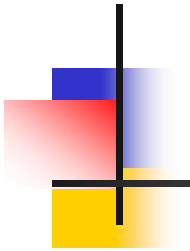


# System Programming

## Software Development: g++ and make

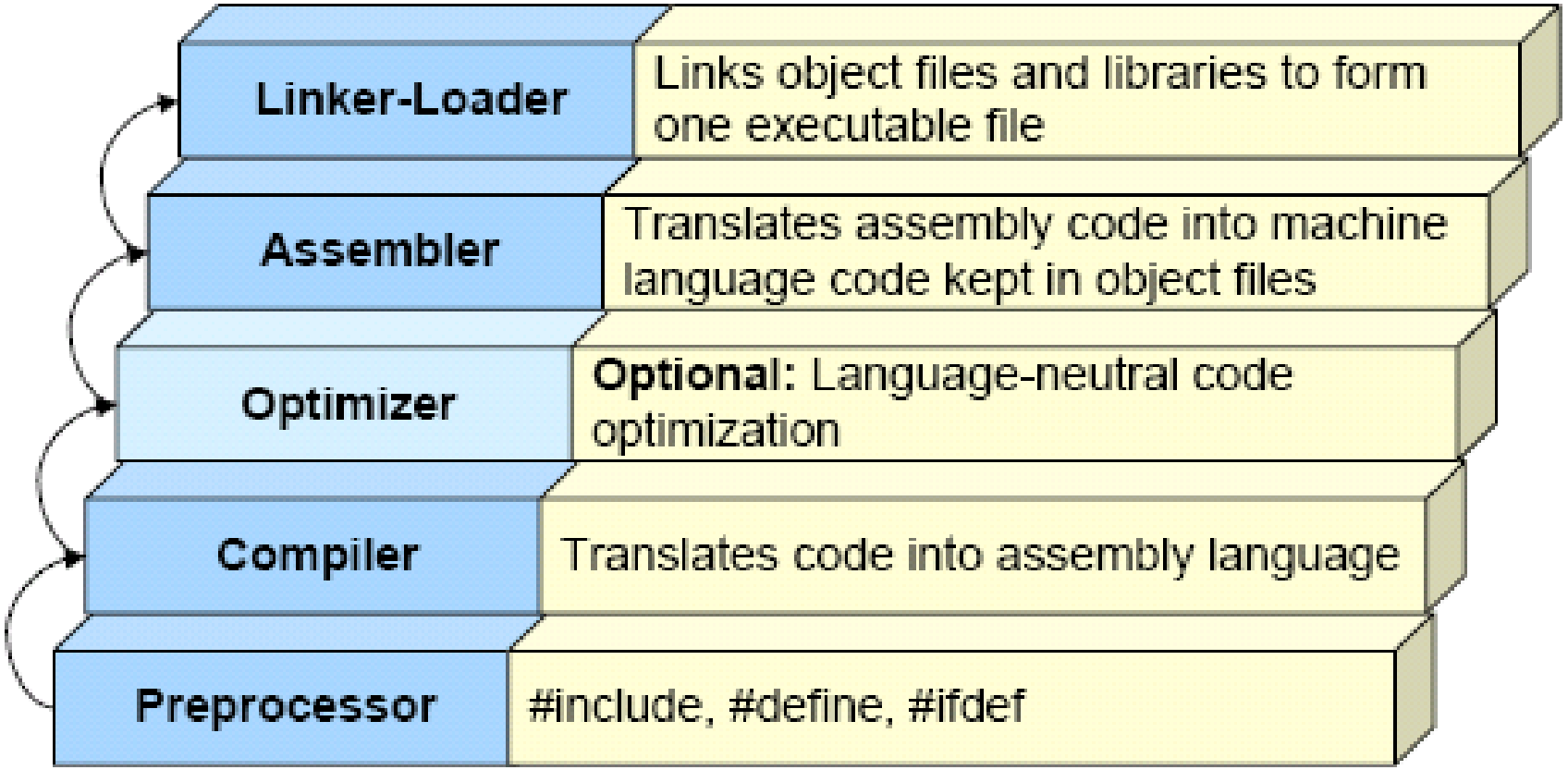
# Software Development Process

- Creation of source files (.c,.h,.cpp)
- Compilation (e.g. *.c →*.o) and linking
- Running and testing programs

# Development Tools

- Creation of source files (*.c, *.h, *.cpp)
  - Text editors
    - `vi, emacs`
  - Revision (version) control systems
    - `rcs, cvs`
- Compilation (*.o) and linking
  - Compilers
    - `gcc, g++`
  - Automatic building tools
    - `make`
- Running and testing (xdb, gdb)

# Compilation Process



# Basic g++ Examples

- `g++ hello.cpp`
  - compile `hello.cpp`
  - produce executable `a.out`
- `g++ -o hello hello.cpp`
  - compile `hello.cpp`
  - produce executable `hello`
- `g++ -o hello hello.cpp util.cpp`
  - compile `hello.cpp` and `util.cpp`
  - produce executable `hello`

# Separate Compilation

- From any source file you can produce an object file to be linked in later to make an executable

```
g++ -c hello.cpp
g++ -c util.cpp
g++ -o hello hello.o util.o
```

# g++ Options

- `-c`
  - compile source files, but do not link
  - output is an object file corresponding to source file
- `-o <file>`
  - puts output in file called `<file>`
- `-g`
  - include debugging symbols in the output
  - to be used later by debugging program (`gdb`)
- `-Wall`
  - display all warnings – program may still compile

# g++ Options

- `-D<macro>`
  - defines macro with the string ‘1’
- `-l<name>`
  - include library called `lib<name>.a`
- `-I<path>`
  - look for include files in the directory provided
- `-L<path>`
  - look for libraries in the directory provide
- There are default directories in which g++ looks for include files and libraries

# Defines in g++

- Often programs contain conditional parts based on defines:

```
#ifdef DEBUG
printf("value of var is %d", var);
#endif
```

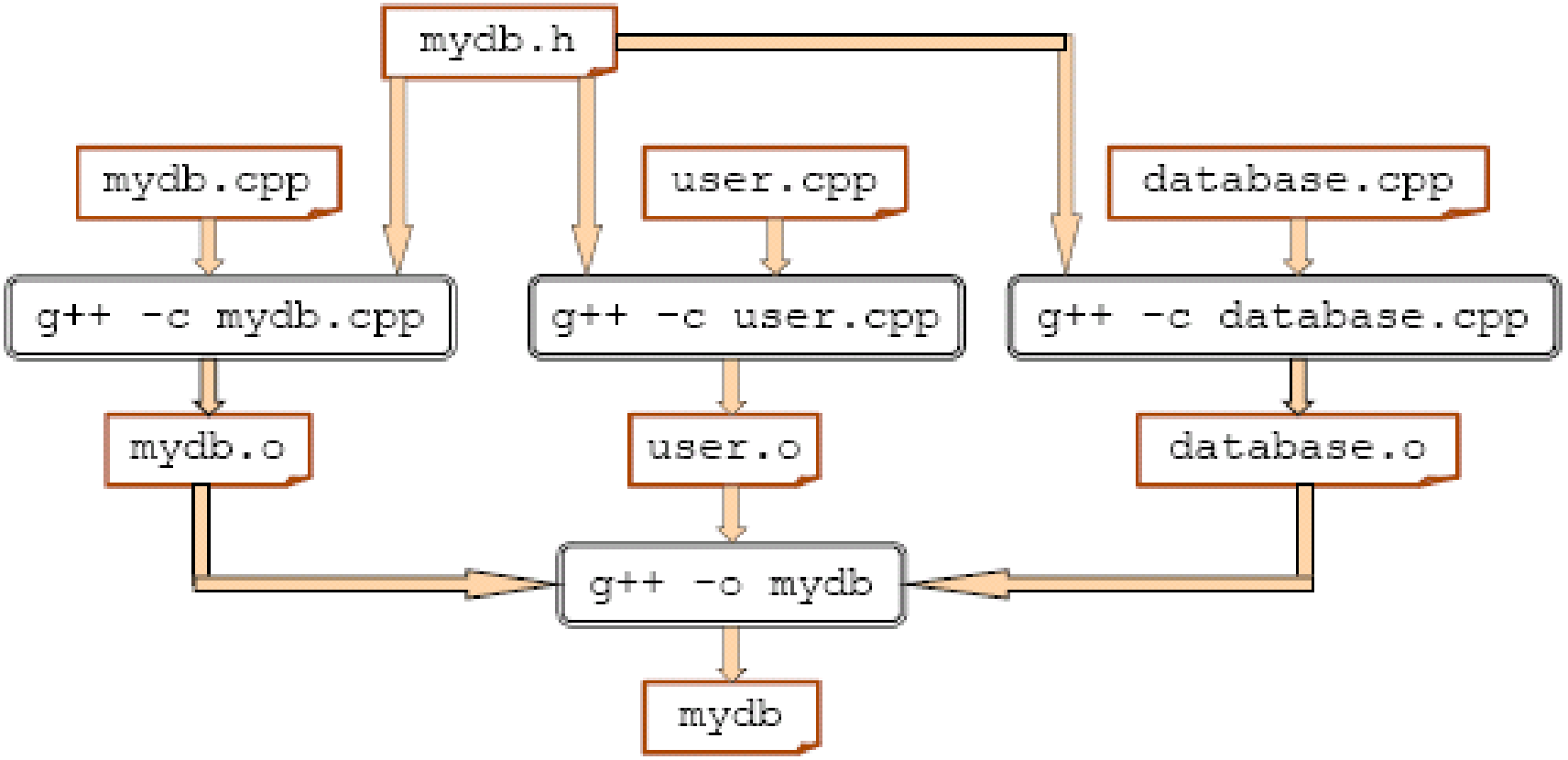
- You can set preprocessor defines on the command line

```
g++ -DDEBUG -o prog prog.c
```

# Separate Compilation Scenario

- You build a personal database and an interface program called `mydb` that has a user interface and database backend
- Source files: `mydb.cpp`, `user.cpp`, `database.cpp`
- Common header file: `mydb.h`
- Executable: `mydb`

# Build Dependencies



# Using `make` in Compile

- With medium to large software projects containing many files, it is difficult to:
  - Type commands to compile all the files correctly each time
  - Keep track of which files have been changed
  - Keep track of dependencies among files
- `make` automates this process

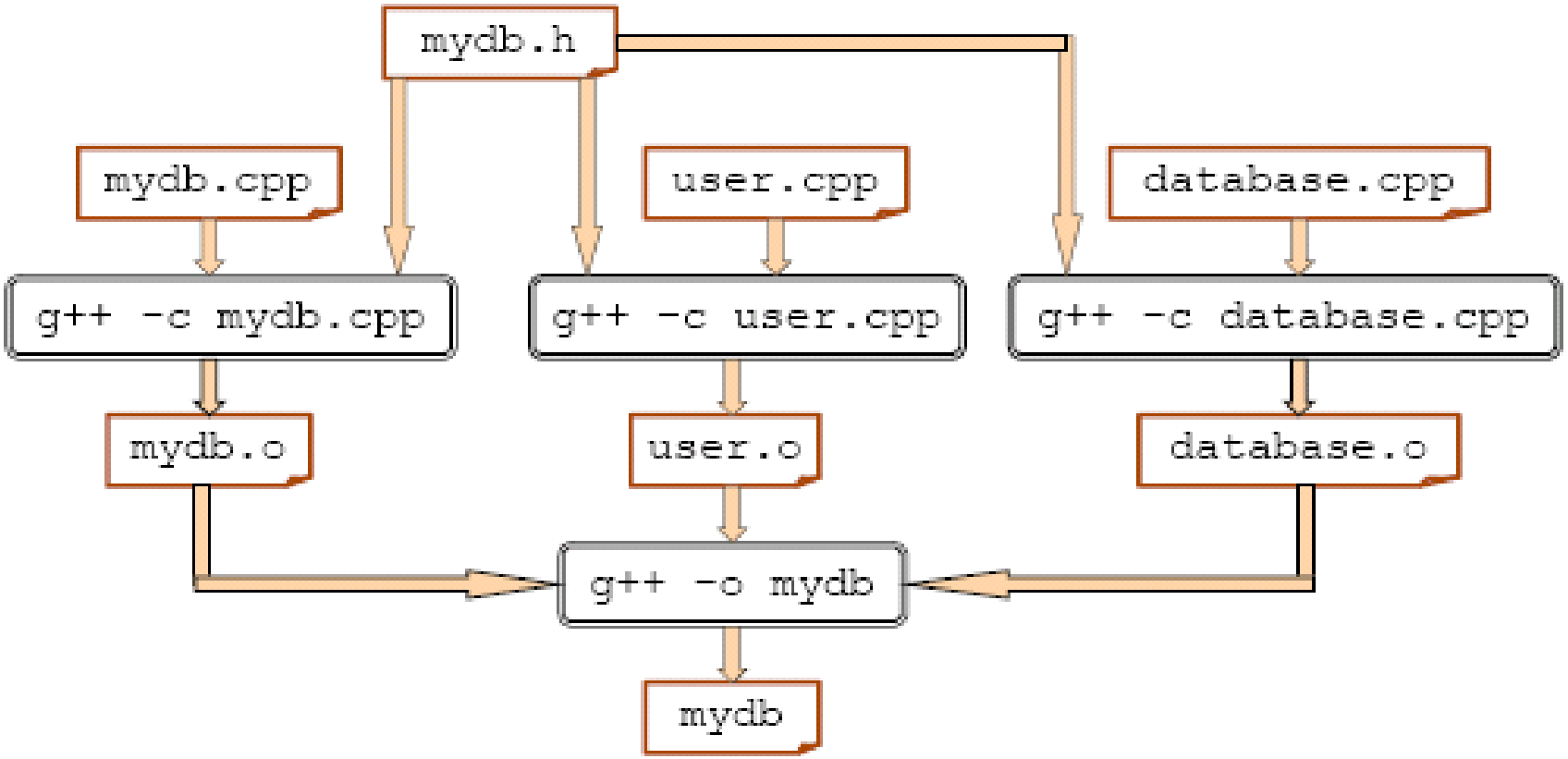
# Basic Operation of **`make`**

- Reads a file called `[Mm]akefile` that contains rules for building a program
  - if program is dependent on another file, then that file is built
  - all dependencies are built, working backward through the chain of dependencies
  - programs are only built if they are older than the files they depend upon

# Basic **Makefile** Example

```
# Makefile for mydb
mydb: mydb.o user.o database.o
    g++ -o mydb mydb.o user.o database.o
mydb.o : mydb.cpp mydb.h
    g++ -c mydb.cpp
user.o : user.cpp mydb.h
    g++ -c user.cpp
database.o : database.cpp mydb.h
    g++ -c database.cpp
```

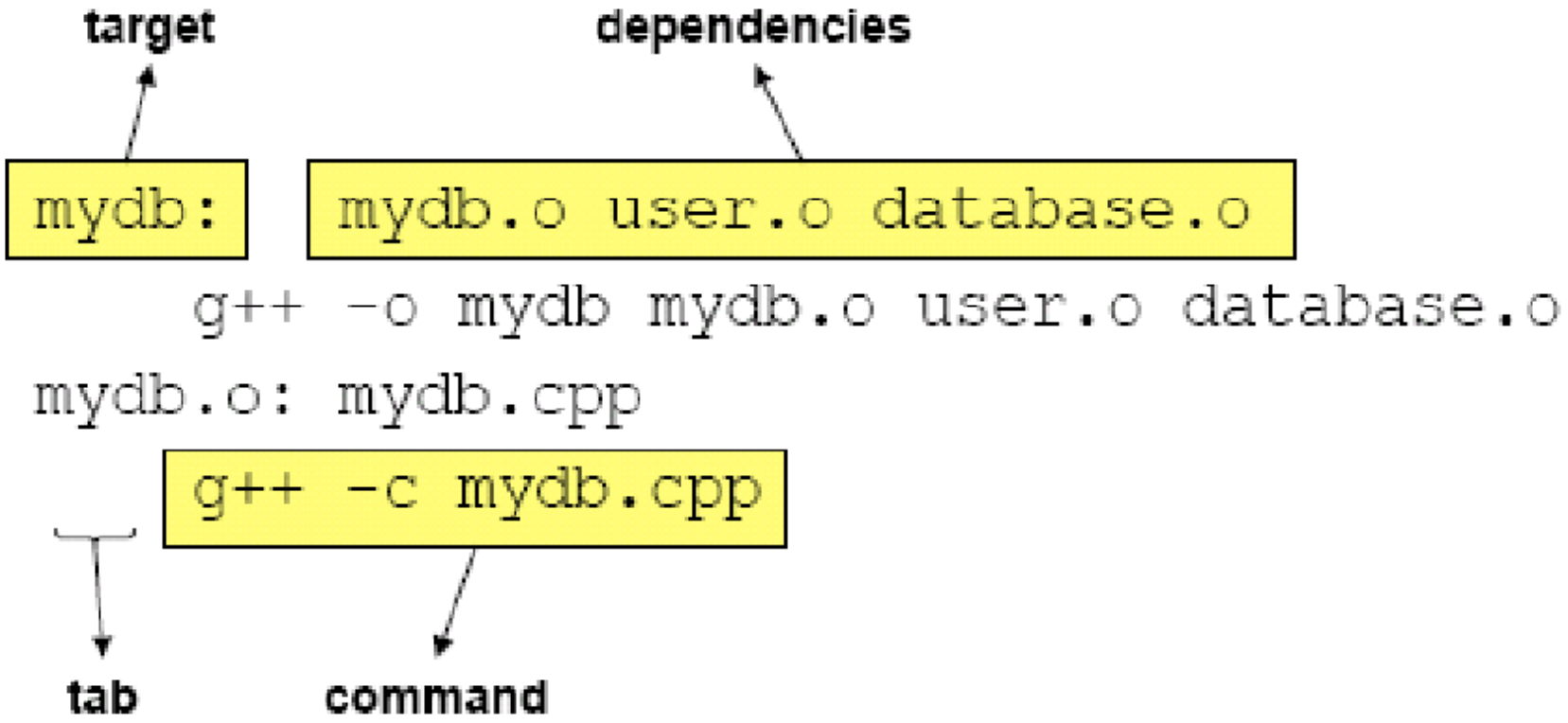
# Build Dependencies



# Parts of a `Makefile`

- Dependency Lines
  - contain target names and dependencies (optional)
  - dependencies
    - files
    - targets
- Commands
  - below dependency line
  - **always** begin with a tab
  - commands to satisfy the dependency

# Parts of a **Makefile** (cont)



# Macros and Special Variables

- Use macros to represent text in `Makefile`
  - saves typing
  - allows easy modification of `Makefile`
  - Assignment
    - `MACRONAME = macro value`
  - Usage: `${MACRONAME}`
- Special variables are used in commands
  - `$@` represents the target
  - `$?` represents the dependencies

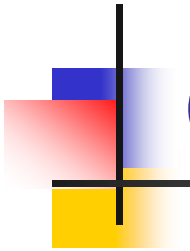
# Simplifying the Example

```
OBJS = mydb.o user.o database.o
CC = /usr/bin/g++

mydb: ${OBJS}
    ${CC} -o $@ $?
mydb.o: mydb.cpp mydb.h
    ${CC} -c $?
user.o: user.cpp mydb.h
    ${CC} -c $?
database.o: database.cpp mydb.h
    ${CC} -c $?
```

# Invoking **`make`**

- Be sure that the description file
  - is called `makefile` or `Makefile`
  - is in the directory where the source files are
- `make`
  - builds the first target in the file
- `make target(s)`
  - builds target(s)
- Other options
  - `-n`: don't run the commands, just list them
  - `-f <file>`: use `<file>` instead of `[Mm]akefile`



# Other Makefile Notes

- Comments begin with a ‘#’
- Can be placed at the beginning of a line or after a non-comment line
- Lines that are too long can be continued on the next line by placing a ‘\ ’ at the end of the first line

# Suffix Rules

- Still tedious to specifically tell `make` how to build each .o file from source file
- Suffix rules can be used to generalize such situations
- A default suffix rule turns source files into .o files by running the command:

```
${CC} ${CFLAGS} -c $<
```

- $< refers to the prerequisite (file.cpp)

# Simplest **Makefile** Example

```
OBJS = mydb.cpp user.cpp database.cpp
CC = /usr/bin/g++

mydb: ${OBJS}
    ${CC} -o $@ $?
```

# Other Useful Makefile Tips

- Include a way to remove intermediate files

```
clean:
    rm –f mydb
    rm -f *.o
```

- Include a target to build multiple programs

```
all:mydb mycalendar myhomework
```