Code Organization and Templates

Preprocessors, Header and Source Files, Templated Code

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#cpp-oop

Preprocessor Directives

#include, #define, #if…

Preprocessor Directives

- Executed before compilation
- Instruct compiler how and what to compile
  - Not part of the code, they modify the code
  - `#include` – adds code to the compilation unit
  - `#define` – essentially a find-and-replace in the code
  - `#if`, `#ifdef`, `#else`… – use/skip code based on an expression
  - `#pragma` – compiler-specific settings (e.g. optimization level)

#include and #define

- `#include <X>` copies system `X` source in this file
  - `#include "X"` first looks for local file `X` , then for system `X`

```
#include <iostream> // directly looks for system file iostream
#include "01. Macros.h" // looks for local file "01. Macros.h"
```

- `#define X Y` – macro, replaces `X` in the code with `Y`

```
#define PI 3.14
cout << PI << endl; // prints 3.14
```

- `#define F(X) code-using-X` – macro function

```
#define SHOW(something) cout << something << endl;
SHOW("hello macros"); // prints "hello macros"
```

Quick Quiz

- What will the following code do?

```
#define HALF(value) value / 2
cout << HALF(4 + 2) << endl;
```

a) Print 3

b) Print 5

c) Cause a compilation error

d) Behavior is undefined

C++ PITFALL: MISSING BRACKETS ON MACRO PARAMETERS WHICH COULD BE EXPRESSIONS

Macro parameters are just copy-pasted into the macro code – they are not values, they are code.

A good practice is to put any macro and its parameters into brackets ( )

Preprocessor Directives

LIVE DEMO

Conditional Inclusions & Header Guards

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- Similar to if-else, when condition is NOT met, code is ignored
  - `#if`, `#elif` – "else if", `#else`, "closed" with `#endif`
  - `#ifdef X` – if macro `X` is defined, `#ifndef` – if macro `X` is NOT defined

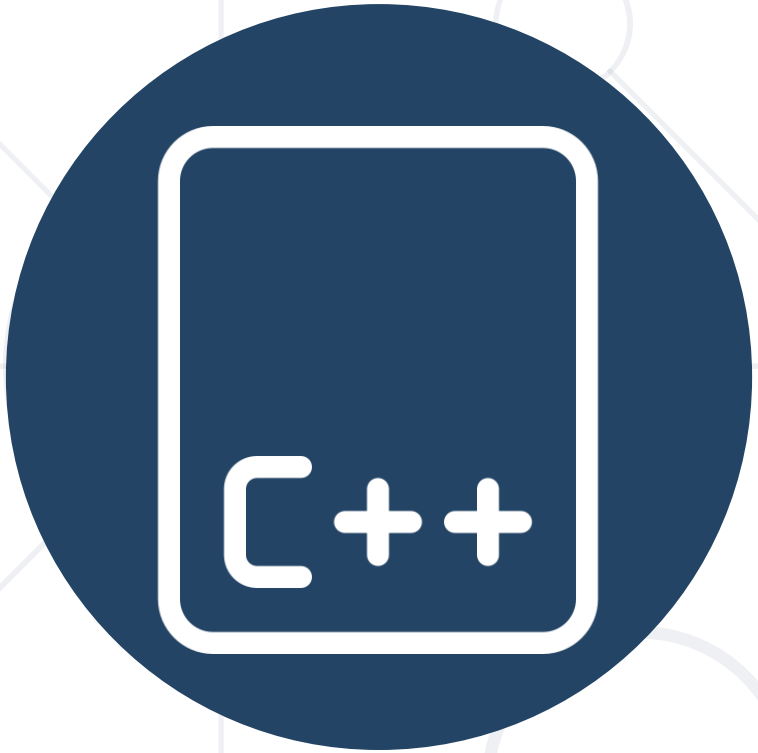
```
#ifdef _WIN32
system("cls");
#else
system("clear");
#endif
```

- **Header guards** – avoid `#include`-ing code multiple times

```
#ifndef SOME_FILE_H // use any macro name unique for the file
#define SOME_FILE_H
// code here safe from multi-inclusion
#endif // !SOME_FILE_H
```

Conditional Inclusion & Header Guards

LIVE DEMO



Separating Declaration and Implementation

Separating Declaration and Implementation

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- C++ allows separate declaration & implementation
  - For functions, methods, operators, classes
- Class members‘ "implementation" is often separated
  - Cleaner view of class "interface"
  - Sometimes necessary (static fields or stream operators)
  - Allows separate build objects for faster rebuilds and dynamic linking

Why Separate?

- *Is it easy to determine what can be called on this class?*

```
class Company {    // PART ONE
private:
int id;
string name;
vector<std::pair<char, char> > employees;

public:
Company(int id, string name, vector<pair<char, char> > employees)
: id(id), name(name), employees(employees) {}

int getId() const {
  return this->id;
}

string getName() const {
  return this->name;
} // more on the next slide ->
```

Why Separate?

- *Is it easy to determine what can be called on this class?*

```
vector<pair<char, char> > getEmployees() const {    // PART TWO
  return this->employees;
}

string toString() {
  ostringstream stream;
  stream << id << " " << name << " ";

  for (int i = 0; i < employees.size(); i++) {
    auto initials = employees[i];
    stream << initials.first << initials.second;
    if (i < employees.size() - 1) {
      stream << " ";
    }
  }
  return stream.str();
} // more on the next slide ->
```

Why Separate?

- *Is it easy to determine what can be called on this class?*

```
bool operator==(const Company& other) const {    // PART THREE
  return this->id == other.id;
}

string operator+(const string& s) {
  return this->toString() + s;
}

Company& operator+=(const pair<char, char>& employee) {
  this->employees.push_back(employee);

  return *this;
}

};  // end
```

Separating Declarations and Implementation

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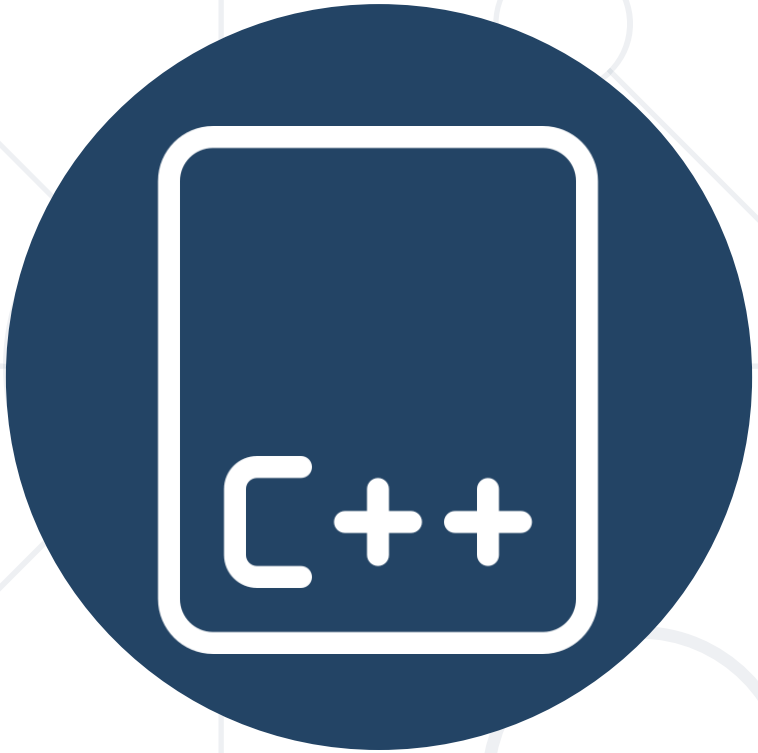
```
class Company {
private:
    int id;
    string name;
    vector<pair<char, char> > employees;

public:
    Company(int id, string name, vector<pair<char, char> > employees);

    int getId() const;
    string getName() const;
    vector<pair<char, char> > getEmployees() const;
    string toString() const;
    bool operator==(const Company& other) const;
    std::string operator+(const char* s) const;
    std::string operator+(const string& s);

    Company& operator+=(const pair<char, char>& employee);
};
```

Separating Member Definitions

- Syntax same as a member inside a class, however:
  - Prefixed with namespaces & class name, joined by **operator:**

```
Company::Company(int id, string name, vector<pair<char, char> > employees)
: id(id), name(name), employees(employees) {}
...
int Company::getId() const {
  return this->id;
}
...
bool Company::operator==(const Company& other) const {
  return this->id == other.id;
}
...
```



Separating Member Definitions

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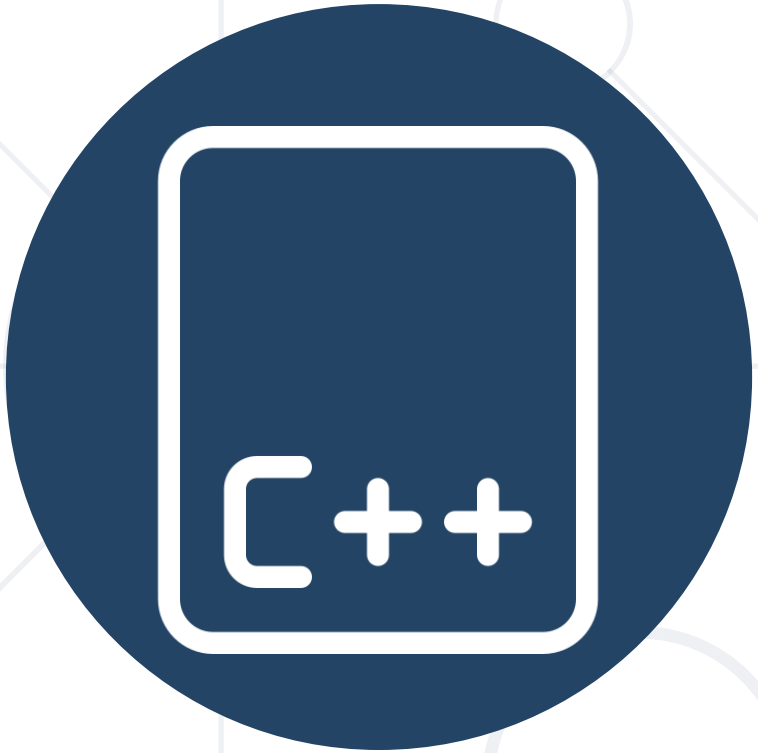

Header and Source Files

Header and Source Files

- **Header files** – mostly declarations
  - Use **header guards** to avoid multi-inclusion
  - Extension – **`.h`**/**`.hpp`**/**`.h++`**
- **Source files** – implements header declarations
  - Usually **`1`** per header, **`#include`** the header
  - Extension – **`.cpp`**

Header Files - Company.h

```
#ifndef COMPANY_H
#define COMPANY_H

#include <string>
#include <vector>
class Company {
private:
  int id; string name;
  vector<pair<char, char> > employees;
public:
Company(int id, string name,
  vector<pair<char, char> > employees);
...
int getId() const;
...
bool operator==(const Company& other) const;
};
#endif // !COMPANY_H
```

Source Files - Company.cpp

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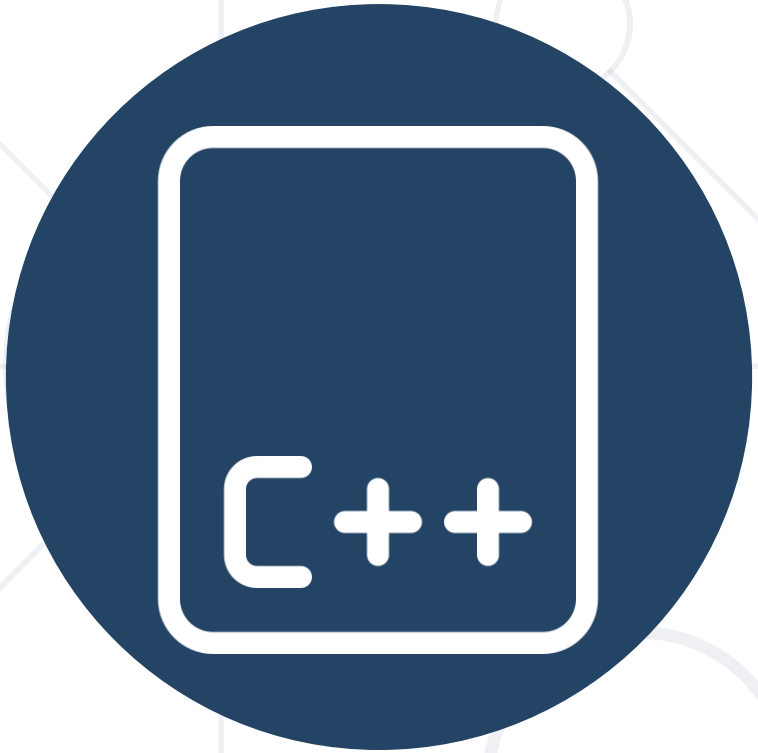
```
#include "Company.h"
#include <sstream>

Company::Company(int id, string name,
  vector<pair<char, char> > employees)
  : id(id), name(name), employees(employees) {}
...
int Company::getId() const {
  return this->id;
}
...
bool Company::operator==(
    const Company& other) const {
  return this->id == other.id;
}
...
```



Header and Source Files

LIVE DEMO

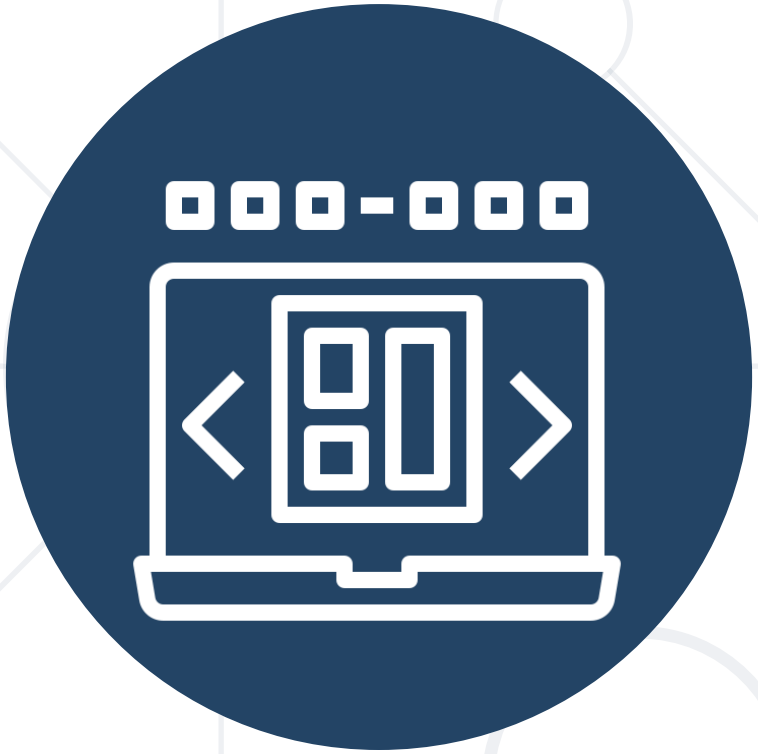
Build

Building Multiple Sources in C++ (1)

- **Compilation unit** – a file (usually **`.cpp`**) the compiler works on
- C++ build process for each unit:
  - ***`.cpp`*** -> expanded source (insert **`#include`** code, macros, etc.)
  - expanded source -> platform code -> assembly code
  - assembly code -> object code, ***`.o`***/***`.obj`*** (**`1`**'s & **`0`**'s)
- Linking: object code files -> **linked** -> final executable

Building Multiple Sources in C++ (2)

- Different approaches to building a multi-source "Project"
  a) Single **.cpp**, implementation in headers – compile the **.cpp**
  b) Only declaration in **.h**, multiple **.cpp** – compile & link all **.cpp**
  c) Mixed – some **.h** contain implementation – same as **b)**
- Compiler needs instructions on which files to compile
  - IDEs automate the process – compile & link all **.cpp** files



Templates

Generalizing Functions and Classes for any Type

Algorithm vs. Data Type

- Algorithms rarely depend on a single data type
- E.g. calculate what percentage **a** is of **b**
  - **a** percent of **b** == **a * 100 / b**
  - **1** out of **4** == **a * 100 / 4** == **25%**
  - **1.5** out of **3** == **1.5 * 100 / 3** == **50%**
  - ¼ out of ½ == ¼ * **100 / ½** == **25 / ½** == **50%**

Templates

- What should `T` be here: `T calcPercentage(T a, T b)`?
  - `int`, `double` or `Fraction`? All of them can be `T`
  - `T` here only needs `operator*` and `operator/`
- **Templates**
  - Declare function or class with a "placeholder" type
  - Can use with different types
  - Types should support the used methods/operators

Function Templates

- `template<typename T>` – makes `T` a placeholder type
  - Can have multiple placeholders

```
template<typename T>
T calcPercentage(const T& a, const T& b) {
  return (a * 100) / b;
}
```

  - Applies only to function/class directly after it

```
template<class T1, class T2>
void printValues(const T1& a, const T2& b) {
  cout << a << " " << b << endl;
}
```

  - `template<class T>` has same meaning

Calling Templated Functions

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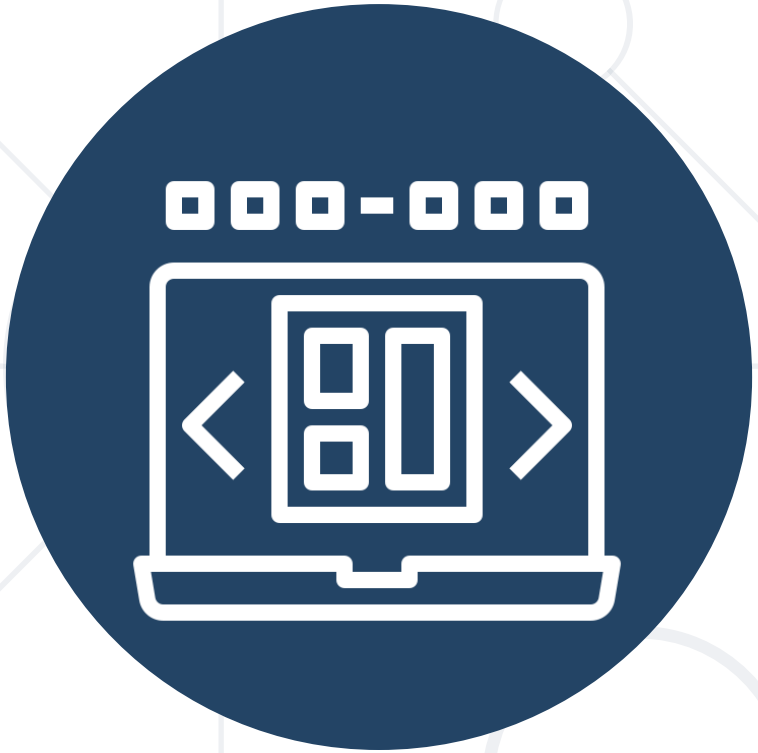
- Call like normal function – C++ guesses types

```
calcPercentage(5, 10) // compiles & executes for int
```

  - If type doesn't support operations in function – compilation error

```
calcPercentage(5, " ")
// compilation error in calcPercentage for operator* and operator/
```

- May need `<Type>` after name to specify type
  - E.g. `calcPercentage<double>(0.5, 1)`



Function Templates

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Class Templates

- Classes can receive templates to use as data types
  - `vector<T>`, `list<T>`, `map<K, V>`
- Defining class template – same as with function

```
template<typename T> class ClassName { ... }
```

  - Can use `T` for fields, methods, etc. – like any actual type
- Using a class template

```
ClassName<int> a;
ClassName<Fraction> b;
```

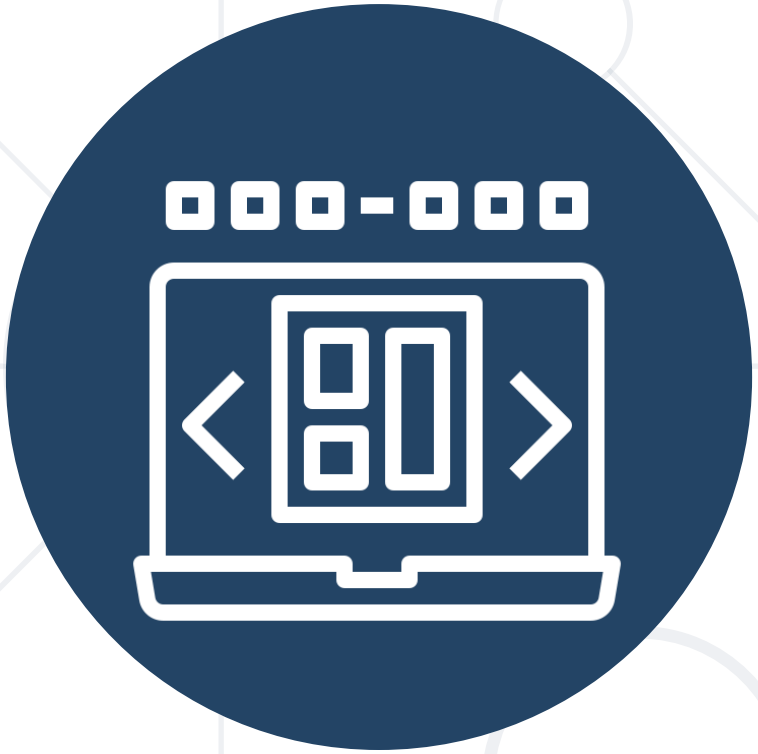
C++ Class Templates – Example

- Making a **`Pair`** class similar to **`std::pair`**
  - Use the same way

```
Pair<string, int> ben{
  "Ben Dover", 42
};

cout << ben.first << " "
  << ben.second;
```

```
#ifndef PAIR_H
#define PAIR_H
template<class T1, class T2>
class Pair {
public:
  T1 first; T2 second;
  Pair(T1 first, T2 second)
    : first(first)
    , second(second) {
  }
};
#endif // !PAIR_H
```



Class Templates

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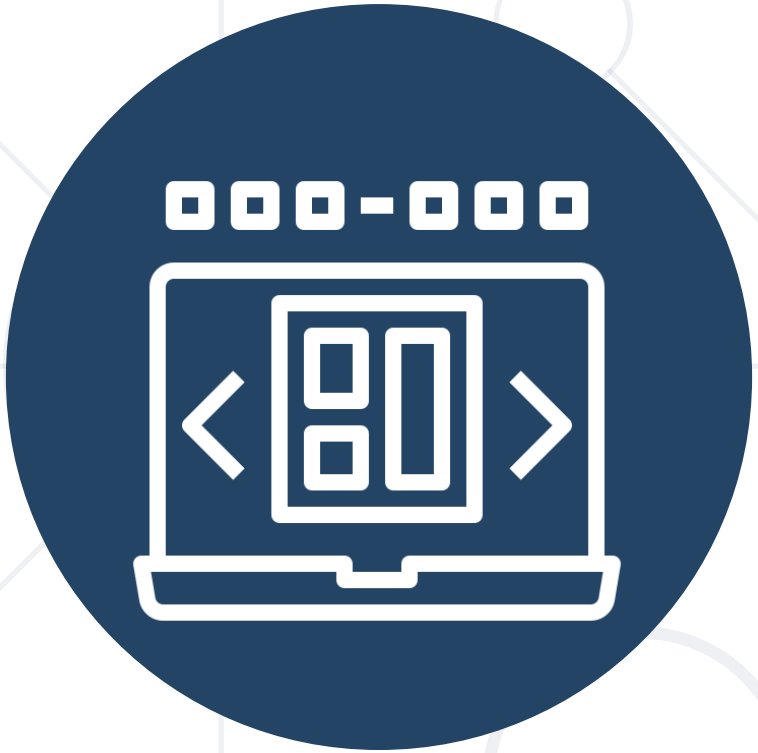
Access Template Subtype – `typename`

- **`operator::`** to access class inside **`T`**, prefix with **`typename`**
  - **`typename T::SubClassName subClassObject;`**
  - Can also use **`class`** instead of **`typename`**

```
template<typename Container> void print(Container container) {
  typename Container::iterator i;
  for (i = container.begin(); i != container.end(); i++) {
    std::cout << *i << " ";
  }
  std::cout << std::endl;
}
```



Access Template Subtype

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Template Specialization

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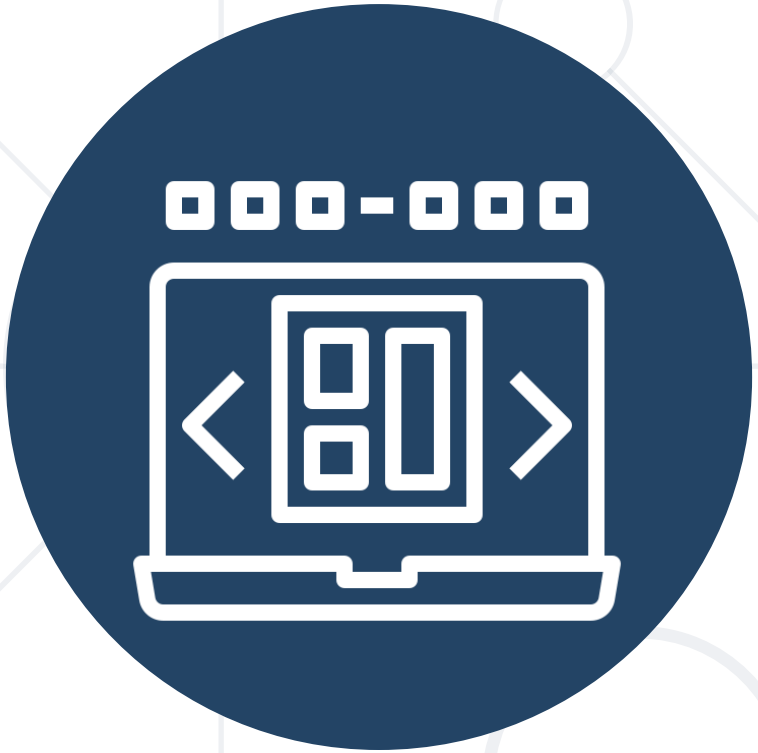
- Can define different behavior for specific template value

```
template<typename T> void print(T container) {
  typename T::iterator i;
  ...
}
template<> void print<string>(string container) {
  cout << container << endl;
}
```

```
vector<int> numbers{ 1, 2, 3 }; string s = "hello specialization";
print(numbers); // prints "1 2 3 "
print(s); // prints "hello specialization"
```



Template Specialization

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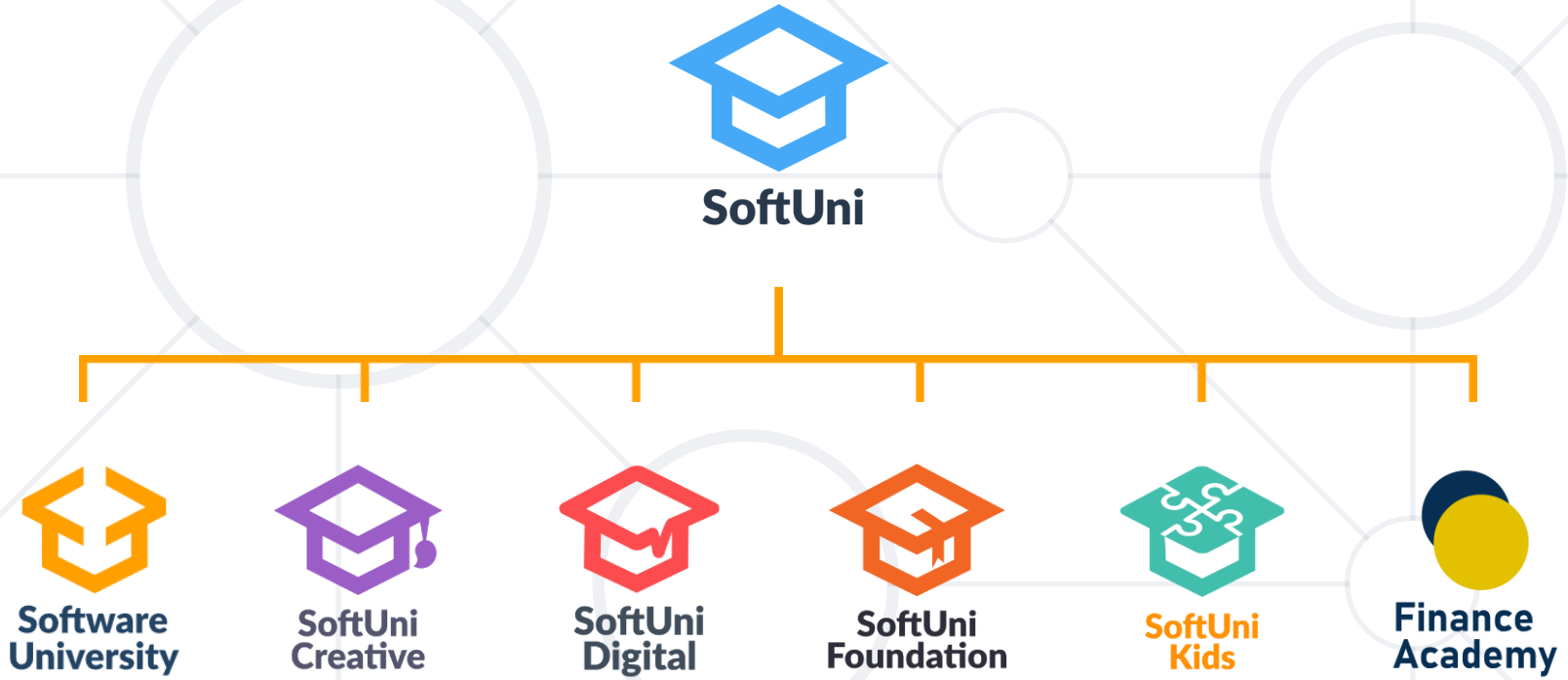
C++ Template Specifics

- Template declaration and definition must be in the SAME file!
  - Can not separate class template in `.h` and `.cpp` files
- Templates can be constant values
  - `template<int N>` - use N as a constant in function/class
- Templates don't exist in code until used
  - When used, compiler copies template with the type
- Template metaprogramming
  - Uses templates to generate results compile-time (e.g. Fibonacci)

Summary

- **Preprocessor directives**
  - Execute before compilation and edit code
  - Macros, Inclusions & Header-guards
- Code is often split into **header** and **source files**
  - `.h` contains declarations, `.cpp` contains definition
  - IDEs usually compile & link all `.cpp` files
- **Templates** allow using the same code for different types
  - Functions and classes can be templates

Questions?



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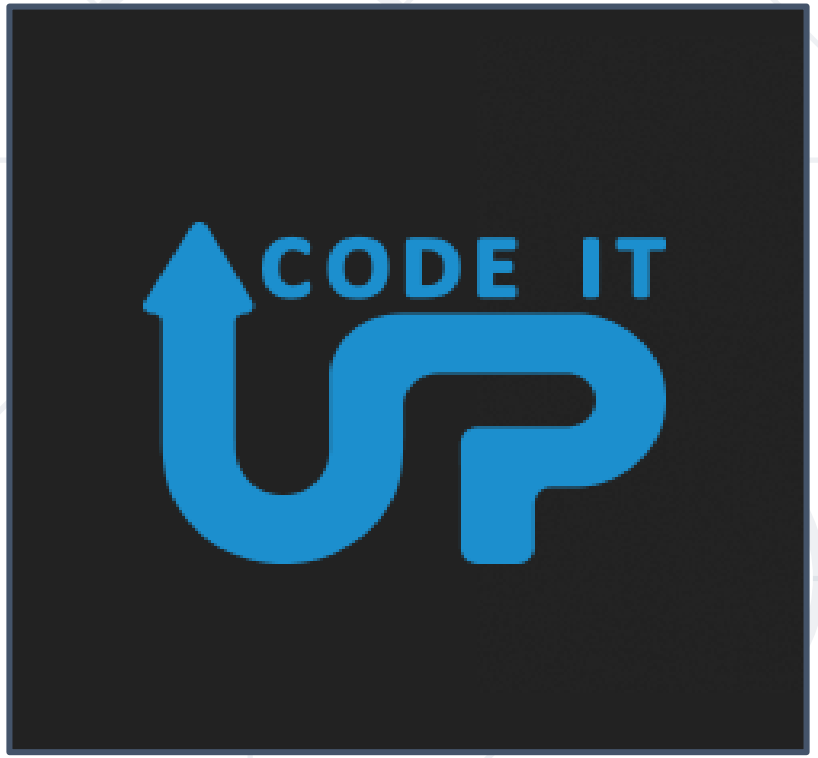

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