Templates I

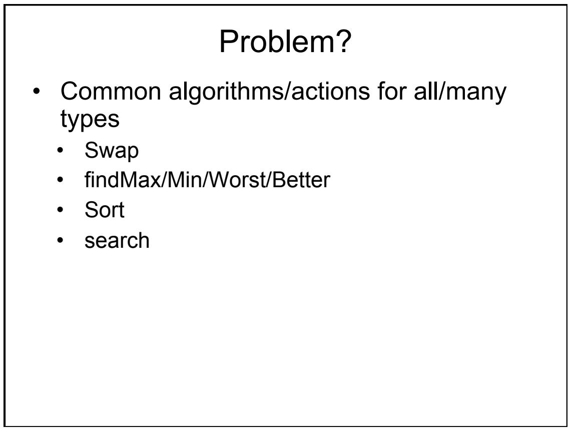
CMSC 202

Warmup

- Define a class that represents an index out of bounds exception
  - Your class should have:
    - Data member that is the index requested
    - Data member that is the function name that throws the exception
    - Data member that is the vector/array that the index was out of bounds on

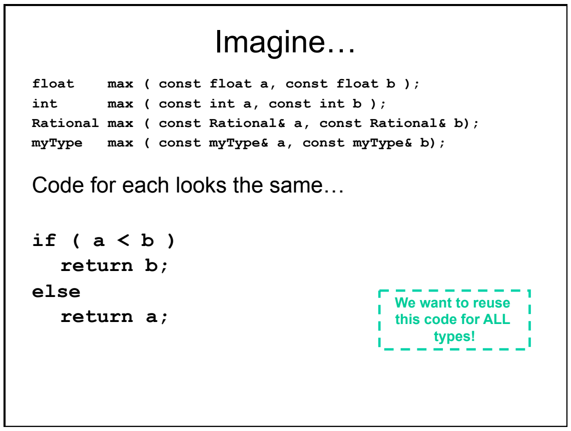
Recall…

- Polymorphism
  - “Many shapes”
- Types seen so far?
  - Ad-hoc
    - Functional overloading
  - Dynamic (true)
    - Virtual member functions, dynamic binding
- What’s left?
  - Parameterized
    - Parameter-based (type based), static binding
      - Function & class-based templates



Problem?

- Common algorithms/actions for all/many types
  - Swap
  - findMax/Min/Worst/Better
  - Sort
  - search



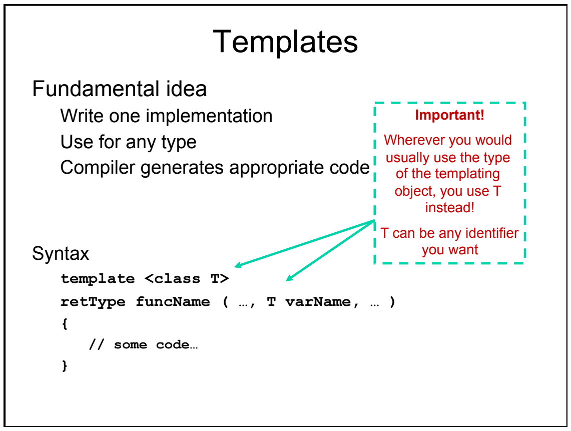
Imagine…

```
float    max ( const float a, const float b );
int      max ( const int a, const int b );
Rational max ( const Rational& a, const Rational& b);
myType   max ( const myType& a, const myType& b);
```

Code for each looks the same…

```
if ( a < b )
   return b;
else
   return a;
```

We want to reuse this code for ALL types!



Templates

Fundamental idea

Write one implementation

Use for any type

Compiler generates appropriate code

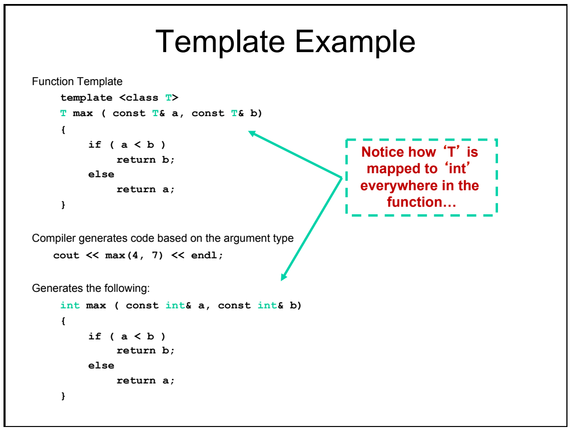
Important!

Wherever you would usually use the type of the templating object, you use T instead!

T can be any identifier you want

Syntax

```
template <class T>
retType funcName ( …, T varName, … )
{
   // some code…
}
```



Template Example

Function Template

```
template <class T>
T max ( const T& a, const T& b)
{
     if ( a < b )
          return b;
     else
          return a;
}
```

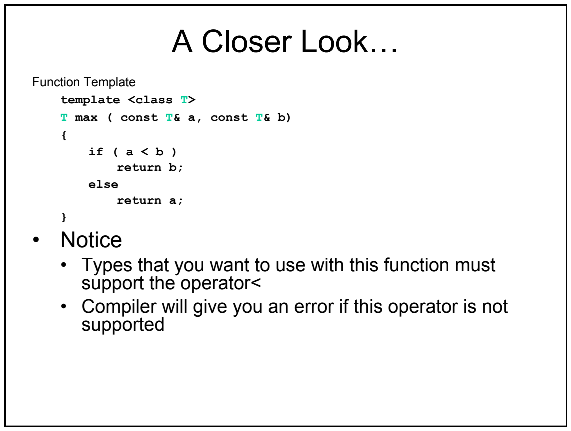
Notice how ‘T’ is mapped to ‘int’ everywhere in the function…

Compiler generates code based on the argument type

```
cout << max(4, 7) << endl;
```

Generates the following:

```
int max ( const int& a, const int& b)
{
     if ( a < b )
          return b;
     else
          return a;
}
```

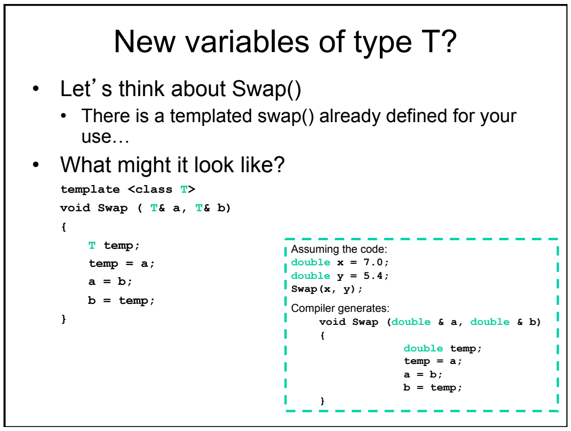


A Closer Look…

Function Template

```
template <class T>
T max ( const T& a, const T& b)
{
     if ( a < b )
          return b;
     else
          return a;
}
```

- Notice
  - Types that you want to use with this function must support the operator<
  - Compiler will give you an error if this operator is not supported



New variables of type T?

- Let’s think about Swap()
  - There is a templated swap() already defined for your use…
- What might it look like?

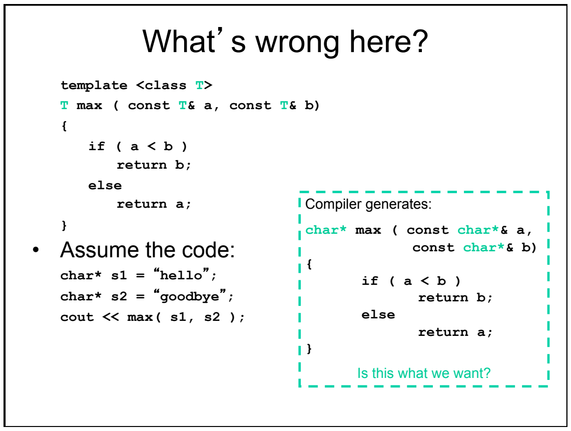
```
template <class T>
void Swap ( T& a, T& b)
{
     T temp;
     temp = a;
     a = b;
     b = temp;
}
```

Assuming the code:

```
double x = 7.0;
double y = 5.4;
Swap(x, y);
```

Compiler generates:

```
     void Swap (double & a, double & b)
     {
                    double temp;
                    temp = a;
                    a = b;
                    b = temp;
     }
```



What’s wrong here?

```
template <class T>
T max ( const T& a, const T& b)
{
   if ( a < b )
      return b;
   else
      return a;
}
```

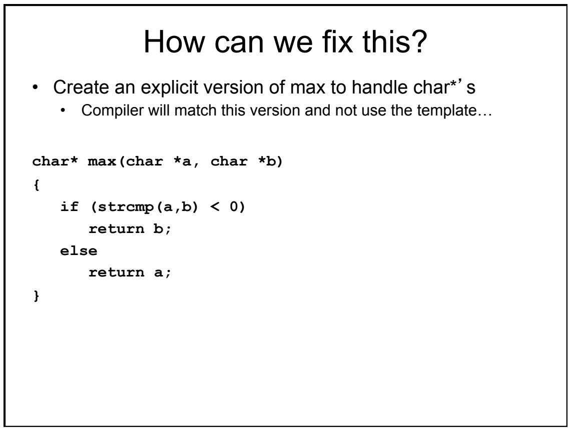
- Assume the code:

```
char* s1 = “hello”;
char* s2 = “goodbye”;
cout << max( s1, s2 );
```

Compiler generates:

```
char* max ( const char*& a,
            const char*& b)
{
      if ( a < b )
            return b;
      else
            return a;
}
```

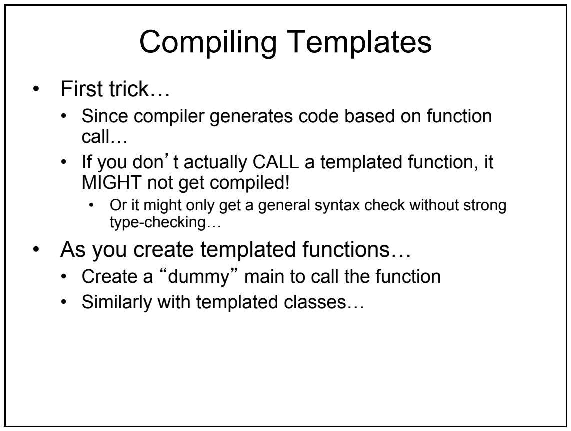
Is this what we want?



How can we fix this?

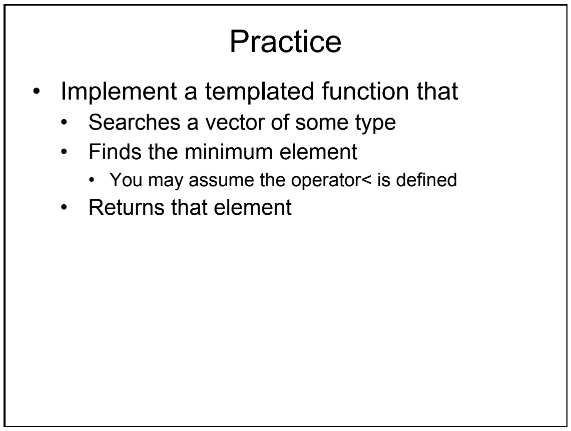
- Create an explicit version of max to handle char*’s
  - Compiler will match this version and not use the template…

```
char* max(char *a, char *b)
{
   if (strcmp(a,b) < 0)
      return b;
   else
      return a;
}
```



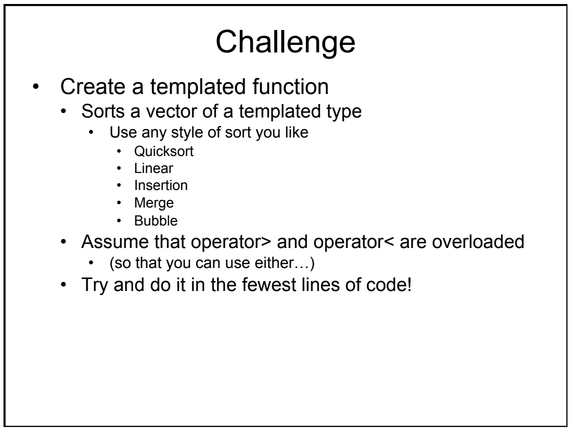
Compiling Templates

- First trick…
  - Since compiler generates code based on function call…
  - If you don’t actually CALL a templated function, it MIGHT not get compiled!
    - Or it might only get a general syntax check without strong type-checking…
- As you create templated functions…
  - Create a “dummy” main to call the function
  - Similarly with templated classes…



Practice

- Implement a templated function that
  - Searches a vector of some type
  - Finds the minimum element
    - You may assume the operator< is defined
  - Returns that element



Challenge

- Create a templated function
  - Sorts a vector of a templated type
    - Use any style of sort you like
      - Quicksort
      - Linear
      - Insertion
      - Merge
      - Bubble
  - Assume that operator> and operator< are overloaded
    - (so that you can use either…)
  - Try and do it in the fewest lines of code!