C++ For C Coders 8

Build Process

Data Structures
C++ for C Coders

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build process
compile & link
static library
make & Makefile

Build Process

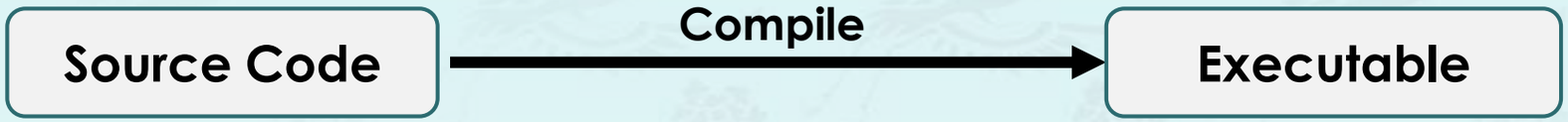
Build Process

1. Compile
2. Link
3. Build a static library
4. Make and Makefile

Build Process

The term build process here refers to the steps starting with source code (**a set of .cpp and .h files**) ending with an executable file representing your program.

- A simplistic view of the build process




```
$ g++ sort.cpp print_list.cpp bubble.cpp quicksort.cpp -I../include -o sort
```

- A simple but realistic view of the build process


```
$ g++ -c sort.cpp print_list.cpp -I../include
$ g++ sort.o print_list.o -L../lib -lsort -o sort
```

Compile

Link

or

```
$ g++ -c sort.cpp print_list.cpp -I../include -L../lib -lsort -o sort
```

(Assume that you have **`libsort.a`** in **`../lib`** folder.)

Compile & Link

Building an executable for a program consists of two major stages:

- **Compile stage (.cpp, .h → .o)**
  - **Syntax** checked for correctness.
  - Variables and function calls checked to insure that correct declarations were made and that they match.
  - It **doesn't match function definitions** to their calls at this point.
  - Translation into **object code**. It is not an executable.
- **Linking stage (.o, .a → .exe)**
  - Links the object code into an executable.
  - May involve one or more object code files.
  - **Function calls** are matched up with their definitions, and the compiler checks to make sure it has one, and only one, definition for every function.
  - The end result of linking is usually an executable.

Compiling options

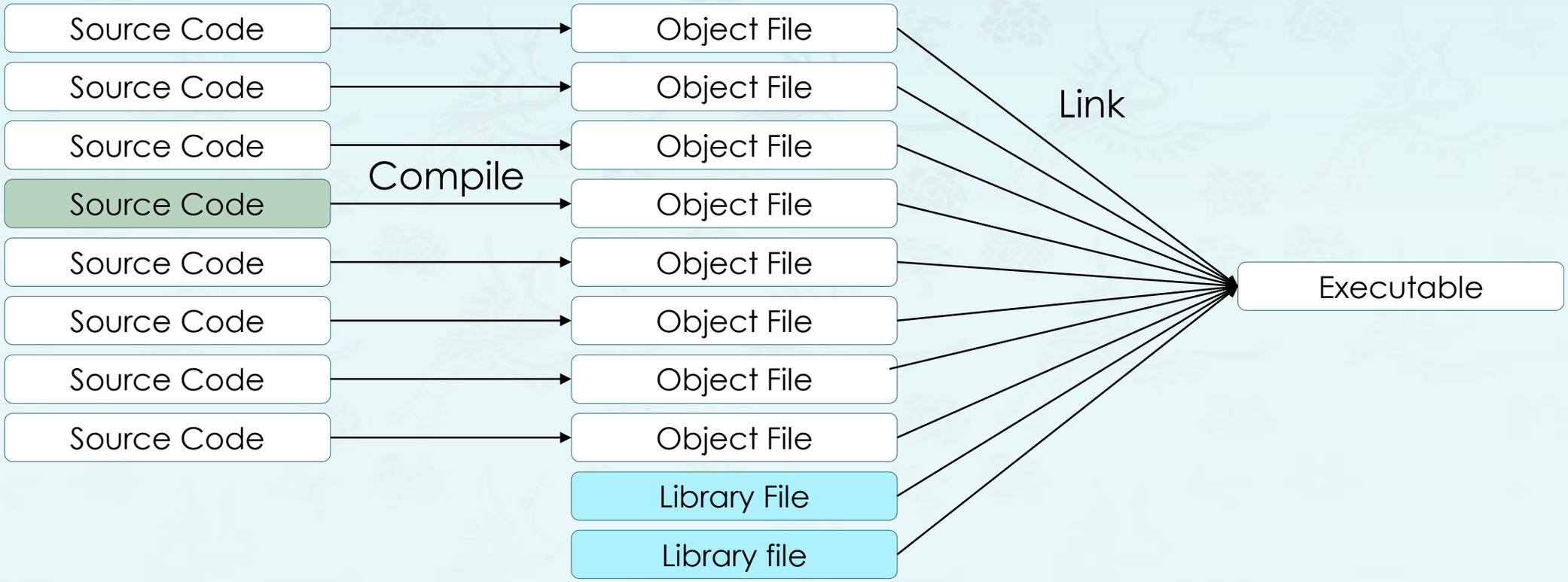
- **`-g`** - turn on debugging (so GDB gives more friendly output)
- **`-Wall`** - turns on most warnings
- **`-O`** or **`-O2`** - turn on optimizations
- **`-o <name>`** - name of the output file
- **`-c`** - output an object file (**`.o`**)
- **`-I<include path>`** - specify an **`include`** directory
- **`-L<library path>`** - specify a **`lib`** directory
- **`-l<library>`** - link with library **`lib<library>.a`**

- Use `-L`*`dir`* option such that linker looks for library files in in ***dir*** folder.
  Use `-l`*`library`* such that linker searches the library named *`library`*.

Build Process

Addressing the build process efficiency:

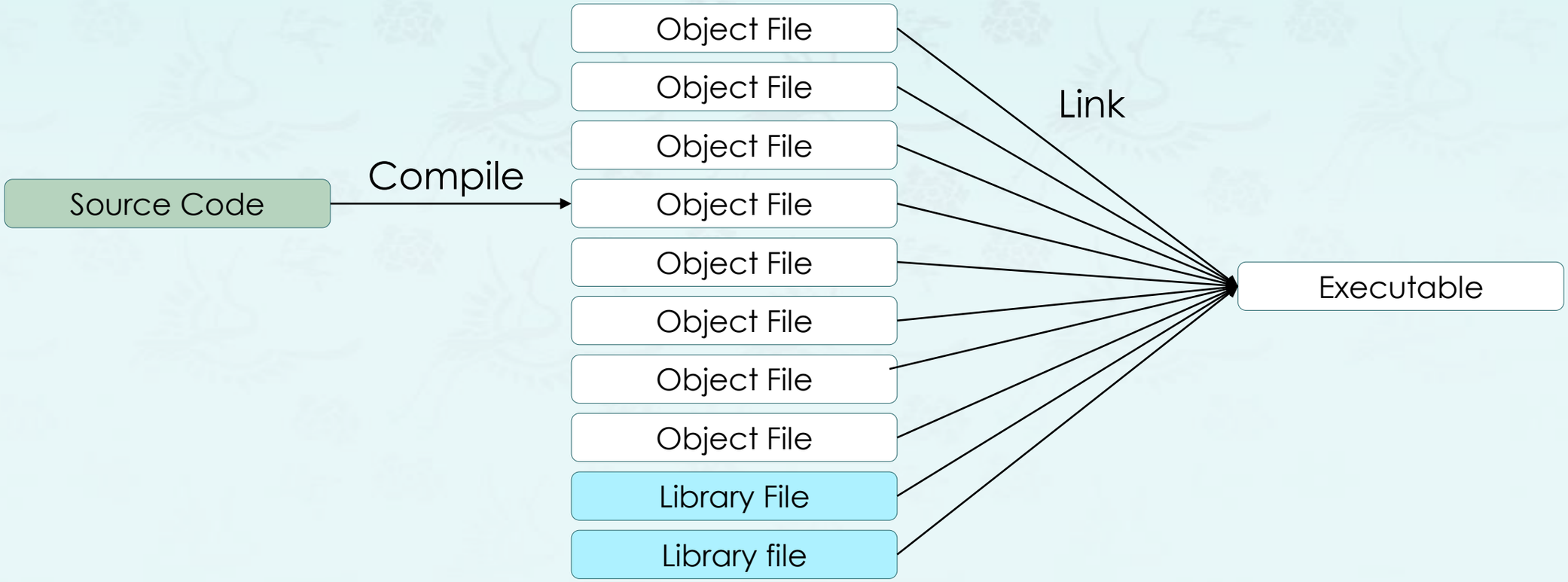
- In this case we highlight the situation where ONE of those files has changed since the previous build. In building the naive brute-force way, ALL source code is recompiled, even those source code files that have not changed.



Build Process

Addressing the build process efficiency:

- Only one source file has changed since the last build. This is the only file re-compiled on the following build. The build otherwise uses the unchanged object files from the previous build, shortening the overall build time.



Creating a Library Archive

An archive in C/C++ is a file that bundles a set of object files into a single file.

- This file always follows the naming convention of starting with **lib** and ending with **.a**, e.g., `libsort.a` and `libnowic.a` in our library examples.

- An archive file can be build from object files using the **ar** command:

```
$ ar cr libsort.a bubble.o insertion.o quicksort.o selection.o
```

- **ar** Options
  - `-c`: Create an archive file
  - `-r`: Insert the files member... into archive (with replacement).
  - `-s`: Write an object-file index into the archive, change is made to the archive
  - `-t`: Display contents of archive (show the list of .o files, use nm ~.o to see functions in ~.o)

Creating a Library Archive

- **ar** Examples:
  - `g++ -c nowic.cpp -I../include` `// produces nowic.o`
  - `ar crs libnowic.a nowic.o` `// produces libnowic.a that includes nowic.o`
  - `ar` `// list all the options available`
  - `ar t libnowic.a` `// list ~.o files archived`
  - `ar x libnowic.a` `// extract ~.o files archived`
  - `nm nowic.o` `// list the actual function names in .o file`

- You may refer to **/nowic/UsingStaticLib.md**.

The make utility

- Building a program from its source files can be a complicated and time-consuming operation. The commands are too long to be typed in manually every time. However, a straightforward shell script is seldom used for compiling a program, because it's too time-consuming to recompile all modules when only one of them has changed.
- However, it's too error-prone to allow a human to tell the computer which files need to be recompiled. Forgetting to recompile a file can mean hours of frustrating debugging. A reliable automatic tool is necessary for determining exactly which modules need recompilation.
- A standard tool for solving exactly this problem is called **make**. It relies either on its own built-in knowledge, or on a file called a ***Makefile*** that contains a detailed recipe for building the program.

references
- http://nuclear.mutantstargoat.com/articles/make/
- https://skandhurkat.com/post/makefile-dependencies/

The make utility

- You may need to install some packages.
  (Install it as **admin privilege**. 관리자모드로 설치하십시오)

```
$ pacman –S base-devel                  #install the build toolchain
$ pacman –Syu                           #update msys2
Alternatively,
$ pacman -S --needed base-devel mingw-w64-i686-toolchain mingw-w64-x86_64-toolchain
```

- For macOS, use 'Homebrew' to install these kinds of packages in general.
  - https://osxdaily.com/2018/03/07/how-install-homebrew-mac-os/
  - https://whitepaek.tistory.com/3
- For Linux,

```
$ ./configure
$ make
$ sudo make install
```

The make utility – a simple example of Makefile

- **Basic syntax for Makefile:**

```
target: dependencies
<tab>system command(s)
```

- **Example:**

  Source files: quicksort.cpp,
  print_list.cpp

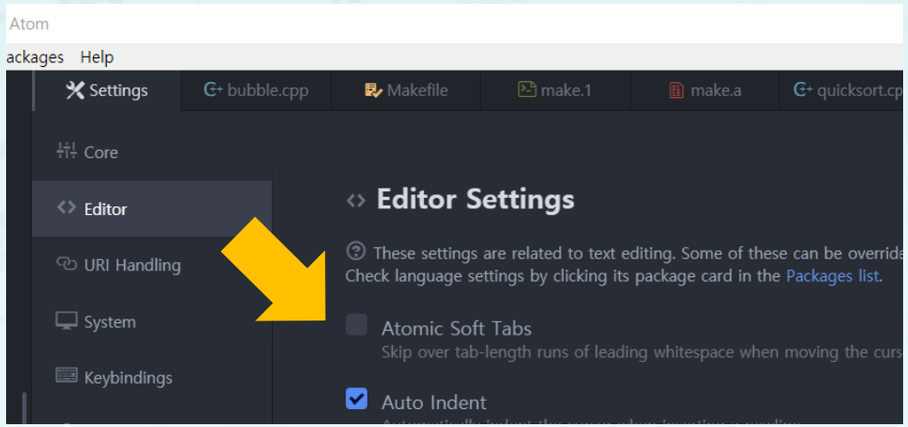
  Executable: qsort.exe

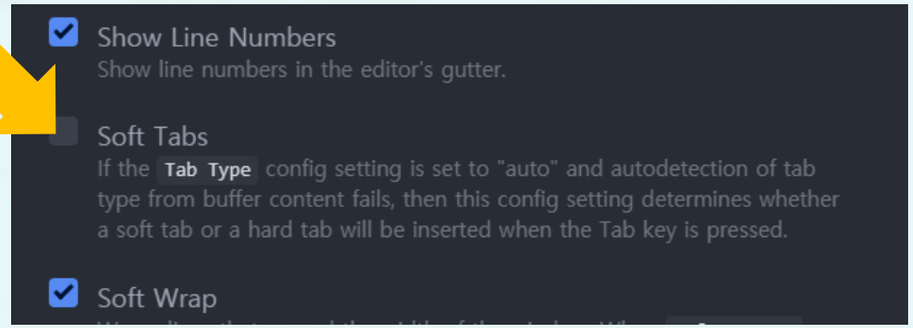
- **Makefile:**

```
qsort: quicksort.o print_list.o
    g++ quicksort.o print_list.o -o qsort

quicksort.o: quicksort.cpp
    g++ -c quicksort.cpp
print_list.o: print_list.cpp
    g++ -c print_list.cpp
clean:
<tab> rm -f *.o qsort.exe qsort
```

- Use a hard <tab>
- Restart atom after turning on Hard Tabs





The make utility – a simple example of Makefile

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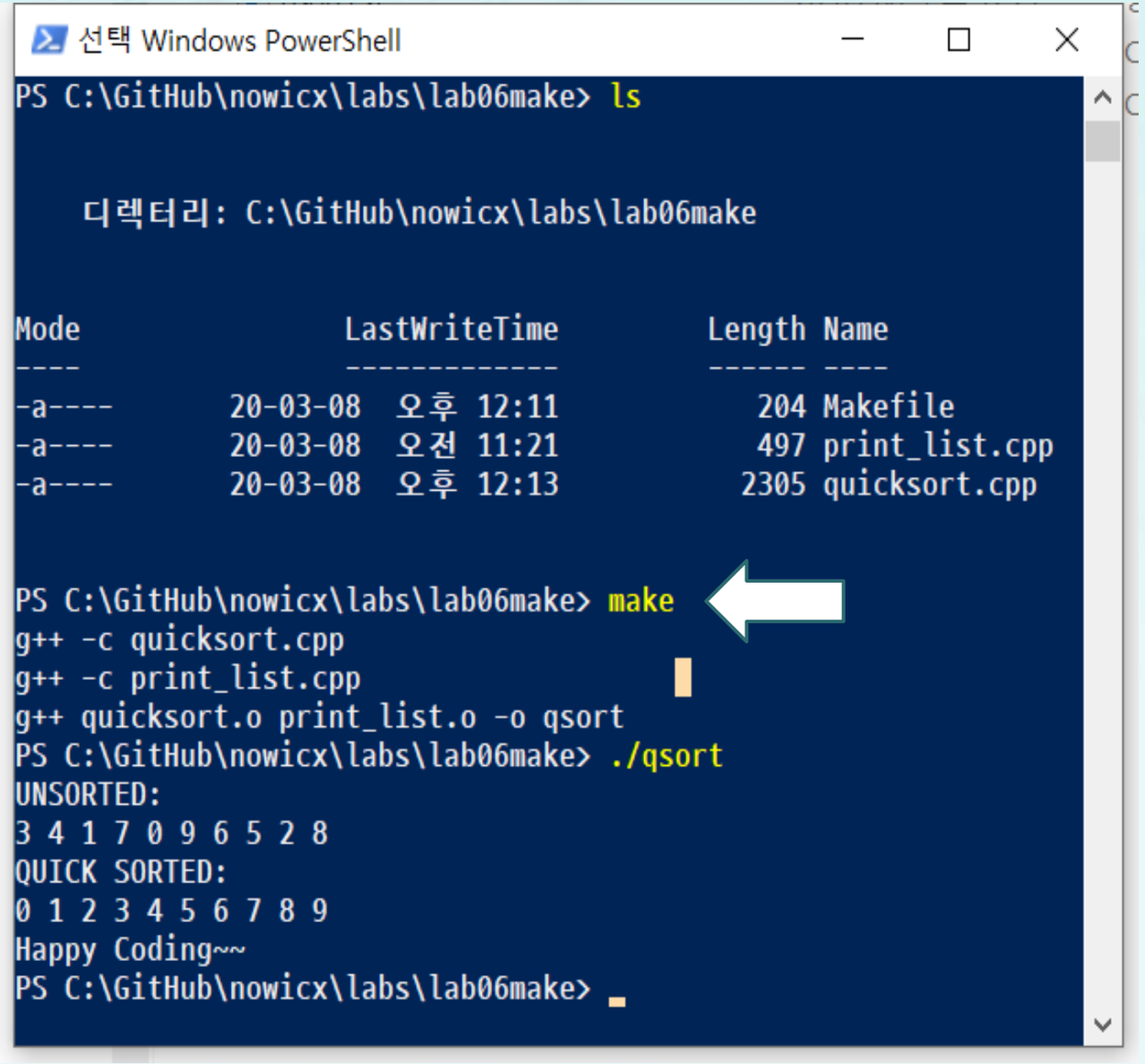
  Executable: qsort.exe

- **Makefile:**

```
qsort: quicksort.o print_list.o
    g++ quicksort.o print_list.o -o qsort

quicksort.o: quicksort.cpp
    g++ -c quicksort.cpp
print_list.o: print_list.cpp
    g++ -c print_list.cpp
clean:
<tab> rm -f *.o qsort.exe qsort
```



The make utility – a cruel example of Makefile

```
sortx: sortx.o print_list.o bubble.o insertion.o quicksort.o selection.o
	g++ -o sortx sortx.o print_list.o bubble.o insertion.o quicksort.o selection.o
sortx.o: sortx.cpp
	g++ -c sortx.cpp -I../../include
print_list.o: print_list.cpp
	g++ -c print_list.cpp
bubble.o: bubble.cpp
	g++ -c bubble.cpp
insertion.o: insertion.cpp
	g++ -c insertion.cpp
quicksort.o: quicksort.cpp
	g++ -c quicksort.cpp
selection.o: selection.cpp
	g++ -c selection.cpp
clean:
	rm -f *.o
cleanx:
<tab>	rm -f *.o sortx.exe sortx
```

```
# Using Rules
INCDIR = ../../include
SRCS = sortx.cpp print_list.cpp bubble.cpp ...
OBJS = $(SRCS:.cpp=.o)
TARGET = sortx
$(TARGET): $(OBJS)
    g++ –I$(INCDIR) $(SRCS) -o $(TARGET)
```

The make utility – a typical Makefile

```
CC = g++
CCFLAGS = -Wall -std=c++11
LDFLAGS = -L$(LIBDIR) -lsort –lnowic –lm
LIBDIR = ../lib
INCDIR = ../include
SRCS = $(wildcard *.cpp)
OBJS = $(SRCS:.cpp=.o)
TARGET = sortx
TARGET: $(OBJS)
    $(CC) $(CCFLAGS) –I$(INCDIR) -o $@ $^ $(LDFLAGS)

.PHONY: clean
clean:
    rm -f $(OBJS) $(TARGET)
```

$@ - refers to the target
$^ - refers to all dependencies
$< - refers to the first dependency
% - make a pattern that we want to watch in both the target and the dependency

The make utility – make.1

```
# make.1 – incomplete makefile without automatic dependencies
CC = g++
CCFLAGS = -Wall -std=c++11
LDFLAGS = -L$(LIBDIR)
LIBDIR = ../../lib
INCDIR = ../../include
SRCS = sortx.cpp print_list.cpp bubble.cpp insertion.cpp quicksort.cpp selection.cpp
OBJS = $(SRCS:.cpp=.o)
TARGET = sortx
%.o: %.cpp
    $(CC) -c -I$(INCDIR) -o $@ $< $(CCFLAGS)
$(TARGET): $(OBJS)
<tab>$(CC) -o $@ $^ $(LDFLAGS)
.PHONY:clean cleanx
clean:
    rm -f $(OBJS)
cleanx:
    rm -f $(OBJS) $(TARGET).exe $(TARGET)
```

```
The following dependency is unchecked.
sortx.cpp depends on include/sort.h
```

```
$ make –f make.1
$ make clean –f make.1
$ make cleanx –f make.1
```

The make utility – make.2

```
# make.2 – make using auto dependencies
CC = g++
CCFLAGS = -Wall -std=c++11
LDFLAGS = -L$(LIBDIR)
LIBDIR = ../../lib
INCDIR = ../../include

SRCS = sortx.cpp print_list.cpp \
       bubble.cpp insertion.cpp \
       quicksort.cpp selection.cpp
OBJS = $(SRCS:.cpp=.o)
DEPS = $(SRCS:.cpp=.d)
TARGET = sortx
# make target (executable)
$(TARGET): $(OBJS)
    $(CC) -o $(TARGET) $(OBJS) $(LDFLAGS)
```

```
# compile & automatic dependency generation
%.o: %.cpp
 <tab>(CC) -c $(CCFLAGS) -I$(INCDIR) $< -o $@
 <tab>(CC) -I$(INCDIR) -MM -MF $*.d $<
-include $(DEPS)

.PHONY: all debug clean cleanx
all: $(TARGET)
debug: CCFLAGS += -DDEBUG -g
debug: all
clean:
    rm -f $(OBJS) $(DEPS)
cleanx:
    rm -f $(OBJS) $(DEPS) $(TARGET).exe $(TARGET)
```

```
$ make –f make.2
$ make debug –f make.2
$ make clean –f make.2
$ make cleanx –f make.2
```

Build a static library – libsort.a

```
~/include>          sort.h
~/lib>              libsort.a
~/labs/lab06        sort.cpp print_list.cpp bubble.cpp insertion.cpp ...

~/labs/lab06$ g++ -c bubble.cpp
~/labs/lab06$ g++ -c insertion.cpp
~/labs/lab06$ g++ -c quicksort.cpp
~/labs/lab06$ g++ -c selection.cpp
~/labs/lab06$ ar cru libsort.a bubble.cpp insertion.cpp quicksort.cpp selection.cpp
~/labs/lab06$ ar t libsort.a
~/labs/lab06$ cp libsort.a ../../lib
```

Build an executable using a static lib

```
~/include>          sort.h
~/lib>              libsort.a
~/labs/lab06        sort.cpp print_list.cpp

~/labs/lab06> g++ sort.cpp print_list.cpp -I../../include -L../../lib -lsort -o sort
```

Build a static library – make.3

```
# make.3 - build a static library
CC = g++
CCFLAGS = -Wall -std=c++11
SRCS = bubble.cpp insertion.cpp quicksort.cpp selection.cpp
OBJS = $(SRCS:.cpp=.o)
DEPS = $(SRCS:.cpp=.d)
TARGET = libsort.a
$(TARGET): $(OBJS)
    ar cru $@ $^
    ranlib $@
$(OBJS): %.o: %.cpp
    $(CC) -c $(CCFLAGS) $< -o $@
    $(CC) -MM -MF $*.d $<
-include $(DEPS)
clean:
      rm -f $(OBJS) $(DEPS) $(TARGET)
```

$@ - refers to the target
$^ - refers to all dependencies
$< - refers to the first dependency
$* - wildcard (or any number of characters)
% - make a pattern that we want to watch in both the target and the dependency

Build an executable using a static lib – make.4

```
# make.4 - makefile using a static lib
CC = g++
CC = g++
CCFLAGS = -Wall -std=c++11
LDFLAGS = -L$(LIBDIR) –lsort
LIBDIR = ../../lib
INCDIR = ../../include

SRCS = sortx.cpp print_list.cpp
OBJS = $(SRCS:.cpp=.o)

TARGET = sortx
# make target (executable)
$(TARGET): $(OBJS)
    $(CC) -o $(TARGET) $(OBJS) $(LDFLAGS)
```

```
# compile & automatic dependency generation
$(OBJS): %.o: %.cpp
    $(CC) -c $(CCFLAGS) -I$(INCDIR) $< -o $@
    $(CC) -I$(INCDIR) -MM -MF $*.d $<
-include $(SRCS:.cpp=.d)

.PHONY: all debug clean cleanx
all: $(TARGET)
debug: CCFLAGS += -DDEBUG -g
debug: all
clean:
    rm -f $(OBJS) *.d
cleanx:
    rm -f $(OBJS) *.d $(TARGET).exe $(TARGET)
```

```
$ make –f make.4
$ make debug –f make.4
$ make clean –f make.4
$ make cleanx –f make.4
```

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