Introduction to Reflection

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Outline of Topics

- **What is Reflection**
- **The `Class` class**
- **Run Time Type Identification (RTTI)**
- **Getting Class Information**
- **Accessing an arbitrary object's fields**
- **Advanced features**

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Reflection

- Introduced in Java 1.1
- Allows you to find out information about any object, including its methods and fields, even if the type of the object is not known at compile time
- Added to the language to support Beans, Serialization, RMI, and other goodies.
- Reflection is an *enabling* technology.

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The `Class` Object

- `Class` objects represent a loaded class
- Can find out information about the class
  - its methods
  - its fields
  - its superclass
  - the interfaces it implements
  - whether it is an array

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Obtaining a `Class` Object

- **If you know a class name, can get it:**

```
  Class c1 = String.class;
  Class c2 = Employee[].class;
```

- **Can get it from any object, using `getClass`:**

```
void printType( Object obj )
{
  Class c3 = obj.getClass( );
  System.out.println( c.toString( ) );
}
```

- **Can get it by loading the class using the `forName` static method:**

```
Class c = Class.forName( "java.util.Date" );
```

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What's In `Class`?

```
public class Class
{
  public String getName( );
  public boolean isInterface( );
  public boolean isArray( );
  public Class getSuperclass( );
  public Class[] getInterfaces( );
  public Class[] getClasses( ); // inner classes
  public Object newInstance( );
  public static Class forName( String name );
  public Method[] getDeclaredMethods( );
  public Method[] getMethods( );
}
```

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Reflection Classes

- **Found in `java.lang.reflect`**
- **`Method`: Allows you to get info about an arbitrary method, and even invoke one**
- **`Field`: Allows you to get the name and access an arbitrary field**
- **`Constructor`: Allows you to get info about an arbitrary constructor, and even invoke one**
- **`Array`: Contains static methods to create and access arbitrary arrays**

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Example: Array Expansion

- **Want to write automatic array doubling code.**
- **Here is typical idea, but it does not work**

```
public Object[] doubleArray( Object[] arr )
{
  int newSize = arr.length * 2 + 1;
  Object[] newArray = new Object[ newSize ];
  for( int i = 0; i < arr.length; i++ )
      newArray[ i ] = arr[ i ];
  return newArray;
}
```

- **But: even if `arr` is `Foo[]`, actual returned object `Object[]` can't be downcast to `Foo[]`.**

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Solution

```
public Object doubleArray( Object arr )
{
  Class cl = arr.getClass( );
  if( !cl.isArray( ) ) return null;
  int oldSize = Array.getLength( arr );
  int newSize = oldSize * 2 + 1;
  Object newArray = Array.newInstance(
         c1.getComponentType( ), newLength );
  System.arraycopy( a, 0, newArray, oldSize );
  return newArray;
}
```

- **Notes: `array` can be `int[]`; `arraycopy` is faster than a loop (fewer bounds checks)**

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The `Array` Class

```
public class Array
{
    // All of these are static
  public int getLength( Object arr );
  public Object newInstance( Class comp, int length );

  public Object get( Object arr, int index );
  public void set( Object arr, int index, Object val );

    // Various specialized versions:
  public int getInt( Object arr, int index );
  public void setInt( Object arr, int index, int val );
}
```

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Accessing a Class' Members

- From `Class` object, you can get `Method` objects that reflect all methods, `Field` objects that reflect all fields, and `Constructor` objects that reflect all constructors.
- Two versions (use `Field` as example)
  - `getField` gets a public field given name
  - `getDeclaredField` gets a field declared in this class (but not superclass); could be private
  - `getFields` gets an array of public fields
  - `getDeclaredFields` gets an array of fields declared in this class (but not superclass); could be private

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Example: List Visible Class Functions

```
public void printClassMethods( String name )
{
  try {
    Class cl = Class.forName( name );
    Constructor c = cl.getConstructors( );
    for( int i = 0; i < c.length; i++ )
      System.out.println( c.toString( ) );
    Method m [] = cl.getMethods( );
    for( int i = 0; i < m.length; i++ )
      System.out.println( m.toString( ) );
  } catch( ClassNotFoundException e ) {
    System.out.println( name + " not found" );
  }
```

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Using a `Method` Object

- **From `Method` object**
  - **Can find out everything about method signature**
  - **Invoke a method with normal dynamic binding.**
  - **You can obtain a `Method` from a signature, or get a list of all methods.**
- **To specify the signature, give an array of `Class` objects that represent the types of the parameters.**
  - **Array will be zero-length if no parameters**
  - **Special `Class` objects for primitives**

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What's In `Method` Class

- **Various accessors to get info. Also `invoke`.**

```
public class Method
{
  public Class getReturnType( );
  public Class[] getParameterTypes( );
  public String getName( );
  public int getModifiers( );
  public Class[] getExceptionTypes( );
  public Object invoke( Object o, Object[] args);
}
```

- **The modifiers are stored as a bit pattern; class `Modifier` has methods to interpret the bits.**

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Some Details

- **Parameters and return types are Objects. If the actual types are primitives, they will be wrapped using one of the eight wrapper classes.**
- **The first parameter to invoke is the controlling object (good idea to use `null` for static methods, but not required). The second parameter is the parameter list.**
- **When you use `invoke` beware:**
  - **It is much much slower than static invocation**
  - **You have to handle all the exceptions**
  - **You lose lots of compile-time checks**

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Exceptions

- **If invoked method throws an exception, `invoke` will throw an `InvocationTargetException`**
- **Can get original via `getException`**
- **Lots of other exceptions to worry about before you call `invoke`:**
  - **Did class load? `ClassNotFoundException`**
  - **Was method found? `NoSuchMethodException`**
  - **Can you access method? `IllegalAccessException`**

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Representing the Primitive Types

- **Special `Class` objects for the primitives:**
  - **`Integer.TYPE` is the `Class` object for `int`**
  - **There is a type for each of the eight primitives**
  - **`Void.TYPE` is the `Class` object for `void`**
- **Not the same as**
  - **`Integer.class` which is the `Class` object for `Integer` wrapper**
- **Also `Class` types for arrays**
  - **for example, class type for `int[][]` is `Integer.TYPE[][].class`**

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Steps To Invoke A Method

- **Get a `Class` object for the class that contains the method**
- **Get a `Method` object, `m`. Will need name of method, and an array of `Class` objects.**
- **Form an array of `Object` that contains the parameters to pass (second argument to `m.invoke`). Pass the controlling object or null (if static method) as the first parameter.**
- **Catch `InvocationTargetException`**

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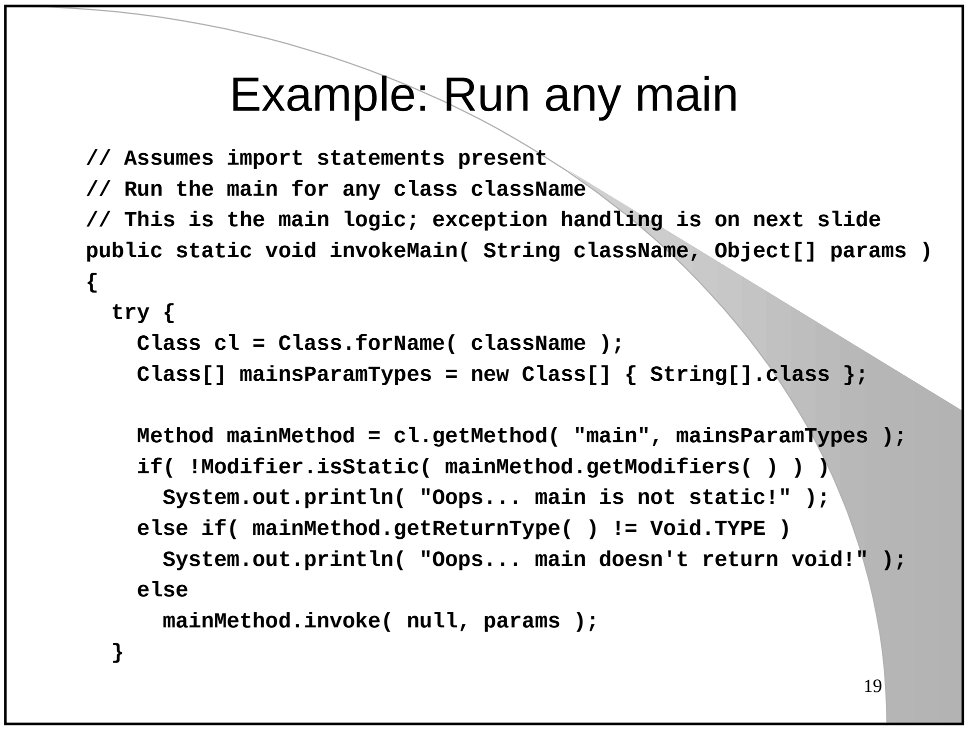

Example: Run any main

```
// Assumes import statements present
// Run the main for any class className
// This is the main logic; exception handling is on next slide
public static void invokeMain( String className, Object[] params )
{
  try {
    Class cl = Class.forName( className );
    Class[] mainsParamTypes = new Class[] { String[].class };

    Method mainMethod = cl.getMethod( "main", mainsParamTypes );
    if( !Modifier.isStatic( mainMethod.getModifiers( ) ) )
      System.out.println( "Oops... main is not static!" );
    else if( mainMethod.getReturnType( ) != Void.TYPE )
      System.out.println( "Oops... main doesn't return void!" );
    else
      mainMethod.invoke( null, params );
  }
```

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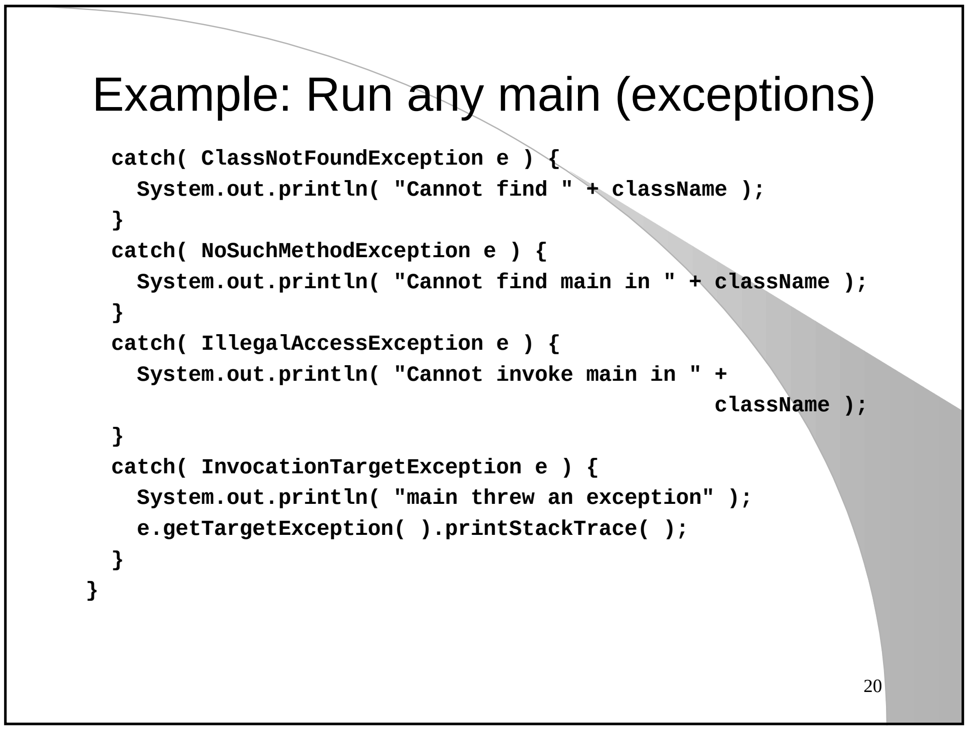

Example: Run any main (exceptions)

```
  catch( ClassNotFoundException e ) {
    System.out.println( "Cannot find " + className );
  }
  catch( NoSuchMethodException e ) {
    System.out.println( "Cannot find main in " + className );
  }
  catch( IllegalAccessException e ) {
    System.out.println( "Cannot invoke main in " +
                                             className );
  }
  catch( InvocationTargetException e ) {
    System.out.println( "main threw an exception" );
    e.getTargetException( ).printStackTrace( );
  }
}
```

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The `Field` Class

- **Can get list of all fields from a `Class` object.**
- **Once you have a `Field` class representation of an object, you can get or set its value.**
- **For instance (assume `Date` has `month` field, as a string):**

```
Object d = new Date( "July 1, 1993" );
Field f = d.getClass( ).getField( "month" );
System.out.println( f.get( d ) );
```

- **Security check is performed: if field is inaccessible, an `IllegalAccessException` is thrown. And fields should be private!!**

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`get` and `set` For `Field`

- **`get` and `set` return value in an `Object`.**
- **Primitives are wrapped.**
- **Special versions for convenience (e.g. `getInt`, `getDouble`, `setInt`, etc.)**

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Java 1.2: Accessible Objects

- **Can request that `Field`, `Method`, and `Constructor` objects be "accessible."**
- **Request granted if no security manager, or if the existing security manager allows it.**
- **Can invoke method or access field, even if inaccessible via privacy rules.**
- **Blatant security hole, means now you need to know what a security manager is. Stay tuned....**

Example Of Accessing Private Data

```
import java.lang.reflect.*;

class Hidden
{
  private static int SECRET = 3737;
}

class Spy
{
  public static int getHiddenSecret( ) {
    try {
      Field f = Hidden.class.getDeclaredField( "SECRET" );
      f.setAccessible( true );  // Make private field accessible
      return f.getInt( null );
    }
    catch( NoSuchFieldException e ) { }
    catch( IllegalAccessException e ) { }
    catch( java.security.AccessControlException e ) {
      System.out.println( "Security manager objects to this!" );
    }
    return -1;
  }
}
```

Added In Java 1.3

- Dynamic Proxy Classes
- Automates the creation of proxies
- We will discuss a use of the proxy pattern in more detail later in the course when we discuss Java 1.2 garbage collection

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The Problem

- Suppose you have an interface and an implementation

```
public interface Foo
{
  void meth1( );
  int  meth2( );
   ...
}
class FooImpl implements Foo
{
 ...
}
```

- You want to have a new class that does everything each `Foo` method in `FooImpl` does, with a little before or after the call

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You Need a Proxy Class

- **Easy to write: Proxy class stores a reference to the `Foo`. For instance to print Hello,**

```
class FooProxy implements Foo
{
  public FooProxy( Foo d )
    { delegate = d; }

  public void meth1( )
    { System.out.println( "Hello" ); delegate.meth1( ); }
  public int  meth2( );
    { System.out.println( "Hello" ); return delegate.meth2( ); }
   ...

  Foo delegate;
}
```

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Proxy Pattern

- **With the proxy pattern, `FooImpl` and `FooProxy` are not usually constructed directly by the user. Instead, they are handed out by a `FooFactory` class and only `Foo` is visible:**

```
public class FooFactory
{
  public static Foo allocateFoo( )
    { return new FooProxy( new FooImpl( ) ); }
  private FooFactory( ) { } // No FooFactory objects
}
```

- **With this pattern, user is oblivious to the fact that they have a proxy!**
- **Easy to change implementation of the concrete `Foo` instances**

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Dynamic Proxies

- **Proxies useful to**
  - **do security checks prior to each call**
  - **do logging that calls are being made and completed**
  - **do lazy loading or copying**
  - **represent remote objects**
- **If interfaces are large, the code to write new proxies is cumbersome and repeated.**
- **Reflection can do this for you automatically.**
- **Downside is that reflection might be too slow; depends on what the proxy is doing.**

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Code Is Straightforward

- **Uses two classes:**
  - **`InvocationHandler` interface; must implement its `invoke` method to do delegation**
  - **`Proxy`; usually call its `newProxyInstance` method with parameters that explain the class loader to use, interface being implemented, and a ref to an invocation handler object.**
  - **Proxy pattern is important; you should understand the pattern; automatic generation is not so important now**

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Generation of Foo Proxy Class

```
public class FooFactory {
  public static Foo allocateFoo( ) {
    return (Foo) Proxy.newProxyInstance( Foo.class.getClassLoader( ),
         new Class[] { Foo.class }, new FooHandler( new FooImpl( ) ) );
  }
  private FooFactory( ) { } // No FooFactory objects
}

class FooHandler  implements InvocationHandler {
  public FooHandler( Object d ) {
    delegate = d;
  }
  public Object invoke( Object proxy, Method meth, Object[] args )
                      throws Throwable {
    System.out.println( "Hello" );
    return meth.invoke( delegate, args );
  }
  private Object delegate;
}
```

Dynamic Proxy Details

- **Can have several interfaces implemented; order of interfaces matters if interfaces declare common methods**
- **Generated Proxy classes**
  - **public, final, not abstract**
  - **extend `java.lang.reflect.Proxy`**
  - **implement the specified interfaces**
  - **constructor populates `Proxy` base class public reference `h` to invocation handler by calling super**
- **`newProxyInstance` actually calls `getProxyClass` to get a `Class` object, and then `newInstance` on the `Class` object.**

What The New Proxy Class Is

```
public final class GeneratedProxy extends Proxy implements Foo {
  public GeneratedProxy( InvocationHandler h )
    { super( h ); handler = super.h; }

  public int meth2( ) {
    Object ret = null;
    try {
      Method m = myClass.getMethod( "meth2", new Class[] { } );
      ret = handler.invoke( this, m, new Object[] { } );
    } catch( Throwable e ) {
      if( e instanceof RuntimeException ) throw (RuntimeException) e;
      if( e instanceof Error )            throw (Error) e;
    }
    return ((Integer)ret).intValue( );
  }
    ...
  private InvocationHandler handler;
  private static final Class myClass = Foo.class;
}
```

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Summary

- **Reflection lets you do some cool stuff and is relatively easy to use.**
- **Allows RTTI, which is occasionally useful to you, and crucial for other Java stuff.**

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