Fondamenti della Programmazione: Metodi Evoluti

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Lezione 13: Multiple inheritance

Combining abstractions

Given the classes

- TRAIN_CAR, RESTAURANT

how would you implement a DINER?

Examples of multiple inheritance

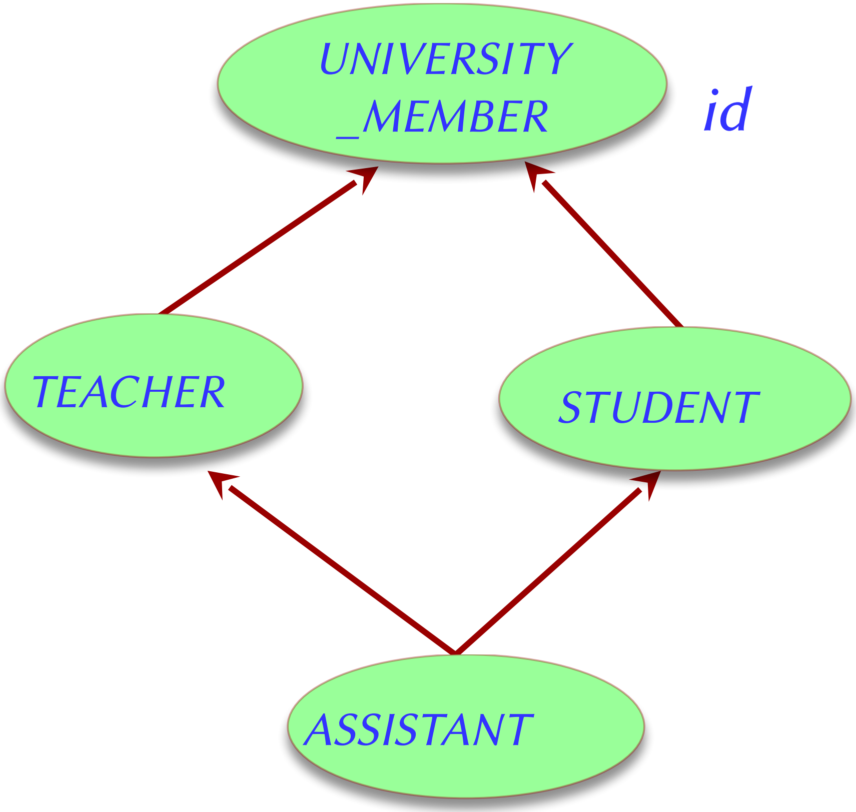
Combining separate abstractions:

- Restaurant, train car
- Calculator, watch
- Home, vehicle
- Taxi, bus

An example of repeated inheritance

A class with two or more parents sharing a same grand-parent.

Examples that come to mind: *ASSISTANT* inherits from *TEACHER* and *STUDENT*.



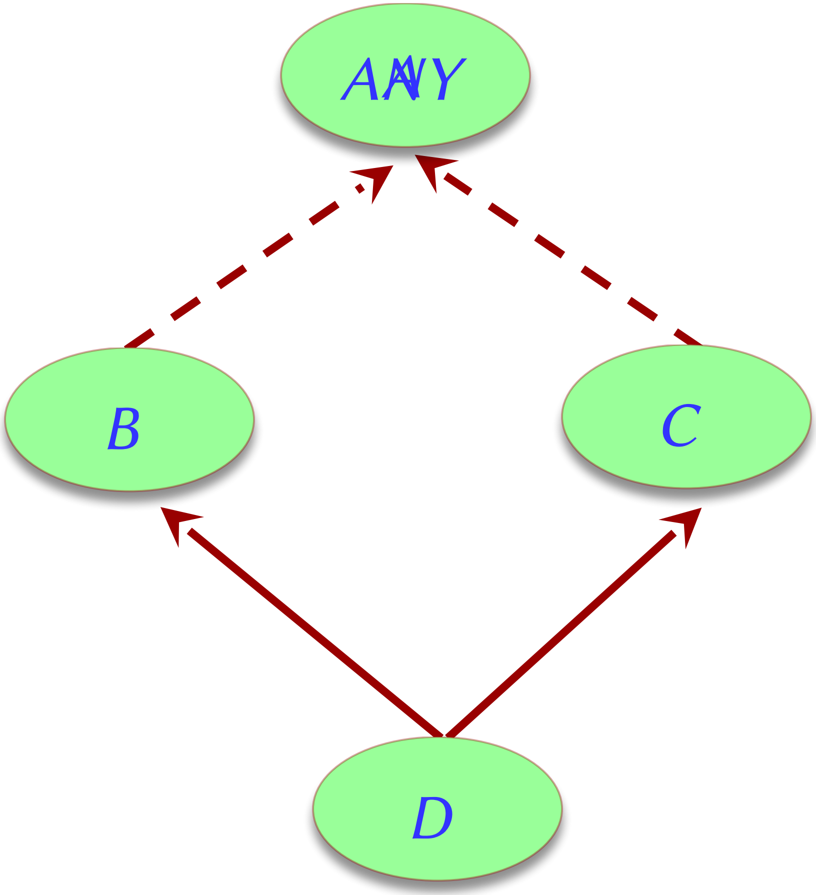
This is a case of repeated inheritance

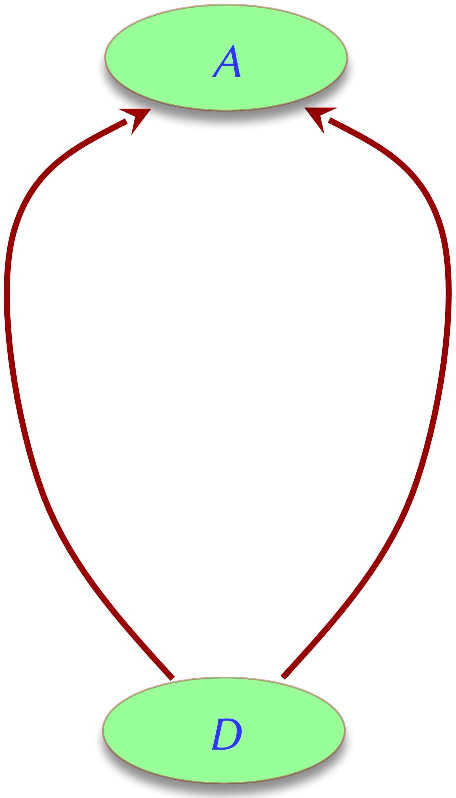
repeated and multiple inheritance

Multiple inheritance from B and C

Repeated inheritance from A

(In Eiffel is found often; why?)





This form of repeated inheritance cannot happen in Eiffel

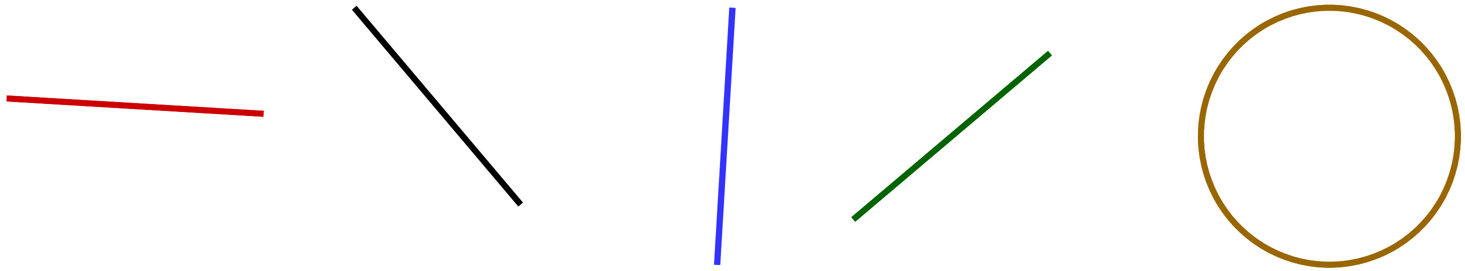
Another warning

The language part of this lecture are Eiffel-oriented

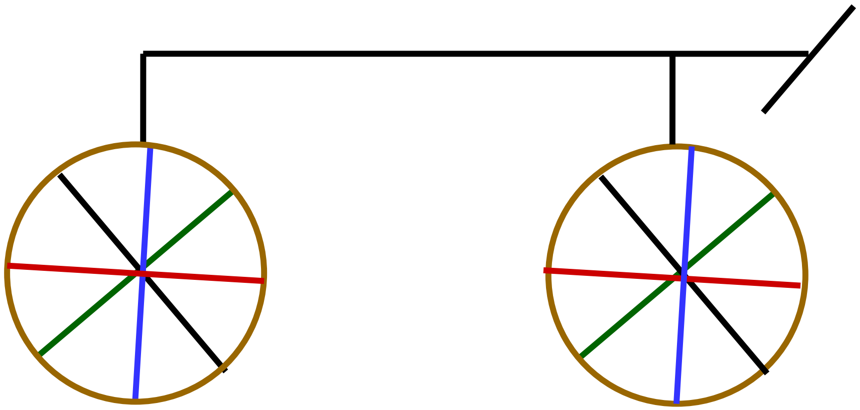
Java and C# mechanisms (single inheritance from classes, multiple inheritance from interfaces) will also be discussed

C++ also has multiple inheritance, but it will not be described

Multiple inheritance: Composite figures



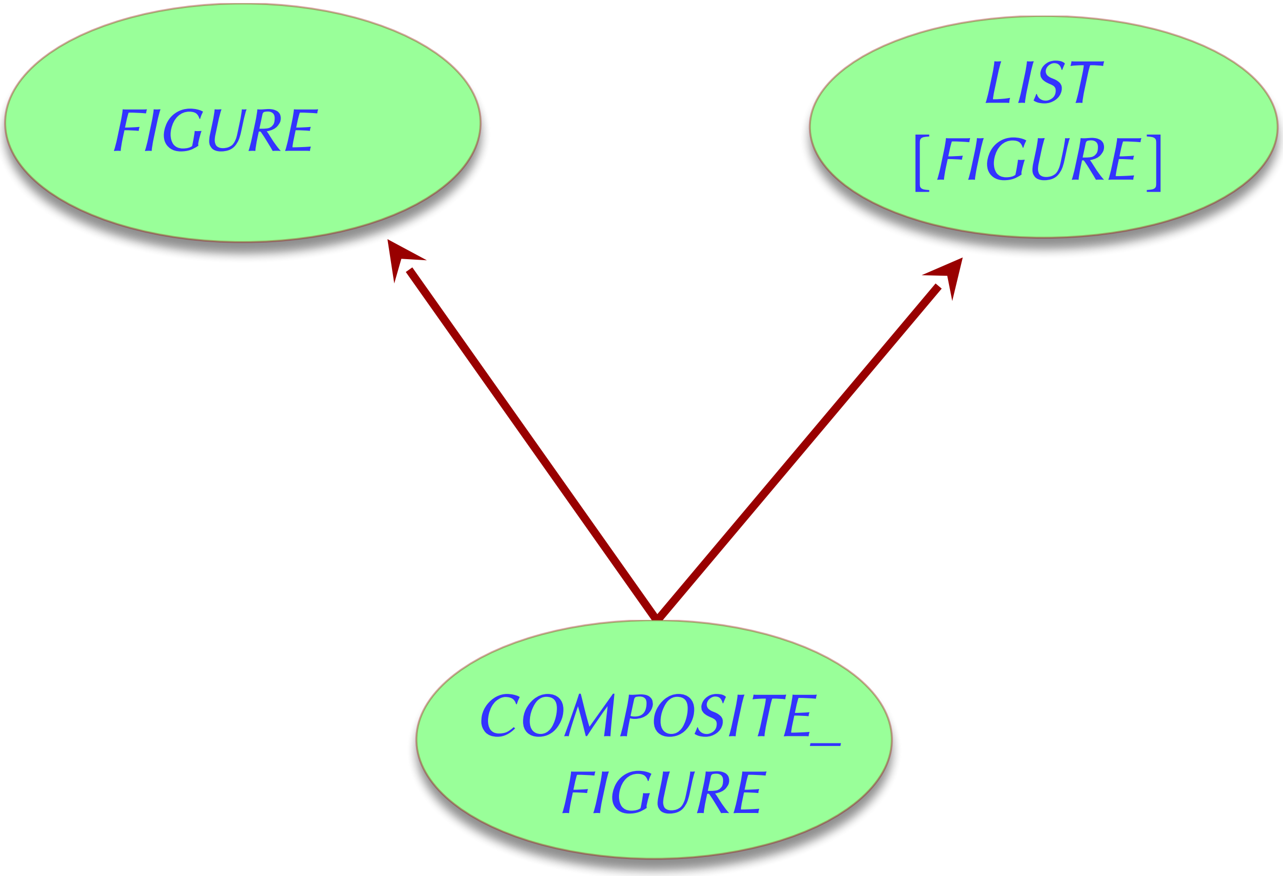
Simple figures



A composite figure

Defining the notion of composite figure

center
display
hide
rotate
move
…



FIGURE

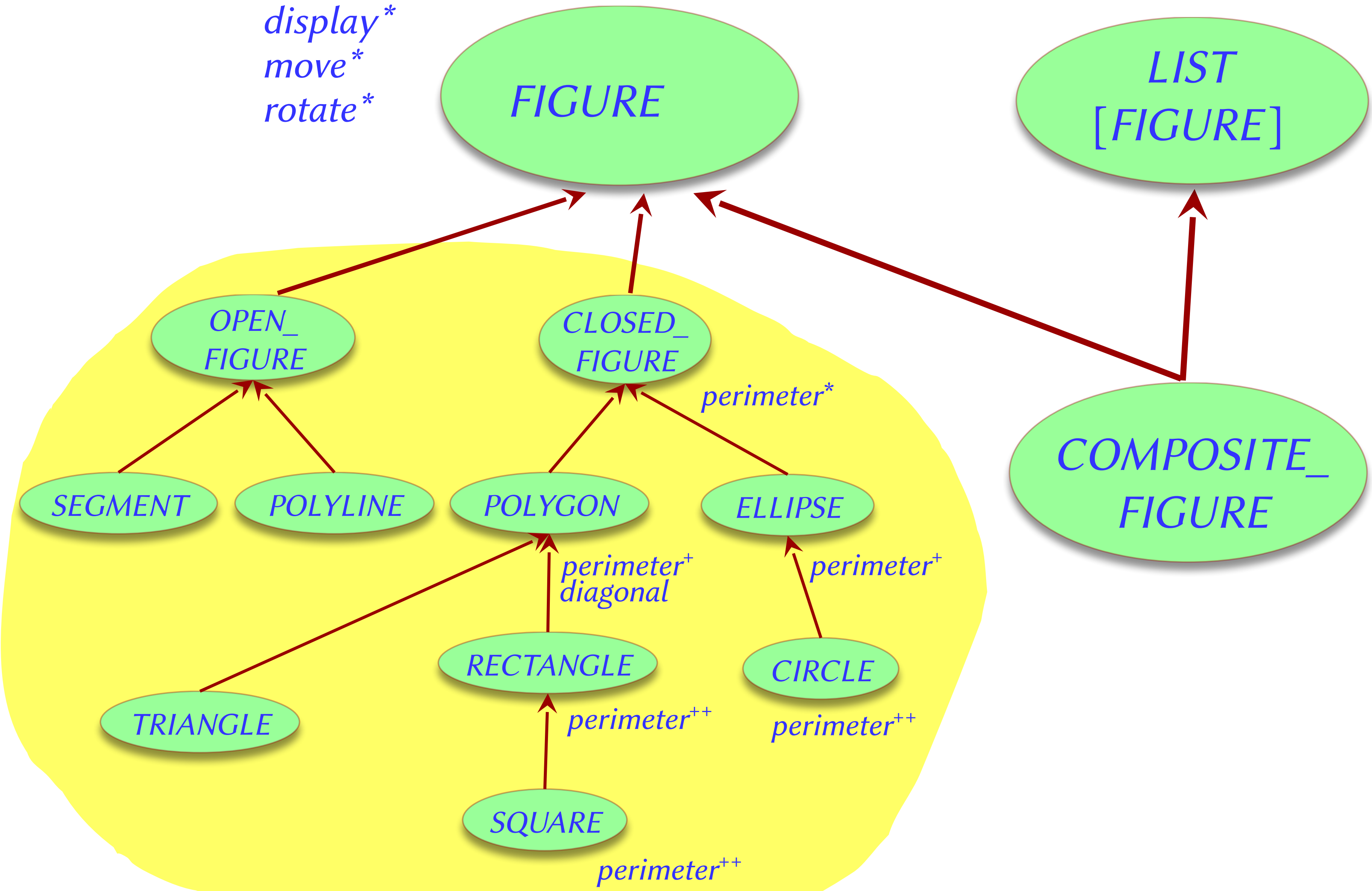
LIST [FIGURE]

COMPOSITE_FIGURE

count
put
remove
…

COMPOSITE_FIGURE inherits different features from more than one parent: this is multiple inheritance

In the overall structure

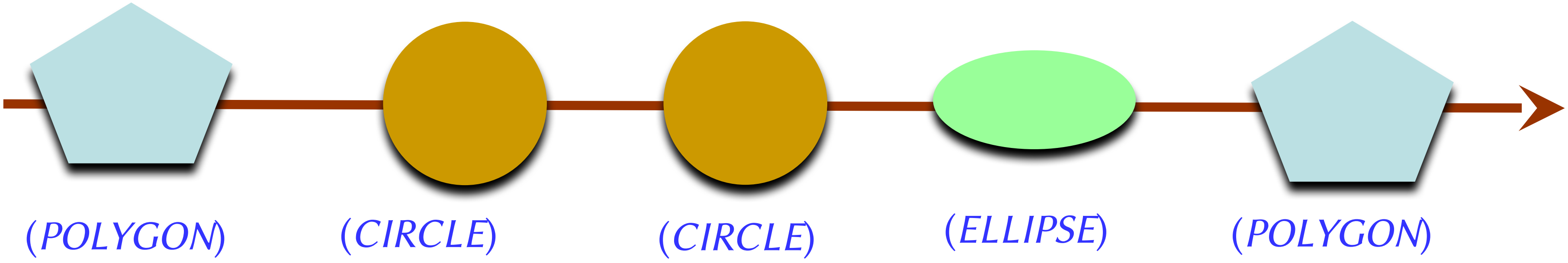


Working with polymorphic data structures

(from 10-EREDITARIETA')

```
figs: LIST [FIGURE]

…

from figs.start until figs.after loop
        figs.item.display
        figs.forth
end
```

Dynamic binding

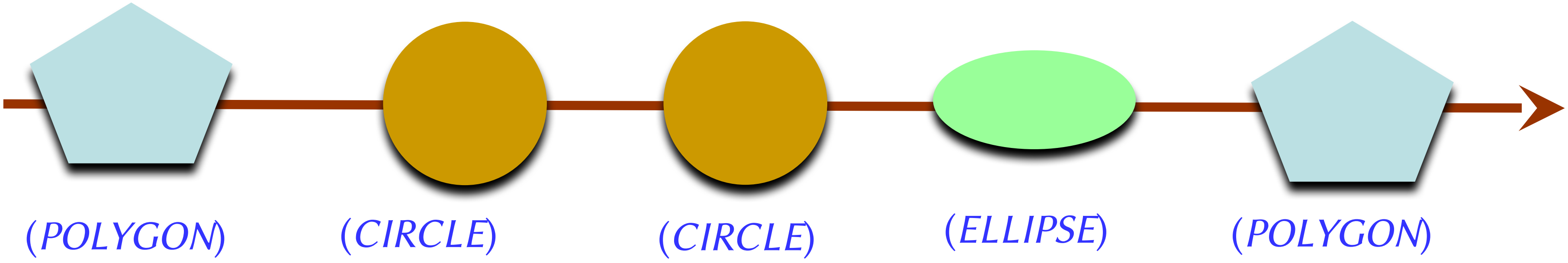


Working with polymorphic data structures

(from 10-EREDITARIETA')

```
figs: LIST [FIGURE]

…

across figs as c loop

        c.item.display

end
```

Dynamic binding



Definition (Polymorphism, adapted)

(from 10-EREDITARIETA')

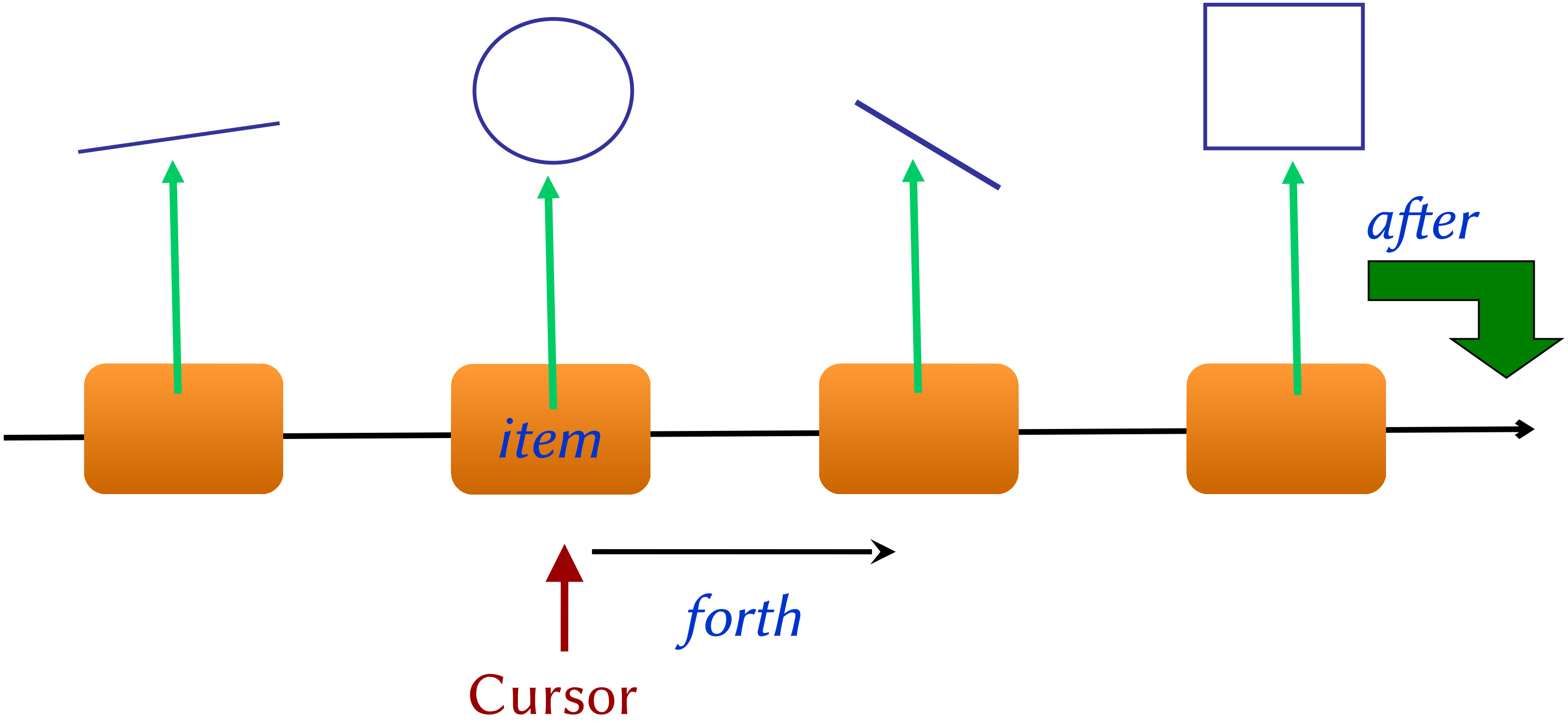
An **attachment** (assignment or argument passing) is **polymorphic** if its target entity and source expression have different types.

An **entity** or **expression** is **polymorphic** if – as a result of polymorphic attachments – it may at runtime become attached to objects of different types.

A **container data structure** is **polymorphic** if it may contain references to objects of different types.

Polymorphism is the existence of these possibilities.

A composite figure as a list

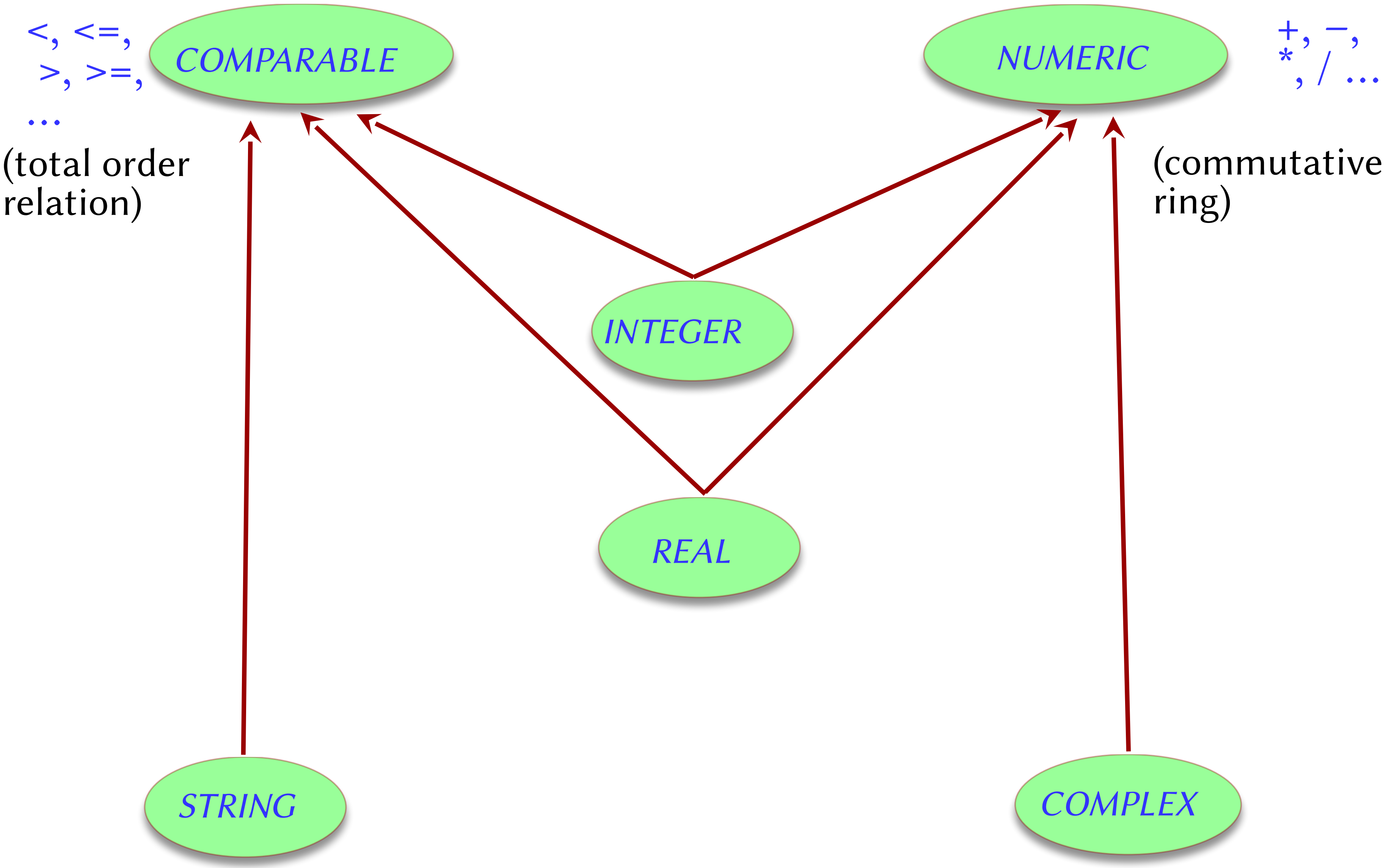


Composite figures

```
class COMPOSITE_FIGURE inherit
        FIGURE
        LIST [FIGURE]
feature
        display
                -- Display each constituent figure in turn.
        do
                from start until after loop
                        item.display
                        forth
                end
        end
        ... Similarly for move, rotate etc. ...
end
```

Requires dynamic binding

Multiple inheritance: Combining abstractions



How do we write *COMPARABLE*?

```
deferred class COMPARABLE [G] feature

      less alias "<" (x: COMPARABLE [G]): BOOLEAN
         deferred
         end

   less_equal alias "<=" (x: COMPARABLE [G]): BOOLEAN
         do
               Result := (Current < x or (Current = x))
         end

   greater alias ">" (x: COMPARABLE [G]): BOOLEAN
         do Result := (x < Current) end

   greater_equal alias ">=" (x : COMPARABLE [G ]): BOOLEAN
         do Result := (x <= Current) end

end
```

Java and .NET and C# solution

Single inheritance only for classes

Multiple inheritance only for **interfaces**

Classes can have multiple inheritance from **interfaces**

An interface is like a fully deferred class, with no implementations (**do** clauses), no attributes (and also no contracts): it's only specification

A class may inherit from:

- At most one class
- Any number of interfaces

Deferred classes vs Java interfaces (1)

- Java interfaces are “entirely deferred”
  - Only method (routine) definitions
  - No method implementations
  - No attributes
  - No contracts

- Eiffel deferred classes can include effective features, possibly relying on deferred ones, as in the *COMPARABLE* example
  - Flexible mechanism to implement abstractions progressively

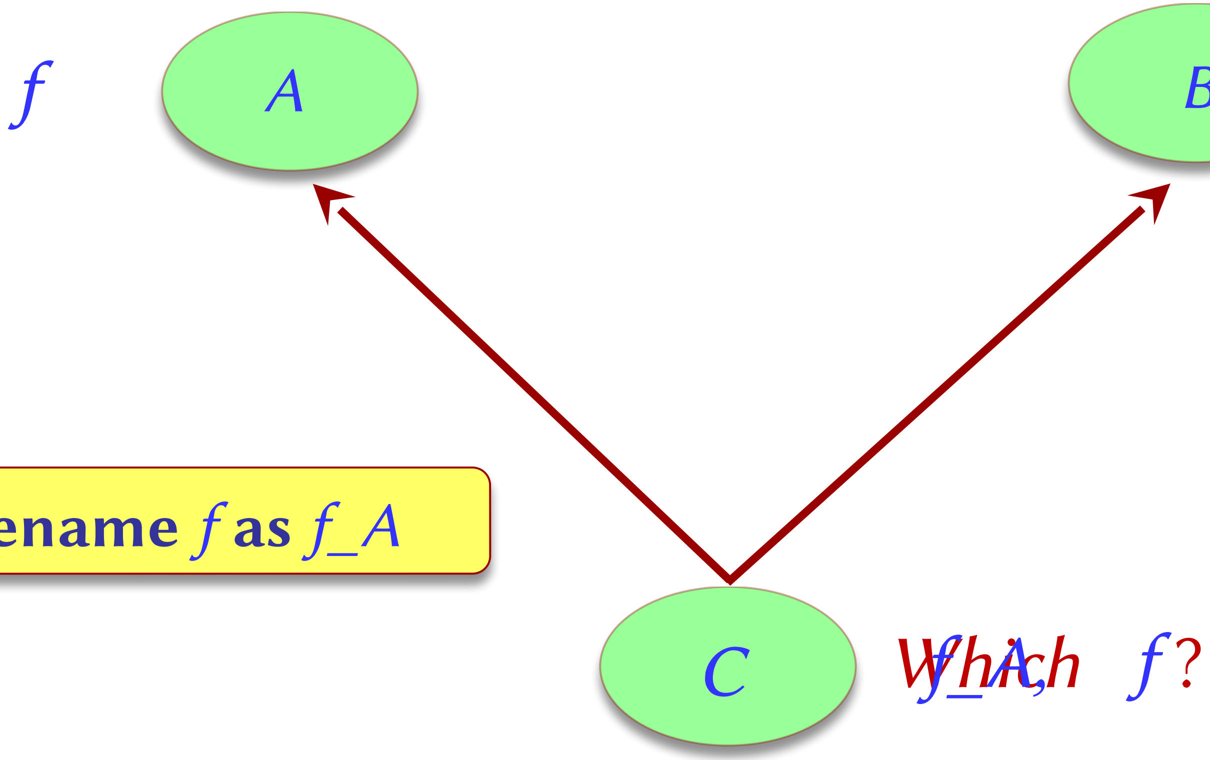
Deferred classes vs Java interfaces (2)

Java requires that every class which is descendant of an interface must provide implementations of *all* interface's features.

To be able to flexibly model reality we need the full spectrum from fully abstract (i.e., fully deferred) to fully implemented classes provided by Eiffel

Multiple inheritance is here to help us combine abstractions

Resolving name clashes



rename *f* **as** *f_A*

```
class C inherit
        A rename f as f_A, ...
        B
        end
```

...

Consequences of renaming (1)

In class *C*

a1: *A*
b1: *B*
c1: *C*

…

OK *c1*.*f* — Version from *B*

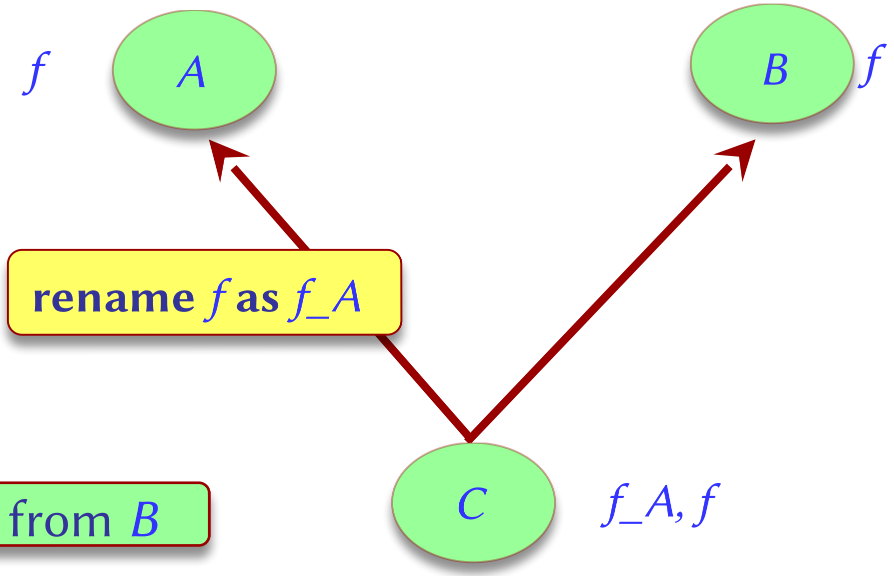
OK *c1*.*f_A* — Version from *A*

OK *a1*.*f* — Version from *A*

Invalid! *a1*.*f_A*

OK *b1*.*f* — Version from *B*

Invalid! *b1*.*f_A*



Consequences of renaming (2)

In class *C*

```
a1: A
b1: B
c1: C
...
a1:= c1
```

OK *c1.f* — Version from *B*

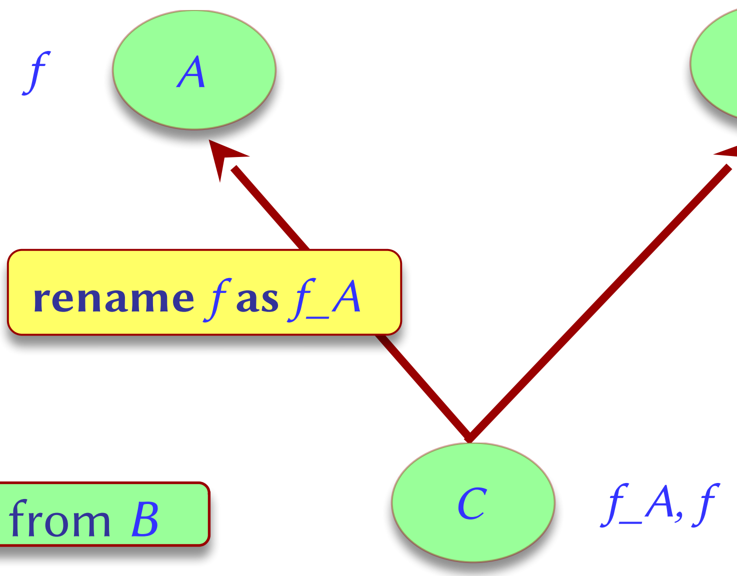
OK *c1.f_A* — Version from *A*

OK *a1.f* — Version from *A*, not from B !

Invalid! *a1.f_A*

OK *b1.f* — Version from *B*

Invalid! *b1.f_A*

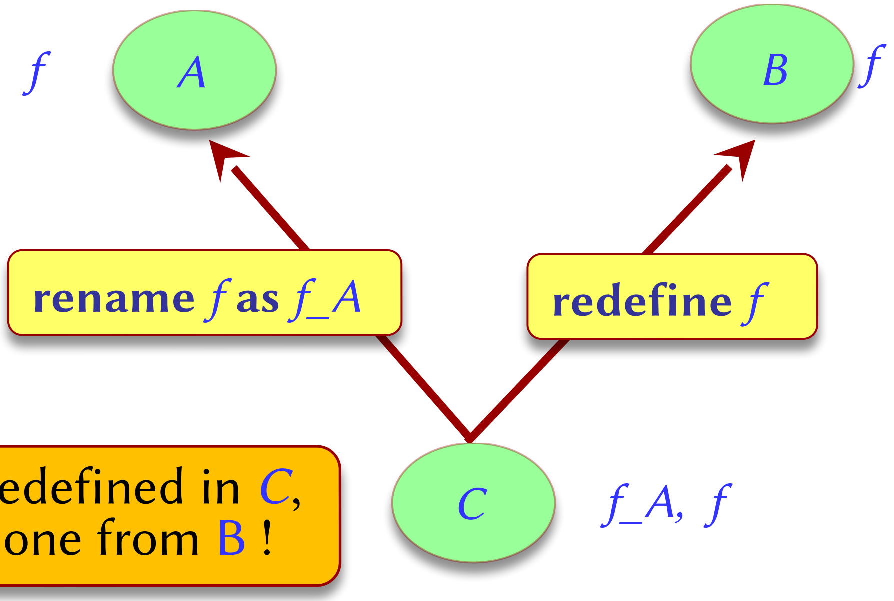


Instances of ***C*** do not have a more specialized version for name ***f*** coming from ***A*** and must use the version of ***A***

Consequences of renaming (3) and redefining

In class *C*

a1: A
b1: B
c1: C
…
a1:= c1
b1:= c1



OK *c1.f*

Version redefined in *C*, not the one from B !

OK *c1.f_A*

Version from *A*

OK *a1.f*

Version from *A*, not from B !

Invalid! *a1.f_A*

OK *b1.f*

Version redefined in *C*, not the one from B !

Invalid! *b1.f_A*

Instances of ***C*** inherit name ***f*** from ***B*** and redefine its implementation

Renaming and redefinition

Renaming keeps the feature behavior and changes its name

Redefinition changes the feature behavior and keeps its name

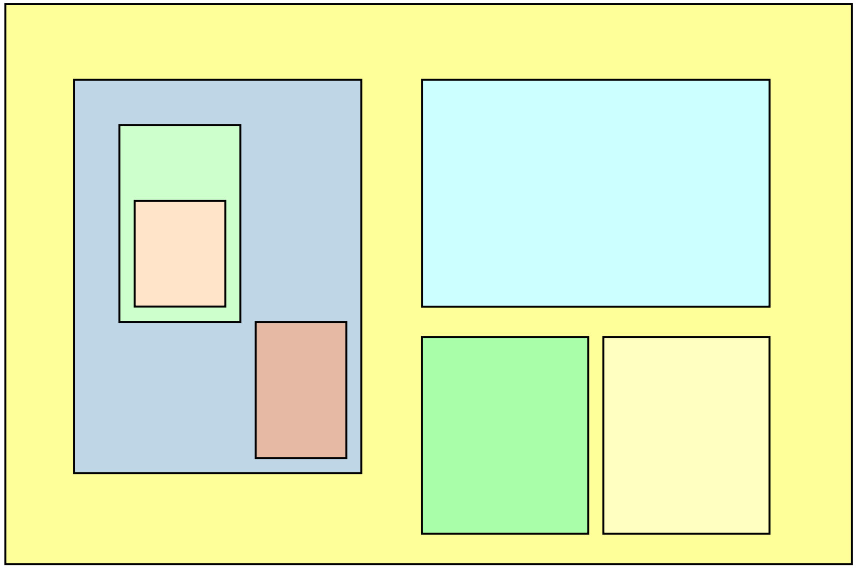
It is possible to combine both:

```
class B
    inherit
        A
            rename f as f_A, ...
            redefine f_A, ...
            end
        ...
```

An application of renaming

Provide locally better adapted terminology.

Example: *child (TREE)*; *subwindow (WINDOW)*

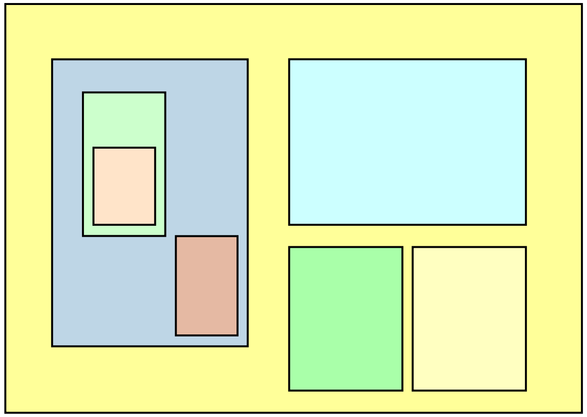


Renaming to improve feature terminology

"Graphical" features: *height, width, change_height, change_width, xpos, ypos, move...*

"Hierarchical" features: *superwindow, subwindows, change_subwindow, add_subwindow...*

```
class WINDOW inherit
    RECTANGLE
    TREE [WINDOW]
        rename
            parent as superwindow,
            children as subwindows,
            add_child as add_subwindow
            ...
        end
feature
    ...
end
```



BUT: see style rules about uniformity of feature names

Are all name clashes bad?

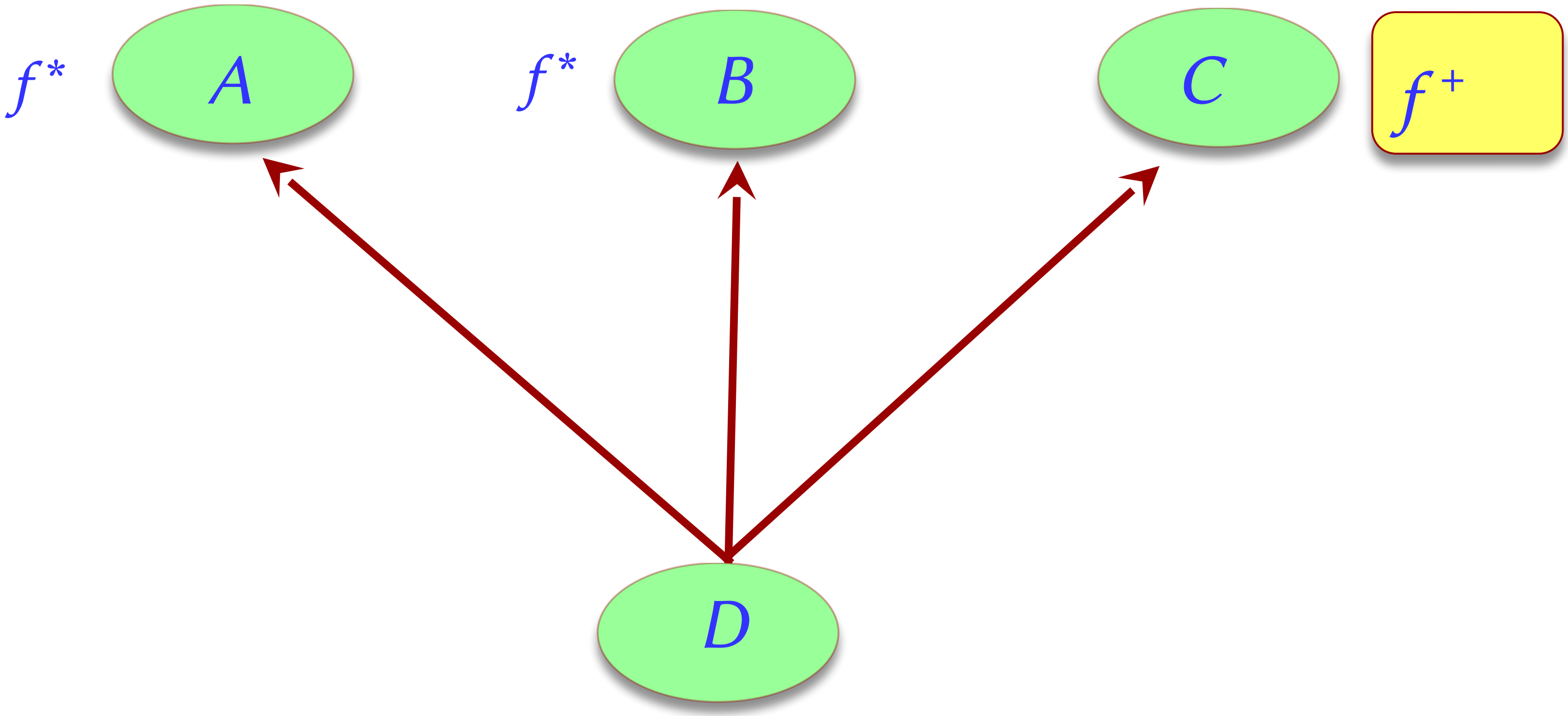
A name clash must be removed unless it is:

- Under repeated inheritance (i.e. not a real clash), OR
- All inherited features with the same name are such that
  - They all have compatible signatures
  - At most one of them is effective

Semantics of the latter case:

- All features are merged into a single one
- If there is an effective feature, its implementation is the one which is used

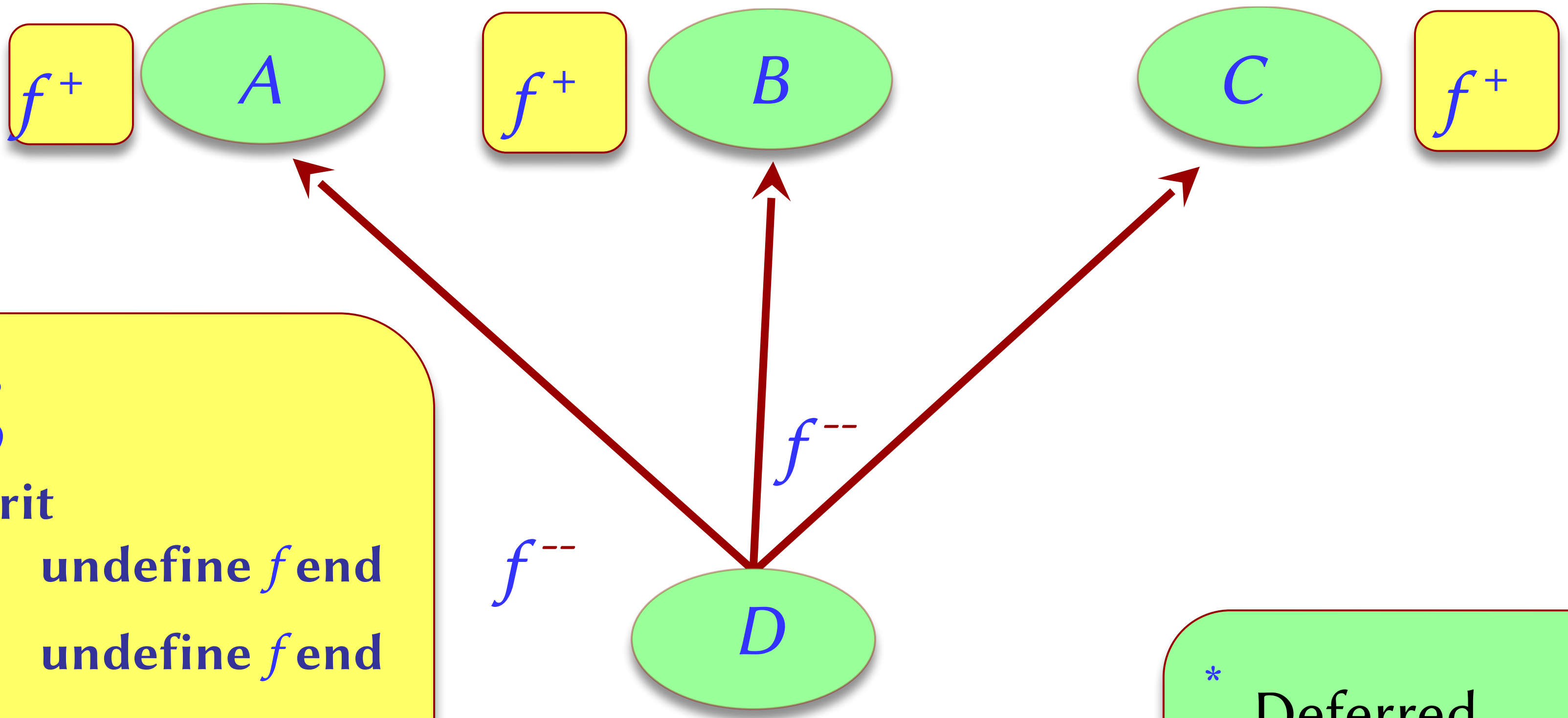
Feature merging



* Deferred

$^+$ Effective

Feature merging: case of effective features



```
class
    D
inherit
    A   undefine f end

    B   undefine f end

    C

feature
        ...
end
```

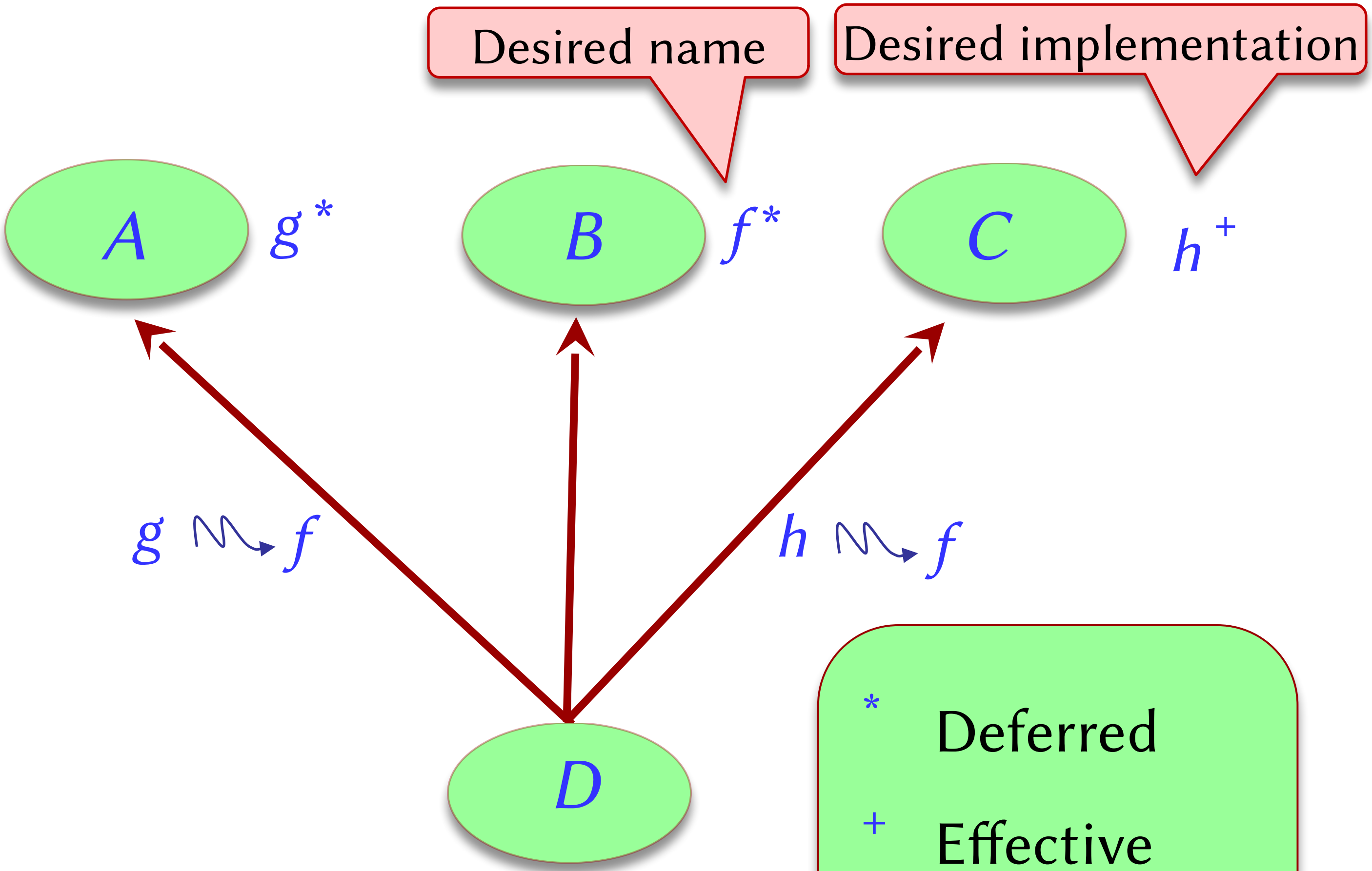
* Deferred

+ Effective

-- Undefine

Feature merging: case of different names (1)

```
class
    D
inherit
    A
        rename
            g as f
        end

    B

    C
        rename
            h as f
        end

feature
            ...
end
```



* Deferred

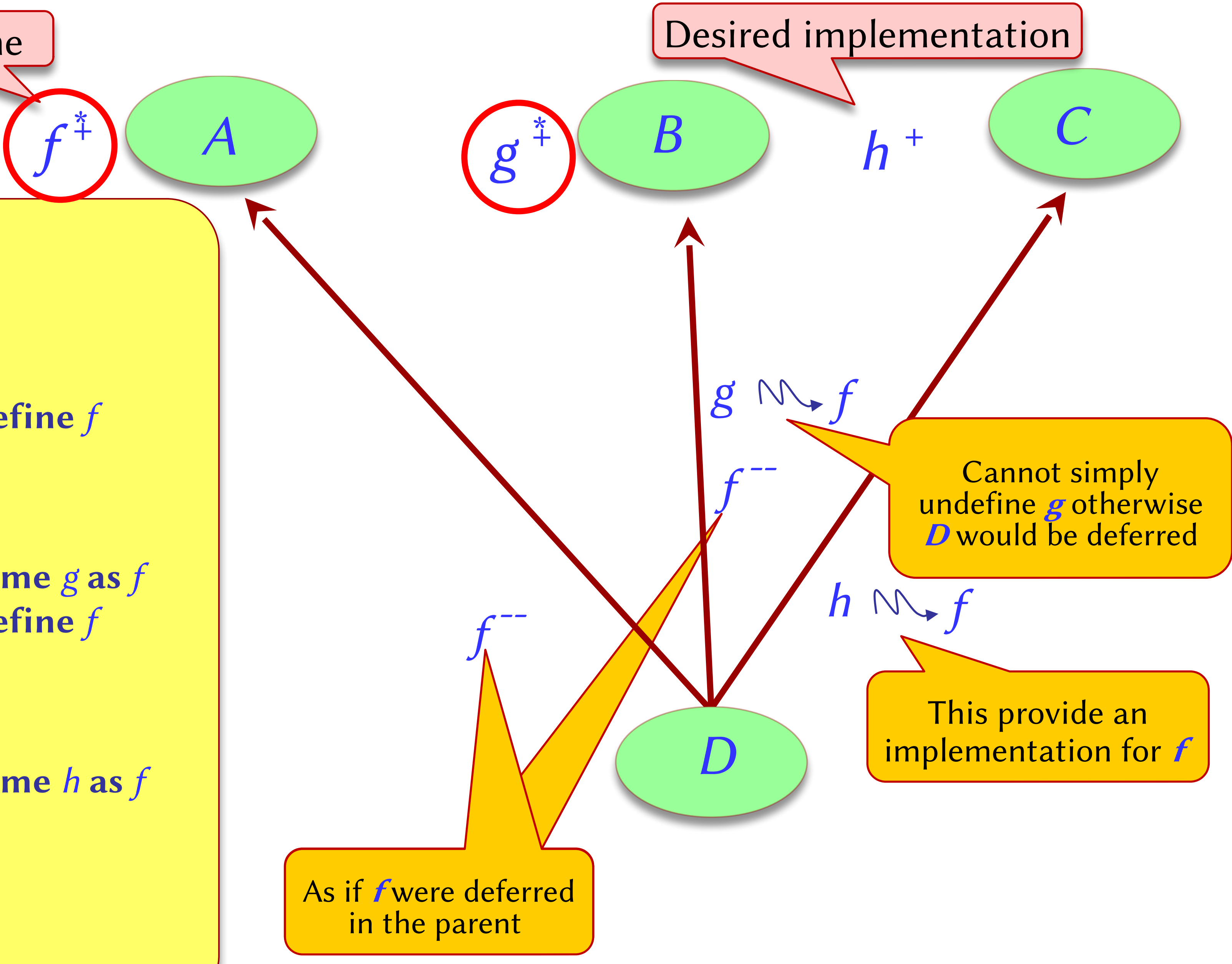
+ Effective

-- Undefine

⇝ Rename

Feature merging: case of different names (2)

```
class
    D
inherit
    A
        undefine f
        end

    B
        rename g as f
        undefine f
        end

    C
        rename h as f
        end
feature
    …
end
```

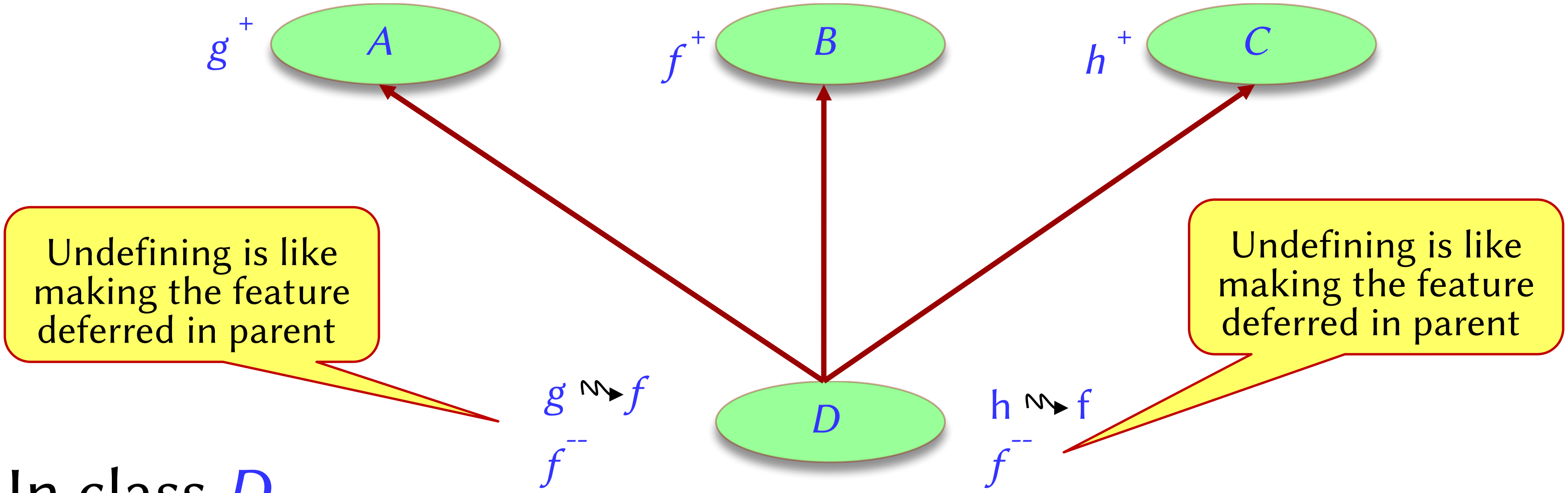


Cannot simply undefine ***g*** otherwise ***D*** would be deferred

This provide an implementation for ***f***

As if ***f*** were deferred in the parent

Feature call after merging



Undefining is like making the feature deferred in parent

Undefining is like making the feature deferred in parent

In class *D*

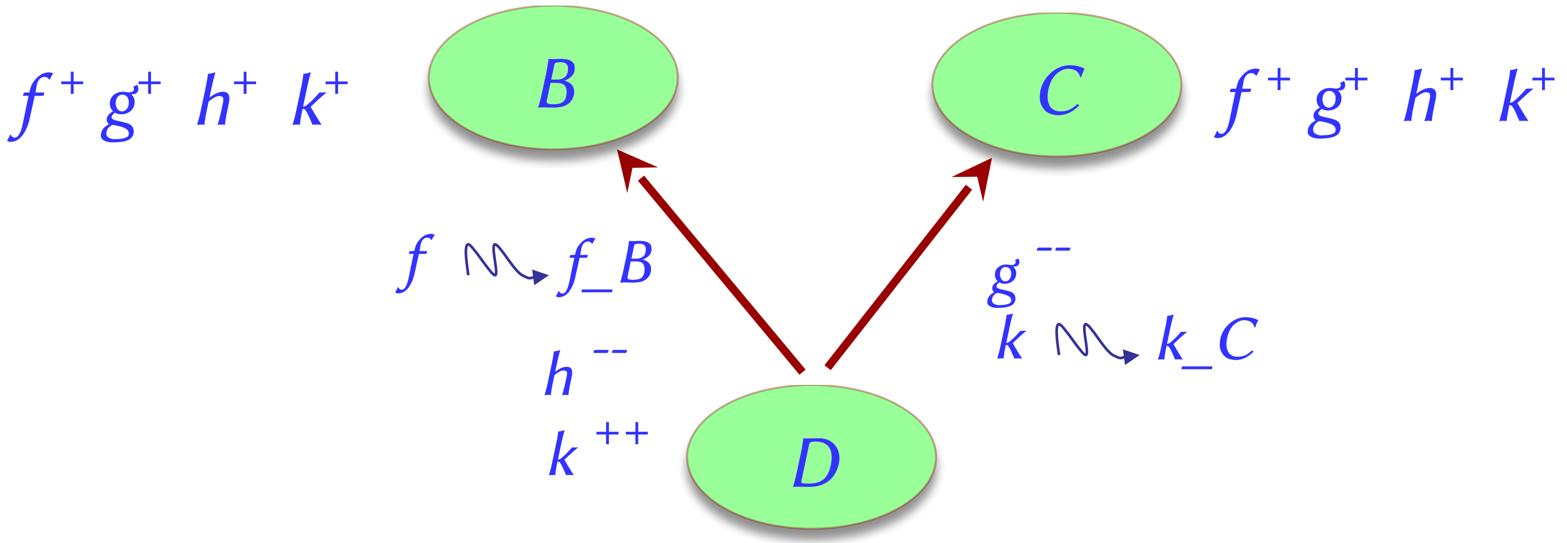
a1: A
a1.g OK

b1: B
b1.f OK

c1: C
c1.h OK

d1: D
d1.f OK
d1.g Invalid!
d1.h Invalid!

Feature merging: case of equal names (1)



f (from C) *f_B* *g* (from B) *h* (from C) *k* (from D) *k_C*

In the root class *b1: B* *d1: D*

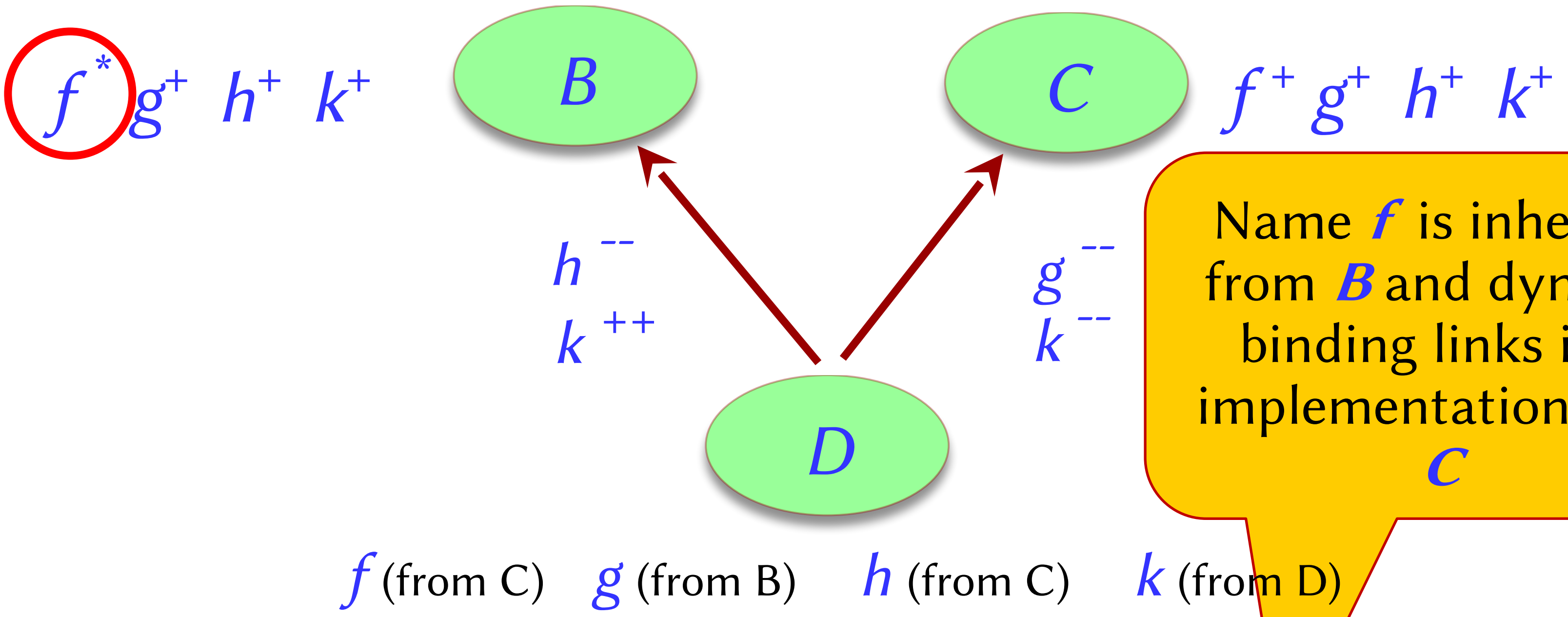
d1.f	C
d1.g	B
d1.h	C
d1.k	D

Dynamic binding cannot be applied since name *f* has been removed in inheritance toward ***D***

Then *b1 := d1*

b1.f	B
b1.g	B
b1.h	C
b1.k	D

Feature merging: case of equal names (2)



f^{*} g^{+} h^{+} k^{+}

B

C

f^{+} g^{+} h^{+} k^{+}

h^{--}
k^{++}

g^{--}
k^{--}

D

f (from C) *g* (from B) *h* (from C) *k* (from D)

Name ***f*** is inherited from ***B*** and dynamic binding links it to implementation from ***C***

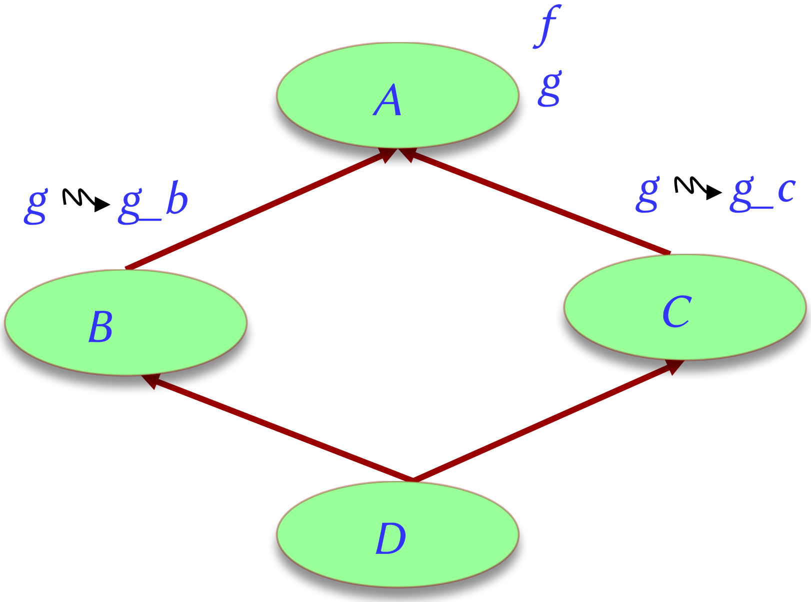
In the root class *b1: B* *d1: D*

Then *b1 := d1*

b1.f	*d1.f*	C	*b1.f*	C
b1.g	*d1.g*	B	*b1.g*	B
b1.h	*d1.h*	C	*b1.h*	C
b1.k	*d1.k*	D	*b1.k*	D

Since ***B*** is deferred, direct instances cannot be created and the compiler will prevent these feature calls, unless instances of effective subclasses are attached to *b1*

Sharing and replication



Features such as *f*, not renamed along any of the inheritance paths, will be **shared**.

Features such as *g*, inherited under different names, will be **replicated**: there are two names to execute the same action

The need for select

A potential ambiguity arises because of polymorphism and dynamic binding:

a1 : ANY; t1 : LIST; d1 : D

…

a1.copy (…) — ***ANY*** version

t1.copy (…) — ***LIST*** version

d1.copy (…) — ***LIST*** version

a1 := t1

a1.copy (…) — ***LIST*** version

t1 := d1

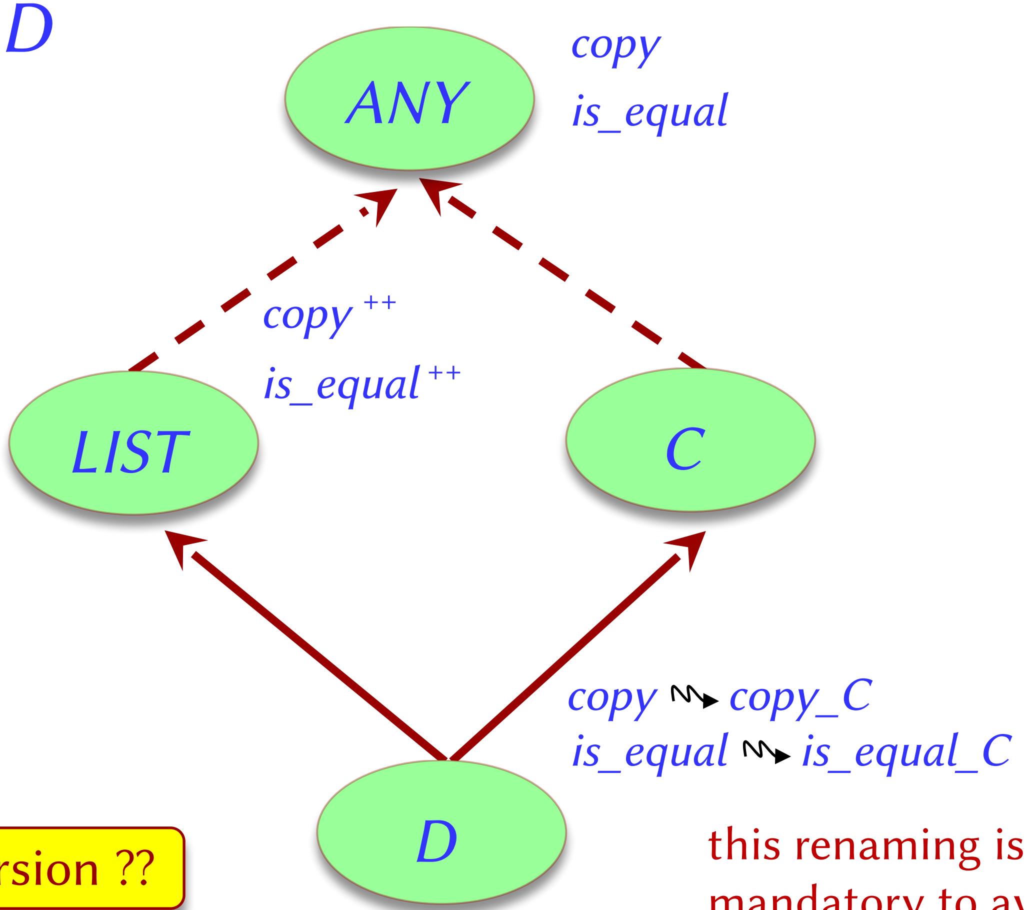
t1.copy (…) — ***LIST*** version

a1 := d1

a1.copy (…) — ***LIST*** or ***ANY*** version ??

The run-time cannot decide !

.



this renaming is mandatory to avoid name clash

When the need arises?

- This happens whenever, through the combination of renaming (and possibly redefinition) in different inheritance paths, in a class ***X*** there is more than one version of an inherited feature ***f*** (**repeatedly inherited feature**)

- These versions will have different names (due to renaming) and might have different behaviours (due to redefinition)

- If a variable of the ancestor class which has provided the original version of the feature get assigned a variable of class ***X*** neither the compiler nor the runtime can decide which version of feature ***f*** should be used

Removing the ambiguity

```
class
    D
inherit
    LIST [T]
        select
            copy,
            is_equal
        end

    C
        rename
            copy as copy_C,
            is_equal as is_equal_C,
                ...
        end
```

The version from ***LIST*** is used under dynamic binding in the case of a polymorphic target with a possible ambiguity

Order for redeclaration clauses (standard specif.)

Prescribed in ECMA, not yet implemented!

(checked May 2021)

```
class
        AN_HEIR

inherit
        A_PARENT
                undefine
                        feature_A, feature_B, …

                redefine
                        feature_C, feature_D, …

                rename
                        feature_C, feature_D, …

                export
                        {class_X, class_Y, …} feature_A, feature_B, …
                        {class_W, class_Z, …} feature_C, feature_D, …

                select
                        feature_C, feature_D, …
                end

end
```

undefine: make deferred

redefine: change implementation

rename: give a new name

export: change the visibility status

select: selection for dynamic binding

Order for redeclaration clauses (actual)

The one actually implemented in Eiffel

(checked May 2021)

```
class
        AN_HEIR

inherit
        A_PARENT
                rename
                        feature_C, feature_D, ...

                export
                        {class_X, class_Y, ...} feature_A, feature_B, ...
                        {class_W, class_Z, ...} feature_C, feature_D, ...

                undefine
                        feature_A, feature_B, ...

                redefine
                        feature_C, feature_D, ...

                select
                        feature_C, feature_D, ...
                end

end
```

rename: give a new name

export: change the visibility status

undefine: make deferred

redefine: change implementation

select: selection for dynamic binding

What we have seen

A number of games one can play with inheritance:

- Multiple inheritance
- Feature merging
- Repeated inheritance