3. Java - Language Constructs I

Names and Identifiers, Variables, Assignments, Constants, Datatypes, Operations, Evaluation of Expressions, Type Conversions

Educational Objectives

- You know the basic blocks of the programming language Java
- You understand the use of **variables** in a program and you can use them properly
- You know how **values** are defined in the source code (**literals**)
- You are able to read and interpret simple **arithmetic expressions**
- You understand the reasons for a **type system** and are able to determine the type of an expression

Definition: Names and Identifiers

Names denote entities in a program like variables, constants, types, methods, or classes.

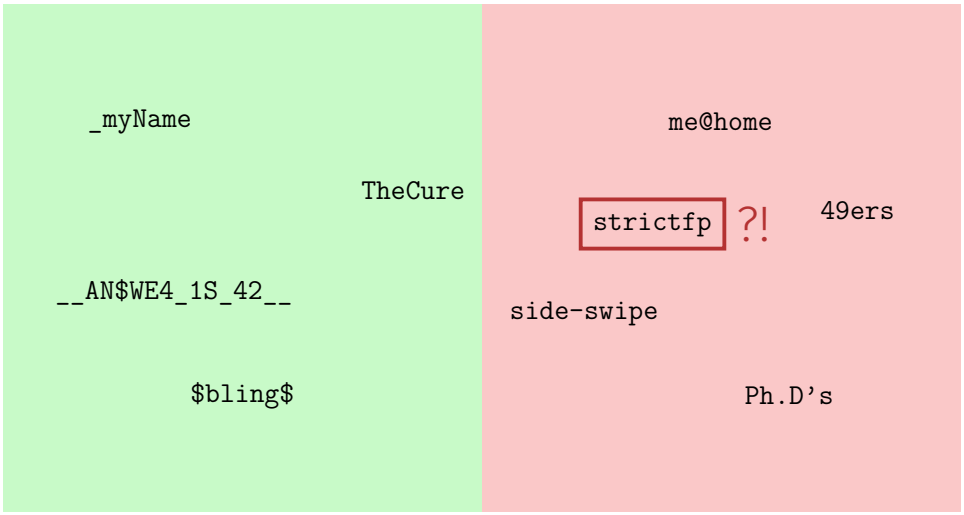
Book on page 21

Names and Identifiers

Allowed names for entities in a program:

- Names begin with a **letter** or the symbols **_** or **$**
- Then, optionally, a sequence of **letters**, **numbers** or the symbols **_** or **$**

Names - what is allowed



Keywords

The following words are already used by the language and cannot be used as names:

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

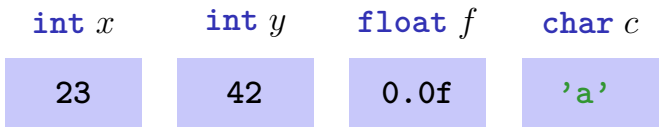
Definition: Variables

*Variables are buckets for values and have a specified **type**.*
*Variables need to be **declared** before first use.*

Book on page 23

Variables

- Variables are **buckets** for a value
- Have a **data type** and a **name**
- The data type determines what kind of values are allowed in the variable



Declaration in Java:

```
int x = 23, y = 42;
float f;
char c = 'a';
```

Initialization

Definition: Constants

Constants are variables that are initialized upon declaration and may not change their value later on.

Book on page 35

Constants

- Keyword **`final`**
- The value of the variable can be set exactly once

```
final int maxSize = 100;
```

Hint: Always use **`final`**, unless the value actually needs to change over time.

Definition: Types

A Type defines a set of values that belong to the type as well as a set of operations that can be performed with the values of the type.

Book on page 24

Definition: Standard Types

Java provides several predefined types for various numeric ranges as well as boolean values and strings.

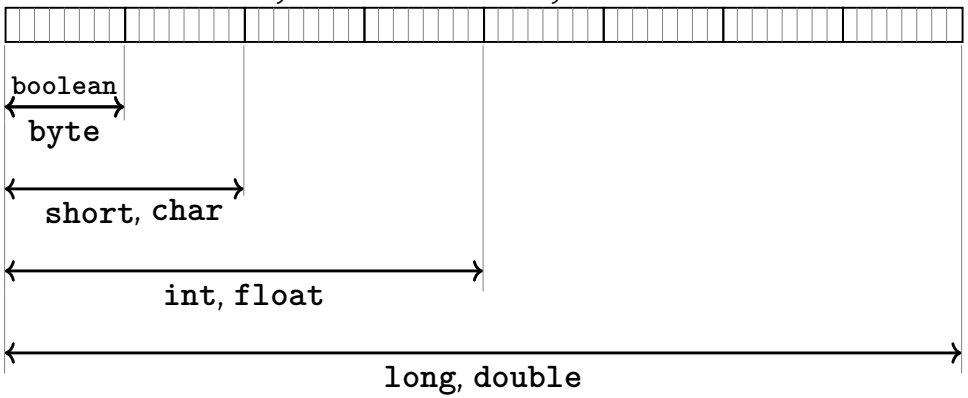
Book on page 24

Standard Types

Data Type	Definition	Value Range	Initial Value
`byte`	8-bit integer	$-128, \ldots, 127$	`0`
`short`	16-bit integer	$-32'768, \ldots, 32'767$	`0`
`int`	32-bit integer	$-2^{31}, \ldots, 2^{31}-1$	`0`
`long`	64-bit integer	$-2^{63}, \ldots, 2^{63}-1$	`0L`
`float`	32-bit floating point	$\pm 1.4E^{-45}, \ldots, \pm 3.4E^{+38}$	`0.0f`
`double`	64-bit floating point	$\pm 4.9E^{-324}, \ldots, \pm 1.7E^{+308}$	`0.0d`
`boolean`	logical value	`true`, `false`	`false`
`char`	unicode-16 character	`'\u0000'`,...,`'a'`,`'b'`,...,`'\uFFFF'`	`'\u0000'`
`String`	string	∞	`null`

Types and Memory Usage

Reminder: Memory cells contain 1 Byte = 8 bit



Definition: Literals

Representation of a value of a standard type in the source code.

Book on page 22 - 23

Literals: Integer Numbers

- Type `int` (or `short`, `byte`)

  `12` : value 12
  `-3` : value -3

- Type `long`

  `25_872_224L` : value $25'872'224$

Hint: Underscores between digits are allowed!

Literals: Floating Point Numbers

are different from integers by providing

- decimal comma

```
1.0 : type double, value 1
1.27f : type float, value 1.27
```

- and/or exponent.

```
1e3 : type double, value 1000
1.23e-7 : type double, value 1.23 · 10^-7
1.23e-7f : type float, value 1.23 · 10^-7
```


Literals: Characters and Strings

- Characters are put into single quotes

```
'a' : Type char, value 97
```

- Strings are put into double quotes:

```
"Hello There!" : Type String
"a" : Type String
```

Mind: Characters and Strings are two different things!

Character: In ASCII Table

0	<NUL>	32	<SPC>	64	@	96	`	128	Ä	160	†	192	¿	224	ǂ
1	<SOH>	33	!	65	A	97	a	129	Å	161	°	193	¡	225	·
2	<STX>	34	"	66	B	98	b	130	Ç	162	¢	194	¬	226	‚
3	<ETX>	35	#	67	C	99	c	131	É	163	£	195	√	227	„
4	<EOT>	36	$	68	D	100	d	132	Ñ	164	§	196	ƒ	228	‰
5	<ENQ>	37	%	69	E	101	e	133	Ö	165	•	197	≈	229	Â
6	<ACK>	38	&	70	F	102	f	134	Ü	166	¶	198	Δ	230	Ê
7	<BEL>	39	'	71	G	103	g	135	á	167	ß	199	«	231	Á
8	<BS>	40	(	72	H	104	h	136	à	168	®	200	»	232	Ë
9	<TAB>	41	)	73	I	105	i	137	â	169	©	201	…	233	È
10	<LF>	42	*	74	J	106	j	138	ä	170	™	202		234	Í
11	<VT>	43	+	75	K	107	k	139	ã	171	´	203	À	235	Î
12	<FF>	44	,	76	L	108	l	140	å	172	¨	204	Ã	236	Ï
13	<CR>	45	-	77	M	109	m	141	ç	173	≠	205	Õ	237	Ì
14	<SO>	46	.	78	N	110	n	142	é	174	Æ	206	Œ	238	Ó
15	<SI>	47	/	79	O	111	o	143	è	175	Ø	207	œ	239	Ô
16	<DLE>	48	0	80	P	112	p	144	ê	176	∞	208	–	240	
17	<DC1>	49	1	81	Q	113	q	145	ë	177	±	209	—	241	Ò
18	<DC2>	50	2	82	R	114	r	146	í	178	≤	210	“	242	Ú
19	<DC3>	51	3	83	S	115	s	147	ì	179	≥	211	”	243	Û
20	<DC4>	52	4	84	T	116	t	148	î	180	¥	212	‘	244	Ù
21	<NAK>	53	5	85	U	117	u	149	ï	181	µ	213	’	245	ı
22	<SYN>	54	6	86	V	118	v	150	ñ	182	∂	214	÷	246	ˆ
23	<ETB>	55	7	87	W	119	w	151	ó	183	∑	215	◊	247	˜
24	<CAN>	56	8	88	X	120	x	152	ò	184	∏	216	ÿ	248	¯
25	<EM>	57	9	89	Y	121	y	153	ô	185	π	217	Ÿ	249	˘
26	<SUB>	58	:	90	Z	122	z	154	ö	186	∫	218	⁄	250	˙
27	<ESC>	59	;	91	[	123	{	155	õ	187	ª	219	€	251	°
28	<FS>	60	<	92	\	124	|	156	ú	188	º	220	‹	252	˝
29	<GS>	61	=	93	]	125	}	157	ù	189	Ω	221	›	253	˛
30	<RS>	62	>	94	^	126	~	158	û	190	æ	222	fi	254	ˇ
31	<US>	63	?	95	_	127	<DEL>	159	ü	191	ø	223	fl	255	

Definition: Assignments

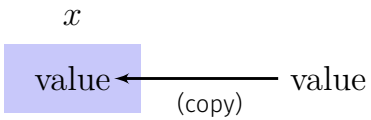
An assignment is used to store a (computed) value into a variable.

Book on page 27

Value Assignment

Copies a value into variable x

- In pseudo code: $x \leftarrow \text{value}$
- In Java: x = value



"=" is the assignment operator **and not a comparison!**
Therefore, `int y = 42` is both a declaration + an assignment.

Value Assignment - Example

```
int a = 3;
double b;

b = 3.141;

int c = a = 0;

String name = "Inf";
```

A **nested** assignment:
The expression `a = 0` stores the value `0` into variable `a`. **and then returns the value**

Definition: Arithmetic Expressions

An arithmetic expression consists of operands and operators and computes a numeric value of a given type.

Book on page 28

Arithmetic Binary Operators

Infix notation: x op y with the following operators

op: + — * / %

modulo

Arithmetic Binary Operators

- Division x `/` y: Integer division if x and y are integer.
- Division x `/` y: Floating-point division if x **or** y is a floating-poing number!

Integer division and modulo

- `5 / 3` evaluates to `1` `-5 / 3` evaluates to `-1`
- `5 % 3` evaluates to `2` `-5 % 3` evaluates to `-2`

Arithmetic Assignment

```
x = x + y
```

⇕

```
x += y
```

```
x -= 3;      // x = x - 3
name += "x"  // name = name + "x"
num *= 2;    // num = num * 2
```

Analogous for `-`, `*`, `/`, `%`

Arithmetic Unary Operators

Prefix notation: `+` x or `-` x

Assuming `x` is `3`

- `2 * -x` evaluates to `-6`
- `-x - +1` evaluates to `-4`

Increment/Decrement Operators

Increment operators `++x` and `x++` have the same effect: $x \leftarrow x + 1$.But different return values:

- **Prefix operator** `++x` returns the **new** value:

```
a = ++x;   ⟺   x = x + 1; a = x;
```

- **Postfix operator** `x++` returns the **old** value:

```
a = x++;   ⟺   temp = x; x = x + 1; a= temp;
```

Analogous for `x--` and `--x`.

Increment Operator - Example

Assuming `x` is initially set to `2`

- `y = ++x * 3` evaluates to: `x` is `3` and `y` is `9`
- `y = x++ * 3` evaluates to: `x` is `3` and `y` is `6`

Expressions

- represent **computations**
- are either **primary**
- or **composed** …
- …from other expressions, using **operators**
- are statically typed

Analogy: Construction kit

Expressions - Example

primary: "`-4.1d`" or "`x`" or `"Hi"`

composed: "`x + y`" or "`f * 2.1f`"

The type of "`12 * 2.1f`" is `float`

Celsius to Fahrenheit

```
public class Main {
    public static void main(String[] args) {
        Out.print("Celsius: ");
        float celsius = In.readFloat();
        float fahrenheit = 9 * celsius / 5 + 32;
        Out.println("Fahrenheit: " + fahrenheit);
    }
}
```

15° Celsius are 59° Fahrenheit

Celsius to Fahrenheit - Analysis

```
9 * celsius / 5 + 32
```

- Arithmetic expression,
- contains three literals, one variable, three operator symbols

Where are the brackets in this expression?

Rule 1: Precedence

Multiplicative operators (`*`, `/`, `%`) have a higher precedence ("bind stronger") than additive operators (`+`, `-`).

```
9 * celsius / 5 + 32
```

means

```
(9 * celsius / 5) + 32
```


Rule 2: Associativity

Arithmetic operators (`*`, `/`, `%`, `+`, `-`) are left-associative: in case of the same precedence, the evaluation happens from left to right.

```
9 * celsius / 5 + 32
```

means

```
((9 * celsius) / 5) + 32
```


Rule 3: Arity

Unary operators `+`, `-` before binary operators `+`, `-`.

```
9 * celsius / + 5 + 32
```

means

```
9 * celsius / (+5) + 32
```

Bracketing

Any expression can be bracketed unambiguously using the

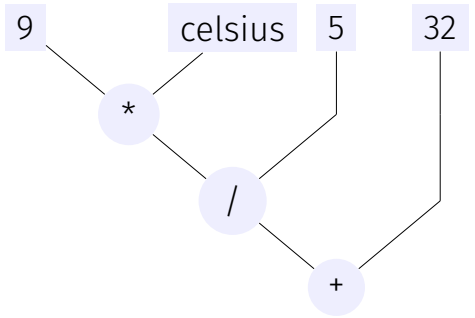
- associativities
- precedences
- arities (number of operands)

of the involved operators.

Expression Trees

Bracketing leads to an expression tree

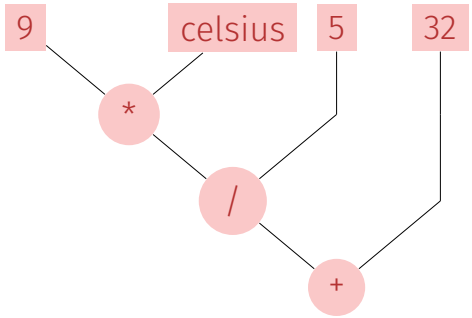
```
(((9 * celsius) / 5) + 32)
```



Evaluation Order

"From leafs to the root" in the expression tree

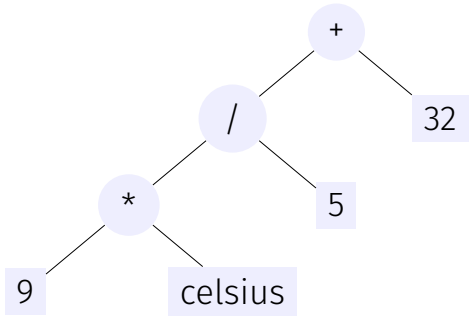
```
9 * celsius / 5 + 32
```



Expression Trees – Notation

Usual notation: root on top

```
9 * celsius / 5 + 32
```



Definition: Type System

A type system is a set of rules that are applied to the different constructs of the language.

Book on page 24

Type System

Java festures a **static** type system:

- All types must be declared
- If possible, the compiler checks the typing …
- …otherwise it's checked at run-time

Advantages of a static type system

- **Fail-fast** Bugs in the program are often found already by the compiler
- Understandable code

Type errors - by Example

```
int pi_ish;
float pi = 3.14f;

pi_ish = pi;
```

Compiler error:

```
./Root/Main.java:12: error: incompatible types: possible lossy conversion
                                                    from float to int
        pi_ish = pi;
                 ^
```


Explicit Type Conversion

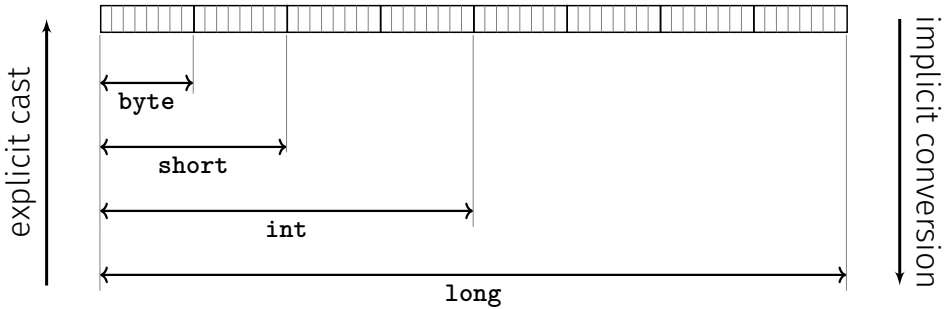
```
int pi_ish;
float pi = 3.14f;

pi_ish = (int) pi;
```

Explicit type conversion using casts (type)

- Statically type-correct, compiler is happy
- Run-time behavior: depends on the situation

  Here: loss of precision: `3.14` $\Rightarrow$ `3`
- Can crash a program at run-time

Type Conversion - Visually



Potential loss of information when casting explicitly, because less memory available to represent the number

Definition: Mixed Expressions

A mixed expression consists of operands of different types.

Book on page 70

Mixed Expressions, Conversion

- Floating point numbers are more general than integers.
- In mixed expressions integers are converted to floating point numbers.

```
9 * celsius / 5  + 32
```


Type Conversions for Binary Operations

Numeric operands in a binary operation are being converted according to the following rules:

- If both operands have the same type, no conversion will happen
- If one operand is **`double`**, the other operand is converted to **`double`** as well
- If one operand is **`float`**, the other operand is converted to **`float`** as well
- If one operand is **`long`**, the other operand is converted to **`long`** as well
- Otherwise: Both operands are being converted to **`int`**