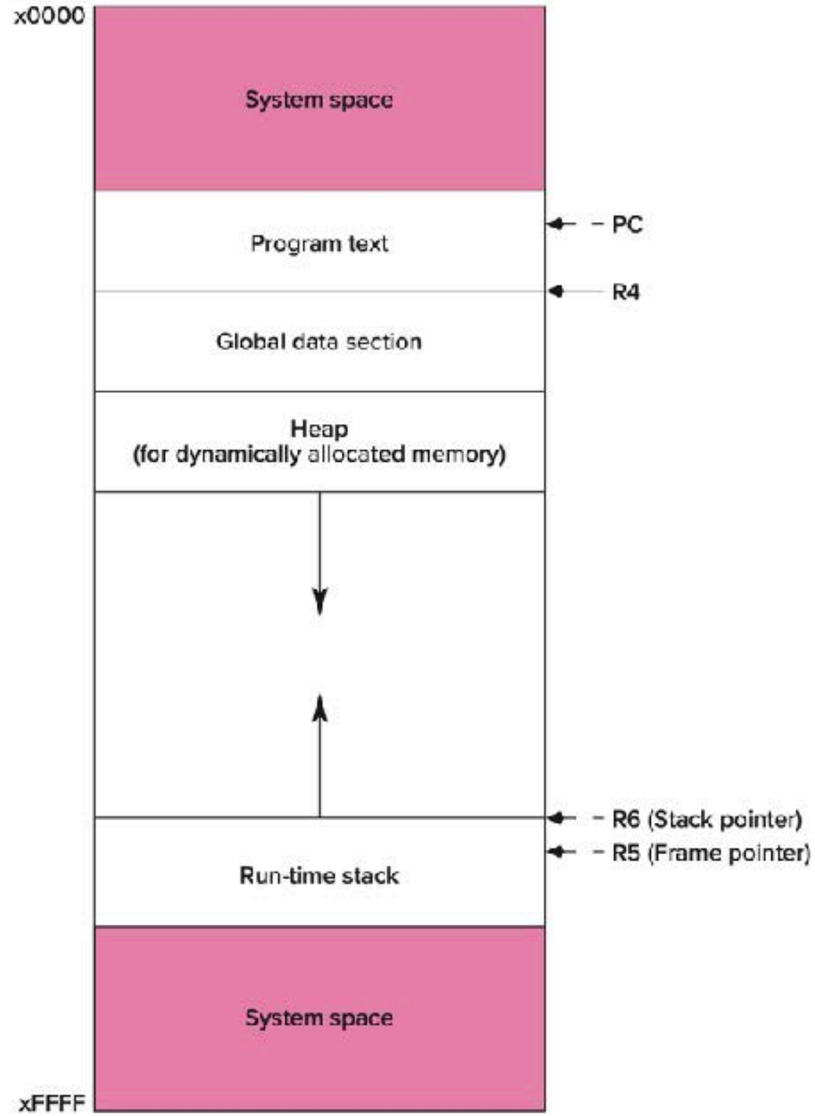
  - If usually only ~10 flights, then memory is wasted.
  - If we read in a large file >50 then not enough memory is allocated.
- Ideally, we want to allocate as much memory as needed rather than a pre-set amount.
- In most cases, this memory comes from an area of the architecture called the *heap*.

Dynamic memory allocation

- During the execution, a program makes a request to the memory allocator for a contiguous piece of memory of a particular size



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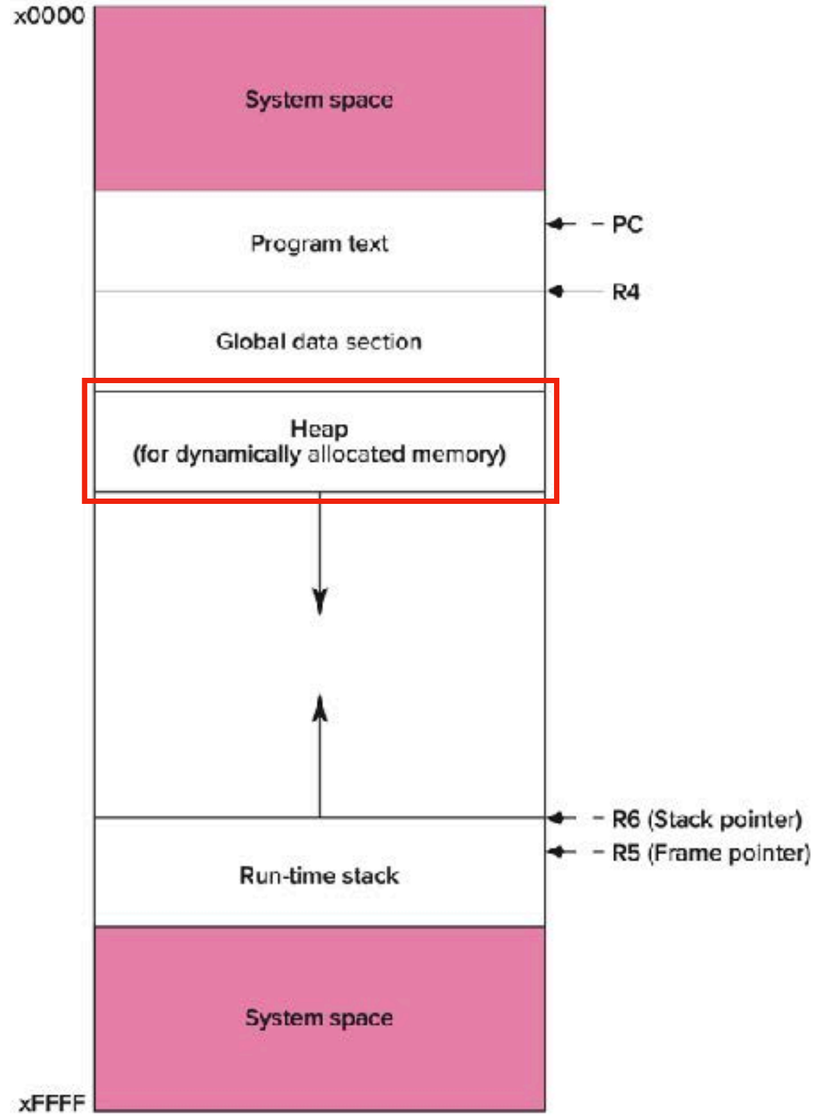
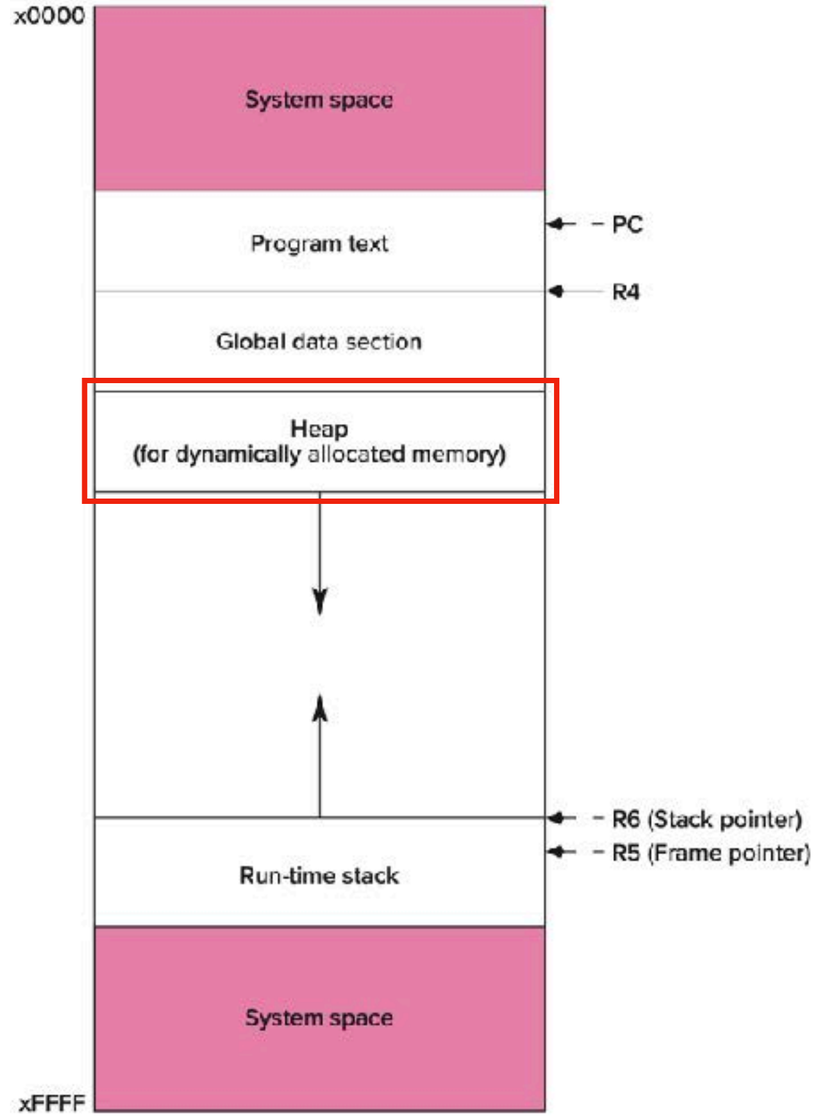


Dynamic memory allocation

- During the execution, a program makes a request to the memory allocator for a contiguous piece of memory of a particular size
- The allocator reserves the memory and returns a pointer to it. We interact with the memory allocation manager by using *malloc* family & *free* functions.



Automatic vs dynamic memory

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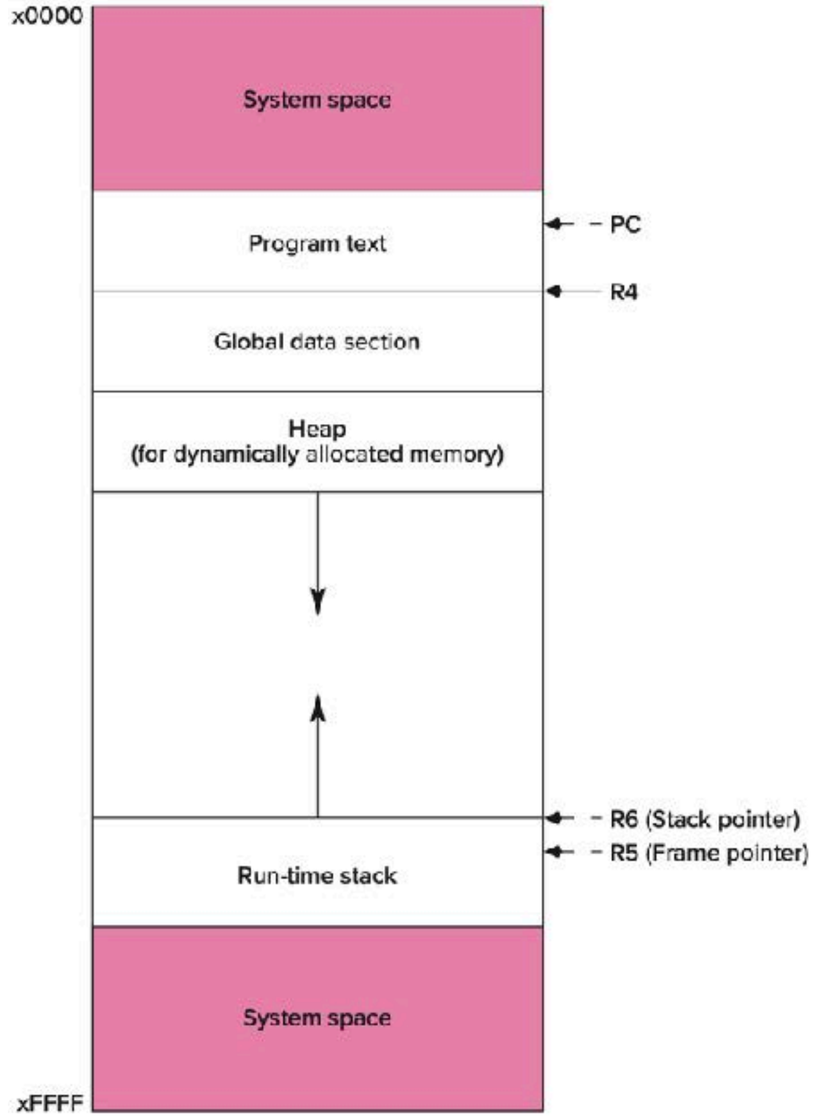

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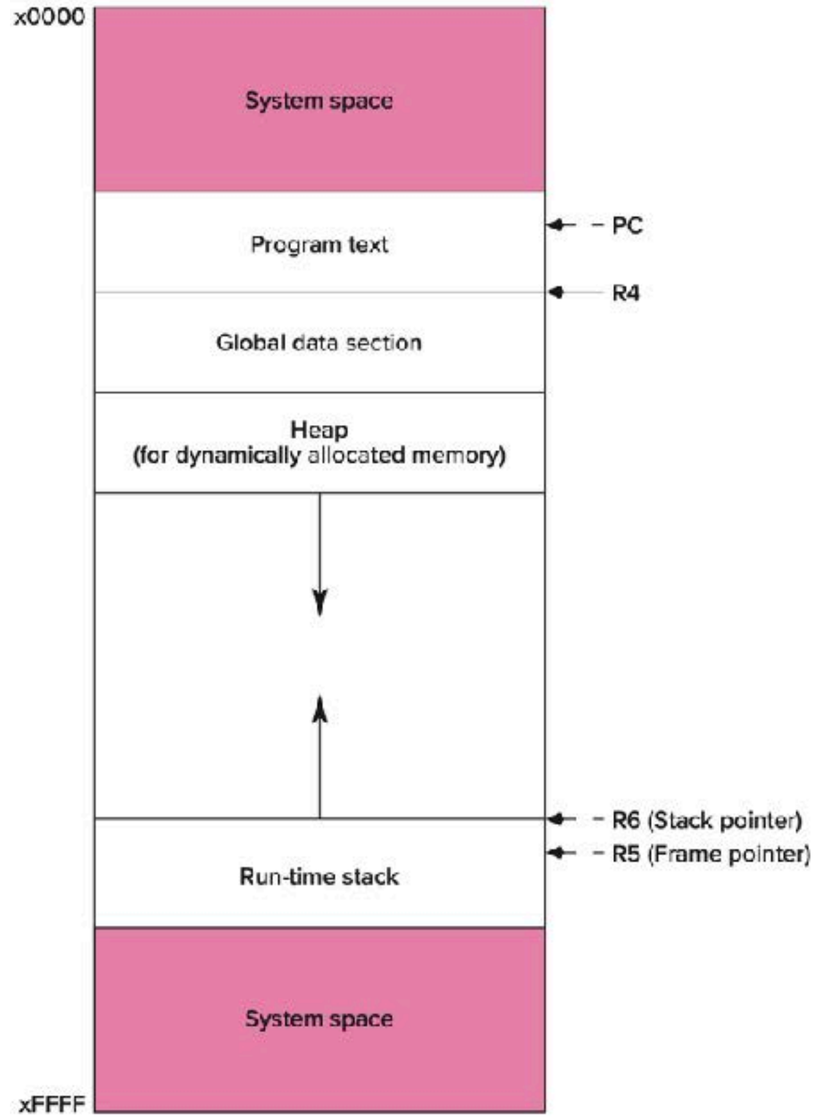

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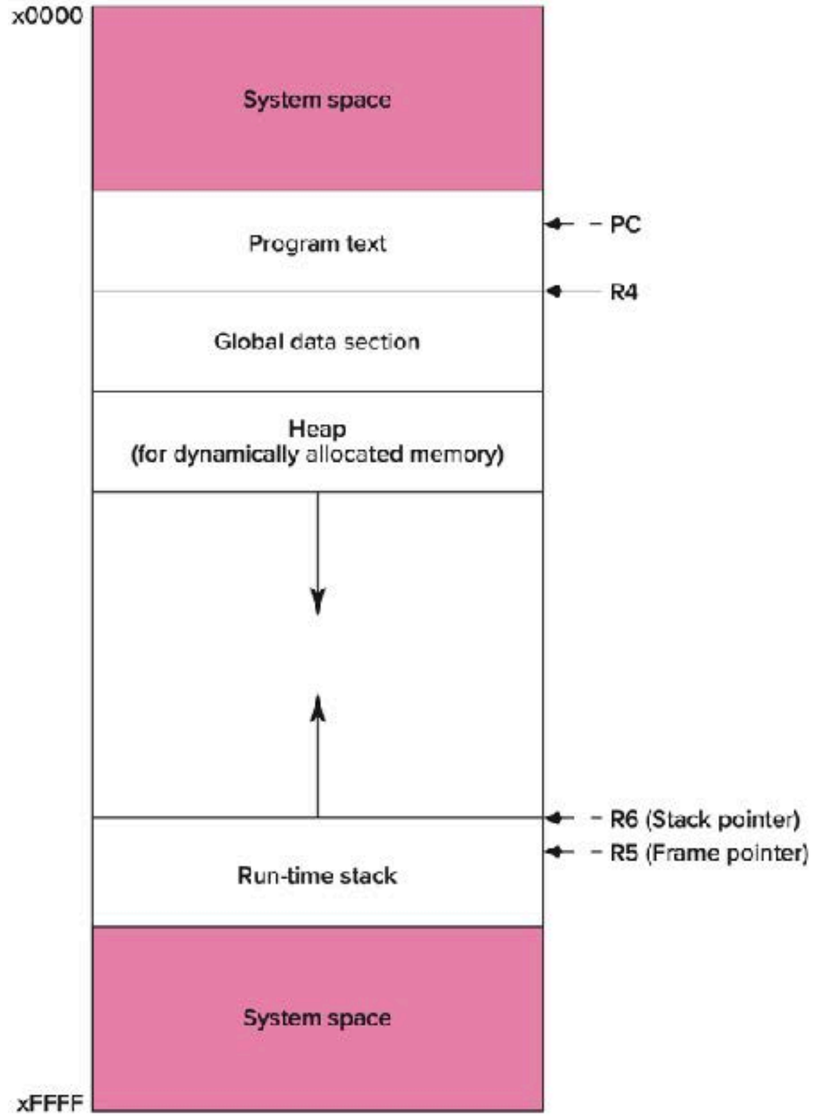

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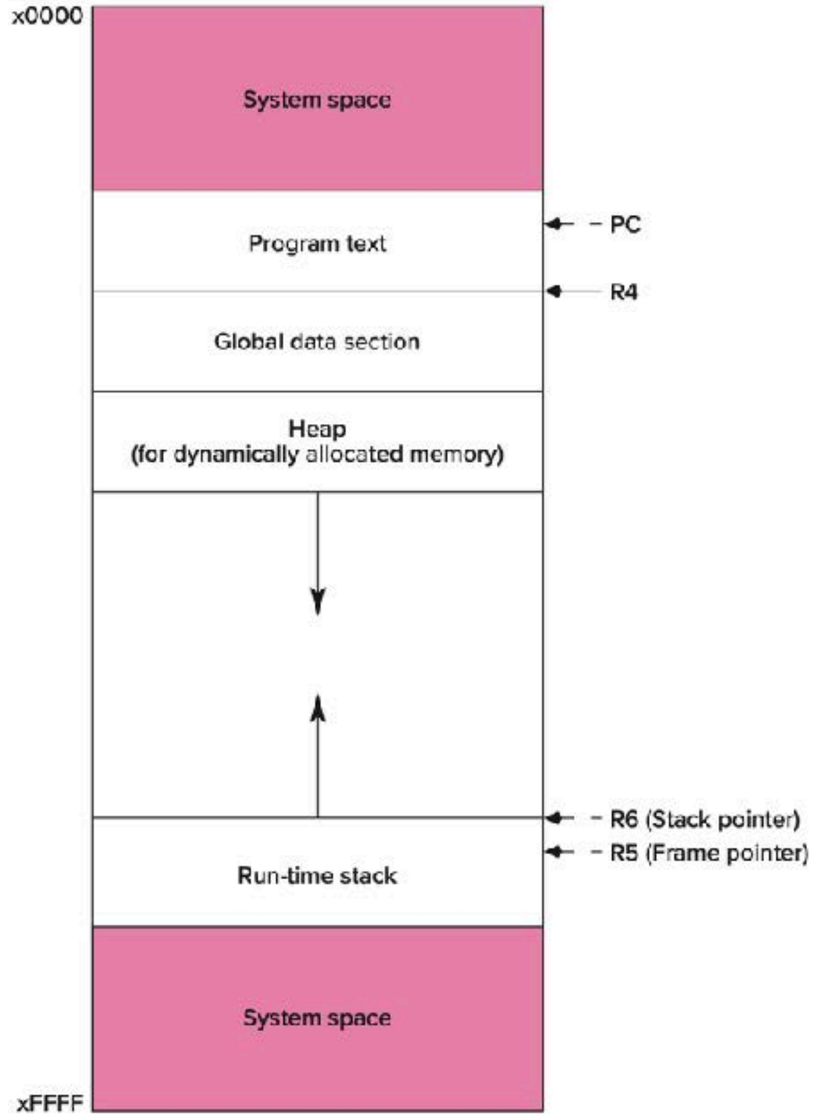

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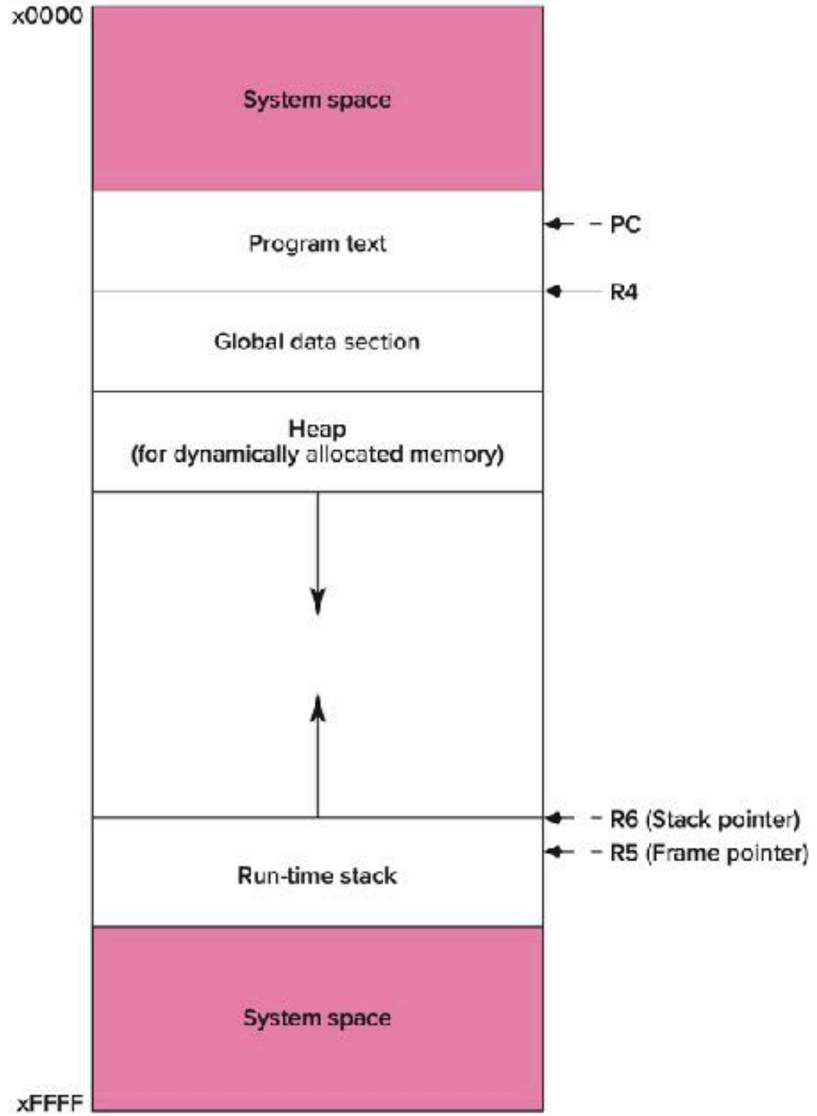

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Juxtaposition with *(int *) casts* the *void* pointer as an *int* pointer

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- Use `valgrind` to check for memory leaks

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- Identical to `malloc`, except `calloc` initializes memory to zero.

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  - If `size` is 0 and `ptr` is not NULL, same as `free`
  - `ptr` must have been returned by the `malloc` family

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- Why: recall C is *statically* typed; so compiler needs to know what type to assign to allocated memory locations.

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- Types can be built-in or user-defined.

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Didn’t free memory allocated!

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```c
int *ptr;
int *ptr_new;

// What does this code do?
ptr = (int *) calloc(2, sizeof(int));
*ptr = 10;

// What is the contents of memory now?
ptr_new = (int *) realloc(ptr, 4*sizeof(int));
*(ptr_new+2) = 30;
*(ptr_new+3) = 40;

// How much memory are we deallocating here?
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Do we need `free(ptr)`?

Allocating 2D arrays

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```
FILE *infile = fopen("mat.csv", "r");
int nr, nc;
fscanf(infile, "%d, %d", &nr, &nc);
int *mat = (int *) malloc(sizeof(int)*nr*nc);

for (int i=0; i < nr; i++)
  for (int j=0; j< nc; j++)
    fscanf(infile, "%d, ", &mat[i*nc+j]);

fclose(infile);
```

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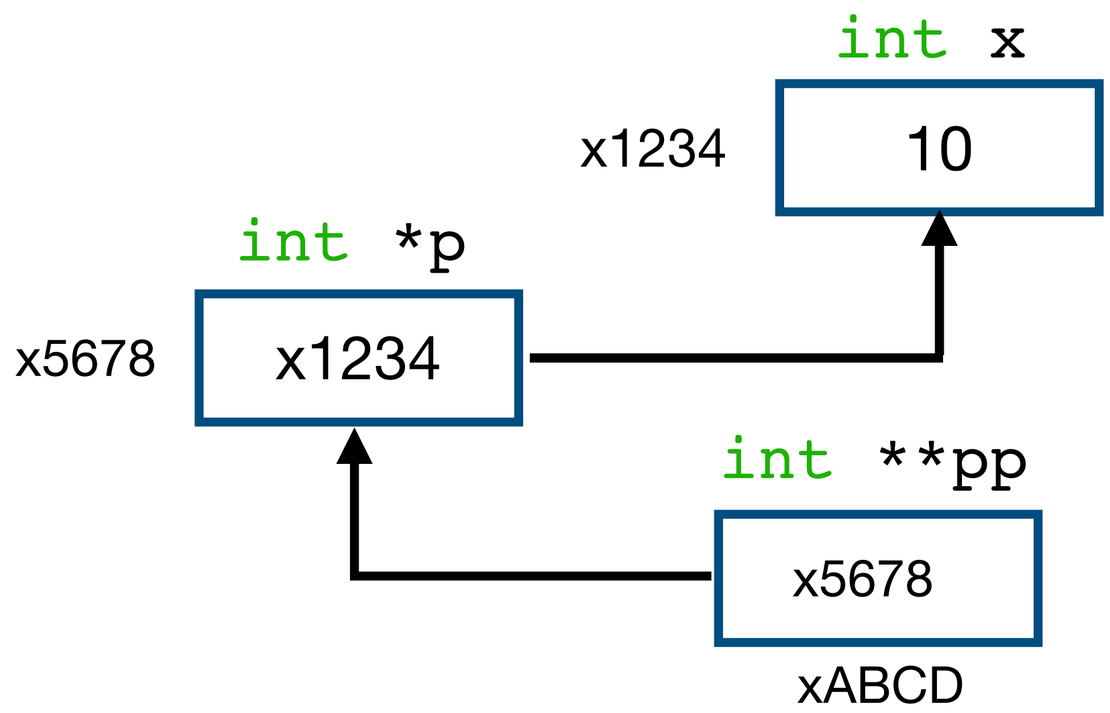

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array = (int**) malloc(nrows*sizeof(int*));
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  array[i] = (int*) malloc(ncols*sizeof(int));
array[0][0] = 3;
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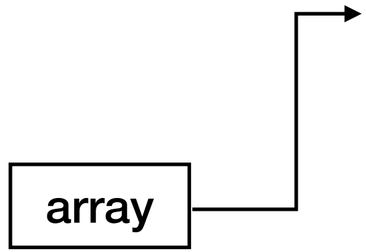

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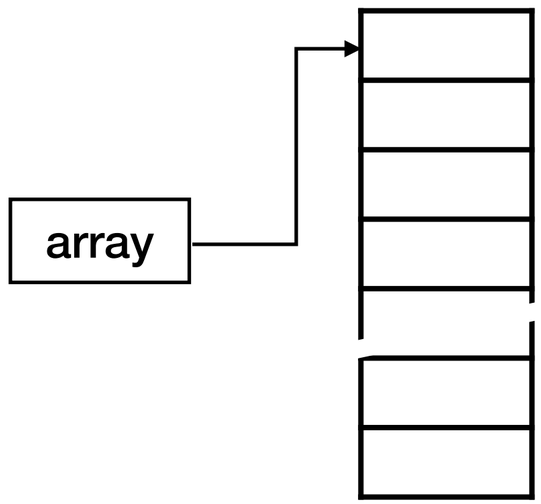

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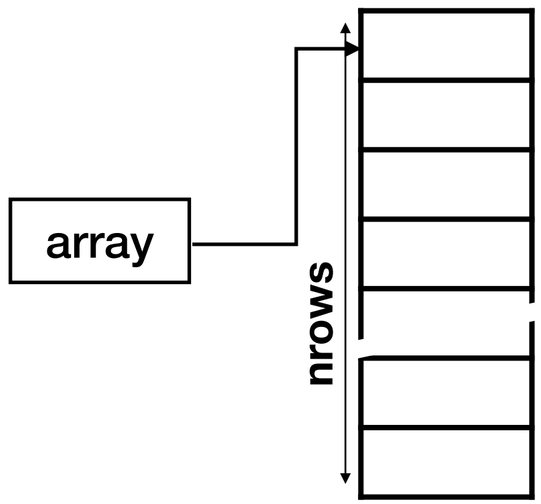

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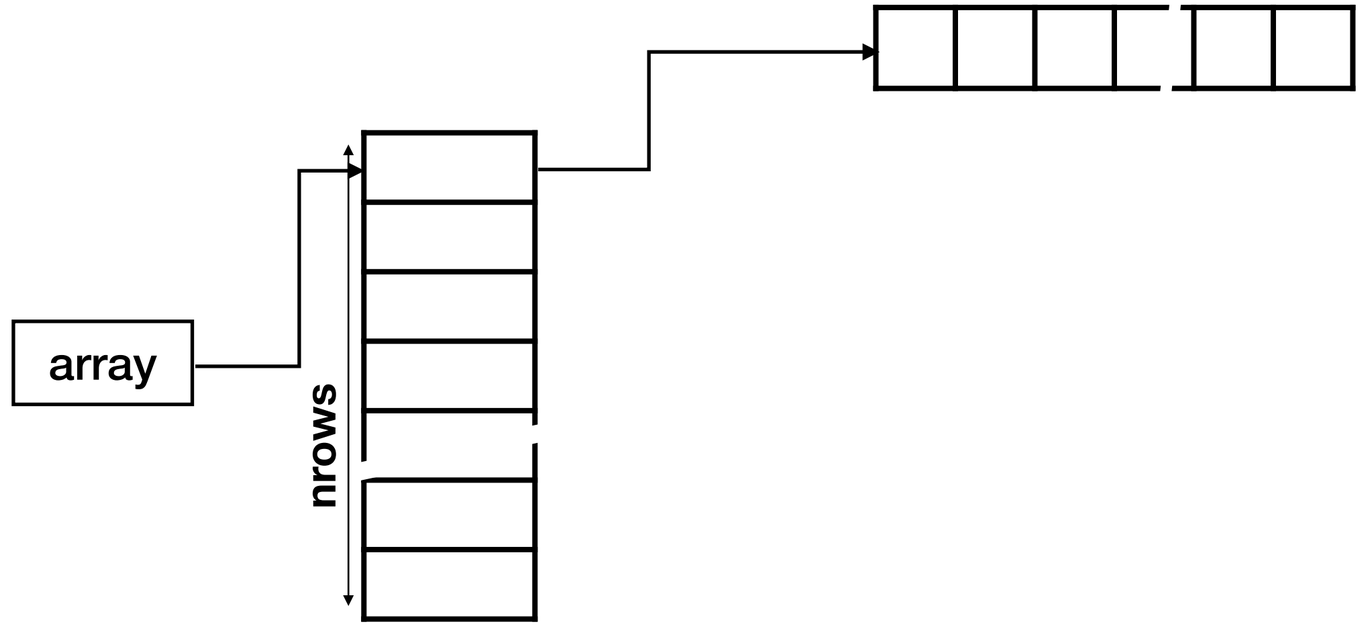

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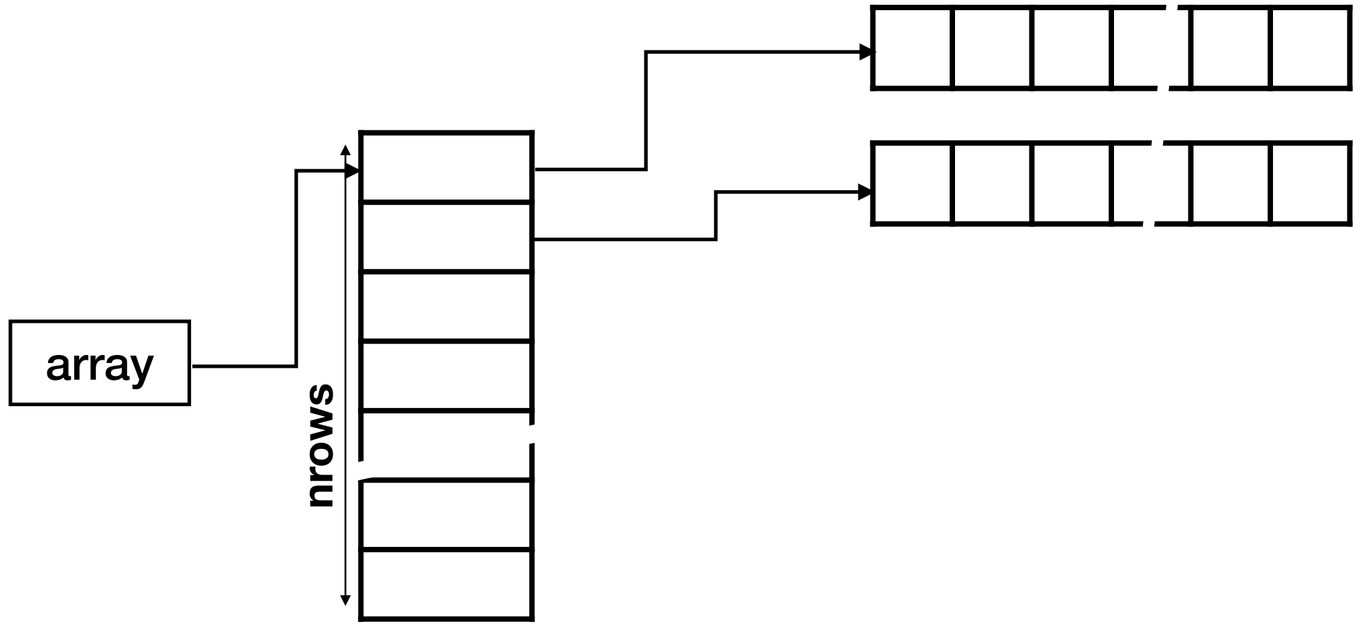

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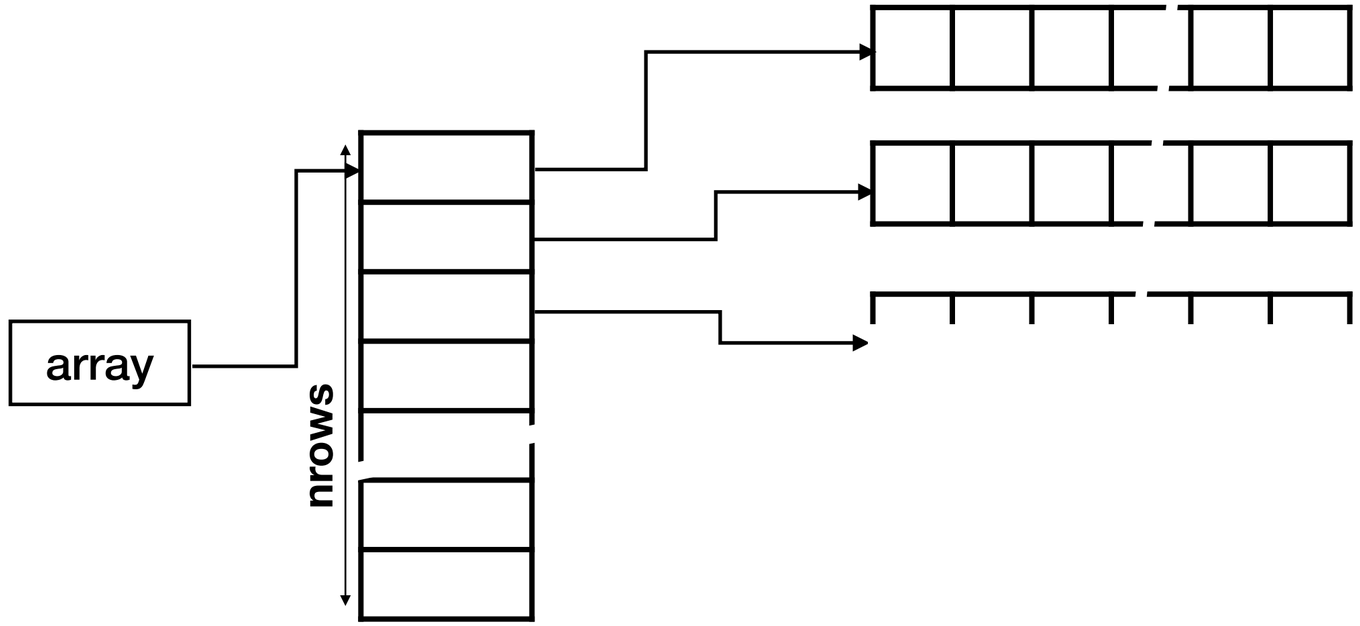

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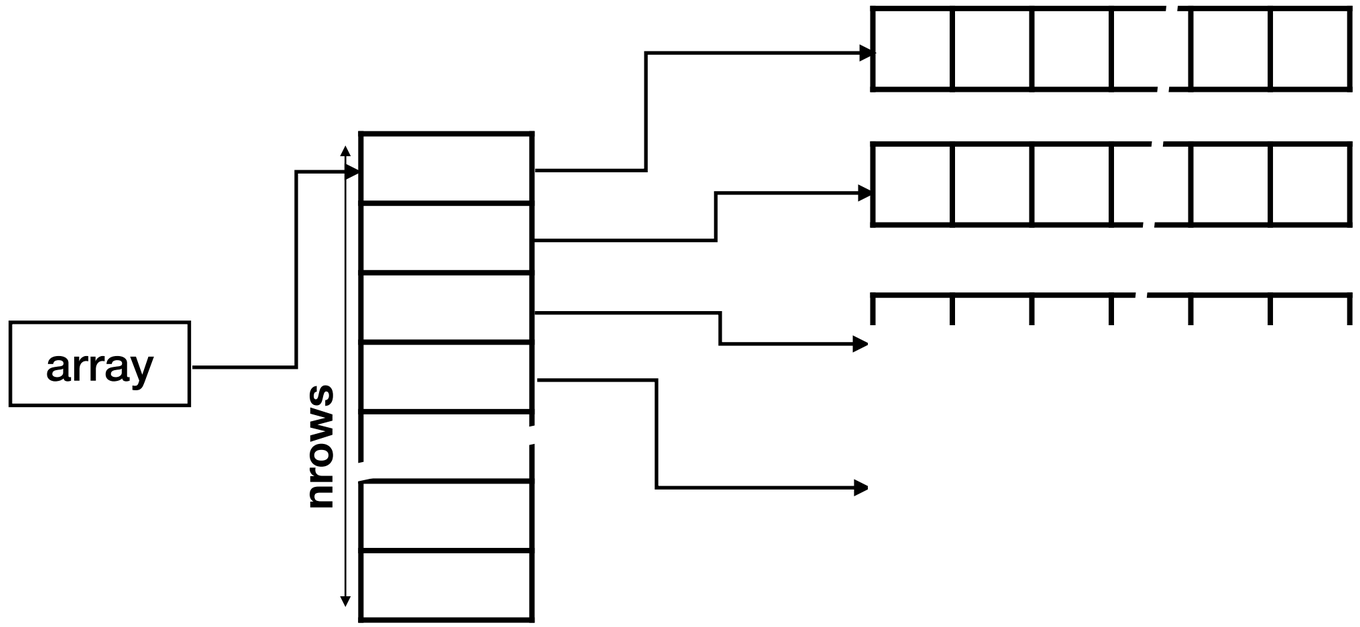

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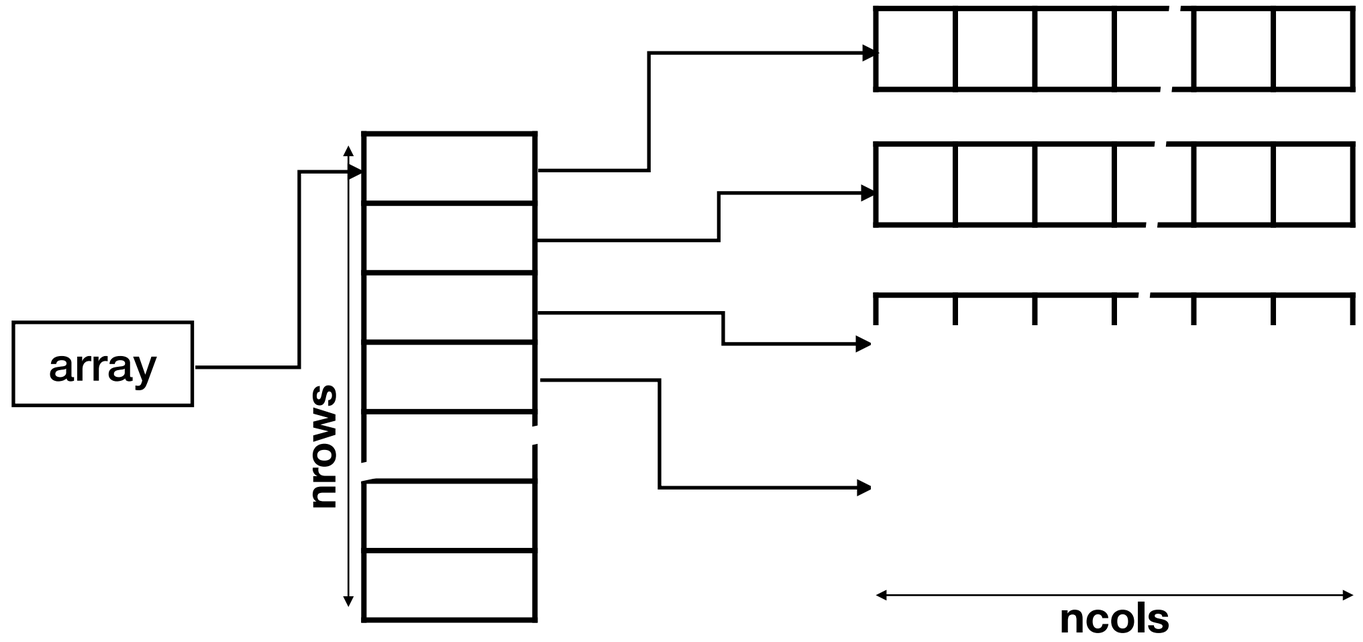

Pointer to pointer - caveat

- How do you **deallocate** a 2D array?
  - Method 1: Free the single pointer: `int * mat`
  - Method 2: Need to free ***each*** pointer separately!!
    - **Not** enough to free the top level pointer `(int **array)`
      - Unless made free, lower level pointers `(int *)` will leak memory!

Exercise

- Use this second method of memory allocation for 2D arrays to read in a given file (`matrix.csv`) and print out its transpose.

- The first row of the file lists the number of rows and columns of the matrix.

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```
void fun(int n)
{
 int arr[n];
 /* More code follows
 ...
 ...
 */
}
int main()
{
   fun(6);
}
```

Example with *valgrind*

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- Get on to EWS. Compile the standard way. Then run:

```
> valgrind ./a.out
```

- Can you figure out where the leaks are?

Example with *valgrind*

```c
#include <stdio.h>
#include <stdlib.h>

int main(void){
  char *p;

  /* Allocation #1 of 19 bytes */
  p = (char *) malloc(19);

  /* Allocation #2 of 12 bytes */
  p = (char *) malloc(12);
  free(p);

  /* Allocation #3 of 16 bytes */
  p = (char *) malloc(16);

  return 0;
}
```

- Get on to EWS. Compile the standard way. Then run:

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Flight * nth_flight(char *filename, int num_total, int N)
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- Make sure to free memory!

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- So far our use of `malloc` has been to load records or data from a file
- Thus we no longer have to know the sizes at compile time
- Nevertheless `realloc/malloc/free` is cumbersome to keep using
- Need a data structure that takes care of this automatically - enter *linked-lists*.

Time permitting - *key idea*

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- Basic idea of a linked list:

```
typedef struct node{
  char *name;
  struct node * next;
}node;
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```

- Definition is *recursive*; a node is either
  - *NULL* or
  - Contains a reference to another node