Technische Hochschule Rosenheim
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Programming Basics – WiSe21/22

Control structures

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Concept of control structures

- Control structures = all linguistic resources which control the execution order of statements

- Control structures can be used to formulate complex algorithms that solve challenging problems.

- Description forms for algorithms:
  - Natural language
  - Source code
  - Neutral, abstract form
    (e.g. structure chart or flow diagram)
    -> presentation of the solution idea, visualisation key structures

Chapter 3: Control structures

3.1 Statement series (sequence)

3.2 Selection structures (selections)

3.3 Repeating structures (loops or iterations)

3.4 Effects on variables

Statement series (sequence) (1)

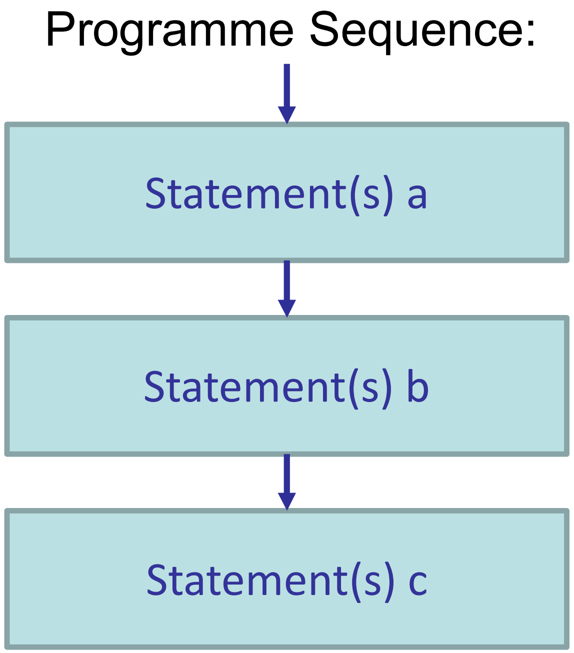
- So far: simple statements (instructions)
  - Variable definitions, value assignments and output statements
  - Cannot be broken down into smaller statements

- Control structures = compound statements
  - Complete, subordinate statements as building blocks

- Simplest control structure: sequence
  = statement series = succession of statements (instructions)

Statement series (sequence) (2)

- Individual statements that are processed sequentially from top to bottom



Based on: Habelitz (2012): Programmieren lernen mit Java

Statement series (sequence) (3)

- Recommended implementation in the programme:
  - Each individual statement should be on a new line

```
Statement a:  System.out.println("The first line!");
Statement b:  System.out.println("The second line!");
Statement c:  System.out.println("The third line!");
```

Chapter 3: Control structures

3.1 Statement series (sequence)

3.2 Selection structures (selections)

3.3 Repeating structures (loops or iterations)

3.4 Effects on variables

Selection structures

- A branch allows conditional execution of statements (selection)
  - Execution of individual statements can be made dependent on whether a certain condition is fulfilled

- Two different types:
  - `if` statements
  - `switch case` statements

`if` statement (1)

- `if` statement (= "conditional statement", "branch") consists of
  1. a condition and
  2. a subordinate statement

- Subordinate statement is only executed if the condition is met, otherwise it is skipped
- Syntax:

```
if (condition)
    statement;
```

```
if (condition)
{
    statementA;
    statementB;
}
```

`if` statement (2)

- Example: output the text "Warning!" if the variable `temperature` has a negative value; otherwise do not output anything

```
if (temperature < 0)
  System.out.println(“Warning!");
```

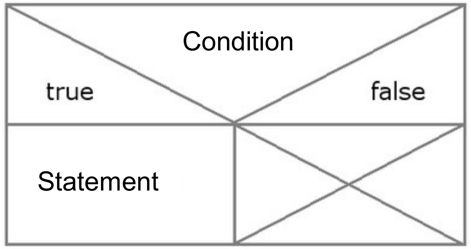
- First check the condition `temperature < 0` ….
  - *Evaluates the condition to `true`?*

    Execute the output statement
  - *Evaluates the condition to `false`?*

    Skip the output statement

`if` statement (3)

- Structure chart for `if` statements:



- Condition = expression with true/false result
  - Expression is a `boolean` expression
  - Expression can either be "true" or "false“, no third possibility

`if` statement (4)

- Condition: comparison of two (numerical) expressions
- Comparison using relational operator (= comparison operator)

Operator	Meaning	Precedence
<	less than	5
<=	less than or equal to	5
>	greater than	5
>=	greater than or equal to	5
==	equal to	6
!=	not equal to	6

Examples:

```
if (a == 0)
if (b > 10)
if (number <= 100)
```

Exercise – Simple `if` statement

- Live exercise
  - Complete Task 1 on the live exercises sheet “Control structures”
  - You have 5 minutes.

Two-way `if` statements (1)

- Two-way `if` statement: extension of the simple `if` statement
- Semantics:
  - *Is the condition met?*

    Execute the first statement
  - *Otherwise (if the condition is not met)*

    Execute the second statement
- Syntax:

```
if (condition) {
    statement a
}
else {
    statement b;
}
```

Multiple statement series are combined into one unit
= block

Blocks as statement (instruction) groups

- Sequence is grouped into a block with curly brackets
- Syntax:

```
{
   statement;
   statement;
   statement;
     . . .
}
```

- Empty block: Block without statements (instructions)

```
{   }
```

- Empty statement: equivalent to an empty block

```
;
```

Two-way `if` statements (2)

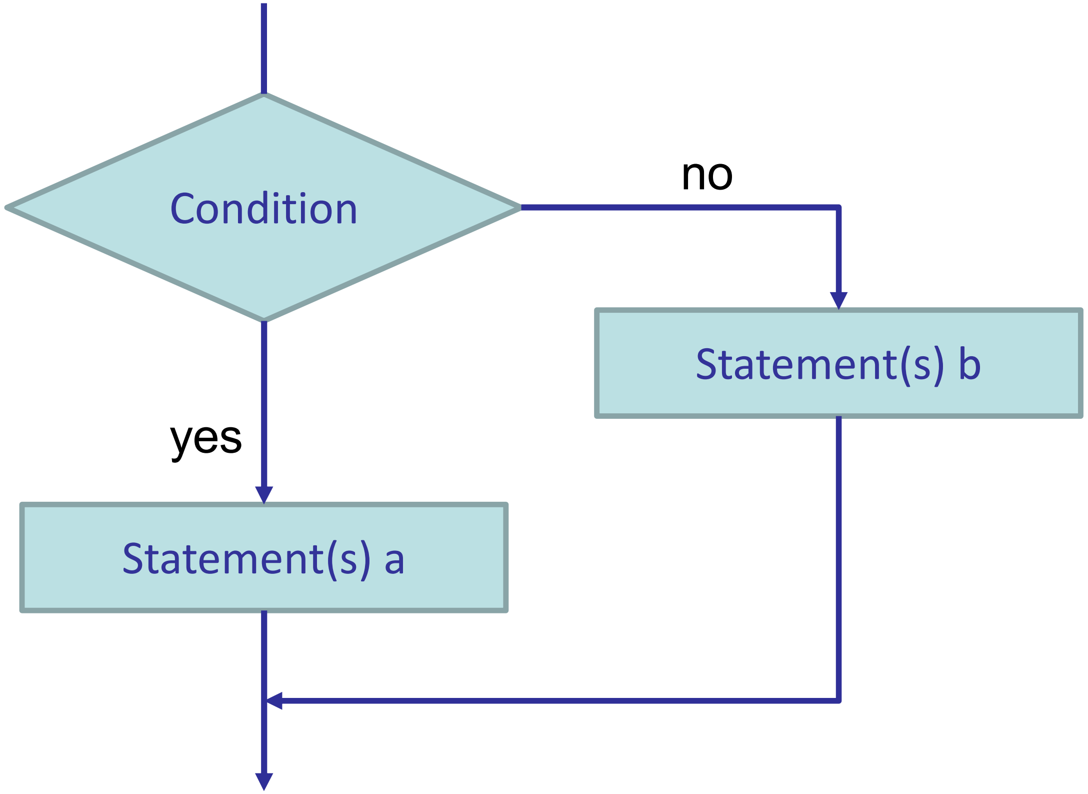
- Example:

```
double x = ...;
if (x >= 0)
  System.out.println(Math.sqrt(x));
else
  System.out.println("undefined");
```

- Important note: there is always
  - precisely one of the two statements executed, but
  - never both, and
  - never none.

Two-way `if` statements (3)

- Programme Sequence:



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Exercise – Two-way `if` statement

- Live exercise
  - Complete Task 2 on the live exercises sheet “Control structures”
  - You have 5 minutes.

Excursus:
Comparison of floating-point values

- Floating-point arithmetic is affected by rounding errors!
- Example:

```
double a = 1.0/3.0;
double b = 10 + a – 10;
if (a == b)
  System.out.println("the same");
else
  System.out.println("different");
```

Unexpected results!

- Compare floating-point values to ranges, not individual values

```
if (Math.abs(a-b) < 1E-10))
   ...
```

Appropriate tolerance limit, depending on the purpose

Nested `if` statements

- `if` statement
  - controls other statements
  - is itself a statement
  - can be subordinated to another one: nested `if` statements
- Example: does x lie between 0 and 100?

```
if (x < 0) {
    System.out.println("below 0");
} else {
       if (x > 100) {
              System.out.println("over 100");
       } else {
             System.out.println("between 0 and 100");
       }
}
```

Dangling else (1)

- Assignment problem with two `if` and one `else`
- Interpretation options:

1. `else` assigned to the first `if`

```
if (condition)
  if (condition)
        statement 1;
else
    statement 2;
```

2. `else` assigned to the second `if`

```
if (condition)
  if (condition)
        statement 1;
  else
        statement 2;
```

Dangling else (2)

- However, compiler ignores indentation, orients itself based on the programme text: in both cases the same!
- Ambiguity not allowed => rule:
  - `else` belongs to the last free `if` in the text of the same block ("free" `if` = not yet assigned to an `else`)
- Explicit brackets create clarity and avoid errors

```
if (condition) {
  if (condition)
        statement 1;
}
else
    statement 2;
```

```
if (condition) {
  if (condition)
        statement 1;
  else
        statement 2;
}
```

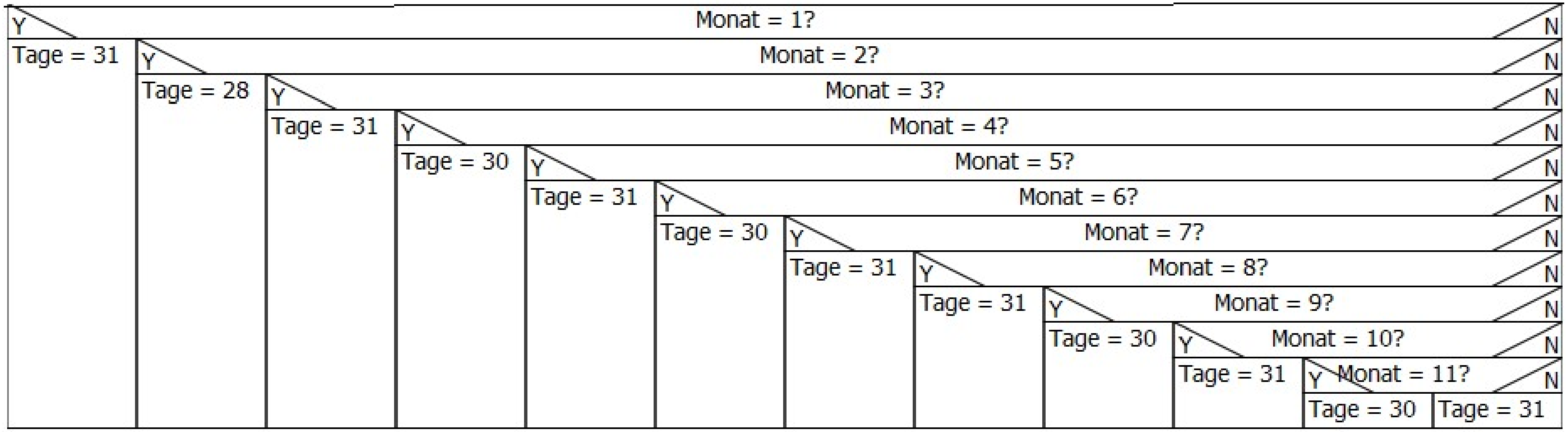
Exercise – `if` statement

- Live exercise
  - Complete Task 3 on the live exercises sheet “Control structures”
  - You have 5 minutes.

`if` cascade (1)

- ➢ Deep nesting of `if` statements = `if` cascade
- ➢ Typically: comparison of a value with a list of possibilities
- ➢ Example: convert month number to number of days

Legend:
Monat = month
Tage = days
Y = yes
N = no



Monat = 1? Y N
Tage = 31
Monat = 2? Y N
Tage = 28
Monat = 3? Y N
Tage = 31
Monat = 4? Y N
Tage = 30
Monat = 5? Y N
Tage = 31
Monat = 6? Y N
Tage = 30
Monat = 7? Y N
Tage = 31
Monat = 8? Y N
Tage = 31
Monat = 9? Y N
Tage = 30
Monat = 10? Y N
Tage = 31
Monat = 11? Y N
Tage = 30
Tage = 31

`if` cascade (2)

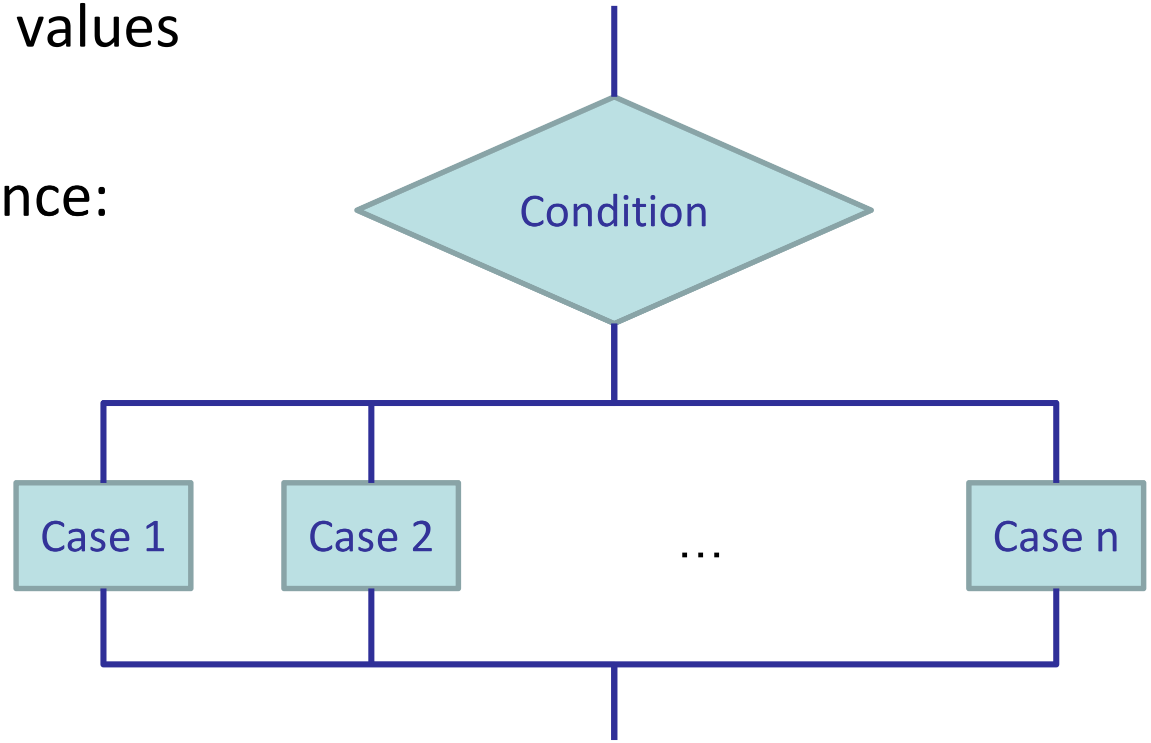
- Layout for `if` cascade: consistent indentation is abandoned to limit the depth of indentation

```
if (month == 1)
  days = 31;
else if (month == 2)
  days = 28;
else if (month == 3)
  days = 31;
else if (month == 4)
  days = 30;
. . .
else if (month == 12)
  days = 31;
```

`switch case` statements (1)

- A `switch case` statement is basically a simple type of `if` cascade in which the result of a particular expression is compared to a list of fixed values

- Program Sequence:



Based on: Habelitz (2012): Programmieren lernen mit Java

`switch case` statements (2)

- Syntax:

```
switch (expression) {
 case label:
      statement(s);
 case label:
     statement(s);
   . . .
}
```

- Processing:
  1. The expression is calculated (only once)
  2. The result is searched for under the `case` labels
  3. Statements in the appropriate branch are executed until a `break` statement is reached
- If no `case` label matches: no effect

switch case statements (3)

- Example: converting months into days

```
switch (month) {
 case 1:
  days = 31;
     break;
 case 2:
  days = 28;
    break;
 case 3:
    . . .
 case 12:
  days = 31;
     break;
}
```

`switch case` statements (4)

- case labels
  - Must be unique
  - Must all be calculable by the compiler
  - Only constant expressions allowed, which consist of `final` variables and literals
- Multiple `case` labels allowed per branch:

```
switch (month) {
 case 1:
 case 3:
 case 5:
 case 7:
 case 8:
 case 10:
 case 12:
   days = 31;
      break;
 ...
}
```

switch case statements (5)

- Default branch
  - The label default will be executed if no other label is applicable
  - May only occur once
  - Must be the last label
  - Corresponds to a final else in the if cascade
  - Always useful!

```
switch (month) {
 case 2:
   days = 28;
      break;

 case 4:
 case 6:
 case 9:
 case 11:
   days = 30;
      break;

 default:  //all remaining months
   days = 31;
      break;
}
```

Exercise – `switch case` statements

- Live exercise
  - Complete Task 4 on the live exercises sheet “Control structures”
  - You have 8 minutes.

switch case statements (6)

- Fall through
  - Behaviour in case of a missing break statement at the end of a branch
  - Rarely useful

```
switch (n) {
 case 1:
   System.out.println("one");
      //no break - fall through
 case 2:
   System.out.println("two");
   //no break - fall through
 case 3:
   System.out.println("three");
   //no break - fall through
}
```

Chapter 3: Control structures

3.1 Statement series (sequence)

3.2 Selection structures (selections)

3.3 Repeating structures (loops or iterations)

3.4 Effects on variables

Repeating structures

- Instruments for programme control
  - Certain statement blocks are not only executed once, but executed several times
  - Decision about repetition depends on a condition
    - Pre-test (top-controlled) loops
      (statements may possibly be skipped and not executed at all)
    - Post-test (bottom-controlled) loops
      (statements are executed at least once)

`while` loop (1)

- Java syntax with example:

```
while (condition) {
    statement(series);
}
```

Top of loop

Bottom of loop

- `boolean` expression condition controls the flow:

1. Evaluate condition
2. If `true`:
   a) Execute statement (or statement series)
   b) Back to 1

   If `false`: loop ends

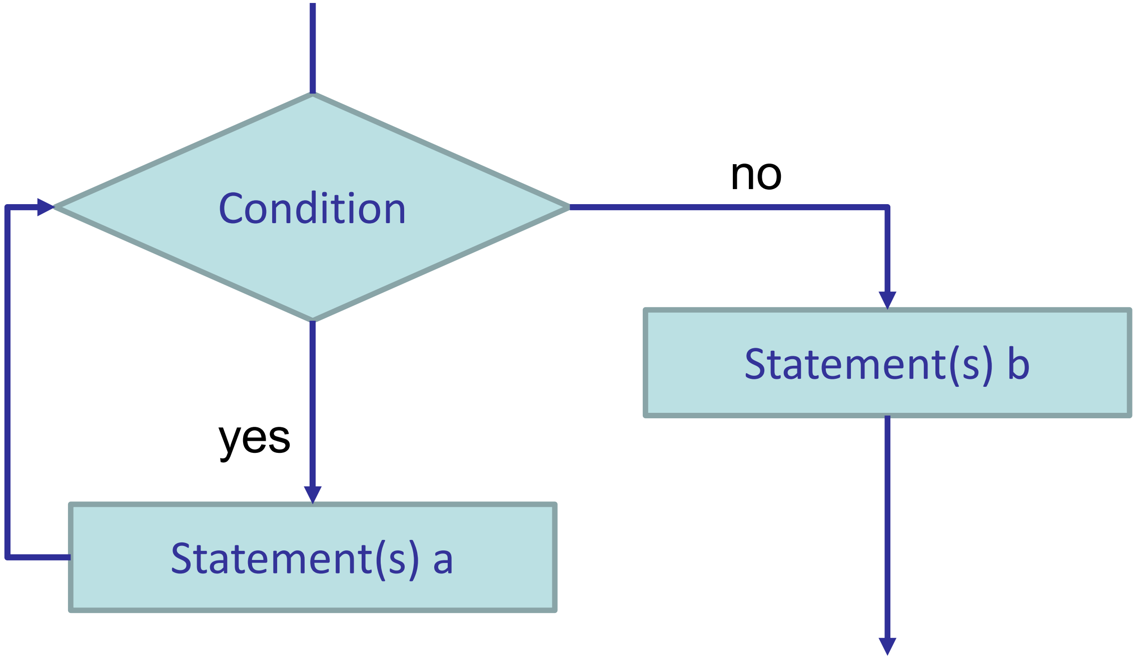
`while` loop (2)

- Example:

```
int counter = 0;

while (counter < 10) {
  System.out.println(counter);
    counter = counter + 1;
}
```

- Programme Sequence:



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while loop (3)

- Alternatives to formulating count-controlled (i.e. for) loops:
  - Start with 0 or 1
  - Test the end value with < or <=
- Common practice: start with 0, test with <
  - End value = number of loop iterations

- Frequently used: short form for value assignments (operator assignment)

```
x = x + 2;      is equivalent to      x += 2;
```

```
x = x * 7;      is equivalent to     x *= 7;
```

  - …. further binary operators

Exercise – `while` loop

- Live exercise
  - Complete Task 5 on the live exercises sheet “Control structures”
  - You have 8 minutes.

Increment and decrement operators (1)

- Loop variables are often counted up or down in increments of one
  - Initial situation:

```
variable = variable + 1;
variable = variable -1;
```

  - With operator assignments:

```
variable += 1;
variable -= 1;
```

  - With increment operator ++ (decrement operator --)

```
variable++;
variable--;
```

Increment and decrement operators (2)

- Java distinguishes between two types:

1. Prefix operators

```
++variable;
--variable;
```

✓ Statement changes variable

✓ Expression: new value of the variable

```
int a = 1;
System.out.println(++a);   // a = 2, then output 2
System.out.println(++a);   // a = 3, then output 3
System.out.println(a);    //output 3
```

2. Postfix operators

```
variable++;
variable--;
```

✓ Statement changes variable

✓ Expression: old value of the variable

```
int a = 1;
System.out.println(a++);  // output 1, then a = 2
System.out.println(a++);  // output 2, then a = 3
System.out.println(a);    // output 3
```

Nested loops

- Nested loops: `while` loop is itself a statement => can be in the body of another loop

- Schematic representation:

```
while (condition) {           //outer loop
  while (condition) {       //inner loop
        statement(series);
    }
}
```

Exercise – Nested `while` loop

- Live exercise
  - Complete Task 6 on the live exercises sheet “Control structures”
  - You have 8 minutes.

`do` loop (1)

- Syntax:

```
do {
     statement(series);
} while (condition);
```

- Method of operation:
  1. Execute statement
     (or statement series)
  2. Evaluate condition
  3. If `true`: back to 1

     If `false`: loop ended

ONLY FOR COMPARISON:

```
while (condition) {
     statement(series);
}
```

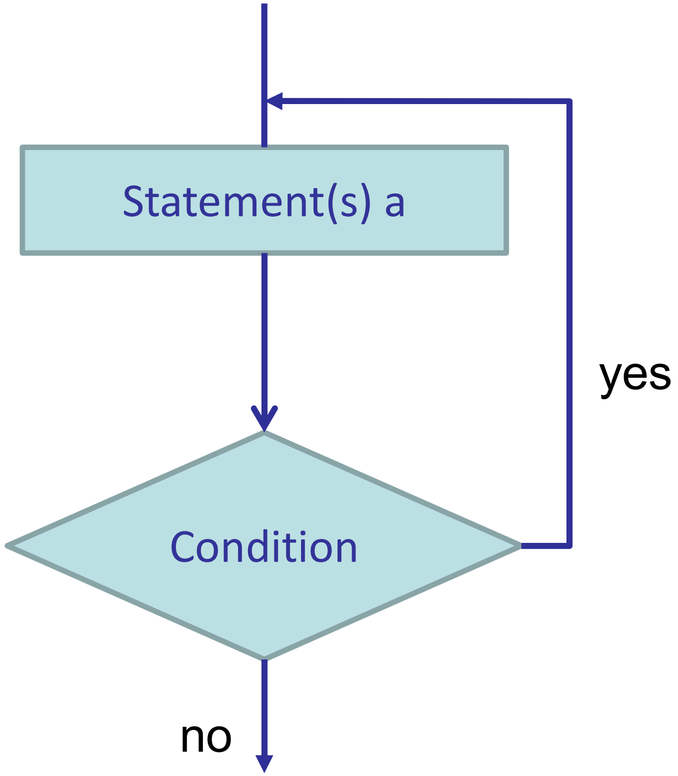
do loop (2)

Example:

```
int number = 0;

do {
   System.out.println(number);
      number++;
    } while (number < 100);
```

Programme Sequence:



Based on: Habelitz (2012): Programmieren lernen mit Java

`for` loop (1)

- `for` loops = linguistic devices for counting loops
- Syntax:

```
for (start; condition; update) {
    statement(series);
}
```

- Method of operation:
  1. Execute “Start” statement
  2. As long as the condition is met
     a) Execute statement (or statement series)
     b) Execute “update” statement
- Programme sequence same as `while` loop, no distinction

`for` loop (2)

- Example:

```
for (int i = 0; i < 10; i++) {
      System.out.println(i);
}
```

is equivalent to

```
int i = 0;

while (i < 10) {
  System.out.println(i);
    i++;
}
```

- `for` loop is more compact than `while` loop

Exercise – `for` loop

- Live exercise
  - Complete Task 7 on the live exercises sheet "Control structures"
  - You have 8 minutes.

`for` loop vs. `while` loop

- `for` and `while` loops can replace each other

```
for (start; condition; update) {
    statement(series);
}
```

```
{
  start;
   while (condition) {
         statement(series);
         update;
    }
}
```

- Validity range of the counter variables of `for` loops: header and body => consecutive `for` loops with the same control variables allowed

```
for (int i= 0; i < 10; i++) {
    System.out.println(i);
}
for (int i = 0; i < 10; i++) {
    System.out.println(i);
}
```

Selection of loop variant

- When `for`, when `while`?
- Criteria:
  - Number of loop iterations known beforehand => `for`
  - Single loop variable, simple counting up or down (increment, decrement, etc.) => `for`
  - Initialisation, test, count up or down fit in one line => `for`
  - Otherwise : `while`

jump statements (1)

- Should not be used in well-structured programmes
- However, there are situations in which the source code can be simplified and/or structured more clearly

- Loop termination with `break`

```
while (true) {
  int n;
    // determine n …
  if (n == 0)
         break;
    //process n
}
```

Leaving an **endless loop** with `break`

jump statements (2)

- Skipping statement(s) with `continue`

```
for (int i = 1; i <= 10; i++) {
   if (i == 5) {
     continue;
       }
   System.out.println(i);
}
```

What do the following do?

- `break` statement
  - Terminates a `switch`, `while`, `do` or `for` statement, that immediately surrounds the `break` statement

- `continue` statement
  - Interrupts the current loop iteration of a `while` , `do` or `for` loop and jumps to the repeat condition of the immediately surrounding loop

Chapter 3: Control structures

3.1 Statement series (sequence)

3.2 Selection structures (selections)

3.3 Repeating structures (loops or iterations)

3.4 Effects on variables

Validity ranges - scope (1)

- Validity range (i.e. scope) of a variable
  - starts with the definition (declaration)
  - ends with the block containing the definition
- Outside the scope: variable does not exist anymore
- Compiler checks validity ranges

Validity ranges - scope (2)

- Example:

```
public class Summation {
  public static void main(String[] args) {
        int n = 100;
        int sum = 0;
        int z = 0;
        while (z < n) {
          int square = z * z;
            z++;
            sum = sum + square;
        }
        System.out.println(sum);
    }
}
```

Scope of the variable `square`

Scope of the variable `z`

Naming conflicts

```
public class Summation {
  public static void main(String[] args) {
        int n = 100;
        int sum = 0;
        int z = 0;
        while (z < n) {
            int n = z * z;
            z++;
            sum = sum + n;
        }
        System.out.println(sum);
    }
}
```

Duplicate local variable n;
Compiler Message:
Variable ‘n’ already defined in this scope

- ➢ Within the scope of a variable, there must be no other variable with the same name in the source code!

Lifetime

- Time interval in which the variable exists during the runtime of the programme
  - At variable definition (declaration) = creation of the variable
  - At the end of the block: destruction of the variable

```
public class Summation {
  public static void main(String[] args) {
        int n = 100;
        int sum = 0;
        int z = 0;
        while (z < n) {
          int square = z * z;
            z++;
            sum = sum + square;
        }
        System.out.println(sum);
    }
}
```

The variable `square` is repeatedly generated and also destroyed again during programme execution