Tracking which types are principally known in OCaml

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Cambium - INRIA & PSL

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1. Principality, definition and use in OCaml

2. Annotating types with levels

3. How to use levels for principality

4. What about modular implicits ?

1 Principality, definition and use in OCaml

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3 How to use levels for principality

4 What about modular implicits ?

What is principality ?

```
> ocaml --help
Usage: ocaml <options> <files>
Options are:
    ...
    -principal  Check principality of type inference
    -no-principal  Do not check principality of type inference (default)
    ...
```

What is principality ?

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> *A principal typing in S for a term M is a typing for M which somehow represents all other possible typings in S for M*

J. B. Wells

An example of principal type

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let id = fun x → x
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- `unit → unit`

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- `'a → 'a`

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x = y ⇒ x : <m : ’a. ’a -> ’a>	x#m 3 ⇒ x : <m : int -> ’b>
x#m 3 ⇒ principality warning	x = y ⇒ Fails

The type of x was not principal when typing x#m 3.

Principality warning with constructors

```
type ’a ta = C of ’a | A
type tb = C of int | B



let id x =
    let _ = C x in x
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type ’a ta = C of ’a | A
type tb = C of int | B

let id x =
    let _ = [A; C x] in x
```

Principality with labels

```
let foo (f : a:int → b:int → int) : int = ...

(* val bar : (a:int → b:int → int) → int *)
let bar f =
    foo f + f ∼b:1 ∼a:2
```

Principality with labels

```
let foo (f : a:int → b:int → int) : int = ...

(* val bar : (a:int → b:int → int) → int *)
let bar f =
    foo f + f ~b:1 ~a:2
```

- Left to right ⇒ warning
- Right to left ⇒ error

Principality with first-class modules

```
(* val foo : ((module S) → ’a) → ’a * ’a *)
let foo bar =
    (bar (module M1 : S),
     bar (module M2))
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Types have levels

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type bool = True | False

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Types have levels

int^1

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Introducing int

Types have levels

int^1 $bool^2$

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Introducing bool

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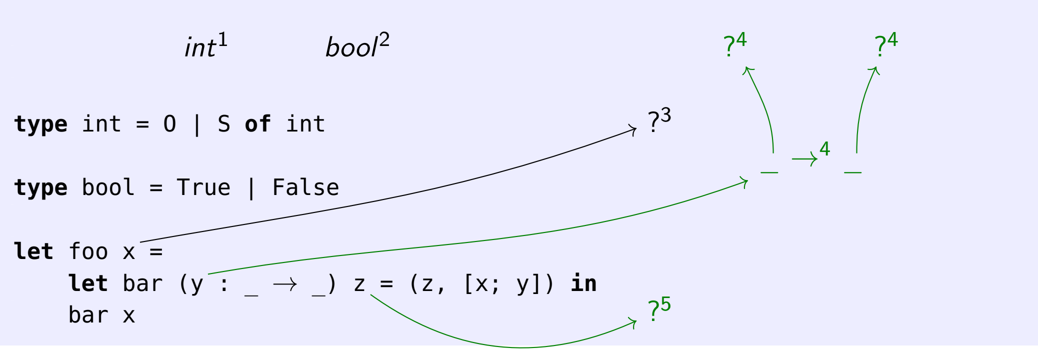
Introducing x

Types have levels



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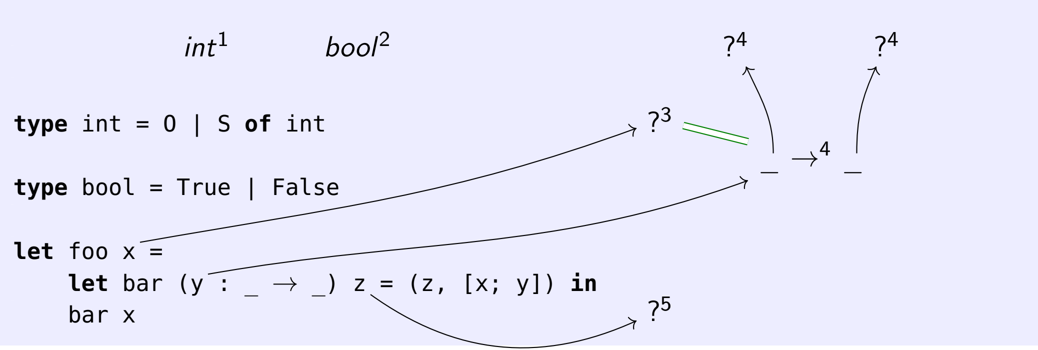
Introducing y and z

Types have levels



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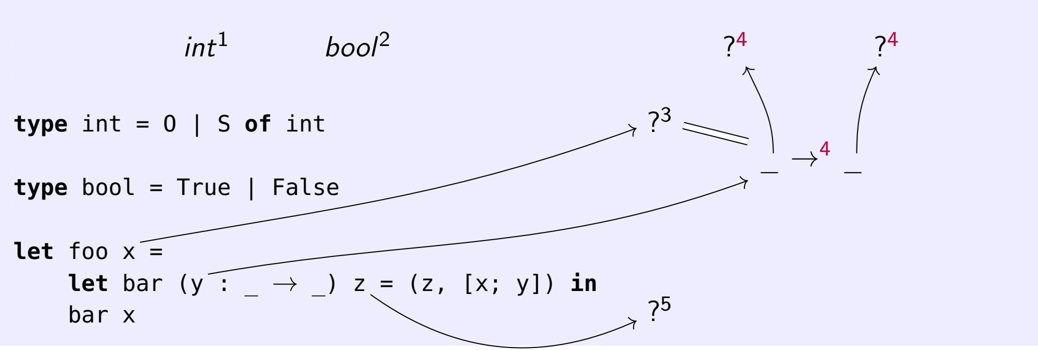
Typing [x; y]

Types have levels



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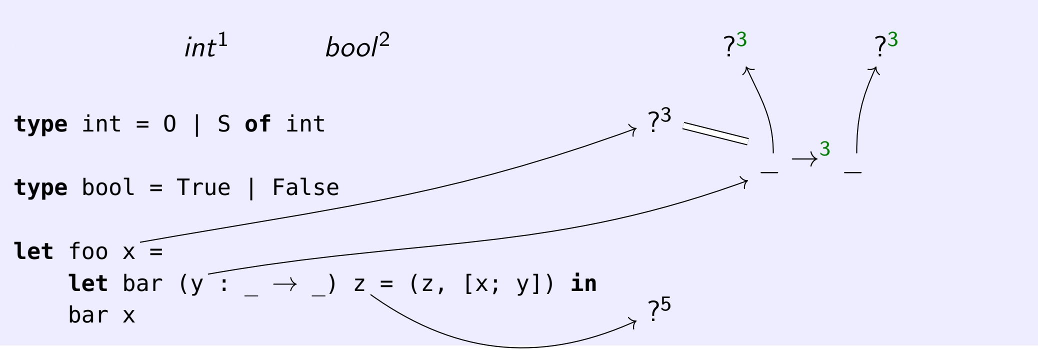

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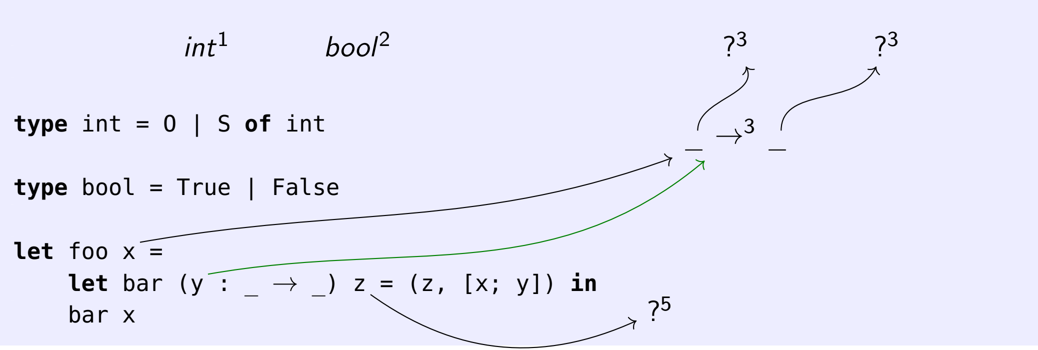

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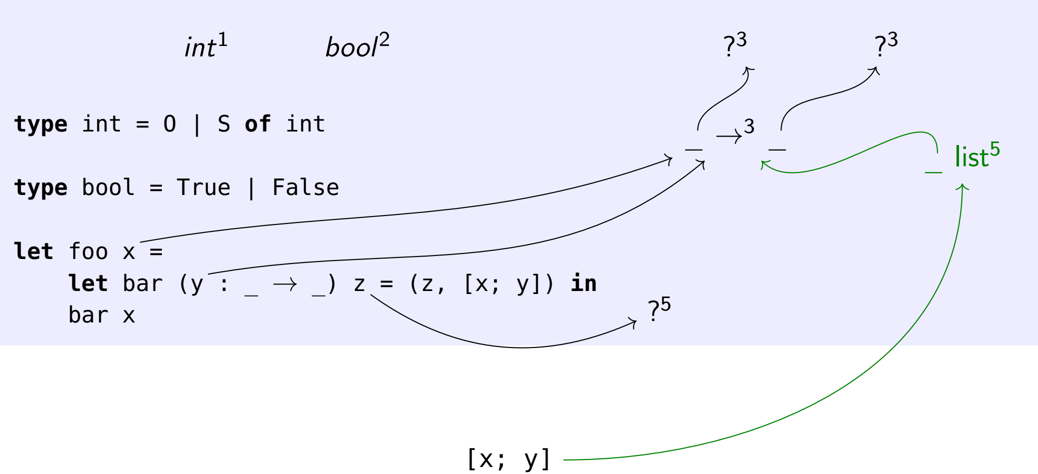

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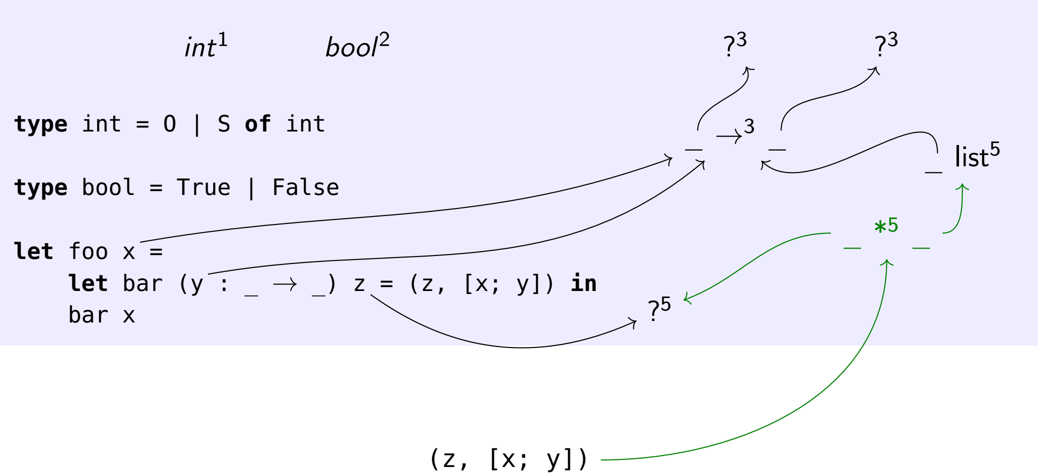

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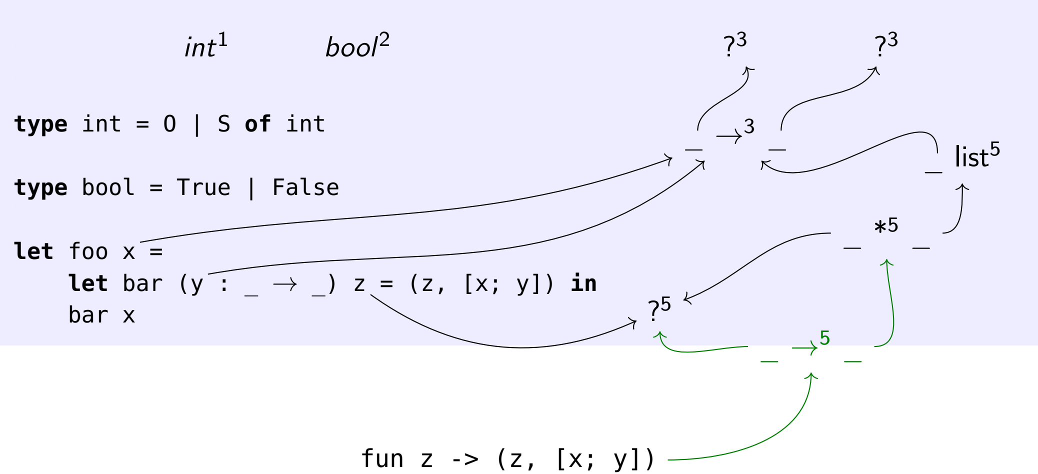

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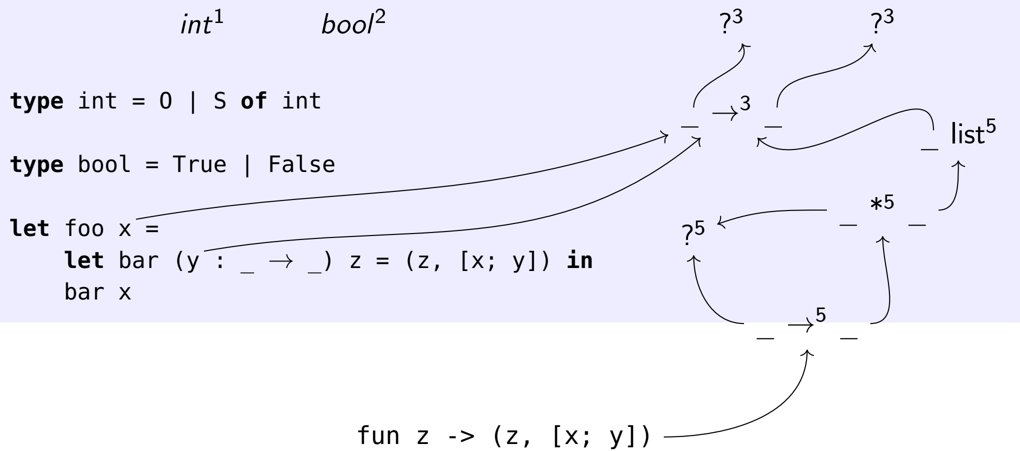

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int^1 $bool^2$

$?^3$ $?^3$

$\_ \rightarrow^3 \_$

$\_\ list^5$

$?^5$ $\_ *^5 \_$

$\_ \rightarrow^5 \_$

`fun z -> (z, [x; y])`

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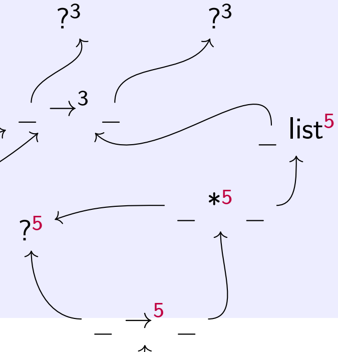

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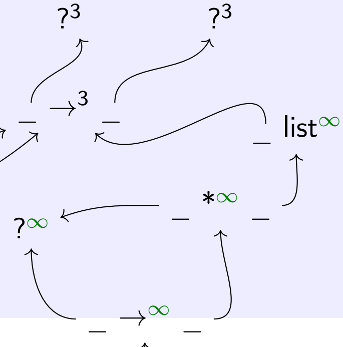

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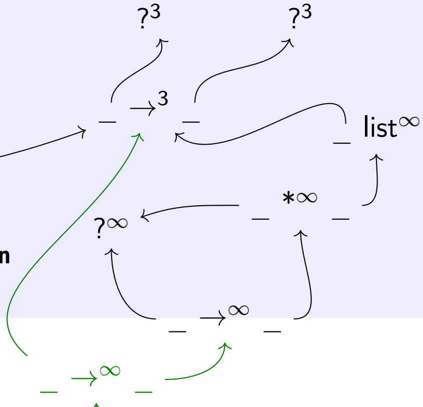

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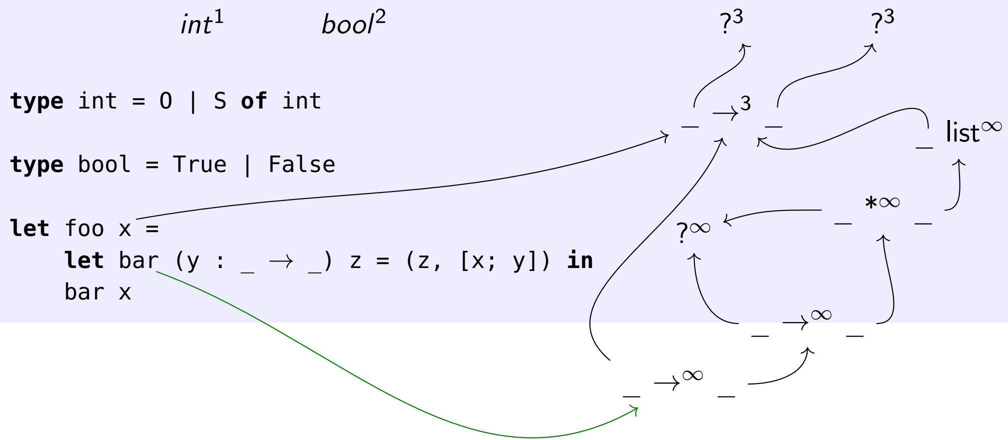

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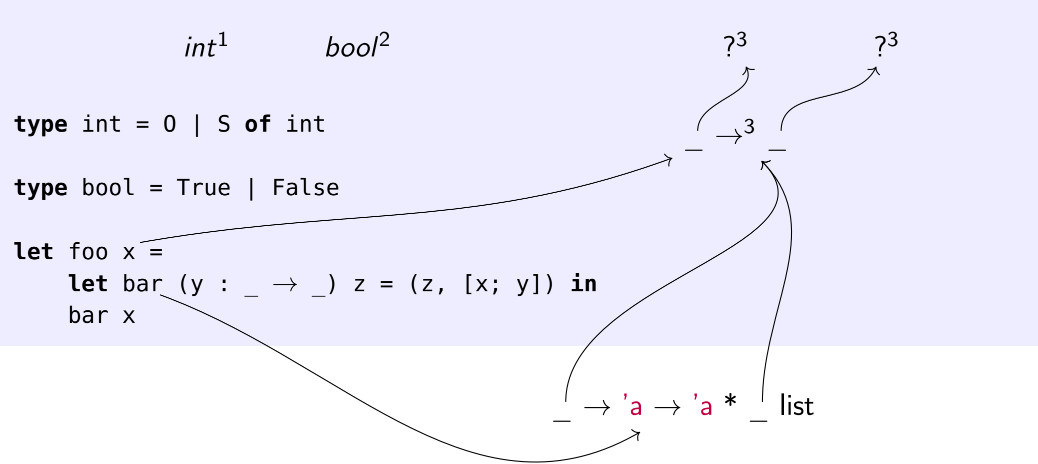

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$\_ \rightarrow$ 'a $\rightarrow$ 'a * $\_$ list

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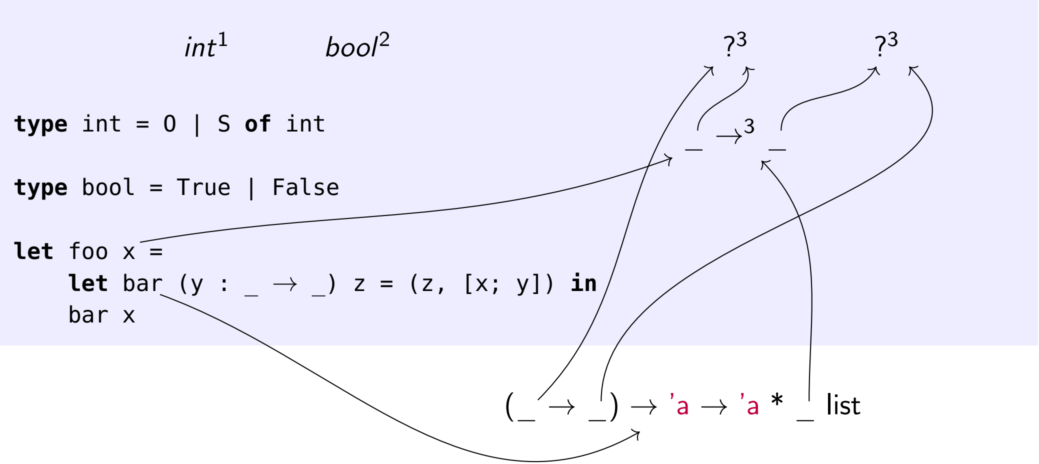

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(_ → _) → 'a → 'a * _ list

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- Allows easy error detection/reporting :

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```ocaml
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- Also works with GADTs !

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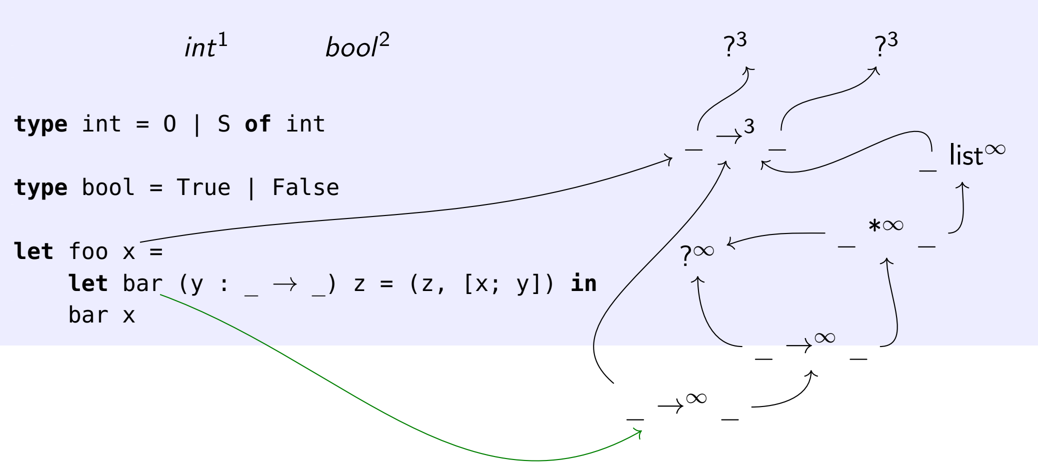

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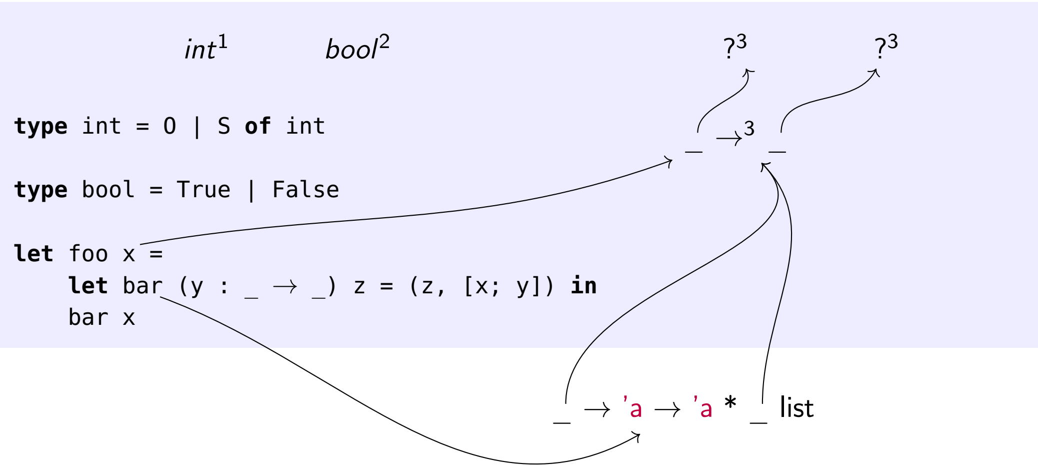

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x#m 3	⇒ principality warning	x = y	⇒ Fails

The type of x was not principal when typing x#m 3, because the level of . is not ∞.

What about y ?

```
let f (y : <m : 'a. 'a → 'a>) =
    y#m 3
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Does this code raise a warning ?

What about y ?

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Does this code raise a warning ?

No, because

$$\texttt{y : <m : 'a.}^{\infty}\ \texttt{'a ->}^{\infty}\ \texttt{'a>}^{\infty}$$

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Code infered from type can be :

- Labelled arguments
- Constructor/record disambiguation
- First-class modules
- Modular implicits (?)

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    type t
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implicit module PInt = struct ... end
implicit module PString = struct ... end
implicit module PList (X : Print) = struct ... end
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implicit module PInt = struct ... end
implicit module PString = struct ... end
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let () =
    print 3;
    print [1; 2; 3];
    print "Hello world\n"
```

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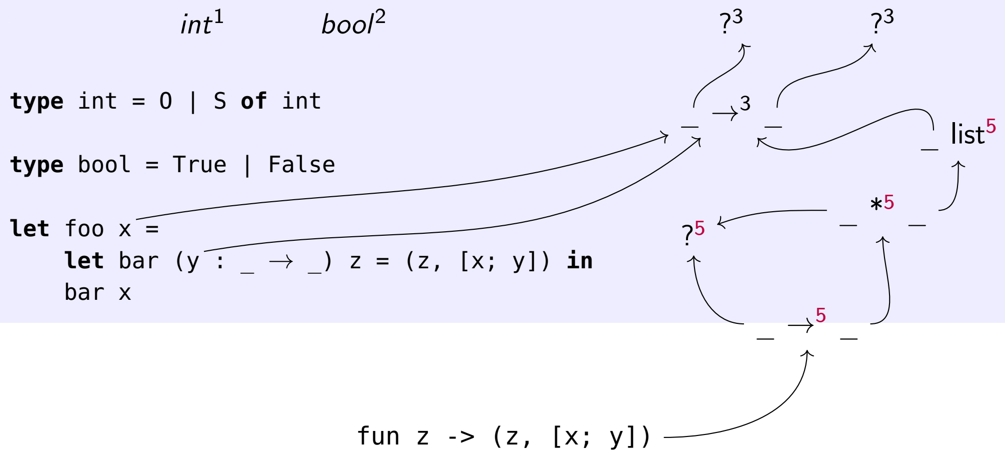
Current principality tracing in OCaml cannot handle such a feature.

Types have levels



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type bool = True | False

let foo x =
    let bar (y : _ → _) z = (z, [x; y]) in
    bar x
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fun z -> (z, [x; y])
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Types have levels

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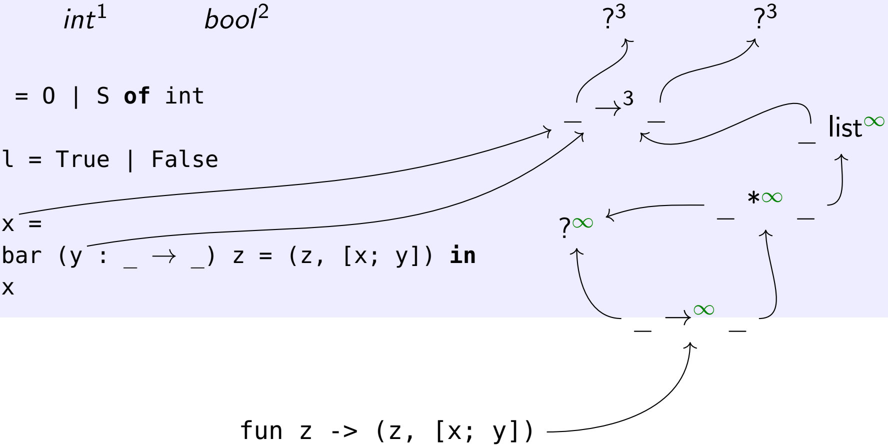

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What if we didn't want types to become principal

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module type Default = sig type t val d : t end

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end

(* val f : a:int → b:int → int *)
let f = default ()

(* val _ : int *)
let _ = f ~b:2 ~a:1
```

A fix ?

Proposal : add a boolean saying whether this type is or can become principal.

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(* val id : (a:int → b:int → 'a) → (a:int → b:int → 'b) *)
let id f =
    let _ f ∼a:1 ∼b:2 in f
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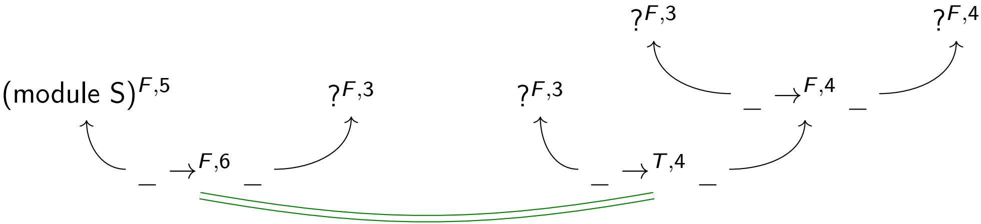
let id f =
    let _ f ∼a:1 ∼b:2 in f
```

```
let fail f = id f ∼b:1 ∼a:1
```

```
             ^^
Error: This function is applied to arguments
       in an order different from other calls.
       This is only allowed when the real type is known.
```

Unification with a boolean



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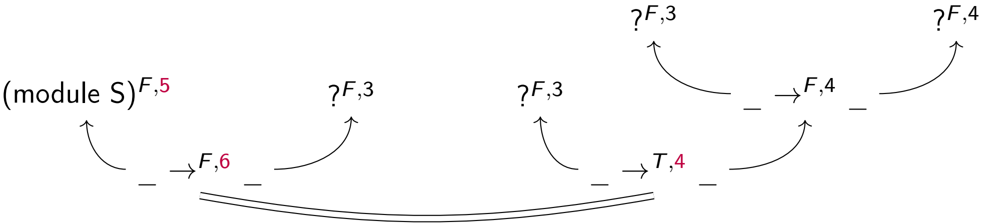

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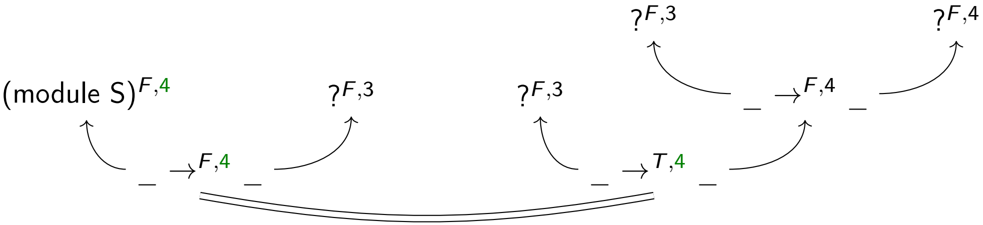
$(\text{module S})^{F,4}$
$\_ \rightarrow^{F,4} \_$
$?^{F,3}$
$?^{F,3}$
$\_ \rightarrow^{T,4} \_$
$?^{F,3}$
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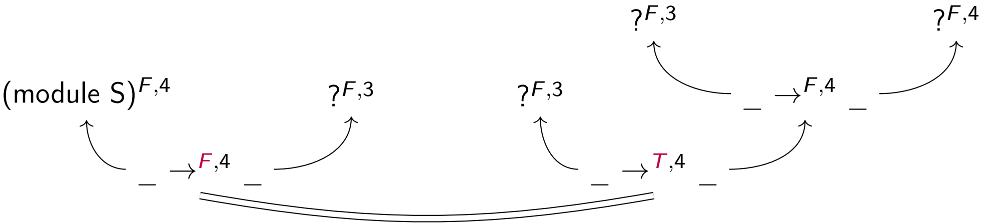
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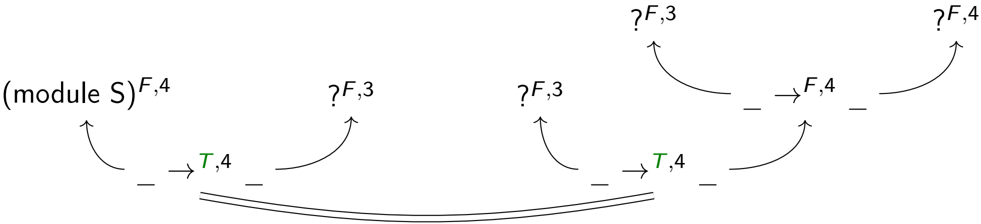

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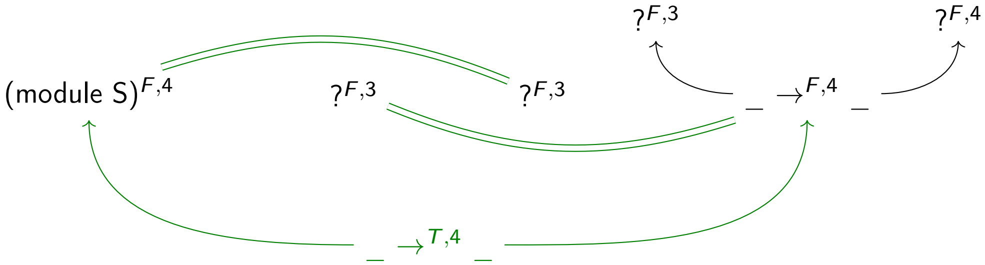
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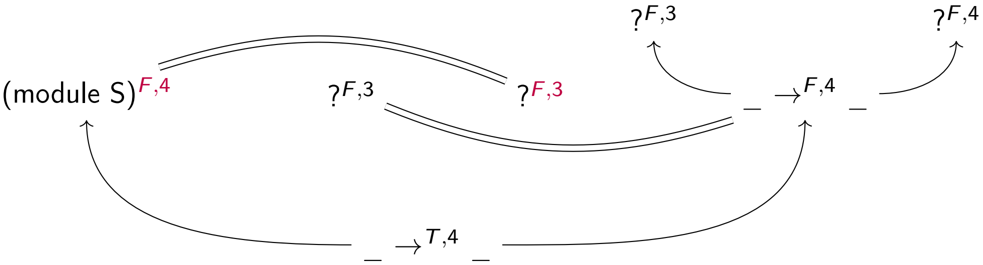

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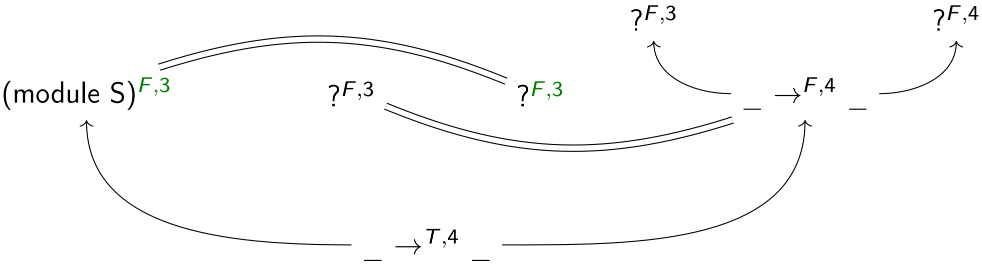

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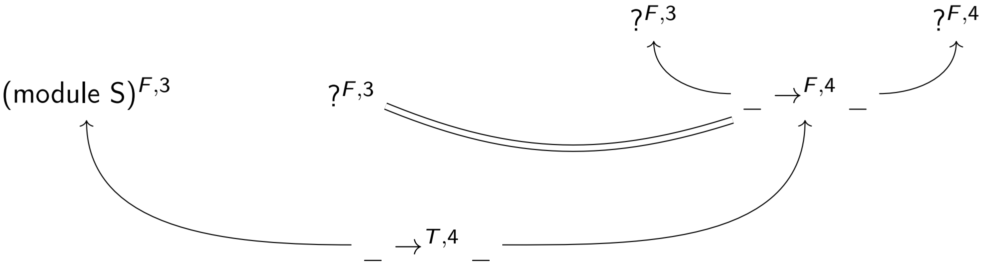

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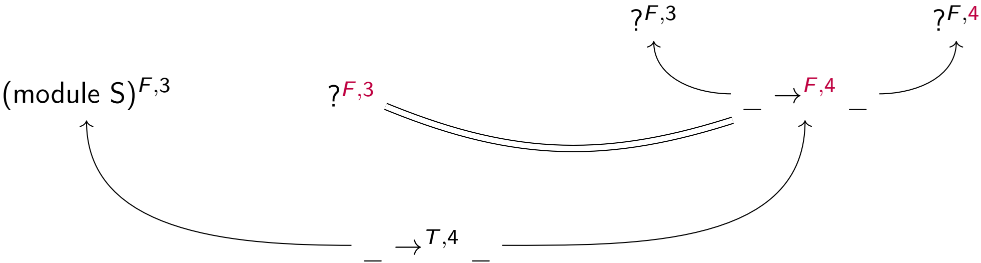
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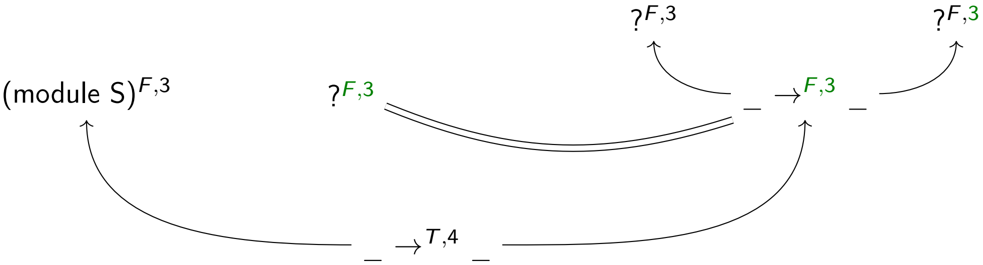
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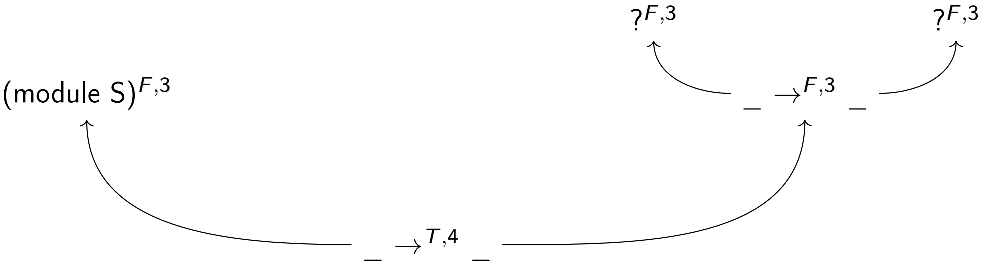

Questions ?

Do you have any questions ?