

# Lecture 9:

# Some practical aspects of compiling C

John Wickerson

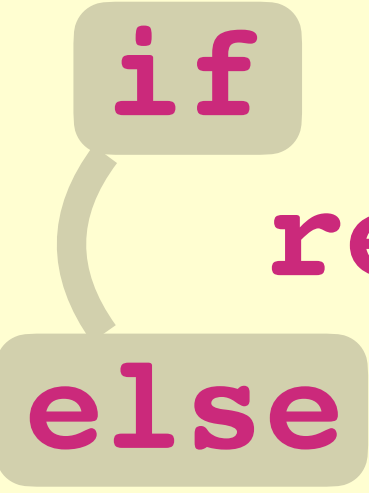
Compilers

# Lecture outline

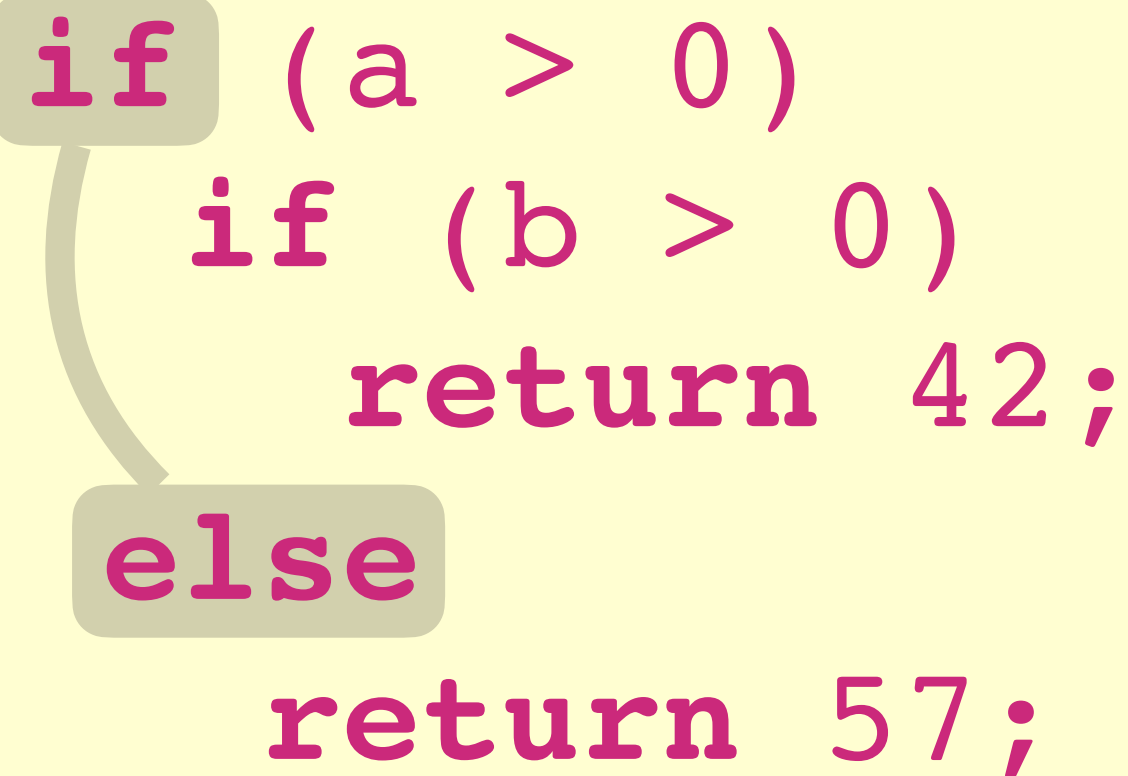
- Parsing C: the *dangling-else* problem.
- Parsing C: the *lexer hack*.
- Generating RISC-V assembly for function calls.

# The dangling-else problem

```
if (a > 0)
    if (b > 0)
        return 42;
    else
        return 57;
```



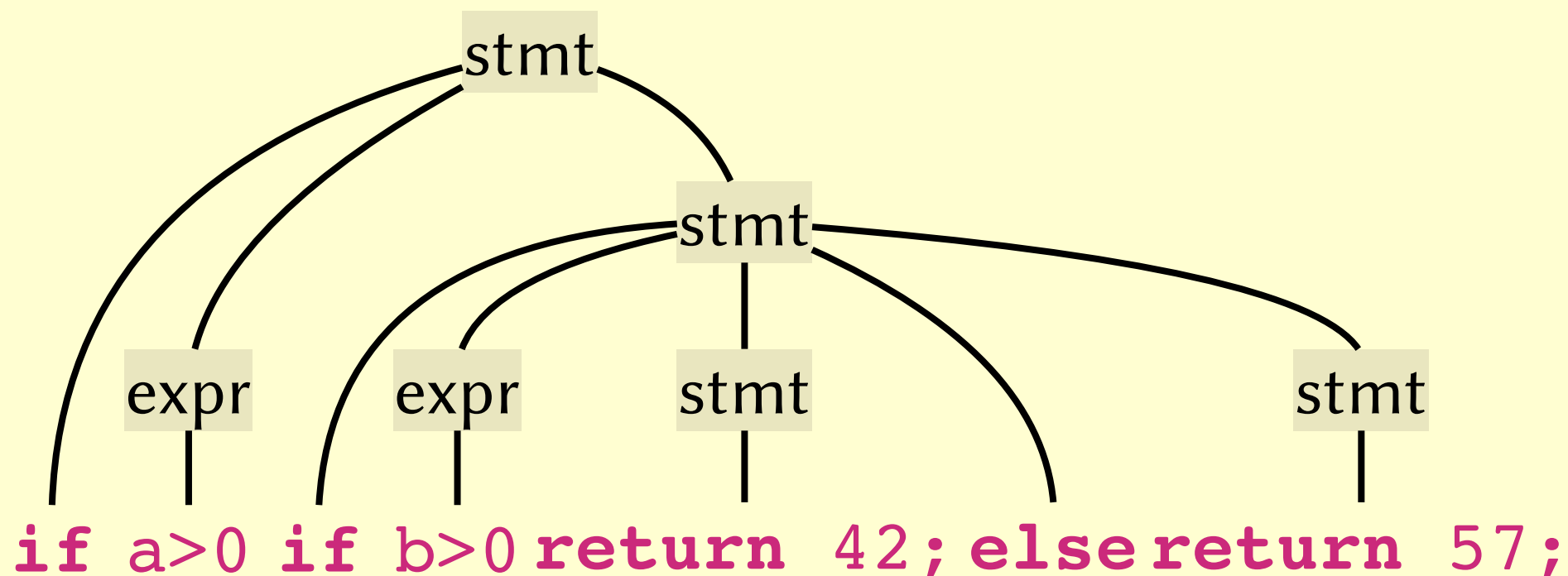
# The dangling-else problem



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if (a > 0)
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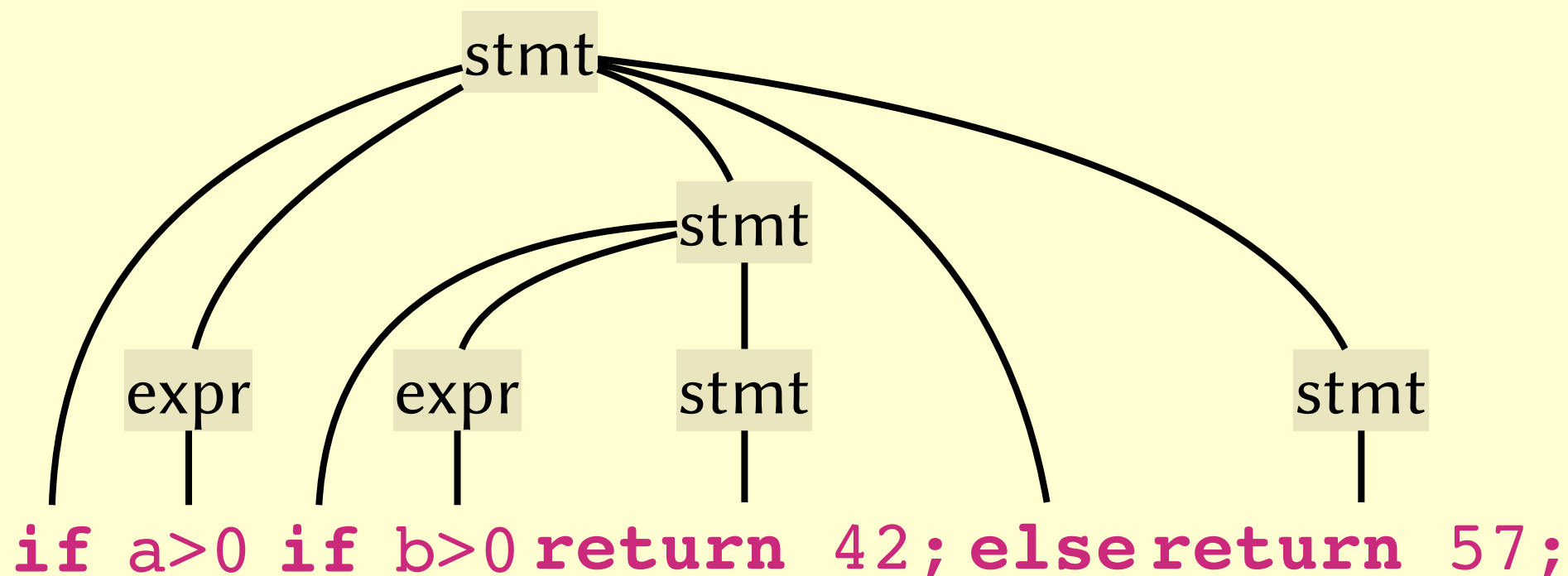
# The dangling-else problem

stmt ::= **if** ( expr ) stmt **else** stmt  
| **if** ( expr ) stmt  
| **return** expr ;



# The dangling-else problem

```
stmt ::= if ( expr ) stmt else stmt  
      | if ( expr ) stmt  
      | return expr ;
```



# The dangling-else problem

```
stmt ::= open_stmt  
      | closed_stmt  
open_stmt ::= if ( expr ) stmt  
            | if ( expr ) closed_stmt else open_stmt  
closed_stmt ::= if ( expr ) closed_stmt else closed_stmt  
              | return expr ;
```

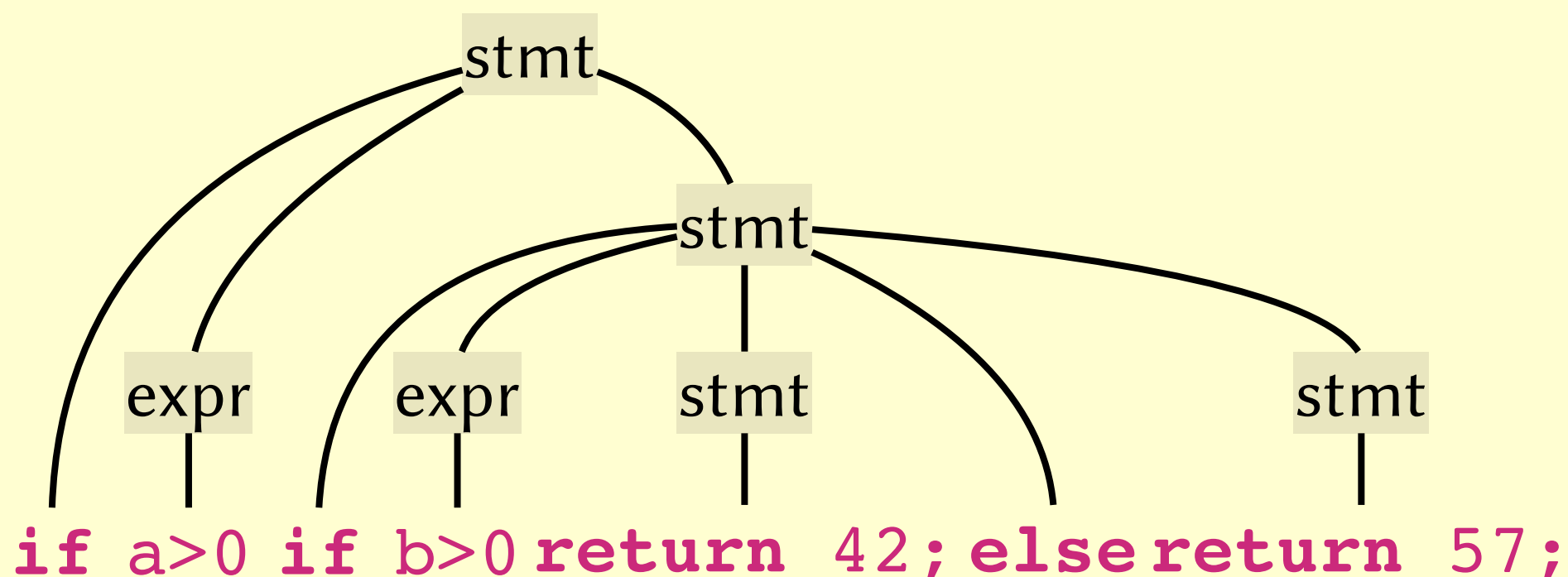
# The dangling-else problem

*%nonassoc* **NOELSE**

*%nonassoc* **else**

*%%*

stmt ::= **if** ( expr ) stmt **else** stmt  
| **if** ( expr ) stmt *%prec* **NOELSE**  
| **return** expr ;





# Lecture outline

- ✓ Parsing C: the *dangling-else* problem.
- Parsing C: the *lexer hack*.
- Generating RISC-V assembly for function calls.

# C is not context-free!

```
int a, b;
```

```
a * b;
```

# C is not context-free!

```
typedef int a;
```

```
a * b;
```

# The lexer hack

- When the parser sees a typedef instruction, e.g.  
`typedef int a;`  
it adds `a` to a list of 'type variables'.
- When the lexer sees a token that looks like an identifier, it looks up the matched string in this list. If it is there, it returns a **TYPEID** token, and otherwise it returns an **ID** token.
- Thus the parser can distinguish between  
`TYPEID * ID; // declaring a pointer to a typedef'd type`  
and  
`ID * ID; // a multiplication expression`

# Lecture outline

- ✓ Parsing C: the *dangling-else* problem.
- ✓ Parsing C: the *lexer hack*.
  - Generating RISC-V assembly for function calls.

# Function calls

```
int f (int a, int b,  
      int c, int d) {  
    int t=6;  
    int u=7;  
    return 42;  
}
```

```
int main () {  
    f(1,2,3,4);  
}
```

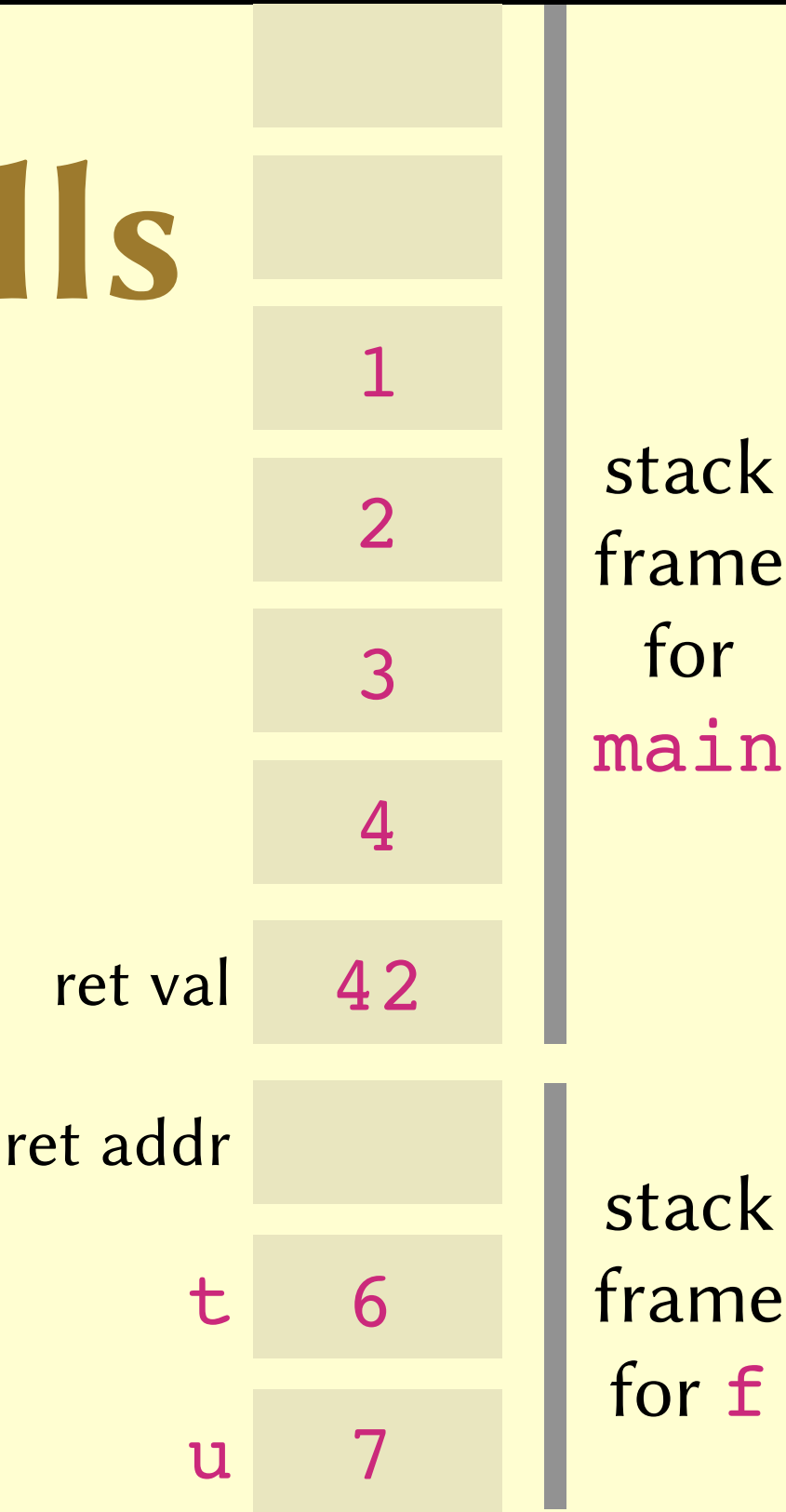
```
f:  
    local t, 4;  
    local u, 4;  
    t = 6;  
    u = 7;  
    return 42;
```

```
main:  
    param 1;  
    param 2;  
    param 3;  
    param 4;  
    call f, 4;
```

# Function calls

```
f:
  local t, 4;
  local u, 4;
  t = 6;
  u = 7;
  return 42;
```

```
main:
  param 1;
  param 2;
  param 3;
  param 4;
  call f, 4;
```




# ABI

- An **Application Binary Interface** defines:
  - how parameters are passed to functions,
  - which registers need to be preserved by a function call,
  - how the fields of a **struct** are laid out,
  - and so on.
- Here's an illustration of the ABI used by GCC when targeting RISC-V...



C source #1 ✎ ✕



A ▾  C ▾

```

1  int f (int a, int b, int c, int d) {
2      int t=6;
3      int u=7;
4      return 42;
5  }
6
7  int main () {
8      f(1,2,3,4);
9  }
10

```


RISC-V (64-bits) gcc (trunk) (Editor #1) ✎ ✕

RISC-V (64-bits) gcc (trunk) ▾  

-std=c90 -O3 -march=rv32imfd -mabi=ilp32d ▾



A ▾  Output... ▾  Filter... ▾  Libraries  Overrides + Add new... ▾  Add tool... ▾







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```



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A ▾  Output... ▾  Filter... ▾  Libraries  Overrides  Add new... ▾  Add tool... ▾

```
1 f:
2     li    a0,42
3     ret
4 main:
5     ret
```



C source #1  

A ▾  + ▾  C ▾





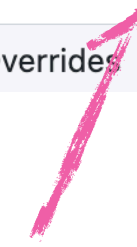
```


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
C source #1  



A ▾    C ▾


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```

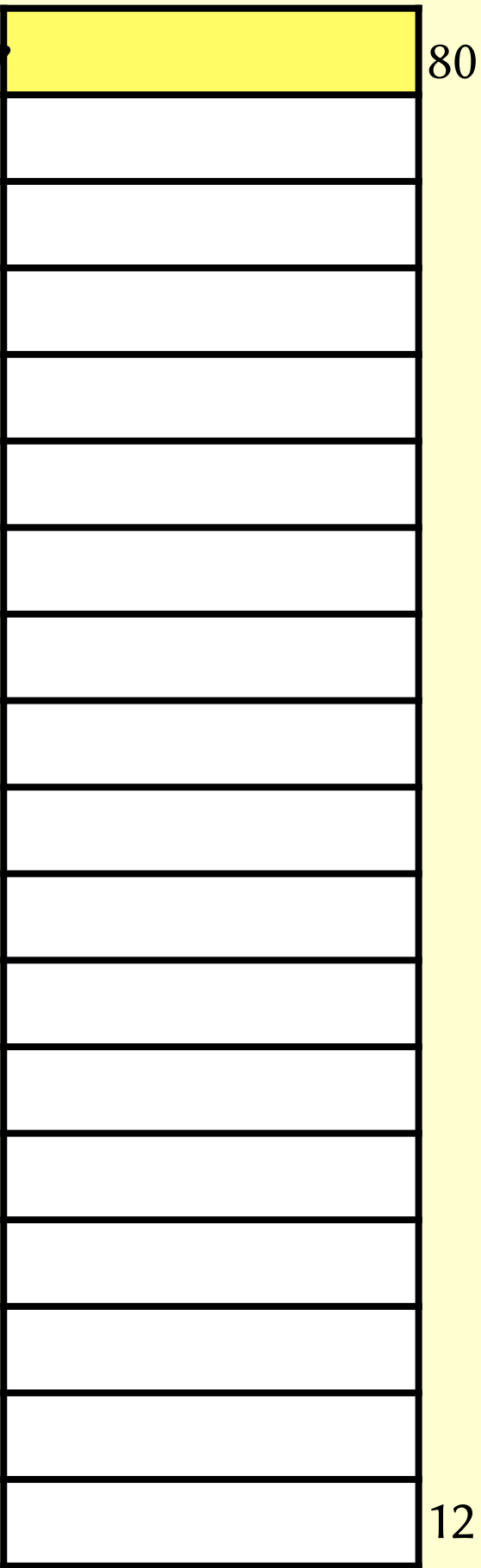
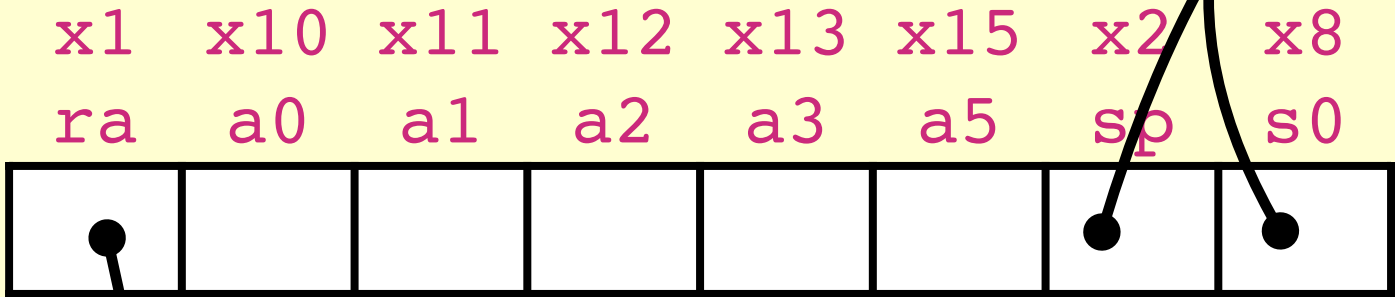
1 f:
2     addi    sp,sp,-48
3     sw      ra,44(sp)
4     sw      s0,40(sp)
5     addi    s0,sp,48
6     sw      a0,-36(s0)
7     sw      a1,-40(s0)
8     sw      a2,-44(s0)
9     sw      a3,-48(s0)
10    li      a5,6
11    sw      a5,-20(s0)
12    li      a5,7
13    sw      a5,-24(s0)
14    li      a5,42
15    mv      a0,a5
16    lw      ra,44(sp)
17    lw      s0,40(sp)
18    addi    sp,sp,48
19    jr      ra
20 main:
21    addi    sp,sp,-16
22    sw      ra,12(sp)
23    sw      s0,8(sp)
24    addi    s0,sp,16
25    li      a3,4
26    li      a2,3
27    li      a1,2
28    li      a0,1
29    call    f
30    nop
31    mv      a0,a5
32    lw      ra,12(sp)
33    lw      s0,8(sp)
34    addi    sp,sp,16
35    jr      ra

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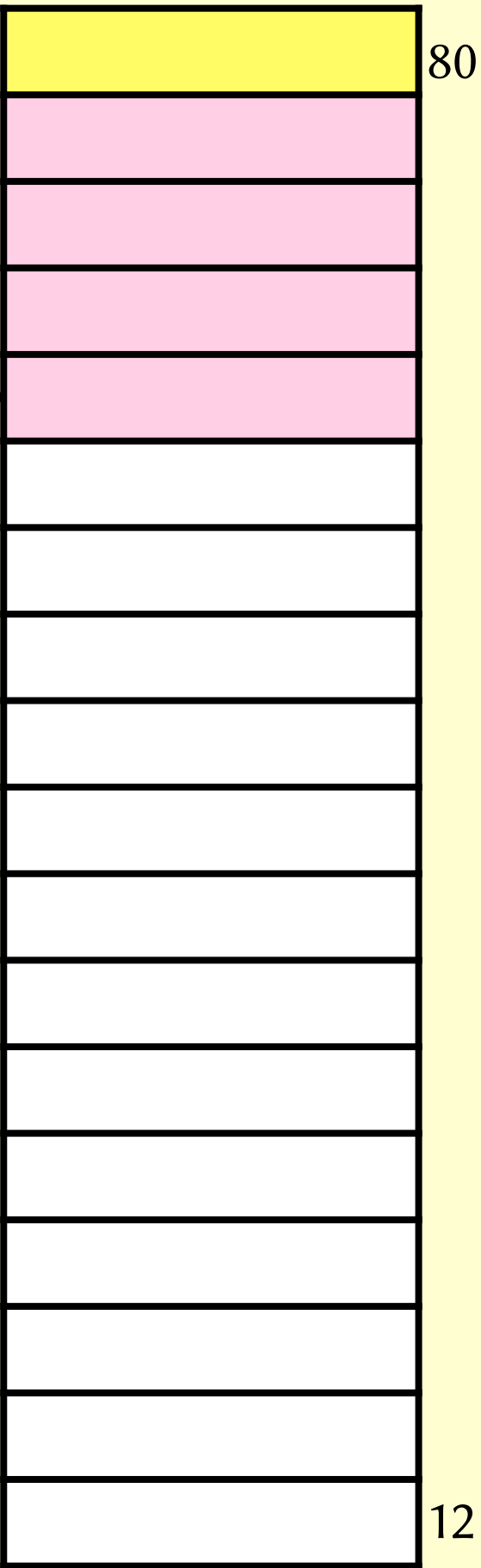
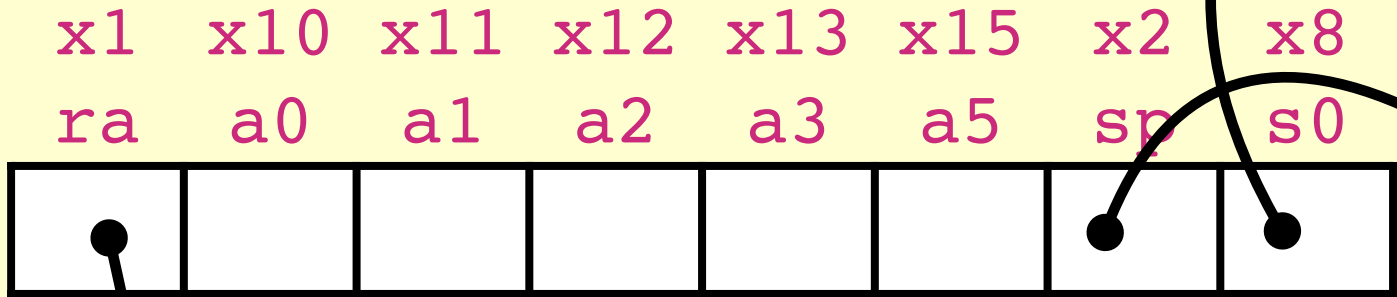
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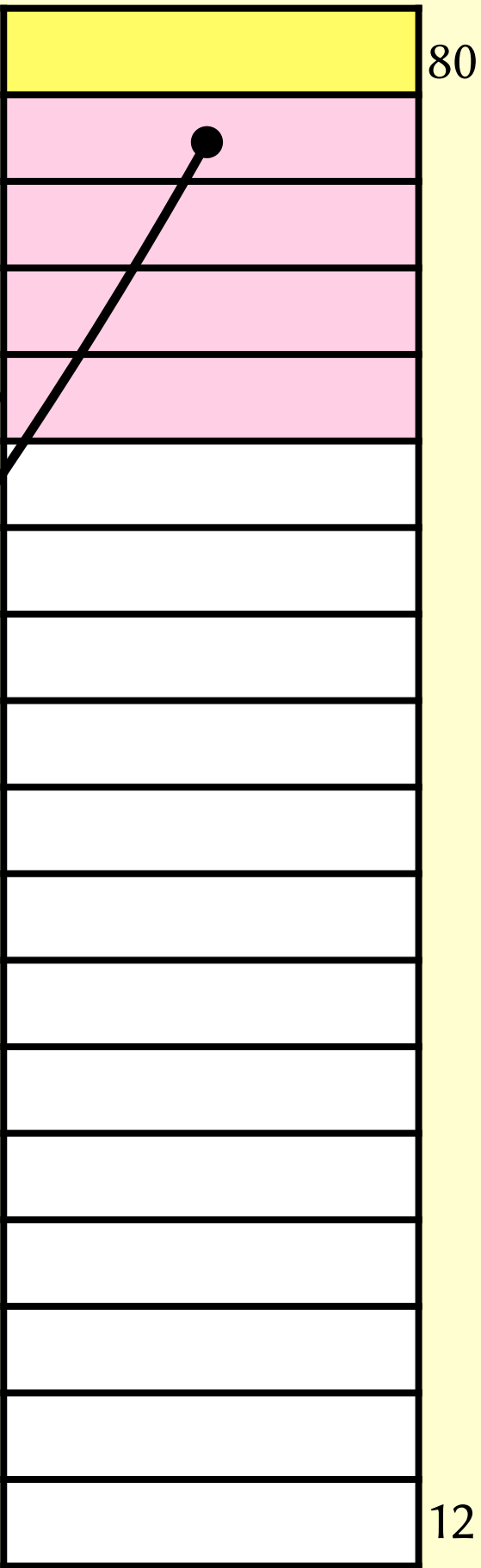
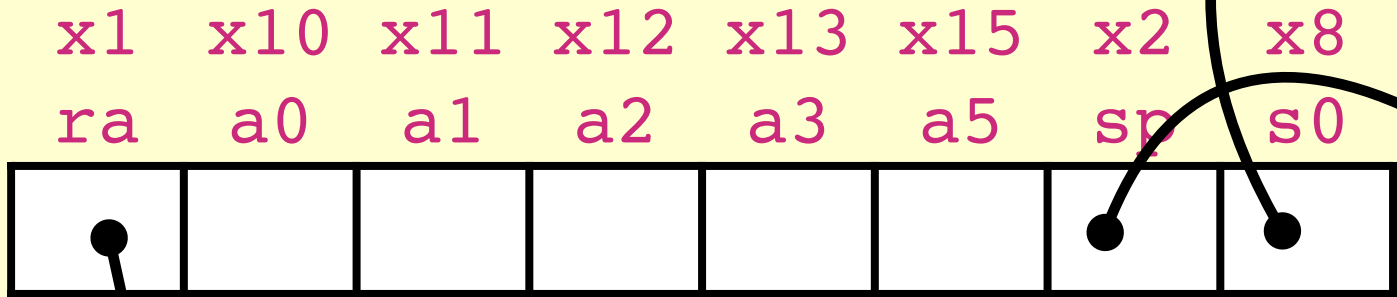
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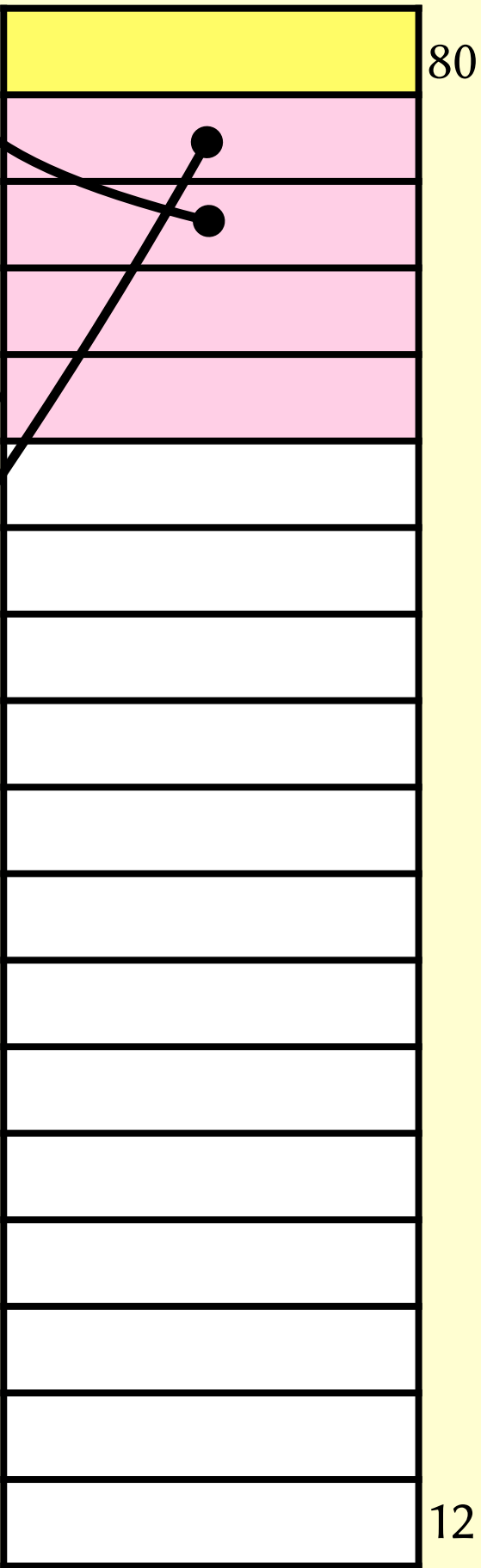
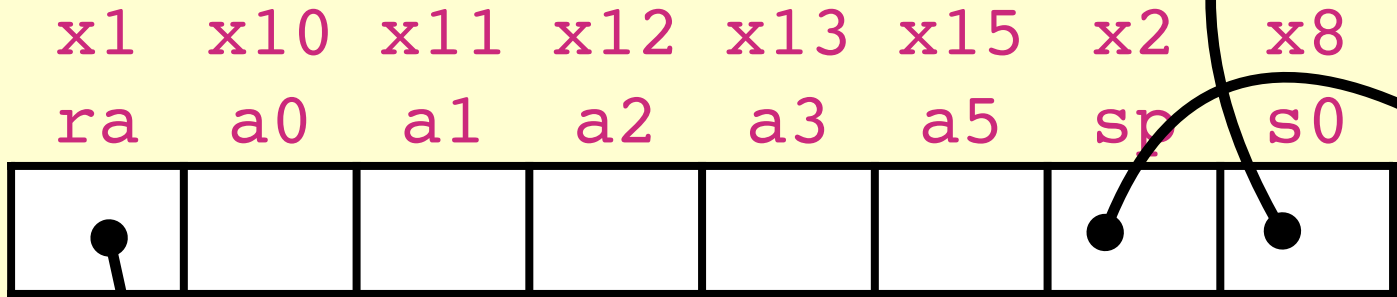
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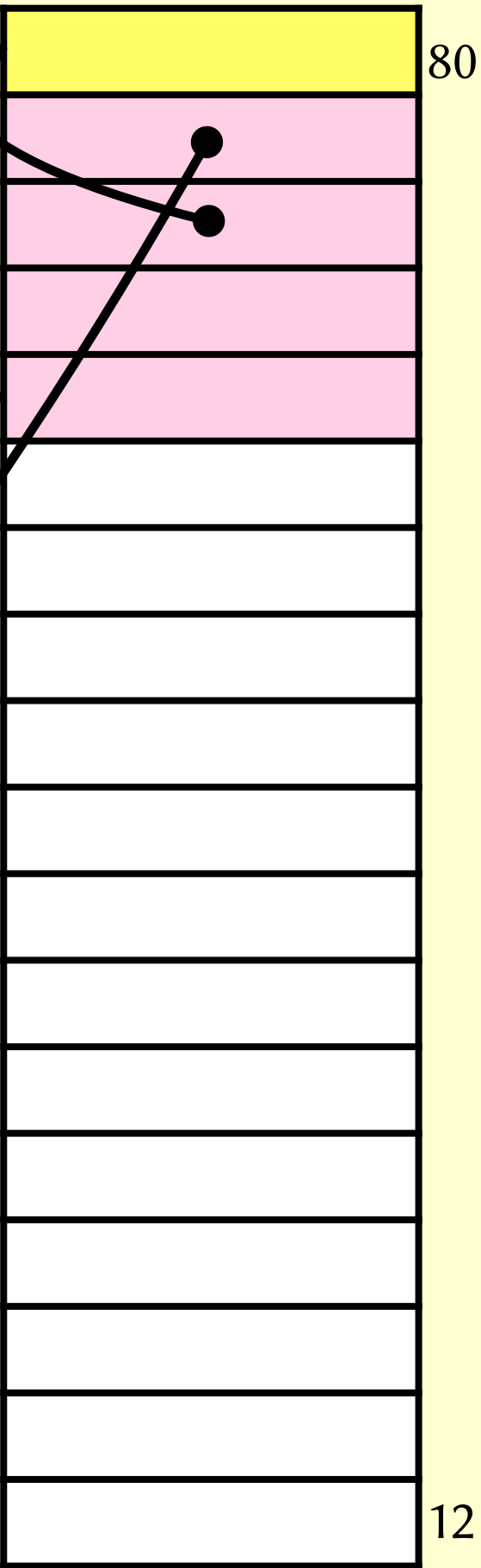
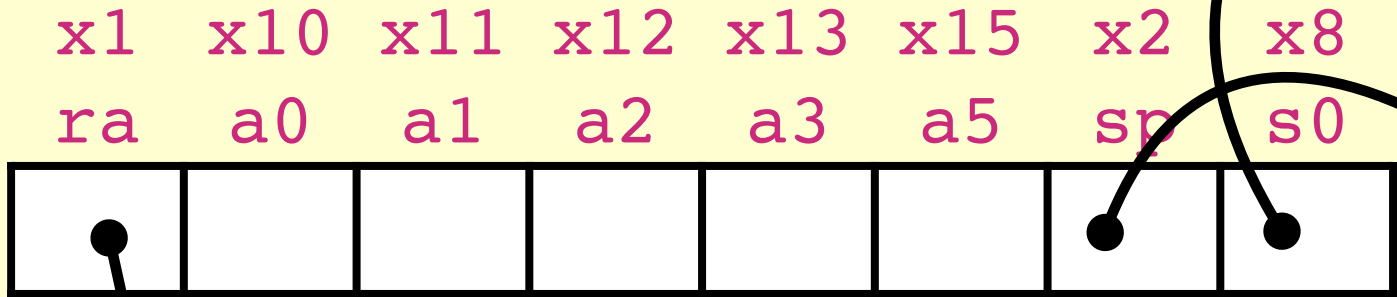




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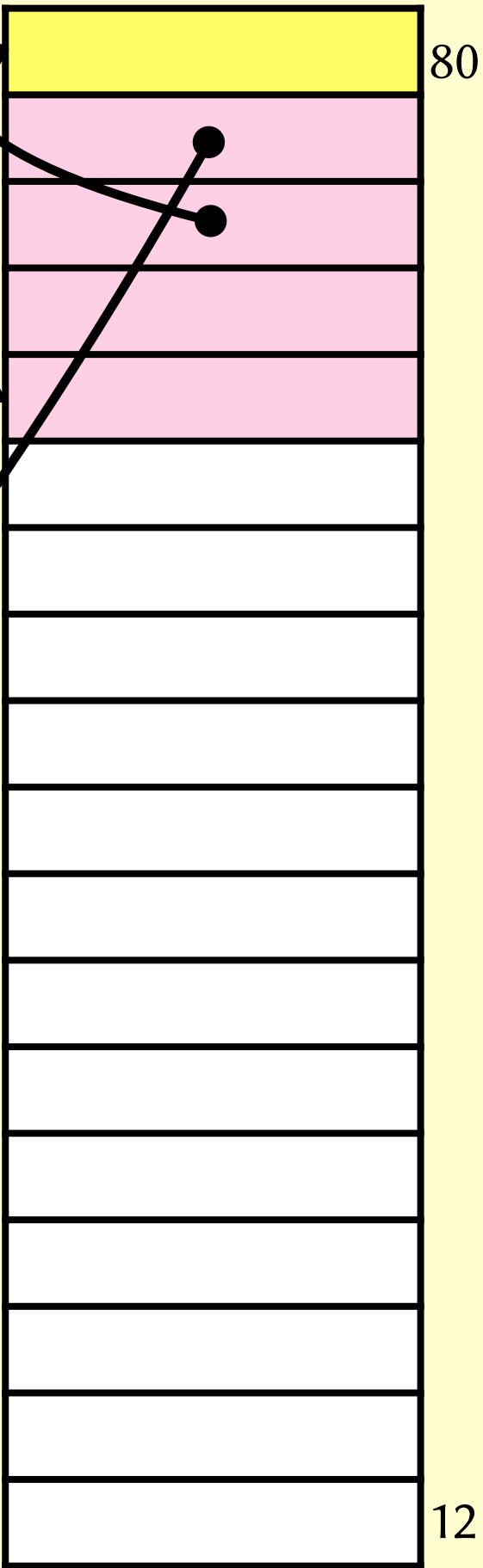
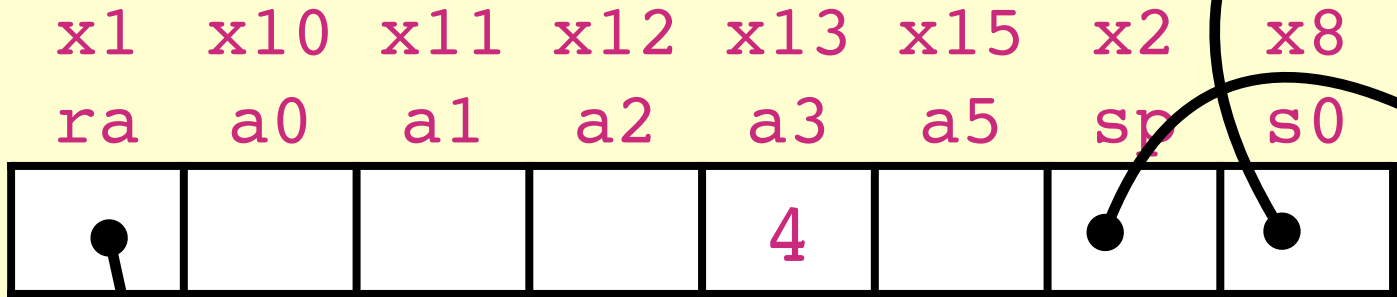
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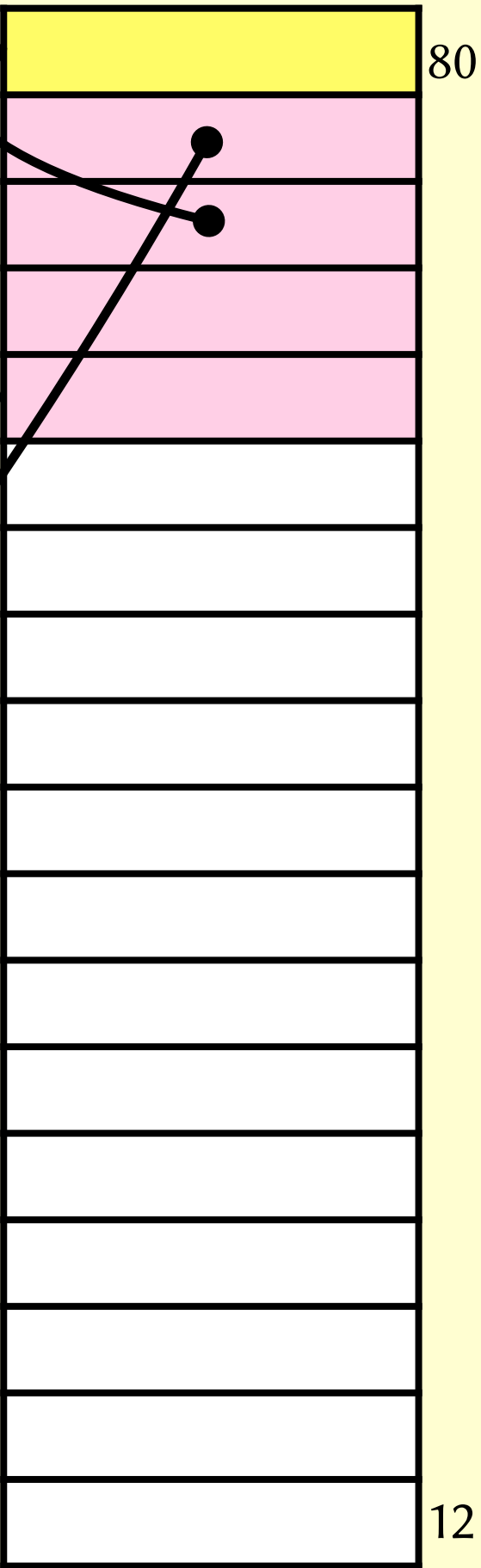
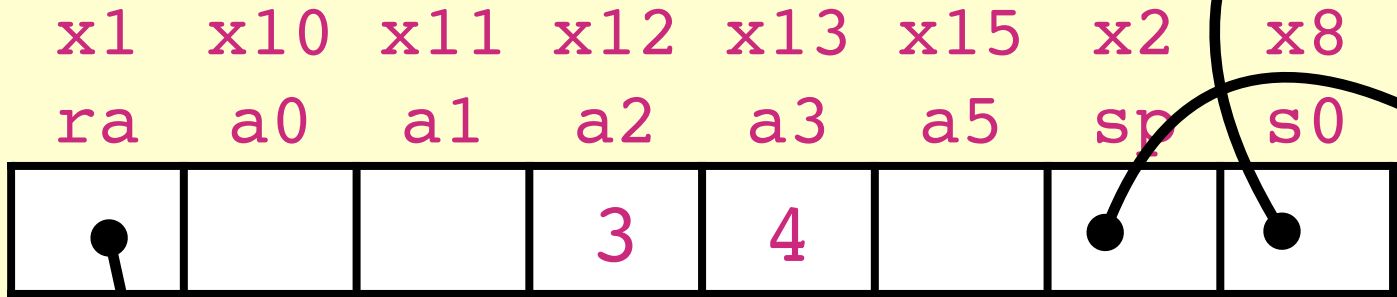
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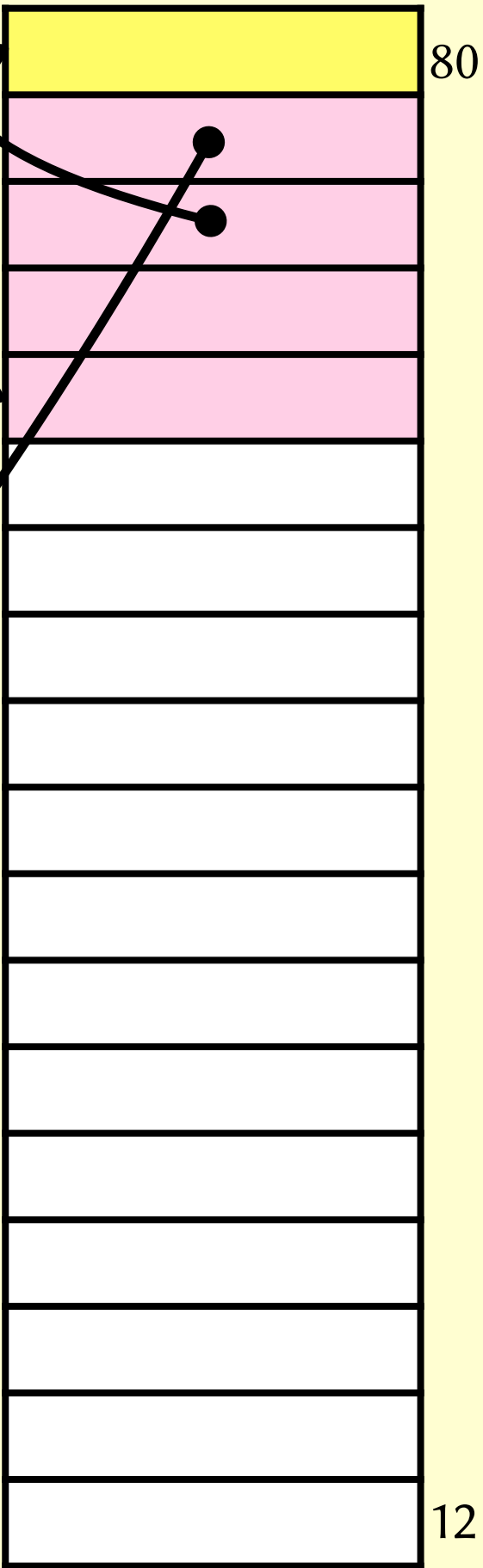
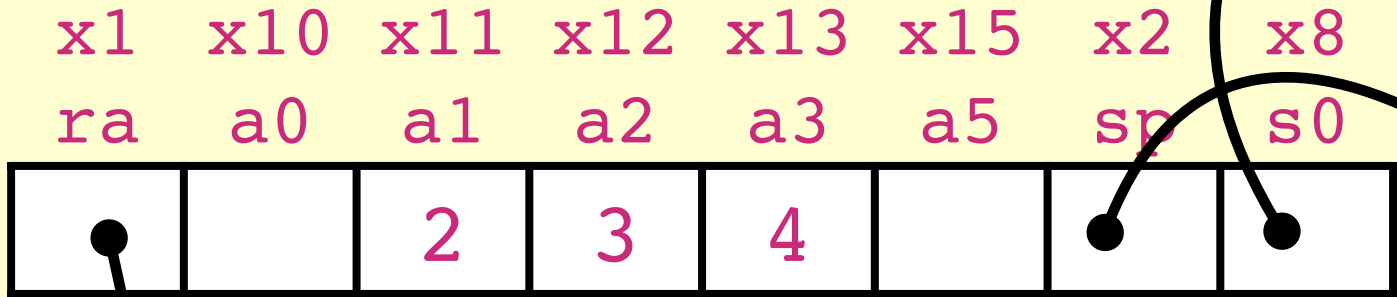
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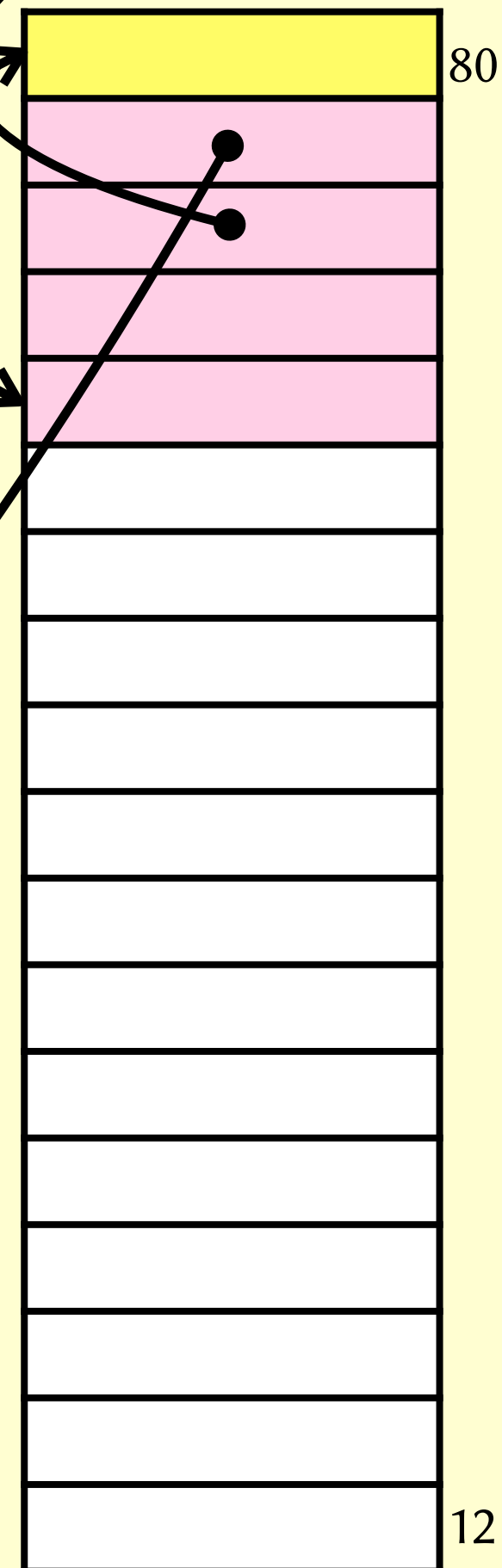
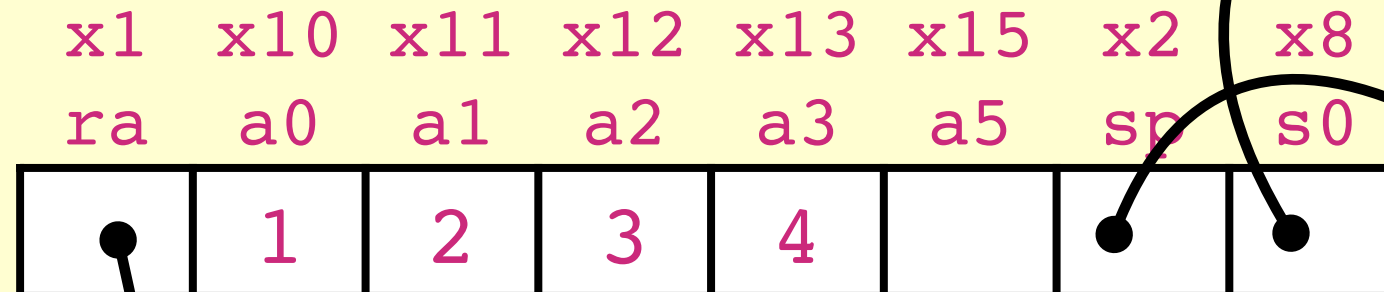
$f:$ 

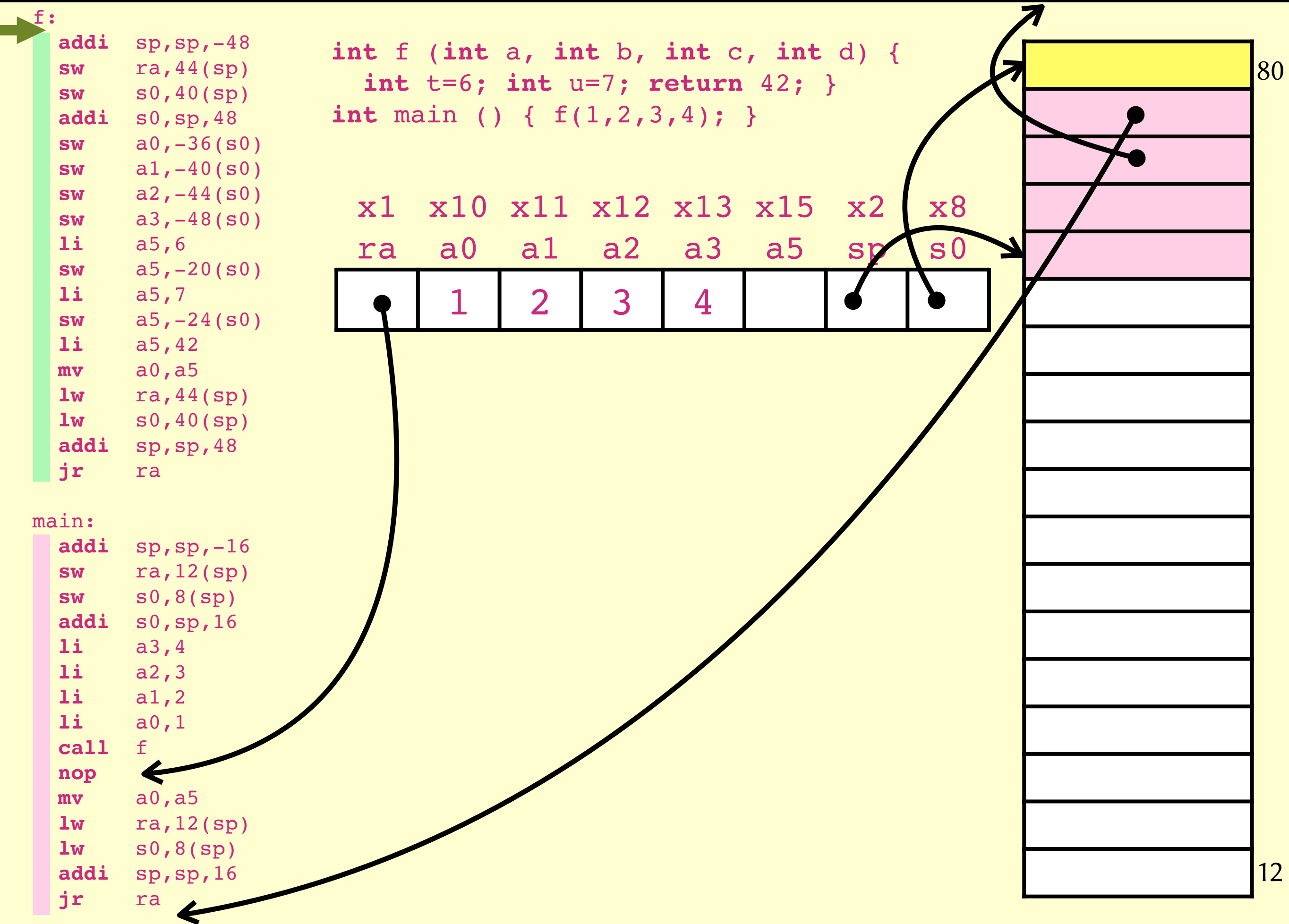
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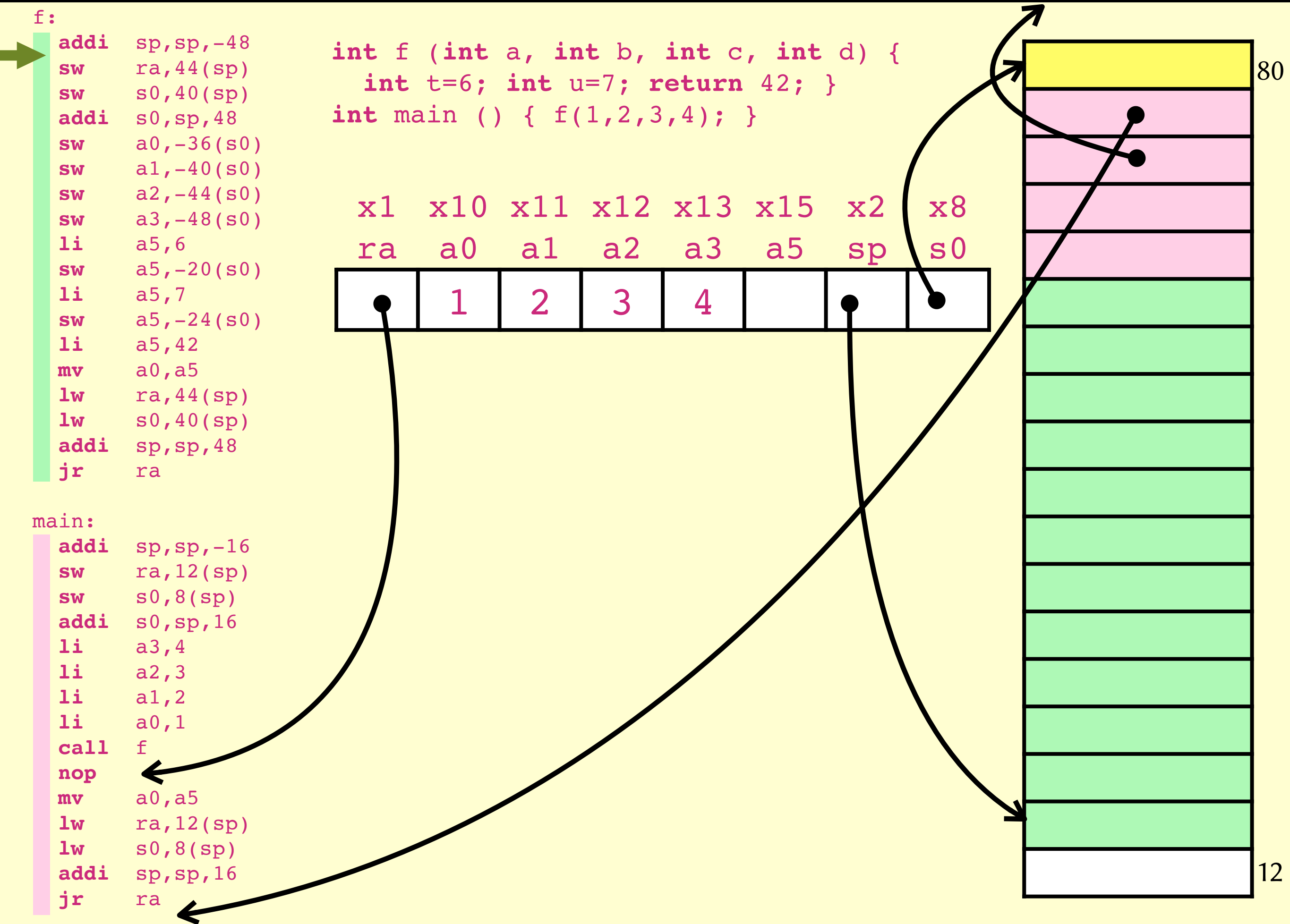
```
main:
```

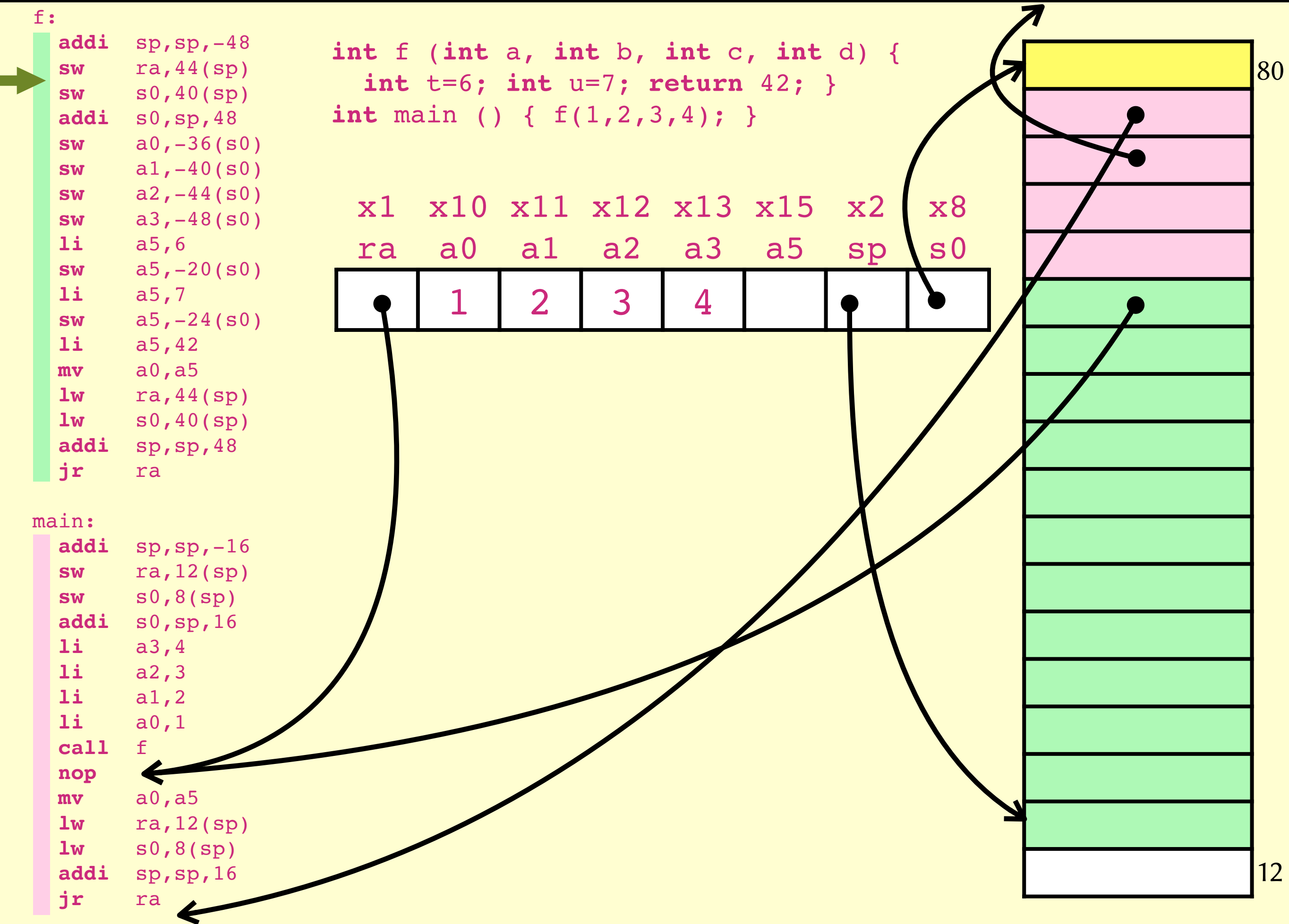
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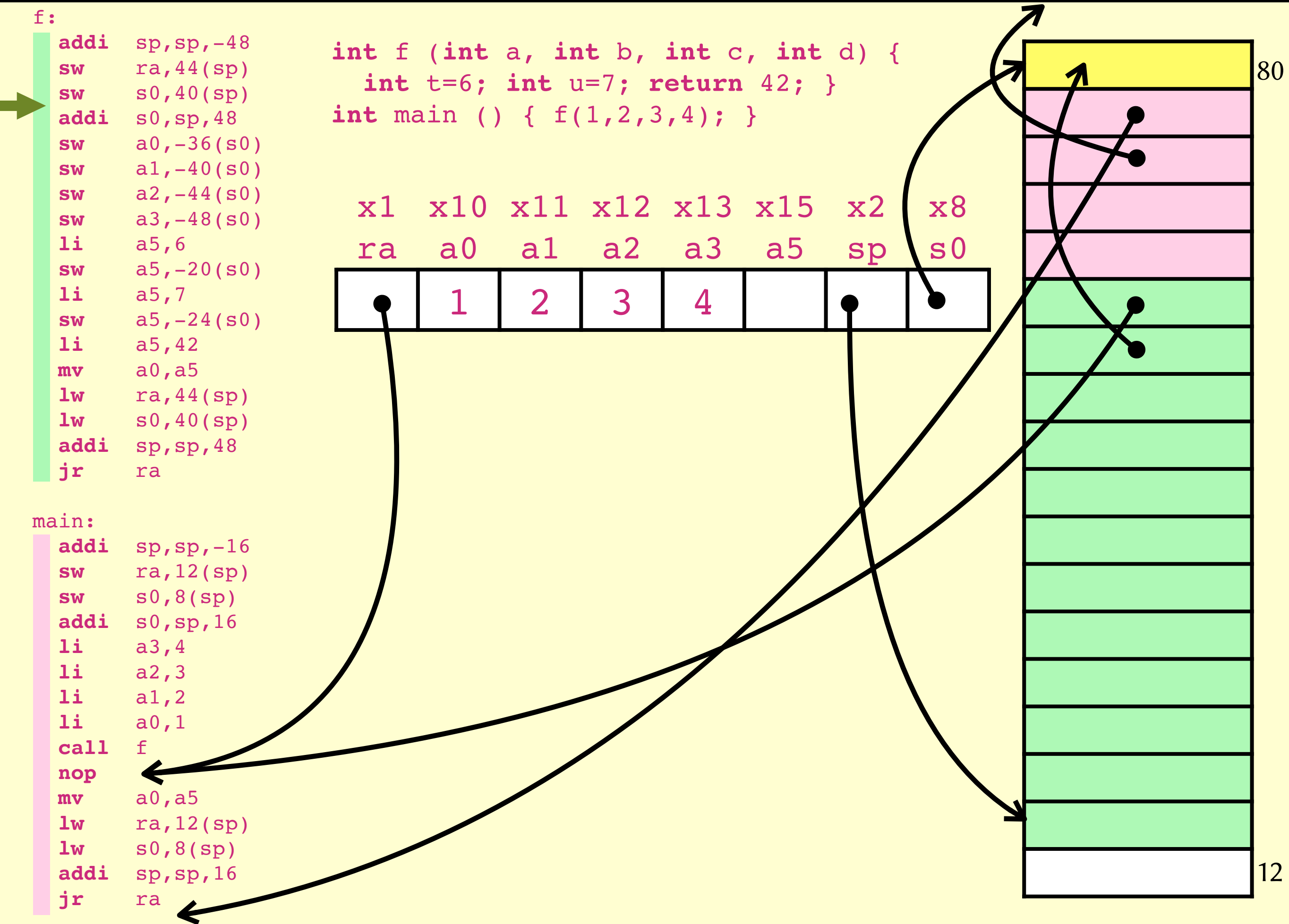


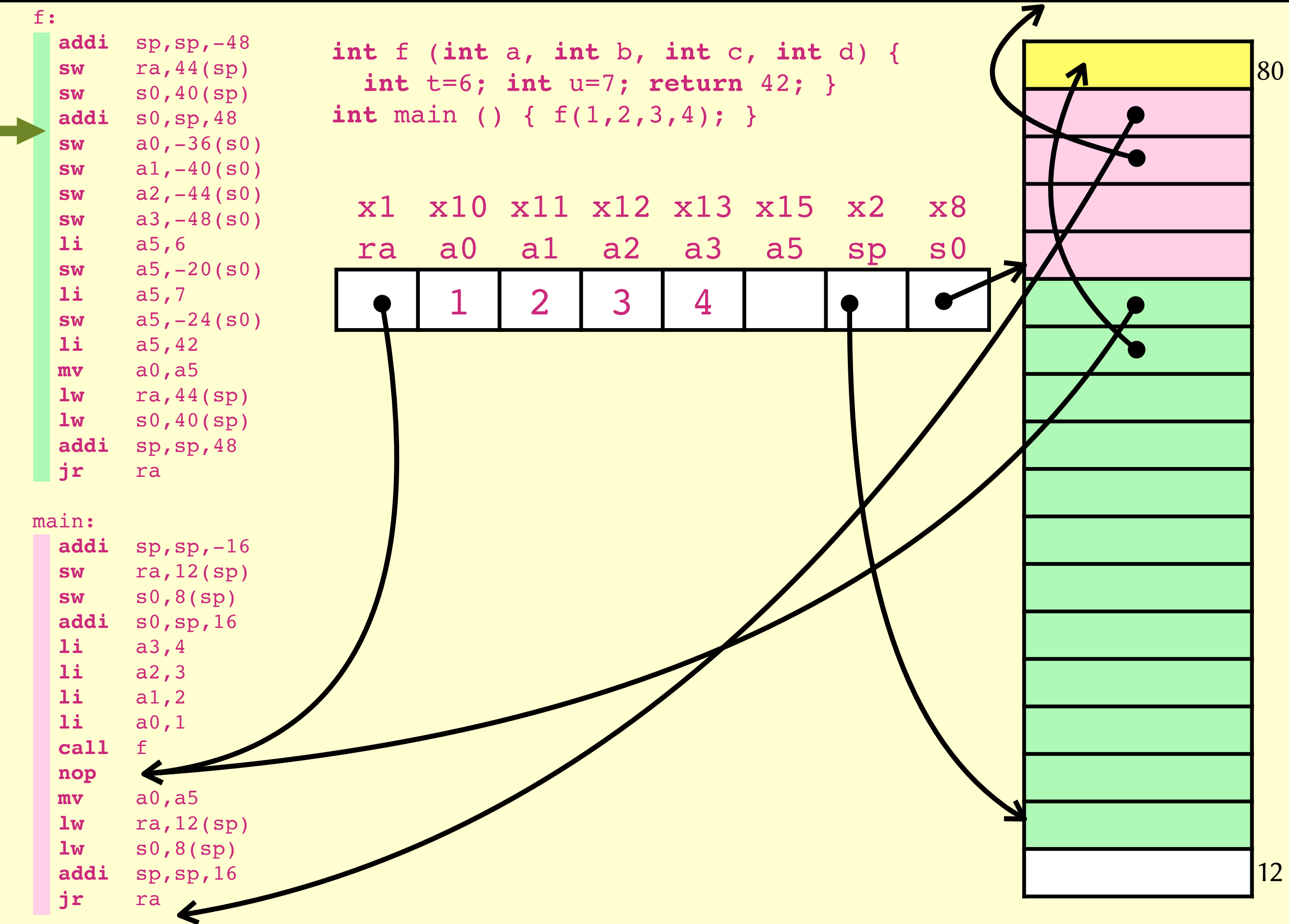








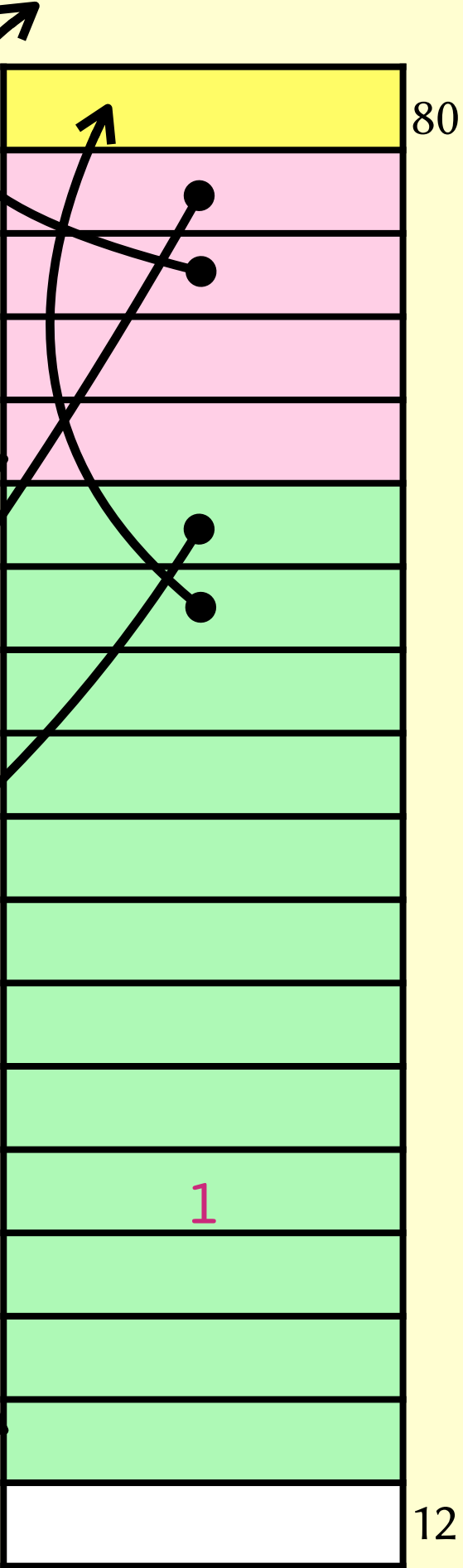
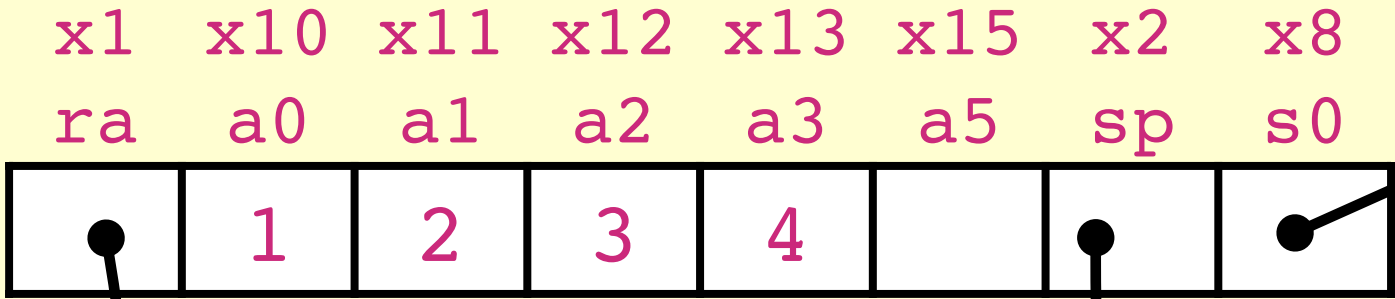




```
f:
addi sp,sp,-48
sw ra,44(sp)
sw s0,40(sp)
addi s0,sp,48
sw a0,-36(s0)
sw a1,-40(s0)
sw a2,-44(s0)
sw a3,-48(s0)
li a5,6
sw a5,-20(s0)
li a5,7
sw a5,-24(s0)
li a5,42
mv a0,a5
lw ra,44(sp)
lw s0,40(sp)
addi sp,sp,48
jr ra
```

```
main:
addi sp,sp,-16
sw ra,12(sp)
sw s0,8(sp)
addi s0,sp,16
li a3,4
li a2,3
li a1,2
li a0,1
call f
nop
mv a0,a5
lw ra,12(sp)
lw s0,8(sp)
addi sp,sp,16
jr ra
```

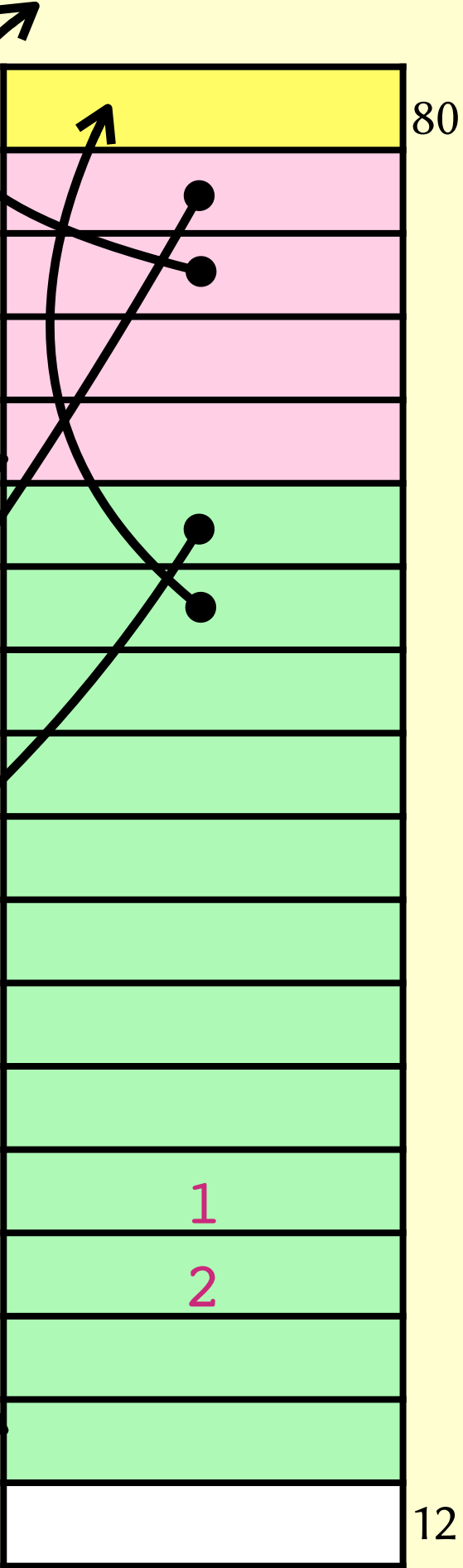
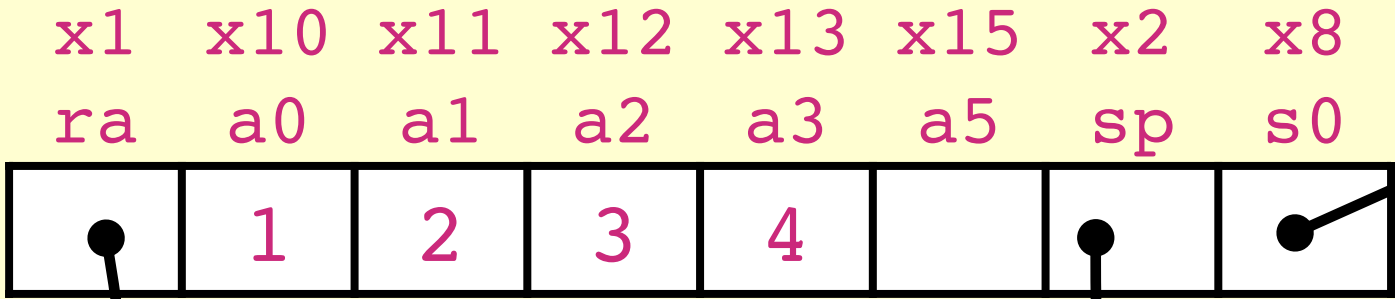
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    int t=6; int u=7; return 42; }
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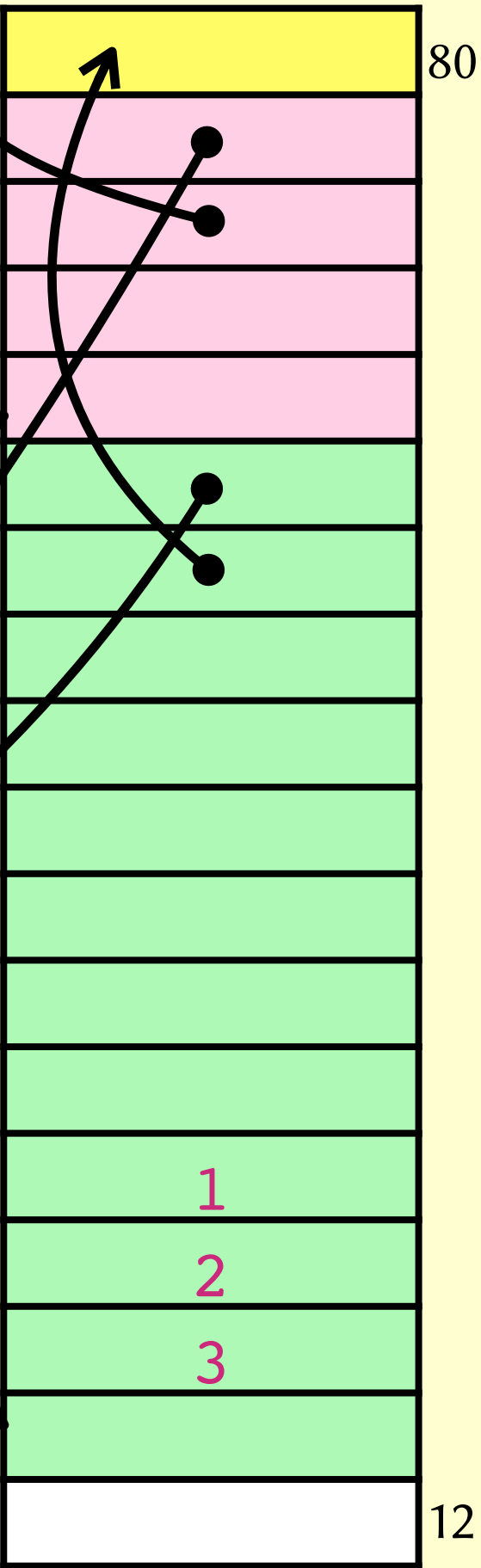
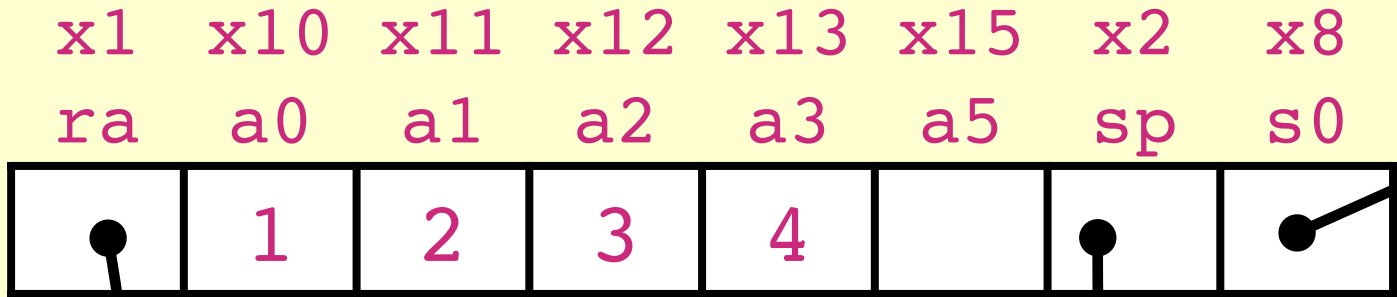
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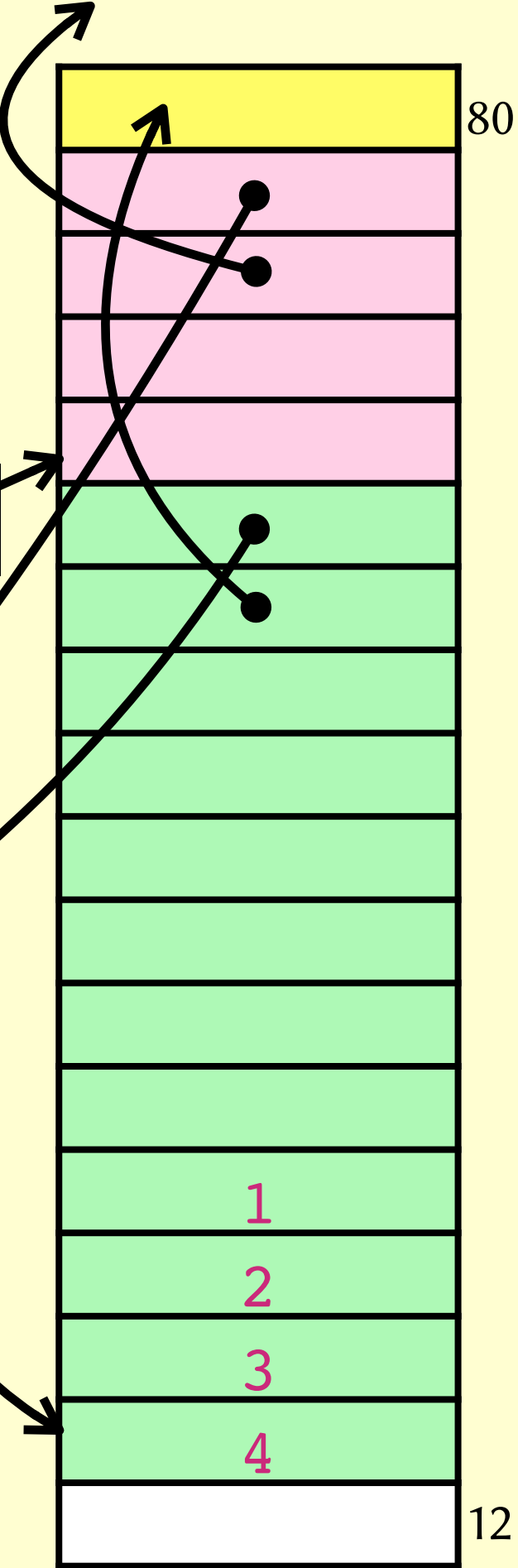
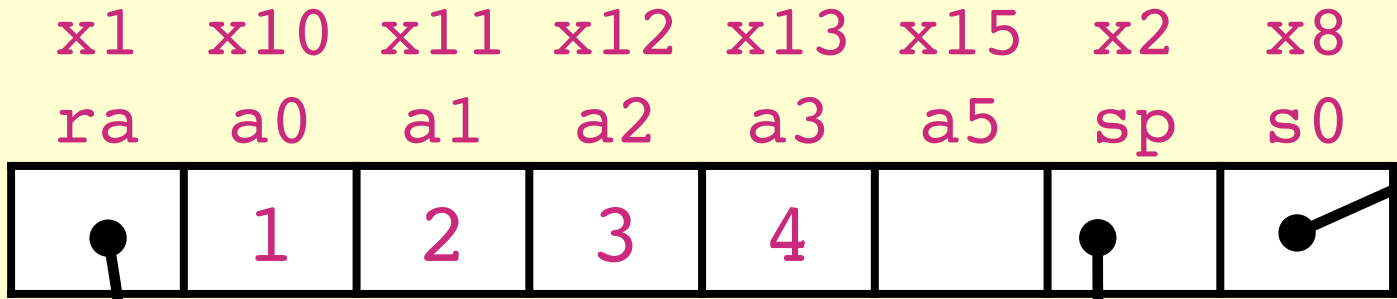
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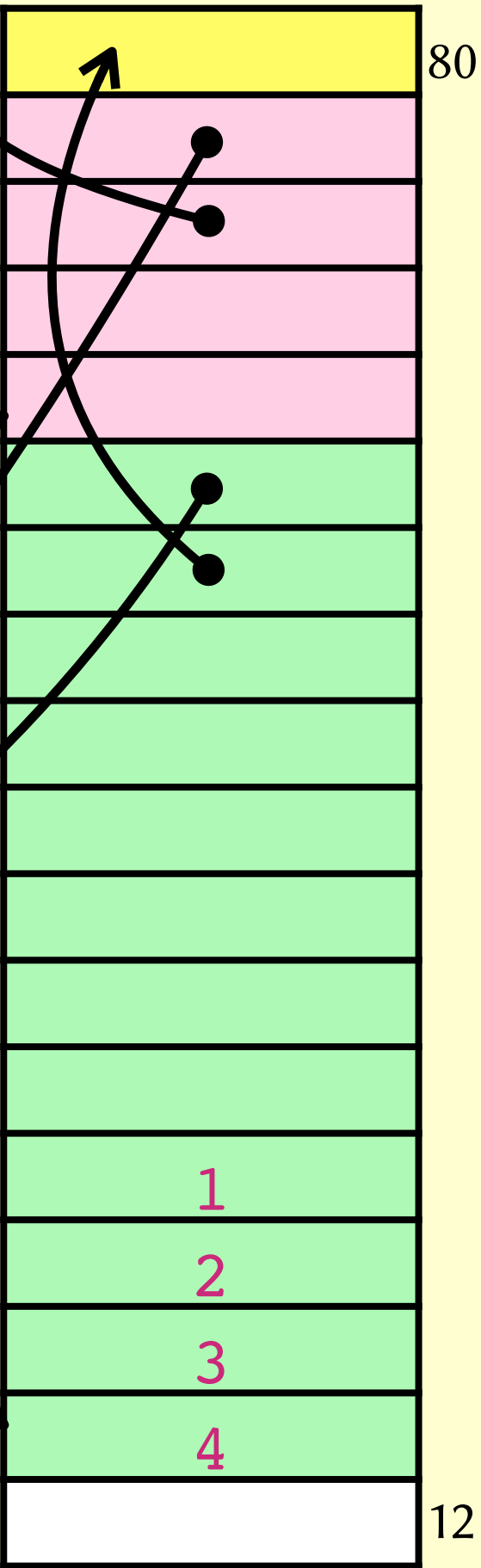
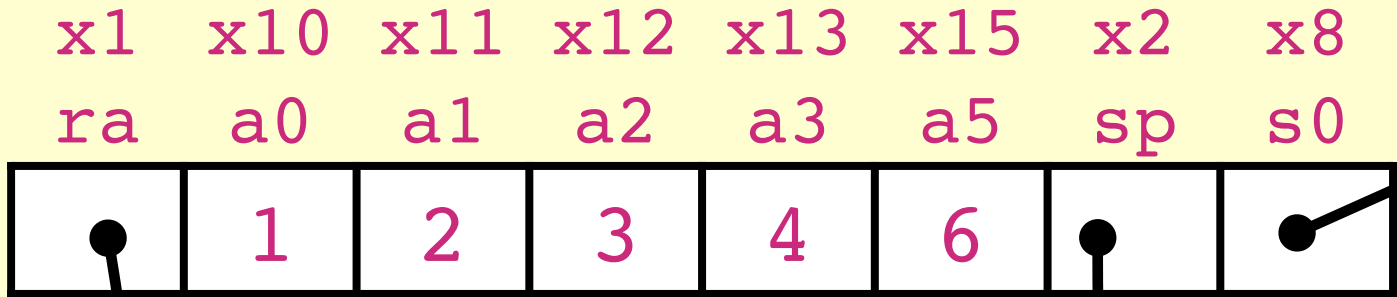
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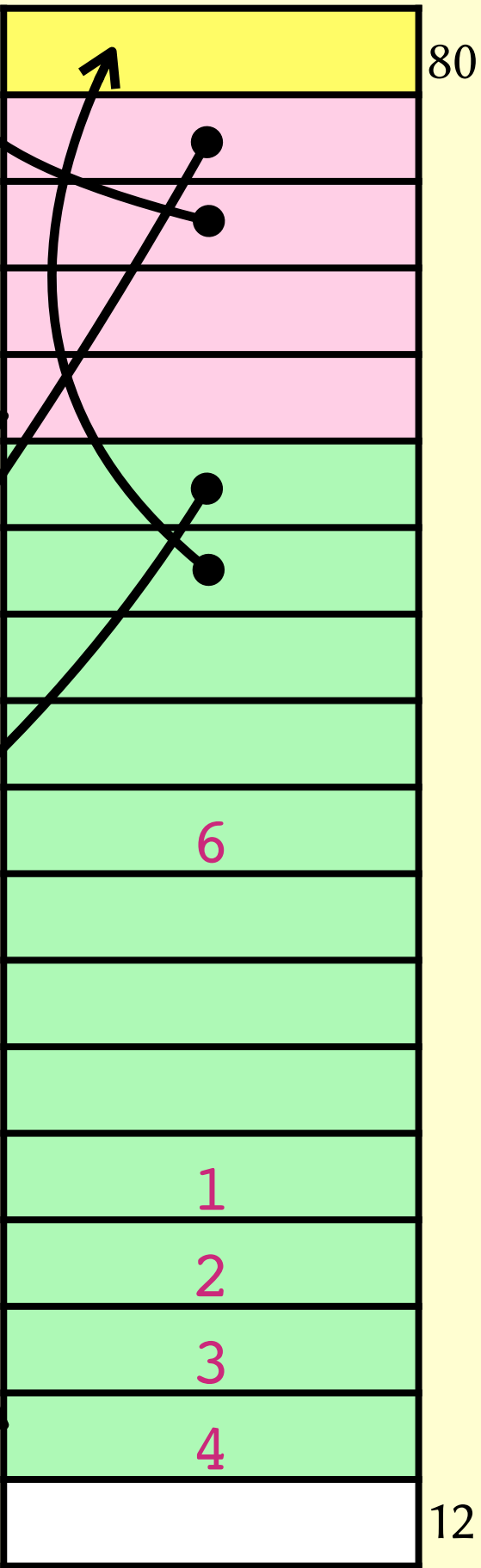
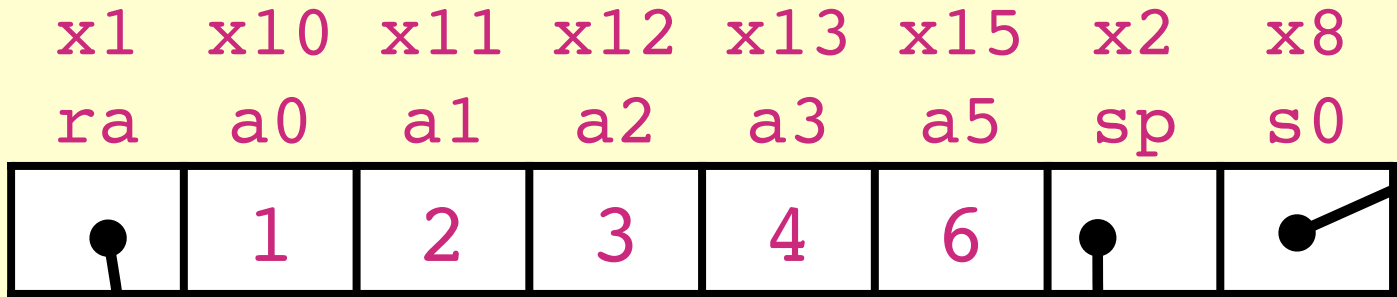
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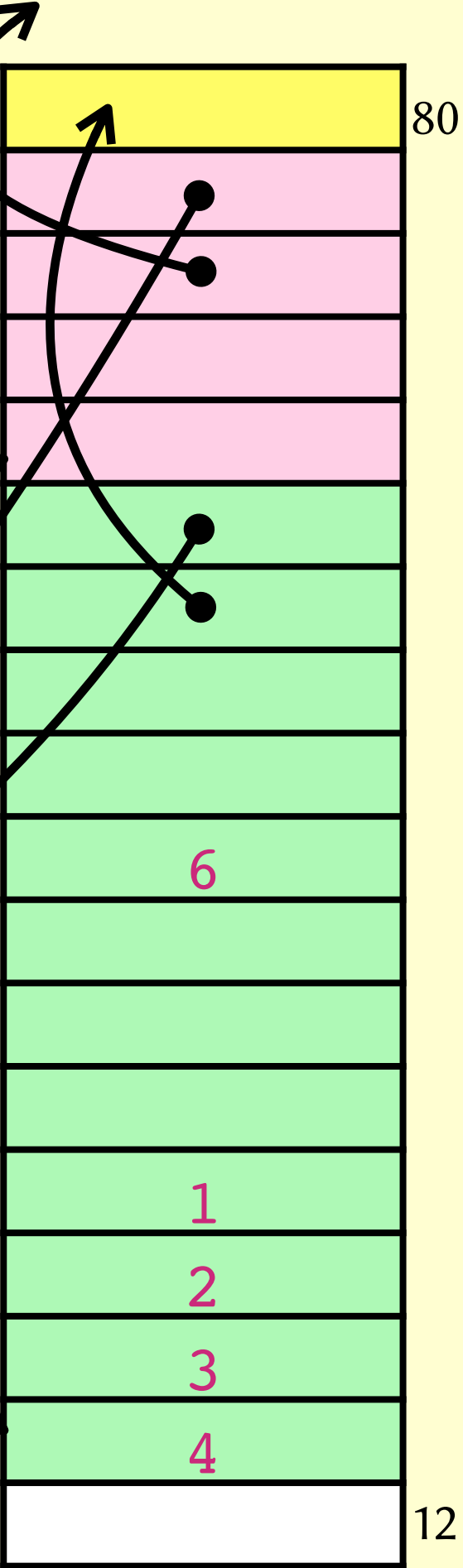
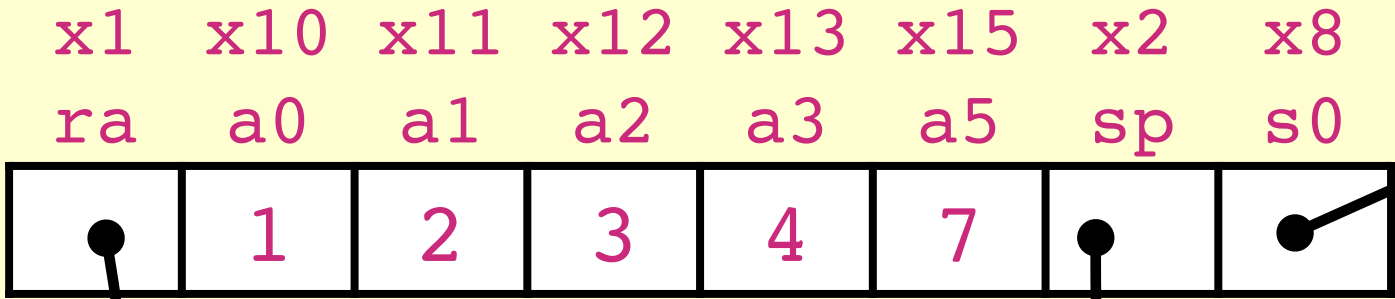




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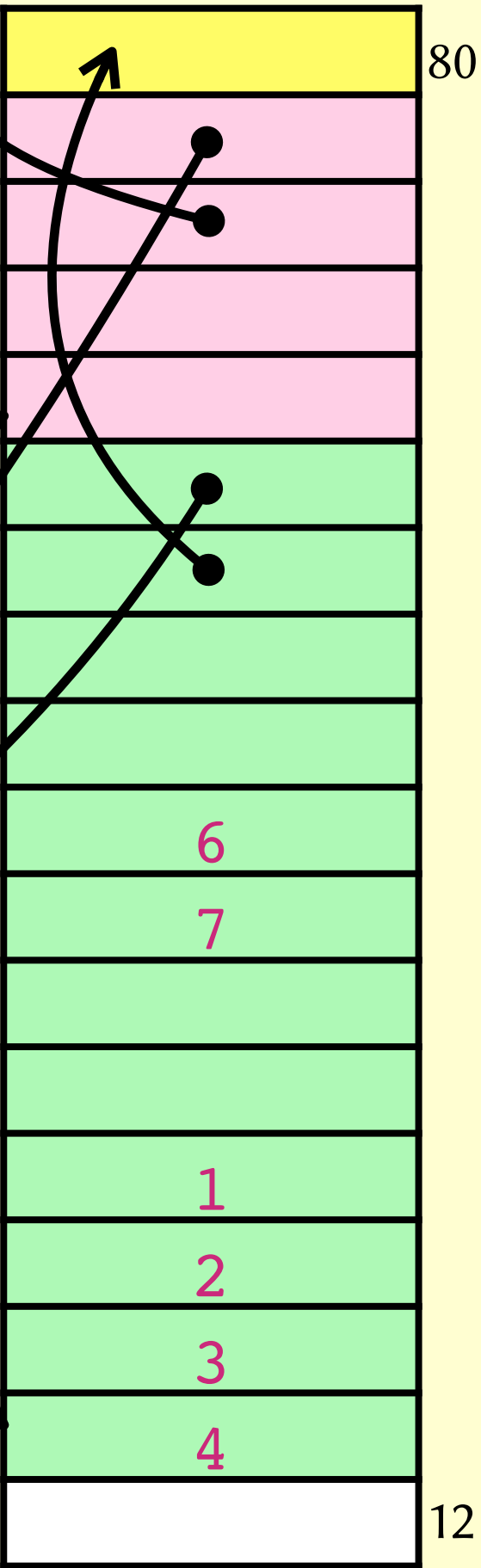
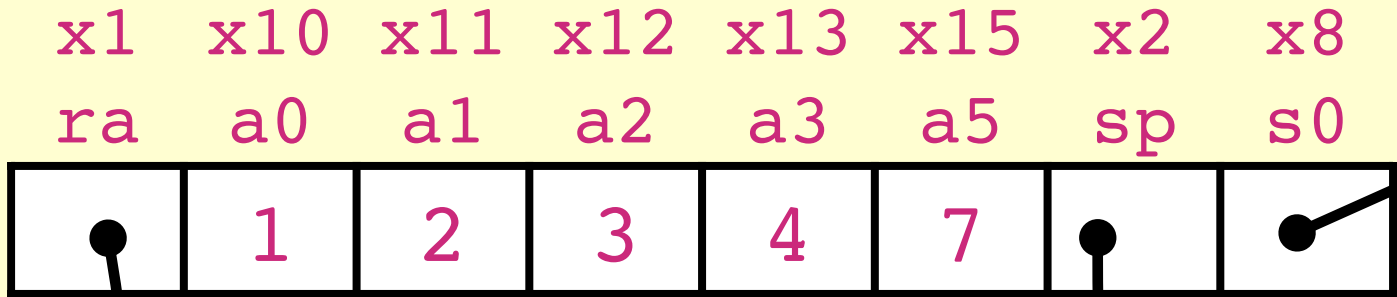
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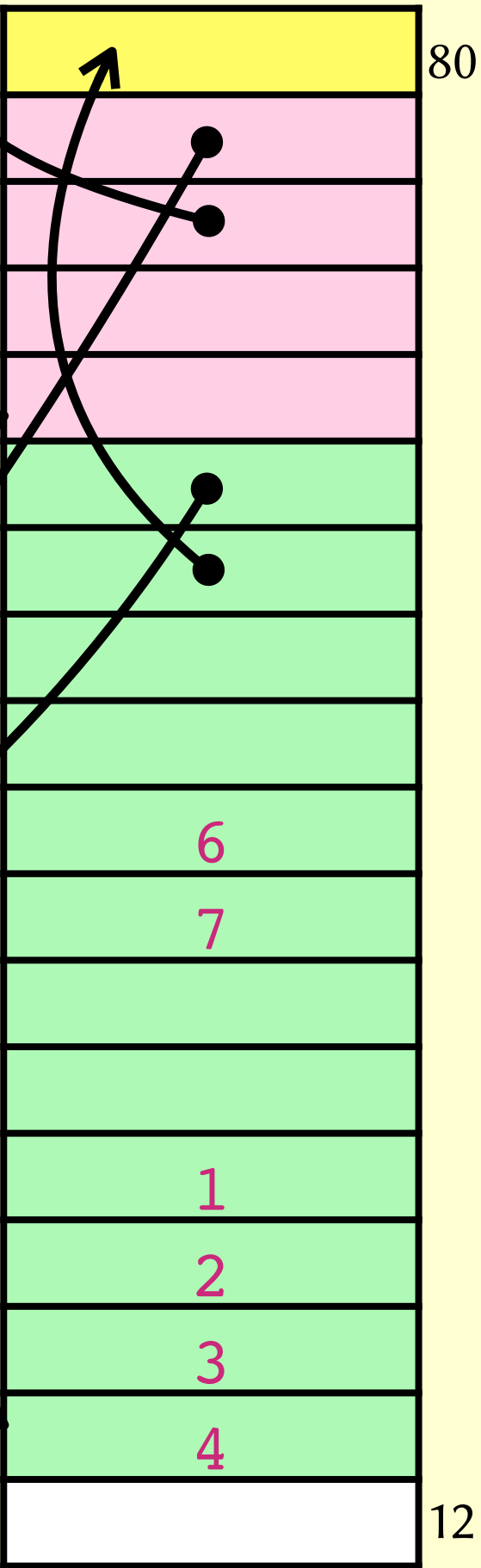
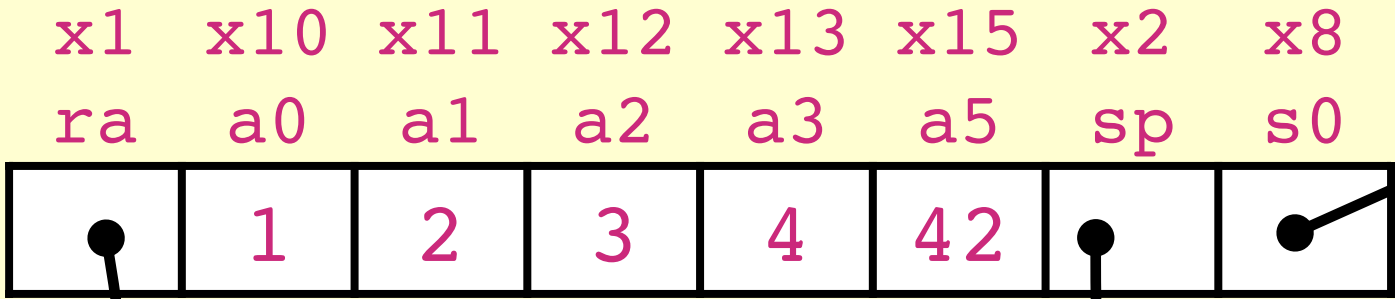
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jr ra
```

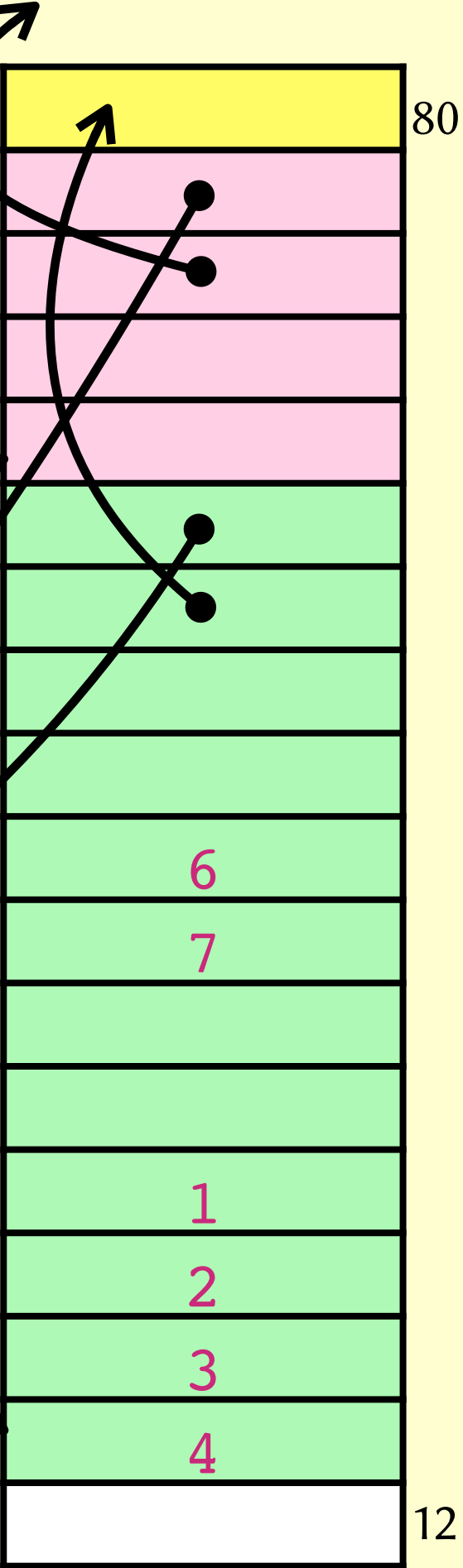
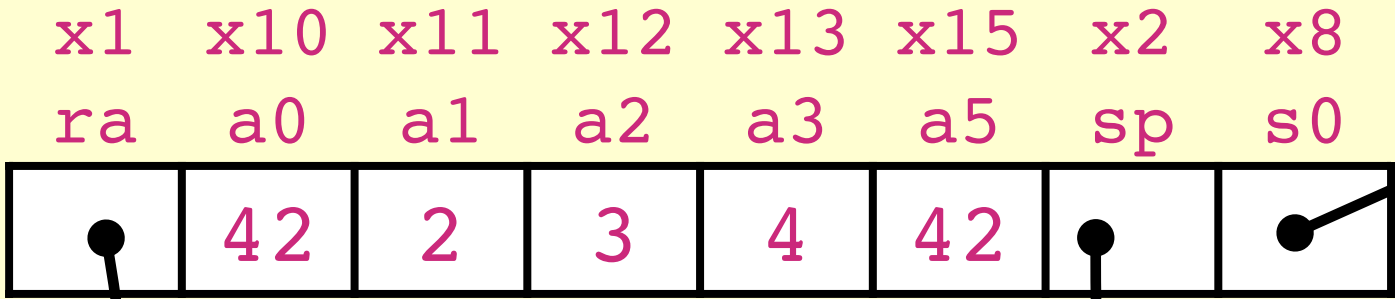
```
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```
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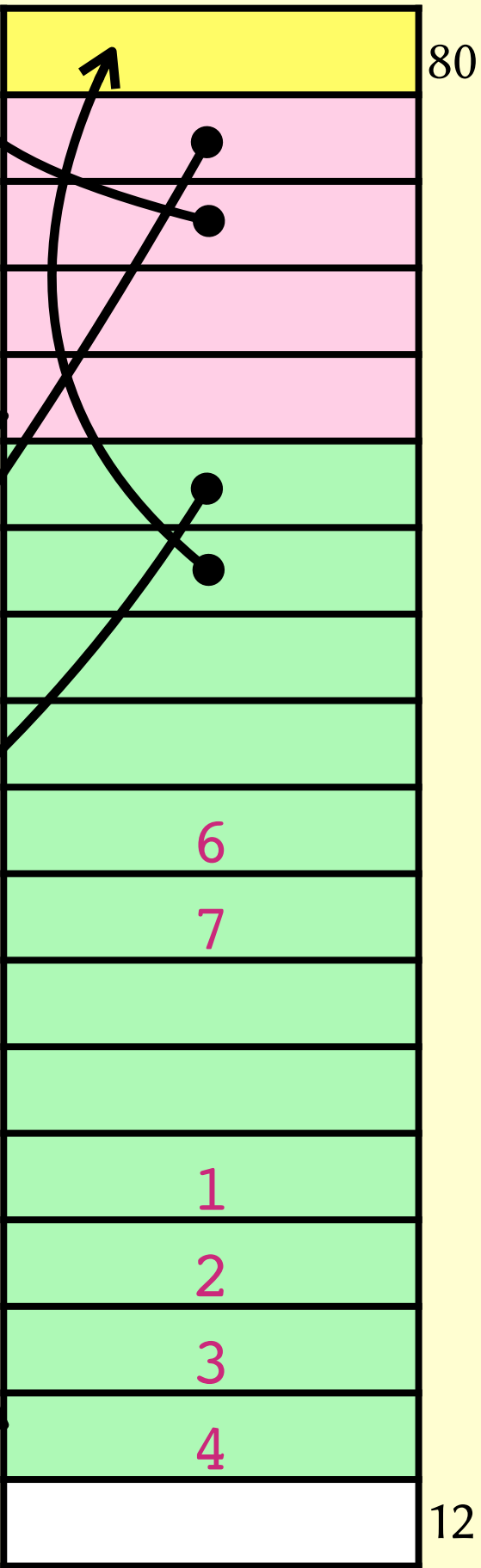
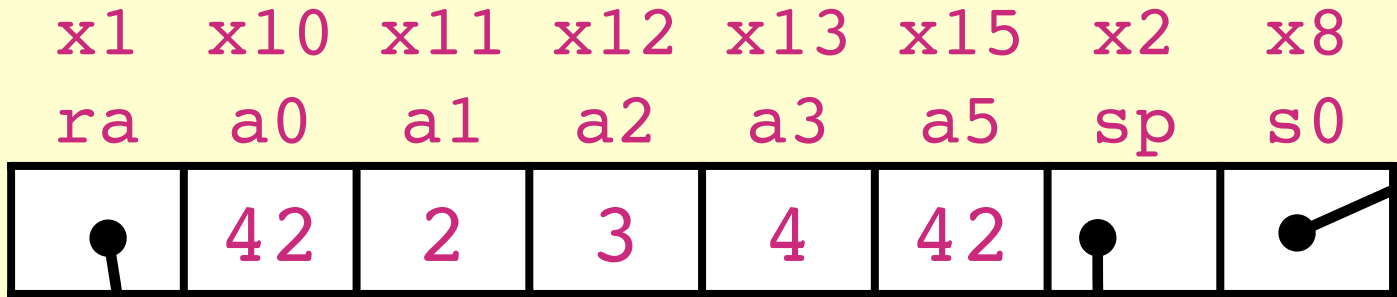
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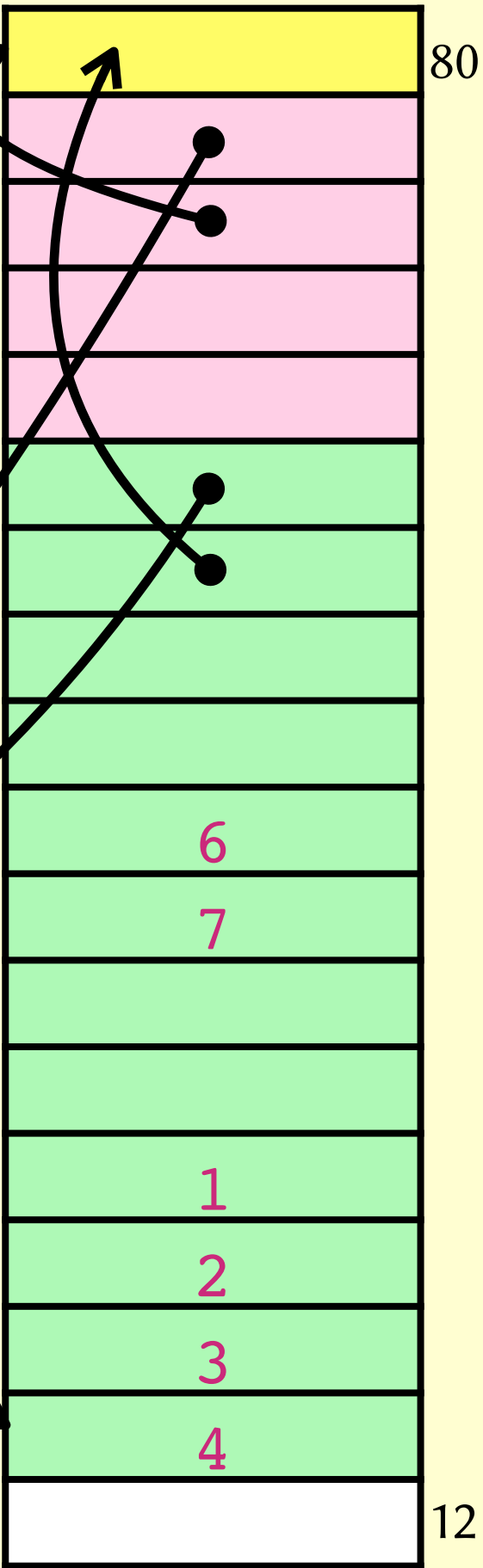
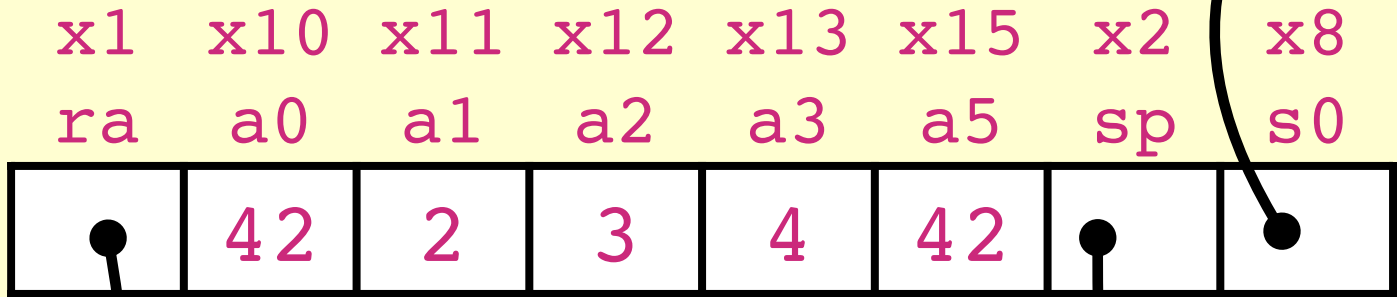
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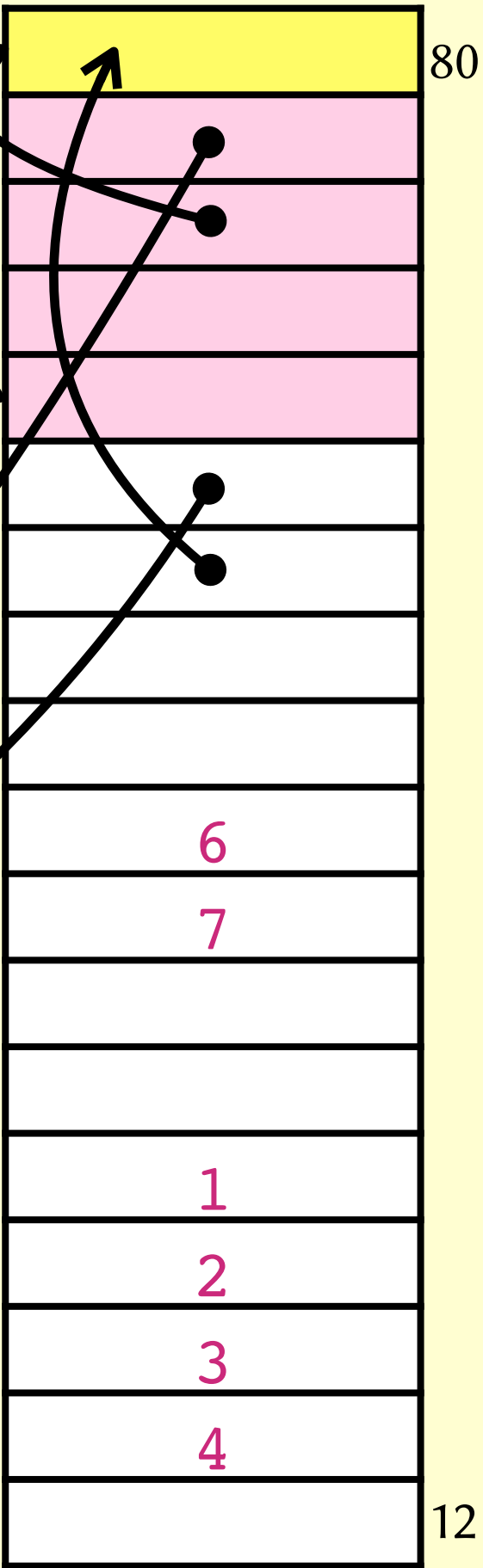
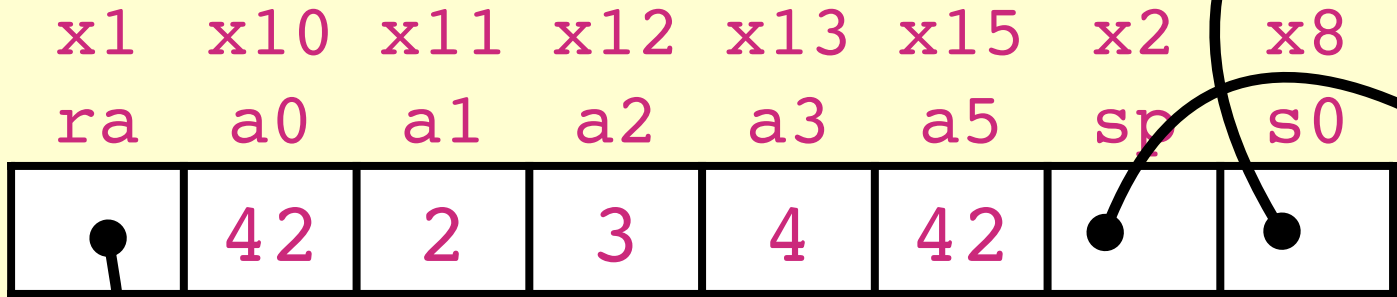
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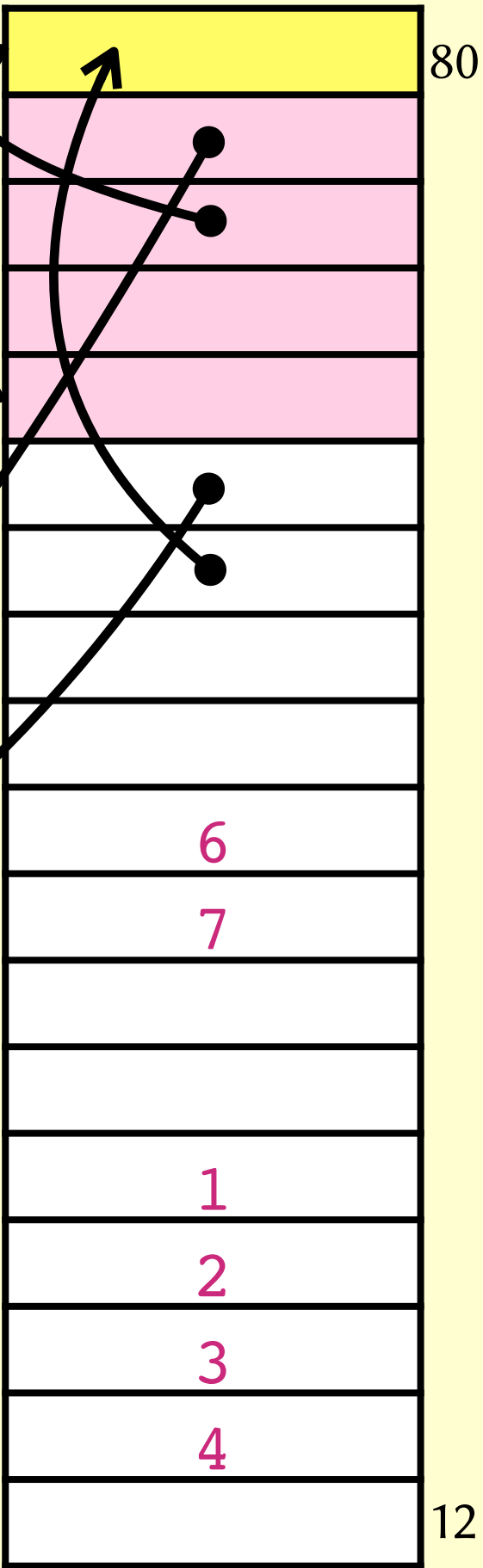
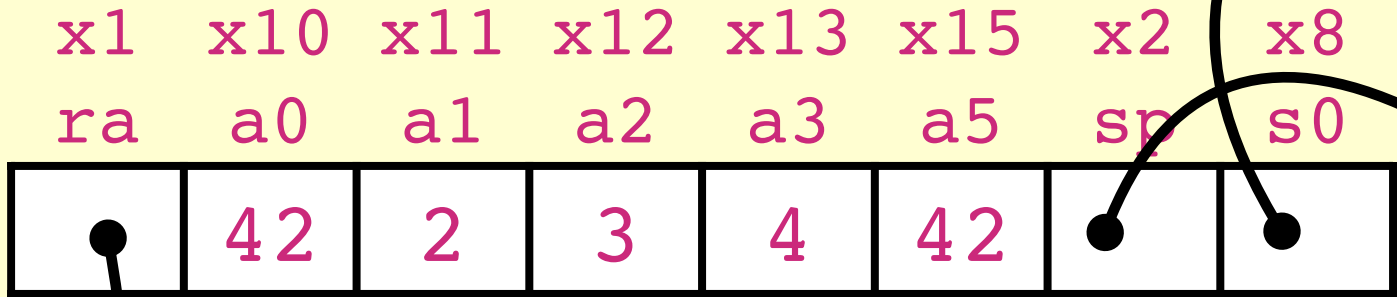
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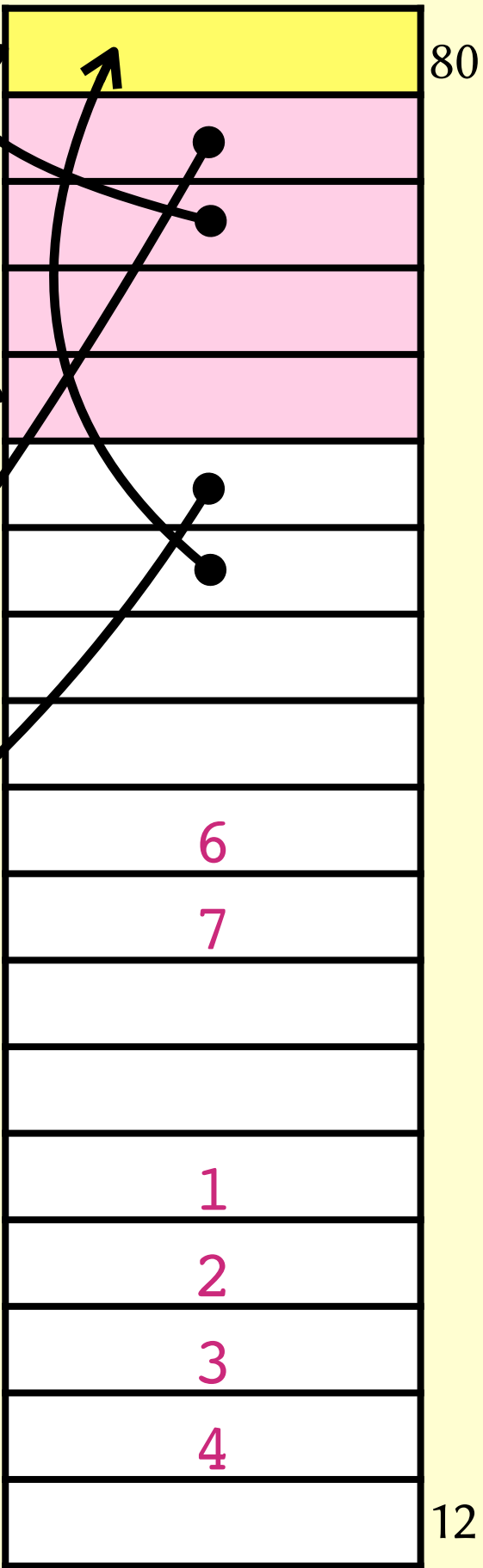
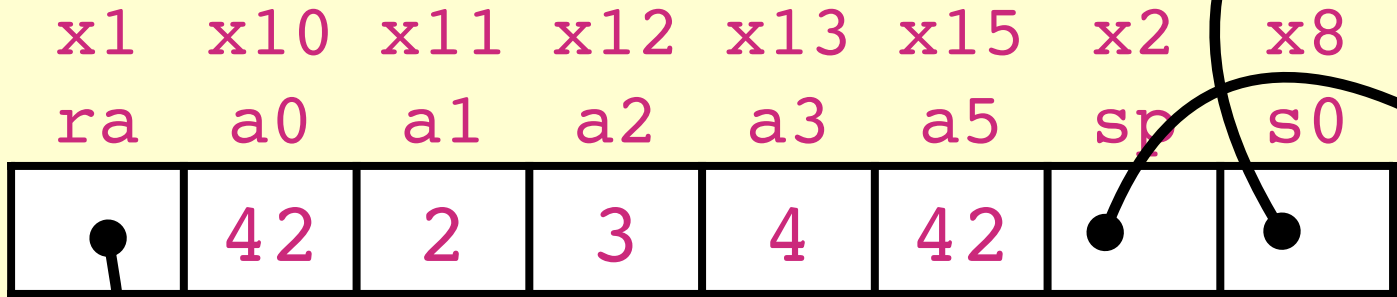




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li      a5,42
mv      a0,a5
lw      ra,44(sp)
lw      s0,40(sp)
addi    sp,sp,48
jr      ra

```

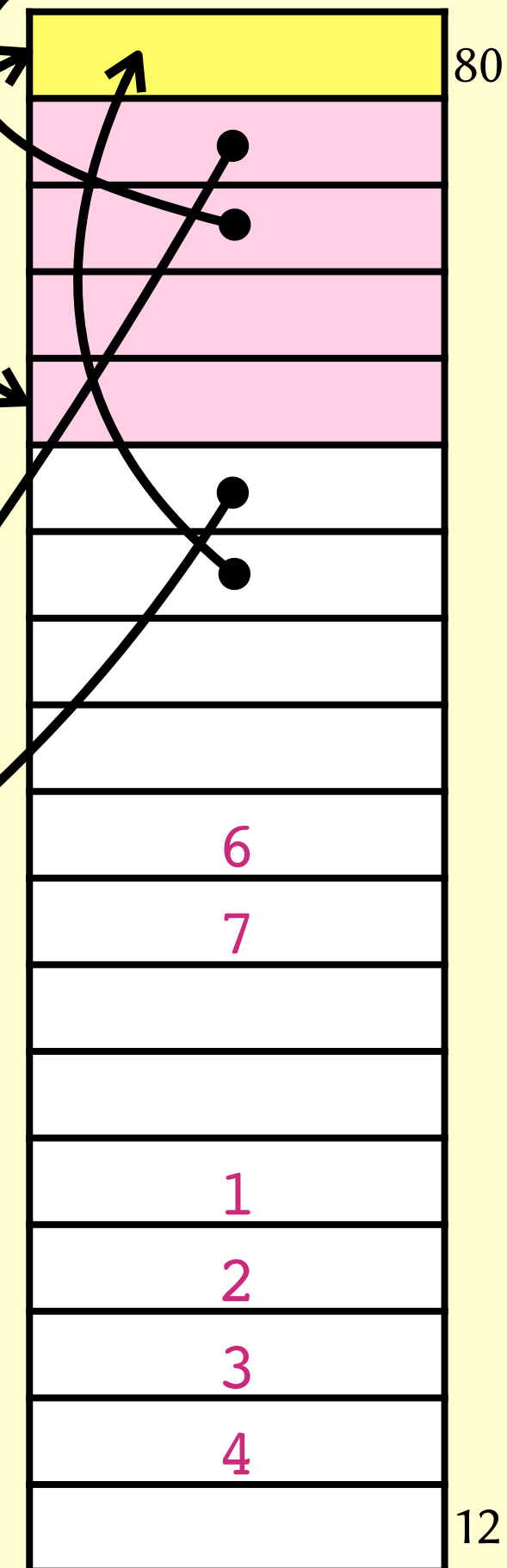
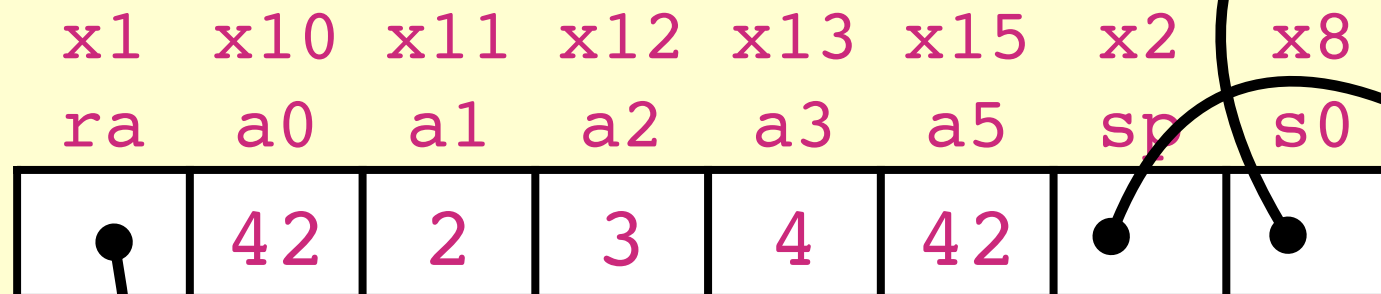
```
main:
```

```

addi    sp,sp,-16
sw      ra,12(sp)
sw      s0,8(sp)
addi    s0,sp,16
li      a3,4
li      a2,3
li      a1,2
li      a0,1
call    f
nop
mv      a0,a5
lw      ra,12(sp)
lw      s0,8(sp)
addi    sp,sp,16
jr      ra

```

```
int f (int a, int b, int c, int d) {
    int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



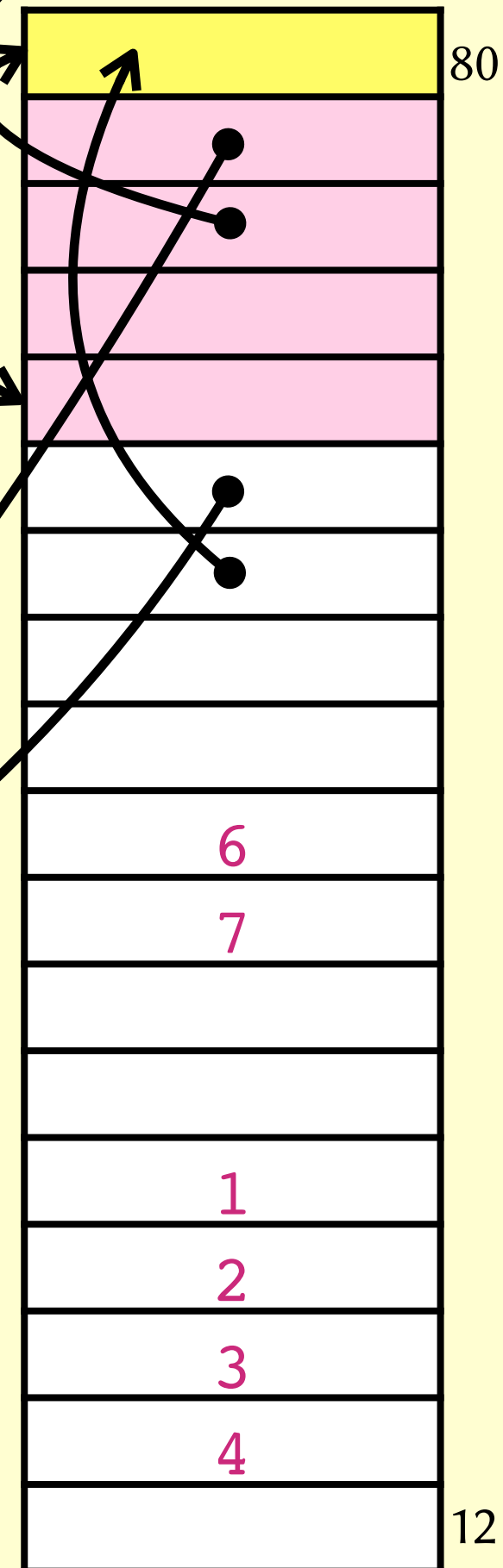
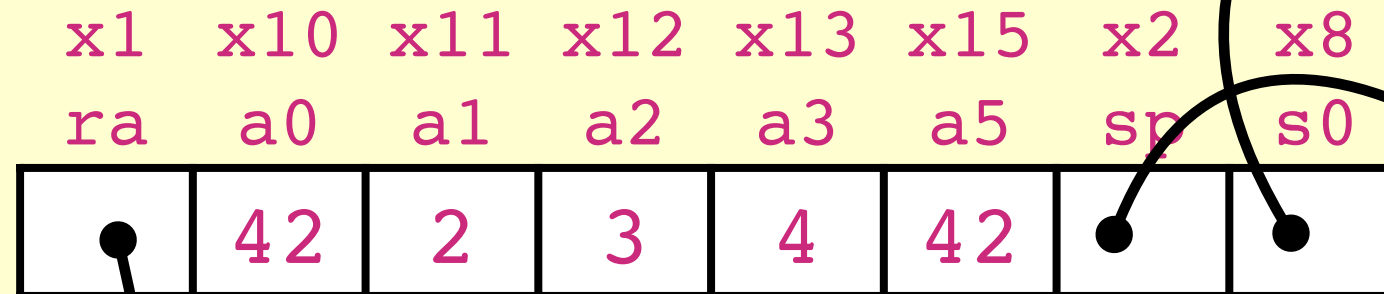
$f:$ 

```
addi    sp,sp,-48
sw      ra,44(sp)
sw      s0,40(sp)
addi    s0,sp,48
sw      a0,-36(s0)
sw      a1,-40(s0)
sw      a2,-44(s0)
sw      a3,-48(s0)
li      a5,6
sw      a5,-20(s0)
li      a5,7
sw      a5,-24(s0)
li      a5,42
mv      a0,a5
lw      ra,44(sp)
lw      s0,40(sp)
addi    sp,sp,48
jr      ra
```

```
main:
```

```
addi    sp,sp,-16
sw      ra,12(sp)
sw      s0,8(sp)
addi    s0,sp,16
li      a3,4
li      a2,3
li      a1,2
li      a0,1
call    f
nop      ←
mv      a0,a5
lw      ra,12(sp)
lw      s0,8(sp)
addi    sp,sp,16
jr      ra
```

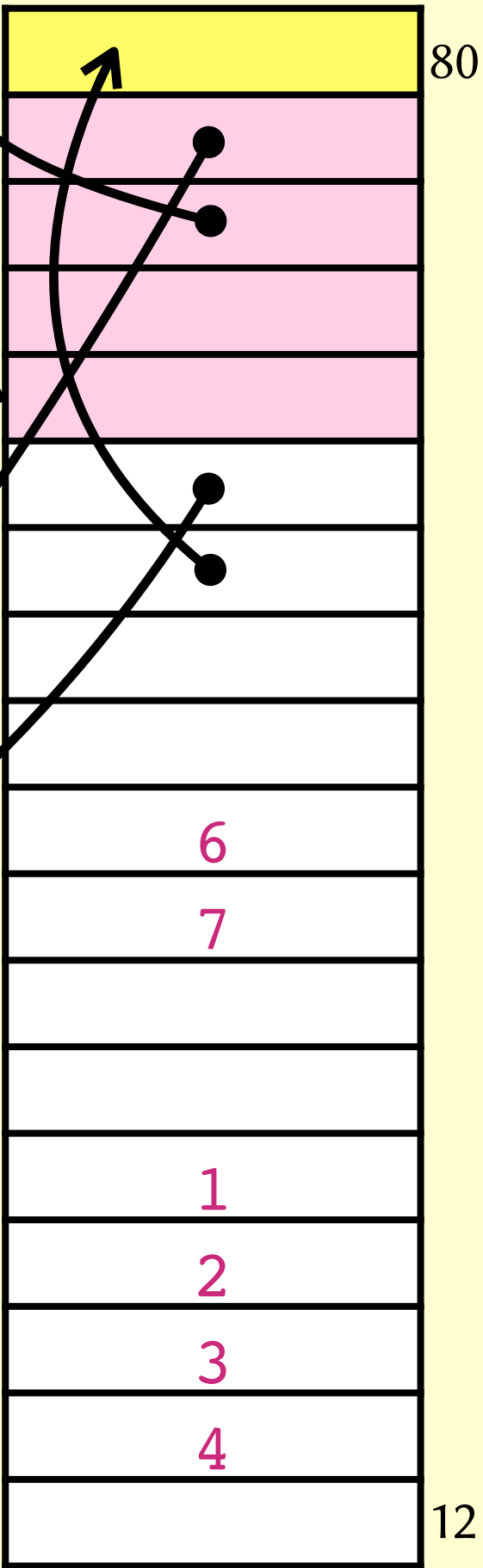
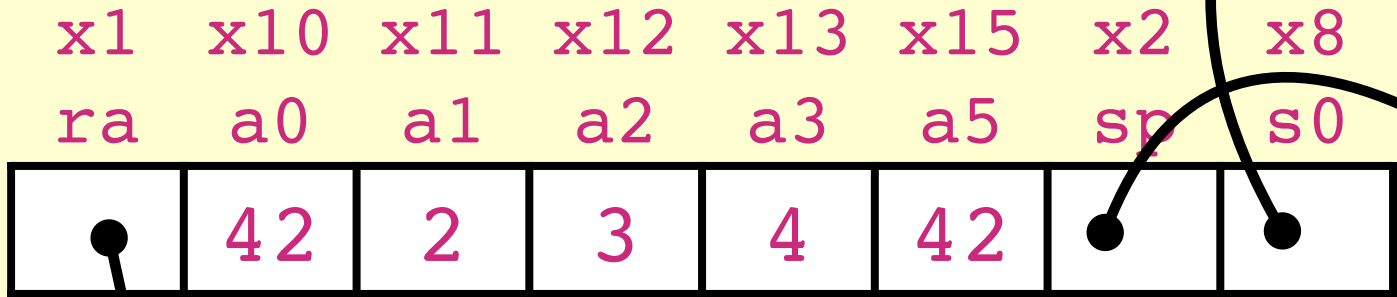
```
int f (int a, int b, int c, int d) {
    int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



```
f:
addi sp,sp,-48
sw ra,44(sp)
sw s0,40(sp)
addi s0,sp,48
sw a0,-36(s0)
sw a1,-40(s0)
sw a2,-44(s0)
sw a3,-48(s0)
li a5,6
sw a5,-20(s0)
li a5,7
sw a5,-24(s0)
li a5,42
mv a0,a5
lw ra,44(sp)
lw s0,40(sp)
addi sp,sp,48
jr ra
```

```
main:
addi sp,sp,-16
sw ra,12(sp)
sw s0,8(sp)
addi s0,sp,16
li a3,4
li a2,3
li a1,2
li a0,1
call f
nop
mv a0,a5
lw ra,12(sp)
lw s0,8(sp)
addi sp,sp,16
jr ra
```

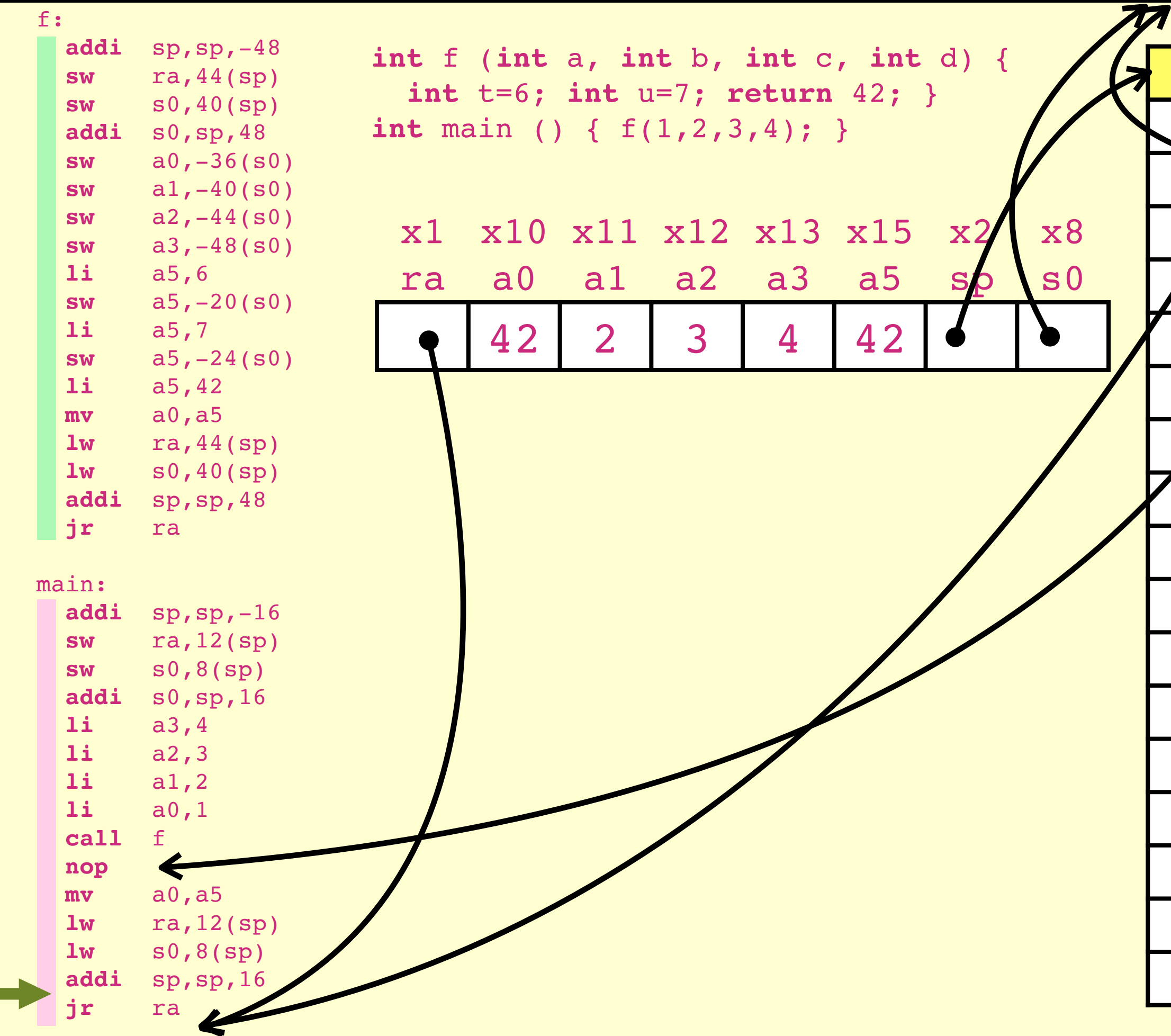
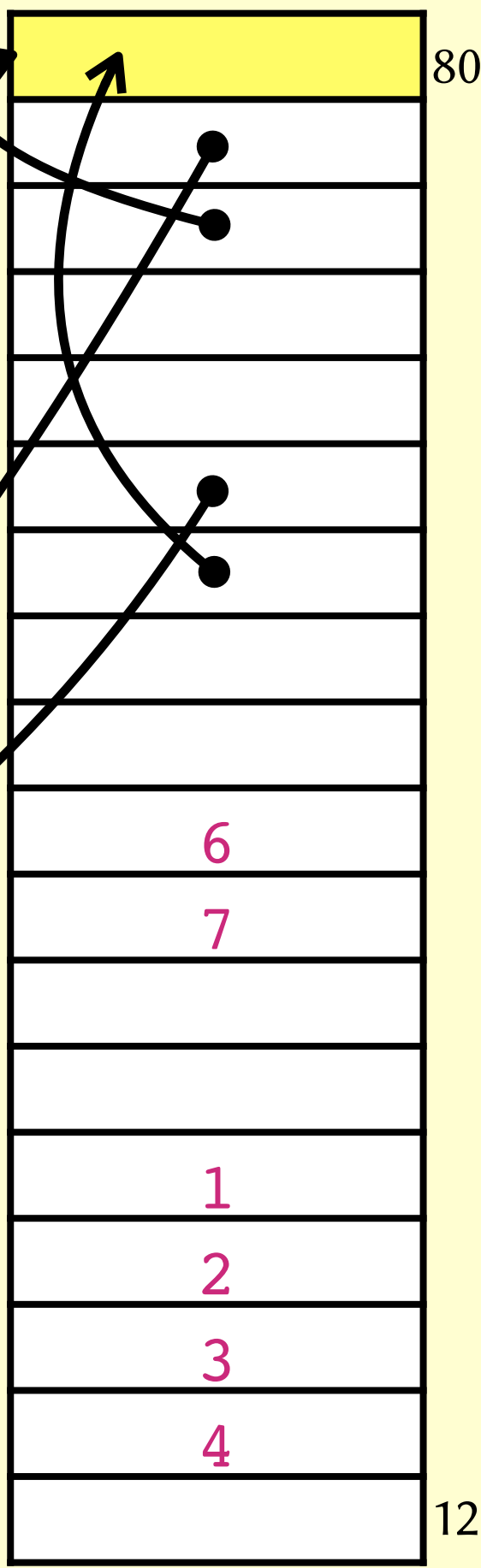
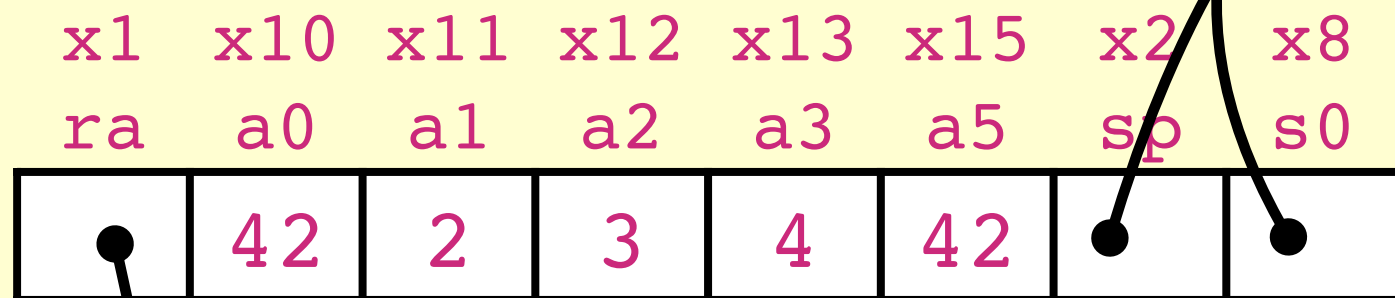
```
int f (int a, int b, int c, int d) {
    int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



```
f:
addi sp,sp,-48
sw ra,44(sp)
sw s0,40(sp)
addi s0,sp,48
sw a0,-36(s0)
sw a1,-40(s0)
sw a2,-44(s0)
sw a3,-48(s0)
li a5,6
sw a5,-20(s0)
li a5,7
sw a5,-24(s0)
li a5,42
mv a0,a5
lw ra,44(sp)
lw s0,40(sp)
addi sp,sp,48
jr ra
```

```
main:
addi sp,sp,-16
sw ra,12(sp)
sw s0,8(sp)
addi s0,sp,16
li a3,4
li a2,3
li a1,2
li a0,1
call f
nop
mv a0,a5
lw ra,12(sp)
lw s0,8(sp)
addi sp,sp,16
jr ra
```

```
int f (int a, int b, int c, int d) {
    int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



$f:$ 

```

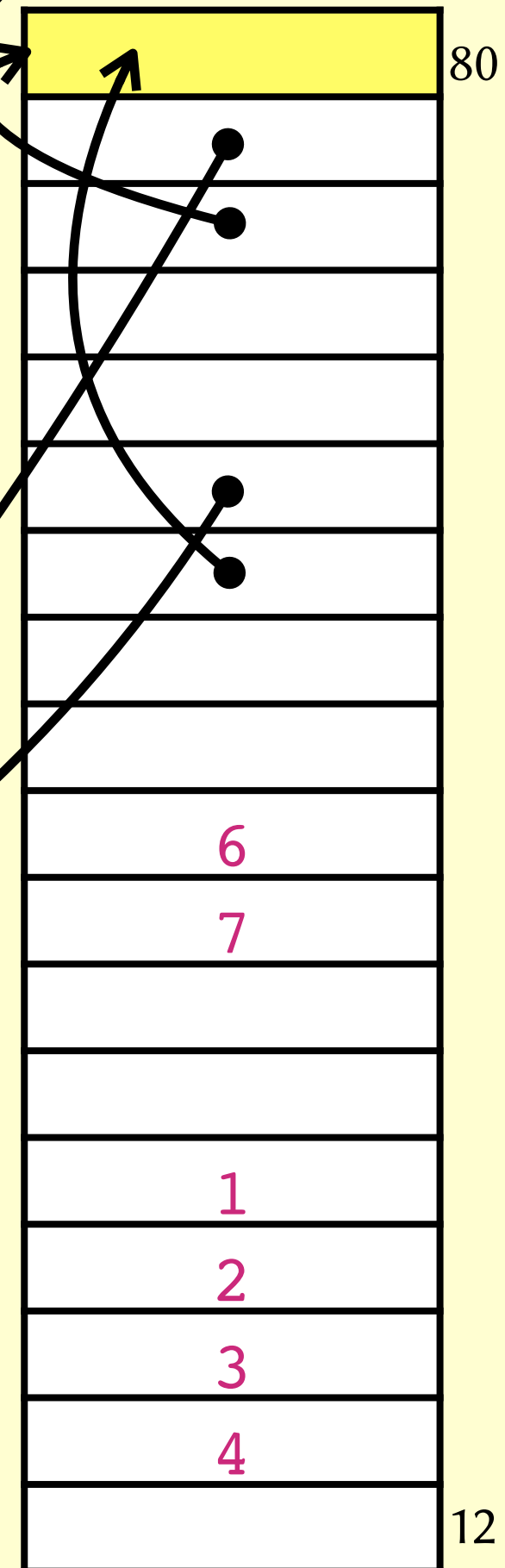
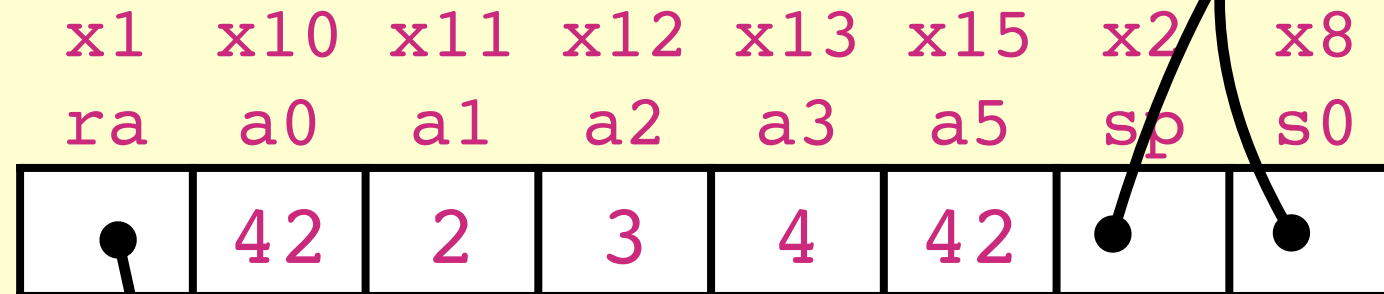
addi    sp,sp,-48
sw      ra,44(sp)
sw      s0,40(sp)
addi    s0,sp,48
sw      a0,-36(s0)
sw      a1,-40(s0)
sw      a2,-44(s0)
sw      a3,-48(s0)
li      a5,6
sw      a5,-20(s0)
li      a5,7
sw      a5,-24(s0)
li      a5,42
mv      a0,a5
lw      ra,44(sp)
lw      s0,40(sp)
addi    sp,sp,48
jr      ra

```

```
main:
```

```
addi    sp,sp,-16
sw      ra,12(sp)
sw      s0,8(sp)
addi    s0,sp,16
li      a3,4
li      a2,3
li      a1,2
li      a0,1
call    f
nop      ←
mv      a0,a5
lw      ra,12(sp)
lw      s0,8(sp)
addi    sp,sp,16
jr      ra
```

```
int f (int a, int b, int c, int d) {
    int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



# Lecture outline

- ✓ Parsing C: the *dangling-else* problem.
- ✓ Parsing C: the *lexer hack*.
- ✓ Generating RISC-V assembly for function calls.