

CPT109: C Programming & Software Engineering I

Lecture 7: Memory & Structures

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Outline of Today's Lecture (7)

- Dynamically Allocating/Freeing Memory
- Introduction to Structures
- Using Structures in a Data Structure
- Linked Lists
- Structures and functions

But first...

Assessments 3

- Release on 30th Oct.
- Due on 10th Dec.
- Assessment 3 is a group project:
 - Groups of 5. Choose your own team.
 - Register your team on LM. Look for GROUP CHOICE “Select Your Team – Assessment 3 Group Project”
 - Select one member to be the group leader.
- Students without a group will be randomly assigned to a group. The results of the random allocation will not be amend.

Memory Allocation

- The OS allocates enough memory for your whole program including variables, arrays and functions.
- But what happens if you need more memory space during program execution?

**C allows for memory to be allocated at runtime
i.e. you can add memory space on demand (as
long as it is available)**

The malloc() function (1/3)

- malloc() requests a **block of memory** to be made available of a specified size
- The **return value** of the function is a **pointer** to the newly available memory
- The **type** of the **pointer** is **generic**

Needs to be typecast to the required type (e.g. int, float, char etc..)

Note malloc() is contained in stdlib.h

The malloc() function (2/3)

Note the typecast
(**double** * ptr)

Input parameter
size of memory needed
6 **double**'s



```
ptr = (double*) malloc(6*sizeof(double));
```

- malloc() finds a suitable block of free memory and returns the address of the first byte
- That address is assigned to a pointer variable (ptr)
- typecast is needed to make sure that the **ptr type** and **malloc() return type** are the same

The malloc() function (3/3)

- If the function fails to obtain the memory NULL ('\0') is returned
- Usually the malloc() function is used with a test for failure.

```
if (ptr == NULL)
{
    printf ("Memory allocation Failed");
    return 1;
}
```

The free() function (1/2)

- To release memory allocated with malloc(), use:
`free(ptr);`
- Frees the block of memory starting at the address stored in ptr.
- Should ONLY be used where the memory block was allocated by malloc()
- **You cannot use free() to free memory allocated by other means**

Note free() is contained in stdlib.h

Creating dynamically sized arrays

Two ways to create an array

- Declare an array using **constant** expressions for the array dimension i.e. **int** array[10]. Once declared the size of this array is fixed. It **cannot be resized** at runtime.
- Declare a pointer then call malloc() with the number of elements you want determined at runtime. The pointer can be used to access the elements of the array. The length of the array is then flexible each time you run the program. The array is said to be **dynamically sized**.

Example program (1/2)

```
#include <stdio.h>
#include<stdlib.h> /*malloc() and free()*/
int main(){
    double *ptr;
    int max, number, i=0;
    puts("How many doubles do you want to enter?");
    scanf("%d",&max);
    ptr = (double *)malloc(max * sizeof(double));
    if(ptr==NULL){
        puts("Memory allocation failed. Goodbye.");
        return 0;
    }
    /*ptr now points to an array of doubles of length max*/
```

Example program (2/2)

```
puts("Enter values or q to quit");
while (i < max && scanf("%lf",&ptr[i])!=1)
    i++;
printf("Here are your %d entries: \n", number = i);
for(i=0; i<number; i++){
    if(i%10 == 0)
        putchar('\n'); /*print 10 numbers per line*/
    printf("%lf", ptr[i]);
}
puts("\nDone");
free(ptr);           /*free the memory*/
return 0;
}
```

Structures...What and Why? (1/2)

- Most objects in the world are identified by a **collection of data**, in which each member data defines one aspect of the object.
- Each **member data** may be a different type e.g. You as a person may be defined by:
 - Name (**char**acter string)
 - ID number (**int**eger)
 - Age (**int**eger)
 - Profession (**char**acter string) etc...etc.


Structures...What and Why? (2/2)

- C provides a way of defining a giant data type that allows **many member data** to be **combined**. The whole data set is its **own data type** or **object**.
- This data type is called a **structure**
- Inside a structure a set of **members** is declared

Creating a Structure

- Structures are declared using the keyword **struct**
- The keyword can be followed by an optional name (e.g. book), to identify the form of the structure.
- The content of the structure is then defined in {};

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;
};
```



/*Don't miss the ;*/

Note: This is like declaring a new data type called book. It has not created any variables of this type...

Declaring a Structure

- Now we have a structure we need to declare a variable of this type:

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;
};
main(){
    struct book my_book;
    /*my_book is now a
    structure*/
```

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;
}my_book;
main(){
    ...
    /*alternative declaration*/
```

Declaring a Structure with **typedef**

- For convenience the keyword **typedef** can be used.

```
#include<stdio.h>
typedef struct {
    char title[20];
    char author[20];
    float value;
} book;
```

```
main(){
book name;
```

Note: book becomes a variable type and can be used like **int** instead of writing **struct book**

Initialising a Structure

- Initialisation can be by a ‘,’ separated list of values.

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;
};
main(){
    struct book my_book={
        "Dracula",
        "Bram Stoker",
        9.99};
```

Note: Do not assume the memory size of the structure is the sum of the sizes of its members. It is usually larger. Use “sizeof(book)” to find actual size.

Accessing a Structure

- Use the dot (.) operator to access structure members
- members can then be used like any other variable

```
struct book{  
    char title[20];  
    char author[20];  
    float value;  
};  
  
main(){  
struct book mybook={  
    "Dracula",  
    "Bram Stoker",  
    9.99};
```

```
    printf("the title is %s", my_book.title);  
  
    my_book.value = 7.99;  
  
    printf("%.2f",my_book.value);  
  
    gets(my_book.author);  
  
    puts(my_book.author);  
}
```

Filling/Accessing a Structure (1/5)

- The content of one book is input from the keyboard

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

```
struct book{  
    char title[20];  
    char author[20];  
    float value;};
```

Declaration not creation. book
ONLY describes structure content

Don't forget the ;

```
main(){
```

```
    struct book lib;  
    gets(lib.title);  
    gets(lib.author);  
    scanf("%f",&lib.value);  
    printf("%s by %s is £%.2f\n", lib.title, lib.author, lib.value);}
```

Creation of
variable

Filling/Accessing a Structure (2/5)

- The content of one book is input from the keyboard

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

```
struct book{
```

```
    char title[20];
```

```
    char author[20];
```

```
    float value;};
```

```
main(){
```

```
    struct book lib;
```

```
    gets(lib.title);
```

```
    gets(lib.author);
```

```
    scanf("%f",&lib.value);
```

```
    printf("%s by %s is £%.2f\n", lib.title, lib.author, lib.value);}
```

Keyword **struct** identifies that the following is a structure variable

book is the name of the structure

Content can be a mix of as many variables and types as wanted (even another structure).

Filling/Accessing a Structure (3/5)

- The content of one book is input from the keyboard

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

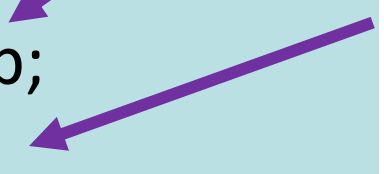
```
struct book{  
    char title[20];  
    char author[20];  
    float value;;
```

```
main(){  
    struct book lib;  
    gets(lib.title);  
    gets(lib.author);  
    scanf("%f",&lib.value);  
    printf("%s by %s is £%.2f\n", lib.title, lib.author, lib.value);}
```

Create a structure of
type book called lib



To gain access, use the name of
the struct variable followed by
the dot then the name of the
member i.e. name.member



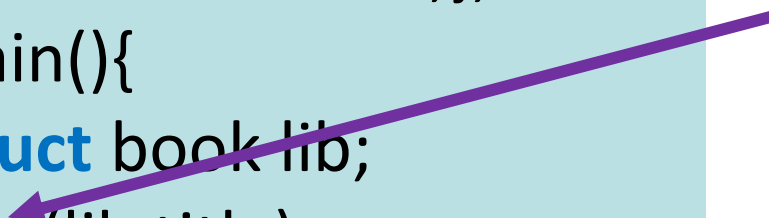
Filling/Accessing a Structure (4/5)

- The content of one book is input from the keyboard

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;};
```

```
main(){
    struct book lib;
    gets(lib.title);
    gets(lib.author);
    scanf("%f",&lib.value);
    printf("%s by %s is £%.2f\n", lib.title, lib.author, lib.value);}
```

gets() copies a string from the keyboard and places it at an address. The member title is an array, remember the name of an array is the address of the first element



Filling/Accessing a Structure (4/5)

- The content of one book is input from the keyboard

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;;
```

```
main(){
    struct book lib;
    gets(lib.title);
    gets(lib.author);
    scanf("%f",&lib.value);
    printf("%s by %s is £%.2f\n", lib.title, lib.author, lib.value);}
```

scanf() is used to get a real number from the keyboard. '&' is required since value is a float variable

member values are accessed with the dot (.) operator

Pointers to Structures

- Yes....they are back again!
- Pointers allow a locally defined **struct** to be modified in a function.

```
main(){  
  char *title;  
  struct book my_book;  
  struct book *pbook;  
  pbook = &my_book;  
  title = pbook ->title;}
```

declaration uses the usual *
type is **struct** book
pbook is pointer name

& gives address of the
struct variable my_book

Access to members using pointers requires
'->' or **(*pbook).title**

Using Pointers to Structures

```
#include<stdio.h>
struct book{
    char title[20];
    char author[20];
    float value;};

main(){
    struct book lib;
    struct book *plib=&lib;
    gets(plib->title);
    gets(plib->author);
    scanf("%f",&plib->value);
    printf("%s by %s is £%.2f\n", plib->title, plib->author,
        plib->value);}
```

plib is a pointer to the address of lib



Note . and -> have the highest precedence of ALL operators

What about more than 1 book?

Arrays of Structures

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

```
struct book{  
    char title[20];  
    char author[20];  
    float value;};
```

```
main(){  
    struct book lib[10];  
    gets(lib[1].title);  
    gets(lib[1].author);  
    scanf("%f",&lib[1].value);  
    printf("%s by %s is £%.2f\n", lib[1].title, lib[1].author,  
                                                lib[1].value);}
```

Declaration statement
declares an array



Array starts at lib[0]. Array
elements accessed as usual i.e.
second structure lib[1]

Beyond Arrays... Linked Lists (1/5)

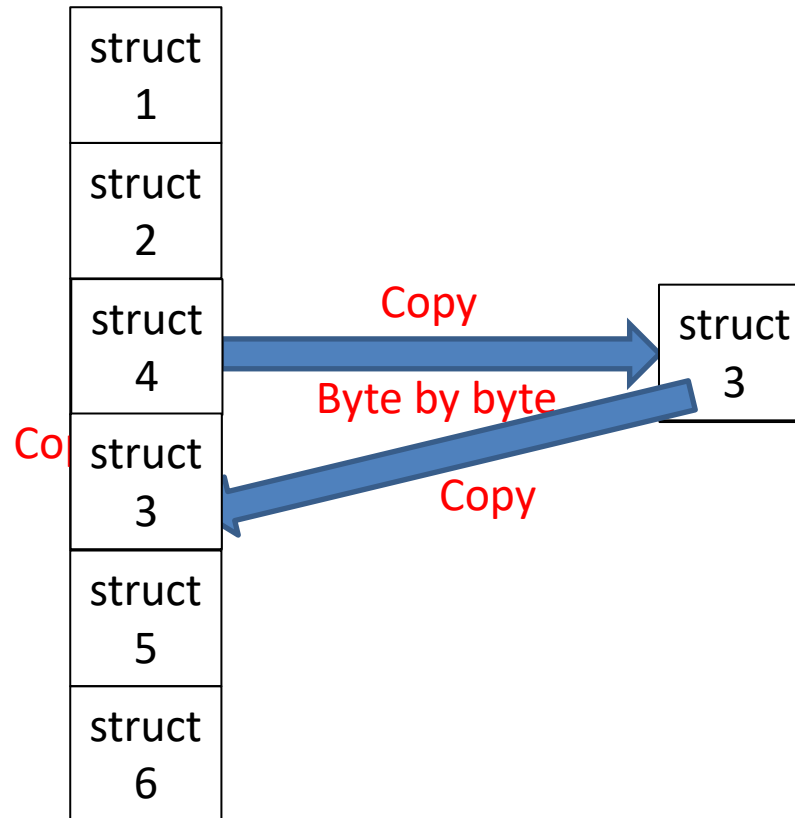
- Normally your program design will require many decisions before coding begins including choice of data structures.
- The **Array** and the **linked list** are fundamental forms of data structure, ways to build sets of structures.
- Suppose you need a program to form a list of your favourite movies. A movie has a variety of info. e.g. title, director, year, genre etc. This suggests a **struct**.
- But how many would you like?
- Could use an array What problems do arrays present?

Beyond Arrays, Linked Lists (2/5)

- Problems with an array of structures :
 - The array is fixed in size, not expandable
 - Difficult to sort the array in a given order

Beyond Arrays, Linked Lists (2a/5)

- Moving array elements: **struct** book lib[6]
- **Swap elements 3 and 4**

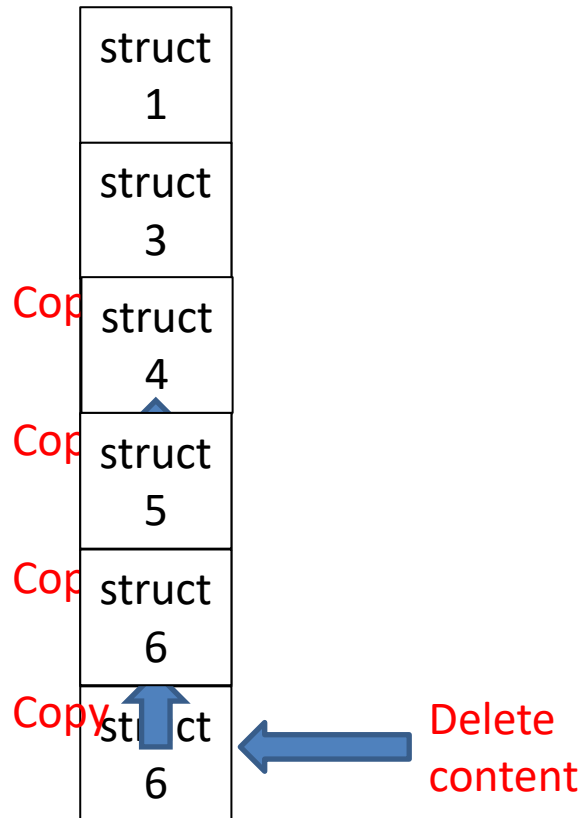


Beyond Arrays, Linked Lists (2/5)

- Problems with an array of structures :
 - The array is fixed in size, not expandable
 - Difficult to sort the array in a given order
 - Difficult to delete an entry

Beyond Arrays, Linked Lists (2b/5)

- Removing array elements: **struct** book lib[6]
- **Delete element 2**



Beyond Arrays, Linked Lists (2/5)

- Problems with an array of structures :
 - The array is fixed in size, not expandable
 - Difficult to sort the array in a given order
 - Difficult to delete an entry
- Any other choice?
- Dynamically create new structures when required using malloc(), allows indefinite expansion
- Any difficulties?
- Need to link the structures together

Linked Lists (3/5)

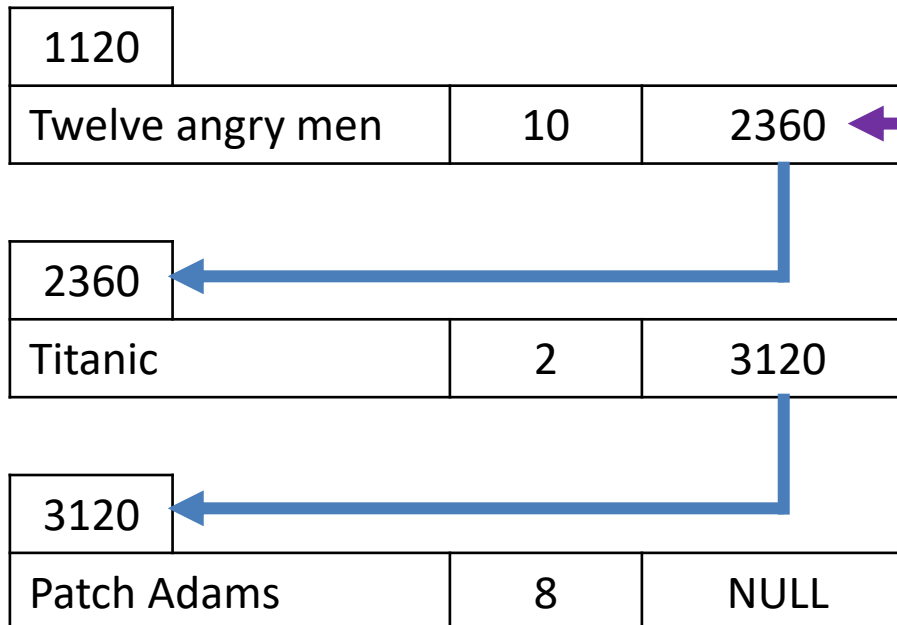
- Each time `malloc()` is called, a pointer to the new memory elements is created.
- These will not usually be created in any particular location order therefore a simple pointer cannot be used to move from one structure to the next
- The linked list includes a pointer variable inside the structure, which is set to point to the next structure in the list.

Linked Lists (4/5)

```
struct movie{  
    char title[50];  
    int rating;  
    struct movie *next;  
};
```

Pointer to
first structure

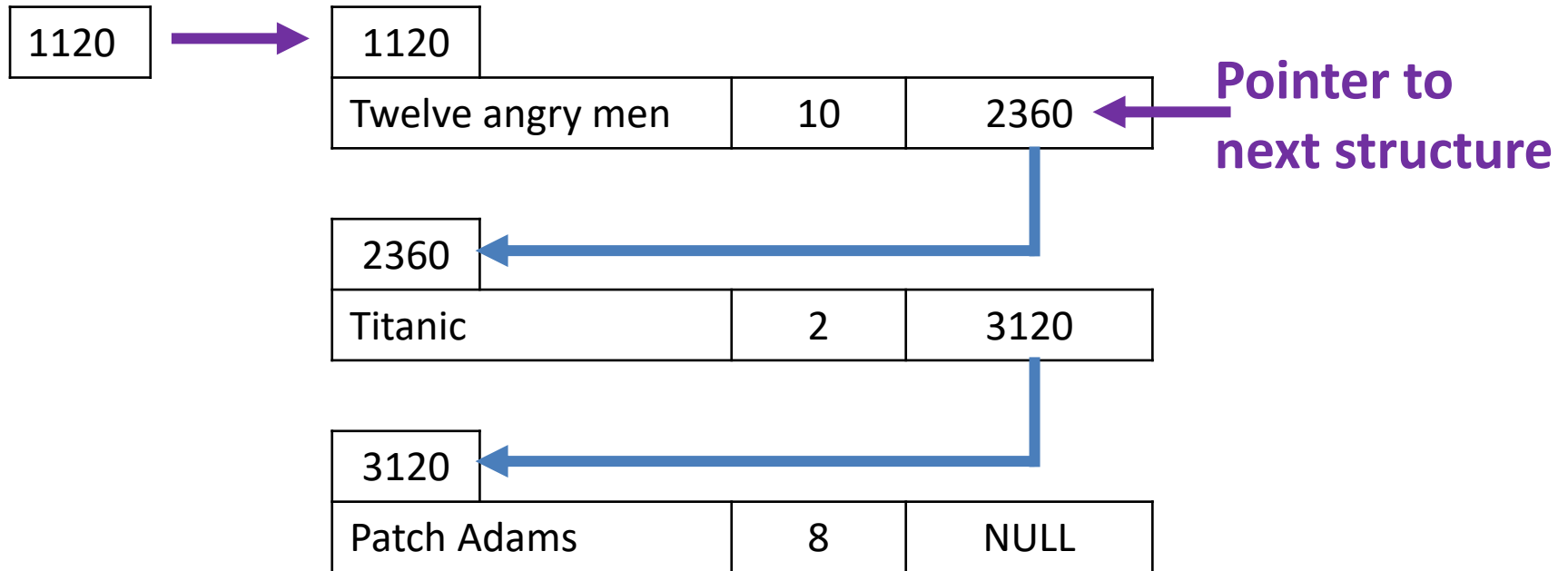
1120



Pointer to
next structure

Linked Lists (5/5)

Pointer to
first structure



How could an element be inserted into or deleted from, the list?

Linked Lists – Inserting (5a/5)

Pointer to
first structure

1120



1120			
Twelve angry men	10	2360	

Pointer to
next structure



Create New
Structure

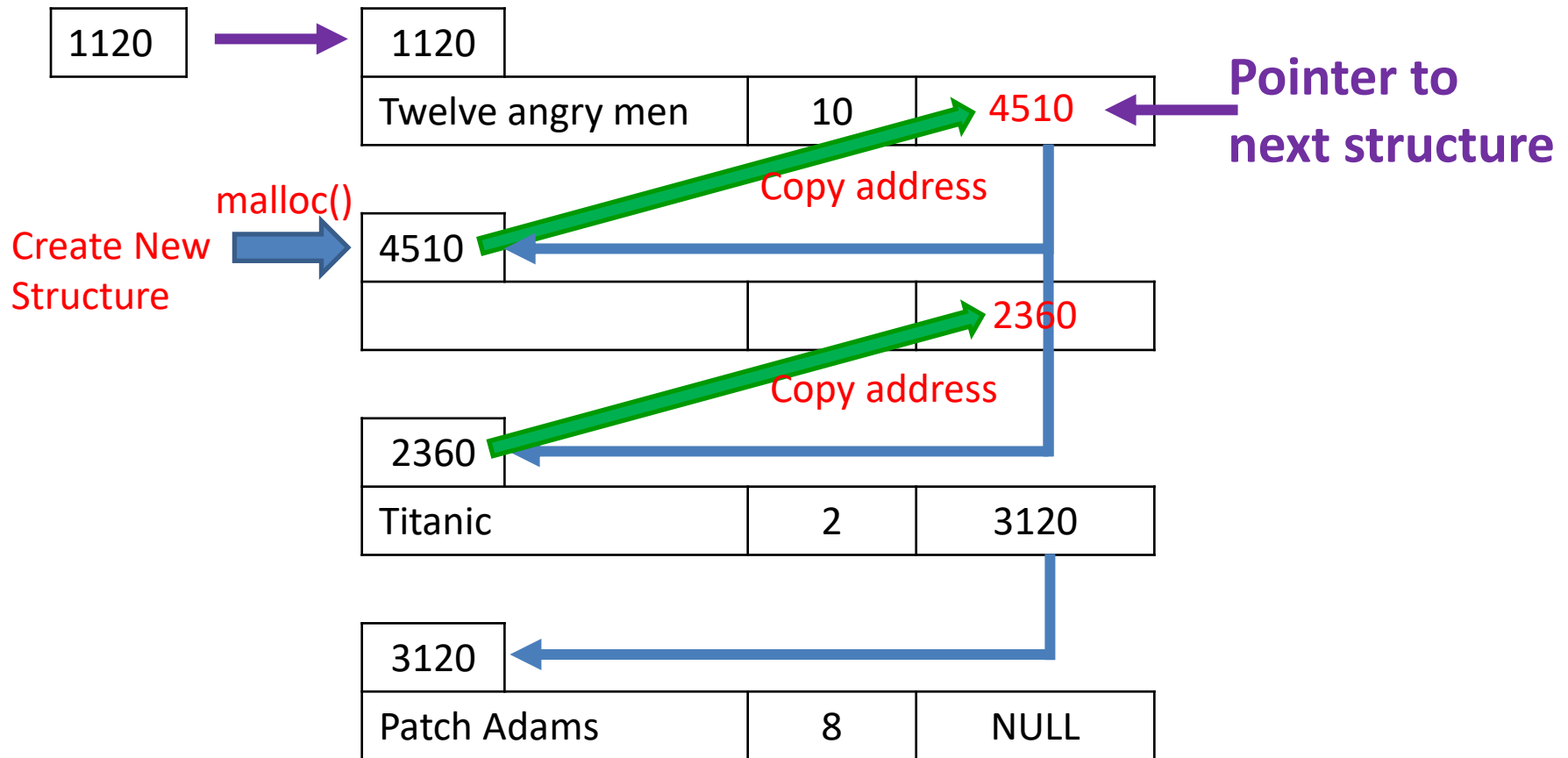
2360			
Titanic	2	3120	

3120			
Patch Adams	8	NULL	



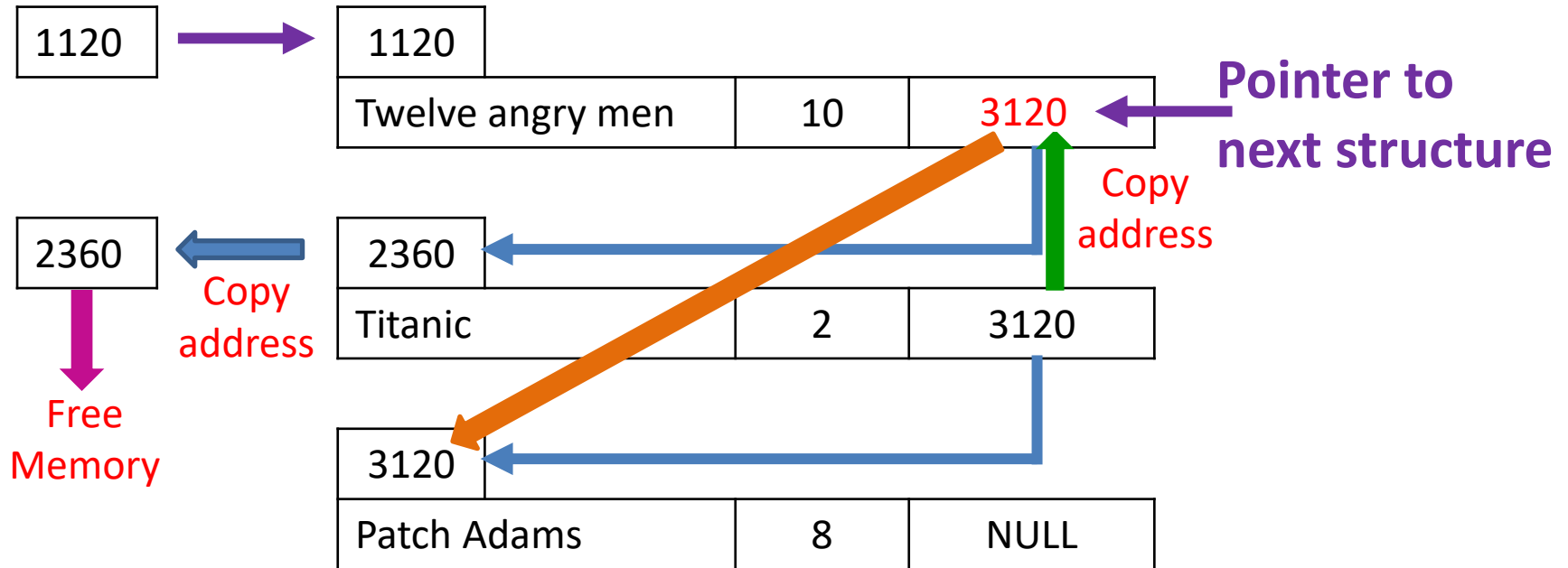
Linked Lists - Inserting (5a/5)

Pointer to
first structure



Linked Lists - Deleting (5b/5)

Pointer to
first structure



Structures as Arguments (1/4)

- Structures can be used as arguments

```
myprint(mystructure);
```

- In this case a copy of the structure “mystructure” is passed to the function “myprint”
 - This can be slow if the structure has many members or contains large arrays
- This is different from passing an array to a function, which passes a pointer.


Structures as Arguments (2/4)

```
#include<stdio.h>

struct funds{      /*declare the structure*/
    double current;
    double savings;
};

double sum(struct funds);

main(){            /*function call sends copy*/
    struct funds ABC;      /*of ABC*/
    ABC.current = 1005;
    ABC.savings = 34.5;
    printf("Total funds in ABC %lf", sum(ABC));
}
```



Structures as Arguments (3/4)

/*function argument is a structure of same type*/



```
double sum(struct funds my_funds){  
    double total;  
    total = my_funds.current + my_funds.savings;  
    return total;  
}
```

Structures as Arguments (4/4)

```
double sum(struct funds *p);  
/*Prototype with pointer*/
```

```
printf("Total funds in ABC %lf", sum(&ABC));  
/*Function call with &*/
```

```
double sum(struct funds *p){  
    double total;  
    total = p->current + p->savings;  
    return total; /*Use -> operator with pointer*/  
}
```

Questions...

- True or False?
 - A **struct** is a data type of C
 - A structure is used to declare a data type containing multiple fields (members).
 - Pointers can be used to access members of a structure
 - An array cannot be a structure member
- How is a linked list different from an array?



Questions?

**Week 8 already...keep it going
we are almost finished 😊**