CH-230-A

Programming in C and C++

C/C++

Tutorial 7

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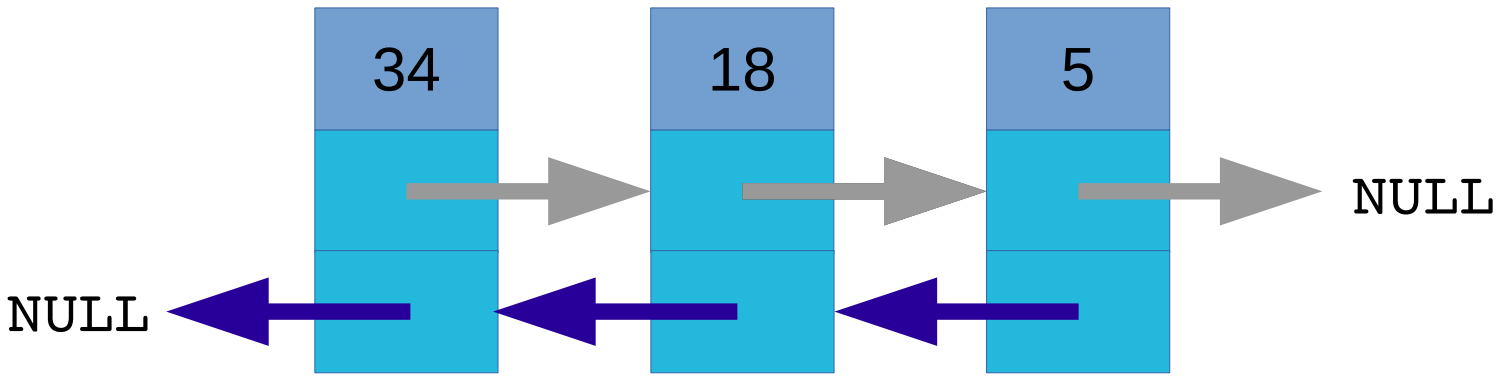
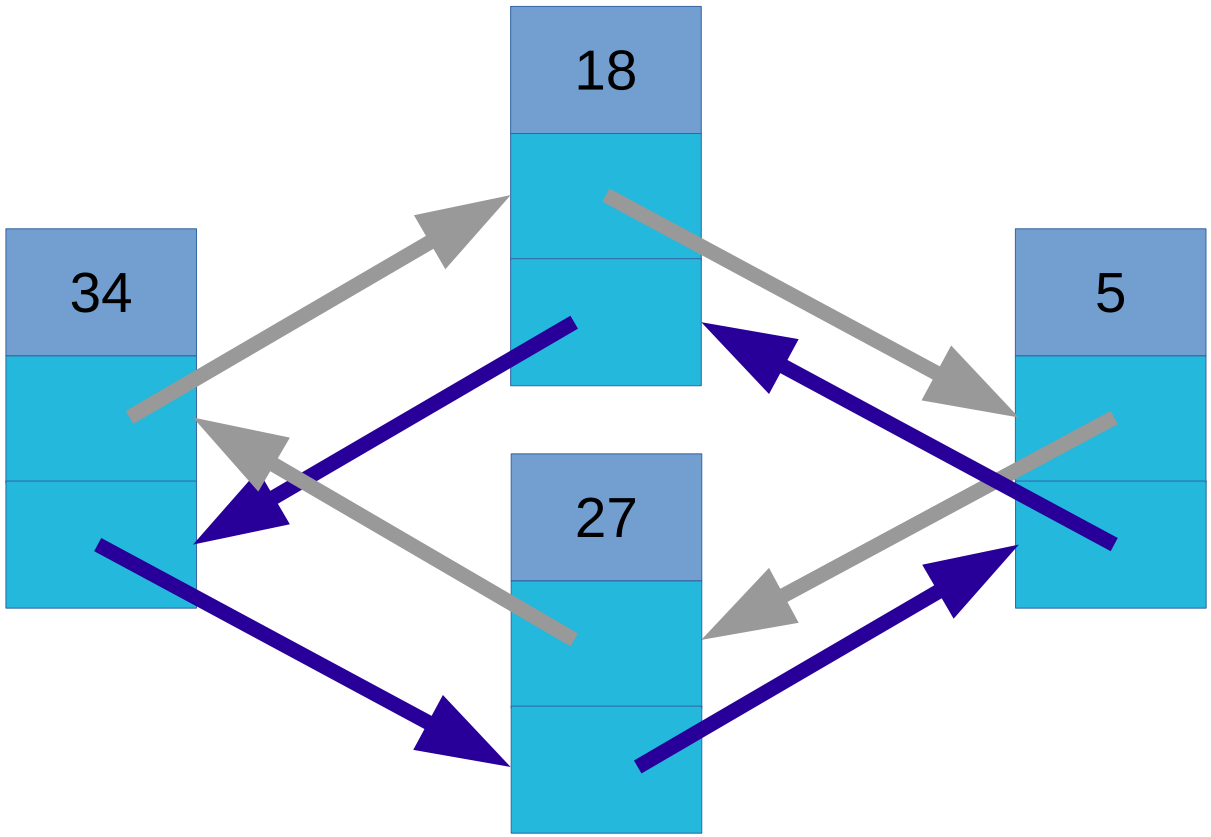
Doubly Linked Lists



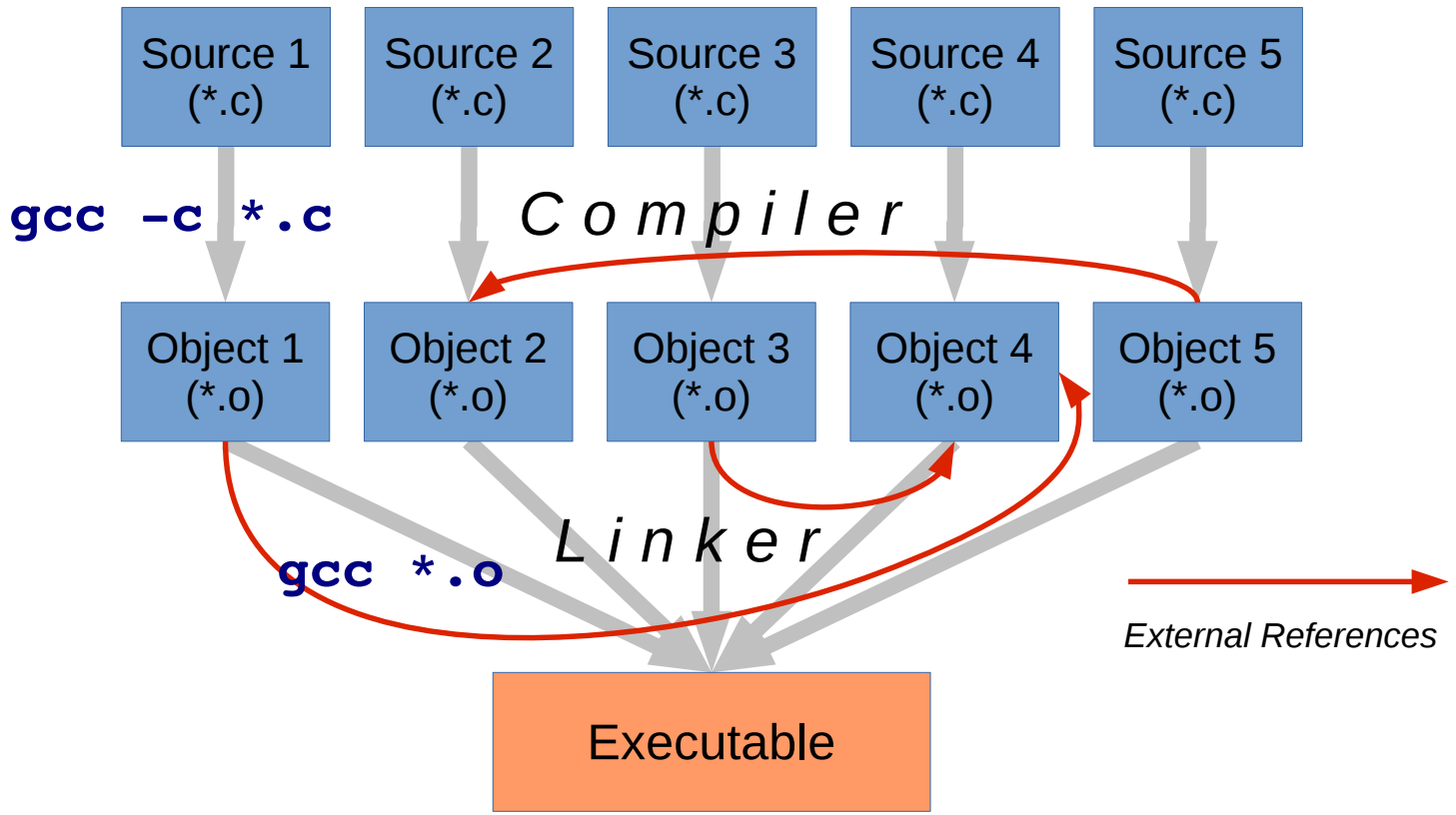
Circular Doubly Linked Lists



Building from Multiple Sources

- C compilers can compile multiple sources files into one executable
- For every declaration there must be one definition in one of the compiled files
  - Indeed also libraries play a role
  - This control is performed by the linker
- `gcc -o name file1.c file2.c file3.c`

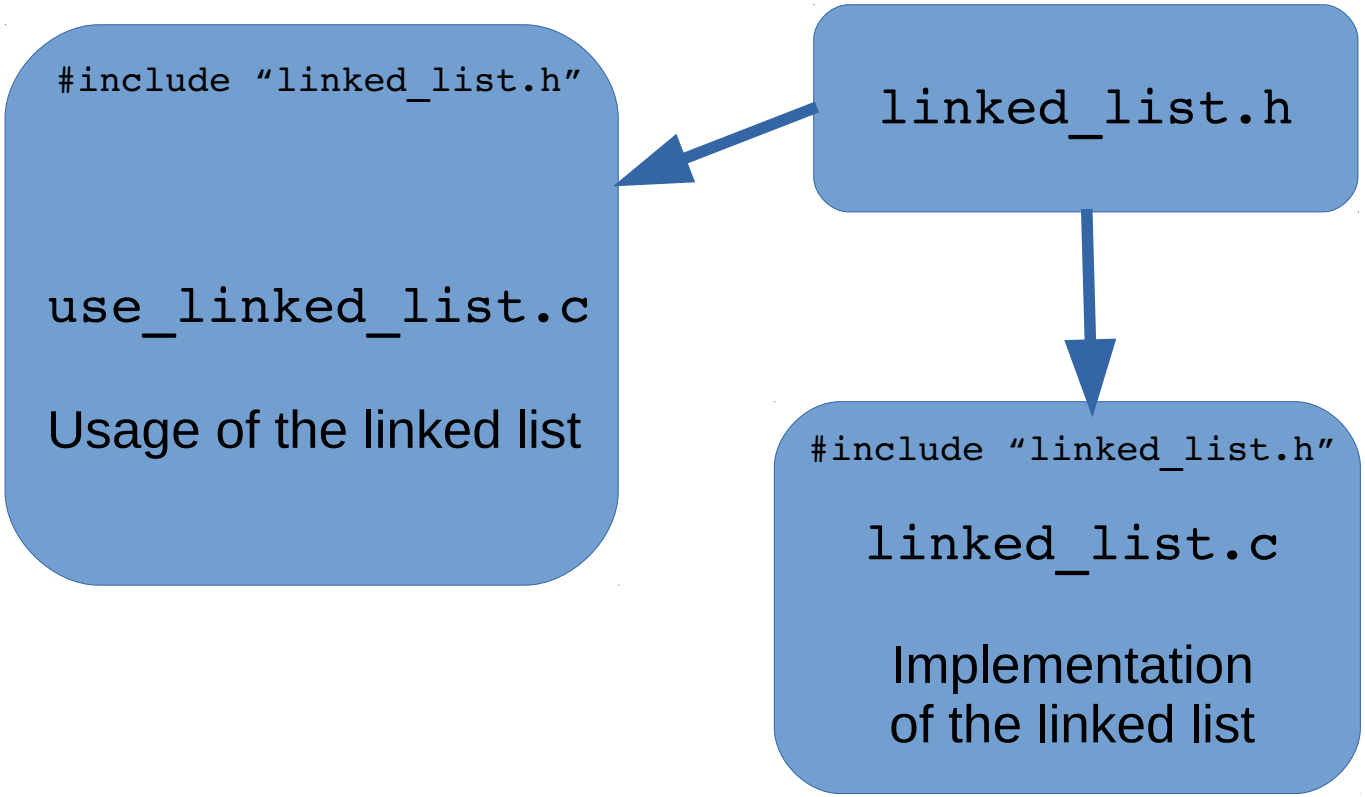
Linking


Source 1 (*.c)
Source 2 (*.c)
Source 3 (*.c)
Source 4 (*.c)
Source 5 (*.c)
gcc -c *.c
Compiler
Object 1 (*.o)
Object 2 (*.o)
Object 3 (*.o)
Object 4 (*.o)
Object 5 (*.o)
Linker
gcc *.o
External References
Executable

Linked List Header File

```
1  /*************************************************************
2   *                                                           *
3   * A simply linked list is linked from node structures       *
4   * whose size can grow as needed. Adding more elements       *
5   * to the list will just cause it to grow and removing       *
6   * elements will cause it to shrink.                         *
7   *-----------------------------------------------------------*
8   * struct ll_node                                            *
9   *       used to hold the information for a node of a        *
10  *       simply linked list                                  *
11  *-----------------------------------------------------------*
12  * Function declaration (routines)                           *
13  *                                                           *
14  *       push_front -- add an element in the beginning       *
15  *       push_back -- add an element in the end              *
16  *       dispose_list -- remove all the elements             *
17  *       ...                                                 *
18  *************************************************************/
```

Definition Import via `#include`



Compile Linked List from Multiple Sources

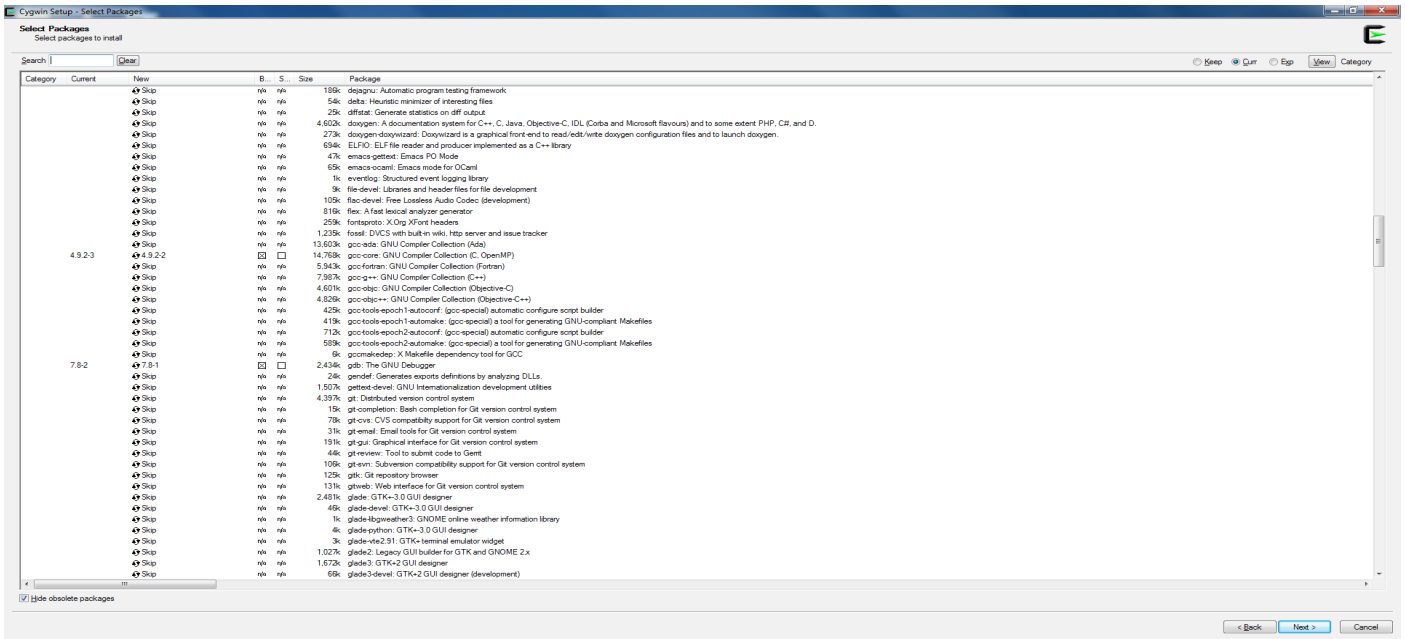
- Create a project with your IDE, add all files including the header file and then compile and execute
- or
- Compile: `gcc -Wall -o use_linked_list linked_list.c use_linked_list.c`
- Execute: `./use_linked_list`

Cygwin

- Cygwin is a Unix-like environment and command-line interface for Microsoft Windows
- Cygwin provides native integration of Windows-based applications, data, and other system resources with applications, software tools, and data of the Unix-like environment
- Thus it is possible to launch Windows applications from the Cygwin environment, as well as to use Cygwin tools and applications within the Windows operating context

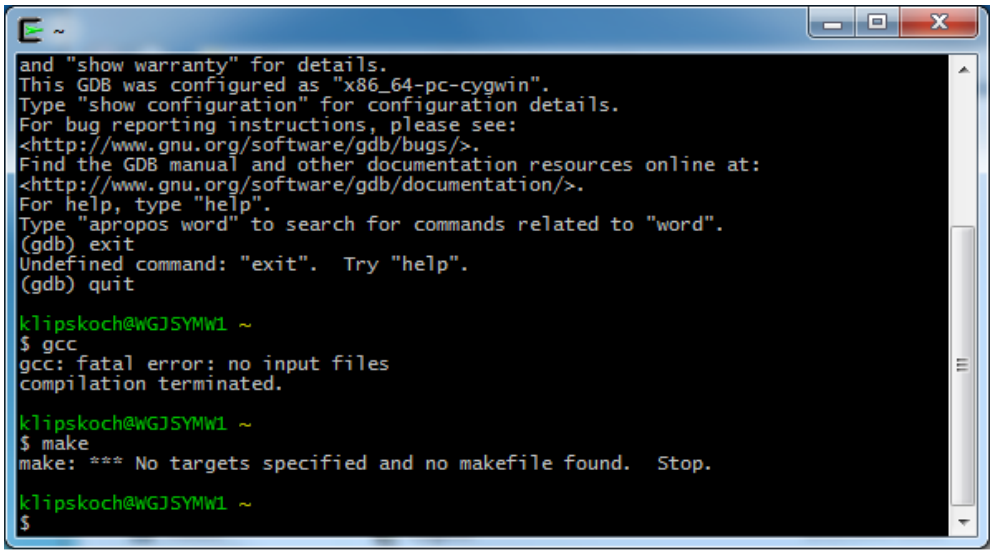
Install Cygwin on Windows (1)

- Go to `https://cygwin.com/install.html`, download `setup-x86_64.exe` and install it
- During installation add `gdb`, `gcc-core` and `make` listed under `Devel`



Install Cygwin on Windows (2)

- Once installed under `C:/cygwin64` you will have a Unix-like environment
- You can use it to compile and debug your code using `gcc` and `gdb`



`make` (1)

- `make` is special utility to help programmer compiling and linking programs
- Programmers had to type in compile commands for every change in program
- With more modules more files need to be compiled
  - Possibility to write script, which handles sequence of compile commands
- Inefficient

`make` (2)

- Compiling takes time
- For only small change in one module, not necessary to recompile other modules
- `make`: compilations depends upon whether file has been updated since last compilation
- Also possible to specify dependencies
- Also possible to specify commands to compile (e.g., depending of suffix of source)

Makefile (1)

- A makefile has the name "Makefile"
- Makefile contains following sections:
  - Comments
  - Macros
  - Explicit rules
  - Default rules

Makefile (2)

- Comments
  - Any line that starts with a # is a comment
- Macro format
  - `name = data`
  - Ex: `OBJ=linked_list.o use_linked_list.o`
  - Can be referred to as `$(OBJ)` from now on

Makefile (3)

Explicit rules

- `target:source1 [source2] [source3]`

  ```
  command1
  [command2]
  [command3]
  ```

- `target` is the name of file to create
- File is created from `source1` (and `source2`, ...)
- `use_linked_list: use_linked_list.o linked_list.o`

  ```
  gcc -o use_linked_list
      use_linked_list.o linked_list.o
  ```

Makefile (4)

Explicit rules

- `target:`

  `command`

  Commands are unconditionally executed each time make is run
- Commands may be omitted, built-in rules are used then to determine what to do

  `use_linked_list.o: linked_list.h use_linked_list.c`
- Create `use_linked_list.o` from `linked_list.h` and `use_linked_list.c` using standard suffix rule for getting to `use_linked_list.o` from `linked_list.c`
- `$(CC) $(CFLAGS) -c file.c`

Example Makefile (1)

- Header file with `struct` definition and function prototypes
  - `header_file.h`
- Implementation file with usage of the `struct` and function definitions
  - `implementation.c`
- Main function where implemented behaviour can be used
  - `main.c`
- Makefile with different targets for different purposes
  - `Makefile.txt`

Run Makefile

- `make`
  Default makefile called `Makefile` and default target all
- `make TargetName`
  Default makefile called `Makefile` and target `TargetName`
- `make -f MyMakeFile.txt`
  Makefile called `MyMakeFile.txt` and default target all
- `make -f MyMakeFile.txt TargetName`
  Makefile called `MyMakeFile.txt` and default target `TargetName`

Example Makefile (2)

```
1  CC = gcc
2  CFLAGS = -Wall
3
4  OBJ = linked_list.o use_linked_list.o
5
6  all: use_linked_list
7
8  use_linked_list: $(OBJ)
9                   $(CC) $(CFLAGS) -o use_linked_list $(OBJ)
10
11 use_linked_list.o: linked_list.h use_linked_list.c
12
13 linked_list.o: linked_list.h linked_list.c
14
15 clean:
16         rm -f use_linked_list *.o
```

Function Pointers

- A pointer may not just point to a variable, but may also point to a function
- In the program it is assumed that the function does what it has to do and you use it in your program as if it was there
- The decision which function will actually be called is determined at run-time

Function Pointer Syntax

- `void (*foo)(int);`
  - `foo` is a pointer to a function taking one argument, an integer, and that returns `void`
- `void *(*foo)(int *);`
  - `foo` is a pointer to a function that returns a `void *` and takes an `int *` as parameter
- `int (*foo_array[2])(int);`
  - `foo_array` is an array of two pointer functions having an `int` as parameter and returning an `int`
- Easier and equivalent:

```
typedef int (*foo_ptr_t)(int);
foo_ptr_t foo_ptr_array[2];
```

Function Pointers: Simple Examples

```
1 void (*func) (void);   /* define pointer to function */
2 void a(void) { printf("func a\n"); }
3 void b(void) { printf("func b\n"); }
4
5 int main() {
6   func = &a;   // calling func() is the same as calling a()
7   func = a;   // calling func() is the same as calling a()
8   func();
9 }
```

One may have an array of function pointers:

```
1 int func1(void);
2 int func2(void);
3 int func3(void);
4 int (*func_arr[3])(void)
5                          = {func1, func2, func3};
```

Another Function Pointer Example

```c
#include <stdio.h>
void output(void) {
  printf("%s\n", "Please enter a number:");
}
int sum(int a, int b) {
  return (a + b);
}
int main() {
  int x, y;
  void (*fptr1)(void);
  int (*fptr2)(int, int);
  fptr1 = output;
  fptr2 = sum;
  fptr1();      // cannot see whether function or pointer
  scanf("%d", &x);
  (fptr1)();    // some prefer this to show it is pointer
  (*fptr1)();   // complete syntax, same as above
  scanf("%d", &y);
  printf("The sum is %d.\n", fptr2(x, y));
}
```

Alternatives for Usage

```
1 int (*fct) (int, int);
2 /* define pointer to a fct */
3 int plus(int a, int b) {return a+b;}
4 int minus(int a, int b) {return a-b;}
5 int a=3; int b=4;
6 fct = &plus;
7 /* calling fct() same as calling plus() */
8 printf("fct(a,b):%d\n", fct(a,b));  /* 7 */
```

or

```
1 printf("fct(a,b):%d\n", (*fct)(a,b));  /* 7 */
2 fct = &minus;
3 /* calling fct() same as calling minus() */
4 printf("fct(a,b):%d\n", fct(a,b));   /* -1 */
```