# Interfaces, Templates, and Exceptions

Sections 2.2.5-2.4

# API and interface

- Classes should provide an application programming interface (API), or simply interface, that specifies how other objects can interact with objects of that class.
- In the ADT-based approach, an interface is specified as a type definition with a collection of member functions, with the arguments for each member function being of specified types.
- Java provides a language construct for specifying interfaces, but C++ does not.

# Informal Interfaces

- We will use informal interfaces which look like a C++ specification but aren't exactly valid C++ constructs.

```
class Stack {
public:
  bool isEmpty() const;
  void push(int x);
  int pop();
};
```

- Note that this does not contain any data members or function bodies.  It is just a documentation aid.

# Abstract Classes

- An abstract class is a C++ class that can only be used as a base class for inheritance—it cannot be used to create instances.
- A class becomes abstract when one or more of its functions are declared as abstract (also known as pure virtual). This is done as follows:

```
class Shape {
        virtual void draw() = 0;
        // …
}
```

# Abstract Classes

- C++ does not allow the creation of an object that has one or more pure virtual functions.
- Thus, any subclass that expects to be instantiated must override all pure virtual functions of its superclass.
- We can use abstract classes in C++ to achieve most of the effect of an interface.

```
class Stack {
public:
   virtual bool isEmpty() const = 0;
   virtual void push(int x) = 0;
   virtual int pop() = 0;
};
```

# Concrete classes

- The opposite of abstract is concrete.

```
class ConcreteStack : public Stack {
public:
    virtual bool isEmpty() { … };
    virtual void push(int x) { … };
    virtual int pop() { … };
private:
    // …
};
```

# Templates

- Another mechanism for polymorphism in C++ is templates.
- I.e., templates allow us to write code that works for a variety of different types.
- Consider:

```
int integerMin(int a, int b)
   { return (a < b ? a : b); }

double doubleMin(double a, double b)
   { return (a < b ? a : b); }
```

# Function Templates

- We can write a single function that works for both of these by using a template:

```
template <typename T>
T generalMin(T a, T b) {
    return (a < b ? a : b);
}
```

- The type parameter T takes the place of an actual type in the declaration of the function.

```
cout << generalMin(3, 4) << ' '
    << generalMin(1.1, 3.1) << ' `
    << generalMin('t', 'g') << endl;
```

# Class Templates

- C++ also allows classes to be templated.
- The Standard Template Library (STL), a common library of C++ data structures, uses class templates extensively.

```
template <typename T>
class BasicVector {
public:
    BasicVector(int capac = 10);
    T& operator[](int i) { return a[i]; }
    // ...
private:
    T* a;
    int capacity;
}
```

# Class Templates

- Outside of the class body, one can specify member functions such as:

```
template <typename T>
BasicVector<T>::BasicVector(int capac) {
    capacity = capac;
    a = new T[capacity];
}
```

- And one can instantiate the class by specifying the type:

```
BasicVector<int>  iv(5);
BasicVector<double>  dv(20);
BasicVector<string> sv(10);
```

# Class Templates

- Any type can be used as the argument for a template specified with **typename**.
- This includes templated types!

```
BasicVector<BasicVector<int> > xv(5);        // this is a vector of vectors
// …
xv[2][8] = 15;
```

- Here each element of the 5-element vector was initialized with the default capacity of 10.

# Exceptions

- Exceptions are unexpected events that happen during the execution of a program, such as an error condition or an unexpected input.
- C++ allows the programmer to create an object that represents the exception.
- This object is then thrown by the code that encounters the unexpected event, and then caught by other code that handles the event.
- If no code catches the exception, the program is terminated.
- The C++ run-time environment can throw exceptions; an example is when a program runs out of memory.

# Exceptions

- An alternative to exceptions is to have a function return special error codes or condition codes to indicate that it encountered unexpected circumstances.
- Exceptions are more modern but you will still encounter many library functions that return condition codes.
- In C++, any object can be thrown, but it is the best practice to define object classes for exceptions, often with Exception or Error as part of its name.

# Sample Exception Classes

```
class MathException {
public:
    MathException(const string& err)
      : errMsg(err) { }
    string getError() { return errMsg;}
private:
    string errMsg;
};

class ZeroDivideException : public MathException {
public:
    ZeroDivideException(const string& err)
      : MathException(err) { }
};
```

# Throwing and Catching

- Exceptions are processed in the context of try and catch blocks.

```
try {
   // ...
   if (divisor == 0)
    throw ZeroDivideException("divide by zero!");
}
catch (ZeroDivideException& zde) {
   // handle division by zero
}
catch (MathException& me) {
   // handle any other math exception
}
```

# Try-Catch statements

- A try-catch statement consists of a try block followed by any number of catch blocks.
- Execution begins in the try block.
- If the try block finishes without any exceptions being thrown, then the catch blocks are not executed.
- If the try block throws an exception, then control is immediately transferred to the first catch block that matches that exception.
- If no catch block matches the exception, then the subroutine/function being executed is exited with the thrown exception.

# Exception Specification

- An exception that is not caught ends a function and this can propagate up through many active functions.
- Therefore, when specifying a function, we should also specify the exceptions it might throw.  This lets the programmer and the compiler know which exceptions to expect.
- This is done with a **throw** declaration as part of the function definition.

```
void calculator() throw(ZeroDivideException,
                        NegativeRootException) {
   // … function body
}
```

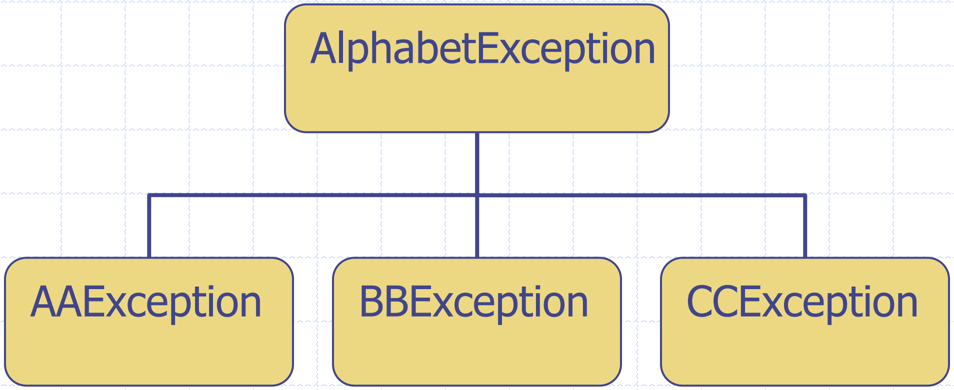
# Exception Specification

- A benefit to specifying exceptions on a function is that it tells us which exceptions the function does not itself need to handle.
- This is appropriate when other code is responsible for the circumstances that led to the exception.
- Here's an example of passing an exception through a function:

```
void getReadyForClass() throw(OutOfMoneyException) {
    goShopping();                    // could throw OutOfMoneyException
    makeCookiesForTA();
}
```

# Exception Specification

- A function can declare that it throws as many exceptions as it likes.
- Such a listing of exceptions can be simplified if several exceptions are derived classes of the same exception. If so, we need only list the appropriate base class.




```
int func() throw(AAException,
                 BBException,
                 CCException) { … }

int func() throw(
               AlphabetException) { … }
```

# Exception Specification

- A function that does not contain a **throw** declaration is assumed to throw any exception.

```
void ICanThrowAnyException();
```

- A function can declare it throws no exceptions by specifying an empty list after the **throw** keyword.

```
void ICanThrowNoExceptions() throw();
```

# General Exception Class

```
class RuntimeException {
private:
    string errorMsg;
public:
    RuntimeException(const string& err) {
        errorMsg = err;
    }
    string getMessage() const {
        return errorMsg;
    }
};
```

- This is an example of an immutable object.