ECE 6504

Embedded and Controls Systems Security: Stack Smashing II

Reading:

T: *Return to LIBC exploits and Advanced return-into-lib(c) exploits*
N: *The Geometry of Innocent Flesh on the Bone*

“Start every day off with a smile and get it over with.”

–W.C. Fields

preventing code injection: $W \oplus X$

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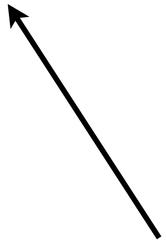


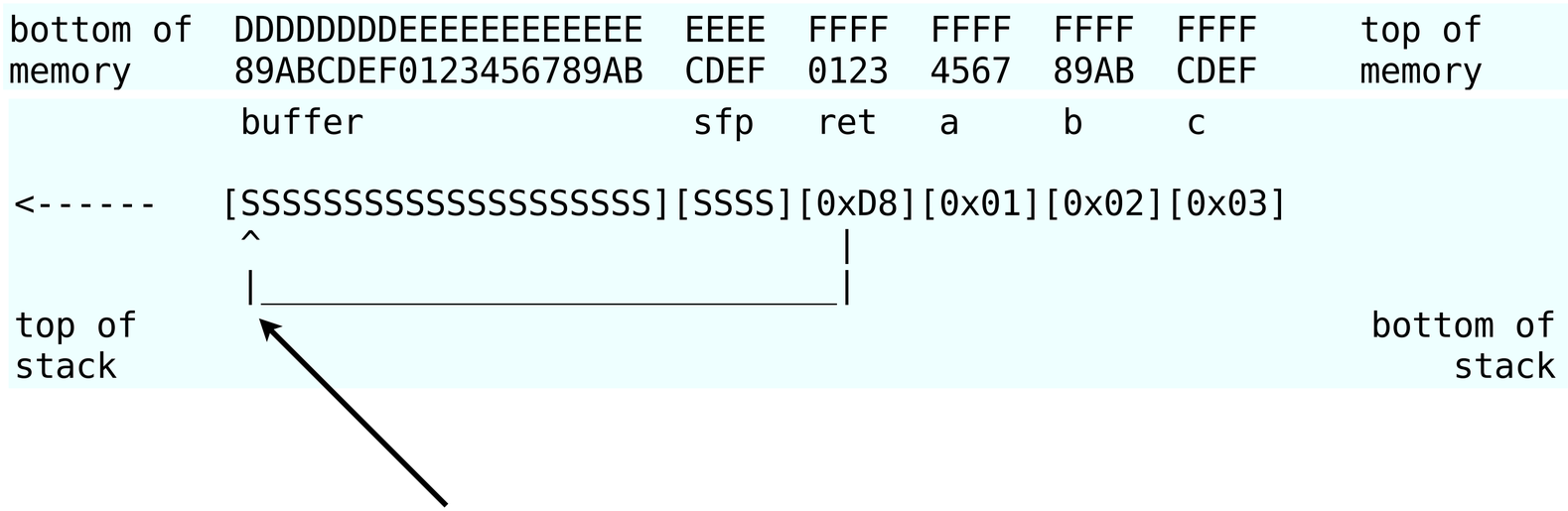
memory marked either writable or executable, not both

```
bottom of                                                          top of
memory                                                             memory
          buffer2       buffer1   sfp   ret   a     b     c
<------   [           ][        ][   ][   ][   ][   ][   ]

top of                                                          bottom of
stack          W     W   W  W                                      stack
```

$W \oplus X$

memory after buffer overflow:



jump causes seg. fault

(no execute data)

circumventing $W \oplus X$

attacker:

return-into-libc:

you don’t like my code, I’ll use yours

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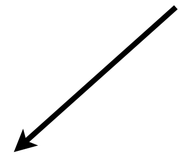
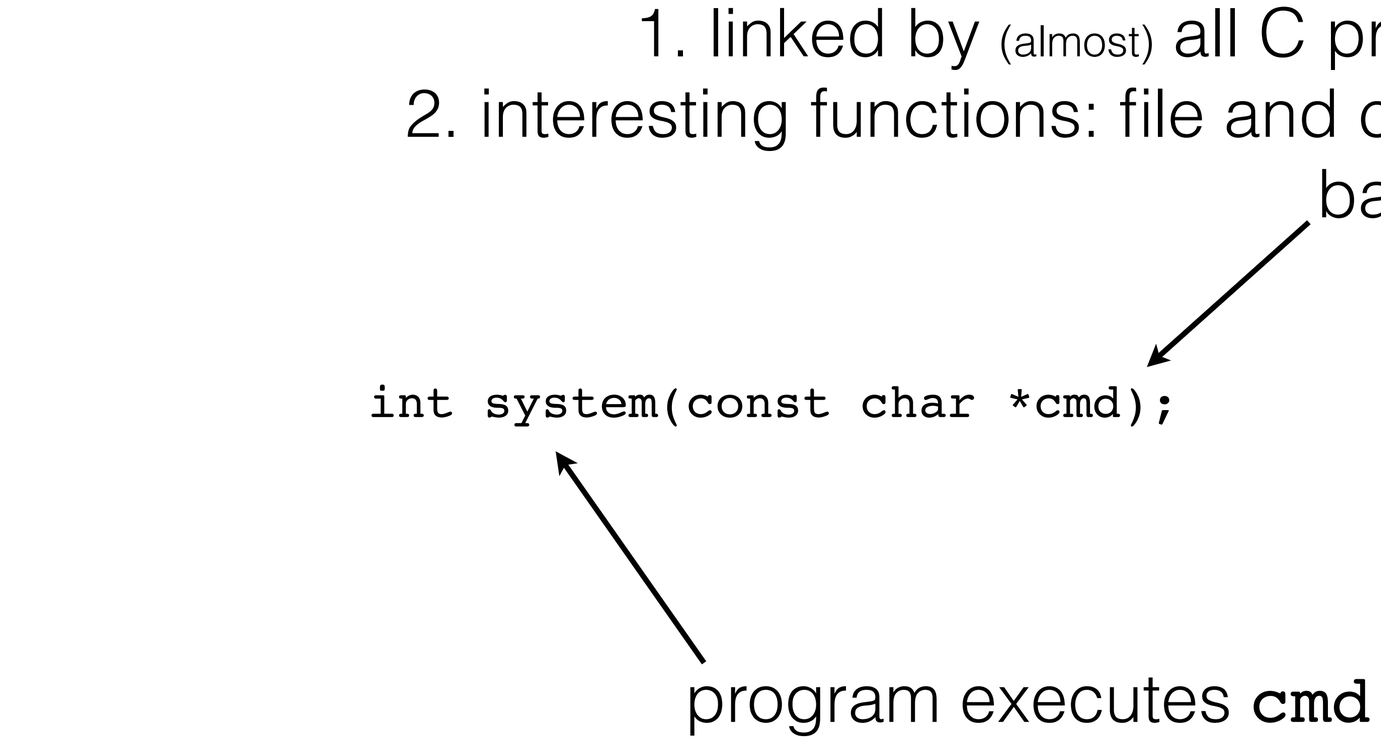


```
int system(const char *cmd);
```

return-into-libc

libc:

1. linked by (almost) all C programs
2. interesting functions: file and console-based I/O



attack:

make function
return to libc function

attack:

make function
return to libc function

Q: is this possible?

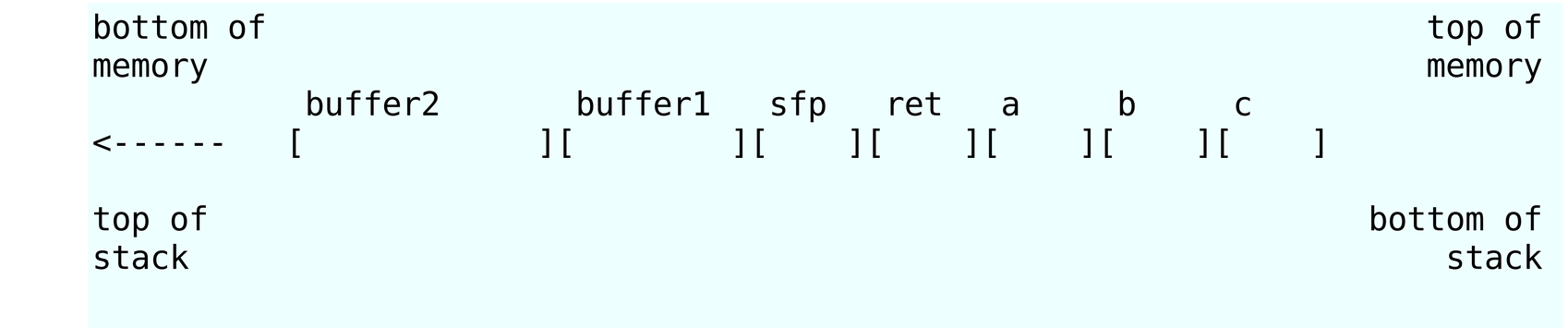
A: remember state w/r/t function call

stack after function called

```
void function(int a, int b, int c) {
   char buffer1[5];
   char buffer2[10];
}

void main() {
  function(1,2,3);
}
```

```
pushl %ebp
movl %esp,%ebp
subl $20,%esp
```



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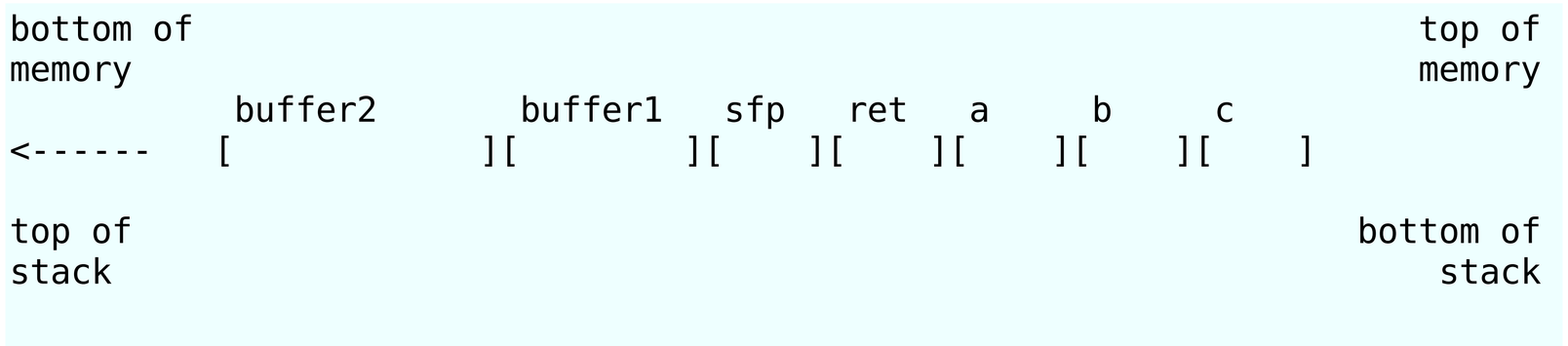

to return-to-libc:

1. ret => addr. of libc function
2. a,b,c => arguments of libc function

return-into-libc: stack after buffer overflow

memory addr grow ⟶

stack after call:

```
[function(int a, int b, int c)]
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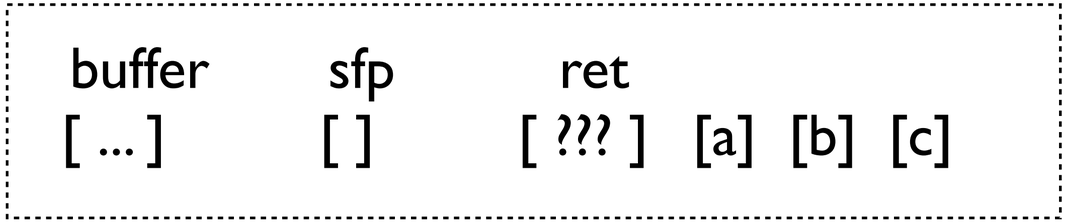

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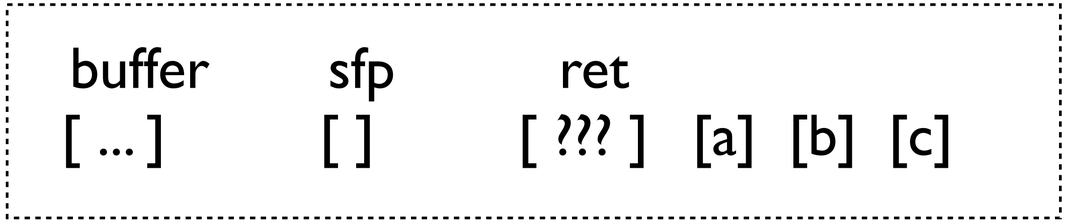

after overflowing buffer:

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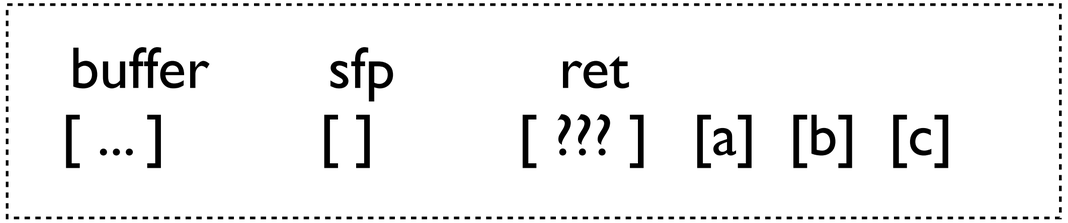

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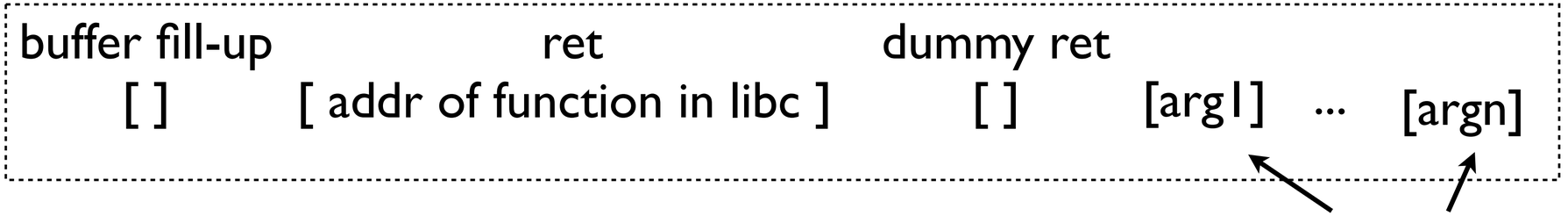

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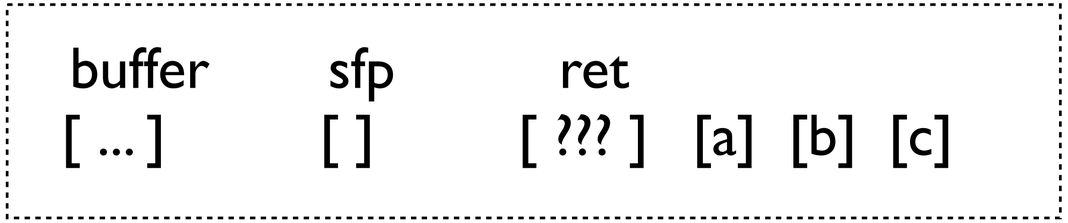

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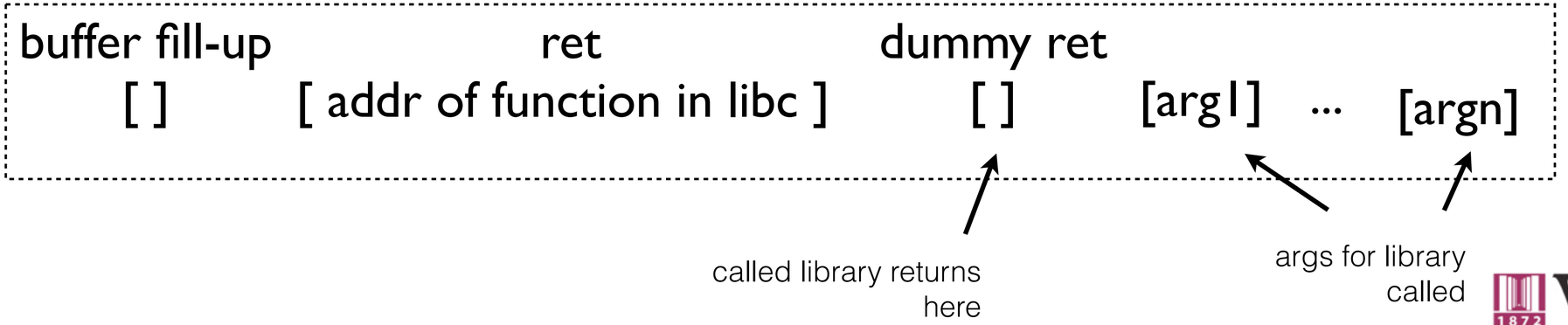

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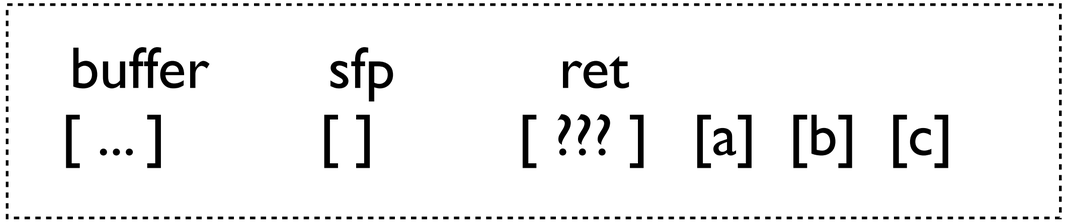

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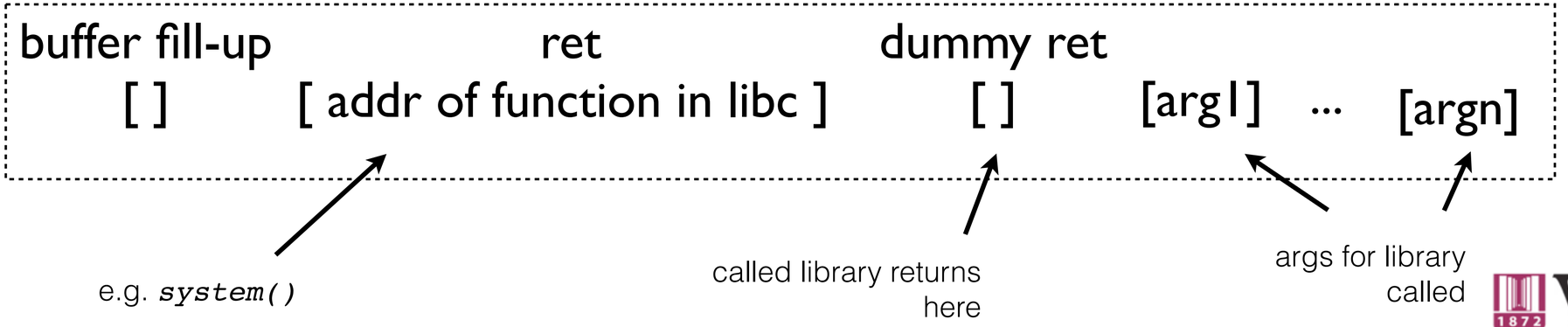

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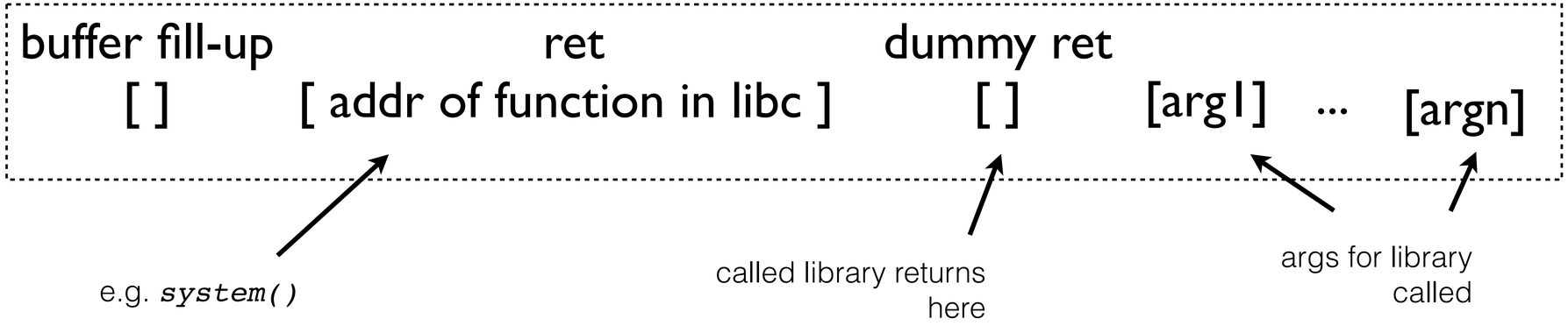

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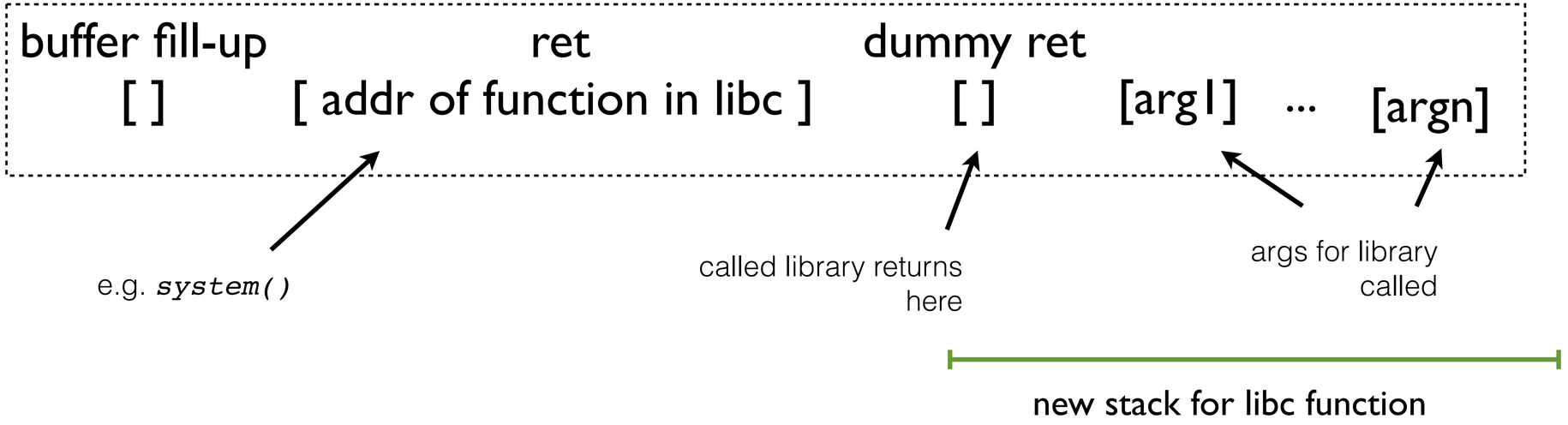

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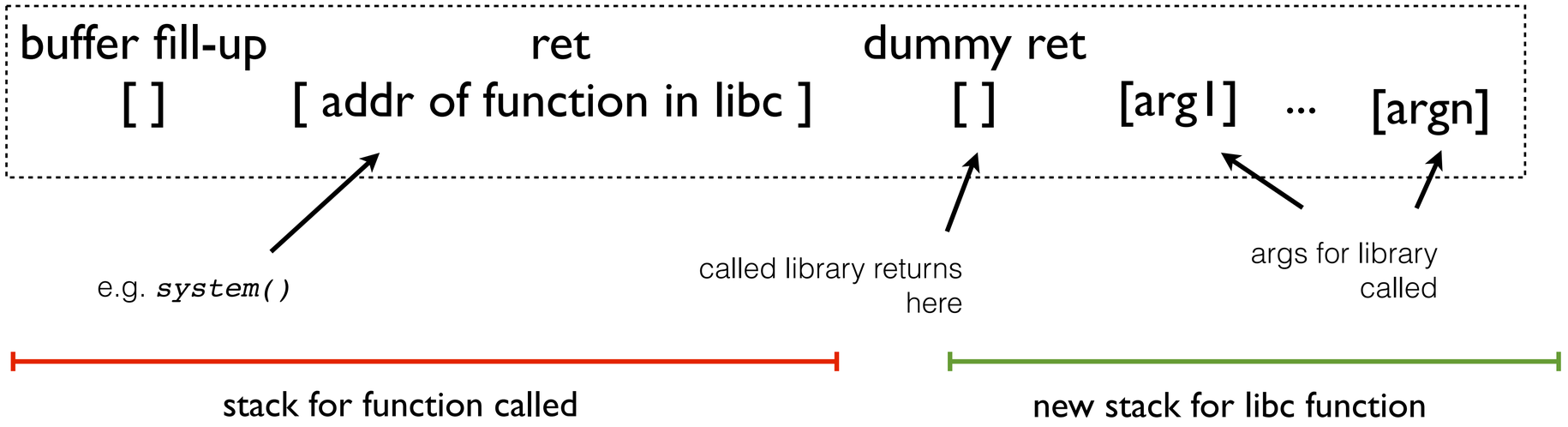

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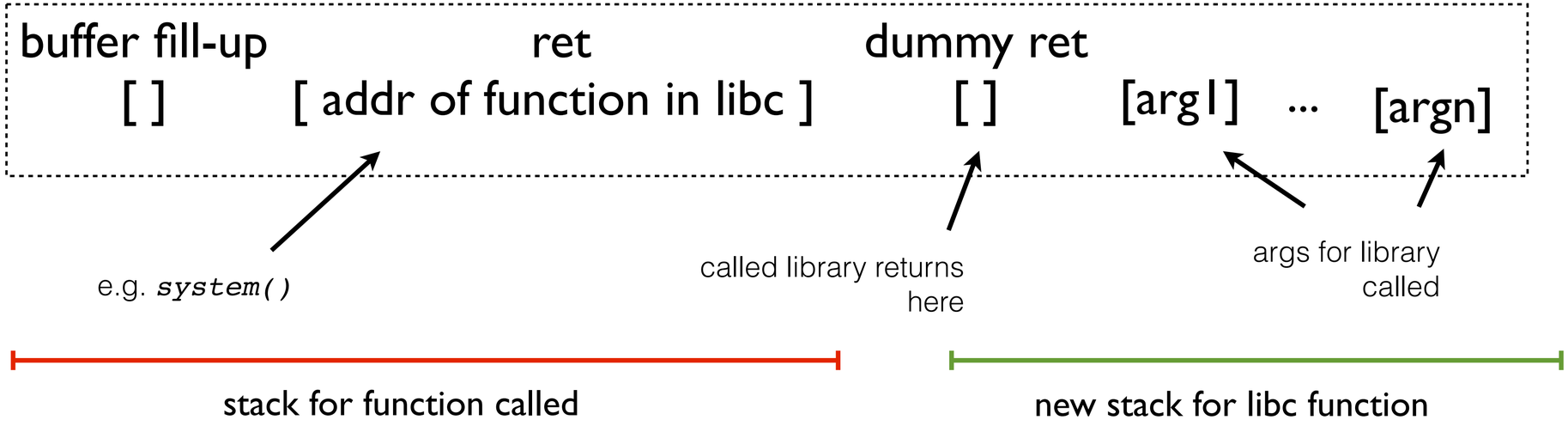

Q: limitation?

return-into-libc: stack after buffer overflow

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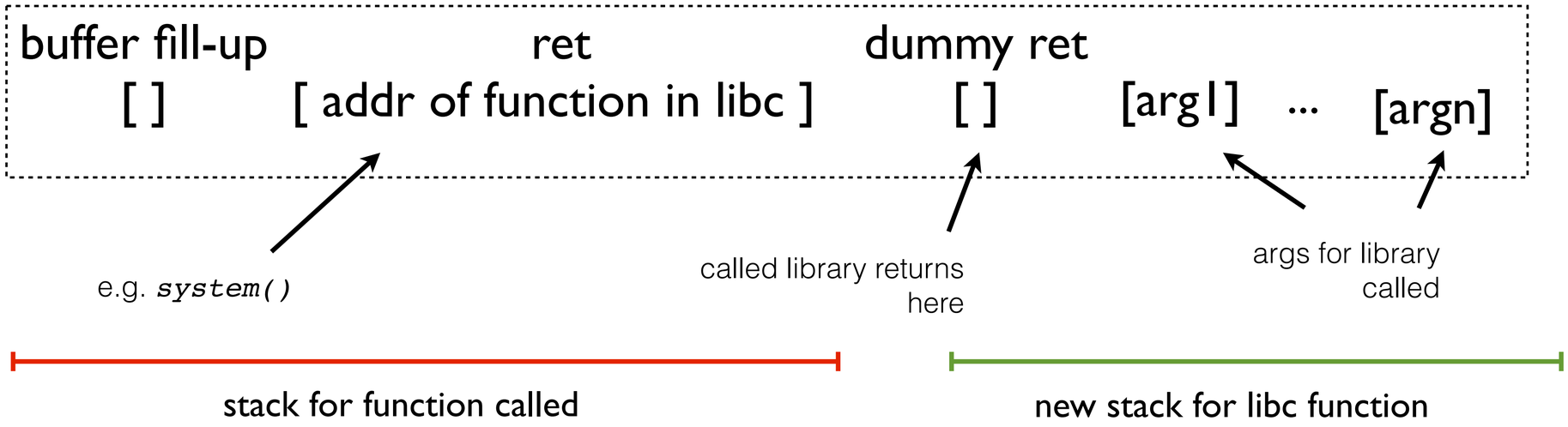
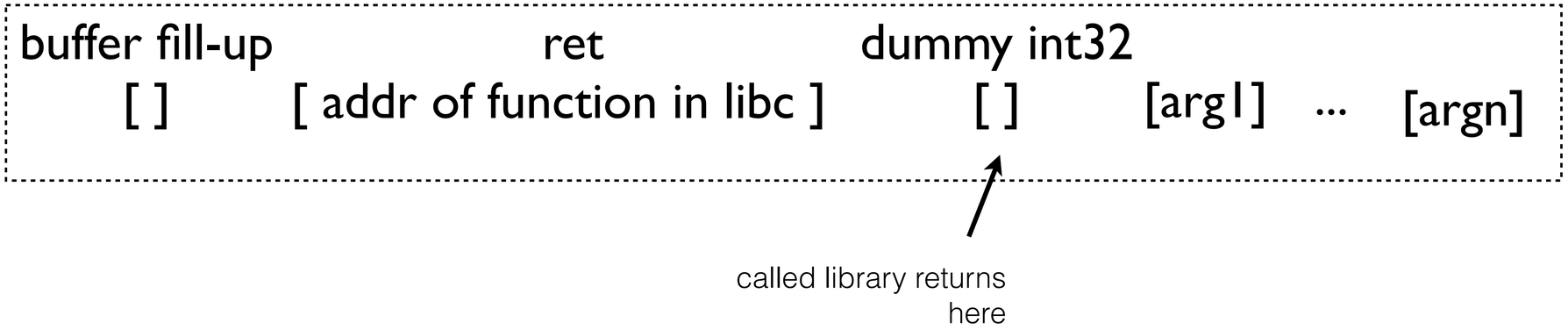


Q: limitation?

A: one function call

return-into-libc: one function call



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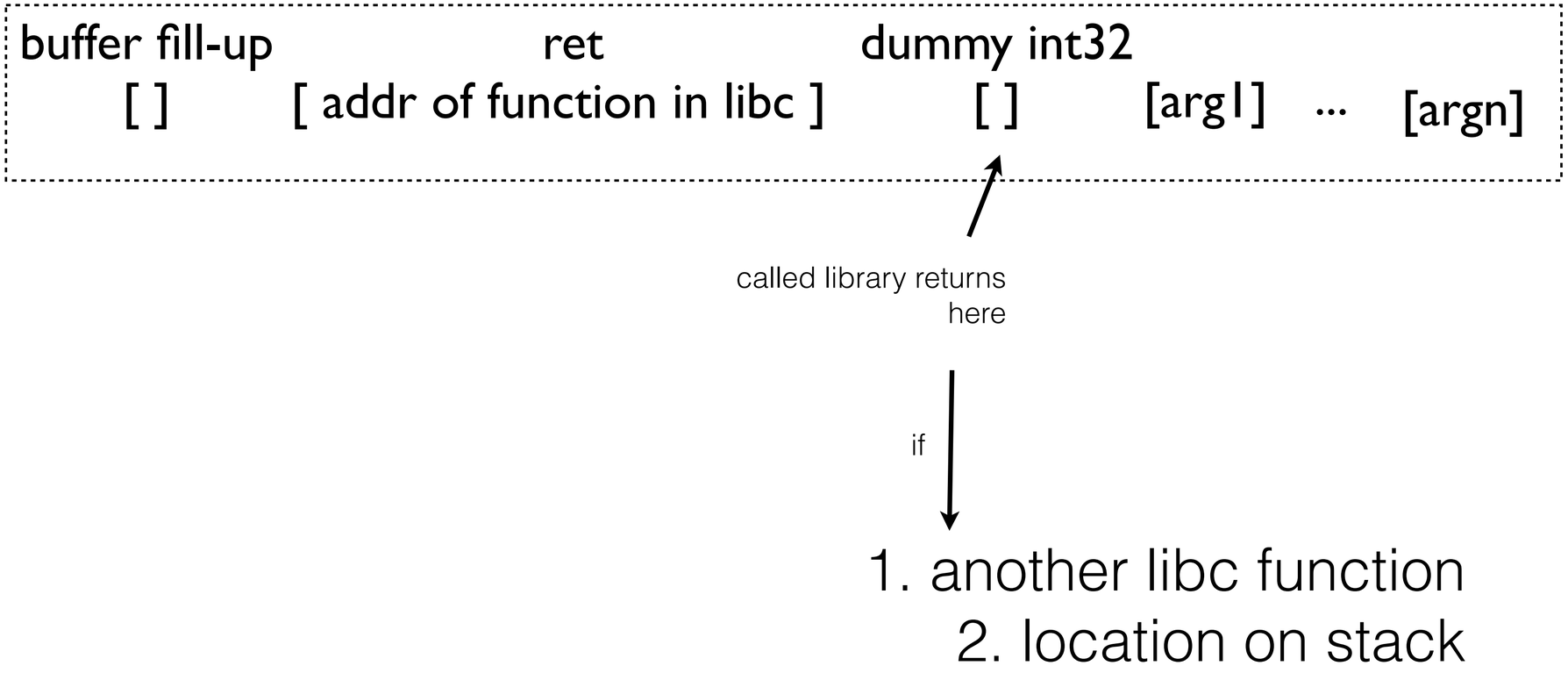

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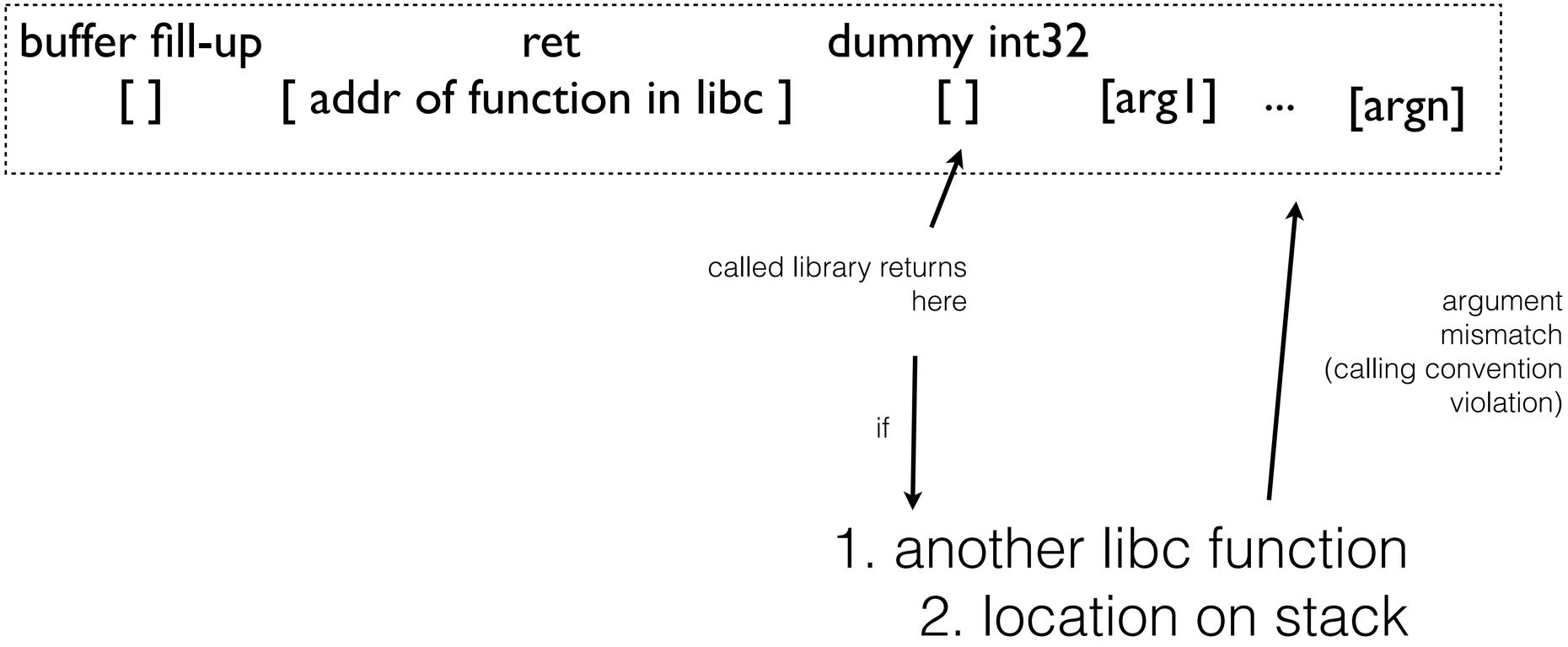

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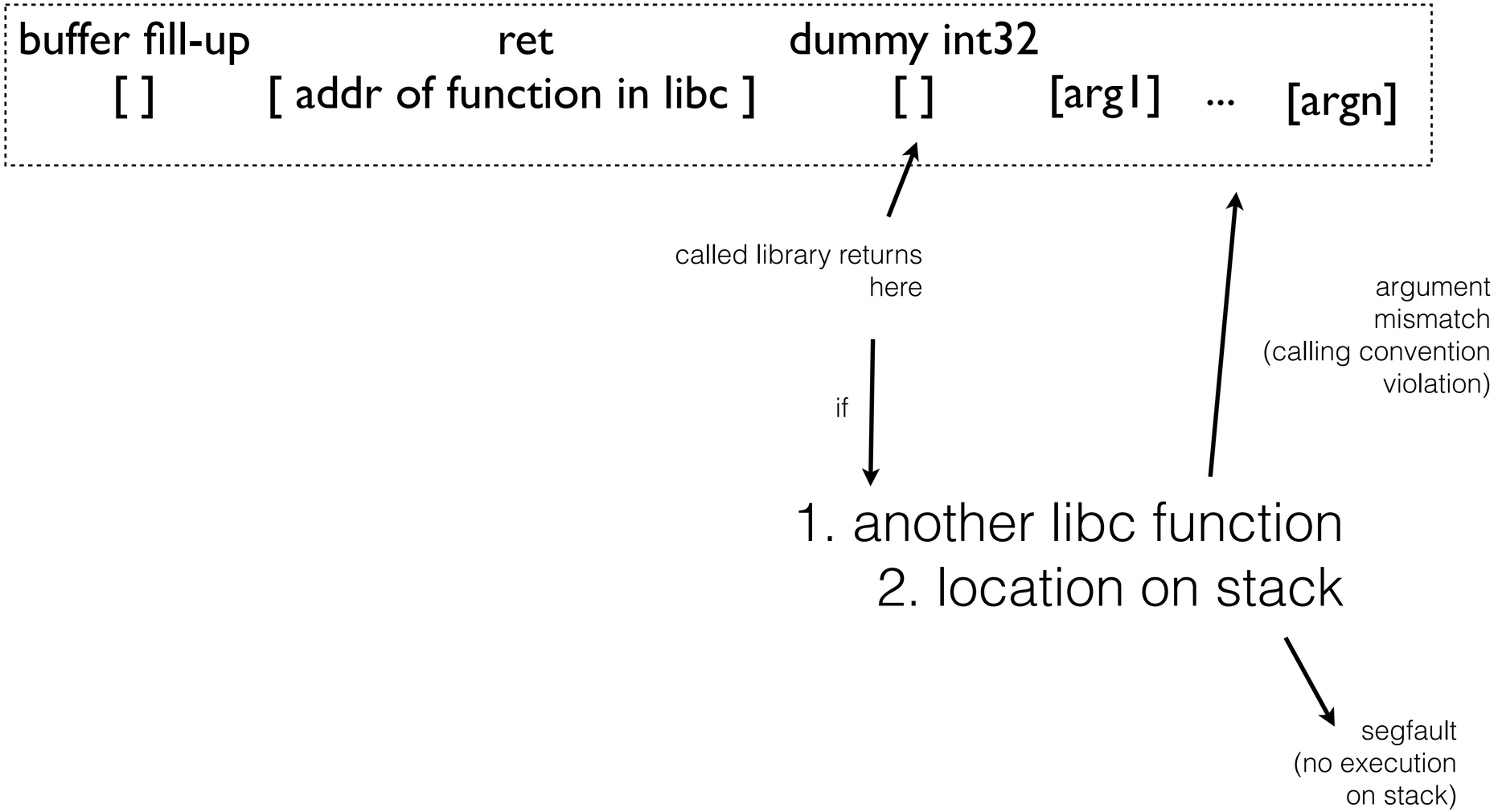

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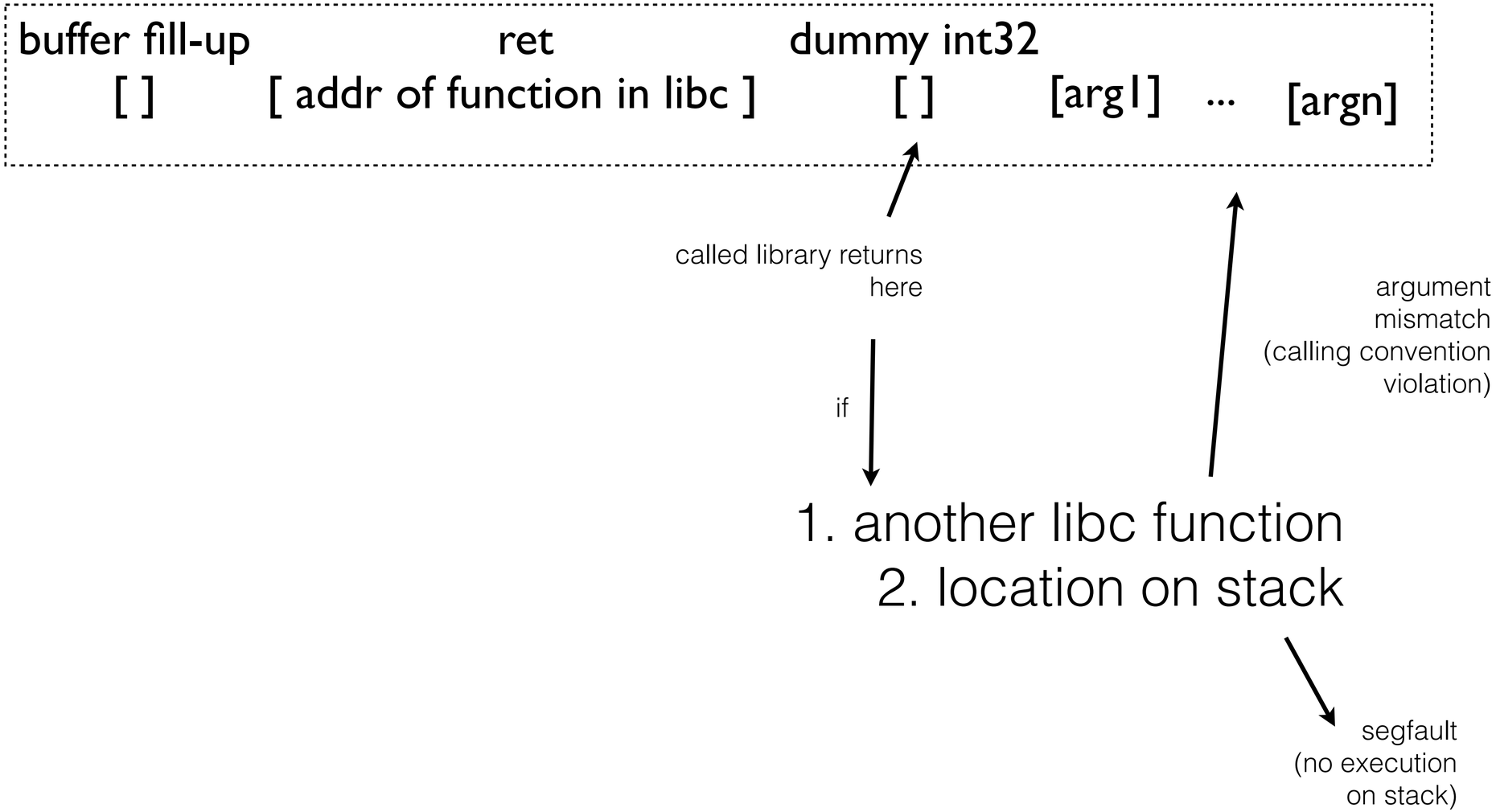

stack is not prepared for another call

classic return-into-libc prevention:

```
seteuid(getuid())
```

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program drops privileges

1. `getuid`: get uid of calling process
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two calls....

`seteuid(getuid())` example

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`passwd`:

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1. `seteuid(getuid())`

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`seteuid(getuid())` example

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4. `setuid()`

`seteuid(getuid())` example

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5. write hash

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exploit here:

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advanced return-into-libc: `esp` lifting (1)

if program compiled with:

`-fomit-frame-pointer`

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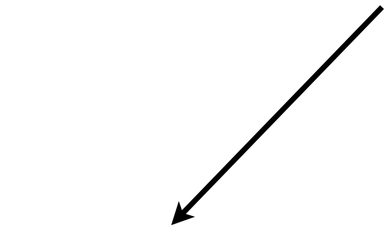

epilogue:

code at end of function

advanced return-into-libc: `esp` lifting (1)

if program compiled with:

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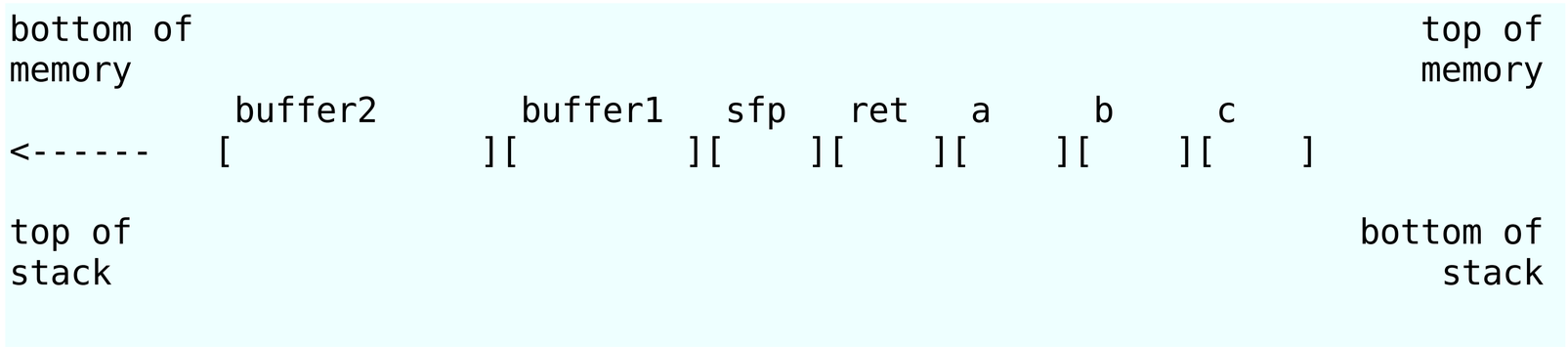
epilogue:

```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

resetting stack pointer

code at end of function

-fomit-frame-pointer



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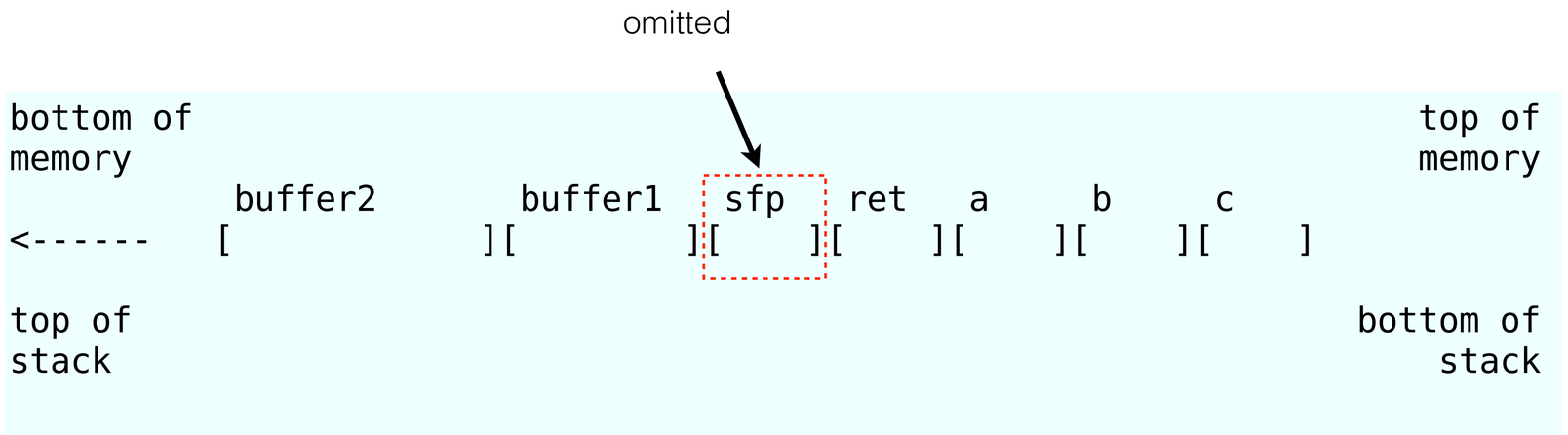

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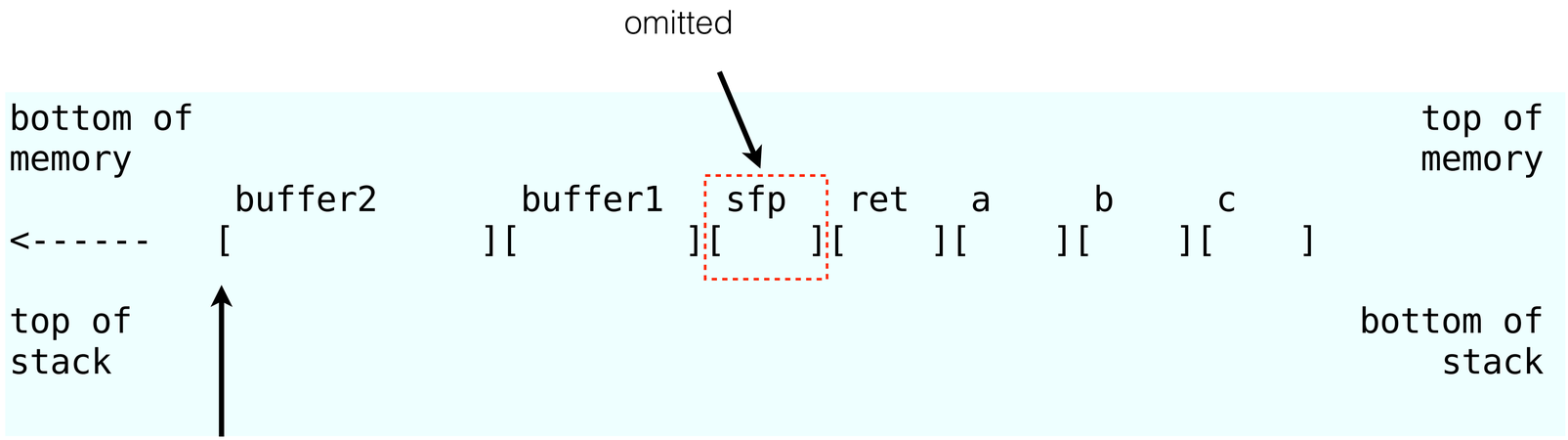

before **`eplg`**, **`%esp`**

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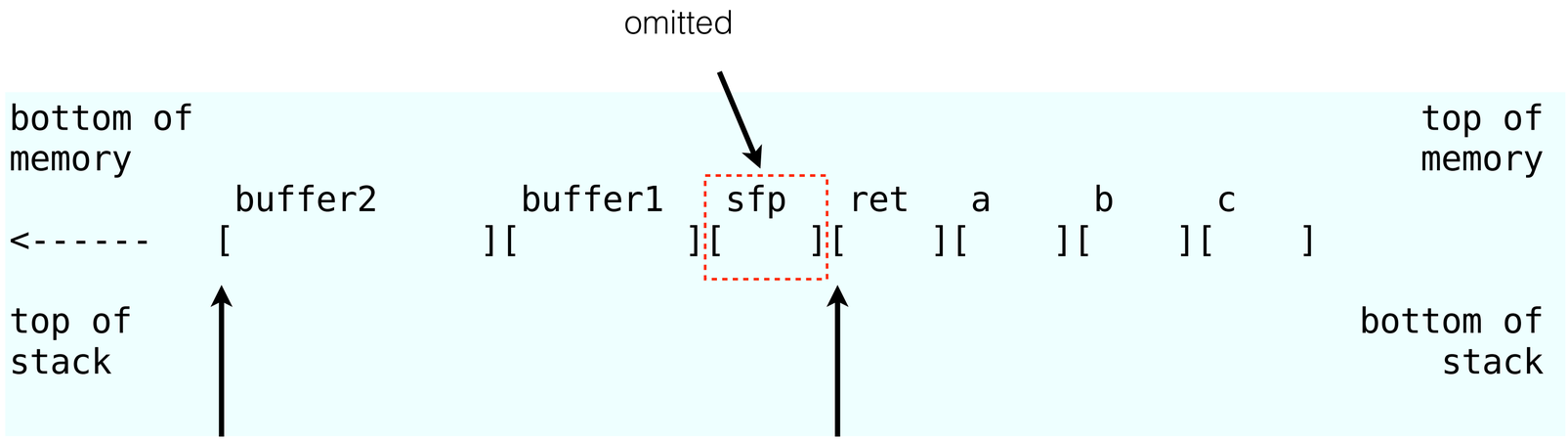

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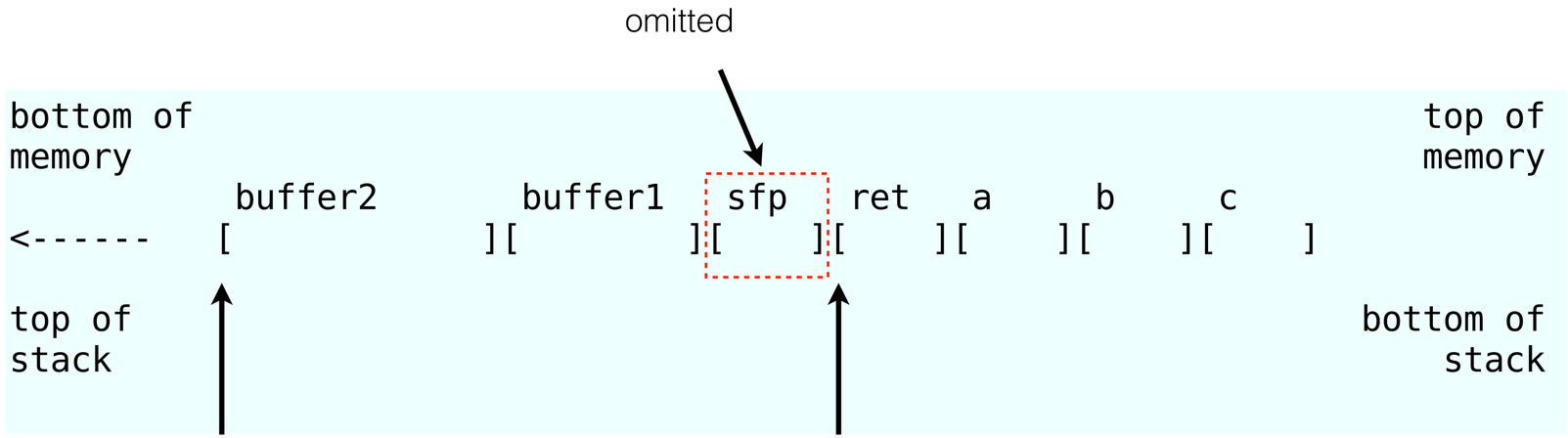

before **eplg**, **%esp** after **eplg**, **%esp**

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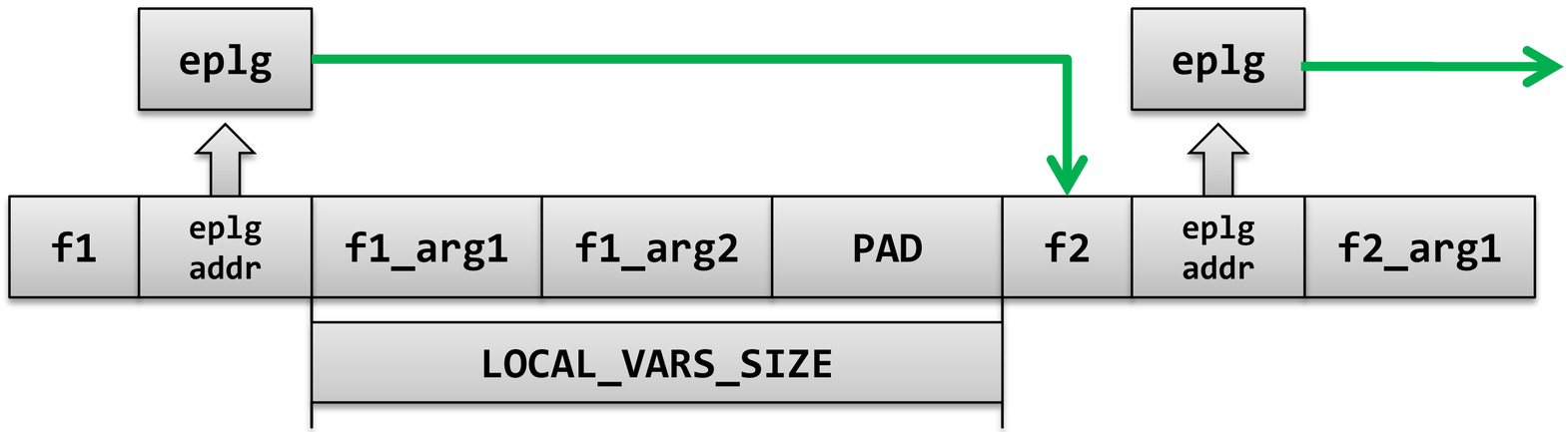
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

pops **ret** addr. off stack and branches to it

advanced return-into-libc: `esp` lifting (1)

(libc [or other function] should return to epilog of exploited [or other] function)



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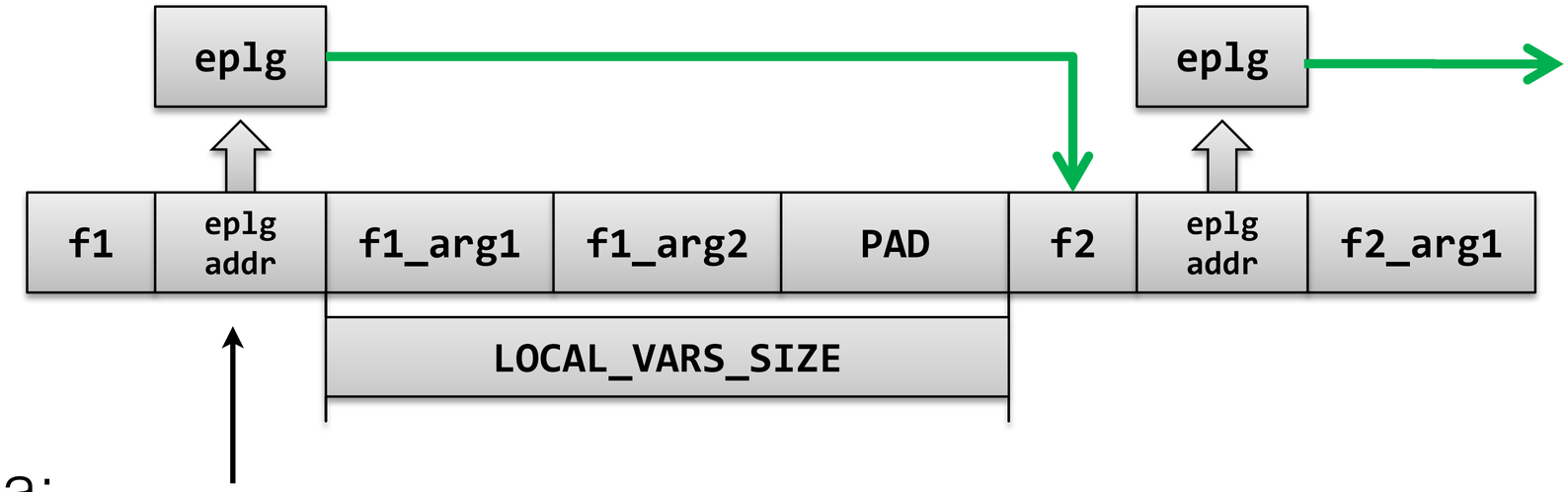

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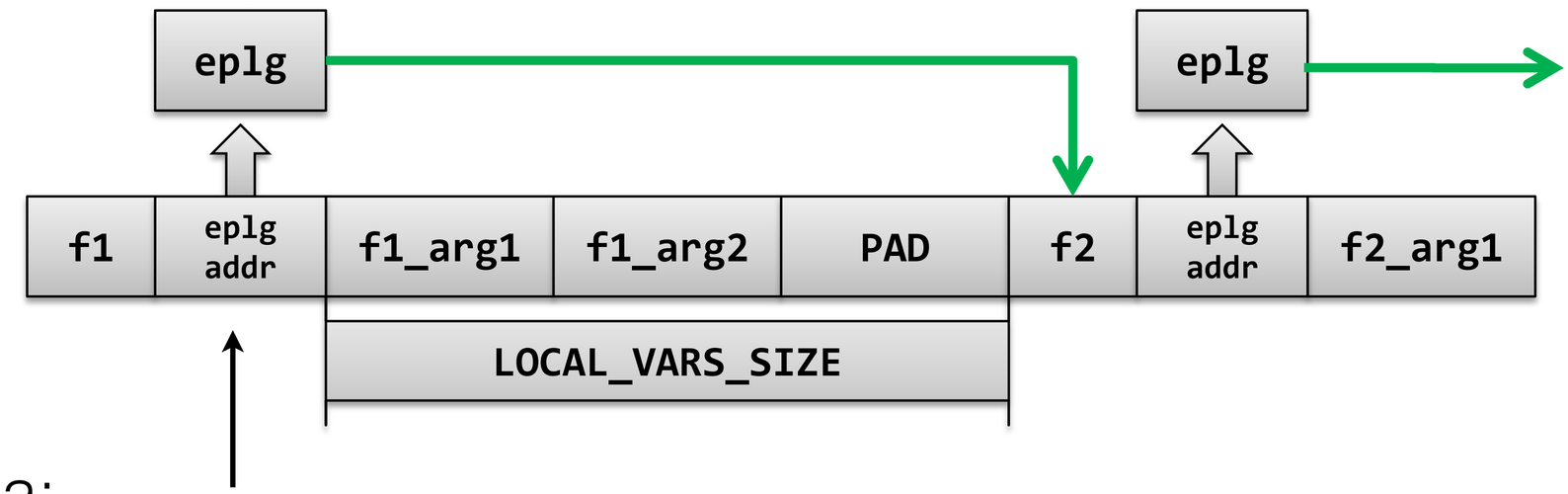

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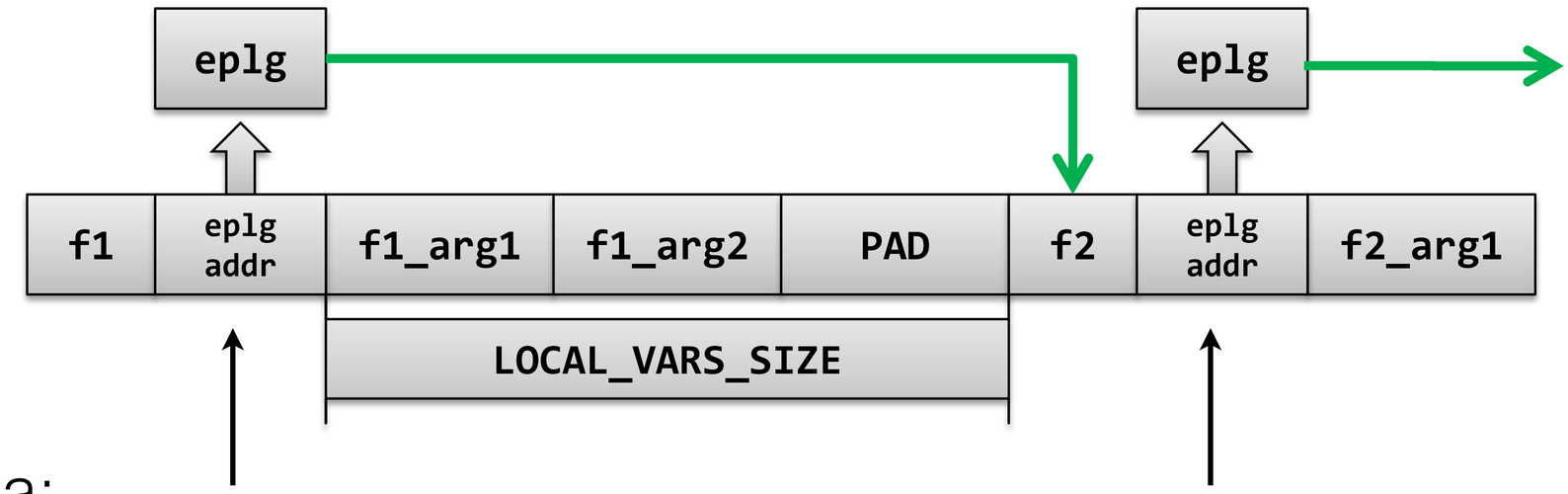

idea:

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(stack we build: part one)

stack after call:

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[function(int a, int b, int c)]
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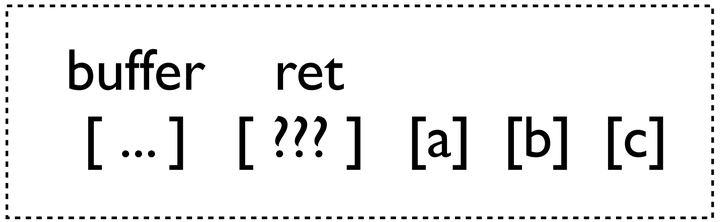

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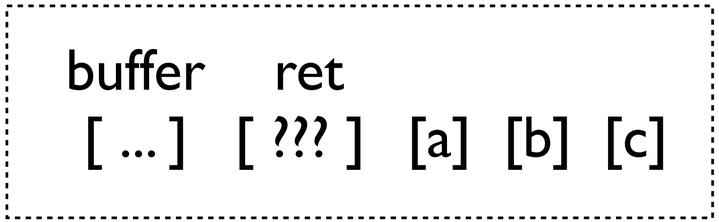

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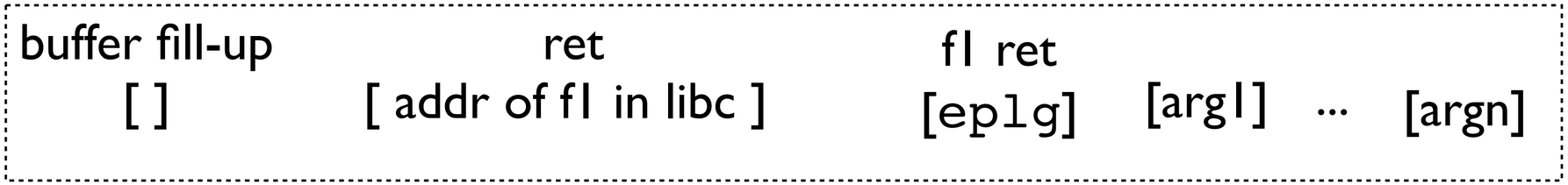

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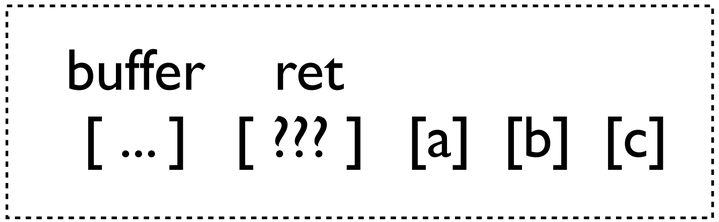

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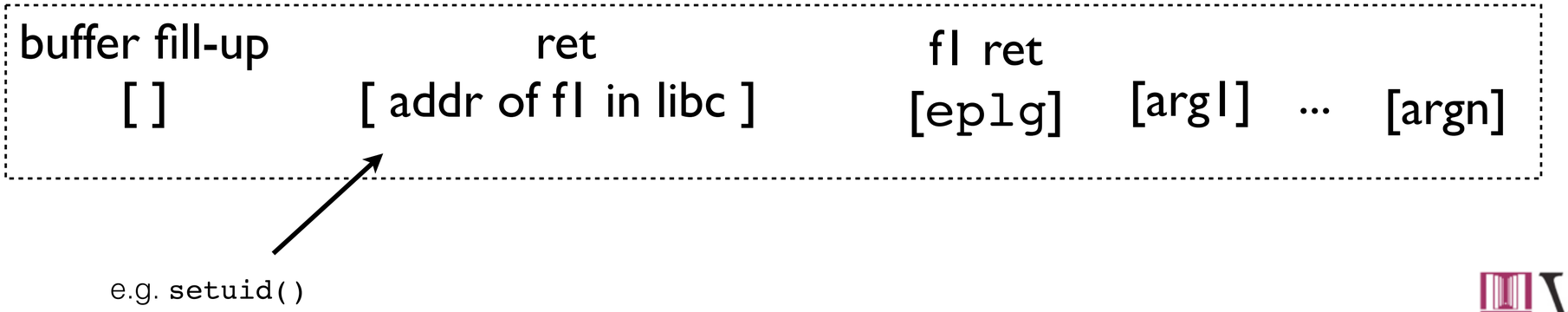

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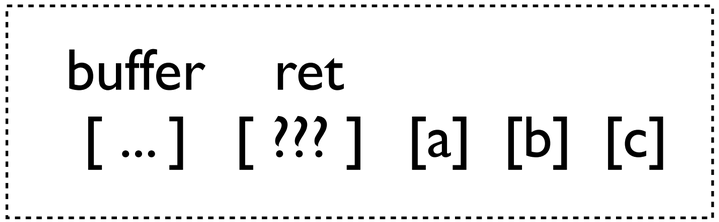

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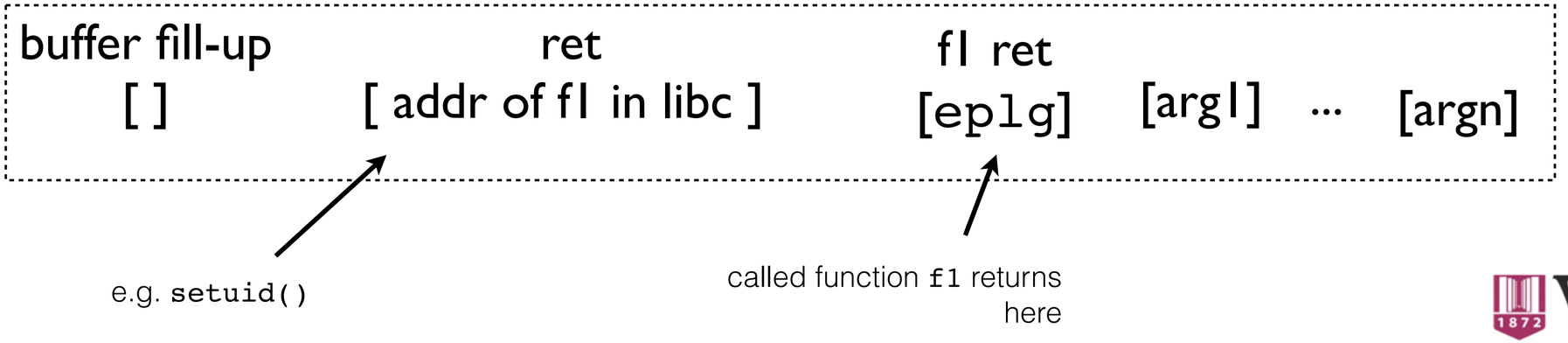

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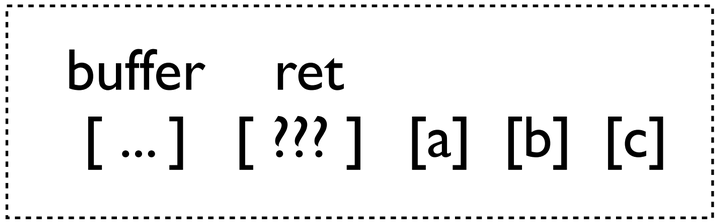
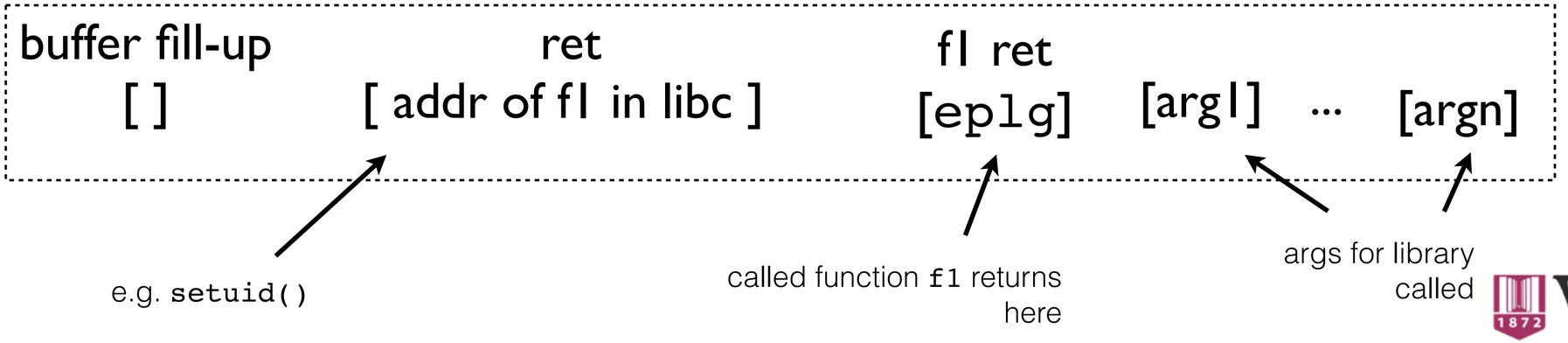


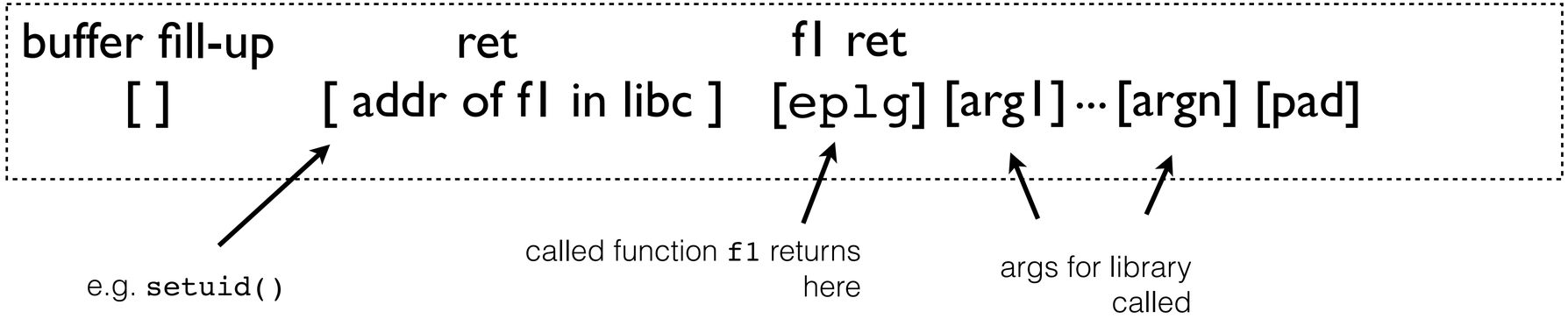
after overflowing buffer:



advanced return-into-libc: `esp` lifting (1)

(stack we build: part two)

after overflowing buffer:

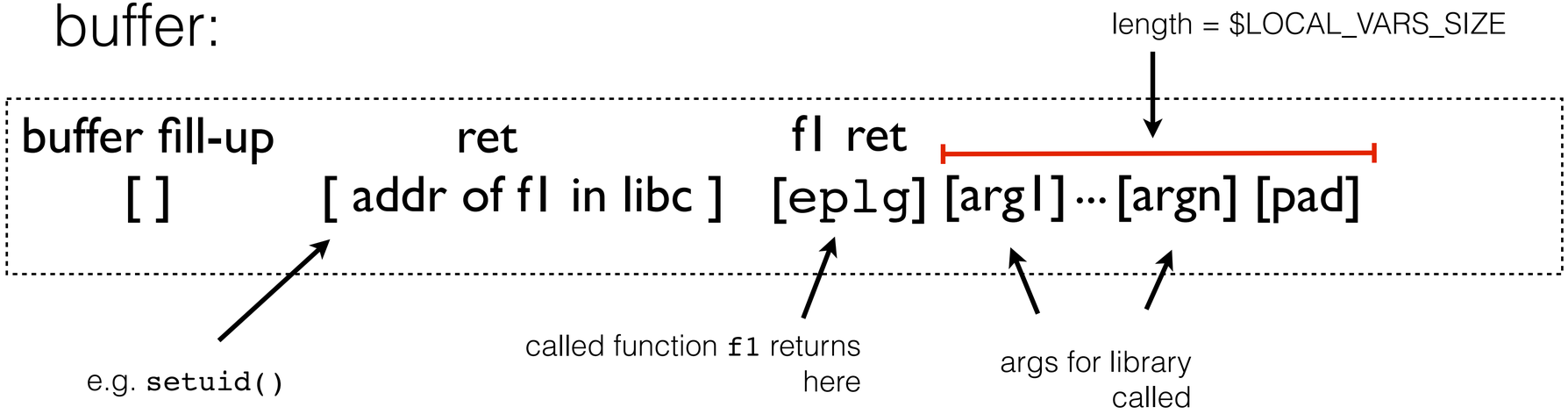



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part two)

after overflowing buffer:

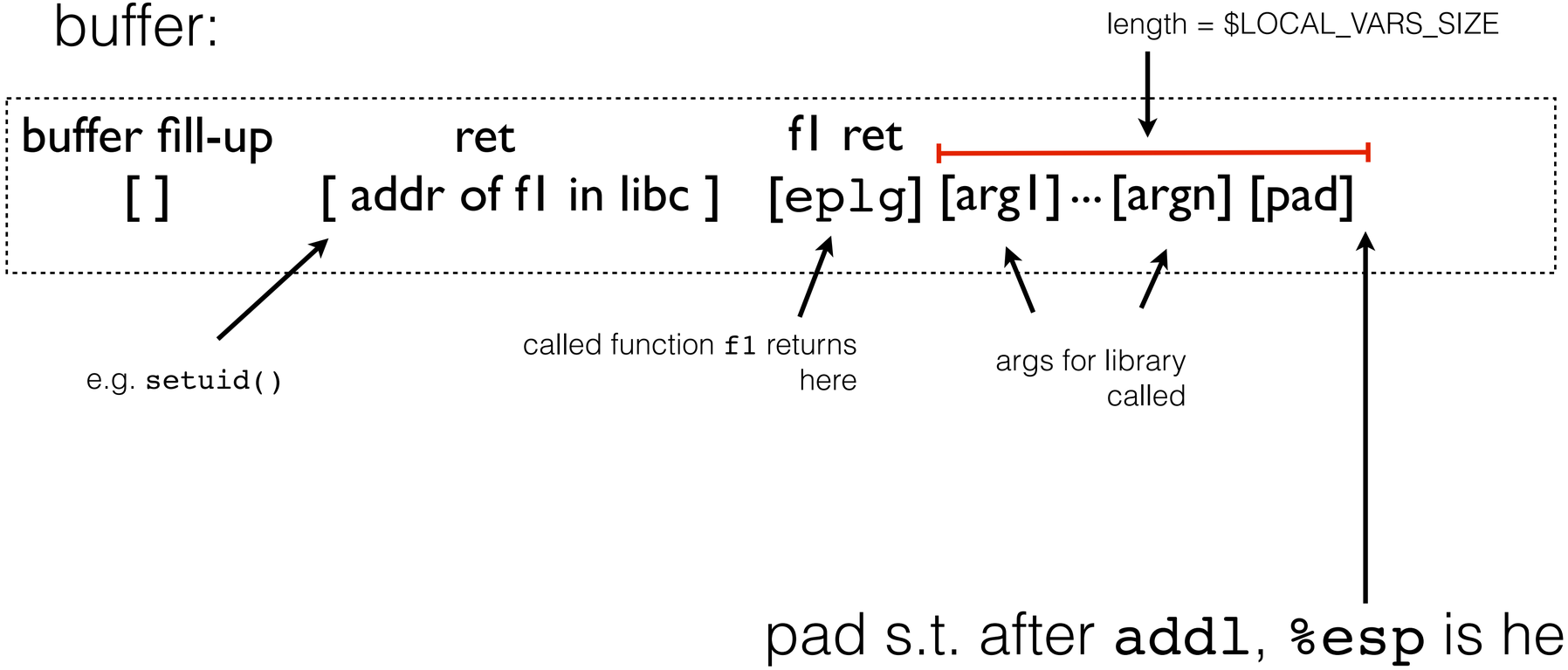



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part two)

after overflowing buffer:

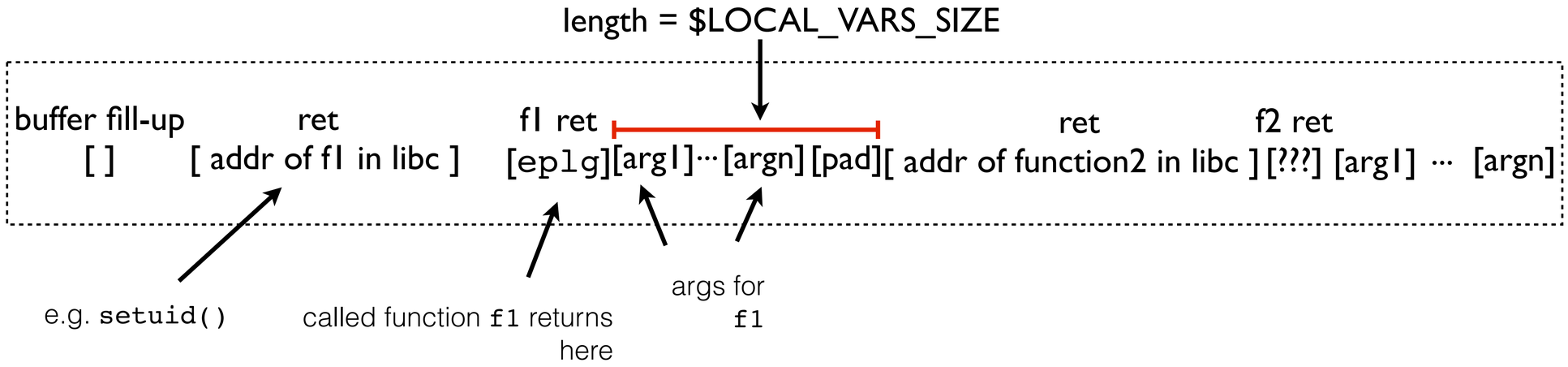



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part three)

after overflowing buffer:

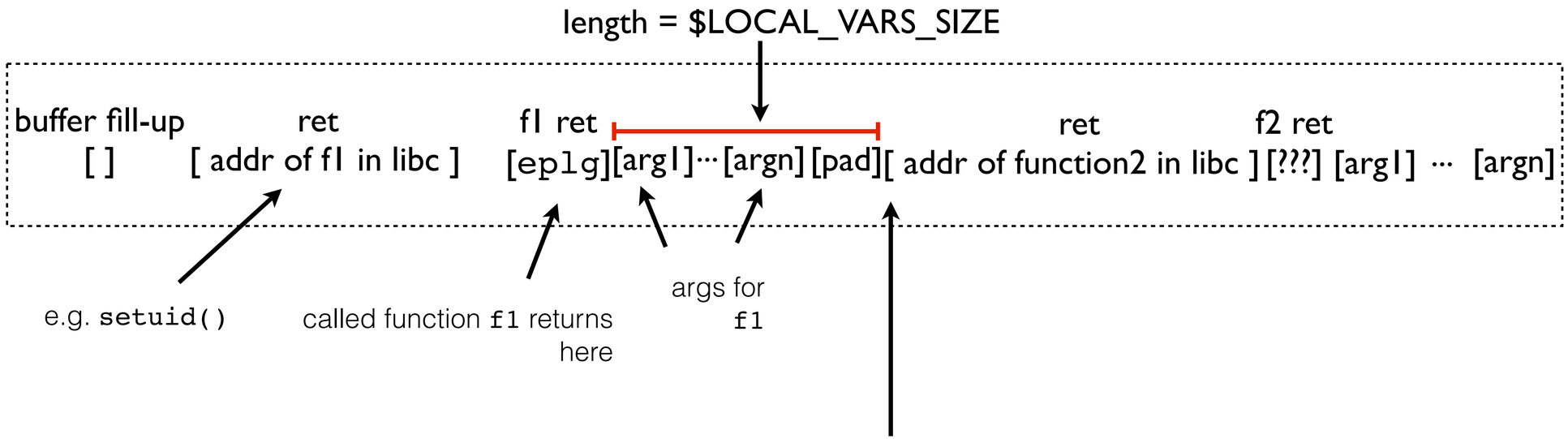



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part three)

after overflowing buffer:



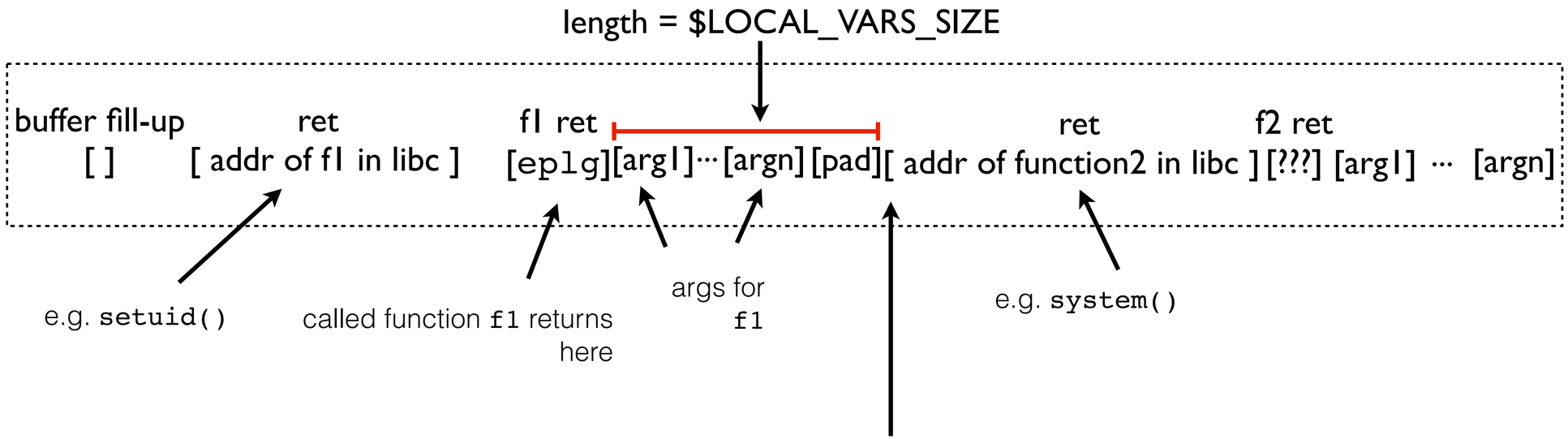
`ret` of `eplg` pops and uses this addr

```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part three)

after overflowing buffer:



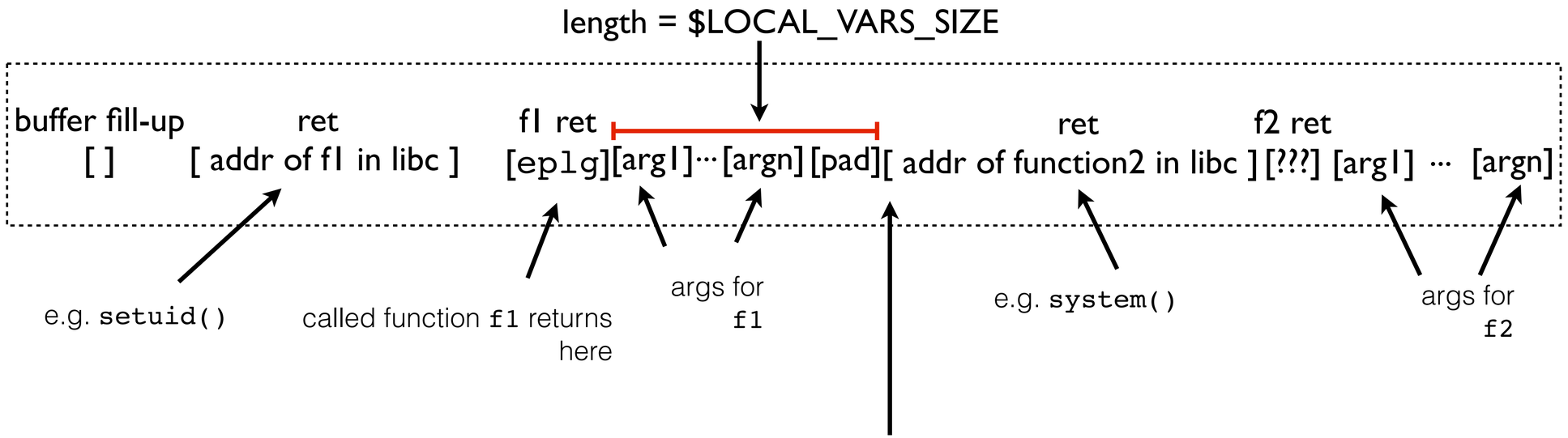
`ret` of `eplg` pops and uses this addr

```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(stack we build: part three)

after overflowing buffer:



`ret` of **`eplg`** pops and uses this addr

```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

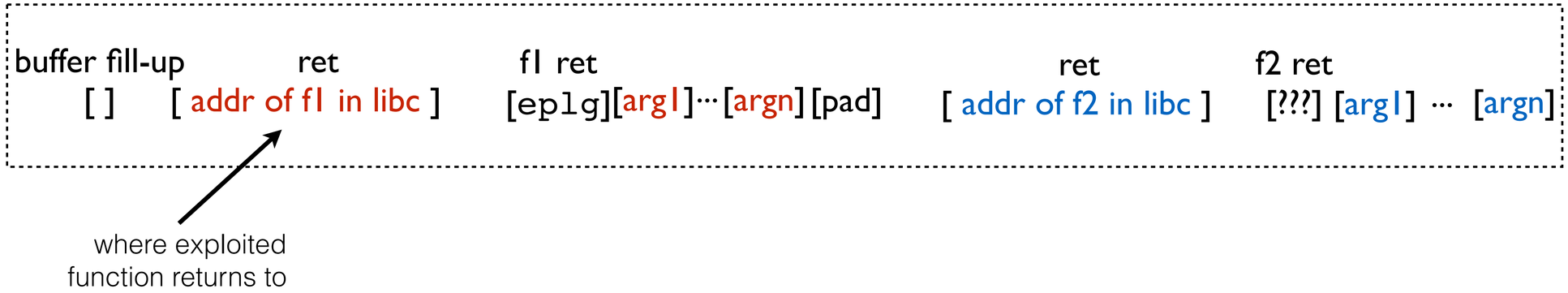
after overflowing buffer:


```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

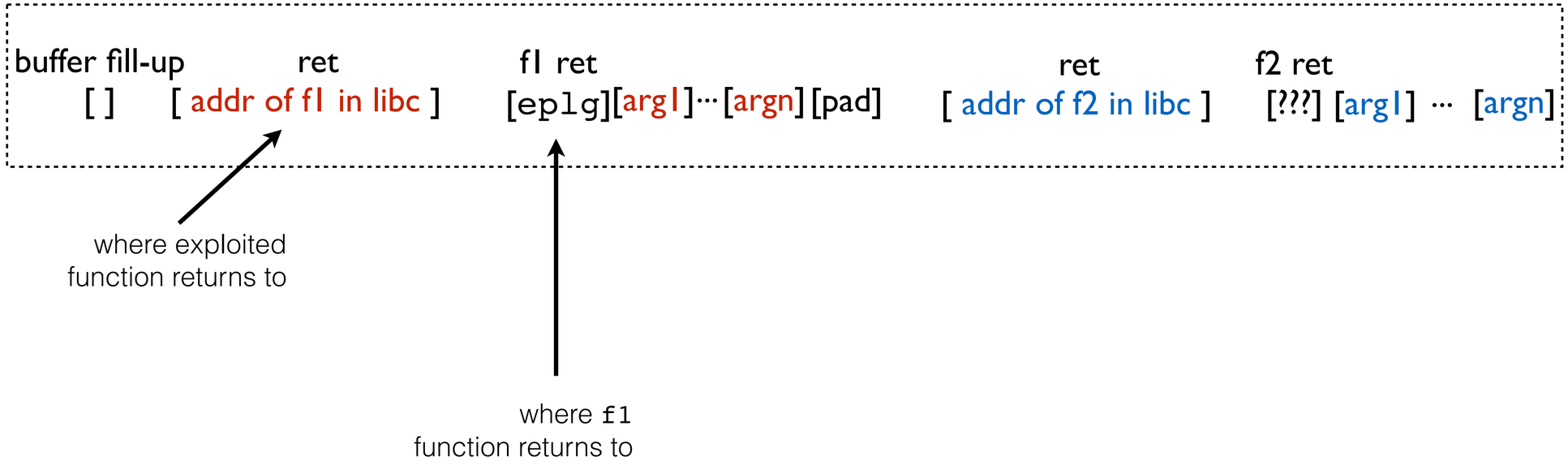



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

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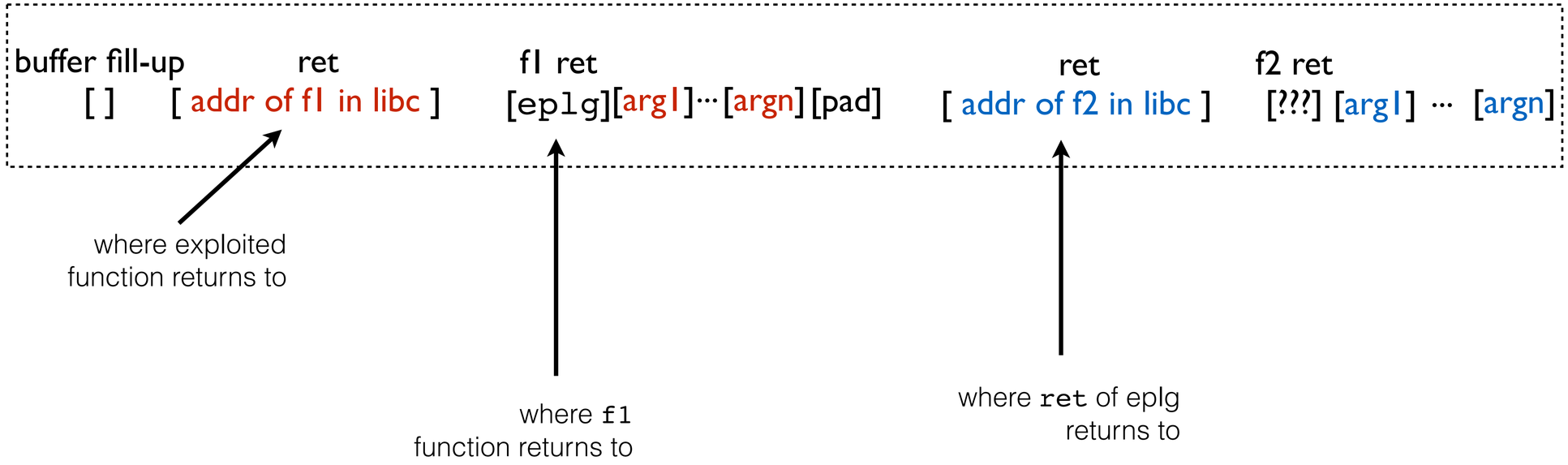
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

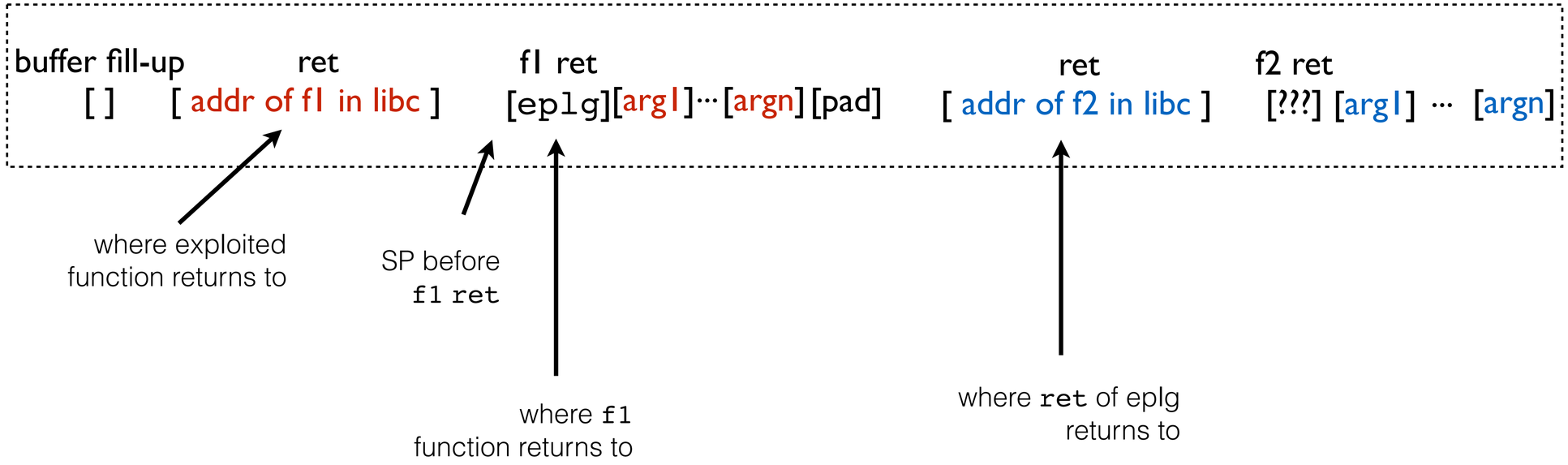



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

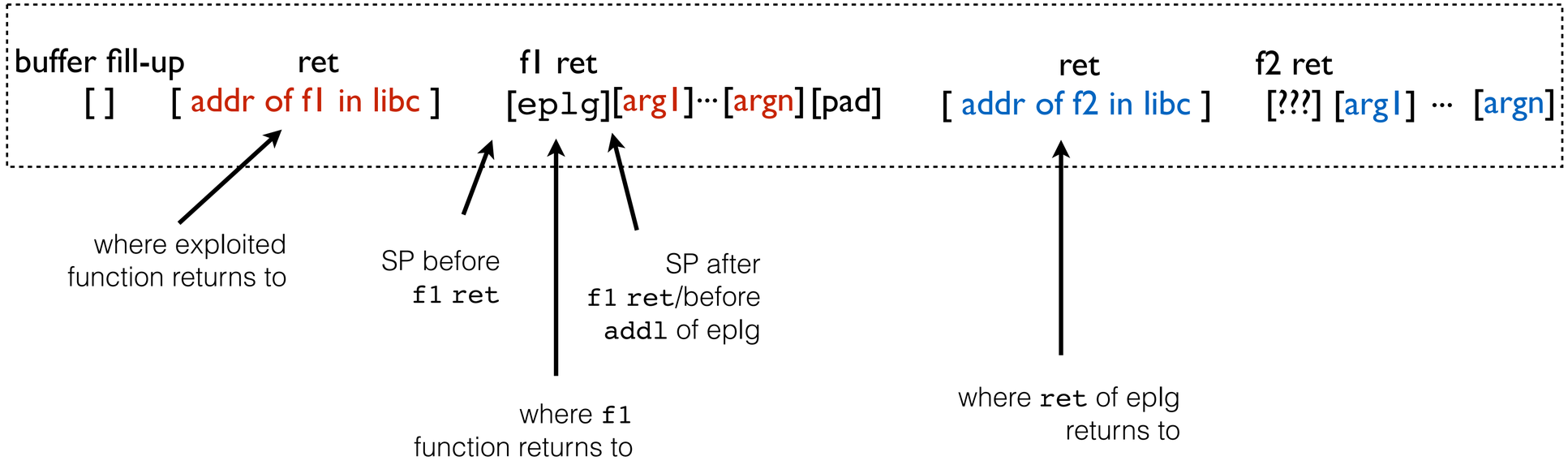



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

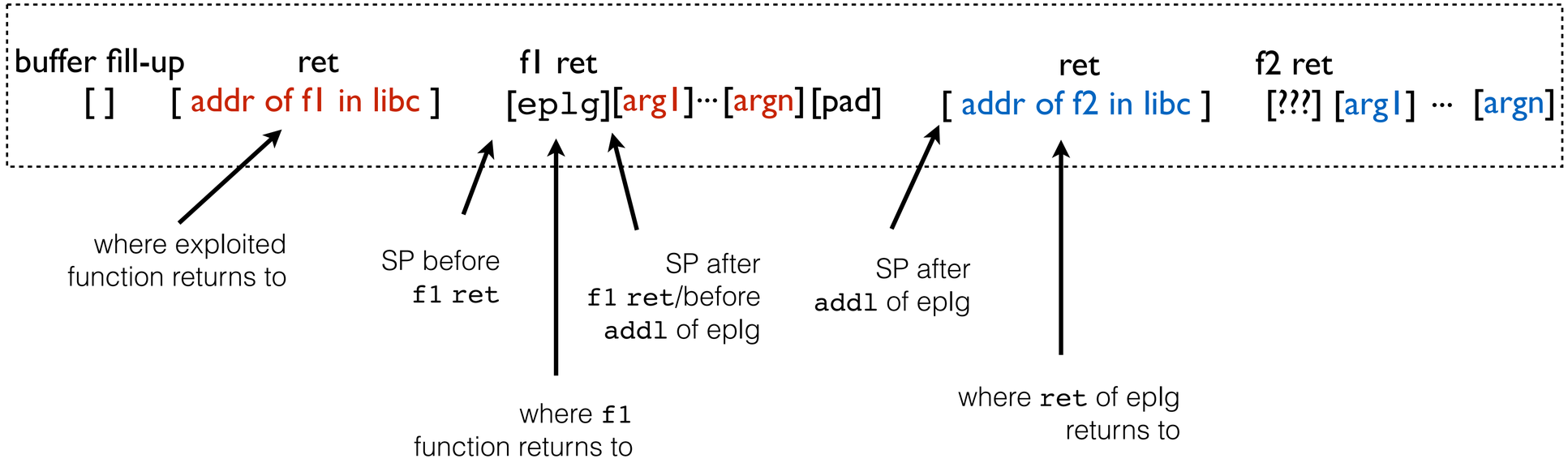



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:

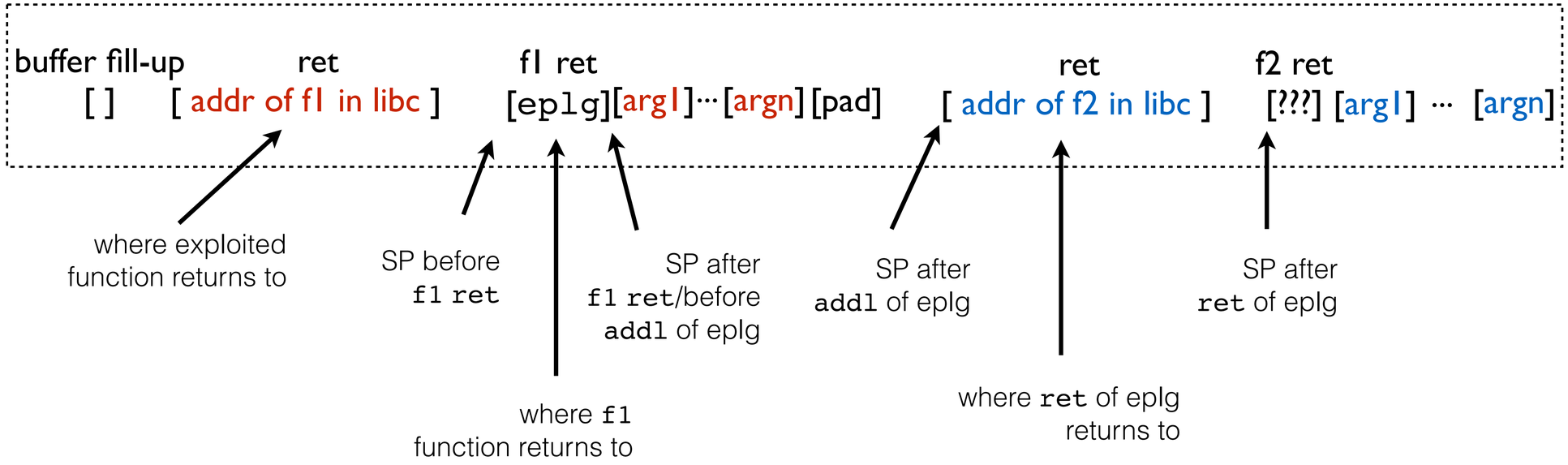



```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (1)

(execution)

after overflowing buffer:




```
eplg:
        addl    $LOCAL_VARS_SIZE,%esp
        ret
```

advanced return-into-libc: `esp` lifting (2)

(move stack pointer to functions via `pop`)

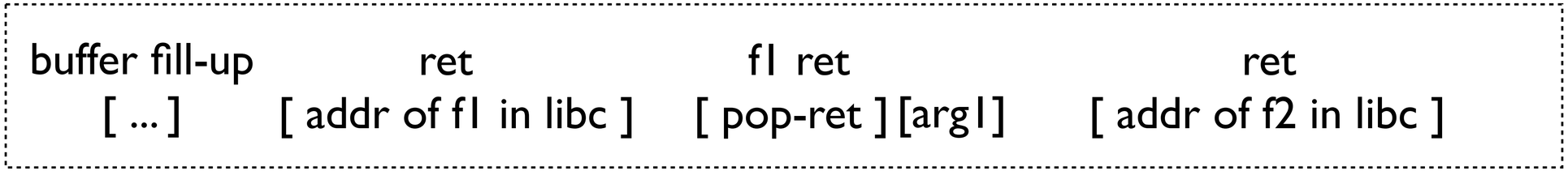
find addr. of following instructions in linked library(ies):

```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(move stack pointer to functions via `pop`)

after overflowing buffer:

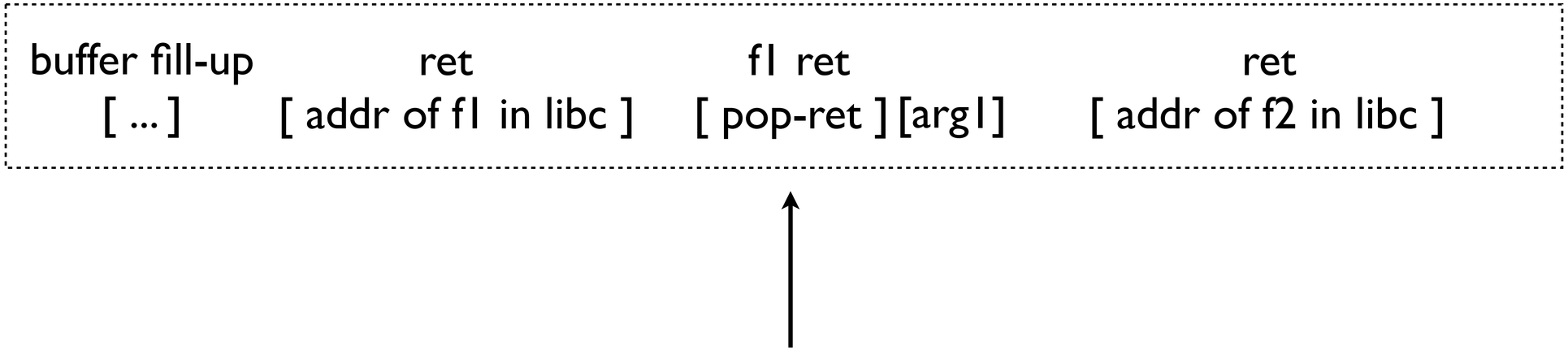



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(move stack pointer to functions via `pop`)

after overflowing buffer:



1. takes four bytes off of stack

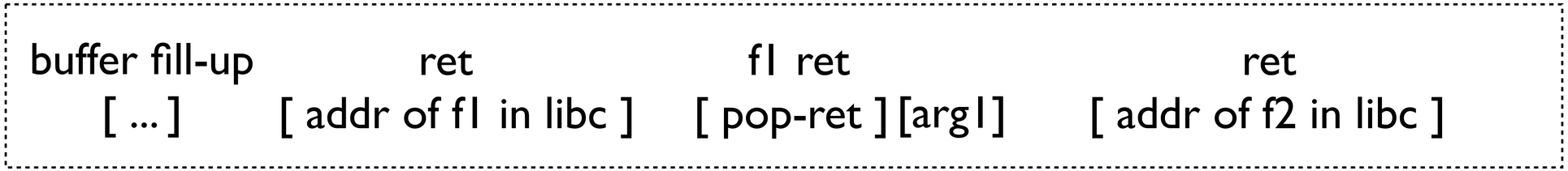
(SP moved four bytes back/up)

```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(move stack pointer to functions via `pop`)

after overflowing buffer:



1. takes four bytes off of stack

(SP moved four bytes back/up)

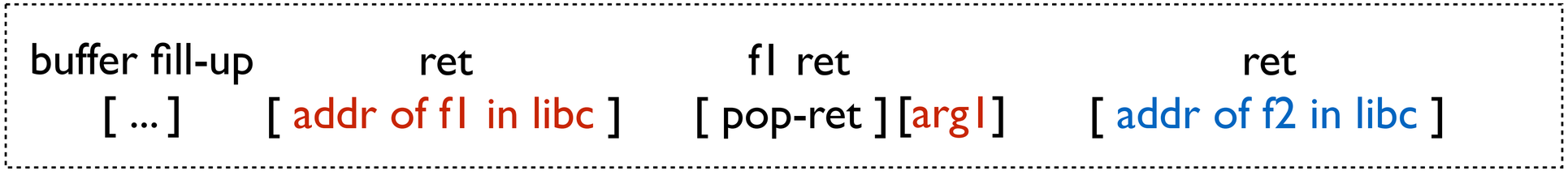
2. `ret` uses this addr after `popl`

```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

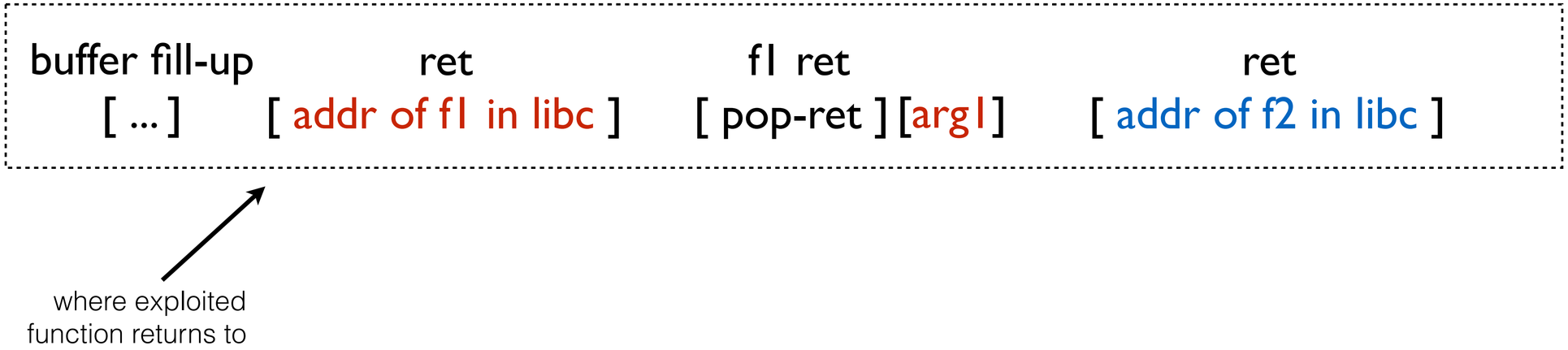



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

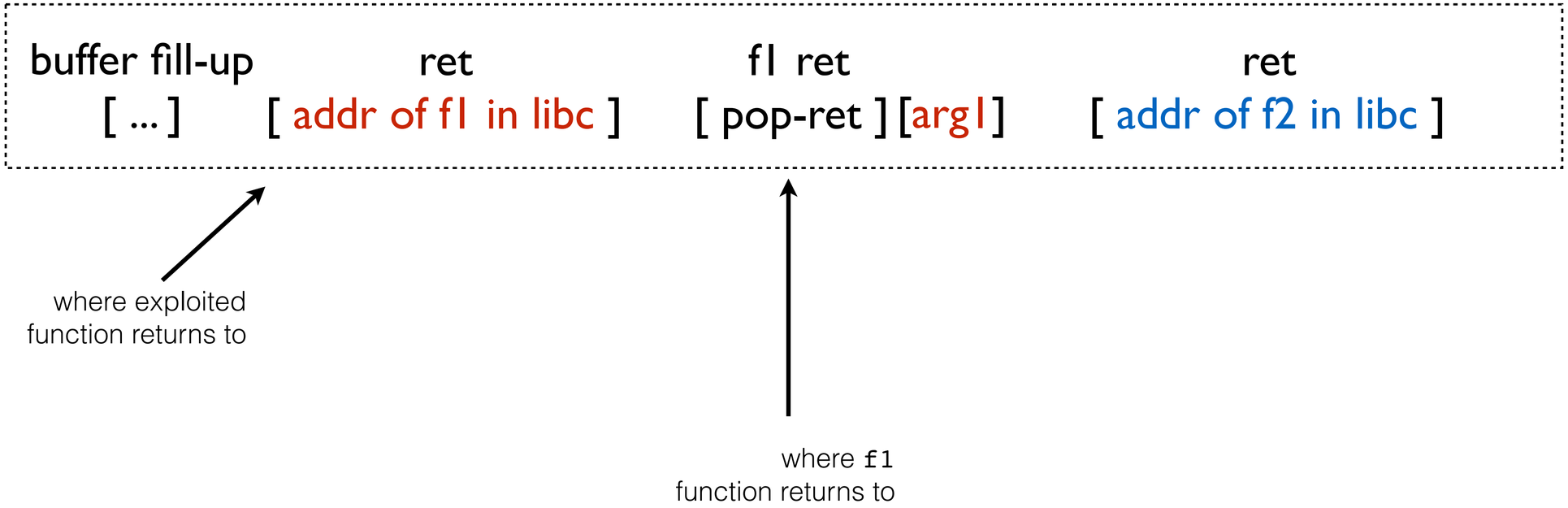



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

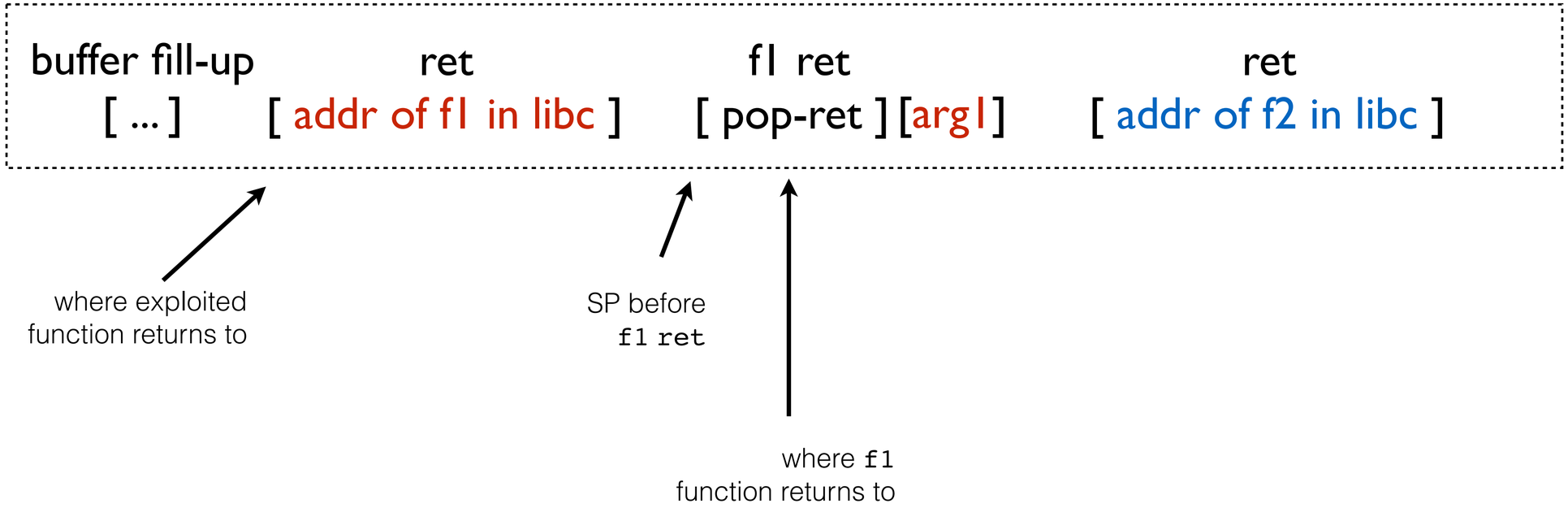



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

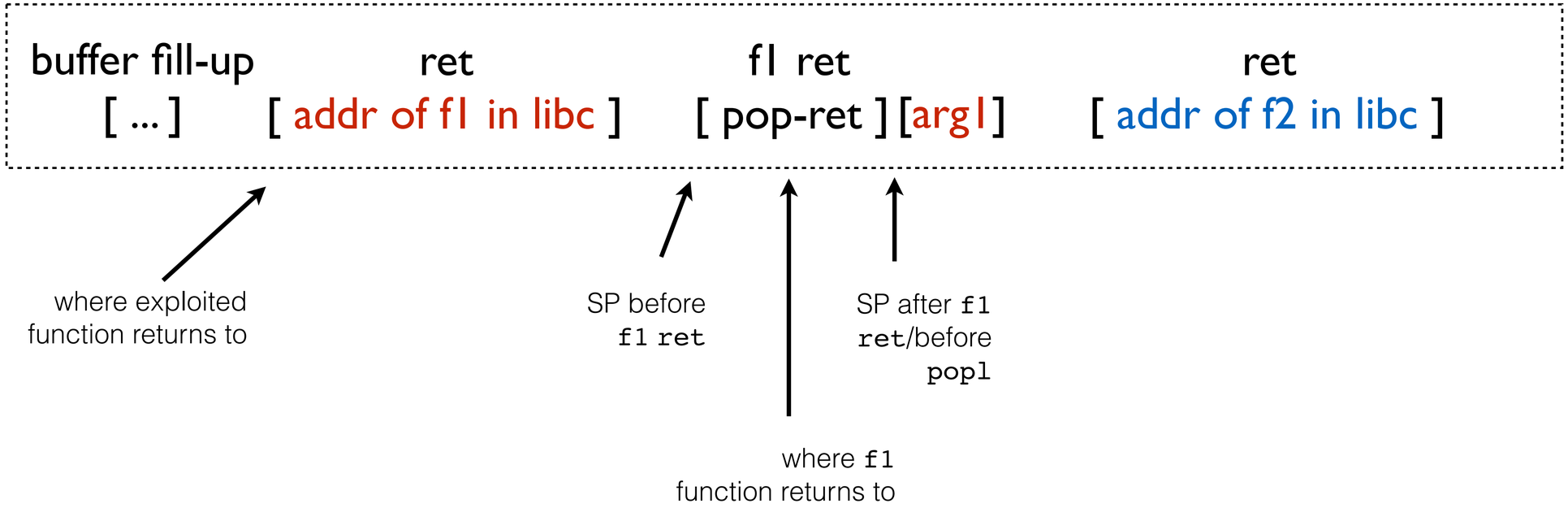



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

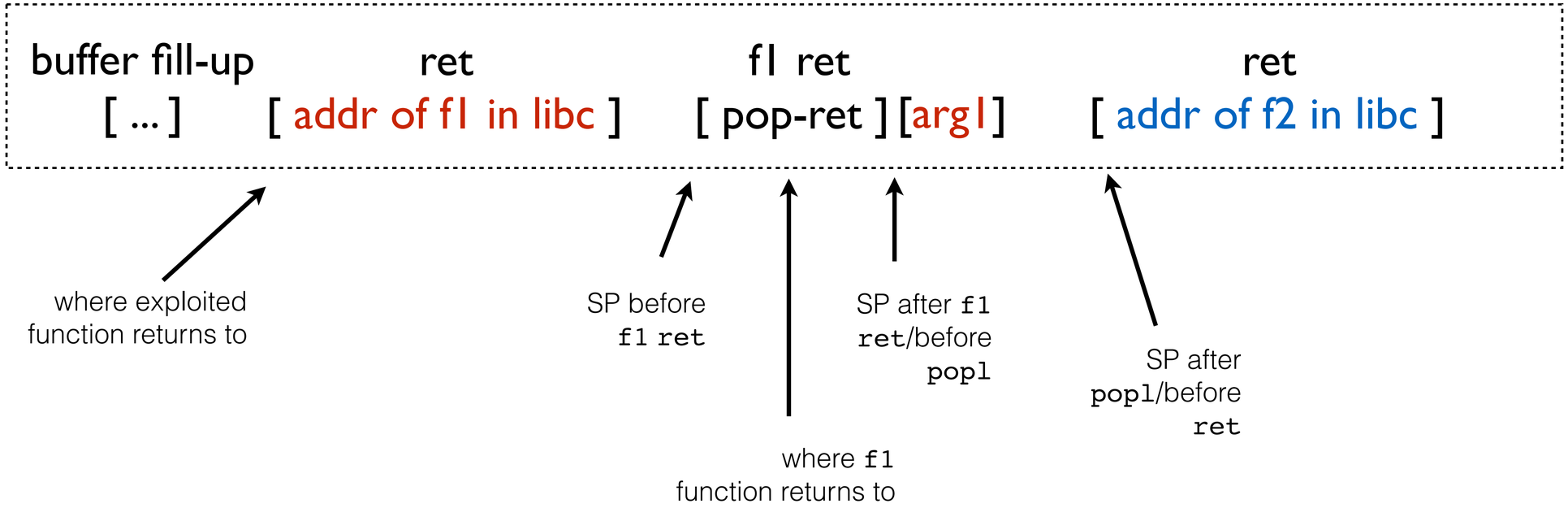



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:

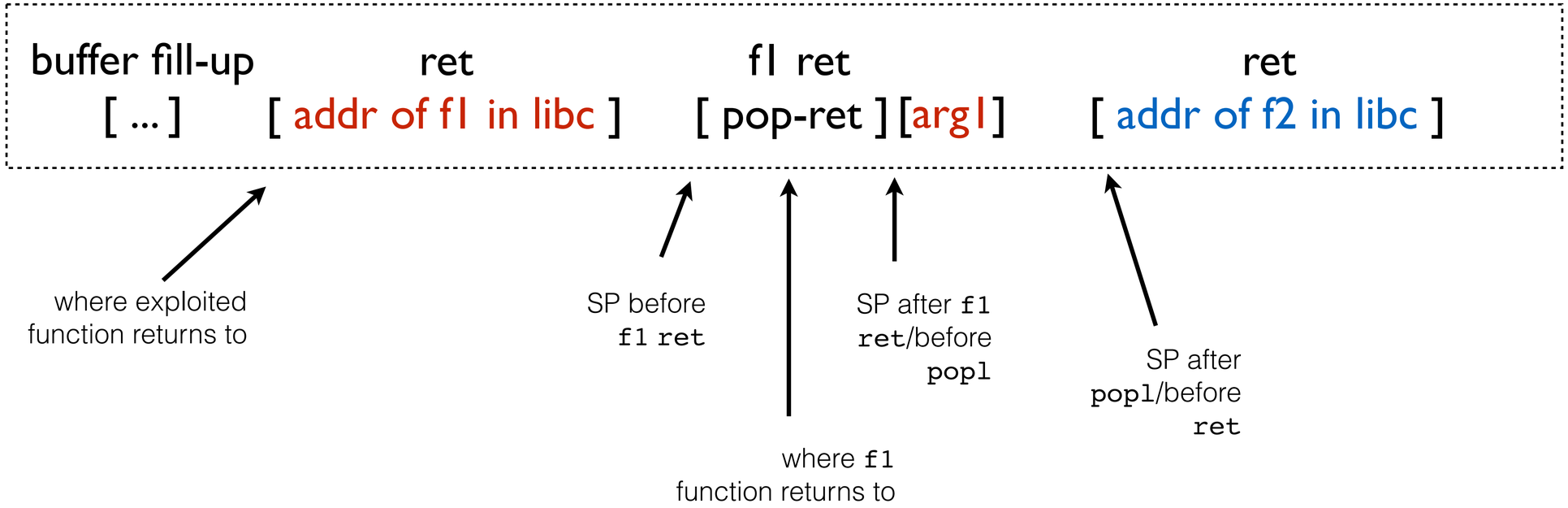



```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(execution)

after overflowing buffer:



limitation: argument can only be four bytes

```
pop-ret:
        popl any_register
        ret
```

advanced return-into-libc: `esp` lifting (2)

(arguments more than four bytes)

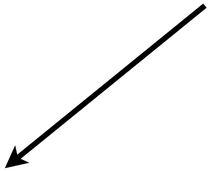
after overflowing buffer:

find sequence:

```
pop-ret:
        popl any_register
        popl any_register
        ret
```

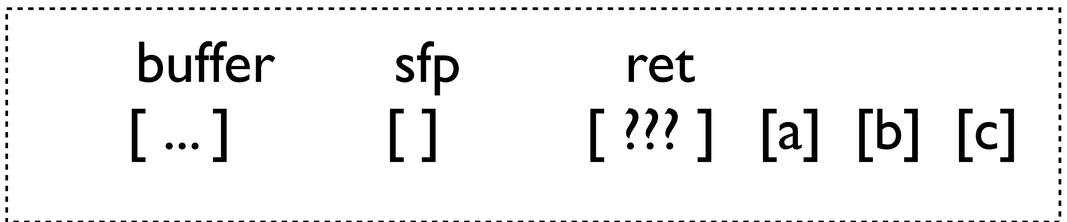
→ eight bytes for arguments

advanced return-into-libc: frame stacking

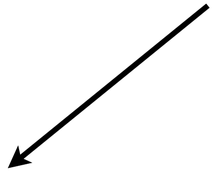


if program compiled *without*:

`-fomit-frame-pointer`



advanced return-into-libc: frame stacking

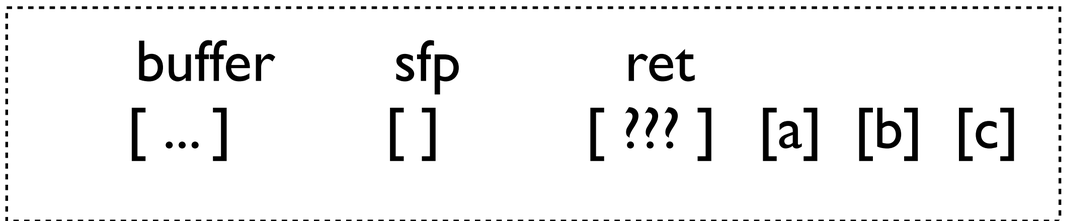


if program compiled *without*:

```
-fomit-frame-pointer
```

epilogue:

```
leaveret:
        leave
        ret
```



advanced return-into-libc: frame stacking

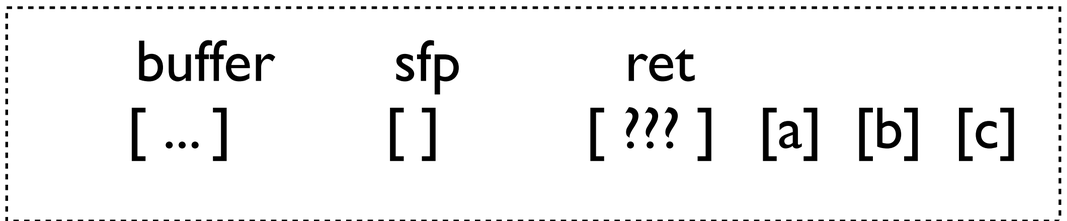
if program compiled *without*:

```
-fomit-frame-pointer
```

epilogue:

```
leaveret:
        leave
        ret
```

1. EBP -> ESP
2. then old frame pointer popped from stack onto EBP

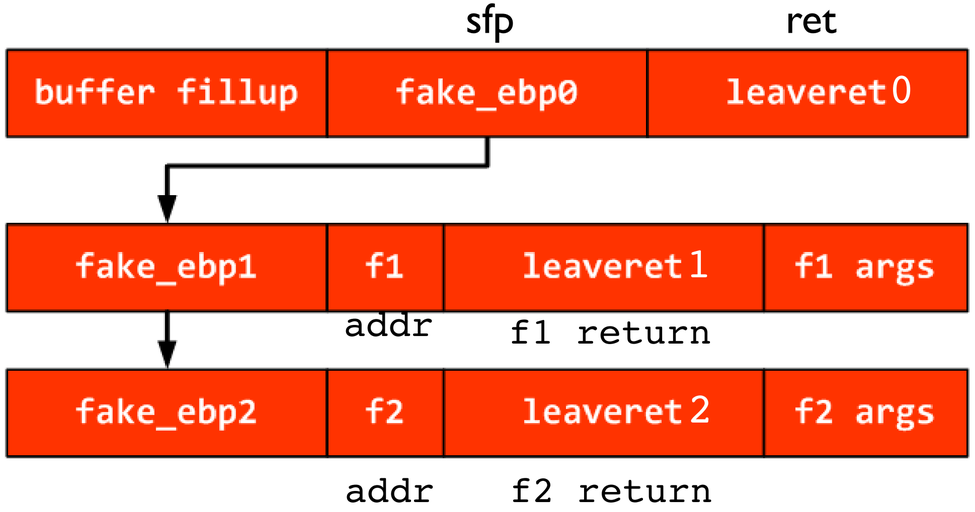


advanced return-into-libc: frame stacking

(stack after buffer overflow)

vulnerable function epilogue (function executes leaveret normally):

`fake_ebp0` into **`%ebp`** and returns into **`leaveret0`**



note:

1. exploited function executes **`leaveret`** eplg as normal (actual ebp->esp; fake_ebp0->ebp; esp at leaveret0)
2. then returns to **`leaveret`** eplg again (**`leaveret0`**) (fake_ebp0->esp; fake_ebp1->ebp; esp at f1 addr)

```
leaveret:
 1.%ebp->%esp,popl  %ebp
                    2.ret
```

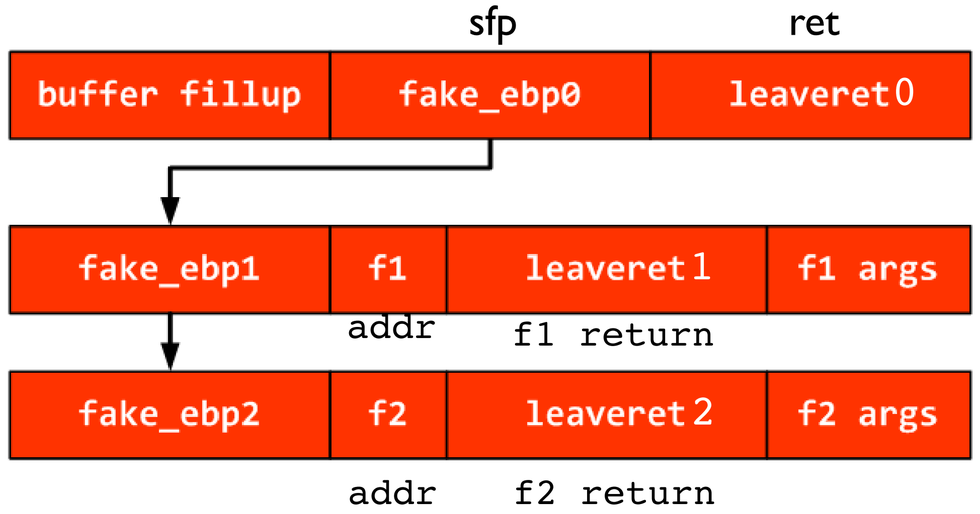
advanced return-into-libc: frame stacking

(stack after buffer overflow)

vulnerable function epilogue (function executes leaveret normally):

`fake_ebp0` into **`%ebp`** and returns into **`leaveret0`**

`leaveret0:`



note:

1. exploited function executes **`leaveret`** eplg as normal
   (actual ebp->esp; fake_ebp0->ebp; esp at leaveret0)
2. then returns to **`leaveret`** eplg again (**`leaveret0`**)
   (fake_ebp0->esp; fake_ebp1->ebp; esp at f1 addr)

```
leaveret:
 1.%ebp->%esp,popl  %ebp
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advanced return-into-libc: frame stacking

(stack after buffer overflow)

vulnerable function epilogue (function executes leaveret normally):
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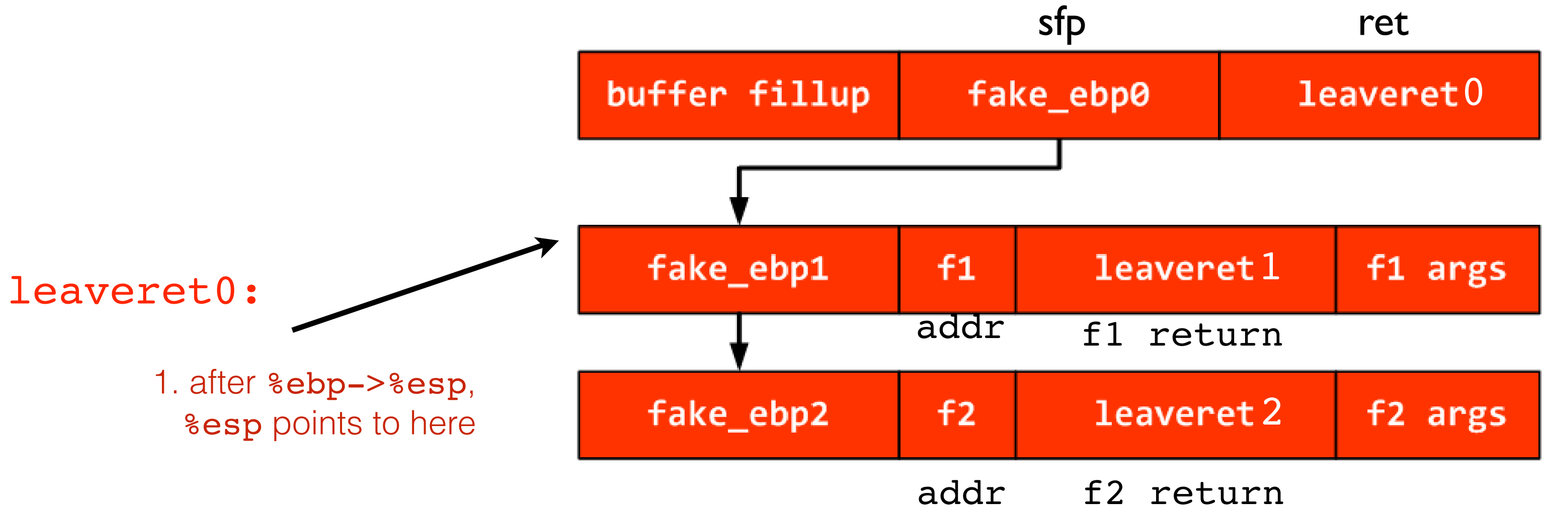

note:

1. exploited function executes `leaveret` eplg as normal
   (actual ebp->esp; fake_ebp0->ebp; esp at leaveret0)
2. then returns to `leaveret` eplg again (`leaveret0`)
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leaveret:
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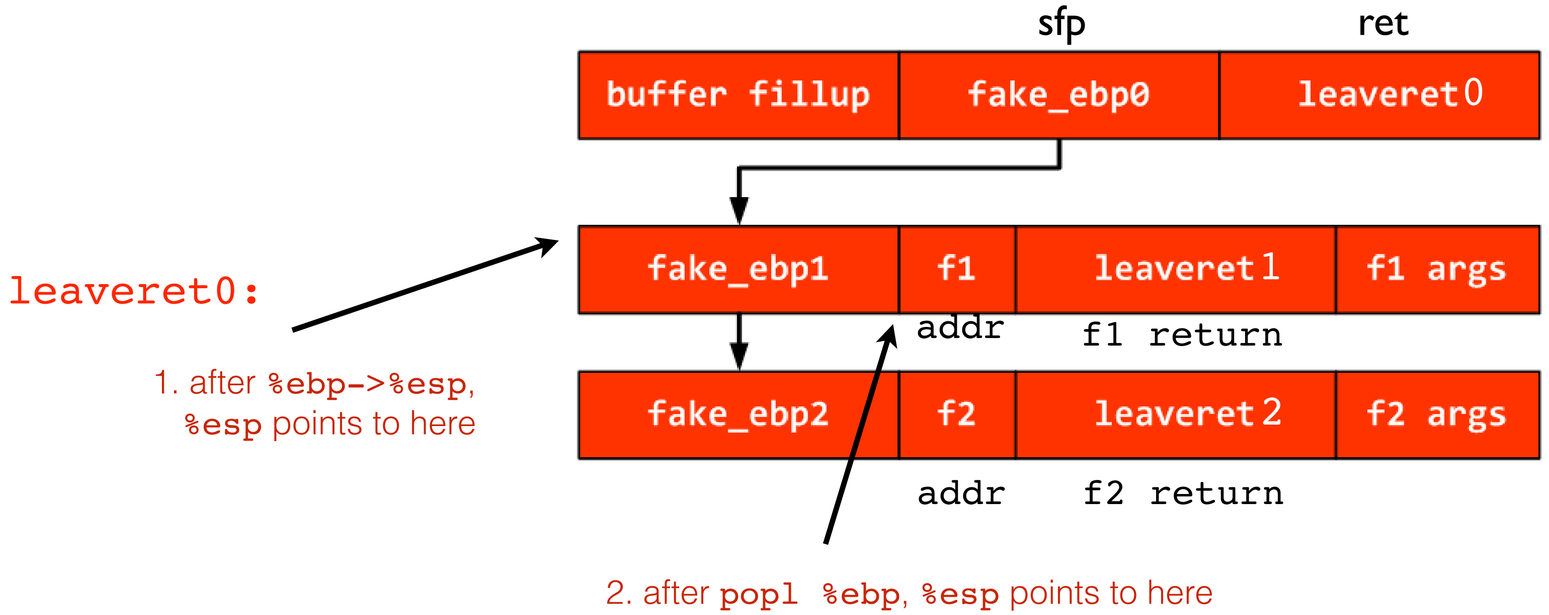
                2.ret
```

advanced return-into-libc: frame stacking

(stack after buffer overflow)

vulnerable function epilogue (function executes leaveret normally):
`fake_ebp0` into `%ebp` and returns into `leaveret0`



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1. exploited function executes **`leaveret`** eplg as normal (actual ebp->esp; fake_ebp0->ebp; esp at leaveret0)
2. then returns to **`leaveret`** eplg again (**`leaveret0`**) (fake_ebp0->esp; fake_ebp1->ebp; esp at f1 addr)

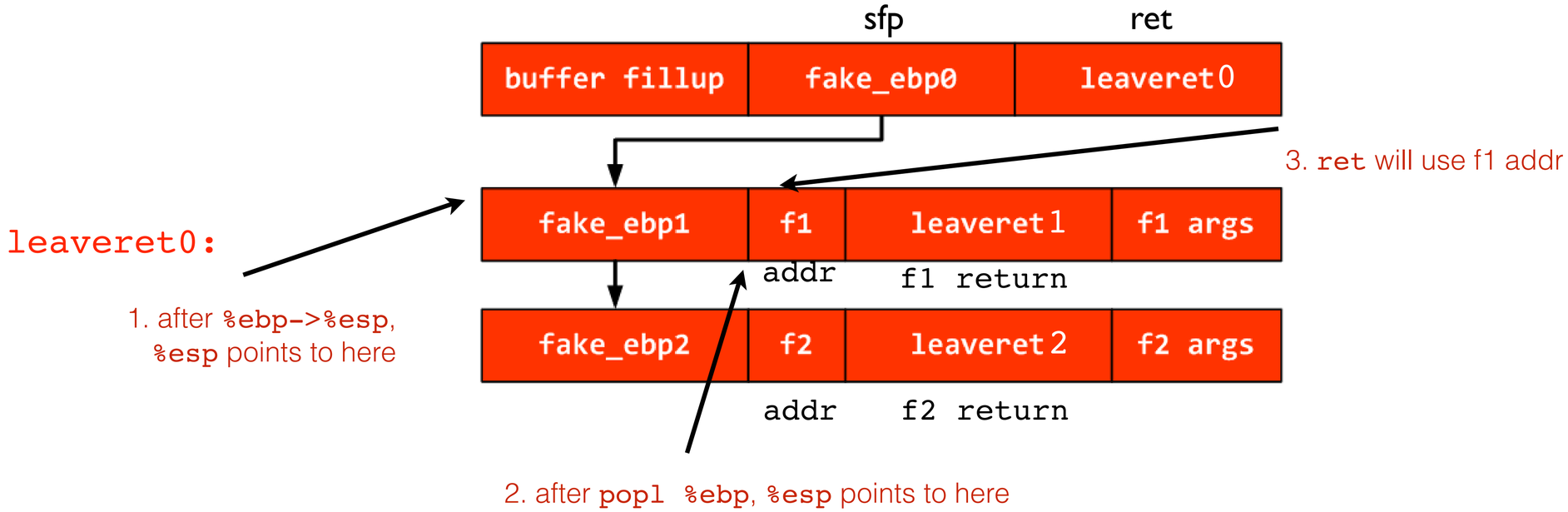
```
leaveret:
 1.%ebp->%esp,popl  %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(stack after buffer overflow)

vulnerable function epilogue (function executes leaveret normally):

`fake_ebp0` into `%ebp` and returns into `leaveret0`



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1. exploited function executes `leaveret` eplg as normal (actual ebp->esp; fake_ebp0->ebp; esp at leaveret0)
2. then returns to `leaveret` eplg again (`leaveret0`) (fake_ebp0->esp; fake_ebp1->ebp; esp at f1 addr)

```
leaveret:
 1.%ebp->%esp,popl %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

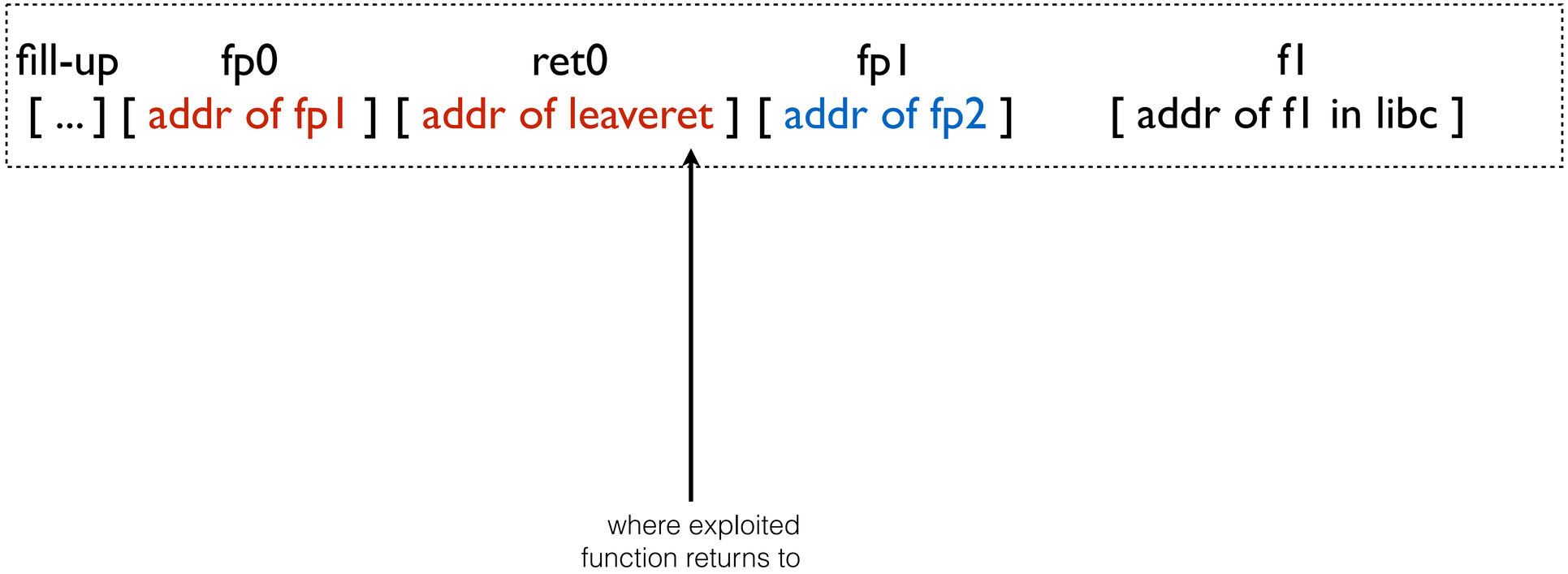
after overflowing buffer:


```
leaveret:
 1.%ebp->%esp,popl %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

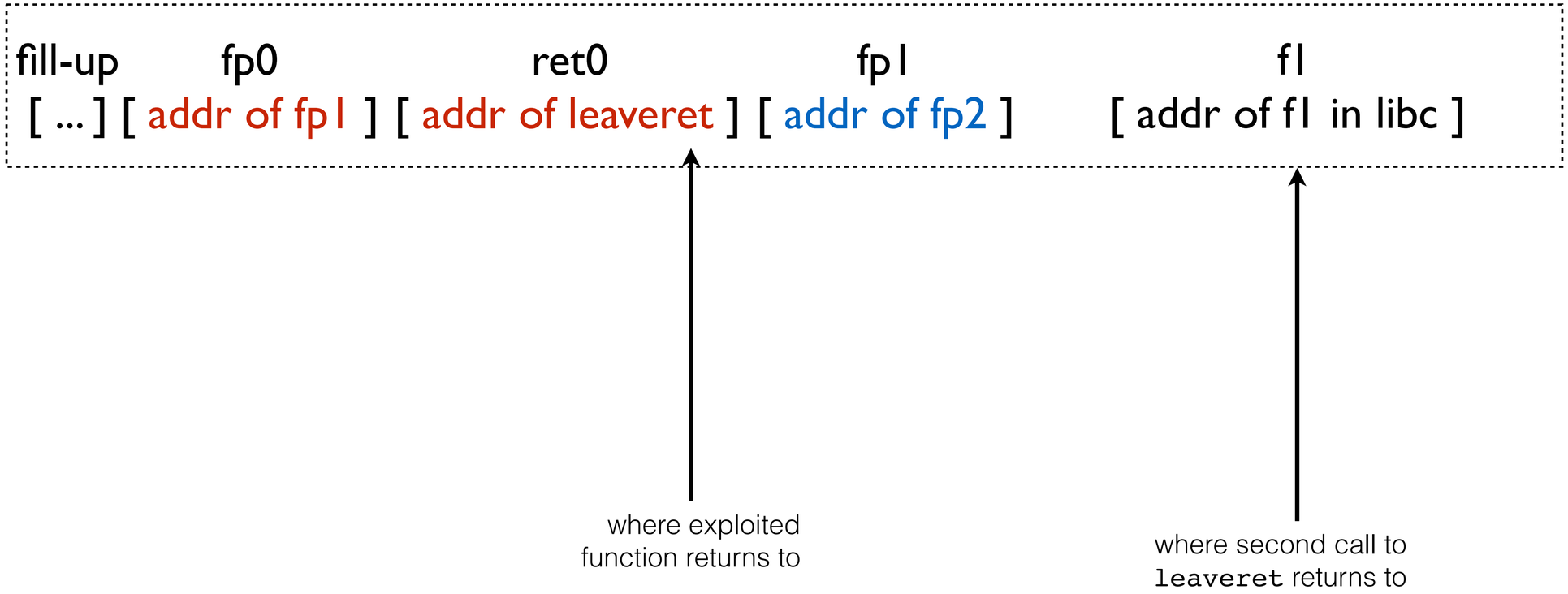



```
leaveret:
 1.%ebp->%esp,popl %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

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 1.%ebp->%esp,popl %ebp
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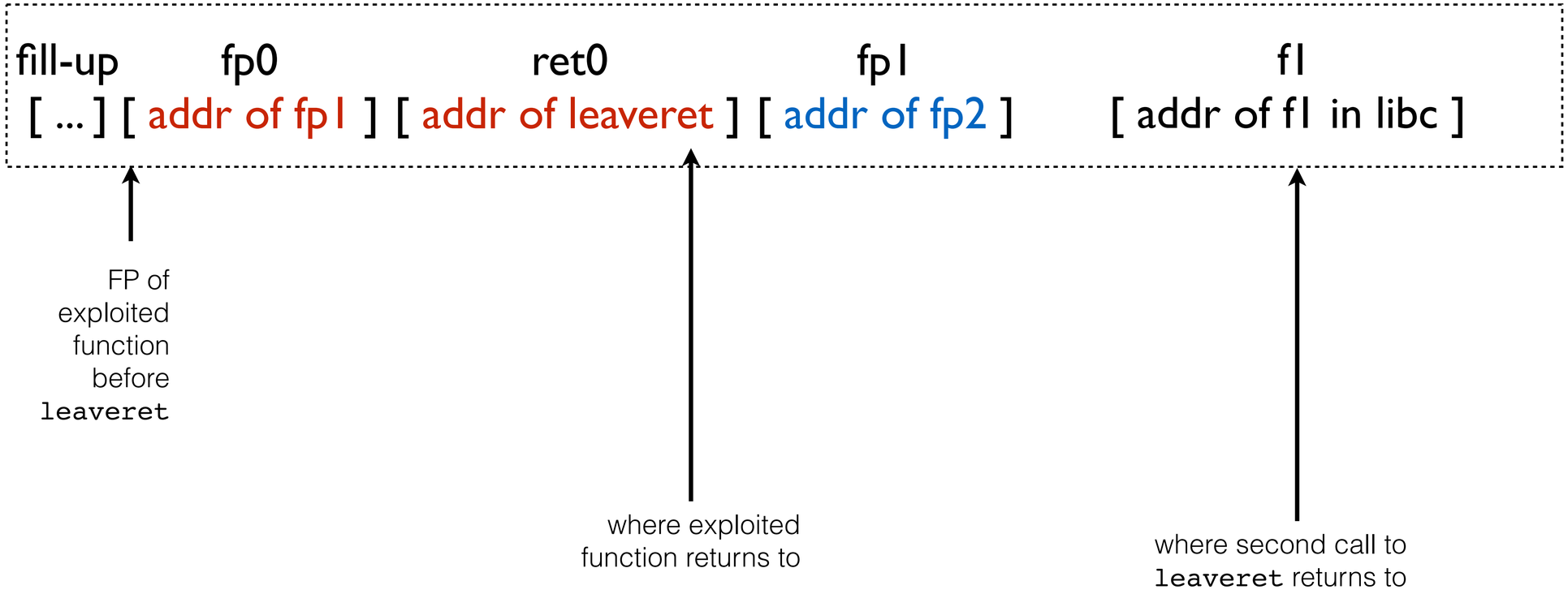
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

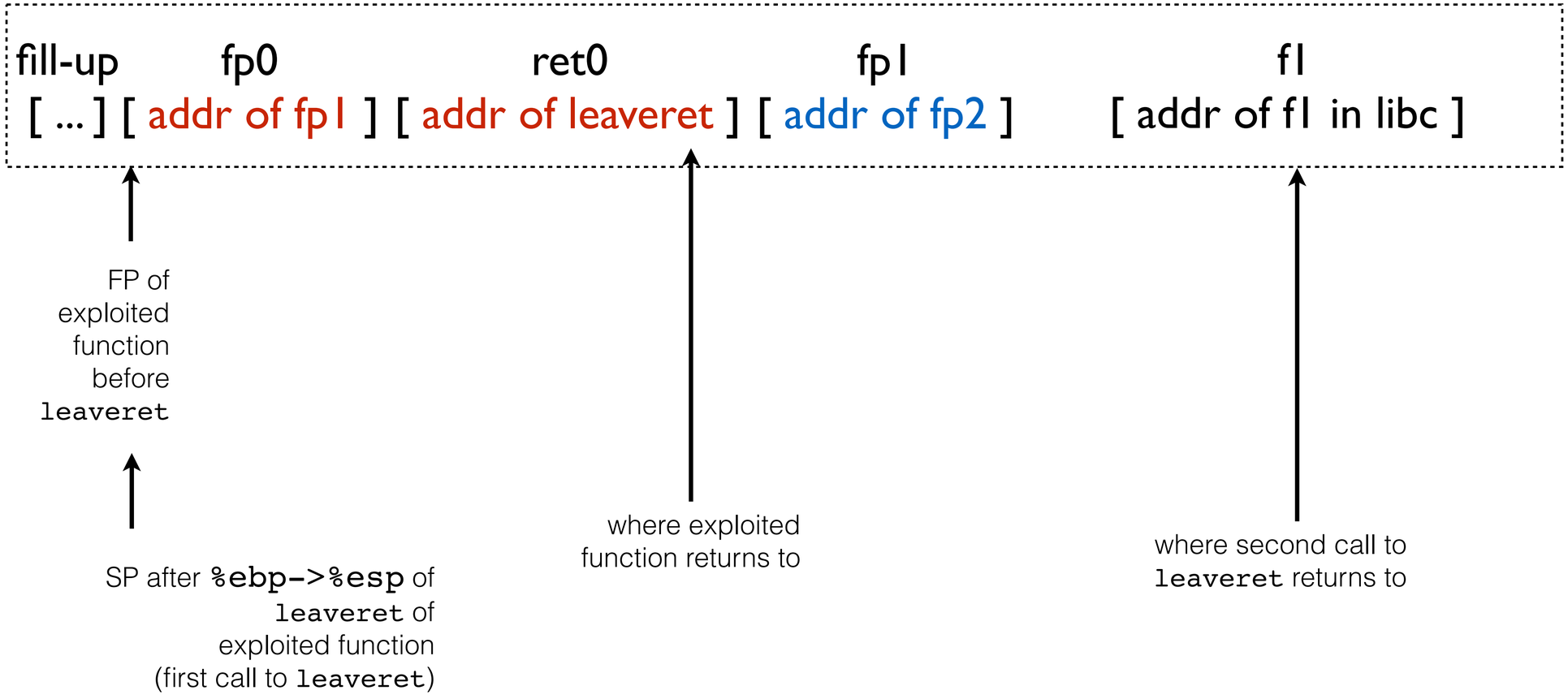



```
leaveret:
 1.%ebp->%esp,popl %ebp
                  2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

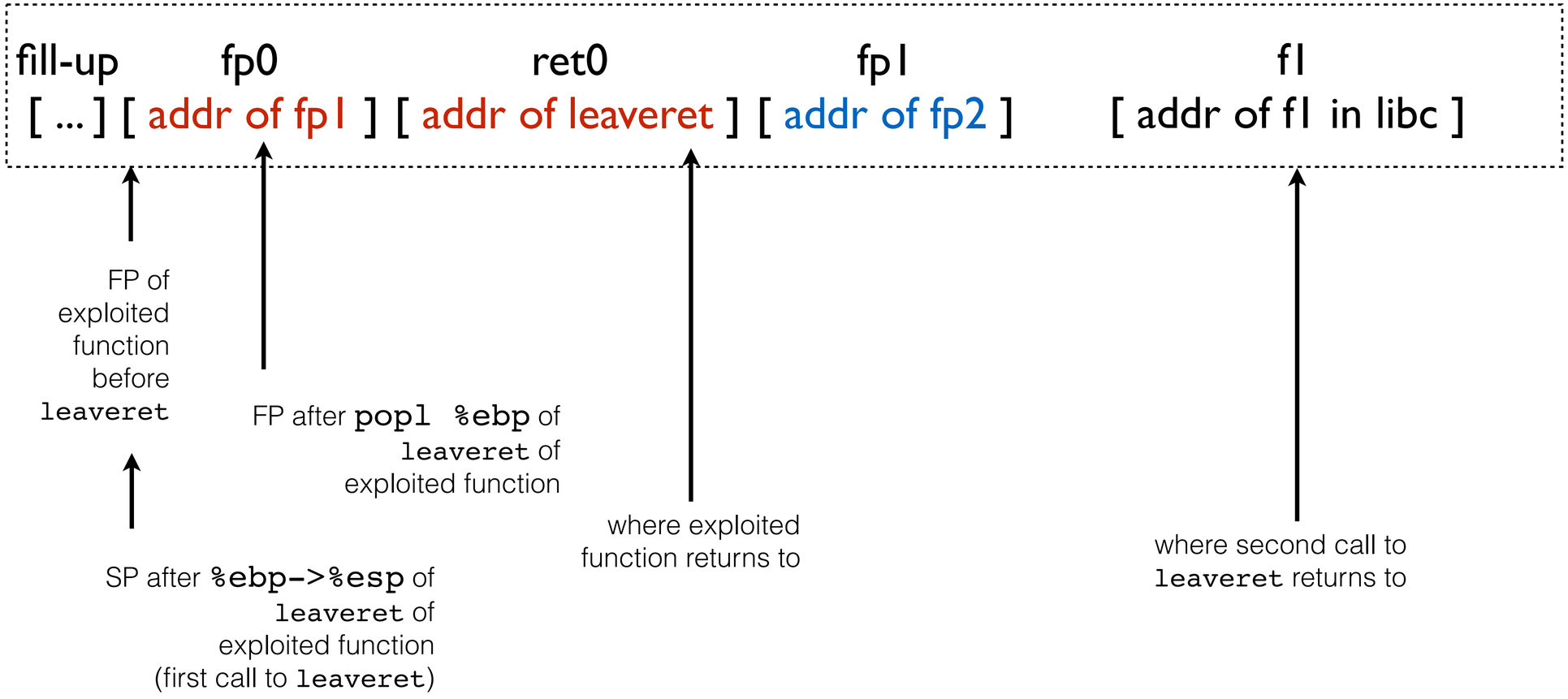



```
leaveret:
 1.%ebp->%esp,popl %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

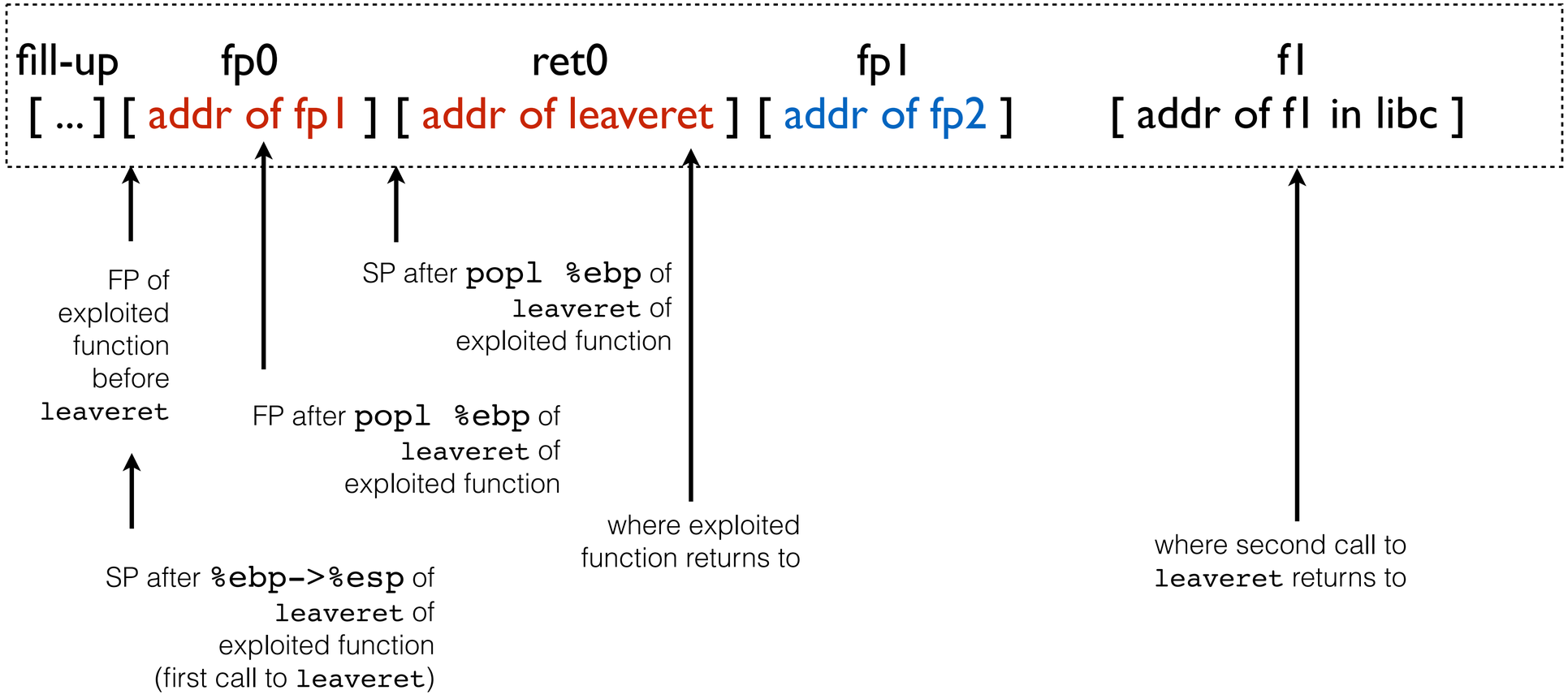



```
leaveret:
 1.%ebp->%esp,popl %ebp
                2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

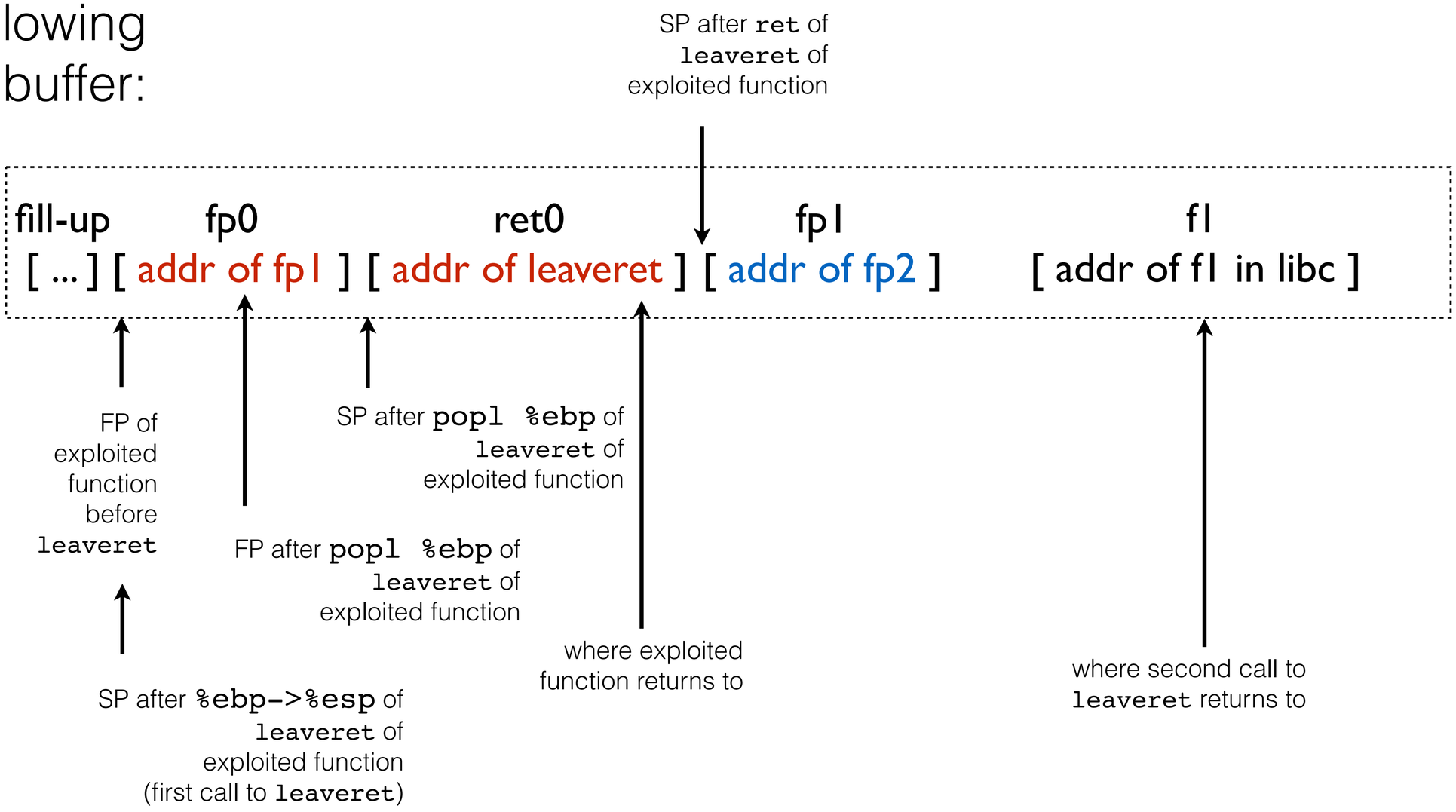



```
leaveret:
 1.%ebp->%esp,popl %ebp
               2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

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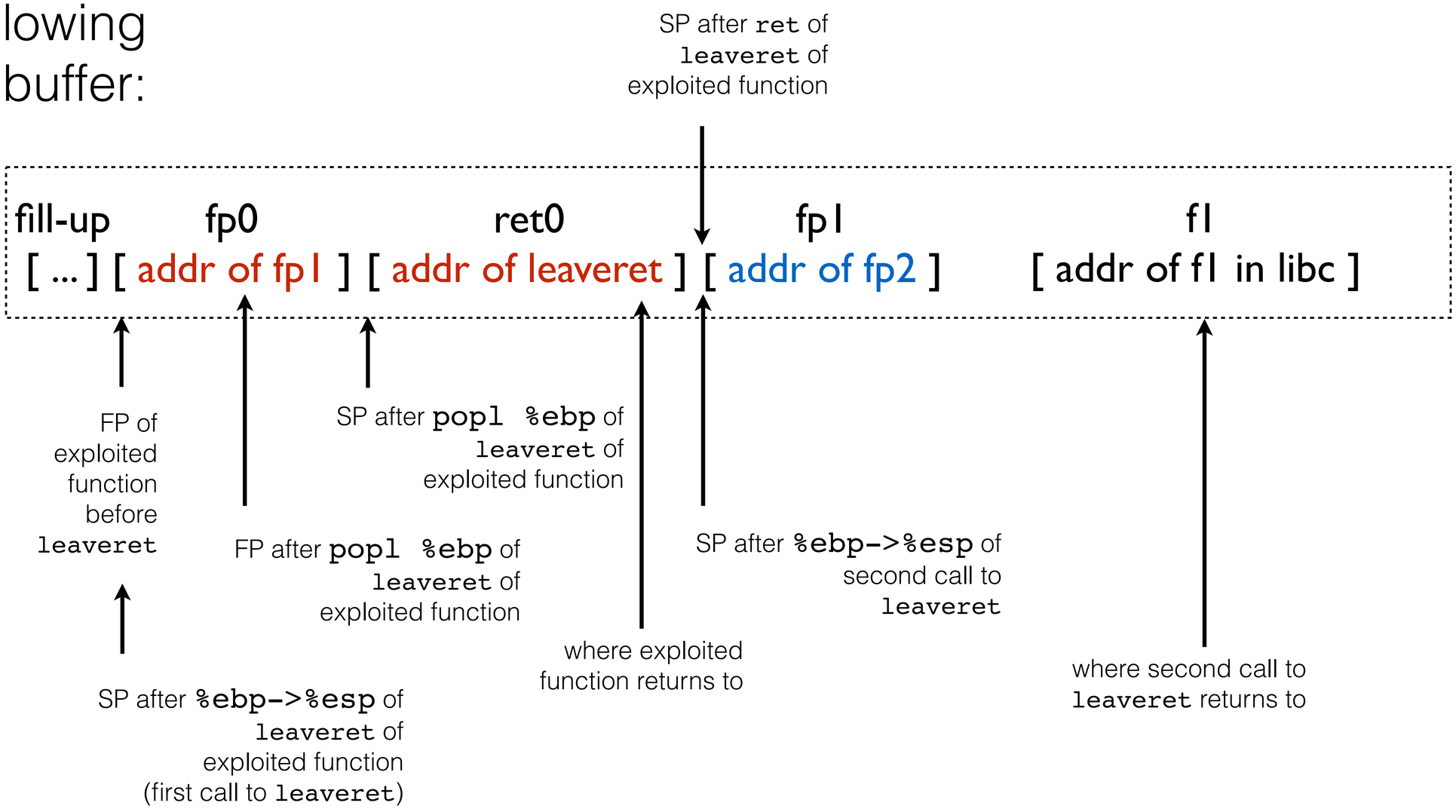
leaveret:
 1.%ebp->%esp,popl %ebp
               2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:

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leaveret:
 1.%ebp->%esp,popl %ebp
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advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

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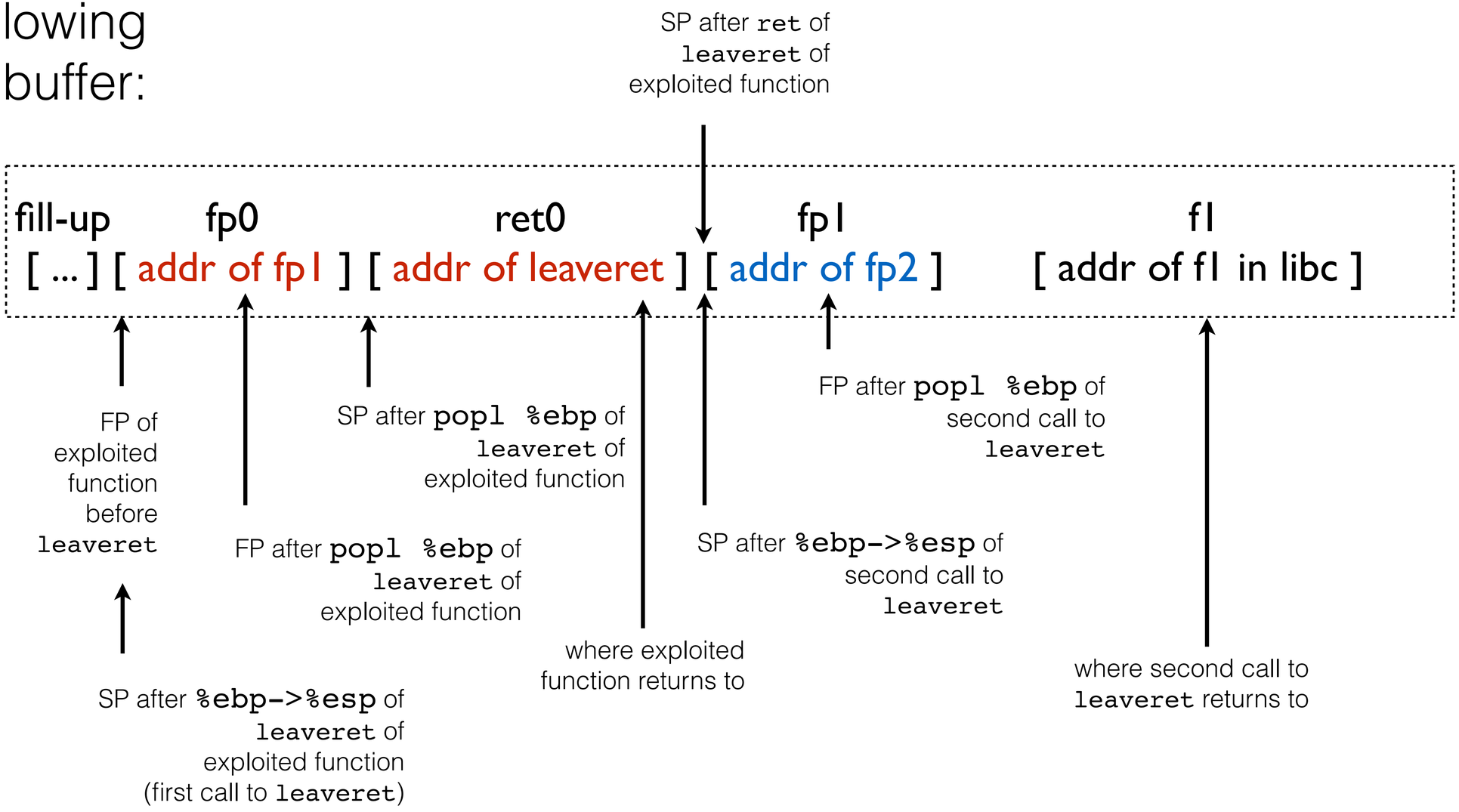
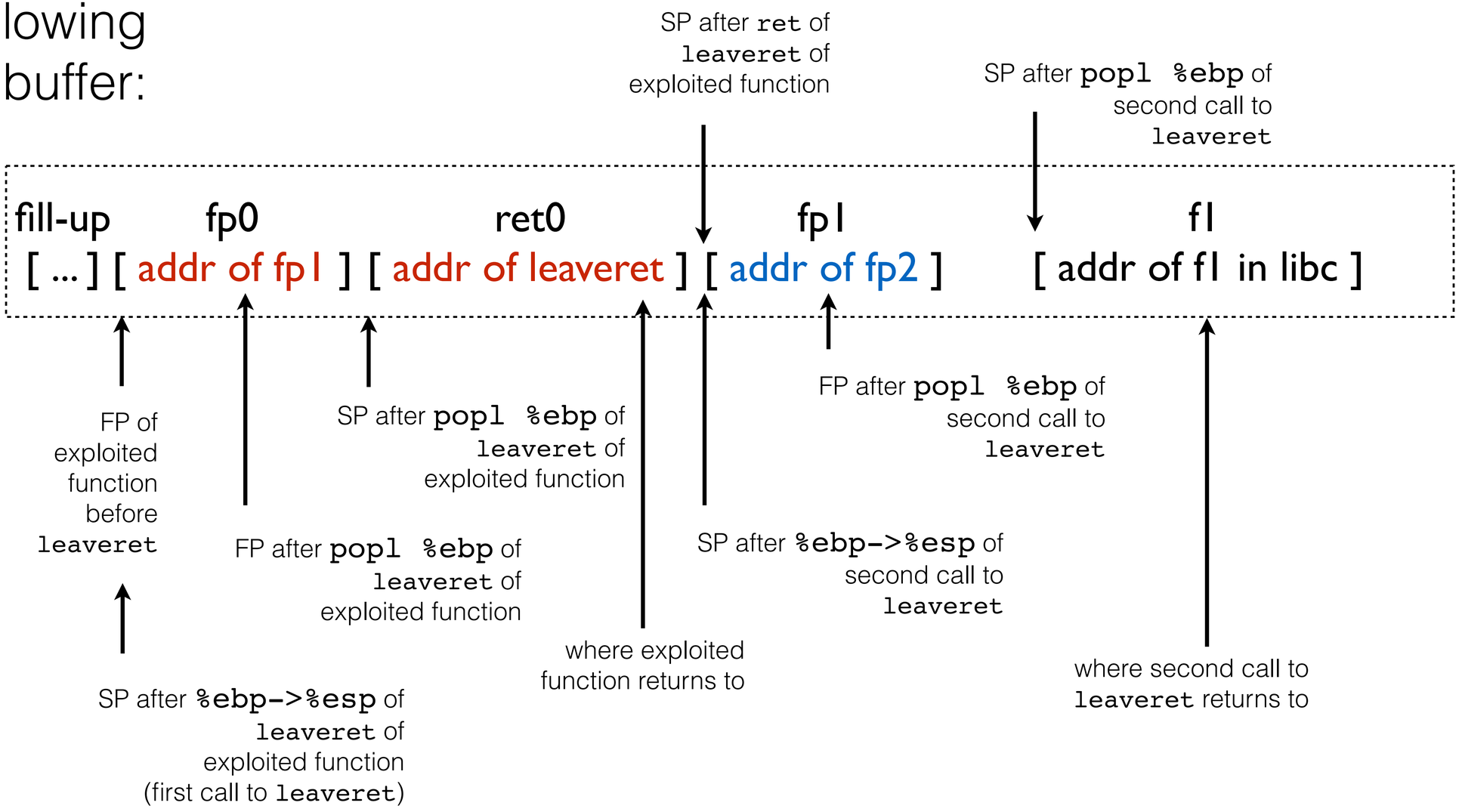



```
leaveret:
 1.%ebp->%esp,popl %ebp
               2.ret
```

advanced return-into-libc: frame stacking

(execution; remember: exploited function uses `leaveret` as usual)

after overflowing buffer:




```
leaveret:
 1.%ebp->%esp,popl %ebp
               2.ret
```