ETH Zürich
Chair of Software Engineering

Einführung in die Programmierung
Introduction to Programming

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Exercise Session 4

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 at all?

- They are executable specifications that evolve together with the code
- Together with tests, they are a great tool for finding bugs
- They help us to reason about an O-O program at the level of classes and routines
- Proving (part of) programs correct without executing them is what cool people are trying to do nowadays. This is easier to achieve if the program properties are clearly specified through contracts

Assertions

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

Condition
(required)

balance_non_negative: *balance* >= 0

Assertion clause

when the condition is violated, the assertion tag, if present, would be used to construct a more informative error message.

Precondition

Property that a feature imposes on every client

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

A feature with no **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 with no **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 with no **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*

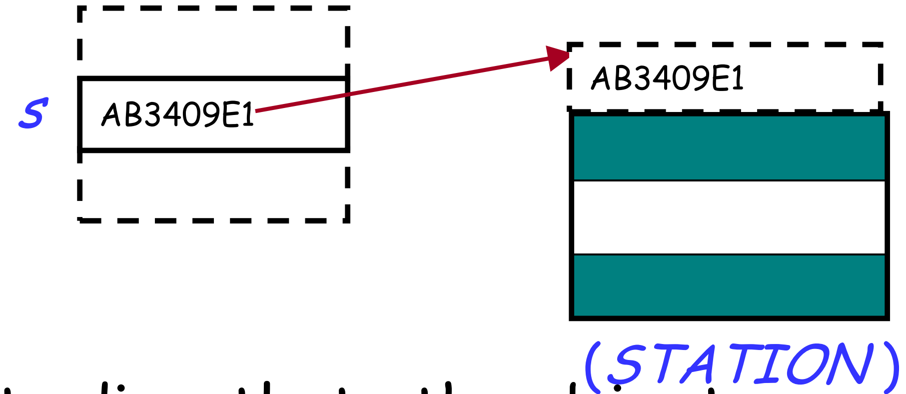
```
class
    ACROBAT_WITH_BUDDY

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:

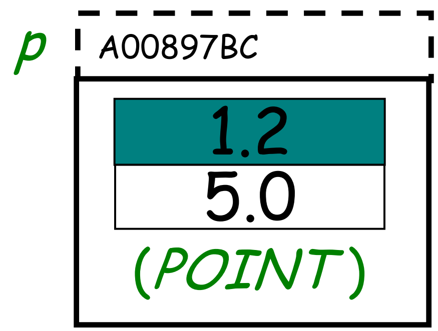
s: *STATION*



Expanded types: *p* points directly to the object.

Example:

p: *POINT*



Why expanded types?

- Representing basic types (*INTEGER*, *REAL*,…)
- Modeling external world objects realistically, i.e. describing objects that have sub-objects (and no sharing), for example a class *WORKSTATION* and its *CPU.*
- Possible efficiency gain.
- Interface with other languages.

How to declare an expanded type

To get an expanded type, declare a class with keyword **expanded**:

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

Now all the entities of type *COUPLE* will automatically become 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

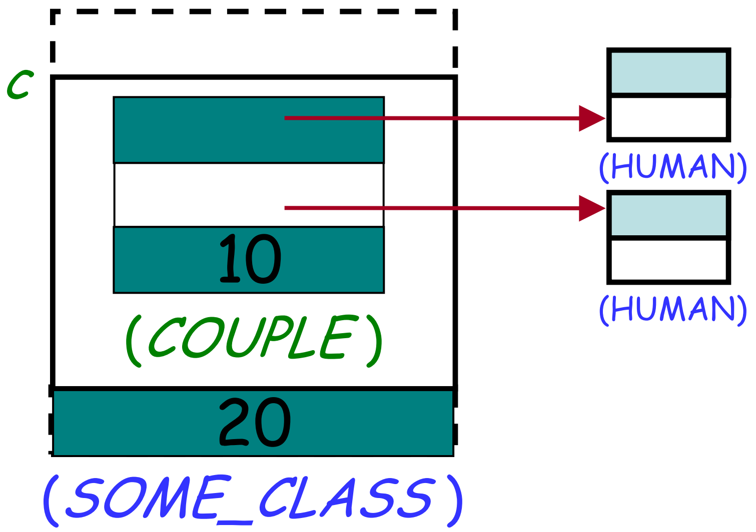
Objects of expanded types: they exist by just declaring them (they are never *Void*)

p: *POINT*

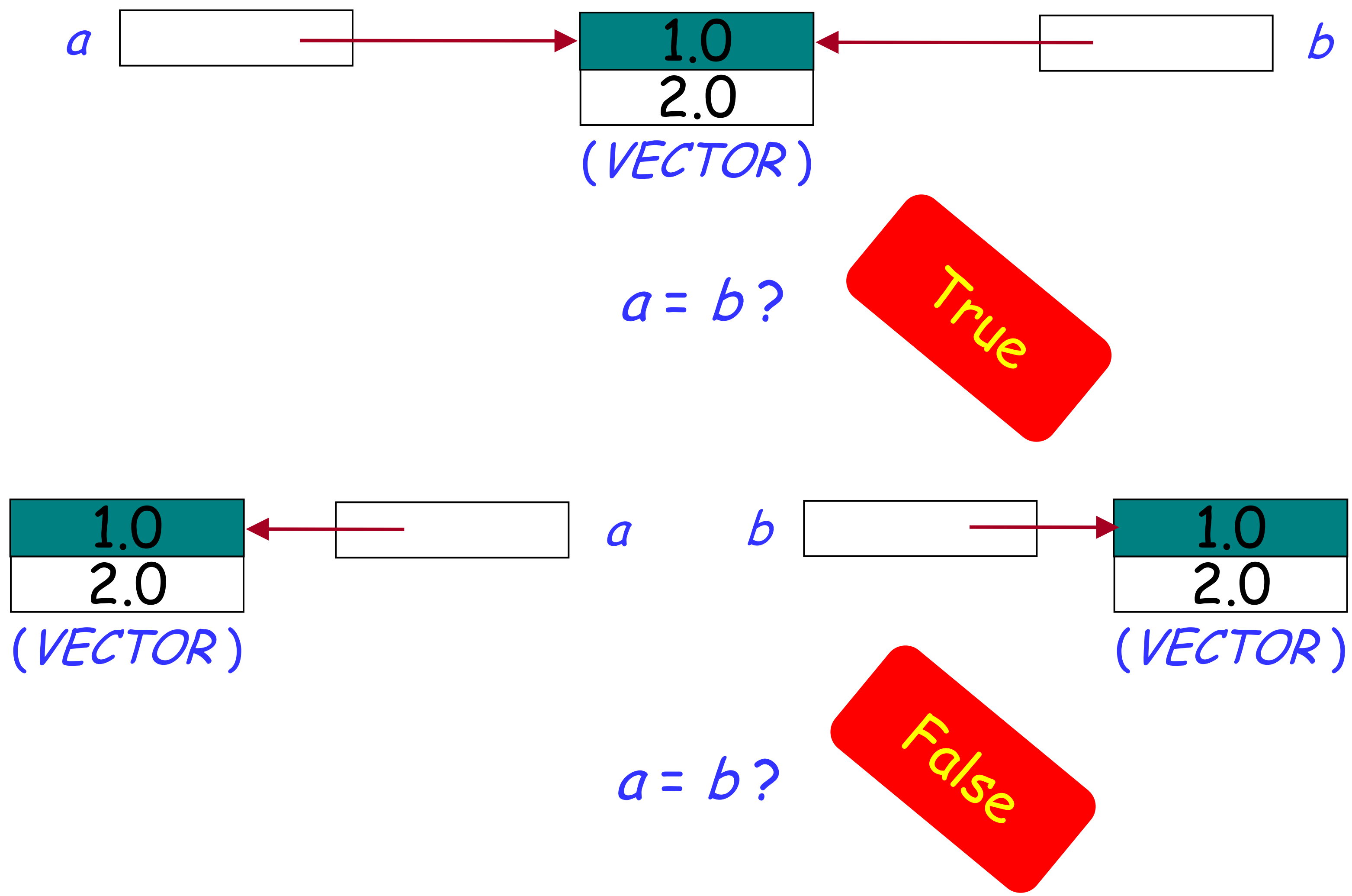
Feature *default_create* from *ANY* is implicitly invoked on them

Can expanded types contain reference types?

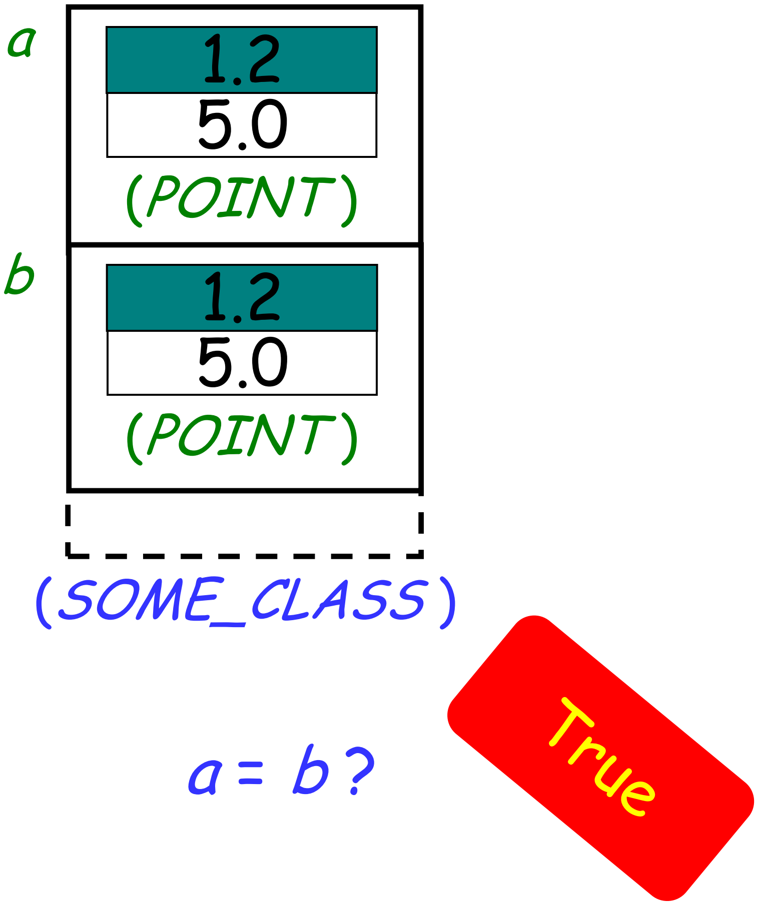
Expanded types can contain reference types, and vice versa.



Reference equality

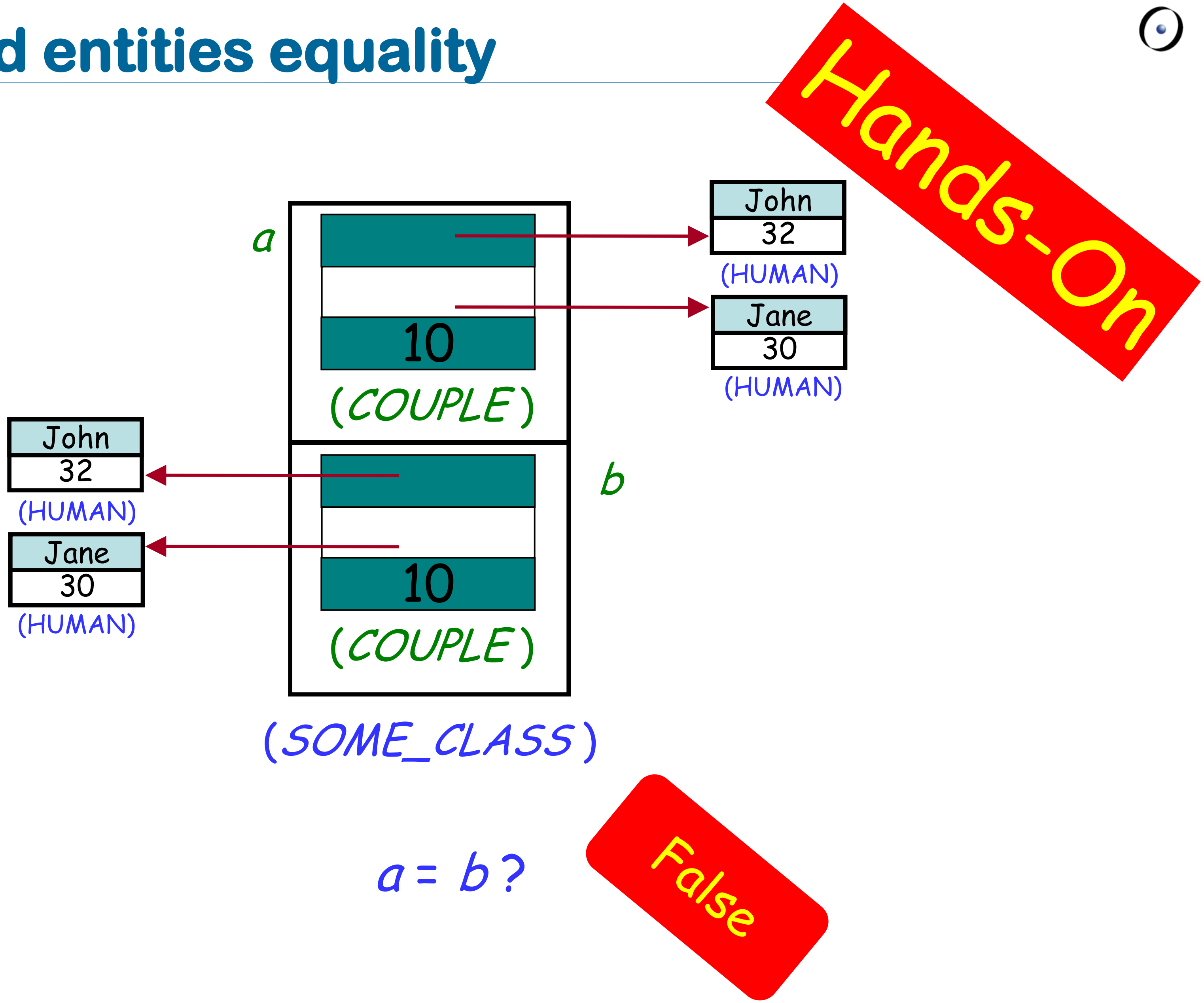


Expanded entities equality

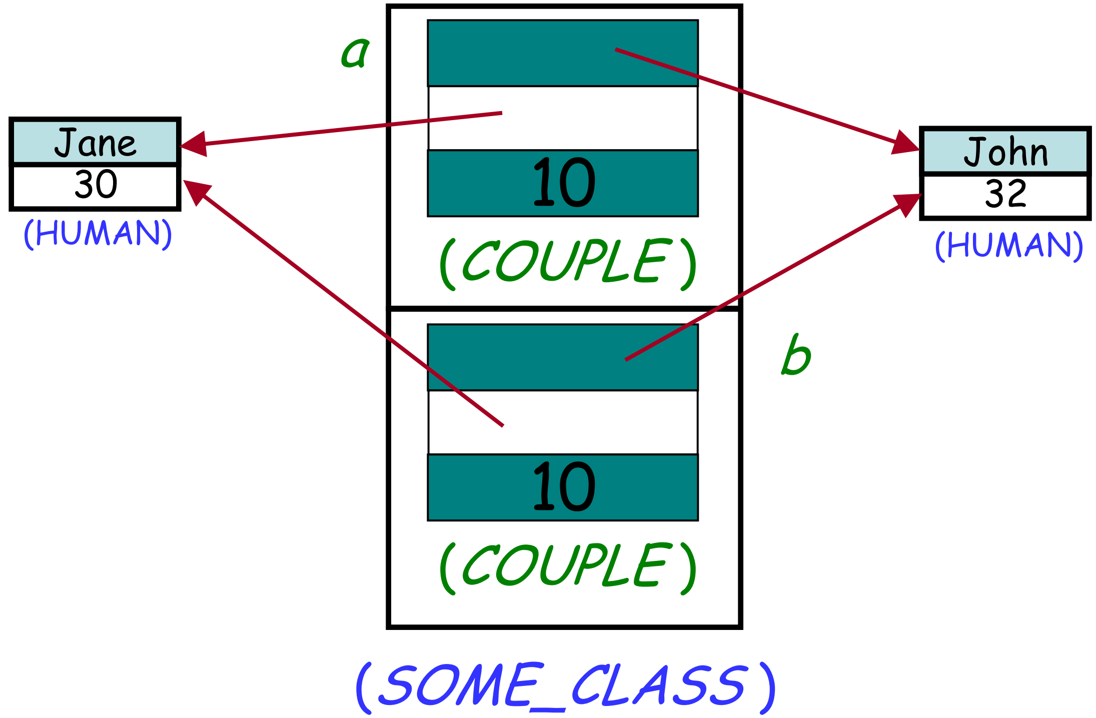


Entities of expanded types are compared by value!

Expanded entities equality



Expanded entities equality



a = b ?

True

Hands-On

Basic types

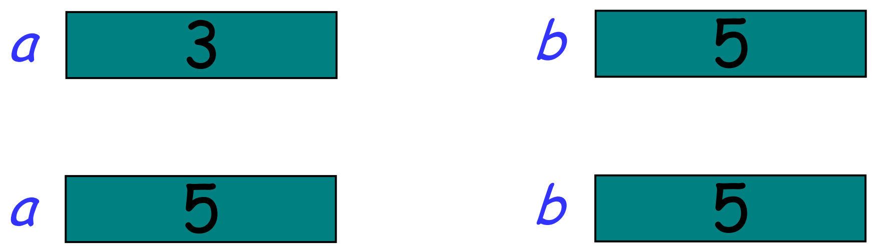
Their only privilege is to use manifest constants to construct their instances:

```
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*



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

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

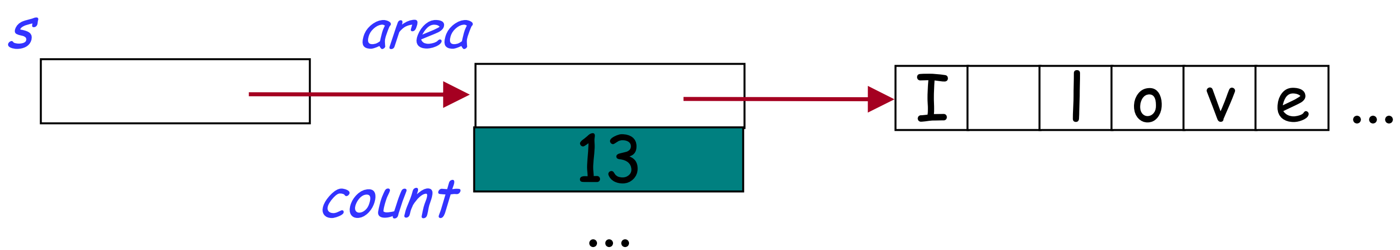
a + *b*

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!")

String comparison: *=* versus *is_equal*

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

s1.is_equal (s2) -True
…
```

Now you know what to do if interested in comparing the content of two strings

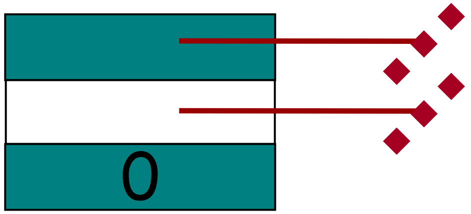
Initialization

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



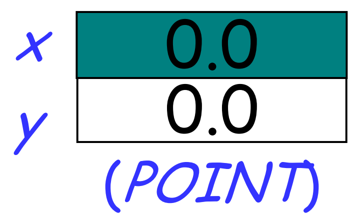
(*COUPLE*)

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

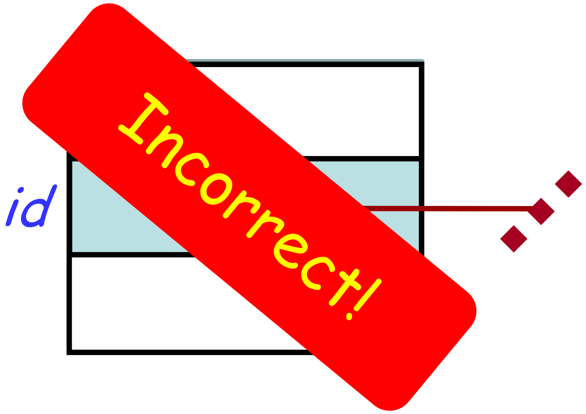
STRING

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
```

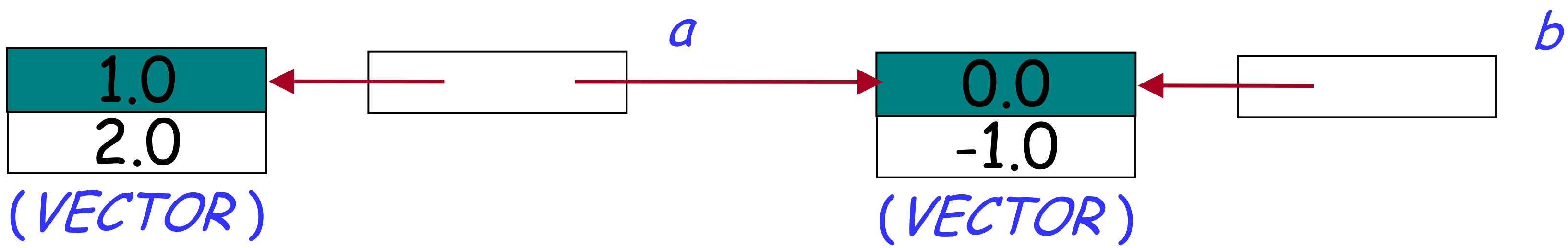
Assignment

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

$$a := b$$

  - where *a* is a variable (e.g., attribute) and *b* is an expression (e.g. argument, query call);
  - *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*

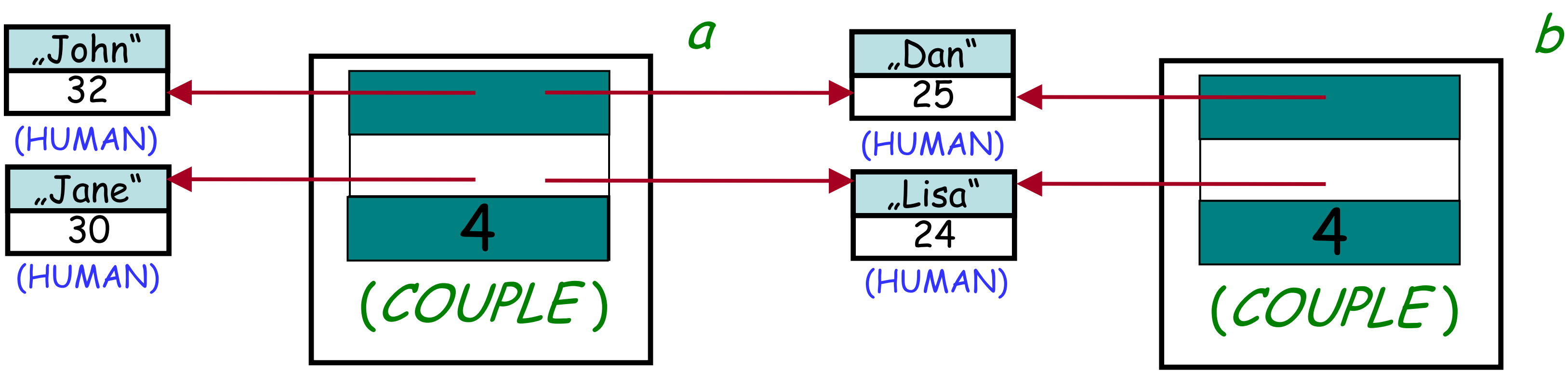
The value of *b* is copied to *a*, but again:

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

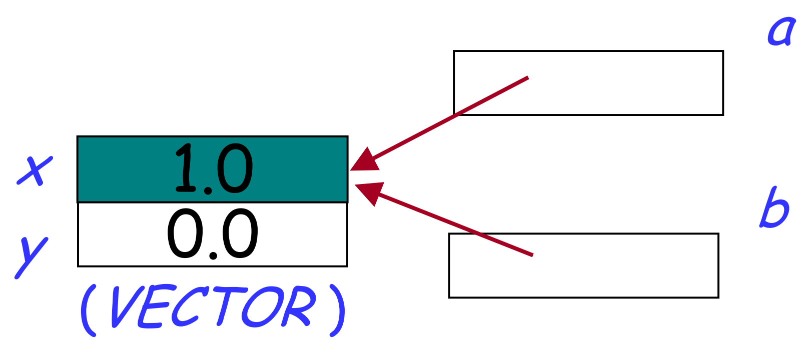
Dynamic aliasing

a, b: VECTOR

…

create *b.make* (1.0, 0.0)

a := *b*



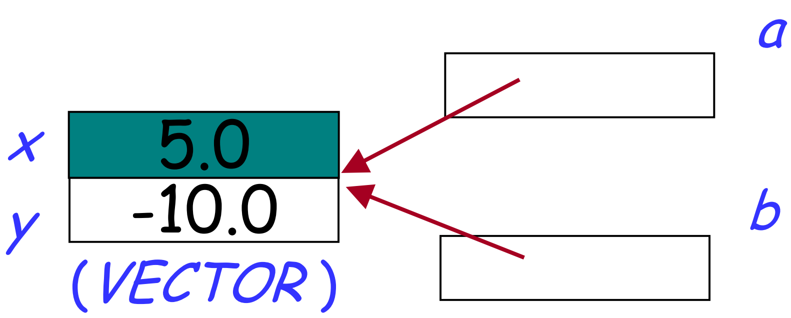
- now *a* and *b* reference the same object (they are two names or aliases of the same object)
- any change to the object attached to *a* will be reflected when accessing it using *b*
- any change to the object attached to *b* will be reflected when accessing it using *a*

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