(Non-Tail) Function Calls

October 4, 2023

Previously on EECS 483…

- Calling into Rust: System V AMD64 calling convention
- Tail Calls: compile directly to jumps

```
def f(y):
  let z = 2 in
  y * z
end
let a = 7 in
let b = 13 in
let x = f(a) in
x + b
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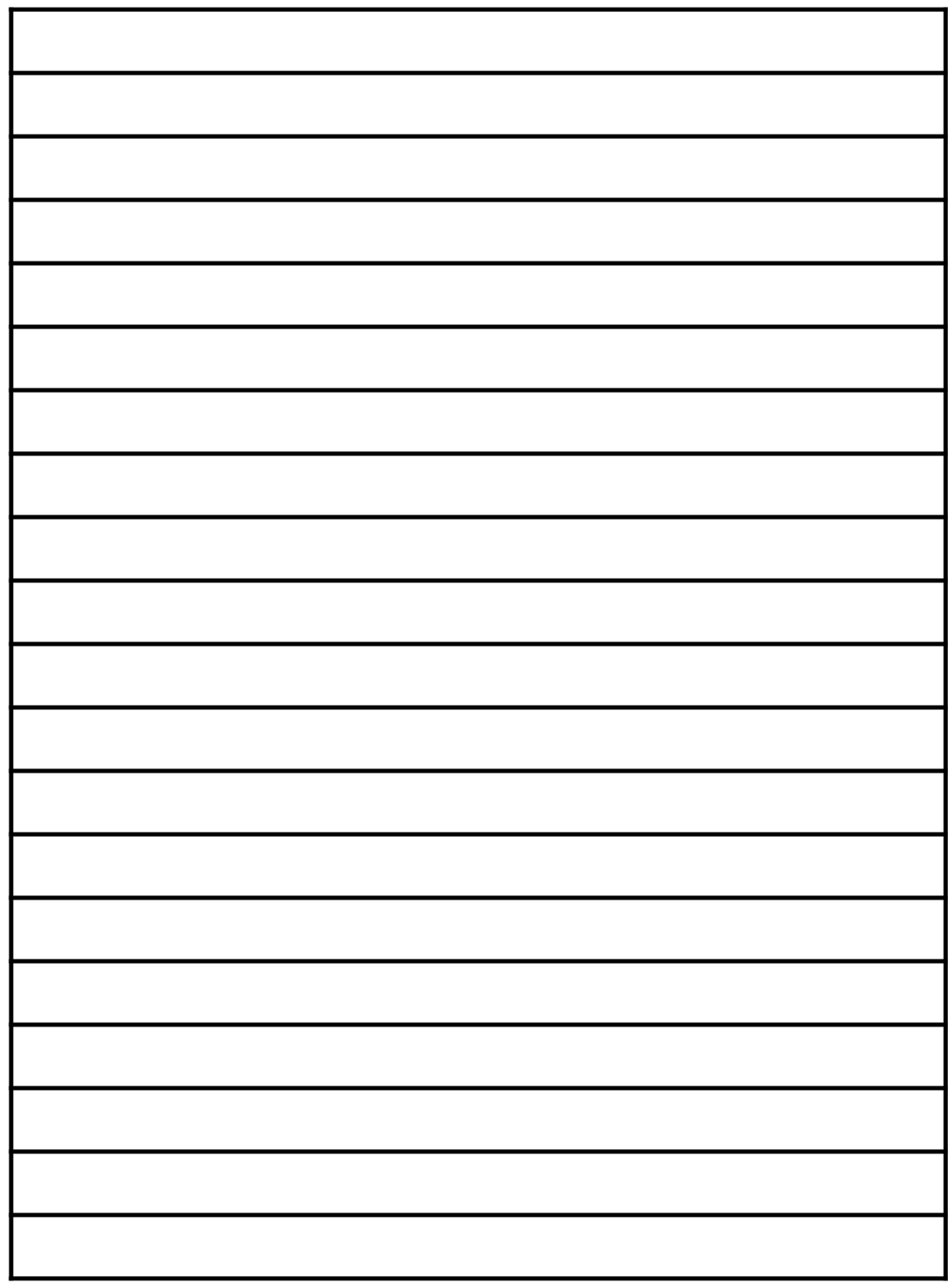
Stack



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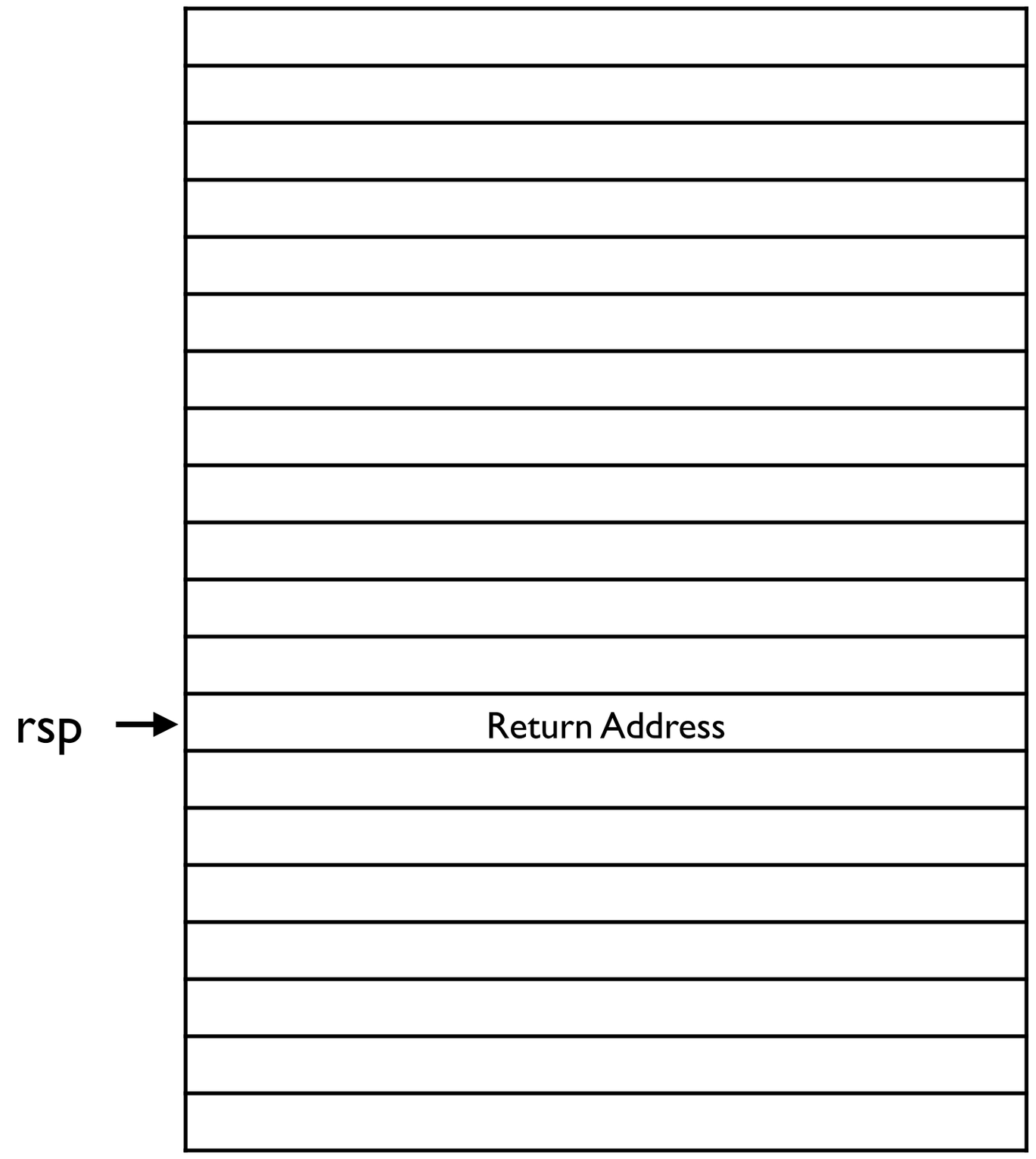

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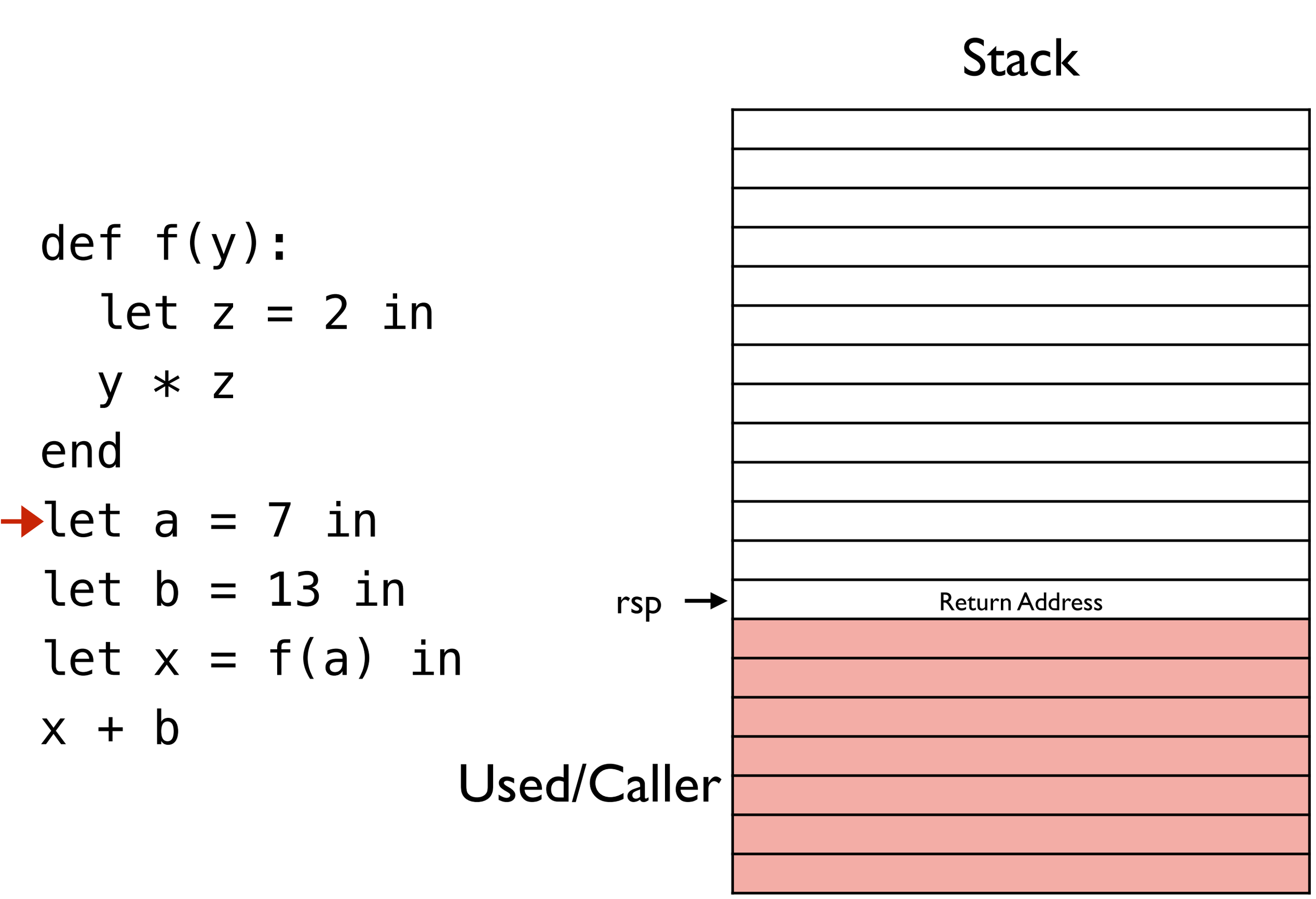

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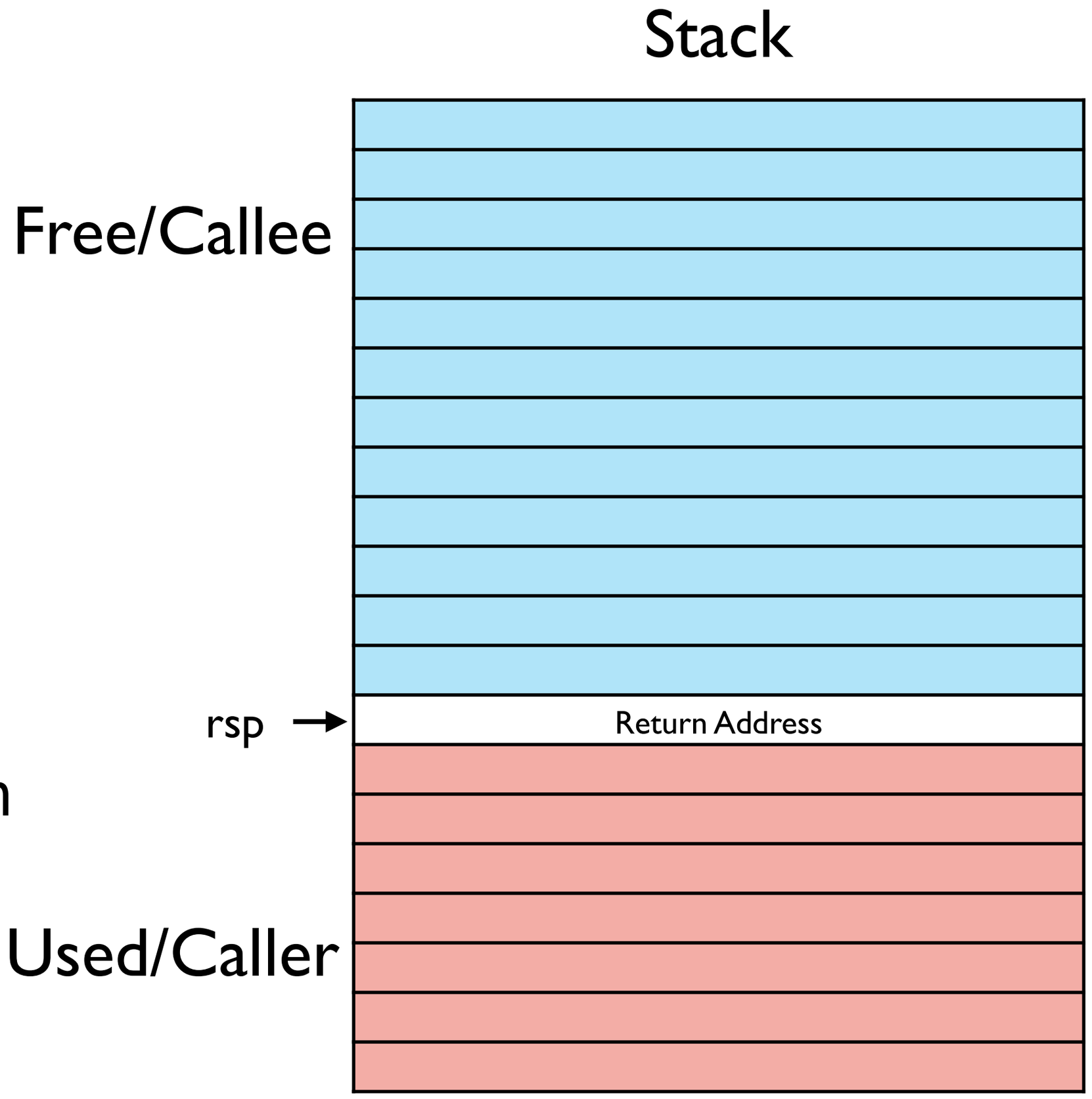

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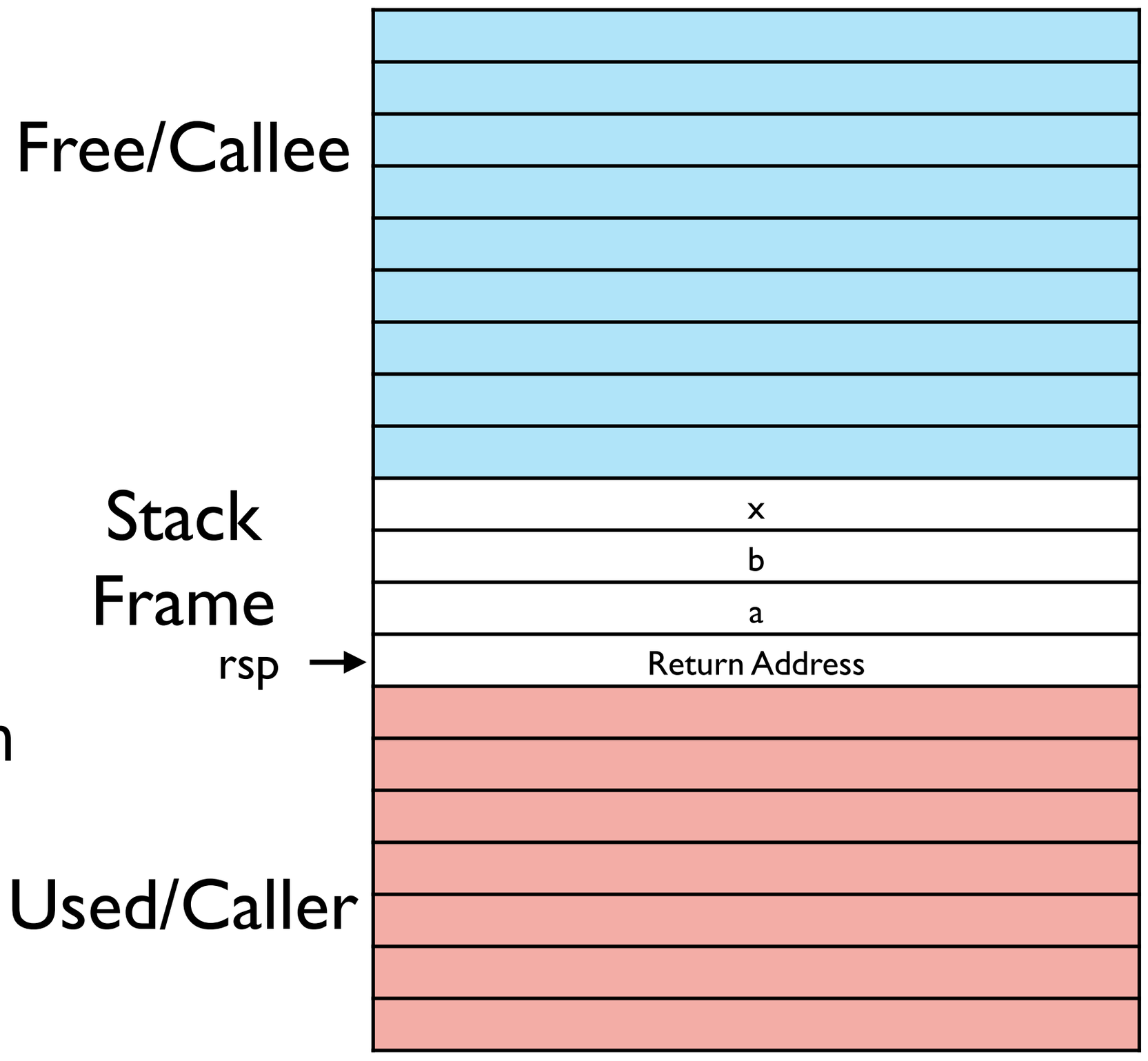

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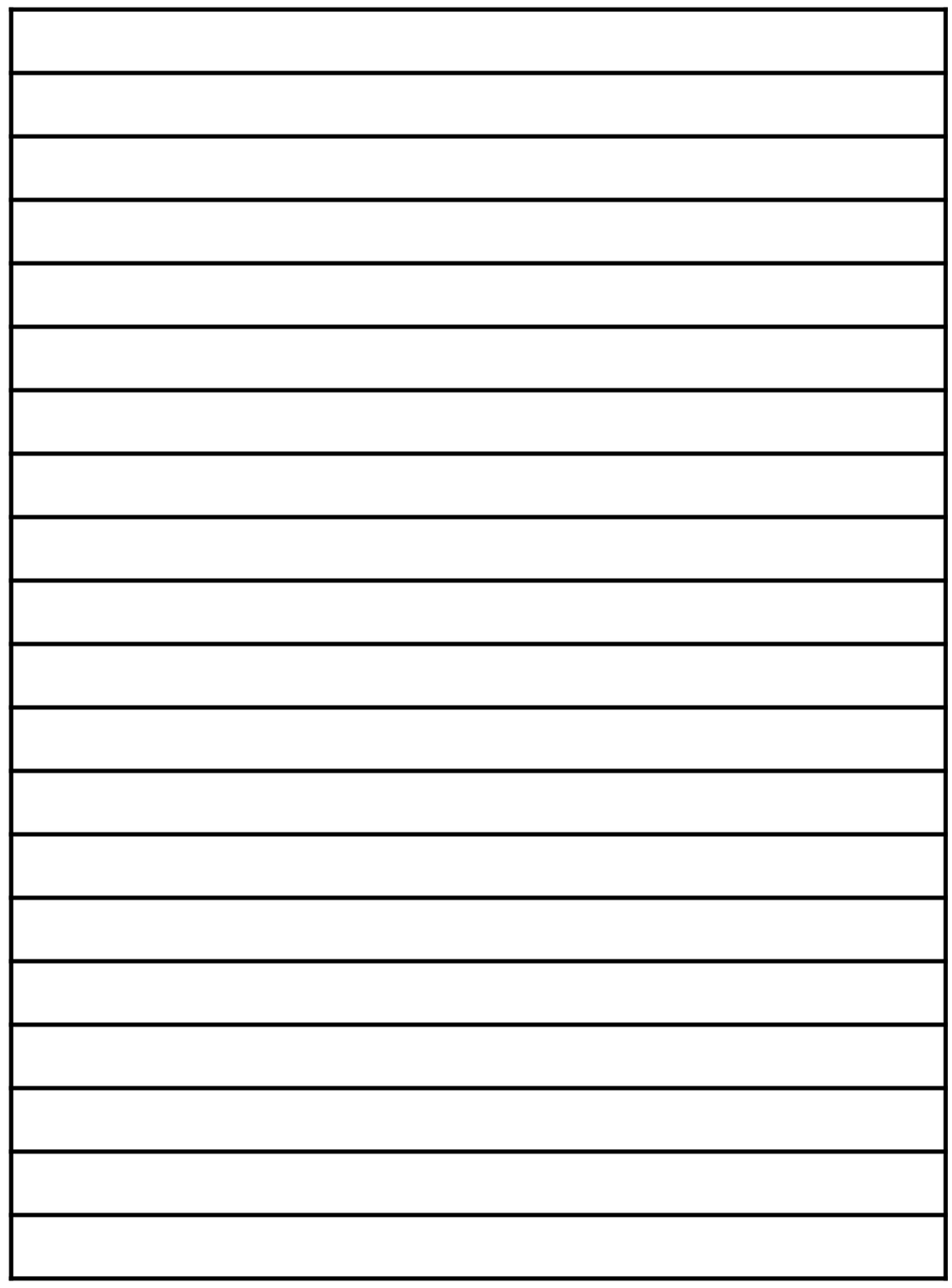

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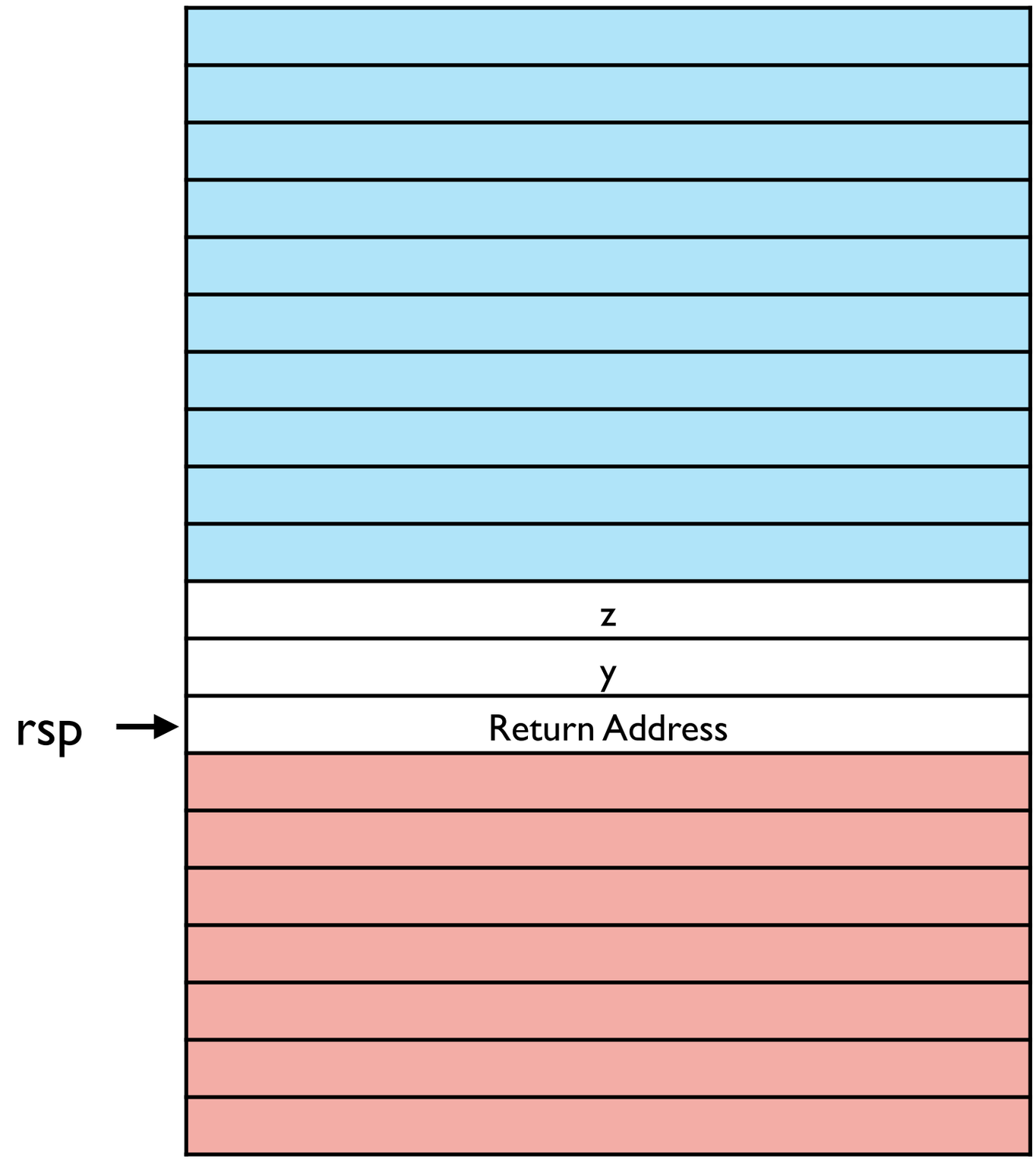

x

b

a

Return Address

z

y

Return Address

x

b

a

Return Address 0

z

y

Return Address 1

Address of a local is *relative* to the base of the stack frame

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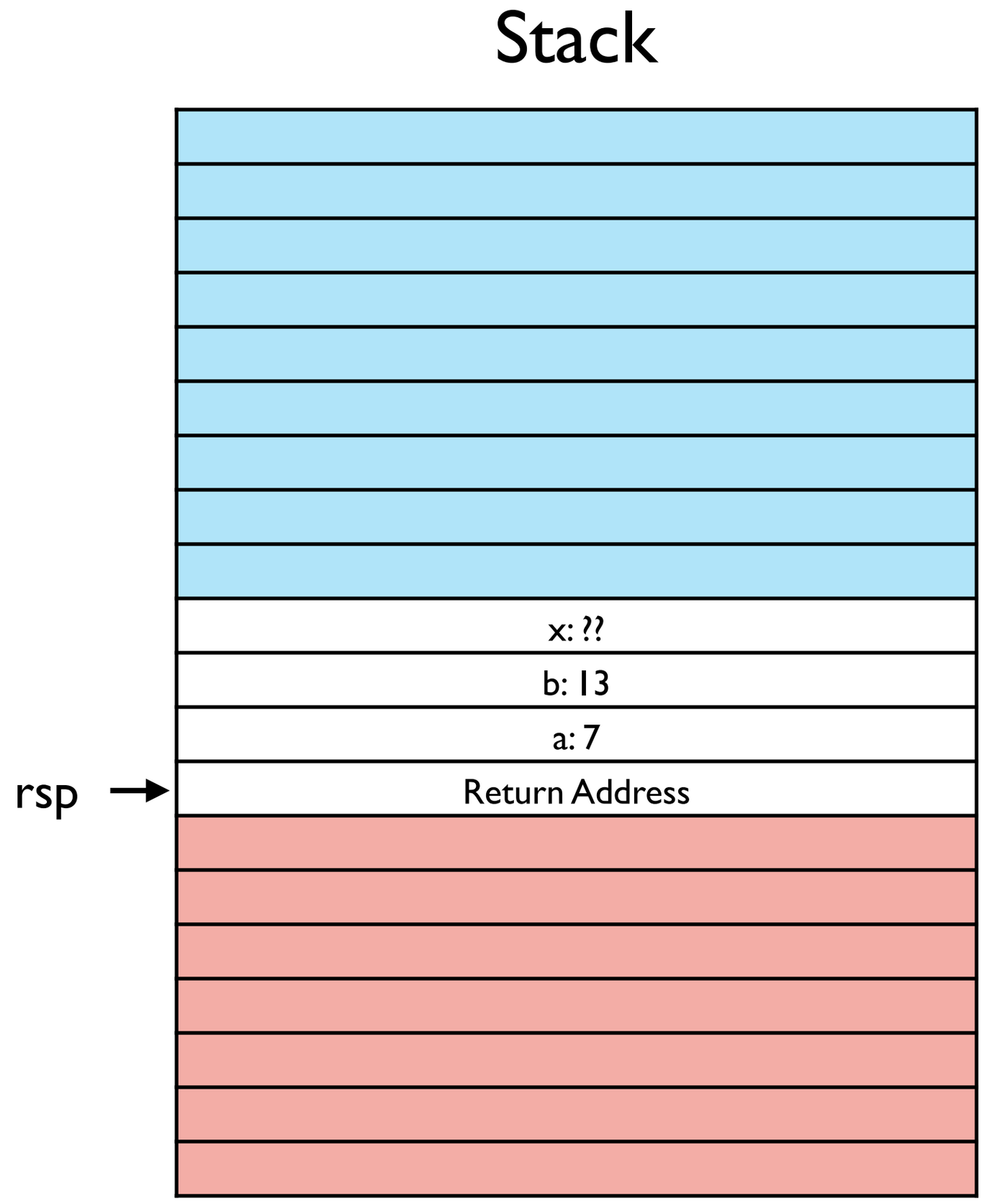

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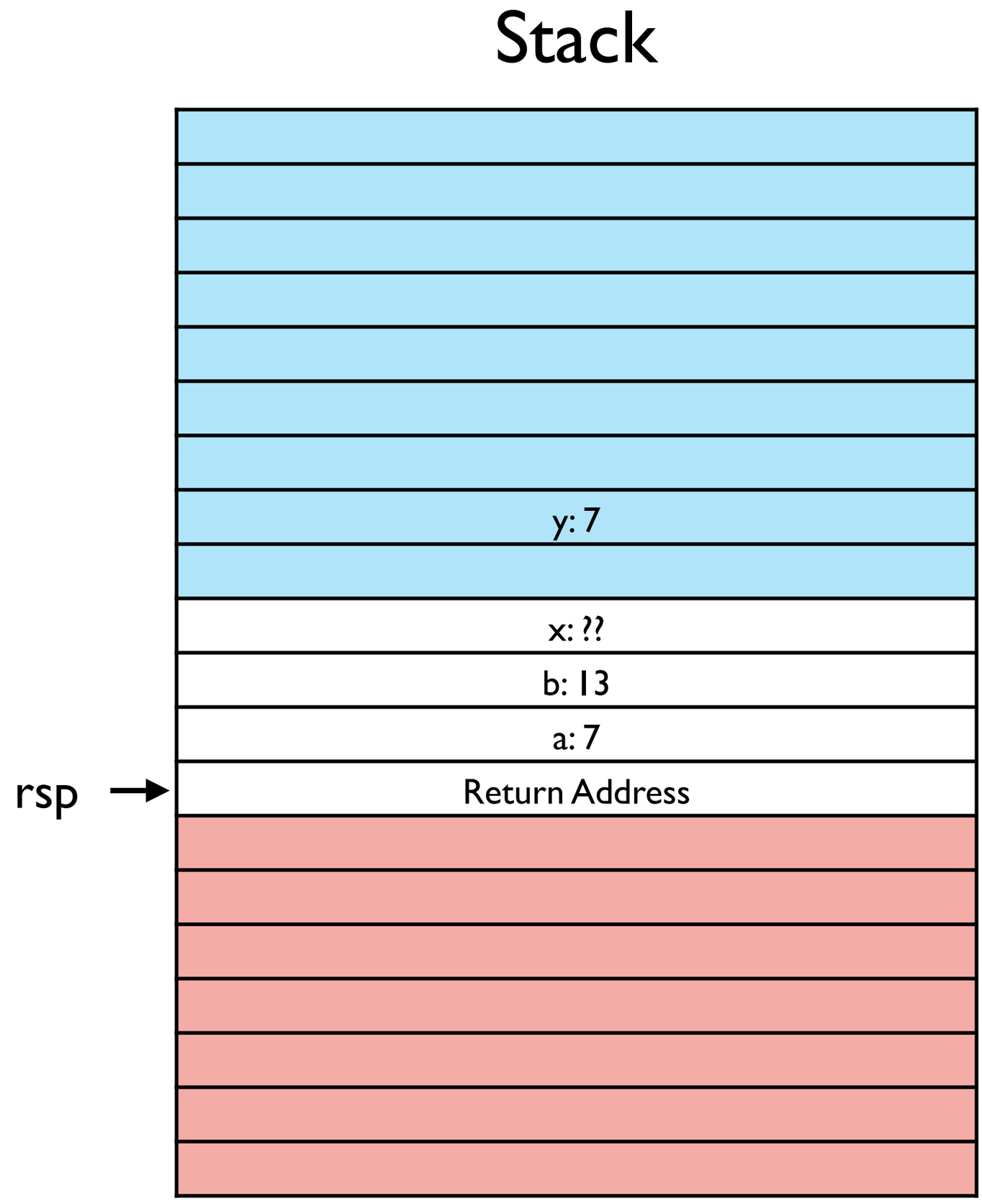

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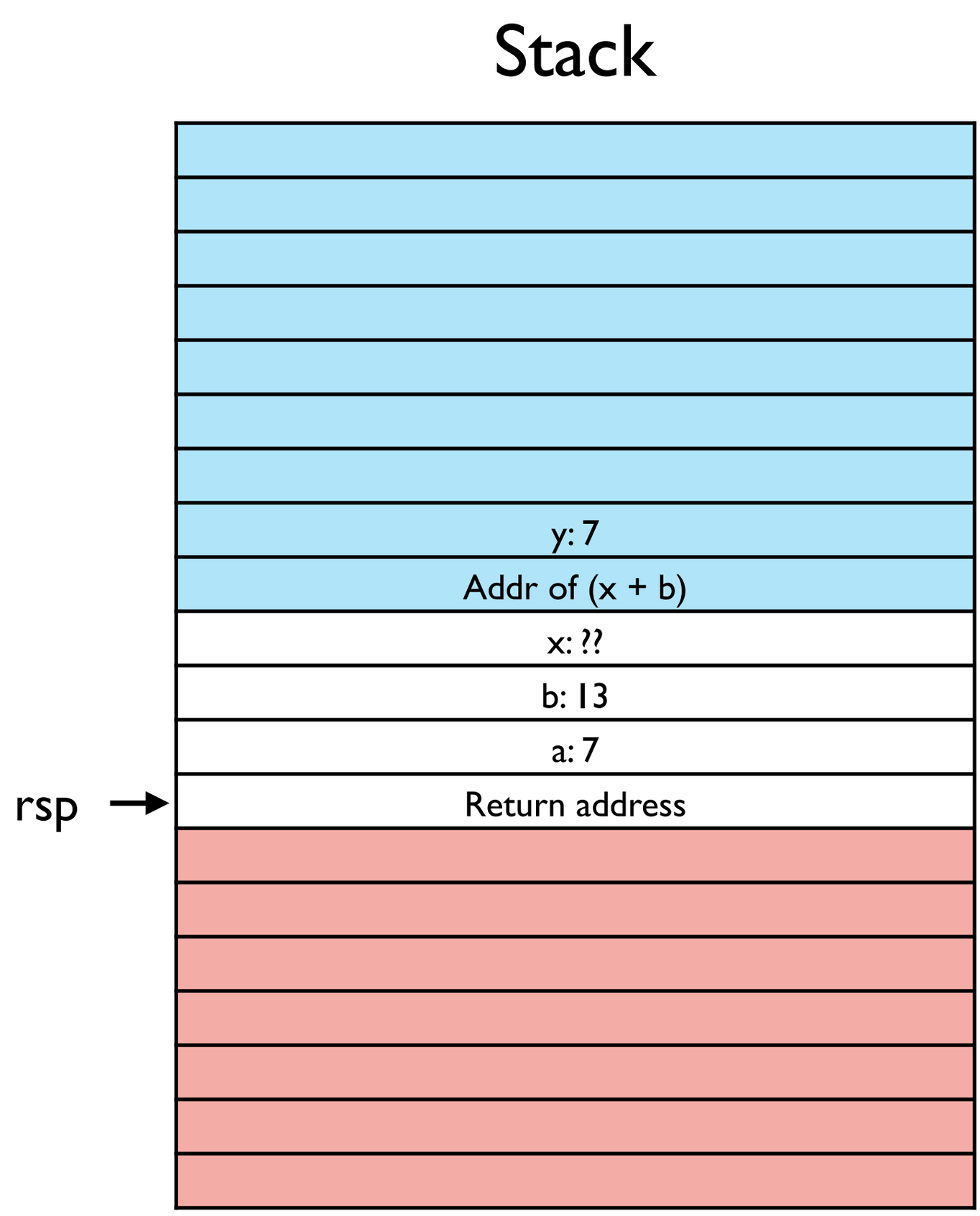

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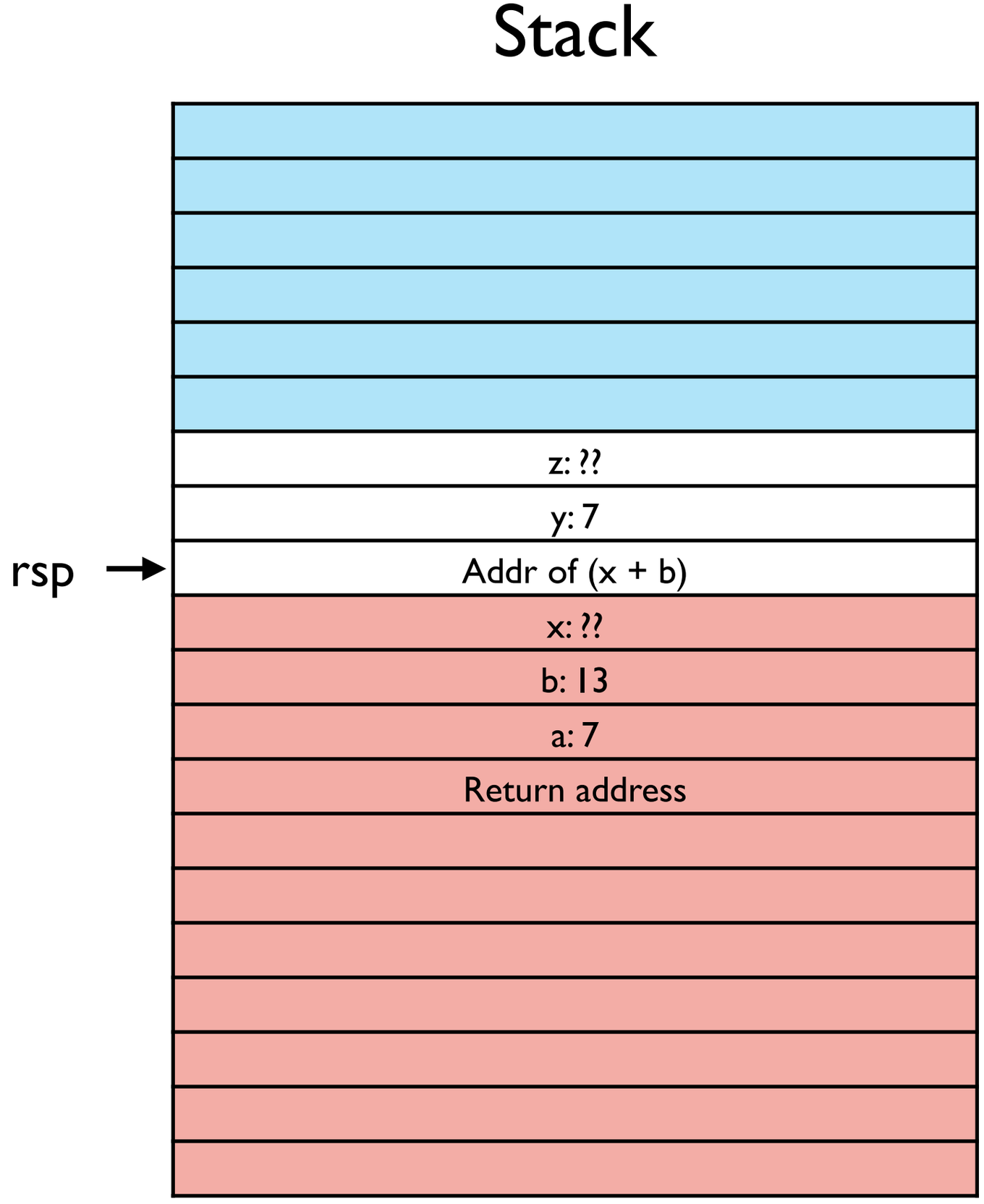

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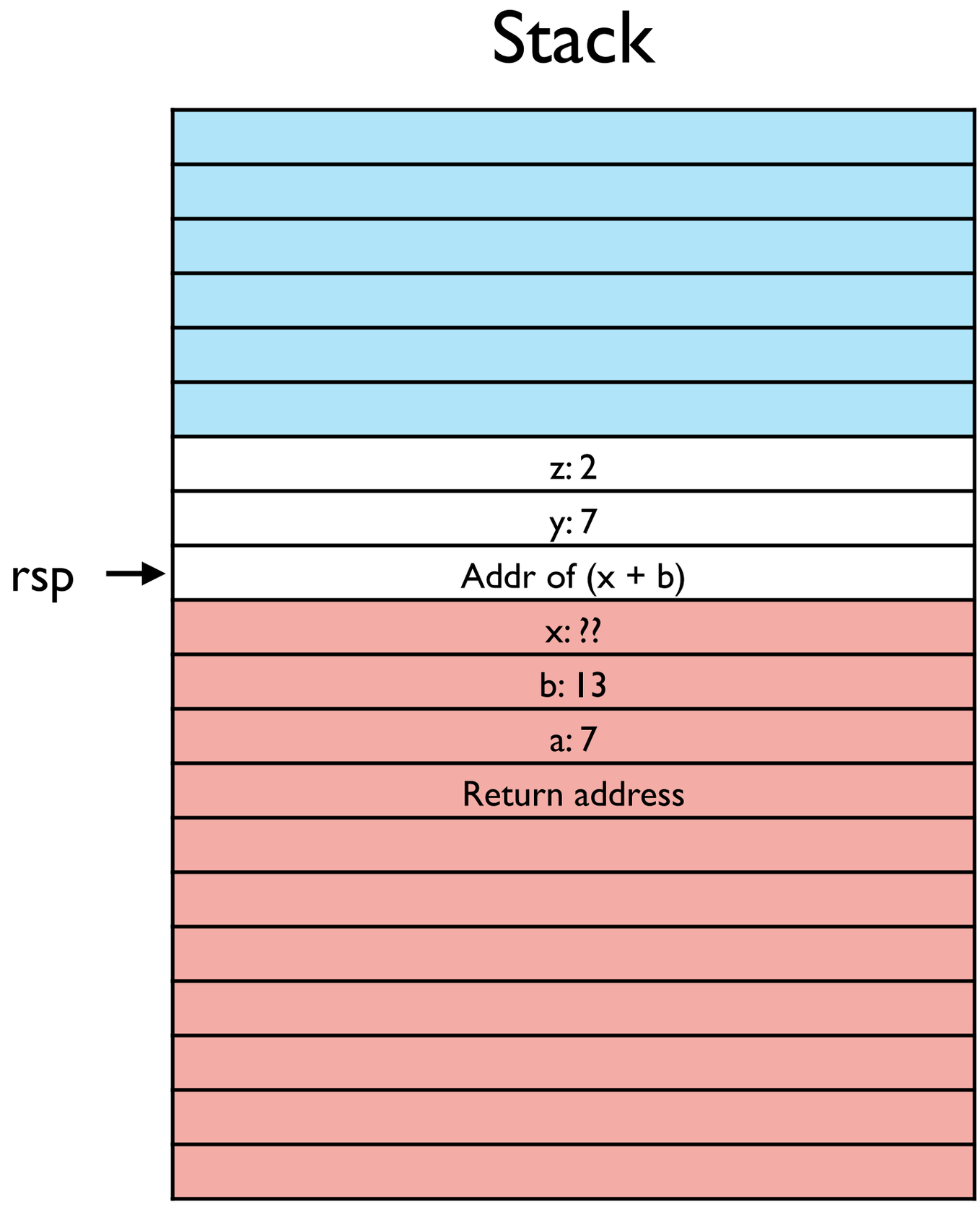

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Snake Calling Convention (v0)

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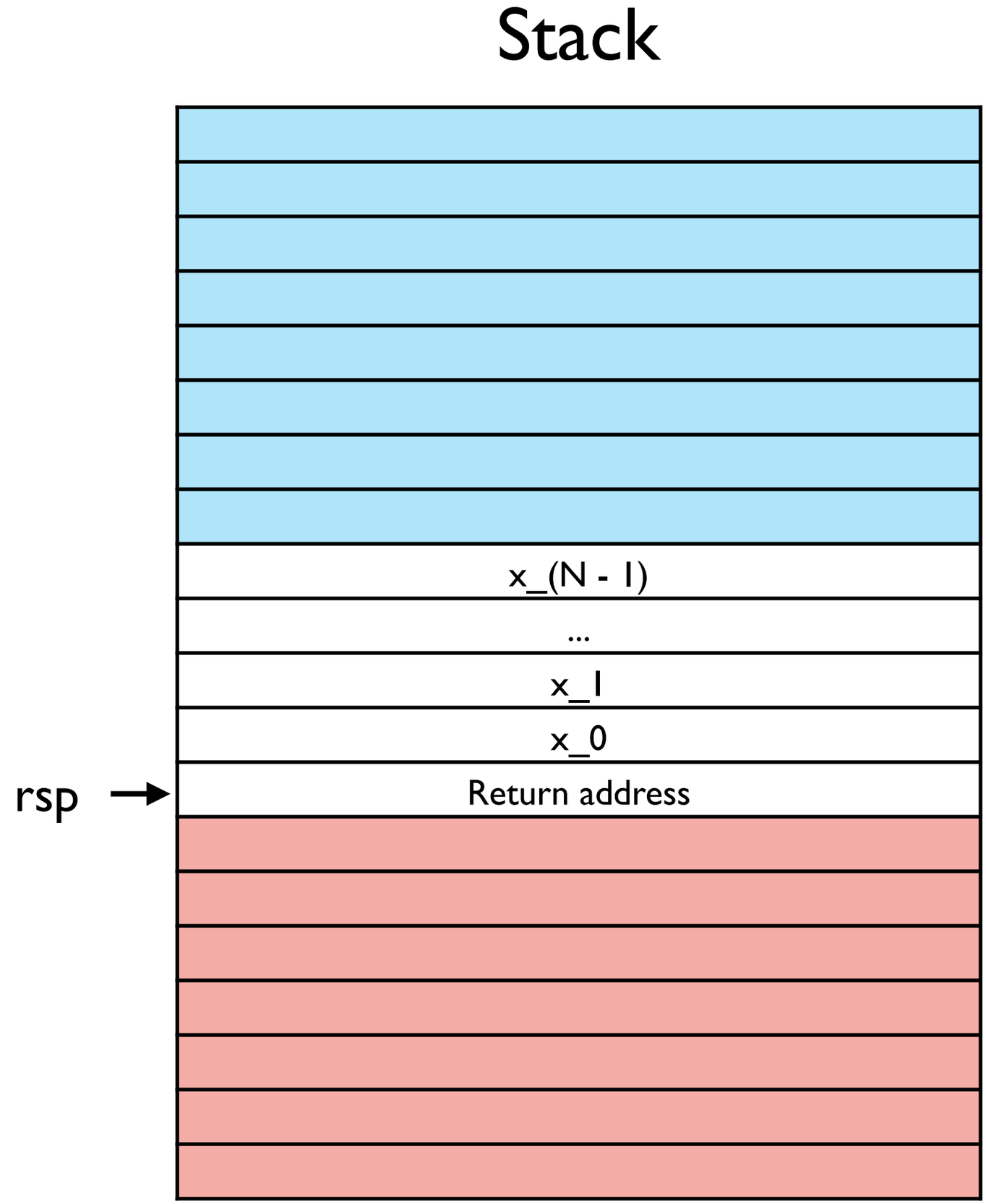
- Where are the arguments stored (relative to rsp)?
- Where is the return address stored (rel to rsp)?
- Where should we put the return value?
- Where should rsp point when we return?
- We don't use registers yet so don't worry about them

To call f with
N arguments
x_0 to x_(N-1)

- Rsp points at the return address
- Args go at lower addresses, with first arg closest to rsp
- Caller's stack frames are at higher addresses
- Return value in RAX
- Upon return, rsp points to top of caller's stack frame



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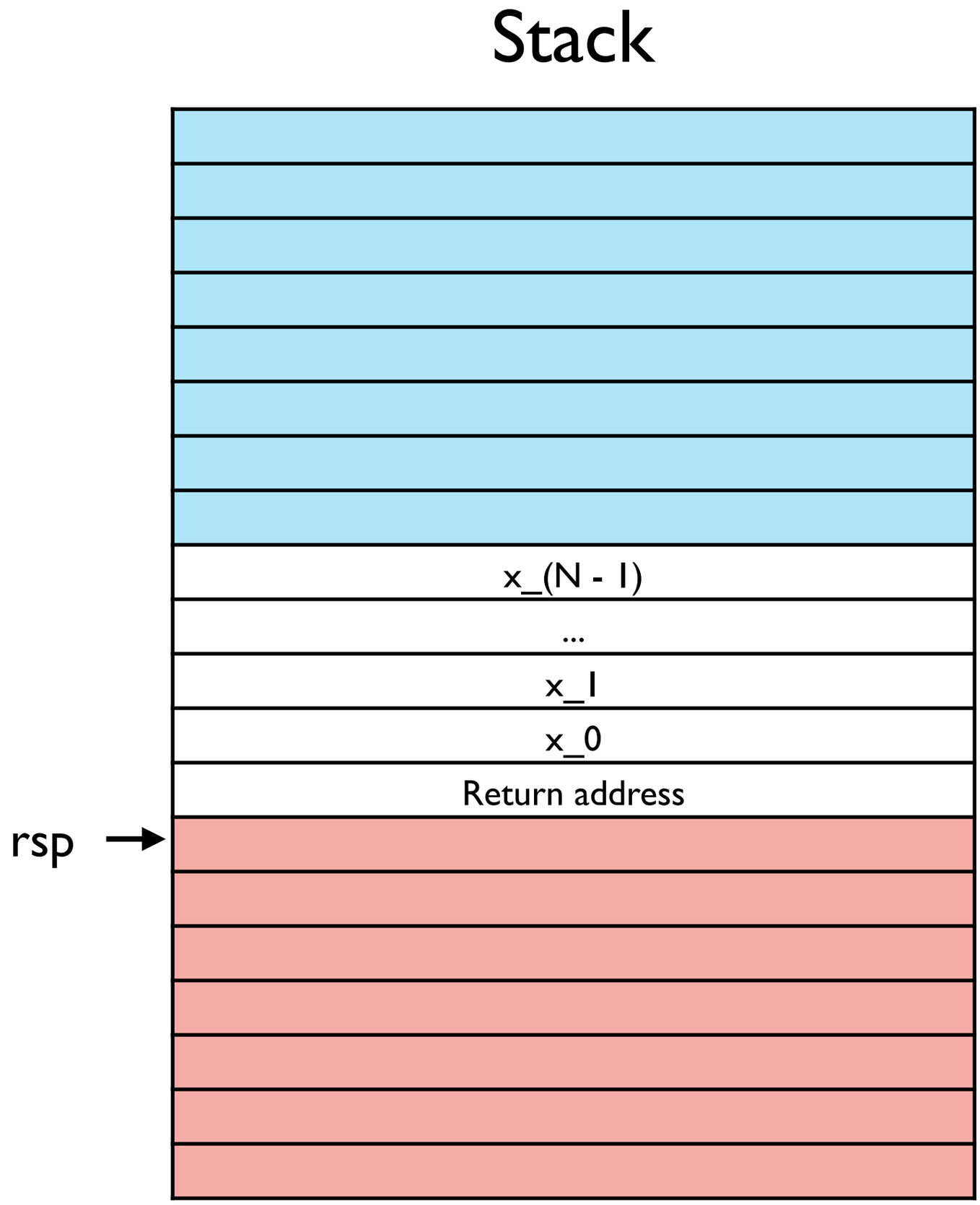


Benefits of Snake CC

- Easy to implement tail calls
- Arguments are treated uniformly with locals
- Return overlaps with SysV CC when there are no stack args

WARNING

WARNING

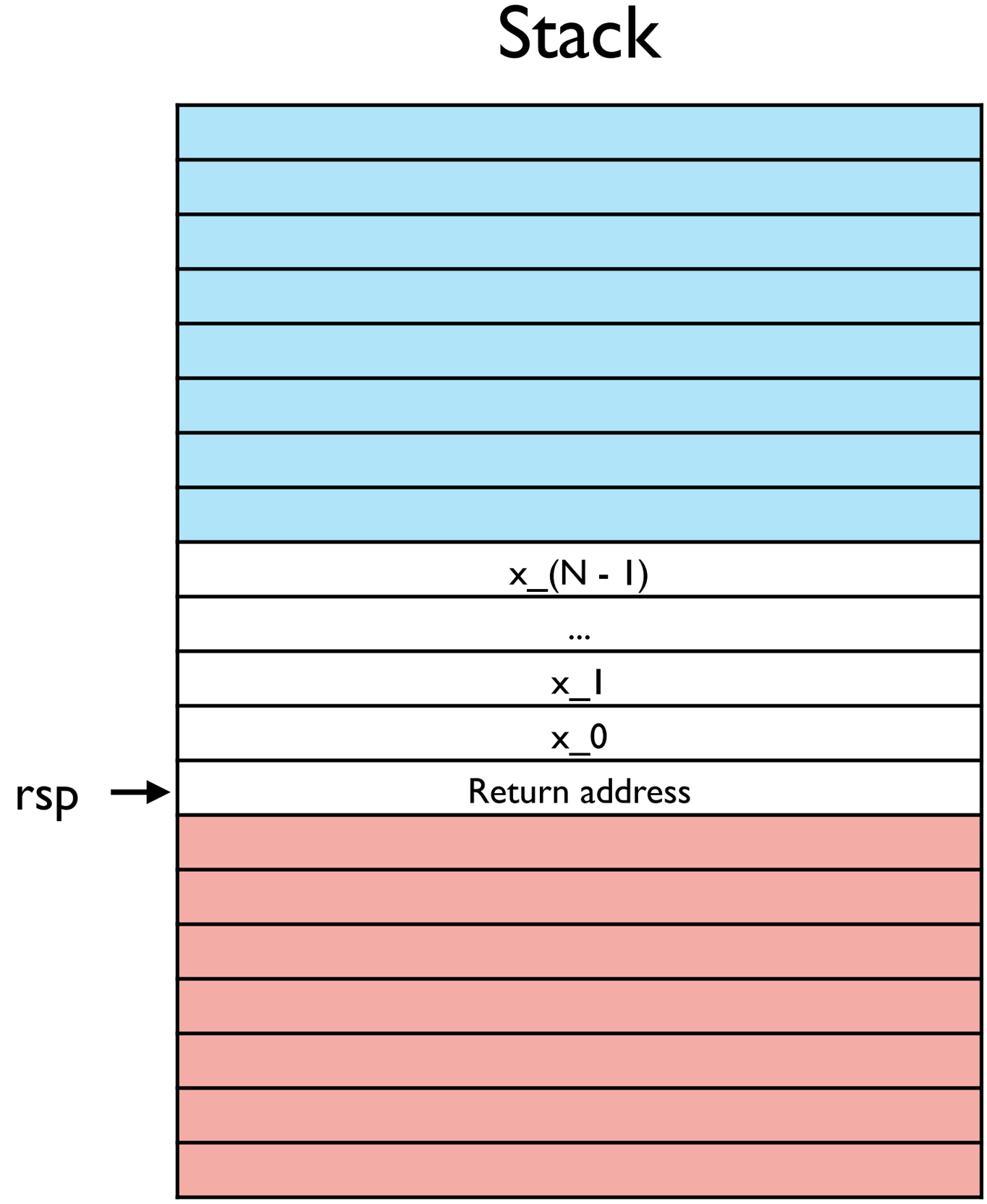
- RBP

WARNING

- RBP
- Different from SysV ABI:
  - No register args (for now)
  - Placement of Args
  - "Caller-cleanup" vs "Callee-cleanup"

To call f with
N arguments
x_0 to x_(N-1)

SYS V ABI



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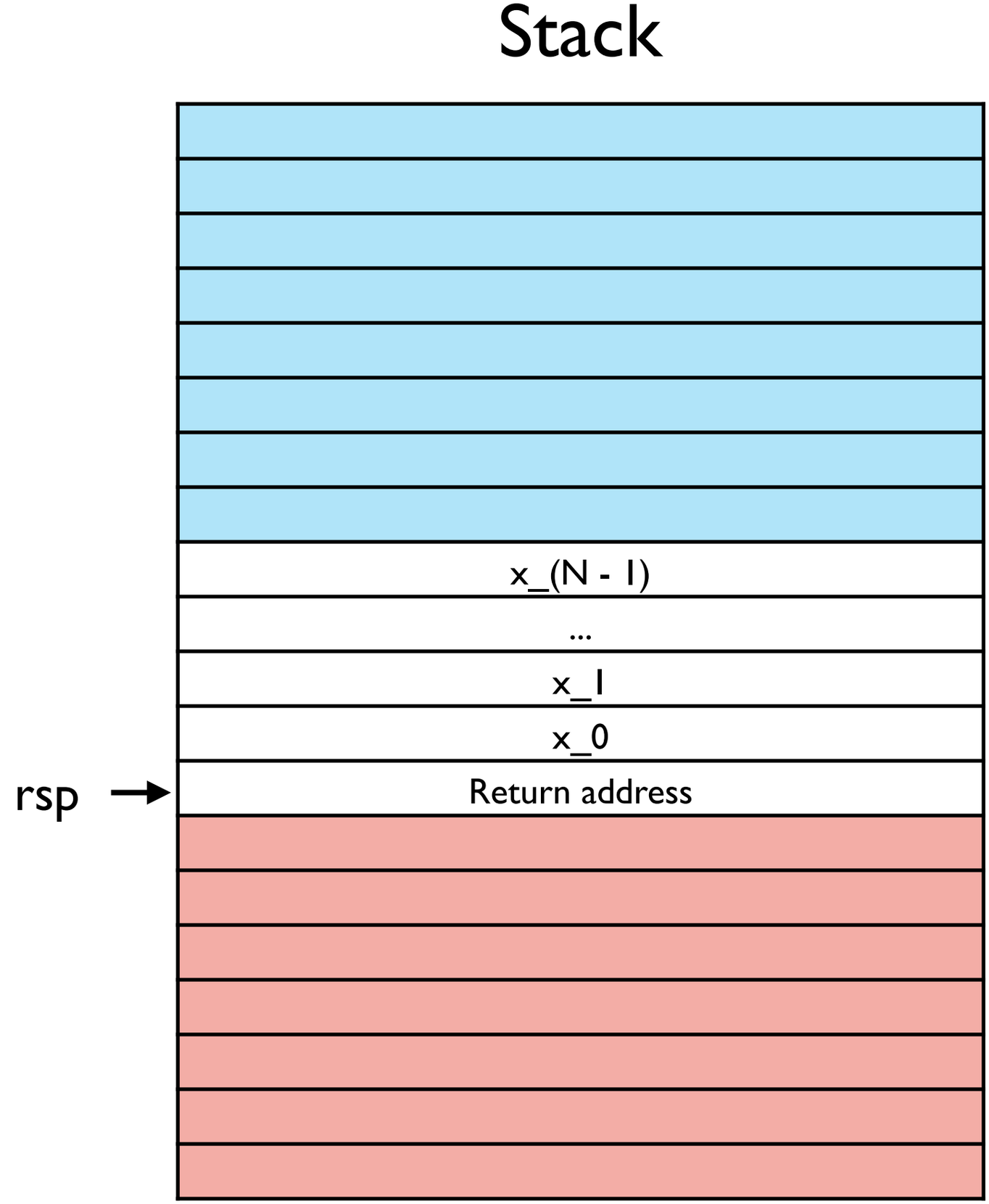
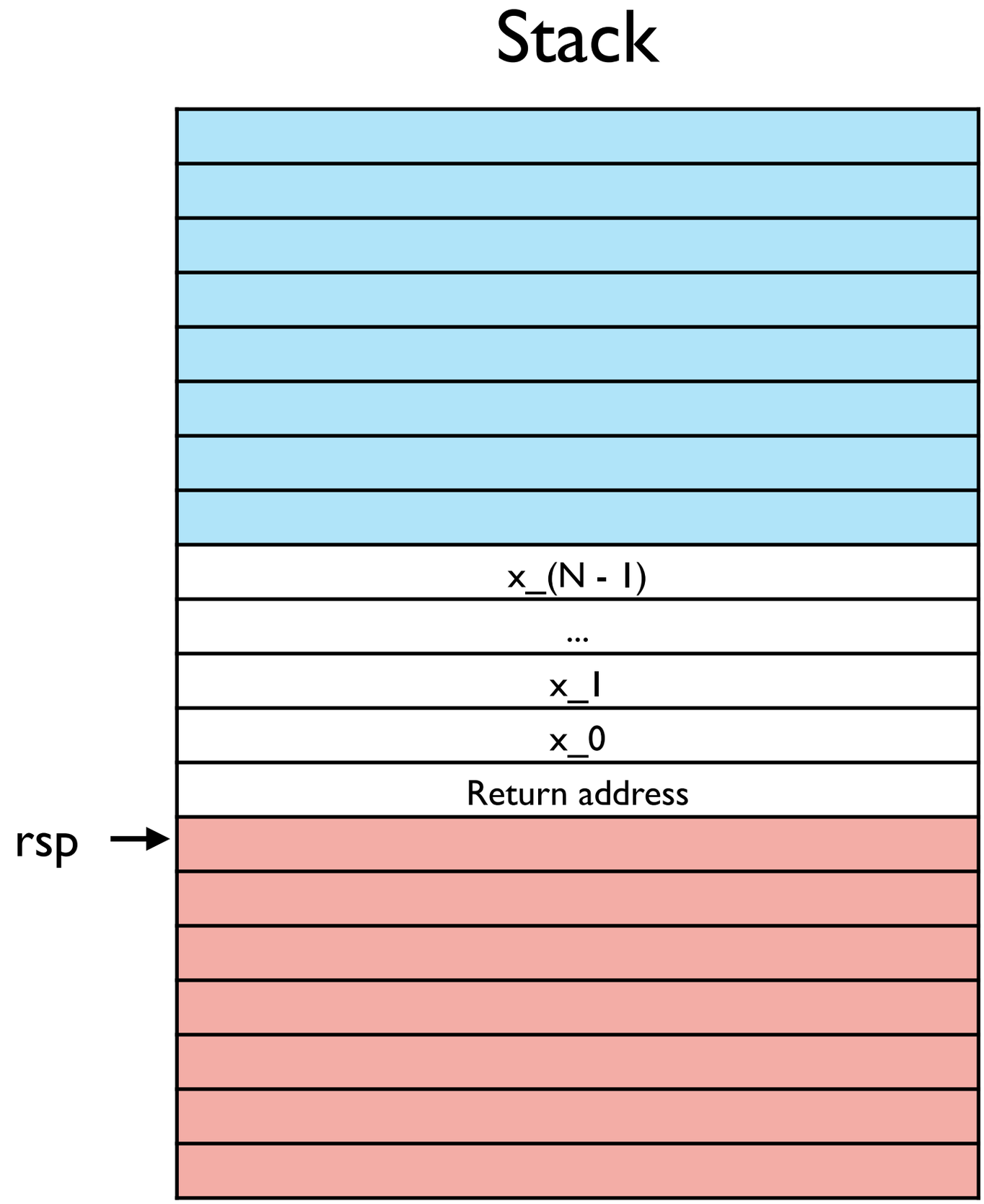
Snake after call



To call f with
N arguments
x_0 to x_(N-1)

Snake after return



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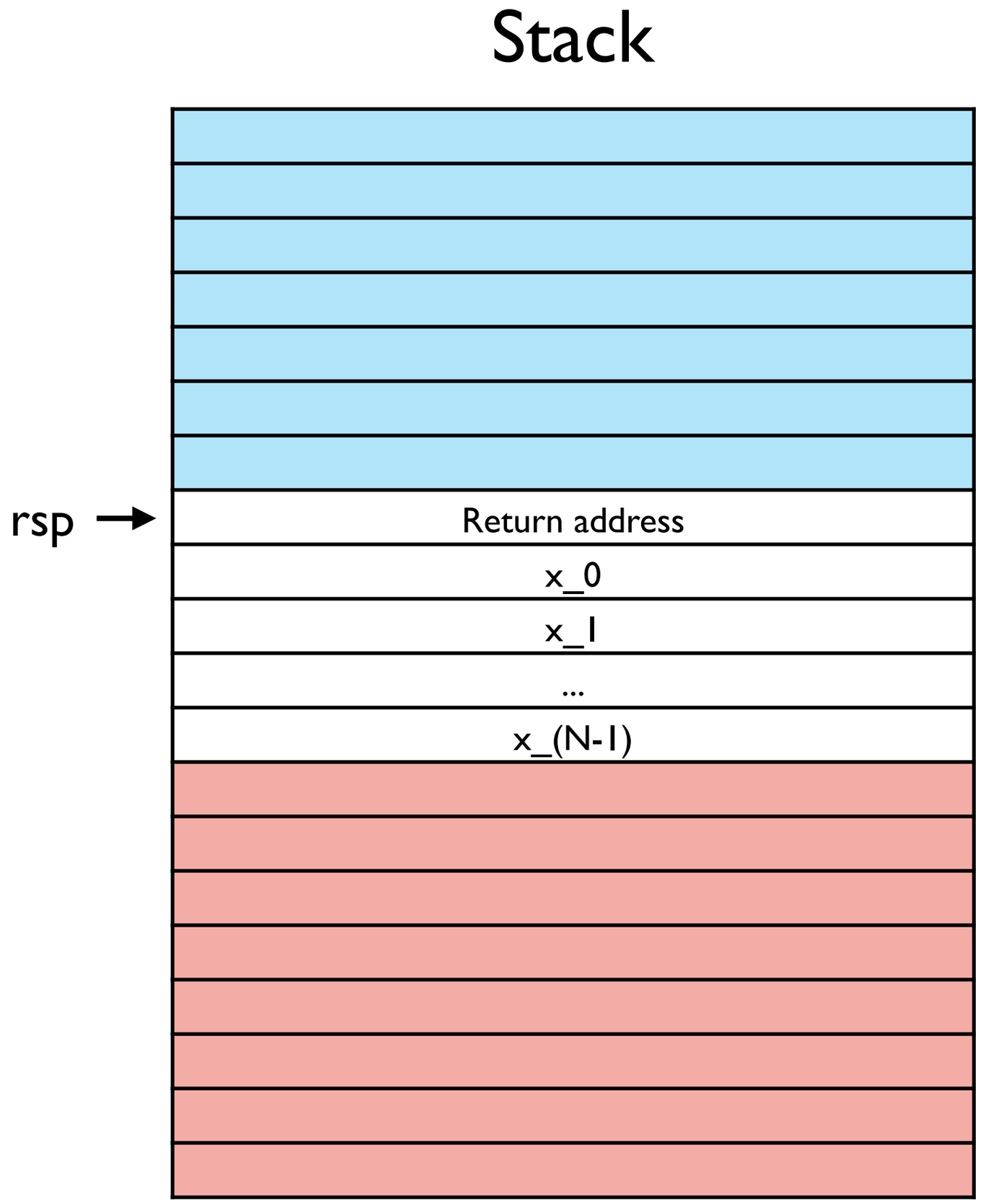
SysV
after call



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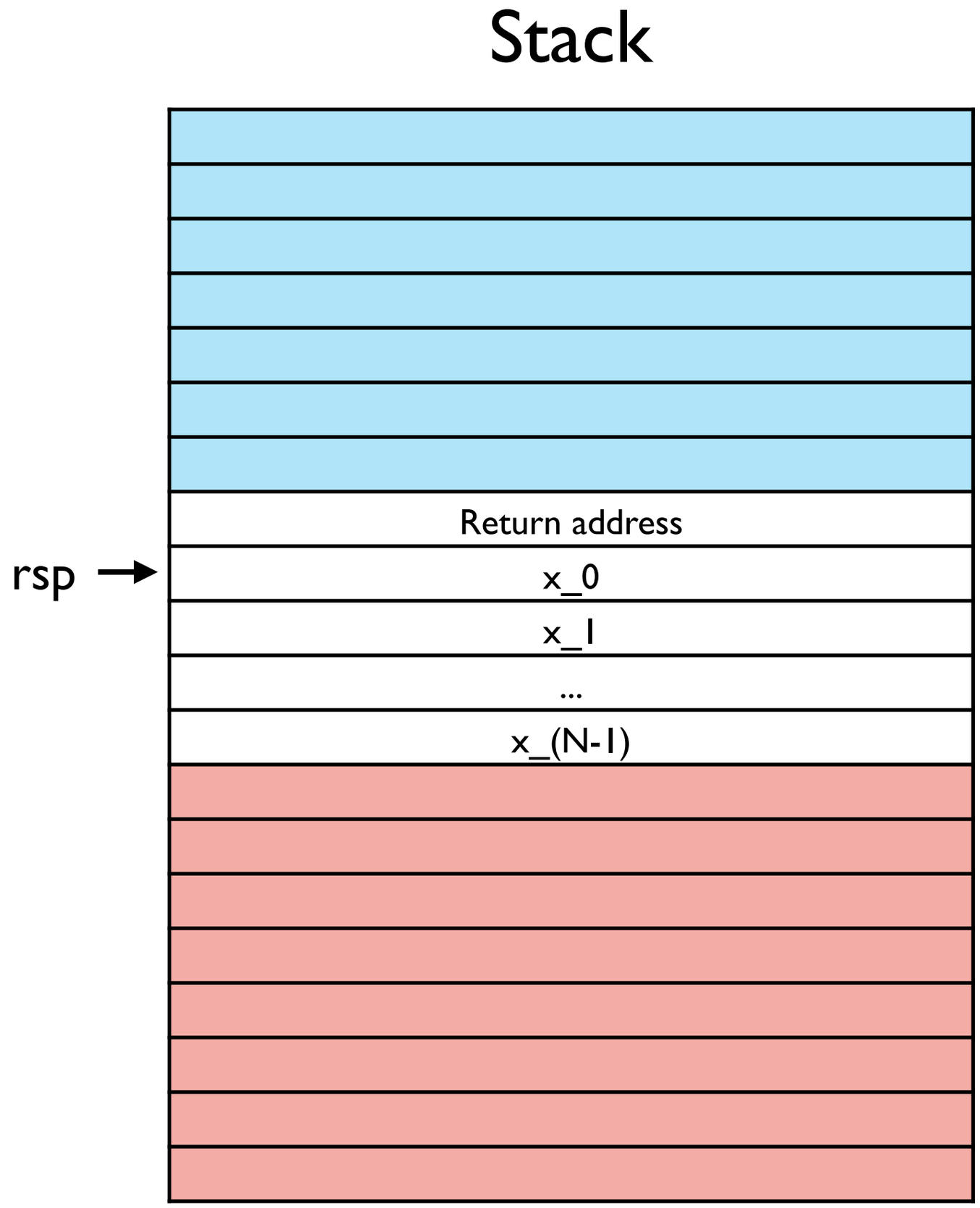
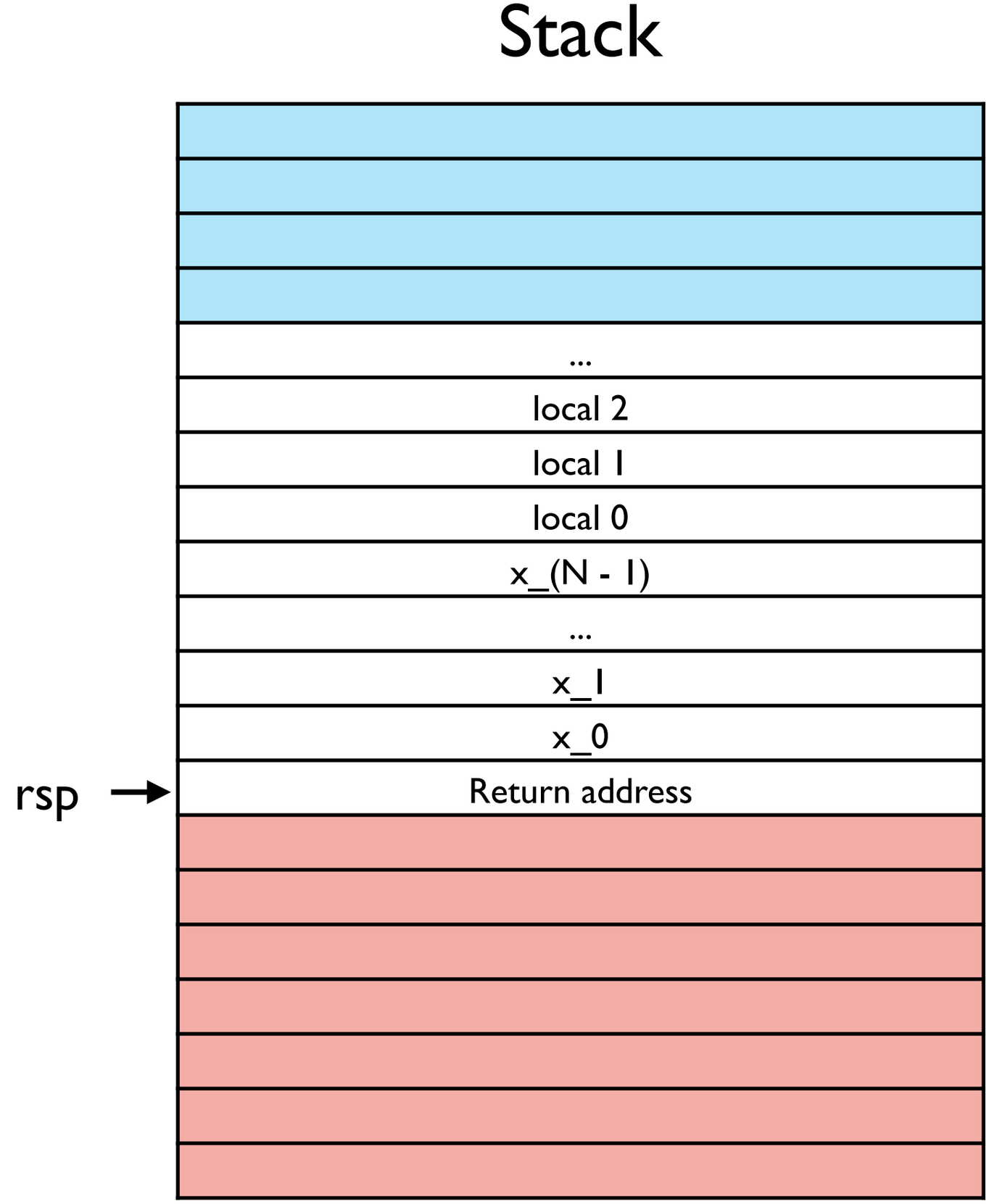


Implementing the Snake CC

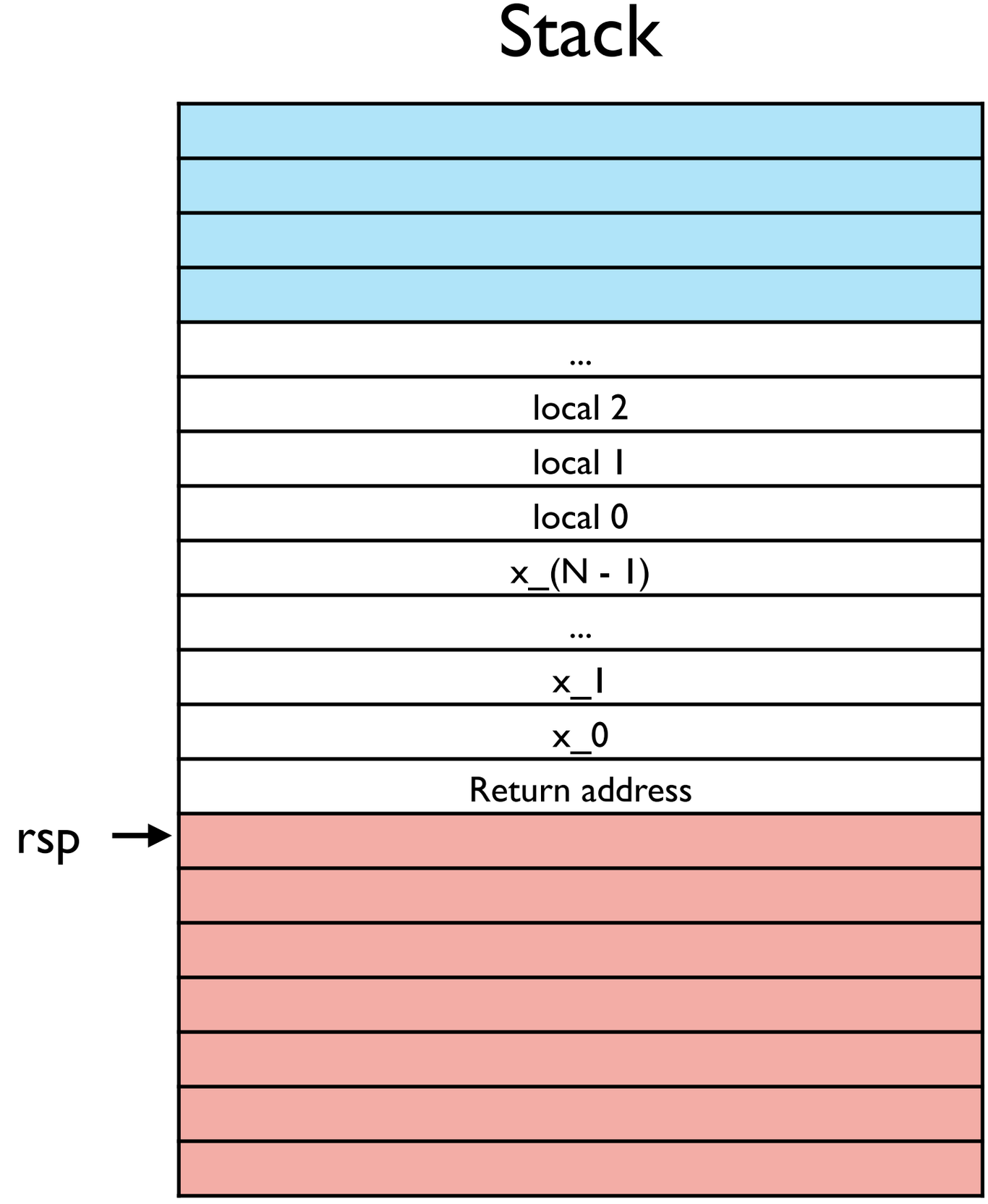
- How to return?
- How to call?
- How to tail call?

To return x



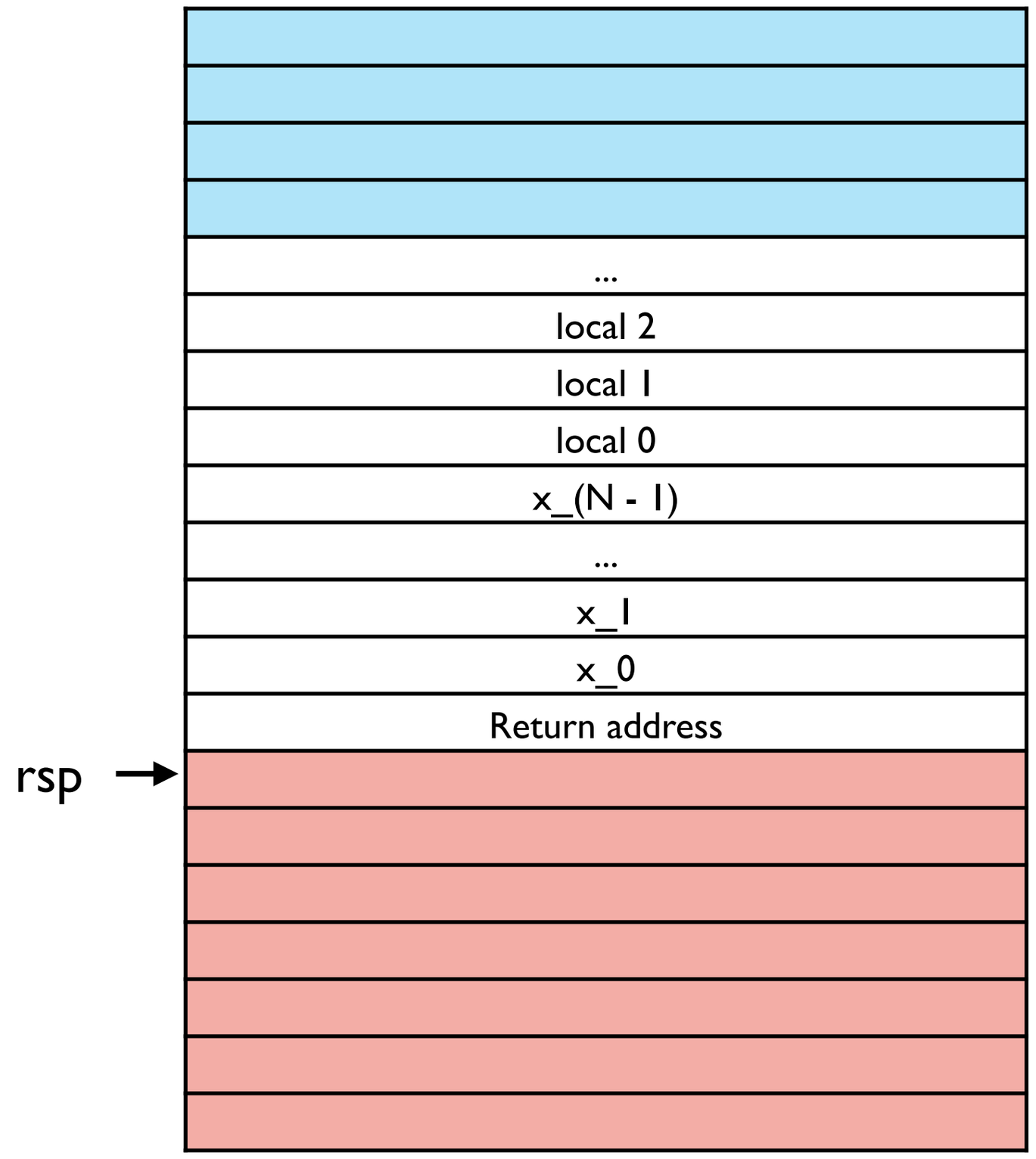
To return x

```
mov rax, [loc of x]
pop rbx
jmp rbx
```



To return x

```
mov rax, [loc of x]
ret
```



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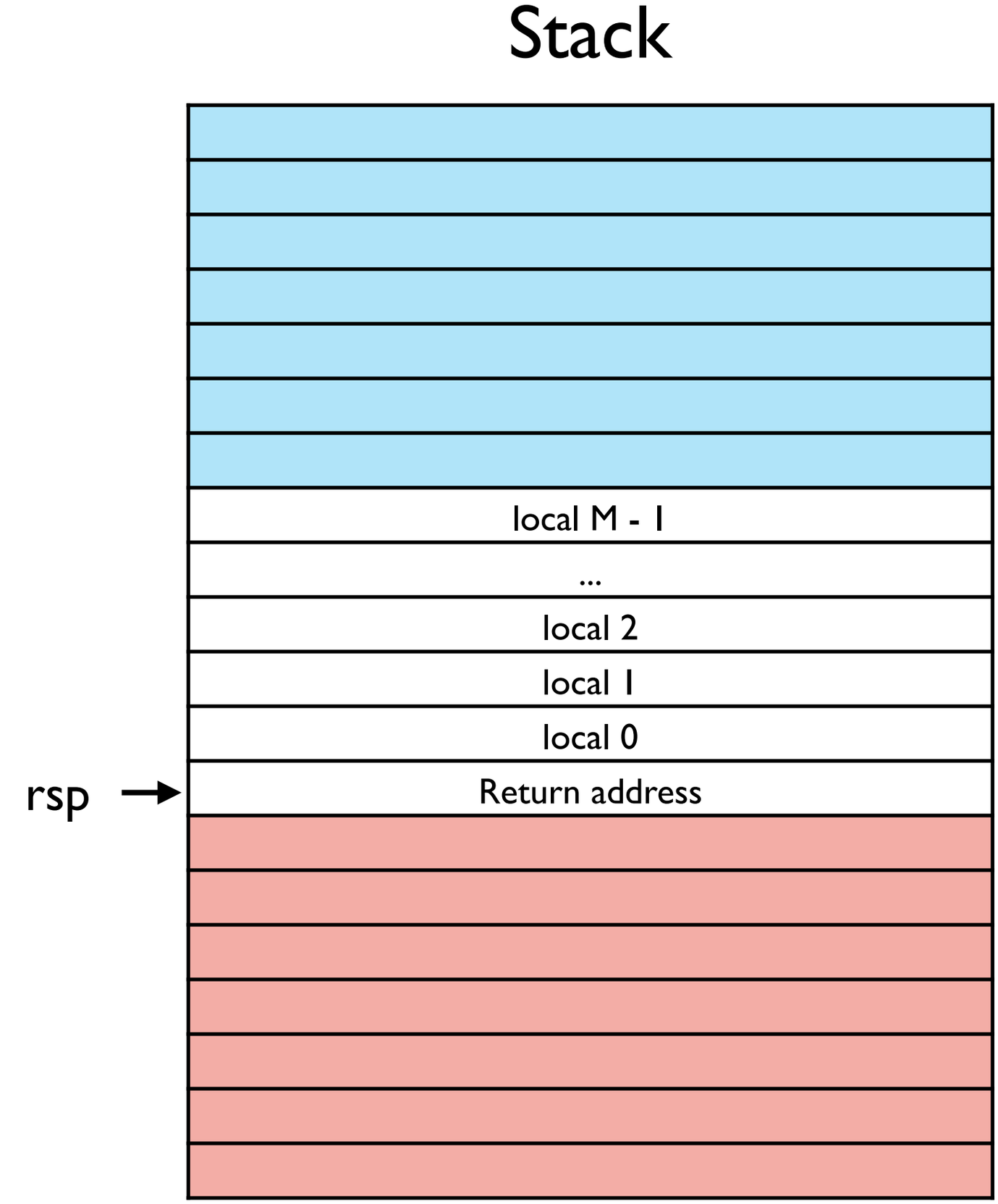

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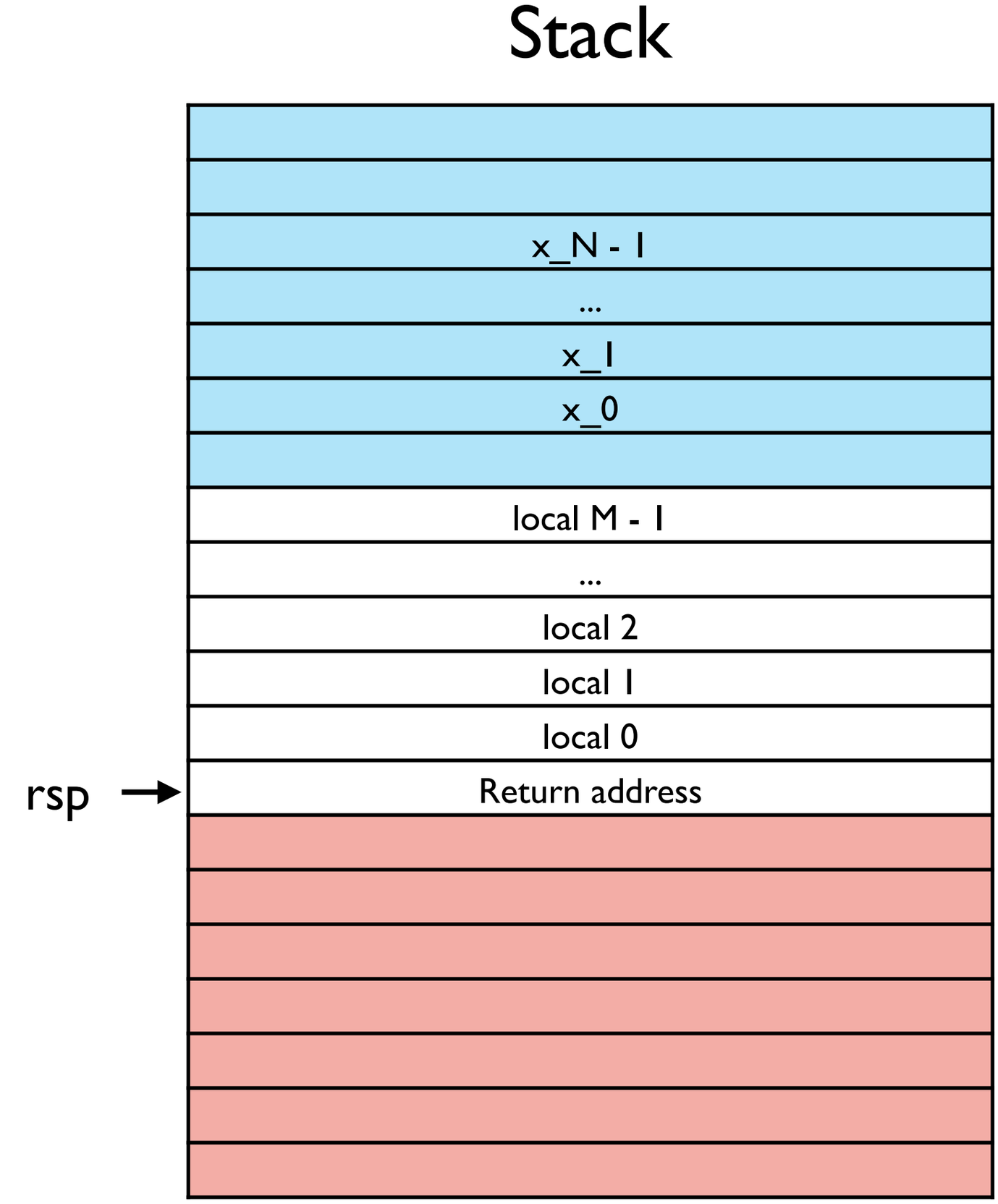

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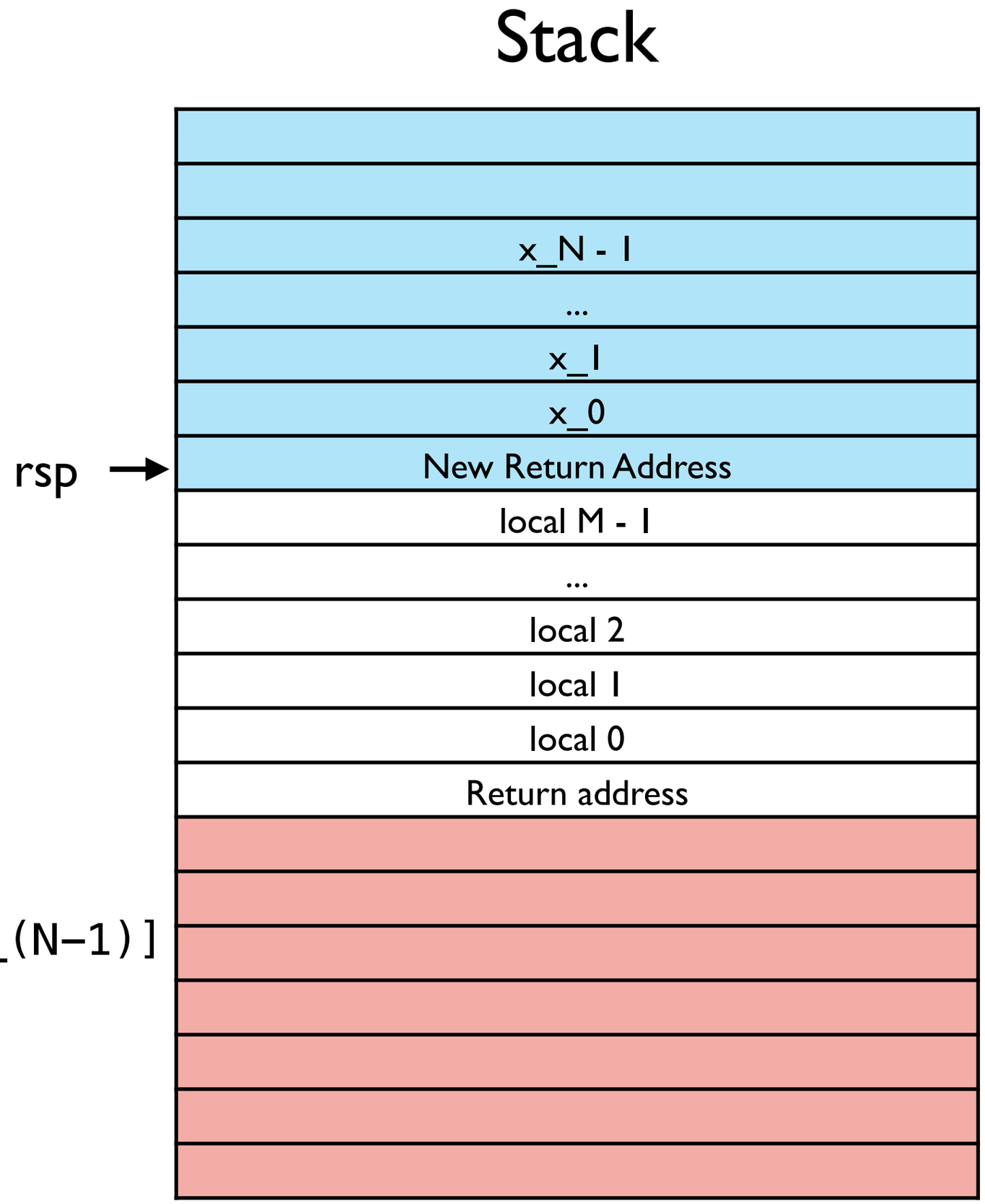
```
mov [rsp - 8 * (M + 2)], [x_0]
mov [rsp - 8 * (M + 3)], [x_1]
...
mov [rsp - 8 * (M + 2 + N)], [x_(N-1)]
sub rsp, 8 * M
call
```



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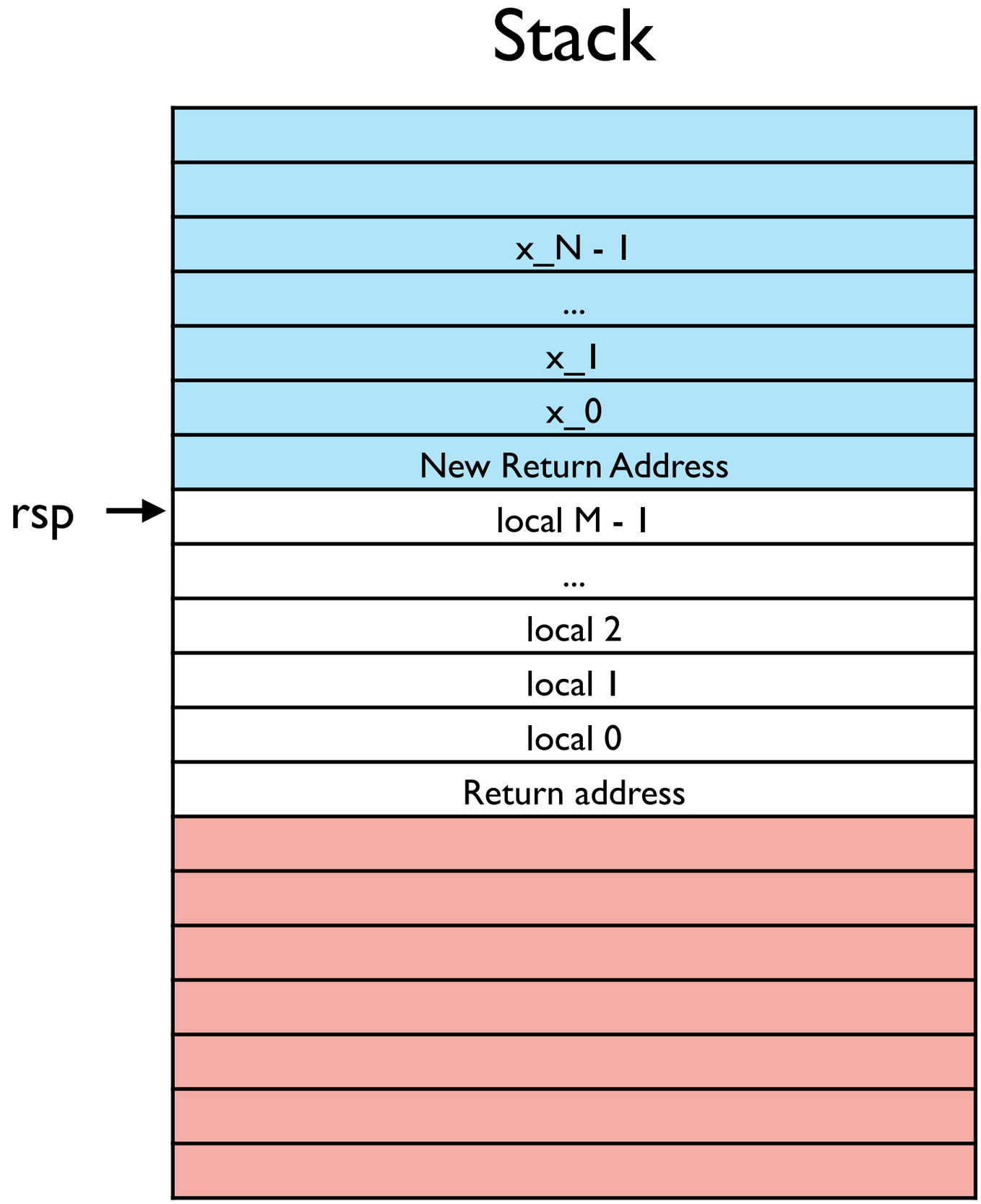

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sub rsp, 8 * M
call
add rsp, 8 * M
```

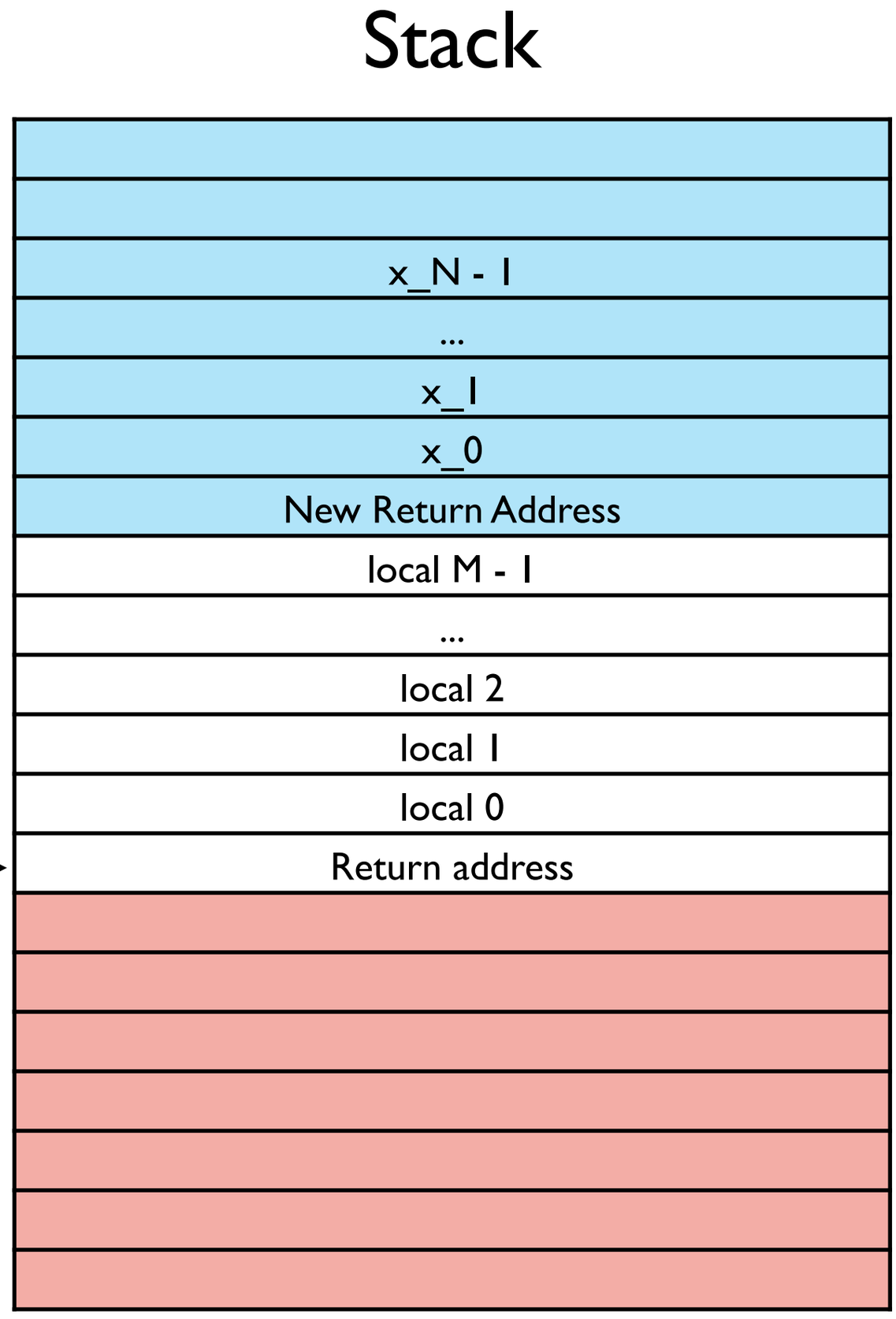

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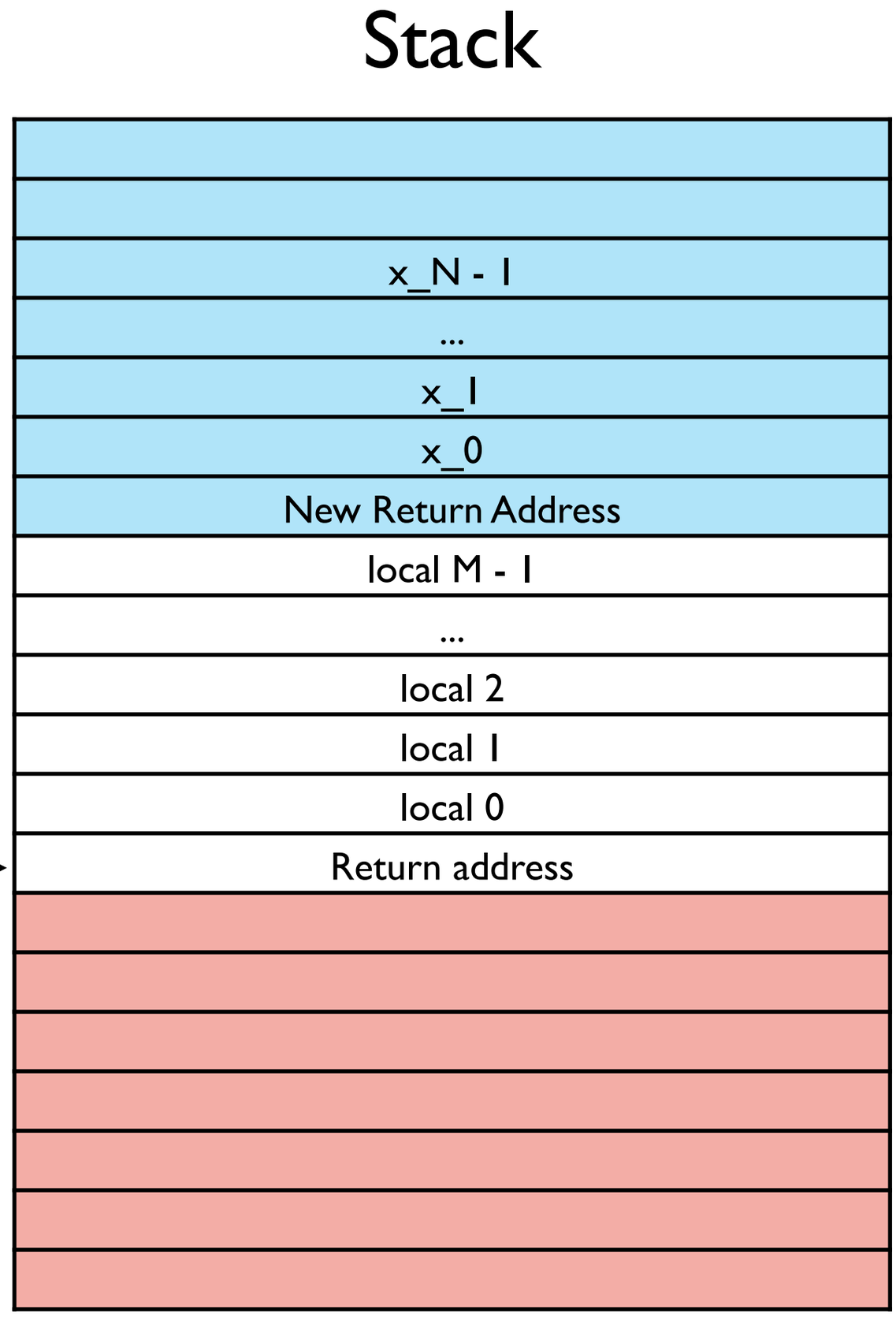

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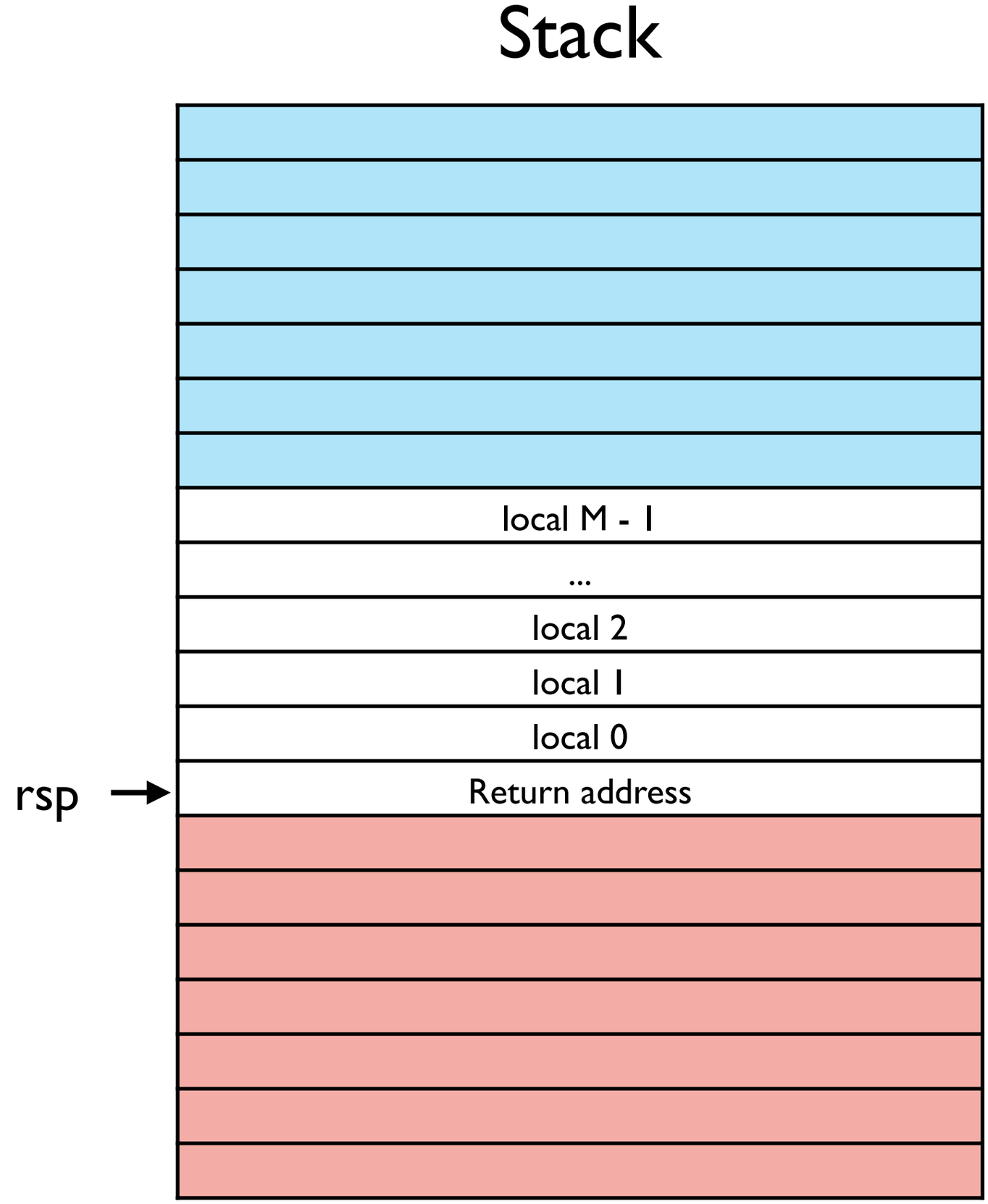

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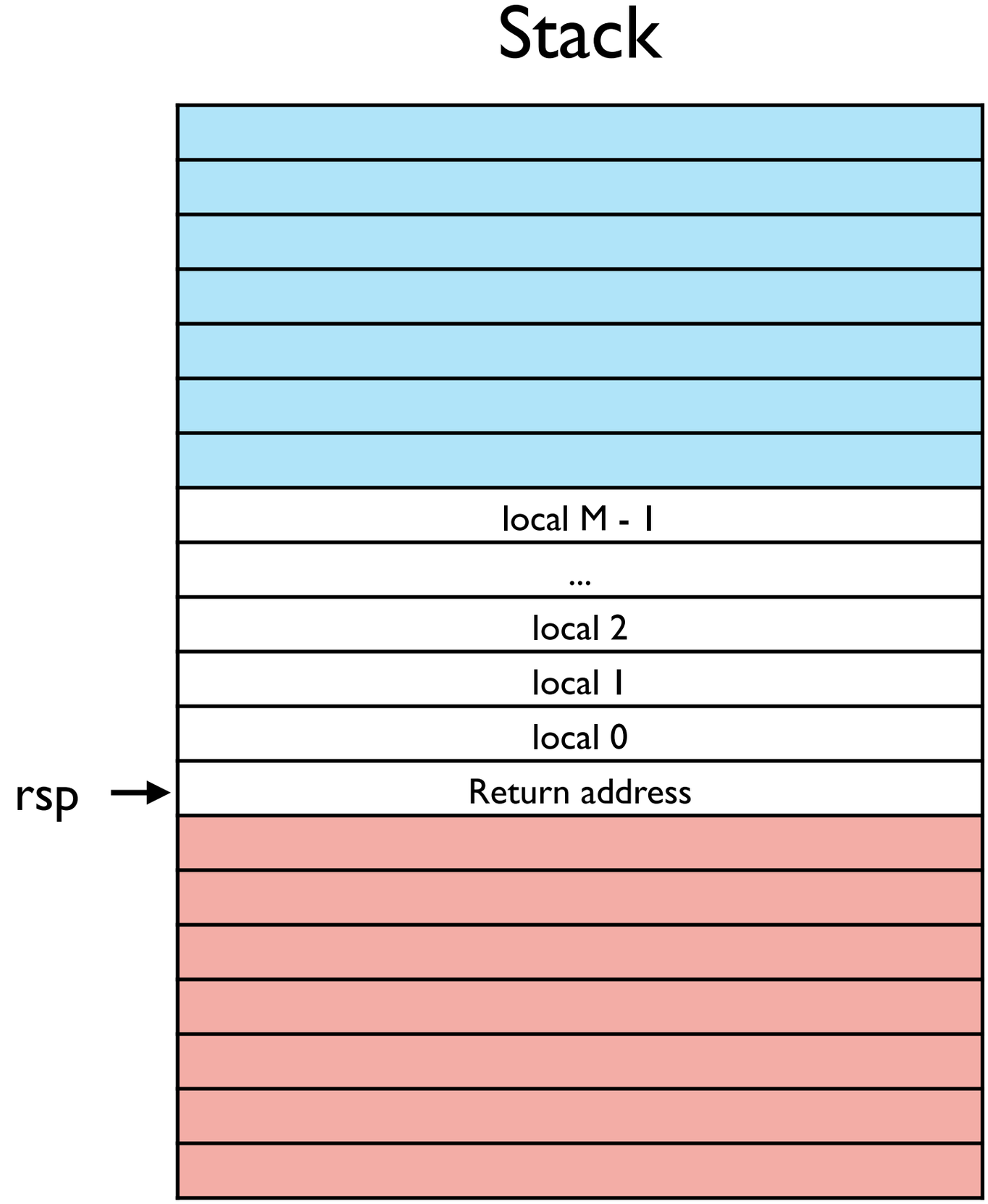
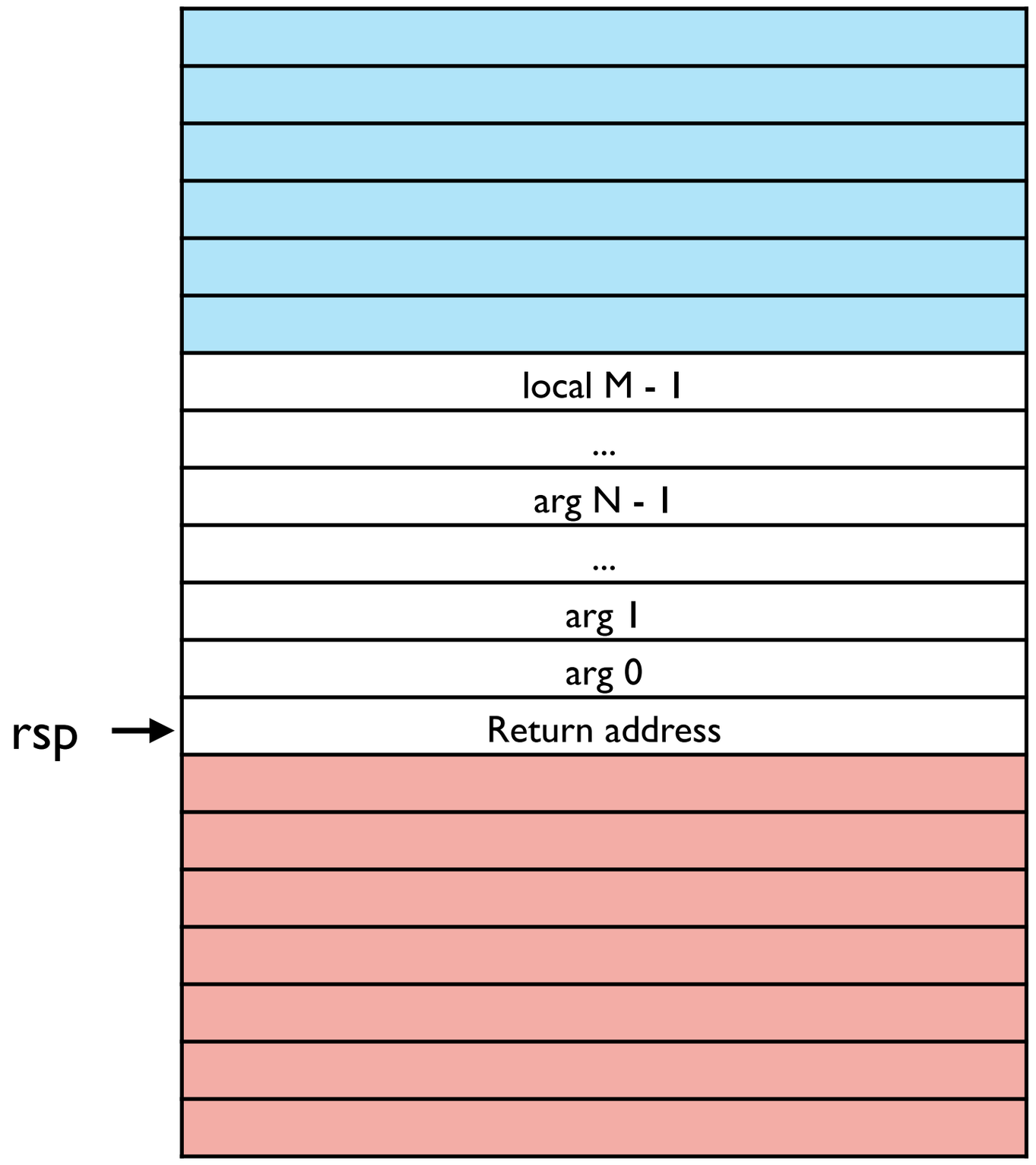


To TAIL call f with

N arguments

if N < M



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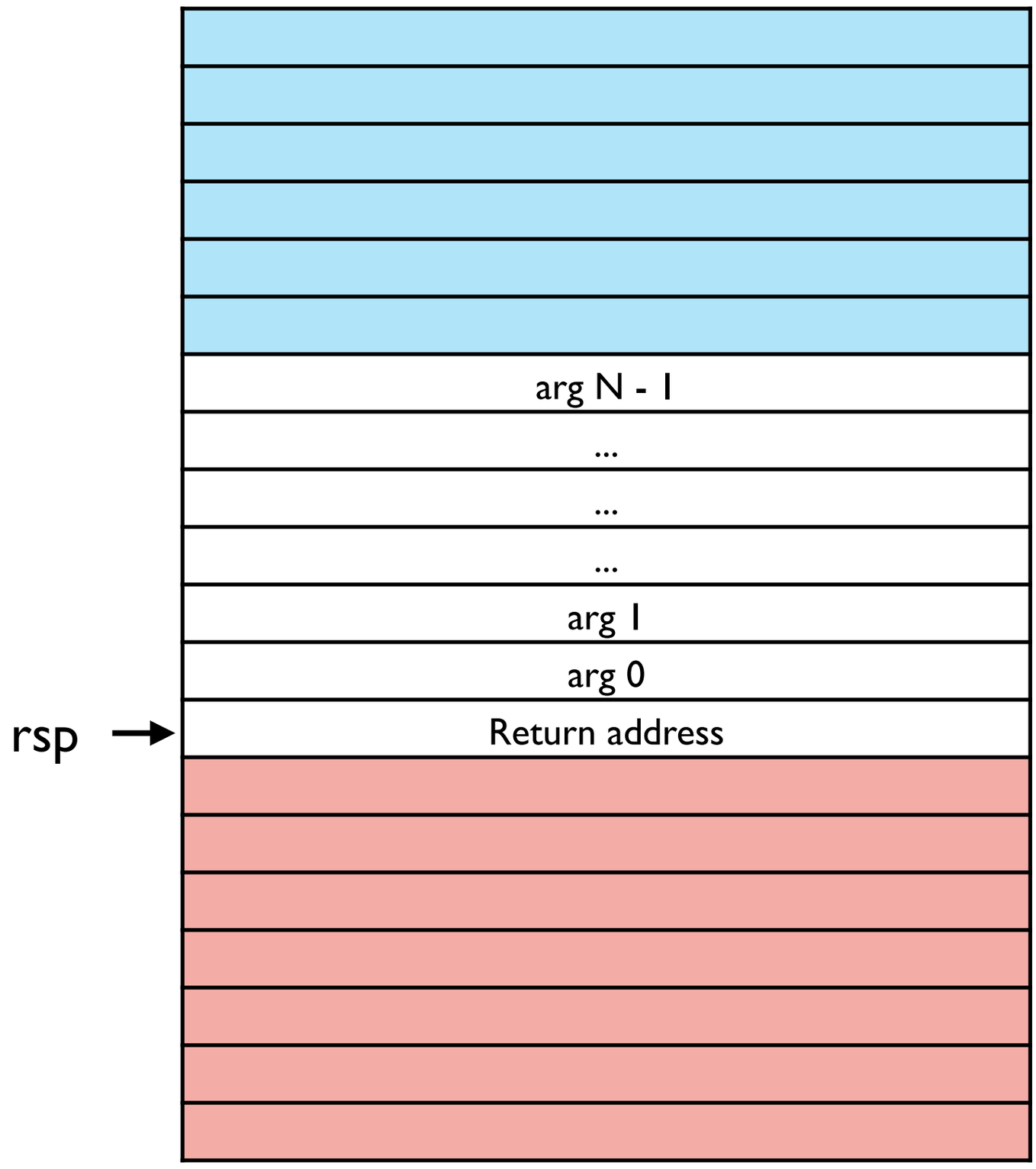
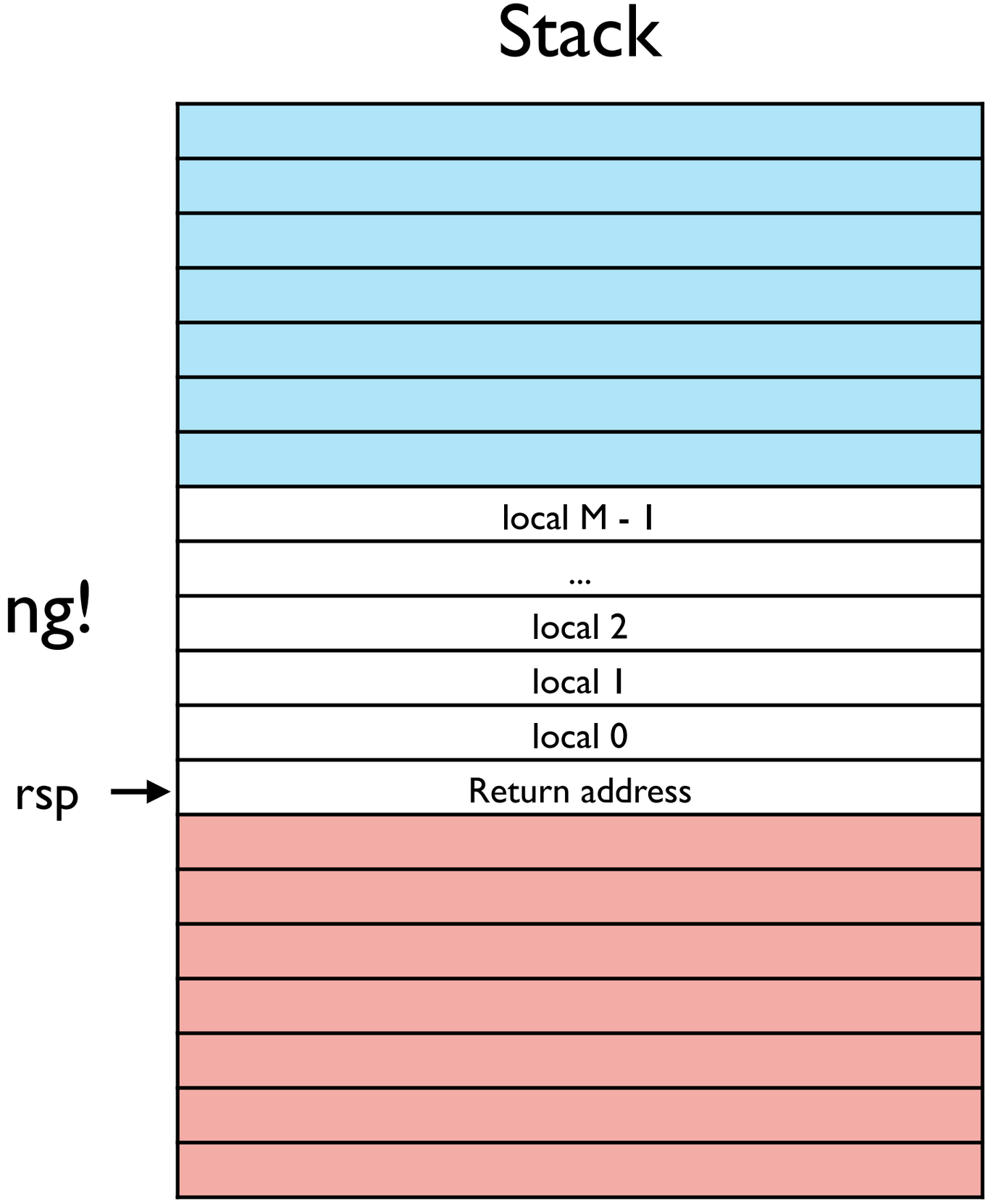
if N > M



To TAIL call f
with

N arguments

Careful not to
overwrite locals we are using!



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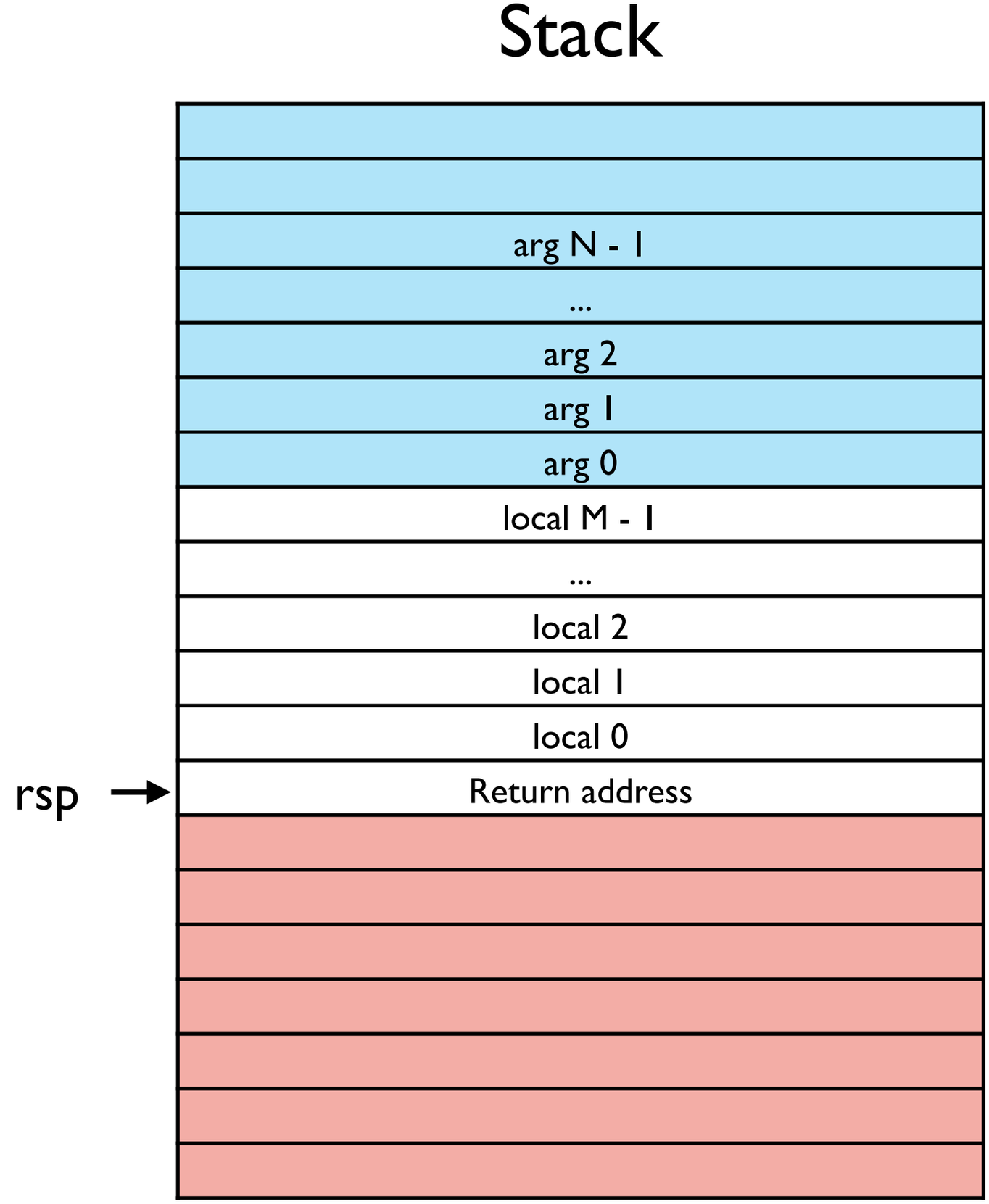

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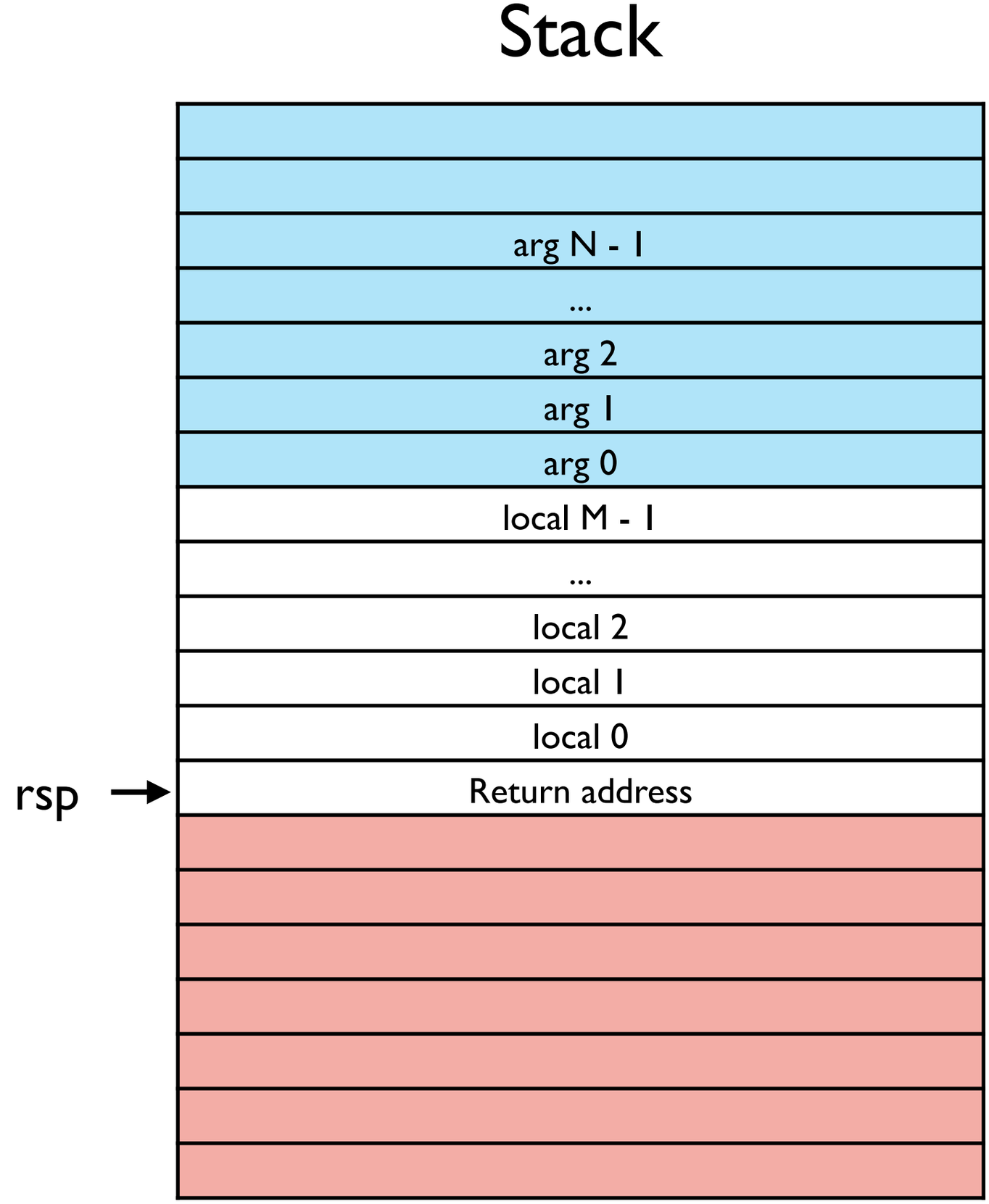

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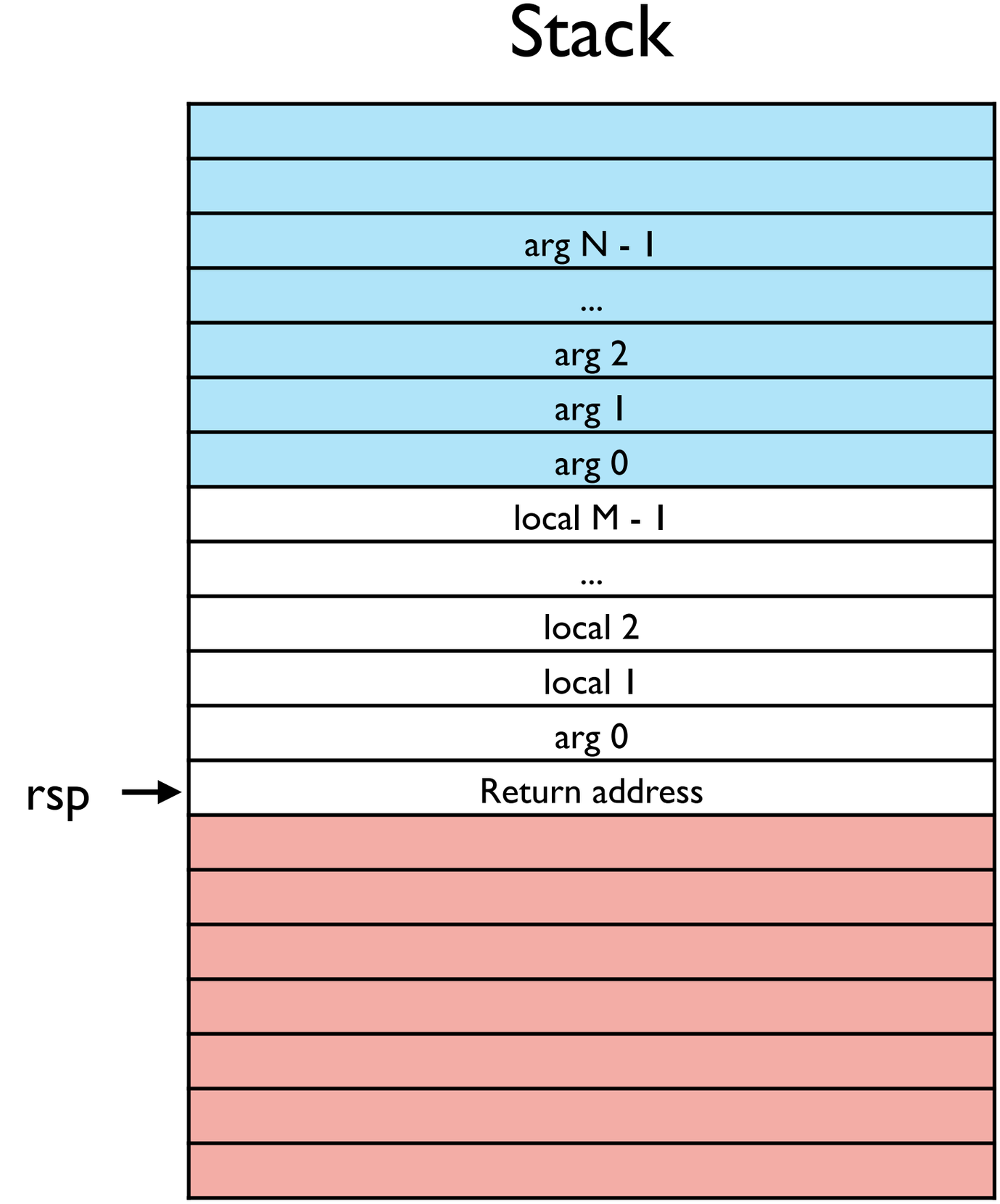

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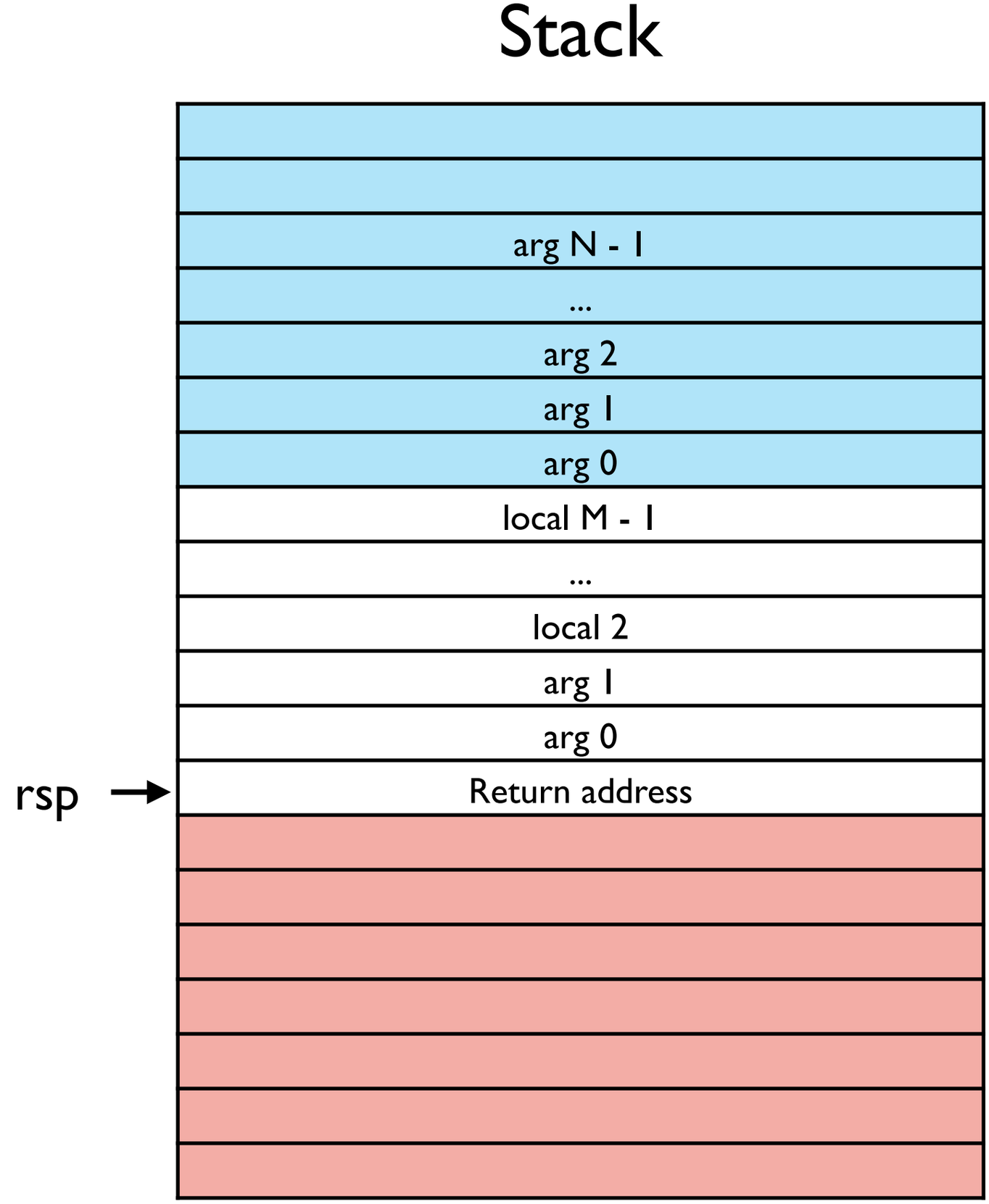

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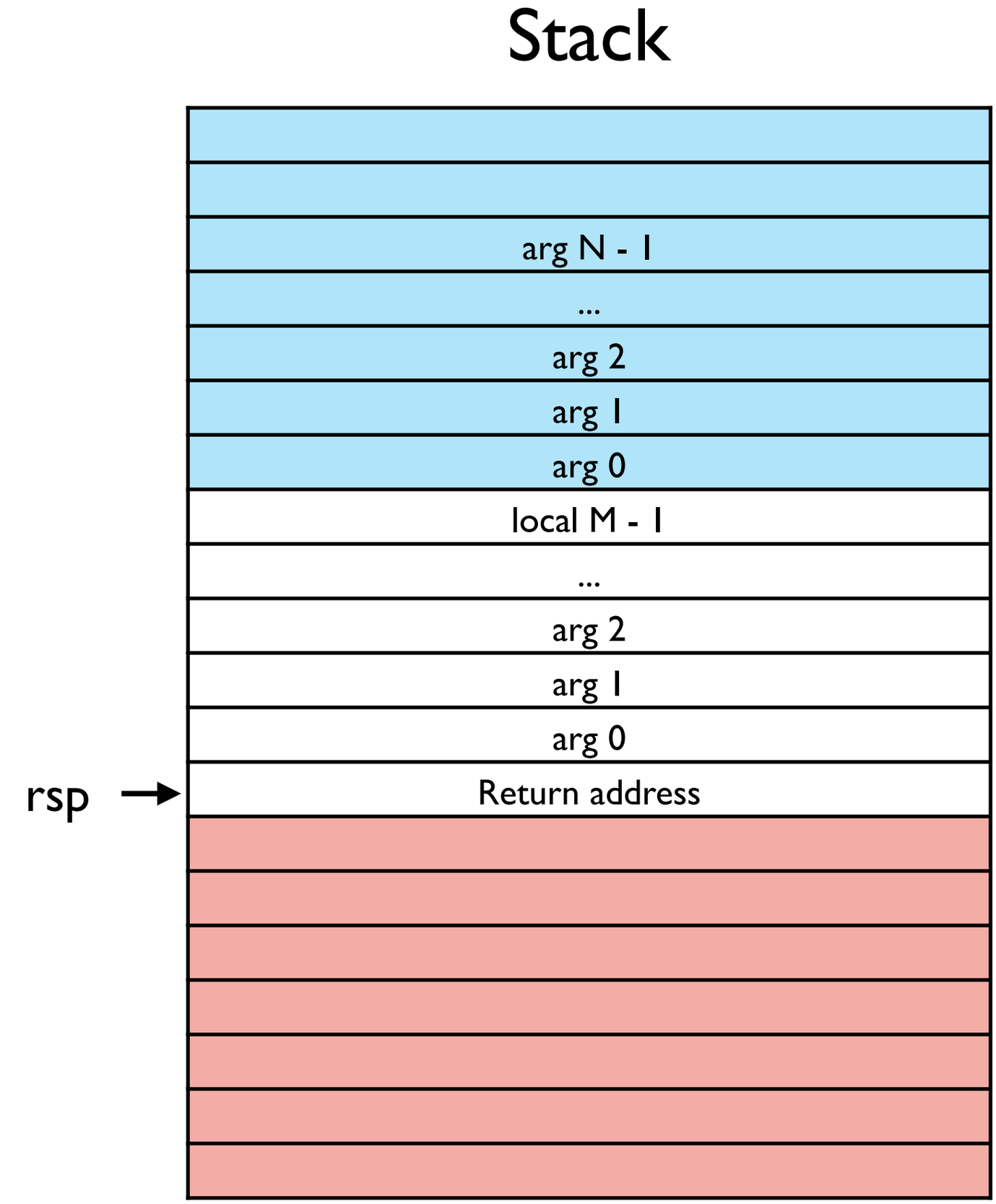

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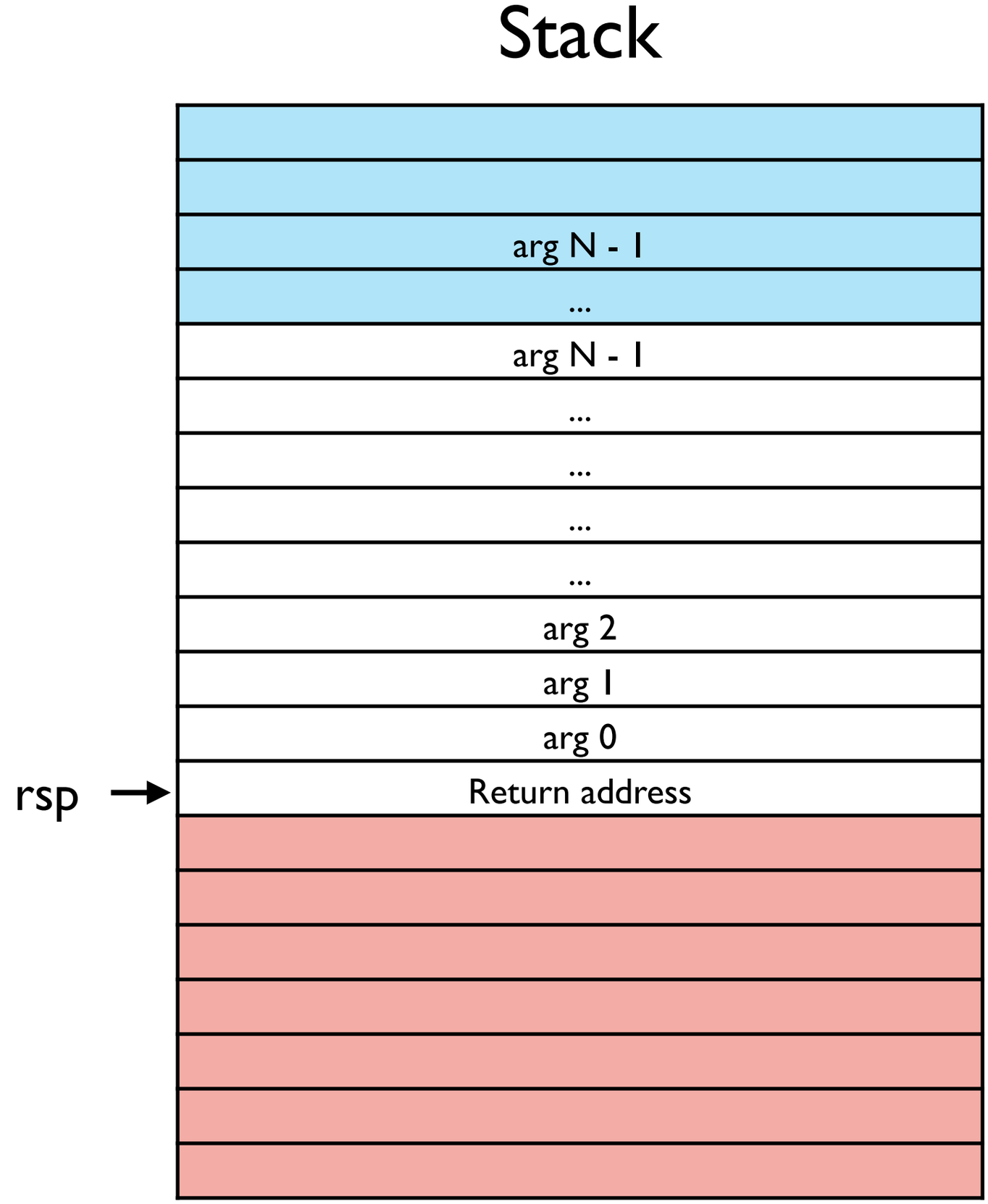

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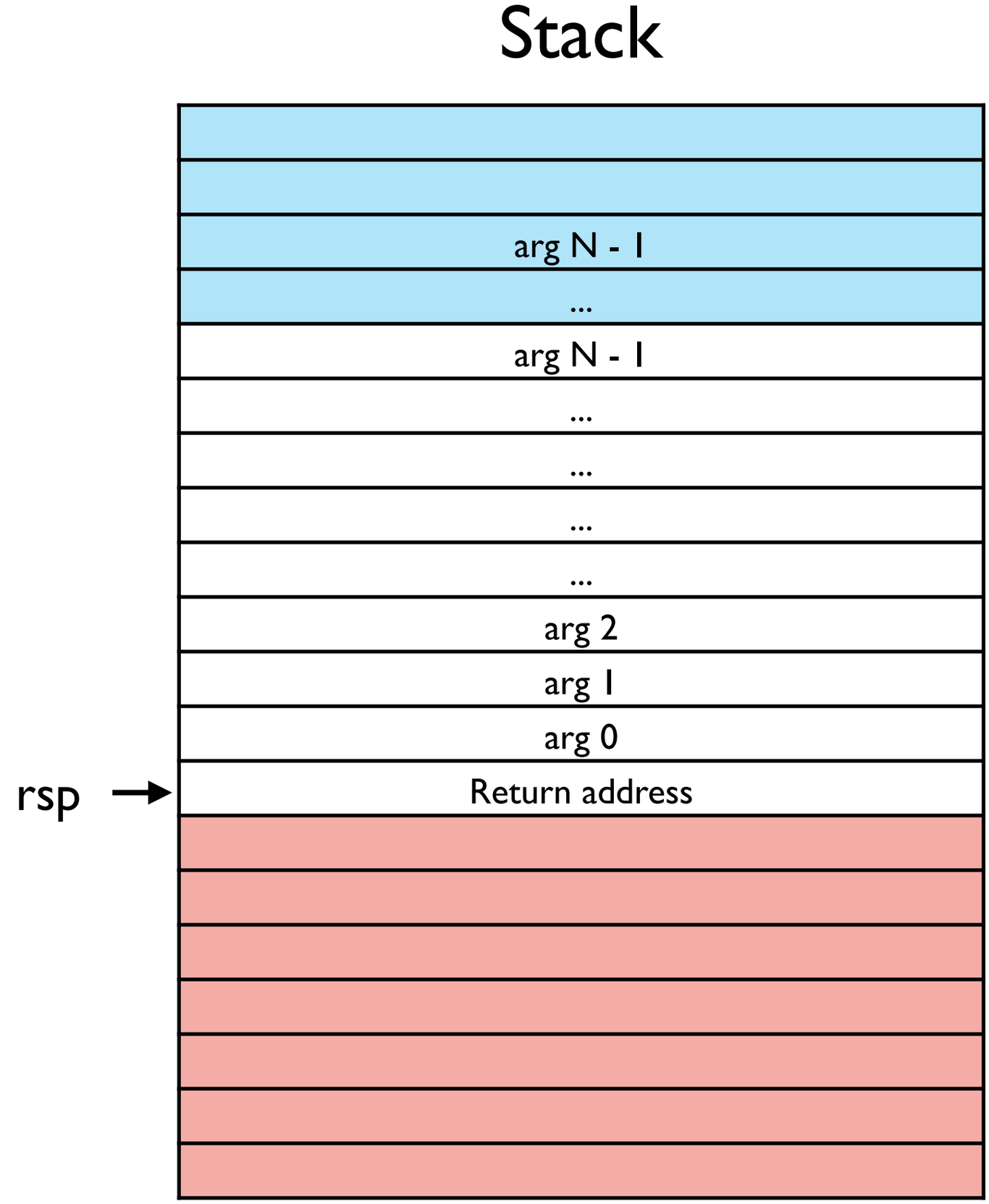
N arguments

```
f(x_0,... x_(N-1))
```



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let y_0 = x_0, ...
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f(y_0, ... y_(N-1))
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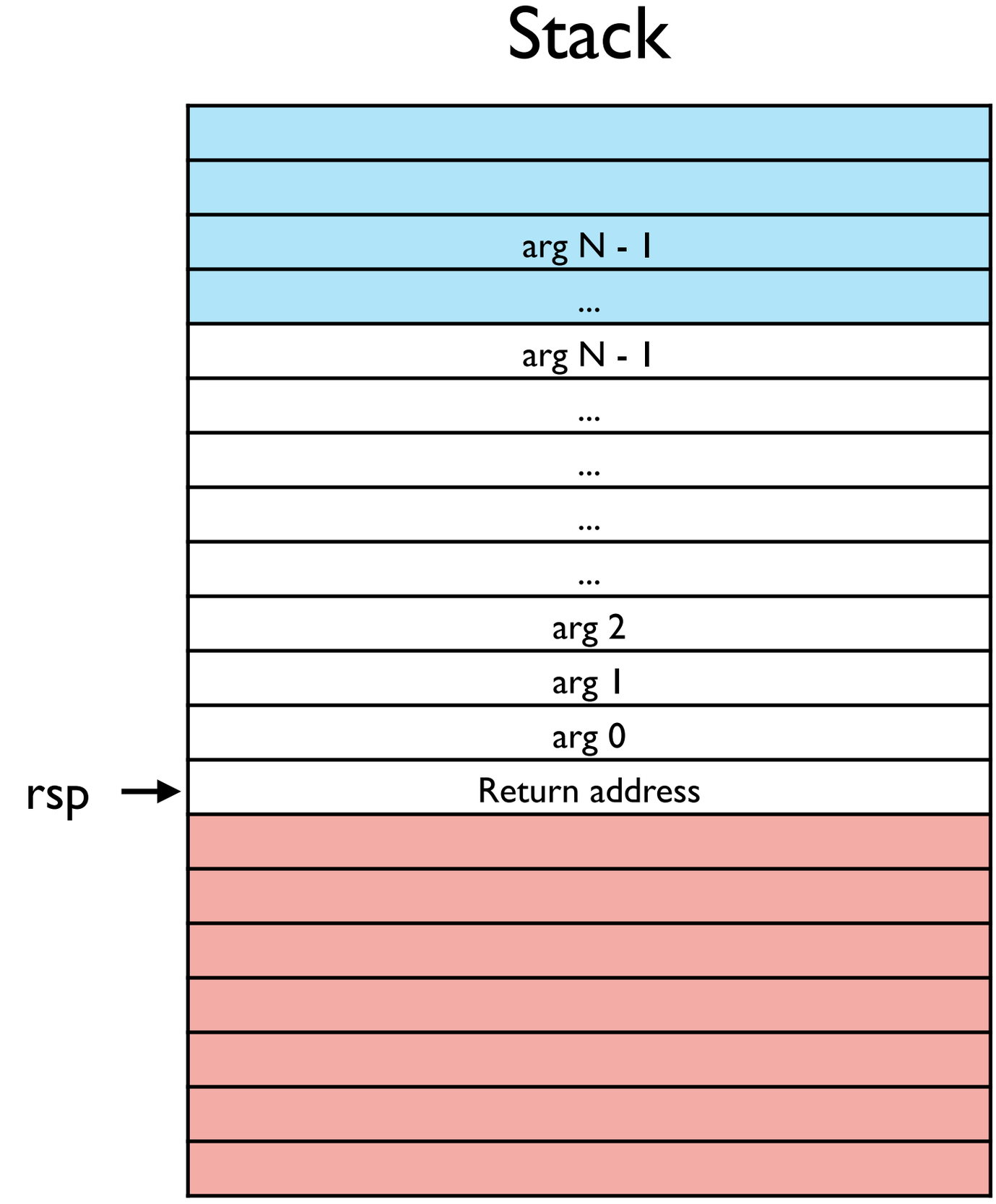

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f(x_0,... x_(N-1))
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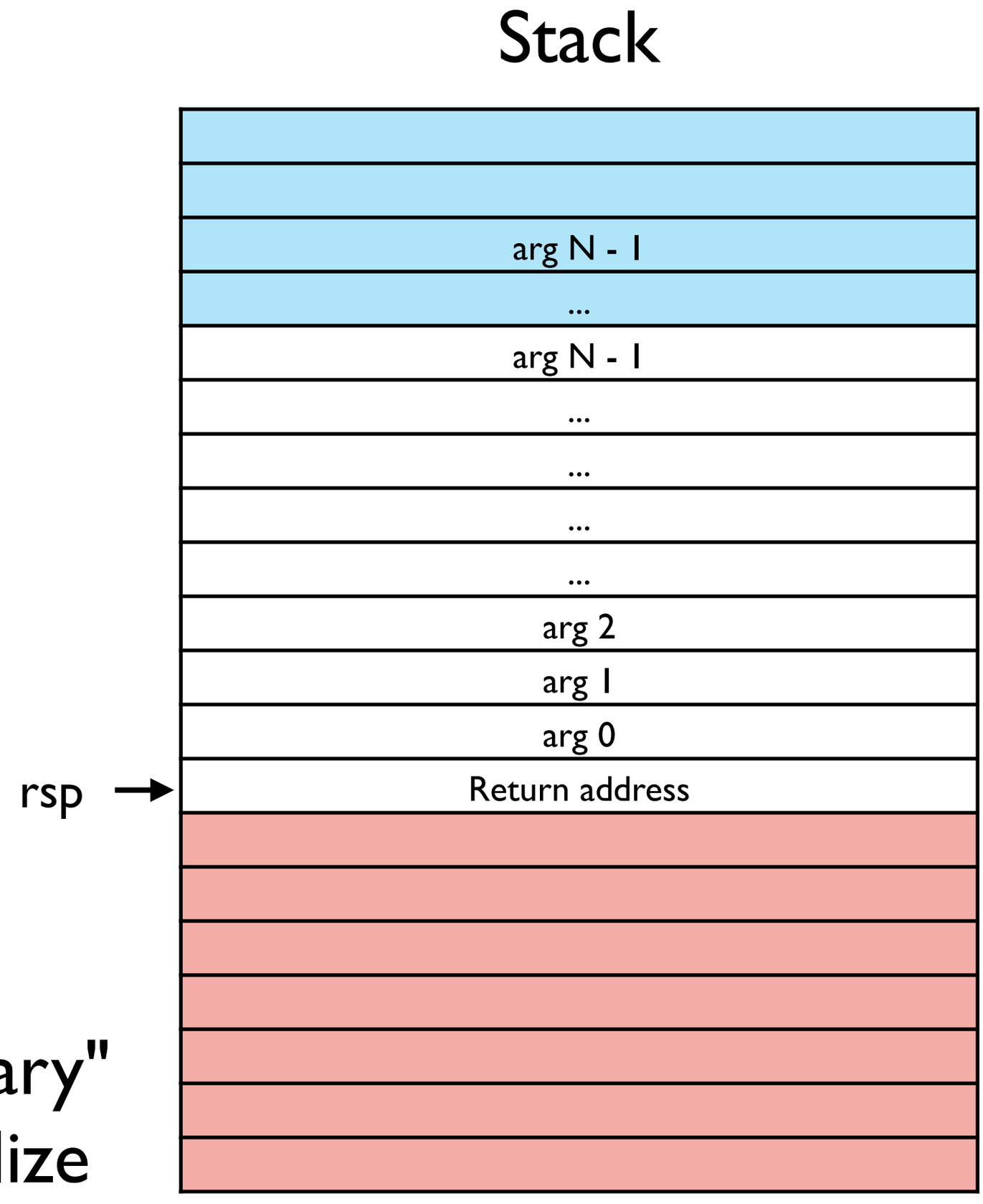
```

generate these "unnecessary" temporaries in sequentialize



Alignment(!)

- We want to be able to call into Rust with the Sys V CC at any time
- But *that* calling convention has an alignment restriction.
- So to make it easy to implement that alignment, we should require a similar alignment so that we don't have to check alignment *dynamically*.
- tradeoff: we use potentially? more space to avoid branches at runtime (v slow)

Alignment(!)

- But Sys V has the following alignment requirement:
  - Upon entry into a function, rsp + 8 % 16 == 0

- To make this statically determined, we add a similar alignment requirement to Snake:
  - Upon entry into a function, rsp % 16 == 0
  - This way if we have no saved locals, we can just call
  - Sometimes need to include a dummy local

Nested Functions

```
def multiply(x, y):
  def loop(i, acc):
    if i == 0:
      acc
    else:
      loop(i - 1,
           acc + x)
  end
  loop(y, 0)
end
```

Nested Functions

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  def loop(i, acc):
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    else:
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  end
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end
```
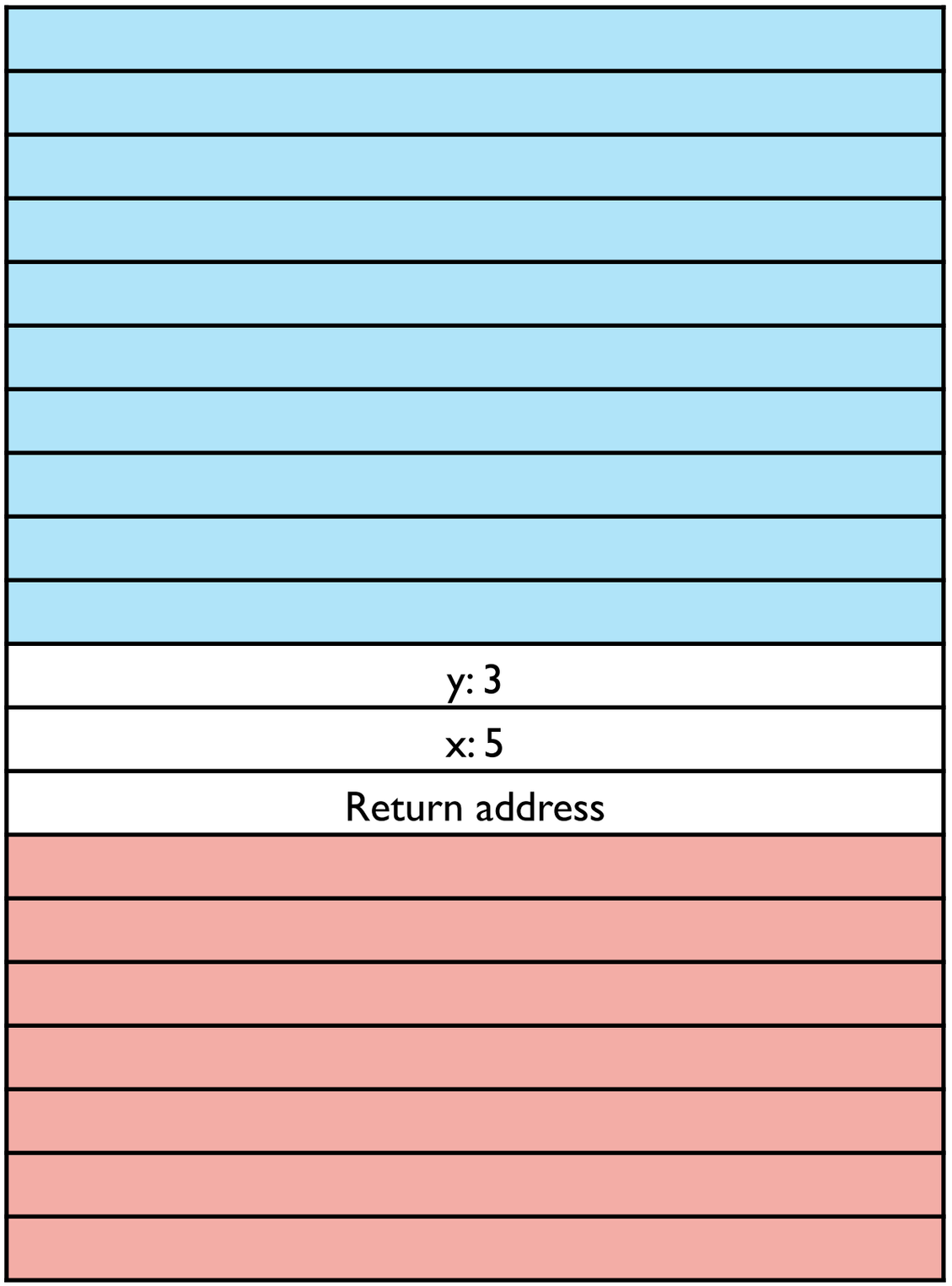
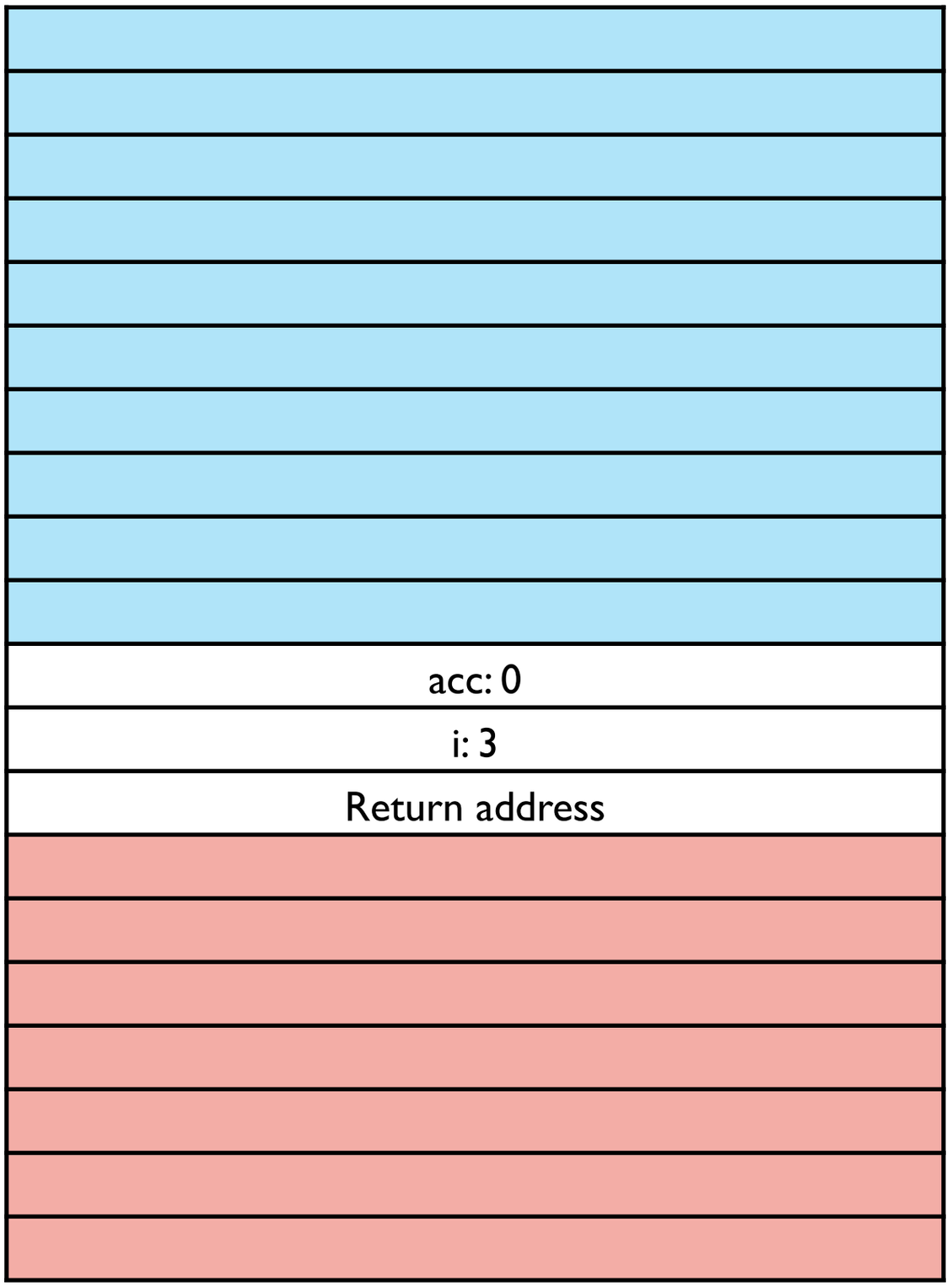



Nested Functions

```
def multiply(x, y):
  def loop(i, acc):
    if i == 0:
      acc
    else:
      loop(i - 1,
           acc + x)
  end
  loop(y, 0)
end
```



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def multiply(x, y):
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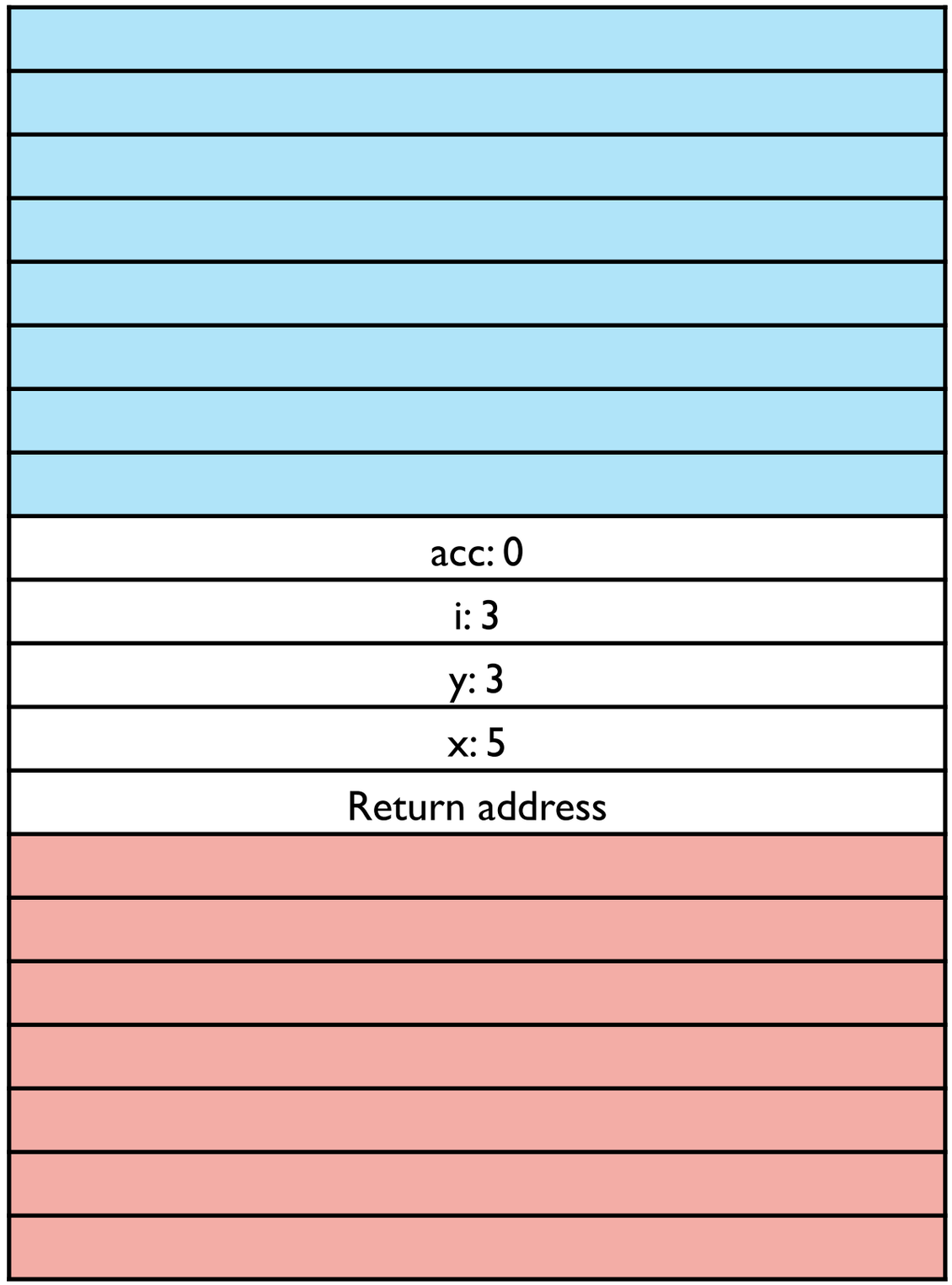
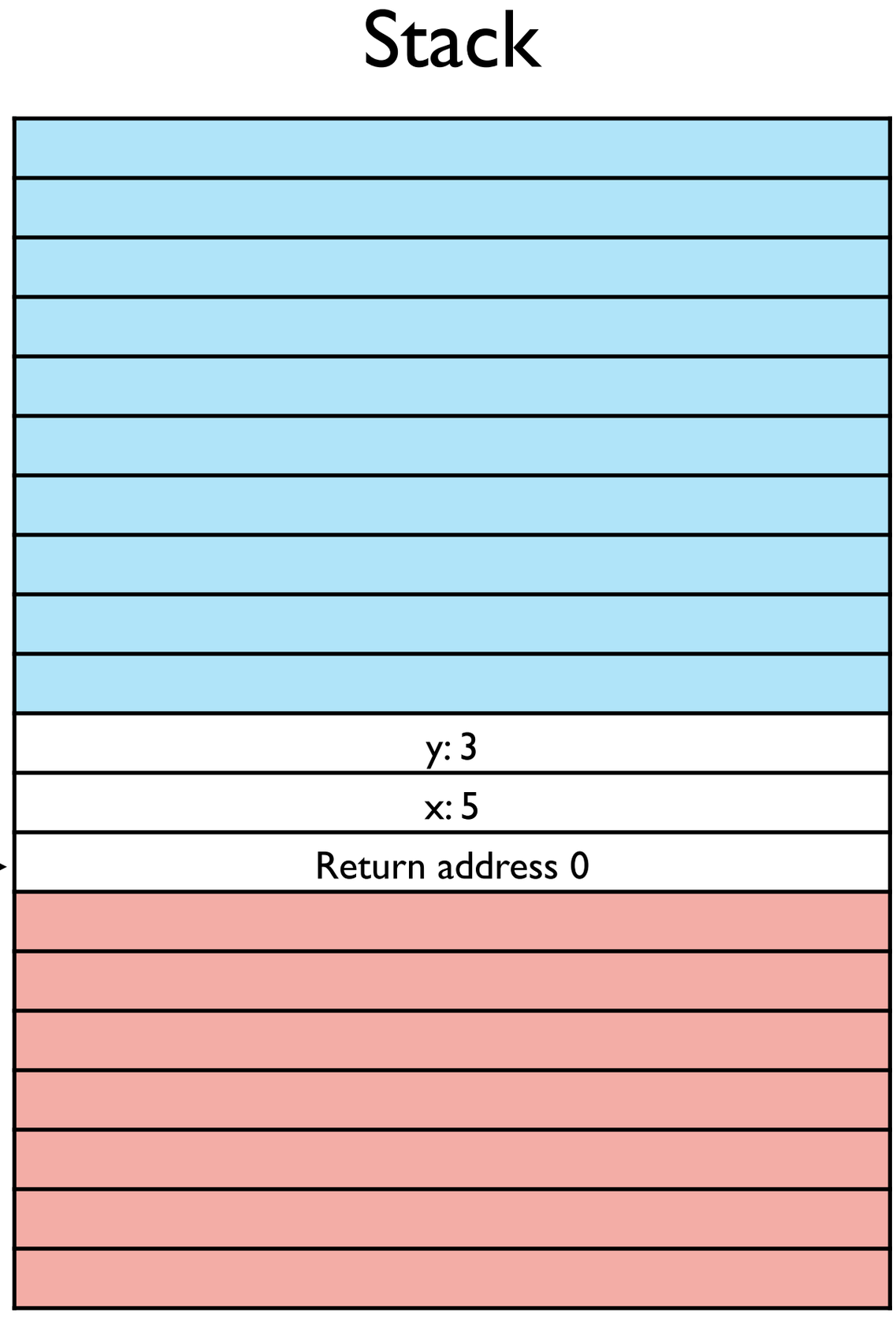


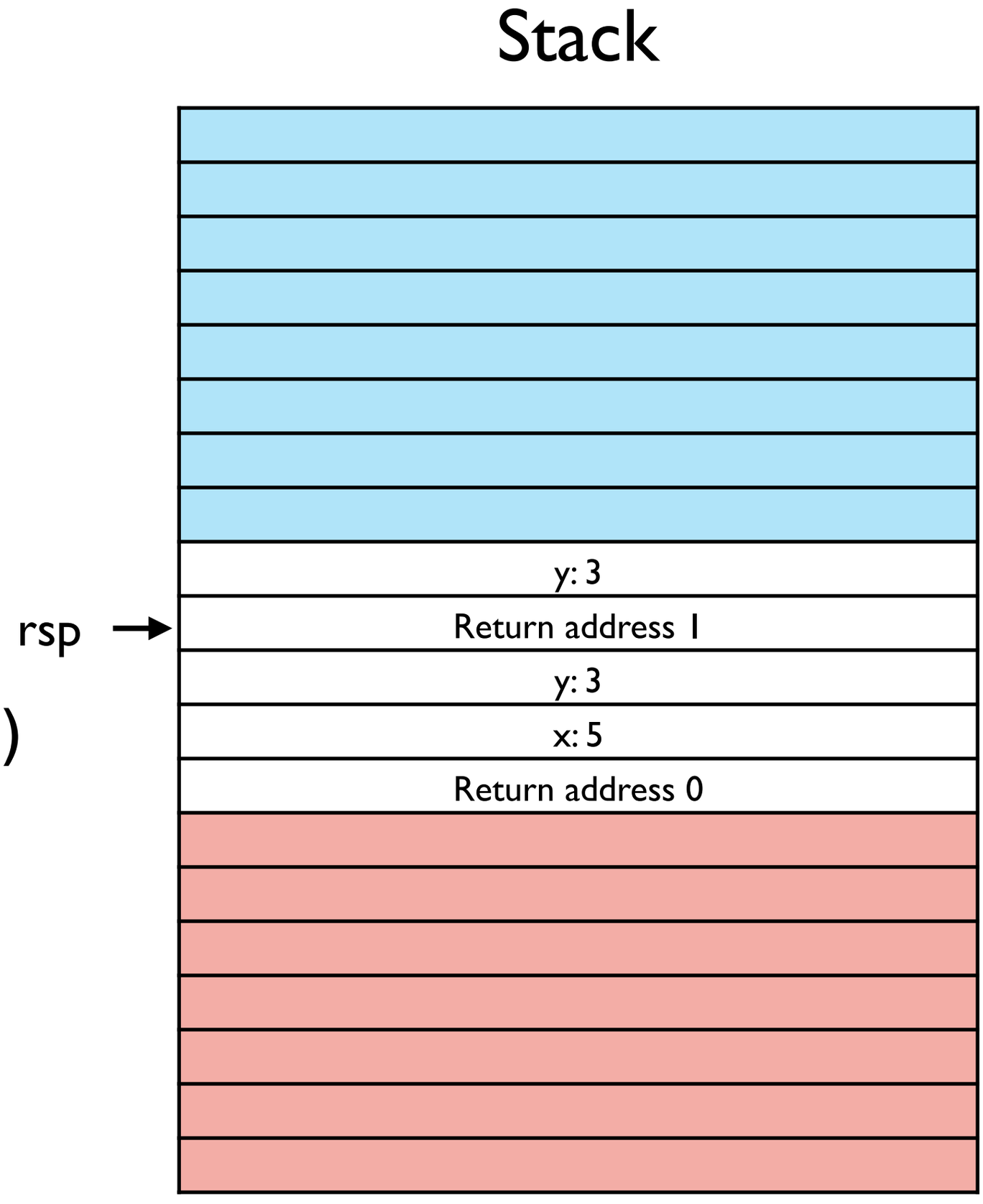
A Problem?

```
def multiply(x, y):
  def loop(y):
    if y == 0:
      0
    else:
      x + loop(y - 1)
  end
end
multiply(5, 3)
```

```
def multiply(x, y):
  def loop(y):
    if y == 0:
      0
    else:
      x + loop(y - 1)
  end
→ loop(y) + 0
end
multiply(5, 3)
```



```
def multiply(x, y):
  def loop(y):
    if y == 0:
      0
    else:
      x + loop(y - 1)
  end
  loop(y) + 0
end
multiply(5, 3)
```



```
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  def loop(y):
  → if y == 0:
      0
    else:
      x + loop(y - 1)
  end
  loop(y) + 0
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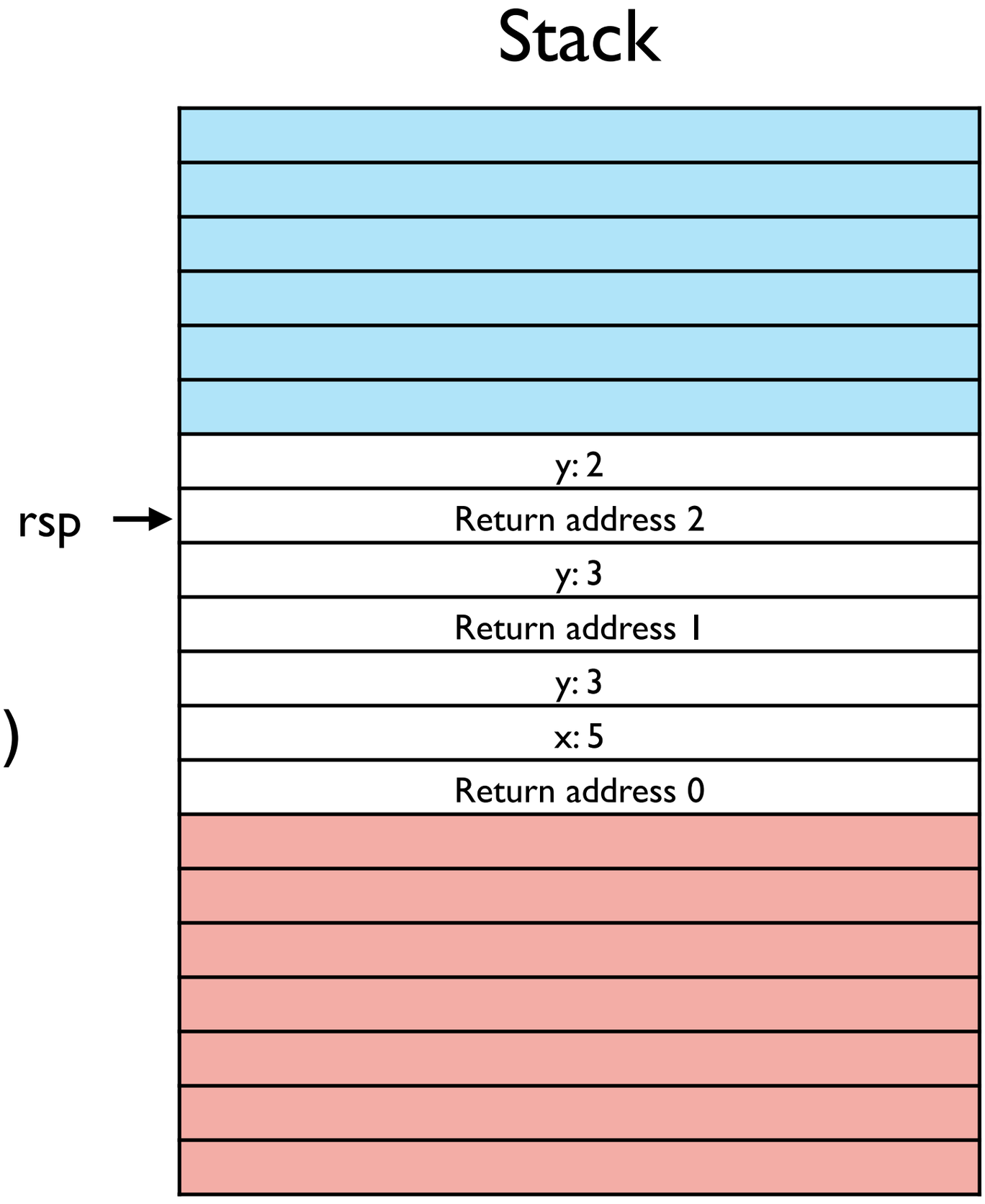

```
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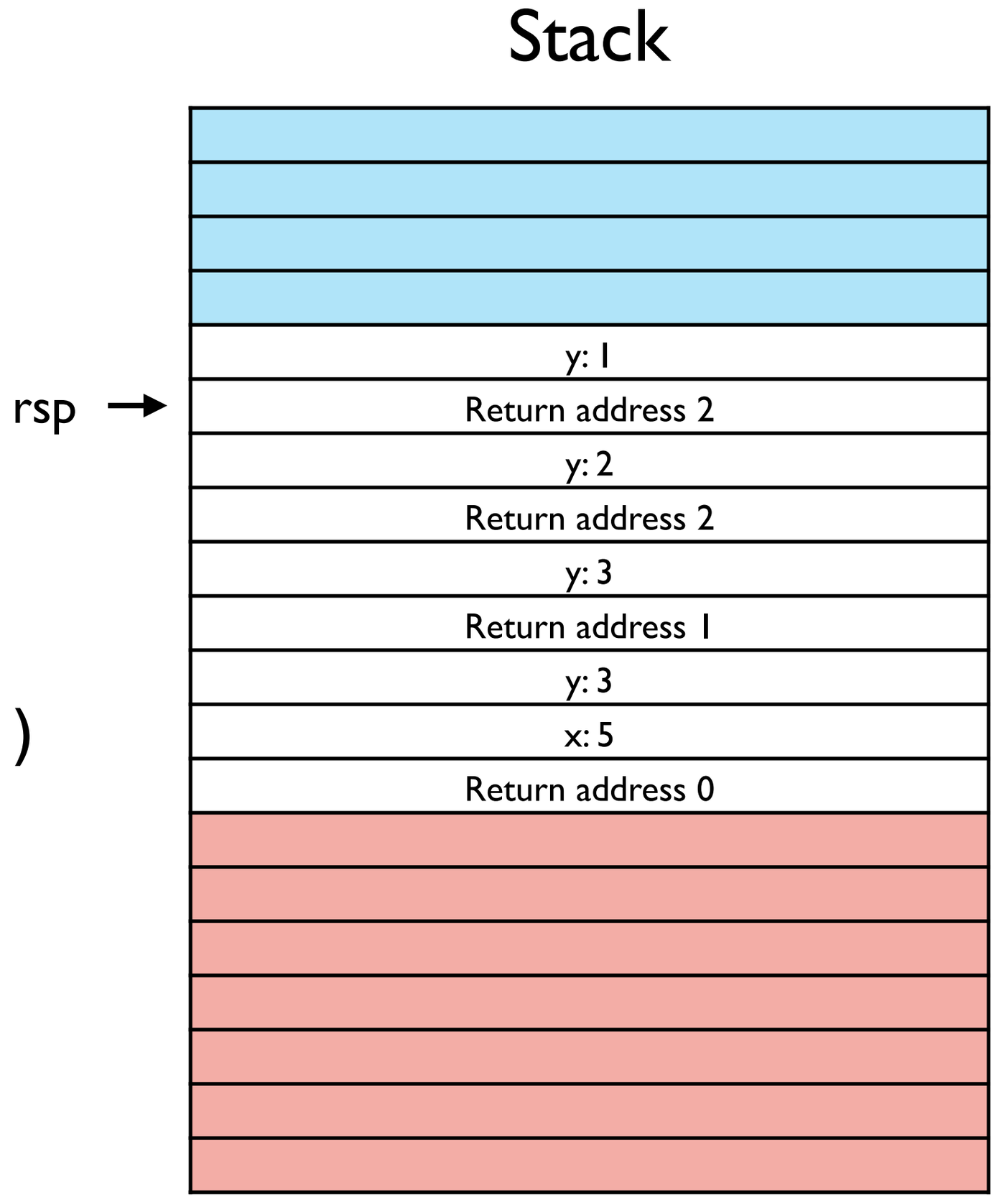
  def loop(y):
  → if y == 0:
      0
    else:
      x + loop(y - 1)
  end
  loop(y) + 0
end
multiply(5, 3)
```



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def multiply(x, y):
  def loop(y):
    if y == 0:
      0
    else:
      x + loop(y - 1)
  end
  loop(y) + 0
end
multiply(5, 3)
```

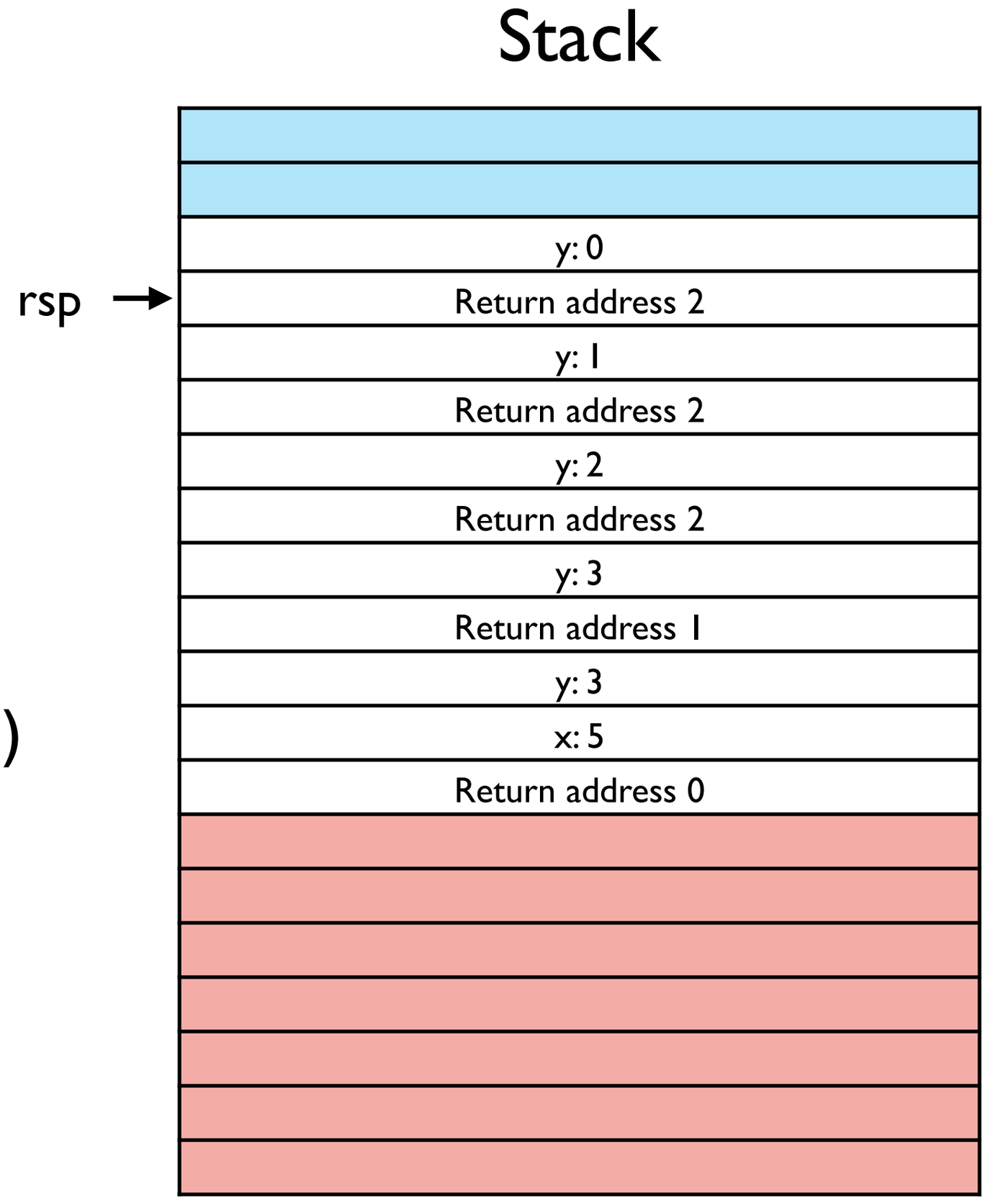

"Lambda Lifting"

```
def multiply(x, y):
  def loop(y):
    if y == 0:
      0
    else:
      x + loop(y - 1)
  end
  loop(y) + 0
end
multiply(5, 3)
```

```
def multiply(x, y):
 loop(x, y) + 0
and
def loop(x, y):
  if y == 0:
    0
  else:
    x + loop(x, y - 1)
end
multiply(5, 3)
```

Summary

- When calling Rust code, use the Sys V
- When calling Snake functions, use the Snake calling convention
  - Tail Call: overwrite our stack frame with arguments
  - Non Tail Call: push return address/args above our stack frame
- Returning:
  - works the same way for both: same "returning convention"
- Alignment
- Lambda Lifting