Simple Functions

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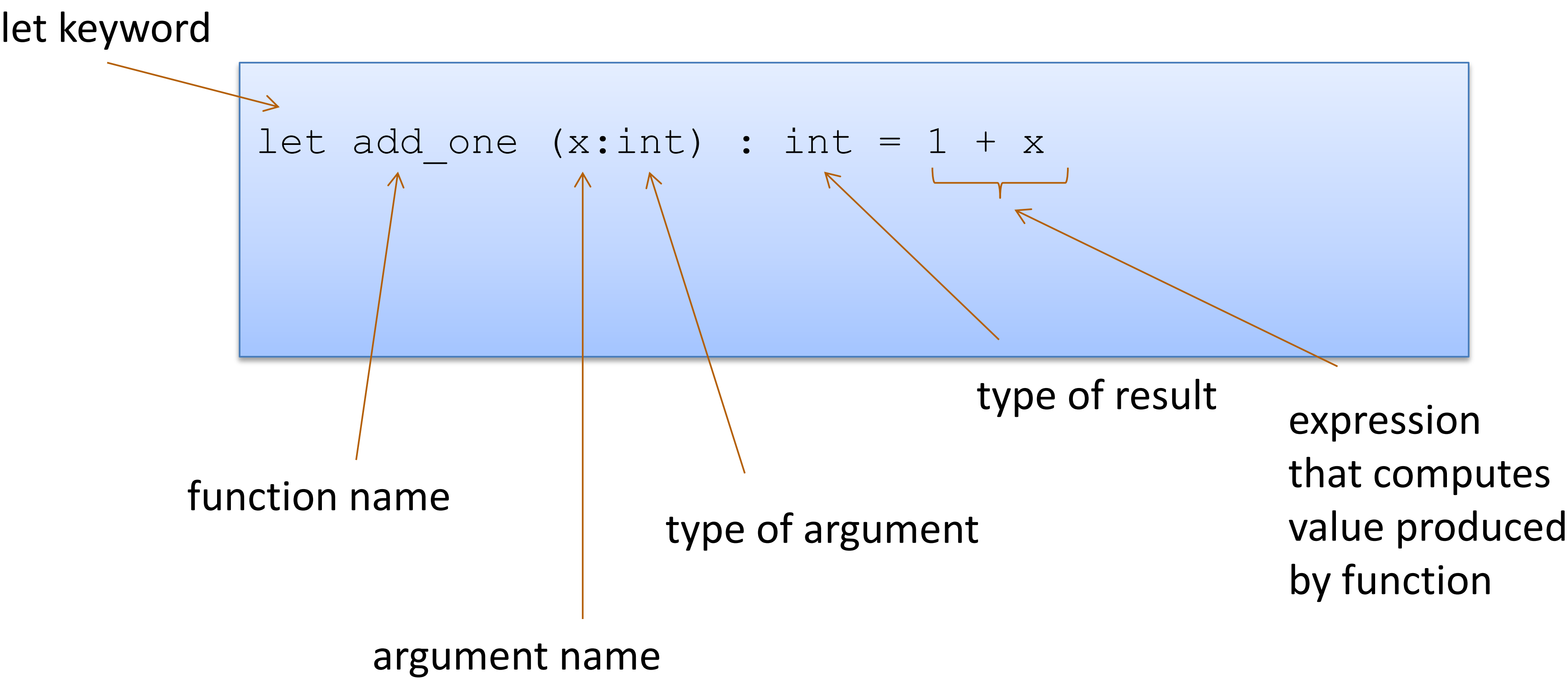
Defining functions

```
let add_one (x:int) : int = 1 + x
```

Defining functions



Note: recursive functions with begin with "**let rec**"

Defining functions

Nonrecursive functions:

```
let add_one (x:int) : int = 1 + x

let add_two (x:int) : int = add_one (add_one x)
```

definition of add_one
must come before use

Defining functions

Nonrecursive functions:

```
let add_one (x:int) : int = 1 + x

let add_two (x:int) : int = add_one (add_one x)
```

With a local definition:

local function definition hidden from clients

```
let add_two' (x:int) : int =
  let add_one x = 1 + x in
  add_one (add_one x)
```

I left off the types.
O'Caml figures them out

Good style: types on top-level definitions

Types for Functions

Some functions:

```
let add_one (x:int) : int = 1 + x

let add_two (x:int) : int = add_one (add_one x)

let add (x:int) (y:int) : int = x + y
```

function with two arguments

Types for functions:

```
add_one : int -> int

add_two : int -> int

add : int -> int -> int
```

Rule for type-checking functions

General Rule:

If a function f : T1 → T2
and an argument e : T1
then f e : T2

Example:

```
add_one : int -> int

3 + 4 : int

add_one (3 + 4) : int
```

Multi-argument Functions

Definition:

```
let add (x:int) (y:int) : int =
  x + y
```

Type:

```
add : int -> int -> int
```

Multi-argument Functions

Definition:

```
let add (x:int) (y:int) : int =
  x + y
```

Type:

```
add : int -> int -> int
```

Same as:

```
add : int -> (int -> int)
```

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A → B → C

same as:

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Example:

```
add : int -> int -> int

3 + 4 : int

add (3 + 4) : ???
```

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Example:

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add : int -> int -> int

3 + 4 : int

add (3 + 4) : int -> int

(add (3 + 4)) 7 : int
```

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add : int -> int -> int

3 + 4 : int

add (3 + 4) : int -> int

add (3 + 4) 7 : int
```

extra parens not necessary

One key thing to remember

- If you have a function f with a type like this:

A → B → C → D → E → F

- Then each time you add an argument, you can get the type of the result by knocking off the first type in the series

f a1 : B → C → D → E → F (if a1 : A)

f a1 a2 : C → D → E → F (if a2 : B)

f a1 a2 a3 : D → E → F (if a3 : C)

f a1 a2 a3 a4 a5 : F (if a4 : D and a5 : E)

DEBUGGING TYPE ERRORS

Debugging Type Errors

Type errors can be confusing sometimes. Consider:

```
let rec concatn s n =
  if n <= 0 then
    ...
  else
    s ^ (concatn s (n-1))
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ocamlbuild says:

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Error: This expression has type int but an
expression was expected of type string
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Type Checking Rules

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merlin inside emacs points to the error above and gives a second error:

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they don't *agree*!

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The type checker points to *some* place where there is *disagreement*.

Moral: *Sometimes you need to look in an earlier branch for the error* even though the type checker points to a later branch. The type checker doesn't know what the user wants.

A Tactic: Add Typing Annotations

```
let rec concatn (s:string) (n:int) : string =
  if n <= 0 then
    0
  else
    s ^ (concatn s (n-1))
```

```
Error: This expression has type int but an
expression was expected of type string
```

Exercise

Given the following code:

```
let munge b x =
  if not b then
    string_of_int x
  else
    "hello"

let y = 17
```

What are the types of the following expressions?
(And what must the types of f and g be?)

```
munge : ??

munge (y > 17) : ??

munge true (f (munge false 3)) : ??

munge true (g munge) : ??
```