What is an Exception

- Imagine the following code in some Applet:

```
int age = Integer.parseInt(ageTF.getText().trim());
```

- Obviously, we are expecting a number will appear in the TextField and that it constitutes a legal integer age.
- Consider, however, the following possibilities:
  1. What if the user types a "$" instead of a 4 by mistake?
  2. What if the user enters a decimal point number rather than an integer?
  3. What if the user holds down the "3" key too long and an extremely long number is accidentally entered?
- We do not expect circumstances such as these -- but they do happen!

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What is an Exception

- Some things that can go wrong during the execution of a program cannot be detected at compile-time - because the user has not yet made the mistake by entering the wrong data!!
- Another example: your program may attempt to divide one number by zero (ex. examSum/numberOfStudents)
- Or your program may require that an integer value be entered into a TextField, and the user of the program enters a float value or some other illegal character.
- From the compiler's point of view, there is nothing wrong with these statements, and problems will arise only when the program is actually executing.
- At that point an internal alarm goes off, and Java attempts to "***throw an exception***" signifying that something untoward has occurred.

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Example

```
import java.awt.*;
import java.applet.*;

public class TrivialApplet extends Applet
{
   //  Deliberately divides by zero to produce an exception.
   public void init()
   {
      int numerator = 10;
      int denominator = 0;
      System.out.println ("This text will be printed.");
      System.out.println (numerator/denominator);
      System.out.println ("This text will not be printed.");
        // because exception occurs prior to execution of this
   }
}
```

Note also: There is no code to handle the exception, if it occurs!

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What is an Exception

- The system then immediately halts its normal mode of execution and goes off looking for help.
- With luck, the system will find some code in your program that will **catch** the exception and deal with it.
- Once caught, the alarm is silenced and the system picks up execution at a location after the block that contained the 'offending' statement.
  - Java has its own terminology for exceptions.
  - *Exceptions are indicted by being thrown, and are detected elsewhere by being caught.*

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Terminology of Exceptions

- An *exception* is an object that describes an unusual or erroneous situation
- Exceptions are *thrown* by a program, and may be *caught* and *handled* by another part of the program
- A program can be separated into a *normal* execution flow and an *exception* execution flow
- An *error* is also represented as an object in Java, but usually represents an unrecoverable situation and should not be caught

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Some Possible Exceptions

ArithmeticException	- something, such as division by zero, has gone wrong in an arithmetic expression
NumberFormatException	- indicates that an illegal number format is being used.
StringIndexOutOfBoundsException	- attempt has been made to use an inappropriate String index.
NullPointerException	- class method called by object instance that is currently null.
EOFException	- an end-of-file mark has been seen.
IllegalArgumentException	- a method has been called with an invalid argument.
IndexOutOfBoundsException	- an index into an array is out of bounds.

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Exceptions

- As indicated on the earlier slide, Java has a predefined set of exceptions and errors that can occur during execution
- A program can deal with an exception in one of three ways:
  - ✓ ignore it
  - ✓ handle it where it occurs
  - ✓ handle it in another place in the program
- The manner in which an exception is processed is an important design consideration

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Lexicon: Actors and Actions

- **Operation**
  A method which can possibly raise an exception.
- **Invoker**
  A method which calls operations and handles resulting exceptions.
- **Exception**
  A concise, complete description of an abnormal event.
- **Raise**
  Brings an exception from the operation to the invoker, called **throw** in Java.
- **Handle**
  Invoker's response to the exception, called **catch** in Java.
- **Backtrack**
  Ability to unwind the stack frames from where the exception was raised to the first matching handler in the call stack.

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Lexicon: Types of Exceptions

- **Hardware**
  Generated by the CPU in response to a fault (e.g. divide by zero, overflow, segmentation fault, alignment error, etc).
- **Software**
  Defined by the developer to represent any other type of failure. These exceptions often carry much semantic information.
- **Domain Failure**
  The inputs, or parameters, to the operation are considered invalid or inappropriate for the requested operation.
- **Range Failure**
  Operation cannot continue, or output is possibly incorrect.
- **Monitor**
  Describes the status of an operation in progress, a mechanism for runtime updates which is simpler than sub-threads.

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Classifying Java Exceptions

- **Unchecked Exceptions**
  It is not required that these types of exceptions be caught or declared on a method.
  - *Runtime exceptions* can be generated by methods or by the JVM itself.
  - *Errors* are generated from deep within the JVM, and often indicate a truly fatal state.
  - Runtime exceptions are a source of major controversy!
- **Checked Exceptions**
  Must either be caught by a method or declared in its signature.
  - Placing exceptions in the method signature generates major complications
  - This requirement is viewed with derision in the hardcore C++ community.
  - A common technique for simplifying checked exceptions is subsumption.

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Keywords for Java Exceptions

- **throws**
  Describes the exceptions which can be raised by a method.
- **throw**
  Raises an exception to the first available handler in the call stack, unwinding the stack along the way.
- **try**
  Marks the start of a block associated with a set of exception handlers.
- **catch**
  If the block enclosed by the try generates an exception of this type, control moves here; watch out for implicit subsumption.
- **finally**
  Always called when the try block concludes, and after any necessary catch handler is complete.

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General Syntax

```
public void setProperty(String p_strValue) throws
   NullPointerException  {
   if (p_strValue == null) { throw new
   NullPointerException("..."); }
}
public void myMethod() {
   MyClass oClass = new MyClass();
   try {
       oClass.setProperty("foo");
       oClass.doSomeWork();
   } catch (NullPointerException npe) {
       System.err.println("Unable to set property:"
              + npe.toString());
   } finally {
       oClass.cleanup();
   }
}
```

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Canonical Example 1

```
public void foo() {
  try { /* marks the start of a try-catch block */
      int a[] = new int[2];
      a[4] = 1; /*causes a runtime exception due to index*/
  } catch (ArrayIndexOutOfBoundsException e) {
      System.out.println("exception: " +
                                  e.getMessage());
      e.printStackTrace();
  }
}
```

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Canonical Example 2

```
/* This code also compiles, but throws an
   exception at runtime! It is both less obvious
   and more common (an off-by-one-error). */
public int[] bar() {
   int a[] = new int[2];
   for (int x = 0; x <= 2; x++) { a[x] = 0; }
   return a;
}
```

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throw(s) Keyword (1)

```
/* The IllegalArgumentException is considered unchecked,
   and remains so even making it part of the signature */
public void setName(String p_strName) throws
   IllegalArgumentException
{
   /* valid names cannot be zero length */
   if (p_strName.length() == 0) {
       throw new IllegalArgumentException("…");
   }
   m_strName = p_strName;
}

public void foo() {
   setName(""); /* No warning about unhandled exceptions.
   */
}
```

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throw(s) Keyword (2)

```
/* Make a bad parameter exception class */
class NuttyParameterException extends Exception { … }

/* To really make an invoker pay attention, use a checked
exception type rather than a Runtime Exception type, but
you must declare that you will throw the type! */
public void setName(String p_strName) /* error here! */
{
   /* valid names cannot be zero length */
   if (p_strName == null || p_strName.length() == 0) {
       throw new NuttyParameterException("…");
   }
   m_strName = p_strName;
}
```

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throw(s) Keyword (3)

```
/* Make a bad parameter exception class */
class NuttyParameterException extends Exception { … }

/* To really make an invoker pay attention, use a checked
 * exception type rather than a Runtime Exception type. */
public void setName(String p_strName) throws
   NuttyParameterException
{
   /* valid names cannot be zero length */
   if (p_strName == null || p_strName.length() == 0) {
        throw new NuttyParameterException("…");
   }
   m_strName = p_strName;
}
public void foo() {
   setName(""); /* This does result in an error. */
}
```

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try Keyword

```
/* The try statement marks the position of the first bytecode
   instruction protected by an exception handler. */
try {

   UserRecord oUser = new UserRecord();
   oUser.setName("Fred Stevens");
   oUser.store();

/* This catch statement then marks the final bytecode instruction
 * protected, and begins the list of exceptions handled. This info
 * is collected and is stored in the exception table for the
   method. */
} catch (CreateException ce) {
   System.err.println("Unable to create user record in the
   database.");
}
```

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catch Keyword (1)

```
/* A simple use of a catch block is to catch the exception raised
   by the code from a prior slide. */
try {
   myObject.setName(“foo”);
} catch (NuttyParameterException npe) {
   System.err.println(“Unable to assign name:” + npe.toString());
}


try { /* example 2 */
   myObject.setName(“foo”);
} catch (NuttyParameterException npe) { /* log and relay this
   problem. */
   System.err.println(“Unable to assign name:” + npe.toString());
   throw npe;
}
```

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catch Keyword (2)

```
/* Several catch blocks of differing types can be concatenated. */
 try {
   URL myURL = new URL("http://www.mainejug.org");
   InputStream oStream = myURL.openStream();
   byte[] myBuffer = new byte[512];
   int nCount = 0;
   while ((nCount = oStream.read(myBuffer)) != -1) {
        System.out.println(new String(myBuffer, 0, nCount));
   }
   oStream.close();
}
   catch (MalformedURLException mue) {
   System.err.println("MUE: " + mue.toString());
}  catch (IOException ioe) {
   System.err.println("IOE: " + ioe.toString());
}
```

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finally Keyword (1)

```
URL myURL = null;
InputStream oStream = null;

/* The prior sample completely neglected to discard the network
 * resources */
try {
   /* Imagine you can see the code from the last slide here... */

} finally { /* What two things can cause a finally block to be
   missed? */
   /* Since we cannot know when the exception occurred, be
   careful! */
   try {
        oStream.close();
   } catch (Exception e) {
   }
}
```


finally Keyword (2)

```
public bool anotherMethod(Object myParameter) {

   try { /* What value does this snippet return? */
        myClass.myMethod(myParameter);
        return true;
   } catch (Exception e) {
        System.err.println("Exception in anotherMethod()"
                + e.toString());
        return false;

   } finally {
        /* If the close operation can raise an exception */
        if (myClass.close() == false) {
               break;
        }
   }
   return false;
}
```

finally Keyword (3)

```
public void callMethodSafely() {

   while (true) { /* How about this situation? */
       try {
             /* Call this method until it returns false. */
             if (callThisOTherMethod() == false) {
                   return;
             }

       } finally {
             continue;
       }
   } /* end of while */
}
```

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Steps of try…catch…finally

- Every try block must have at least one catch or finally block attached.
- If an exception is raised during a try block:
  - The rest of the code in the try block is skipped over.
  - If there is a catch block of the correct, or derived, type **in this stack frame** it is entered.
  - If there is a finally block, it is entered.
  - If there is no such block, the JVM moves up one stack frame.
- If no exception is raised during a try block, and there is no System.exit() statement:
  - If there is a matching finally block, it is entered.

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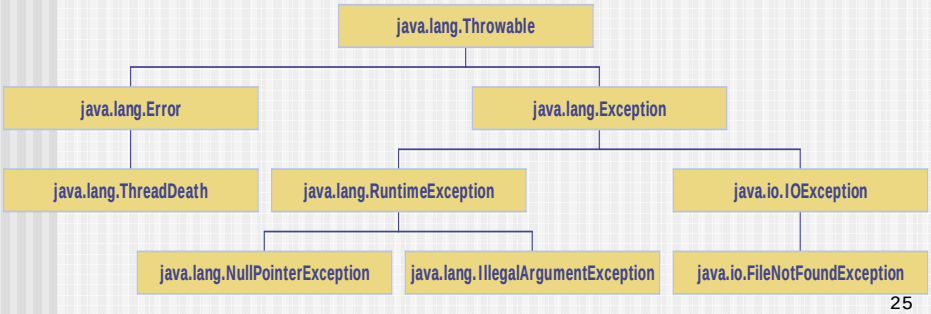
Java Exception Hierarchy

Throwable	The base class for all exceptions, it is required for a class to be the rvalue to a **throw** statement.
Error	Any exception so severe it should be allowed to pass ***uncaught*** to the Java runtime.
Exception	Anything which should be handled by the invoker is of this type, and all but five exceptions are.



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Your exception class?

- Sometimes it's useful to declare your own exception classes that are specific to the problems that can occur when another programmer uses your reusable classes.
- A new exception class must extend an existing exception class to ensure that the class can be used with the exception-handling mechanism.

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Defining your class

- A typical new exception class contains only four constructors:
  - one that takes no arguments and passes a default error message String to the superclass constructor;
  - one that receives a customized error message as a String and passes it to the superclass constructor;
  - one that receives a customized error message as a String and a Throwable (for chaining exceptions) and passes both to the superclass constructor;
  - and one that receives a Throwable (for chaining exceptions) and passes it to the superclass constructor.

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Creating your own exception class

```
/* You should extend RuntimeException to create an unchecked
   exception,  or Exception to create a checked exception. */
class MyException extends Exception {

  /* The common constructor. It takes a text argument. */
  public MyException(String p_strMessage) {
    super(p_strMessage);
  }

  /* A default constructor is also a good idea! */
  public MyException () {
    super();
  }

  /* If you create a more complex constructor, then it is
   critical that you override toString(), since this is the call
   most often made to output the content of an exception. */
```

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Three Critical Decisions

- **How do you decide to raise an exception rather than return?**
  1. Is the situation truly out of the ordinary?
  2. Should it be impossible for the caller to ignore this problem?
  3. Does this situation render the class unstable or inconsistent?
- **Should you reuse an existing exception or create a new type?**
  1. Can you map this to an existing exception class?
  2. Is the checked/unchecked status of mapped exception acceptable?
  3. Are you masking many possible exceptions for a more general one?
- **How do you deal with subsumption in a rich exception hierarchy?**
  1. Avoid throwing a common base class (e.g. IOException).
  2. Never throw an instance of Exception or Throwable classes.

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An Example of Return v. Raise

```
try {
   InputStream oStream = new
   URL("http://www.mainejug.org").openStream();
   byte[] myBuffer = new byte[512];
   StringBuffer sb = new StringBuffer();
   int nCount = 0;
   while ((nCount = oStream.read(myBuffer)) != -1) {
       sb.append(new String(myBuffer));
   }
   oStream.close();
   return sb.toString(); /*if sb.length()==0 NOT exception */
   /* These are certainly exceptional conditions. */
} catch (MalformedURLException mue) {
   throw mue;
} catch (IOException ioe) {
   throw ioe;
}
```

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Mapping to an Exception Class

- When you attempt to map your situation onto an existing Exception class consider these suggestions:
  - Avoid using an unchecked exception, if it is important enough to explicitly throw, it is important enough to be caught.
  - Never throw a base exception class if you can avoid it: **RuntimeException**, **IOException**, **RemoteException**, etc.
  - There is no situation which should cause you to throw the Exception or Throwable base classes. ***Never.***

Using Unchecked Exceptions

- Use unchecked exceptions to indicate a broken contract:

```
public void setName(String p_strName) {
  /* This is a violated precondition. */
  if (p_strName == null || p_strName.length() == 0) {
   throw new InvalidArgumentException("Name parameter
  invalid!");
  }
}
```

- Be careful about creating a type *derived* from **RuntimeException**.
- A class derived from **AccessControlException** is implicitly unchecked because its parent class derives from **RuntimeException**.