

## Templates of templates

https://en.cppreference.com/w/cpp/containers/containers

### Introduction

In this brief article we'll have a look at the topic of building template classes whose parameters are themselves templates.

I'm assuming you're reasonably familiar with template classes. If not, [here's a quick introduction](#).

### The problem

Let's start with a case study. Suppose we want to build a simple hash table class. Our class should be generic for different types of keys and values\*. Obviously, it should be a template class.

```
#include <vector>

template<class Key_Type, class Value_Type>
class SimpleHashTable
{
public:
    void add(Key_Type key, Value_Type val);
    Value_Type get(Key_Type key);
private:
    std::vector<Key_Type> keys;
    std::vector<Value_Type> values;
};

int main()
{
    SimpleHashTable<int, std::string> hash;
    hash.add(1, "Hello");
    hash.add(2, "World");
    std::cout << hash.get(1) << std::endl;
}
```

We might want to add more flexibility to our design by allowing the client to choose the type of container class used by the SimpleHashTable to store its keys and values (for example, for performance reasons we may want to use a fixed-size container).

We need to add the container class as a template parameter. However, a container class is typically a template class itself.

```
template<typename T>
class SequenceContainer
{
    // Implementation...
};
```

Let's modify the SimpleHashTable to allow the container type to be specified:

```
template<class Key_Type,
        class Value_Type,
        template<typename> class Container_Type>
class SimpleHashTable
{
public:
    void add(Key_Type key, Value_Type val);
    Value_Type get(Key_Type key);
private:
    Container_Type<Key_Type> keys;
    Container_Type<Value_Type> values;
};

// ...
```

We must tell the compiler that the template parameter Container\_Type is itself a template class. Notice that the template parameter for the template class must not match any of the other identifiers in the template list.

The Container\_Type parameter is used to instantiate a new container within the SimpleHashTable, whose template parameter is one of the template parameters supplied to the SimpleHashTable. In other words, there is a 'cascading' of template parameters within the class: a parameter supplied to the owning template is used to instantiate a nested template class within.

Let's have a look at what gets created when we instantiate our SimpleHashTable class:

```
template<typename T>
class SequenceContainer
{
    // Implementation...
};

int main()
{
    SimpleHashTable<int, std::string, SequenceContainer> hash;
    // Key_Type    => int
    // Value_Type   => std::string
    // Container_Type => SequenceContainer
    // hash.keys    => SequenceContainer<int>
    // hash.values  => SequenceContainer<std::string>
}
```

As with all template parameters, template-template parameters can be defaulted (the usual rules for defaults apply). Note, however, that the template default must be a template class.

```
template<class Key_Type,
        class Value_Type,
        template<typename> class Container_Type = SequenceContainer>
class SimpleHashTable
{
public:
    void add(Key_Type key, Value_Type val);
    Value_Type get(Key_Type key);
private:
    Container_Type<Key_Type> keys;
    Container_Type<Value_Type> values;
};


// ...

int main()
{
    SimpleHashTable<int, std::string> hash;
    // Key_Type    => int
    // Value_Type   => std::string
    // Container_Type => SequenceContainer (default)
    // hash.keys    => SequenceContainer<int>
    // hash.values  => SequenceContainer<std::string>
}
```

### Summary

Once we start building template classes it becomes natural to incorporate them into other, more complex, template classes. The aim is to build our generic code with as much flexibility as possible.

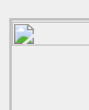
*\*This is a deliberately artificial example. You wouldn't implement a hash table this way, typically; and you don't need to since one is supplied with the Standard Library.*



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Glennan is an embedded systems and software engineer with over 20 years experience, mostly in high-integrity systems for the defence and aerospace industry.  
He specialises in C++, UML, software modelling, Systems Engineering and process development.

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10 Responses to Templates of templates



**EnglishRush** says:  
August 27, 2014 at 1:55 am

In the use of 'class', rather than 'typename' intentional in these examples? In every other article you exclusively use typename.

Great set of articles btw.

Like (0)

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**Ohmide** says:  
September 2, 2014 at 12:30 am

class is used because template template parameters can only be classes. This is not just for emphasis but is the rule.

Like (0)

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**CpWatt** says:  
September 2, 2014 at 10:24 am

Yes, this is the rule, but it should be possible to use both template and class keywords in c++17.

<http://www.open-std.org/jtc1/sc22/wg21/docs/papers/2014/14023.html>

Like (0)

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**Leandreu** says:  
October 2, 2014 at 12:52 am

In your example "Template parameter is a template class" should actually be written as "Template parameter is a class template". This slight inversion of order makes a total difference (check the C++ Standard for examples). Your other example "Default must be a template class" is correct, since in this case you're really pointing to a instantiation of a class template.

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**ArtemT** says:  
October 3, 2014 at 2:10 am

Wanted to point out that using template of template here is not only useless, but is unnecessarily restrictive. In your case simple 'class Container\_Type' would do. Otherwise container is restricted to be a class with a single argument, not more, not less.

There surely are cases where template of template is useful and even necessary, but this example as it is written is not one of them.)

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**Kraut Madlener** says:  
April 23, 2015 at 8:10 am

Another tough concept explained nicely without hiccups.

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**GM** says:  
April 16, 2015 at 12:57 am

Wondering about debugging (which is already difficult on embedded systems)...do we loose any flexibility in later stages, such as debugging?

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