software studio

functions, scope & closures

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functions as values

making functions

function expression

› **function** (args) {body}

functions are 'polymorphic'

› implicit typed

› depends on how args used

```
> three = function () {return 3;}
function () {return 3;}
> three
function () {return 3;}
> three()
3
> id = function (x) {return x;}
function (x) {return x;}
> id(3)
3
> id(true)
true
> id(id)
function (x) {return x;}
> (id(id))(3)
3
```

functions are first class

just like other objects

› can bind to variables
› can put in property slots
› can add property slots

```
> seq = function () {
      seq.c += 1; return seq.c;}
function () {seq.c += 1; return
seq.c;}
> seq.c = 0
0
> seq()
1
> seq()
2
```

note: bad lack of encapsulation! will fix later with closures

```
> seq = function () {return (seq.c = seq.next(seq.c));}
function () {return (seq.c = seq.next(seq.c));}
> seq.c = 0
0
> seq.next = function (i) {return i + 2;}
function (i) {return i + 2;}
> seq()
2
> seq()
4
```

recursion

can you explain

- how a recursive definition works?
- when exactly is the function defined?

```
> fact = function (i) {if (i===0) return 1; else return i * fact(i-1);}
function (i) {if (i===0) return 1; else return i * fact(i-1);}
> fact (4)
24
```

a puzzle: repeated applications

suppose you see an expression e

- eg, e is **f()**
- what might expression do?

evaluation can have 3 effects

- value is returned (or exception thrown)
- objects are modified
- environment is updated

a puzzle

- declare **f** so that **f()===f()** evals to false

evaluating functions

two phases

```
> (function (x) {return x + 1;}) (3)
4
```

creation

› function <u>expression</u> evaluated

application

› function <u>body</u> evaluated

evaluation order for applications

› first evaluate arguments, left to right
› then evaluate body

```
> log = function (s) {console.log(s + seq());}
function (s) {console.log(s + seq());}
> (function () {log('c')}) (log('a'),log('b'))
a1
b2
c3
```

evaluating the body

what environment is body evaluated in?

- same environment application is evaluated in?

let's see!

- hmm...

```
> x = 1
1
> f = (function (x) {return function () {return x;};}) (x)
function () {return x;}
> f()
1
> x = 2
2
> f()
1
```

two environments

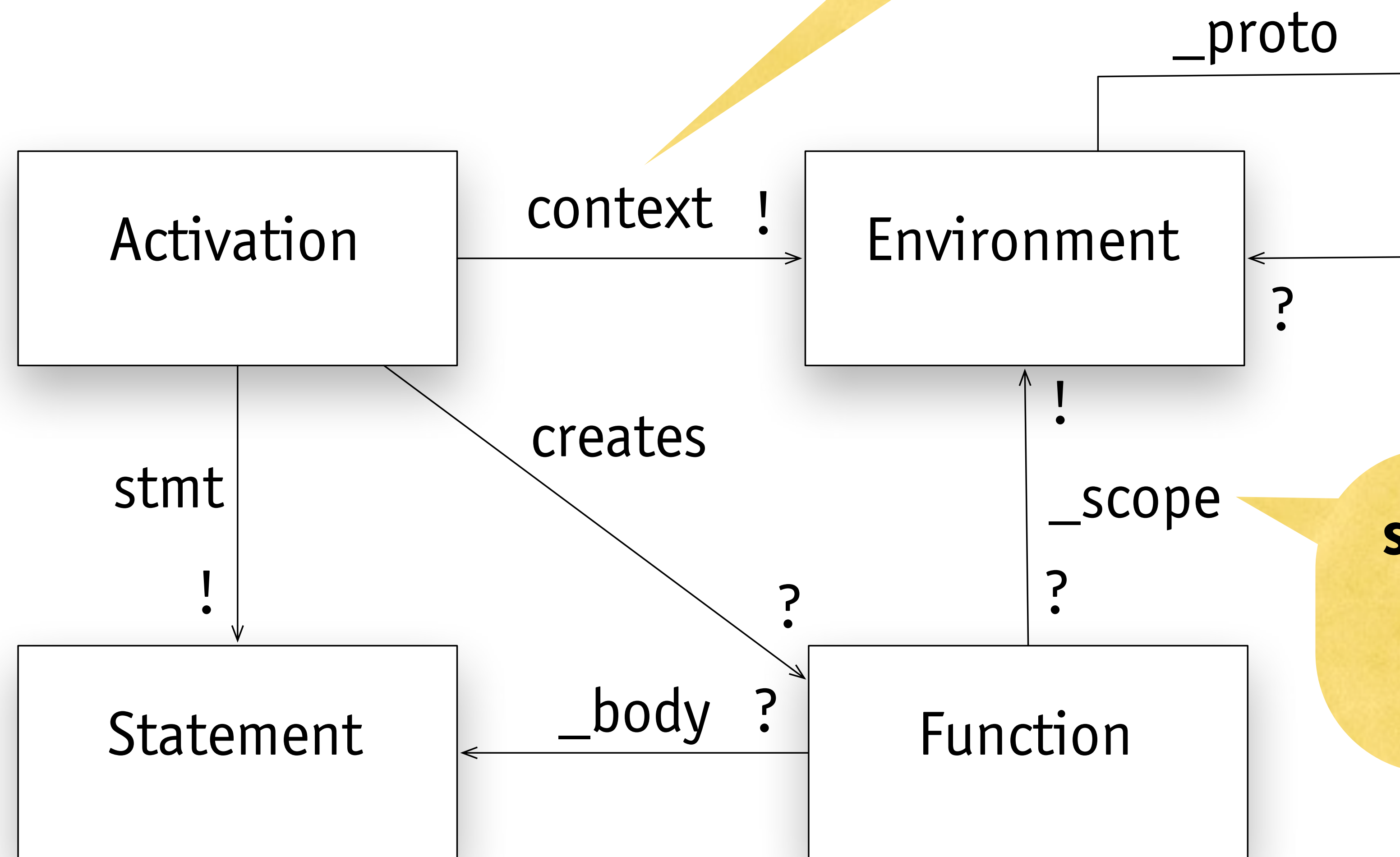
when function is created

› keeps environment as a property
› called ‘function scope’
› uses this environment to evaluate body in

what about arguments?

› new environment (‘frame’) with bindings for args
› linked to function scope

an object model



- activation distinction from (syntactic) statement
- underscores emphasize: not real properties

aah, nostalgia!

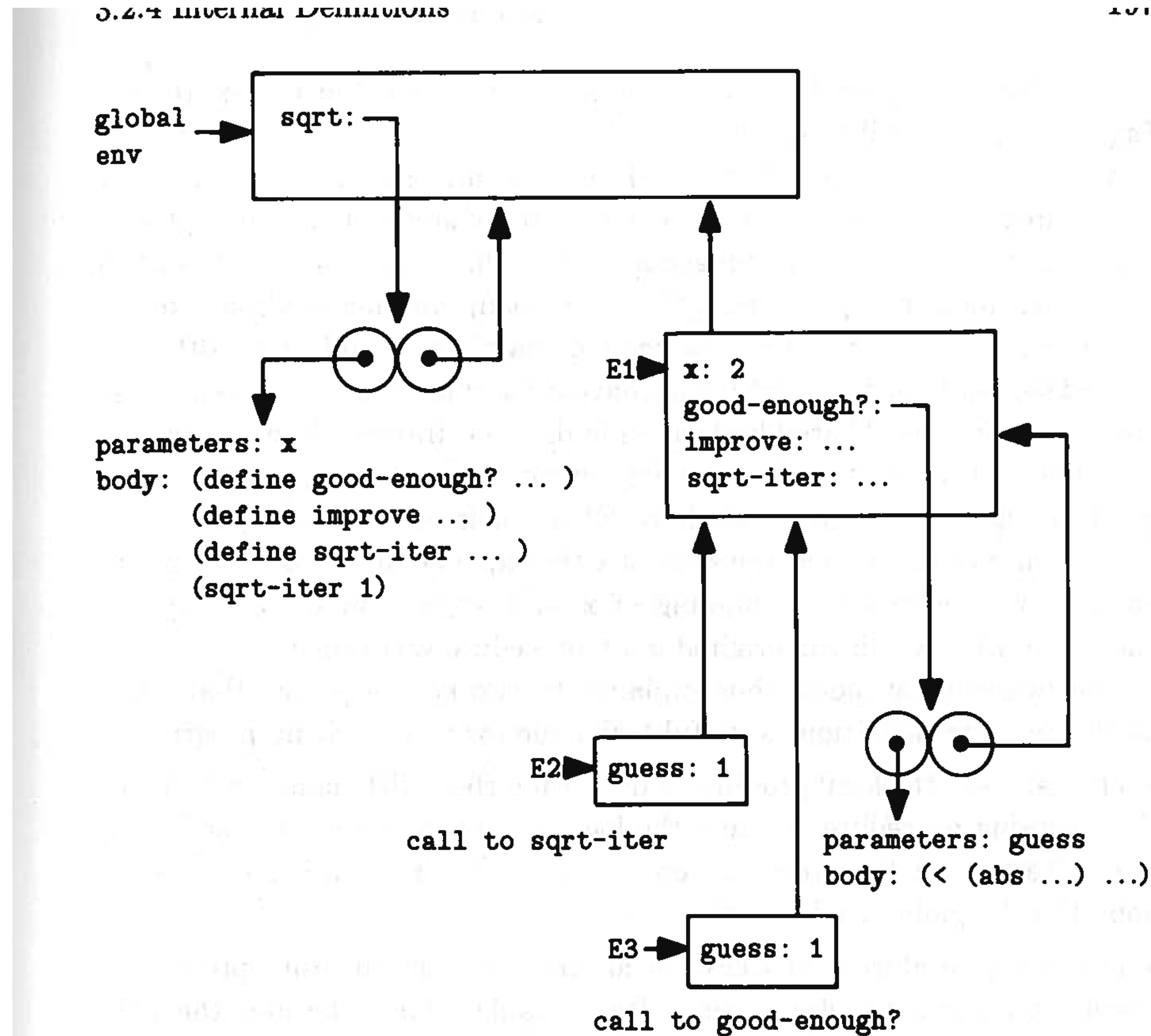


Figure 3.11
Sqrt procedure with internal definitions.

pression (sqrt 2) where the internal procedure good-enough? has been called for the first time with guess equal to 1.

Observe the structure of the environment. Sqrt is a symbol in the

Courtesy of Harold Abelson and Gerald Jay Sussman. Used with permission.

From *Structure and Interpretation of Computer Programs*.

examples

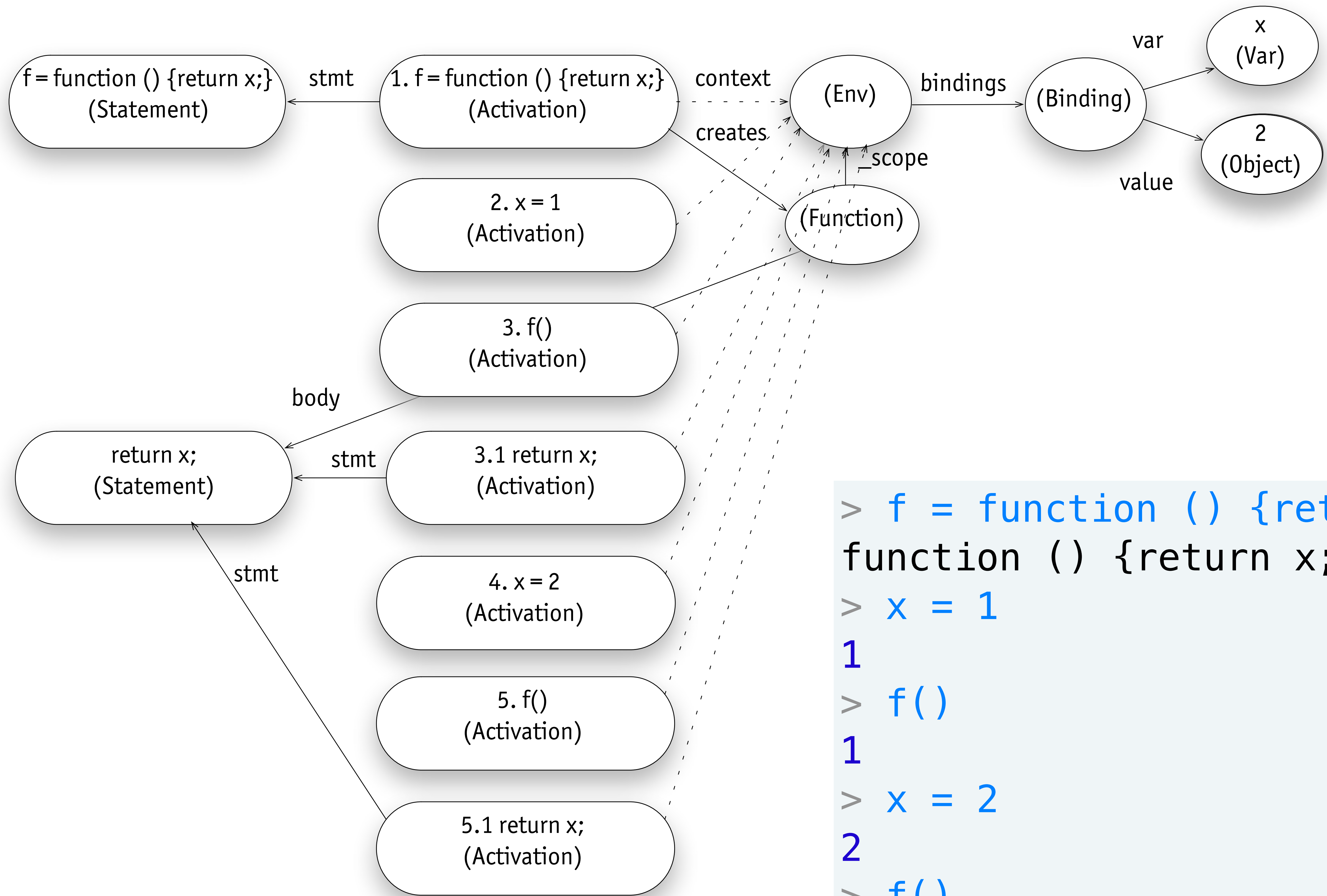
example 1

```
> f = function () {return x;}
function () {return x;}
> x = 1
1
> f()
1
> x = 2
2
> f()
2
```

what happens here?

- function scope is top-level environment
- assignment to x modifies binding in top-level environment
- so in this case x refers to x of application environment too

simulating example 1




```
> f = function () {return x;}
function () {return x;}
> x = 1
1
> f()
1
> x = 2
2
> f()
2
```

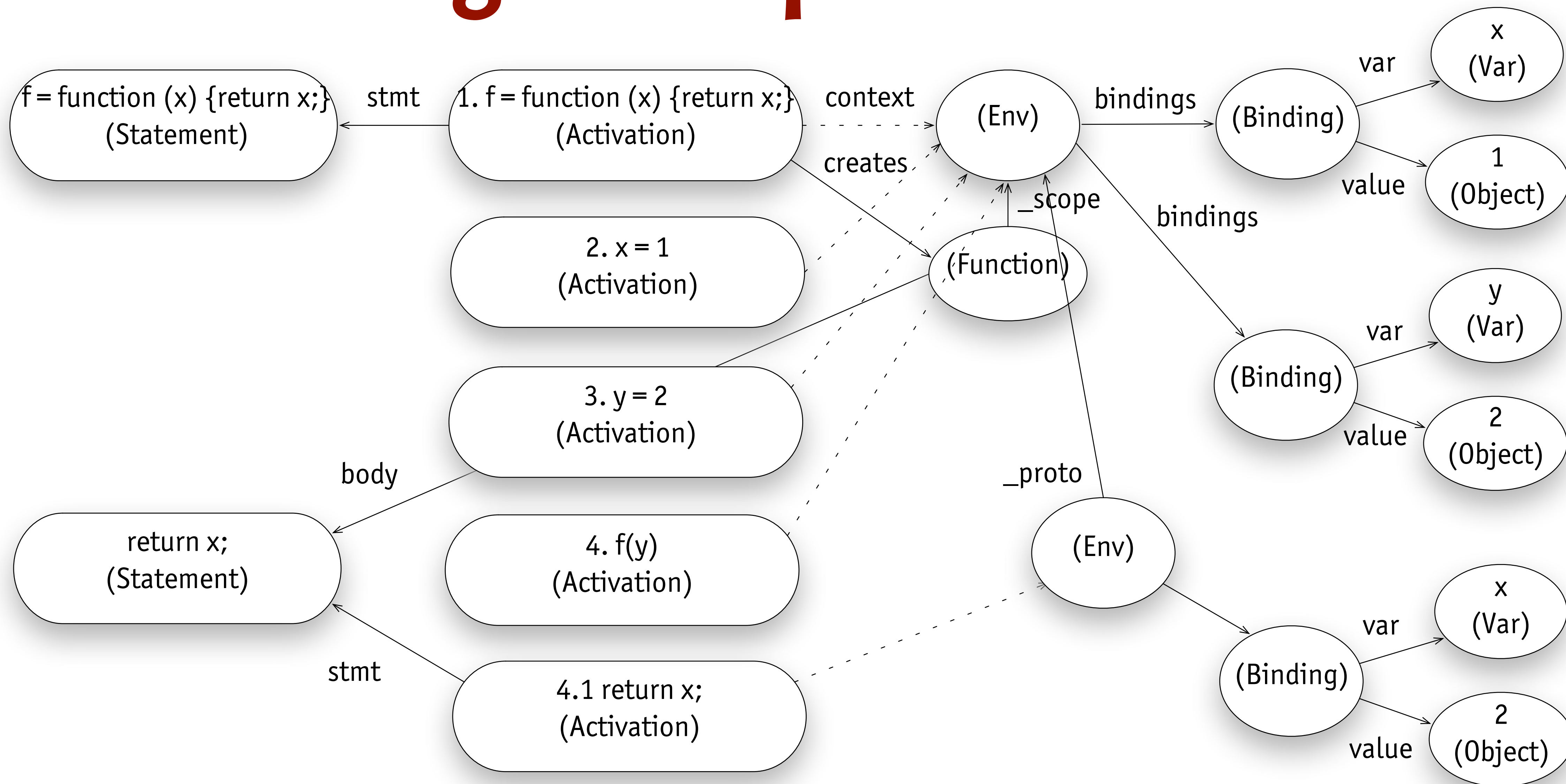
example 2

```
> f = function (x) {return x;}
function (x) {return x;}
> x = 1
1
> y = 2
2
> f(y)
2
```

what happens here?

- function scope is top-level environment
- when application is evaluated, argument x is bound to 2
- local x said to shadow global x

simulating example 2




```
> f = function (x) {return x;}
function (x) {return x;}
> x = 1
1
> y = 2
2
> f(y)
2
```

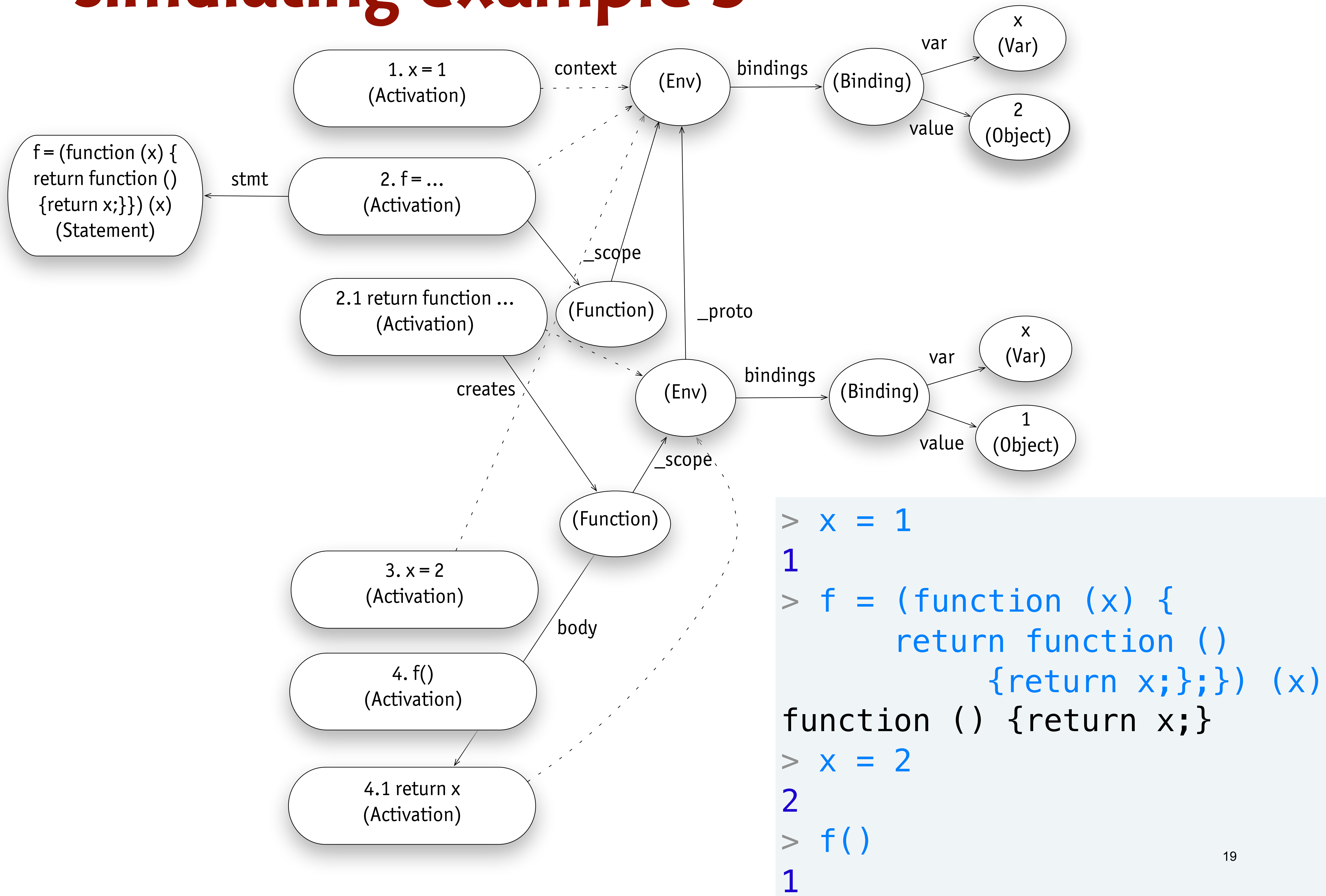
example 3

```
> x = 1
1
> f = (function (x) {return function () {return x;};}) (x)
function () {return x;}
> f()
1
> x = 2
2
> f()
1
```

what happens here?

› when f is applied, x is bound to 1 in new frame
› anonymous function has scope with x bound to 1
› assignment to top-level x does not modify this scope

simulating example 3



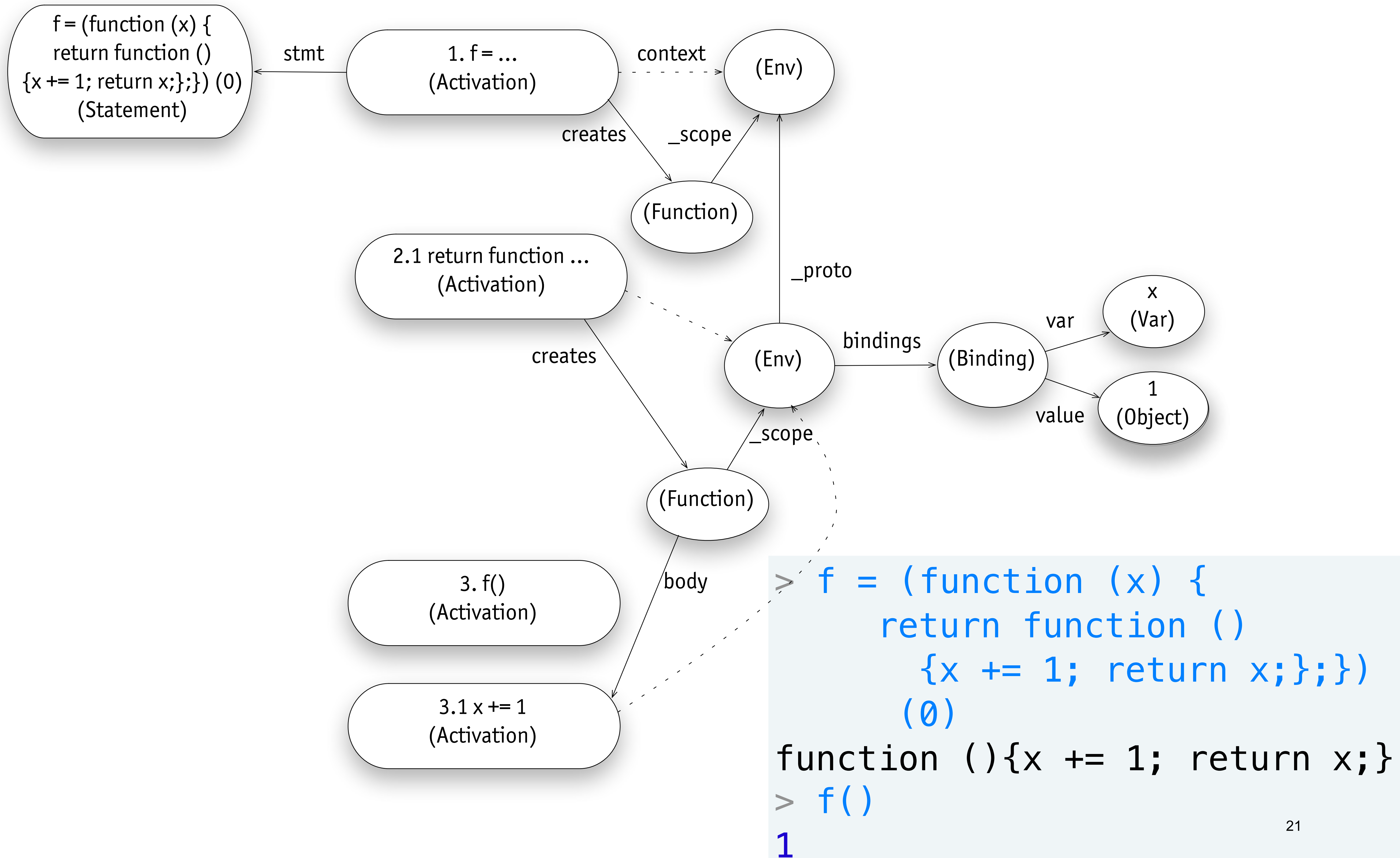
example 4

```
> f = (function (x) {return function () {x += 1; return x;};}) (0)
function () {x += 1; return x;}
> f()
1
> f()
2
```

what if we modify x?

- when f is applied, x is bound to 0 in new frame
- anonymous function has scope with x bound to 0
- this ‘internal’ x is updated every time f is called

simulating example 4



local variables

avoiding pollution

```
> sum = function (a, s, i) {
        s = 0;
        for (i = 0; i < a.length; i += 1) s += a[i];
        return s;}
function...
> sum([1,2,3])
6
> s
ReferenceError
> i
ReferenceError
```

why does this work?

argument mismatch

when arguments are

- missing: initialized to undefined
- extra: ignored

```
> inc = function (x, y) {return y ? x+y : x+1;}
function (x, y) {return y ? x+y : x+1;}
> inc(1)
2
> inc(1,2)
3
> inc(1,2,3)
3
```

var decls

```
> sum = function (a, s, i) {
        s = 0;
        for (i = 0; i < a.length; i += 1) s += a[i];
        return s;}
function...
```

don't want bogus arguments

- so Javascript has a special statement
- "var x" creates a binding for x in the immediate env

```
> sum = function (a) {
        var s = 0;
        for (var i = 0; i < a.length; i += 1) s += a[i];
        return s;}
function...
```

note: doesn't matter where var decl occurs in function
even in dead code!

function declarations

function declaration syntax

- function f () {} short for var f = function () {}
- but not quite, so don't use it!

```
var f = function(){
    if (true) {
        function g() { return 1;};
    } else {
        function g() { return 2;};
    }
    var g = function() { return 3;}
    return g();
    function g(){ return 4;}
    }
var result = f();
```

- ECMA: 2
- Safari, Chrome: 3
- Mozilla: 4

lexical vs dynamic scoping

a language design question

```
x = 1;
g = function(){ console.log(x); x=2; }
f = function(){ var x = 3; g(); }
f();
console.log(x);
```

what does this print?

- lexical scoping: 1, 2
- dynamic scoping: 3, 1

lexical scoping now preferred

- harder to implement
- better for programmer

a common misunderstanding

lookup at activation time

```
var multipliers = function makeMultipliers (max) {
    var result = [];
    for (var i = 0; i < max; i++)
        result.push (function (x) {return x * i;});
    return result;
    }

> multipliers(10) [2] (5)
???
```

what's the value?

- 50, not 5

can you fix it?

summary

functions are first-class

› values created by expressions
› bound to variables
› stored as properties, and can have properties

lexical closures

› free variables bound in ‘declaration’ environment

local vars

› added to local environment, just like function args

next

› exploiting functions & closures in programming

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