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Modul - Fortgeschrittene Programmierkonzepte

Bachelor Informatik

05 - Reflection und Annotations

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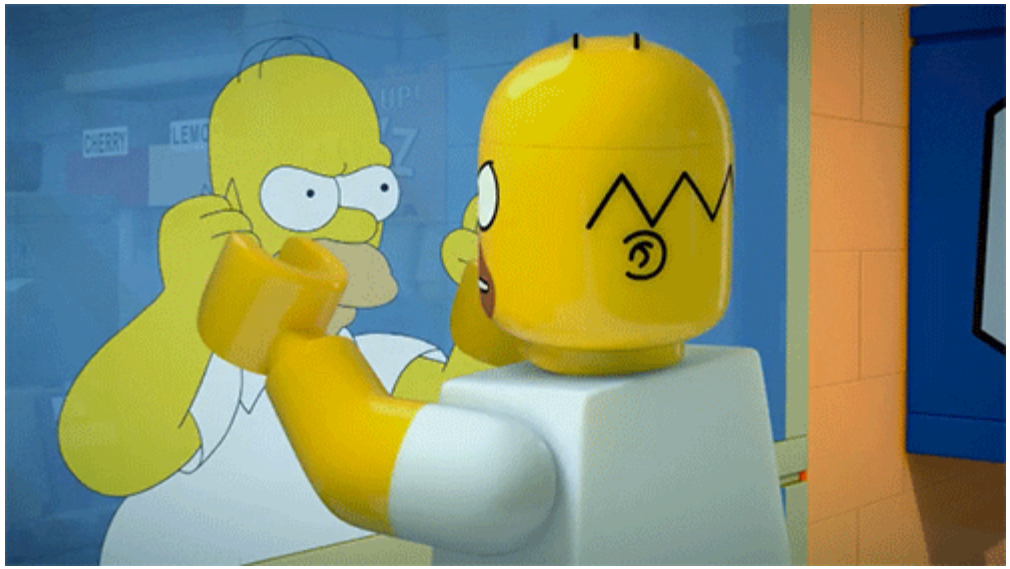
Agenda for today



- `java.lang.Class<T>`: your ticket to reflection
- Messing with Objects
- Basic Java beans (a simple plugin architecture)
- Annotations

Reflection

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- *Type introspection* is the ability of programming languages to determine the type (or its properties) of an arbitrary object at runtime.
- Java takes this concept one step further with *reflection*, allowing not only to determine the type at runtime, but also modifying it.
- At its core, reflection builds on `java.lang.Class`, a generic class that *is* the definition of classes.

> Note that most of the classes we will be using when dealing with reflection are in the package `java.lang.reflection` (package summary), and (almost) none of them have public constructors -- the JVM will take care of the instantiation.

Classes

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There are different ways to get to the class object of a Class:

```
// at compile time
Class<String> klass1 = String.class;

// or at runtime
Class<? extends String> klass2 = "Hello, World!".getClass();
Class<?> klass3 = Class.forName("java.lang.String");
Class<String> klass4 = (Class<String>) new String().getClass();

System.out.println(klass1.toString());  // java.lang.String
System.out.println(klass2.toString());  // ditto...
System.out.println(klass3.toString());
System.out.println(klass4.toString());

klass1.getName();          // java.lang.String
klass1.getSimpleName();    // String
```

Class: Class

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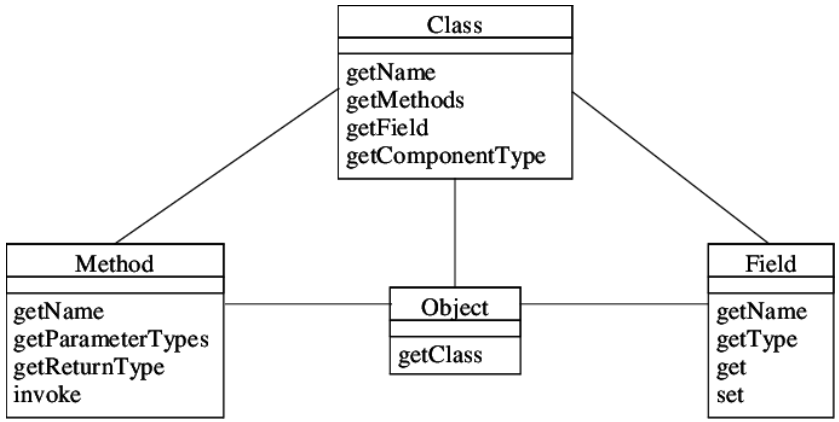
As a note …

- use `Class<T>` to get the class name if known at compile time (or use an unchecked cast at runtime)
- use the `?` (wildcard) and appropriate bounds for *any* type.

So what can you do with a `Class<?>` object?



Basic Type Information

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You can use `Class<?>` object to get basic type information:

```
// all of these will return true
int.class.isPrimitive();

String[].class.isArray();

Comparable.class.isInterface();

(new Object() {})
    .getClass()
    .isAnonymousClass();          // also: local and member classes

Deprecated.class.isAnnotation();  // we will talk about those later
```

> Even primitive type like `int` or `float` have class objects (which are, by the way, different from their wrapper types `Integer.class` etc.!).

Type Internals

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You can get even more ...

```
// family affairs...
String.class.getSuperClass();    // Object.class

// constructors
String.class.getConstructors();  // returns Constructor<String>[]

// public methods
String.class.getMethod("charAt", int.class);
String.class.getMethods();       // returns Method[]

// public fields (attributes)
// Comparator<String>
String.class.getField("CASE_INSENSITIVE_ORDER");
String.class.getFields();       // returns Field[]

// public annotations (more on this later)
String.class.getAnnotation(Deprecated.class);         // null...
String.class.getAnnotationsByType(Deprecated.class);  // []
String.class.getAnnotations();  // returns Annotation[]
```

Some Remarks

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- These methods may throw `NoSuch{Method,Field}Exceptions` and `SecurityExceptions` (more on security later).
- You can distinguish between *declared* fields (methods, ...), and "just" fields: `.getFields()` (and `.getMethods()` etc.) will return *the public* fields of an object, including those inherited by base classes.
- Use `.getDeclaredFields()` (and `.getDeclaredMethods()` etc.) to retrieve *all* fields declared in this particular class.

```
String v = new String();
for (Method m : v.getClass().getDeclaredMethods()) {
    System.out.println(m.getName());
}
```

Object Instantiation

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As you can see, you can also query for *constructors* of a class. This is the base for creating new instances based on class definitions:

```
Class<?> klass = "".getClass();
String magic = (String) klass.newInstance();  // unchecked cast, BTW deprecate

Class<?> klass = "".getClass();
Constructor ctor = klass.getDeclaredConstructor();
String s = (String)ctor.newInstance();
```

Sticking with the example of strings, the documentation tells us that there exist non-default constructors. Consider for example the `String(byte[] bytes)` constructor:

Object Instantiation

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```
Constructor<String> cons = (Constructor<String>)
    String.class.getConstructor(byte[].class);

String crazy = cons.newInstance(new byte[] {1, 2, 3, 4});
```

> Note that this may trigger quite a few exceptions: `InstantiationException`, `IllegalAccessException`, `IllegalArgumentException`, `InvocationTargetException`, all of which make sense if you extrapolate their meaning from the name.

Messing with Objects

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Modifying Fields (Attributes)

Remember Rumpelstiltskin?

In short: A very ambitious father claimed his daughter could produce gold. Put under pressure by the king, she cuts a deal with an imp: it spins the gold and in return she would sacrifice her first child --

unless she could guess the imp's name!

Objects

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Ok, here's the mean imp and the poor daughter:

```
class Imp {
    private String name = "Rumpelstiltskin";
    boolean guess(String guess) {
        return guess.equals(name);
    }
}
```

```
class Daughter {
    public static void main(String... args) {
        Imp imp = new Imp();

        // to save your child...
        imp.guess(???);
    }
}
```

More about it ...

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Since `Imp.name` is private, the imp feels safe (it's dancing around the fire pit...). But can we help the daugher save her firstborn?

Yes, we can!

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Using reflection, we will sneak through the imp's "head" to find the string variable that encodes the name.

```
Imp imp = new Imp();
String oracle = null;
// get all fields
for (Field f : imp.getClass().getDeclaredFields()) {

    f.setAccessible(true);  // oops, you said private? :-)

    // looking for private String
    if (Modifier.isPrivate(f.getModifiers())
            && f.getType() == String.class) {
        oracle = (String) f.get(imp);  // heureka!
    }
}
imp.guess(oracle);  // true :-)
```

Alternatively

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```
Imp imp = new Imp();

for (Field f : imp.getClass().getDeclaredFields()) {
    f.setAccessible(true);
    if (Modifier.isPrivate(f.getModifiers())
        && f.getType() == String.class) {
        f.set(imp, "Pinocchio");  // oops :-)
    }
}

imp.guess("Pinocchio");  // true :-)
```

The `Field` class allows us to retrieve and modify both the modifiers and the values of fields (given an instance).

Calling Functions

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Similar to accessing and modifying fields, you can enumerate and invoke methods. Sticking with the imp above, what if the imp's name were well-known, but nobody knew how to ask for a guess?

```
class WeirdImp {
    static final String name = "Rumpelstiltskin";
    private boolean saewlkhasdfwds(String slaskdjh) {
        return name.equals(slaskdjh);
    }
}
```

Accessability

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This time, the `name` is well known, but the guessing function is hidden. Again, reflection to the rescue.

```
WeirdImp weirdo = new WeirdImp();
for (Method m : weirdo.getClass().getDeclaredMethods()) {
    m.setAccessible(true);

    // ...returns boolean?
    if (m.getReturnType() == boolean.class
            // ...has one arg?
            && m.getParameterCount() == 1
            // which is String?
            && m.getParameterTypes()[0] == String.class) {
        System.out.println(m.invoke(weirdo, Weirdo.name));
    }
}
```

Basic Java Beans

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- Reflection can be used to facilitate an architecture where code is dynamically loaded at runtime.
- This is often called a *plugin mechanism*, and Java Beans have been around for quite a long time.
- Consider this simple example: We want to have a game loader that can load arbitrary text-based games which are provided as a third party `.jar` file.

```
package reflection;
public interface TextBasedGame {
    void run(InputStream in, PrintStream out) throws IOException;
}
```

Beans Example

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A simple *parrot* (echoing) game could be:

```
package reflection.games;
public class Parrot implements TextBasedGame {
    @Override
    public void run(InputStream in, PrintStream out)
        throws IOException {

        BufferedReader reader = new BufferedReader(
            new InputStreamReader(in));
        out.println("Welcome to parrot. Please say something");

        String line;
        while ((line = reader.readLine()) != null
            && line.length() > 0) {
            out.println("You said: " + line);
        }
        out.println("Bye!");
    }
}
```

Load Class

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These games all implement the `TextBasedGame` interface, and their `.class` files can be packaged into a jar.

Later, if you know the location of the jar file, you can load classes by-name:

```
package reflection;
public class TextGameLoader {
    public static void main(String... args) throws Exception {

        // load classes from jar file
        URL url = new URL("jar:file:/...hsro-inf-fpk/example/games.jar!/");
        URLClassLoader cl = URLClassLoader.newInstance(new URL[] {url});

        // you can play "Addition" or "Parrot"
        final String choice = "Parrot";
        TextBasedGame g = (TextBasedGame) cl.loadClass
            ("reflection.games." + choice)
            .newInstance();
        g.run(System.in, System.out);
    }
}
```

Security

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The previous sections showed clearly how powerful the tools of reflection are. Naturally, security is a concern: what if someone loads your jars, enumerates all classes, and then tries to steal passwords from a user?

This has indeed been done, and is the reason why Java was historically considered insecure or even unsafe to use. However, newer versions of Java have a sophisticated system of permissions and security settings that can limit or prevent reflection (and other critical functionality).

Two things that do *not* work, at least out of the box:

- While you can do a forced write on `final` *fields*, this typically does not affect the code at runtime, since the values are already bound at compiletime.
- It is impossible to swap out *methods* since class definitions are read-only and read-once. If you wanted to facilitate that, you would have to write your own class loader.

What is JSON

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- JSON stands for *JavaScript Object Notation*.
- You can find the *spec* here: JSON
- JSON is a lightweight format for storing and transporting data
- JSON is often used when data is sent from a server to a web page
- JSON is "self-describing" and easy to understand
  - No strong schema validation, see XML and XMLSchema
  - but there is JSON Schema

```
{
    "employees":[
        {"firstName":"John", "lastName":"Doe"},
        {"firstName":"Anna", "lastName":"Smith"},
        {"firstName":"Peter", "lastName":"Jones"}
    ]
}
```

How to Convert an Object into JSON?

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- *JSON is nice for storing and transporting*: **JSON is used to serialization and deserialization**

```
public class Person {

    private String firstName;
    private String lastName;
    private int age;

    public Person(String firstName, String lastName, int age) {
        this.firstName = firstName;
        this.lastName = lastName;
        this.age = age;
    }
}
```

How to serialize an object of this class to JSON?

Use Reflection

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Idea: We can use the *reflection API* to introspect and access data!

```
public static String toJson(Object obj) {
    StringBuffer sb = new StringBuffer("{");

    Class cl = obj.getClass();
    for (Field f: cl.getDeclaredFields()) {
        f.setAccessible(true);

        sb.append("\"" + f.getName() + "\" : ");
        if (f.getType().equals(int.class))
            sb.append(f.get(obj));
        else
            sb.append("\"" + f.get(obj) + "\",");
    }

    sb.append("}");

    return sb.toString();
}
```

Would this work?

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Actually, this works great!

```
    public static void main(String[] args) throws Exception {
        Person p = new Person("Max", "Mustermann", 33);
        System.out.println(toJson(p));
        //{"firstName" : "Max","lastName" : "Mustermann","age" : 3}
    }
```

What about `fromJson()` and other data types, e.g. Date, float, arrays ...

Annotations

Annotations are *meta-information*, they can be attached to classes, methods or fields, and can be read by the compiler or using reflection at runtime.

They are denoted using the `@` character, for example `@Override`.

Defining Annotations

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Annotations are similar to interfaces: both as in syntax and as in a method or field can have multiple annotations.

```
public @interface Fixed {
    String author() ;
    String date() ;
    String bugsFixed() default "" ;
}
```

This defines the annotation `@Fixed(...)` with three arguments; the last one is optional and defaults to the empty string.

```
@Fixed(author="mustermann", date="2011-11-11")
void method() { ... }
```

Meta-Annotations

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Even annotations can be annotated. *Meta annotations* define where and how annotations can be used.

- `@Target({ElementType.FIELD, ElementType.METHOD})`: Use this to limit your custom annotation to fields or methods.
- `@Retention(RetentionPolicy.{RUNTIME,CLASS,SOURCE)}`: This controls if the annotation is available at runtime, in the class file, or only in the source code.
- `@Inherited`: Use this to make an annotation to be passed on to deriving classes.

Method Annotations

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In general, there are *marker anotations* (e.g. `@Deprecated`) without arguments, *value annotations* (e.g. `@SuppressWarnings("...")`) that take exactly one value, and more sophisticated annotations (e.g. `@Fixed(...)` above).

```
class K {
    @Override
    public boolean equals(Object o) {
        // ...
    }
    @Deprecated
    public void useSomethingElseNow() {
        // ...
    }
    @SuppressWarnings("unchecked")
    public void nastyCasts() {

    }
}
```

Marker Annotations

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What are they good for?

- `@Override` is used to signal the intent of overwriting; results in compile error if its actually no overwrite (e.g. `@Override public boolean equals(K k)`)
- `@Deprecated` marks a method not to be used anymore; it might be removed in the future.
- `@SuppressWarnings(...)` turns off certain compiler warnings

Type (Attribute) Annotations

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`@NonNull`: The compiler can determine cases where a code path might receive a null value, without ever having to debug a `NullPointerException`.

`@ReadOnly`: The compiler will flag any attempt to change the object.

`@Regex`: Provides compile-time verification that a `String` intended to be used as a regular expression is a properly formatted regular expression.

`@Tainted` and `@Untainted`: Identity types of data that should not be used together, such as remote user input being used in system commands, or sensitive information in log streams.

```
abstract void method(@NonNull String value, @Regex re);
```

Annotations: JUnit5

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The new JUnit5 test drivers inspect test classes for certain annotations.

```
class MyTest {
    BufferedReader reader;

    @BeforeAll
    void setUp() {
        reader = new BufferedReader();  // ...
    }

    @Test
    void testSomeClass() {
        // ...
    }
}
```

Most of the time, you will get around with `@BeforeAll`, `@AfterAll` and `@Test`; see this complete list of annotations.

Annotations: Gson by Google

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Gson by Google helps with de/serializing objects (see today's assignment).

It allows you to map between JSON and Java objects:

```
class Klass {

    private int value1 = 1;
    private String value2 = "abc";
    @SerializedName("odd-name") private String oddName = "1337";
    private transient int value3 = 3;  // will be excluded

    Klass() {
        // default constructor (required)
    }

}
```

How to use it?

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Serializes an object to JSON format.

```
// Serialization
Klass obj = new Klass();
Gson gson = new Gson();
String json = gson.toJson(obj);
// ==> json is {"value1":1,"value2":"abc","odd-name": "1337"}

// Deserialization
Klass obj2 = gson.fromJson(json, Klass.class);
// ==> obj2 is just like obj
```

> JSON (JavaScript Object Notation) is a lightweight data-interchange format. Often use for exchangig data between platforms (see REST). It consists of key-value pairs!

*RE*presentational *S*tate *T*ransfer

A Word about REST

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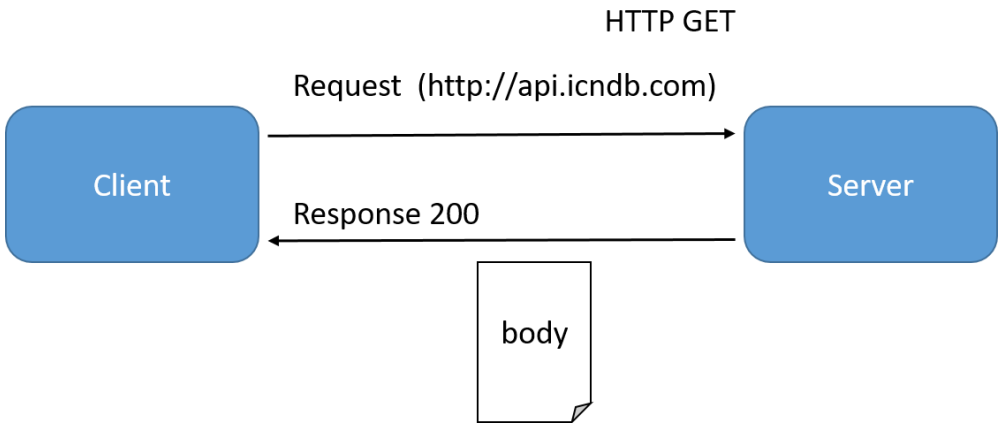
REST = REpresentational State Transfer

- REST, or **RE**presentational **S**tate **T**ransfer, is an architectural style for providing standards between computer systems on the web.
- making it easier for systems to communicate with each other.
- REST-compliant systems, often called RESTful systems, are characterized by how they are stateless and separate the concerns of client and server.



Statelessness

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- Systems that follow the REST paradigm are *stateless*
  - meaning that the server does not need to know anything about what state the client is in and vice versa.
- In this way, both the server and the client can understand any message received, **even without seeing previous messages**.
- This constraint of statelessness is enforced through the use of *resources*, rather than *commands*.
- *Resources* describe any object, document, or thing that you may need to store or send to other services.
- Because REST systems interact through standard operations (**CRUD**) on resources, they do not rely on the implementation of interfaces.

Making Requests

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REST requires that a client make a request to the server in order to retrieve or modify data on the server. A request generally consists of:

- an **HTTP verb** (Standard Operation), which defines what kind of operation to perform
- a **header**, which allows the client to pass along information about the request
- a path to a resource (URL)
- an optional message body containing data

```
curl -X GET http://heise.de
```

```
wget http://heise.de
```

```
curl -d '{"key1":"value1", "key2":"value2"}'
     -H "Content-Type: application/json"
     -X POST http://localhost:3000/data
```

HTTP Verbs

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There are 4 basic HTTP verbs we use in requests to interact with resources in a REST system:

- **GET** — retrieve a specific resource (by id) or a collection of resources
- **POST** — create a new resource
- **PUT** — update a specific resource (by id)
- **DELETE** — remove a specific resource by id

Get a random Chuck Norris Joke:

```
curl -X GET https://api.icndb.com/jokes/random
```


```
{ "type": "success",
  "value": {
      "id": 273, "joke": "Chuck Norris does not kick ass and take
      names. In fact, Chuck Norris kicks ass and assigns the corpse
      a number. It is currently recorded to be in the billions.",
  "categories": [] }
```

A WebRequest in Java

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How would we implement a HTTPRequest in Java?

- Use `URL`-class to represnet the Url
- Use `HttpURLConnection`-class to connect to the server
- `BufferedReader`and `InputStream` to read the request

HTTPRequest in Java

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Get a joke from ICNDB:

```
public static void main(String[] args) throws Exception {
    URL url = new URL("https://api.icndb.com/jokes/random");
    HttpURLConnection con = (HttpURLConnection) url.openConnection();
    con.setRequestMethod("GET");
    con.connect();
    BufferedReader in = new BufferedReader(
            new InputStreamReader(con.getInputStream()));
    String inputLine;
    StringBuffer content = new StringBuffer();
    while ((inputLine = in.readLine()) != null) {
        content.append(inputLine);
    }
    // close resources here!
}
```

Can you make it a base class and design your own typed version?

Because it is cumbersome...

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... we can use a framework.

Retrofit: consume REST interfaces without any pain

```
public interface ICNDBApi {
  @GET("jokes/random")
  Call<Sring>> getRandomJoke();
}
```

```
Retrofit retrofit = new Retrofit.Builder()
        .baseUrl("https://api.icndb.com/")
        .addConverterFactory(ScalarsConverterFactory.create())
        .build();
ICNDBApi2 service = retrofit.create(ICNDBApi2.class);
Call<String> repos = service.getRandomJoke();
String s = repos.execute().body();
```

Annotations: Retrofit

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Retrofit: consume REST interfaces without any pain

```
public interface GitHubService {
  @GET("users/{user}/repos")
  Call<List<Repo>> listRepos(@Path("user") String user);
}

Retrofit retrofit = new Retrofit.Builder()
    .baseUrl("https://api.github.com/")
    .build();

GitHubService service = retrofit.create(GitHubService.class);

Call<List<Repo>> repos = service.listRepos("octocat");
```

Summary

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Lessons learned today:

- Reflections
  - Classes, Methods, Attributes
  - Security
- Annotations
- Frameworks
  - Butterknife
  - GSON
  - Retrofit

Final Thought!