What do you think?

Work together!

What surprised you about the debugging assignment?

What types of things will you remember to try in the future?

CSE 374 Lecture 16

Week 6: More preprocessor, Multiple Files

Function Stubbing

test.c
db.h
curve.h
curve.c

linkedlist_1.c

Linkedlist.h
Linkedlist.c
linkedlistclient.c

```c
/**
 * Integer linked list example
 * CSE 374
 */

#ifndef LINKEDLIST_H
#define LINKEDLIST_H

// A single list node that stores an integer as data.
typedef struct IntListNode {
  int data;
  struct IntListNode* next;
} IntListNode;


// Allocates a new node on the heap.
IntListNode* makeNode(int data, IntListNode* next);

// Builds a heap-allocated linked from array.
IntListNode* fromArray(int* array, int length);

// Frees all nodes in the linked list.
void freeList(IntListNode* list);

// Prints the contents of the linked list.
void printList(IntListNode* list);

#endif
```

```c
/**
 * Integer linked list client example
 * CSE 374
 */

#include <stdlib.h>
#include "linkedlist.h"

int main(int argc, char **argv) {
  int arr1[3] = {1, 2, 3};
  IntListNode* list1 = fromArray(arr1, 3);
  printList(list1);

  int arr2[4] = {4, 3, 2, 1};
  IntListNode* list2 = fromArray(arr2, 4);
  printList(list2);

  freeList(list1);
  freeList(list2);
  return EXIT_SUCCESS;
}
```

API: Application Programming Interface

- Defines input and output for ‘applications’
  - Can be entire apps, or subfunctions, or classes
  - Library APIs describe available functions in library
- Useful for writing & testing
  - API dictates function prototype
  - (Black box?) Tests that show API adherence

C Header files:

- Define variable and function signatures
- Only what outside code might need to use
- Different header files can allow different visibility

Encapsulation (computer programming)

34 languages

Article Talk Read Edit View history Tools

From Wikipedia, the free encyclopedia

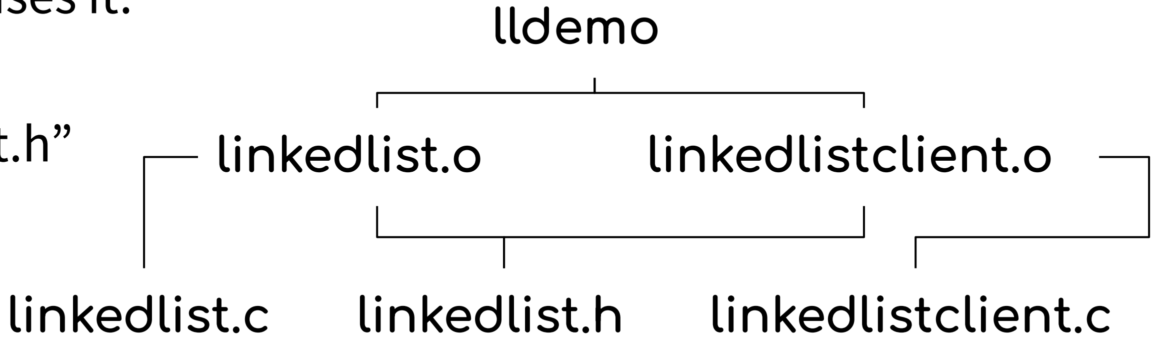
In software systems, **encapsulation** refers to the bundling of data with the mechanisms or methods that operate on the data. It may also refer to the limiting of direct access to some of that data, such as an object's components.[1] Encapsulation allows developers to present a consistent and usable interface which is independent of how a system is implemented internally. As one example, encapsulation can be used to hide the values or state of a structured data object inside a class, preventing direct access to them by clients in a way that could expose hidden implementation details or violate state invariance maintained by the methods.

Linked List Continued

- One set of code to define linked list:
  - Linkedlist.h
  - Linkedlist.c
- Another piece of code uses it:
  - Linkedlistclient.c
  - #include “linkedlist.h”

Compile with

```
$gcc -o lldemo linkedlist.c
    linkedlistclient.c
```



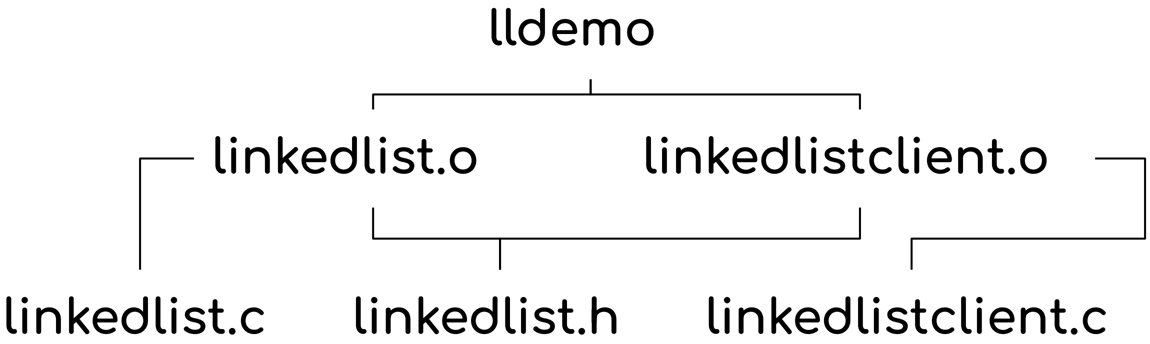
Dependency Tree - *helps decide what to do*

Each target T is dependent on one or more sources S

If any S is newer than T, remake T.

Recursive: If a source is also a target for other sources, must also evaluate its dependencies and possibly remake

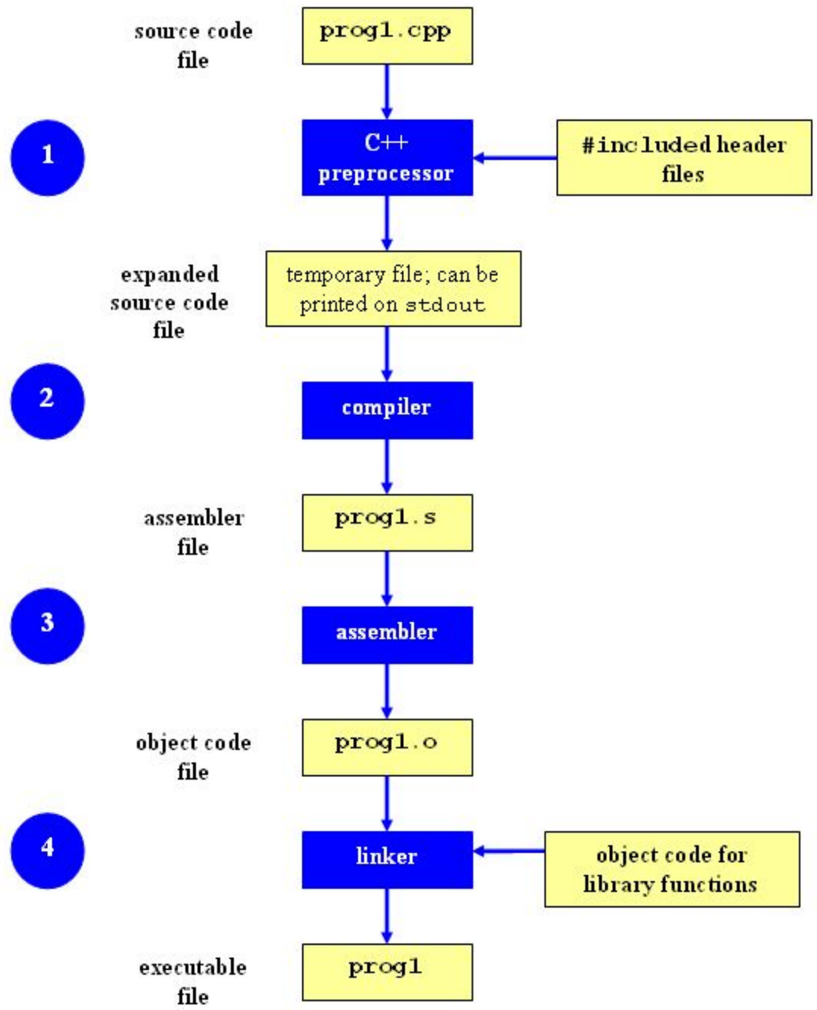
Directed-acyclic-graph
(cycles make no sense)



Compiling in more detail

Compilation process is actually multi-step

Multi-file compilation requires knowing more details



# Stop after the preprocessor and store the preprocessed C file in file.pp
$ gcc -E file.c > file.pp

# Stop after the compiler and store the assembly code in file.s
$ gcc -S file.c

# Stop after the assembler and store the machine code in file.o
$ gcc -c file.c

Preprocessor Review (and header files)

- **The preprocessor rewrites code before the compiler gets it.**
- **Has multiple roles:**
  - **Include header files**
  - **Define Constants**
  - **Define Macros**
  - **Conditional Compilation**

```
#include <stdlib.h>
#include "userfile.h"
```

- Header files
  - Always use '.h',
  - Headers include function, struct, constant declarations
  - Never include function implementations
  - Never include '.c'

```
$gcc -l : look in specific directories
```

What to Include file

1. You create a .h file to share code with another calling module
   a. Declare any variables and functions you want another caller to user
   b. Functions you want to use only in the same file are declare in the .c file
   c. Include libraries needed to compile the header file
2. If you have `a.c`, which uses `printf` include `<stdio.h>` in `a.c`
3. If you also have `b.c`, which uses `printf`, you could include `<stdio.h>` in "`a.h`" and not in `a.c` or `b.c`, however
4. Generally, include any header files needed for directly-called functions (promotes encapsulation), so `b.c` would include `<stdio.h>`

Symbolic Constants & Macros

- Creates TOKEN to represent more text
- Preprocessor:
  - Replaces all matching TOKENS in rest of file
  - Knows where words start and end
  - Has no notion of scope (not the compiler)
- Can shadow another #define
- Use #undef to remove

Constants:

```
#define SYMBOLIC_CONSTANT value
#define NOT_PI 22/7
#define VERSION 3.14
#define FEET_PER_MILE 5280
#define MAX_LINE_SIZE 5000
```

Macros

Replace all matching "calls" with "body" but with text of arguments where the parameters are (just string substitution)

Gotchas (understand why!) ->

Macros DO NOT avoid performance overhead of a function call (maybe true in 1975, not now)

Macros CAN BE more flexible though (type-inspecific)

```
#define TWICE_AWFUL(x) x*2
#define TWICE_BAD(x) ((x)+(x))
#define TWICE_OK(x) ((x)*2)
double twice(double x) {
    return x+x; }
```

```
y=3;
z=4;
w=TWICE_AWFUL(y+z);    [y+z*2]
z=TWICE_BAD(++y);      [++y + ++y]
z=TWICE_BAD(y++);      [y++ + y++]
```

Macros: debugging

Remember - it's just pure string replacement.

```
#define TWICE_AWFUL(x) x*2

int main(int argc, char **argv) {
  int x = 1;
  int y = 2;

  // This gives 5 instead of 6
  printf("Twice(1+2) is 6, but %d\n",
    TWICE_AWFUL(x+y));

  ...
```

Macros: debugging

Remember - it's just pure string replacement.

```
#define TWICE_AWFUL(x) x*2

int main(int argc, char **argv) {
  int x = 1;
  int y = 2;

  // This gives 5 instead of 6
  printf("Twice(1+2) is 6, but %d\n",
    x+y*2);

  ...
```

Justifiable Macros

Parameterized macros are generally to be avoided (use functions)

There are things functions cannot do:

```
#define NEW_T(t, howmany) ((t*)malloc((howmany)*sizeof(t))

#define PRINT(x) printf("%s:%d %s\n", __FILE__, __LINE__,x)
```

Be very careful with syntax if you do use them

Conditional Compilation

```
#ifdef FOO
// only compiled if FOO is defined
#endif

#ifndef FOO
// only compiled if NOT FOO
#endif

#if FOO > 2
// only compiled if FOO > 2
#endif
```

```
// use DBG_PRINT for debug-printing
#ifdef DEBUG
#define DBG_PRINT(x) printf("%s",x)
#else
// replace with nothing
#define DBG_PRINT(x)
#endif

DBG_PRINT("hello world!\n");

$ gcc -D DEBUG foo.c
// or with #define
```

#ifndef: header file inclusion

```
#ifndef FOO_H

#define FOO_H
```

and end it with:

```
#endif
```

- Assuming nobody else defines SOME_HEADER_H (convention)
  - first #include "some_header.h" will do the define and include the rest of the file
  - second and later will skip everything
- More efficient than copying the prototypes over and over again
- In presence of circular includes, necessary to avoid “creating” an infinitely large result of preprocessing

Global Variables

Declared with normal syntax, but outside any functions

Must be declared within file to be 'known' (could be put in header).

```
#include <stdio.h>

#define TWICE_AWFUL(x) x*2
#define TWICE_BAD(x) ((x)+(x))
#define TWICE_OK(x) ((x)*2)

int ex_global;

int main(int argc, char **argv) {
```

Extern & Static Variables

- Global variables have space allocated in the global memory section, not the stack.
  - Persist and can be used by all the functions within scope
  - This is within the same source file
  - UNLESS, keyword `extern` is used
  - If you want to use a global variable across multiple source files put an extern declaration in the header file

```
extern int var;
int var = 0;
int main(void) {
 var = 10;
 return 0;
}
```

- C keyword `static` allocates space in the global memory section, not the stack.
  - Memory persists outside of scope
  - Can not have a static variable in a struct

```
int fun() {
  static int count = 0;
  count++;
  return count;
}
```

- A static function limits the scope of the function
  - Only called within the same source file
  - Allows for encapsulation

Static-Global Variables

Using ‘static’ with global variables, or with functions explicitly limits visibility to current module.

In truth, if you HAVE to use global variables, you should always make them static; C doesn’t require this but it is good software engineering.

Notes: Using ‘static’ here is promoting encapsulation - a concept strongly developed in object oriented programming. It allows you to repeat names in different modules, and to limit visibility for implementation control.