Java

Platforms, etc.
Java

- object oriented
  - (almost) all is object
- interpreted
  - source code (.java) – compiled to the bytecode
  - bytecode (.class) – interpreted by the virtual machine
- platform independent
- programs run in the virtual machine
Historie

- JDK 1.0 – 1996
- JDK 1.1 – 1997
  - Inner classes
- Java 2 platform – 2000
  - JDK 1.2, 1.3 – changes in libraries only
- JDK 1.4 – 2002
  - Assert
- JDK 5.0 – 2004
  - Changes in the language
    - generics
    - annotations
    - ...
- JDK 6 – 2006
- JDK 7 – 2011
  - „small“ changes in the language
- JDK 8 – 2014
  - „big“ changes in the language
Java platform

- JSE – standard edition
- JEE – enterprise edition
- JME – micro edition
Performance

• originally (~ JDK 1.1, 1998)
  – Java programs 6 times slower than C
• now:
  – Just-In-Time (JIT) compilation
    • during launching the program is compiled to native code
    • native code is executed
    • slow start, then fast
• performance ~ comparable with native applications
• big memory consumption
Java implementations

- Oracle (Sun Microsystems)
  - "official" implementation
  - Windows, Solaris, Linux
- OpenJDK
  - http://openjdk.java.net/
  - open-source
  - supported by Oracle (Sun Microsystems)
  - official implementation created from OpenJDK
- IcedTea
  - http://icedtea.classpath.org/
  - based on OpenJDK
  - completely “free”
- IBM
  - IBM JDK
Java implementations

- Jikes RVM
  - Research Virtual Machine
  - open-source
  - for testing extensions
  - written in Java
    - "self-hosting"
      - does need another JVM to run
    - boot-image writer
      - a Java program, which is executed in an existing JVM
    - boot-image loader
      - a program written in C++
  - does not support complete Java API
Other... (mostly “historical”)

- Blackdown (do 1.5)
  - open-source implementation of JVM for Linux
  - based on the code of Sun JVM
- Jikes
  - Jikes compiler
    - open-source
    - fast
    - strict compatibility with Java (till 1.5)
- GNU classpath – an implementation of core Java libraries
- Guavac – compiler
- Kaffe – virtual machine
- Apache Harmony
  - open source Java SE
- ...
source: http://developer.android.com/
Bck2brwsr

- Java running in a browser
- Project goals
  - „Create small Java capable to boot fast and run in 100% of modern browsers including those that have no special support for Java.
  - Demonstrate that Java has benefits over JavaScript when creating larger HTML5 applications“
  - ...

## Popularity

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<th>Feb 2017</th>
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<th>Change</th>
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Zdroj: http://www.tiobe.com/tiobe_index
Popularity

TIOBE Programming Community Index
Source: www.tiobe.com

Java, Summer semester 2017
27.2.2017

zdroj: http://www.tiobe.com/tiobe_index
History and future
Changes in the language – Java 5

- static import
- auto-boxing and auto-unboxing
- new `for` cycle
- generics
- `enum`
- methods with variable number of parameters (printf)
- annotations (metadata)
Java 7, 8

• Java 6 – changes in libraries only
• Java 7 – 2011
  – „small“ changes in the language
• Java 8 – 2014
  – „bigger“ changes in the language
  – „Java 8 will be revolution, not evolution“
    
    Mark Reinhold, conference JavaOne, October 2011

  – but
    • September 2012 – plans to include modules dropped
    • modules moved to Java 9
Java 7

• changes
  – changes in syntax
  – support for dynamic languages (a new instruction in bytecode)
  – changes in NIO
  – Nimbus (Swing LaF)
  – new version of JDBC
  – ...

Java 7 – changes in syntax

- expressing constants
  - binary constants
    - \(0b010101\)
  - underscores in numerical literals
    - \(1_000_000\)
- String type in the switch

```java
String month;
...
switch (month) {
  case "January":
    case "February":
      ...
}
```
Java 7 – changes in syntax

- operator <>
  - simplified instantiation of generics
  - type in <> is automatically inferred
  - ex.

```java
List<String> list = new ArrayList<>();
List<List<String>> list = new ArrayList<>();
List<List<List<String>>> list =
    new ArrayList<>();
Map<String, Collection<String>> map =
    new LinkedHashMap<>();
```

- question
  Why <> is necessary? I.e. why is not sufficient

```java
List<String> list = new ArrayList();
```
Java 7 – changes in syntax

• the interface **AutoClosable** and extended **try**
  - ex:
    ```java
class Foo implements AutoClosable {
    ...  
    public void close() { ... }
}

try ( Foo f1 = new Foo(); Foo f2 = new Foo() ) {
    ...  
} catch (...) {
    ...  
} finally {
    ...  
}

  - at the end of **try** (normally or by an exception), **close()** is always called on all the objects in the **try** declaration
  • called in the reverse order than declared
Java 7 – changes in syntax

- multi-\texttt{catch} for several exceptions
  
  \texttt{try} {
  \hspace{1cm} \ldots
  \}
  \texttt{catch} (\texttt{Exception1 | Exception2 ex}) {
  \hspace{1cm} \ldots
  \}

- better type control during re-\texttt{throw}
private void foo(int i) throws Ex1, Ex2 {
    try {
        if (i < 0) {
            throw new Ex1();
        } else {
            throw new Ex1();
        }
    } catch (Exception ex) {
        throw ex;
    }
}

- in Java 7 yes
- in Java 6 no
  - the compiler prints out an error here
What will be in 8

- type annotations
  - type use can be annotated
  - repeating annotations
- default and static methods in interfaces
- lambda expressions
- generic type inference
- std library enhancements
- profiles
  - a “subset” of the std library
    - javac -profile ...
Java 9

- Modules

- Problems with current Java
  - issues with CLASSPATH
  - cannot declare explicit dependences
  - cannot hide public types

- Goals of modules
  - reliable configuration
  - strong encapsulation
Modules (Java 9)

• Module
  - named and self-describing collection of packages with types (classes,...) a data

  - declares
    • dependences (required modules)
    • provided packages

```java
module com.foo.bar {
    requires com.foo.baz;
    exports com.foo.bar.alpha;
    exports com.foo.bar.beta;
}
```

module-info.class
Modules (Java 9)

- modular JAR
  - JAR with module-info.java

- JMOD
  - a new format for modules distribution

- module path
  - searching modules
Modules (Java 9)

- JSE platform – divided into a set of modules

```
module java.base {
    exports java.io;
    exports java.lang;
    exports java.lang.annotation;
    exports java.lang.invoke;
    exports java.lang.module;
    exports java.lang.ref;
    exports java.lang.reflect;
    exports java.math;
    exports java.net;
    ...
}
```
Modules (Java 9)

• Unnamed module
  - reads all other modules
  - exports all public types
  - backward compatibility with CLASSPATH
Java

Miscellaneous...
Type system

- strongly typed language
  - classes
  - primitive types (int, boolean, char, ...)
- "everything" is in a class
- no global variables, functions, ...
  - static methods and fields can seen as global elements
public class InitTest {
    static int i = 1;
    { i+=2; };
    static { i++; };
    public static void main(String argv[]) {
        System.out.println(i);
        System.out.println(new InitTest().i);
    }
};

The program prints out:
   a)  2  4
   b)  1  3
   c)  3  5
   d)  4  4
   e) cannot be compiled
Solution

• correct is a) 2 4

• `{ ...... }` in the class body
  – initializer
  – executed when an instance is created
  – used for initialization of anonymous inner classes

• `static { ...... }`
  – static initializer
  – executed during class loading to VM
  – can access only static elements of the class
public class InitTest {
    static int i = 1;
    { i+=2; }
    public InitTest() {
        System.out.println(i++);
    }
    static { i++; }
    public static void main(String argv[]) {
        System.out.println(i);
        System.out.println(new InitTest().i);
    }
};

Results:
a) 1 3 5
b) 2 3 5
c) 2 4 5
Solution of test 2

• correct us  C)  2  4  5

• the initializer is executed before execution of a constructor

• first, a superclass is initialized
  – initializers and constructors
Exceptions and initializers

- initializers can throw only exceptions that are defined in constructors
  - there must be at least one constructor

- initializers of anonymous inner classes can throw any exceptions
  - the class is instantiated just once
  - no problem to catch/declare the exceptions
Static initializers

- have to terminate without an exception
  - otherwise cannot be compiled
- run in the order as in the source file
- cannot contain `return`
  - otherwise cannot be compiled
Threads

- Java Language Specification
  - defines the "memory model"
    - defines possible behavior of a program (regarding threads)
    - for a given program and execution flow it determines whether the flow is legal
- **volatile** class fields
  - always consistent
    - threads can have copied non-volatile fields in own memory
      - because of speed
    - changes of non-volatile field need not be immediately visible to other threads
- assigning (and reading) primitive types $\leq 32$ bits – atomic
  - i.e. long and double are not atomic
    - but volatile long and double are atomic
- assigning (and reading) references – atomic
Visibility in classes

- is it possible to change element's visibility in children?
  - e.g.
    ```java
    class A { public void foo() {} }
    class B extends A { private void foo() {} }
    ```

- visibility cannot be “restricted” but can be “increased”

- why
  - if it would be possible
    ```java
    class A { public void foo() {} }
    class B extends A { private void foo() {} }
    ```
  - then the following code would be possible
    ```java
    A a = new B();
    a.foo();
    ```
Java

Generics
Introduction

• similar to the templates in C#/C++
  – but only on first view
• typed arguments
• goal
  – clear code
  – type safety
Motivational example

• without generics (<=Java 1.4)

List myIntList = new LinkedList();
myIntList.add(new Integer(0));
Integer x = (Integer)myIntList.iterator().next();

• >= Java 5

List<Integer> myIntList = new LinkedList<Integer>();
myIntList.add(new Integer(0));
Integer x = myIntList.iterator().next();

• no explicit casting
• type checks during compilation
public interface List<E> {
    void add(E x);
    Iterator<E> iterator();
    E get(int i);
}

public interface Iterator<E> {
    E next();
    boolean hasNext();
}

- List<Integer> can be seen as

public interface IntegerList {
    void add(Integer x);
    Iterator<Integer> iterator();
}

- but in reality no such code exists
  - no code is generated as in C++
Type relations

- no changes in typed arguments are allowed

```java
List<String> ls = new ArrayList<String>();
List<Object> lo = ls;

lo.add(new Object());
String s = ls.get(0);

error – assigning Object to String

- second line causes compilation error
- List<String> is not subtype of List<Object>
```
Type relations

- example – printing all elements in a collection
  <= Java 1.4
  ```java
  void printCollection(Collection c) {
    Iterator i = c.iterator();
    for (k = 0; k < c.size(); k++) {
      System.out.println(i.next());
    }
  }
  ```

  naive attempt in Java 5
  ```java
  void printCollection(Collection<Object> c) {
    for (Object e : c) {
      System.out.println(e);
    }
  }
  ```
  - does not work (see the previous example)
Type relations

- Collection<Object> is not supertype of all collections
- correctly
  ```java
  void printCollection(Collection<?> c) {
    for (Object e : c) {
      System.out.println(e);
    }
  }
  ```
- Collection<?> is supertype of all collections
  - collection of unknown
  - any collection can be assigned there
- BUT – to Collection<?> nothing can be added
  ```java
  Collection<?> c = new ArrayList<String>();
  c.add(new Object());  // <= compilation error
  ```
- get() can be called – return type is Object
Type relations

- ? - wildcard
- bounded wildcard

```java
public abstract class Shape {
    public abstract void draw(Canvas c);
}

public class Circle extends Shape {
    ...
}

public class Canvas {
    public void drawAll(List<Shape> shapes) {
        for (Shape s : shapes) {
            s.draw(this);
        }
    }
}
```

- can draw lists of the type `List<Shape>` only but not e.g. `List<Circle>`
Type relations

• solution – bounded?

```java
public void drawAll(List<? extends Shape> shapes){
    for (Shape s:shapes) {
        s.draw(this)
    }
}

• but still you cannot add to this List

    shapes.add(0, new Rectangle()); // compilation error
```
Generic methods

```java
static void fromArrayToCollection(Object[] a, Collection<?> c) {
    for (Object o : a) {
        c.add(o); ← compilation error
    }
}

static <T> void fromArrayToCollection(T[] a, Collection<T> c) {
    for (T o : a) {
        c.add(o); ← OK
    }
}
```
Generic methods

• usage
  – the compiler determines actual types automatically

```java
Object[] oa = new Object[100];
Collection<Object> co = new ArrayList<Object>();
fromArrayToCollection(oa, co); // T → Object
String[] sa = new String[100];
Collection<String> cs = new ArrayList<String>();
fromArrayToCollection(sa, cs); // T → String
fromArrayToCollection(sa, co); // T → Object
```

• bounds can be used with methods also

class Collections {
    public static <T> void copy(List<T> dest, List<? extends T> src) {...}
}
Type inference

• compiler cannot always determine the type
  - example
    ```java
class Collections {
    static <T> List<T> emptyList();
    ...
}
```
  - List<String> listOne = Collections.emptyList();
    • OK
  - void processStringList(List<String> s) {
    ...
  }
  processStringList(Collections.emptyList());
    • cannot be compiled (in Java 7)
Type inference

• we can provide “help” to the compiler
  – `processStringList(Collections.<String>emptyList());`

• in Java 8 the example can be compiled without the “help”
  – better type inference
Generic methods and ?

• when use generic methods and when wildcards

```java
interface Collection<E> {
    public boolean containsAll(Collection<?> c);
    public boolean addAll(Collection<? extends E> c);
}

interface Collection<E> {
    public <T> boolean containsAll(Collection<T> c);
    public <T extends E> boolean addAll(Collection<T> c);
}
```

• What is better?
Generic methods and ?

- when use generic methods and when wildcards

```java
interface Collection<E> {  
    public boolean containsAll(Collection<?> c);  
    public boolean addAll(Collection<?> c);  
}

interface Collection<E> {  
    public <T> boolean containsAll(Collection<T> c);  
    public <T extends E> boolean addAll(Collection<T> c);  
}
```

- generic methods – relations among several types
Generic methods and ?

- it is possible to use both generic methods and wildcards together

```java
class Collections {
    public static <T> void copy(List<T> dest, List<? extends T> src) {....}
}
```

- it can be also written as

```java
class Collections {
    public static <T, S extends T> void copy(List<T> dest, List<S> src) {....}
}
```

- first variant is “correct”
Array and generics

- array of generics
  - can be declared
  - cannot be instantiated

List<String>[] lsa = new List<String>[10];  // wrong
List<??>[] lsa = new List<??>[10];  // OK + warning

- why? arrays can be cast to Object

List<String>[] lsa = new List<String>[10];
Object[] oa = (Object[]) o;
List<Integer> li = new ArrayList<Integer>();
li.add(new Integer(3));
oa[1] = li;
String s = lsa[1].get(0);  // ClassCastException
“Old” and “new” code

• “old” code without generics

```java
public class Foo {
    public void add(List lst) { ... }
    public List get() { ... }
}
```

• “new” code that uses the “old” one

```java
List<String> lst1 = new ArrayList<String>();
Foo o = new Foo();
o.add(lst1); ← OK - List corresponds to List<?>
List<String> lst2 = o.get(); ← compilation warning
```
“Old” and “new” code

- “new” code with generics

```java
public class Foo {
    public void add(List<String> lst) { ... }
    public List<String> get() { ... }
}
```

- “old” code that uses the “new” one

```java
List lst1 = new ArrayList();
Foo o = new Foo();
o.add(lst1); ← compilation warning
List lst2 = o.get(); ← OK - List corresponds to List<?>
```
"Erasure"

```java
public String loophole(Integer x) {
    List<String> ys = new LinkedList<String>();
    List xs = ys;
    xs.add(x); ← warning
    return ys.iterator().next();
}
```

- at runtime, it behaves as

```java
public String loophole(Integer x) {
    List ys = new LinkedList();
    List xs = ys;
    xs.add(x);
    return (String)ys.iterator().next(); ← runtime error
}
```
"Erasure"

- during compilation, all information about generic types are erased
  - "erasure"

  - type parameters are erased (List<Integer> → List)
  - type variables are replaced by the most common type
  - casts added
List<String> l1 = new ArrayList<String>();
List<Integer> l2 = new ArrayList<Integer>();
System.out.println(l1.getClass() == l2.getClass());

• What is printed out?
   a) true
   b) false
Code of generic classes

List<String> l1 = new ArrayList<String>();
List<Integer> l2 = new ArrayList<Integer>();
System.out.println(l1.getClass() == l2.getClass());

• What is printed out?
  a) true
  b) false
Casts, instanceof

Collection cs = new ArrayList<String>();
if (cs instanceof Collection<String>) ....
   \- impossible

Collection<String> cstr = (Collection<String>) cs;
   \- warning
   \- cannot be obtain at runtime

<T> T badCast(T t, Object o) {return (T) o;}
   \- warning

<T> T[] makeArray(T t) {
    return new T[100]; \- impossible
• `java.lang.Class` is generic
  – e.g. `String.class` is of type `Class<String>`

class `Class<E>`

    ....
    E newInstance() { .... }
    ....

}
Additional type relations

class Collections {
    public static <T> void copy(List<T> dest, List<? extends T> src) {...}
}

- actual declaration is

class Collections {
    public static <T> void copy(List<? super T> dest, List<? extends T> src) {...}
}

- it is possible to add to the <? super T> collection
Additional type relations

- super can be used with gen. methods only
- cannot be used with gen. types
  - would not bring anything
    ```java
class Foo<T super Number> {
    private T v;
    public Foo(T t) { v = t; }
}
```
  - after erasure
    ```java
class Foo {
    private Object v;
    public Foo(Object t) { v = t; }
}
```
  - it would only guarantee that as a parameter a supertype of Number can be used
  - it would not guarantee that in the variable is always an instance of a supertype of Number
Converting "old" code to new

```java
interface Comparator<T>
    int compare(T fst, T snd);
}

class TreeSet<E> {
    TreeSet(Comparator<E> c)
    ...
}

• TreeSet<String>
  - it is possible to use both Comparator<String> and Comparator<Object>

  → class TreeSet<E> {
    TreeSet(Comparator<? super E> c)
    ...
  }
```
Converting "old" code to new

Collections {
    public static <T extends Comparable<T>>
        T max(Collection<T> coll);
}

class Foo implements Comparable<Object> {...}
Collection<Foo> cf = ...
Collections.max(cf) does not work

• correctly
    public static <T extends Comparable<? super T>>
        T max(Collection<T> coll);
Converting "old" code to new

```java
public static <T extends Comparable<? super T>> T max(Collection<T> coll);
```

• erasure
  - public static Comparable max(Collection coll)
  - is not compatible with the “old” method max
    - public static Object max(Collection coll)

• more correctly
  ```java
  public static <T extends Object & Comparable<? super T>> T max(Collection<T> coll);
  ```
  - several type can be specified: T1 & T2 & ... & Tn
  - "erasure" takes the first one

• fully correctly
  ```java
  public static <T extends Object & Comparable<? super T>> T max(Collection<T> coll);
  ```
Java

Annotations
Overview

- annotations ~ metadata
  - “data about data”
  - additional information about a part of code, which does not (directly) influence program functionality

- since JDK 5

- examples
  - @Deprecated
  - @SuppressWarnings
  - @Override
Motivation for annotations

- in fact, annotations have existed before JDK 5
  - but were not defined systematically, and
  - could not be added (easily)
  - e.g.:
    - the modifier `transient`
    - `@deprecated` element in a javadoc comment
    - ...

- XDoclet
  - adding annotations to “old” Java
  - as definable tags in javadoc comments
  - anything can be generated from them
    - contains many predefined tags and transformations
  - originally, it was a tool supporting development of EJB components
Usage

- annotations can be used in fact to any element of a program
  - classes
  - interfaces
  - fields
  - methods
  - constructors
  - packages
  - type usage (since Java 8)
- general rule
  annotation can be used on places, where modifiers can be used
  - exception – annotations for packages (written to the special file `package-info.java`) and
  - type usage
- an annotation usage can be restricted
Usage

- e.g.:

```java
class A {
    @Override public boolean equals(A a) { ... }
    @Deprecated public void myDeprecatedMethod() {
        ...
    }
}
```

- annotations can have parameters

```java
@SuppressWarnings("unchecked") public void foo() {
```
Usage

- annotation of type use (Java 8)
  - new @Interned MyObject();
  - myString = (@NonNull String) str;
  - class UnmodifiableList<T> implements @Readonly List<@Readonly T> { ... }
  - void monitorTemperature() throws @Critical TemperatureException { ... }
Usage

• can be used among modifiers in any order
  – common usage – first annotations, then modifiers
• any number of annotations can be used to a single element

• Java 5-7 – a single annotation cannot be applied several times to a single element
  – even if used with different parameters
• Java 8 – a single annotation can be applied several times to a single element
Definition

• similarly to interfaces
  • @interface
  • methods without implementation

• e.g.

```java
public @interface RequestForEnhancement {
    int id();
    String synopsis();
    String engineer() default "[unassigned]";
    String date() default "[unimplemented]";
}
```
**Definition**

- “special” annotations

- marker
  - no body
  - no parameters when annotation is used

  ```java
  public @interface Preliminary { }
  ```

- single-member
  - a single method named `value`
  - any type
  - when used, only annotation and parameter value is written

  ```java
  public @interface Copyright { String value(); }
  ```
Definition

- usage of the previous annotations

```java
@RequestForEnhancement(
    id = 2868724,
    synopsis = "Enable time-travel",
    engineer = "Mr. Peabody",
    date = "4/1/3007"
)
public static void travelThroughTime(Date destination)
{ ... }

@Preliminary public class TimeTravel { ... }

@Copyright("2002 Yoyodyne Propulsion Systems")
public class OscillationOverthruster { ... }
```
Definitions

- same as for interfaces
  - place of declaration
  - scope validity
  - scope of visibility
- must not be a generic type
- must not contain extends
  - by default the extends java.lang.annotation.Annotation
- any number of methods
- annotation T must not contain a method returning T
  - directly but also indirectly

```java
@interface SelfRef { SelfRef value(); }
@interface Ping { Pong value(); }
@interface Pong { Ping value(); }
```
Definition

- methods must not have any parameters
- methods must not be generic
- methods must not declare throws
- returning value must be either:
  - primitivní typ
  - String
  - Class
  - Enum
  - anotace
  - pole předchozích typů
Definition

• when used, annotation must contain a tuple name-value for each method
  – does not hold for methods with default value
• values must not be null
Pre-defined annotations

- annotations for usage on annotations
  - restrict usage of the annotation
  - in package java.lang.annotation
- **@Target**
  - single-member
  - restricts applicability of the annotation
  - possible values (enum ElementType)
    - ANNOTATION_TYPE
    - CONSTRUCTOR
    - FIELD
    - LOCAL_VARIABLE
    - PACKAGE
    - METHOD
    - PARAMETER
    - TYPE – can be used on class, interface, enum, annotation
    - TYPE_PARAMETER – since Java 8
    - TYPE_USE – since Java 8
Pre-defined annotations

- **@Retention**
  - single-member
  - defines when the annotation can be used
  - possible values (enum RetentionPolicy)
    - SOURCE – source code only
    - CLASS – at compiler time
    - RUNTIME – at run-time

```java
@Retention(RetentionPolicy.RUNTIME)
public @interface Foo { }
```
Repeating annotations

- since Java 8

```java
@Schedule(dayOfMonth="last")
@Schedule(dayOfWeek="Fri", hour="23")
public void foo() { ... }
```

- for compatibility reasons, repeating annotations are stored in an automatically generated container
  - the container has to be prepared
    ```java
    @Repeatable(Schedules.class)
    public @interface Schedule { ... }
    
    public @interface Schedules {
        Schedule[] value;
    }
    ```
Obtaining annotations at runtime

- via Reflection API
- the interface `AnnotatedElement`
  - `isAnnotationPresent` – if an annotation present
  - `getAnnotation` – returns annotation of the given type, if it is applied
  - `getAnnotations` – returns all annotations
  - `getDeclaredAnnotations` – returns declared annotations (without inherited)
Processing SOURCE annotations

- annotation processors
  - specified to the compiler
  - the parameter `-processor`
  - `javax.annotation.processing.Processor`
  - since Java 6

- Annotation Processing Tool (APT)
  - an external tool for annotation processing
  - Java 5
  - since JDK 8 – APT and corresponding API marked as deprecated
Example – Unit Testing

```java
import java.lang.annotation.*;
@Retention(RetentionPolicy.RUNTIME)
@Target(ElementType.METHOD)
public @interface Test { }

public class Foo {
    @Test public static void m1() {
        ...
    }
    public static void m2() {
        ...
    }
    @Test public static void m3() {
        ...
    }
}
```
import java.lang.reflect.*;
public class RunTests {
    public static void main(String[] args) throws Exception {
        int passed = 0, failed = 0;
        for (Method m : Class.forName(args[0]).getMethods()) {
            if (m.isAnnotationPresent(Test.class)) {
                try {
                    m.invoke(null);
                    passed++;
                } catch (Throwable ex) {
                    System.out.printf("Test %s
                        failed: %s %n", m, ex.getCause());
                    failed++;
                }
            }
        }
        System.out.printf("Passed: %d,
            Failed %d\n", passed, failed);
    }
}