ETH Zürich
Chair of Software Engineering

Einführung in die Programmierung
Introduction to Programming

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Exercise Session 4

Problems in Assignment-2 Solutions

- Command or query?
  - connecting_lines
  (a_station_1, a_station_2: STATION): V_SEQUENCE [LINE]
  - Noun phrases for query names; verb phrases for command names

- Instruction separation?
  - Comma (,), space( ), semicolon (;), or nothing

- STRING_8 Vs. STRING_32

```
make
    local
        l_line: STRING_32
        c: UTF_CONVERTER
    do
        Io.read_line
        l_line := c.utf_8_string_8_to_string_32 (Io.last_string)
        print (l_line.count)
    end
```

Today

- Understanding contracts
  (preconditions, postconditions, and class invariants)
- Reference types vs. expanded types
- Basic types
- Entities and objects
- Object creation
- Assignment

Why do we need contracts?

- They are executable specifications that evolve together with the code
- Together with tests, they are a great tool for finding bugs
- They help us reason about an O-O program at the level of classes and routines
- Proving (part of) programs correct requires some way to specify how the program *should* operate. Contracts are a way to specify the program

Assertions

Assertion **tag** (optional, but recommended)

Condition (required)

balance_non_negative: *balance* >= 0

Assertion clause

The assertion tag (if present) is used to construct a more informative error message when the condition is violated.

Precondition

Property that a feature imposes on clients

```
clap (n: INTEGER)
        -- Clap n times and update count.
    require
        not_too_tired: count <= 10
        n_positive: n > 0
```

A feature without a **require** clause is always applicable, as if the precondition reads

```
    require
        always_OK: True
```

Postcondition

Property that a feature guarantees on termination

```
clap (n: INTEGER)
        -- Clap n times and update count.
    require
        not_too_tired: count <= 10
        n_positive: n > 0
    ensure
        count_updated: count = old count + n
```

A feature without an **ensure** clause always satisfies its postcondition, as if the postcondition reads

```
    ensure
        always_OK: True
```

Class Invariant

Property that is true of the current object at any *observable* point

```
class ACROBAT
    ...
invariant
    count_non_negative: count >= 0
end
```

A class without an **invariant** clause has a trivial invariant

```
always_OK: True
```

Pre- and postcondition example

Hands-On

Add pre- and postconditions to:

```
smallest_power (n, bound: NATURAL): NATURAL
		-- Smallest x such that `n'^x is greater or equal `bound'.
	require
		???
	do
		...
	ensure
		???
	end
```

One possible solution

```
smallest_power (n, bound: NATURAL): NATURAL
    -- Smallest x such that `n'^x is greater or equal `bound'.
  require
    n_large_enough: n > 1
    bound_large_enough: bound > 1
  do
    ...
  ensure
    greater_equal_bound: n ^ Result >= bound
    smallest: n ^ (Result - 1) < bound
  end
```

Hands-on exercise

Hands-On

Add invariant(s) to the class *ACROBAT_WITH_BUDDY*.

Add preconditions and postconditions to feature *make* in *ACROBAT_WITH_BUDDY*.

Class *ACROBAT_WITH_BUDDY*

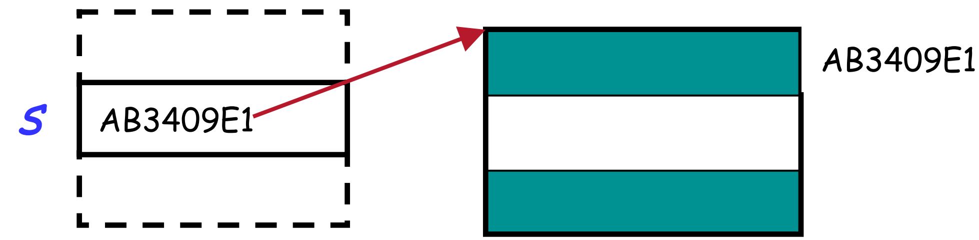
```
class
    ACROBAT_WITH_BUDDY

inherit
    ACROBAT
        redefine
            twirl, clap, count
        end

create
    make

feature
    make (p: ACROBAT)
        do
            -- Remember `p' being
            -- the buddy.
        end

    clap (n: INTEGER)
        do
            -- Clap `n' times and
            -- forward to buddy.
        end

    twirl (n: INTEGER)
        do
            -- Twirl `n' times and
            -- forward to buddy.
        end

    count: INTEGER
        do
            -- Ask buddy and return his
            -- answer.
        end

    buddy: ACROBAT
end
```

What are reference and expanded types?

Reference types: s contains the address (reference or location) of the object.

Example:

s : $STATION$

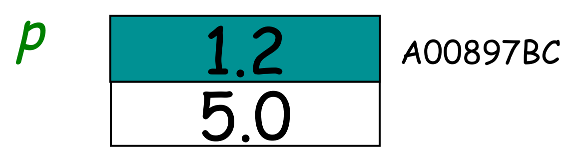


($STATION$)

Expanded types: p points directly to the object.

Example:

p : $POINT$



($POINT$)

Why expanded types?

To represent basic types (*INTEGER*, *REAL*,…)

To model external world objects realistically, i.e. objects that have sub-objects (and no sharing), for example a class *WORKSTATION* and its *CPU*.

How to declare an expanded type?

To create an expanded type, declare the class with keyword **expanded**:

```
expanded class COUPLE
feature -- Access
    man, woman : HUMAN            Reference
    years_together : INTEGER      ?
end
```

Now all the entities of type *COUPLE* are automatically expanded:

```
    pitt_and_jolie: COUPLE        Expanded
```

Objects of reference or expanded types

Objects of reference types: they don't exist when we declare them (they are initially *Void*).

s: *STATION*

We need to explicitly create them with a create instruction.

create s

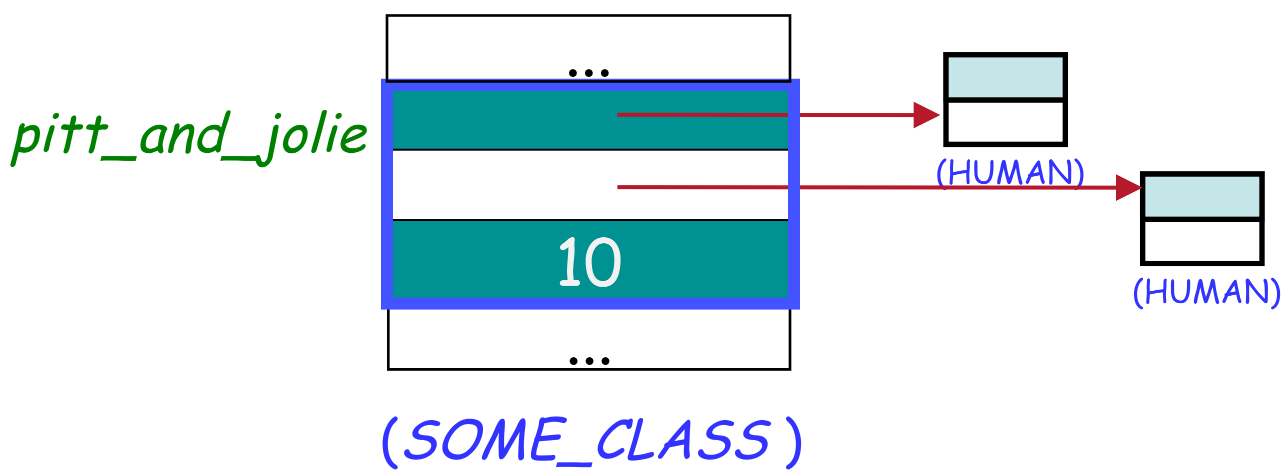
Objects of expanded types: they exist by just declaring them (they are never *Void*)

p: *POINT*

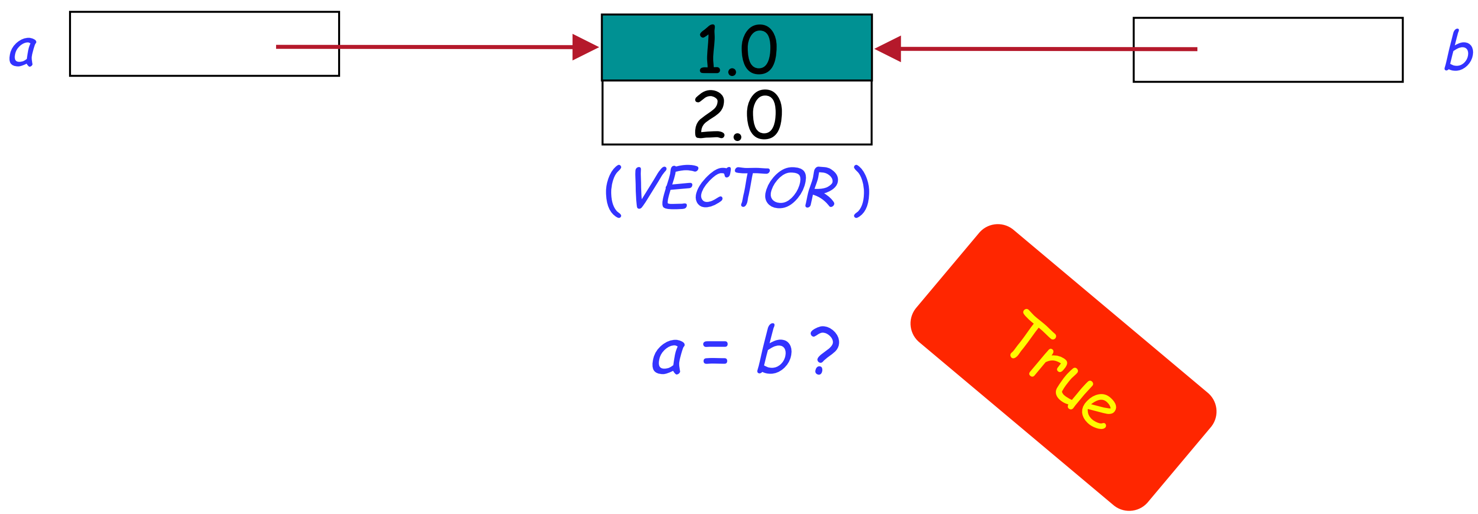
Feature *default_create* from *ANY* is implicitly invoked on them

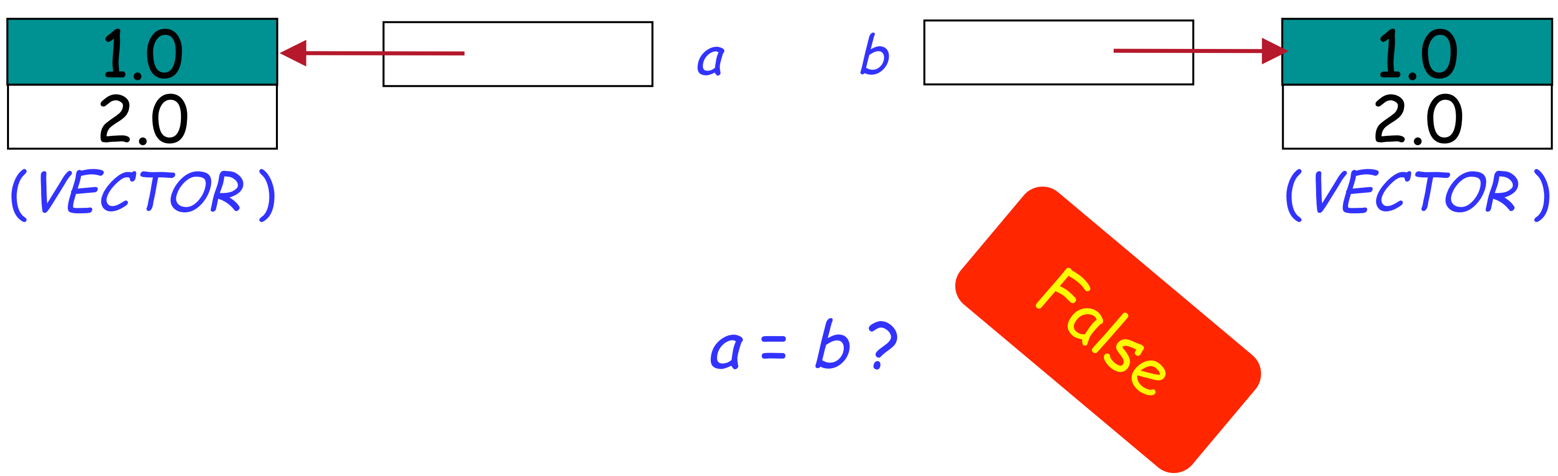
Can expanded types contain reference types?

Expanded types can contain reference types, and vice versa.

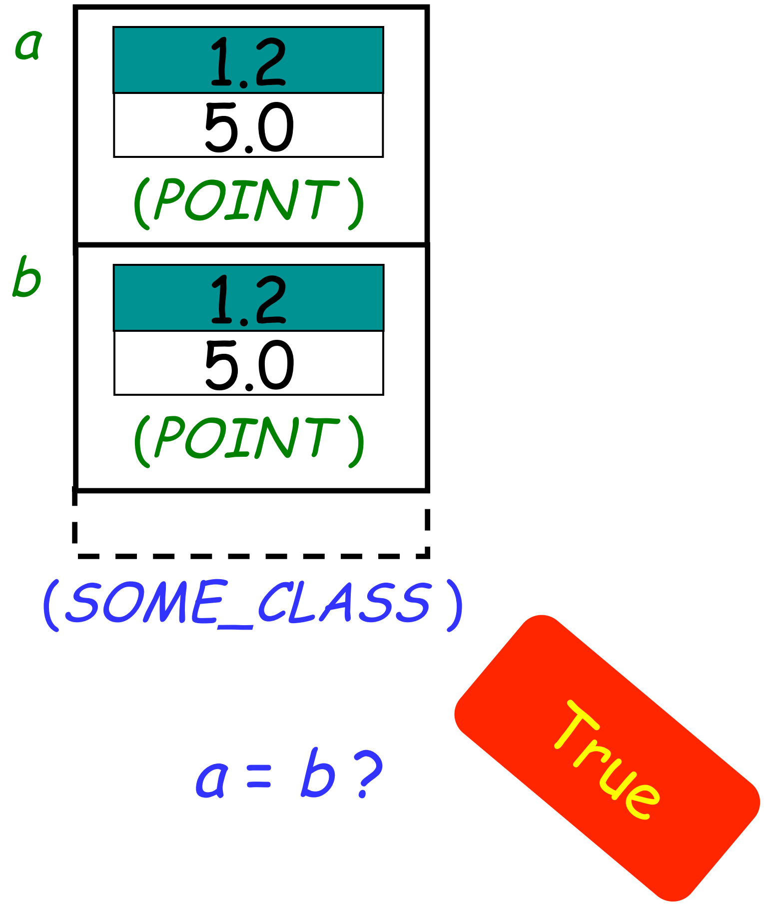


Reference equality



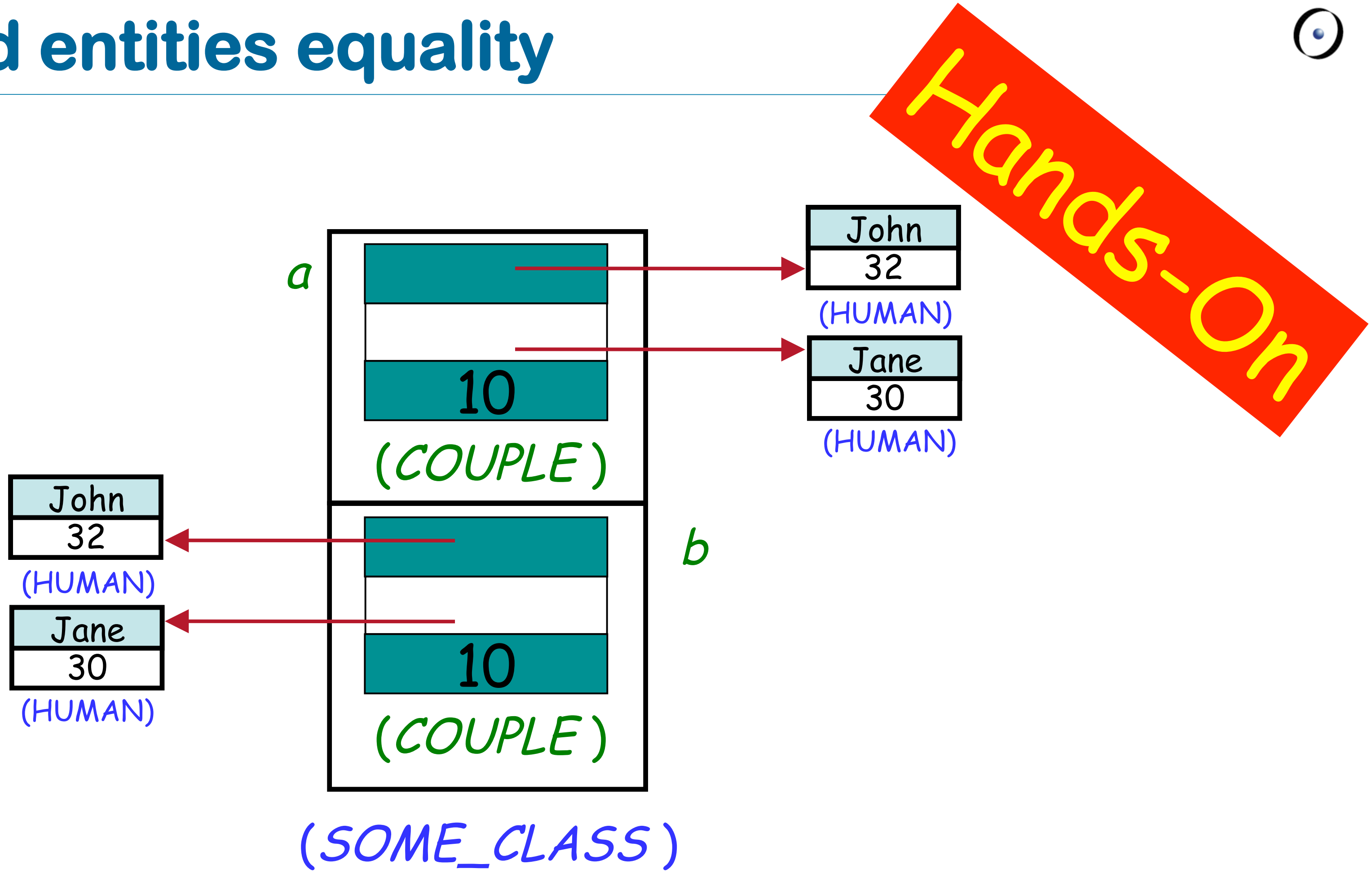


Expanded entities equality



Entities of expanded types are compared by value!

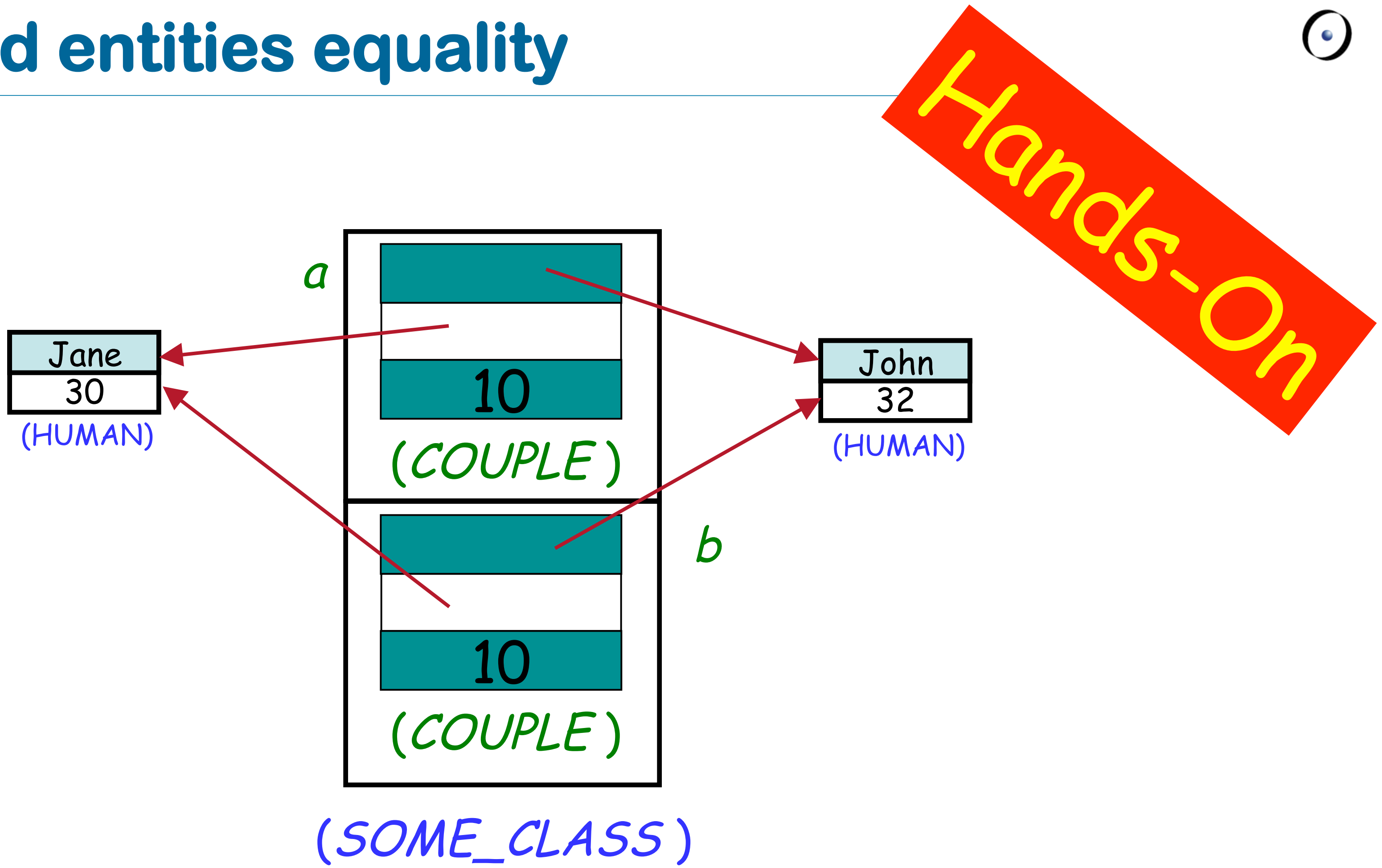
Expanded entities equality



$a = b$?

False

Expanded entities equality



a = b ?

True

Basic types

Their only privilege is to use manifest constants to construct their instances:

```
b: BOOLEAN
x: INTEGER
c: CHARACTER
s: STRING
…
b := True
x := 5          -- instead of create x.make_five
c := 'c'
s := "I love Eiffel"
```

Basic types

Some basic types (*BOOLEAN*, *INTEGER*, *NATURAL*, *REAL*, *CHARACTER*) are expanded…

a := *b*

a	3	*b*	5
a	5	*b*	5

… and immutable (they do not contain commands to change the state of their instances)…

a := *a.plus* (*b*) instead of *a.add* (*b*)

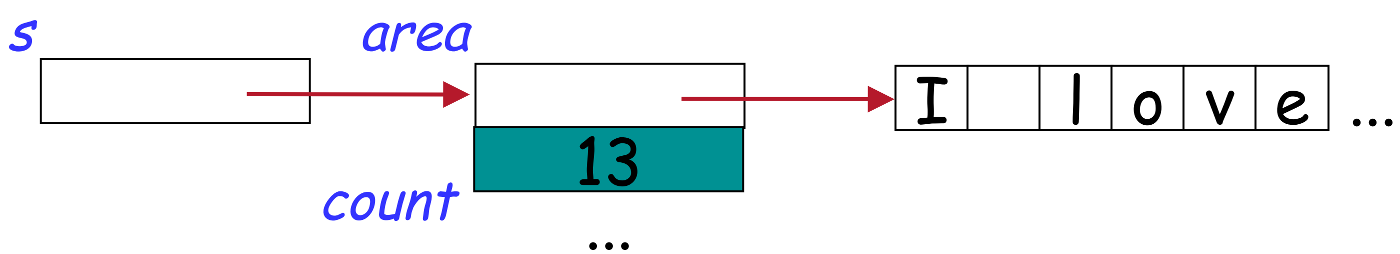
a + *b*

Alias for *plus*

Strings are a bit different

Strings in Eiffel are not expanded...

s: *STRING*



... and not immutable

s := "I love Eiffel"

s.append (" very much!")

Object comparison: = versus ~

```
s1: STRING = "Teddy"
s2: STRING = "Teddy"
…
s1 = s2 -- False: reference comparison on different objects

s1 ~ s2 --True
…
```

Now you know how to compare the content of two objects

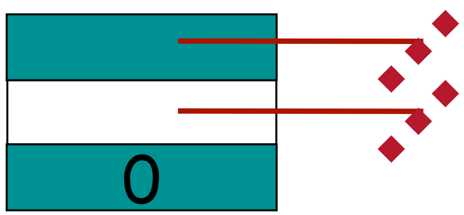
Initialization

Default value of any reference type is **Void**

Default values of basic expanded types are:

- **False** for *BOOLEAN*
- 0 for numeric types (*INTEGER*, *NATURAL*, *REAL*)
- "null" character (its *code* is 0) for *CHARACTER*

Default value of a non-basic expanded type is an object, whose fields have default values of their types



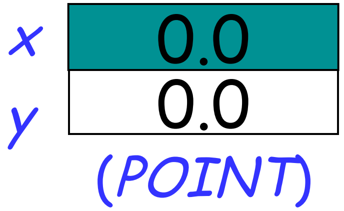
(*COUPLE*)

Initialization

Hands-On

What is the default value for the following classes?

expanded class *POINT*
feature *x*, *y*: *REAL* **end**



class *VECTOR*
feature *x*, *y*: *REAL* **end**

Void

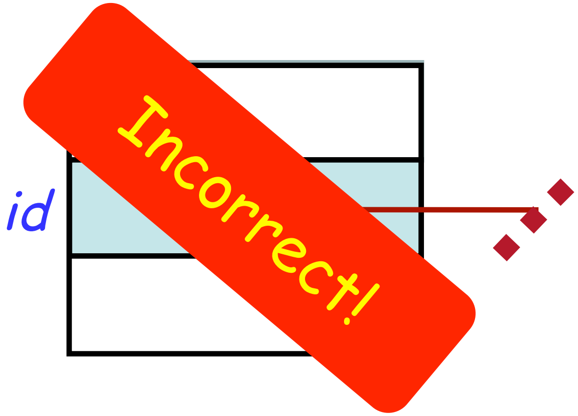
STRING

Void

Creation procedures

- Instruction **create** *x* will initialize all the fields of the new object attached to *x* with default values
- What if we want some specific initialization? E.g., to make object consistent with its class invariant?

```
Class CUSTOMER
…
    id : STRING
invariant
    id /= Void
```



- Use creation procedure:

create *a_customer.set_id* ("13400002")

Class *CUSTOMER*

```
class CUSTOMER

create set_id

feature
        id : STRING
            -- Unique identifier for Current.

        set_id (a_id : STRING)
                -- Associate this customer with `a_id'.
            require
                id_exists : a_id /= Void
            do
                id := a_id
            ensure
                id_set : id = a_id
            end

invariant
        id_exists : id /= Void
end
```

List one or more creation procedures

May be used as a regular command and as a creation procedure

Is established by *set_id*

Object creation

To create an object:

- If class has no **create** clause, use basic form:

  create *x*

- If the class has a **create** clause listing one or more procedures, use

  create *x.make* (...)

  where *make* is one of the creation procedures, and (...) stands for arguments if any.

Some acrobatics

Hands-On

```
class DIRECTOR
create prepare_and_play
feature
    acrobat1, acrobat2, acrobat3: ACROBAT
    friend1, friend2: ACROBAT_WITH_BUDDY
    author1: AUTHOR
    curmudgeon1: CURMUDGEON

    prepare_and_play
      do
          author1.clap (4)
          friend1.twirl (2)
          curmudgeon1.clap (7)
          acrobat2.clap (curmudgeon1.count)
          acrobat3.twirl (friend2.count)
          friend1.buddy.clap (friend1.count)
          friend2.clap (2)
      end
end
```

What entities are used in this class?

What's wrong with the feature *prepare_and_play*?

Some acrobatics

Hands-On

```
class DIRECTOR
create prepare_and_play
feature
    acrobat1, acrobat2, acrobat3: ACROBAT
    friend1, friend2: ACROBAT_WITH_BUDDY
    author1: AUTHOR
    curmudgeon1: CURMUDGEON

    prepare_and_play
        do
1           create acrobat1
2           create acrobat2
3           create acrobat3
4           create friend1.make_with_buddy (acrobat1)
5           create friend2.make_with_buddy (friend1)
6           create author1
7           create curmudgeon1
        end
end
```

Which entities are still **Void** after execution of line 4?

Which of the classes mentioned here have creation procedures?

Why is the creation procedure necessary?

Custom initialization for expanded types

- Expanded classes are not creatable using a creation feature of your choice

```
expanded class POINT
create make
feature make do x := 5.0; y := 5.0 end
    ...
end
```

Incorrect

- But you can use (and possibly redefine) default_create

```
expanded class POINT
inherit ANY
    redefine default_create
feature
    default_create
        do
            x := 5.0; y := 5.0
        end
end
```

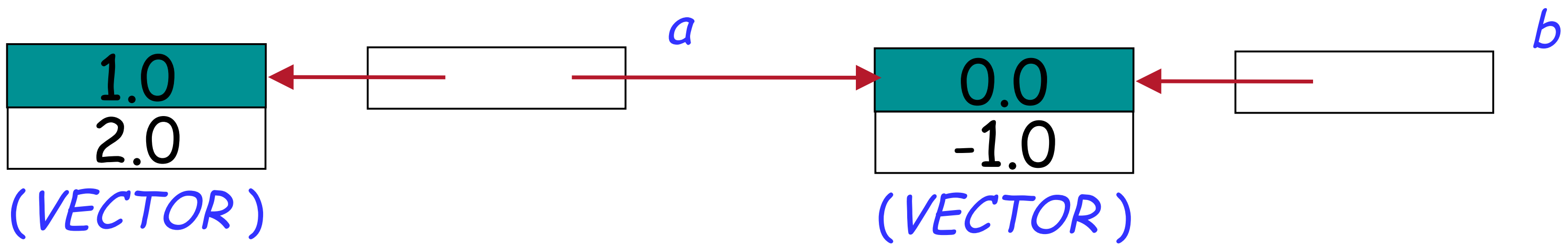
Assignment

- Assignment is an instruction (What other instructions do you know?)
- Syntax:

  $$a := b$$

  - where a is a variable (e.g., an attribute) and b is an expression (e.g. an argument or a query);
  - a is called the target of the assignment and b the source.
- Semantics:
  - after the assignment a equals b ($a = b$);
  - the value of b is not changed by the assignment.

Reference assignment



a := *b*

a references the same object as *b*:

a = *b*

Expanded assignment

a := *b*

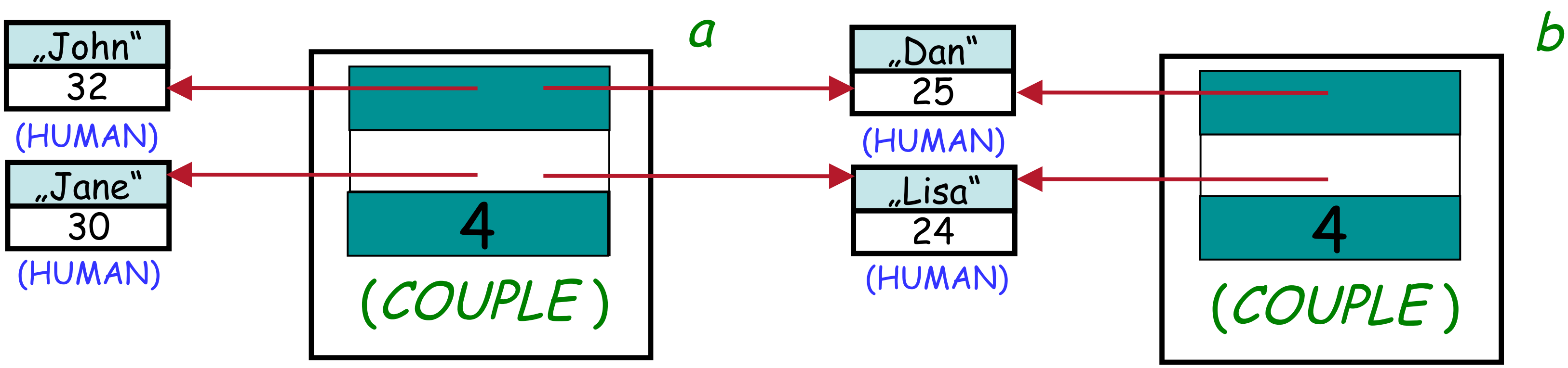
The value of *b* is copied to *a*, but again:

a = *b*

Assignment

Hands-On

Explain graphically the effect of an assignment:



a := *b*

Here *COUPLE* is an expanded class, *HUMAN* is a reference class

Attachment

More general term than assignment

- Includes:
  - Assignment

    a := *b*

  - Passing arguments to a routine

    f (*a*: *SOME_TYPE*)

    do … **end**

    f (*b*)
- Same semantics

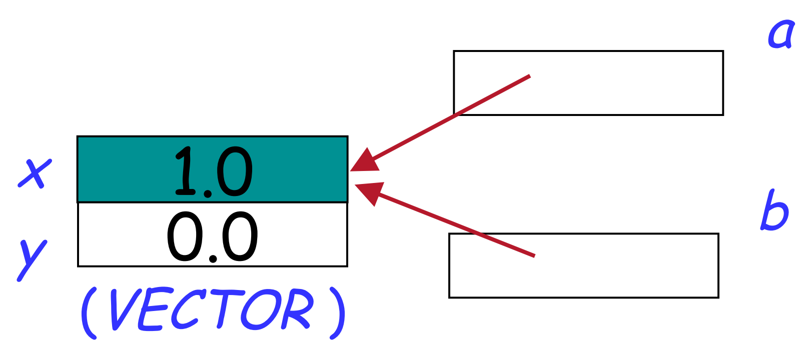
Dynamic aliasing

a, b: VECTOR

…

create *b.make* (1.0, 0.0)

a := *b*



- now *a* and *b* reference the same object (they are two names or aliases of the same object)
- any change to the object attached to *a* will be reflected when accessing it using *b*
- any change to the object attached to *b* will be reflected when accessing it using *a*

Dynamic aliasing

Hands-On

What are the values of *a.x*, *a.y*, *b.x* and *b.y* after executing instructions 1-4?

a, *b*: *VECTOR*

…

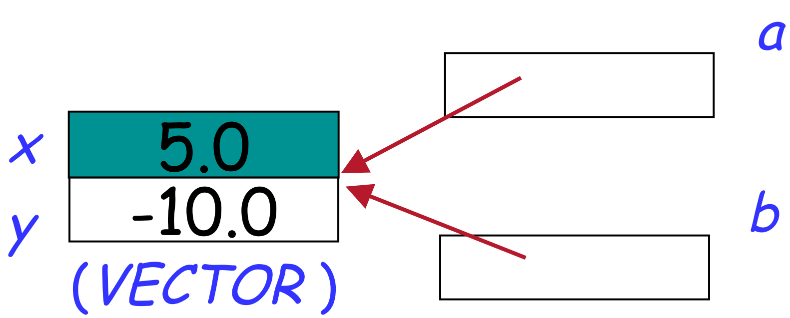
create *a.make* (-1.0, 2.0)

1 **create** *b.make* (1.0, 0.0)

2 *a* := *b*

3 *b.set_x* (5.0)

4 *a.set_y* (-10.0)



Meet Teddy