```
(def (g y)
  (+ y 1))

(def (f x)
  (+ (g (+ x 2)) 3))

(def (main input)
  (f (+ y 4)))
```

fun name to call | argument value

fun name defined

function body

argument name

Late May/Early June

```
type expr =
  | ENum of int
  | EBool of bool
  …
  | EDef of string * string * expr
  | EApp of expr * expr
```

This week

```
type expr =
  | ENum of int
  | EBool of bool
  …
  | EApp of string * expr

type def =
  | Def of string * string * expr

type prog =
  | Prog of def list * expr
```

Which representation do you want to implement first?

Some things to discuss:

- Compiling the new abstract syntax (getting its answer into EAX)
- How the environment works (a new kind of name)
- Are there programs we can represent with one but not the other?

```
type expr =
  | ENum of int
  | EBool of bool
  …
  | EApp of string * expr

type def =
  | Def of string * string * expr

type prog =
  | Prog of def list * expr
```

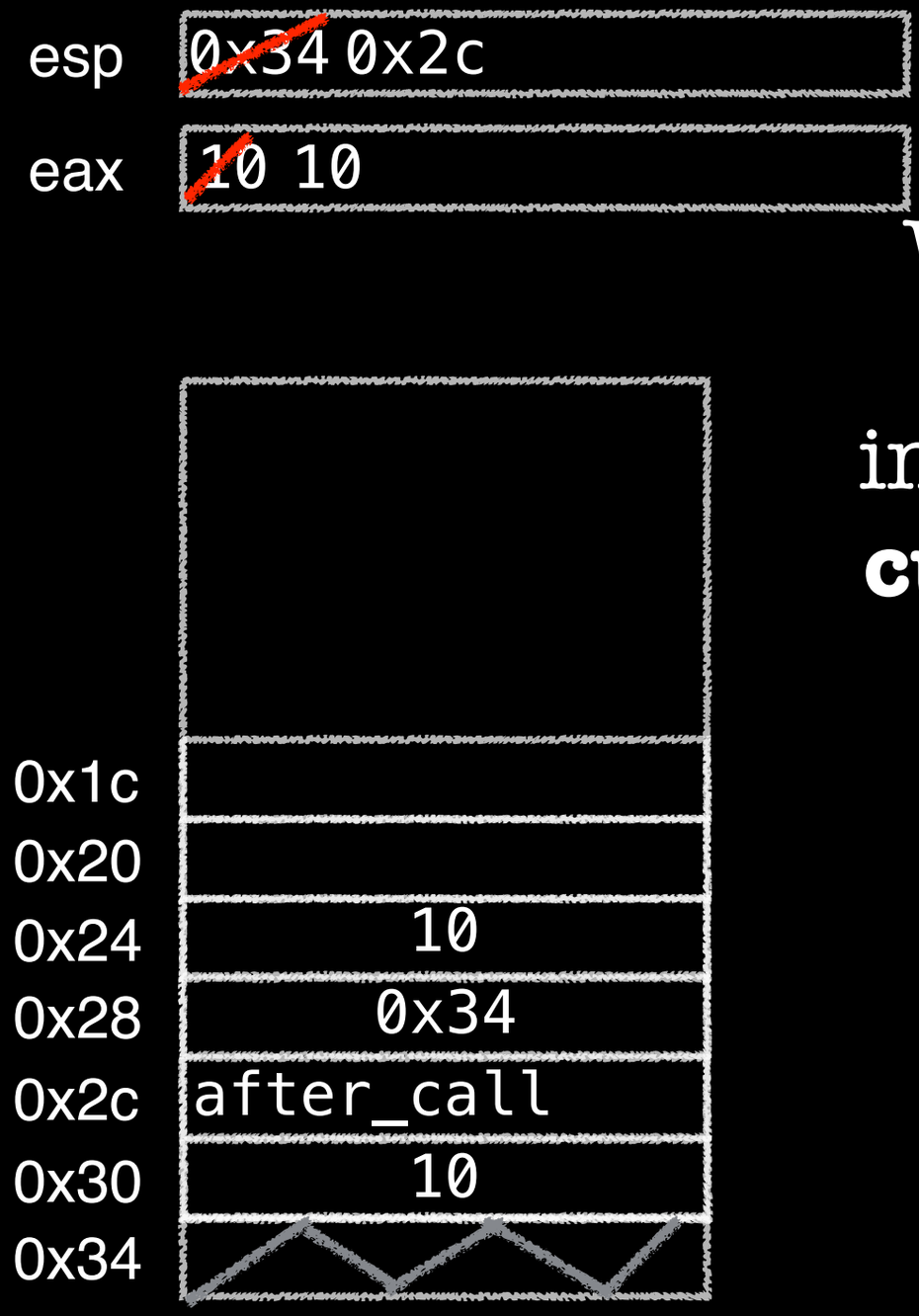
```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) -> …


let compile_def d … =
  …

let compile_prog p … =
  …
```

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
(let (x 10)
 (let (z (g x))
  (+ 3 z)))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-12], esp
  mov [esp-16], eax
  sub esp, 8
  jmp g
  after_call:
```




```
(def (g y)
  (+ y 1))
```

```
g:
```

Where is the argument y in terms of the **current value** of esp?

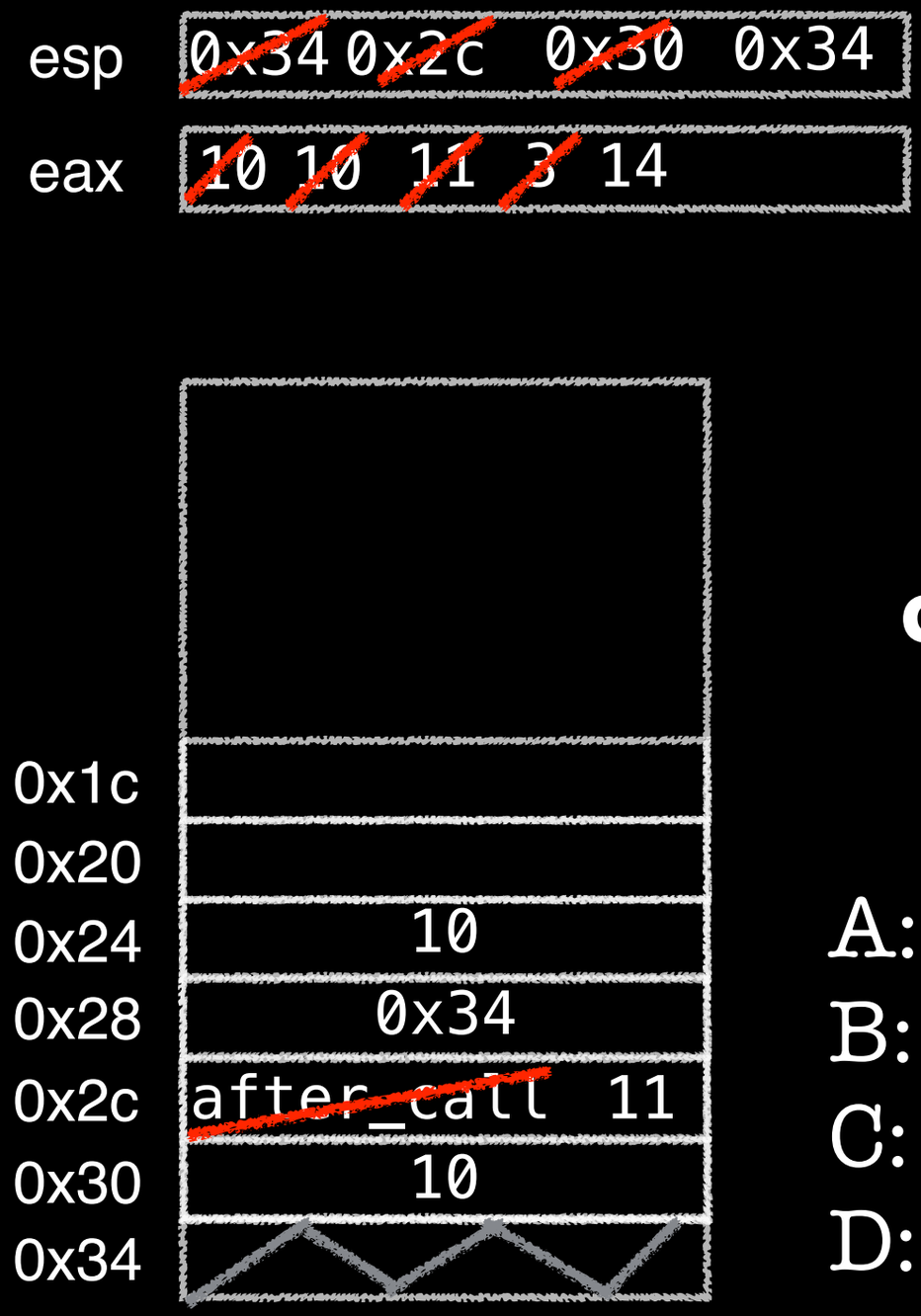
A: esp
B: esp−4
C: esp−8
D: esp+4
E: esp−12

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
(let (x 10)
 (let (z (g x))
  (+ 3 z)))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-12], esp
  mov [esp-16], eax
  sub esp, 8
  jmp g
  after_call:
  mov esp, [esp-8]
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```




```
(def (g y)
  (+ y 1))
```

```
g:
mov eax, [esp-8]
add eax, 1
ret
```

What is the **current value** in [esp-8]?

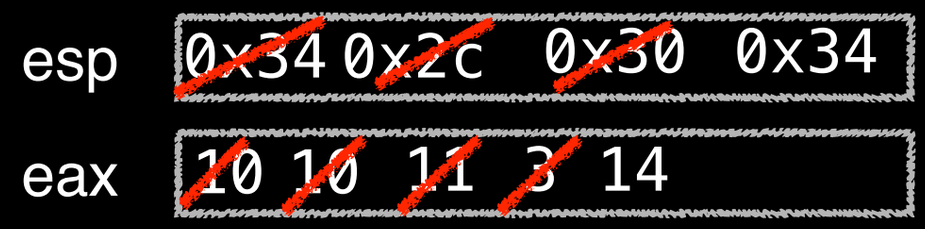
A: 10
B: 0x34
C: after_call
D: the other 10

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
(let (x 10)
 (let (z (g x))
  (+ 3 z)))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-12], esp
  mov [esp-16], eax
  sub esp, 8
  jmp g
  after_call:
  mov esp, [esp-8]
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```




```
(def (g y)
  (+ y 1))
```

```
g:
mov eax, [esp-8]
```

Call setup:

- Always these 3 values
- Always this order
- Always start at current si
- Always subtract to point esp at the return address

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
    (let (x 10)
     (let (z (g x))
      (+ 3 z)))
```

```
(def (g y)
  (+ y 1))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-1
  mov [esp-1
  sub esp, 8
  jmp g
  after_call
  mov esp, [
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```

esp	0x34	0x2c	0x30	0x34
eax	10	10	11	3 14

```
g:
mov eax, [esp-8]
add eax, 1
ret
```

Callee has an easy job:

- Rely on (first) argument in [esp-8], so env starts with [(arg, 2)]
- Start at a “higher” si=3 for any local vars
- Expect [esp] to contain return pointer, use ret

0x2c	after_call	11
0x30	10	
0x34		

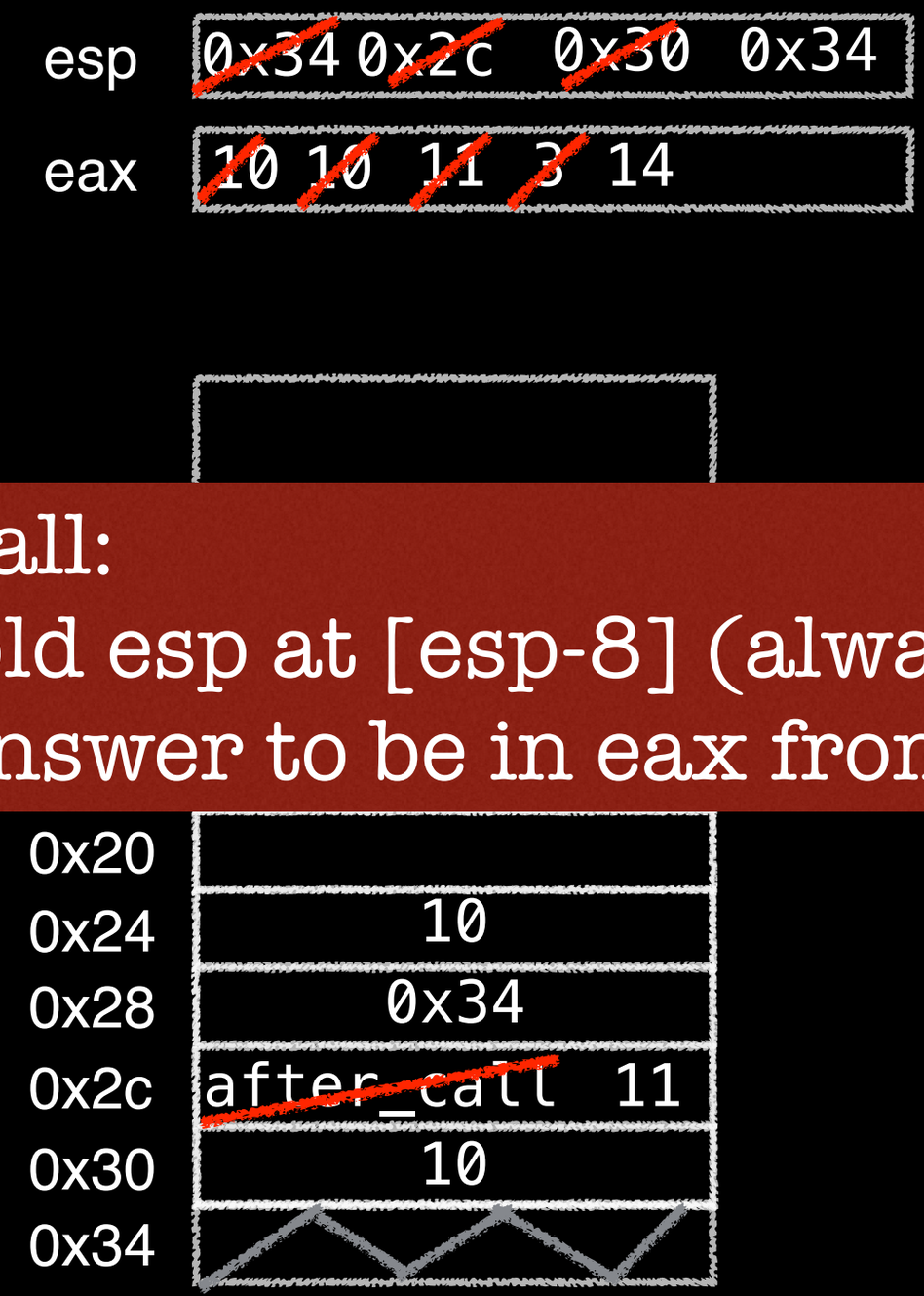
```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
(let (x 10)
 (let (z (g x))
  (+ 3 z)))
```

```
(def (g y)
  (+ y 1))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-1
  mov [esp-1
  sub esp, 8
  jmp g
 after_call:
 mov esp, [esp-8]
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```




```
g:
mov eax, [esp-8]
add eax, 1
ret
```

After the call:

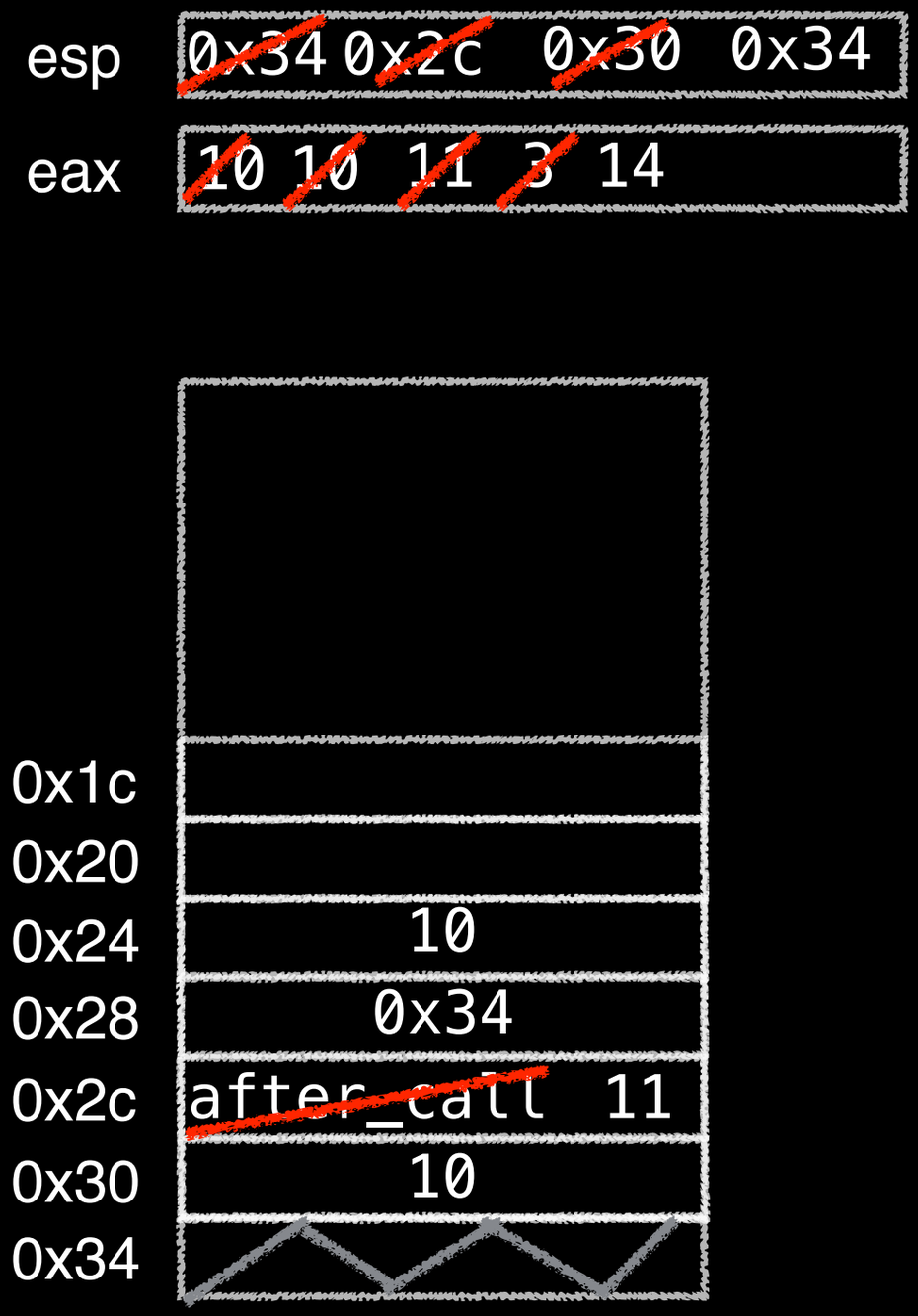
- Rely on old esp at [esp-8] (always)
- Expect answer to be in eax from callee

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
(let (x 10)
 (let (z (g x))
  (+ 3 z)))
```

```
mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-12], esp
  mov [esp-16], eax
  sub esp, 8
  jmp g
  after_call:
  mov esp, [esp-8]
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```




```
(def (g y)
  (+ y 1))
```

```
g:
mov eax, [esp-8]
add eax, 1
ret
```

```
let rec compile_expr e si env =
  match e with
    …
    | EApp(fname, arg) ->
      INSTRUCTIONS FOR FUNCTION CALL
```

```
let compile_def d … =
  INSTRUCTIONS FOR FUNCTION BODY
```

```
[cs131s@ieng6-201]:pa2-grading:509$ /software/nonrdist/valgrind-3.10.0/bin/valgrind ./output/foo.run
==31414== Memcheck, a memory error detector
==31414== Copyright (C) 2002-2013, and GNU GPL'd, by Julian Seward et al.
==31414== Using Valgrind-3.10.0 and LibVEX; rerun with -h for copyright info
==31414== Command: ./output/foo.run
==31414==
==31414== Invalid write of size 4
==31414==    at 0x80488E9: ??? (in /home/linux/ieng6/cs131s/cs131s/pa2-grading/output/foo.run)
==31414==    by 0x408BA42: (below main) (in /usr/lib/libc-2.17.so)
==31414==  Address 0xfe9e2318 is on thread 1's stack
==31414==  4 bytes below stack pointer
==31414==
==31414== Invalid write of size 4
==31414==    at 0x80488F1: ??? (in /home/linux/ieng6/cs131s/cs131s/pa2-grading/output/foo.run)
==31414==    by 0x408BA42: (below main) (in /usr/lib/libc-2.17.so)
==31414==  Address 0xfe9e2314 is on thread 1's stack
==31414==  8 bytes below stack pointer
==31414==
```

How much stack space is used by this expression (what will be the largest N in an esp-N generated)?

(let (x 5) (+ x 1))

A: 16 bytes (some instruction has stack index 4)
B: 12 bytes (some instruction has stack index 3)
C: 8 bytes (some instruction has stack index 2)
D: 4 bytes (some instruction has stack index 1)

```
    (let (x 10)
     (let (z (g x))
      (+ 3 z)))

mov eax, 10
mov [esp-4], eax
  mov eax, [esp-4]
  mov [esp-8], after_call
  mov [esp-12], esp
  mov [esp-16], eax
  sub esp, 8
  jmp g
  after_call:
  mov esp, [esp-8]
mov [esp-8], eax
mov eax, 3
add eax, [esp-8]
```

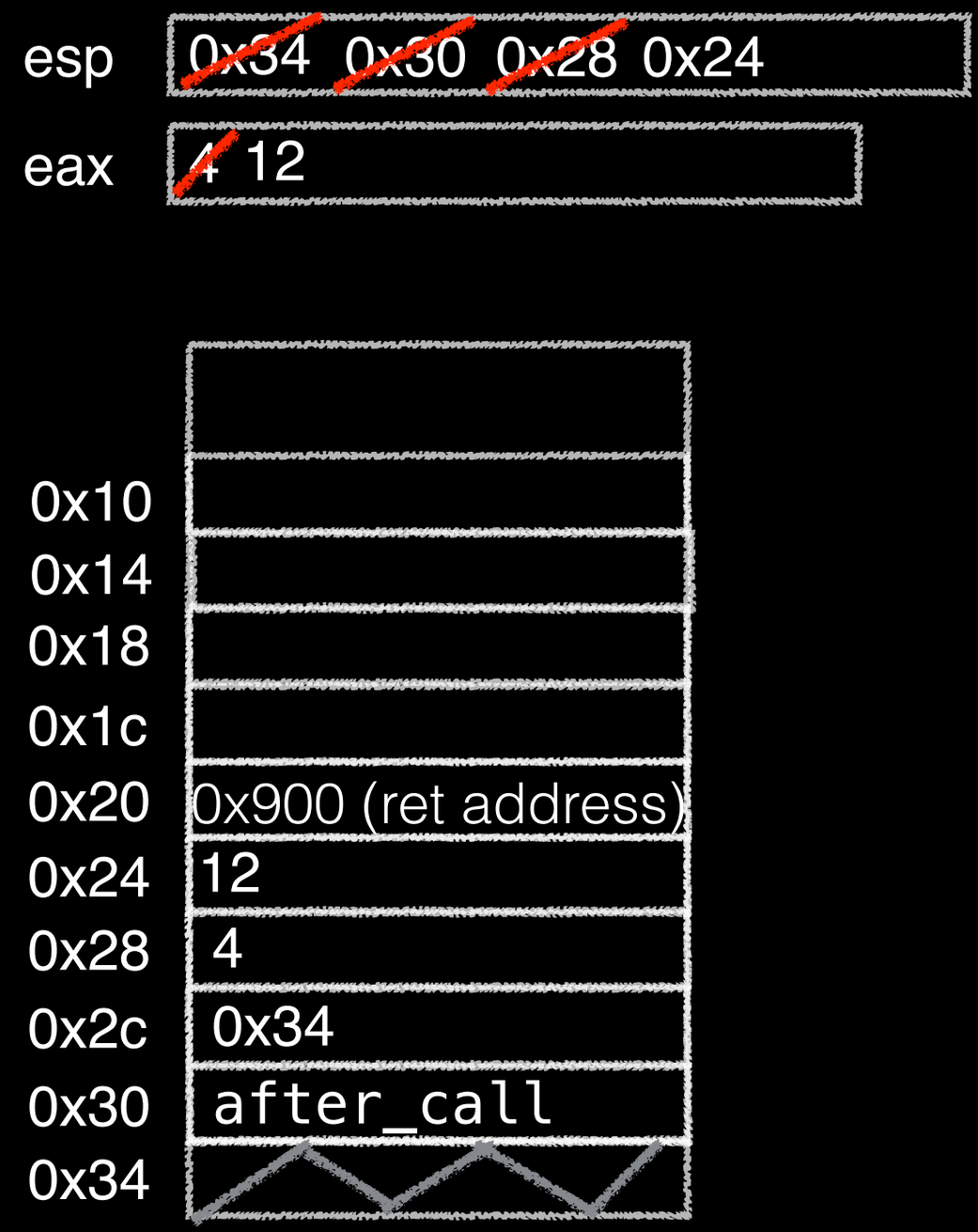
```
(def (twosqrt3x x)
 (let (ans (do_sqrt (* x 3)))
  (* 2 ans)))
(twosqrt3x 4)
```

```
int do_sqrt(int val) {
  float asF = (float)val;
  return (int)(sqrt(asF));
}
```

```
twosqrt3x:
    mov eax, [esp-8]
    imul eax, 3
    sub esp, 8
    push eax
    call do_sqrt
```

0x900

```
mov eax, 4
mov [esp-4], after_call
mov [esp-8], esp
mov [esp-12], eax
sub esp, 4
jmp twosqrt3x
after_call:
```



```
(def (twosqrt3x x)
 (let (ans (do_sqrt (* x 3)))
  (* 2 ans)))
(twosqrt3x 4)
```

```
int do_sqrt(int val) {
  float asF = (float)val;
  return (int)(sqrt(asF));
}
```

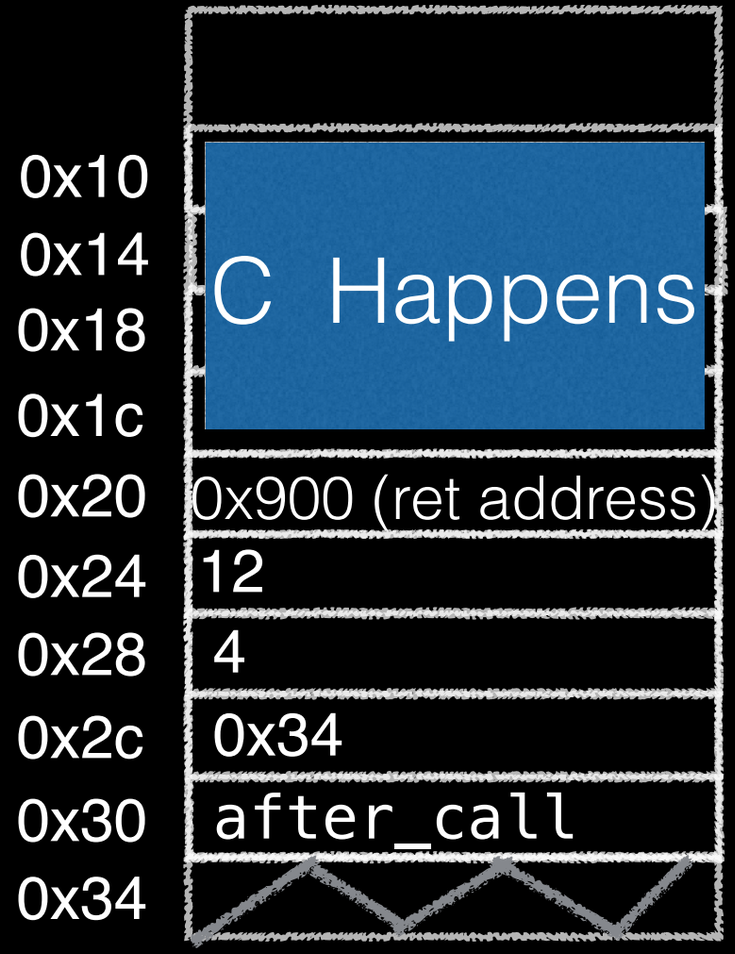
```
twosqrt3x:
    mov eax, [esp-8]
    imul eax, 3
    sub esp, 8
    push eax
    call do_sqrt
```

0x900

What will be in ESP when do_sqrt is complete?

A: 0x24 (the value of ESP before call)
B: 0x20 (do_sqrt's return address)
C: 0x30 (the original ret address)
D: We can't possibly know
E: None of the above

```
after_call:
```



```
(def (twosqrt3x x)
 (let (ans (do_sqrt (* x 3)))
  (* 2 ans)))
(twosqrt3x 4)
```

```
int do_sqrt(int val) {
  float asF = (float)val;
  return (int)(sqrt(asF));
}
```

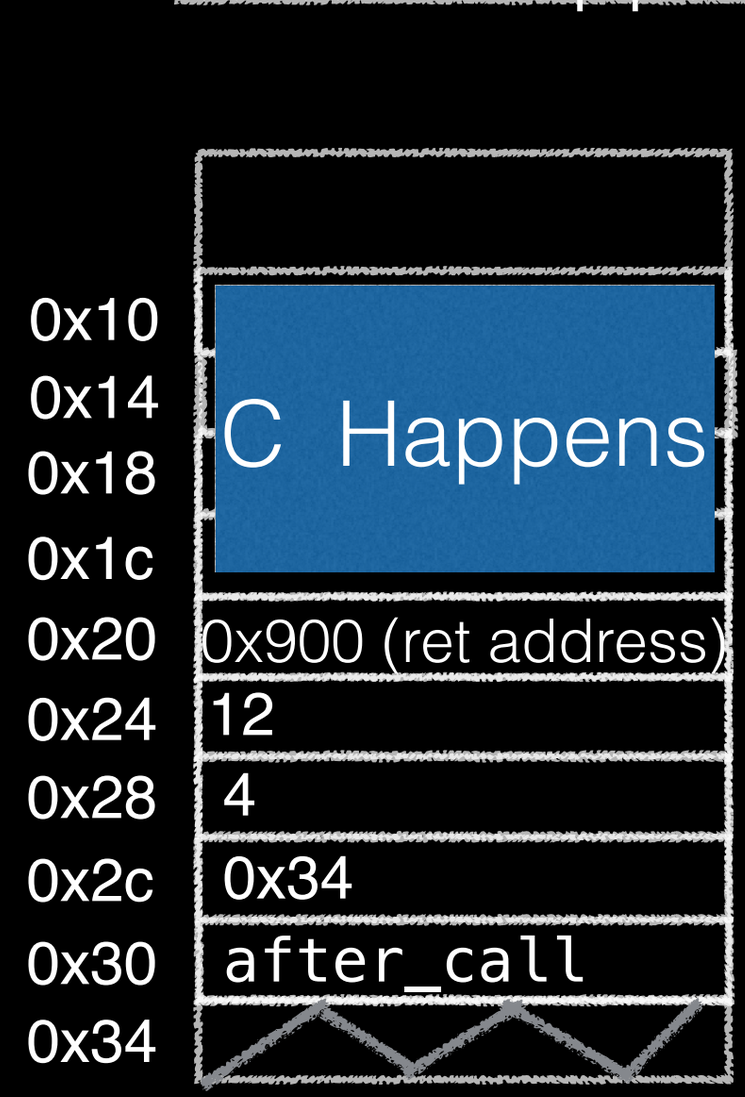
```
twosqrt3x:
    mov eax, [esp-8]
    imul eax, 3
    sub esp, 8
    push eax
    call do_sqrt
```

0x900

What will be in EAX when do_sqrt is complete?

A: We can't possibly know
B: 3 (the return value)
C: 12
D: 4
E: None of the above

```
after_call:
```



```
(def (twosqrt3x x)
 (let (ans (do_sqrt (* x 3)))
  (* 2 ans)))
(twosqrt3x 4)
```

```
int do_sqrt(int val) {
  float asF = (float)val;
  return (int)(sqrt(asF));
}
```

```
twosqrt3x:
    mov eax, [esp-8]
    imul eax, 3
    sub esp, 8
    push eax
    call do_sqr
```

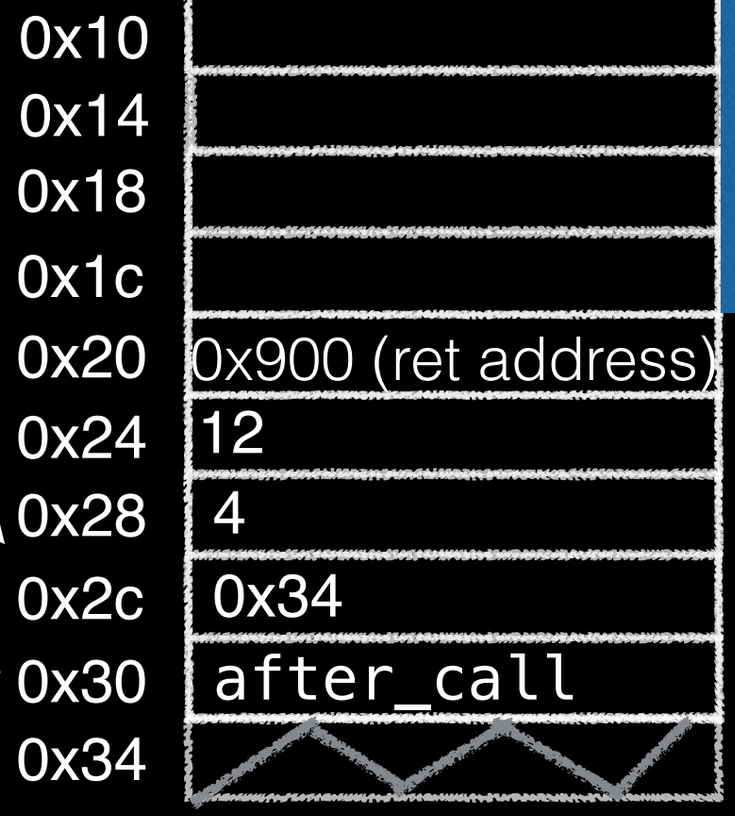
0x900

Just as it was before `call`

esp

eax


```
mov eax, 4
mov [esp-4], after_call
mov [esp-8], esp
mov [esp-12], eax
sub esp, 4
jmp twosqrt3x
after_call:
```

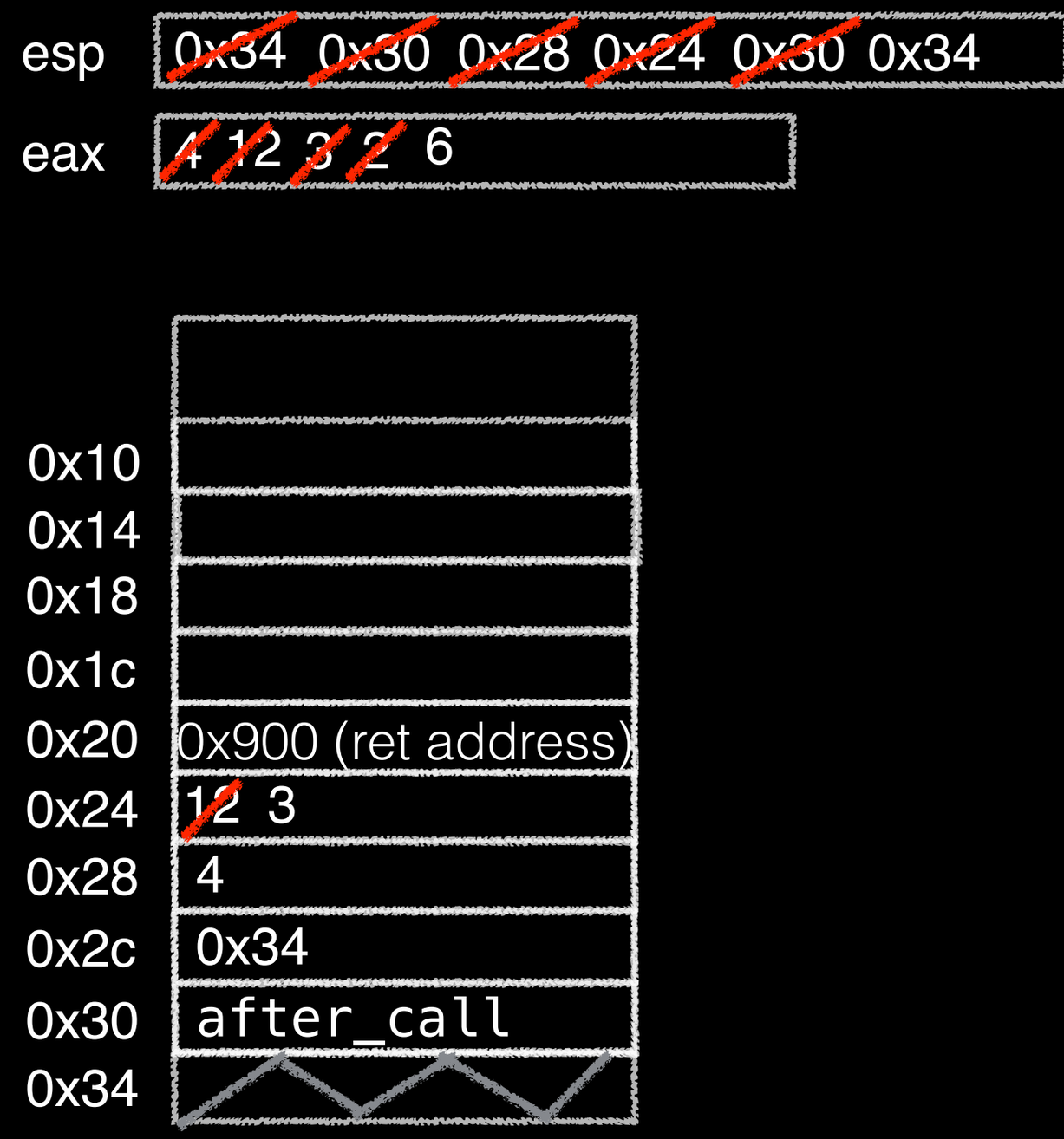


Return value

```
(def (twosqrt3x x)
 (let (ans (do_sqrt (* x 3)))
  (* 2 ans)))
(twosqrt3x 4)
```

```
int do_sqrt(int val) {
  float asF = (float)val;
  return (int)(sqrt(asF));
}
```

```
  twosqrt3x:
      mov eax, [esp-8]
      imul eax, 3
      sub esp, 8
      push eax
      call do_sqrt
0x900 add esp, 12
      mov [esp-12], eax
      mov eax, 2
      imul eax, [esp-12]
      ret
mov eax, 4
mov [esp-4], after_call
mov [esp-8], esp
mov [esp-12], eax
sub esp, 4
jmp twosqrt3x
after_call:
mov esp, [esp-8]
ret
```



```
sum:
  mov eax, [esp-8]
  cmp eax, 1
  jne false_branch
   mov eax, 1
   jmp after_if
  false_branch:
   mov eax, [esp-8]
   sub eax, 1
   mov [esp-12], after_call
   mov [esp-16], esp
   mov [esp-20], eax
   sub esp, 12
   jmp sum
   after_call:
   mov esp, [esp-8]
   mov [esp-12], eax
   mov eax, [esp-8]
   add eax, [esp-12]
 after_if:
   ret
```

```
def sum(x):
  if x = 1: 1
  else:
    x + sum(x - 1)
```

eq	~~NO~~	~~NO~~	YES	
esp	~~0x30~~	~~0x24~~	~~0x18~~	~~0x1c~~
	~~0x24~~	~~0x28~~	~~0x30~~	0x34
eax	~~3~~	~~3~~	~~2~~	~~1~~	~~2~~	~~3~~	6

0x10	1
0x14	0x24
0x18	~~after_call~~ 1
0x1c	2
0x20	0x30
0x24	~~after_call~~ 3
0x28	3
0x2c	old_esp
0x30	return_ptr
0x34	

What values will be stored in 0x10, 0x14, 0x18 by the next three instructions?

A: 1, 0x20, after_call
B: 2, 0x24, after_call
C: 2, 0x20, after_call
D: 1, 0x24, after_call

```
def twosqrt3x(x):
  let ans = do_sqrt(x * 3) in
  2 * ans
twosqrt3x(4)
```

```
int do_sqrt(int val) {
  float asD = (float)val;
  return (int)(sqrt(asD));
}
```

```
  twosqrt3x:
      mov eax, [esp-8]
      imul eax, 3
      sub esp, 8
      push eax
      call do_sqrt
0x900 add esp, 12
      mov [esp-12], eax
      mov eax, 2
      imul eax, [esp-12]
      ret
mov eax, 4
mov [esp-4], after_call
mov [esp-8], esp
mov [esp-12], eax
sub esp, 4
jmp twosqrt3x
after_call:
mov esp, [esp-8]
ret
```

Inter-EBP Range