Malloc, Structs, Queue Lab

void Pointer

- “A pointer that has no associated data type with it.”

- Can point to the address of a variable of any data type and can be type-casted to the any type

https://www.youtube.com/watch?v=ij2jrsUmwCI

Example

```
int main()
{
        int a = 10;
        char b = 'A';

        void *p = &a;
        p = &b;
        return 0;
}
```

This is allowed. Code will compile and run successfully!

Exercise 1 – What is the output?

```
int main()
{
        int a = 10;
        char b = 'A';

        void *p = &a;
        p = &b;
        printf("Address : %p\n", p);   //Address : 0x56F......
        return 0;
}
```

Address of variable b

Exercise 2 – What is the output?

```
int main()
{
        int a = 10;
        char b = 'A';

        void *p = &a;
        p = &b;
        printf(“Value : %c\n", *p);  //Compilation error
        return 0;
}
```

Exercise 2 - Solution

- **Typecast** the void pointer to the type of pointer whose value you are trying to print.

```
int main()
{
        int a = 10;
        char b = 'A';

        void *p = &a;
        p = &b;
        printf(“Value : %c\n", *(char*)p); //Value : A
       return 0;
}
```

Why do we need malloc()?

- To be able to allocate space in runtime (or dynamically).
- Example: You do NOT know the size of an array and require user input to determine it.
  - This means size of the array is determined at run time
  - Space has to be allocated in run time (or dynamically!)
    - Time to use malloc()

malloc(size in Bytes)

Why is the return type of malloc() void*??

```
int* p = (int*) malloc (n * sizeof(int));
```

Return type of malloc() is void* , so we need to typecast it to the correct type (int* in this case)

Stores either:
1) Address of the 1st byte of the allocated space in memory, or
2) **NULL**, if the allocation fails.

Size in bytes of n integers

Revisiting Strings

- Dynamically allocate space for a string containing ‘n’ characters
  - Initialize the string to “CS449”
  - Modify the string to “CS44_”

```
char *p = (char*) malloc (sizeof(char) * (n + 1));

strcpy(p, “CS449”);

p[4] = ‘_’;
```

Why did we use strcpy() to initialize?

```
char *p = (char*) malloc (sizeof(char) * (n + 1));

p = “CS449”;

p[4] = ‘_’;

printf(“%s”, p);
```

Undefined behavior. Will result in segmentation fault most likely.

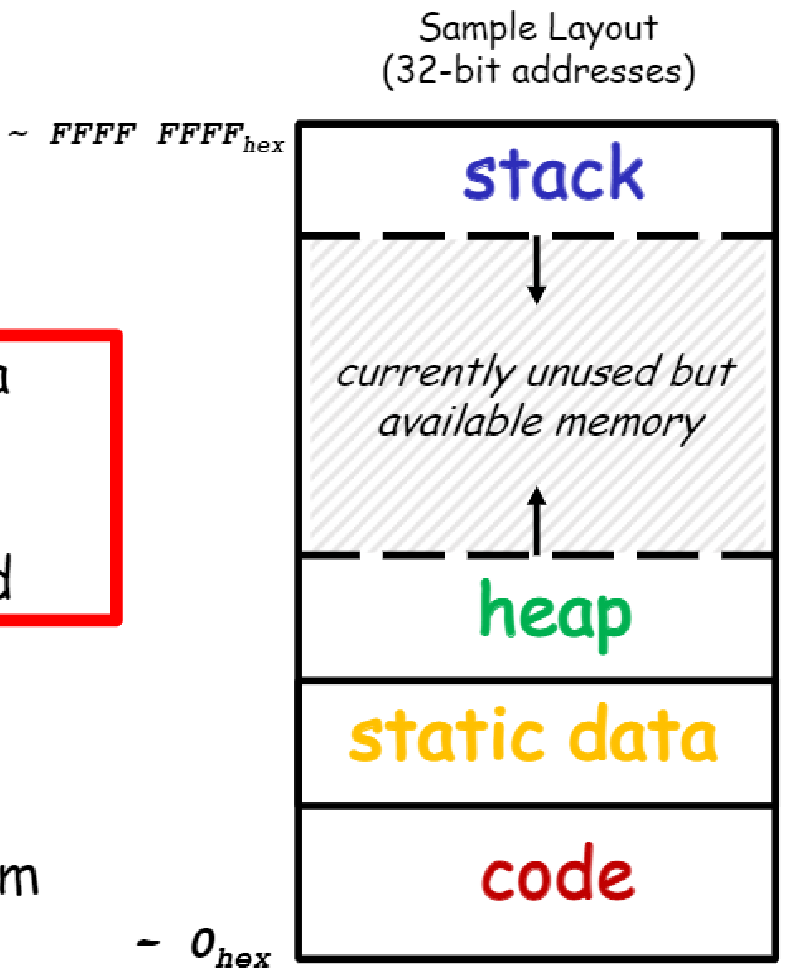
Use **strcpy()** to INITIALIZE a dynamically allocated string

Some Important Points

- malloc() does NOT **initialize** the dynamically allocated space.
  - calloc() initializes the allocated memory space to 0.
- Make sure to do conditional check on whether malloc returned **NULL**
- After you have finished using the dynamically allocated space using malloc, make sure that you **free** the space.

C Memory Layout

- Program's *address space* contains 4 regions:
  - Stack: local variables, grows downward
  - Heap: space requested via `malloc()` and used with pointers; resizes dynamically, grows upward
  - Static Data: global and static variables, does not grow or shrink
  - Code: loaded when program starts, does not change



Why do we need to free the allocated memory?

int *p = malloc(…)

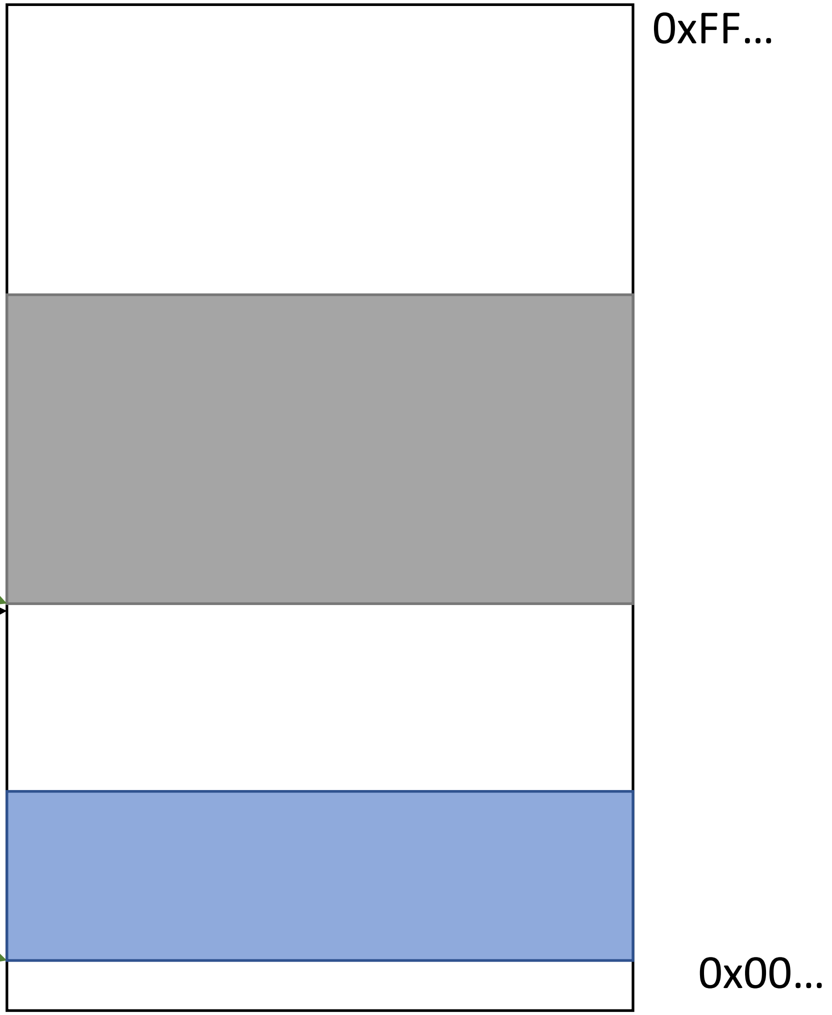
..

..

//work with the allocated space

..

int *q = malloc(…)



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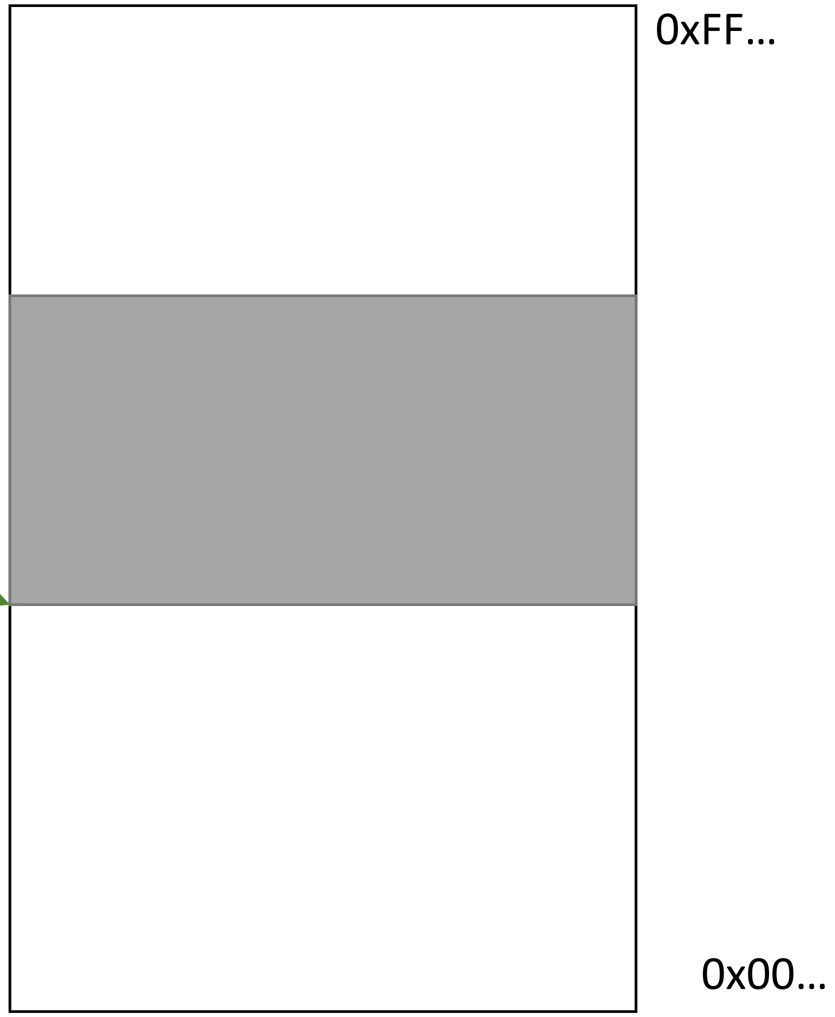
int *p = malloc(…)

..

//work with the allocated space

..



Why do we need to free the allocated memory?

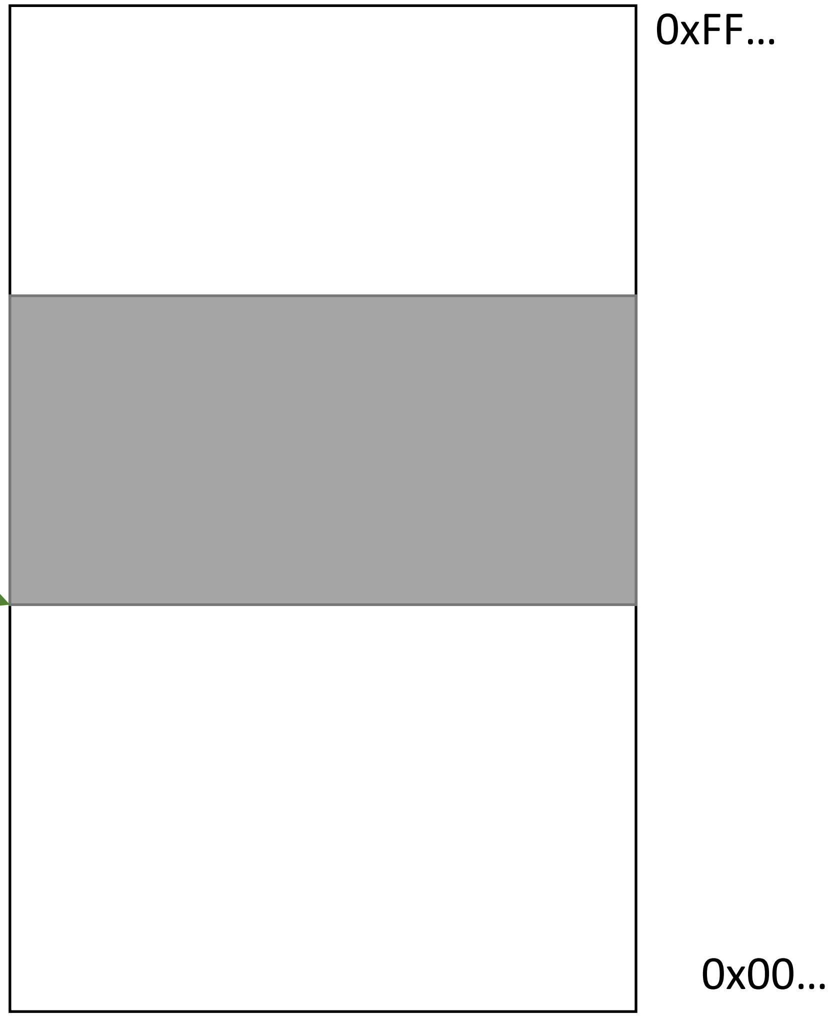
int *p = malloc(…)

..

//work with the allocated space

..

free(p);



Why do we need to free the allocated memory?

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int *p = malloc(…)
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//work with the allocated space
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free(p);
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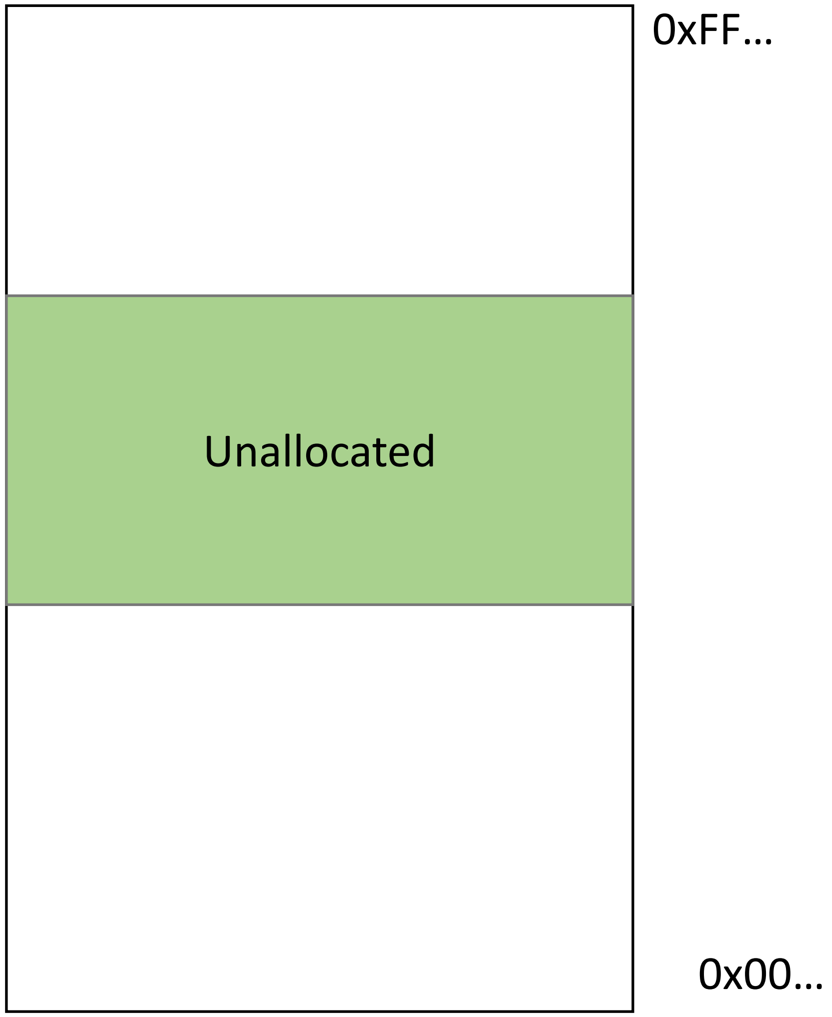
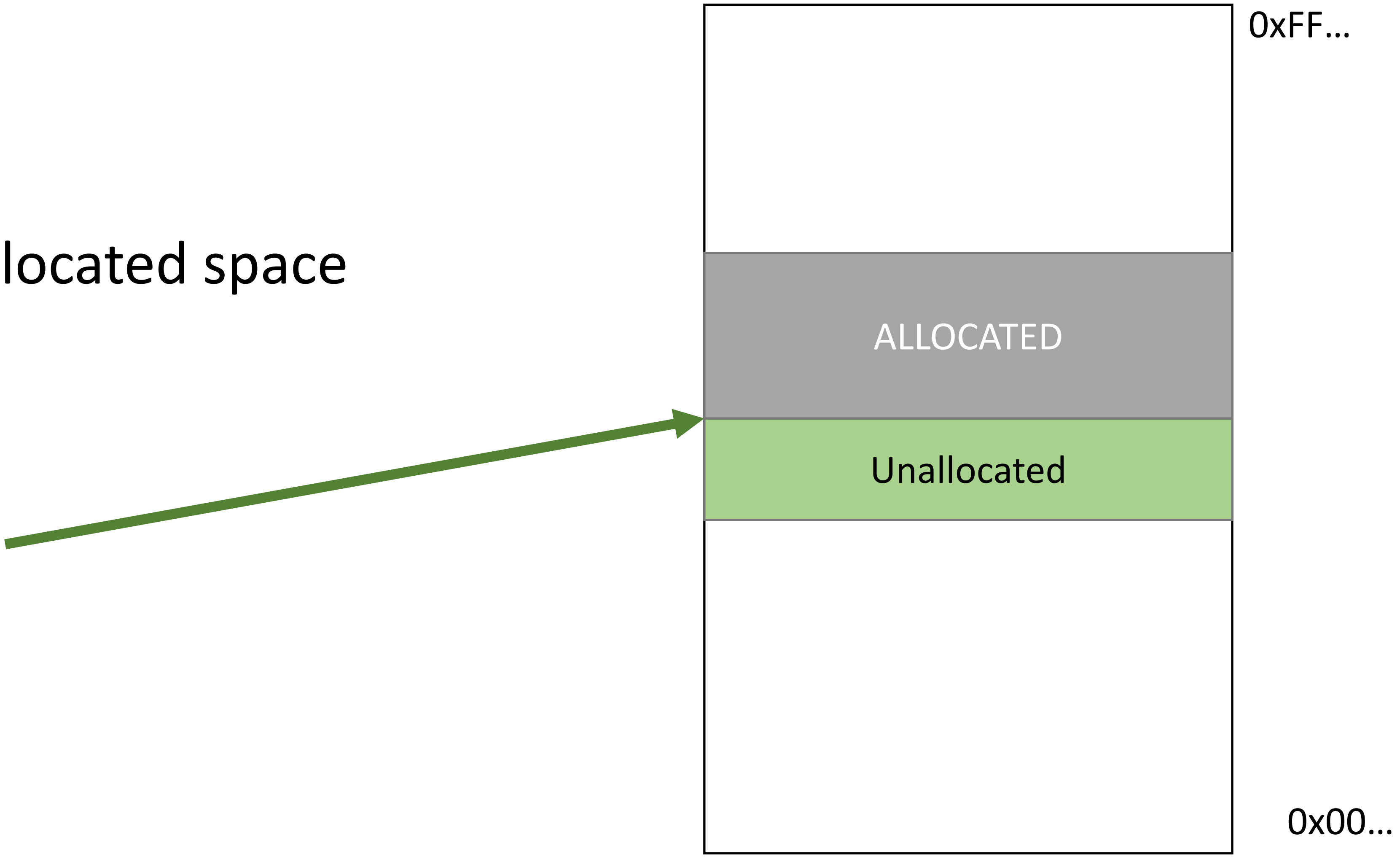


Why do we need to free the allocated memory?

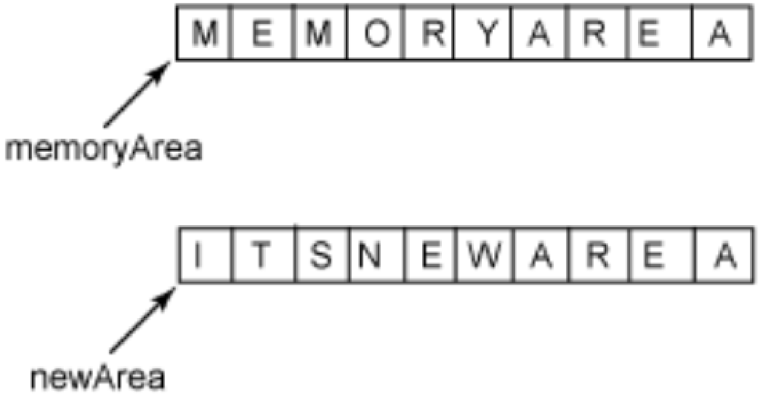
```
int *p = malloc(…)
..
//work with the allocated space
..
free(p);
int *q = malloc(…)
```



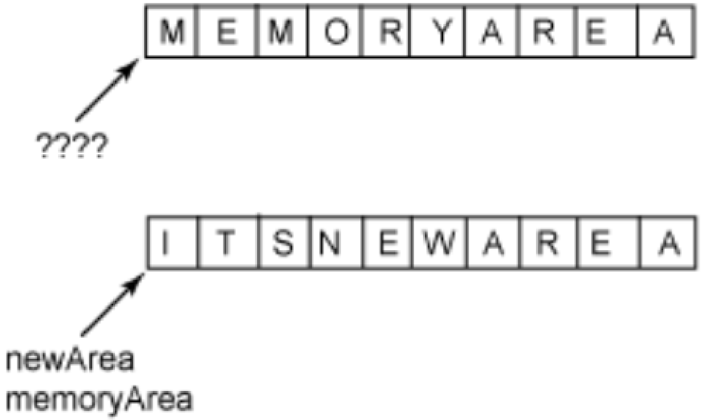
Correct Utilization of free()

- Call free with the pointer that points to the starting address of the allocated space. Otherwise, there will likely be memory leak.

```
char *memoryArea = malloc(10);
char *newArea = malloc(10);
```




```
memoryArea = newArea;
```



https://developer.ibm.com/technologies/systems/articles/au-toughgame/#fig04

struct

- User defined data type
  - Can hold several data items of different types

- C is not object oriented like Java but structs can be utilized the same way you can use java classes

- C struct vs JAVA class
  - C struct can hold only data items
  - Java class can hold both data items and functions

C struct and Java class

Java

```
 public class MyJavaClass
{
        private int x;
        public int getX() {
            return x;
        }
        public int setX(int
value){
            x = value;
        }
 }
```

C

```
struct MyJavaClass {
    int x;
};


int MyJavaClass_getX(struct MyJavaClass*
this)
{
    return this->x;
}
void MyJavaClass_setX(struct MyJavaClass*
this, int value)
{
    this->x = value;
}
```

https://stackoverflow.com/questions/5413001/what-is-the-difference-between-c-structures-and-java-classes

Example

- Use struct to create the profile of two students in Pitt
- The attributes of a student are:
  - First name
  - Last Name
  - Peoplesoft #

Design the struct

```
typedef struct Student
{
        char * first_name;
        char * last_name;
        int Peoplesoft;
}Student;
```

Initialize the credentials of the 1st student

```
int main()
{
        Student *s1 = (Student*)malloc (sizeof(Student));

        s1->first_name = (char*)malloc(25 * sizeof(char));
        strcpy(s1->first_name, “Harry”);

        s1->last_name = (char*)malloc(25 * sizeof(char));
        strcpy(s1->first_name, “Potter”);

        s1->Peoplesoft = 123456;

}
```

Initialize the credentials of the 2nd student

```
int main()
{
        …
        …
        Student *s2 = (Student*)malloc (sizeof(Student));

        s2->first_name = (char*)malloc(25 * sizeof(char));
        strcpy(s2->first_name, “Hermione”);

        s2->last_name = (char*)malloc(25 * sizeof(char));
        strcpy(s2->first_name, “Granger”);

        s1->Peoplesoft = 654321;

}
```

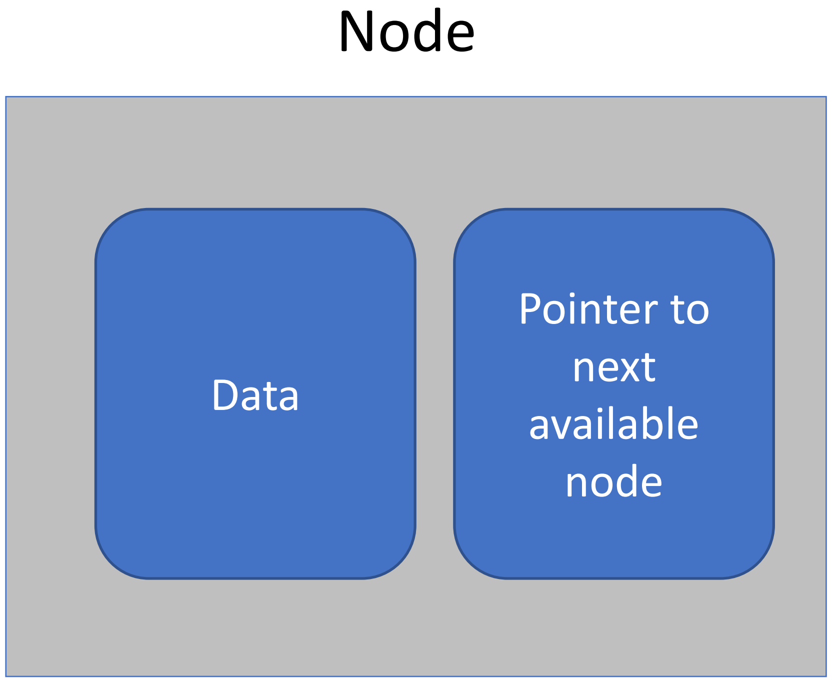
Free all the allocated space

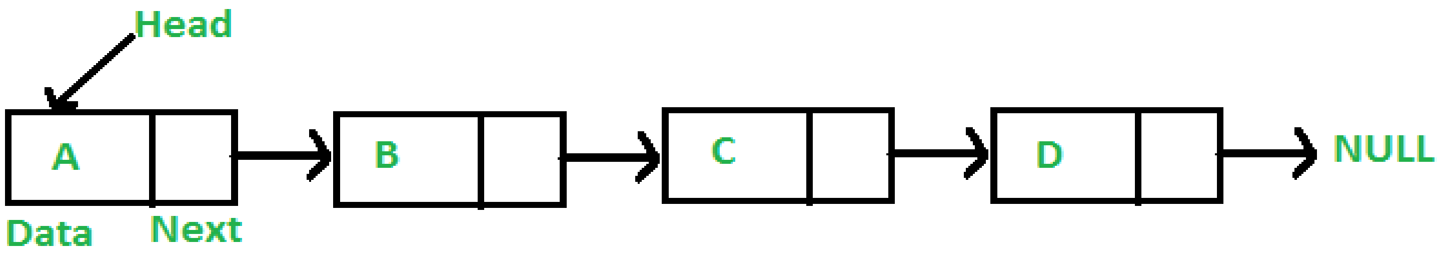
```
int main()
{
        …
        …
        free(s1->first_name);
        free(s1->last_name);
        free(s2->first_name);
        free(s2->last_name);

        free(s1);
        free(s2);
}
```

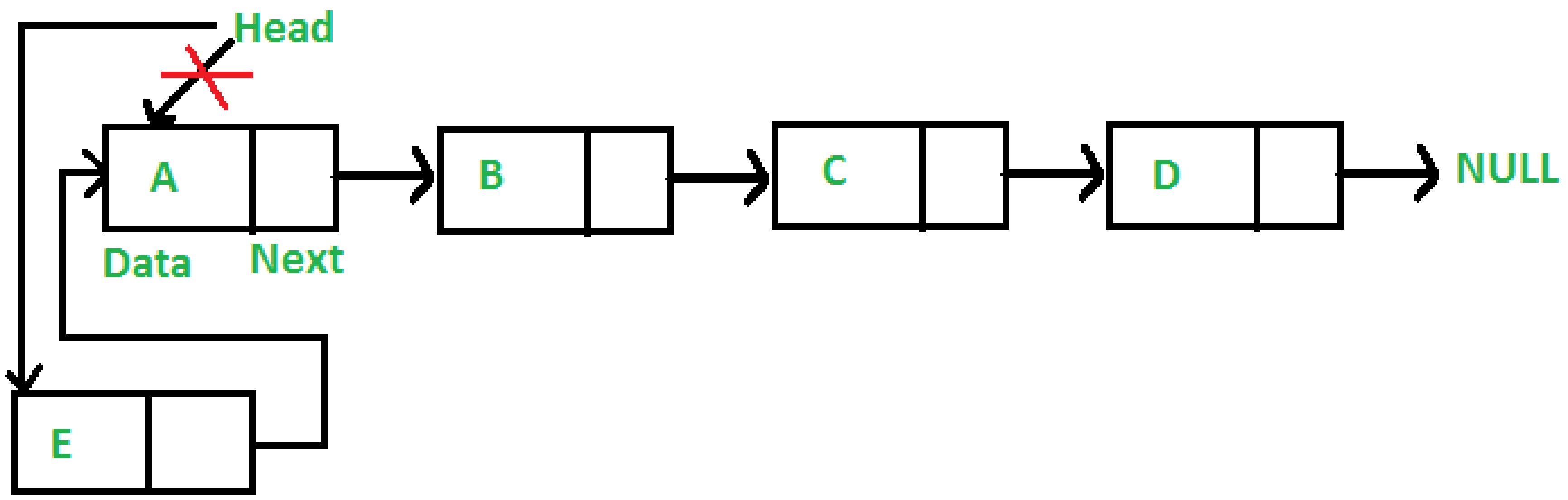
Linked List

```
// A linked list node
struct Node
{
  int data;
  struct Node *next;
};
```





Insertion – At the front



Insertion – At the front

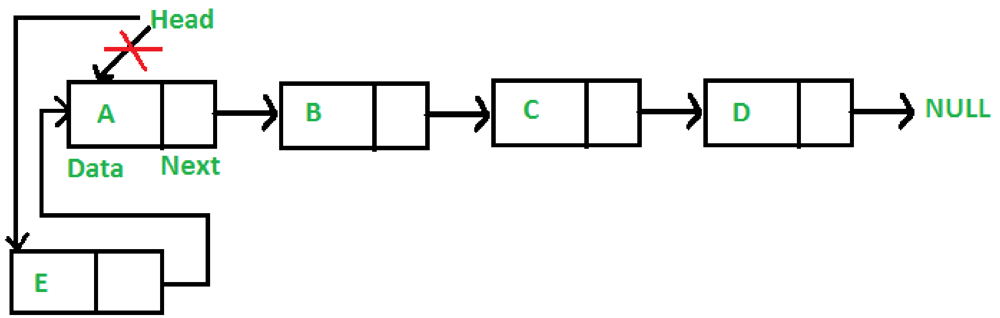
Check the top answer(answer with most votes) in this link to see why head is passed as a double pointer:
Link

```
void insert_front(struct Node** head, int new_data)
{
/* 1. allocate node */
struct Node* new_node = (struct Node*) malloc(sizeof(struct Node));

/* 2. put in the data  */
new_node->data  = new_data;

/* 3. Make next of new node as head */
new_node->next = (*head);

/* 4. move the head to point to the new node */
(*head) = new_node;
}
```

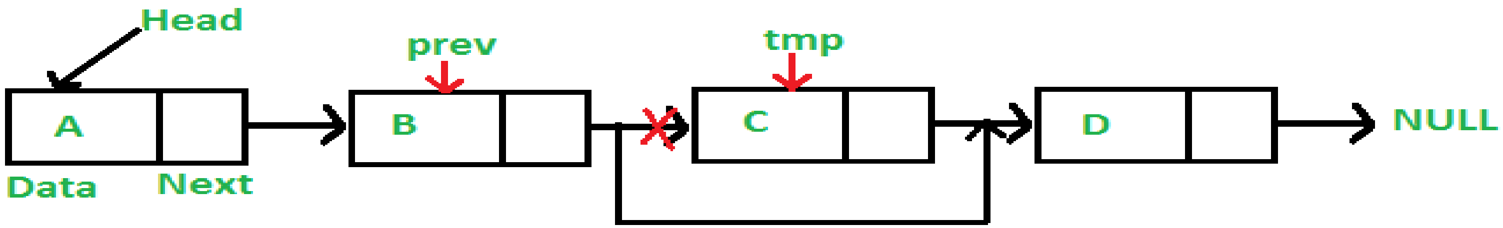


Deleting a node

Given a ‘key’, delete the first occurrence of this key in linked list.

To delete a node from linked list, we need to do following steps.

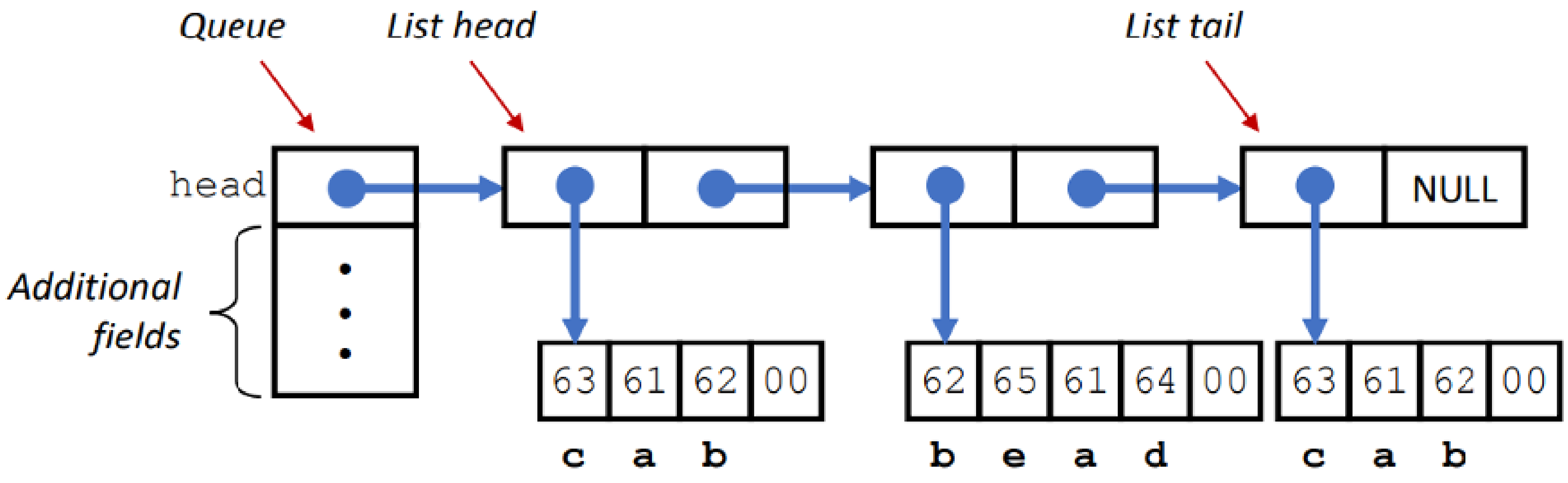
1) Find previous node of the node to be deleted.
2) Change the next of previous node.
3) Free memory for the node to be deleted.



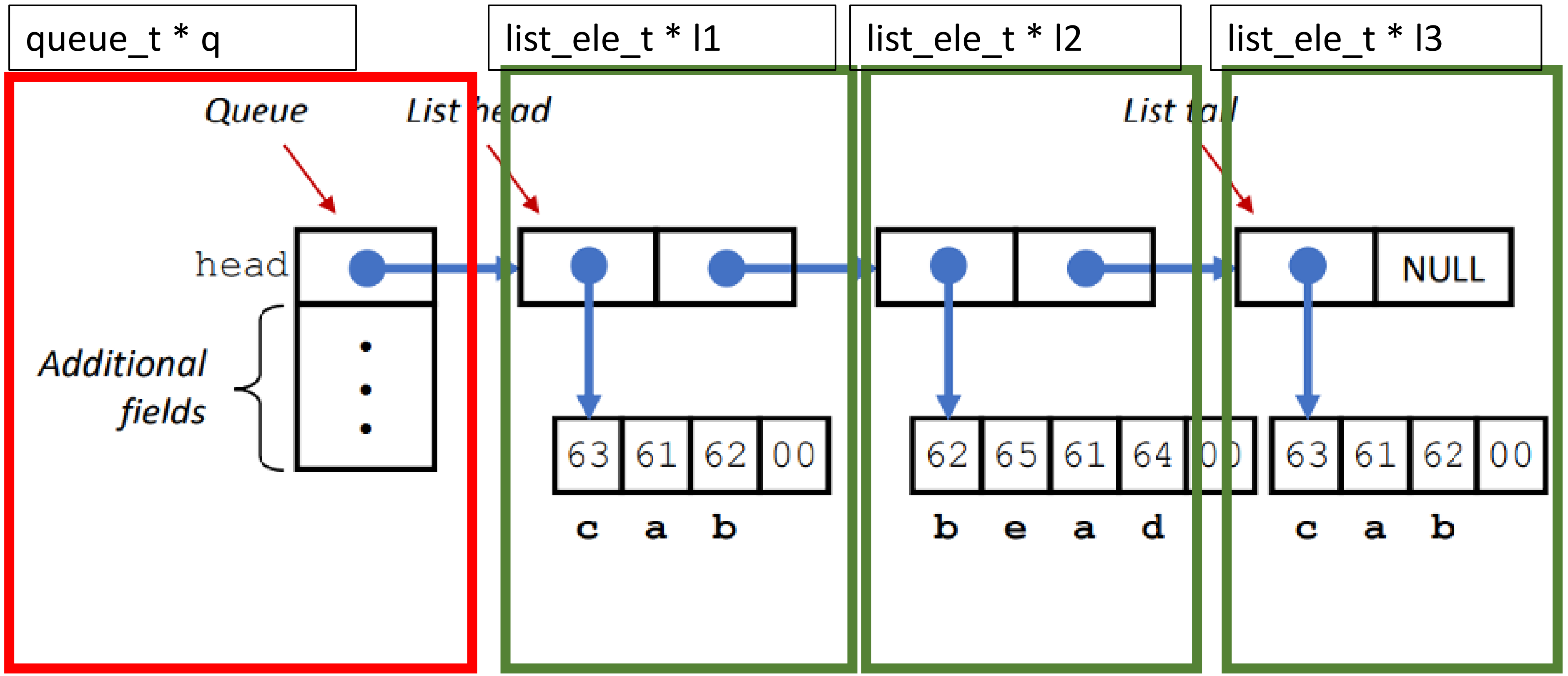
Queue Lab

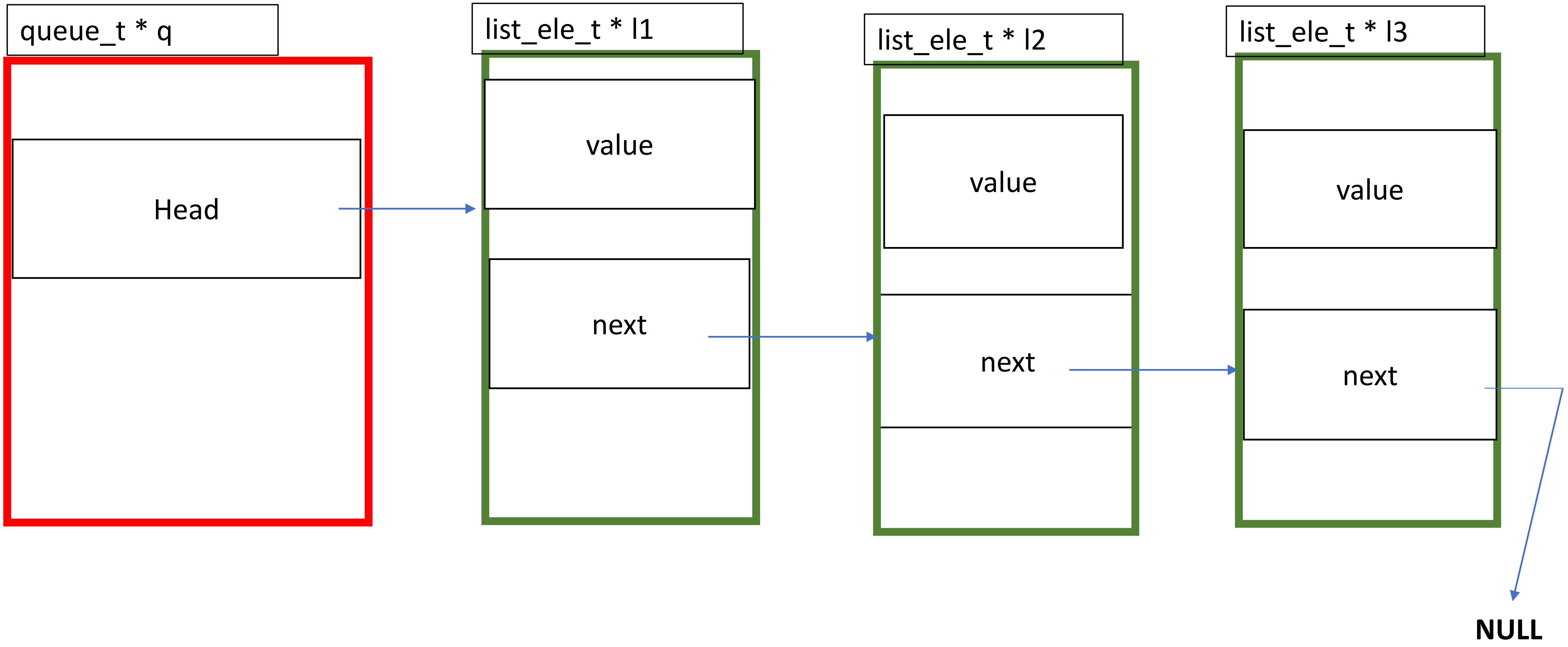
```
/* Linked list element */ typedef struct ELE {
    char *value;
    struct ELE *next;
} list_ele_t;

/* Queue structure */ typedef struct {
    list_ele_t *head; /* Linked list of elements */
} queue_t;
```



Queue Lab


queue_t * q
list_ele_t * l1
list_ele_t * l2
list_ele_t * l3
Queue
List head
List tail
head
Additional fields
63 61 62 00
c a b
62 65 61 64 00
b e a d
NULL
63 61 62 00
c a b


queue_t * q
Head
list_ele_t * l1
value
next
list_ele_t * l2
value
next
list_ele_t * l3
value
next
NULL

Now, do the linked list implementations