Exception Handling
(A light introduction)

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Today's Plan

Motivation

Exceptions (light)

Something should really bother you about the List class…

What?

```
template<class T>
T List<T>::getItem(size_t position) const
{

    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr != nullptr)
        return pos_ptr->getItem();
    else
        //MUST RETURN SOMETHING!!!!
}
```

```
template<class T>
T List<T>::getItem(size_t position) const
{
    T dummy;
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr != nullptr)
        return pos_ptr->getItem();
    else
        return dummy;
}
```

If there is no item at position, can we just return a dummy object?

```cpp
template<class T>
T List<T>::getItem(size_t position) const
{
    T dummy;
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr != nullptr)
        return pos_ptr->getItem();
    else
        return dummy; //problem/warning may return
                      // uninitialized object
}
```

The calling function has no way of knowing the returned object is uninitialized -> UNDEFINED BEHAVIOR

Fail-safe Programming

What happens when preconditions are not met or input data is malformed?

- Do nothing
- Return false - `bool add(const T& newEntry);`
- Use sentinel value: return error codes

Fail-safe Programming

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???

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Fail-safe Programming

What happens when preconditions are not met or input data is malformed?

- Do nothing
- Return false - `bool add(const T& newEntry);`

Rely on user to handle problem

- Use sentinel value: return error codes

Rely on user to handle problem

Sometimes it is not possible to return an error code

Fail-safe Programming

What happens when preconditions are not met or input data is malformed?

- Do nothing
- Return false - `bool add(const T& newEntry);`
- Use sentinel value: return error codes

What happens there is no item at position when calling `getItem(size_t position)`?

Lecture Activity

What would you do?

assert

```
#include <cassert>

// ...
assert(getPointerTo(position) != nullptr);
```

Make sure this is true

If assertion is false, program execution terminates

assert

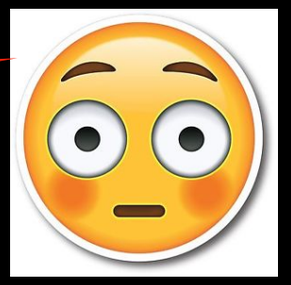
```
#include <cassert>

// ...
assert(getPointerTo(position) != nullptr);
```

Make sure this is true

If assertion is false, program execution terminates

Good for testing and debugging

So drastic! Give me another chance!



Exceptions:

A Light Introduction

Exceptions

Software: calling function

Client might be able to recover from a violation or unexpected condition

Communicate Exception (error) to client:

- Bypass normal execution
- Return control to client
- Communicate error

Exceptions

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Communicate Exception (error) to client:

- Bypass normal execution
- Return control to client
- Communicate error

Throw and Exception

Throwing Exceptions

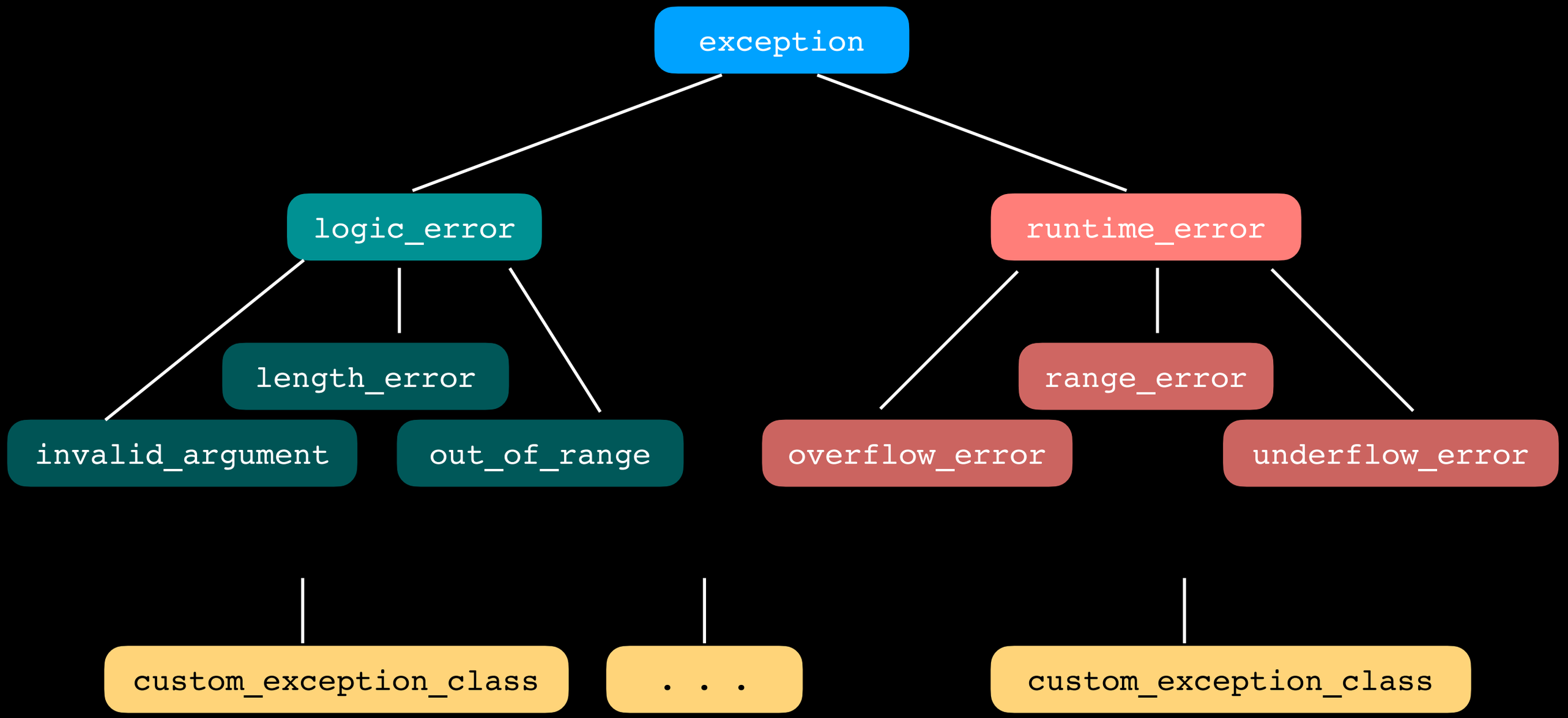
Type of Exception

```
throw( ExceptionClass( stringArgument) )
```

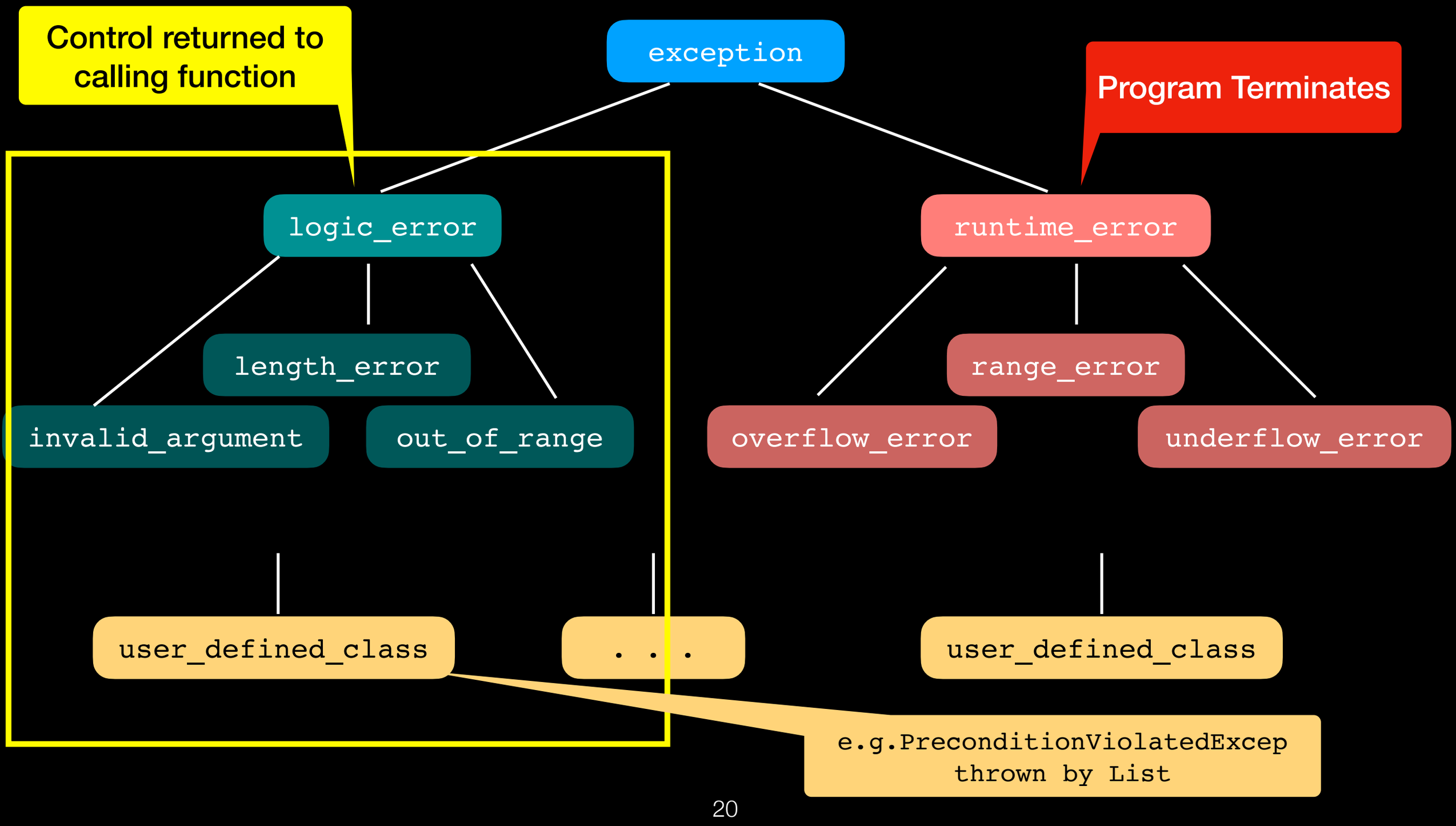
Message describing Exception

```
template<class T>
T List<T>::getItem(size_t position) const
{
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr == nullptr)
            throw (std::out_of_range("getItem called with empty list
                                      or invalid position"));
    else
        return pos_ptr->getItem();
}
```

C++ Exception Classes



C++ Exception Classes



Exception Type		Header File
exception		<exception>
	bad_alloc	<new>
	bad_cast	<typeinfo>
	bad_exception	<exception>
	bad_typeid	<typeinfo>
	ios_base::failure	<ios>
	logic_error	<stdexcept>
	length_error	<stdexcept>
	domain_error	<stdexcept>
	out_of_range	<stdexcept>
	invalid_argument	<stdexcept>
	runtime_error	<stdexcept>
	overflow_error	<stdexcept>
	range_error	<stdexcept>
	underflow_error	<stdexcept>

Exception Handling

Can handle only exceptions of class `logic_error` and its derived classes

Exception Handling Syntax

```
try
{
    //statement(s) that might throw exception
}
catch(ExceptionClass1 identifier)
{
    //statement(s) that react to an exception
   // of type ExceptionClass1
}
```

Exception Handling Syntax

```
try
{
    //statement(s) that might throw exception
}
catch(ExceptionClass1 identifier)
{
    //statement(s) that react to an exception
   // of type ExceptionClass1
}
catch(ExceptionClass2 identifier)
{
    //statement(s) that react to an exception
   // of type ExceptionClass2
}
. . .
```

Exception Handling Syntax

Arrange catch blocks in order of specificity, catching most specific first (i.e. lower in the Exception Class Hierarchy first)

```
try
{
    //statement(s) that might throw exception
}
catch(const ExceptionClass1& identifier)
{
    //statement(s) that react to an exception
    // of type ExceptionClass1
}
catch(const ExceptionClass2& identifier)
{
    //statement(s) that react to an exception
    // of type ExceptionClass2
}
. . .
```

Good practice to catch exceptions by `const reference` whenever possible (due to memory management, avoiding copying and slicing issues)

Exception Handling Usage

You know `getItem()` may throw an exception so call it in a `try` block

```
try
{
     some_object = my_list.getItem(n);
}
catch(const std::out_of_range& problem)
{
     //do something else instead
     bool object_not_found = true;
}
```

```
template<class T>
T List<T>::getItem(size_t position) const
{
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr == nullptr)
        throw(std::out_of_range("getItem called with empty list or invalid position"));
    else
        return pos_ptr->getItem();

}
```

```
try
{
    some_object = my_list.getItem(n);
}
catch(const std::out_of_range& problem)
{
    std::cerr << problem.what() << std::endl;
    //do something else instead
     bool object_not_found = true;
}
```

Returns string parameter to thrown exception

Error Output Stream:
getItem called with empty list or invalid position

Uncaught Exceptions

```
template<class T>
T List<T>::getItem(size_t position) const
{
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr == nullptr)
        throw(std::out_of_range("getItem called with empty list or invalid position"));
    else
        return pos_ptr->getItem();

}
```

out_of_range exception thrown here

```
T someFunction(const List<T>& some_list)
{

    T an_item;
    //code here
    an_item = some_list.getItem(n);

}
```

out_of_range exception not handled here

```
int main()
{
    List<string> my_list;
    try
    {
        std::string some_string = someFunction(my_list);
    }
    catch(const std::out_of_range& problem)
    {
        //code to handle exception here
    }
    //more code here
    return 0;
}
```

out_of_range exception handled here

Uncaught Exceptions

```
template<class T>
T List<T>::getItem(size_t position) const
{
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr == nullptr)
        throw(std::out_of_range("getItem called with empty list or invalid position"));
    else
        return pos_ptr->getItem();

}
```

out_of_range exception thrown here

```
T someFunction(const List<T>& some_list)
{

    T an_item;
    //code here
    an_item = some_list.getItem(n);

}
```

out_of_range exception not handled here

```
int main()
{
    List<string> my_list;
    std::string some_string = someFunction(my_list);
    //code here
    return 0;
}
```

out_of_range exception not handled here

Abnormal program termination

Implications

There could be several
. . . out of the scope of this course

We will discuss one:

What happens when program that dynamically allocated memory relinquishes control in the middle of execution because of an exception?

Implications and Complications

There could be many
. . . out of the scope of this course

We will discuss one:

What happens when program that dynamically allocated memory relinquishes control in the mic' '' of execution because of an exception?

Dynamically allocated memory never released!!!

Implications and Complications

Whenever using dynamic memory allocation and exception handling together must consider ways to prevent memory leaks

Memory Leak

out_of_range exception thrown here

```
template<class T>
T List<T>::getItem(size_t position) const
{
    Node<T>* pos_ptr = getPointerTo(position);
    if(pos_ptr == nullptr)
        throw(std::out_of_range("getItem called with empty list or invalid position"));
    else
        return pos_ptr->getItem();

}
```

```
T someFunction(const List<T>& some_list)
{
    //code here that dynamically allocates memory
    T an_item;
    //code here
    an_item = some_list.getItem(n);

}
```

out_of_range exception not handled here

```
int main()
{
    List<string> my_list;
    try
    {
        std::string some_string = someFunction(my_list);
    }
    catch(const std::out_of_range& problem)
    {
        //code to handle exception here
    }
    //more code here
    return 0;
}
```

out_of_range exception handled here

Possible solution coming soon