Technische Hochschule Rosenheim
Technical University of Applied Sciences

Programming Basics – WiSe21/22

Classes

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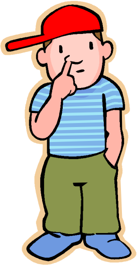
Chapter 7: Classes

5.1 Definition of terms and characteristic features of classes

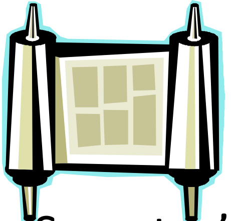
5.2 Programming classes in Java

Similar objects

- Some objects are somehow similar
- Can be grouped together



Peter



Socrates' scroll

Peter's bike

Tina

Luther's book

Lara

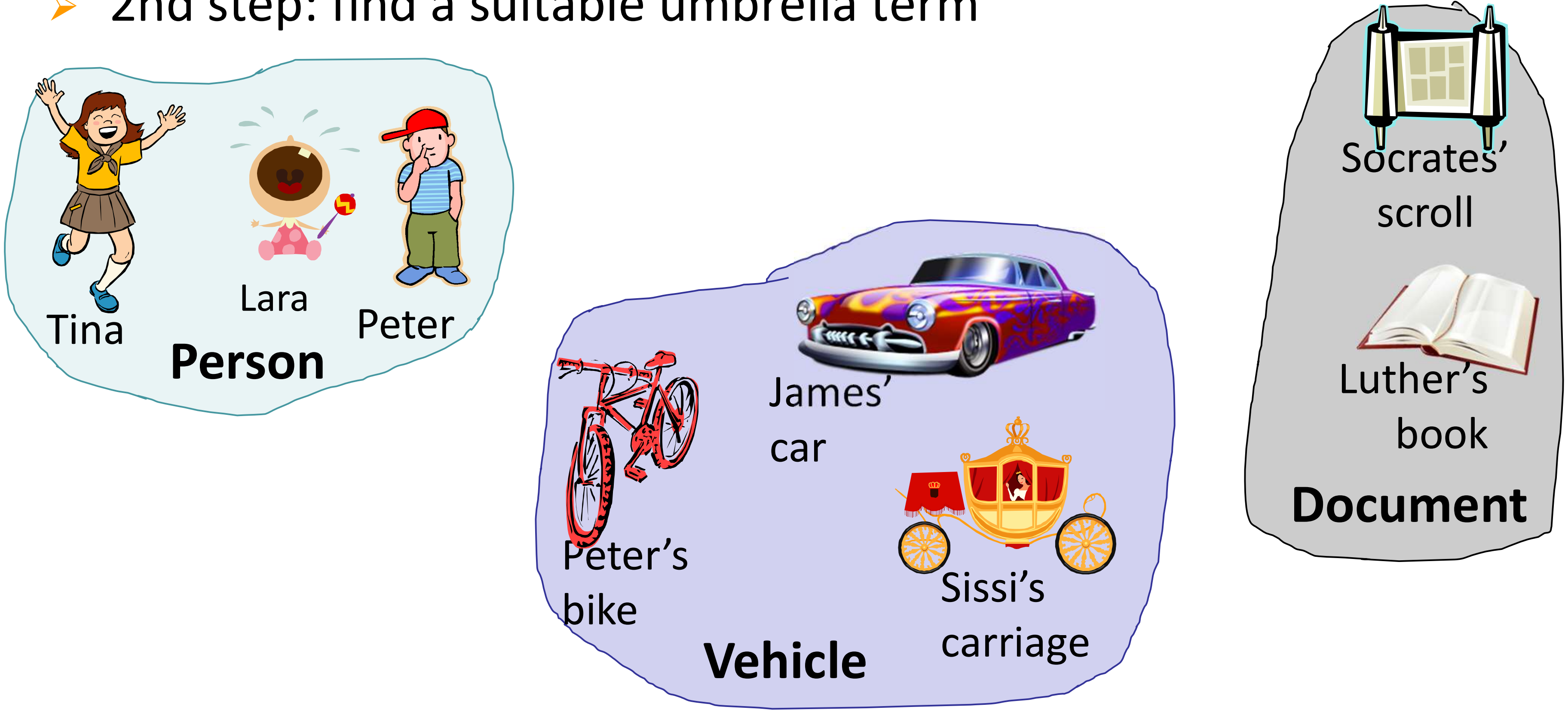
Sissi's carriage

James' car

What groupings do you recognise?

Grouping similar objects

- 1st step: group similar objects together
- 2nd step: find a suitable umbrella term



Tina

Lara

Peter

Person

Peter's bike

James' car

Sissi's carriage

Vehicle

Socrates' scroll

Luther's book

Document

Why objects? – Classes in Java, the better type

- Types in Java are declared (defined) by class.
  - In addition to primitive data types, classes also contain methods and can be inherited.

- Advantages:
  - Consistency is ensured by exclusively using the methods and restricting access to primitive types of a class.
  - Redundant programme code can be drastically reduced by skilful inheritance.

Classes and objects

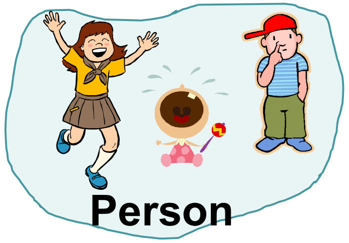
A ***class*** is a general description of things that can occur in different forms/versions, but all have a ***common structure*** and ***common behaviour***. It is a ***blueprint*** for the creation of individual specific versions. These versions are referred to as ***objects or instances*** of the class.

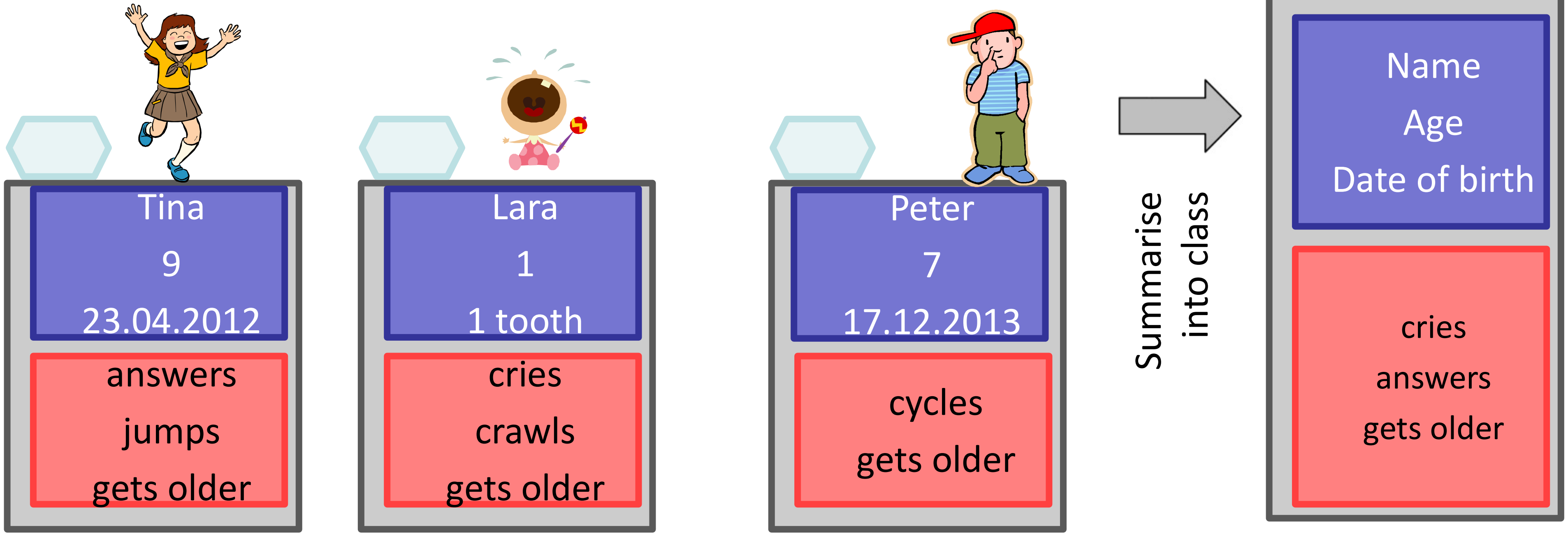
Source: D. Abts, *Grundkurs Java*, 9th edition, Springer

More examples from everyday life of classes and objects?

What is a class?

- Class = description of a set of objects with common attributes and behaviours
  - Bundles similar objects in a schema
  - Summarises relevant properties
  - Defines possible behaviour





Tina
9
23.04.2012
answers
jumps
gets older

Lara
1
1 tooth
cries
crawls
gets older

Peter
7
17.12.2013
cycles
gets older

Summarise into class

Person
Name
Age
Date of birth
cries
answers
gets older

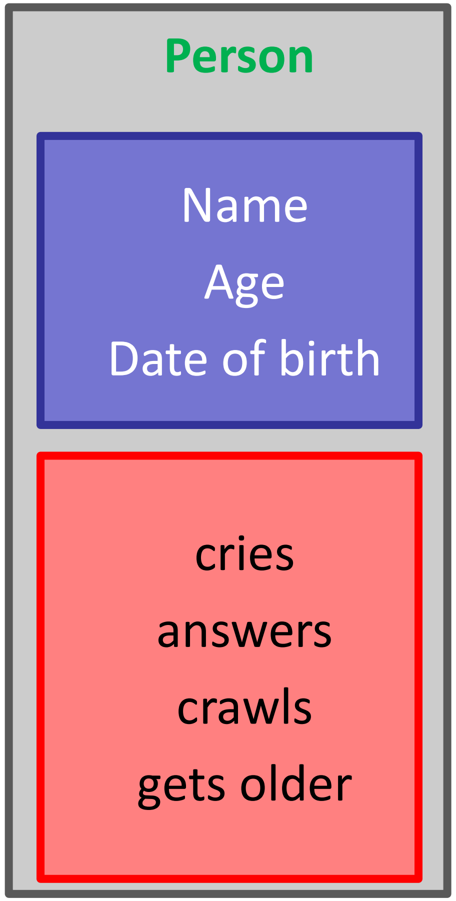
Characteristics of a class - schema

Concept **Class** bundling, abstraction **Real world**

Class name -
uniquely names the class

State -
describes an object of the class with relevant values (properties and relationships)

Behaviour -
Operations that an object in the class can perform



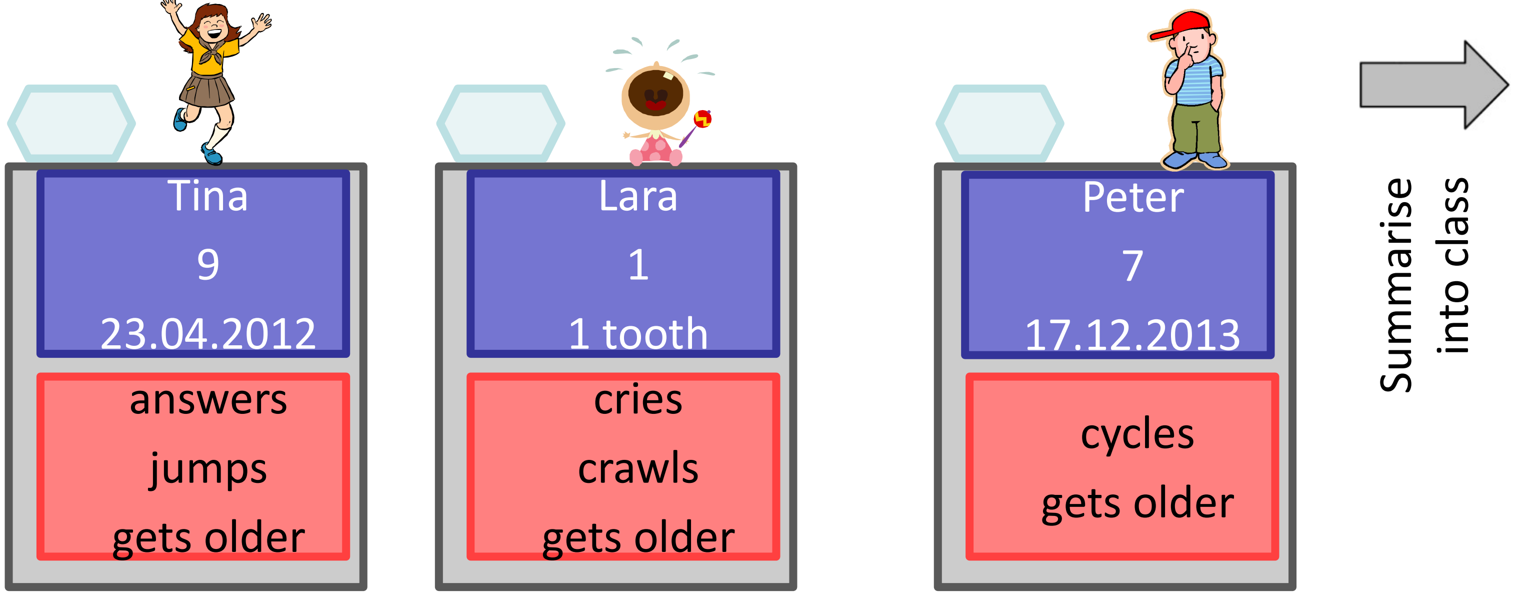
Person

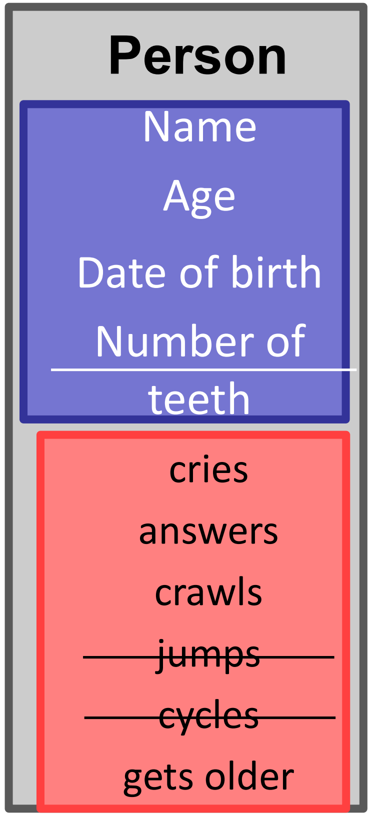
Name
Age
Date of birth

cries
answers
crawls
gets older

Procedure for forming classes

- Hybrid approach
  - Form set union (intersection)
  - Then thin out selectively
    - Properties / behaviour possible anywhere?
    - Properties / behaviour relevant everywhere?





Relationship between class and object (1)

Classes and objects in software systems

- At development time
  - Software system consists of a family of classes
  - Class is named programme unit/module
  - Class structure of a software system is static

Class =
static programme element

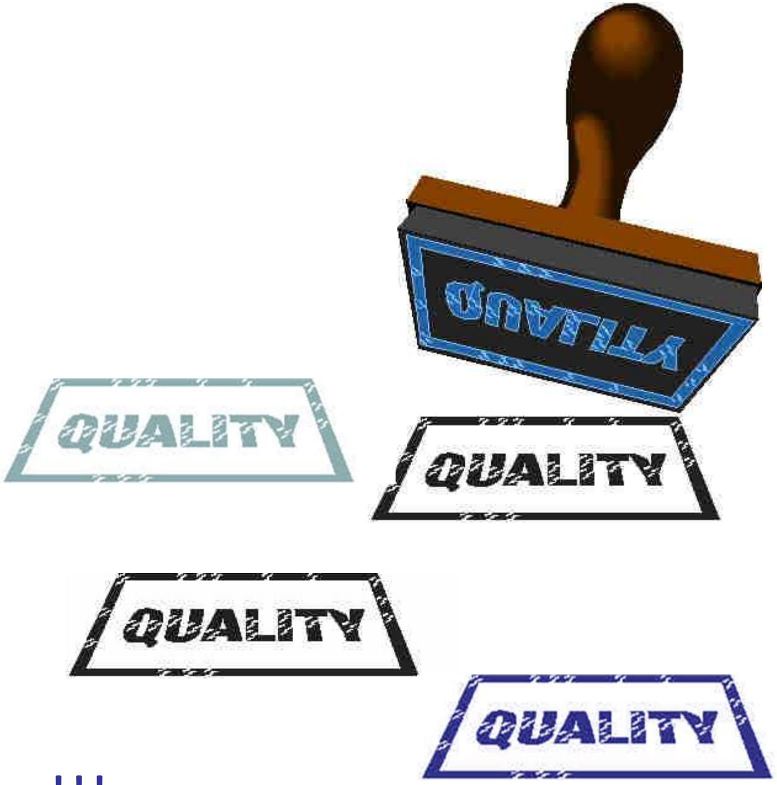
- At runtime
  - Objects perform the behaviour of the software system during runtime
  - Objects are derived from classes as needed
  - Object encapsulates data
  - Access to this data via methods of the associated class
  - Objects determine the dynamics of the programme sequence

Objects =
dynamic programme elements

Relationship between class and object (2)

- Class is pattern / template / blueprint

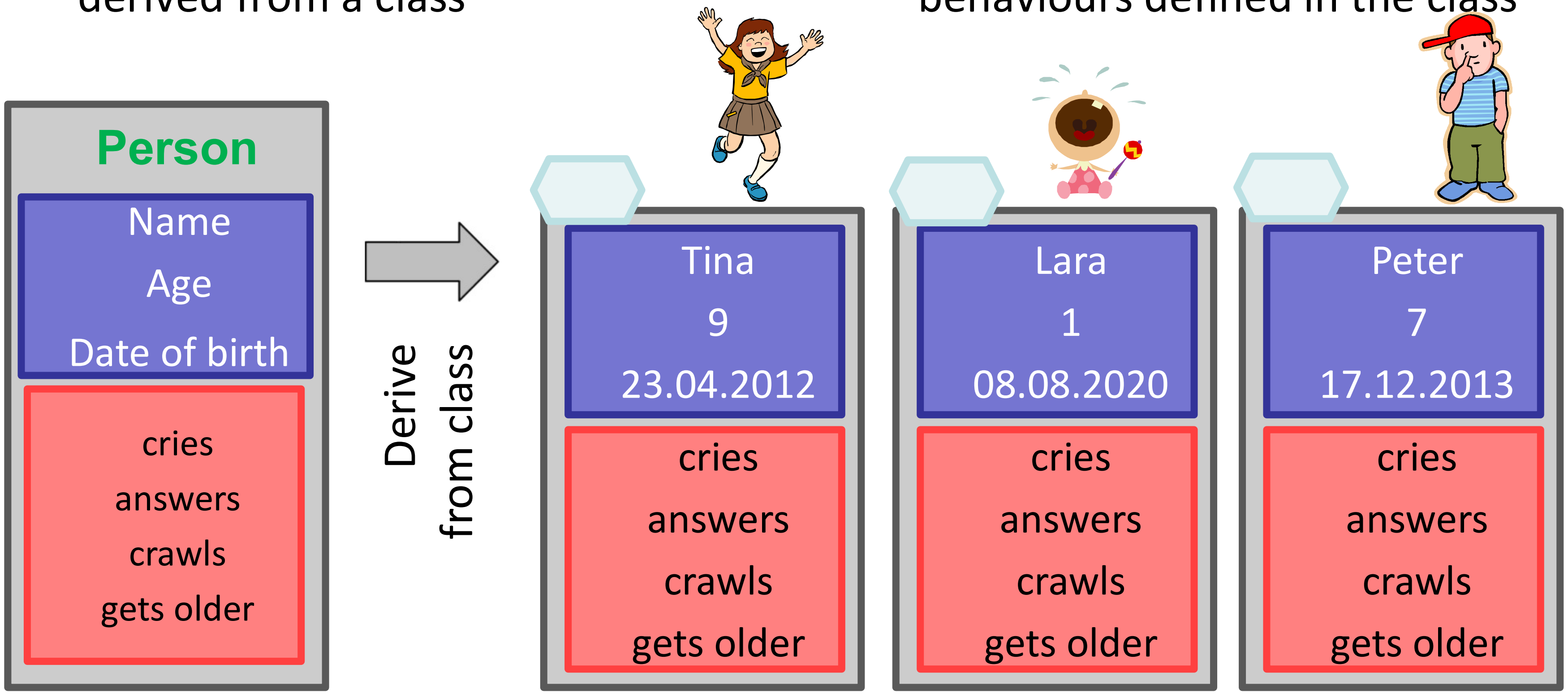
- Object is the stamped image



Object does not change its class at runtime!!!

Relationship between class and object (3)

- Class == abstraction
  - Pattern / blueprint for objects
  - Any number of objects can be derived from a class
- Object == concretisation
  - Derived from class (instance)
  - Has exactly the properties / behaviours defined in the class



Person

Name

Age

Date of birth

cries

answers

crawls

gets older

Derive from class

Tina

9

23.04.2012

cries

answers

crawls

gets older

Lara

1

08.08.2020

cries

answers

crawls

gets older

Peter

7

17.12.2013

cries

answers

crawls

gets older

How is this drawn in a standardised manner?

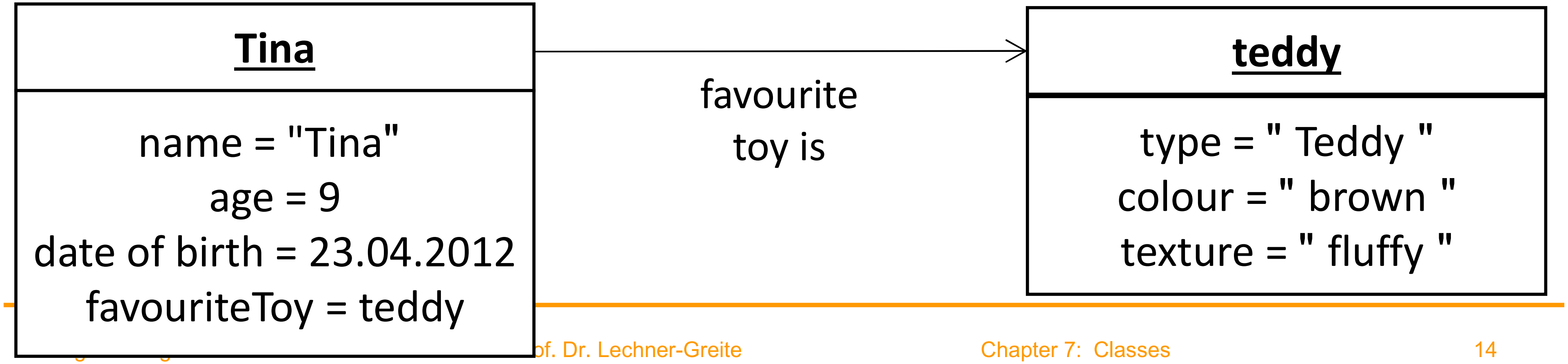
- Reminder: UML object diagram from the last chapter

Tina

favourite

toy is

Teddy



Tina

name = "Tina"
age = 9
date of birth = 23.04.2012
favouriteToy = teddy

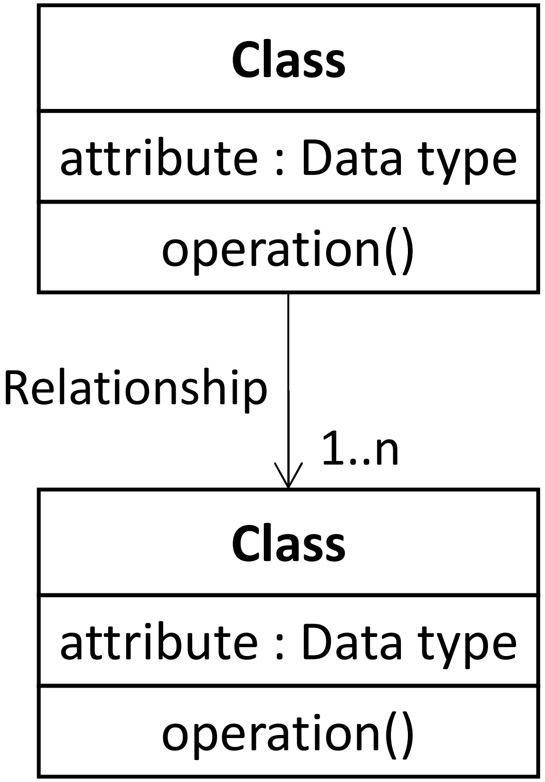
favourite
toy is

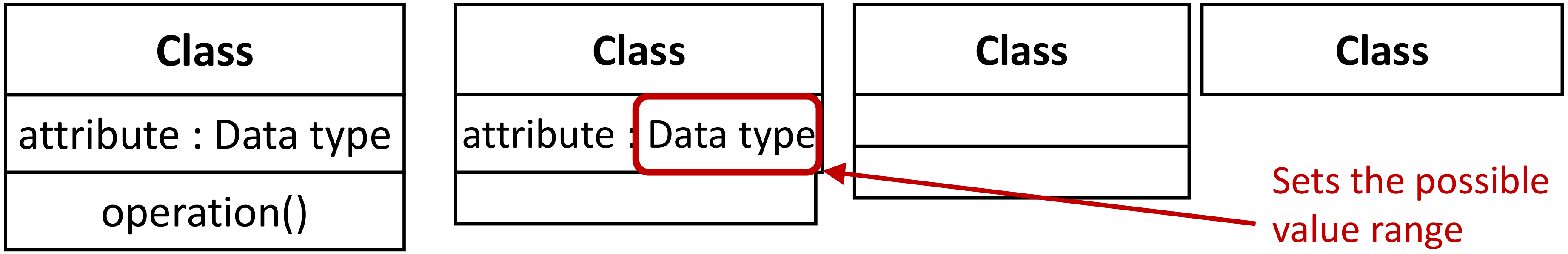
teddy

type = " Teddy "
colour = " brown "
texture = " fluffy "

Class diagram

- Representation of classes in UML
  - Rectangle with three areas
    - Class name
    - Attributes
    - Operations
  - Relationships to other classes possible
    - Multiplicity specifies the number of combinable objects
- Variants: leave individual areas out

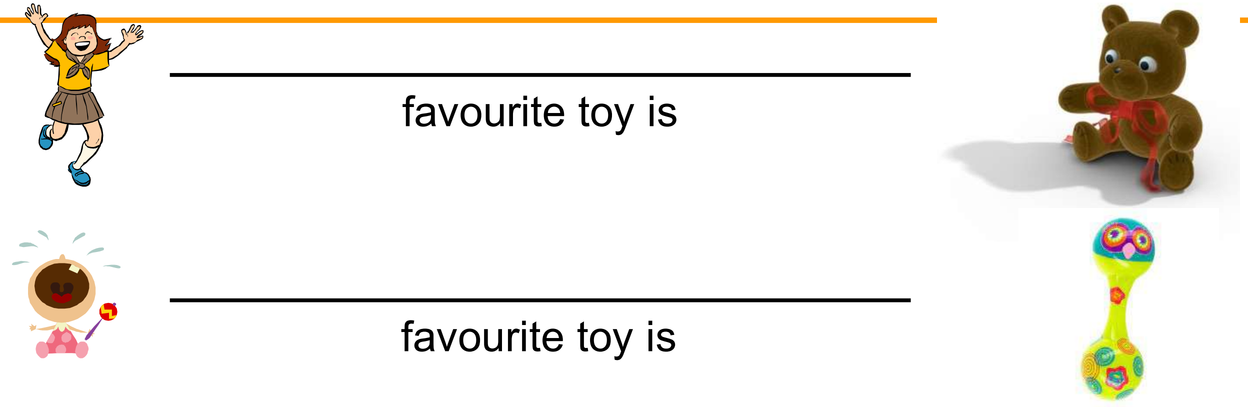




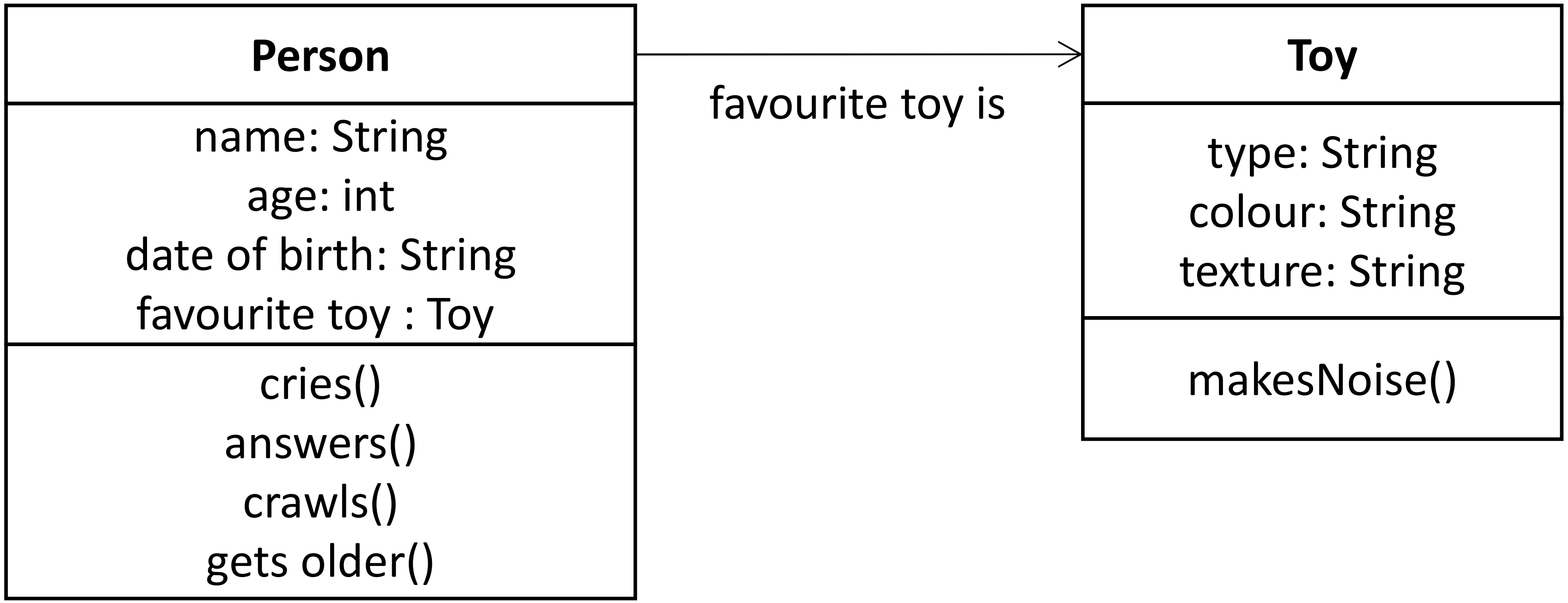
Sets the possible value range

Class diagram - example

Objects



Classes



Person

name: String
age: int
date of birth: String
favourite toy : Toy

cries()
answers()
crawls()
gets older()

favourite toy is

Toy

type: String
colour: String
texture: String

makesNoise()

Standardised representation in UML

- Class is abstraction / blueprint
- Object is concretisation

Person

name : String
age : int
date of birth : String
favourite toy : Toy

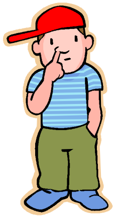
cries()
answers()
crawls()
gets older()

tina : Person

name = " Tina "
age = 9
date of birth = " 23.04.2012 “
favourite toy = teddy

lara : Person

name = " Lara "
age = 1
date of birth = " 08.08.2020 “
favourite toy = rattle

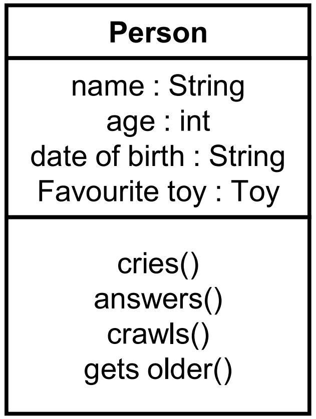


peter : Person

name = " Peter "
age = 7
date of birth = " 17.12.2013 “
favourite toy = ball

Important similarities / differences

- Class diagram
  - Identifier



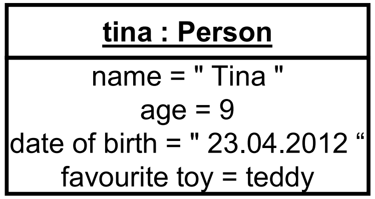
Person

name : String
age : int
date of birth : String
Favourite toy : Toy

cries()
answers()
crawls()
gets older()

  - Attributes
    - Specify data types
  - Behaviour
    - Only represented for classes

- Object diagram
  - Identifier
    - Underlined
    - Usually refers to class names



tina : Person

name = " Tina "
age = 9
date of birth = " 23.04.2012 “
favourite toy = teddy

  - Attributes
    - Set specific values
  - Behaviour
    - Not explicitly specified
    - Results from the corresponding class!

No relationship arrows between class and derived objects!

Chapter 7: Classes

5.1 Definition of terms and characteristic features of classes

5.2 Programming classes in Java

Declaration of classes (1)

- Classes define new data types
  - `int`, `double`, `boolean` are predefined types
  - Fractions, for example, are not predefined ($\frac{1}{2}, \frac{3}{4}, \frac{7}{13}, \ldots$)
- Syntax:

```
class ClassName {
      ...
}
```

- Example:

```
class Rational {
      ...
}
```

Convention:

– Each class declaration in its own source code file
  => `Rational.java`

Declaration of classes (2)

- Attributes of a fraction: numerator, denominator
- List the attributes in class declaration:

```
class Rational {
  int numer;
  int denom;
   ...
}
```

Instance variable for the numerator

Instance variable for the denominator

Any number and sequence!

- Individual components = instance variable
  - Same syntax as previously used for variables (local variables => statements in methods)
  - Only different location of the declaration (=> element of a class)

Exercise – Declare Java class

- Live exercise
  - Complete Task 1 on the
    live exercises sheet “Class declaration and use”
  - You have 5 minutes.

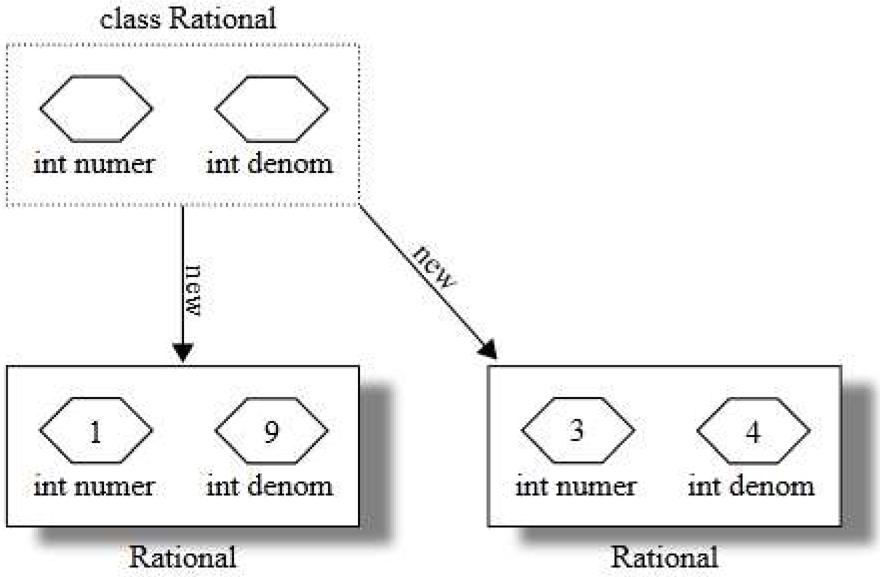
Declaration of classes (3)

- Comparison of primitive types versus non-primitive (reference) types

Primitive types	Non-primitive (reference) types
Assortment fixed; cannot be redefined	Can be redefined for specific problems
Atomic, internal structure of a value does not matter	Consists of different components (instance variables); can be addressed and processed individually
`int, double, boolean, …`	`Rational, Customer, Person, …`
	Some non-primitive (reference) types are already predefined in Java: `String` for strings or `System` for input and output data streams

Objects (1)

- Class declaration = blueprint, design specification
- Objects of the class must be explicitly created
- Example: two `Rational` objects with the values $\frac{1}{9}$ *und* $\frac{3}{4}$



1 class declaration

↓

any number of objects

Object = instance of the class

Objects (2)

- Creating a new object = instantiation
  (also "construction", "allocation")
- With operator `new`:

```
new Rational()
```

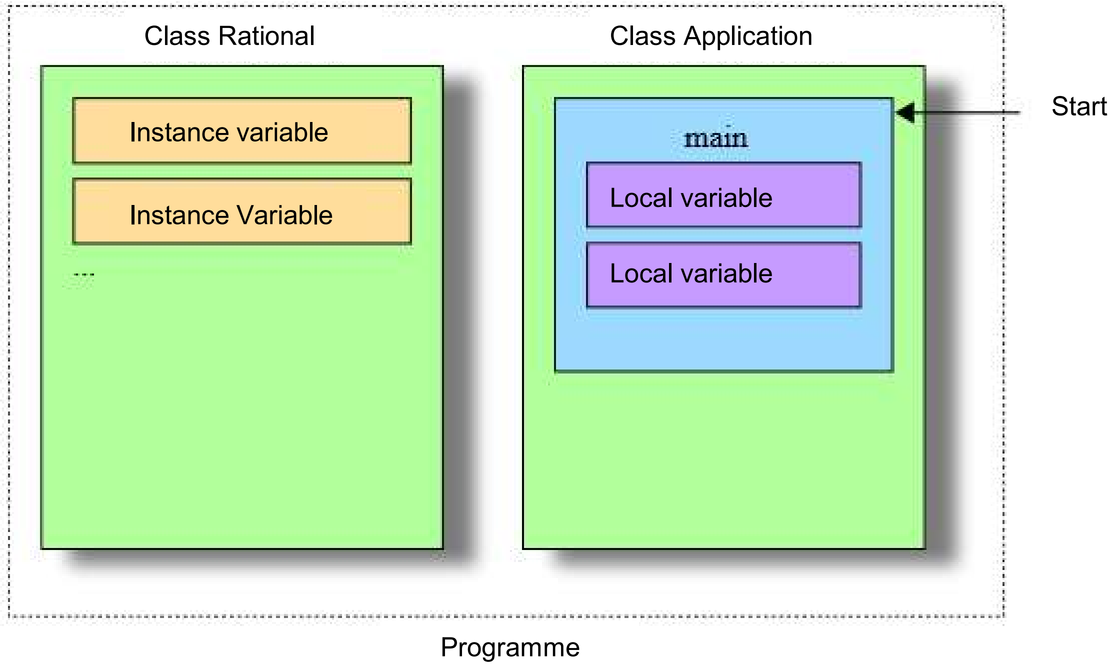
- `new` produces a single, new object of this class from a class declaration
- Multiple objects => multiple calls of `new`
- `new` calls a special method of the class (constructor - details later)

Objects (3)

- Java programme with classes consists of:
  - Declaration of the class
  - Use of the class

(usually) in different source code files

- Structure:



Objects (4)

- Example:

```
class Rational {
  int numer;
  int denom;
   ...
}
```

```
class Application {
  public static void main (String[] args){
    … new Rational() …
  }
}
```

In Java, there is no code outside of classes!
However, the class `Application` merely serves as a "container" for the main-method.
It mimics a use case of how the application reacts dynamically.

Non-primitive (reference) variables (1)

- == variables of non-primitive (reference) types
- Declaration of non-primitive (reference) variables is analogous to variable declaration of primitive data type (primitive variables)
- Example:

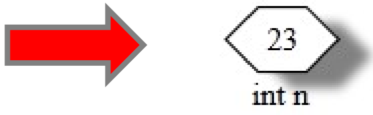
```
Rational r;
```

Declaration of a variable `r` of the non-primitive (reference) type `Rational`

Non-primitive (reference) variables (2)

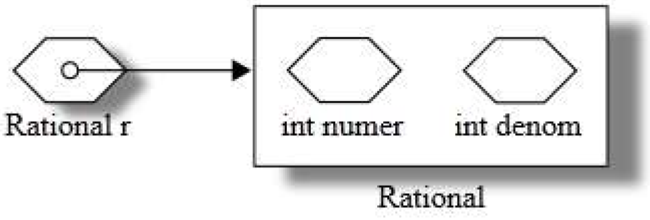
- Value assignment: fundamental difference between primitive variables and non-primitive (reference) variables
  - Primitive variable

```
int n = 23;
```



Variable and memory space for value coincide

  - Non-primitive (reference) variable
    - Variable and value (= object) exist independently and separately

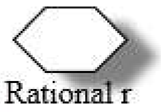


Non-primitive (reference) variables (3)

- Individual steps when initialising a non-primitive (reference) variable

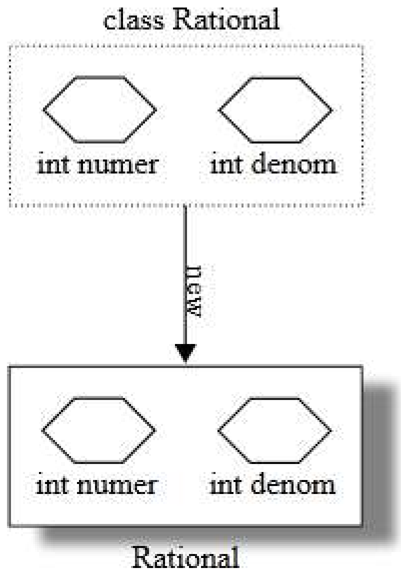
1. Declare non-primitive (reference) variable

```
Rational r;
```



2. Allocate new object in memory with `new`

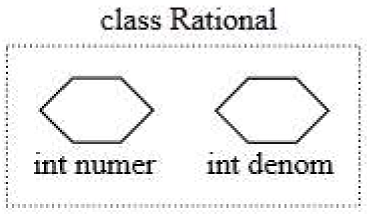
```
new Rational()
```

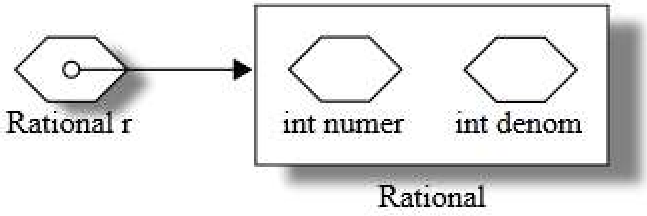


Non-primitive (reference) variables (4)

3. Assign object to reference variable

```
r = new Rational();
```





Variable references object

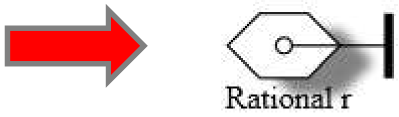
- All steps together: initialise a non-primitive (reference) variable during declaration

```
Rational r = new Rational();
```

Non-primitive (reference) variables (5)

- `null` non-primitive (reference)
  - `null` stands for no object
  - `null` can be assigned to any non-primitive (reference) variable

```
Rational r = null;
```



  - `null` is a well-defined value, can be compared

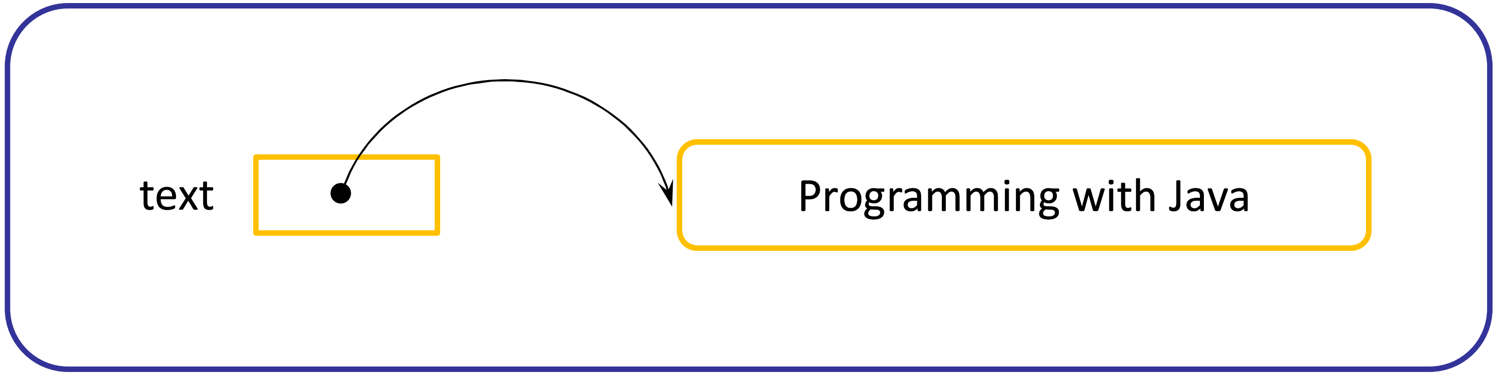
```
if (r == null)
   System.out.println("no object");
```

Always assign `null` to a non-primitive (reference) variable if there is no object!

Example `String (1)`

- Create and reference to the String object:

```
String text;
text = new String("Programming with Java");
```



- Short form (and preferred version):

```
String text;
text ="Programming with Java";
```

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Example `String`

- Comparison of strings (test for equal contents)
  - `boolean equals(Object anObject)`
  - Compares character-by-character and returns `true` if equal

```
String       s1 = "Hello";
String       s3 = new String("Hello");
boolean b3 = s3.equals(s1); // b3 is true
```

⚠ Operator `==` checks the identity of `String` objects, not the contents!

Instance variables (1)

- Access
  - Instance variables are declared outside a method definition.
  - Each class contains the instance variables specified in the class declaration
  - Instance variables of an object can be addressed individually: element access
  - Object to which element access is directed: target object
  - Syntax:

```
targetObject.objectVariable
```

Instance variables (2)

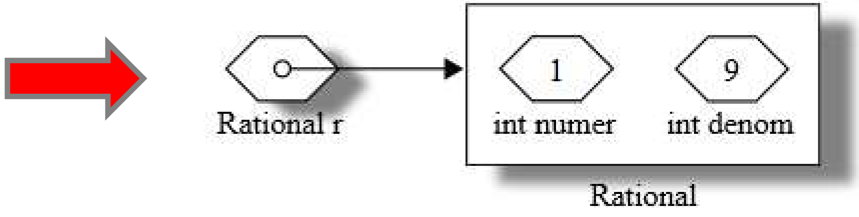
- Example: create a `Rational` object with value $\frac{1}{9}$

1. Create `Rational` object and assign to variable

```
Rational r = new Rational();
```

2. Assign the numerator and denominator of the target object `r` individually

```
r.numer = 1;
r.denom = 9;
```



Instance variables (3)

- Handling
  - Only access qualifiers show the difference between instance variables and local variables
  - Same use as local variables
  - Examples:

```
int i = 10 – r.numer * 5;
```

```
r.numer = r.numer + 8;
```

```
r.numer++;
```

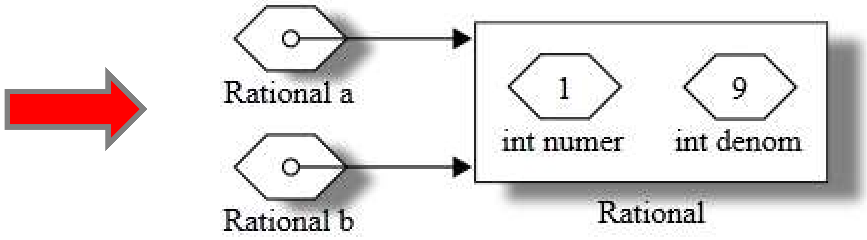
```
if (r.denom != 0) …
```

```
...
```

Instance variables (4)

- Value assignments for non-primitive (reference) types
  - Reference is duplicated, not the object!

```
Rational a = new Rational();
a.numer = 1;
a.denom = 9;
Rational b = a;
```



Both variables `a` and `b` reference the same object with value $\frac{1}{9}$

```
...
b.numer++;
System.out.println(a.numer);   //outputs 2!
```

Changes to an object are visible in both variables

Instance variables (5)

- Comparison of non-primitive (reference) types
  - Comparison with `==` checks the identity and ignores the content
    - `true` if both operands are one and the same object
    - `false` if the operands are different objects

```
Rational a = new Rational();
a.numer = 1;
a.denom = 9;
Rational b = new Rational();
b.numer = 1;
b.denom = 9;

if (a == b)    //false
   ...
```

```
Rational a = new Rational();
a.numer = 1;
a.denom = 9;
Rational b = a;

if (a == b)    //true
   ...
```

  - Content comparison of objects: compare instance variables in pairs

```
if (a.numer == b.numer && a.denom == b.denom)
   ...
```

Instance variables (6)

- Validity range (scope)
  - In the entire own class

- Lifetime
  - Coincides with the object they are part of
  - Are created as soon as an object is created
  - Are released when the object is no longer accessible

Exercise – Programme Java class

- Live exercise
  - Complete Task 2 on the live exercises sheet “Class declaration and use”
  - You have 5 minutes.

Methods (1)

- Describe the behaviour of objects
- Correspond to processes => named with (English) verbs

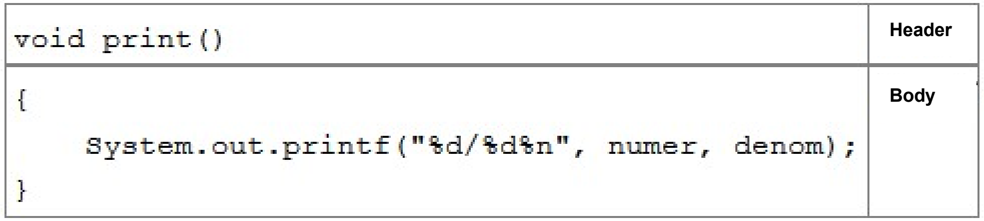
- Example:

```
class Rational {
  int numer;
  int denom;

  void print() {
    System.out.printf("%d/%d\n", numer, denom);
   }
}
```

Methods (2)

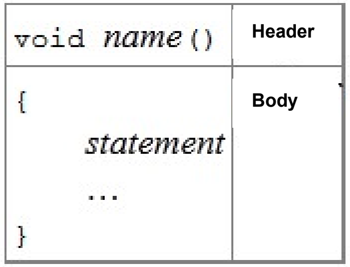
- Signature and body
  - Method declaration = (method) header + (method) body



`void print()`	**Header**

`{`
`    System.out.printf("%d/%d%n", numer, denom);`
`}`
	Body

  - General



void *name*()	**Header**

{
    statement
    ...
}
	Body

  - Note: Brackets in the body are mandatory, even with one (or without any) statement!

Methods (3)

Calling methods

- A method is called with target object
- Syntax similar to element access:

```
targetObject.methodName();
```

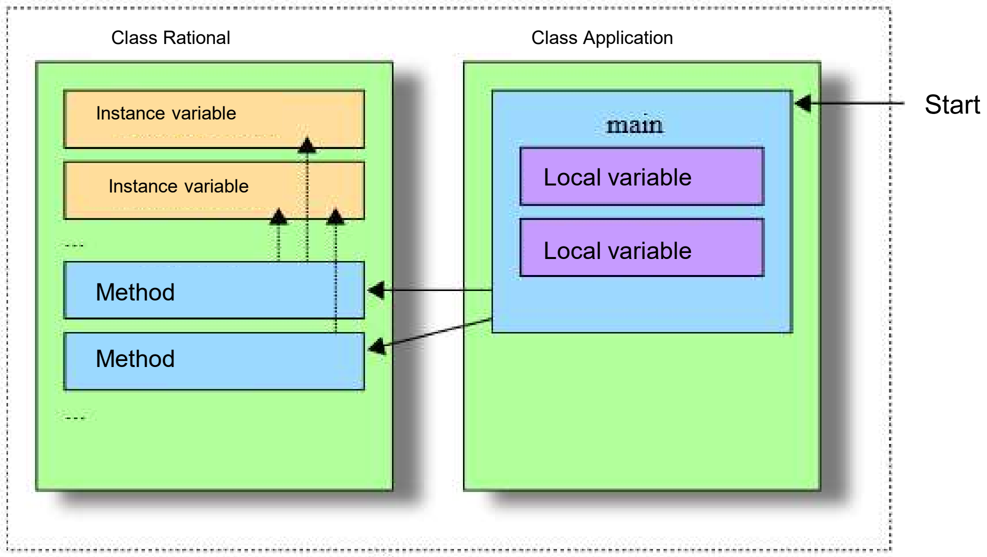
Round brackets mark method call

- Example:

```
Rational r = new Rational();
r.numer = 1;
r.denom = 8;
r.print();             //Method call outputs 1/8
```

Methods (4)

- Structure:
  - Programme consists of multiple classes,
  - Class consists of instance variables and methods

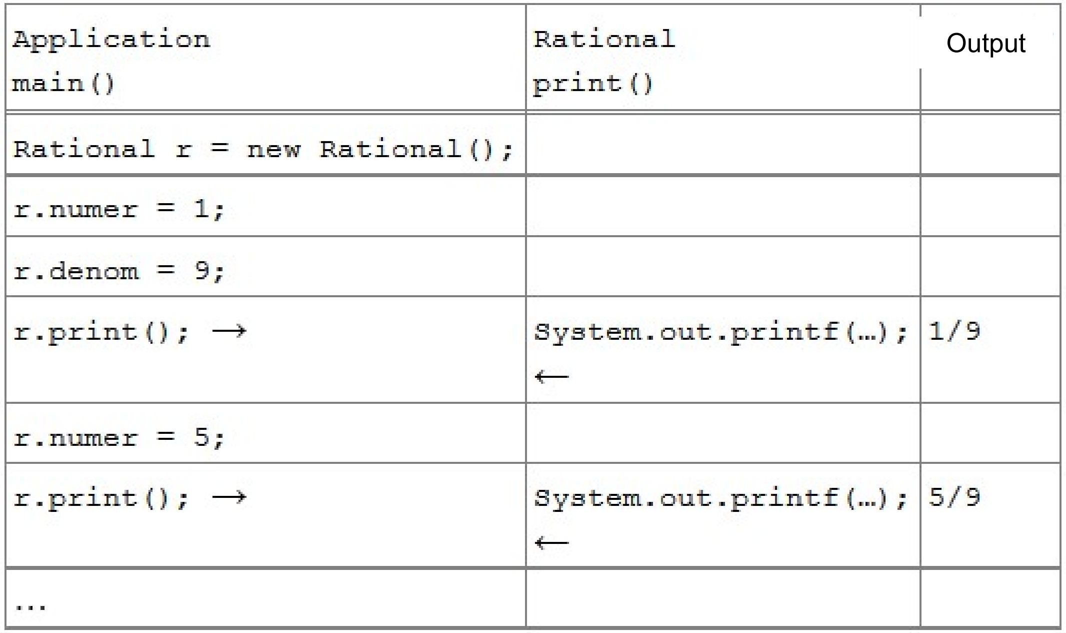


Programme

- Method declarations only allowed in classes,
  - not outside of a class declaration
  - not within another method declaration
- Any number, sequence and arrangement of method declarations in a class
- The application initializes objects from the classes and accesses them i.e. through method calls.

Methods (5)

- Sequence of a method call in several individual steps = call sequence
  1. Interrupt the calling programme ("caller")
  2. Run through the method body
  3. Continue the caller after the call
- Example sequence:

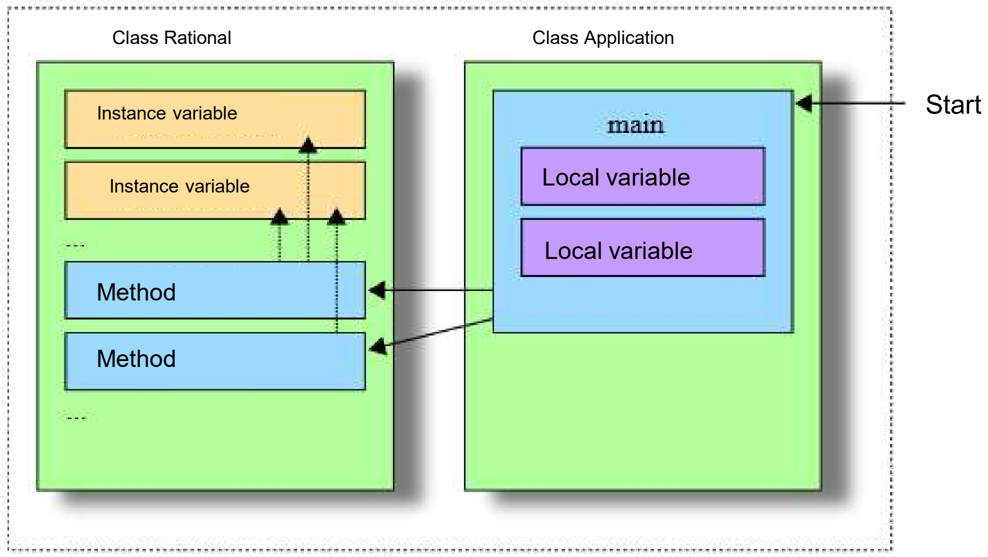


Application main()	Rational print()	Output
`Rational r = new Rational();`		
`r.numer = 1;`		
`r.denom = 9;`		
`r.print();` →	`System.out.printf(…);` ←	1/9
`r.numer = 5;`		
`r.print();` →	`System.out.printf(…);` ←	5/9
...		

Caller is interrupted every time

Methods (6)

- Method body = block
  - Any statements allowed (all control structures and declarations)
  - Validity range (scope) of local declarations
  - Lifetime of local variables: one call each (created on call; released again on return)



Programme

Programme consists of multiple classes, class consists of instance variables and methods, methods contain local variables

Methods (7)

- Example:
  - Method to reduce a fraction:

```
class Rational {
  int numer;
  int denom;

  void reduce() {
    int gcd = …;
    numer = numer /gcd;
    denom = denom / gcd;
   }
}
```

  - Call of `reduce`:

```
Rational r = new Rational();
r.numer = 6;
r.denom = 9;
r.print();   //outputs 6/9
r.reduce();
r.print();   //outputs 2/3
```

Local variable `gcd` only valid in the body, exists for one call at a time!

Methods (8)

- Access from a method body
  - To own instance variables without specifying a target object => instance variables can be addressed like local variables
  - Call of methods of the own class without specifying the target object

```
class Rational {
  int numer;
  int denom;

  void print() {…}

  void reduce() {…}

  void printReduced() {
    reduce();                 //Method of the own class
    print();                  //Method of the own class
    }
}
```

Methods (9)

- Access from a method body
  - To instance variables and methods of another object: specifying the target object

```
class Application {
  public static void main (String[] args){
   Rational r =new Rational();
   r.numer = 6;
   r.denom = 9;
   r.printReduced();
  }
}
```

Methods (10)

- Naming conflicts
  - Names of local variables and instance variables do not conflict

```
class DemoName {
  int numer = 8;                        //instance variable
   …
  void output() {
    int numer = 5;                     // local variable
    System.out.println(numer);     // outputs 5
  }
}
```

Local declaration "hides" instance variable

Technically possible but bad style!

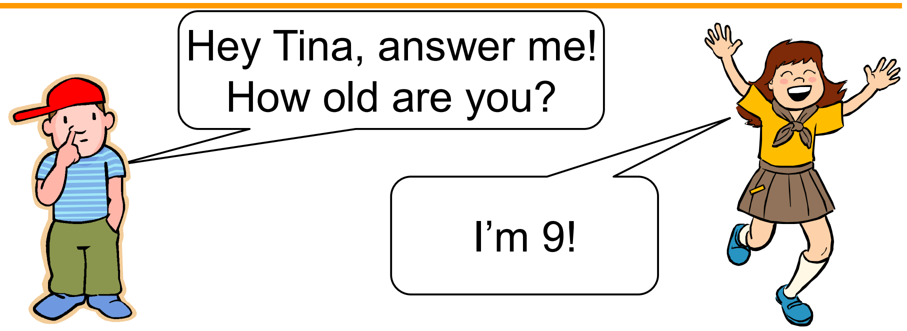
Methods (11)

- Self-reference `this`
  - Is automatically declared in every class, always available
  - Reserved keyword = self-reference to the current object
  - **Allows access to instance variables**

```
class DemoName {
  int numer = 8;                                     //instance variable
   …
  void output() {
    int numer = 5;                                 // local variable
    System.out.println(numer);                     // outputs 5
    System.out.println(this.numer);                // outputs 8
  }
}
```

Parameters (1)

- Parameters pass information from caller to methods
- Two language elements coupled:
  1. Method lists the required parameters
  2. Caller passes arguments for the required parameters



- A parameter list can be specified in the method header

```
void methodName(type1 name1, type2 name2, . . .)
```

- Any number of parameters allowed
  (previously: no parameters, empty list)

Parameters (2)

- Example:

```
class Rational {
   …
   void extend(int f) {       //header with parameter int f
      numer = numer * f;
      denom = denom * f;
   }
   …
}
```

- Caller must specify a compatible argument for each call:

```
r.extend(2);
```

When called, compiler checks if arguments and parameters match!

Parameters (3)

- Example with multiple parameters:

```
class Rational {
    …
  void set(int n, int d) {        //2 parameters
    numer = n;
    denom = d;
   }
  void setZero() {                //0 parameters
    numer = 0;
    denom = 1;
    }
}
```

- Correct calls:

```
Rational r = new Rational();
r.set(5,8);                         // r = 5/8
Rational s = new Rational();
s.setZero();                        // s = 0/1
```

Parameters (4)

- Primitive types as parameters
  - Hidden value assignment when passing parameters
  - Values of primitive types are copied
  - Implicit and explicit type conversions as for value assignments

```
Rational r = new Rational();
r.extend(5.18);                    // Error incorrect type!
r.extend((int)5.18);               // OK
```

- Local variables as parameters

```
Rational r = new Rational();
int x = 5;
r.extend(x);
```

Parameters (5)

- Non-primitive (reference) types as parameters
- Example:
  - Method `mult` expects another `Rational` object as a parameter

```
class Rational {
...
  void mult (Rational frac) {
    numer = numer * frac.numer;
    denom = denom * frac.denom;
   }
}
```

  - From the perspective of `mult`: `frac` is another reference variable
    - Addressing the own instance variables without a target object
    - Addressing the foreign instance variables with target object `frac`

Overloading (1)

- Overloading = multiple methods with the same name but different parameter lists
- Useful for related methods with a similar purpose
- Example: three methods `set` for specifying a fraction

```
class Rational {
  void set() {
    numer = 0;
    denom = 1;
   }
  void set(int n) {
    numer = n;
    denom = 1;
  }
  void set(int n, int d) {
    numer = n;
    denom = d;
    }
    . . .
}
```

Overloading with different number of parameters or different types of parameters or both

Overloading (2)

- Based on the argument list provided by the caller, the compiler decides which method is called.
-
```
r.set();          // calls set()
r.set(1);         // calls set(int)
r.set(1,2);       // calls set(int,int)
r.set(1,2,3);     // Error! No suitable method declared
```

- Overloaded methods lead toward polymorphism – another core property of object orientation.