Introduction to Programming in C
Department of Computer Science and Engineering

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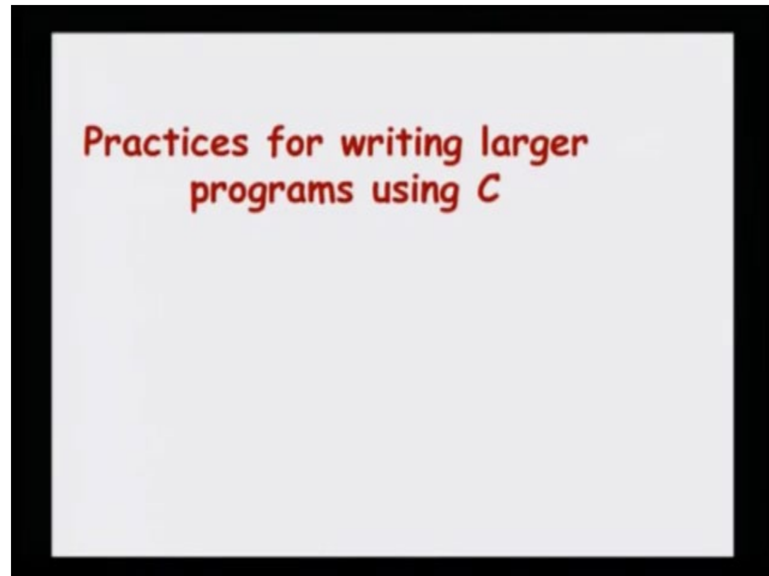

In this lecture we will see some practices for writing larger programs using c. As far as we have seen so far, we always wrote our code in a single file; and this is not practical for very large programs running into C 1000 of lines or millions of lines. So, we will see what is the usual practice for organizing a code when we have larger programs.

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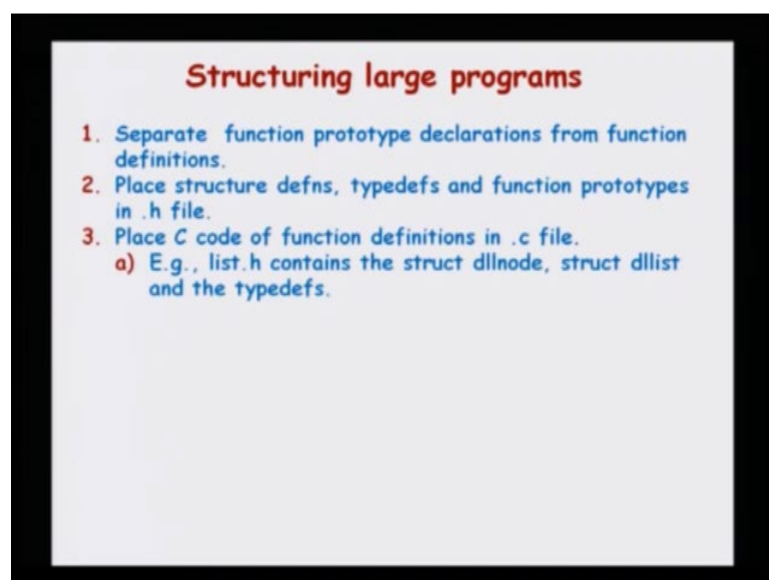

So, one of the basic principles is to separate the function prototype declarations from the function definitions. We have seen that when we have a function we have two things to do - one is to declare a function which is just the types involved in the function, and then the definition of the function which is actually the code of the function. So, one way to structure it, one principle in structuring is that we will separate out the function prototype from the function definition.

Now, place all prototype definitions, structure definitions, typedefs, so just the declarations, you will place it in a file with suffix .h. So, right now we have been coding in a file call .c. So, right now what we are proposing is that the declarations alone we will place it in a separate file with suffix .h. You have already seen such an example which is stdir.h, we never bothered about what is inside a stdir.h. Now, we are talking about how to write these header files.

Now, decelerations are only half the function, right. I mean we have to write the definition of the function, the code of the function; the actual code of the function you place it in a .c file separately. So, for example, list.h contains the definitions of the struct dllnode for doubly link list and so on, and list.c would contain the bodies of the function.

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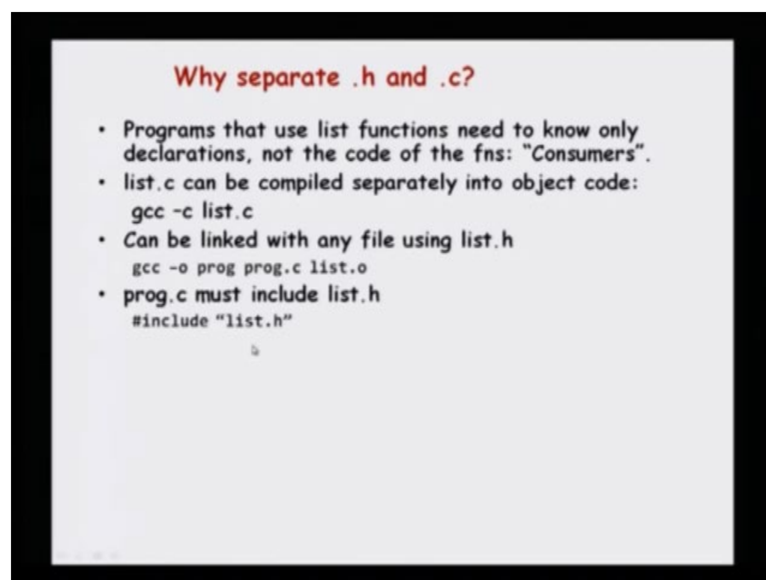

Now, we will see why separate .h and .c? Programs that use the doubly link list need to know only the declarations actually. These are, think of these programs as the consumers of this code. Now, it does not need to know how the code is implemented, just what to call and what is the declaration of the function. Now, if we do this, then list.c can be

compiled separately into object code. So, we can say gcc -c list.c, this will produce just file call list.o. List.o is not executable, but it can be used in other programs to create executables.

So, how can we do this? This is the procedure known as linking. So, we can link the list.o. So, notice the difference here. When we see gcc -c list.c, what it could produce is a .o function, .o file; and this .o file can be included to produce output. So, this says that we are compiling prog.c file, with list.o object file, and the output we will produce is called prog. So, gcc -o prog means, the output file we will produce will be called prog. So, if we omit -o prog, and the simply say gcc prog.c list.o, then the file that we will get is, a.out. If you specify an output file we will get that output file.

Now, inside prog.c, let say that we need to use list functions. So, prog.c will include “list.h”; this is the important thing. It will not say include “list.c”, it will just say include “list.h”. This is similar to what we have seen with stdio; we did not bother about whether there was an stdio.c file. We said we will include <stdio.h>. Also, notice the difference that we are using double quotes instead of angular brackets. So, when we wrote <stdio.h>, what we had was angular brackets, open angular bracket and close angular bracket, here we have quotes; why use that? We will see this.

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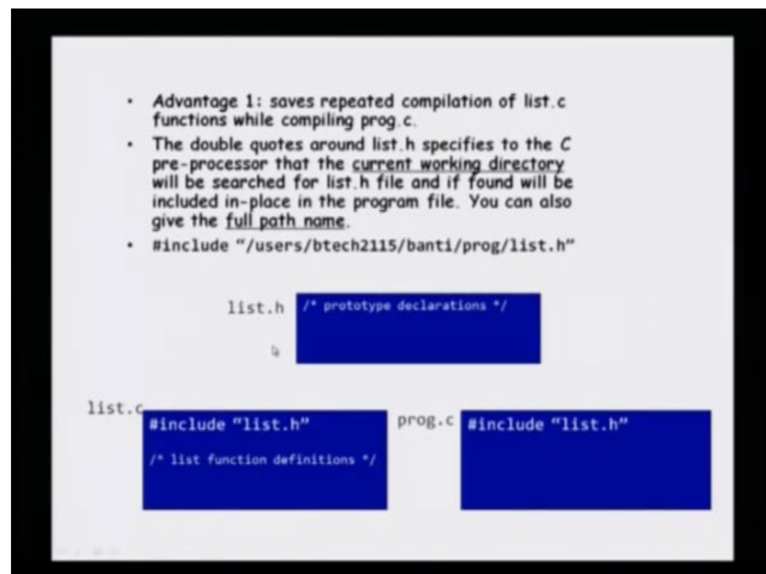

So, what is the advantage of separating list.c from prog.c, why break it up into multiple files? One advantage is that it saves a repeated compilation of list.c functions while

compiling prog.c. So, the “list.h” specifies to the c pre-processor; we will see this is in a subsequent lecture, that the current working directly will be searched for list.h file.

So, since we are saying that include “list.h” within double quotes, what it means is that, where is list.h found? It will be found in the current directory. If it is not found in the current directory it will search for some standard library parts, some standard header file parts. So, in the case of <stdio.h> we put <stdio.h>; that means, that <stdio.h> will be found not in the current directory, but in some standard header directories.

So, when you use double quotes you can also use some full path names. Suppose, your full path name in a Linux system is “/users/btech2115/banti/prog/list.h”, you can specify the hole path as well. This is the more general notation. So, currently the structure is as follows: you have a list.h file, it has just the prototype declarations; list.c will define those functions. So, first inside list.c you would say, include “list.h”, and then have all the function definitions. prog.c needs list.c functions, but instead of saying include “list.c” it will say include “list.h”. Now, we will see how to compile such a setup.

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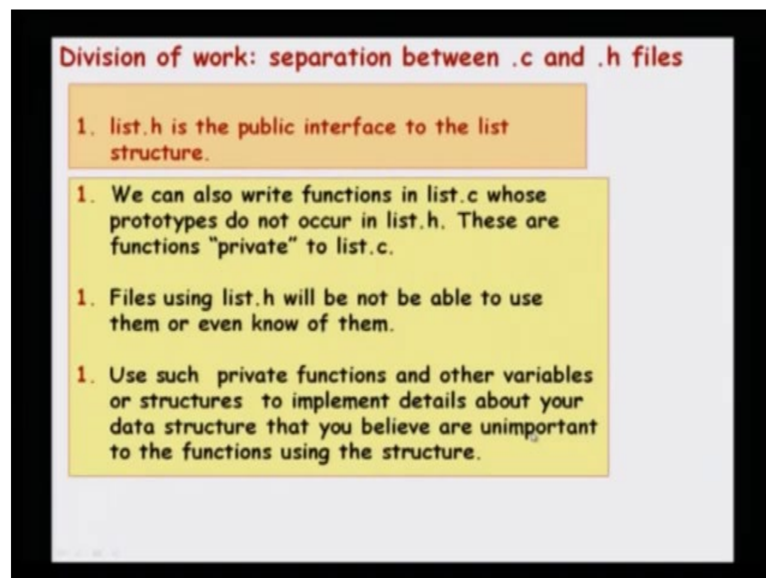

So, what is the division of work? What is the separation between the .c and the .h files? .h file is the public interface; that, if anybody else, any other program wants to use the list functions what you would do is, include the list.h functions, include the list.h file. Now, list.c implements, defines all the functions that list.h has declared. In addition, it can also define other functions, but these functions will not be available to other

programs that are using the list.h file.

So, files using list.h will not be able to use these extra functions or even know about these functions. These are thought of as private functions. So, this can be used to implement certain details of your code that other uses of this program need not know about.

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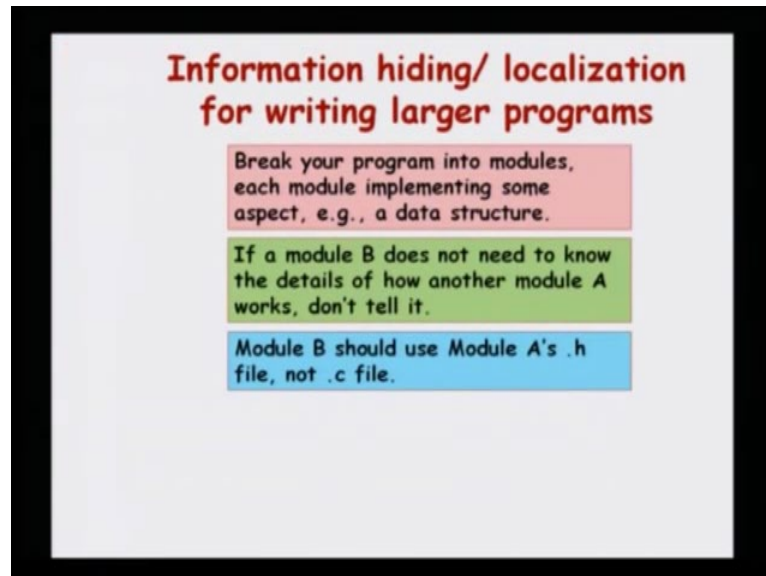

So, the general principle is what is known as information hiding or localization. So, break your programs into modules. We have already seen one way to break a program into modules, which is by writing functions. Now, this is another way to, this is another level of module array station where you say that take a collection of functions and put them in a file and have multiple files.

Now, each module implementing some aspect; for example, data structures like a link list. Now, if a module B does not need to know the details of how another module A works, then we do not need to tell B about how it is done. But, module B should use module A's .h file, not the .c file.

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- Why do we separate into definitions and code: .h and .c? There are several reasons.

(Did you care about how scanf or printf worked? We still used them!)

- Programs that use the list functions are typically "consumers". They do not need to know the code behind the functions or how the functions work.
- To use the list functions, such programs can use the prototypes using the include command:

  #include "list.h"

- The double quotes around list.h specifies to the C pre-processor that the current working directory. You can also give the full path name (it is more general).
- #include "/users/btech2115/banti/prog/list.h"

Why do we separate definitions into .h and .c? There are some reasons. Programs that use the list functions, for example, are typically consumers, and they do not need to know the exact details behind how these functions work. And we have already done this in other, we do not know about how scanf or printf worked. We just know that scanf needs these two arguments, for example, it needs a format string and it needs the variable to be printed; the printf needs the format string and the variable to be printed. Similarly, scanf needs the format string and the variables to be assigned.

So, we just knew that, we do not know anything about how scanf or printf is actually defined or implemented; we just know that it needs these arguments, and therefore we can call them. So, this is the kind of separation of detail that we are hoping to achieve. Now, so if some program wants to use the list functions, such programs can use the prototypes using the include command, #include “list.h”. So, again to remind the double quotes specify that it is the current working directory that list.h is present in; you can also give full paths.

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.h vs .c (fast compilation)

- The list.c program will contain all the function definitions.
- Usually header files .h are much smaller than .c files.
- If list.h and list.c are separated, then, list.c can be compiled ahead of time. This can be done by generating the object code (but not executable code)

  gcc -c list.o list.c
- The list.c program is complete, except for a main() function. So it can be compiled into an object code file, usually ending in the suffix .o in Unix environments. The above compilation creates an object file list.o from list.c.
- Suppose we have written a function called prog.c that uses many of the list functions and includes list.h.
- We can compile prog.c to generate object code:

  gcc -c prog.o prog.c

List.c program will contain all the actual function definitions. Now, usually header files are much smaller than the c files. If list.h and list.c are separated, then list.c can be compiled ahead of time, and you can generate the object file. Now, notice that list.o in this case will be not executable; it is just an object file that can be used to build executables.

Now, list.c programs is complete, except for a main function. So, it has a lot of functions; it defines all the functions there list.h has declared, plus optionally some more functions. And it can be compiled to produce an object code, but it cannot be done, it cannot be compiled into an executable code because it does not have a main function.

Now, suppose we have written function called prog.c that uses many of the list functions, that uses list.h. We can compile prog.c to generate an object code: gcc -c prog.o prog.c. So, now, we have 2 object files, list.o and prog.o; and then we can use these two object files to create the executable file.

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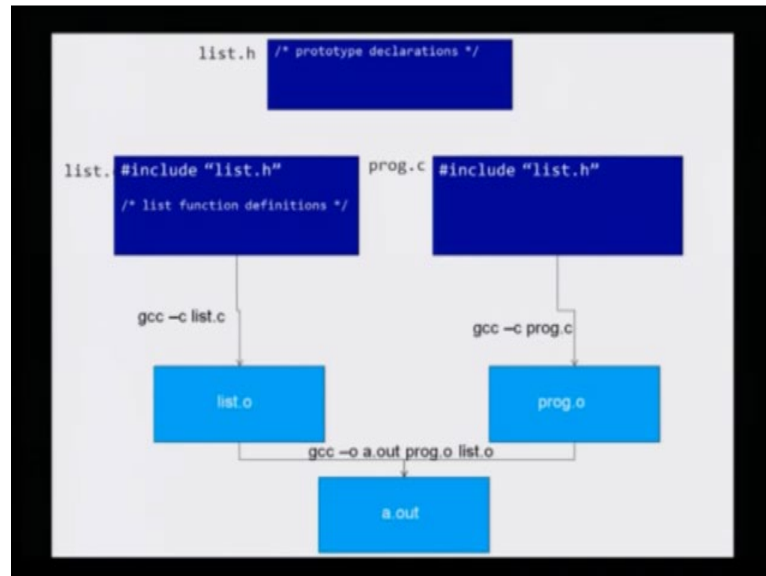

Let us look at a diagram which will hopefully be helpful. So, list.h includes a prototype declarations, but not the function definitions; list.c defines these functions. So, in order to define these functions, first it says, include "list.h", therefore, it will get all the declarations, and then it has this code which implements the list function definitions. prog.c is a consumer which needs these functions. So, how does it do it? It does not say list.c, it says include "list.h". So, the declarations of all the functions are available to prog.c.

Now, I separately compile list.c into list.o using gcc -c, and prog.c into prog.o using gcc -c. So, now, I have 2 object files, list.o and prog.o. And these will be combined using gcc -o. So, this says that the output file will be called, a.out; the compilation units that I need are prog.o and list.o. So, use these two files, in order to create the output file, a.out.

And what is the big advantage here? Let us consider a scene where the prog.c file changes. I need some changes to be made into prog.c; maybe I add some more functions, modify some functions and all. So, now I need to recompile and produce the output file. I have changed prog.c, but not list.c.

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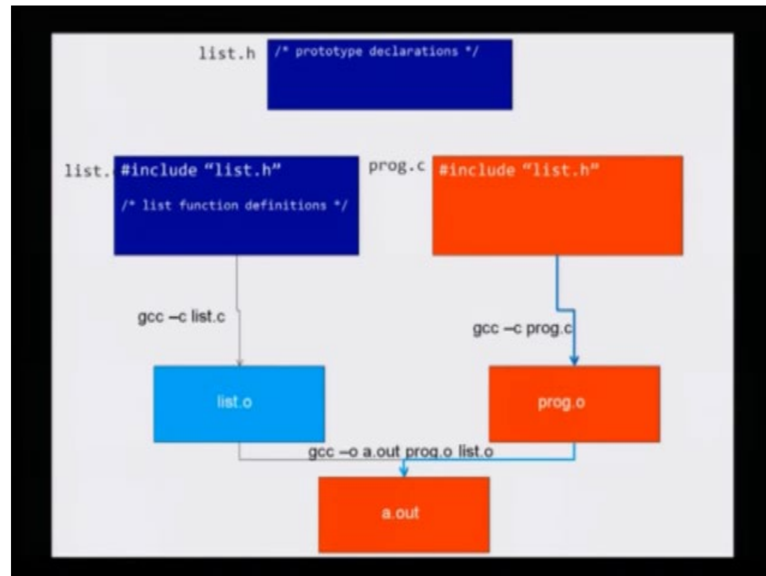

So, let us say prog.c has changed. What should I do now? I should compile only the prog.c. I can say gcc -c prog.c; now, I will produce a new prog.o file. Notice, list.c has not changed. So, we do not need to recompile list.c. So, we can just say, gcc -c prog.c; list.o is same as before. And then I can use the new prog.o, the old list.o, in order to produce the new a .o. So, notice the, a.out depends on prog.o and prog.c has changed.

So, only this path gets recompiled which is saving a lot of effort. And in large programs, when one particular file changes and you recompile the project, only the necessary files get recompiled. It does not recompile the whole project which will take a lot of time, instead it will compile only those files which are necessary. So, this is the huge advantage.

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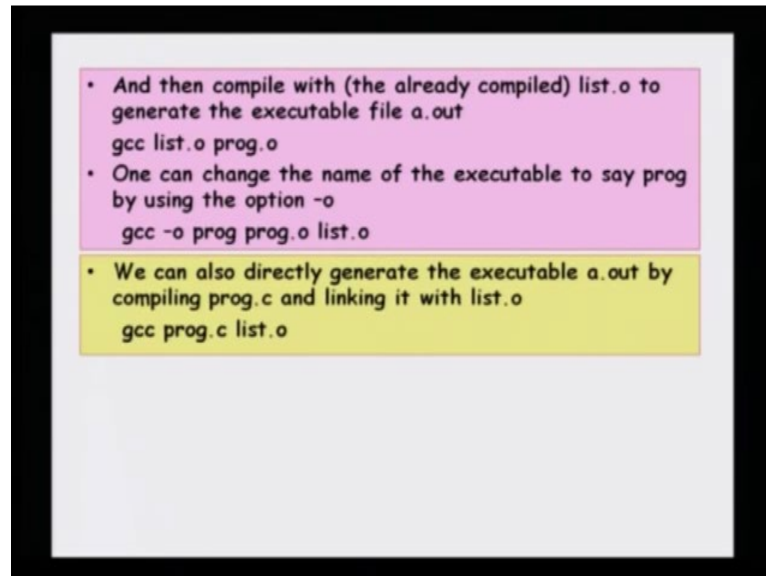

So, this just repeats what was said in the last slide.

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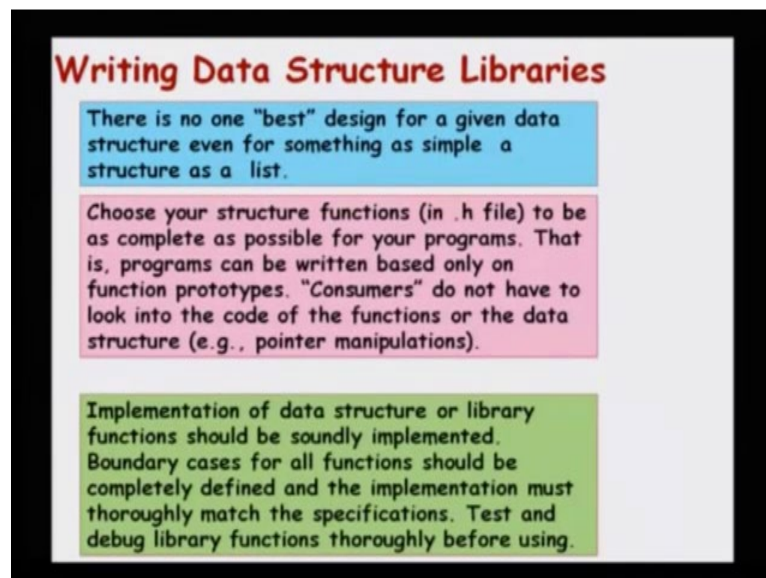

Now, couple of thoughts about a writing data structure libraries. There is no one design which is best for a data structure library. Choose your structure functions to be as complete as possible for your programs. Now, programs can be based only on the function prototypes. Suppose I write a program which needs a list function, I can just look at the function prototypes in the .h file and then write by program. Consumers do not need to know how the program is implemented; just what the functions are, what are

its arguments, not the details about how it is implemented.

Now, implementation of libraries should be very sound. All boundary cases should be completely defined and the implementation should thoroughly match the specifications. So, libraries need to be tested and debug thoroughly before other users can use it.

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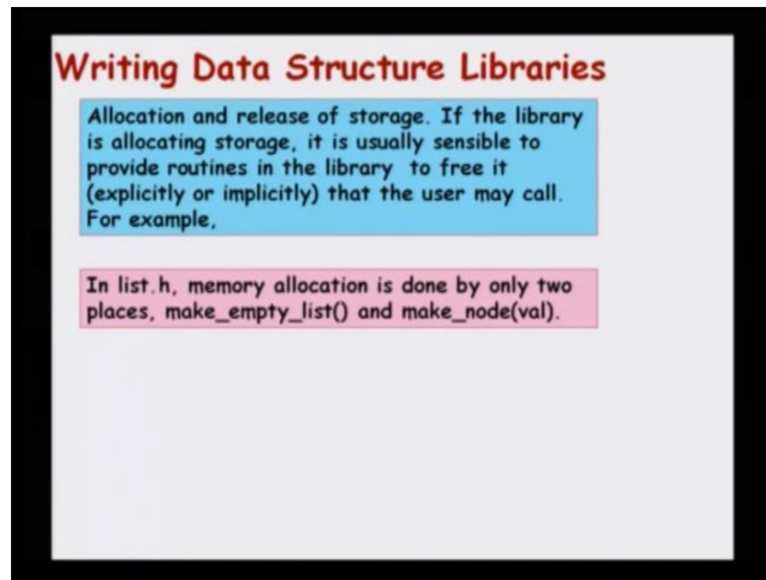

Also one more thing, allocation and release of storage. If the library is allocating storage, it is only sensible to provide routines in the library itself which can free those storage. So, it cannot be that libraries allocating a storage and the freeing of storage has to be done outside the library, that is not a sensible design. So, if the library itself is allocating storage, you give library functions to free the storing as well. For example, in list.h, memory allocation is done only in two places, make empty list and make node. So, to deallocate that you should provide a free functions for these functions, corresponding to these functions.

Thanks.