Dependency management in C++

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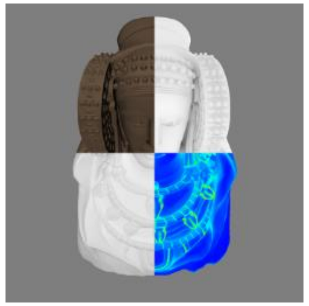
About me

- I…
  - studied software engineering
  - created a 3D model visualization tool in C++ and OpenGL during my PhD
    https://github.com/limdor/quoniam (~10.000 LOC) (2010 - 2015)
  - moved to Munich to work in 2015
  - started attending the C++ User Group Munich (MUC++) to realize that I knew nothing about C++
  - decided to do this presentation about dependencies after 4 years attending to C++ meetups every month
  - remembered that I developed the 3D model visualization tool when I knew nothing about C++



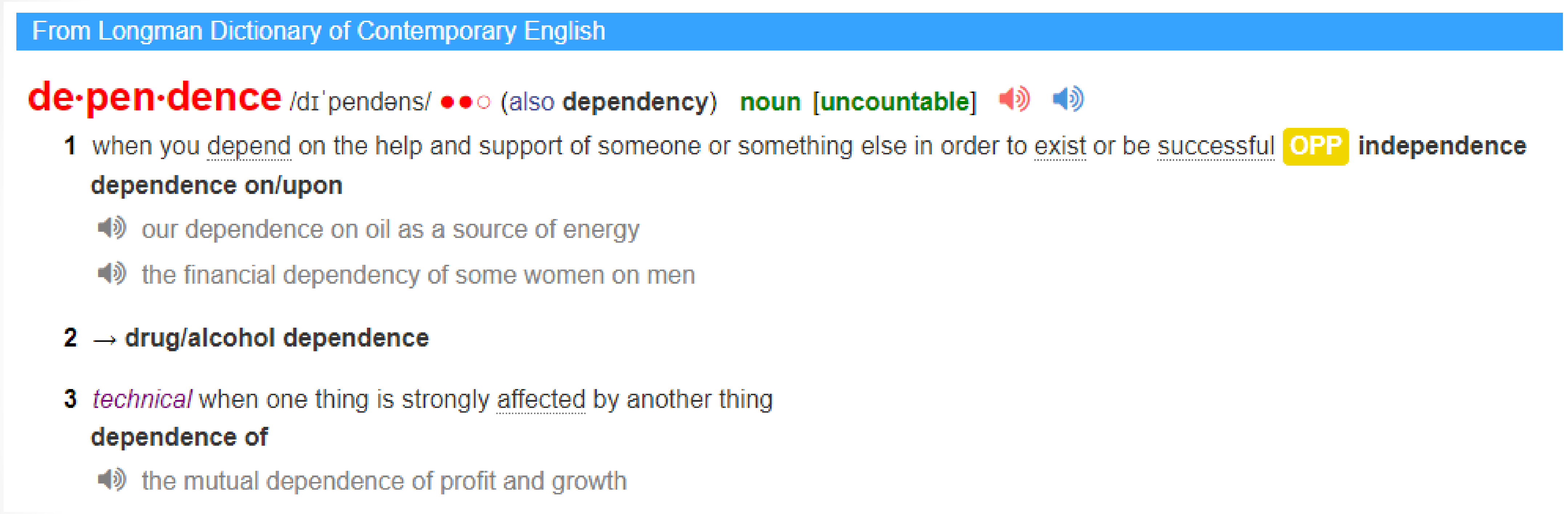
Goal

Awareness and better understanding of the dependencies in your project

What will we see?

- Basic dependency concepts
- Difference between declaration and definition
- Building process
- Execution sequence of a process
- Implications of the design of a library
- Examples with code

What are dependencies?


From Longman Dictionary of Contemporary English

de·pen·dence /dɪˈpendəns/ ●●○ (also **dependency**) **noun [uncountable]**

1 when you depend on the help and support of someone or something else in order to exist or be successful OPP **independence**

dependence on/upon

- our dependence on oil as a source of energy
- the financial dependency of some women on men

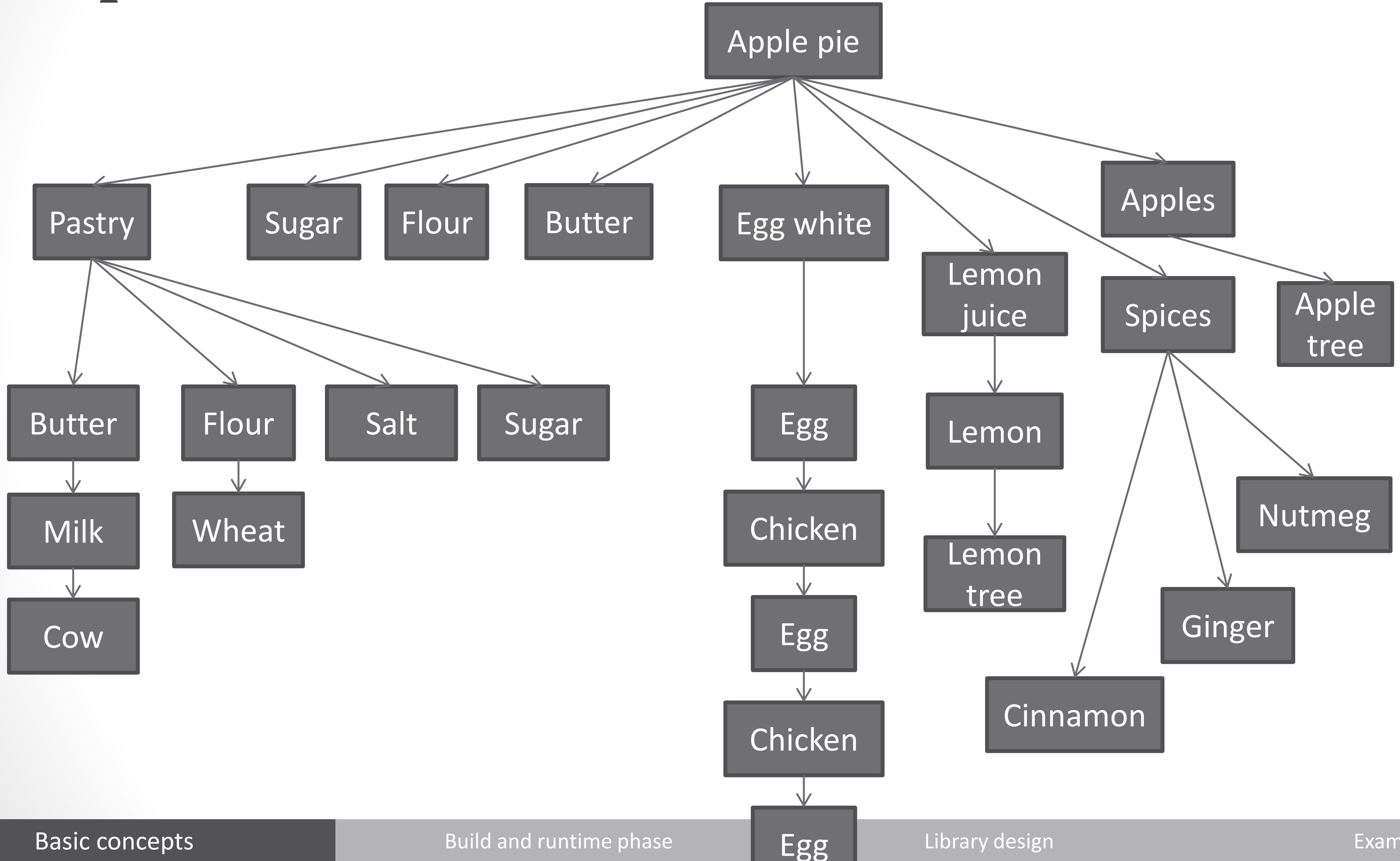
2 → **drug/alcohol dependence**

3 *technical* when one thing is strongly affected by another thing

dependence of

- the mutual dependence of profit and growth

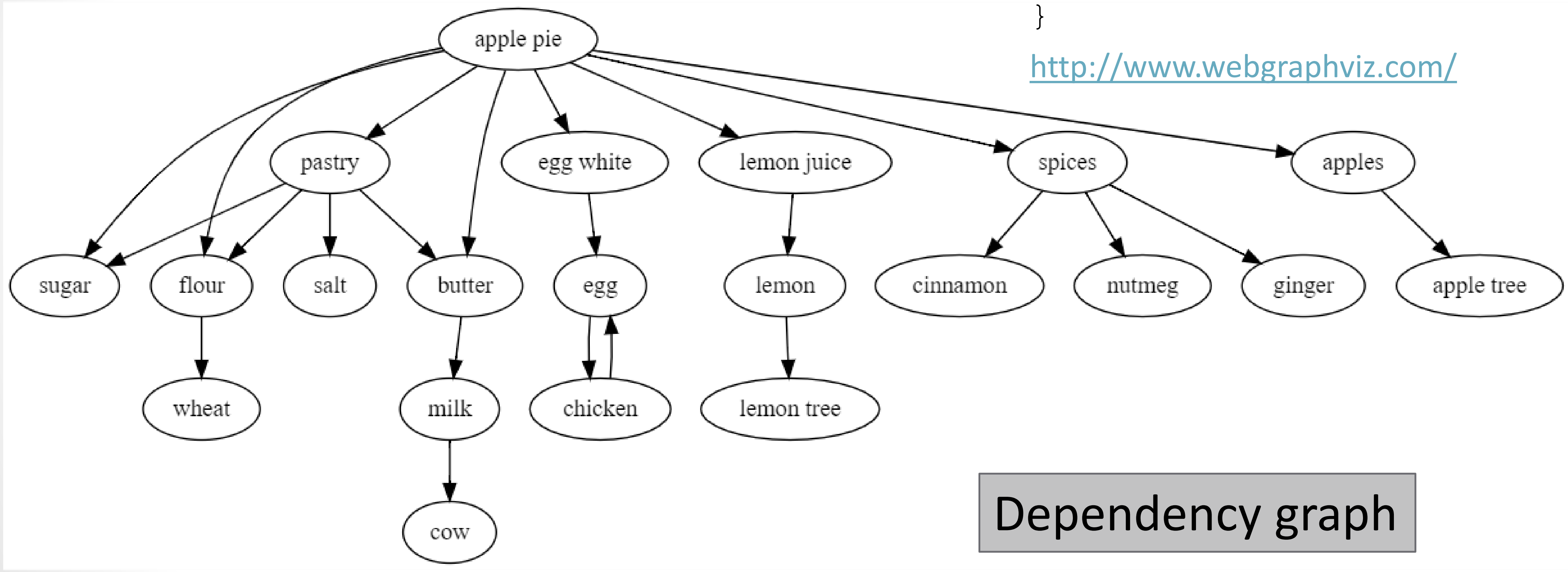
Dependencies in real life



Dependencies in real life

```
digraph G {
  "apple pie" -> apples
  apples -> "apple tree"
  ...
}
```

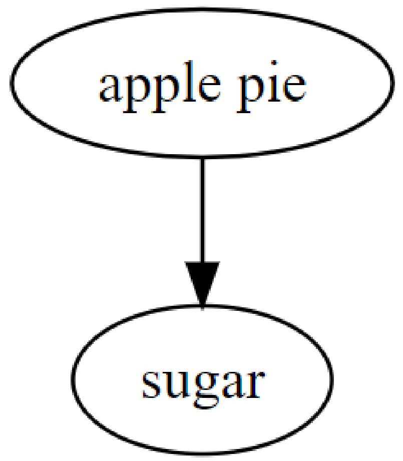
http://www.webgraphviz.com/



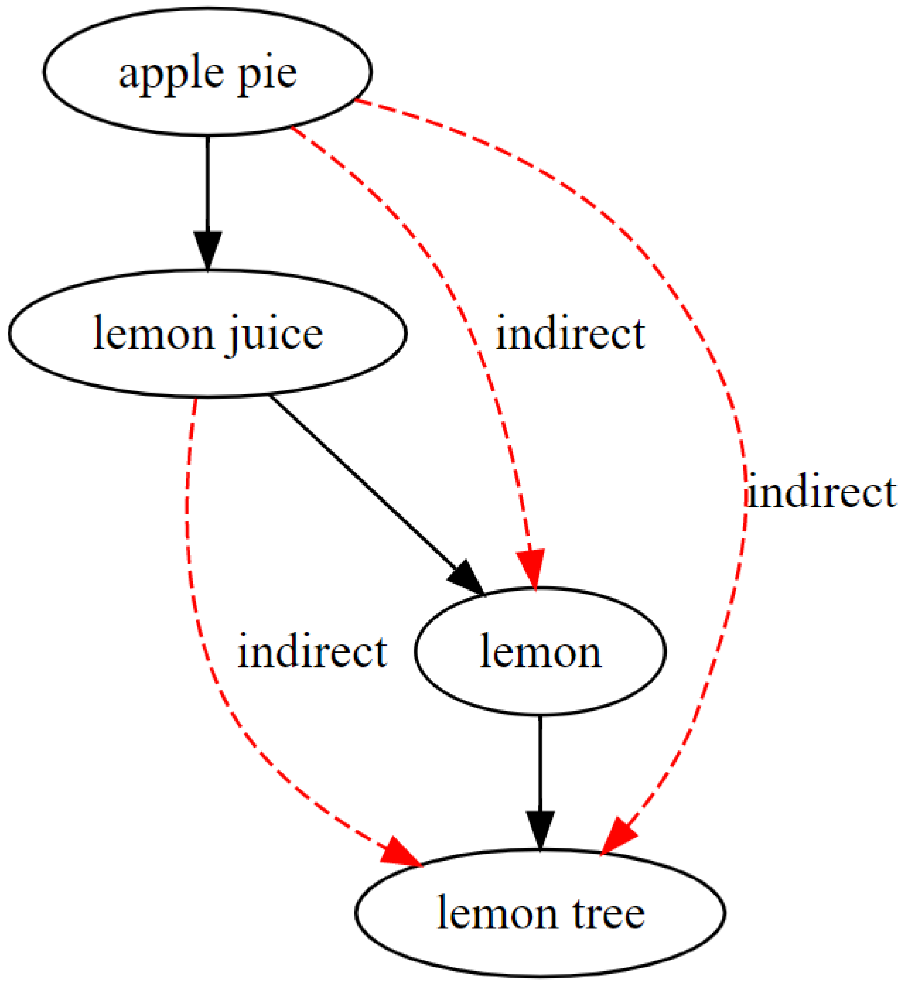
Dependency graph

Direct vs indirect

- Direct dependency

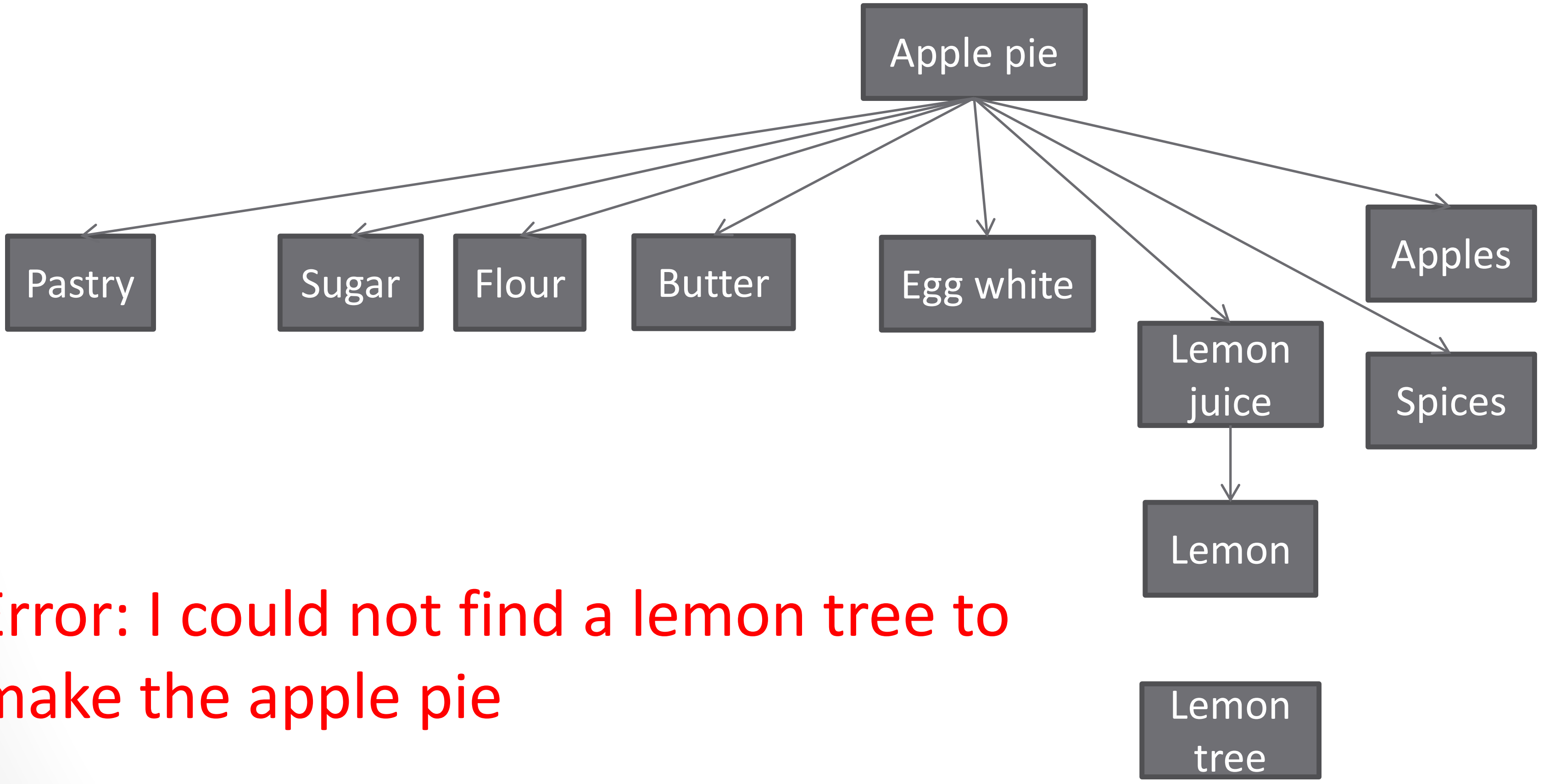


- Indirect or transitive dependency



Direct vs indirect

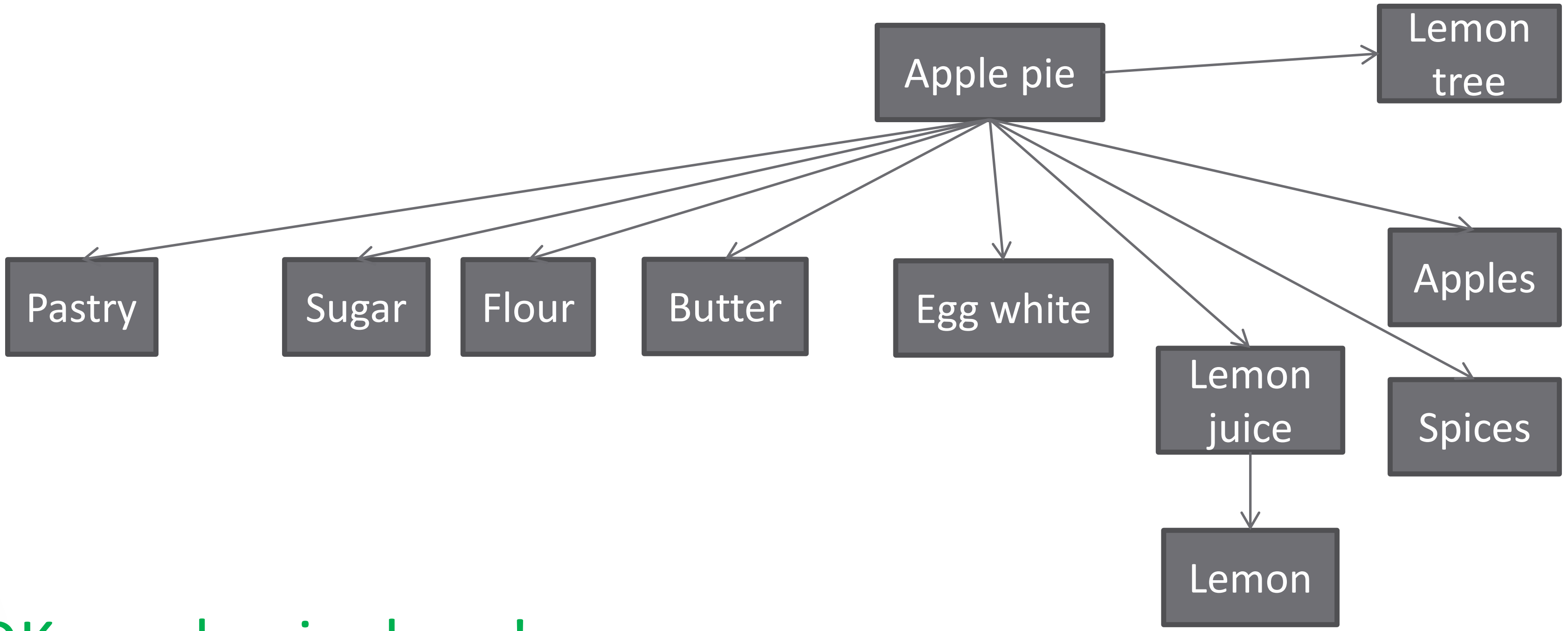
- What happens when a dependency is missing?



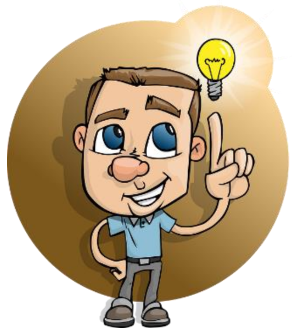
Error: I could not find a lemon tree to make the apple pie

Direct vs indirect

- What happens when a dependency is missing?

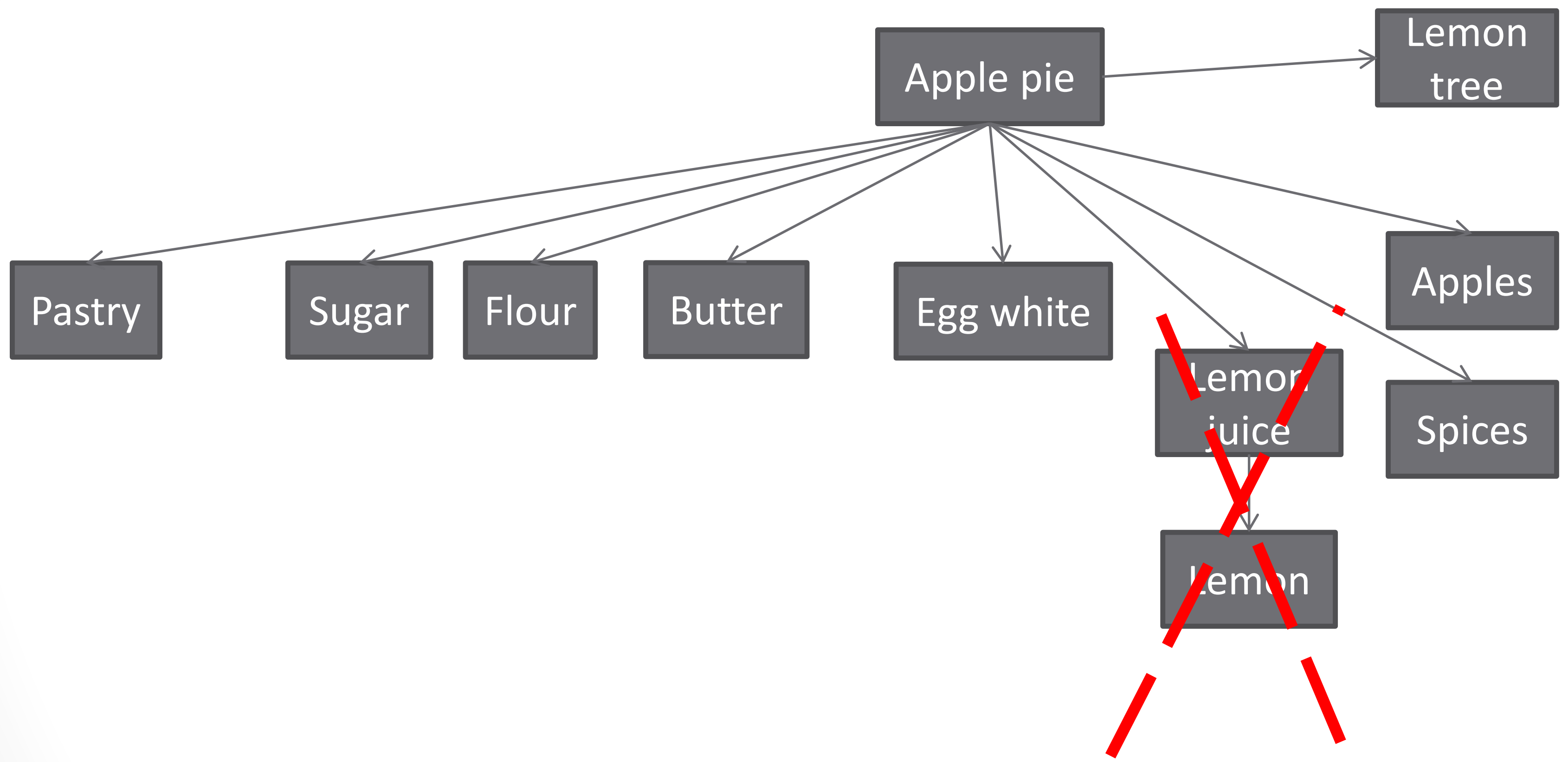


OK, apple pie done!



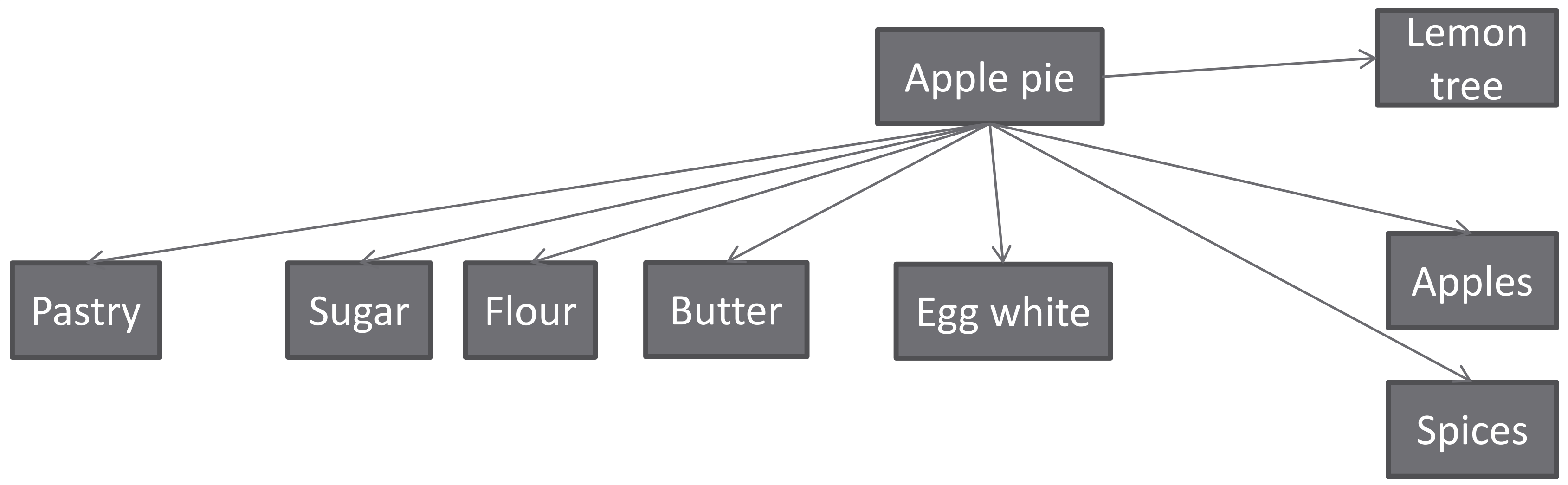
Direct vs indirect

- What happens when a dependency is missing?



Direct vs indirect

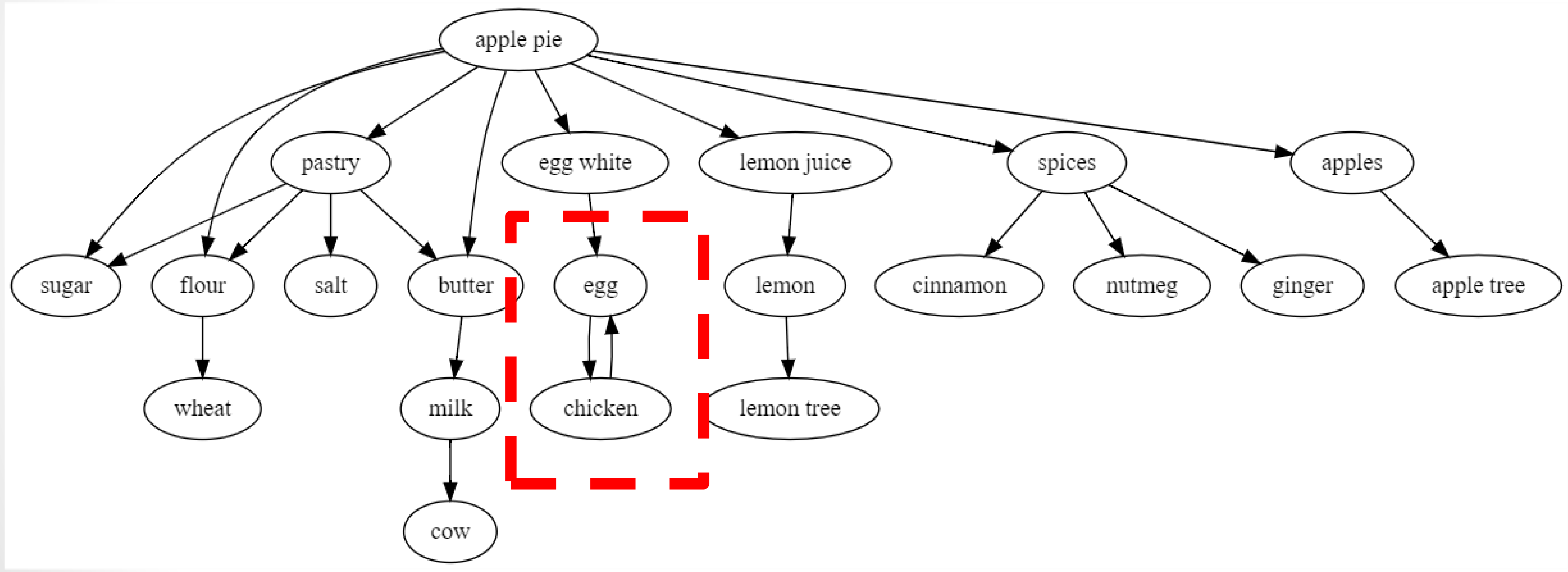
- What happens when a dependency is missing?



Why do I need a lemon tree for an apple pie?

Only define direct dependencies

Cyclic dependency



Declaration vs definition

- Declarations introduce (or re-introduce) names into the C++ program
  https://en.cppreference.com/w/cpp/language/declarations

```
int add_values(int, int);
```

- Definitions are declarations that fully define the entity introduced by the declaration
  https://en.cppreference.com/w/cpp/language/definition

```
int add_values(int a, int b) {
        return a + b;
}
```

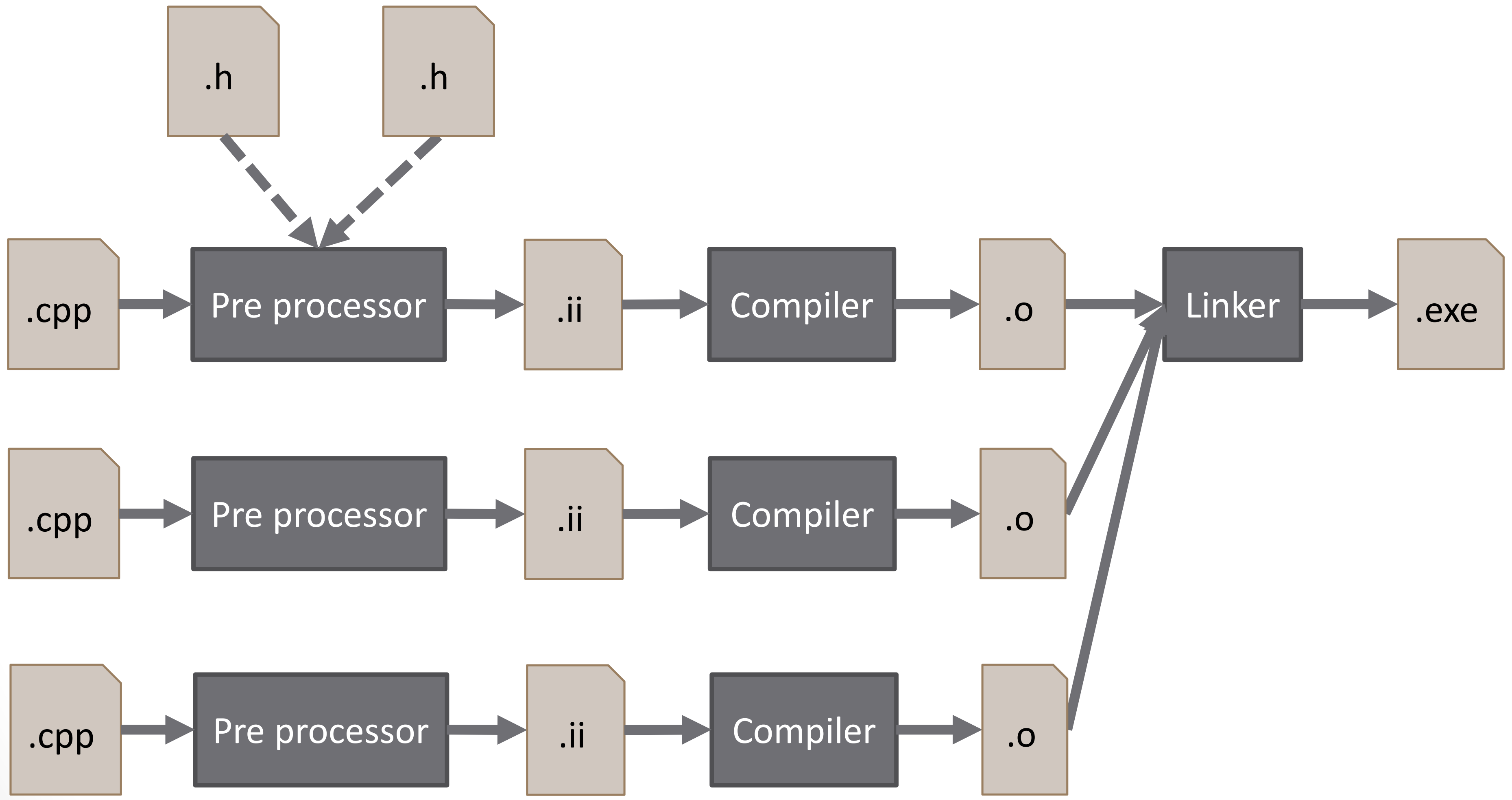
One definition rule: Only one definition is allowed in one translation unit and in the entire program

Declaration vs definition

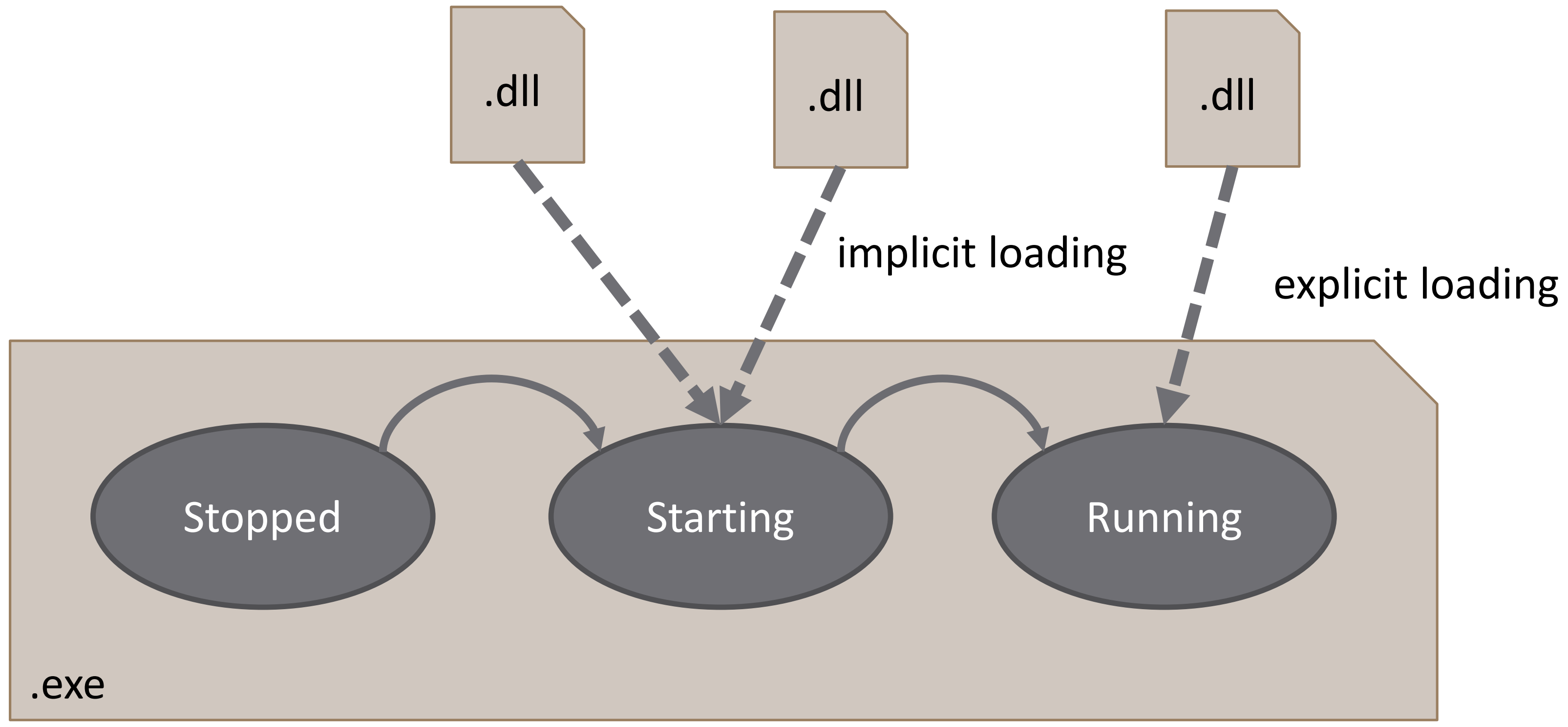
```
extern int foo;

int add_values(int, int);




class Calculator;




template<typename T>
T add_values(T a, T b);
```

```
int foo;

int add_values(int a, int b) {
        return a + b;
}

class Calculator {
        void add_value();
};

template<typename T>
T add_values(T a, T b)
{
    return a + b;
}
```

Building phase

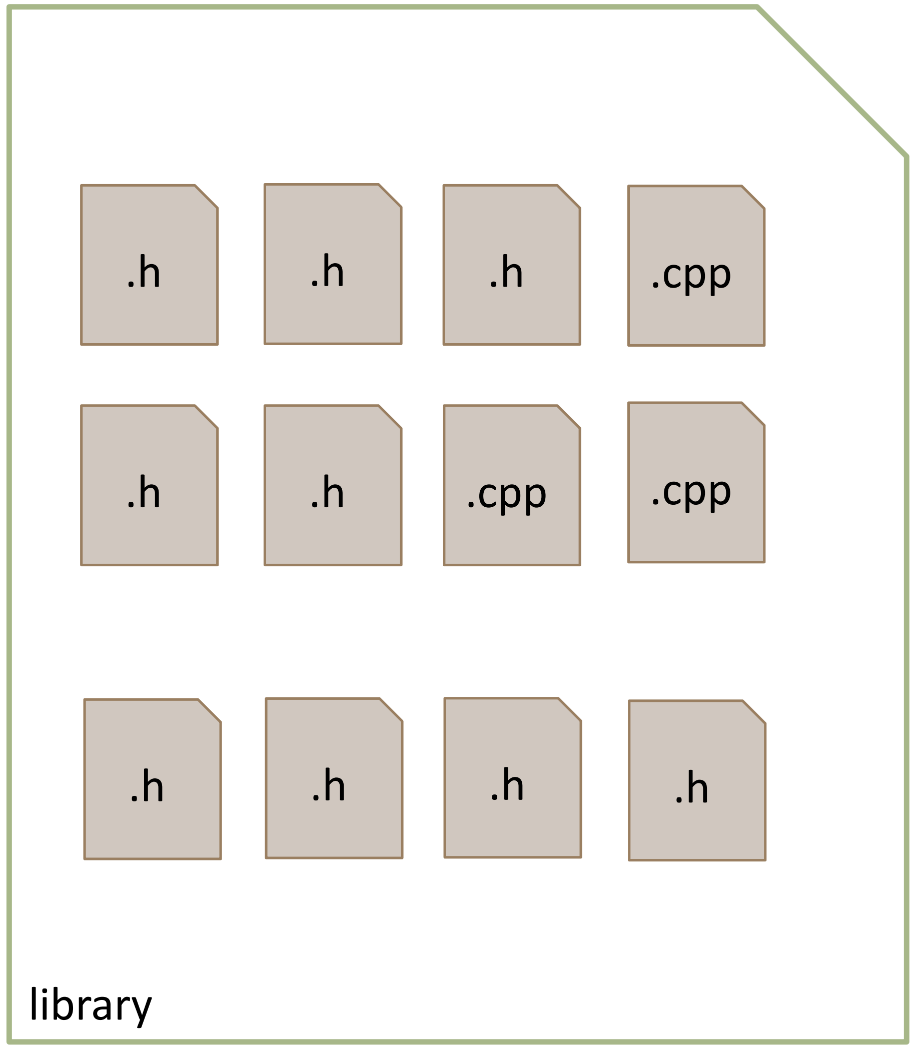


Runtime

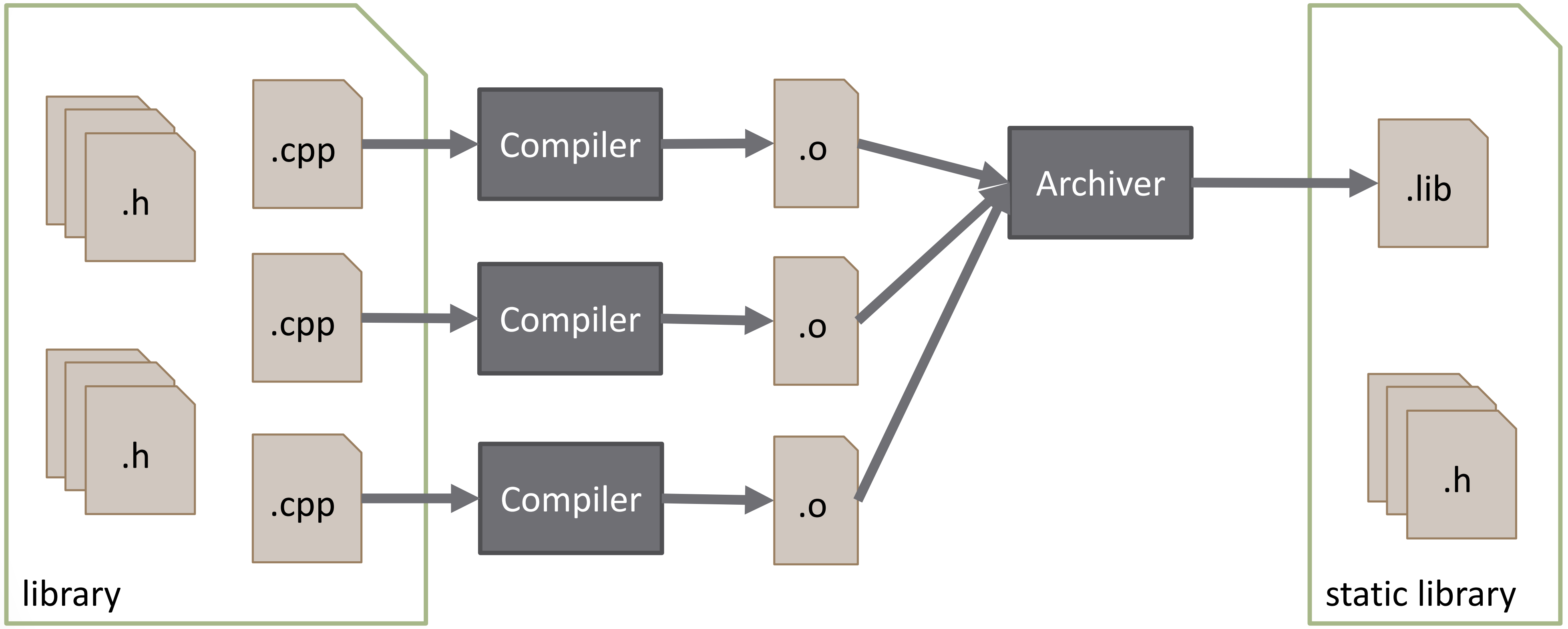


CppCon 2017: James McNellis “Everything You Ever Wanted to Know about DLLs”
https://www.youtube.com/watch?v=JPQWQfDhICA

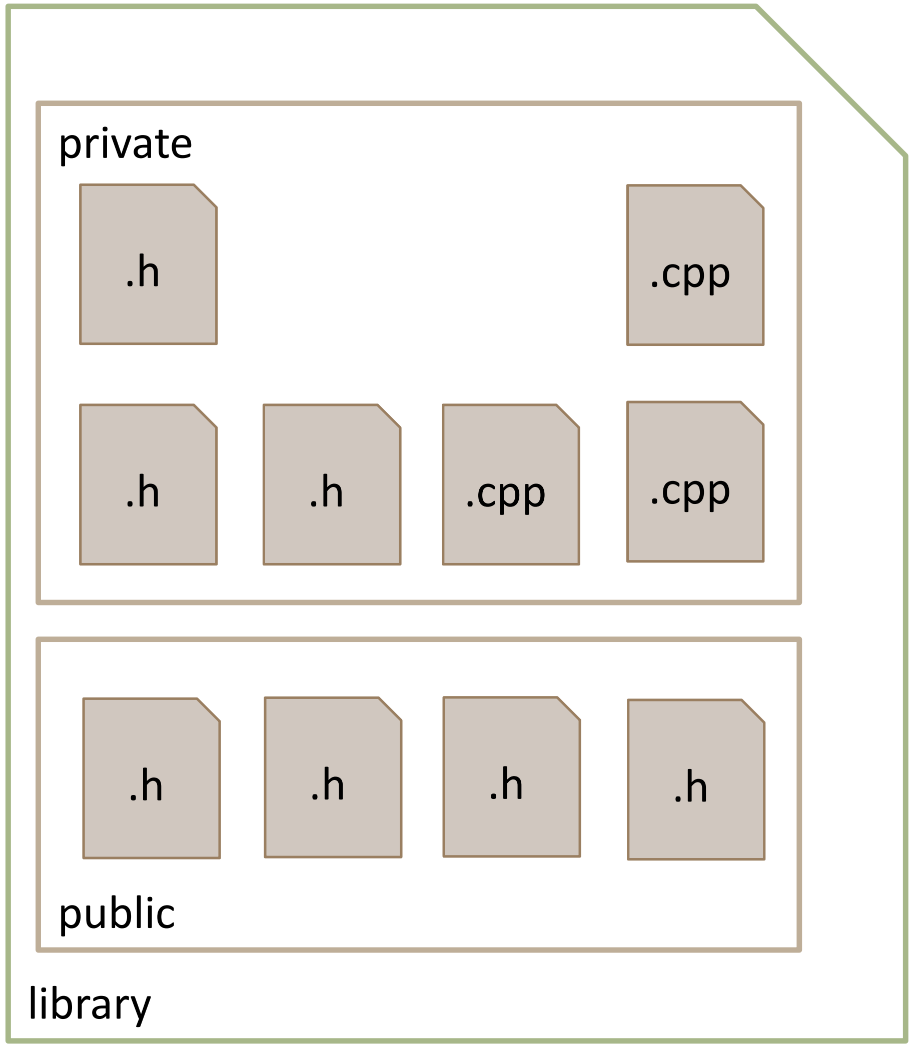
Building a library



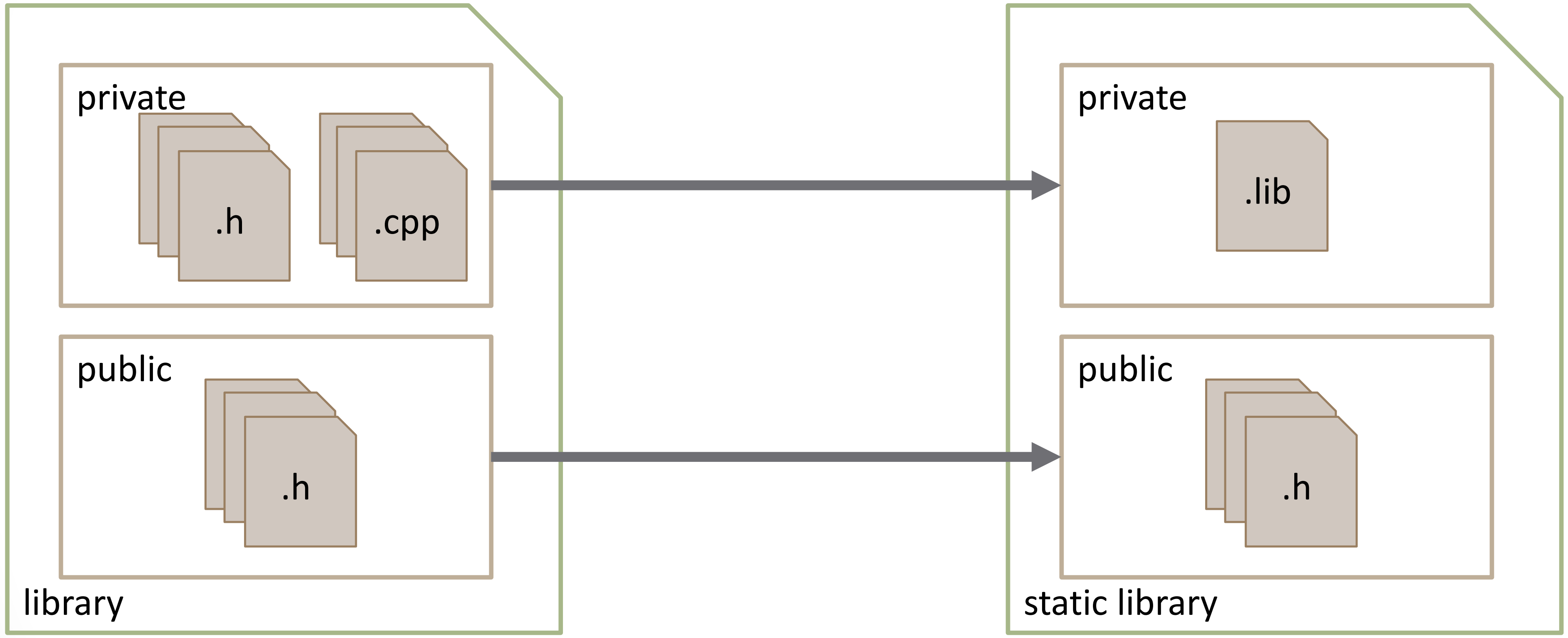
Building a static library



Building a static library



Building a static library



Building a library

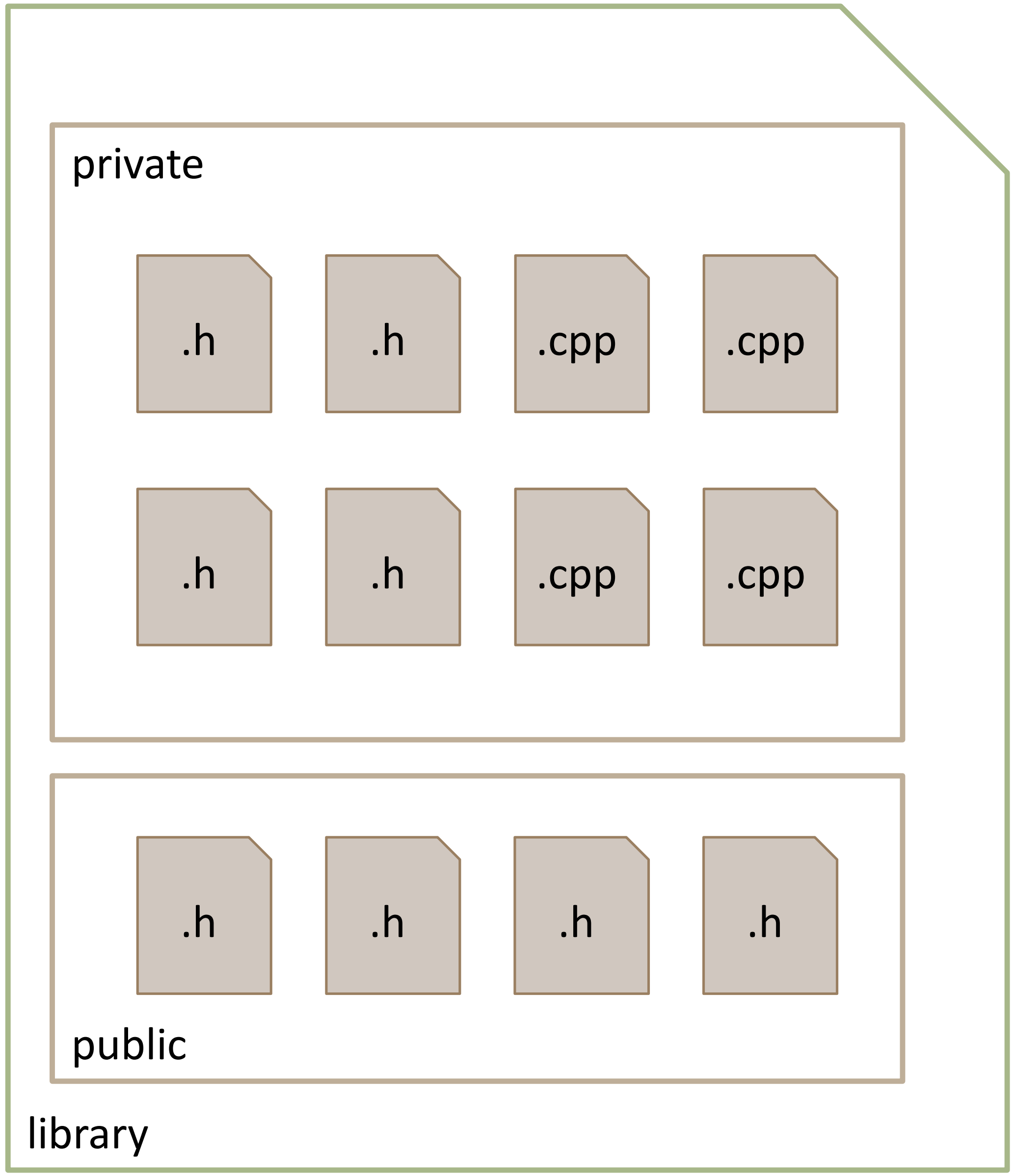
- Where to put declarations and definitions?

declarations for public entities

definitions for public entities

declarations for private entities

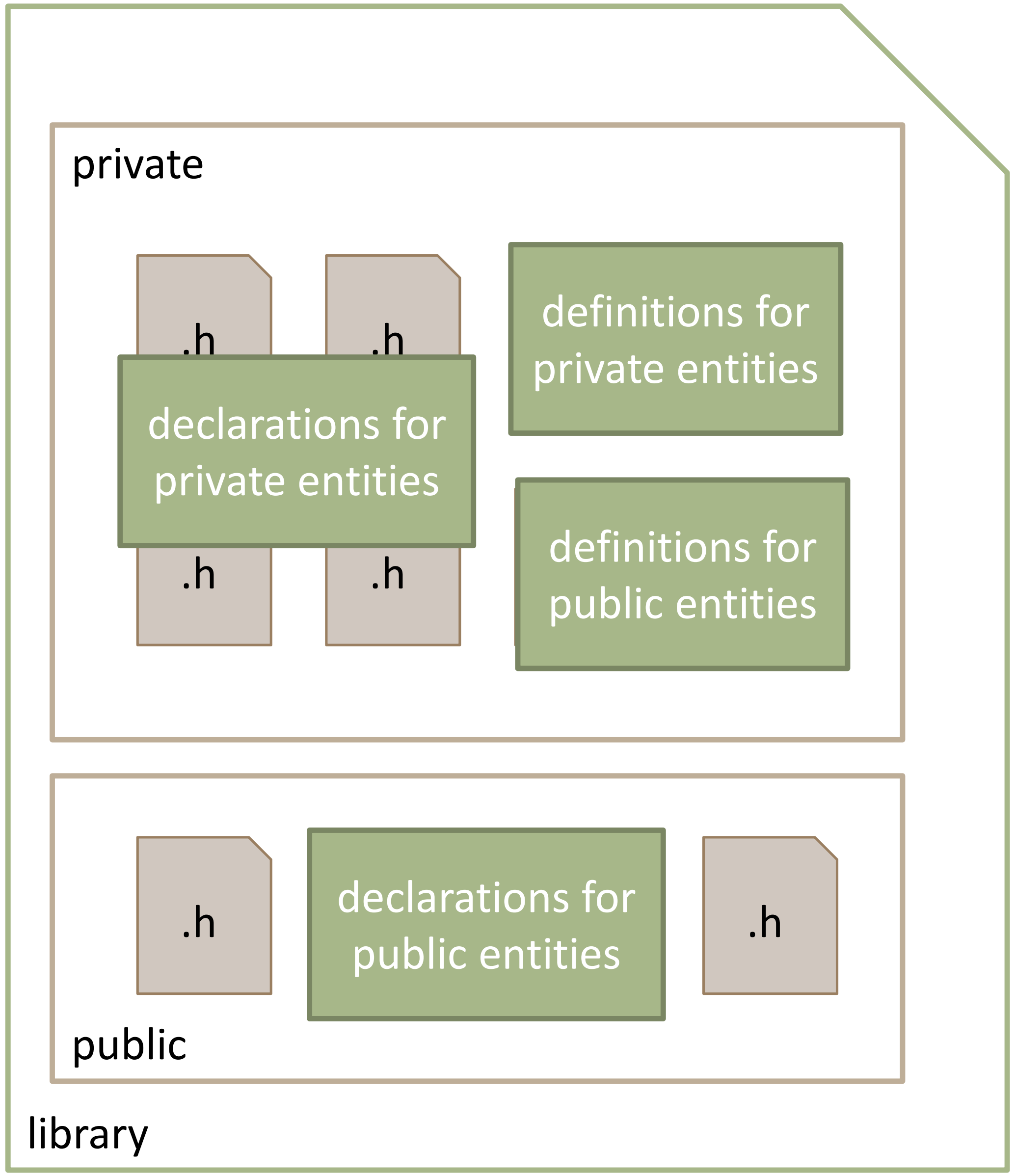
definitions for private entities



Forward declaration of classes help with the separation

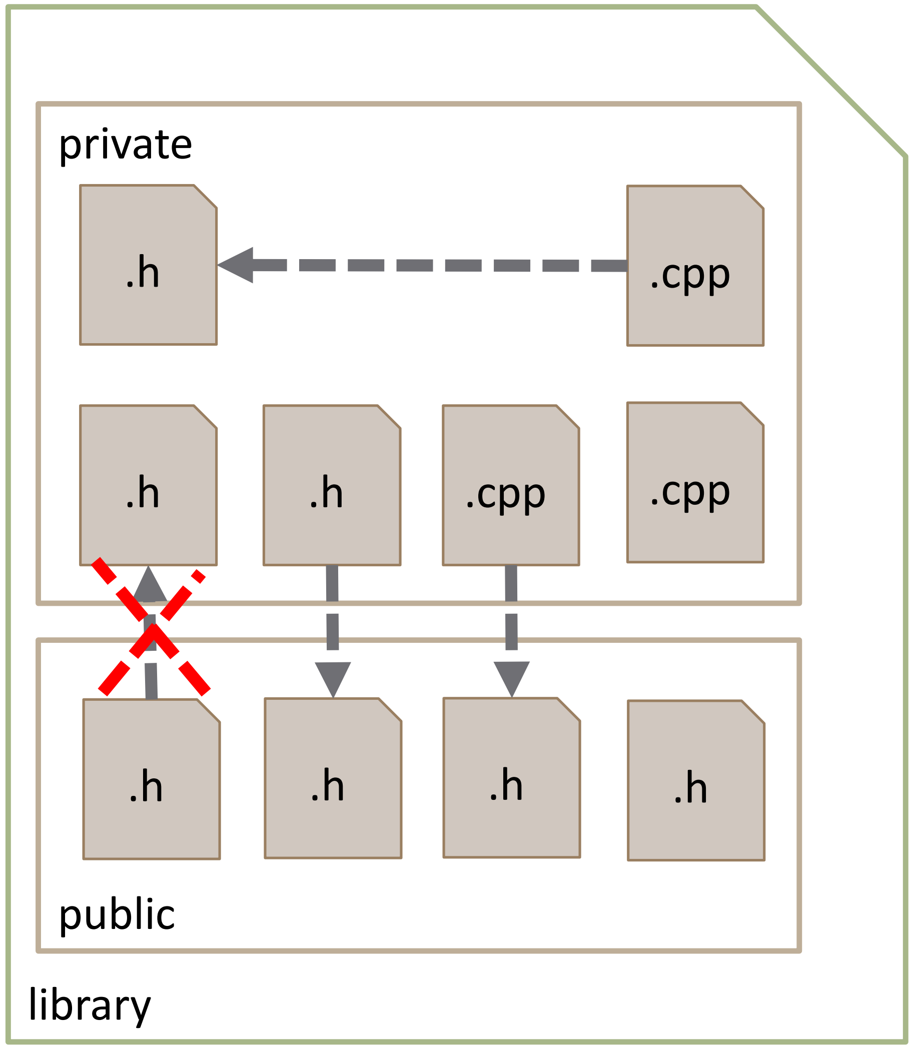
Building a library

- Where to put declarations and definitions?

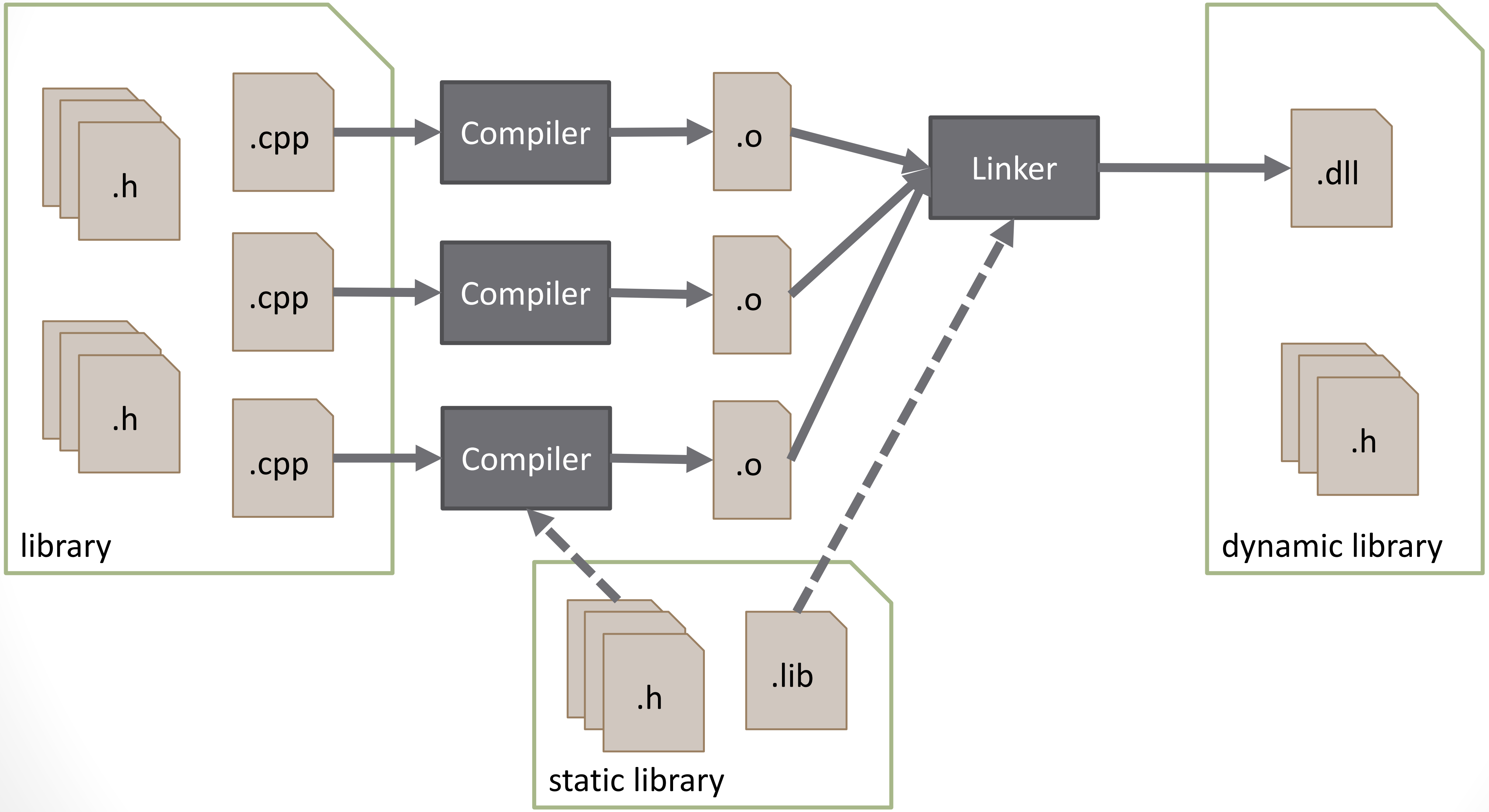

private
.h
.h
declarations for private entities
.h
.h
definitions for private entities
definitions for public entities
.h
declarations for public entities
.h
public
library

Forward declaration of classes help with the separation

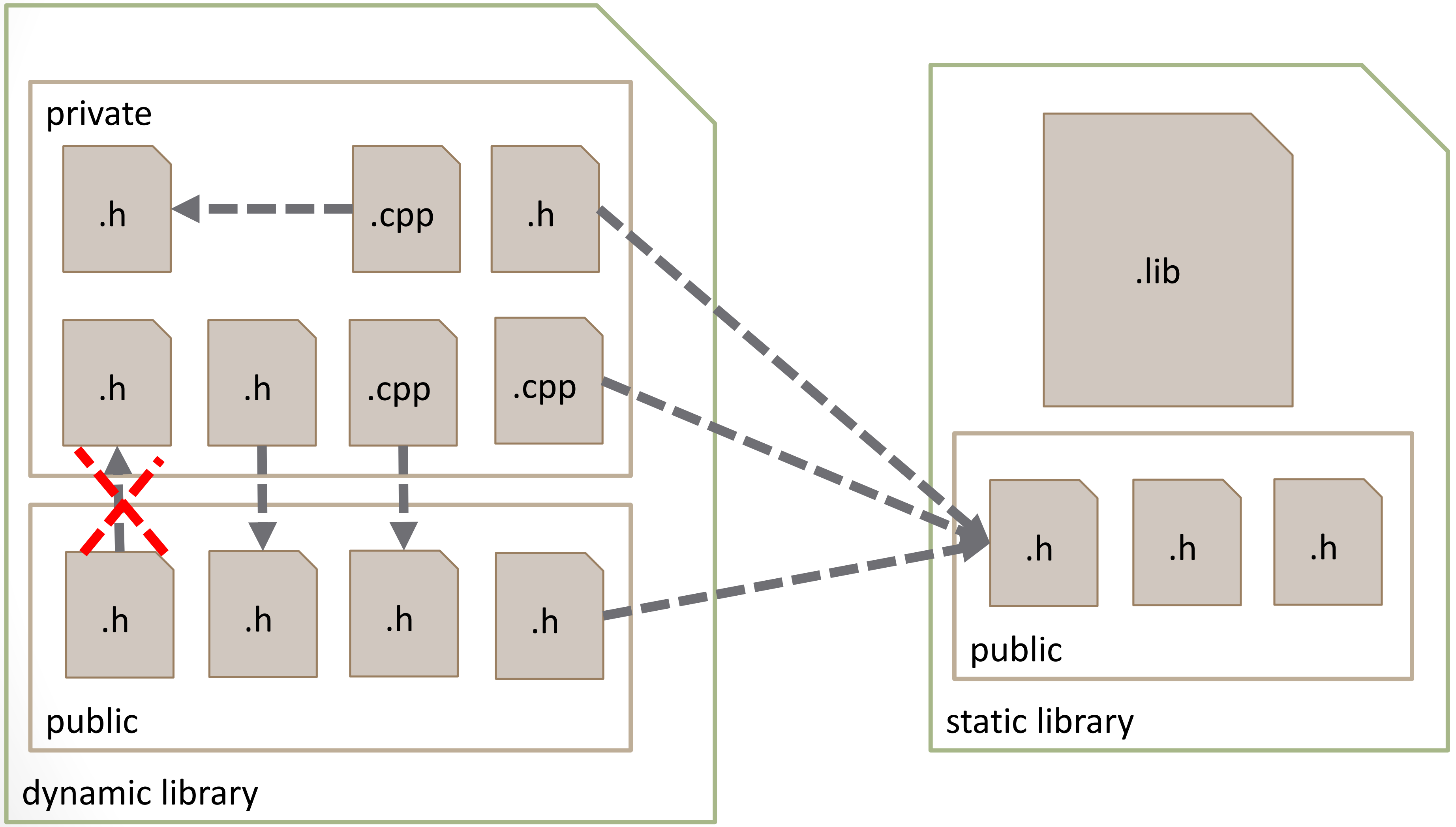
Building a static library



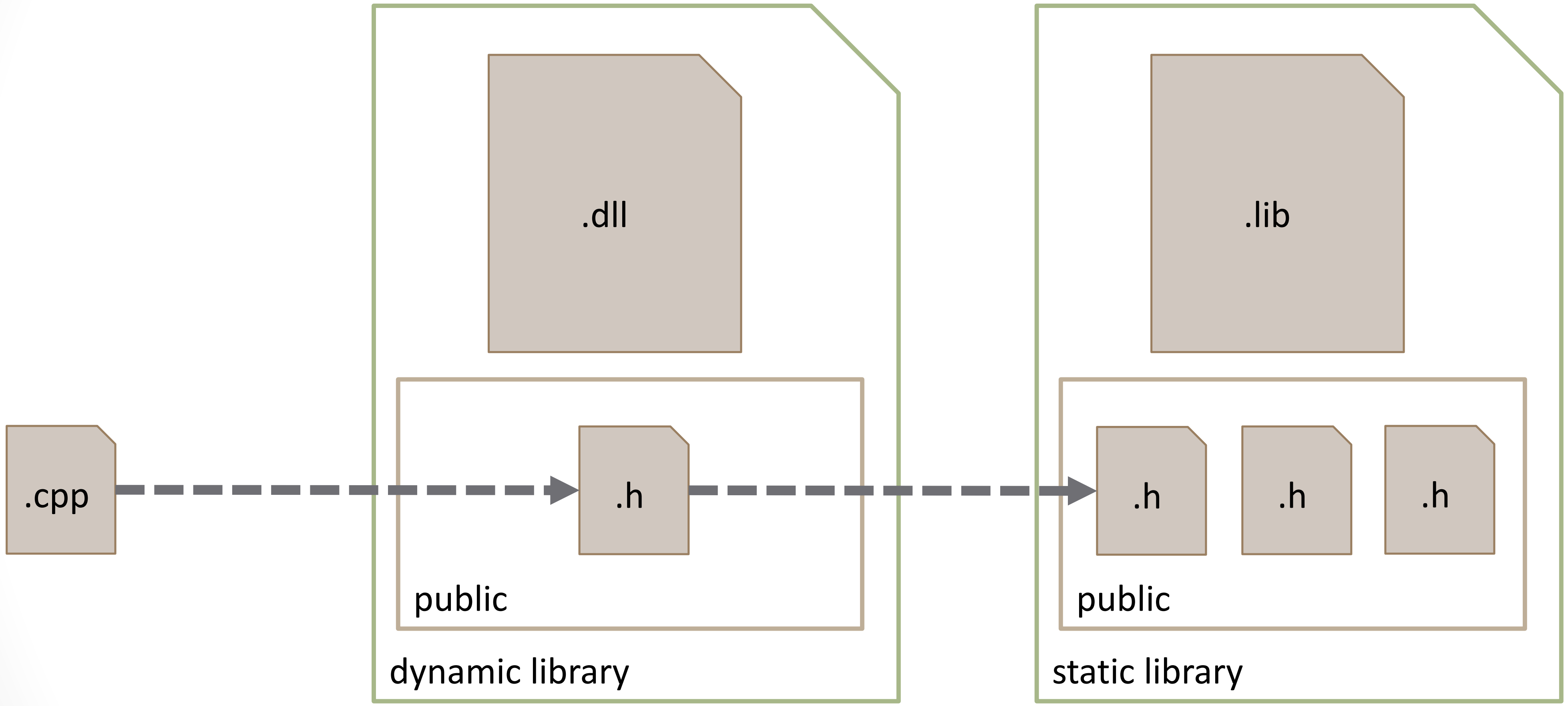
Building a dynamic library



Building a dynamic library

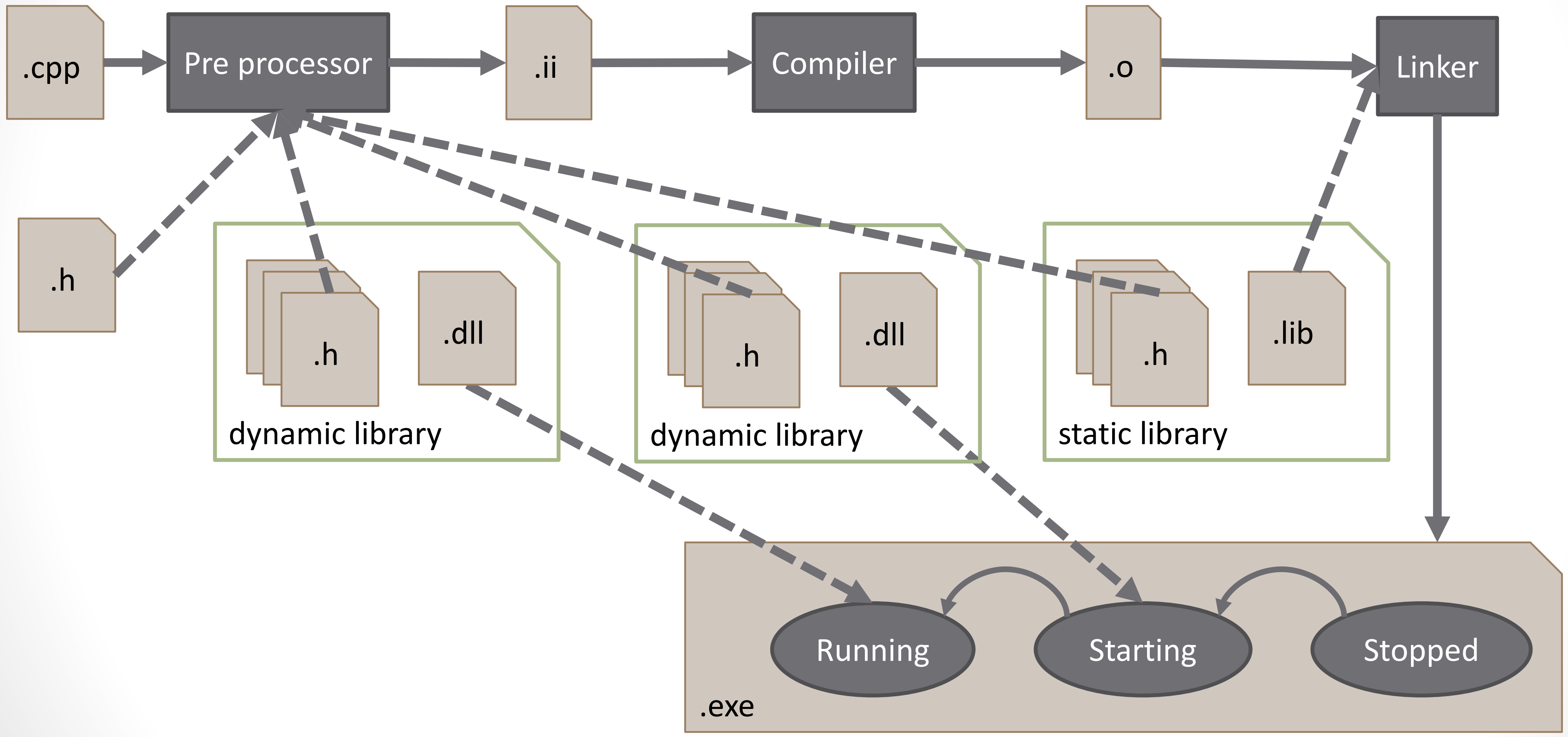


Building a dynamic library



10 differences between static and dynamic libraries every C++ developer should know
https://www.acodersjourney.com/cplusplus-static-vs-dynamic-libraries/

Library usage



Installing clang

```
$ pacman -S mingw-w64-x86_64-clang
resolving dependencies...
looking for conflicting packages...

Packages (18) mingw-w64-x86_64-binutils-2.32-3  mingw-w64-x86_64-crt-git-7.0.0.5524.2346384e-1
              mingw-w64-x86_64-gcc-9.2.0-2  mingw-w64-x86_64-gcc-libs-9.2.0-2
              mingw-w64-x86_64-gmp-6.1.2-1  mingw-w64-x86_64-headers-git-7.0.0.5524.2346384e-1
              mingw-w64-x86_64-isl-0.21-1  mingw-w64-x86_64-libffi-3.2.1-4
              mingw-w64-x86_64-libiconv-1.16-1
              mingw-w64-x86_64-libwinpthread-git-7.0.0.5522.977a9720-1  mingw-w64-x86_64-llvm-8.0.1-3
              mingw-w64-x86_64-mpc-1.1.0-1  mingw-w64-x86_64-mpfr-4.0.2-2
              mingw-w64-x86_64-windows-default-manifest-6.4-3
              mingw-w64-x86_64-winpthreads-git-7.0.0.5522.977a9720-1  mingw-w64-x86_64-z3-4.8.6-1
              mingw-w64-x86_64-zlib-1.2.11-7  mingw-w64-x86_64-clang-8.0.1-3

Total Download Size:    436.85 MiB
Total Installed Size:  2346.90 MiB
```

Installing clang

```
$ pactree mingw-w64-x86_64-clang
mingw-w64-x86_64-clang
├─mingw-w64-x86_64-llvm provides mingw-w64-x86_64-llvm=8.0.1-3
│ ├─mingw-w64-x86_64-libffi
│ └─mingw-w64-x86_64-gcc-libs
│   ├─mingw-w64-x86_64-gmp
│   ├─mingw-w64-x86_64-mpc
│   │ └─mingw-w64-x86_64-mpfr
│   │   └─mingw-w64-x86_64-gmp
│   ├─mingw-w64-x86_64-mpfr
│   └─mingw-w64-x86_64-libwinpthread-git provides mingw-w64-x86_64-libwinpthread
├─mingw-w64-x86_64-gcc
│ ├─mingw-w64-x86_64-binutils
│ │ ├─mingw-w64-x86_64-libiconv
│ │ └─mingw-w64-x86_64-zlib
│ ├─mingw-w64-x86_64-crt-git provides mingw-w64-x86_64-crt
│ │ └─mingw-w64-x86_64-headers-git
│ ├─mingw-w64-x86_64-headers-git provides mingw-w64-x86_64-headers
│ ├─mingw-w64-x86_64-isl
│ ├─mingw-w64-x86_64-libiconv
│ ├─mingw-w64-x86_64-mpc
│ ├─mingw-w64-x86_64-gcc-libs provides mingw-w64-x86_64-gcc-libs=9.2.0-2
│ ├─mingw-w64-x86_64-windows-default-manifest
│ ├─mingw-w64-x86_64-winpthreads-git provides mingw-w64-x86_64-winpthreads
│ │ ├─mingw-w64-x86_64-crt-git
│ │ └─mingw-w64-x86_64-libwinpthread-git provides mingw-w64-x86_64-libwinpthread-git=7.0.0.5522.977a9720
│ └─mingw-w64-x86_64-zlib
└─mingw-w64-x86_64-z3
```

Does llvm/clang still need MinGW gcc after built?
https://stackoverflow.com/questions/9348197/does-llvm-clang-still-need-mingw-gcc-after-built

Dependencies in code

```
// hello.h
#ifdef WE_ARE_IN_DEBUG
#include "hello_debug.h"
#else
#include "hello_release.h"
#endif
```

```
// hello_debug.h
const char* HELLO_WORLD = "Hello slow world!";

// hello_release.h
const char* HELLO_WORLD = "Hello fast and optimized world!";

// main.cpp
#include "hello.h"
#include <iostream>

int main() {
    std::cout << HELLO_WORLD << "\n";
}
```

```
$ clang main.cpp -DWE_ARE_IN_DEBUG -o main -lstdc++ && ./main
Hello slow world!
```

Dependencies depending on macro definitions

Dependencies in code

```
// config.h
#ifdef _DEBUG
#define WE_ARE_IN_DEBUG
#endif
```

```
// hello_debug.h
const char* HELLO_WORLD = "Hello slow world!";

// hello_release.h
const char* HELLO_WORLD = "Hello fast and optimized world!";
```

```
// hello.h
#ifdef WE_ARE_IN_DEBUG
#include "hello_debug.h"
#else
#include "hello_release.h"
#endif
```

```
// main.cpp
#include "hello.h"
#include "config.h"
#include <iostream>

int main() {
    std::cout << HELLO_WORLD << "\n";
}
```

```
$ clang main.cpp -D_DEBUG -o main -lstdc++ && ./main
Hello fast and optimized world!
```

Dependencies depending on include order

Dependencies in code

```
// basics.h
#include <vector>
#include <iostream>
#include <string>
```

```
// hello.h
#include "basics.h"
const char* HELLO_WORLD = "Hello slow world!";

// main.cpp
#include "hello.h"

int main() {
    std::cout << HELLO_WORLD << "\n";
}
```

```
$ clang main.cpp -o main -lstdc++ && ./main
Hello slow world!
```

Missing includes go unnoticed

Dependencies in code

- Order of includes affects our dependencies
  - One macro defined in one header affects another header
  - One missing include in a header file “will not be an issue” if it is included by another header file

- How can we mitigate it?
  - Include headers from local to global

```
#include "my_file.h"
#include "another_lib.h"
#include <vector>
```

```
#include <vector>
#include "another_lib.h"
#include "my_file.h"
```

  - What happens if my_file.h uses vector without including it?
  - What happens if another_lib.h includes vector without using it?

Dependencies in code

- How can we mitigate it?
  - Automatic tool that shuffle headers and compiles?

```
$ python3 include_checker.py --folder "/my/source/folder/" --command "clang main.cpp -o main -lstdc++"
```

```cpp
// main.cpp
#include "hello.h"
#include "config.h"
#include <iostream>

int main() {
    std::cout << HELLO_WORLD << "\n";
}
```

$\Rightarrow$

```cpp
// main.cpp
#include "hello.h"
#include <iostream>
#include "config.h"

int main() {
    std::cout << HELLO_WORLD << "\n";
}
```

- Does it compiles? If yes, repeat the process, if not, fix it!

Dependencies in code

- Could we have it better in the future?

C++20: Modules

```
// math.cppm
export module math;

export int add(int fir, int sec){
    return fir + sec;
}
```

```
// main.cpp
import math;

int main(){
   add(2000, 20);
}
```

- At least the import of the modules does not depend on the order

CppCon 2019: Boris Kolpackov “Practical C++ Modules”
https://www.youtube.com/watch?v=szHV6RdQdg8

Example from: https://www.modernescpp.com/index.php/c-20-modules

Summary

- What is a dependency graph
- Only direct dependencies should be defined
- For each entity we can have multiple declarations but only one definition per translation unit
- How to structure the declarations and definitions inside a library
- Implications of bad dependency definition

Dependency management in C++

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C++ User Group Munich – 17th October 2019