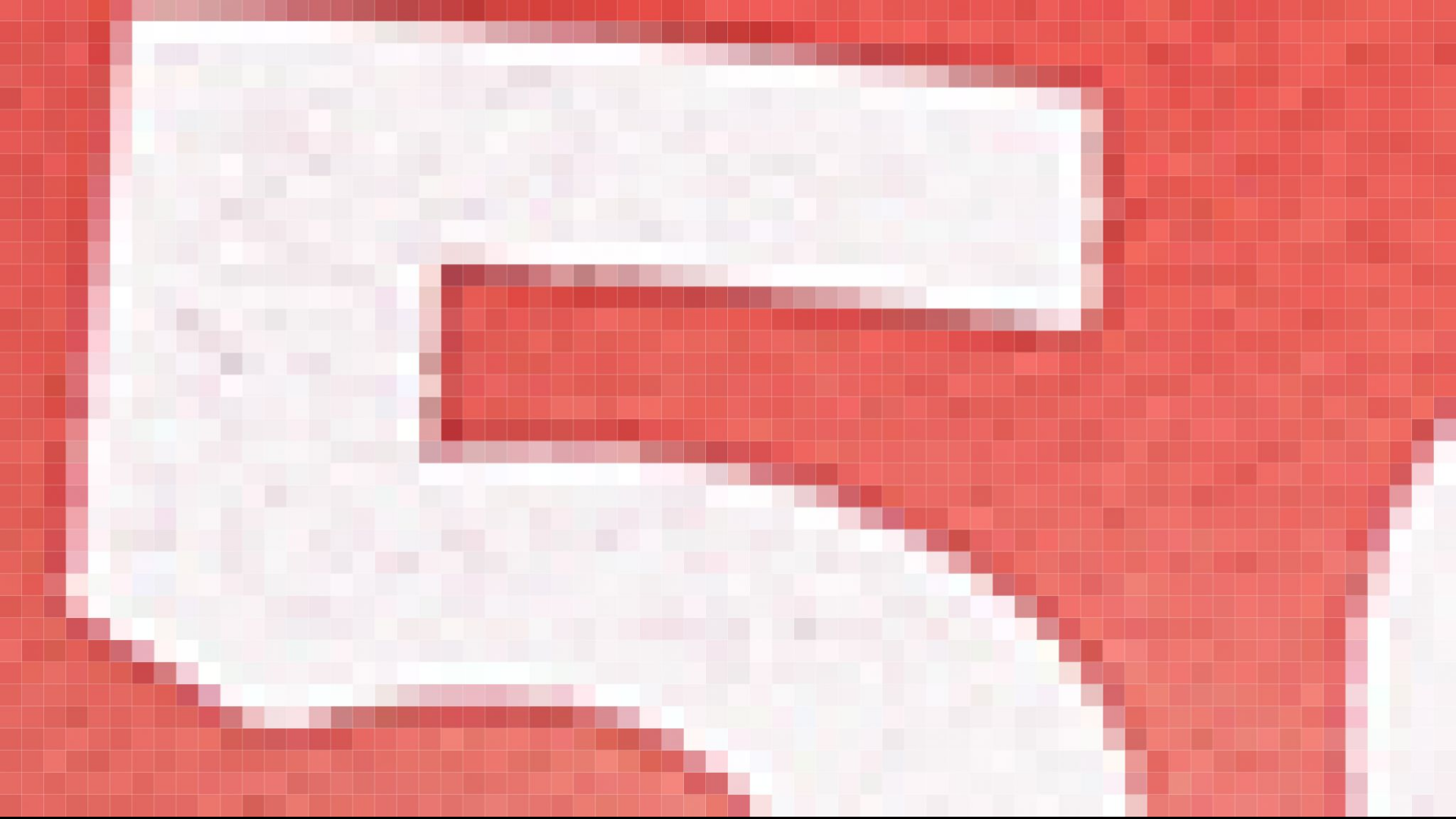
This is CS50

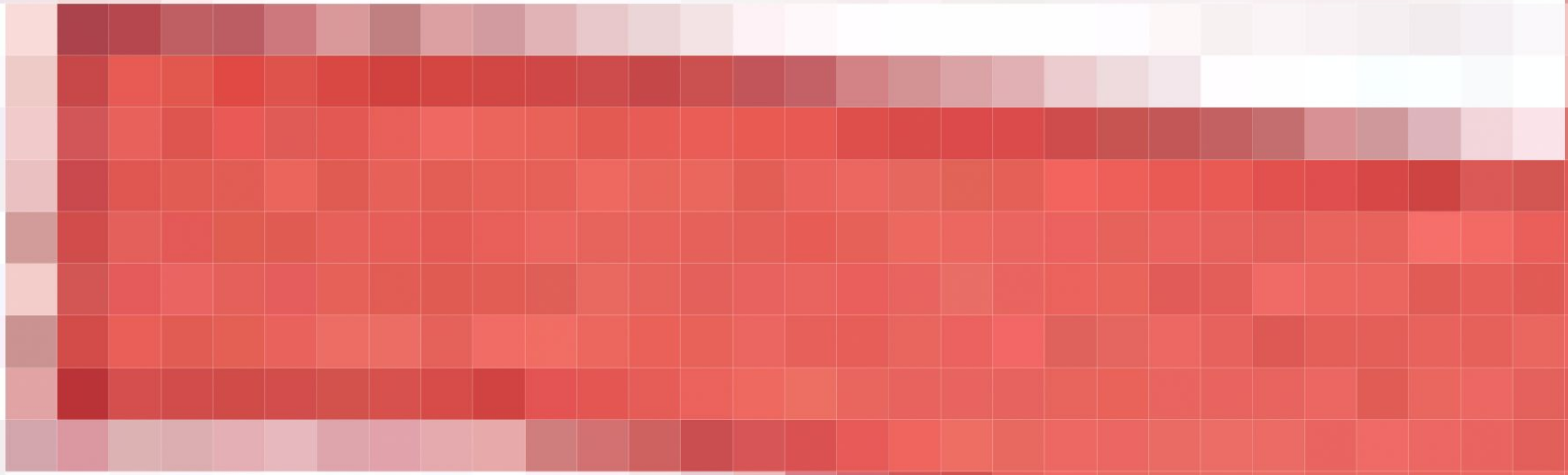

CS50
STRESS BALL
CS50
STRESS BALL


CS50
STRESS BALL

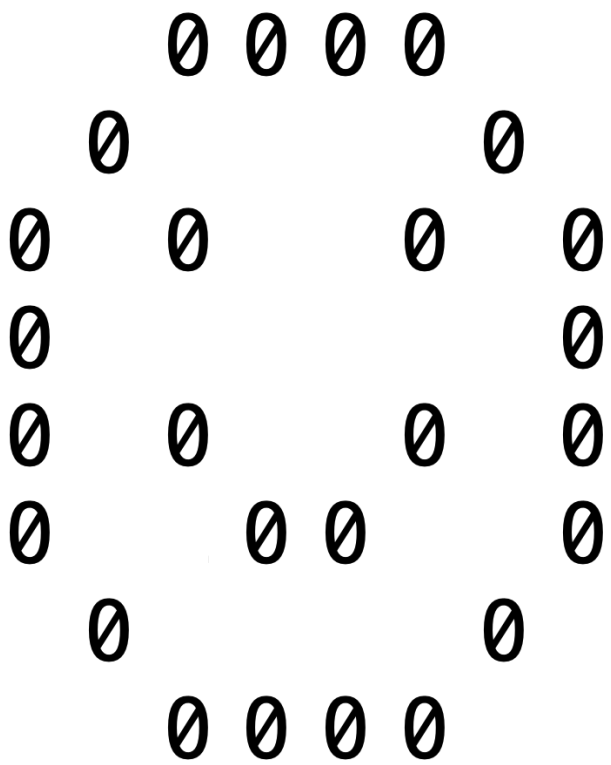

CS50
STRESS BALL


50

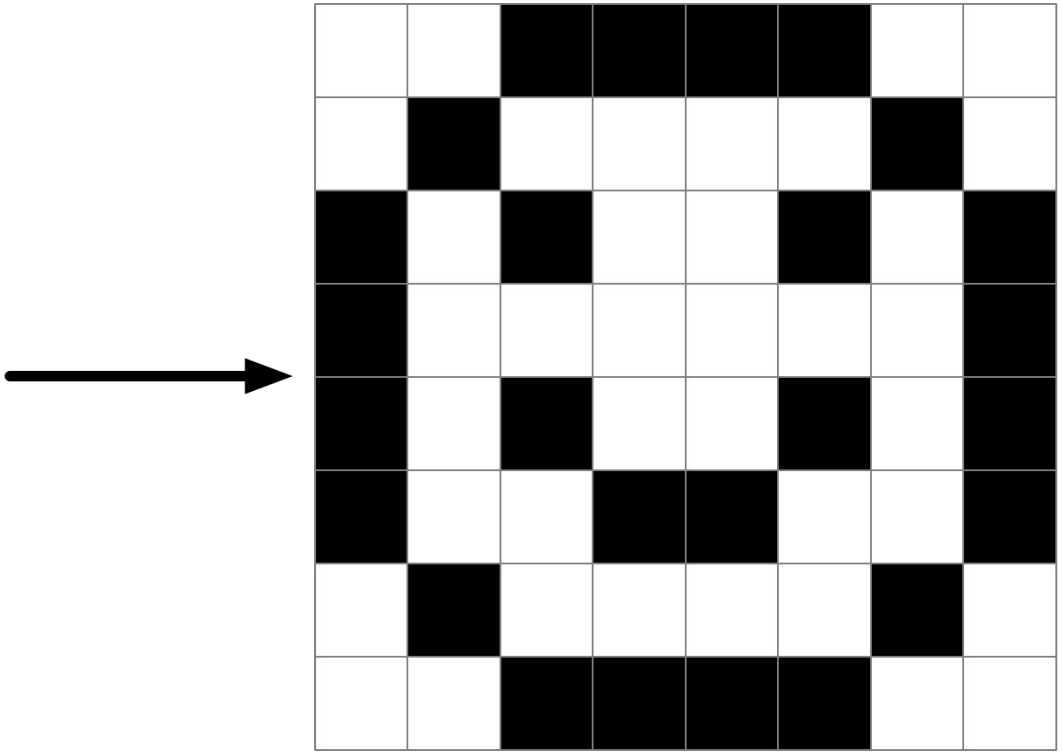




```
1 1 0 0 0 0 1 1
1 0 1 1 1 1 0 1
0 1 0 1 1 0 1 0
0 1 1 1 1 1 1 0
0 1 0 1 1 0 1 0
0 1 1 0 0 1 1 0
1 0 1 1 1 1 0 1
1 1 0 0 0 0 1 1
```

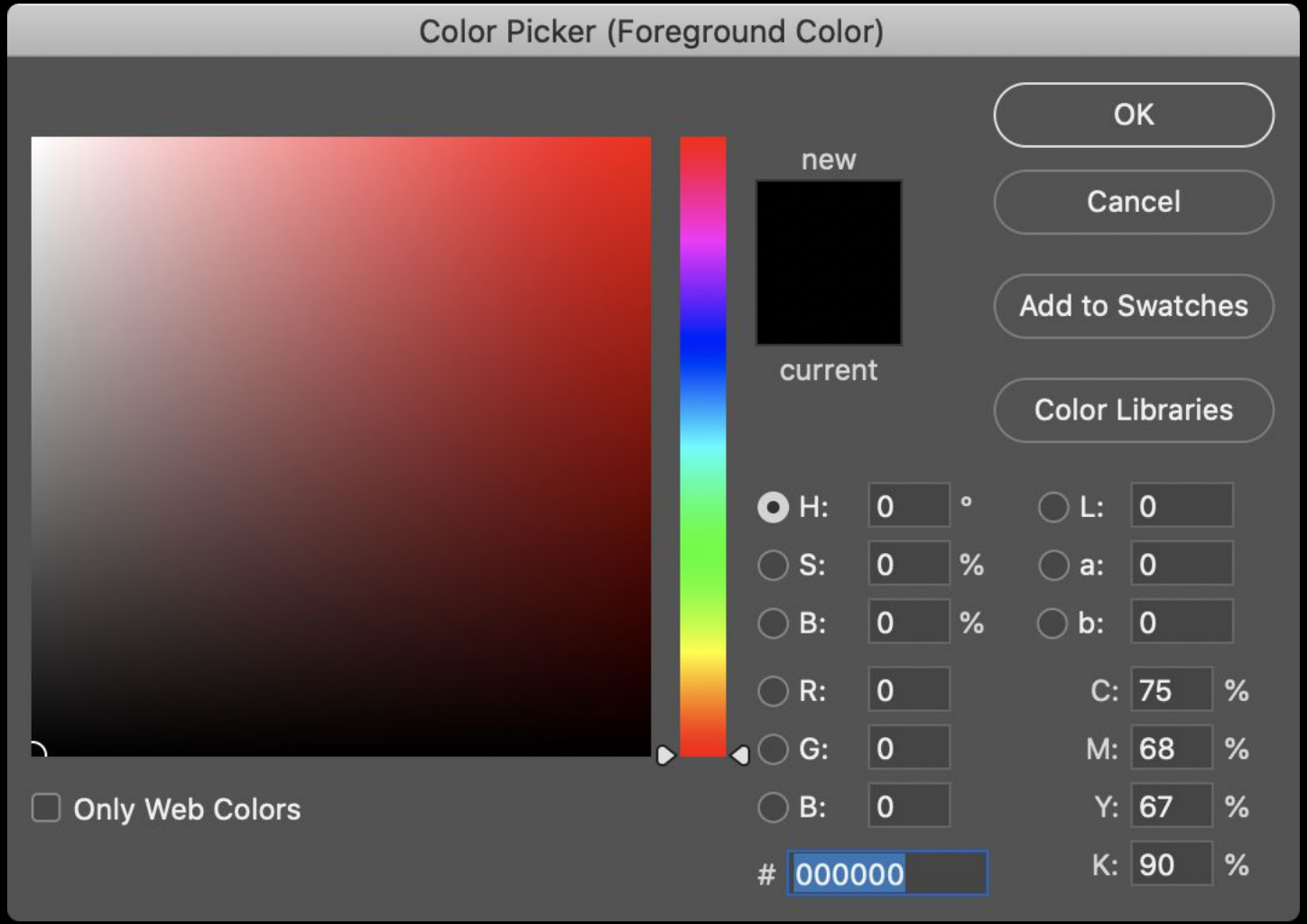


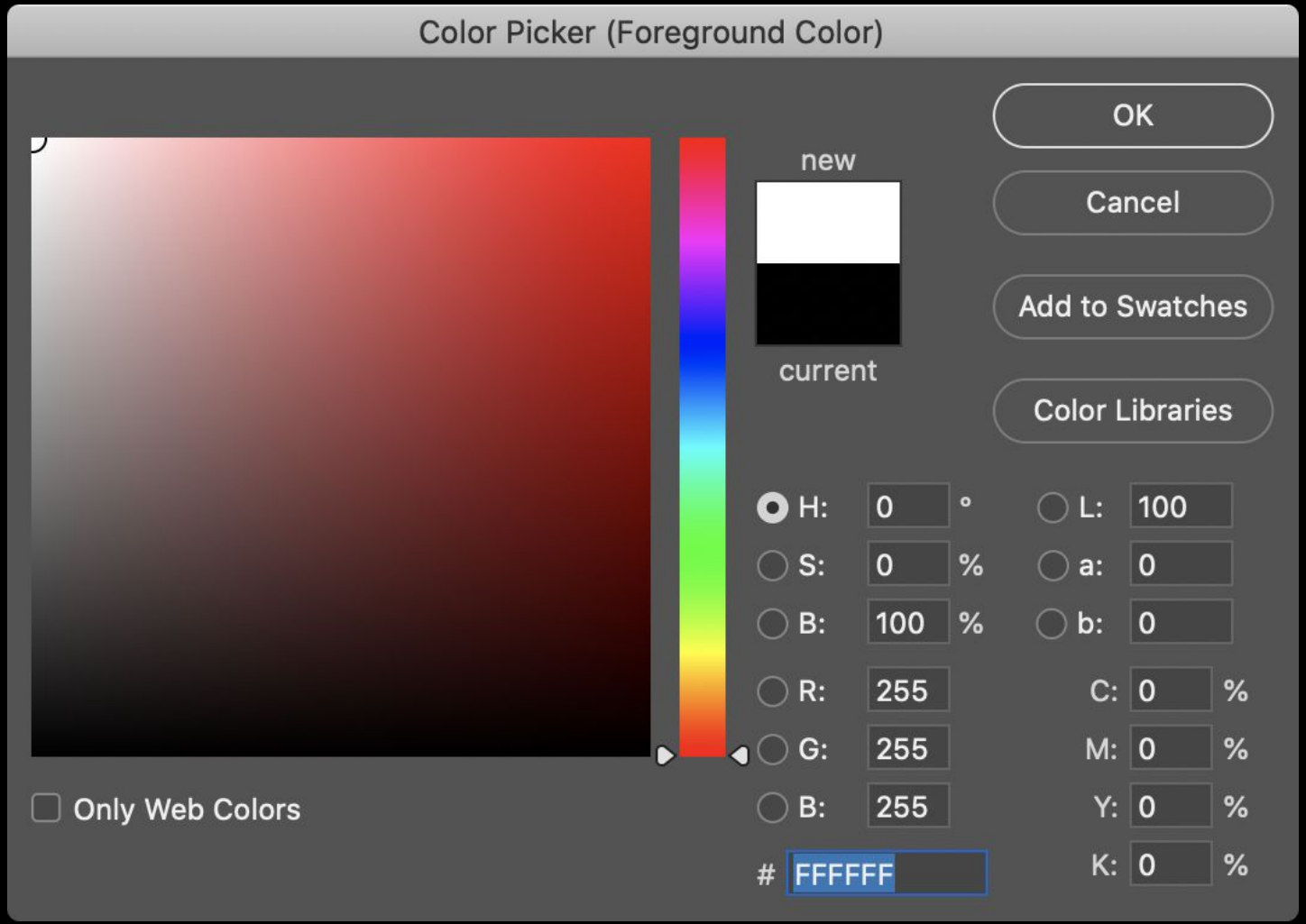
```
1 1 0 0 0 0 1 1
1 0 1 1 1 1 0 1
0 1 0 1 1 0 1 0
0 1 1 1 1 1 1 0
0 1 0 1 1 0 1 0
0 1 1 0 0 1 1 0
1 0 1 1 1 1 0 1
1 1 0 0 0 0 1 1
```



cs50.ly/art

RGB


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 0 °
S: 0 %
B: 0 %
R: 0
G: 0
B: 0
L: 0
a: 0
b: 0
C: 75 %
M: 68 %
Y: 67 %
K: 90 %
000000
Only Web Colors


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 0 °
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B: 100 %
R: 255
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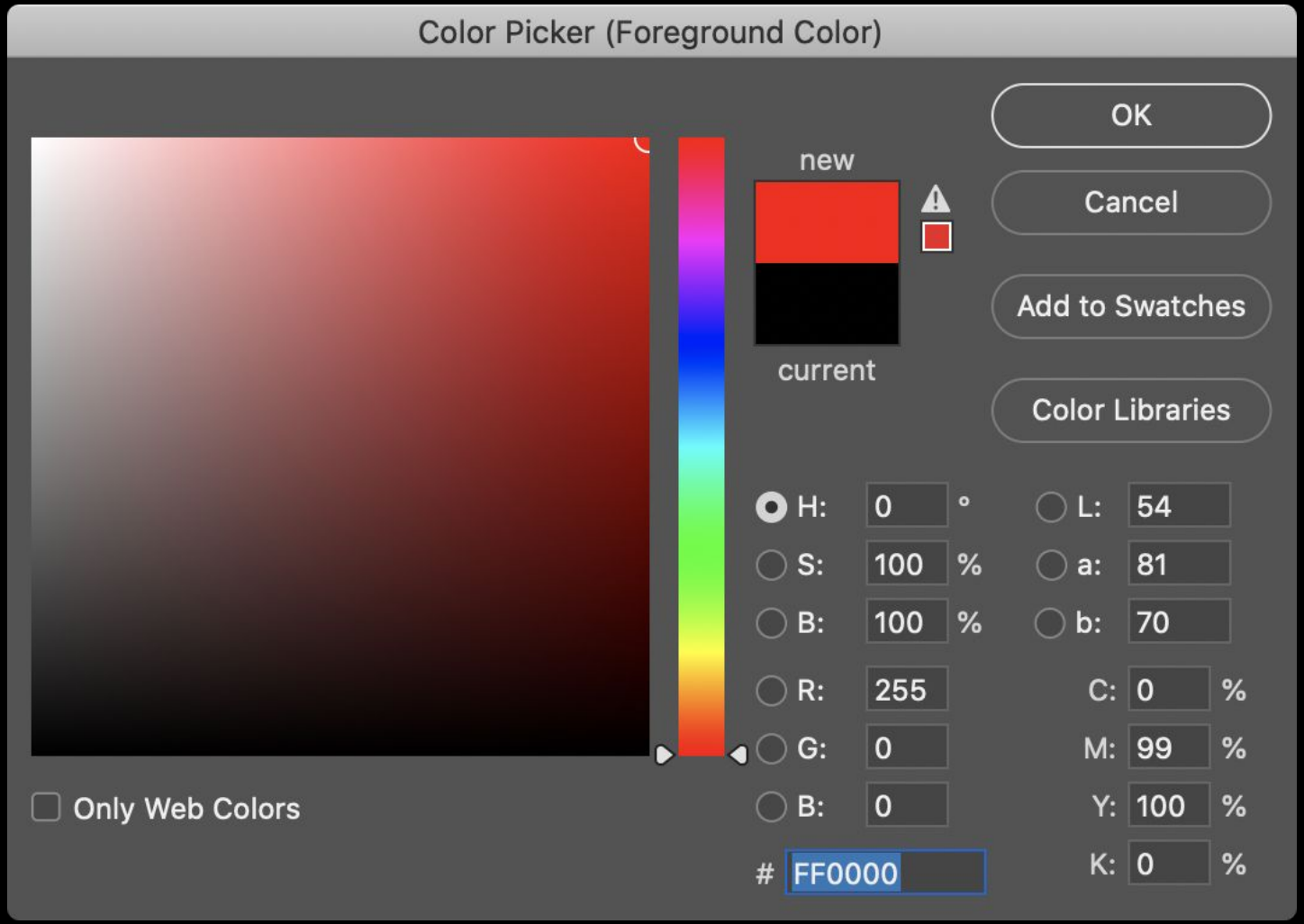
B: 255
FFFFFF
L: 100
a: 0
b: 0
C: 0 %
M: 0 %
Y: 0 %
K: 0 %
Only Web Colors


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 0 °
S: 100 %
B: 100 %
R: 255
G: 0
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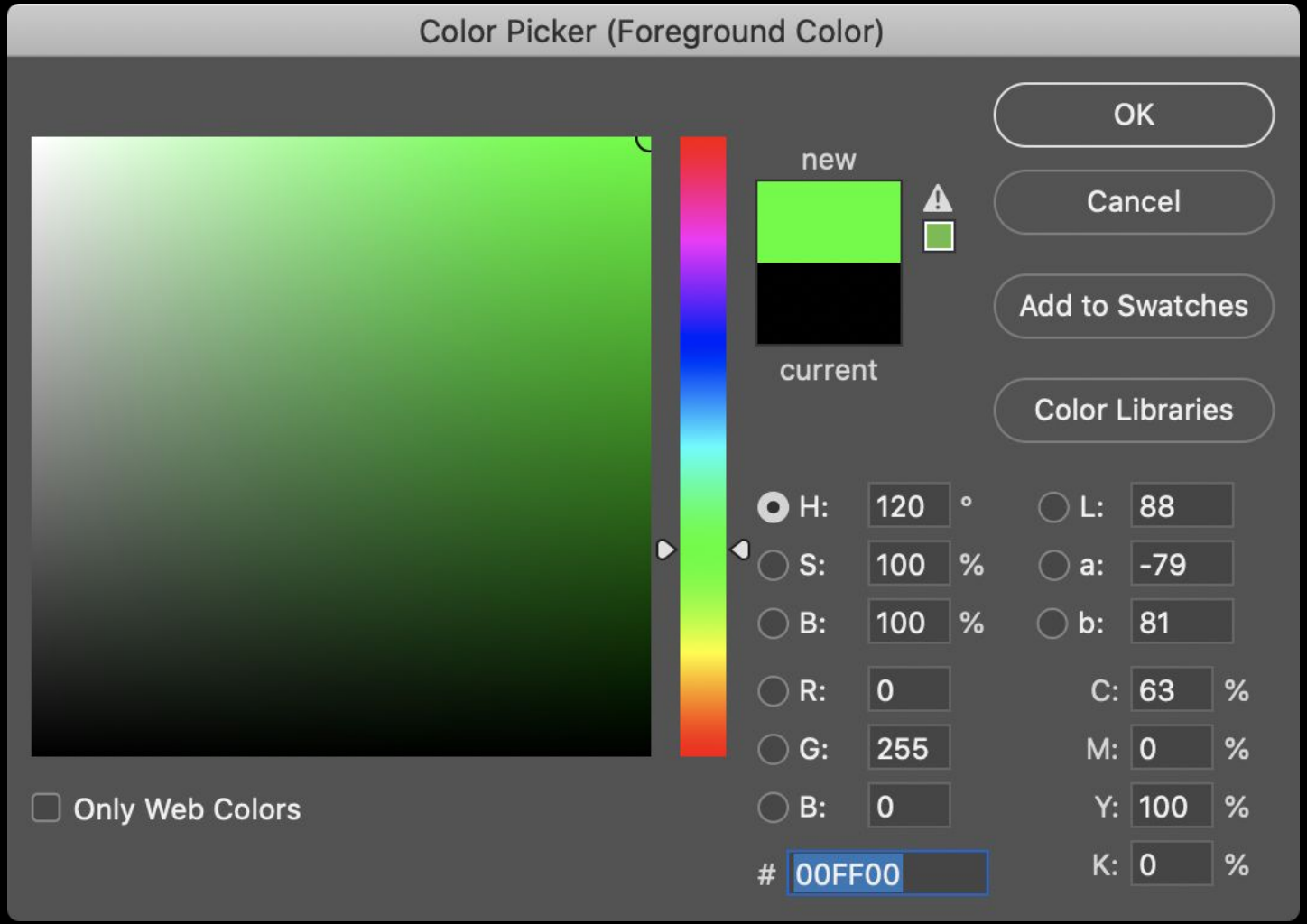
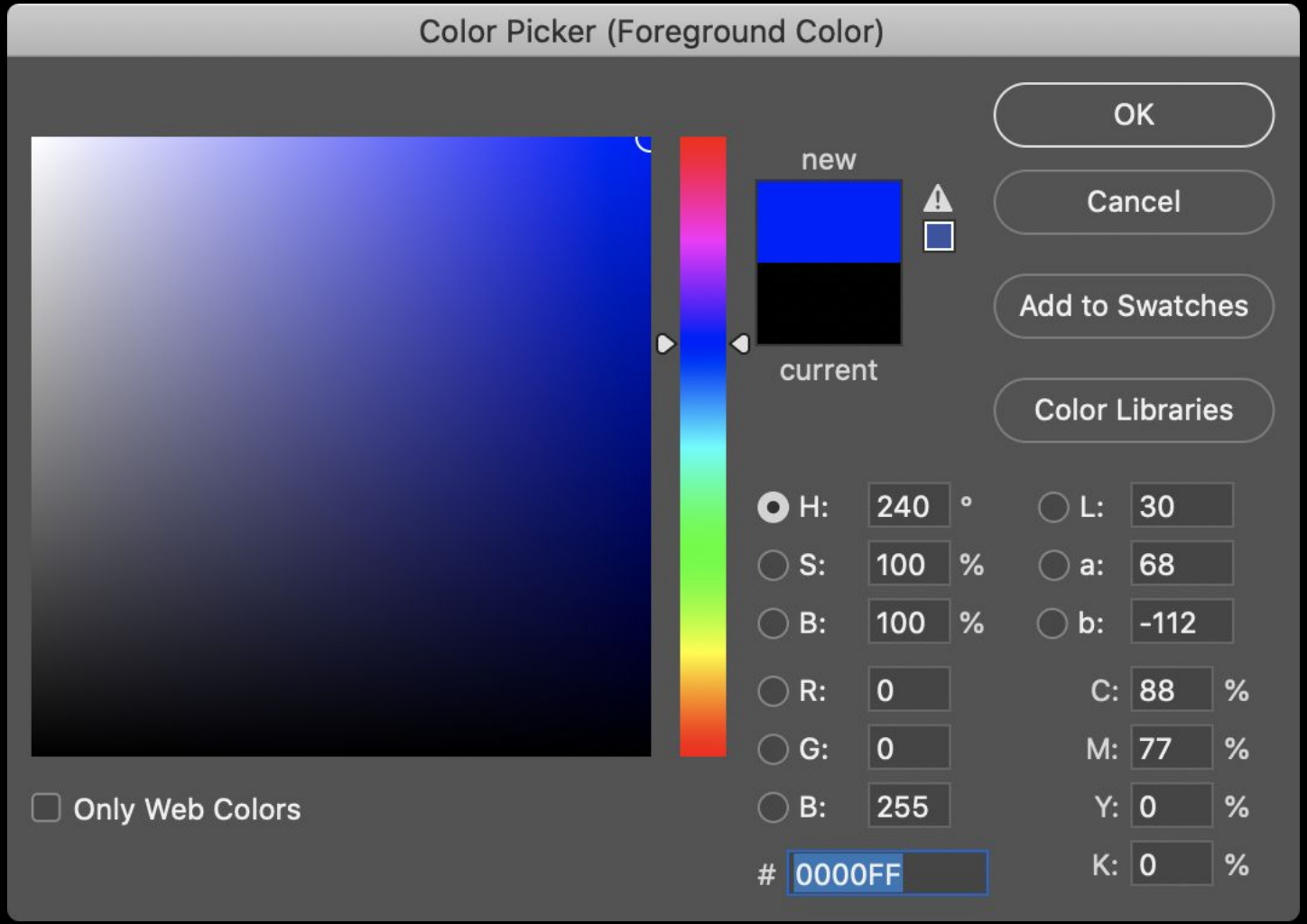
FF0000
L: 54
a: 81
b: 70
C: 0 %
M: 99 %
Y: 100 %
K: 0 %
Only Web Colors


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 120 °
S: 100 %
B: 100 %
R: 0
G: 255
B: 0
00FF00
L: 88
a: -79
b: 81
C: 63 %
M: 0 %
Y: 100 %
K: 0 %
Only Web Colors


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 240 °
S: 100 %
B: 100 %
R: 0
G: 0
B: 255
0000FF
L: 30
a: 68
b: -112
C: 88 %
M: 77 %
Y: 0 %
K: 0 %
Only Web Colors

0 1

0 1 2 3 4 5 6 7 8 9

0 1 2 3 4 5 6 7 8 9 A B C D E F

0 1 2 3 4 5 6 7 8 9 a b c d e f

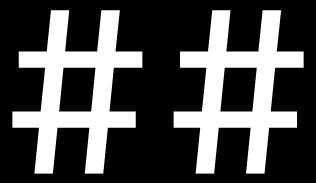
hexadecimal

base-16

16^1 16^0

# #

16 1



16 1

00

16 1

01

16 1

02

16 1

03

16 1

04

16 1

05

16 1

06

16 1

07

16 1

08

16 1

09

16 1

0A

16 1

0B

16 1

0C

16 1

0D

16 1

0E

16 1

0F

16 1

10

16 1

11

16 1

12

16 1

13

16 1

14

16 1

16 1

FF

16 1

F F

16 × F + 1 × F

16 1

F F

16 × 15 + 1 × 15

16 1

F F

240 + 15

16 1

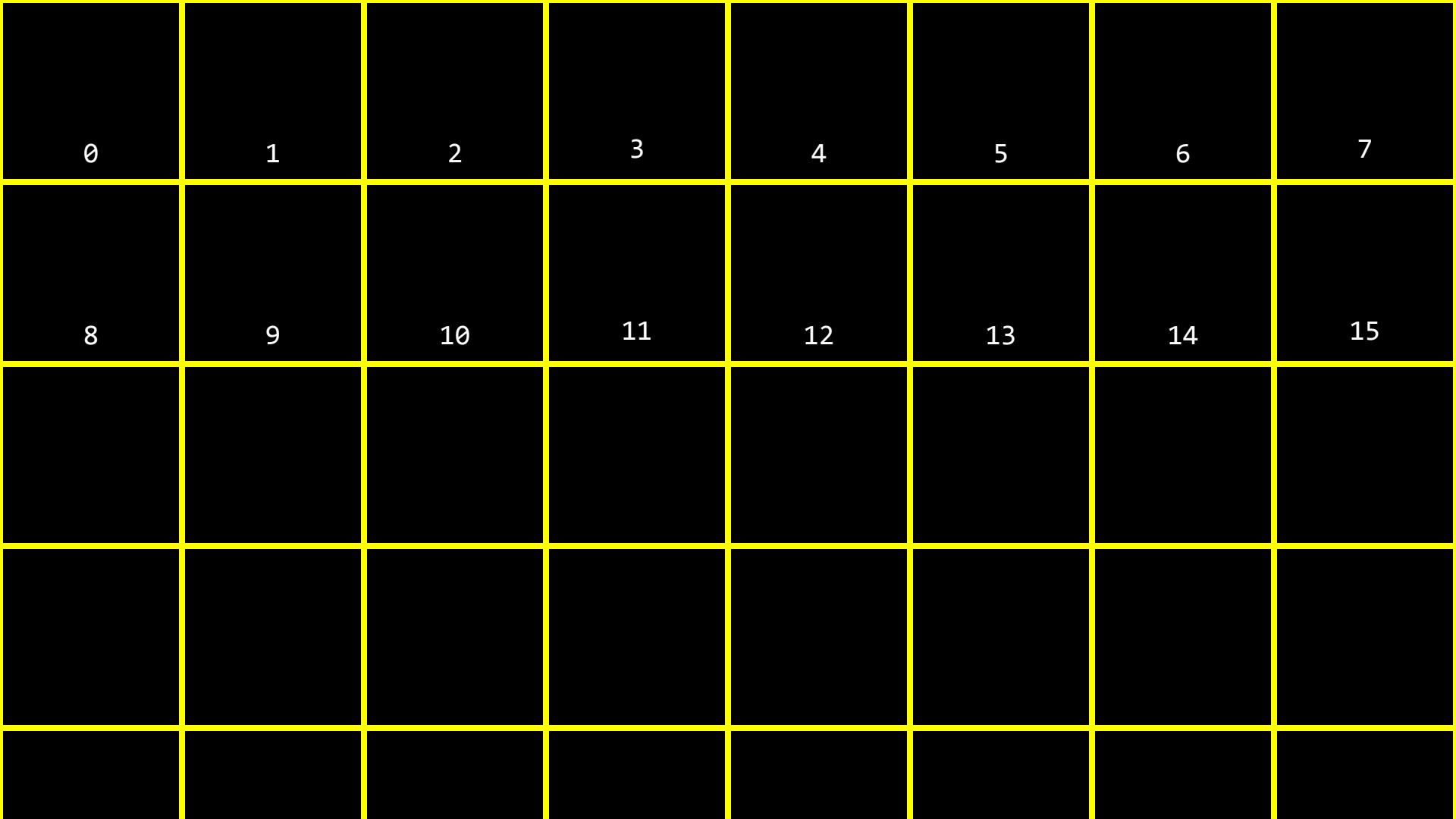
255

F

1111

11111111

FF


0
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12
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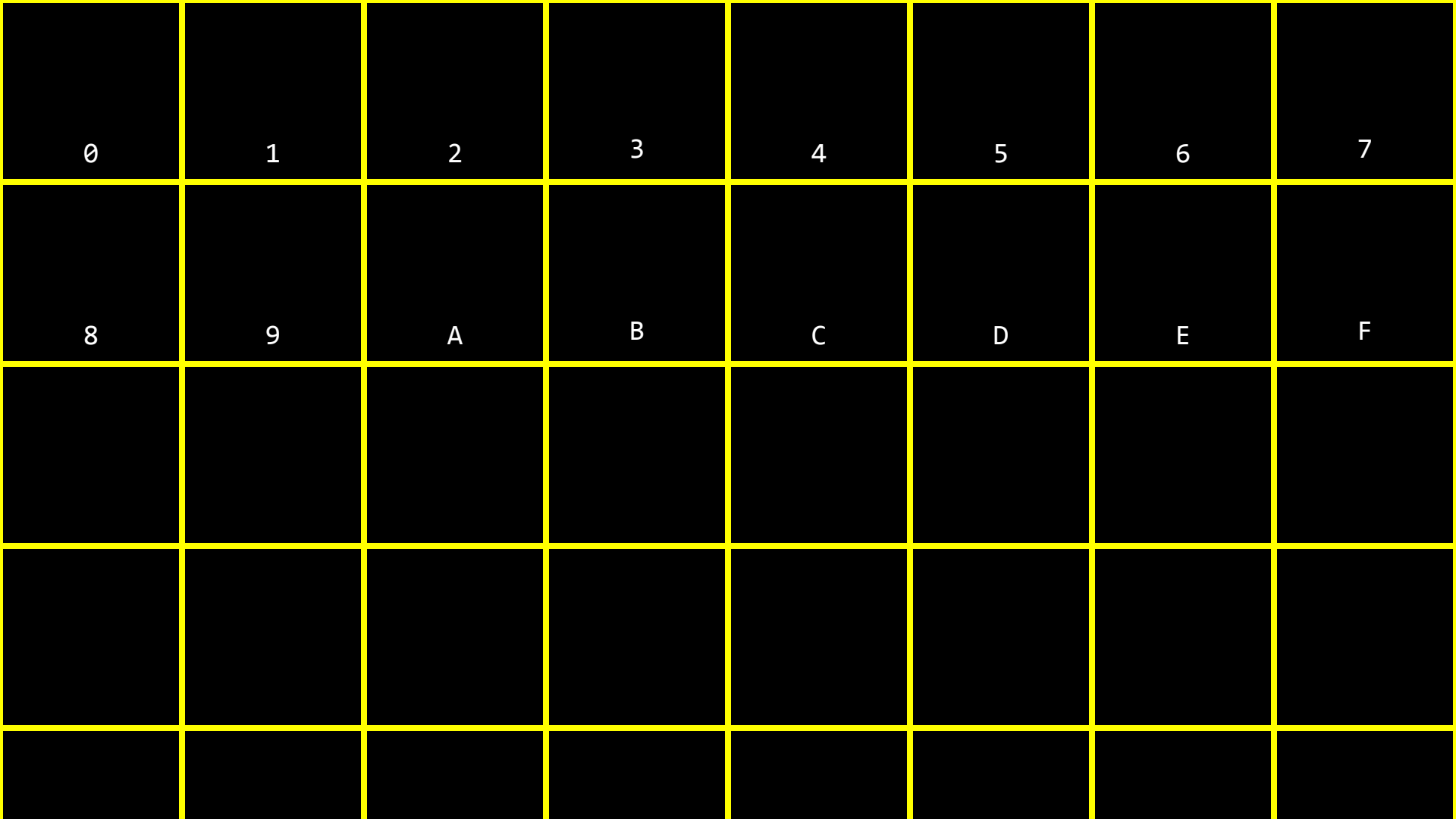
14
15


0
1
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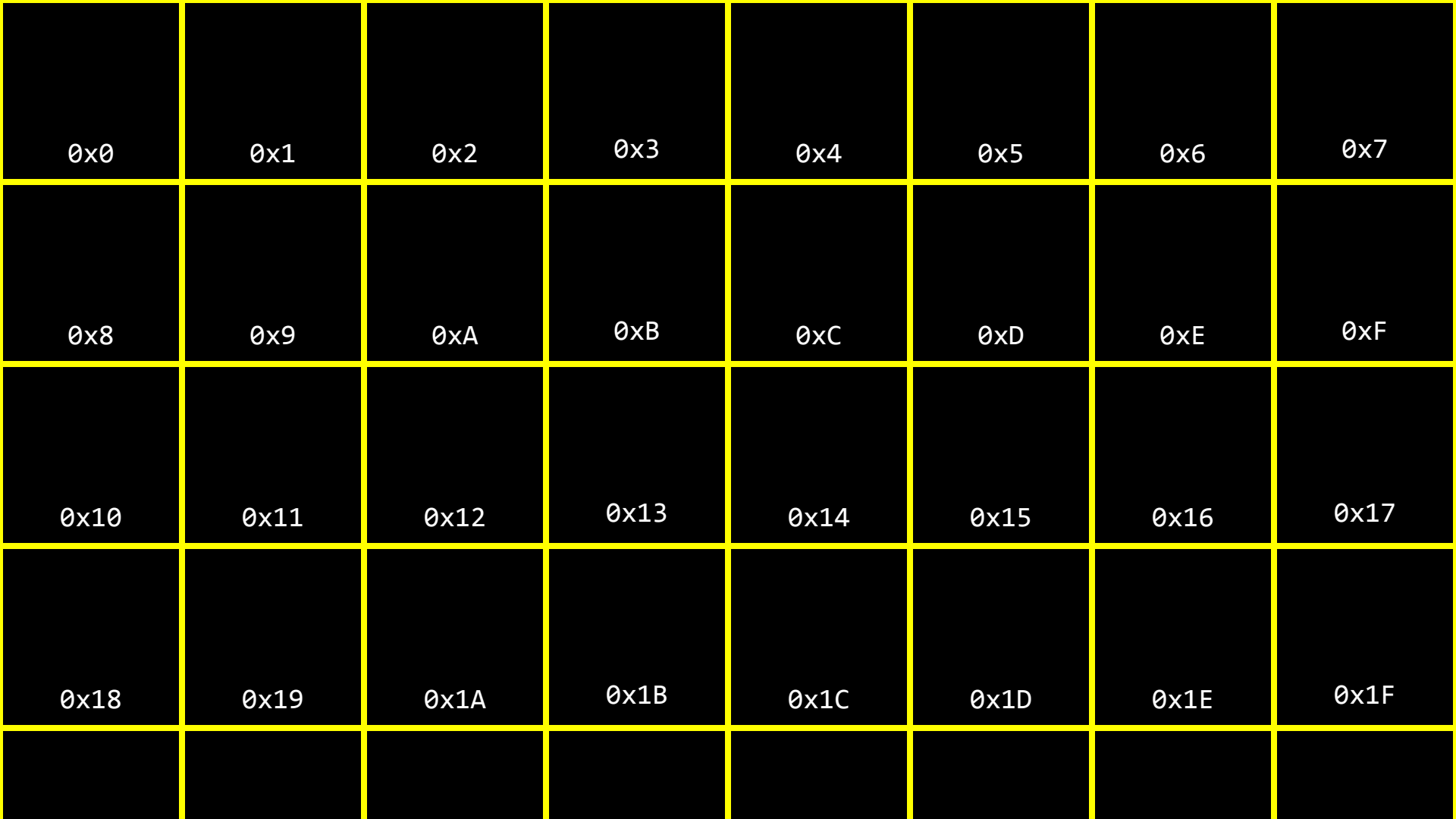
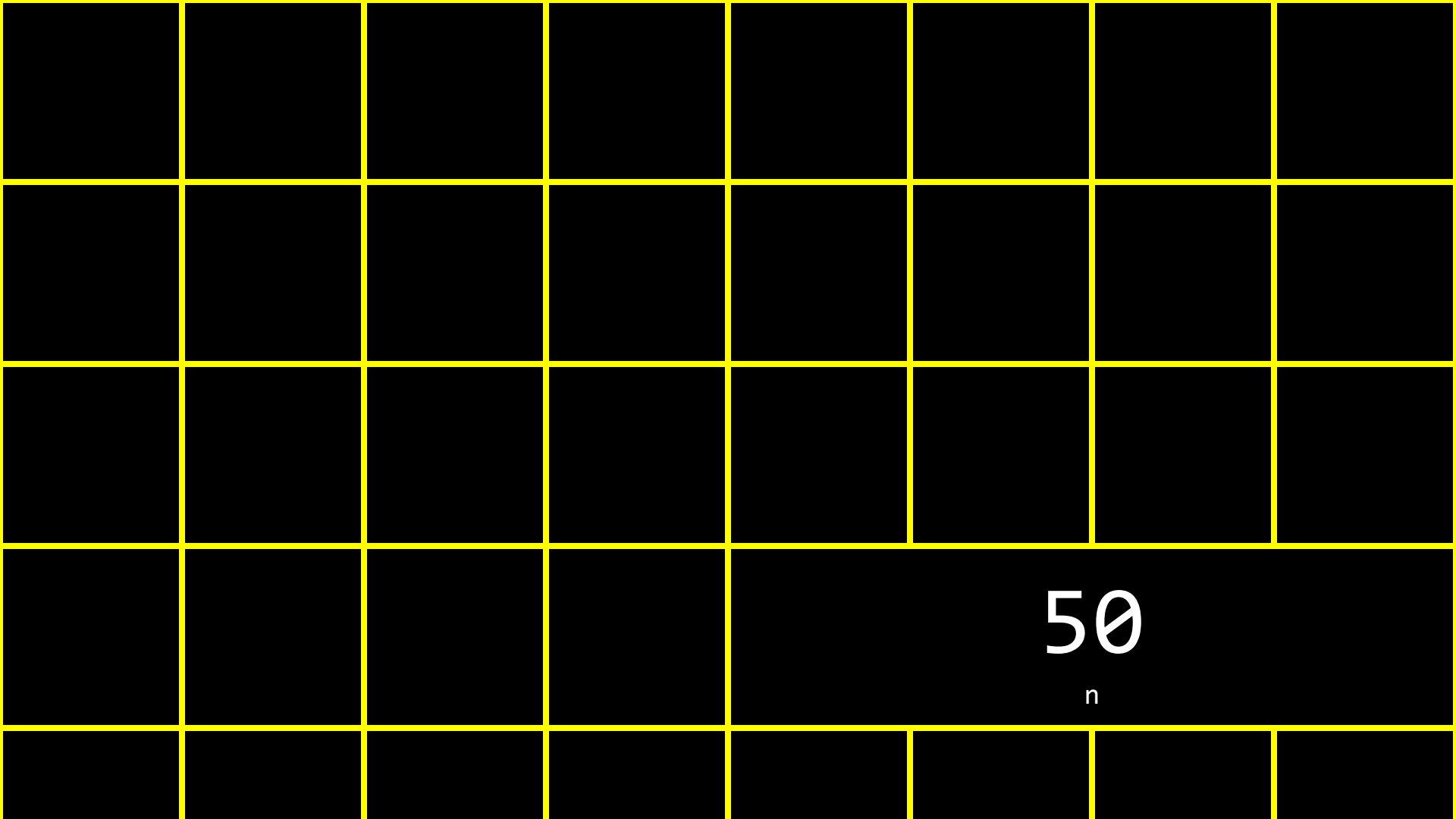
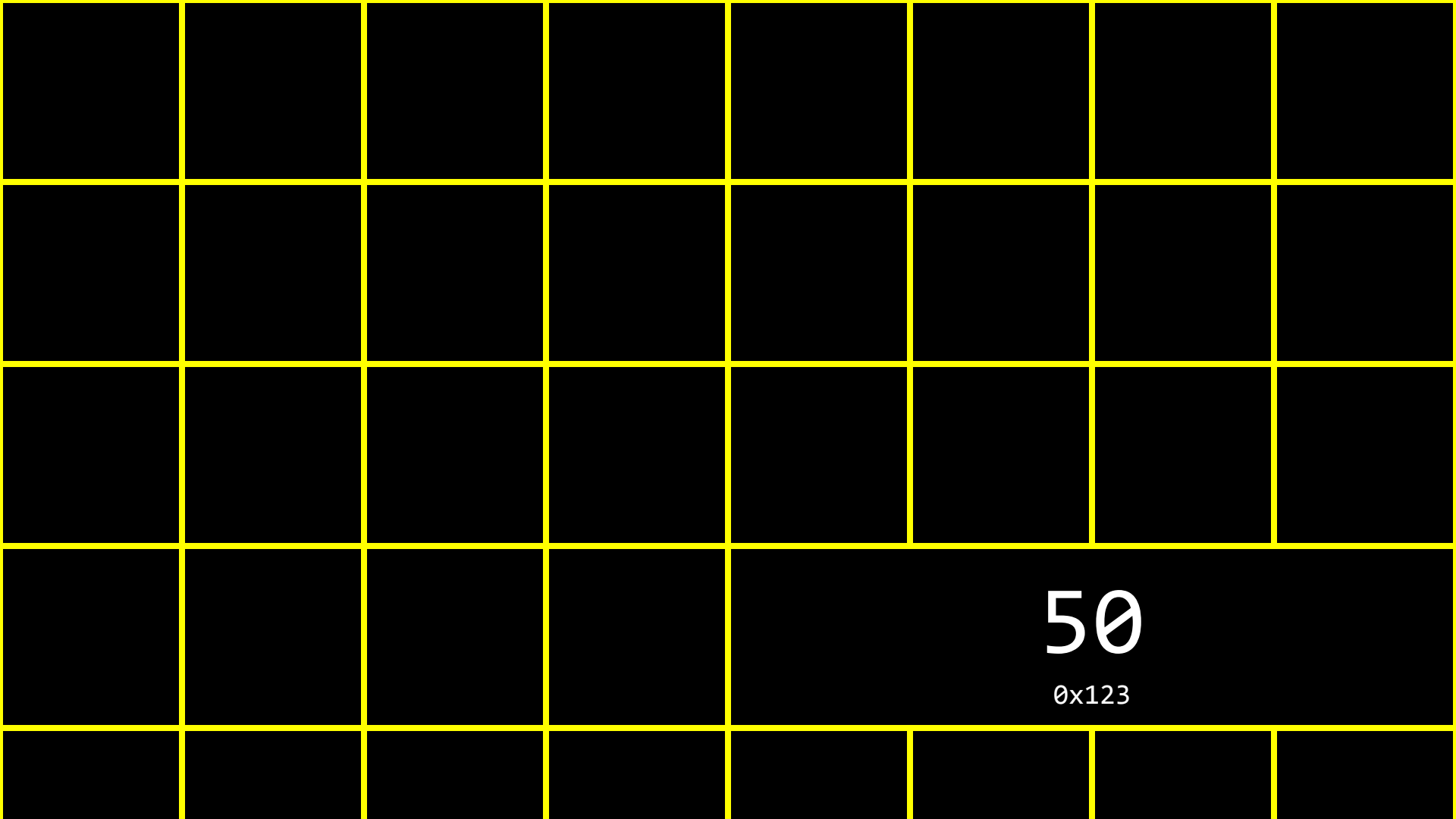
3
4
5
6
7
8
9
A
B
C
D
E
F

0	1	2	3	4	5	6	7
8	9	A	B	C	D	E	F
10	11	12	13	14	15	16	17
18	19	1A	1B	1C	1D	1E	1F


0x0
0x1
0x2
0x3
0x4
0x5
0x6
0x7
0x8
0x9
0xA
0xB
0xC
0xD
0xE
0xF
0x10
0x11
0x12
0x13
0x14
0x15
0x16
0x17
0x18
0x19
0x1A
0x1B
0x1C
0x1D
0x1E
0x1F

```
int n = 50;
```


50
n


50
0x123

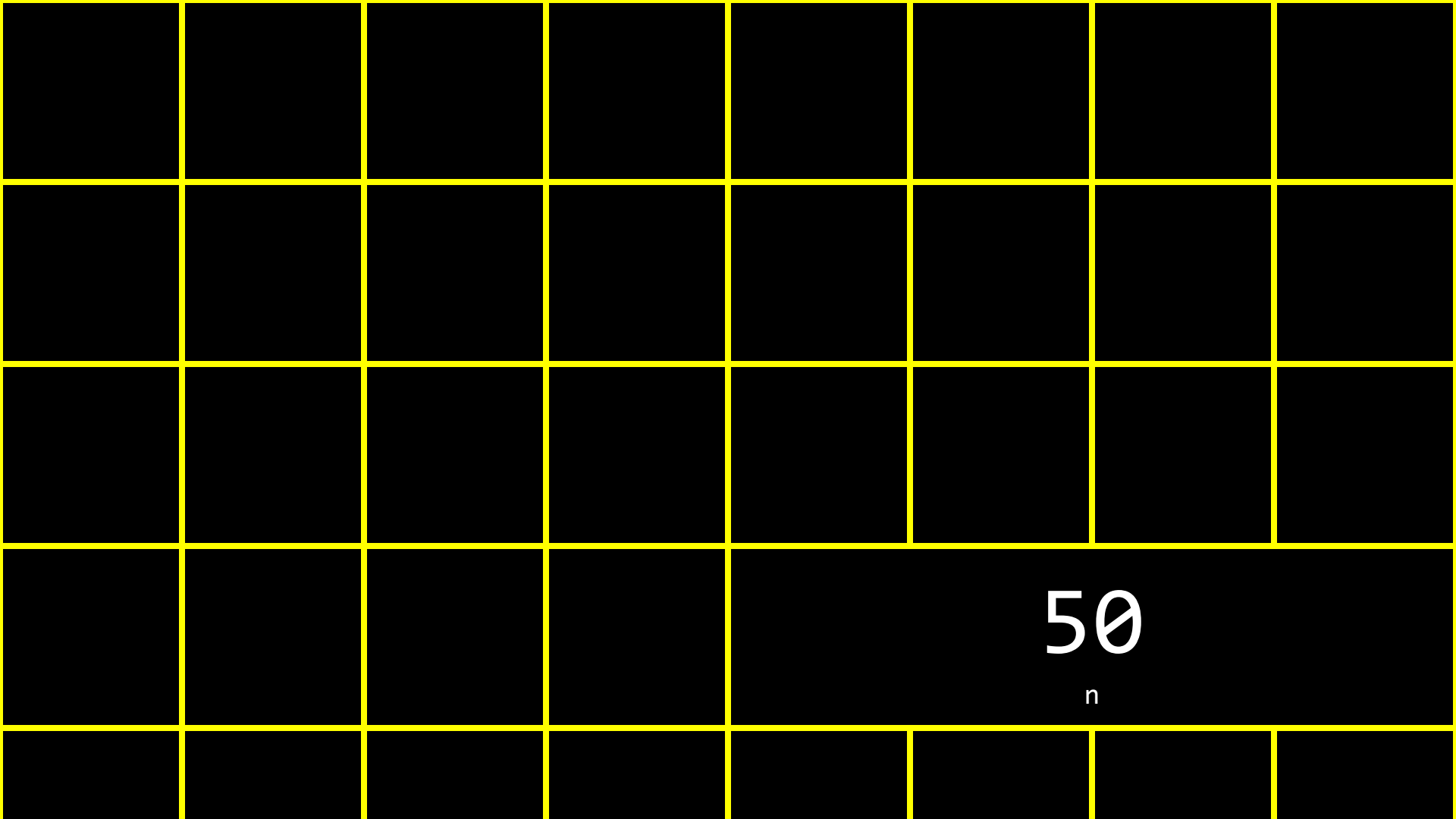
&

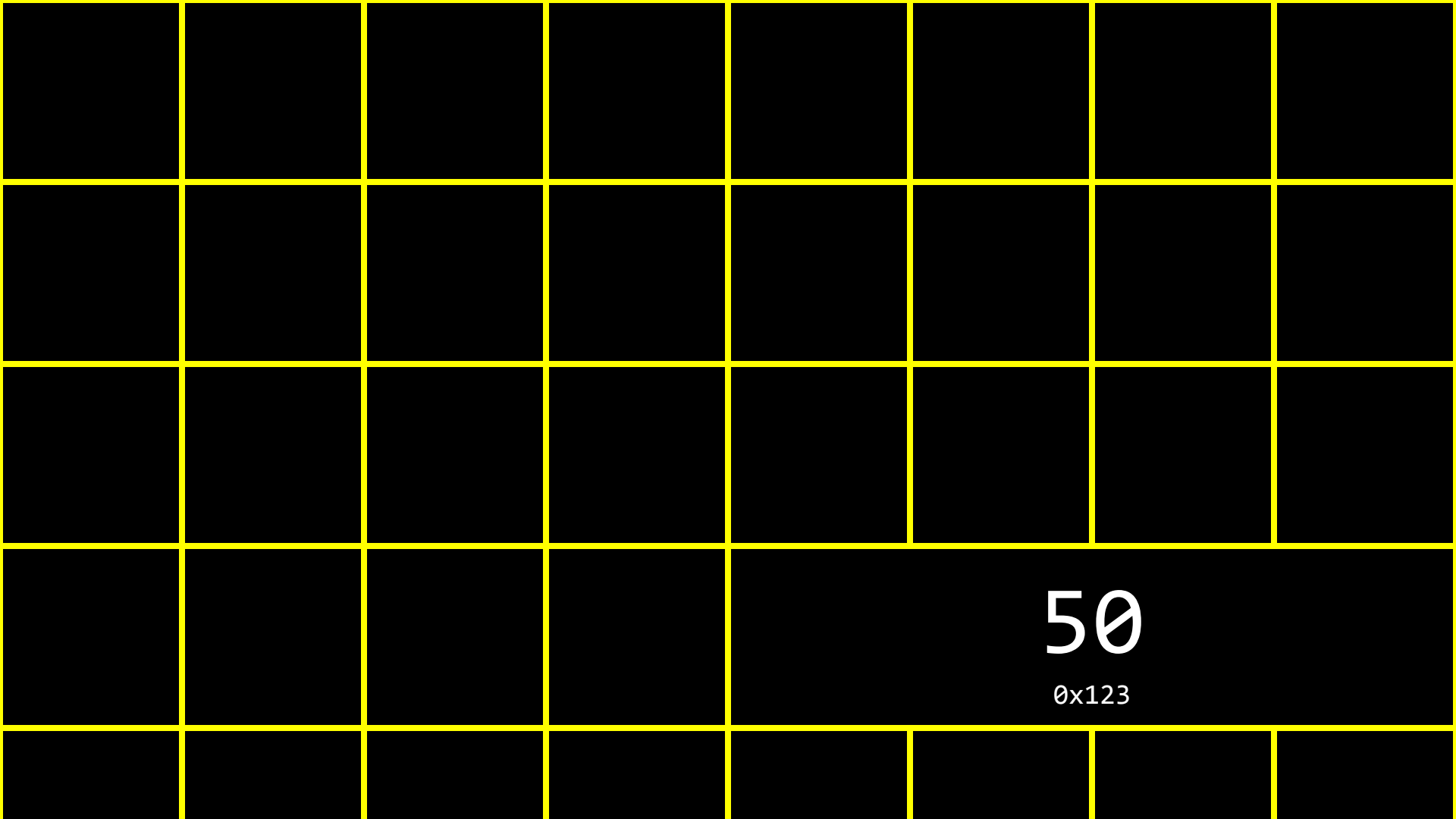
*

pointers

```
int n = 50;

int *p = &n;
```


50
n


50
0x123

0x123

p

50

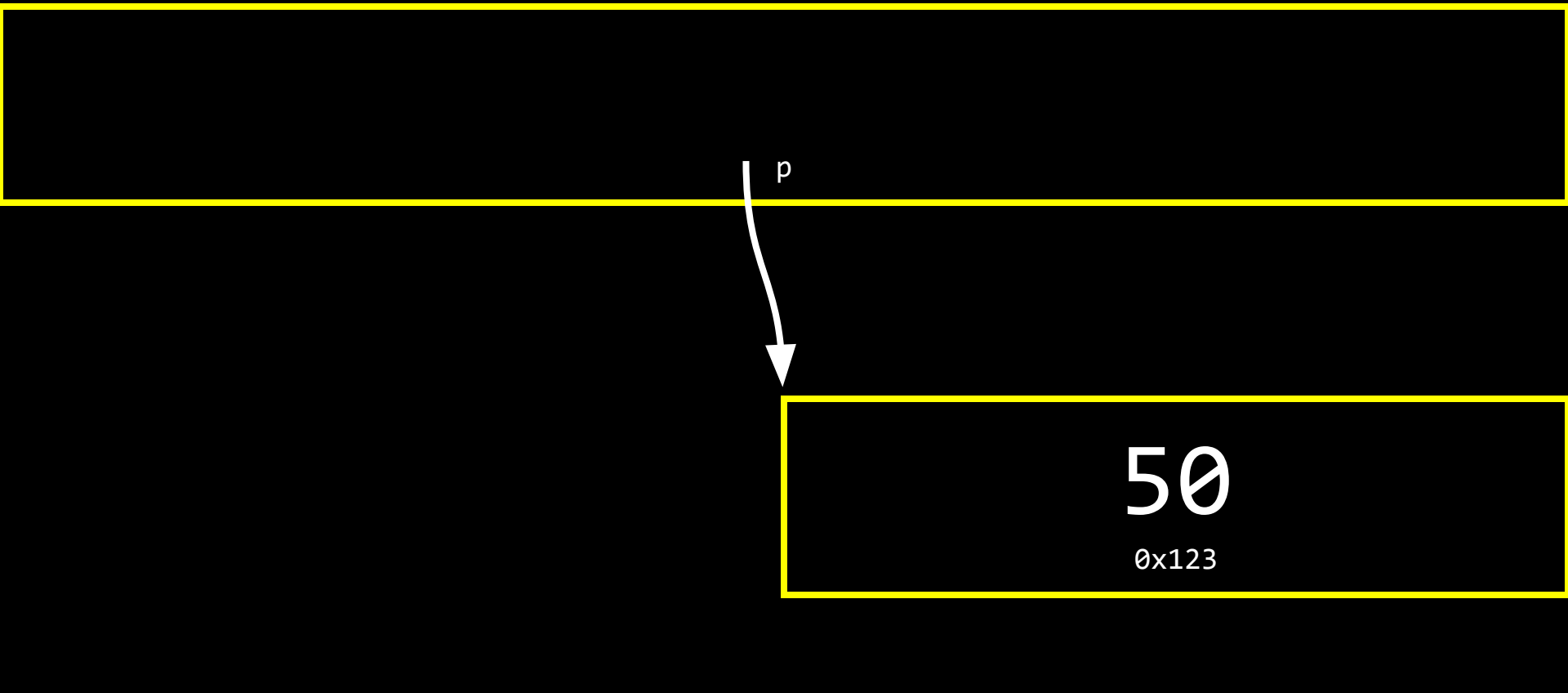
0x123

0x123

p

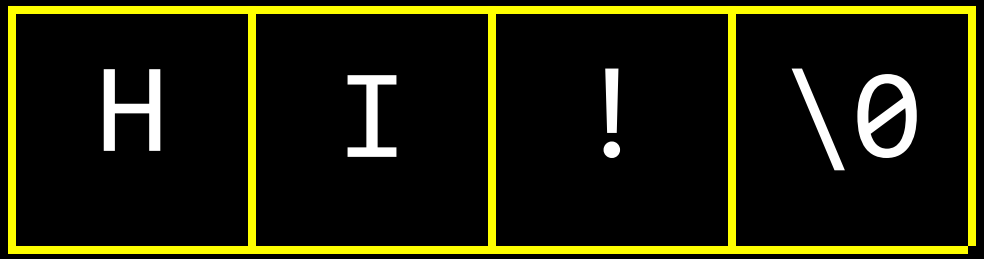
50

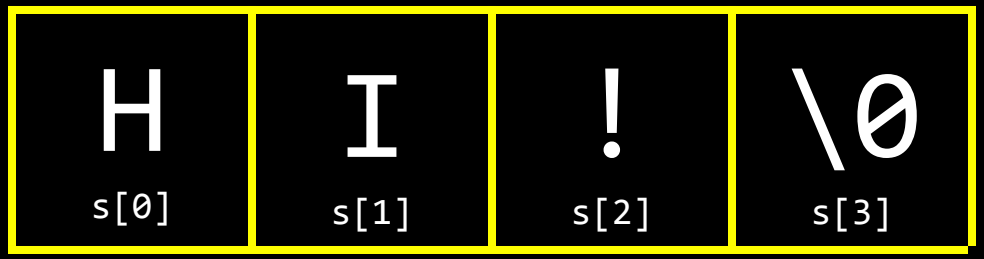
0x123

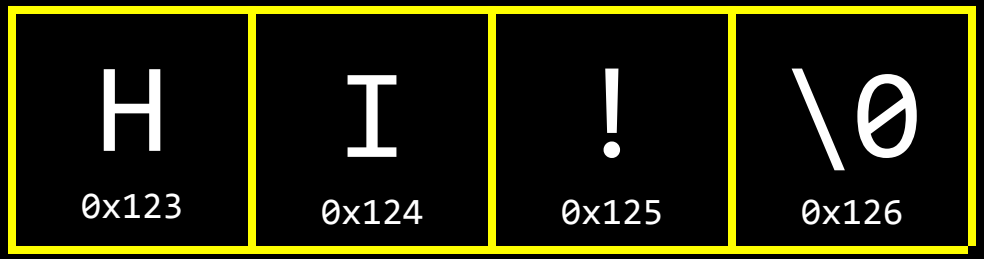

p
50
0x123

string

```
string s = "HI!";
```

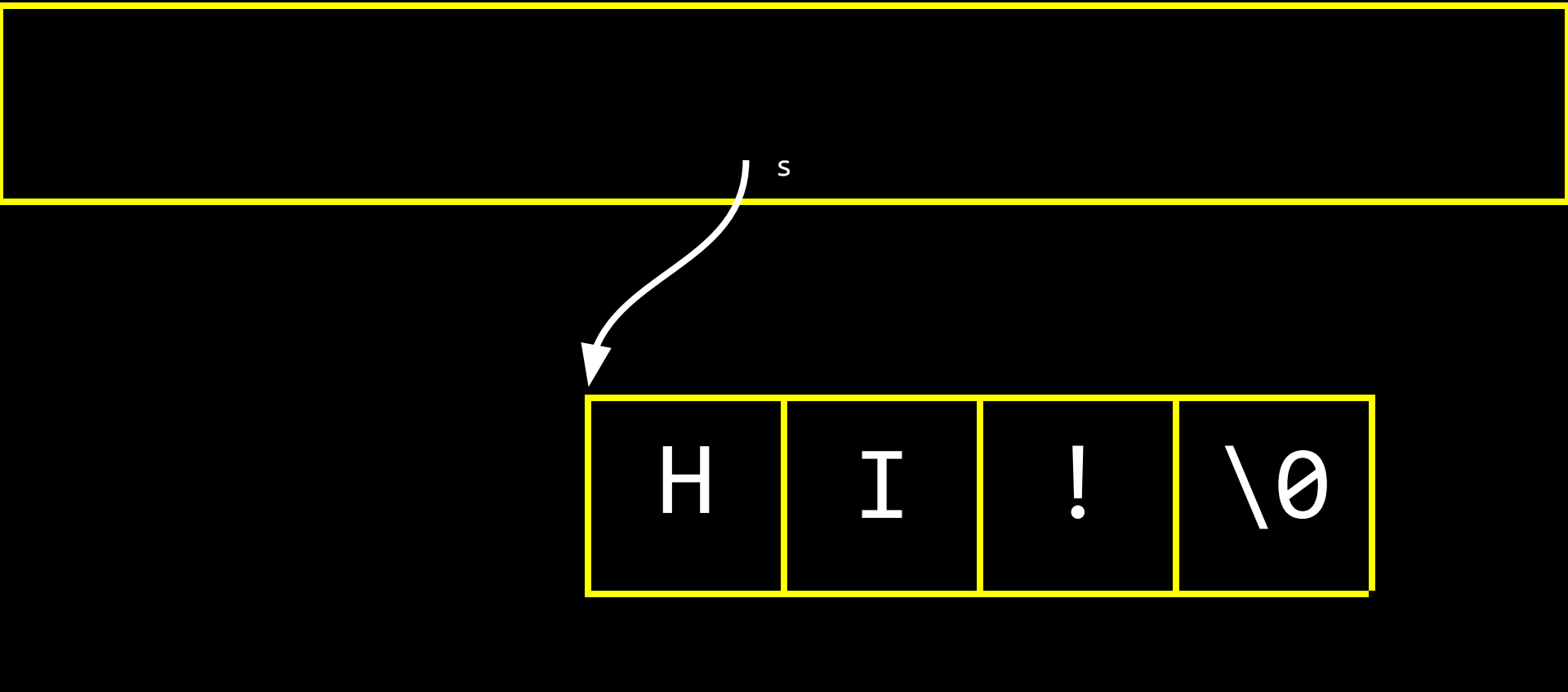

H
I
!
\0


H
s[0]
I
s[1]
!
s[2]
\0
s[3]


H
0x123
I
0x124
!
0x125
\0
0x126

0x123

s


s
H
I
!
\0

```
string s = "HI!";
```

```
string s = "HI!";
```

```
char *s = "HI!";
```

```
typedef struct
{
    string name;
    string number;
}
person;
```

```
typedef struct
{
    string name;
    string number;
}
person;
```

```
typedef struct
{
    string name;
    string number;
}
person;
```

```
typedef struct
{
    string name;
    string number;
}
person;
```

```
typedef int integer;
```

```
typedef int integer;
```

```
typedef int integer;
```

```
typedef char *string;
```

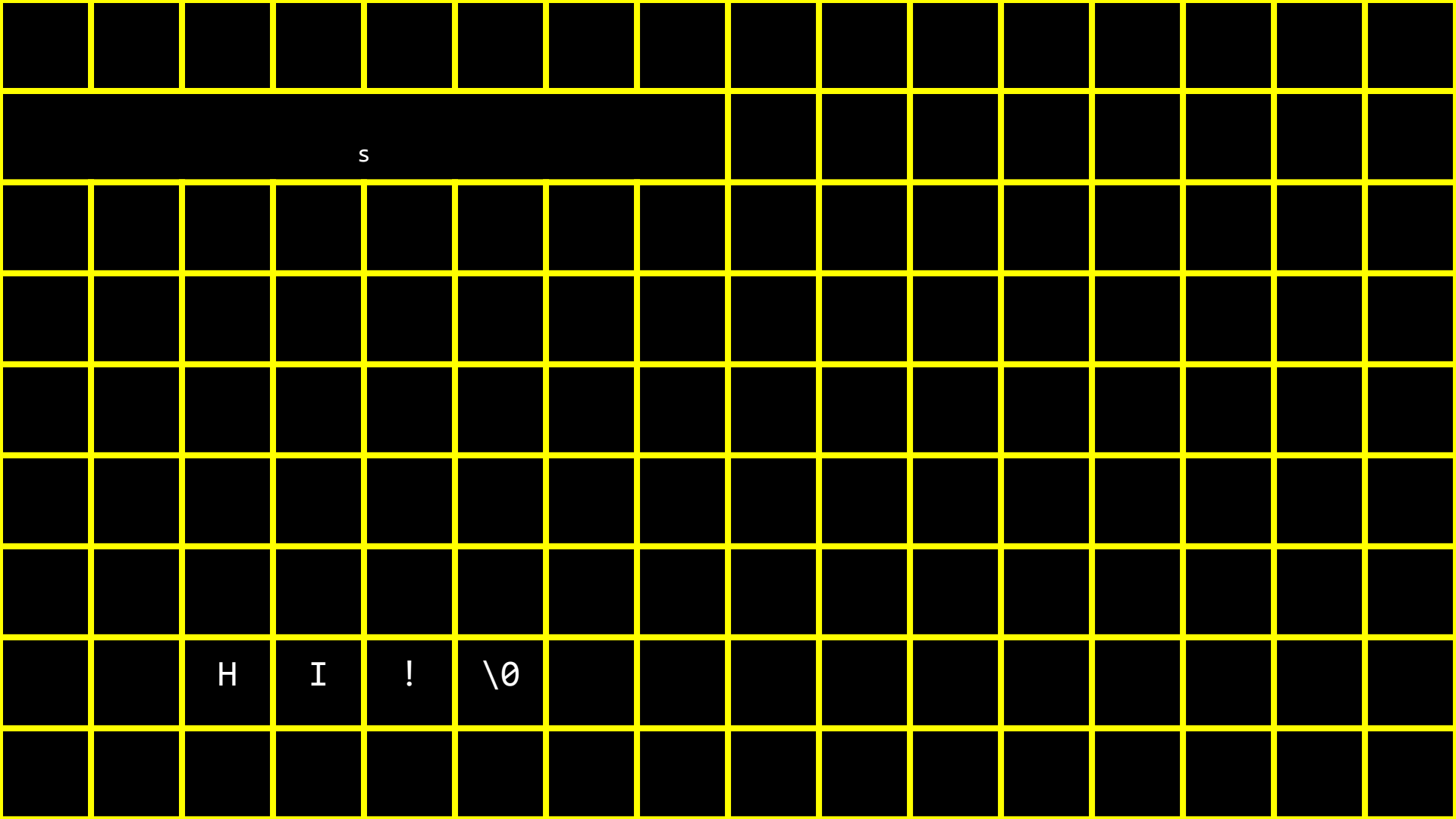
```
typedef char *string;
```

```
typedef char *string;
```

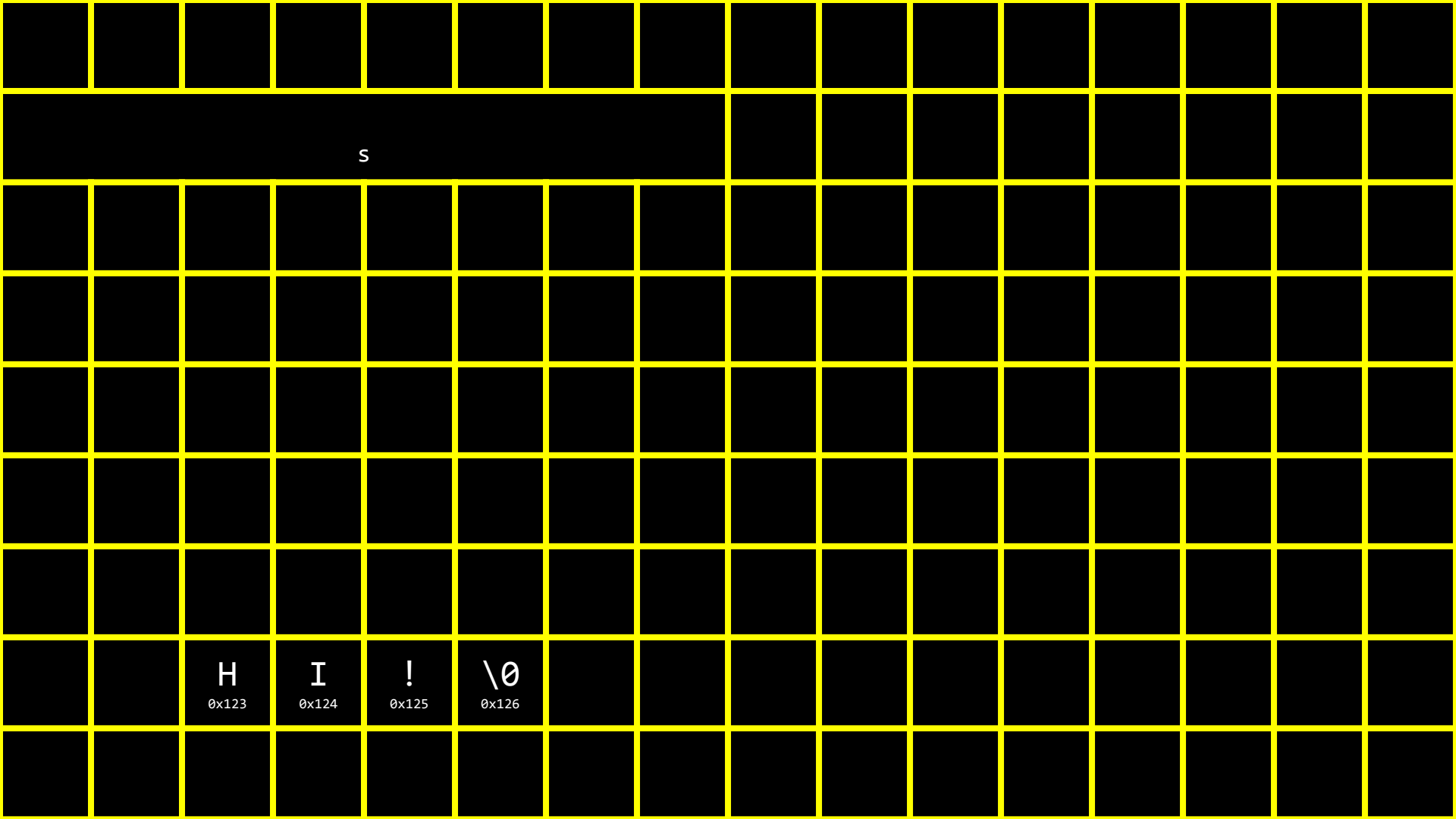
pointer arithmetic

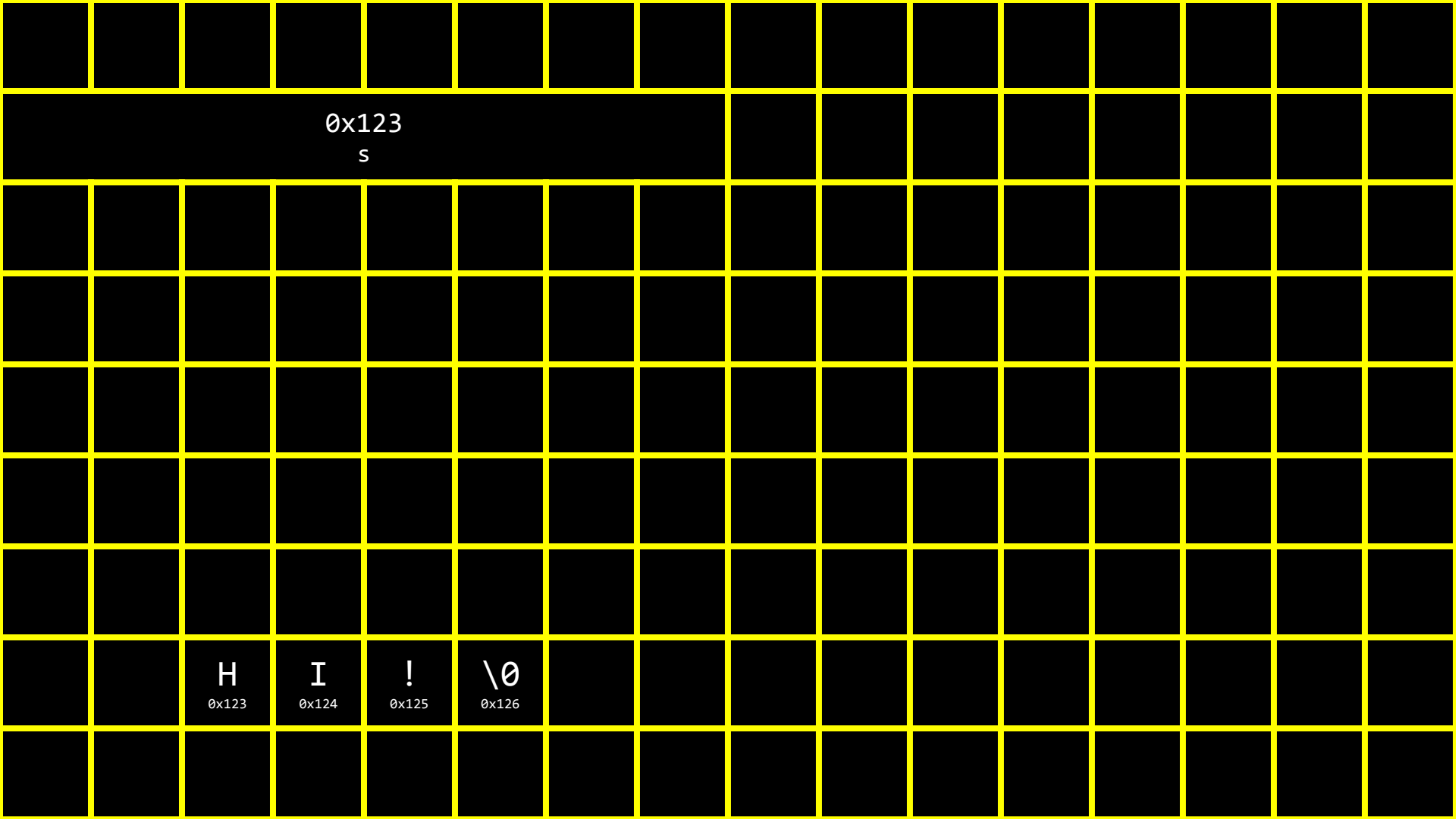
pointer arithmetic

s


s
H
I
!
\0

s




0x123
s
H
0x123
I
0x124
!
0x125
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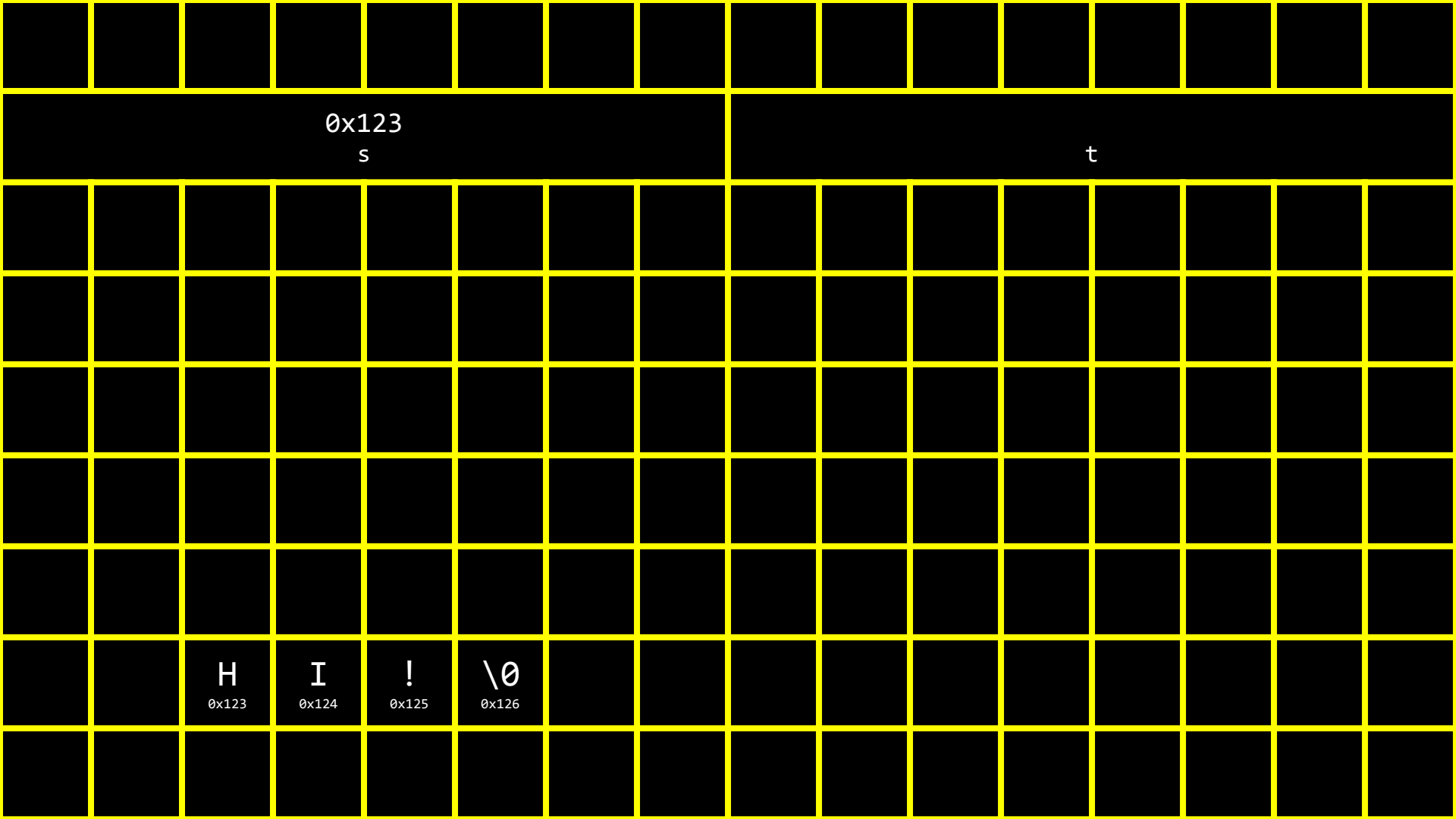
0x126


0x123
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t
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0x123
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0x124
!
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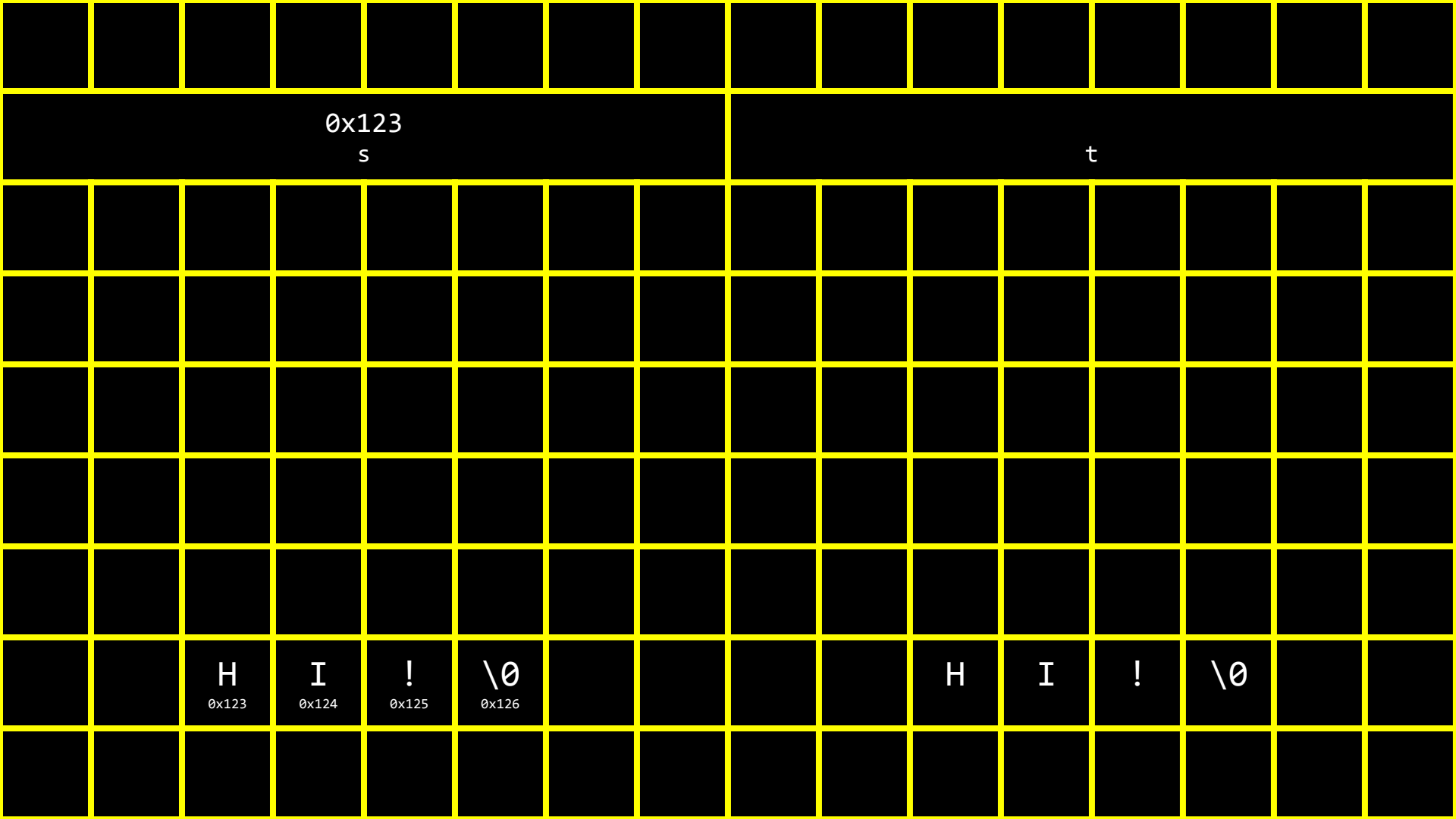
0x126


0x123
s
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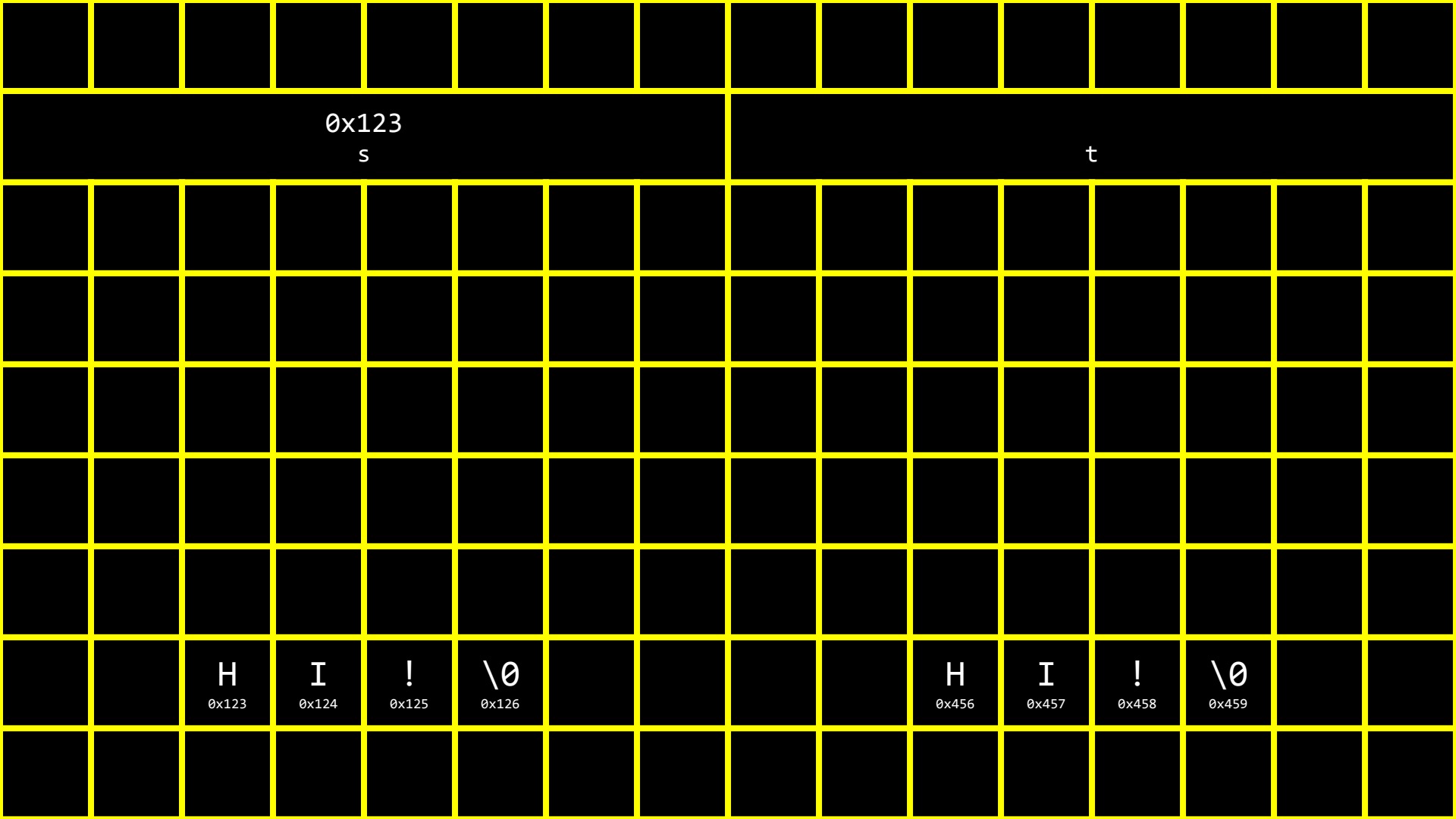
0x123
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0x126
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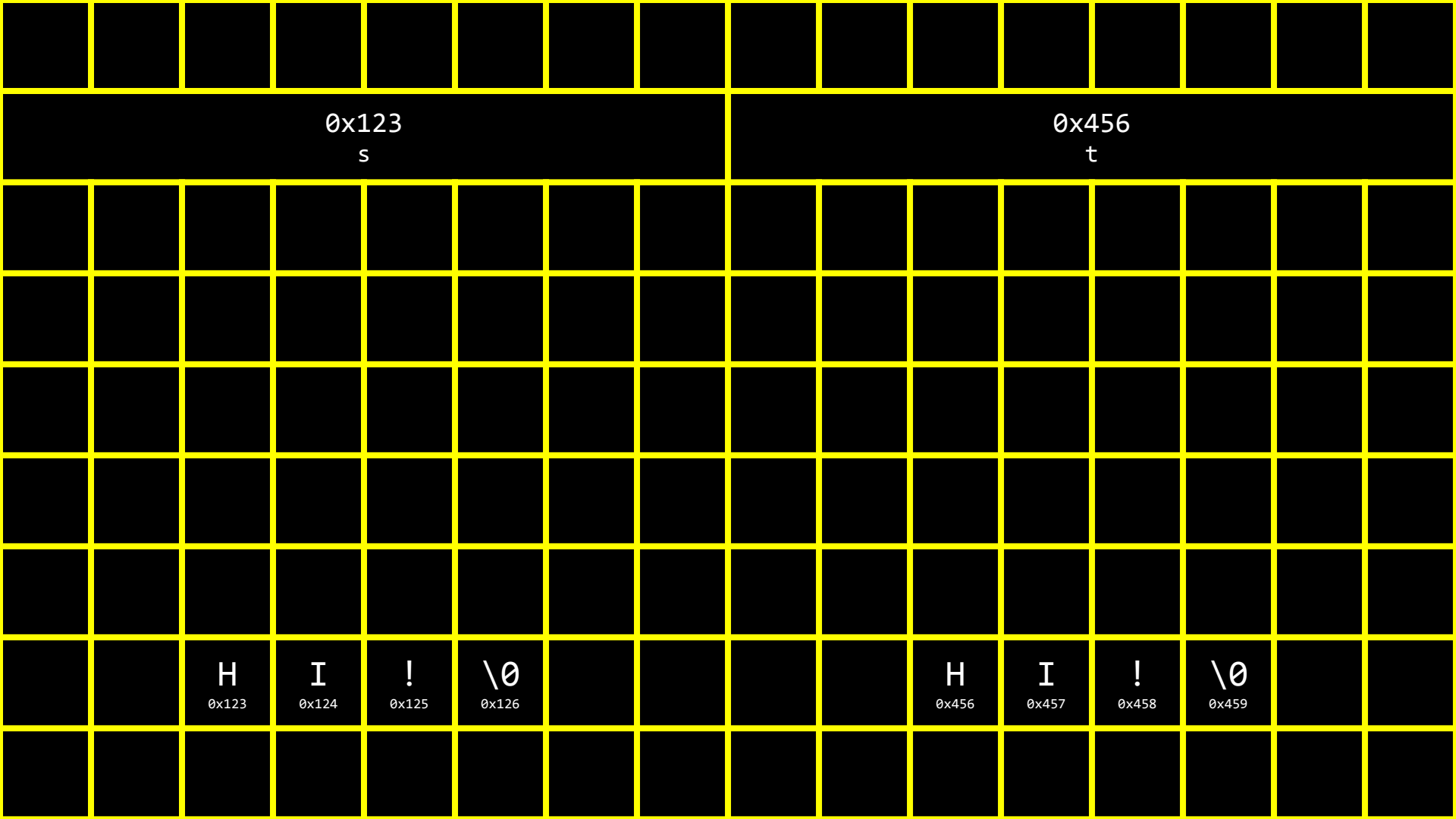
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0x126
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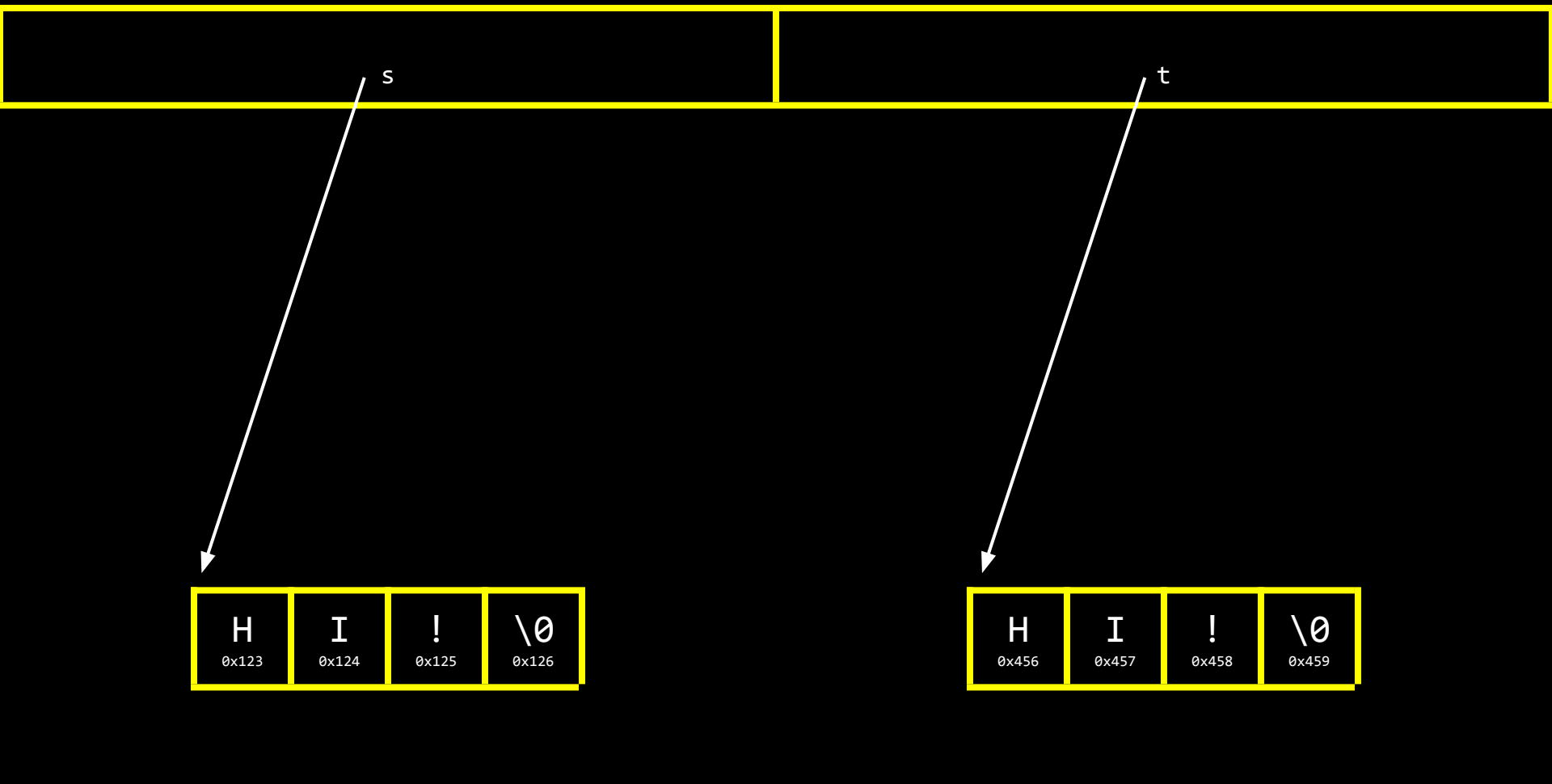
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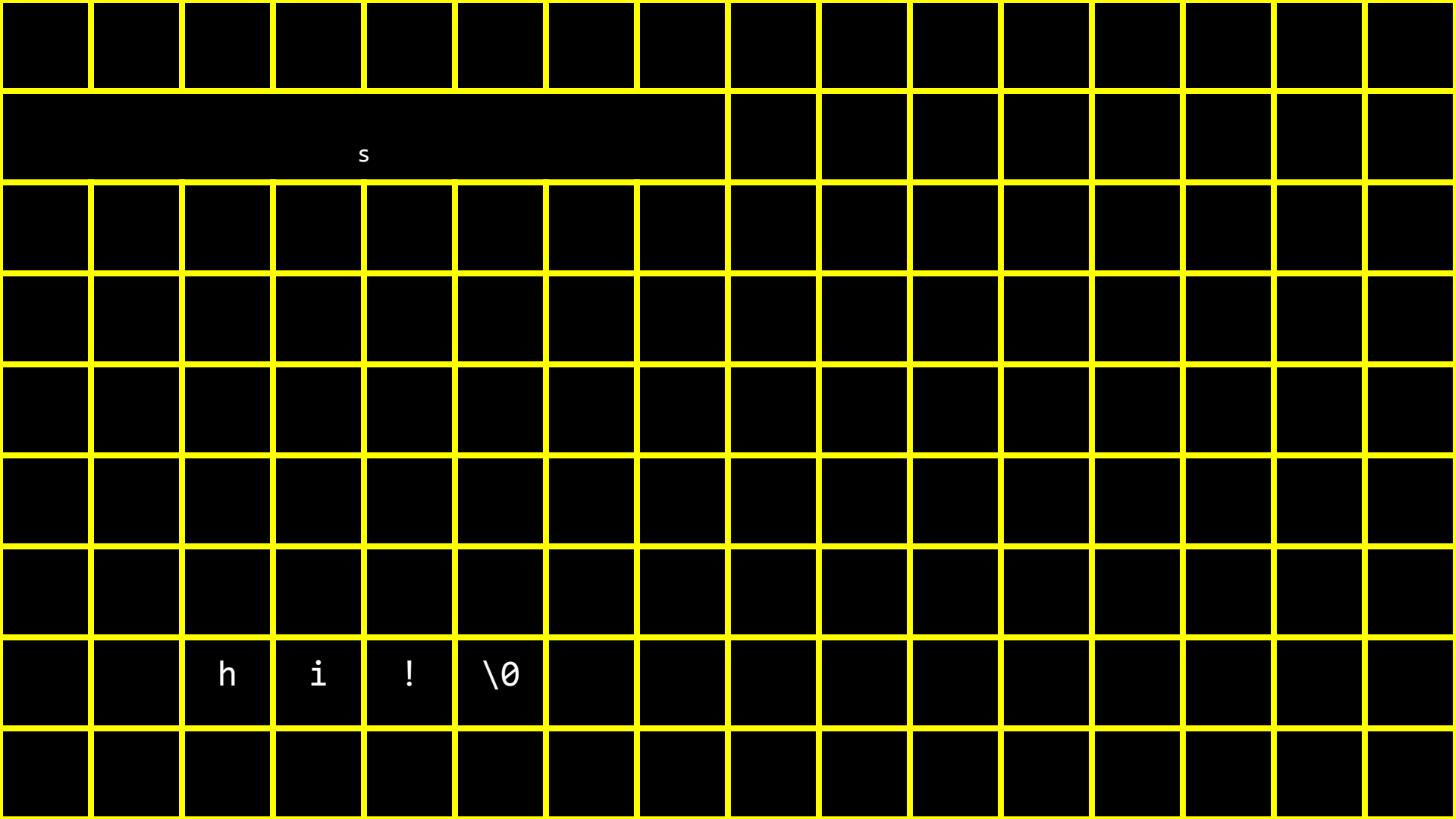
s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s

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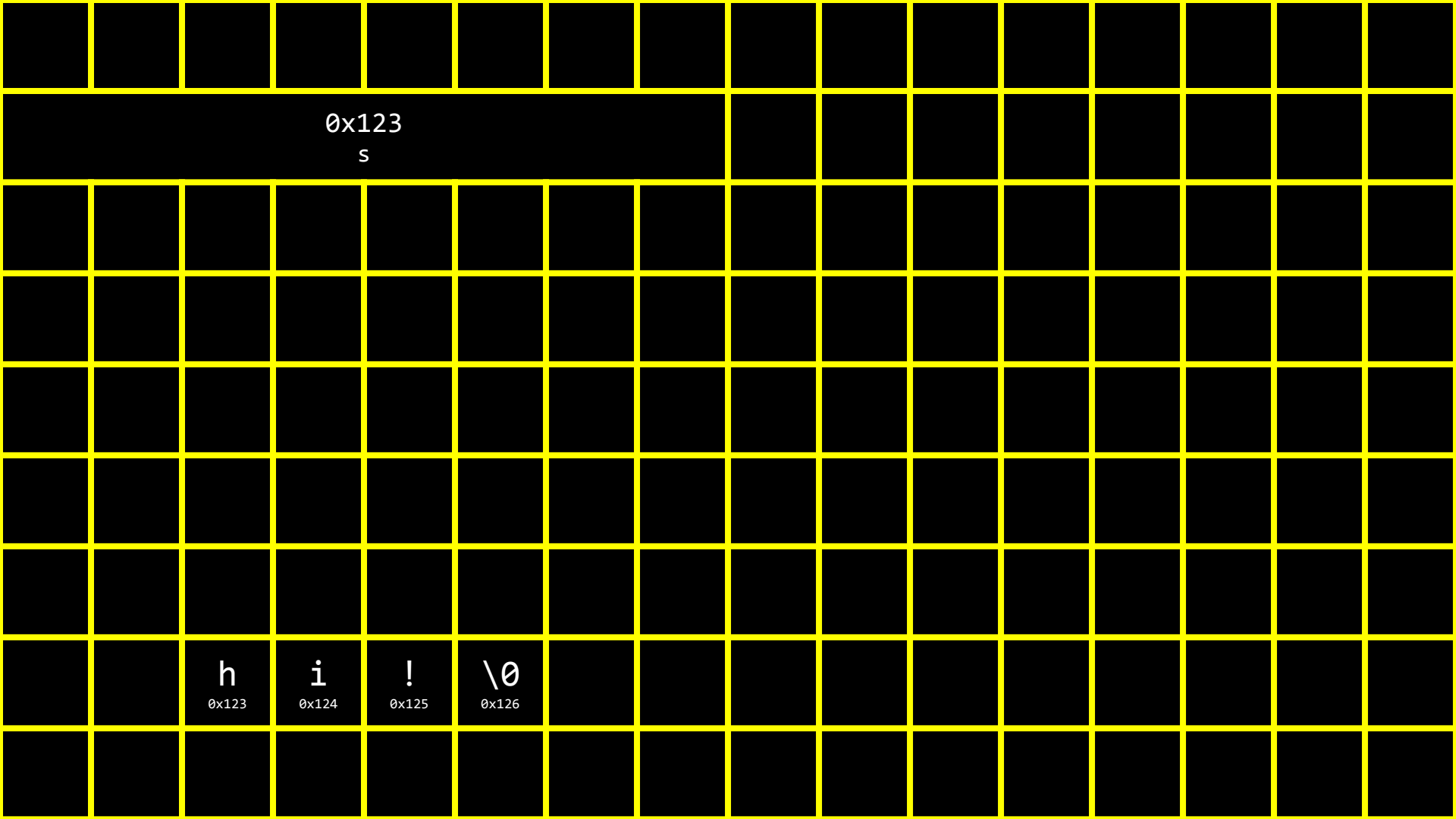
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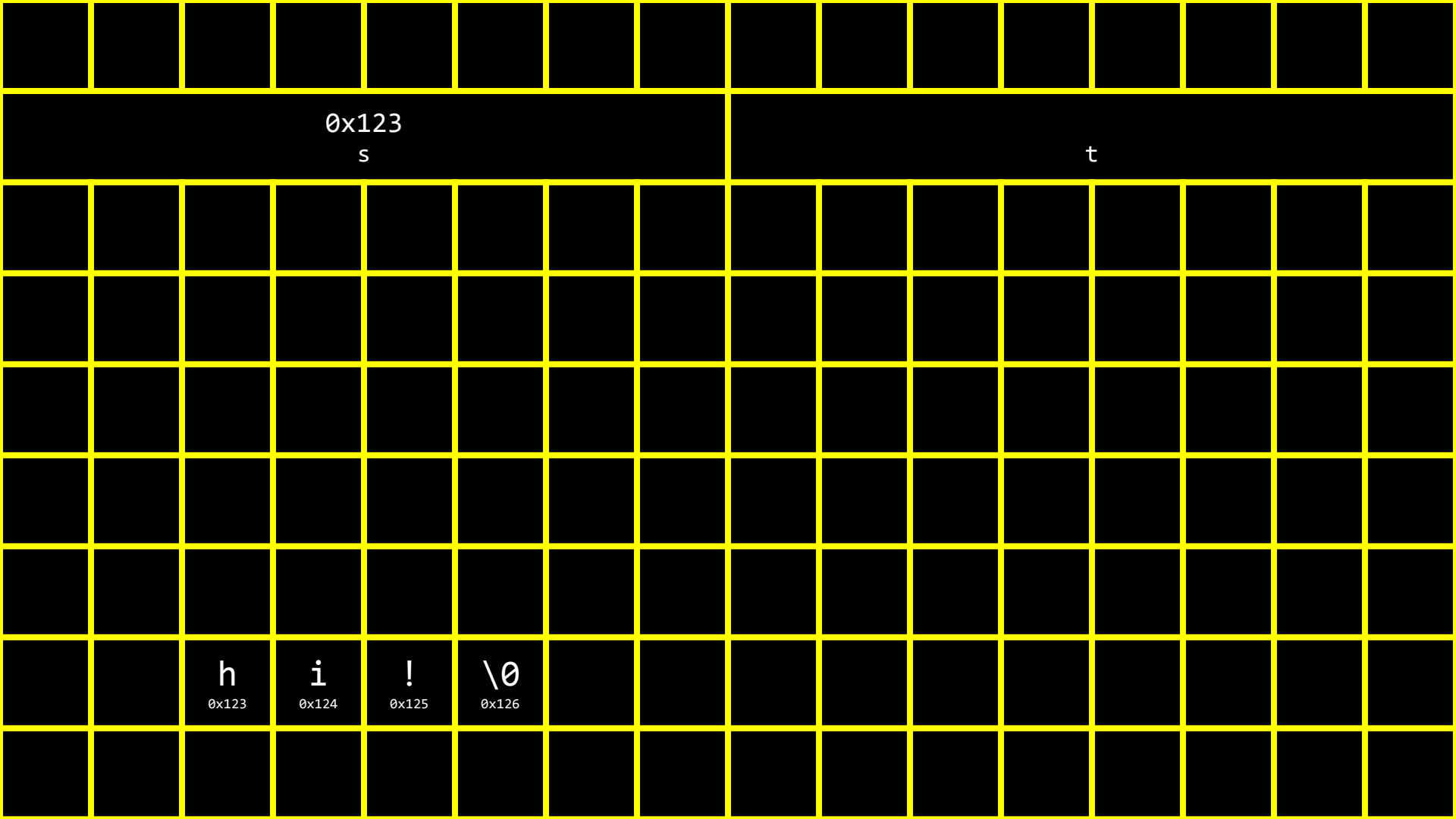
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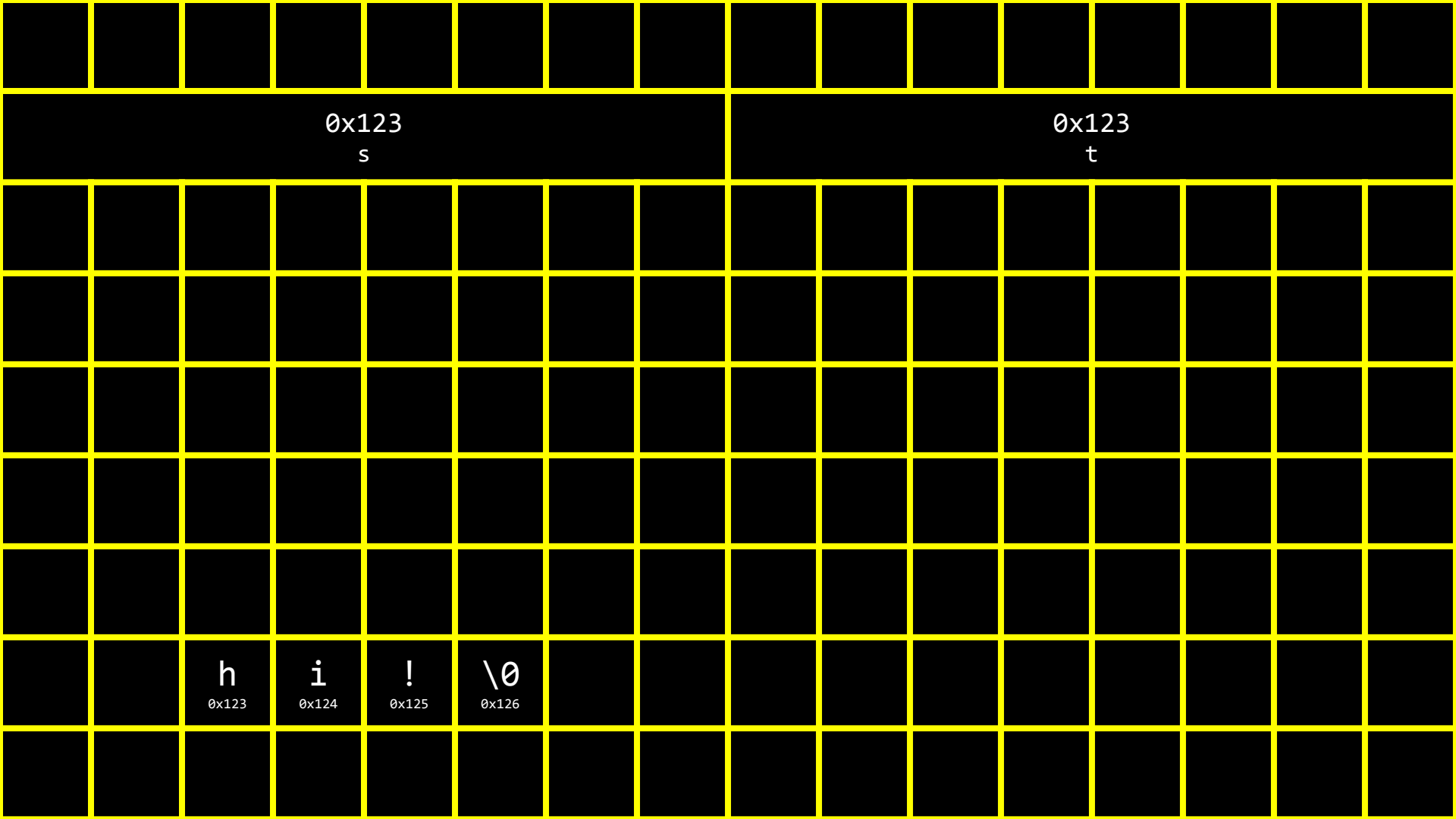
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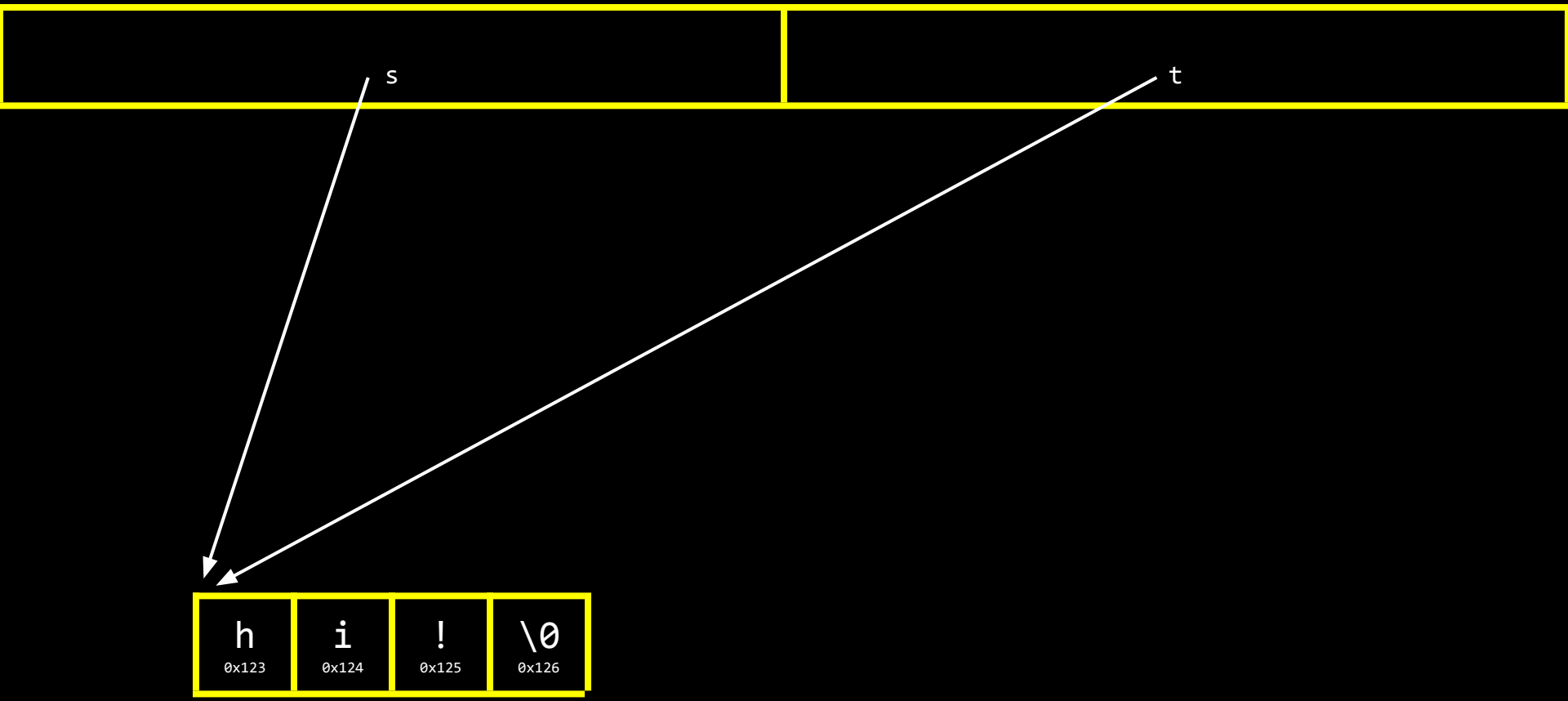
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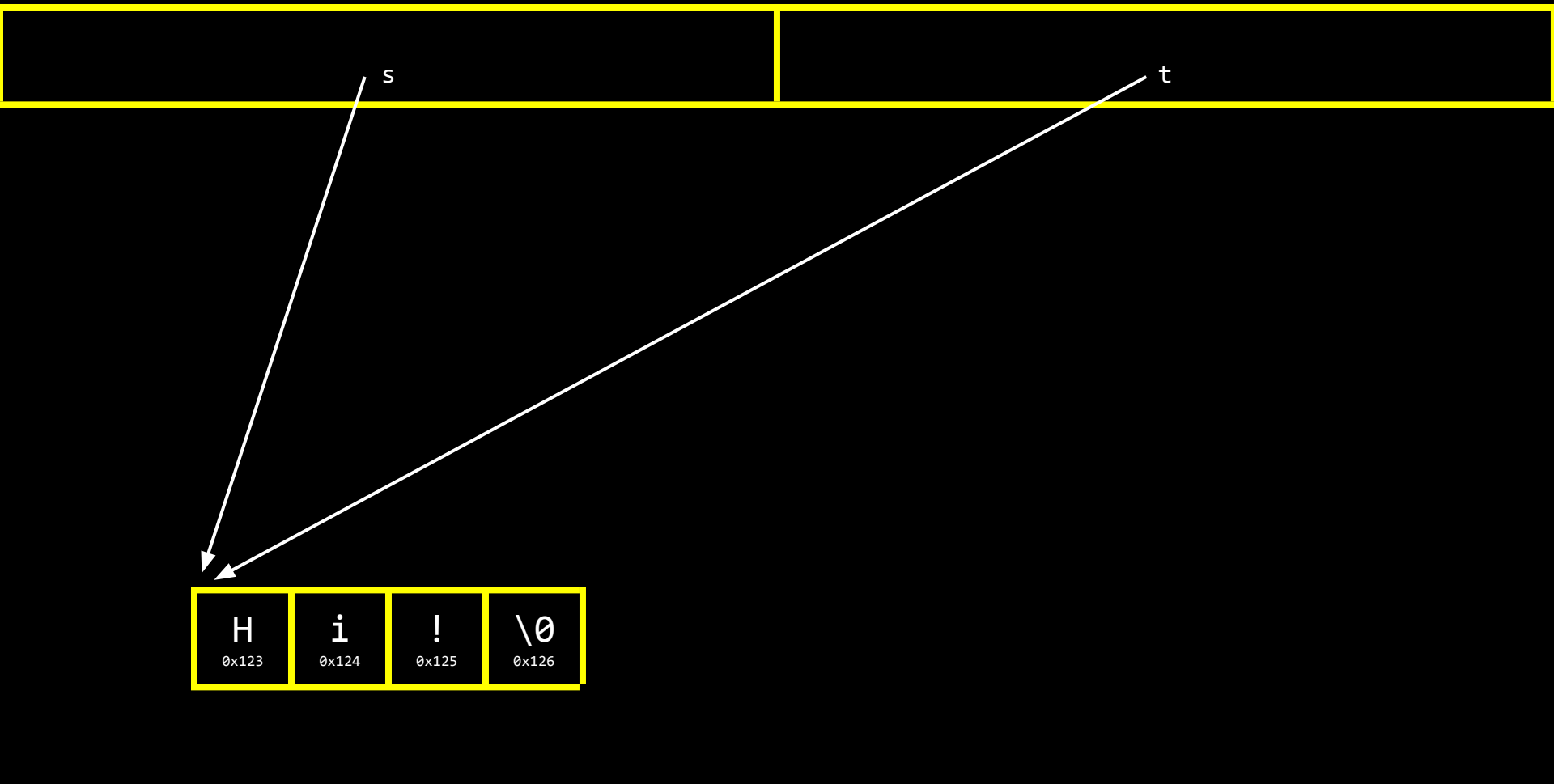
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free

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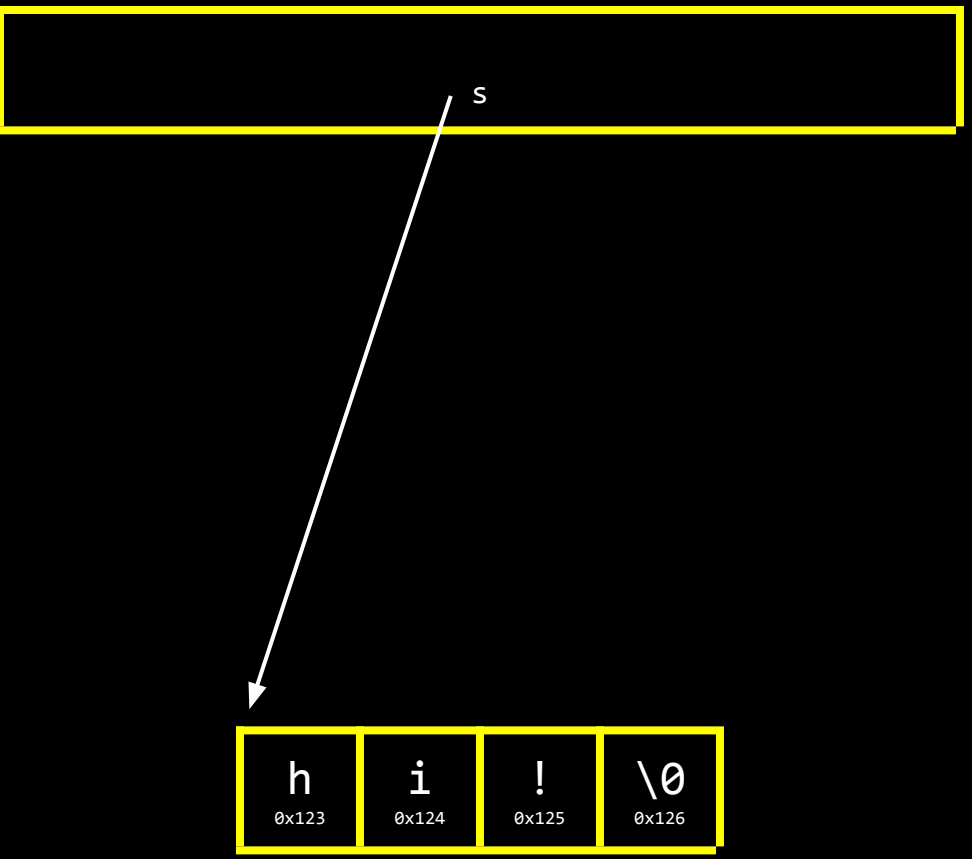
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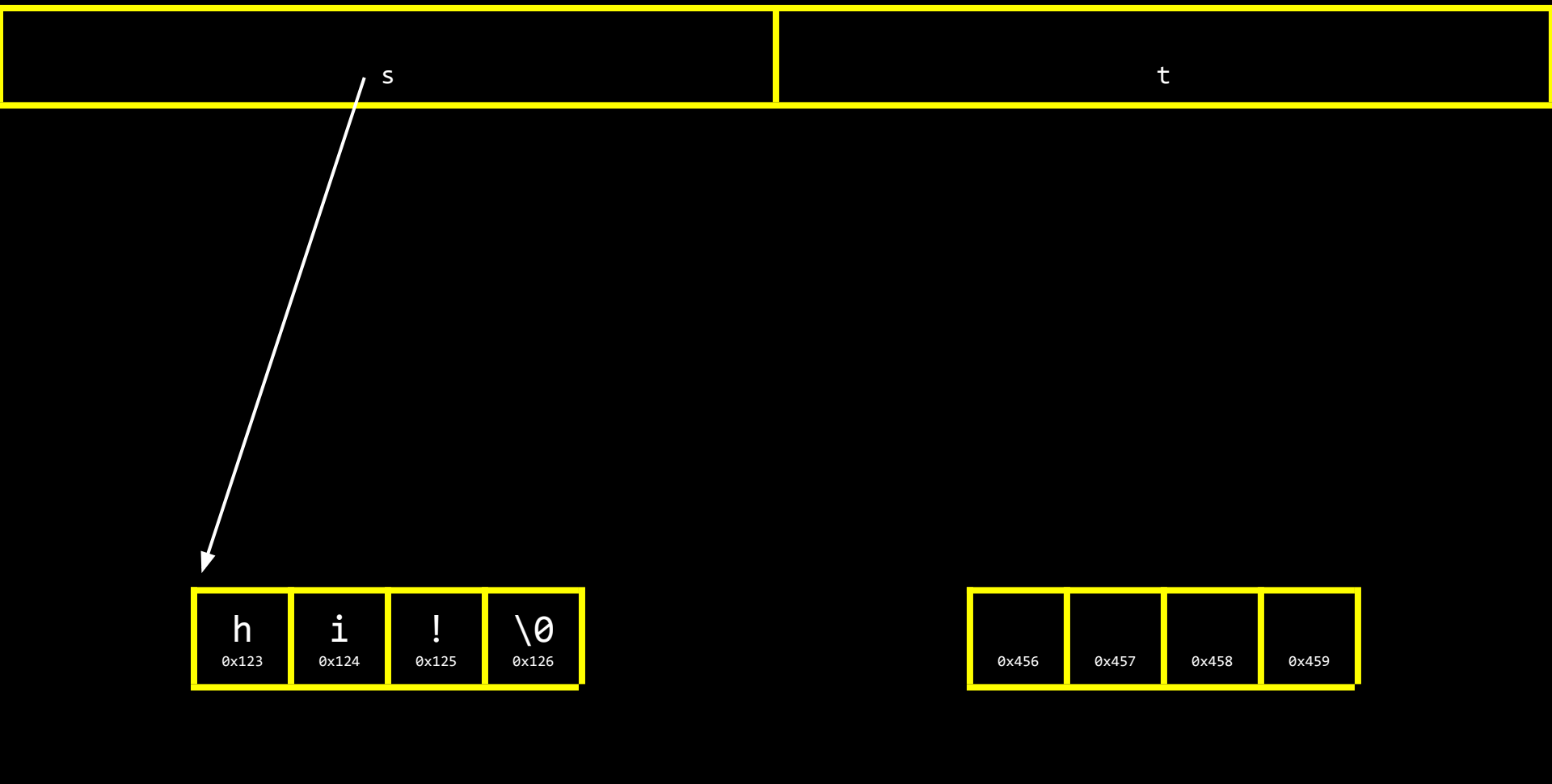
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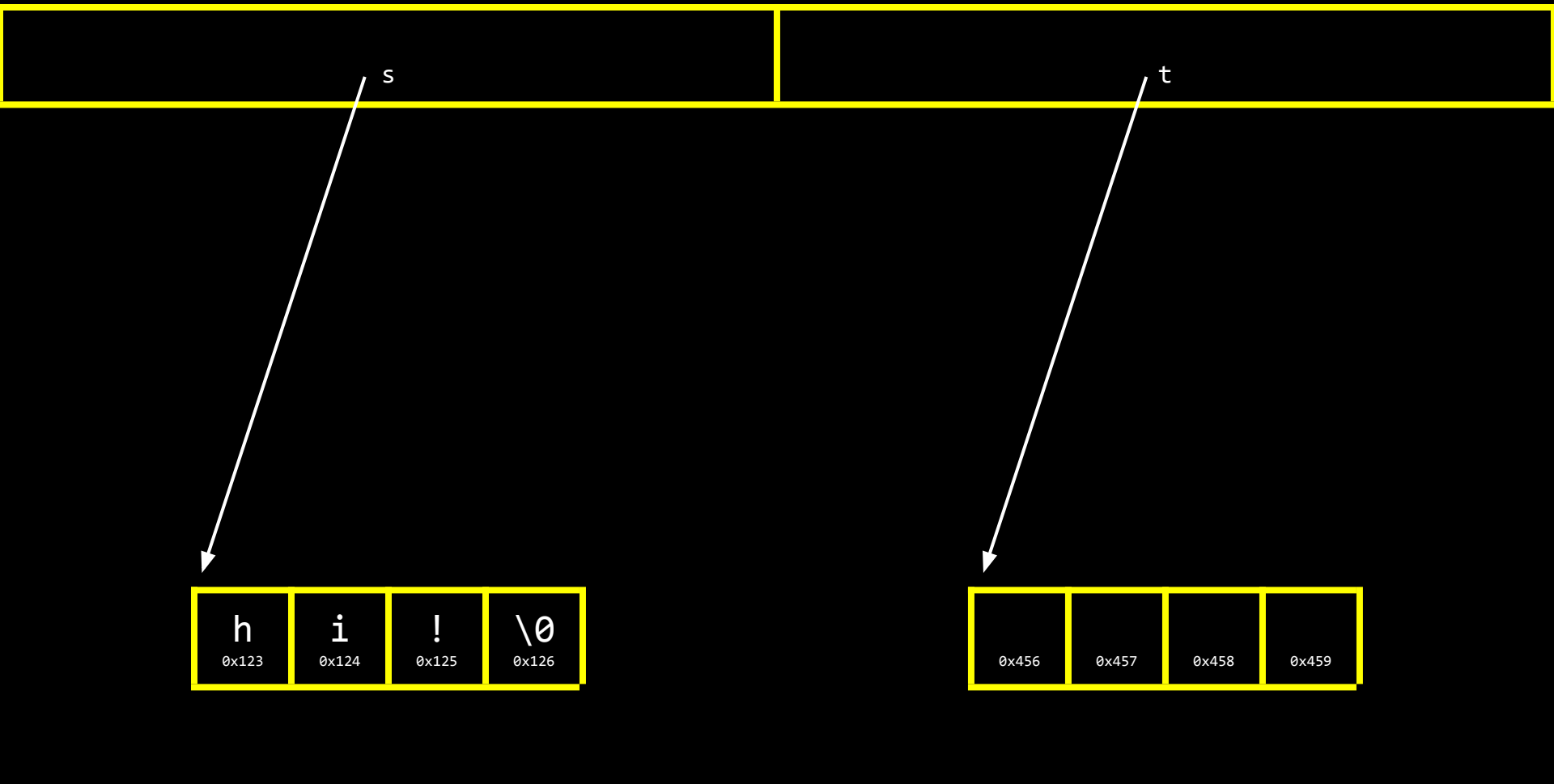
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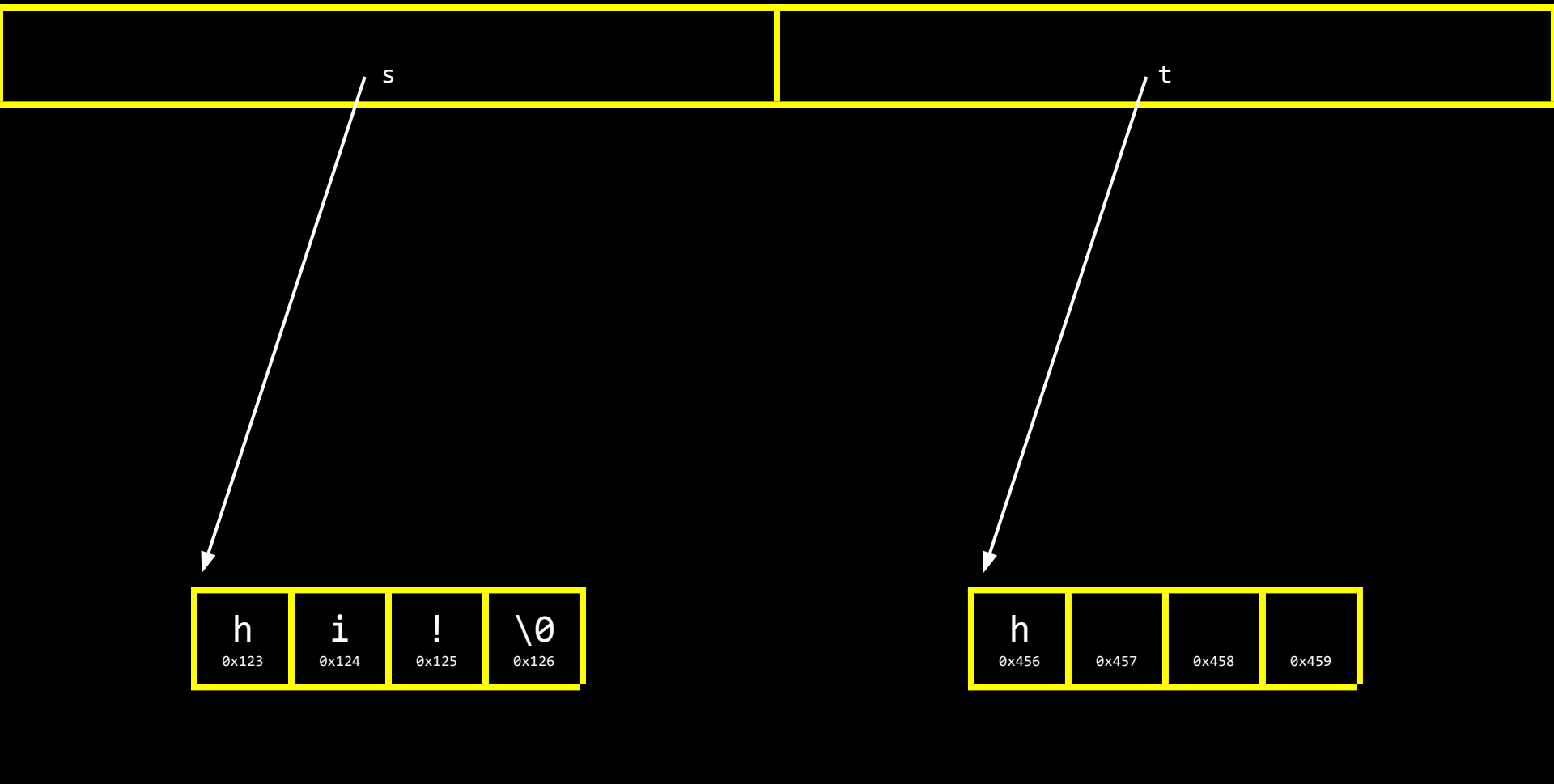
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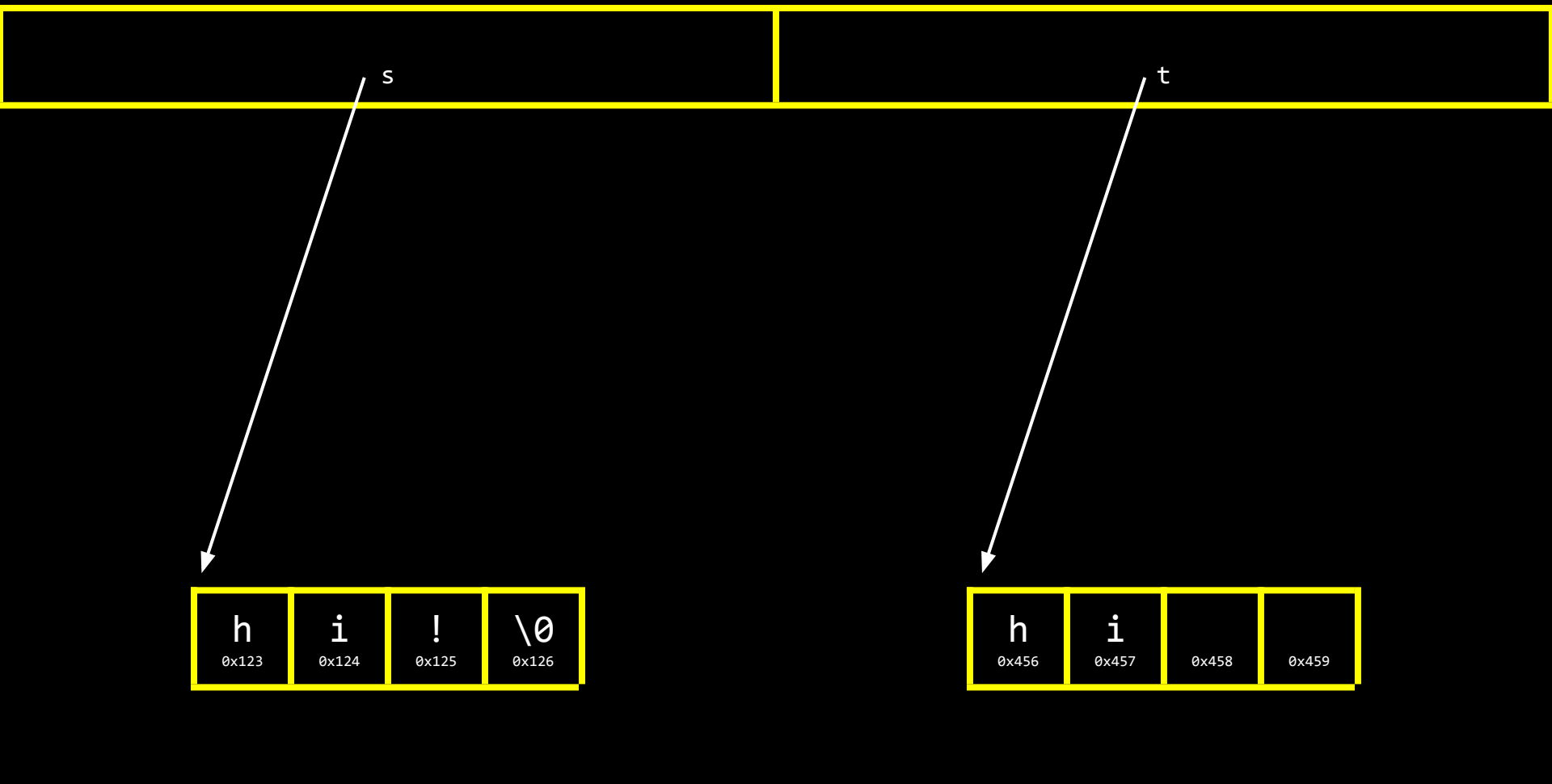
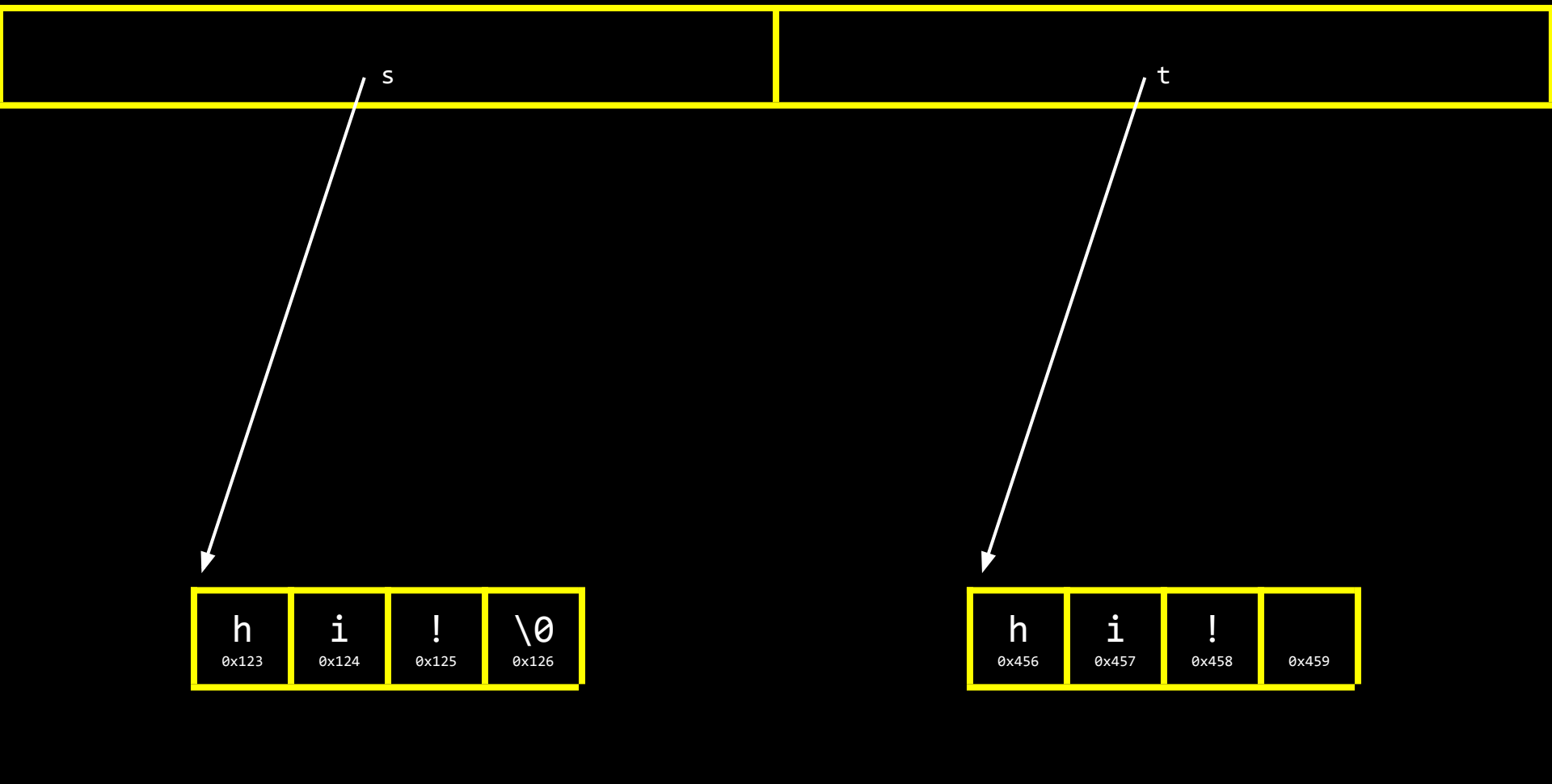
0x458
0x459


s
t
h
0x123
i
0x124
!
0x125
\0
0x126
h
0x456
i
0x457
0x458
0x459


s
t
h
0x123
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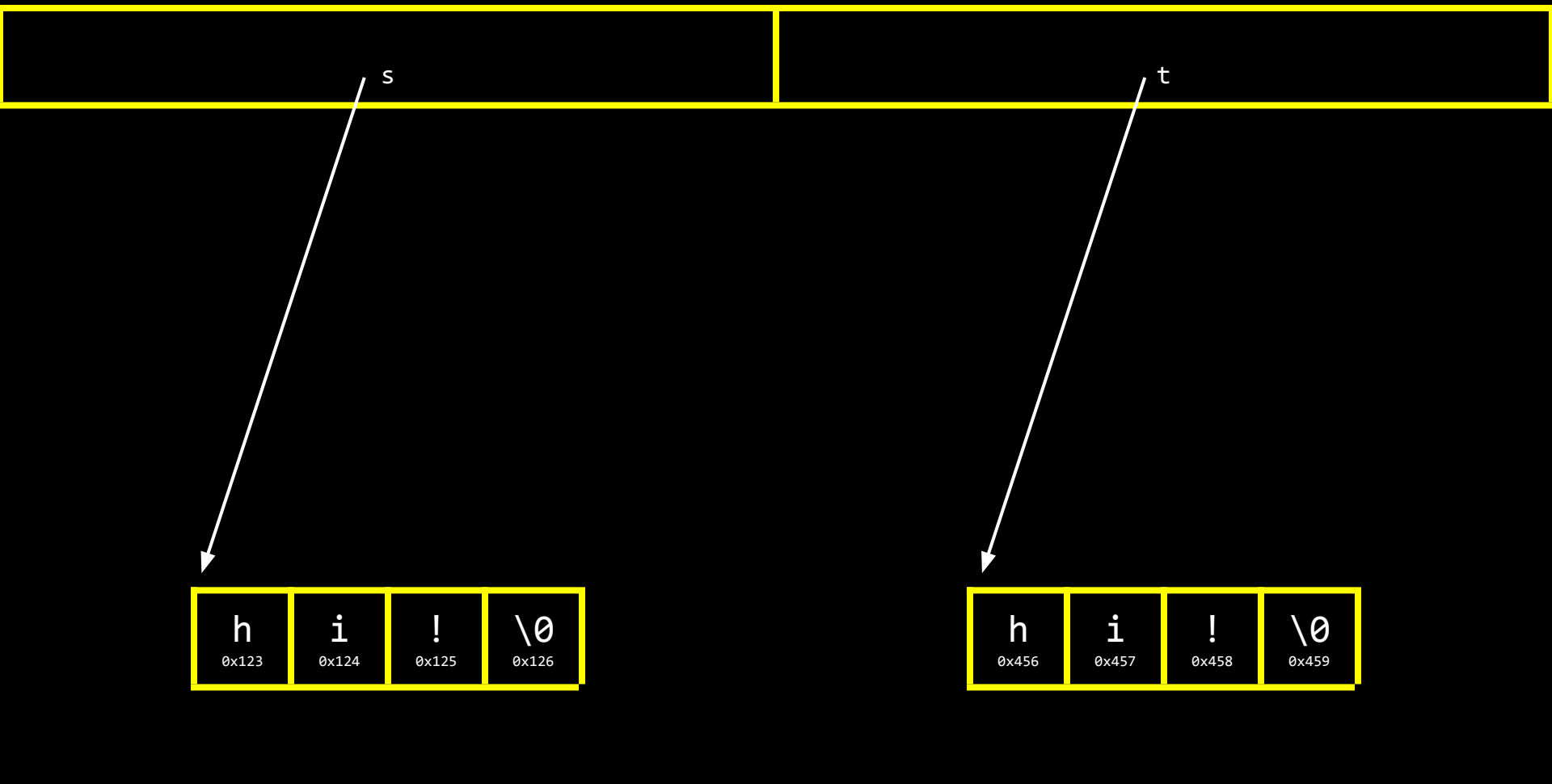
0x125
\0
0x126
h
0x456
i
0x457
!
0x458
0x459


s
t
h
0x123
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0x126
h
0x456
i
0x457
!
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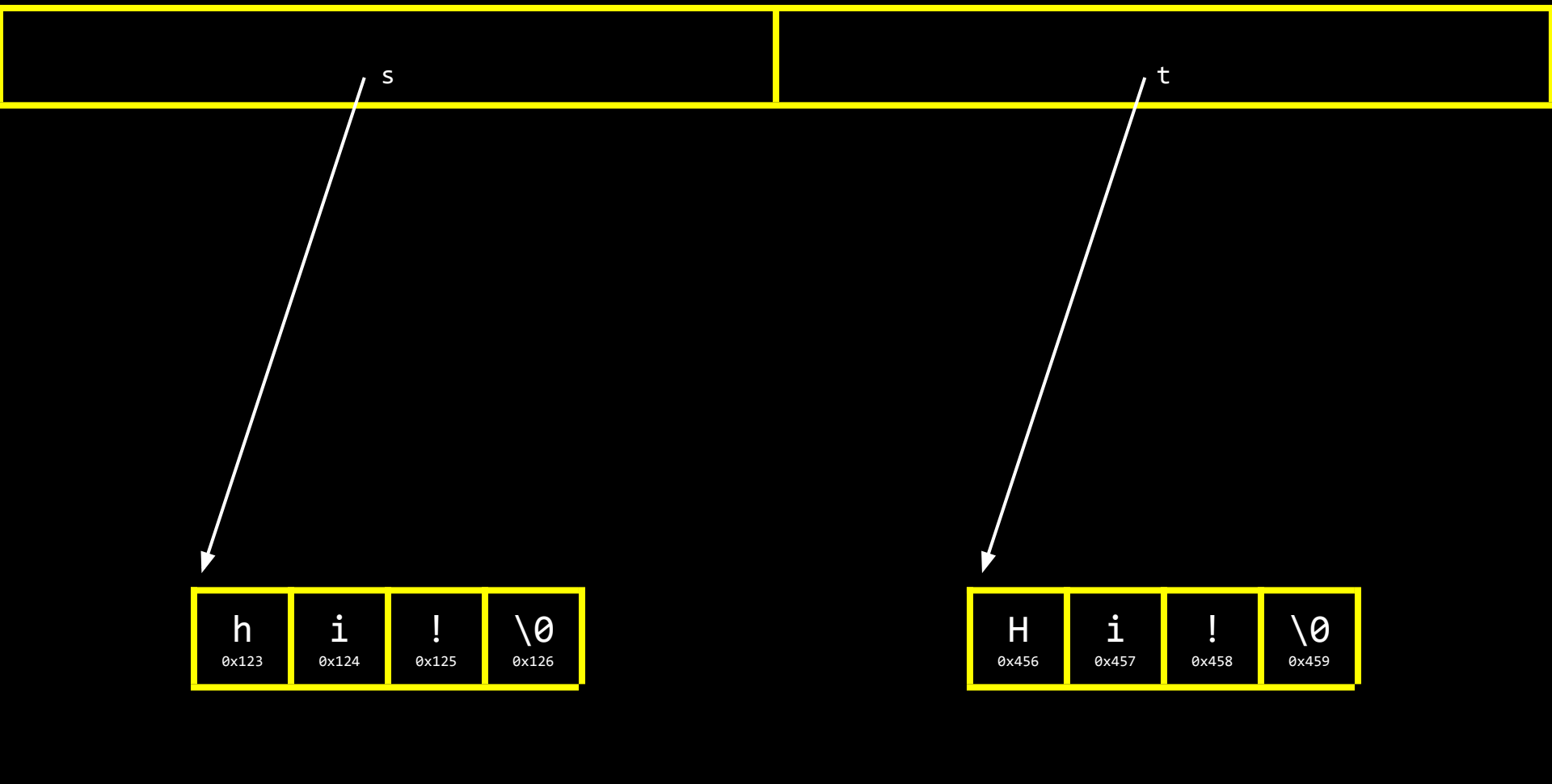
0x459


s
t
h
0x123
i
0x124
!
0x125
\0
0x126
H
0x456
i
0x457
!
0x458
\0
0x459

NULL

valgrind

garbage values

```
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;
    *y = 13;

    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;
    *y = 13;

    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;
    *y = 13;

    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;
    *y = 13;

    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;
    *y = 13;

    y = x;

    *y = 13;
}
```

```
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;


    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;


    y = x;

    *y = 13;
}
```

```c
int main(void)
{
    int *x;
    int *y;

    x = malloc(sizeof(int));

    *x = 42;


    y = x;

    *y = 13;
}
```


```
*y = 13;
```

```
void swap(int a, int b)
{



}
```

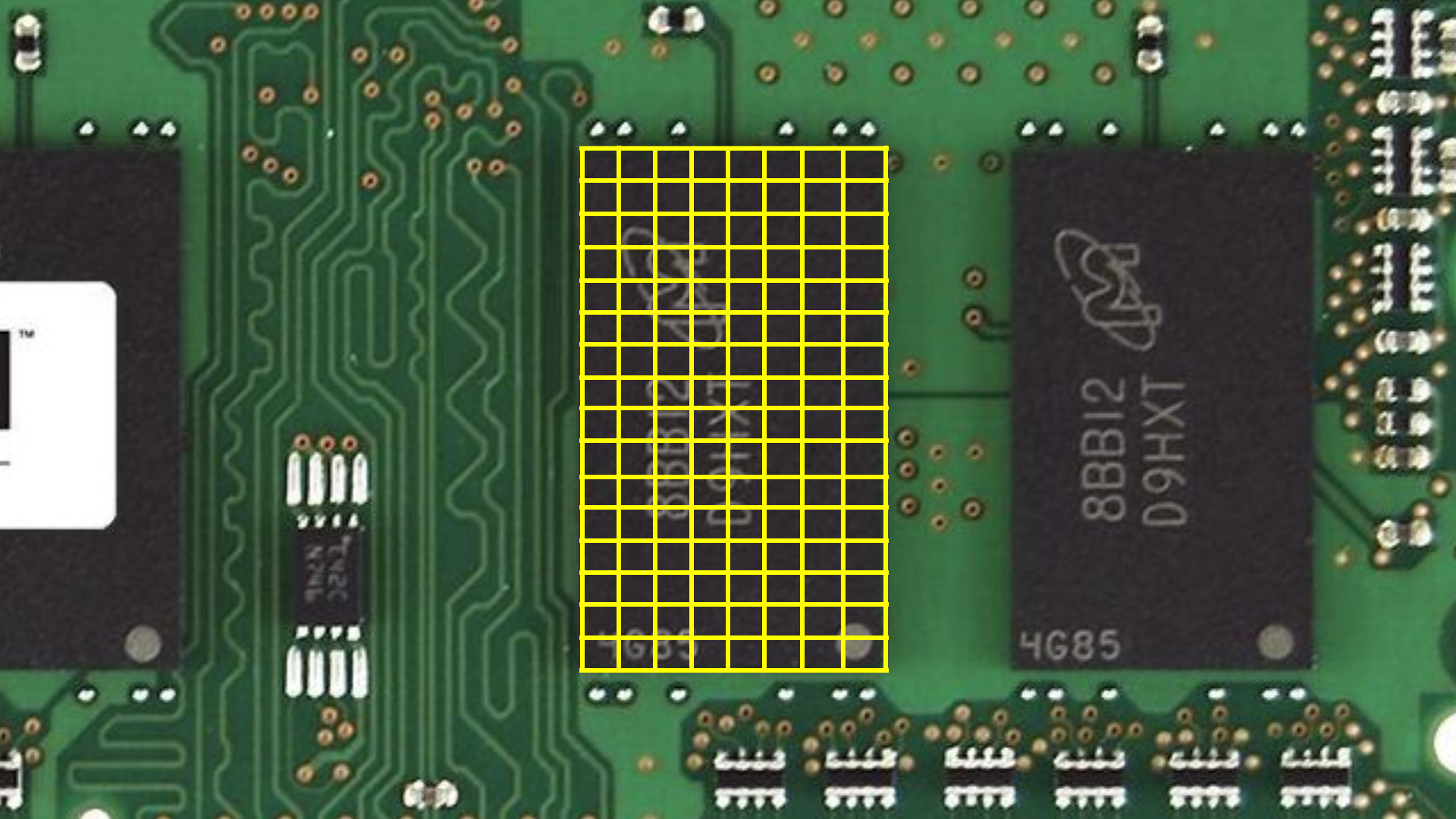
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

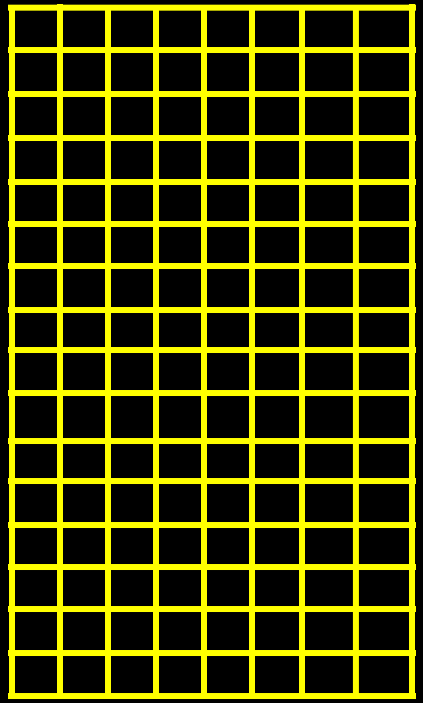
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

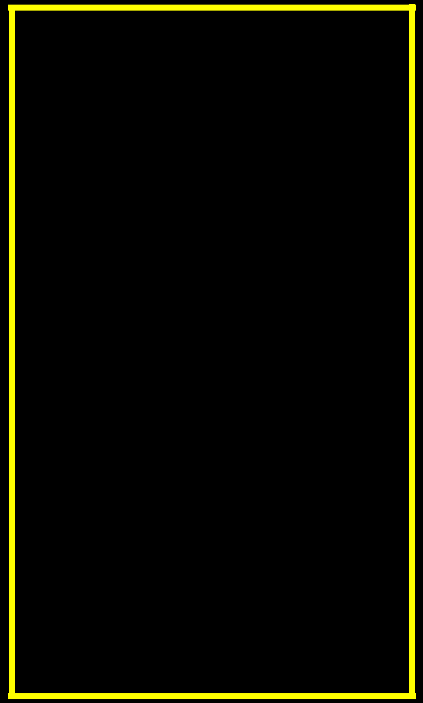
scope

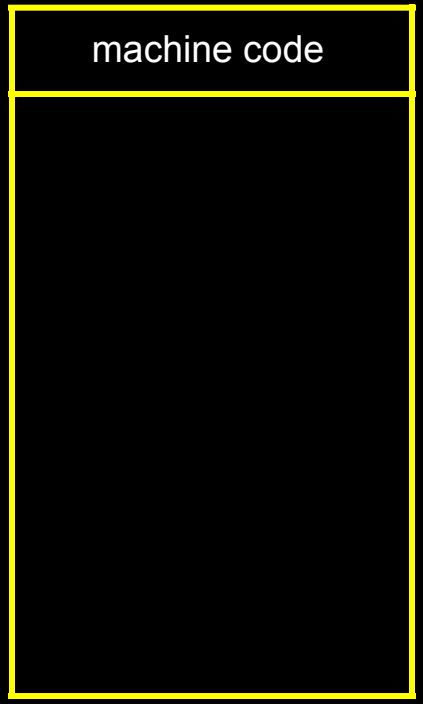

crucial
by Micron
8BBI2
D9HXT
8BBI2
D9HXT
4G85
4G85
4G85
47J6

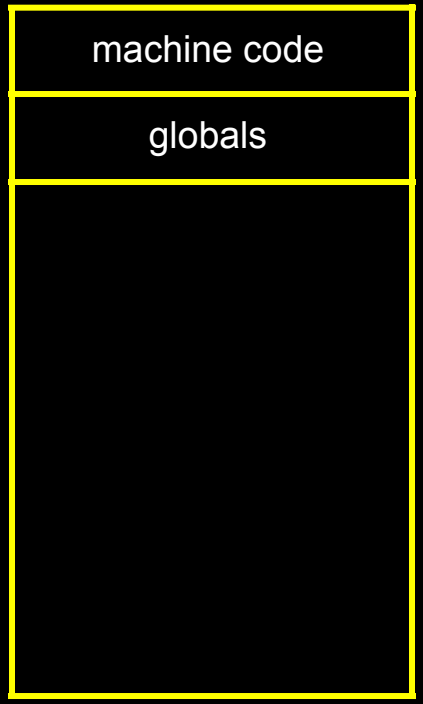

8BBI2
D9HXT
4G85
8BBI2
D9HXT
4G85

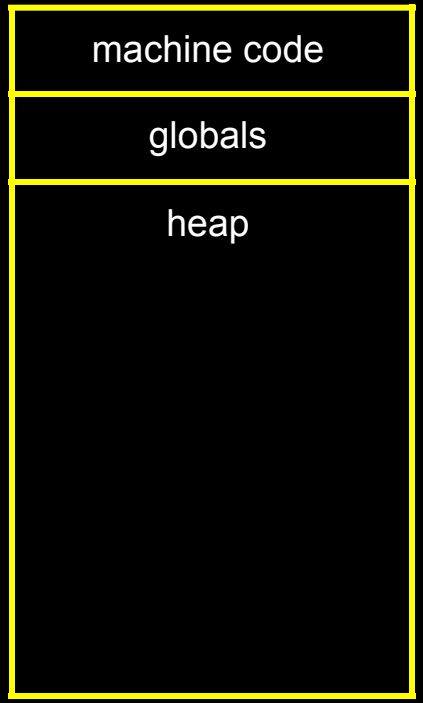

8BBI2
D9HXT
4G85

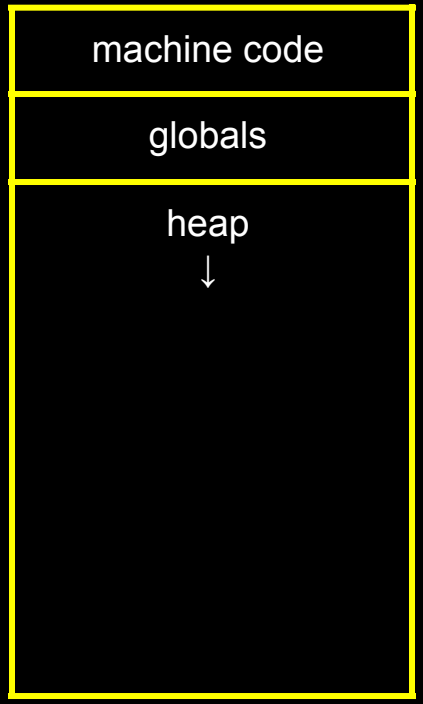


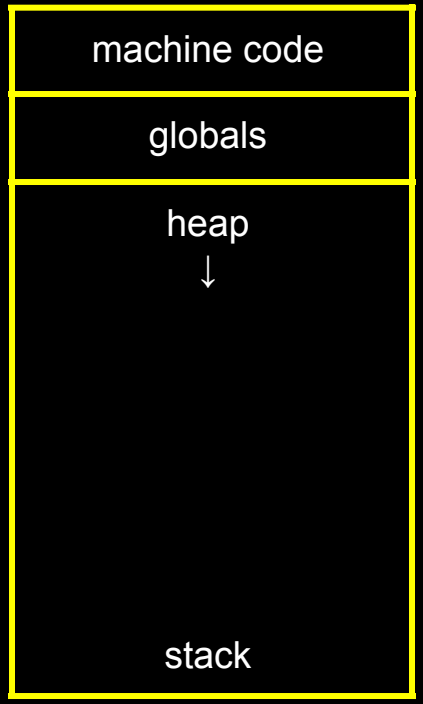


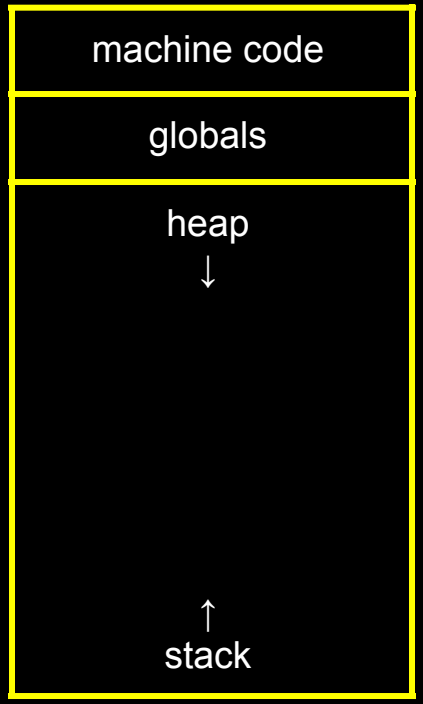

machine code

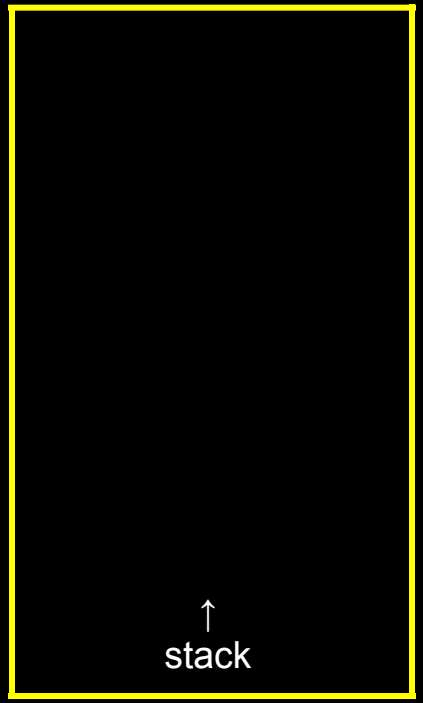

machine code
globals


machine code
globals
heap

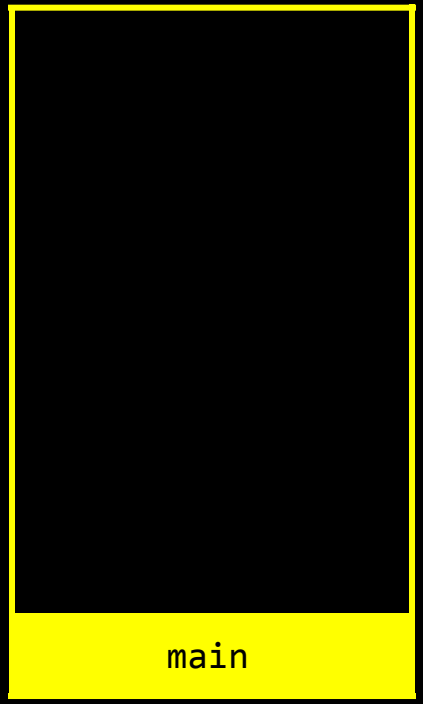

machine code
globals
heap
↓

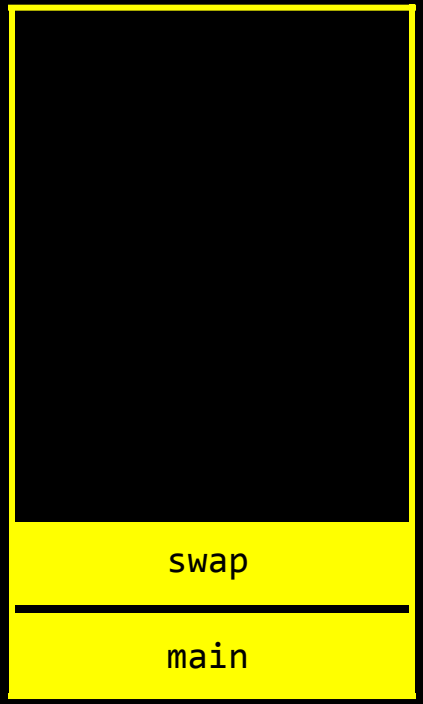

machine code
globals
heap
↓
stack

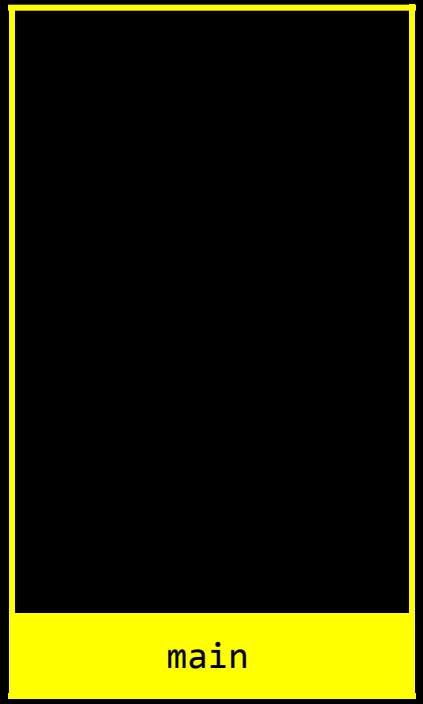

machine code
globals
heap
↓
↑
stack

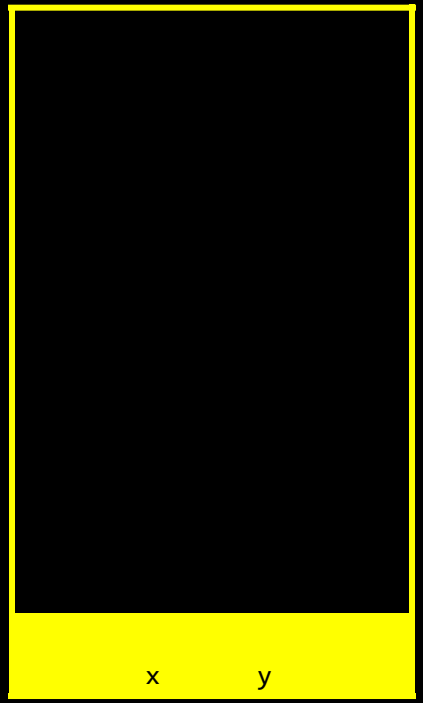

↑
stack

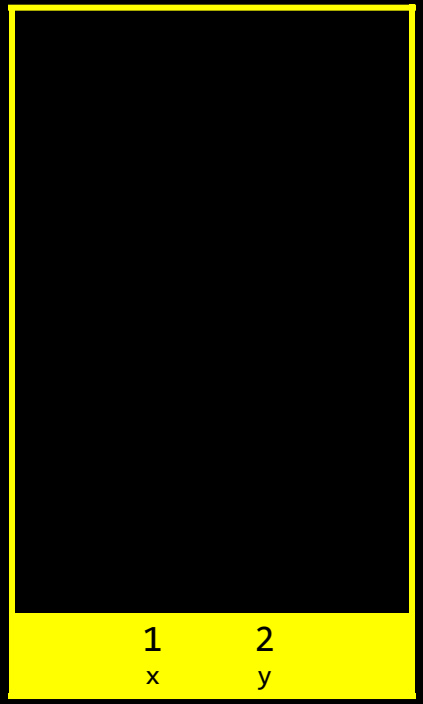
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

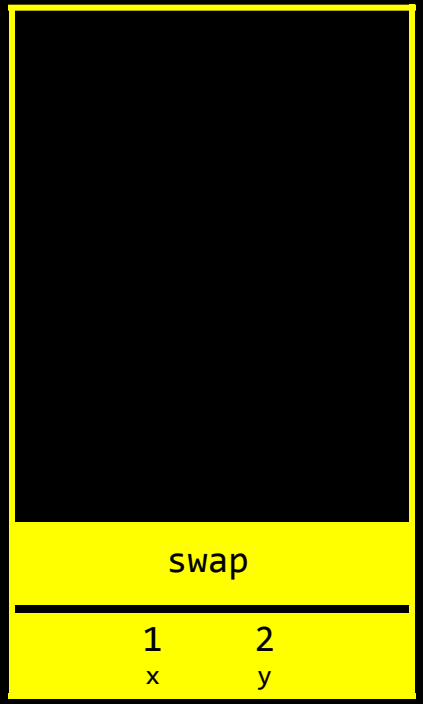

main

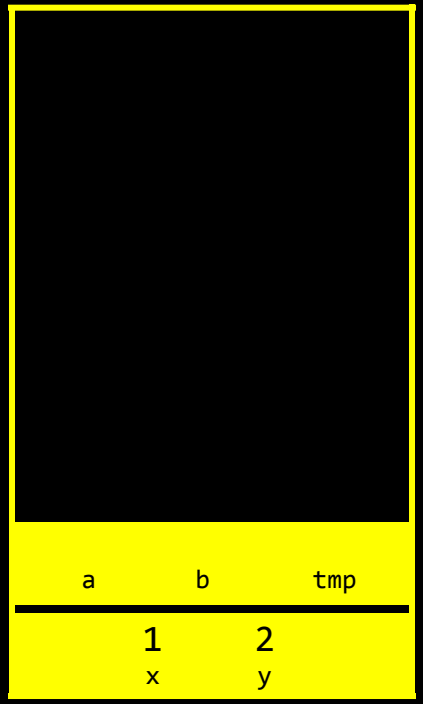

swap
main

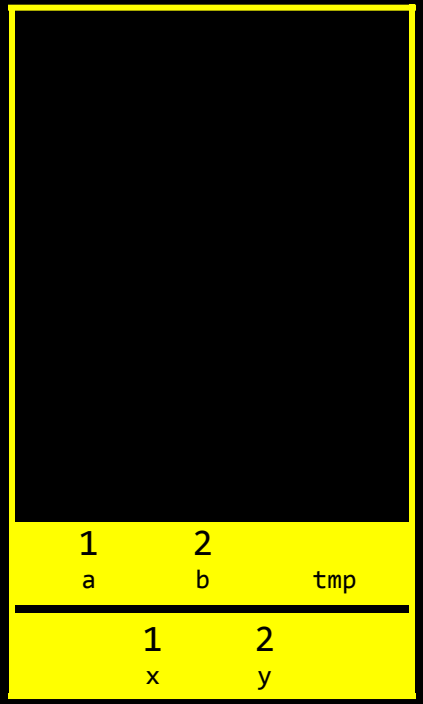

main


x
y

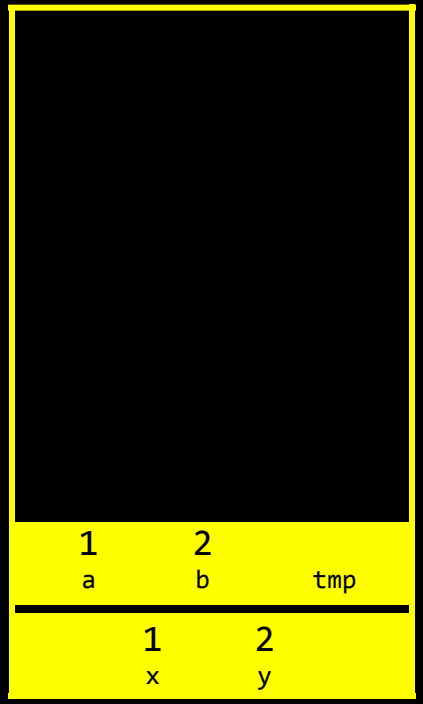

1
x
2
y


swap
1
x
2
y

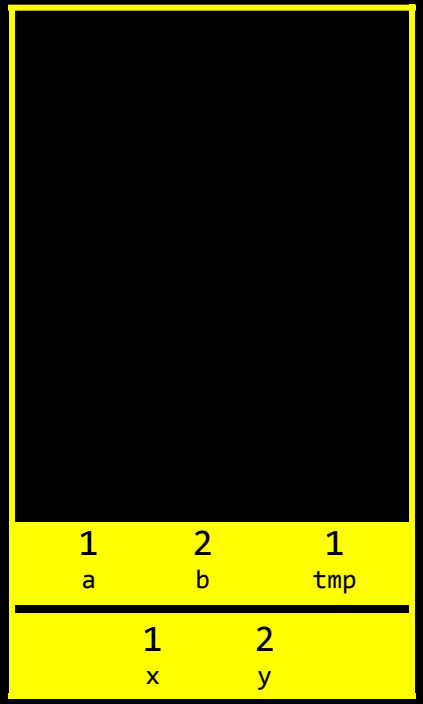

a
b
tmp
1
2
x
y


1
a
2
b
tmp
1
x
2
y

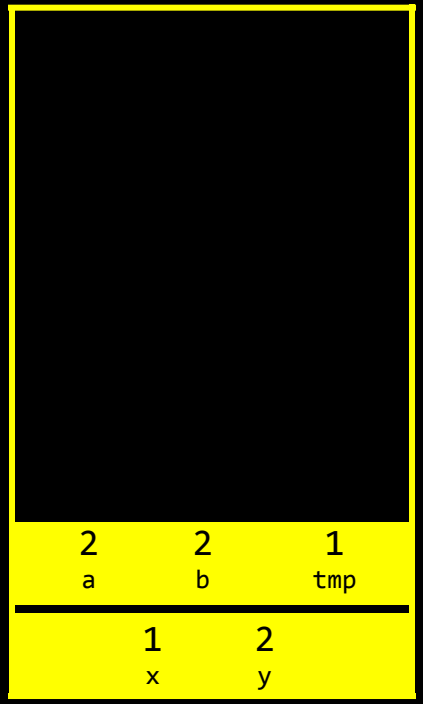
```
int tmp = a;
a = b;
b = tmp;
```



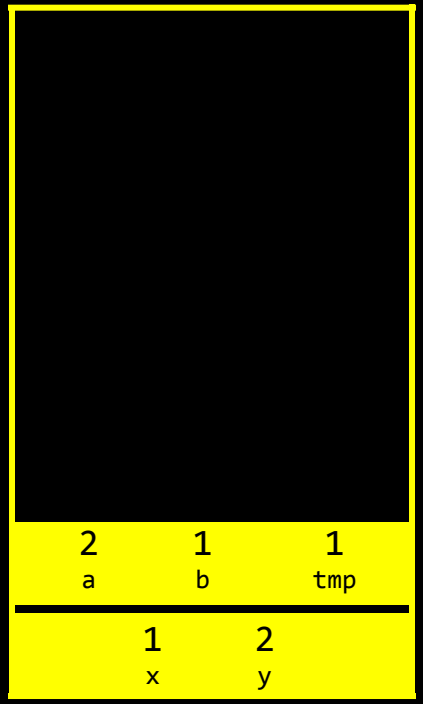
```
int tmp = a;
a = b;
b = tmp;
```

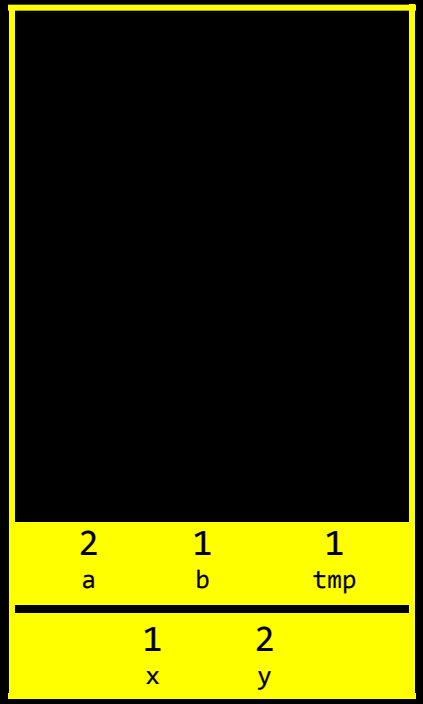


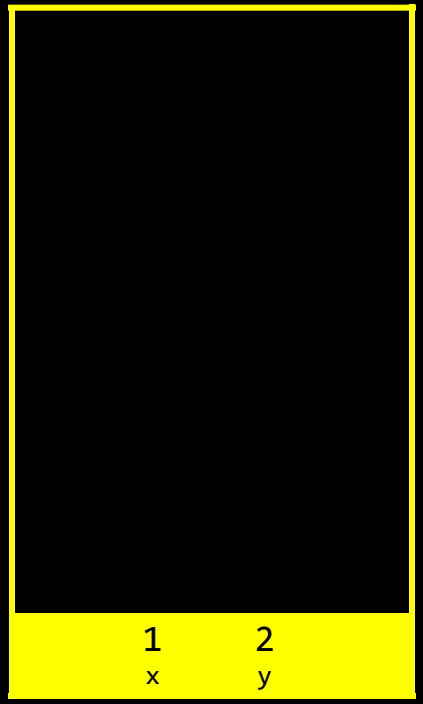
```
int tmp = a;
a = b;
b = tmp;
```



```
int tmp = a;
a = b;
b = tmp;
```

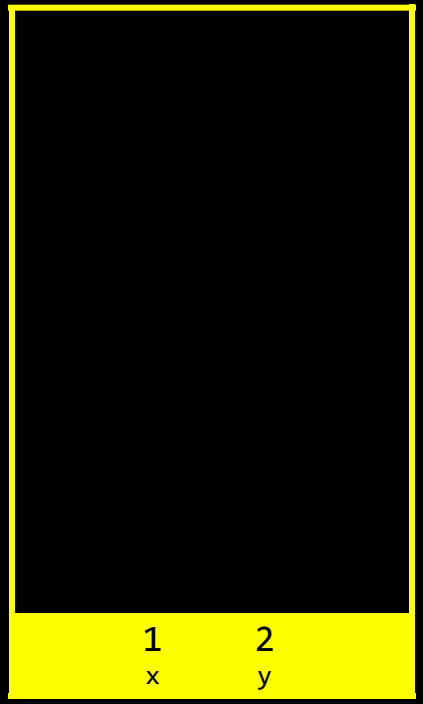


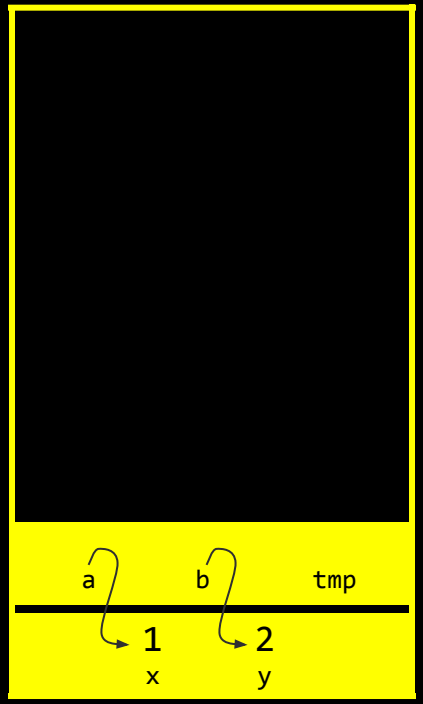

2
a
1
b
1
tmp
1
x
2
y


1
x
2
y

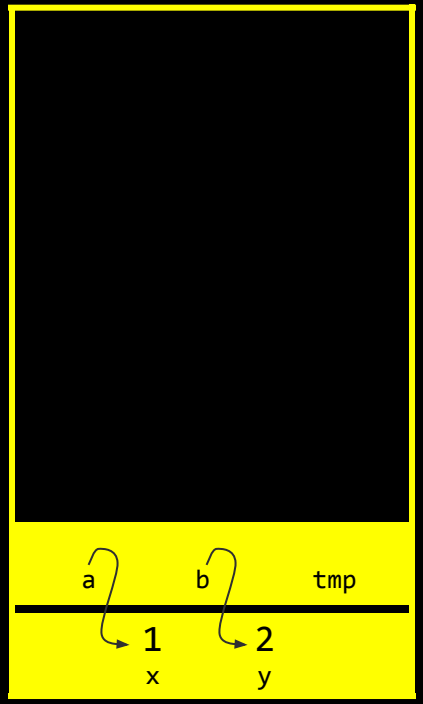
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```

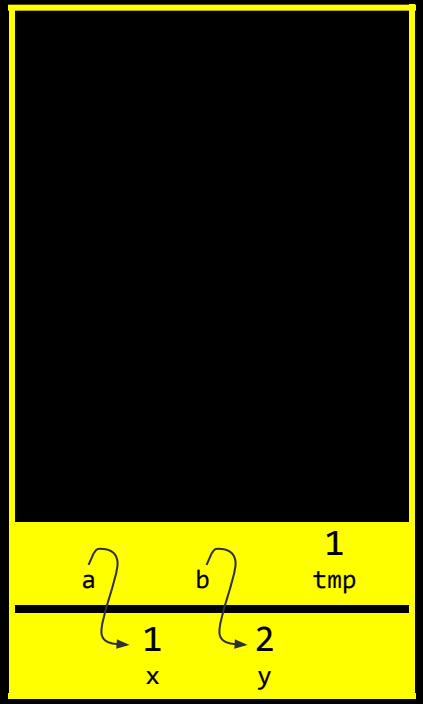

1
x
2
y


a
b
tmp
1
2
x
y

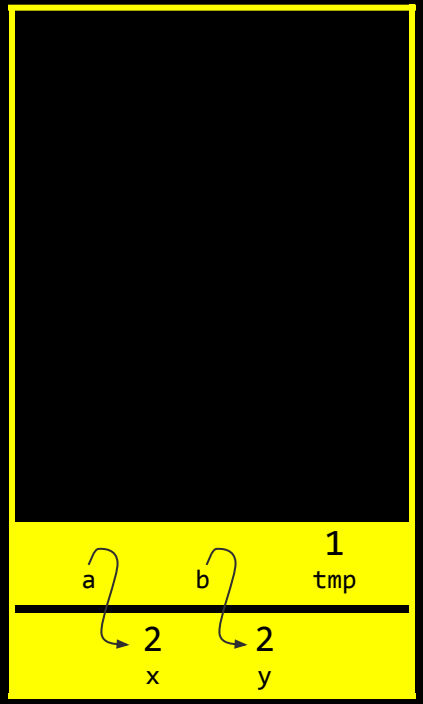
```
int tmp = *a;
*a = *b;
*b = tmp;
```



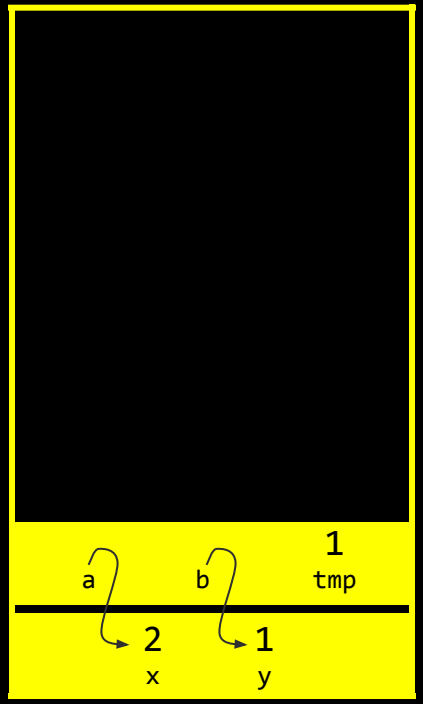
```
int tmp = *a;
*a = *b;
*b = tmp;
```

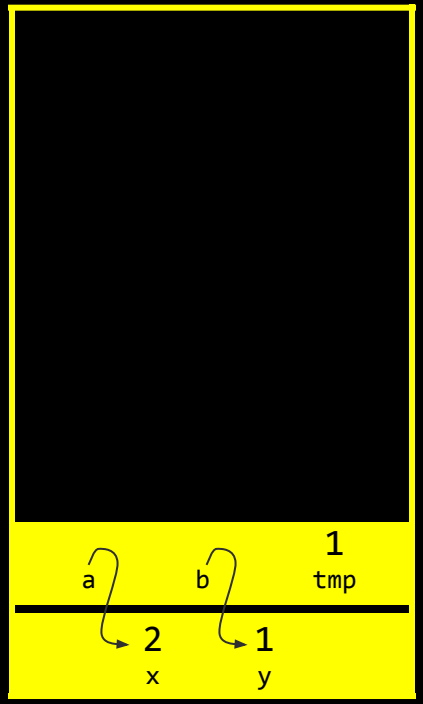


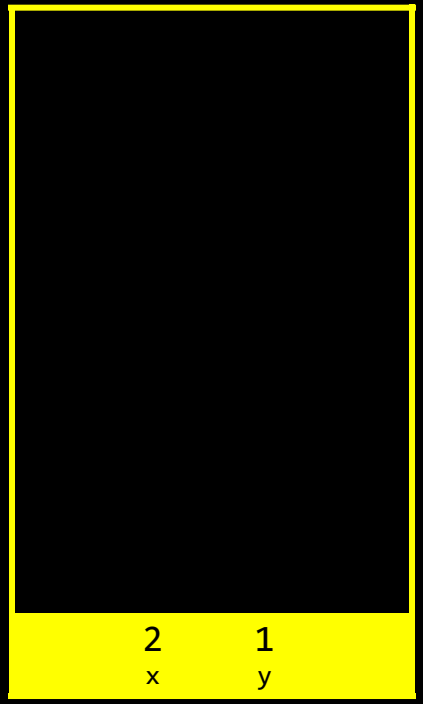
```
int tmp = *a;
*a = *b;
*b = tmp;
```



```
int tmp = *a;
*a = *b;
*b = tmp;
```

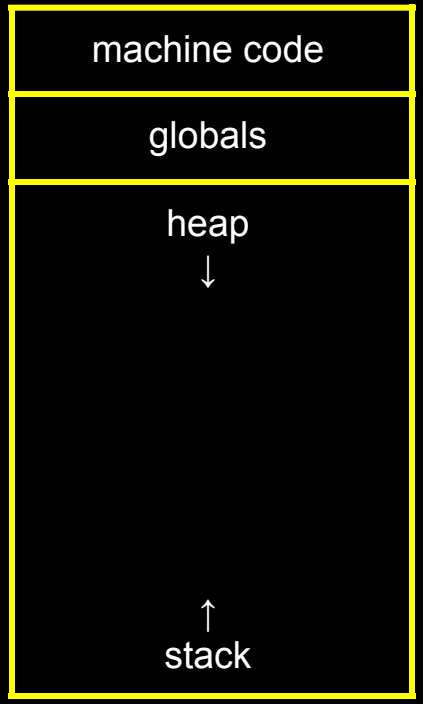


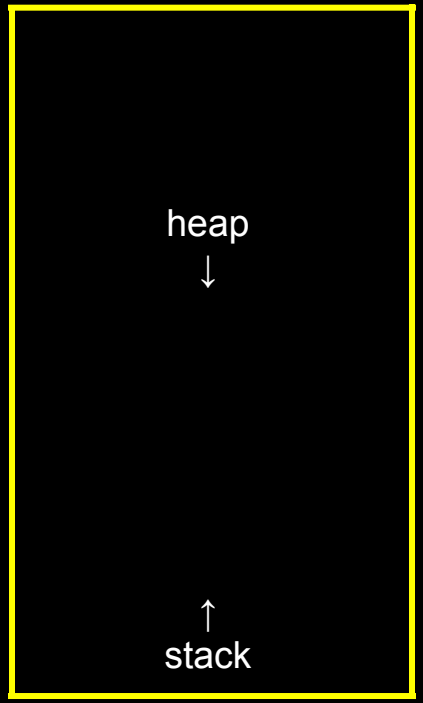

a
b
1
tmp
2
x
1
y


2
x
1
y

```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```


machine code
globals
heap
↓
↑
stack


heap
↓
↑
stack

heap overflow

stack overflow

buffer overflow

```
get_char

get_double

get_float

get_int

get_long

get_string

...
```

scanf

...

file I/O

BMP

This is CS50