Einführung in die Programmierung

Summary/aspects to remember

EBNF

- the order of rules doesn't play any role (***Menge** von Regeln*, set of rules)
- *Linke Seite* (*LHS*) <= *Rechte Seite* (*RHS*)
  - *digit_9* <= 9 or <digit_9> <= 9 (same meaning)

Table

1. Substitute the name of the rule (LHS) with its definition (RHS)
2. Choose an option
3. Decide whether an optional element is present or not
4. Determine the number of repetitions

Ableitungsbäume

For every level:

- parent: LHS
- child: RHS

Special characters

There are two options

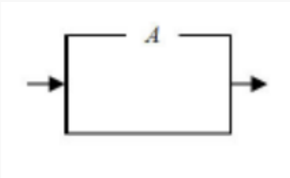
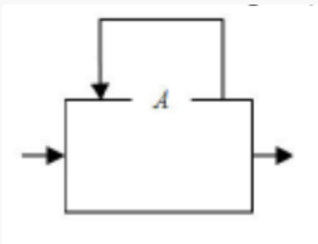
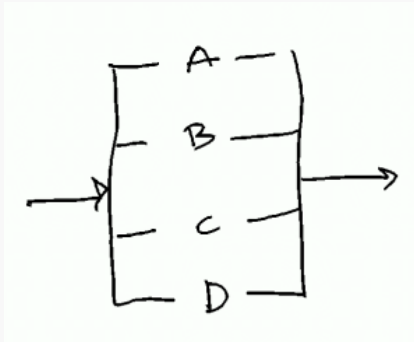
- option 1: frame them
- option 2: put between single quotes → "" to use the single quotes as a special character

Equivalenza fra due regole

B_1 and B_2 are equivalent iff.:

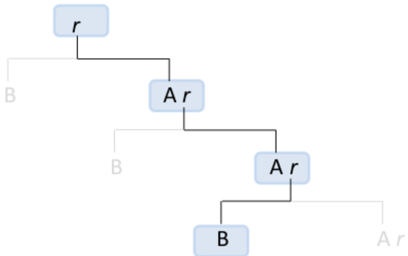
- legal for B_1 $\iff$ legal for B_2
- illegal for B_1 $\iff$ illegal for B_2

Graphic representation

Option	Wiederholung	Auswahl
`[A]`	`{A}`	`A | B | C | D`
		

Recursion in *Ableitungsbaum*

Example `r <= b | Ar`:



$\implies$ AAB is legal

Java

Keyword that cannot be used as *Bezeichner*

```
abstract    default    if           private       this
boolean     do         implements   protected     throw
break       double     import       public        throws
byte        else       instanceof   return        transient
case        extends    int          short         try
catch       final      interface    static        var
char        finally    long         strictfp      void
class       float      native       super         volatile
const       for new    switch       while
continue    goto       package      synchronized
```

Special characters

- `\t` tab
- `\n` new line
- `\"` double quotes
- `\\` backslash

⚠ The forward slash (`/`) is not a special character, `"\/"` gives error.

Primitive types

Seen in class:

Name	Beschreibung	Beispiele
int	ganze Zahlen	42, -3, 0, 2147483647
long	grosse ganze Zahlen	42, -3, 0, 9223372036854775807
double	reelle Zahlen	3.1, -0.25, 9.4e3
char	(einzelne) Buchstaben	'a', 'X', '?', '\n'
boolean	logische Werte	true, false

Type e range	`int`	`long`
From	$-2^{31} = -2147483648$	$-2^{63} = -9223372036854775808$
To	$2^{31} - 1 = 2147483647$	$2^{63} - 1 = 9223372036854775807$

⚠ In order to correctly define a `long` type value out of the `int` range, you have to put a `L` at the end of the number.

Operations

⚠ **Be careful with module!** Some special cases:

```
-1%2; // gives -1, not 1!!
1%7; // gives 1
230857%10; // gives 7, in general, %10^n is useful to get the n last digit of a
number.
230857%2; // gives 1, in general, %2 is useful to check whether a number is
even/odd (0 even, 1 odd).
2.5%1.5; // gives 1.0 (double)! % is also defined for double!
```

Scanner

The scanner is in `java.util.*`.

How to create a scanner with input from the console:

```
Scanner name = new Scanner(System.in);
```

Increment and decrement

Post-Inc/Decrement

```
int x=2;
int y;
y=x++; //*
```

The following happens:

```
//*:
int temp = x;
x=x+1;
y=temp;
```

Pre-Inc/Decrement

```
int x=2;
int y;
y=++x; //*
```

The following happens:

```
//*:
x=x+1;
y=x;
```

off-by one error, or *Zaunpfahlproblem*

Example: `1, 2, 3, 4, 5,` , or `,1 ,2 ,3 ,4, 5`

Strings

`s.toUppercase` returns the string uppercase, but it doesn't modify `s` (`s` remains lowercase).

Method	Description
`equals(`**str**`)`	ob 2 Strings die selben Buchstaben enthalten
`equalsIgnoreCase(`**str**`)`	ob 2 Strings die selben Buchstaben enthalten, ohne Berücksichtigung von Gross- und Kleinschreibung
`startsWith(`**str**`)`	ob der String mit den Buchstaben des anderen (**str**) anfängt
`endsWith(`**str**`)`	ob ... endet
`contains(`**str**`)`	ob der String **str** (irgendwo) auftritt

Class `Random`

`java.util.Random`:

Method name	Description
`nextInt()`	returns a random integer
`nextInt(`**max**`)`	returns a random integer in the range [0, *max*) in other words, 0 to *max* - 1 inclusive
`nextDouble()`	returns a random real number in the range [0.0, 1.0)

Scope (Sichtbarkeitsbereich)

The variables are visible inside the code block where they get declared (`{ //CodeBlock }`).

Example:

```
for (int i = 1; i <= 100; i++) {
    System.out.print("/");
}
for (int i = 1; i <= 100; i++) { // OK
    System.out.print("\\");
}
int i = 5; // OK: outside of loop's scope
```

Array

`new int[number]` gets initialized with zeros, `new String[number]` (and in general every object) with `null`s.

⚠️ To compare two arrays, both `.equals()` and `==` couldn't be used. You can instead use `Arrays.equals(a1,a2)` from class `java.util.Arrays`!

`Arrays.toString(a)` converts the array `a` into a string.

It is also possible to create an array with 0 dimensions: `int[] a = new int[0]`.

Value Semantics vs. Reference Semantics

An object variable (like array's variable) is only used to access to an object, and it is not the object itself (*reference semantics*), unlike primitive type variables (*value semantics*). For example:

```
int[] myArray = new int[] {0,1,2};
myArrayCopy = myArray;
myArray = null;
// myArrayCopy is still {0,1,2}, whereas:
myArray = myArrayCopy;
myArray[1]=18;
// myArrayCopy and myArray are {0,18,2}
```

Furthermore, the changes that happens in another method remains visible even after the method gets called, unlike primitive type variables. For example:

```
public static void main(String[] args) {
    int[] myArray = {0,1,2};
    int k = 1;
    changeMyArray(myArray,k);
    // myArray is {0,18,2}, whereas k is still 1
}

public static void changeMyArray(int[] input, int number) {
    input[1] = 18;
    number = 39;
}
```

Classes and objects

⚠ To compare two objects you have to use `.equals()` and not `==` !

`null` is used to delete the reference of a variable to an object (any object, as strings, arrays too).

Clients

> Klienten sind alle die Programme die Exemplare einer Klasse erstellen oder auf Exemplare zugreifen (können) [z.B. weil sie als Parameter übergeben wurden]

Implicit parameter

> Impliziter ("implicit") Parameter: Das Objekt für das die Methode aufgerufen wird.

For example in `a.update()`, `a` is the implicit parameter.

`toString()` method

It is used to define how to convert an object into a string. The default implementation returns the memory addressof the object.

Objects construction and initialization

A constructor has the following structure (⚠ the output type doesn't have to be specified!):

```
class Foo {
    public Foo(TypeOne ParamOne, TypeTwo ParamTwo [,...]) {
        // code in the constructor
    }
}
```

⚠ The variables has to be declared outside the constructor, otherwise they're visible only inside of it.

`this`

`this` can be used in order to avoid the *shadowing* (*Verdecken von Variablen*) (when an object variable has the same name as a parameter), as well as to call the constructor, by using `this()`. This can be useful to recycle a constructor in a different variant without parameters, avoiding redundancy. For example:

```
public class Point {
    private int x;
    private int y;
    public Point() {
        this(0, 0); // calls (x, y) constructor
    }
    public Point(int x, int y) {
        this.x = x;
        this.y = y;
    }
    ...
}
```

`static` methods

The `static` methods don't refer to an object, but to the class instead. For example: `Class.method()` for a `static method`.

They are mainly used to avoid redundancy between different classes (without redefine them).

`static` variables

They work in a similar way as the methods, but **you have to be careful**.

`static` variables are the same for each class' object!

`static` variables must be either `private` or `final` too.

Handle files

The `File` (`java.io.File`) class allows to operate on files. Here's a list of methods:

`exists()`	Gibt `true` zurück, falls diese Datei existiert, sonst `false`
`canRead()`	Gibt `true` zurück, falls diese Datei gelesen werden kann, sonst `false`
`getName()`	Gibt den Namen dieser Datei zurück
`length()`	Gibt die Dateigrösse, in Bytes, zurück
`delete()`	Löscht die Datei!
`renameTo(file)`	Benennt die Datei um!

To read the content of a text file you can put the file object as parameter when creating a scanner:

```
import java.io.*; // für File
import java.util.*; // für Scanner

File file = new File("input.txt");
Scanner scanner = new Scanner( file );
int zahl = scanner.nextInt();
```

Exceptions

The exceptions can be "caught" (by `catch`, see below), in order to define how to define how the program should react when these exceptions happen.

Some exceptions must be "caught" from the program, because the Java system is not able to handle them correctly. Other exceptions are recognized by the system (for example division by 0, `null` pointer,...).

The exceptions that are recognized and handled by the system are called ***checked Exception***, the others are ***unchecked Exception***.

It is possible to declare that an exception can happen inside a method, by *keyword* `throws` after declaring the method:

```
public static void foo(...) throws type
```

Input/Output

`Scanner` has two exceptions: `NoSuchElementException` e `InputMismatchException`.

You can use `.hasNext[Type]()` to verify if there's an element right after the cursor.

The scanner can also be used with a string as parameter. This can be very useful to read each line (using `.nextLine()`) from a text file, for example:

```
String text = "15 3.2 hello 9 27.5";
Scanner scan = new Scanner(text);
```

Output - `PrintStream` class

It is in `java.io`.

It has methods similar to `System.out`, but it writes in a file instead. Here's an example:

```
import java.io.*;

File file = new File("example.txt");
PrintStream output = new PrintStream(file);
output.print("Hello world!");
```

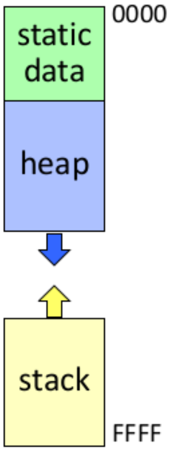
Warning:

1. If the file already exists, it gets overwritten.
2. Never use the same scanner for both *Token* and lines, there's a risk to get empty strings. For example:

   ```
   input.nextInt(); // output: 23
   "23\t3.14\nJoe\t\"Hello\" world\n\t\t45.2 19\n"
      ^
   input.nextDouble(); // output: 3.14
   "23\t3.14\nJoe\t\"Hello\" world\n\t\t45.2  19\n"
            ^
   input.nextLine(); // output: "" (empty!)
   "23\t3.14\nJoe\t\"Hello\" world\n\t\t45.2  19\n"
              ^
   input.nextLine(); // output: "Joe\t\"Hello\" world"
   "23\t3.14\nJoe\t\"Hello\" world\n\t\t45.2  19\n"
                                    ^
   ```

How variables get saved

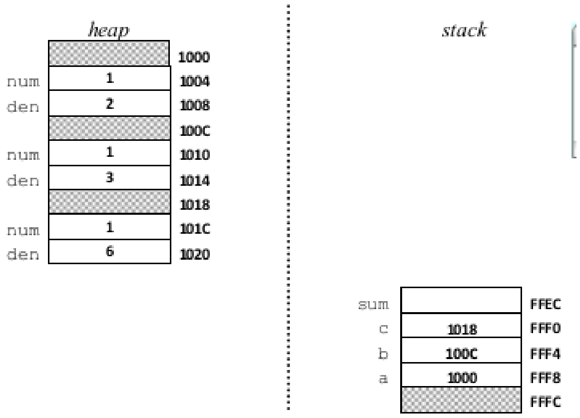
- the ***static data*** contains the informations for the Java virtual machine (not relevant for the programmer and have nothing to do with the *keyword* `static`)
- the ***heap*** contains the objects that gets created by the `new` operator
- the ***stack*** contains the variables used inside methods (for example parameters).



The stack grows upwards, whereas heap downwards.

Example

```java
public void run() {
    Rational a = new Rational(1, 2);
    Rational b = new Rational(1, 3);
    Rational c = new Rational(1, 6);
    Rational sum = a.add(b).add(c);
    println(a + " + " + b + " + " + c + " = " + sum);
}
```



If there are too many variables/objects, the stack and the heap can get overwritten. Java returns in this case an error (`StackOverflowError`, often happens when there are too many recursions).

If there are areas of the *heap* that don't get pointed by the stack, the *garbage collector* frees these areas.

Package

If we make an analogy between class and file, the package represents the folder.

For example a clas `D` from package `a.b.c` must be saved in the file `a/b/c/D.java`.

If no package is specified, Java automatically inserts the program inside the *default* package, from which classes can't get imported and can't be used in other packages.

In this lectures we ony use the default package.

Default **(visibility)**

By using the `default` *keyword* , the package is only visible inside the class and all the other classes inside the same package. A variable gets put in the default package if you don't write anything before its declaration. For example:

```
package pacman.model;
public class Sprite {
    int points; // default: visible to pacman.model.*
    String name; // default: visible to pacman.model.*
}
```

Nested classes

It is possible to create classes inside other classes, for example:

```
public class Inner2 {
    public static void main(String[] args) {
        System.out.println(new InnerClass().foo);
    }
    static class InnerClass {
        int foo = 2;
    }
}
```

Inheritance (*Vererbung*)

The keyword `super` can be used to point to the parent class, for example `super.getSalary()` inside `Administrator extends Angestellte` calls `Angestellte.getSalary()`.

Constructors

When you define a constructor inside the *superclass*, you have also to define it for the *subclasses*.
⚠ **The *subclasses* don't inherit constructors**.

The superclass constructor, can be called using `super(...)`.

⚠ `private` from *superclasses* **can't** be read from the *subclasses*! In order to access them, you have to use an accessor and access to them with `super.get...()` (or use the `protected` attribute instead, discussed later).

Selective (object) behavior *(Selektiv Verhalten von Objekten)*

the *override* can be used to change the behavior of a method that is used inside another method of the subclass. For example:

```
public class Angestellte {
    private int years;
    public Angestellte(int initialYears) {
        years = initialYears;
    }
    public int getVacationDays() {
        return 20 + getSeniorityBonus();
    }
    // vacation days given for each year in the hospital
    public int getSeniorityBonus() {
        return 2 * years;
```

```
    }
}


public class FaGe extends Angestellte {
    public FaGe(int years) {
        super(years);
    }
    // FaGe don't get extra vacation for their years of service.
    @Override
    public int getSeniorityBonus() {
        return 0;
    }
}
```

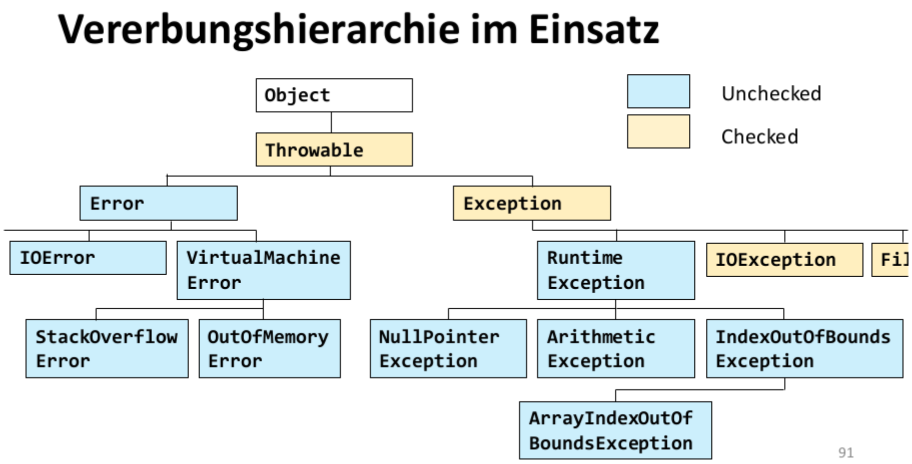
In this case calling `faGe.getVacationDays()` with a `FaGe` object, `getSeniorityBonus()` returns `0`.

This phenomenon is called *dynamic binding* (*dynamische Bindung*).

The `protected` attribute

This attribute allows the subclasses to access the superclass' protected variables, maintaining the property that they are not accessible outside the class (like `private`).

Error hierarchy



The `Object` class

Every new defined class is (by default) a `Object` subclass.

Inside the `Object` class it is defined the method `equals` that can be overridden with another method defined inside the new class, so that you can use it to verify if to objects are the same. For example:

```
public boolean equals(Point other) {
    return (x == other.x && y == other.y);
}
```

Here we have the problem that this method can only get `Point` objects as parameters. For this reason we need a ***cast***.

Cast

The *cast* allows you to change the class (if there's the right relationship of "parent/child" between the two classes).

To verify if a cast is possible, you can use the `instanceof` operator. If the output is `true`, then is possible to make the *cast*.

If you use a cast to pass from a subclass to a superclass, it can also be implicit. For example:

```
class A {}
class B extends A {}

A b = new B();
B x;
x = b; // Doesn't work! The cast goes to the subclass, hence it must be explicit.
x = (B) b; // Correct
b = (A) x; // Correct, but it's not necessary to explicit the cast
b = x; // Correct (implicit)
```

Polymorphism (*Polymorphismus*)

A programm is written in a way that allows to use it with different types of objects and adapt its behaviour depending on these object types.

Class visibility

If you insert the `public` keyword before `class`, the class must be in a file with the same name as the class. If this keyword is not inserted, the visibility will be default, hence only inside the same package.

Dynamic binding (*dynamische Bindung*)

If you define a reference variable like `SuperClass variable = new SubClass()`, you can access to every method defined in the *superclass*, but they get executed as defined inside the subclass. This doesn't happen if the methods are `private`. For example:

```
class T {
    void s0(){
        m();
    }
    void s1(){}
    void s2(){}
    void m(){}
}

class S extends T {
    @Override
    void s1() {
        m();
    }
    @Override
    void s2() {
        p();
    }
    void p() {
```

```
        System.out.print("S");
    }
}

class R extends S {
    @Override
    void p() {
        System.out.print("R");
    }
}
```

If you define `T r = new R()`, when you call `r.s2()` you obtain `R`, because `s2()` will be executed as defined inside `S` class, and `p()` as defined in `R` class. **Please note** that `r.p()` can't be called, because `p()` is not defined in `T`.

⚠ If the two methods `p()` are `private`, then the result would be **`S` and not `R`**! This is because `p()` of `R` is not visible by `S`.

To override a method, the new method must be equal or less restrictive (in terms of visibility) then the method of the superclass, otherwise you'll get an error.

Shadowing

Unlike methods, variables sometimes don't get overridden. Normally a method takes the variables as defined inside the class. The use of variables with same names inside subclasses is discouraged. Here's an example:

```
class X {
    String s = "in X";
    String myS() {
        return s;
    }

    String myS1() {
        return s;
    }
}

class Y extends X {
    String s = "in Y";
    @Override
    String myS() {
      return s;
    }
}

Y yref = new Y();
yref.s;                     // da "in Y"
yref.myS();                 // da "in Y"
yref.myS1();                // da "in X"
((X) yref).myS();           // da "in Y"
((X) yref).s;               // da "in X"
```

Interfaces

The problem about inheritance (`extends`) is that each subclass can have at most one superclass.

We use *interfaces* to solve this problem. Unlike inheritance, they represent similar behaviors between classes (same methods).

⚠️ When a method gets implemented, it **must** be with **public** visibility!

If a class doesn't implement every method declared in the interface, Java will raise an error. But if you want to implement just some methods, than you can define the class as `abstract` (`public abstract class ...`).

When you use the `abstract` keyword, you can't create new object using the keyword `new`, the abstract class must be implemented in another class.

It is also possible to extend interfaces with other interfaces (inherit interfaces).

Overloading

The *overloading* allows you to define more methods with the same name but with different parameters, so that the right method gets called depending on which parameters are inserted when we call that method. Here's an example:

```
class A {
    String foo(X xref) {
        return "foo 0 A";
    }
}
class B extends A {
    String foo(X xref) {
        return "foo 0 B";
    }
}
class C extends B {
    String foo(Y yref) {
        return "foo 0 C";
    }
}

A a = new A();
B b = new B();
C c = new C();
X x = new Y();
Y y = new Y();

a.foo(y); //foo 0 A, because Y extends X
b.foo(x); //foo 0 B
c.foo(x); //foo 0 B!! Since foo() in C takes a Y variable as parameter, it can't
take x (explicit cast is needed), therefore foo() gets executed from class B,
which takes an X variable as parameter.
```

Exceptions

⚠ **Pay attention** to the `catch` blocks' order.. The one about the more restrictive exception must come before and the less restrictive at the end.

Generic programming (*Generische Programmierung*)

For each primitive type there's a corresponding class called *wrapper class* (*Wrapper Klasse*), which can be obtain by writing the first letter uppercase (but **`Character`** for `char` and **`Integer`** for `int`!).

The change from a primitive type to the corresponding wrapper it's automatic and it is called *boxing*.

A new object of `Integer` type can be crated using the method `valueOf(int number)`, for example `Integer i = Integer.valueOf(5)` creates an `Integer i` of value `5`. It is possible to get the value of an object `Integer` by using the methods `intValue()` or `doubleValue()`.

⚠ When you do a boxing and you want to compare two values, it is better to use `.equals()`.

`compareTo()`

`compareTo()` can be use to compare two objects by defining an order relation (as seen in DiskMat). The return value is less or greater then `0` or equal to `0` depending on the order of the two objects (or if they are the same in the order).

Primitive Type	Objects
`if (a < b) { ...`	`if (a.compareTo(b) < 0) { ...`
`if (a <= b) { ...`	`if (a.compareTo(b) <= 0) { ...`
`if (a == b) { ...`	`if (a.compareTo(b) == 0) { ...`
`if (a != b) { ...`	`if (a.compareTo(b) != 0) { ...`
`if (a >= b) { ...`	`if (a.compareTo(b) >= 0) { ...`
`if (a > b) { ...`	`if (a.compareTo(b) > 0) { ...`

To order a *collection* you can use the method `sort()` from the `Collections` class (in which there are other useful methods to handle the collections). This method can be used iff. the `compareTo()` method from the `Comparable` interface is defined inside the class of the collection type. I.e. a `Collection<E>` must implement `Comparable`, by defining the `compareTo(E other)` method. In this way it will be possible to use `Collection.sort()`.

Sometime when implementing the `compareTo()` method it is useful make a subtraction between the two values, but you have to be careful when working with `double` types variables, in this case it is better to use `Math.signum(double)`.

`compareTo()` is consistent (*konsistent*) if ∀ `a`, `b`: `((a.compareTo(b)==0)==(b.compareTo(a)==0))`. It is recommended to have it consistent.

`Collections` framework

Three main important interfaces: `List`, `Map` and `Set`.

ADT	Implementationen	Vorteile	Nachteile	Einsatzbeispiel
List	ArrayList LinkedList	Elemente in Reihenfolge des Einfügens gespeichert, Operationen am Ende schnell	Langsame suche, langsames hinzufügen oder entfernen irgendwelcher (beliebiger) Elemente	Zeilen einer Datei, GUI Elemente, Liste von Konten
Set	HashSet TreeSet	Menge von Unikaten die schnell durchsucht werden kann	Kein Index, kein Zugriff auf beliebige Elemente	Unterschiedliche Wörter in Text, Lotteriezahlen
Map	HashMap TreeMap	Speichert Beziehungen zwischen "key" und "value" Paaren von Objekten	Spezielle Ansammlung, keine Umkehrung der Beziehungen	Zählen von Wörtern oder anderen Objekten, Telefonbuch, Adressbuch

Pros and cons between the different implementation:

ADT	Implementation	Order	Pros	Cons
`List`	`ArrayList`	as inserted	Accessing an element (`get()`, `set()`, ...) requires $\mathcal{O}(1)$	Adding an element at the beginning of the list is in $\mathcal{O}(n)$
	`LinkedList`	as inserted	Adding an element at the beginning of the list is in $\mathcal{O}(1)$	Accessing an element (`get()`, `set()`, ...) requires $\mathcal{O}(n)$
`Set`	`TreeSet`	ascending (with `CompareTo()`)	Extracting min(/max) requires $\mathcal{O}(1)$	Searching an element requires $\mathcal{O}(\log n)$
	`HashSet`	not defined	Almost all operations are in $\mathcal{O}(1)$	The elements don't have a defined order
	`LinkedHashSet` (`extends HashSet`)	as inserted	Like `HashSet` (almost) and elements ordered	A bit less efficient than `HashSet`
`Map`	`TreeMap`	See above	See above	See above
	`HashMap`			
	`LinkedHashMap`			

`Iterator`

With a *foreach* cycle, of the form `for(E e : set){}` each `e` value is *read-only*, hence you're not allowed to delet the element in the set. to solve this problem you can use the iterators. The `Iterator` interface contains three methods:

`hasNext()`	returns `true` if there are more elements to examine
`next()`	returns the next element from the collection (throws a `NoSuchElementException` if there are none left to examine)
`remove()`	removes the last value returned by `next()` (throws an `IllegalStateException` if you haven't called `next()` yet)

Here's an example of its use:

```
Iterator<Integer> itr = scores.iterator();
System.out.println(scores); // [38, 43, 72, 87, 94]
while (itr.hasNext()) {
    int score = itr.next();

    // eliminate any failing grades
    if (score < 60) {
        itr.remove();
    }
}
System.out.println(scores); // [72, 87, 94]
```

Systematic programming

You write a *postcondition* iff. you're sure that the program can reach that point (if there aren't any exceptions before).

***Hoare triple* (*Hoare Tripel*)**

A *hoare triple* is made of a *precondition* `P`, a *statement* (*Anweisung[en]*) `S`, and a *postcondition* `Q`: `{P} S {Q}`. The triple is valid iff.: `P` is valid before the execution of `S` $\implies$ `Q` is valid after the execution of `S`.

Assignment (*Zuweisung*)

To verify the validity of a postcondition with an assignment in `S` you can define a `Q'` by substituting variables in `Q` with their respective definition in `S`. Then you have to verify that `P` $\implies$ `Q'`.

Example

```
{z != 1}
    y = z*z;
{y != z}
```

In this case `Q'` is `{z*z != z}`, we can show that `P` $\not\implies$ `Q'` (for example for `z=0`), hence the triple is not valid.

Sequences of statements (*Folgen von Anweisungen*)

To verify the hoare triple `{P} S1;S2 {Q}`, you have to verify if there's a statement `R` such that:

1. `{P} S1 {R} is valid **and**
2. `{R} S2 {Q} is valid

Example

```
{z >= 1}
    y = z+1;
//R
    w = y*y;
{w > y}
```

In this case `R` is `{y > 1}`, because in that case `{z >= 1} y = z+1; {y > 1}` and `{y > 1} w = y*y; {w > y}` would be both valid.

`If`-*statement*

You have to verify that the postcondition is true whatever if-block the program execute. More formally we have the following: the hoare triple `{P} if b S1 else S2 {Q}` is valid iff.:

1. `{P && b} S1 {Q1}` is valid **and**
2. `{P && !b} S2 {Q2}` is valid **and**
3. `(Q1 || Q2)` $\implies$ `Q`

Example

```
{true}
if (x > 7) { y = x; }
else { y = 20; }
{y > 5}
```

- Let `Q1` be `{y > 7}`, and `Q2` be `{y == 20}` (also other statements can work here).
- With the assignment rules we can say that
  - `{true && x > 7} y = x; {y > 7}` is valid and
  - `{true && x <= 7} y = 20; {y == 20}` is valid
- Furthermore, `(y>7 || y==20)` $\implies$ `y>5`

Hence the triple is valid.

Weakest precondition (*"Schwächste" Vorbedingung*)

- `P1` is stronger *(stärker)* than `P2` $\overset{\text{def.}}{\iff}$ `P1` $\implies$ `P2`
- `P1` is weaker (*schwächer*) then `P2` $\overset{\text{def.}}{\iff}$ `P2` $\implies$ `P1`

The goal is to find the weakest precondition (`wp(S1;S2;...,Q)`) and the strongest postcondition so that we can always substitute them with something stronger or weaker respectively.

Find `wp(S1;S2;...,Q)`

To find `wp(S1;S2;...,Q)` you have to start from `Q` and go backward to `S1`. In case there's an `if`-*statement* you have to do a case distinction; you have that `wp(if b S1 else S2, Q)` is `(b && wp(S1,Q)) || (!b && wp(S2,Q))`

⚠ **Be careful** when variables with the same name swap!

Loop

For loops you can use the invariant , which, always holds, not matter how many times the loop repeat. For an invariant `I` and a loop condition `B` , the triple is valid iff $\exists$ `I` such that:

1. `P` $\implies$ `I` the invariant holds at the beginning (outside the loop)
2. `{I && B} S {I}` After one loop iteration the invariant still holds
3. `(I && !B)` $\implies$ `Q` The invariant and the fact that the loop condition (hence the loop ends) implies the postcondition `B`

Termination (*Terminierung*)

In loops

To prove that a program terminates, you usually show that by assigning a positive integer number to the loop state (after ending each iteration), so that at each step the number decrease. By showing that this number reaches 0 when the loop condition is false, you prove that the loop has a finite number of cycles that bring the number to 0.

Example

You can show that a loop that goes through every element of a `LinkedList` terminates by stating that the size of the uncovered list becomes smaller at each iteration, hence it will get to 0, therefore the loop terminates.

In a recursion

You can show that a recursion terminates in a inductive way:

1. Show that the base case is correctly handled
2. Show that each recursive call work on a problem which is strictly smaller then the current problem
3. Show that, assuming each recursive call correctly solves the subproblem, this method correctly solve the current problem ("induction step")

Liskov substitution principle

> Let $\phi(x)$ be a property provable about objects x of type T. Then $\phi(y)$ should be true for objects y of type S where S is a subtype of T.

from [wikipedia]

Heuristic for planning

1. Identify the classes
2. Elaborate the connections between classes
3. Attributes
4. Methods

Repeat these steps multiple times.