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

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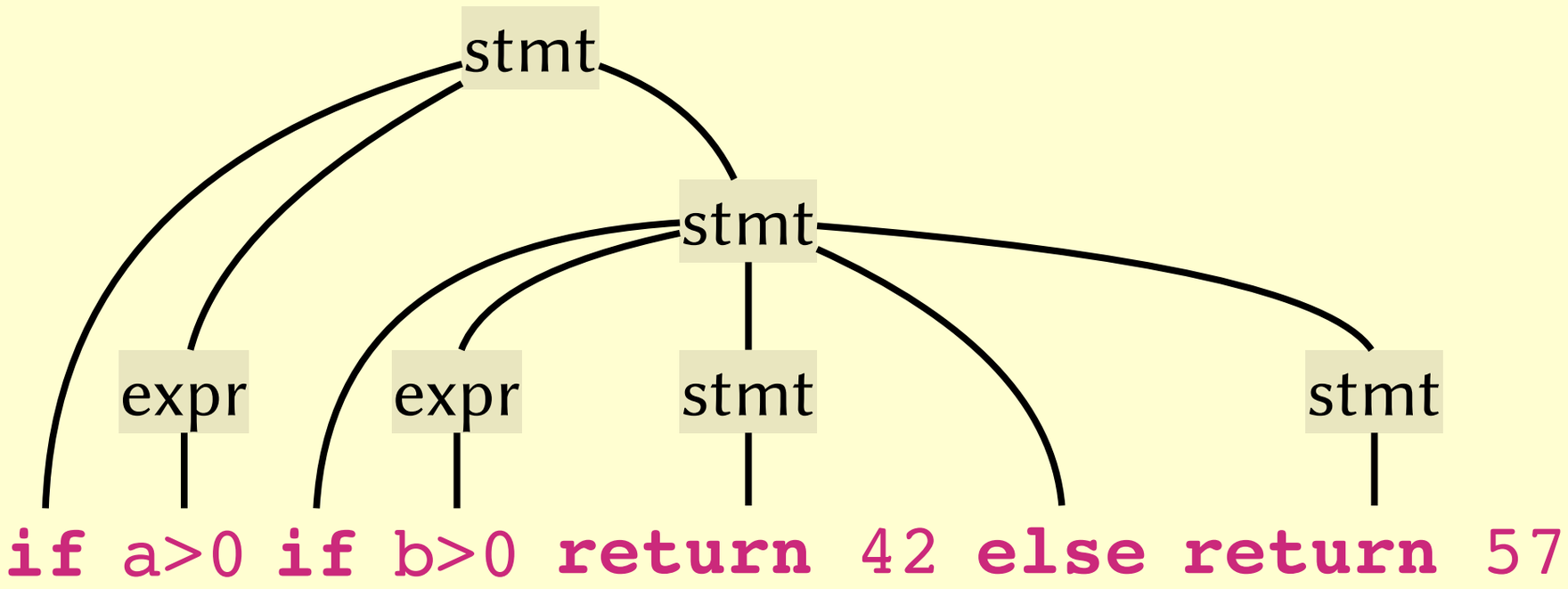

The dangling-else problem

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



The dangling-else problem

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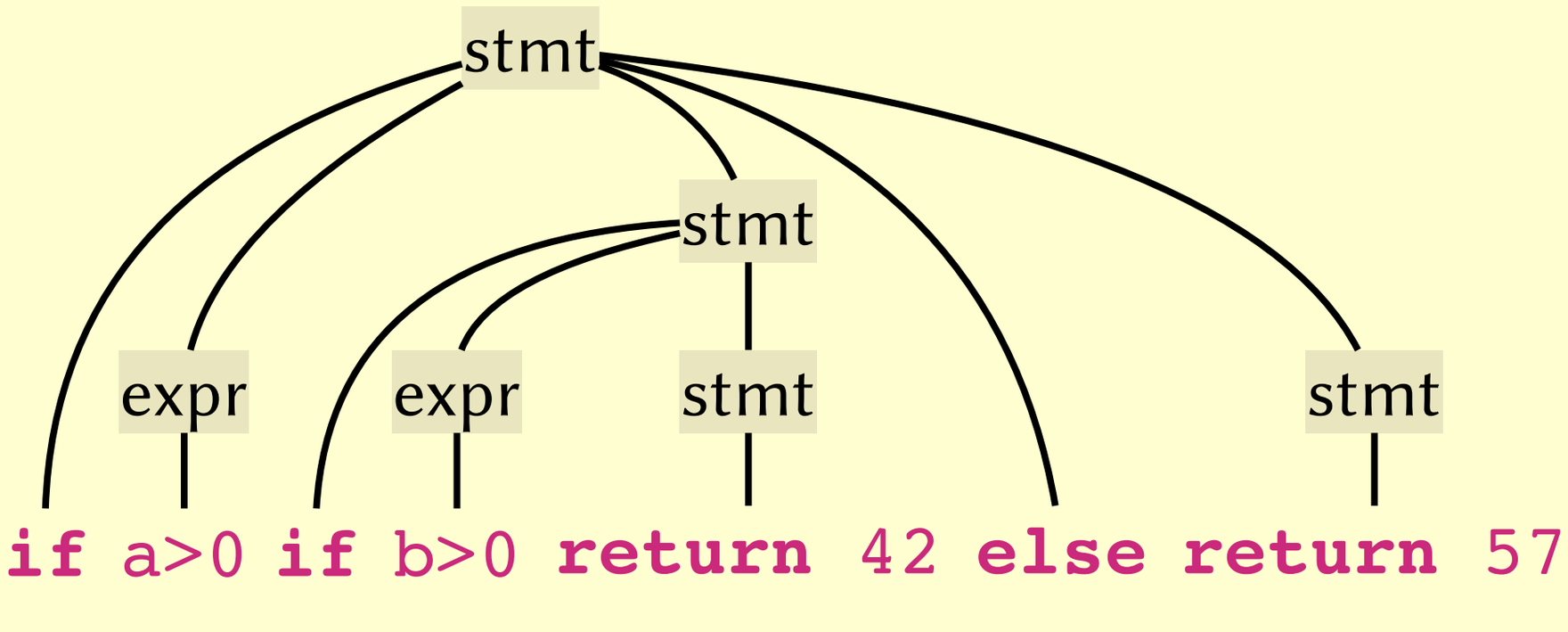


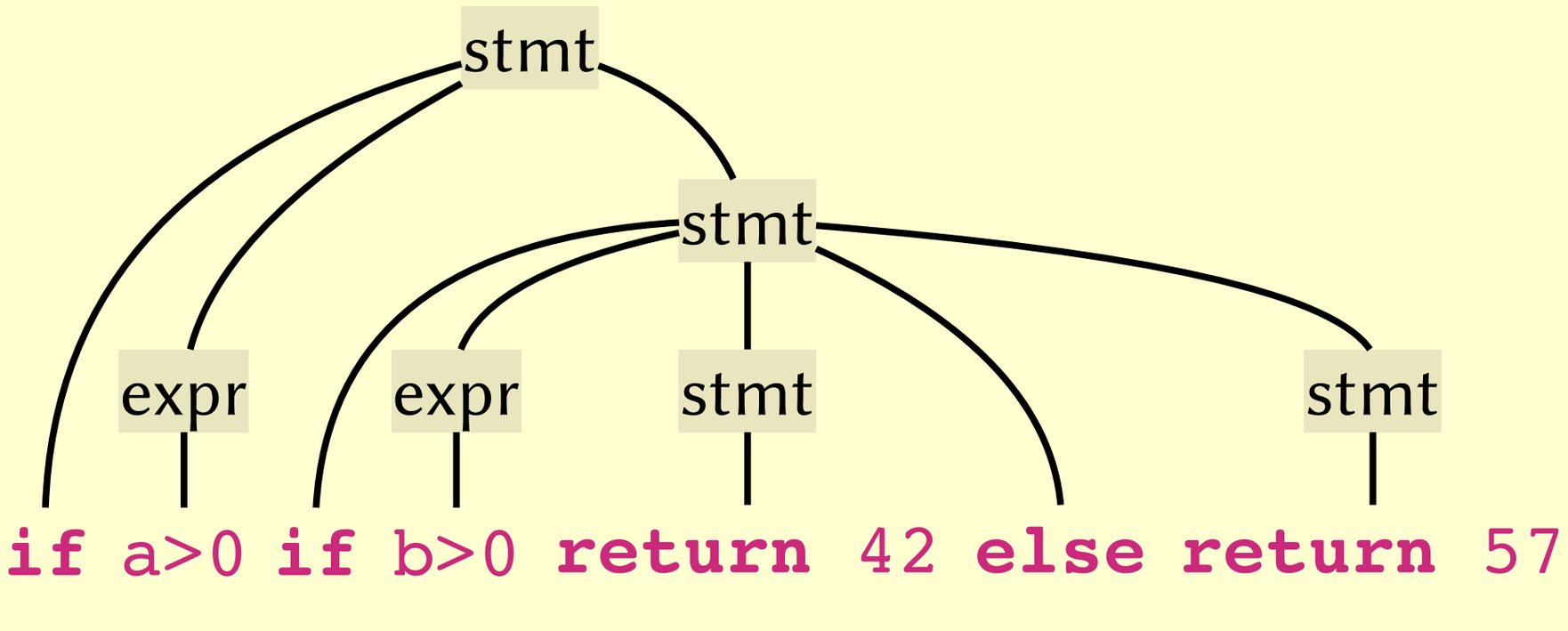
The dangling-else problem

```
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

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f:
  local t, 4;
  local u, 4;
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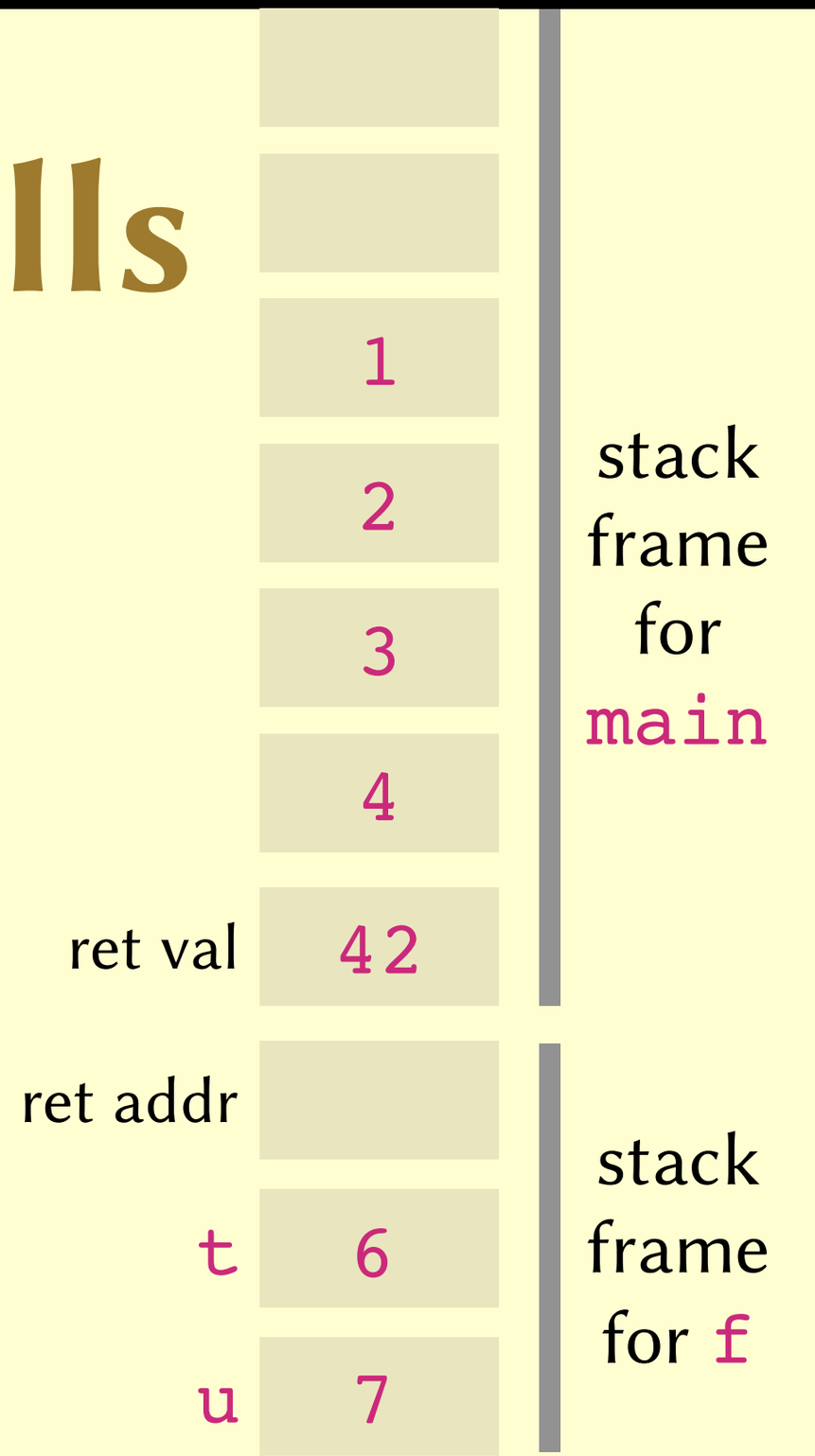

ABI

- 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...

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C source #1

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

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

COMPILER EXPLORER

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```
f:
        li      a0,42
        ret
main:
        ret
```

COMPILER EXPLORER

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C source #1

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        sw      ra,44(sp)
        sw      s0,40(sp)
        addi    s0,sp,48
        sw      a0,-36(s0)
        sw      a1,-40(s0)
        sw      a2,-44(s0)
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        li      a5,6
        sw      a5,-20(s0)
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        sw      a5,-24(s0)
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        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
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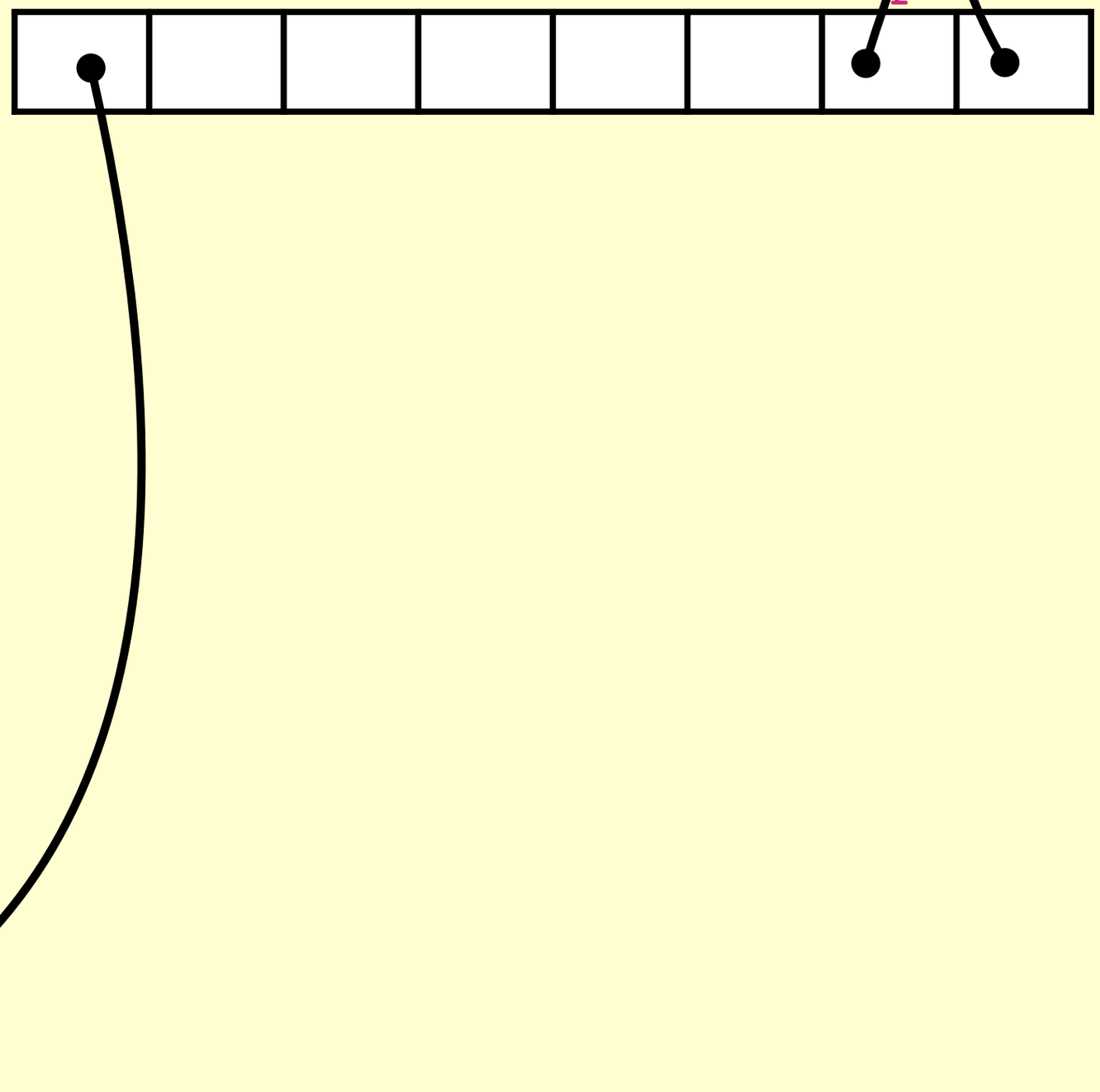

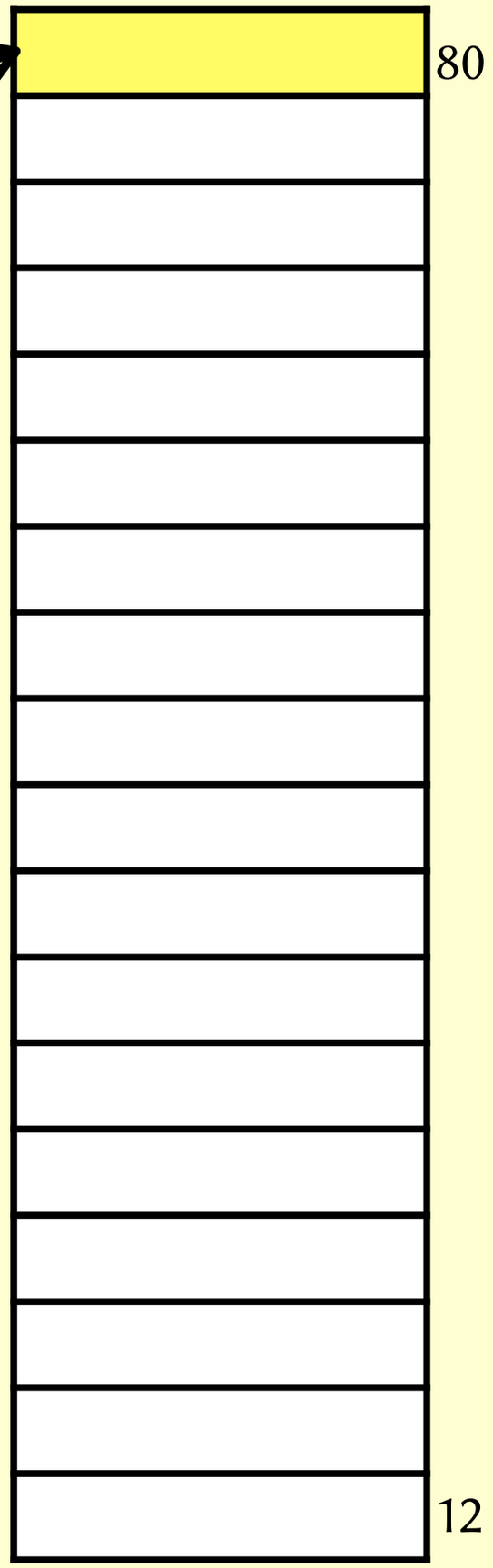

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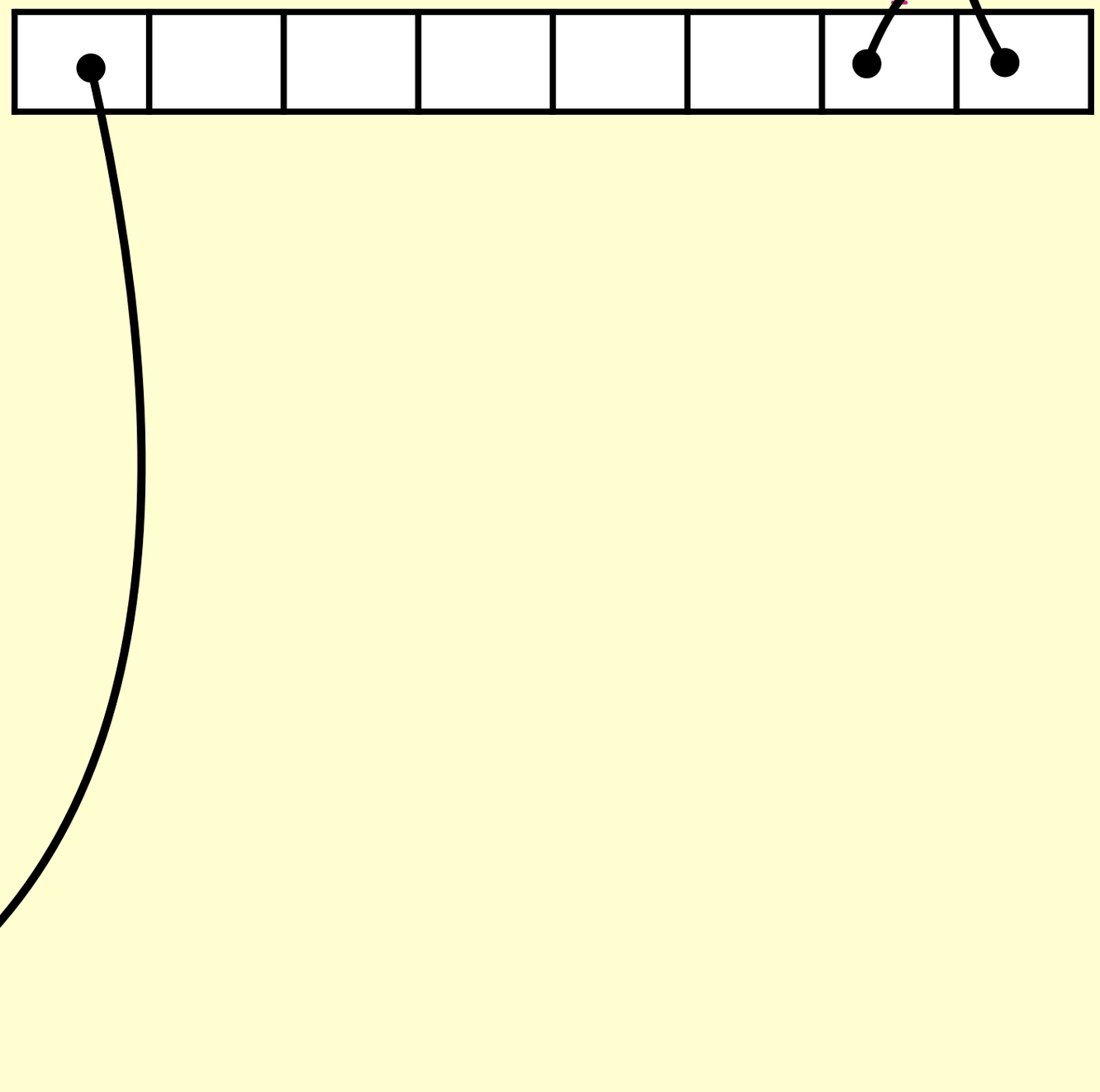

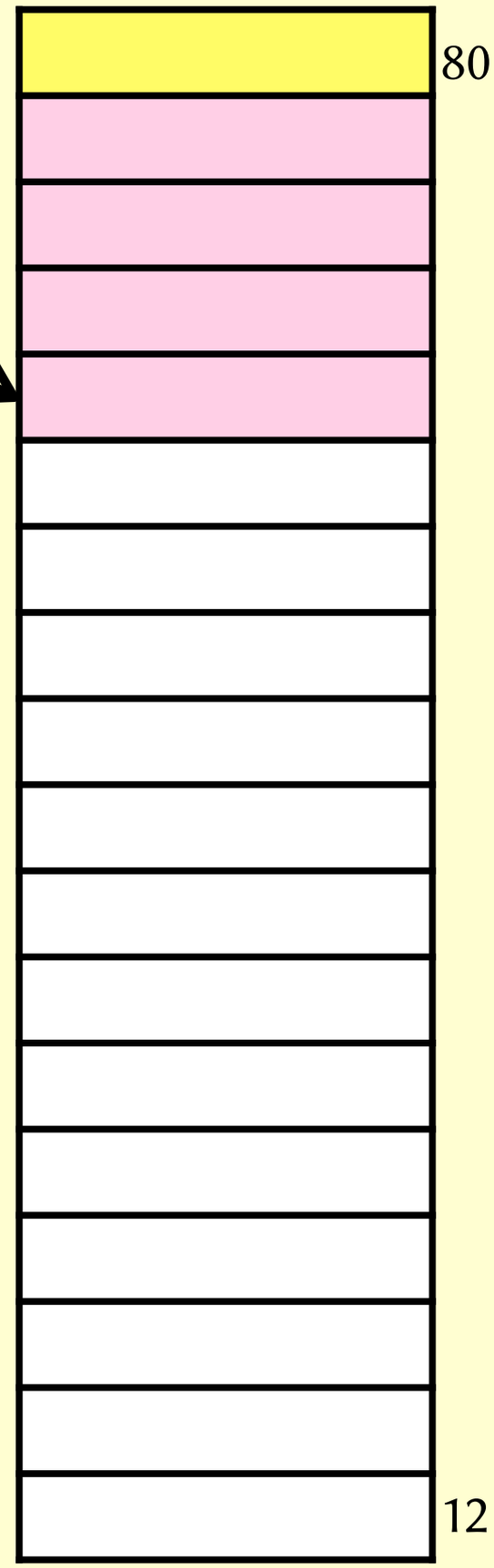

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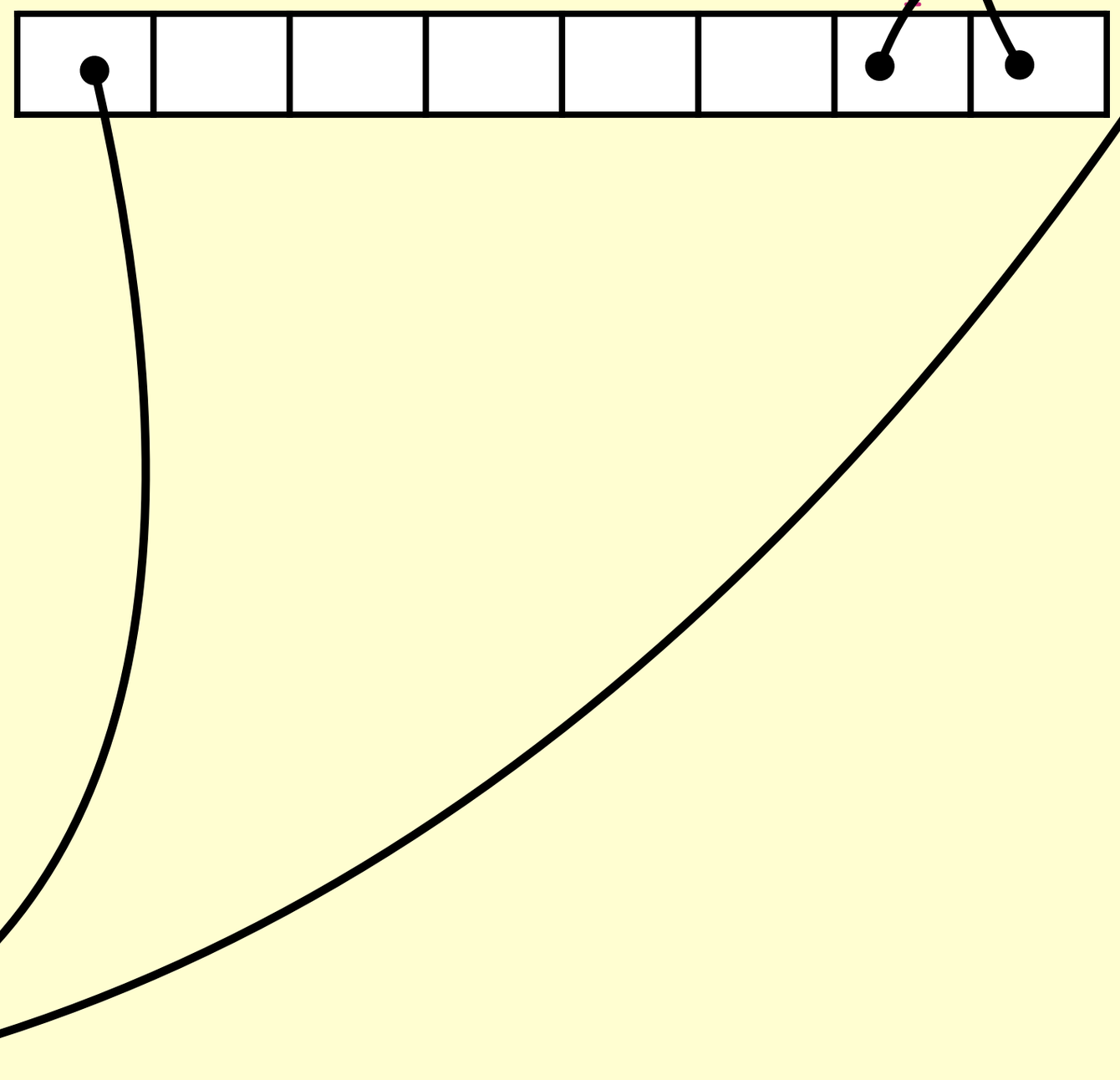

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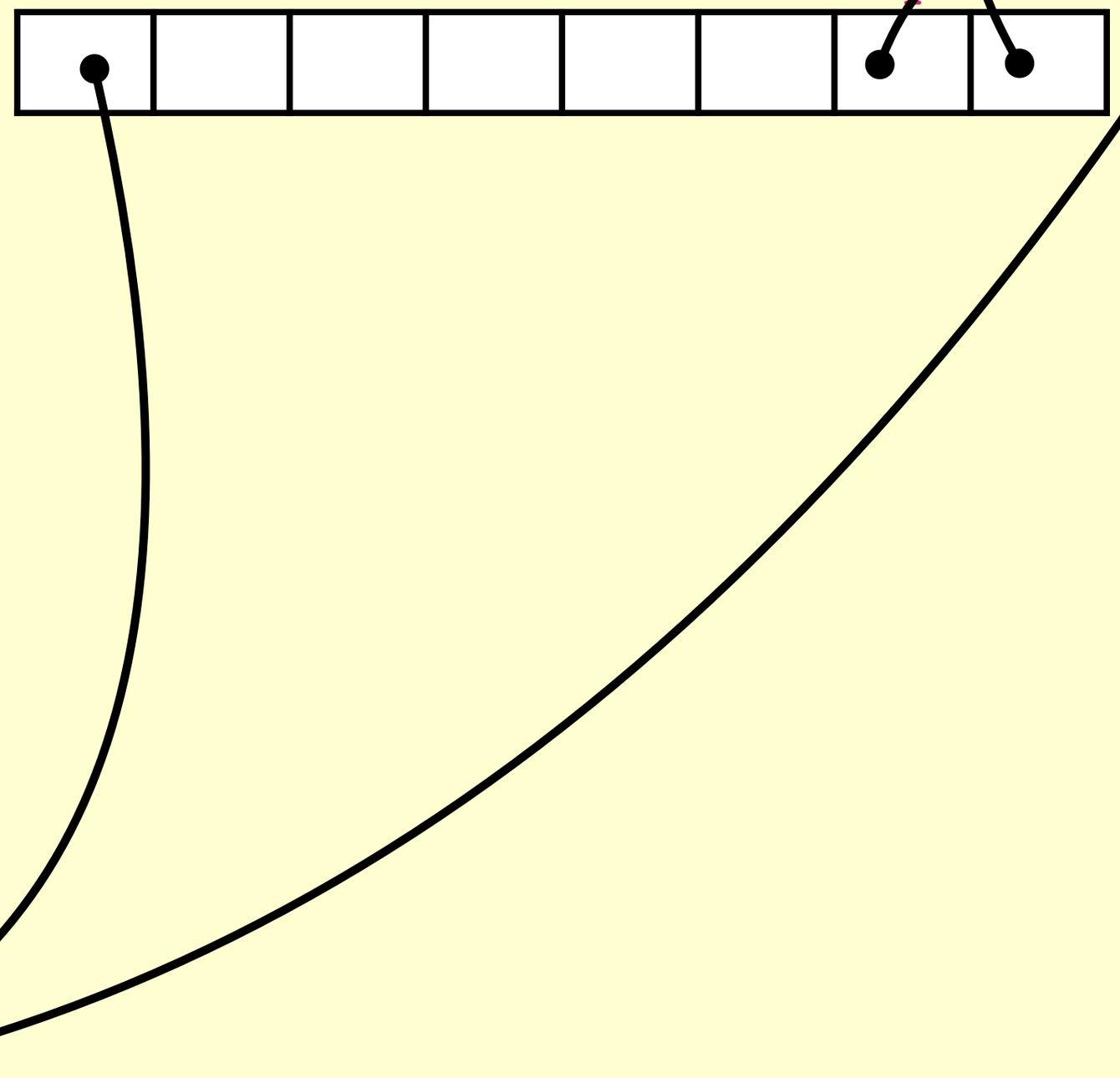

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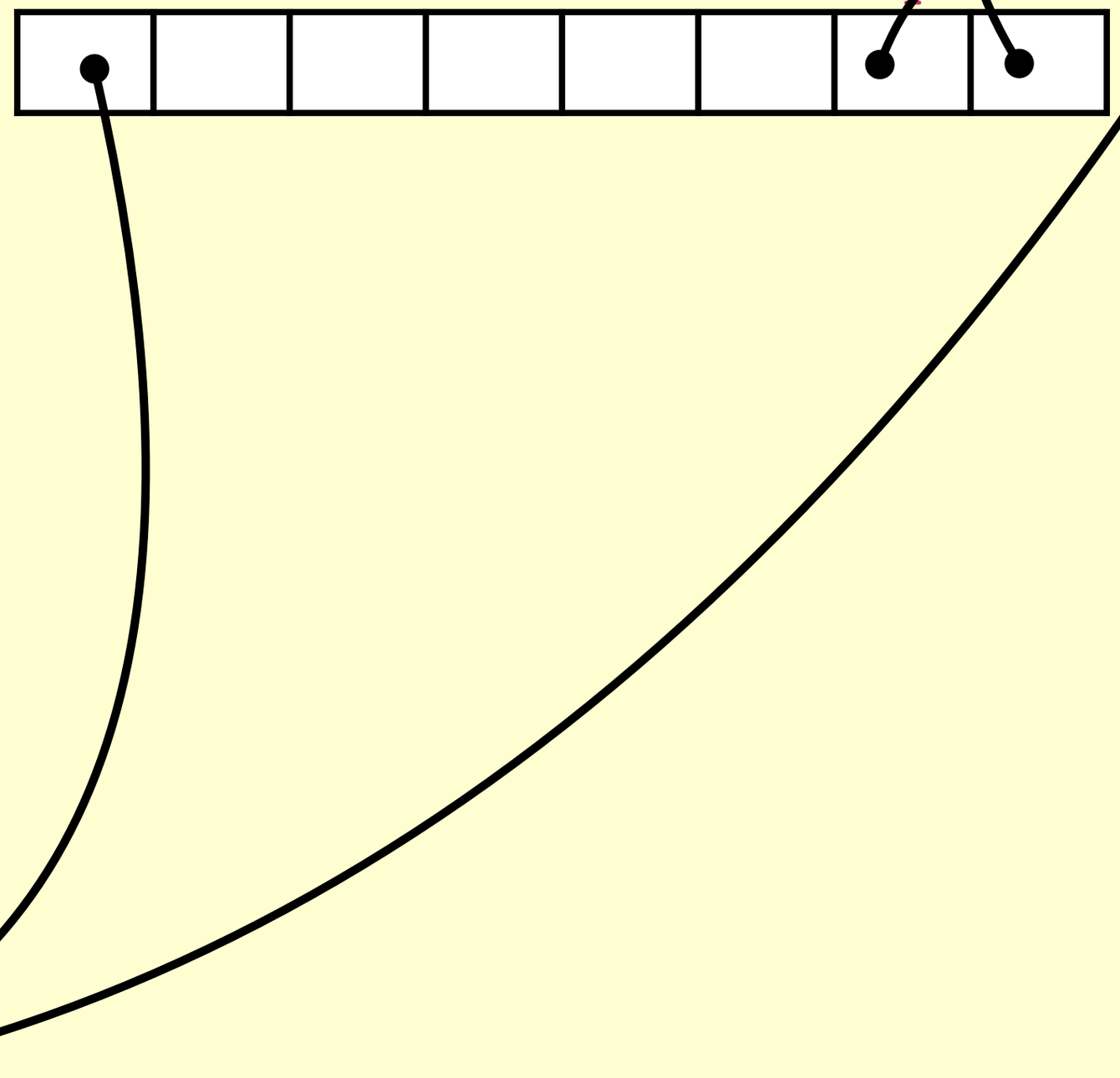

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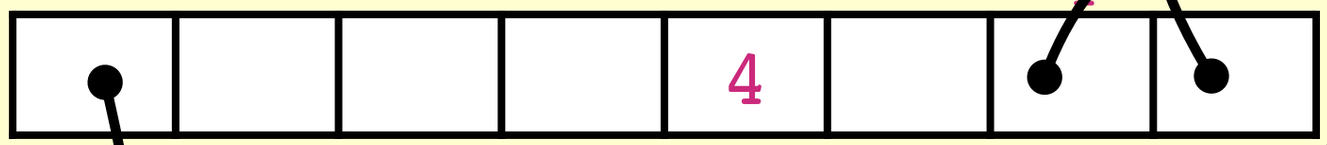

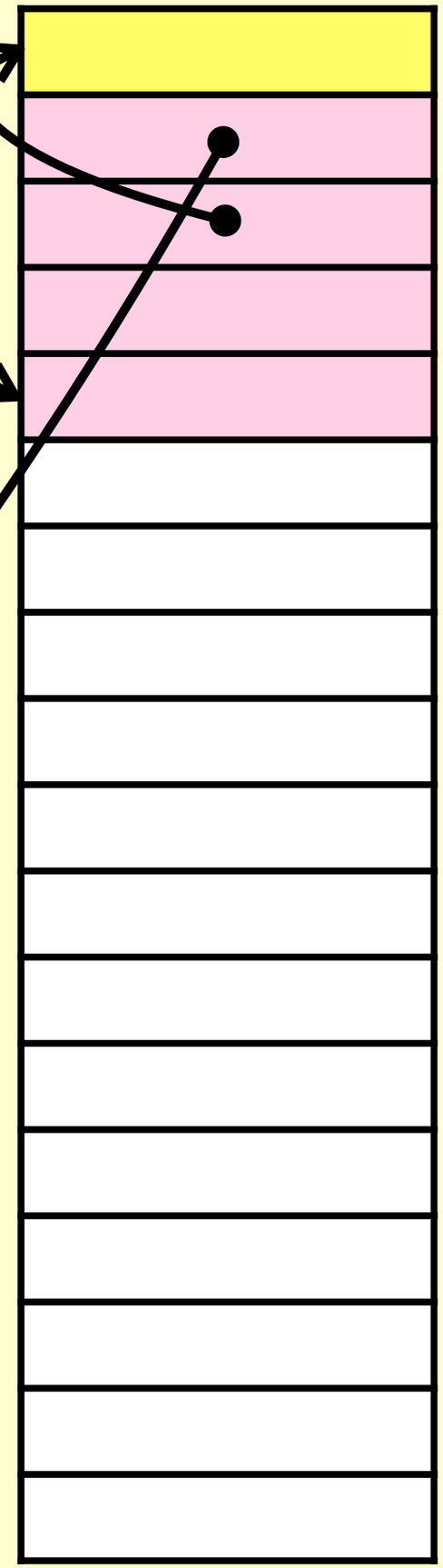

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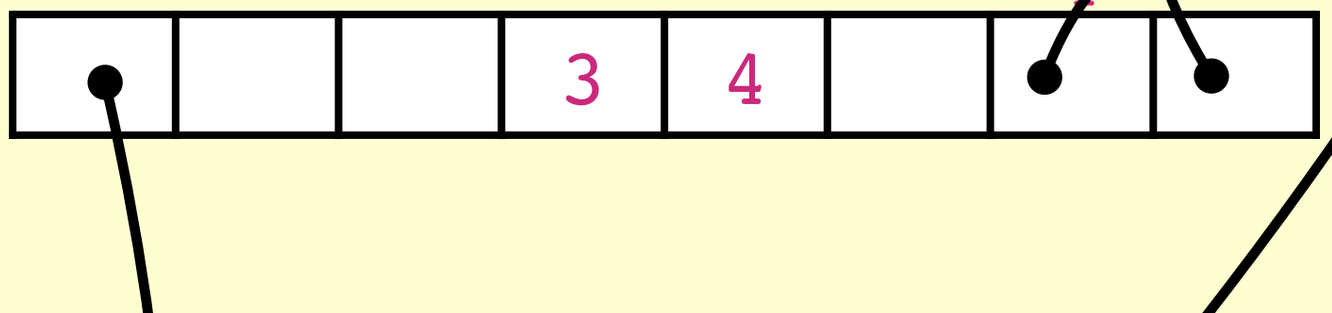

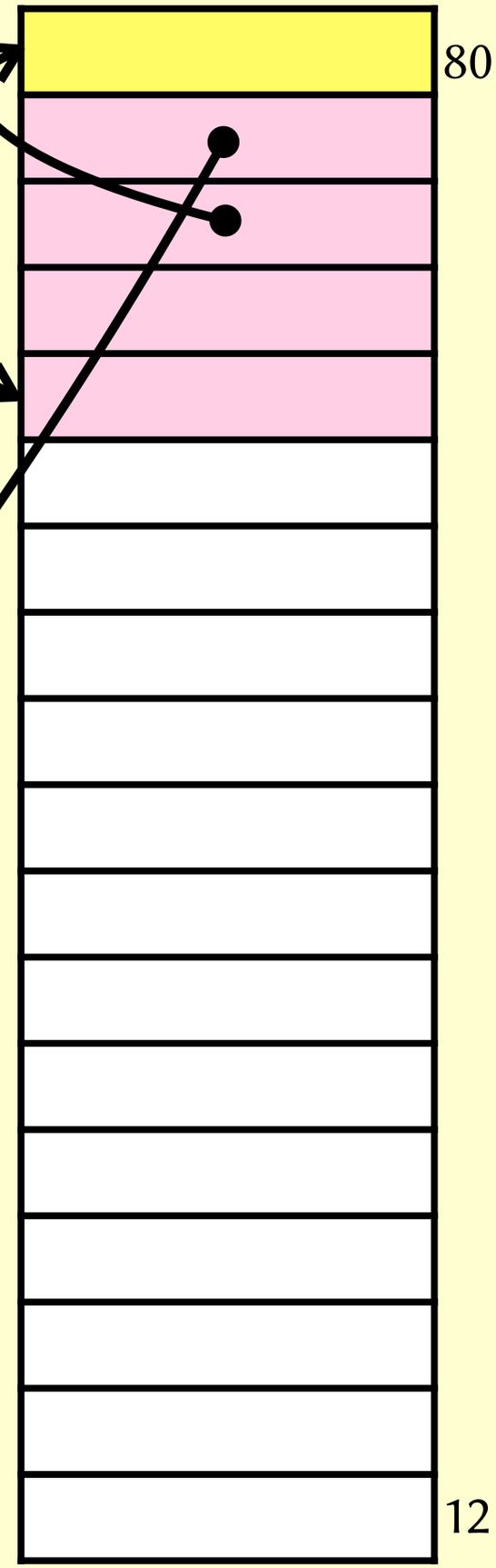

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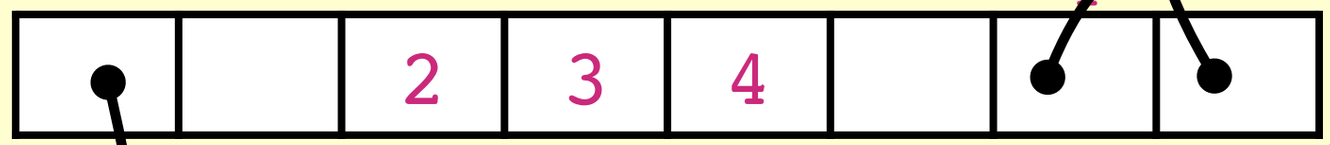
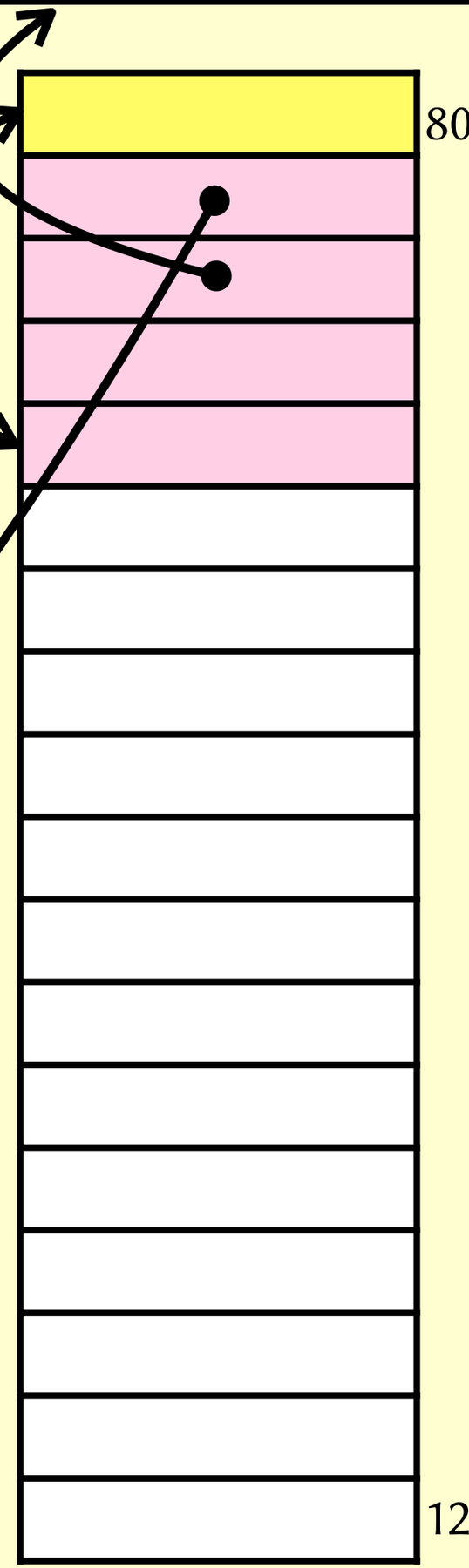
```

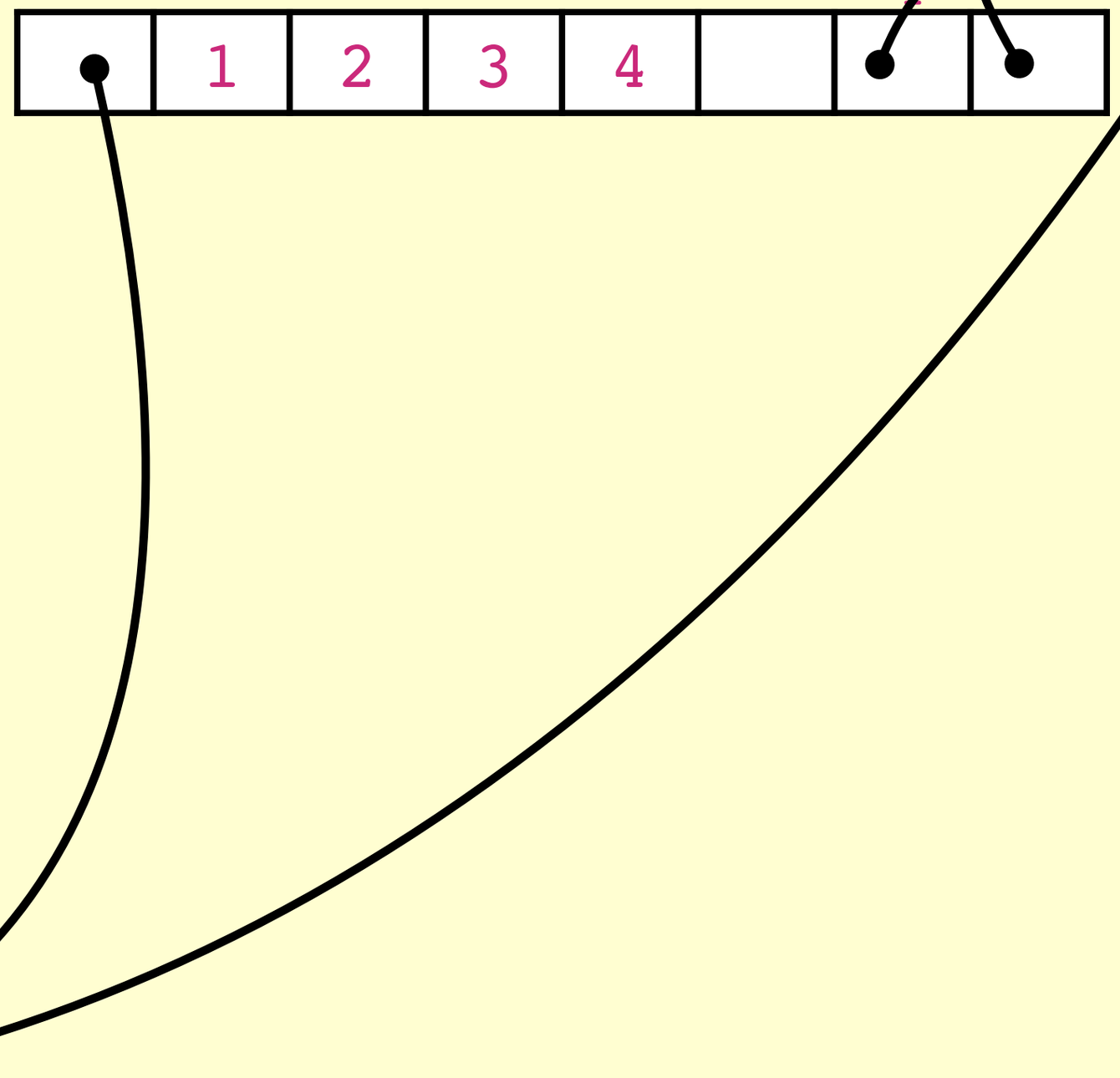




```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
 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



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    addi  sp,sp,-48
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    sw    a0,-36(s0)
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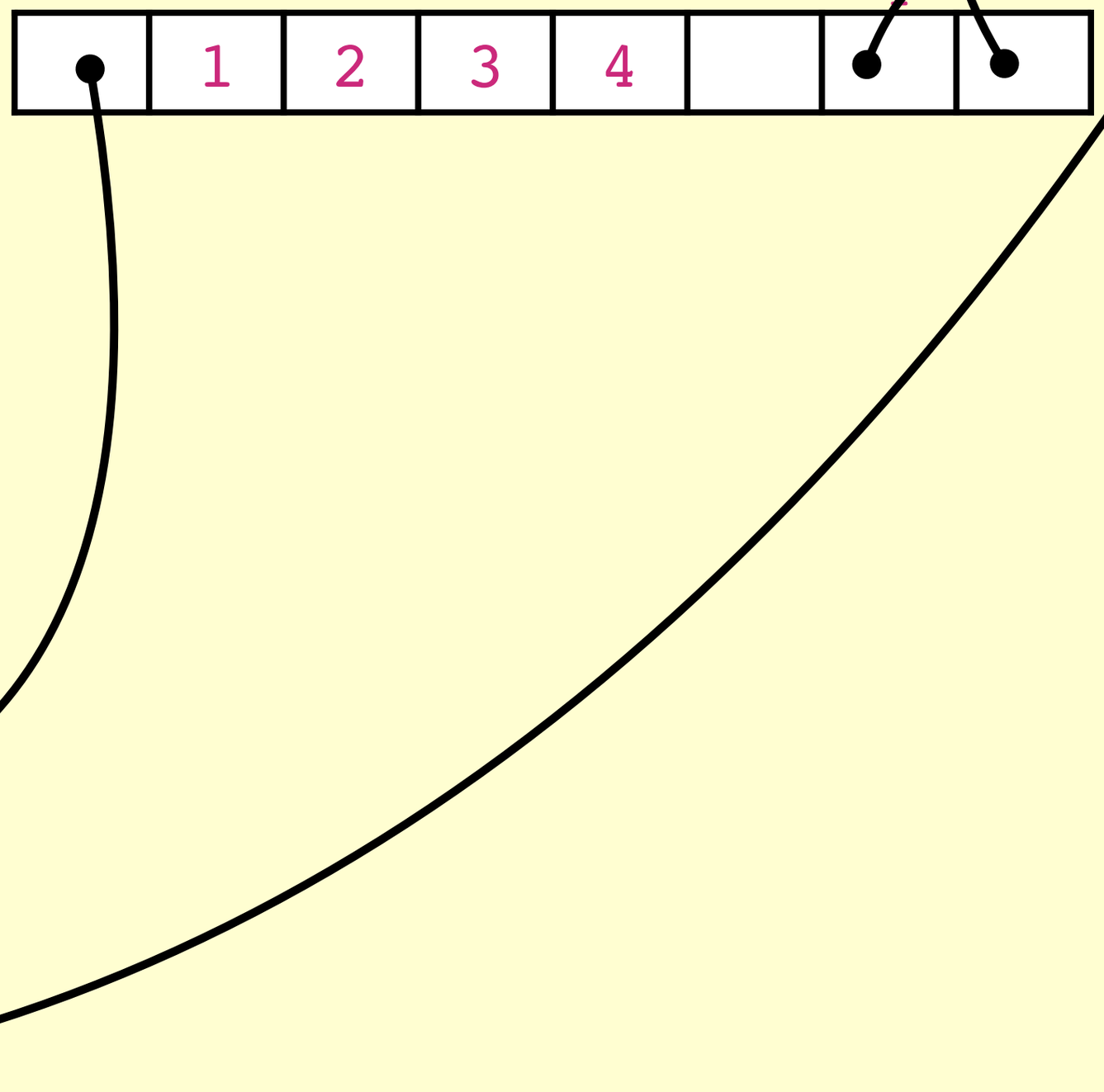

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  sw    ra,44(sp)
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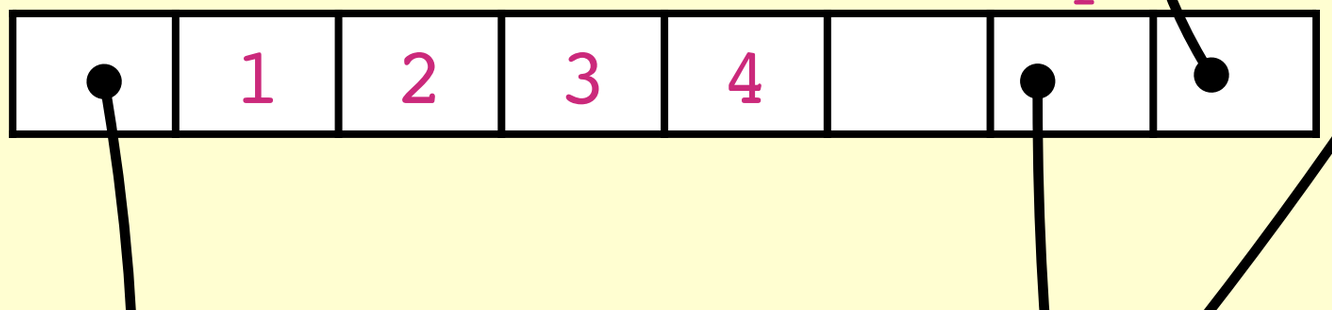

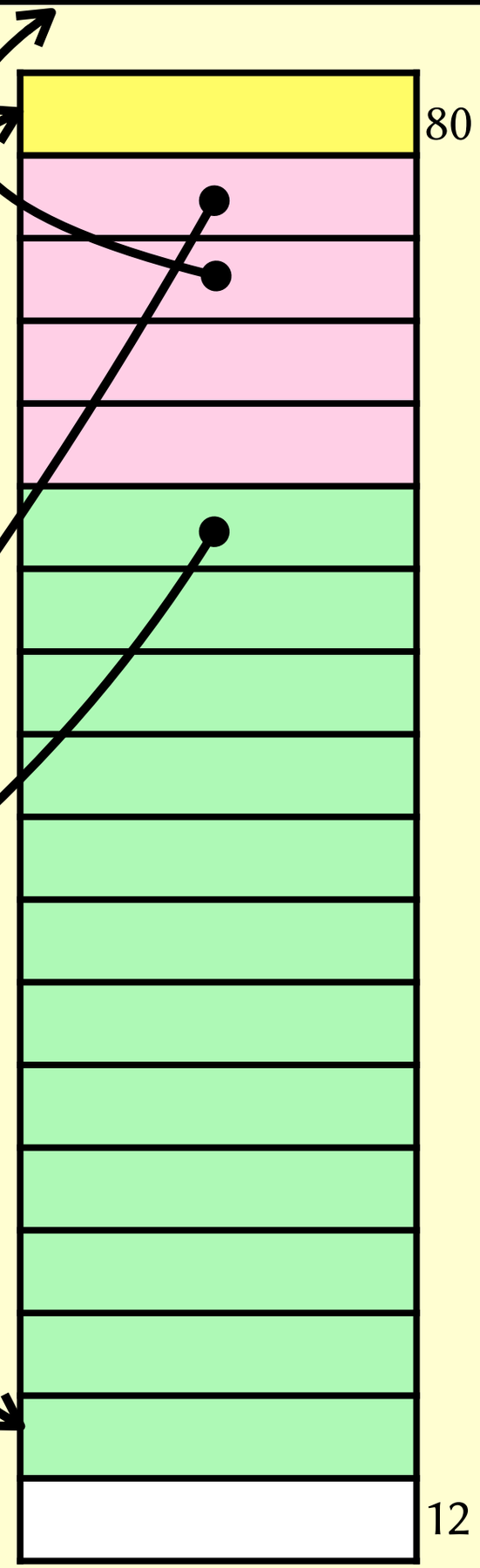

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  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
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  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
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  lw    s0,40(sp)
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  addi  sp,sp,-16
  sw    ra,12(sp)
  sw    s0,8(sp)
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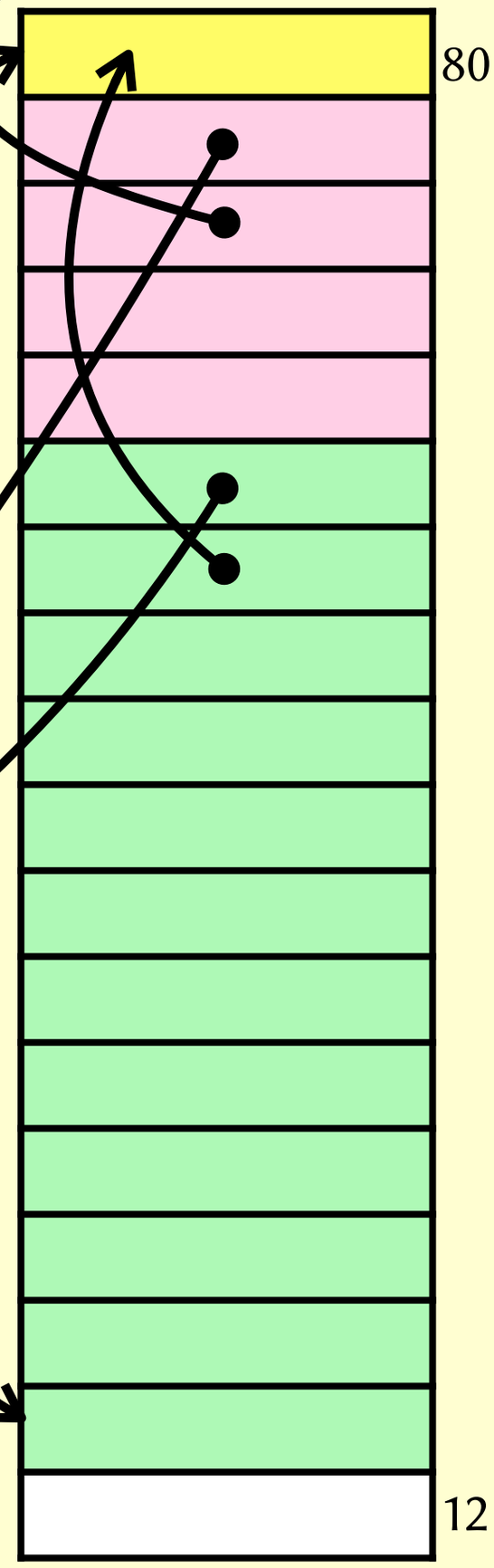

```
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  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
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  li    a5,7
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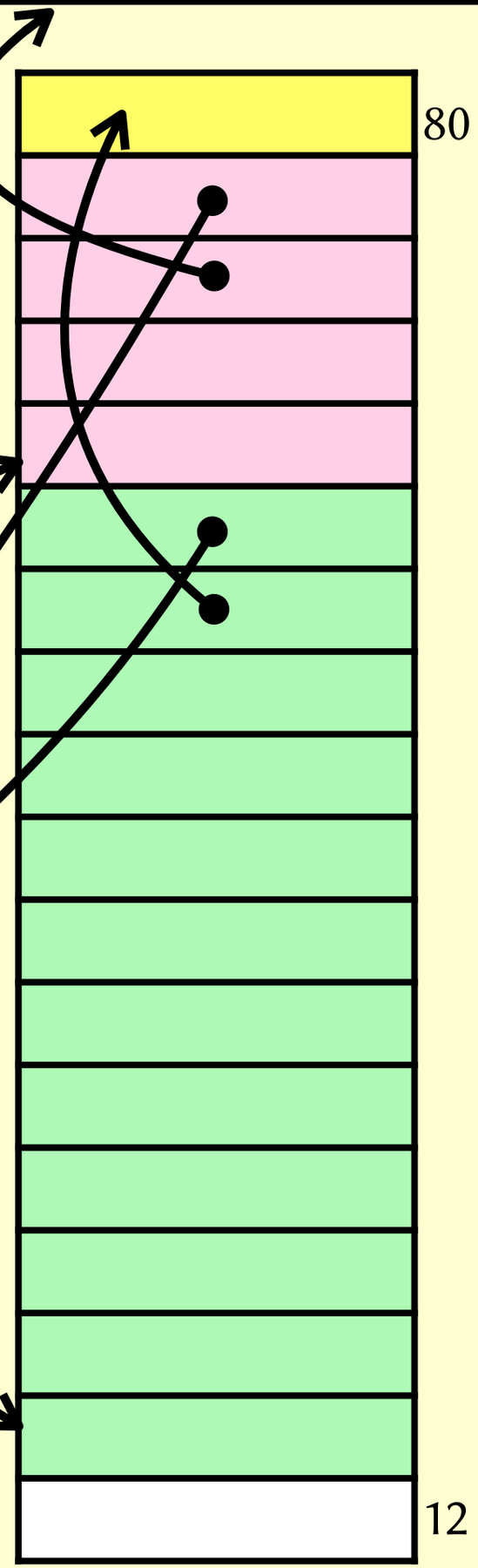

```
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   sw    s0,40(sp)
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   li    a5,7
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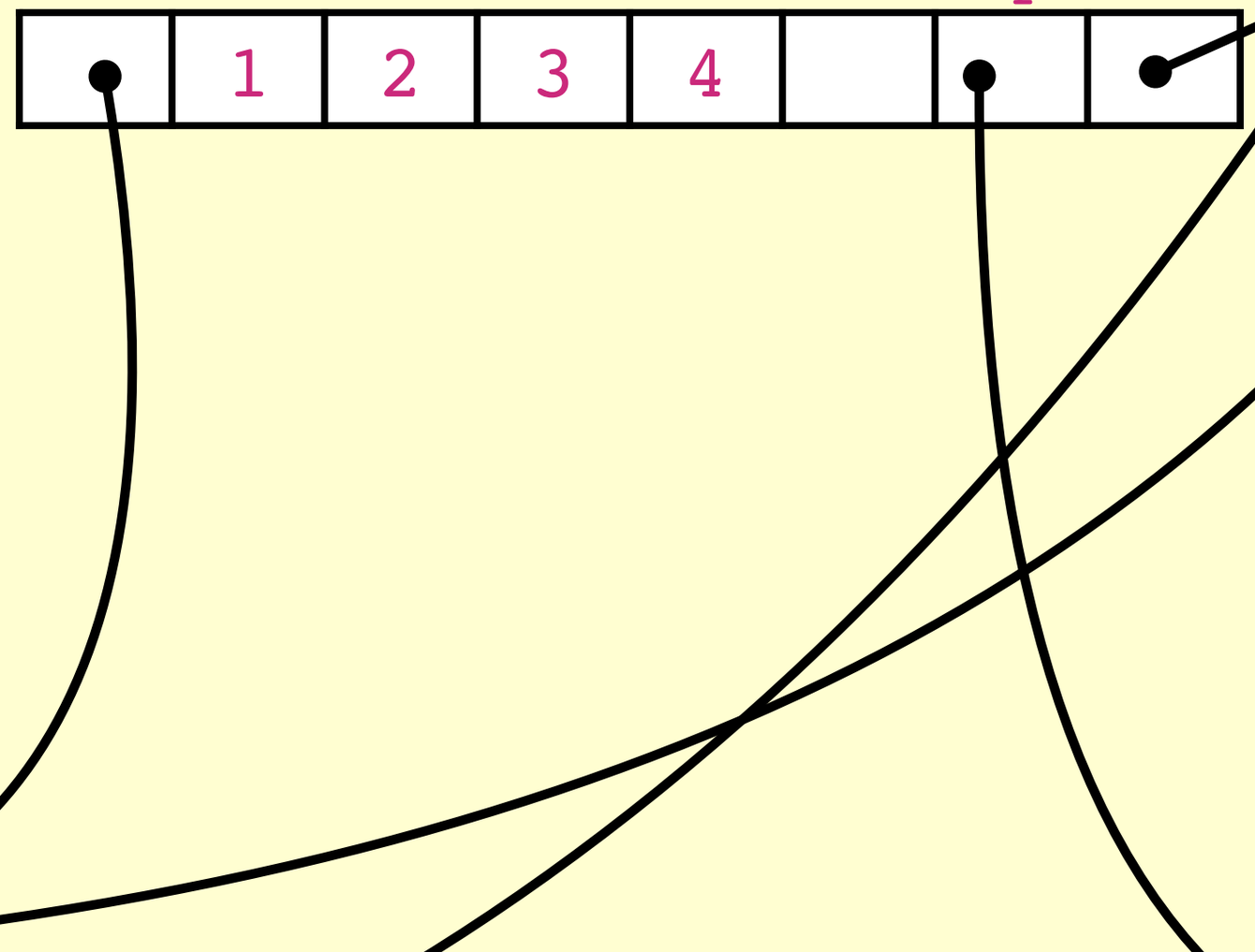

```
f:
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  sw    s0,40(sp)
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  sw    a0,-36(s0)
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  sw    a2,-44(s0)
  sw    a3,-48(s0)
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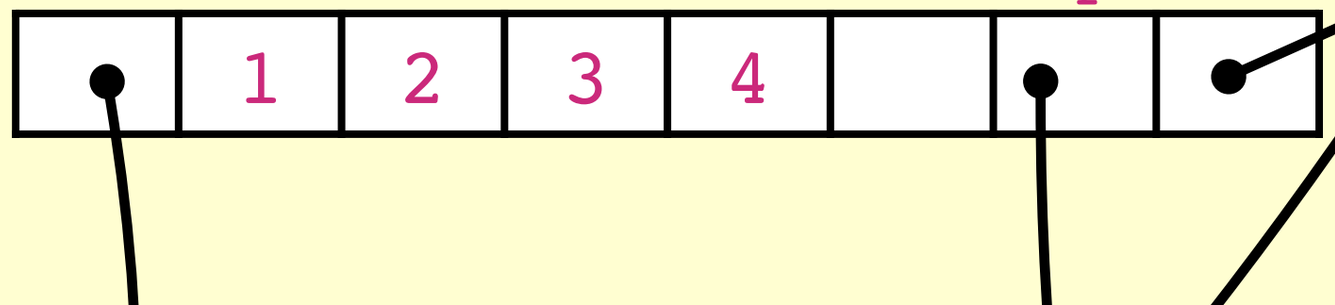

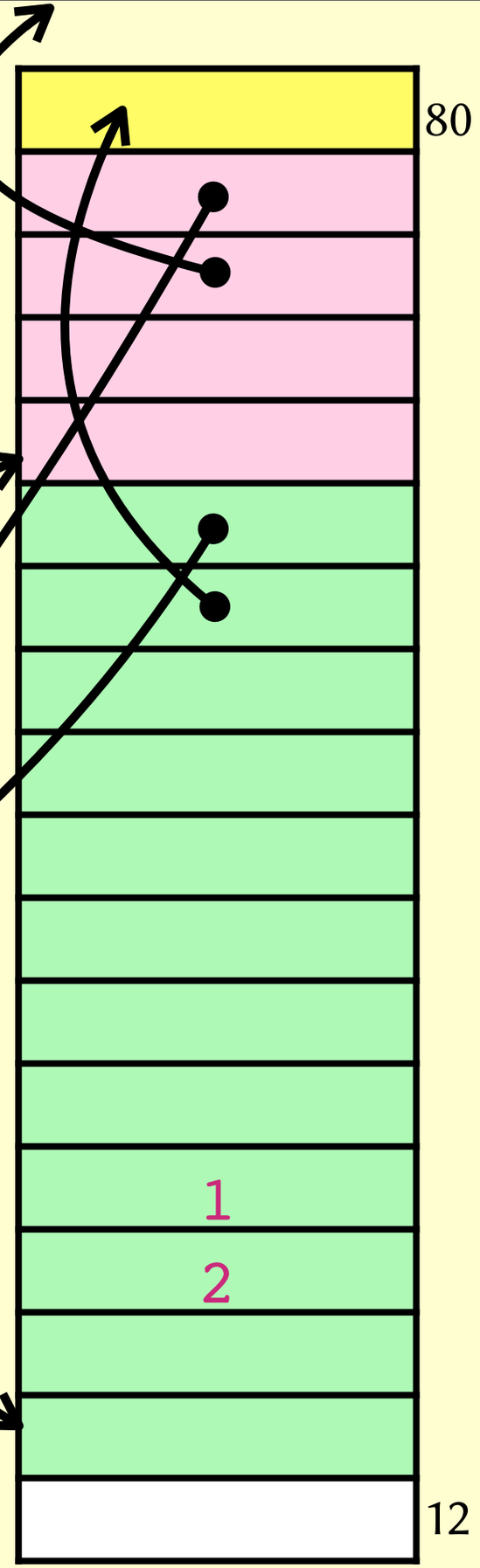

```
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  sw    a0,-36(s0)
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  li    a5,7
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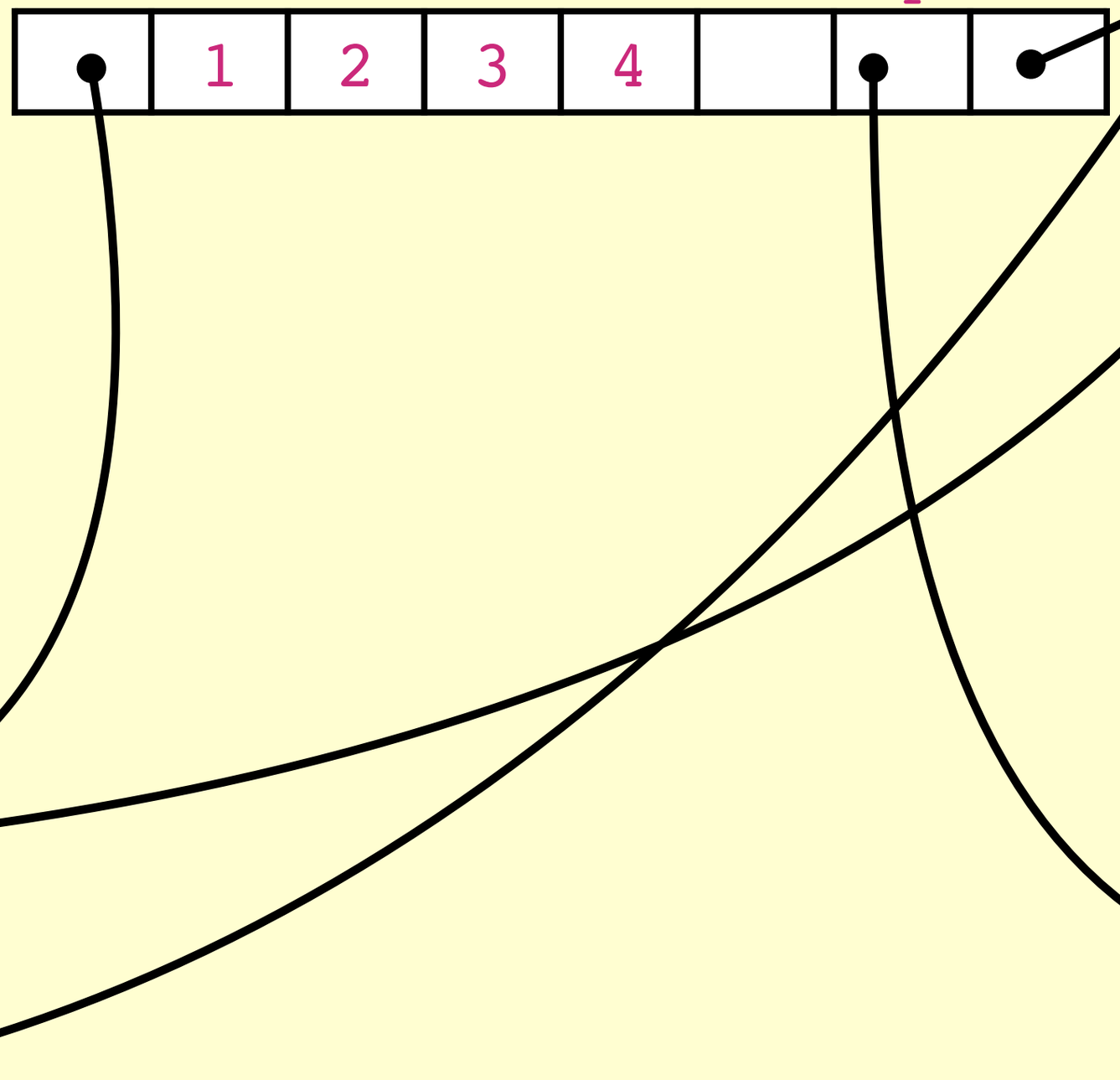

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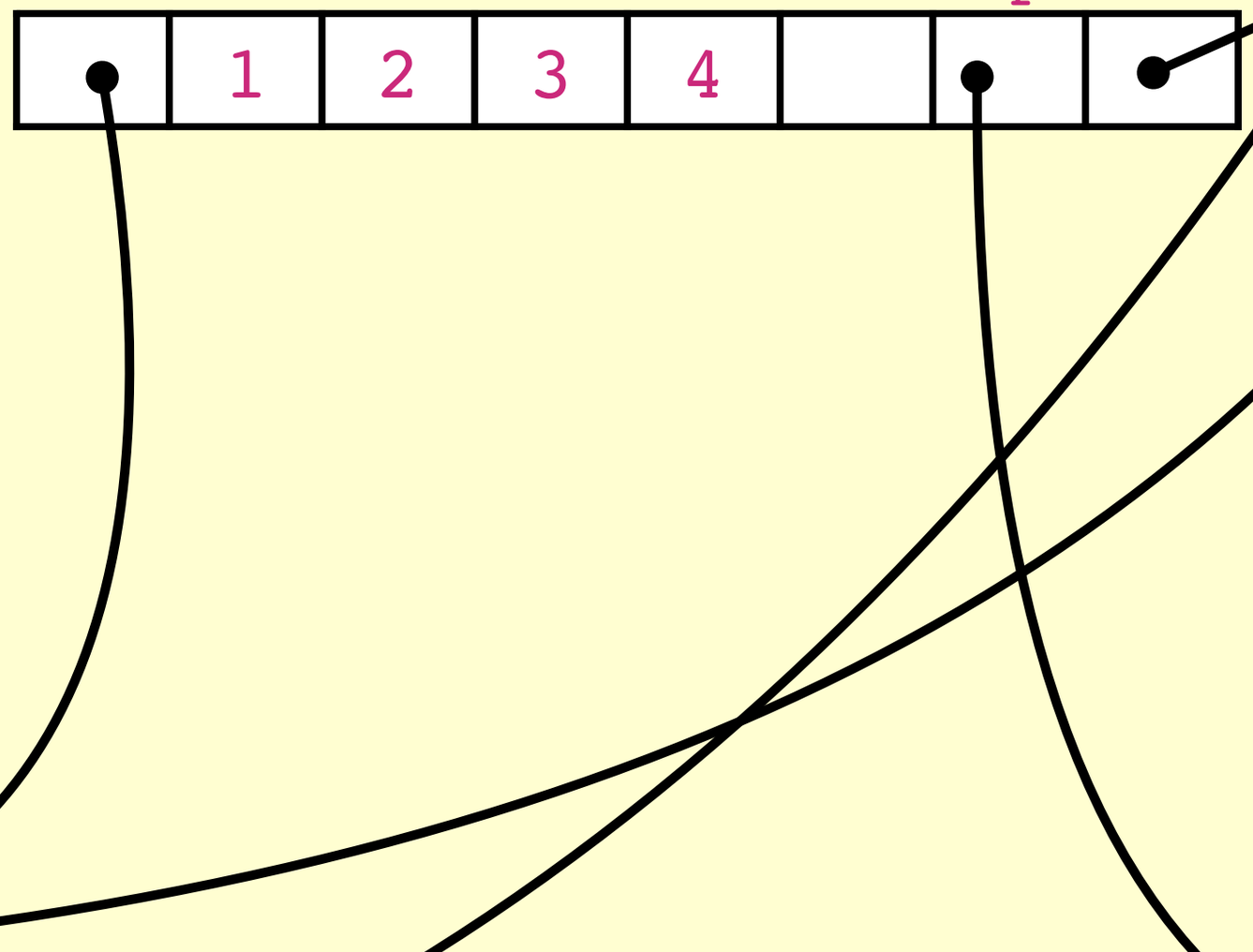

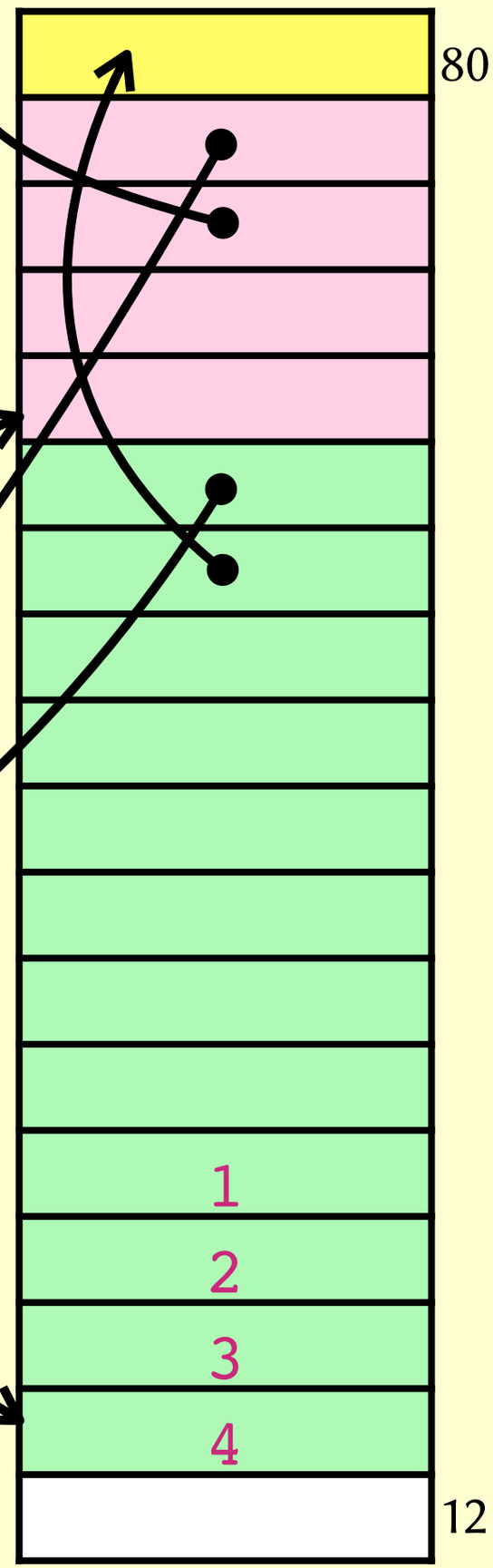

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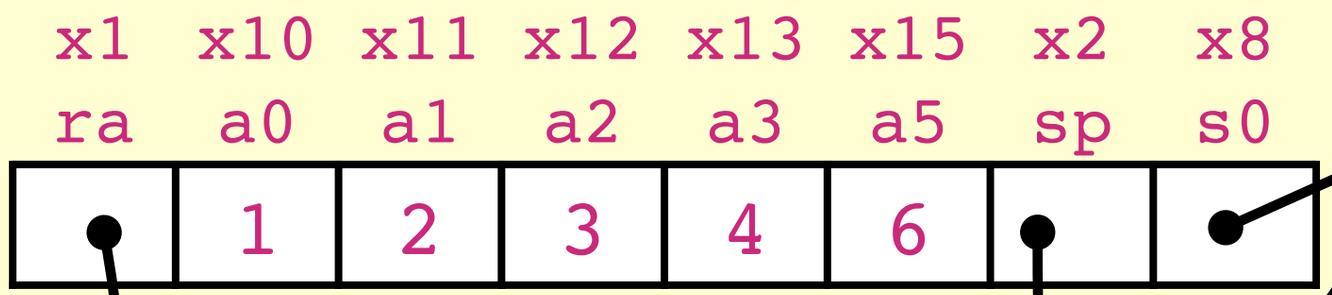

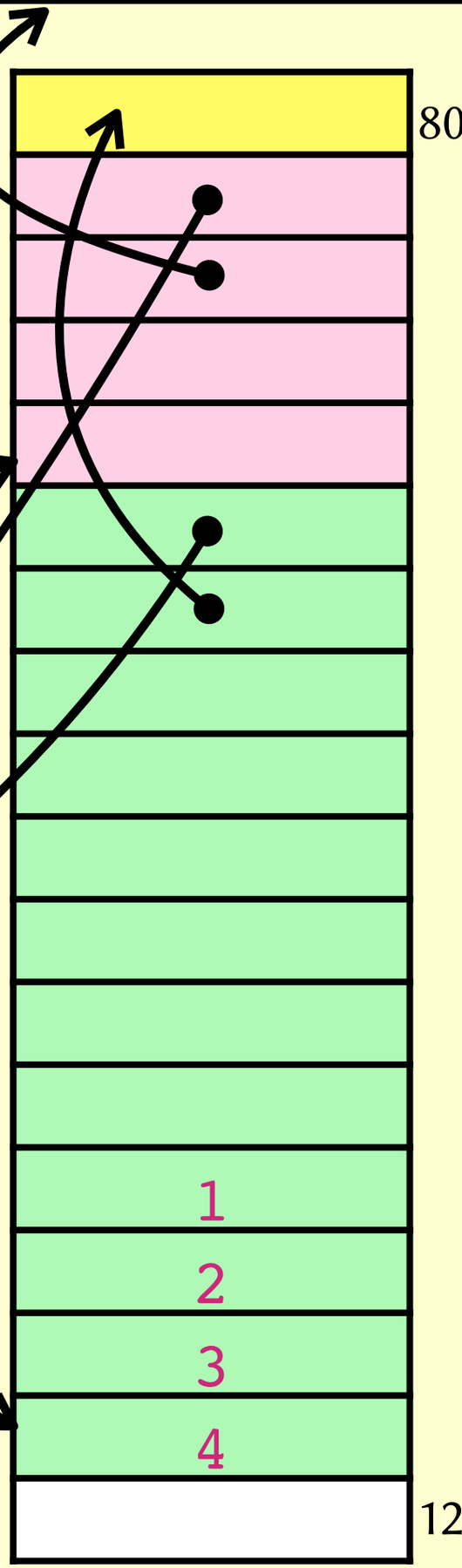

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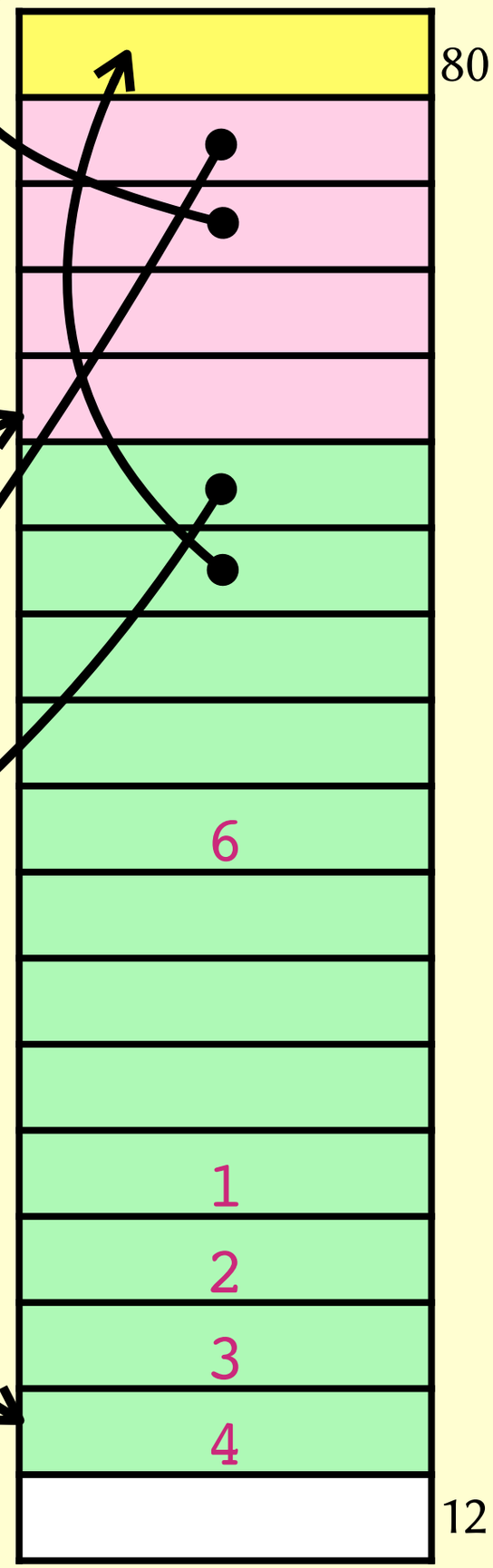

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int main () { f(1,2,3,4); }
```
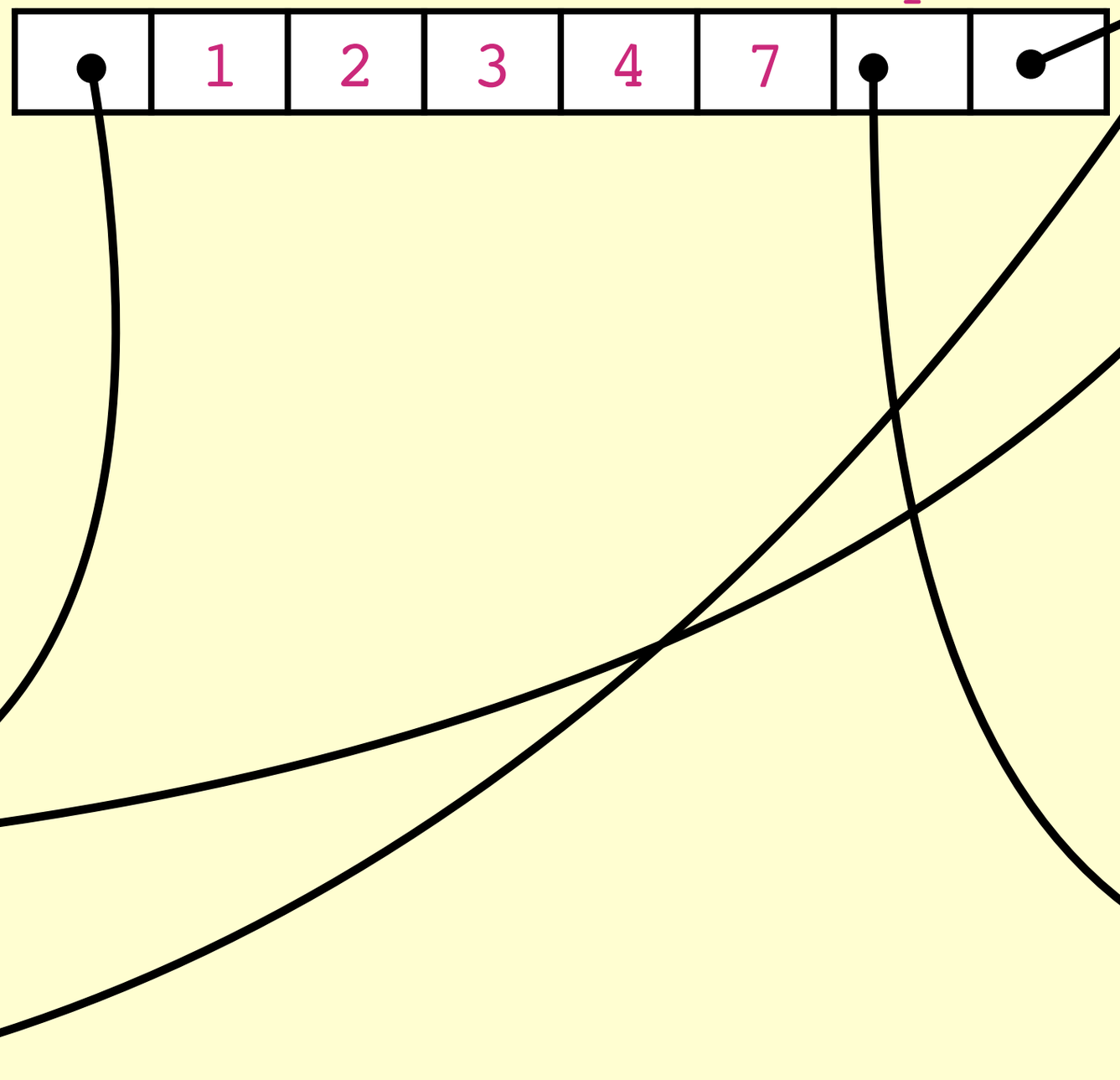
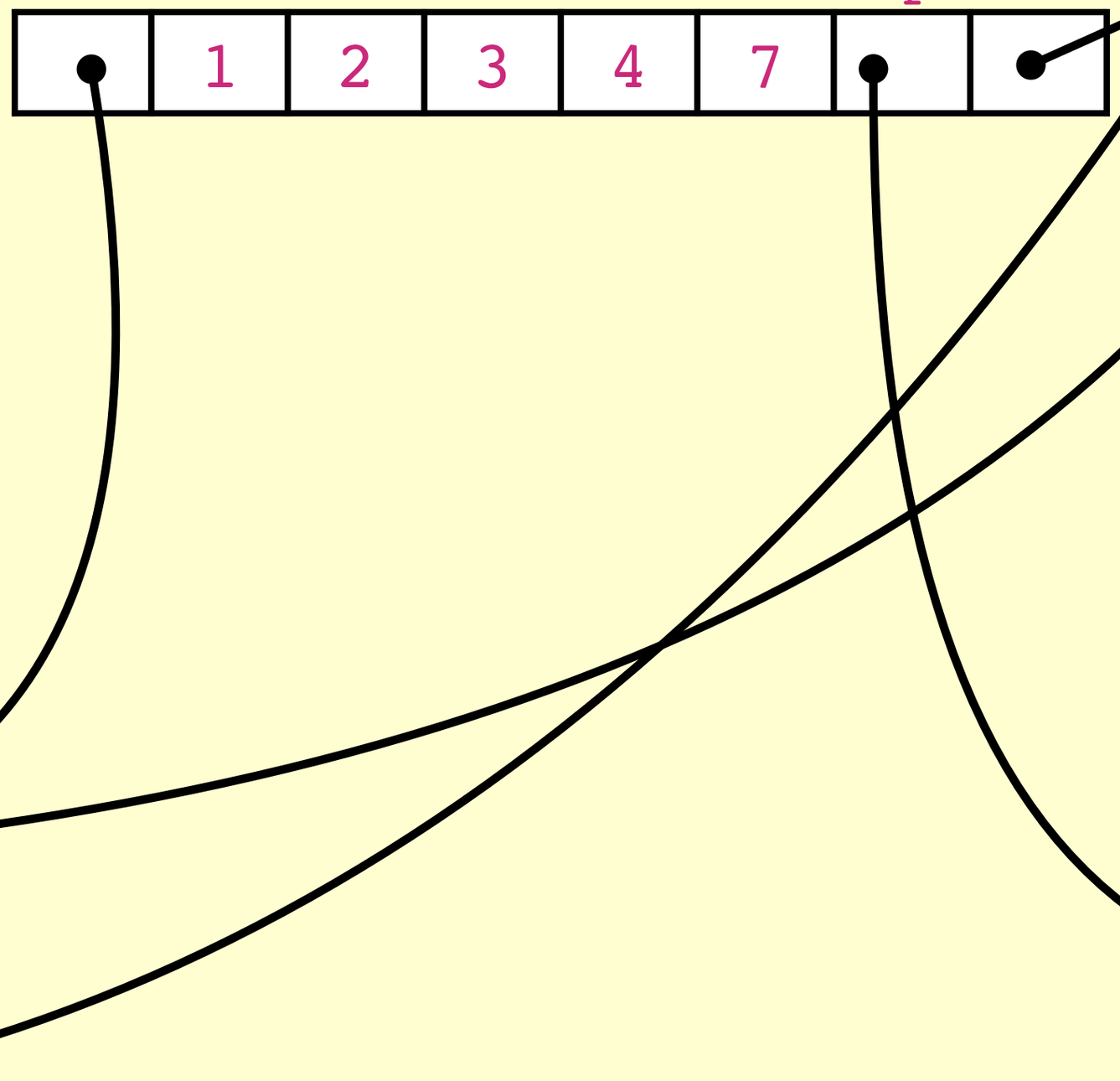



```
f:
   addi  sp,sp,-48
   sw    ra,44(sp)
   sw    s0,40(sp)
   addi  s0,sp,48
   sw    a0,-36(s0)
   sw    a1,-40(s0)
   sw    a2,-44(s0)
   sw    a3,-48(s0)
   li    a5,6
   sw    a5,-20(s0)
   li    a5,7
   sw    a5,-24(s0)
   li    a5,42
   mv    a0,a5
   lw    ra,44(sp)
   lw    s0,40(sp)
  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

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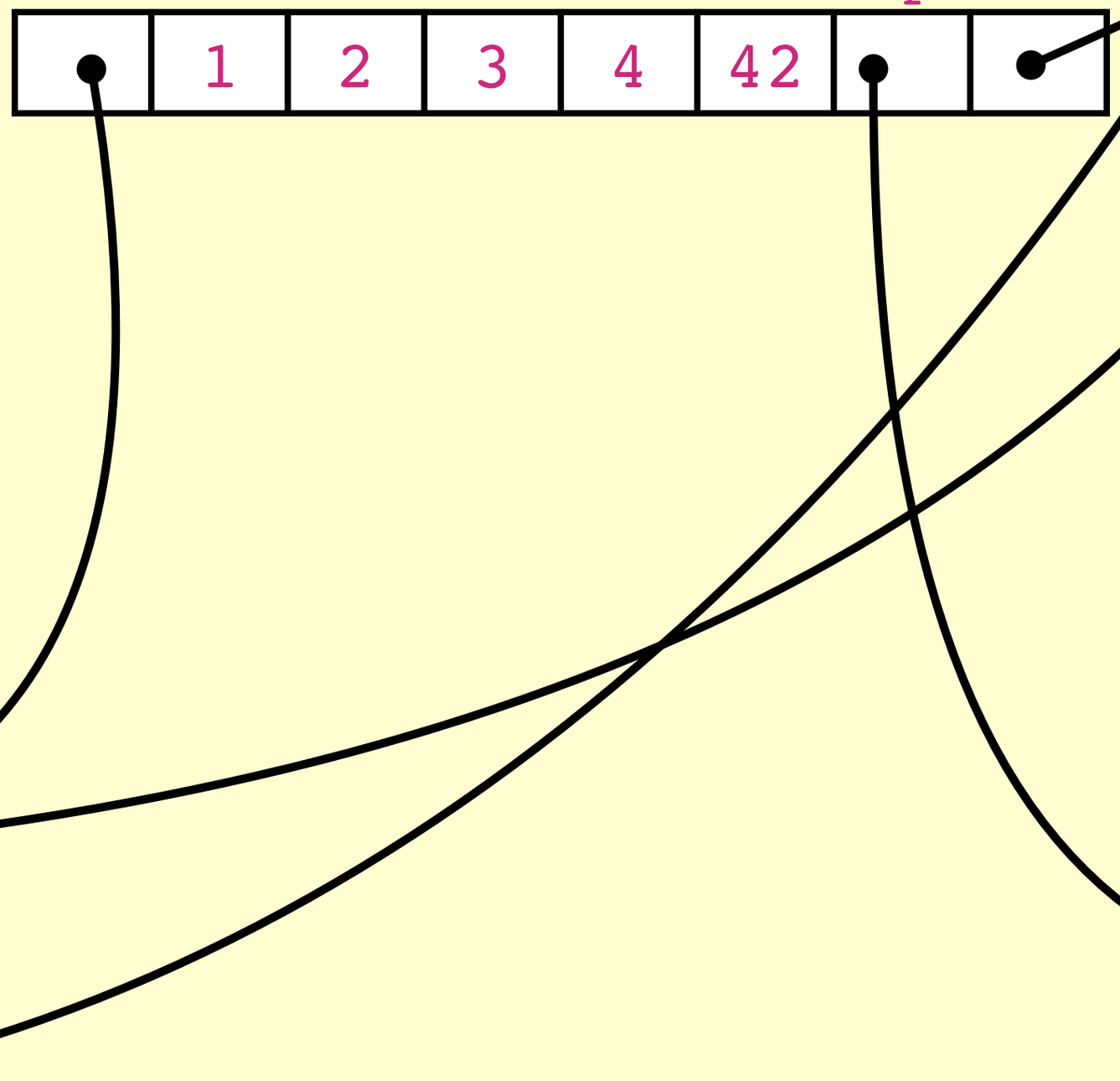

```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
  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
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  nop
  mv    a0,a5
  lw    ra,12(sp)
  lw    s0,8(sp)
  addi  sp,sp,16
  jr    ra
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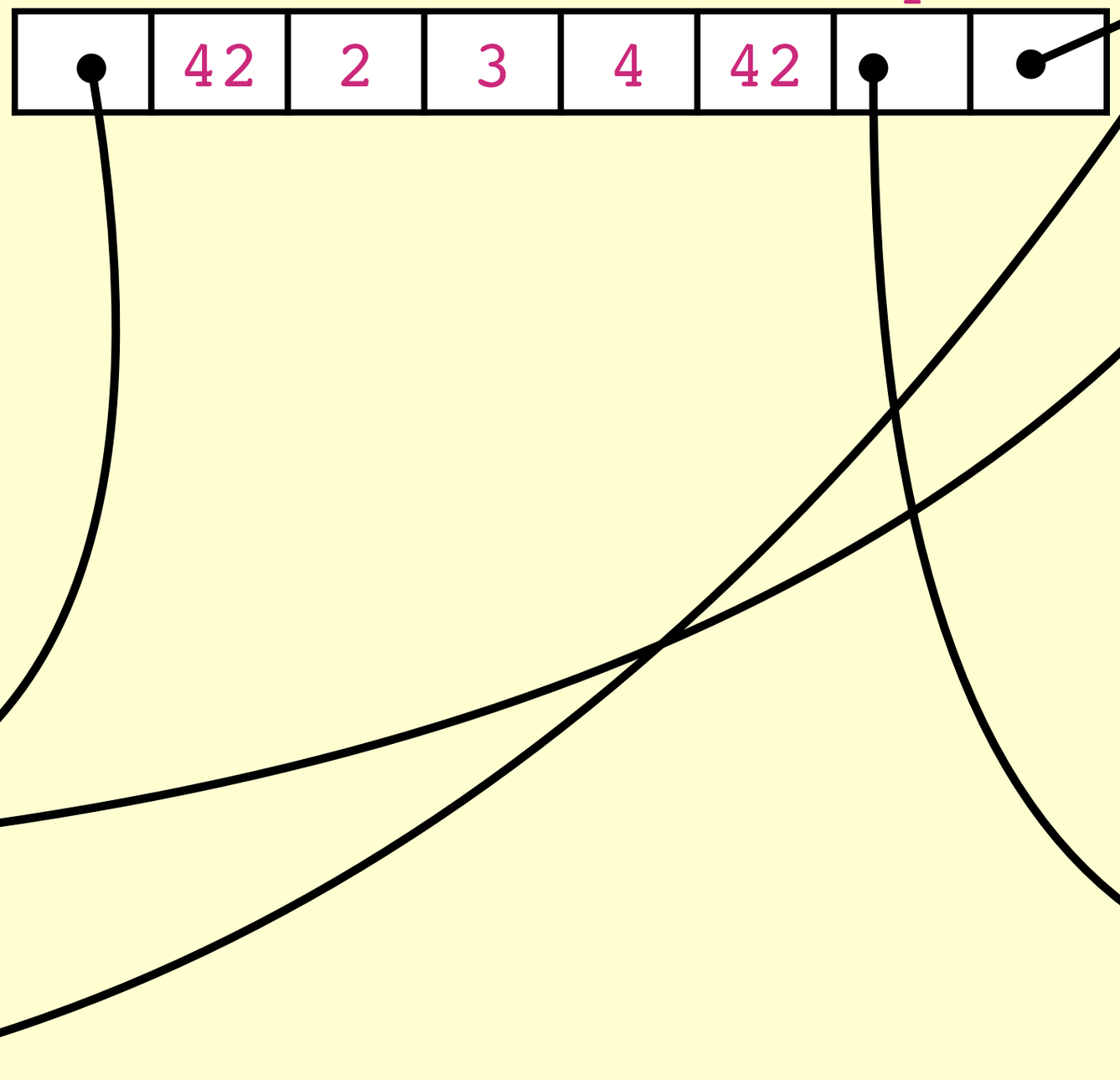

```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
  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; }
int main () { f(1,2,3,4); }
```

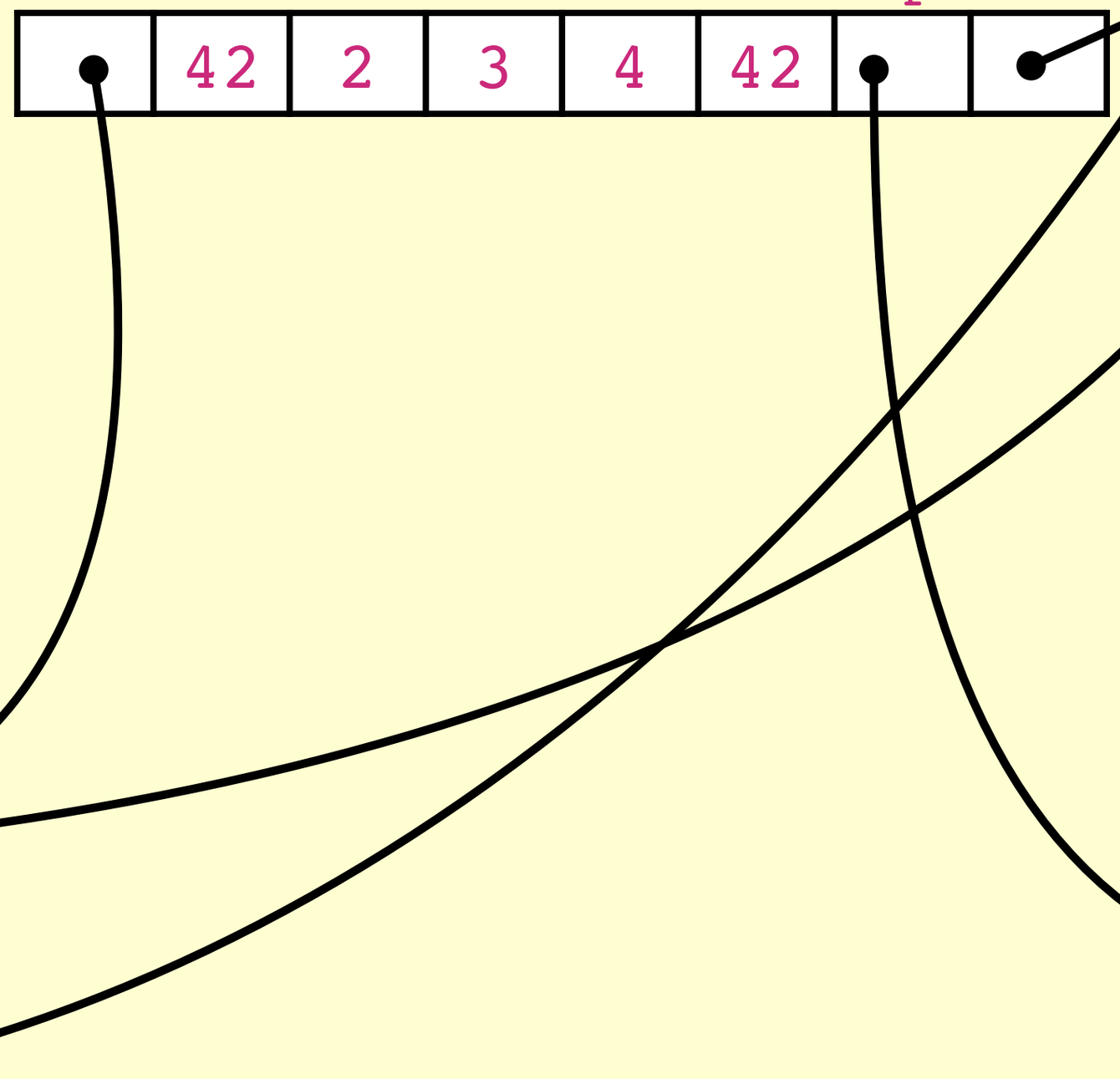

```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
  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)
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  int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```

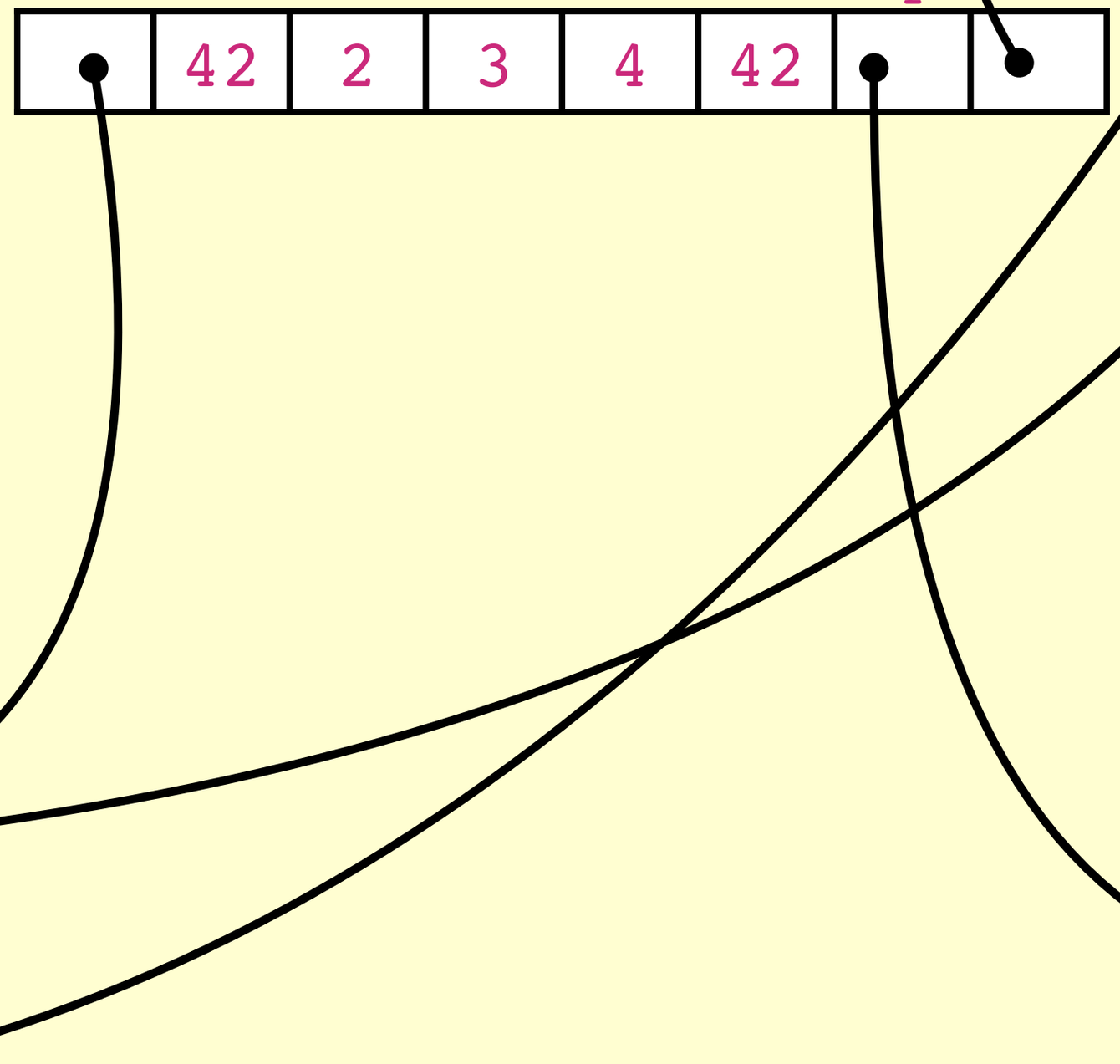

```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
  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
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  nop
  mv    a0,a5
  lw    ra,12(sp)
  lw    s0,8(sp)
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```
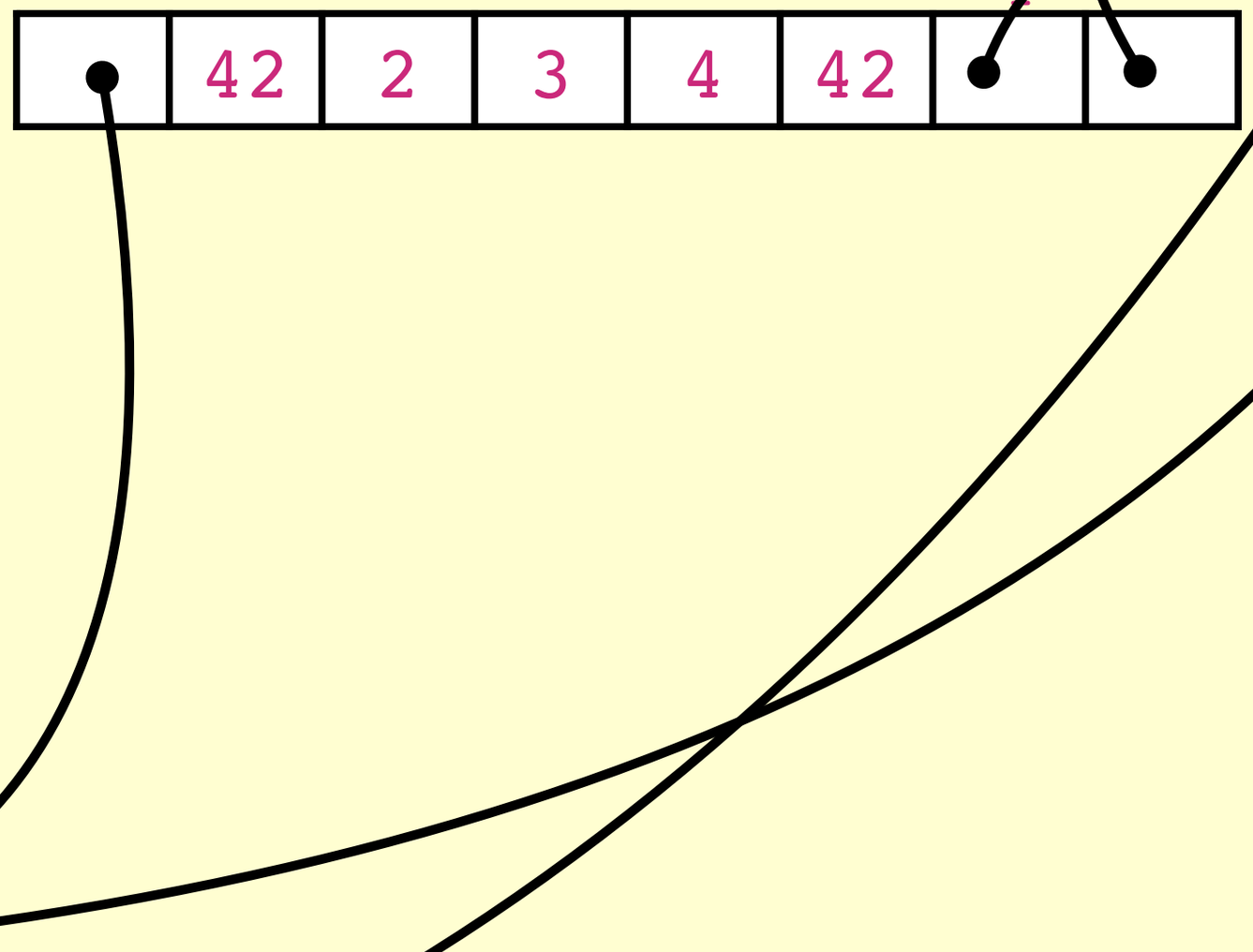
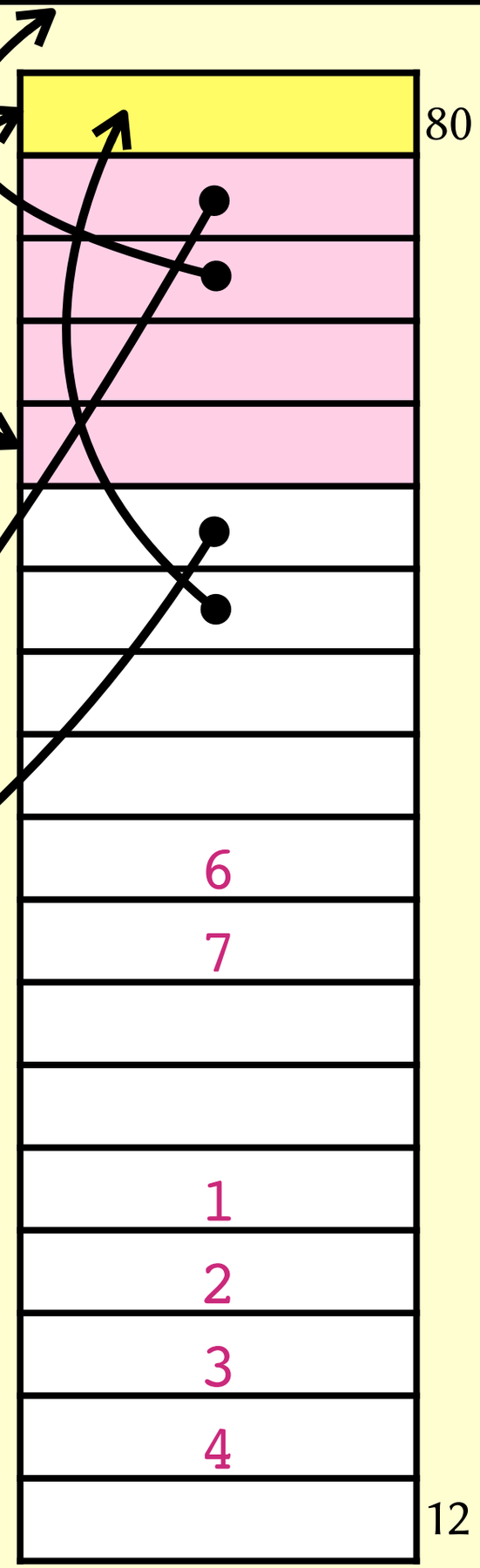
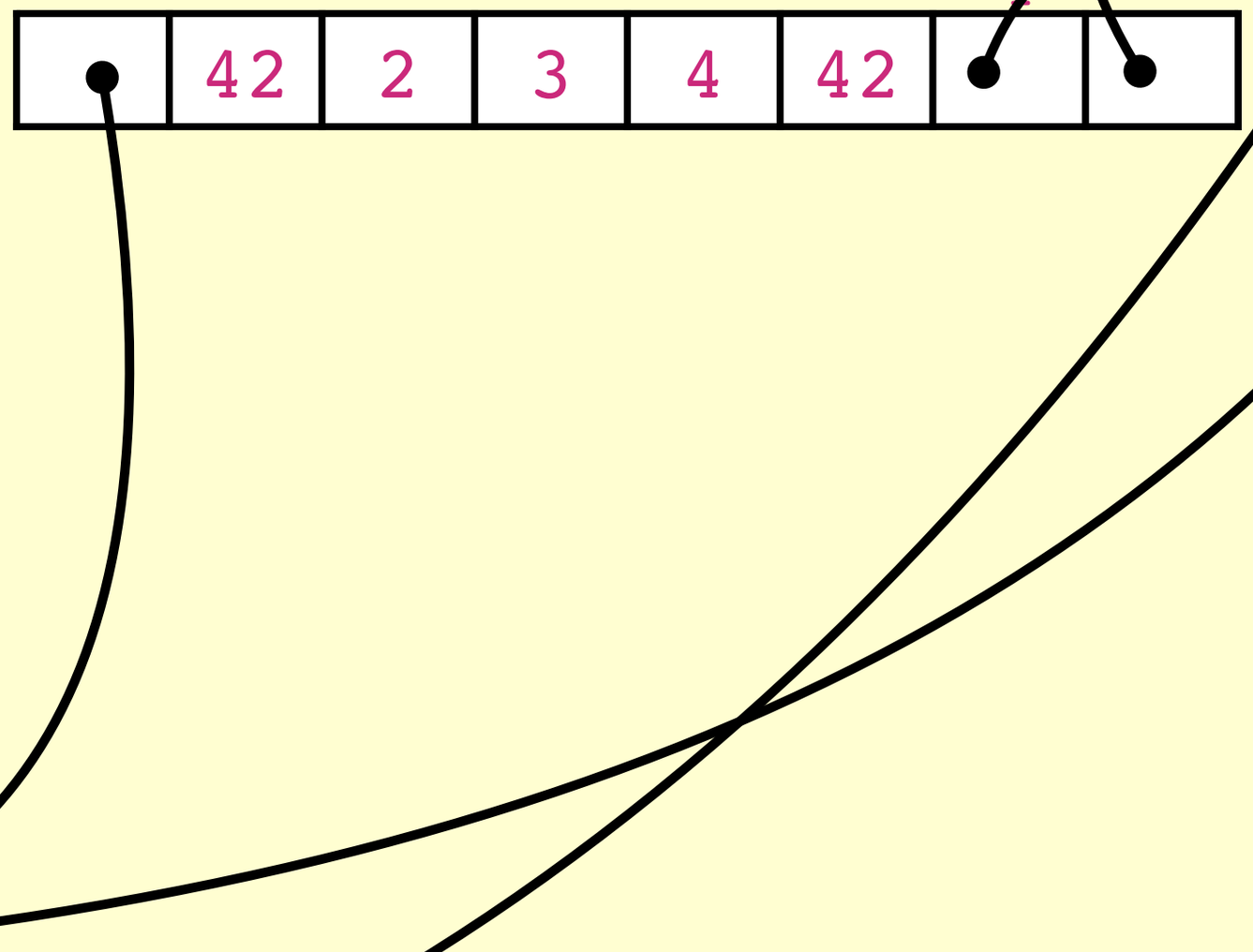





```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
  sw    a1,-40(s0)
  sw    a2,-44(s0)
  sw    a3,-48(s0)
  li    a5,6
  sw    a5,-20(s0)
  li    a5,7
  sw    a5,-24(s0)
  li    a5,42
  mv    a0,a5
  lw    ra,44(sp)
  lw    s0,40(sp)
  addi  sp,sp,48
 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

```
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
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  li    a1,2
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  mv    a0,a5
  lw    ra,12(sp)
  lw    s0,8(sp)
  addi  sp,sp,16
  jr    ra
```
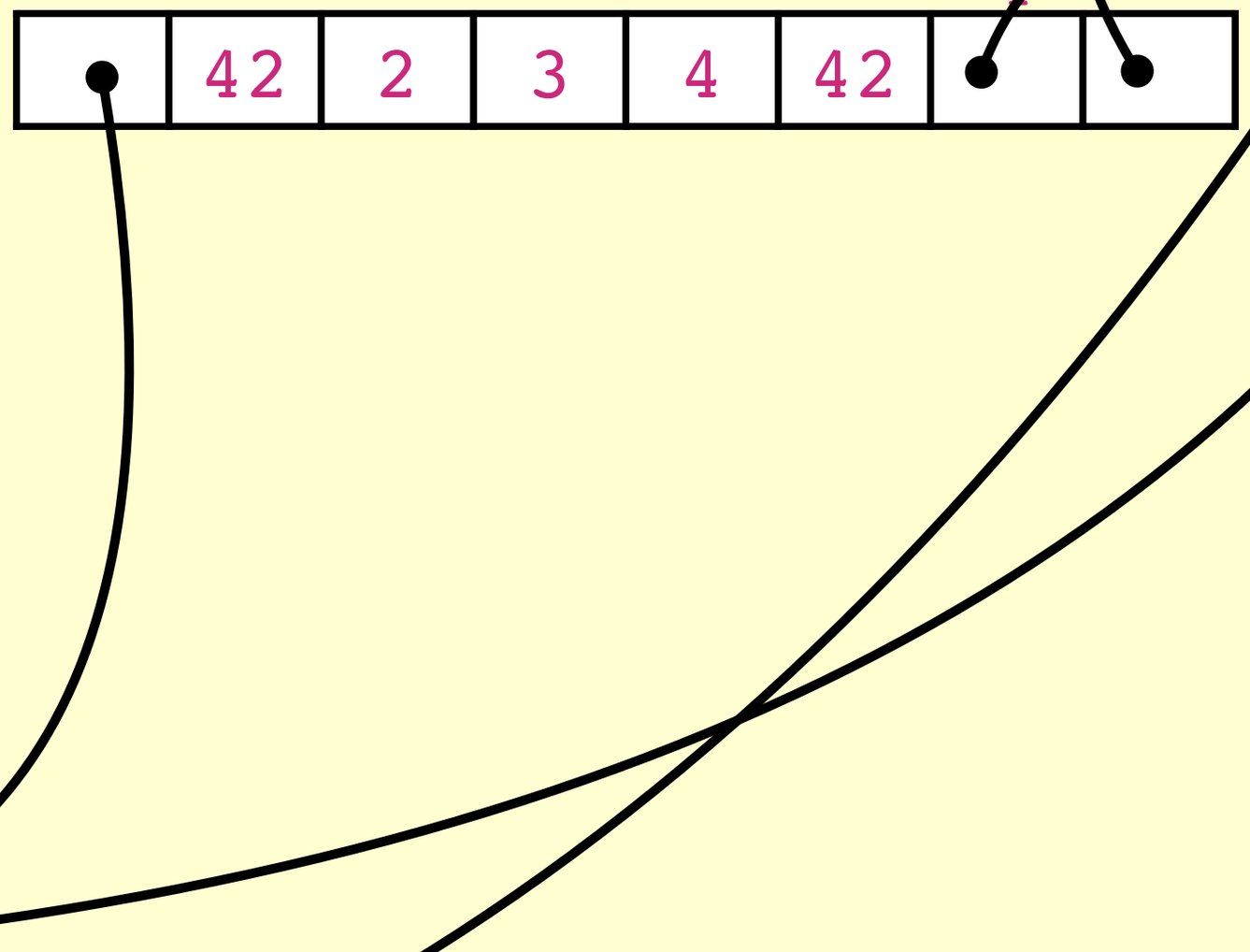

```
int f (int a, int b, int c, int d) {
  int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```



```
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)
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  li    a3,4
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  lw    s0,8(sp)
  addi  sp,sp,16
  jr    ra
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```
int f (int a, int b, int c, int d) {
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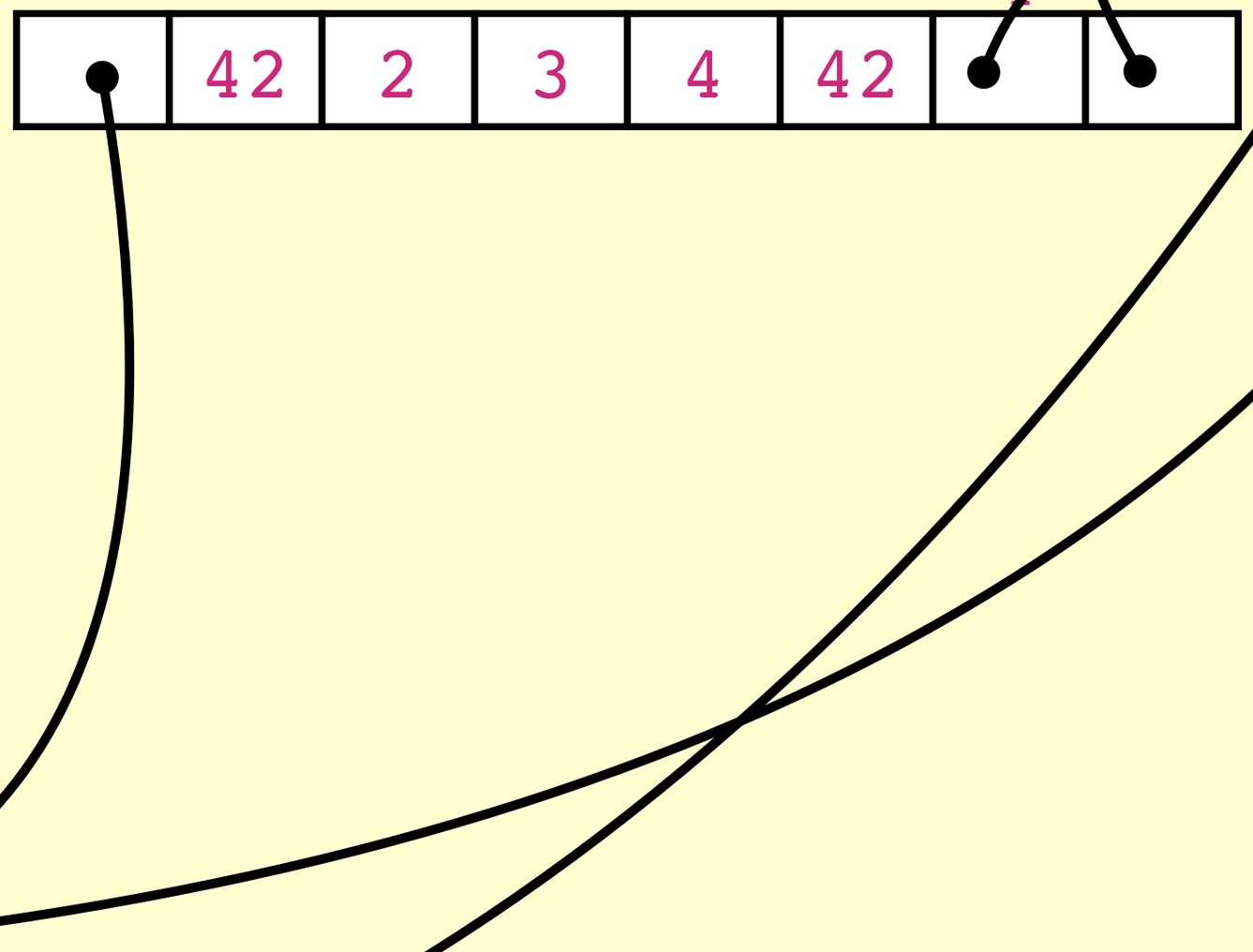
int main () { f(1,2,3,4); }
```



```
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)
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int f (int a, int b, int c, int d) {
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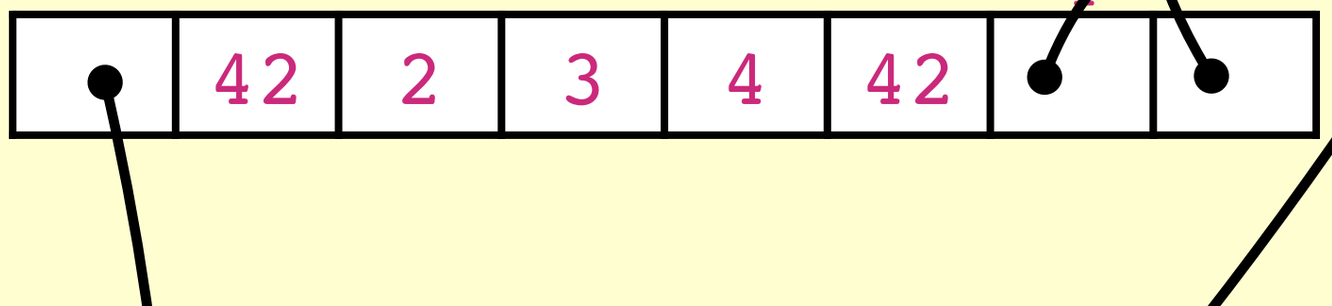

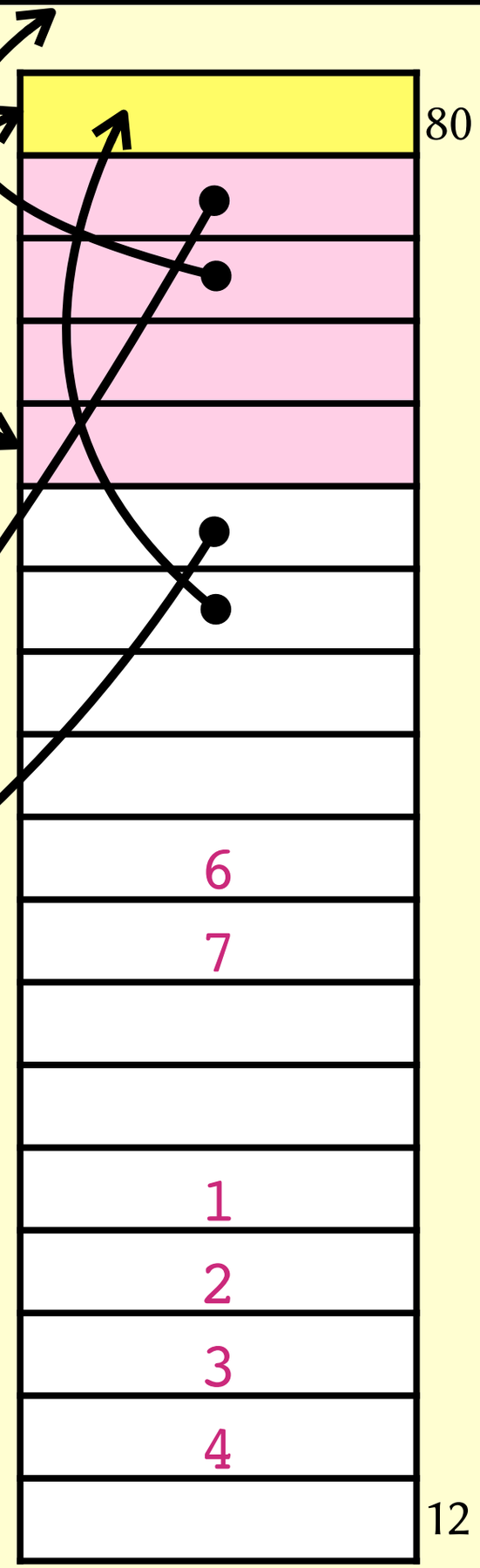

```
f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
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  sw    a2,-44(s0)
  sw    a3,-48(s0)
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```

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

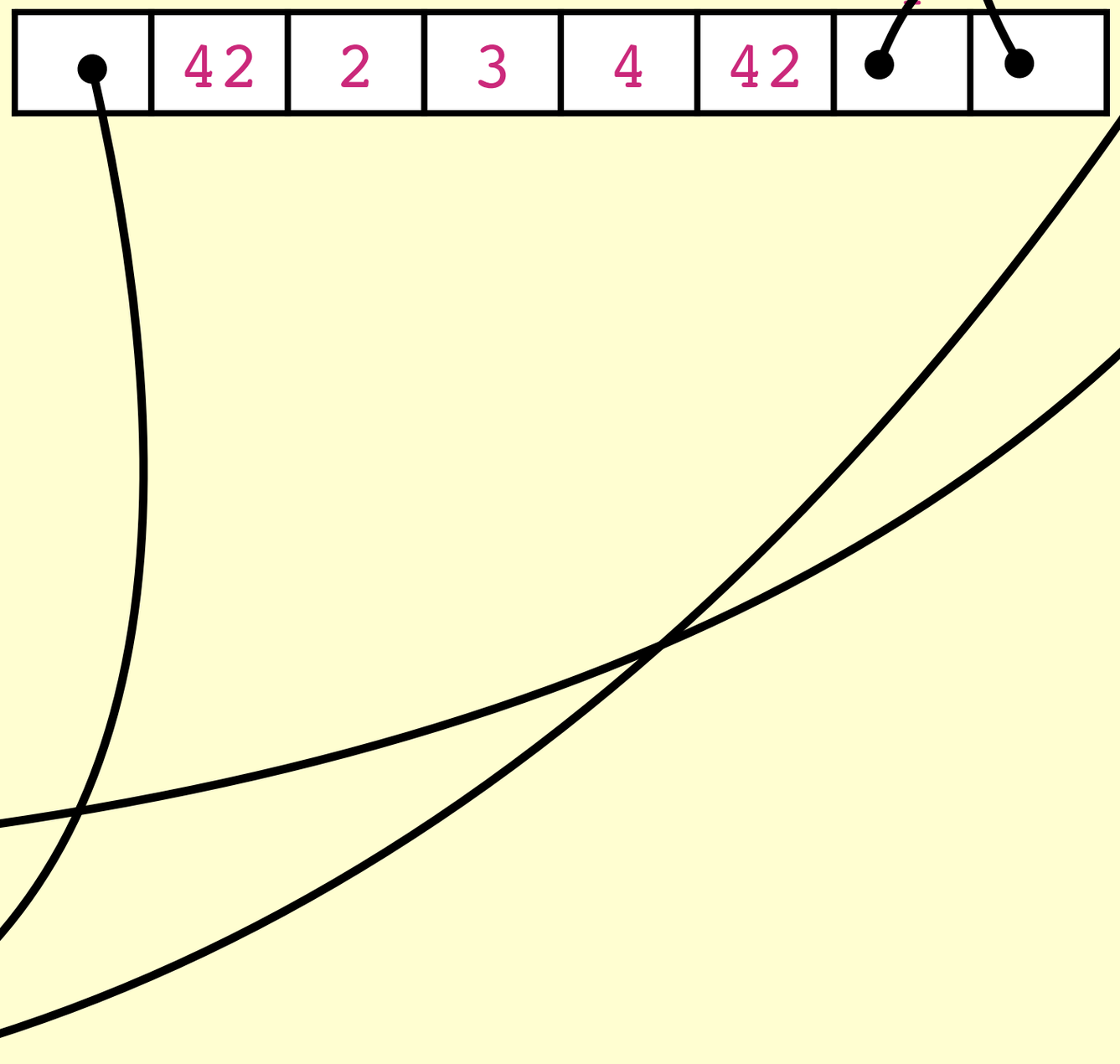

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f:
  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
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  sw    a2,-44(s0)
  sw    a3,-48(s0)
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  lw    s0,8(sp)
  addi  sp,sp,16
  jr    ra
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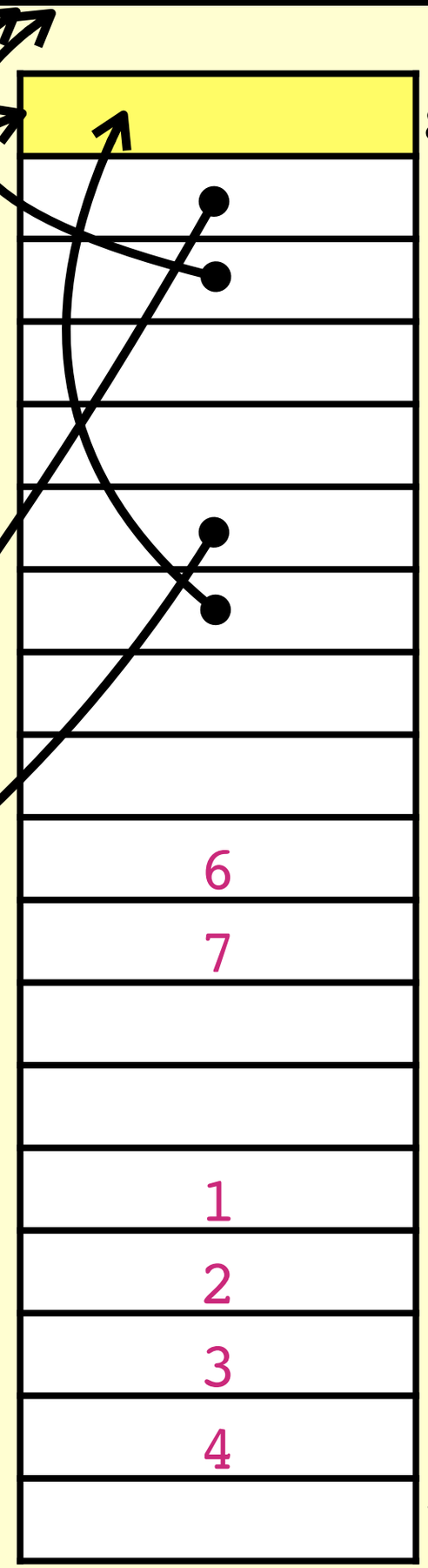
```
int f (int a, int b, int c, int d) {
  int t=6; int u=7; return 42; }
int main () { f(1,2,3,4); }
```

x1	x10	x11	x12	x13	x15	x2	x8
ra	a0	a1	a2	a3	a5	sp	s0
	42	2	3	4	42		



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  addi  sp,sp,-48
  sw    ra,44(sp)
  sw    s0,40(sp)
  addi  s0,sp,48
  sw    a0,-36(s0)
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  sw    a2,-44(s0)
  sw    a3,-48(s0)
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  addi  sp,sp,48
  jr    ra

main:
  addi  sp,sp,-16
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  sw    s0,8(sp)
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  lw    ra,12(sp)
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  addi  sp,sp,16
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```

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```

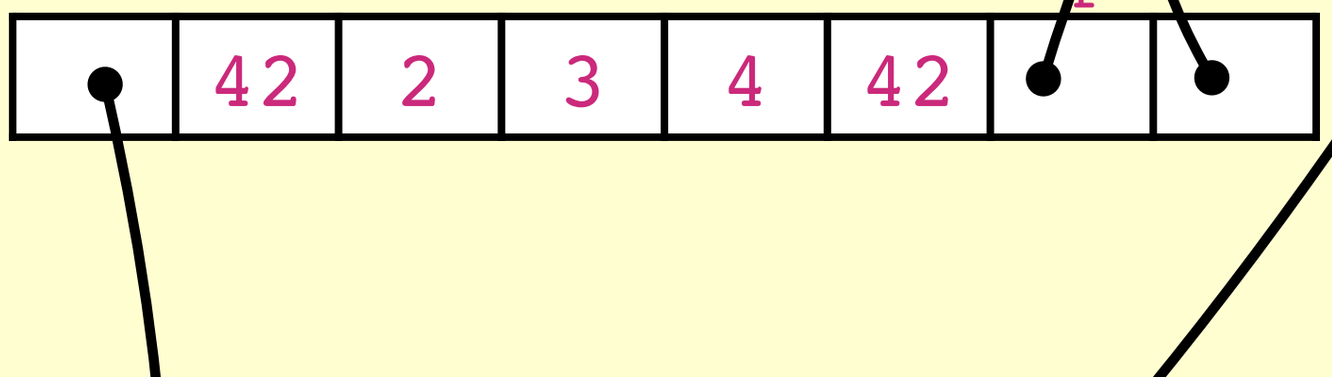

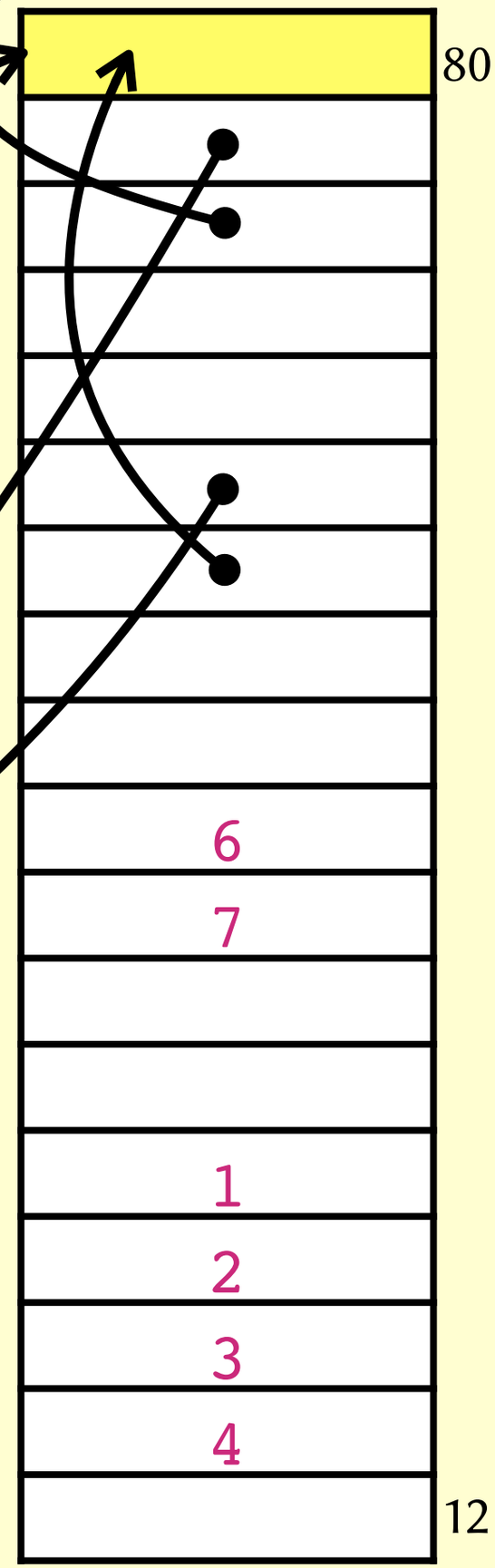

Lecture outline

✔Parsing C: the *dangling-else* problem.

✔Parsing C: the *lexer hack*.

✔Generating RISC-V assembly for function calls.