C++ Programming: Program Design Including Data Structures, Third Edition

Chapter 15: Exception Handling

Objectives

In this chapter you will:

- Learn what an exception is
- Learn how to handle exceptions within a program
- See how a `try`/`catch` block is used to handle exceptions
- Become familiar with C++ exception classes

Objectives (continued)

- Learn how to create your own exception classes
- Discover how to throw and rethrow an exception
- Explore stack unwinding

Exceptions

- Exception: undesirable event detectable during program execution
- If exceptions occurred during execution
  - Programmer-supplied code terminated the program or
  - Program terminated with an appropriate error message
- Can add exception-handling code at point where an error can occur

Handling Exceptions within a Program (continued)

- Function `assert`:
  - Checks if an expression meets certain condition(s)
  - If conditions are not met, it terminates the program
- Example: division by `0`
  - If divisor is zero, `assert` terminates the program with an error message

Example 15-1

```
#include <iostream>

using namespace std;

int main()
{
    int dividend, divisor, quotient;                    //Line 1

    cout << "Line 2: Enter the dividend: ";             //Line 2
    cin >> dividend;                                    //Line 3
    cout << endl;                                       //Line 4

    cout << "Line 5: Enter the divisor: ";              //Line 5
    cin >> divisor;                                     //Line 6
    cout << endl;                                       //Line 7

    quotient = dividend / divisor;                      //Line 8
    cout << "Line 9: Quotient = " << quotient
         << endl;                                       //Line 9

    return 0;                                           //Line 10
}
```

Sample Run 1:

```
Line 2: Enter the dividend: 12

Line 5: Enter the divisor: 5

Line 9: Quotient = 2
```

Sample Run 2:

```
Line 2: Enter the dividend: 24

Line 5: Enter the divisor: 0

abcfgh.exe has encountered a problem and needs to close. We are sorry
for the inconvenience.
```

Example 15-2

```
#include <iostream>

using namespace std;

int main()
{
    int dividend, divisor, quotient;                    //Line 1

    cout << "Line 2: Enter the dividend: ";             //Line 2
    cin >> dividend;                                    //Line 3
    cout << endl;                                       //Line 4

    cout << "Line 5: Enter the divisor: ";              //Line 5
    cin >> divisor;                                     //Line 6
    cout << endl;                                       //Line 7

    if (divisor != 0)                                   //Line 8
    {
        quotient = dividend / divisor;                  //Line 9
        cout << "Line 10: Quotient = " << quotient
             << endl;                                   //Line 10
    }
    else                                                //Line 11
        cout << "Line 12: Cannot divide by zero."
             << endl;                                   //Line 12

    return 0;                                           //Line 13
}
```

Sample Run 1:

```
Line 2: Enter the dividend: 12

Line 5: Enter the divisor: 5

Line 10: Quotient = 2
```

Sample Run 2:

```
Line 2: Enter the dividend: 24

Line 5: Enter the divisor: 0

Line 12: Cannot divide by zero.
```

Example 15-3

```
#include <iostream>
#include <cassert>

using namespace std;

int main()
{
    int dividend, divisor, quotient;                  //Line 1

    cout << "Line 2: Enter the dividend: ";           //Line 2
    cin >> dividend;                                  //Line 3
    cout << endl;                                     //Line 4

    cout << "Line 5: Enter the divisor: ";            //Line 5
    cin >> divisor;                                   //Line 6
    cout << endl;                                     //Line 7

    assert(divisor != 0);                             //Line 8
    quotient = dividend / divisor;                    //Line 9

    cout << "Line 10: Quotient = " << quotient
         << endl;                                     //Line 10

    return 0;                                         //Line 11
}
```

Sample Run 1:

```
Line 2: Enter the dividend: 26

Line 5: Enter the divisor: 7

Line 10: Quotient = 3
```

Sample Run 2:

```
Line 2: Enter the dividend: 24

Line 5: Enter the divisor: 0

Assertion failed: divisor != 0, file c:\chapter 16 source code\ch16_exp3.cpp,
line 19
```

C++ Mechanisms of Exception Handling

- The `try`/`catch` block handles exceptions
- Exception must be thrown in a `try` block and caught by a catch block
- C++ provides support to handle exceptions via a hierarchy of classes

try/catch Block

- Statements that may generate an exception are placed in a `try` block
- The `try` block also contains statements that should not be executed if an exception occurs
- The `try` block is followed by one or more `catch` blocks

try/catch Block (continued)

- The `catch` block:
  - Specifies the type of exception it can catch
  - Contains an exception handler
- If the heading of a `catch` block contains ... (ellipses) in place of parameters
  - Catch `block` can catch exceptions of all types

- General syntax of the try/catch block:

```
try
{
      //statements
}
catch (dataType1 identifier)
{
      //exception handling code
}
.
.
.
catch (dataTypen identifier)
{
      //exception handling code
}
.
.
.
catch (...)
{
      //exception handling code
}
```

try/catch Block (continued)

- If no exception is thrown in a `try` block
  - All `catch` blocks for that `try` block are ignored
  - Execution resumes after the last `catch` block
- If an exception is thrown in a `try` block
  - Remaining statements in that `try` block are ignored

try/catch Block (continued)

- The program searches `catch` blocks in order, looking for an appropriate exception handler
- If the type of thrown exception matches the parameter type in one of the `catch` blocks:
  - Code of that `catch` block executes
  - Remaining `catch` blocks are ignored

```
catch (int x)
{
    //exception handling code
}
```

In this `catch` block:

- The identifier `x` acts as a parameter. In fact, it is called a `catch` block parameter.
- The data type `int` specifies that this `catch` block can catch an exception of type `int`.
- A `catch` block can have *at most* one `catch` block parameter.

Throwing an Exception

- For `try`/`catch` to work, the exception must be thrown in the `try` block
- General syntax to throw an exception is:

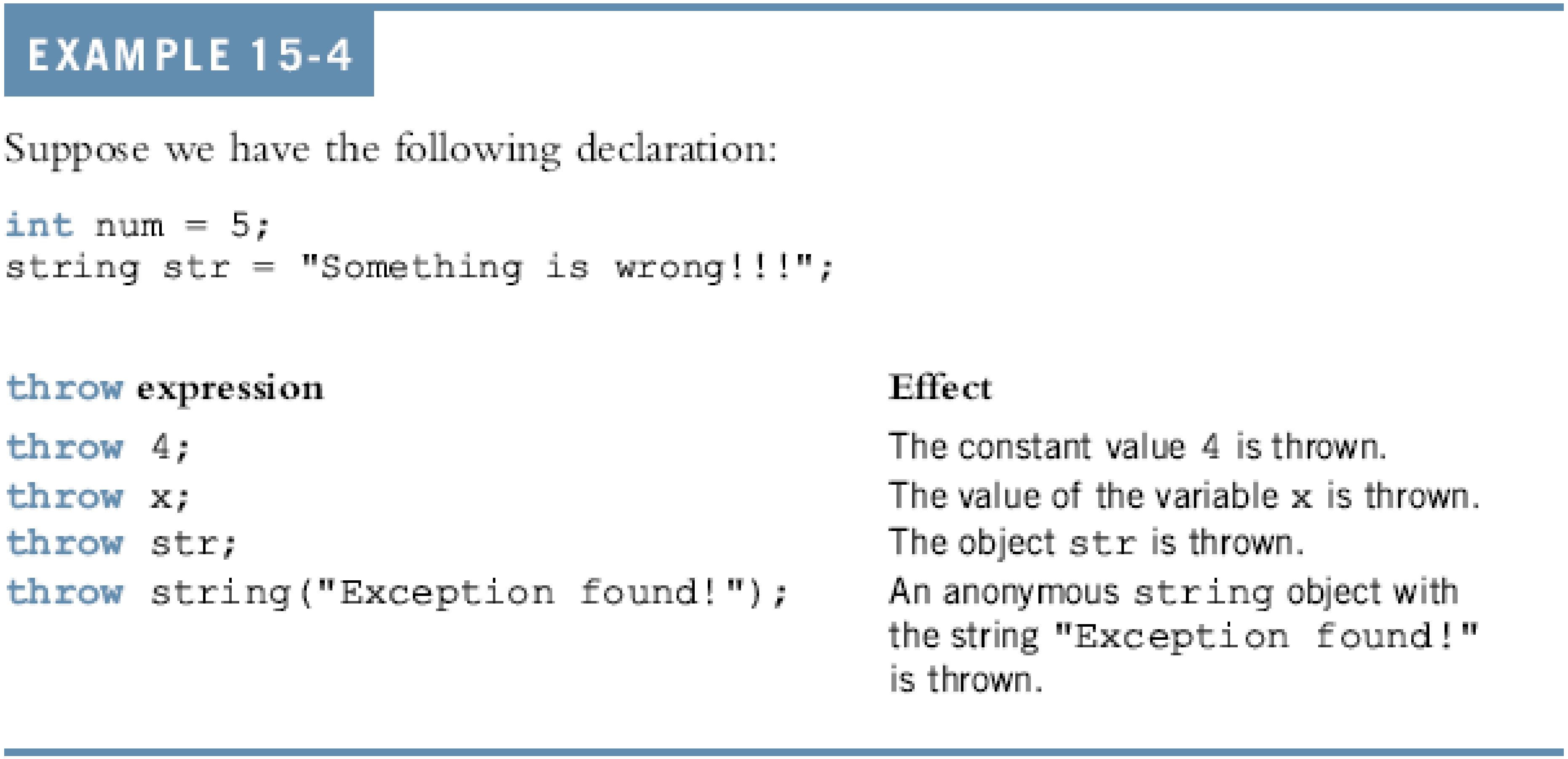
```
throw expression;
```

where `expression` is a constant value, variable, or object

Throwing an Exception (continued)

- The object being thrown can be:
  - Specific object
  - Anonymous object
- In C++
  - An exception is a value
  - `throw` is a reserved word

Throwing an Exception:



EXAMPLE 15-4

Suppose we have the following declaration:

```
int num = 5;
string str = "Something is wrong!!!";
```

`throw` **expression**	**Effect**
`throw 4;`	The constant value 4 is thrown.
`throw x;`	The value of the variable `x` is thrown.
`throw str;`	The object `str` is thrown.
`throw string("Exception found!");`	An anonymous `string` object with the string `"Exception found!"` is thrown.

Order of catch Blocks

- Catch block can catch
  - All exceptions of a specific type
  - All types of exceptions
- A `catch` block with an ellipses (three dots) catches any type of exception
- In a sequence of `try`/`catch` blocks, if the `catch` block with an ellipses is needed
  - It should be the last `catch` block of that sequence

Using try/catch Blocks in a Program:

```
#include <iostream>

using namespace std;

int main()
{
    int dividend, divisor, quotient;                //Line 1

    try                                             //Line 2
    {
        cout << "Line 3: Enter the dividend: ";     //Line 3
        cin >> dividend;                            //Line 4
        cout << endl;                               //Line 5

        cout << "Line 6: Enter the divisor: ";      //Line 6
        cin >> divisor;                             //Line 7
        cout << endl;                               //Line 8

        if (divisor == 0)                           //Line 9
            throw 0;                                //Line 10

        quotient = dividend / divisor;              //Line 11

        cout << "Line 12: Quotient = " << quotient
             << endl;                               //Line 12
    }
    catch (int)                                     //Line 13
    {
        cout << "Line 14: Division by 0." << endl;   //Line 14
    }

    return 0;                                         //Line 15
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 17

Line 6: Enter the divisor: 8

Line 12: Quotient = 2
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 34

Line 6: Enter the divisor: 0

Line 14: Division by 0.
```

Example 15-6

```
#include <iostream>

using namespace std;

 int main()
 {
     int dividend, divisor, quotient;                   //Line 1

     try                                                //Line 2
     {
         cout << "Line 3: Enter the dividend: ";        //Line 3
         cin >> dividend;                               //Line 4
         cout << endl;                                  //Line 5

         cout << "Line 6: Enter the divisor: ";         //Line 6
         cin >> divisor;                                //Line 7
         cout << endl;                                  //Line 8

         if (divisor == 0)                              //Line 9
             throw divisor;                             //Line 10

         quotient = dividend / divisor;                 //Line 11

         cout << "Line 12: Quotient = " << quotient
              << endl;                                  //Line 12
     }
```

```
    catch (int x)                                         //Line 13
    {
        cout << "Line 14: Division by " << x
             << endl;                                     //Line 14
    }

    return 0;                                             //Line 15
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 14

Line 6: Enter the divisor: 5

Line 12: Quotient = 2
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 23

Line 6: Enter the divisor: 0

Line 14: Division by 0
```

Example 15-7

```
#include <iostream>
#include <string>

using namespace std;

int main()
{
    int dividend, divisor = 1, quotient;                //Line 1

    string inpStr
       = "The input stream is in the fail state.";      //Line 2

    try                                                 //Line 3
    {
        cout << "Line 4: Enter the dividend: ";         //Line 4
        cin >> dividend;                                //Line 5
        cout << endl;                                   //Line 6

        cout << "Line 7: Enter the divisor: ";          //Line 7
        cin >> divisor;                                 //Line 8
        cout << endl;                                   //Line 9
        if (divisor == 0)                                          //Line 10
            throw divisor;                                         //Line 11
        else if (divisor < 0)                                      //Line 12
            throw string("Negative divisor.");                     //Line 13
        else if (!cin)                                             //Line 14
            throw inpStr;                                          //Line 15

        quotient = dividend / divisor;                             //Line 16

        cout << "Line 17: Quotient = " << quotient
             << endl;                                              //Line 17
    }
    catch (int x)                                                  //Line 18
    {
        cout << "Line 19: Division by " << x
             << endl;                                              //Line 19
    }
    catch (string s)                                               //Line 20
    {
        cout << "Line 21: " << s << endl;                          //Line 21
    }

    return 0;                                                      //Line 22
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 4: Enter the dividend: 23

Line 7: Enter the divisor: 6

Line 17: Quotient = 3
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 4: Enter the dividend: 34

Line 7: Enter the divisor: -6

Line 21: Negative divisor.
```

Sample Run 3: In this sample run, the user input is shaded.

```
Line 4: Enter the dividend: 34

Line 7: Enter the divisor: g

Line 21: The input stream is in the fail state.
```

Using C++ Exception Classes

- C++ provides support to handle exceptions via hierarchy of classes
- The function *what* returns the string containing exception object thrown by C++'s built-in exception classes
- The `class` *`exception`* is:
  - The base class of the exception classes provided by C++
  - Contained in the header file exception

Using C++ Exception Classes (continued)

- Two classes derived from `exception`:
  - `logic_error`
  - `runtime_error`
- `logic_error` and `runtime_error` are defined in header file `stdexcept`
- The `class invalid_argument` deals with illegal arguments used in a function call

Using C++ Exception Classes (continued)

- The `class out_of_range` deals with the `string` subscript `out_of_range` error
- The `class length_error` handles the error if
  - A length greater than the maximum allowed for a `string` object is used

Using C++ Exception Classes (continued)

- If the operator `new` cannot allocate memory space
  - It throws a `bad_alloc` exception
- The `class runtime_error` deals with errors that occur only during program execution
- Classes `overflow_error` and `underflow_error`
  - Deal with arithmetic overflow and under-flow exceptions
  - Derived from the `class runtime_error`

Example 15-8: exceptions `out_of_range` and `length_error`

```
#include <iostream>
#include <string>

using namespace std;

int main()
{
    string sentence;                                    //Line 1
    string str1, str2, str3;                            //Line 2

    try                                                 //Line 3
    {
        sentence = "Testing string exceptions!";        //Line 4
        cout << "Line 5: sentence = " << sentence
             << endl;                                   //Line 5
        cout << "Line 6: sentence.length() = "
             << static_cast<int>(sentence.length())
             << endl;                                   //Line 6
        str1 = sentence.substr(8, 20);                  //Line 7
        cout << "Line 8: str1 = " << str1
             << endl;                                   //Line 8

        str2 = sentence.substr(28, 10);                 //Line 9
        cout << "Line 10: str2 = " << str2
             << endl;                                   //Line 10

        str3 = "Exception handling. " + sentence;       //Line 11
        cout << "Line 12: str3 = " << str3
             << endl;                                   //Line 12

    }
    catch (out_of_range re)                             //Line 13
    {
        cout << "Line 14: In the out_of_range "
             << "catch block: " << re.what()
             << endl;                                   //Line 14
    }
    catch (length_error le)                             //Line 15
    {
        cout << "Line 16: In the length_error "
             << "catch block: " << le.what()
             << endl;                                   //Line 16
    }

    return 0;                                           //Line 17
}
```

Sample Run:

```
Line 5: sentence = Testing string exceptions!
Line 6: sentence.length() = 26
Line 8: str1 = string exceptions!
Line 14: In the out_of_range catch block: invalid string position
```

Example 15-9: exception `bad_alloc`

```
#include <iostream>

using namespace std;

int main()
{
    int *list[100];                                     //Line 1

    try                                                 //Line 2
    {
        for (int i = 0; i < 100; i++)                   //Line 3
        {
            list[i] = new int[50000000];                //Line 4
            cout << "Line 4: Created list[" << i
                 << "] of 50000000 components."
                 << endl;                               //Line 5
        }
    }
    catch (bad_alloc be)                                //Line 6
    {
        cout << "Line 7: In the bad_alloc catch "
             << "block: " << be.what() << "."
             << endl;                                   //Line 7
    }

    return 0;                                           //Line 8
}
```

Sample Run:

```
Line 4: Created list[0] of 50000000 components.
Line 4: Created list[1] of 50000000 components.
Line 4: Created list[2] of 50000000 components.
Line 4: Created list[3] of 50000000 components.
Line 4: Created list[4] of 50000000 components.
Line 4: Created list[5] of 50000000 components.
Line 4: Created list[6] of 50000000 components.
Line 4: Created list[7] of 50000000 components.
Line 7: In the bad_alloc catch block: bad allocation.
```

Creating Your Own Exception Classes

- Programmers can create exception classes to handle exceptions not covered by C++’s exception classes and their own exceptions
- C++ uses the same mechanism to process the exceptions you define as for built-in exceptions
- You must throw your own exceptions using the `throw` statement
- Any `class` can be an exception class

```
class dummyExceptionClass
{
};
```

Example 15-10

```
#include <iostream>

using namespace std;

class divByZero
{};


int main()
{
    int dividend, divisor, quotient;                           //Line 1
    try                                                 //Line 2
    {
        cout << "Line 3: Enter the dividend: ";         //Line 3
        cin >> dividend;                                //Line 4
        cout << endl;                                   //Line 5

        cout << "Line 6: Enter the divisor: ";          //Line 6
        cin >> divisor;                                 //Line 7
        cout << endl;                                   //Line 8

        if (divisor == 0)                               //Line 9
            throw divByZero();                          //Line 10

        quotient = dividend / divisor;                  //Line 11
        cout << "Line 12: Quotient = " << quotient
             << endl;                                   //Line 12
    }
    catch (divByZero)                                   //Line 13
    {
        cout << "Line 14: Division by zero!"
             << endl;                                   //Line 14
    }

    return 0;                                           //Line 15
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 34

Line 6: Enter the divisor: 5

Line 12: Quotient = 6
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 56

Line 6: Enter the divisor: 0

Line 14: Division by zero!
```

```cpp
#include <iostream>
#include <string>

using namespace std;

class divisionByZero                            //Line 1
{                                               //Line 2
public:                                         //Line 3
    divisionByZero()                            //Line 4
    {
        message = "Division by zero";           //Line 5
    }                                           //Line 6

    divisionByZero(string str)                  //Line 7
    {                                           //Line 8
        message = str;                          //Line 9
    }                                           //Line 10

    string what()                               //Line 11
    {                                           //Line 12
        return message;                         //Line 13
    }                                           //Line 14

private:                                        //Line 15
    string message;                             //Line 16
};                                              //Line 17
```

Example 15-11

```
#include <iostream>
#include "divisionByZero.h"

using namespace std;

int main()
{
    int dividend, divisor, quotient;                    //Line 1

    try                                                 //Line 2
    {
        cout << "Line 3: Enter the dividend: ";         //Line 3
        cin >> dividend;                                //Line 4
        cout << endl;                                   //Line 5

        cout << "Line 6: Enter the divisor: ";          //Line 6
        cin >> divisor;                                 //Line 7
        cout << endl;                                   //Line 8

        if (divisor == 0)                               //Line 9
            throw divisionByZero();                     //Line 10

        quotient = dividend / divisor;                  //Line 11
        cout << "Line 12: Quotient = " << quotient
             << endl;                                   //Line 12
    }
    catch (divisionByZero divByZeroObj)              //Line 13
    {
        cout << "Line 14: In the divisionByZero "
             << "catch block: "
             << divByZeroObj.what() << endl;         //Line 14
    }

    return 0;                                        //Line 15
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 34

Line 6: Enter the divisor: 5

Line 12: Quotient = 6
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 3: Enter the dividend: 56

Line 6: Enter the divisor: 0

Line 14: In the divisionByZero catch block: Division by zero
```

Example 15-13

```
#include <iostream>
#include "divisionByZero.h"

using namespace std;

void doDivision();

int main()
{
    doDivision();                                    //Line 1

    return 0;                                        //Line 2
}

void doDivision()
{
    int dividend, divisor, quotient;                 //Line 3

    try
    {
        cout << "Line 4: Enter the dividend: ";      //Line 4
        cin >> dividend;                             //Line 5
        cout << endl;                                //Line 6
        cout << "Line 7: Enter the divisor: ";          //Line 7
        cin >> divisor;                                 //Line 8
        cout << endl;                                   //Line 9

        if (divisor == 0)                               //Line 10
            throw divisionByZero();                     //Line 11

        quotient = dividend / divisor;                  //Line 12
        cout << "Line 13: Quotient = " << quotient
             << endl;                                   //Line 13
    }
    catch (divisionByZero divByZeroObj)                 //Line 14
    {
        cout << "Line 15: In the function "
             << "doDivision: "
             << divByZeroObj.what() << endl;            //Line 15
    }
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 4: Enter the dividend: 34

Line 7: Enter the divisor: 5

Line 13: Quotient = 6
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 4: Enter the dividend: 56

Line 7: Enter the divisor: 0

Line 15: In the function doDivision: Division by zero
```

Rethrowing and Throwing an Exception

- When an exception occurs in a `try` block
  - Control immediately passes to one of the catch blocks
- A `catch` block either
  - Handles the exception or partially processes the exception and then rethrows the same exception OR
  - Rethrows another exception for the calling environment to handle

Rethrowing and Throwing an Exception (continued)

- The general syntax to rethrow an exception caught by a catch block is:

  ```
  throw;
  ```

  (in this case, the same exception is rethrown) or:

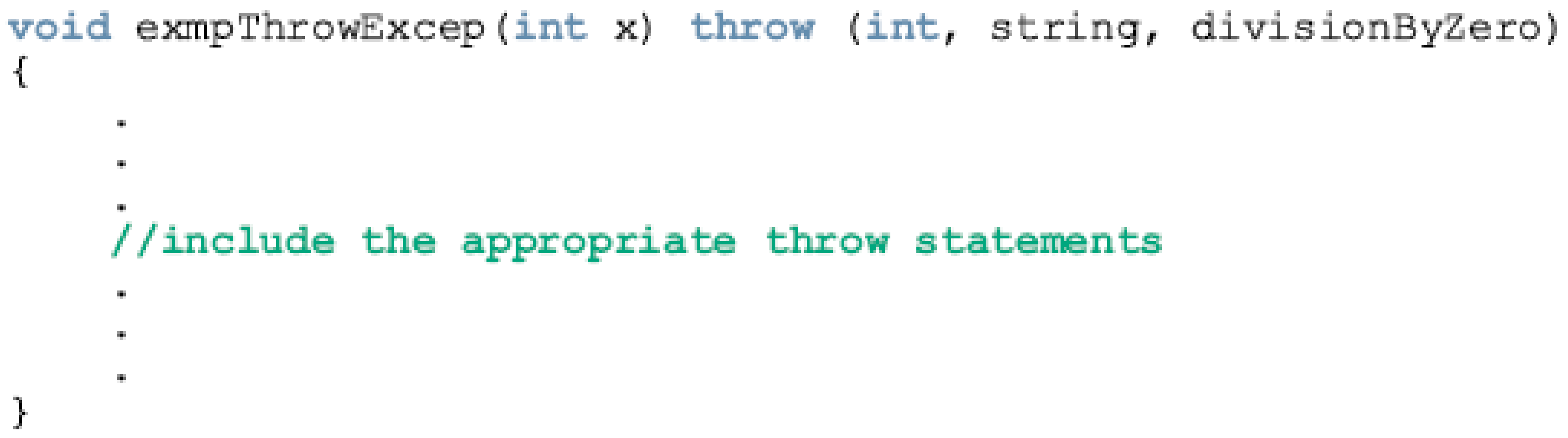
  ```
  throw expression;
  ```

  where `expression` is a constant value, variable, or object

Rethrowing and Throwing an Exception (continued)

- The object being thrown can be
  - A specific object
  - An anonymous object
- A function specifies the exceptions it throws in its heading using the throw clause

- A function specifies the exceptions it throws (to be handled somewhere) in its heading using the throw clause.
- For example, the following function specifies that it throws exceptions of type `int`, `string`, and `divisionByZero`, where `divisionByZero` is the `class` as defined previously.



```
void exmpThrowExcep(int x) throw (int, string, divisionByZero)
{
    .
    .
    .
    //include the appropriate throw statements
    .
    .
    .
}
```

Example 15-14

```
#include <iostream>
#include "divisionByZero.h"

using namespace std;

void doDivision() throw (divisionByZero);

int main()
{
    try                                                        //Line 1
    {
        doDivision();                                          //Line 2
    }
    catch (divisionByZero divByZeroObj)                        //Line 3
    {
        cout << "Line 4: In main: "
             << divByZeroObj.what() << endl;                   //Line 4
    }

    return 0;                                                  //Line 5
}
```

```
void doDivision() throw (divisionByZero)
{
    int dividend, divisor, quotient;                            //Line 6

    try                                                         //Line 7
    {
        cout << "Line 8: Enter the dividend: ";                 //Line 8
        cin >> dividend;                                        //Line 9
        cout << endl;                                           //Line 10

        cout << "Line 11: Enter the divisor: ";                 //Line 11
        cin >> divisor;                                         //Line 12
        cout << endl;                                           //Line 13

        if (divisor == 0)                                       //Line 14
            throw divisionByZero("Found division by 0!");       //Line 15

        quotient = dividend / divisor;                          //Line 16
        cout << "Line 17: Quotient = " << quotient
             << endl;                                           //Line 17
    }
    catch (divisionByZero)                                      //Line 18
    {
        throw;                                                  //Line 19
    }
}
```

Sample Run 1: In this sample run, the user input is shaded.

```
Line 8: Enter the dividend: 34

Line 11: Enter the divisor: 5

Line 17: Quotient = 6
```

Sample Run 2: In this sample run, the user input is shaded.

```
Line 8: Enter the dividend: 56

Line 11: Enter the divisor: 0

Line 4: In main: Found division by 0!
```

Exception Handling Techniques

- When an exception occurs, the programmer usually has three choices:
  - Terminate the program
  - Include code to recover from the exception
  - Log the error and continue

Terminate the Program

- In some cases, it is best to let the program terminate when an exception occurs
- For example, if the input file does not exist when the program executes
  - There is no point in continuing with the program
- The program can output an appropriate error message and terminate

Fix the Error and Continue

- In some cases, you will want to handle the exception and let the program continue
- For example, if a user inputs a letter in place of a number
  - The input stream will enter the fail state
- You can include the necessary code to keep prompting the user to input a number until the entry is valid

Log the Error and Continue

- For example, if your program is designed to run a nuclear reactor or continuously monitor a satellite
  - It cannot be terminated if an exception occurs
- When an exception occurs
  - The program should write the exception into a file and continue to run

Example 15-16

```
#include <iostream>
#include <string>

using namespace std;

int main()
{
    int number;                                          //Line 1
    bool done = false;                                   //Line 2

    string str =
          "The input stream is in the fail state.";      //Line 3

    do                                                   //Line 4
    {                                                    //Line 5
        try                                              //Line 6
        {                                                //Line 7
            cout << "Line 8: Enter an integer: ";        //Line 8
            cin >> number;                               //Line 9
            cout << endl;                                //Line 10

            if (!cin)                                    //Line 11
                throw str;                               //Line 12

            done = true;                                 //Line 13
            cout << "Line 14: Number = " << number
                 << endl;                                //Line 14
        }                                                //Line 15
        catch (string messageStr)                           //Line 16
        {                                                   //Line 17
            cout << "Line 18: " << messageStr
                 << endl;                                   //Line 18
            cout << "Line 19: Restoring the "
                 << "input stream." << endl;                //Line 19
            cin.clear();                                    //Line 20
            cin.ignore(100, '\n');                          //Line 21
        }                                                   //Line 22
    }
    while (!done);                                          //Line 23

    return 0;                                               //Line 24
}
```

Sample Run: In this sample run, the user input is shaded.

```
Line 8: Enter an integer: r5

Line 18: The input stream is in the fail state.
Line 19: Restoring the input stream.
Line 8: Enter an integer: d45

Line 18: The input stream is in the fail state.
Line 19: Restoring the input stream.
Line 8: Enter an integer: hw3

Line 18: The input stream is in the fail state.
Line 19: Restoring the input stream.
Line 8: Enter an integer: 48

Line 14: Number = 48
```

Stack Unwinding

- When an exception is thrown in, say, a function, the function can do the following:
  - Do nothing
  - Partially process the exception and throw the same exception or a new exception
  - Throw a new exception

Stack Unwinding (continued)

- In each of these cases, the function-call stack is unwound
  - The exception can be caught in the next try/catch block
- When the function-call stack is unwound
  - The function in which the exception was not caught and/or rethrown terminates
  - Memory for its local variables is destroyed

Stack Unwinding (continued)

- The stack unwinding continues until
  - A try/catch handles the exception or
  - The program does not handle the exception
- If the program does not handle the exception, then the function *terminate* is called to terminate the program

```
#include <string>

using namespace std;

class myException
{
public:
    myException()
    {
        message = "Something is wrong!";
    }

    myException(string str)
    {
        message = str;
    }

    string what()
    {
        return message;
    }

private:
    string message;
};
```

Example 15-17

```
#include <iostream>
#include "myException.h"

using namespace std;

void functionA() throw (myException);
void functionB() throw (myException);
void functionC() throw (myException);

int main()
{
    try
    {
        functionA();
    }
    catch (myException me)
    {
        cout << me.what() << " Caught in main." << endl;
    }

    return 0;
}
```

```
void functionA() throw (myException)
{
    functionB();
}

void functionB()  throw (myException)
{
    functionC();
}

void functionC() throw (myException)
{
    throw myException("Exception generated in function C.");
}
```

Sample Run:

```
Exception generated in function C. Caught in main.
```

Example 15-18

```
#include <iostream>
#include "myException.h"

using namespace std;

void functionA();
void functionB();
void functionC() throw (myException);

int main()
{
    try
    {
        functionA();
    }
    catch (myException e)
    {
        cout << e.what() << " Caught in main." << endl;
    }

    return 0;
}
```

```
void functionA()
{
    functionB();
}

void functionB()
{
    try
    {
        functionC();
    }
    catch (myException me)
    {
        cout << me.what() << " Caught in functionB." << endl;
    }
}

void functionC() throw (myException)
{
    throw myException("Exception generated in function C.");
}
```

Sample Run:

```
Exception generated in function C. Caught in functionB.
```

Summary

- Exception: an undesirable event detectable during program execution
- `assert` checks whether an expression meets a specified condition and terminates if not met
- `try`/`catch` block handles exceptions
- Statements that may generate an exception are placed in a `try` block
- Catch block specifies the type of exception it can catch and contains an exception handler

Summary (continued)

- If no exceptions are thrown in a `try` block, all `catch` blocks for that `try` block are ignored and execution resumes after the last `catch` block
- Data type of `catch` block parameter specifies type of exception that `catch` block can catch
- Catch block can have at most one parameter
- exception is base class for exception classes
- *`what`* returns string containing the exception object thrown by built-in exception classes

Summary (continued)

- Class exception is in the header file exception
- `runtime_error` handles runtime errors
- C++ enables programmers to create their own exception classes
- A function specifies the exceptions it throws in its heading using the throw clause
- If the program does not handle the exception, then the function *terminate* terminates the program