



Exception Handling

Chapter 14-BlueJ and Chapter 11-Java How to Program
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Runtime Errors

- Divide by zero
 - Result = first / second;
- Casting errors
 - Computer c = (Computer) d;
- Invalid index
 - list.get(index);



Not always programmer error

- Errors often arise from the environment:
 - Incorrect URL entered.
 - Network interruption.
- File processing is particularly error-prone:
 - Missing files.
 - Lack of appropriate permissions.
 - Insufficient storage capacity.



Exploring errors

- Explore error situations through the *address-book* projects.
- Two aspects:
 - Error reporting.
 - Error handling.

An example

- Create an **AddressBook** object.
- Try to remove an entry.
- A runtime error results.
 - Whose ‘fault’ is this?
- Anticipation and prevention are preferable to apportioning blame.

Checking the key

```
public void removeDetails(String key)
{
    if (keyInUse(key)) {
        ContactDetails details = book.get(key);
        book.remove(details.getName());
        book.remove(details.getPhone());
        numberOfEntries--;
    }
}
```

Returning a diagnostic

```
public boolean removeDetails(String key)
{
    if (keyInUse(key)) {
        ContactDetails details = book.get(key);
        book.remove(details.getName());
        book.remove(details.getPhone());
        numberOfEntries--;
        return true;
    }
    else {
        return false;
    }
}
```


Client can check for success

```
if (contacts.removeDetails("..")) {  
    // Entry successfully removed.  
    // Continue as normal.  
    ...  
}  
else {  
    // The removal failed.  
    // Attempt a recovery, if possible.  
    ...  
}
```




Potential Programmer responses

- Test the return value.
 - Attempt recovery on error.
 - Avoid program failure.
- Ignore the return value.
 - Cannot be prevented.
 - Likely to lead to program failure.
- ‘Exceptions’ are preferable.



Exception-throwing principles

- A special language feature.
- No ‘special’ return value needed.
- Errors cannot be ignored.
 - The normal flow-of-control is interrupted.
- Specific recovery actions are encouraged.

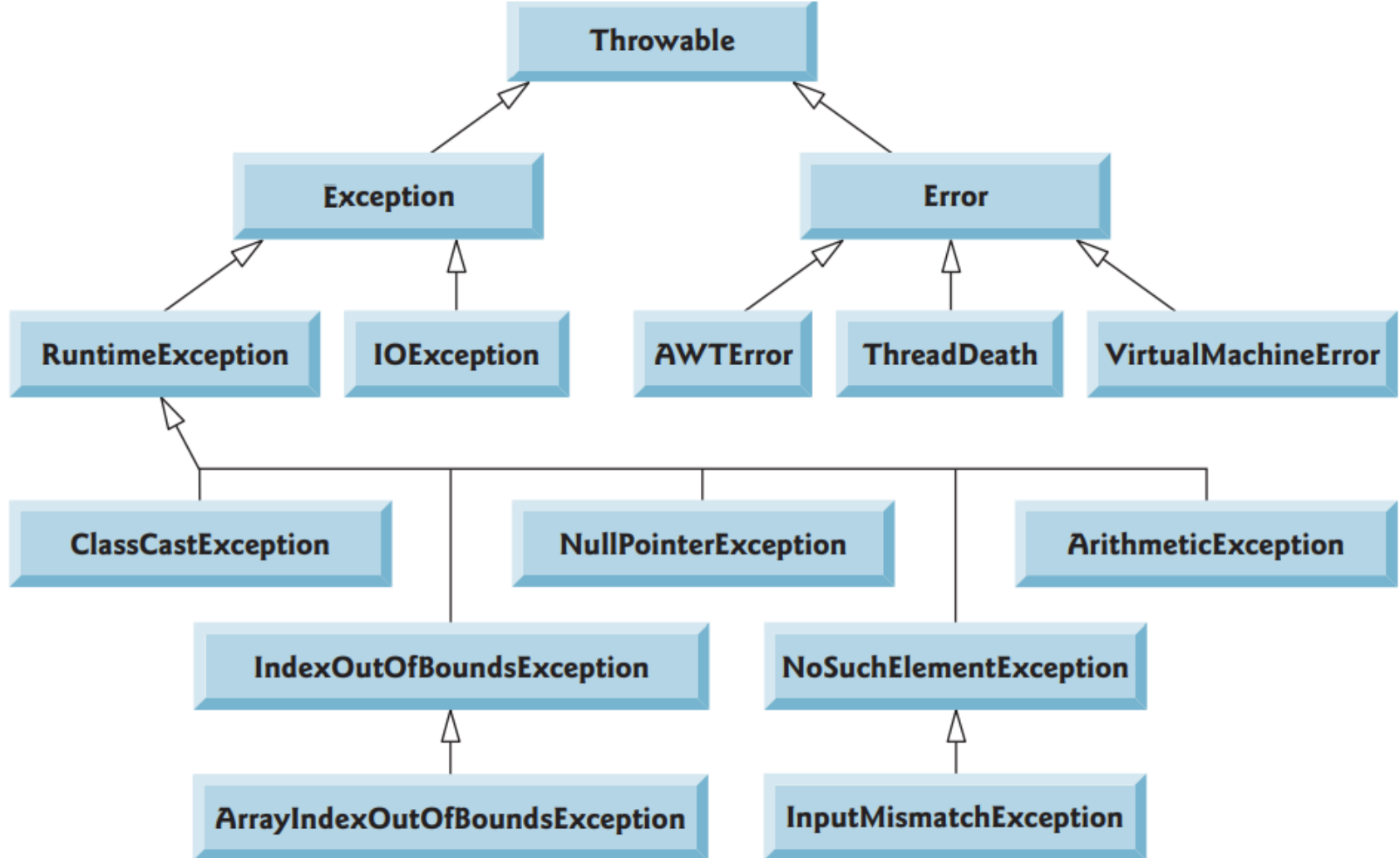
Throwing an exception

```
/**
 * Look up a name or phone number and return the
 * corresponding contact details.
 * @param key The name or number to be looked up.
 * @return The details corresponding to the key,
 *         or null if there are none matching.
 * @throws IllegalArgumentException if
 *         the key is invalid.
 */
public ContactDetails getDetails(String key)
{
    if(key == null) {
        throw new IllegalArgumentException(
            "null key in getDetails");
    }
    return book.get(key);
}
```



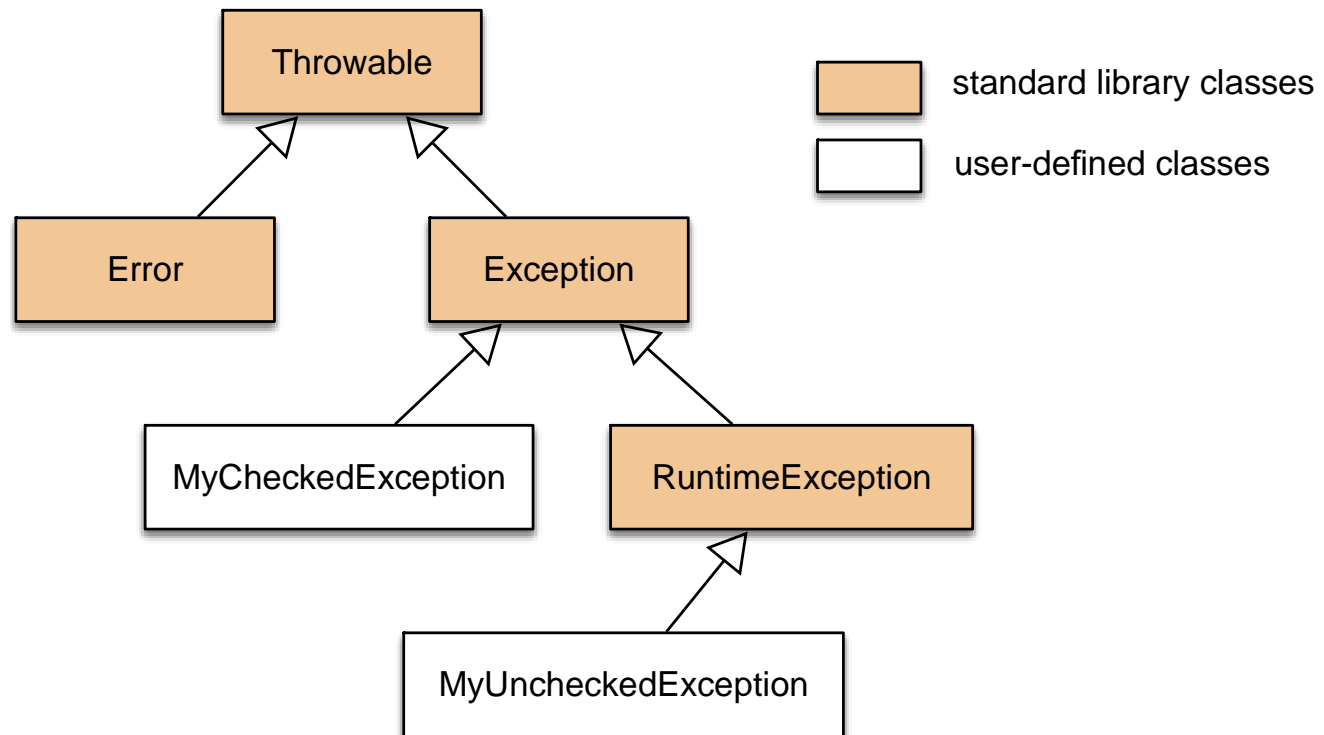
Throwing an exception

- An exception object is constructed:
 - `new ExceptionType("...")`
- The exception object is thrown:
 - `throw ...`
- Javadoc documentation:
 - `@throws ExceptionType reason`



Exception (package `java.lang`) and `IOException` (package `java.io`)—represent exceptional situations that can occur in a Java program and that can be caught by the application. Class **Error** and its subclasses represent *abnormal situations* that happen in the JVM. Most *Errors happen infrequently and should not be caught by applications—it's usually not possible for applications to recover from Errors.*

The exception class hierarchy



Exception categories

- Checked exceptions
 - Subclass of `Exception`
 - Use for anticipated failures.
 - Where recovery may be possible.
 - When an environmental problem exists.
- Unchecked exceptions
 - Subclass of `RuntimeException`
 - Use for unanticipated failures.
 - Where recovery is unlikely.
 - When a logical problem exists.



The effect of an exception

- The throwing method finishes prematurely.
- No return value is returned.
- Control does not return to the client's point of call.
 - So the client cannot carry on regardless.
- A client may 'catch' an exception.

Checked vs. unchecked

- Checked exceptions must be explicitly handled.
- Unchecked exceptions do not have this requirement. They don't have to be caught or declared thrown.

Unchecked exceptions

- Use of these is ‘unchecked’ by the compiler.
- Cause program termination if not caught.
 - This is the normal practice.
- **IllegalArgumentException** is an example.

Argument checking

```
public ContactDetails getDetails(String key)
{
    if(key == null) {
        throw new IllegalArgumentException(
            "null key in getDetails");
    }
    if(key.trim().length() == 0) {
        throw new IllegalArgumentException(
            "Empty key passed to getDetails");
    }
    return book.get(key);
}
```

Preventing object creation

```
public ContactDetails(String name, String phone, String address)
{
    if(name == null) {
        name = "";
    }
    if(phone == null) {
        phone = "";
    }
    if(address == null) {
        address = "";
    }

    this.name = name.trim();
    this.phone = phone.trim();
    this.address = address.trim();

    if(this.name.length() == 0 && this.phone.length() == 0) {
        throw new IllegalStateException(
            "Either the name or phone must not be blank.");
    }
}
```



Exception handling

- Checked exceptions are meant to be caught and responded to.
- The compiler ensures that their use is tightly controlled.
 - In both server and client objects.
- Used properly, failures may be recoverable.

The throws clause

- Methods throwing a checked exception may include a throws clause:

```
public void saveToFile(String destinationFile)  
    throws IOException
```


The try statement

- Methods catching an exception must protect the call with a try statement:

```
try {  
    Protect one or more statements here.  
}  
catch (Exception e) {  
    Report and recover from the  
    exception here.  
}
```

The try statement

1. Exception thrown from here

```
try {  
    addressbook.saveToFile(filename);  
    successful = true;  
}  
catch(IOException e) {  
    System.out.println("Unable to save to " + filename);  
    successful = false;  
}
```

2. Control transfers to here

Catching multiple exceptions

```
try {  
    ...  
    ref.process() ;  
    ...  
}  
catch (EOFException e) {  
    // Take action on an end-of-file exception.  
    ...  
}  
catch (FileNotFoundException e) {  
    // Take action on a file-not-found exception.  
    ...  
}
```

Multi-catch

```
try {  
    ...  
    ref.process() ;  
    ...  
}  
catch(EOFException | FileNotFoundException e) {  
    // Take action appropriate to both types  
    // of exception.  
    ...  
}
```

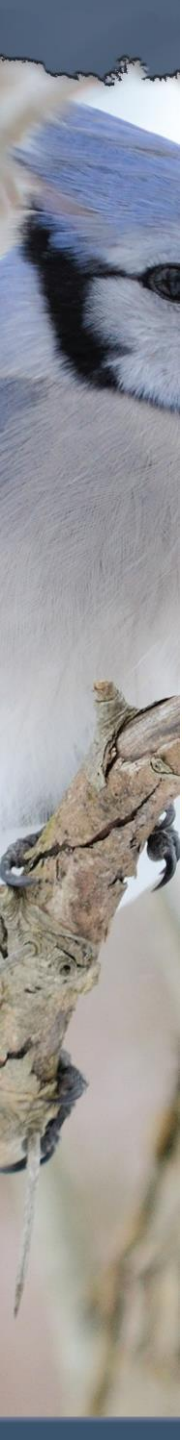
The finally clause

```
try {  
    Protect one or more statements here.  
}  
catch (Exception e) {  
    Report and recover from the exception here.  
}  
finally {  
    Perform any actions here common to whether or  
    not an exception is thrown.  
}
```



The finally clause

- A finally clause is executed even if a return statement is executed in the try or catch clauses.
- A uncaught or *propagated* exception still exits via the finally clause.



```
try {  
    Protect one or more statements here.  
}  
catch(Exception e) {  
    Report and recover from the exception here.  
}  
Perform any actions here common to whether or not an exception is thrown.
```

In fact, there are at least two cases where these two examples would have different effects:

- A finally clause is executed even if a return statement is executed in the try or catch blocks.
- If an exception is thrown in the try block but not caught, then the finally clause is still executed.

```
try {  
    Protect one or more statements here.  
}  
finally {  
    Perform any actions here common to whether or not  
    an exception is thrown.  
}
```




Defining new exceptions

- Extend `RuntimeException` for an unchecked or `Exception` for a checked exception.
- Define new types to give better diagnostic information.
 - Include reporting and/or recovery information.

```
public class NoMatchingDetailsException extends Exception
{
    private String key;

    public NoMatchingDetailsException(String key)
    {
        this.key = key;
    }

    public String getKey()
    {
        return key;
    }

    public String toString()
    {
        return "No details matching '" + key +
            "' were found.";
    }
}
```

Error recovery

- Methods should take note of error notifications.
 - Check return values of calling methods.
 - Don't 'ignore' exceptions.
- Include code to attempt recovery.
 - Will often require a loop.

Attempting recovery

```
// Try to save the address book.
boolean successful = false;
int attempts = 0;
do {
    try {
        contacts.saveToFile(filename);
        successful = true;
    }
    catch(IOException e) {
        System.out.println("Unable to save to " + filename);
        attempts++;
        if(attempts < MAX_ATTEMPTS) {
            filename = an alternative file name;
        }
    }
} while(!successful && attempts < MAX_ATTEMPTS);

if(!successful) {
    Report the problem and give up;
}
```

```
public class MyException extends Exception
{
    public MyException(String msg)
    {
        super("details of the problem:" + msg);
    }
}
-----
```

```
public class Test {

static int divide(int first, int second) throws MyException
{
    if(second==0)
        throw new MyException("can't be divided by zero");

    return first/second;
}

public static void main(String[] args) {
    try {
        System.out.println(divide(4,0));
    }
    catch (MyException exc) {
        exc.printStackTrace();
    }
}
}
```

Stack Unwinding

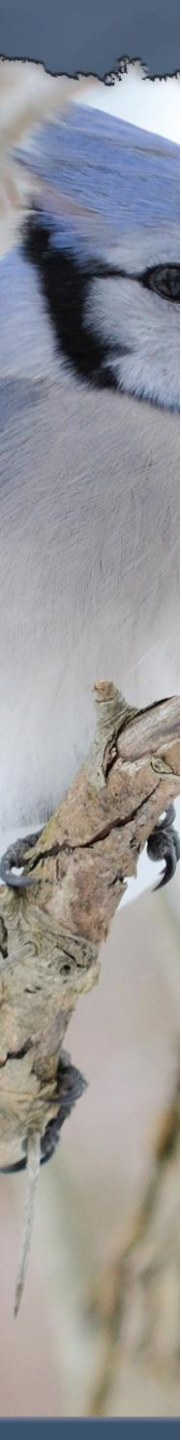
Exception thrown in method3

```
java.lang.Exception: Exception thrown in method3
    at UsingExceptionsStack.method3(UsingExceptionsStack.java:35)
    at UsingExceptionsStack.method2(UsingExceptionsStack.java:31)
    at UsingExceptionsStack.method1(UsingExceptionsStack.java:27)
    at UsingExceptionsStack.main(UsingExceptionsStack.java:4)
```

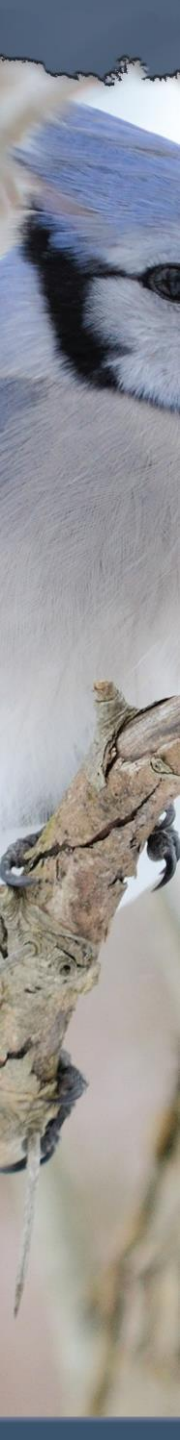
Stack trace from getStackTrace:

Class	File	Line	Method
UsingExceptionsStack	UsingExceptionsStack.java	35	method3
UsingExceptionsStack	UsingExceptionsStack.java	31	method2
UsingExceptionsStack	UsingExceptionsStack.java	27	method1
UsingExceptionsStack	UsingExceptionsStack.java	4	main

```
1 // Fig. 13.1: DivideByZeroNoExceptionHandling.java
2 // An application that attempts to divide by zero.
3 import java.util.Scanner;
4
5 public class DivideByZeroNoExceptionHandling
6 {
7     // demonstrates throwing an exception when a divide-by-zero occurs
8     public static int quotient( int numerator, int denominator )
9     {
10         return numerator / denominator; // possible division by zero
11     } // end method quotient
12
13     public static void main( String args[] )
14     {
15         Scanner scanner = new Scanner( System.in ); // scanner for input
16
17         System.out.print( "Please enter an integer numerator: " );
18         int numerator = scanner.nextInt();
19         System.out.print( "Please enter an integer denominator: " );
20         int denominator = scanner.nextInt();
21
22         int result = quotient( numerator, denominator );
23         System.out.printf(
24             "\nResult: %d / %d = %d\n", numerator, denominator, result );
25     } // end main
26 } // end class DivideByZeroNoExceptionHandling
```

```
Please enter an integer numerator: 100
Please enter an integer denominator: 0
Exception in thread "main" java.lang.ArithmeticException: / by zero
    at DivideByZeroNoExceptionHandling.quotient(
        DivideByZeroNoExceptionHandling.java:10)
    at DivideByZeroNoExceptionHandling.main(
        DivideByZeroNoExceptionHandling.java:22)
```



```
1 // Fig. 13.2: DivideByZeroWithExceptionHandling.java
2 // An exception-handling example that checks for divide-by-zero.
3 import java.util.InputMismatchException;
4 import java.util.Scanner;
5
6 public class DivideByZeroWithExceptionHandling
7 {
8     // demonstrates throwing an exception when a divide-by-zero occurs
9     public static int quotient( int numerator, int denominator )
10         throws ArithmeticException
11     {
12         return numerator / denominator; // possible division by zero
13     } // end method quotient
14
15     public static void main( String args[] )
16     {
```

```
17 Scanner scanner = new Scanner( System.in ); // scanner for input
18 boolean continueLoop = true; // determines if more input is needed
19
20 do
21 {
22     try // read two numbers and calculate quotient
23     {
24         System.out.print( "Please enter an integer numerator: " );
25         int numerator = scanner.nextInt();
26         System.out.print( "Please enter an integer denominator: " );
27         int denominator = scanner.nextInt();
28
29         int result = quotient( numerator, denominator );
30         System.out.printf( "\nResult: %d / %d = %d\n", numerator,
31             denominator, result );
32         continueLoop = false; // input successful; end looping
33     } // end try
34     catch ( InputMismatchException inputMismatchException )
35     {
36         System.err.printf( "\nException: %s\n",
37             inputMismatchException );
38         scanner.nextLine(); // discard input so user can try again
39         System.out.println(
40             "You must enter integers. Please try again.\n" );
41     } // end catch
42     catch ( ArithmeticException arithmeticException )
43     {
44         System.err.printf( "\nException: %s\n", arithmeticException );
45         System.out.println(
46             "Zero is an invalid denominator. Please try again.\n" );
47     } // end catch
48 } while ( continueLoop ); // end do...while
49 } // end main
50 } // end class DivideByZeroWithExceptionHandling
```

Please enter an integer numerator: 100
Please enter an integer denominator: 7

Result: $100 / 7 = 14$

Please enter an integer numerator: 100
Please enter an integer denominator: 0

Exception: java.lang.ArithmeticException: / by zero
Zero is an invalid denominator. Please try again.

Please enter an integer numerator: 100
Please enter an integer denominator: 7

Result: $100 / 7 = 14$

Please enter an integer numerator: 100
Please enter an integer denominator: hello

Exception: java.util.InputMismatchException
You must enter integers. Please try again.

Please enter an integer numerator: 100
Please enter an integer denominator: 7

Result: $100 / 7 = 14$

Review

- Runtime errors arise for many reasons.
 - An inappropriate client call to a server object.
 - A server unable to fulfill a request.
 - Programming error in client and/or server.



Review

- Runtime errors often lead to program failure.
- Defensive programming anticipates errors - in both client and server.
- Exceptions provide a reporting and recovery mechanism.