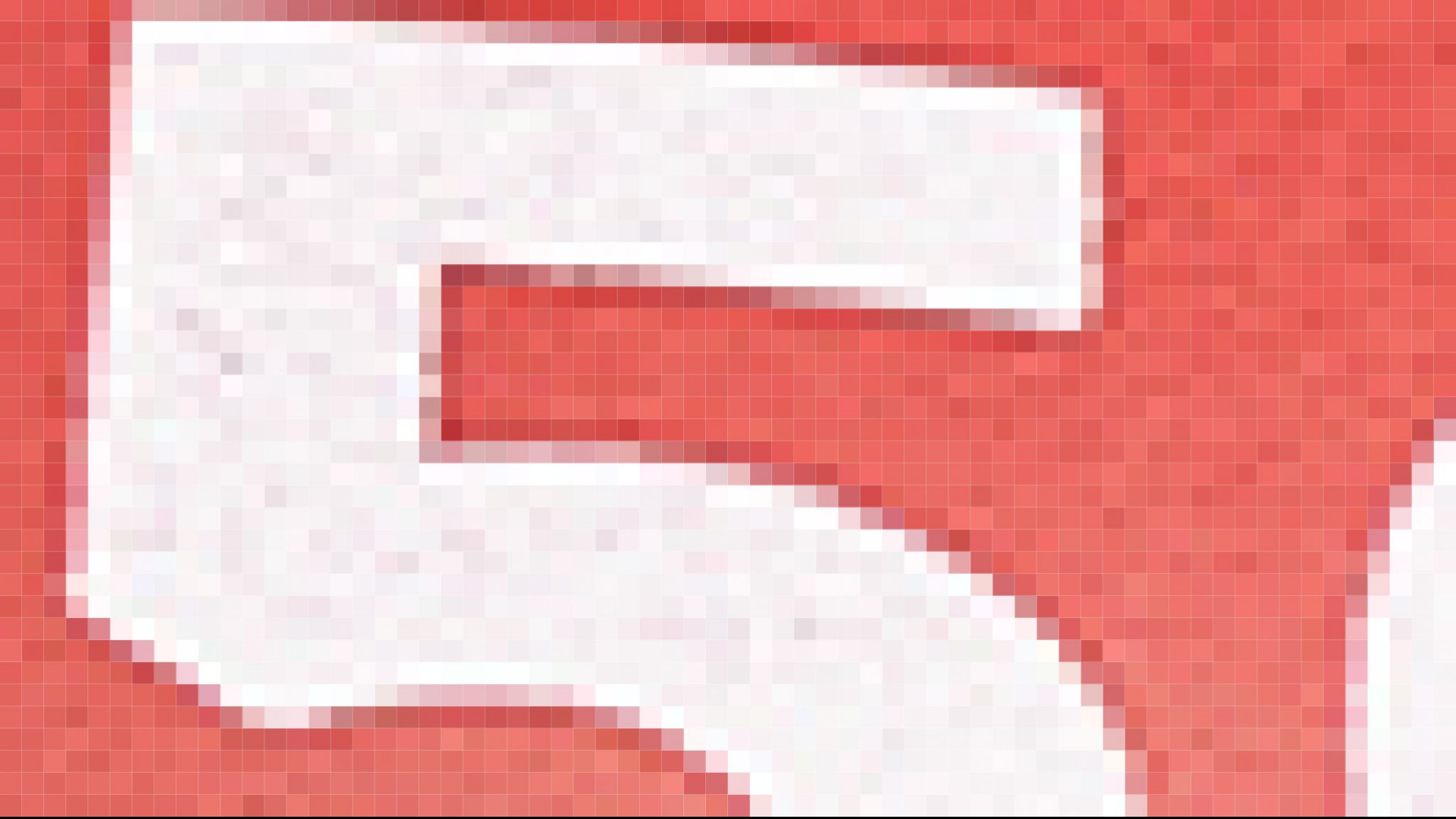
This is CS50

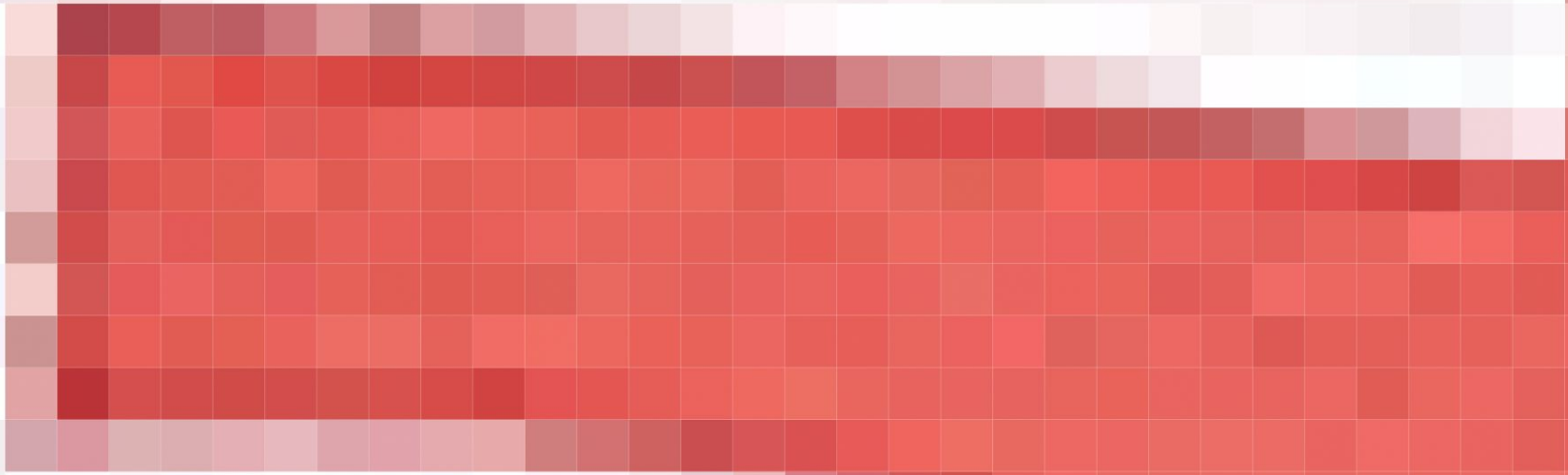

CS50
STRESS BALL
CS50
STRESS BALL


CS50
STRESS BALL

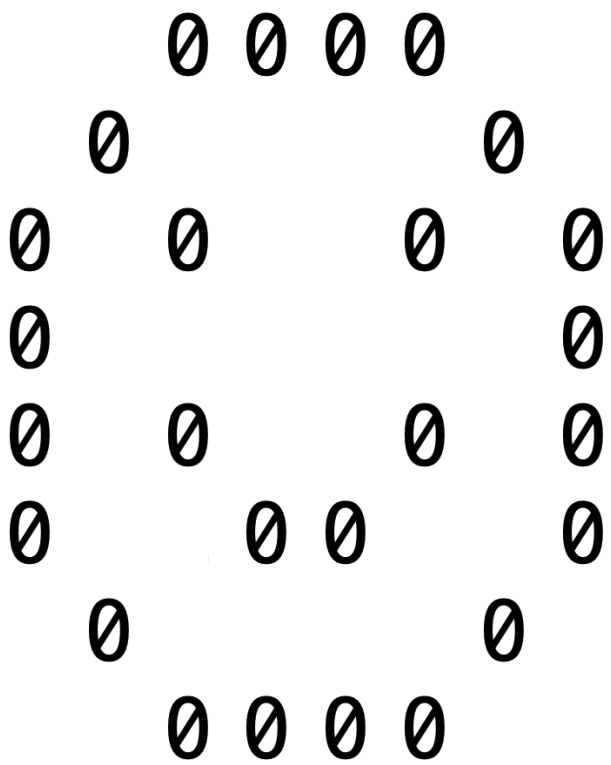

CS50
STRESS BALL


50

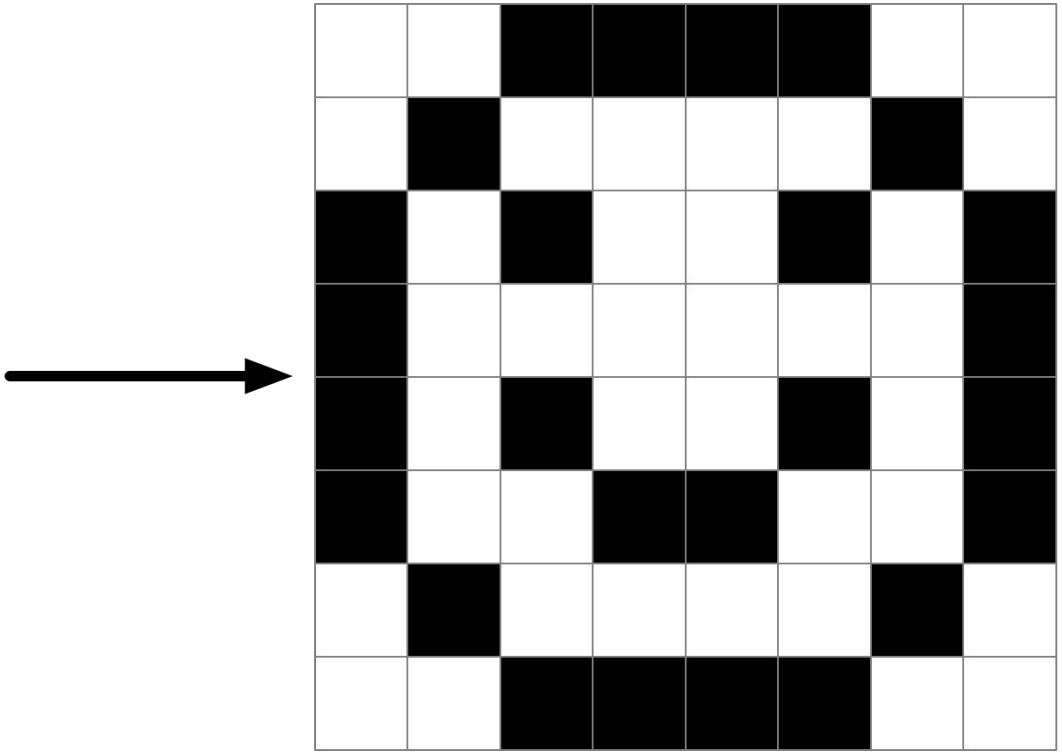




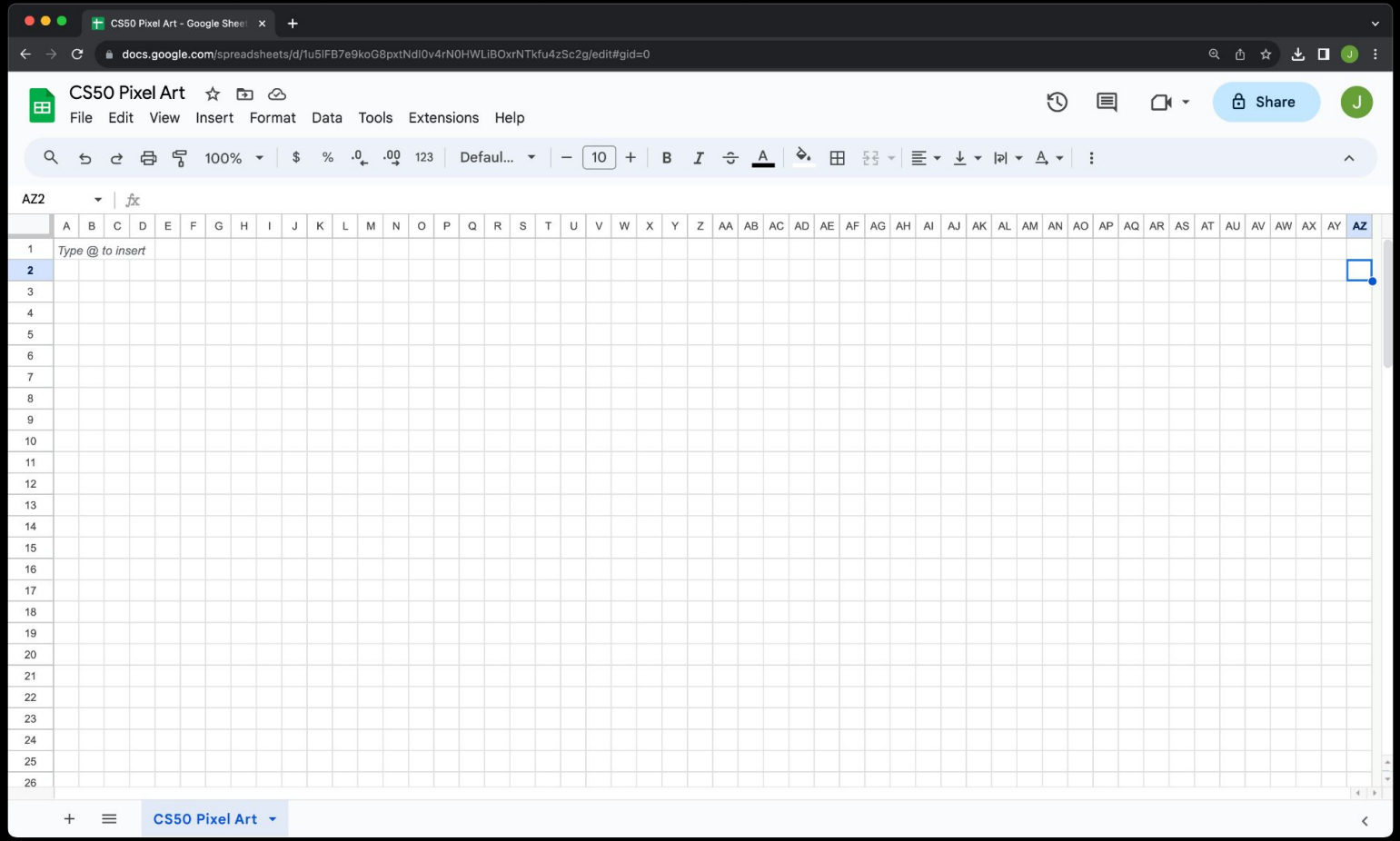
```
1 1 0 0 0 0 1 1
1 0 1 1 1 1 0 1
0 1 0 1 1 0 1 0
0 1 1 1 1 1 1 0
0 1 0 1 1 0 1 0
0 1 1 0 0 1 1 0
1 0 1 1 1 1 0 1
1 1 0 0 0 0 1 1
```

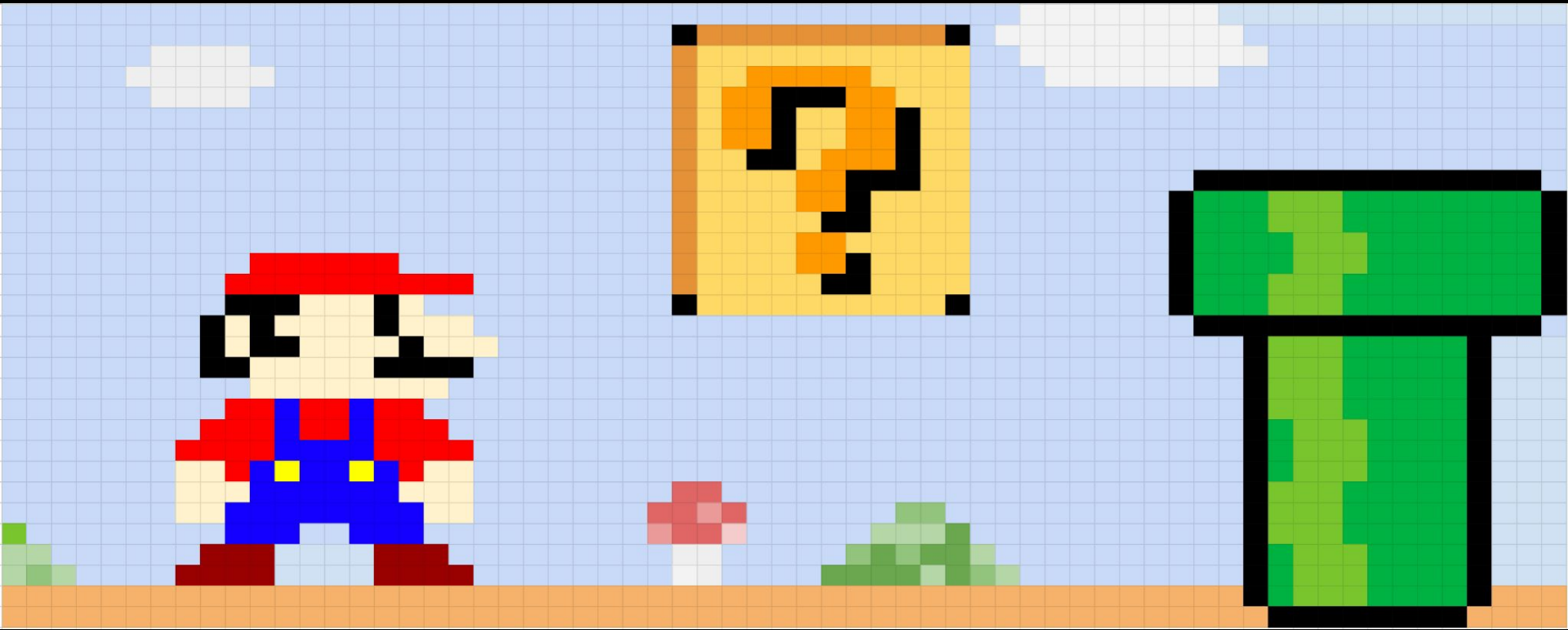


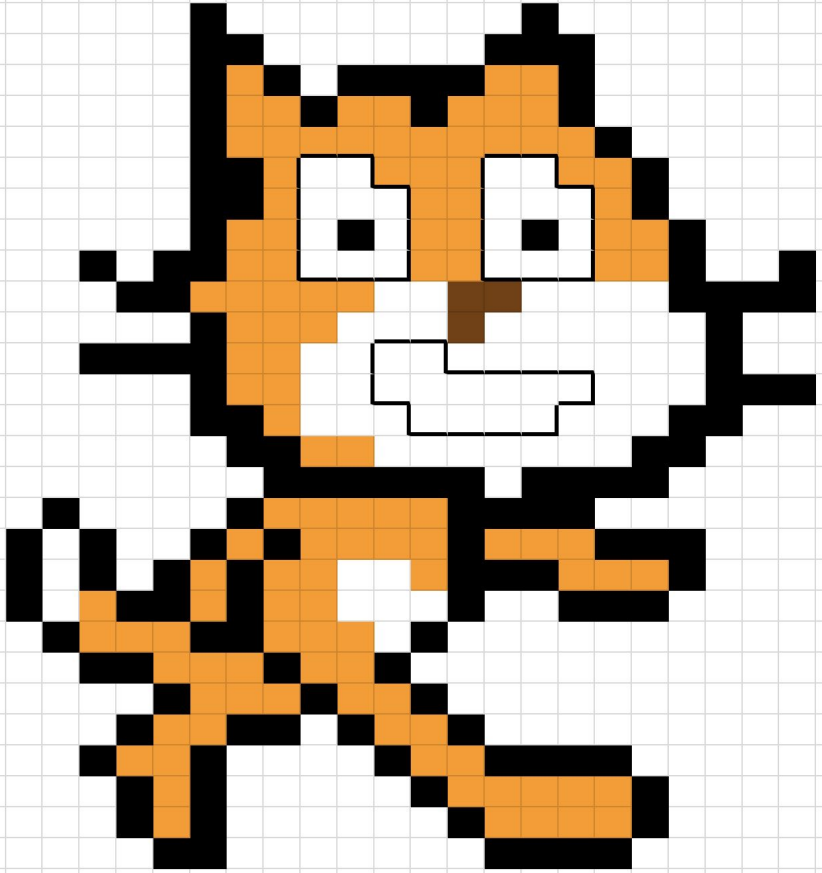
```
1 1 0 0 0 0 1 1
1 0 1 1 1 1 0 1
0 1 0 1 1 0 1 0
0 1 1 1 1 1 1 0
0 1 0 1 1 0 1 0
0 1 1 0 0 1 1 0
1 0 1 1 1 1 0 1
1 1 0 0 0 0 1 1
```



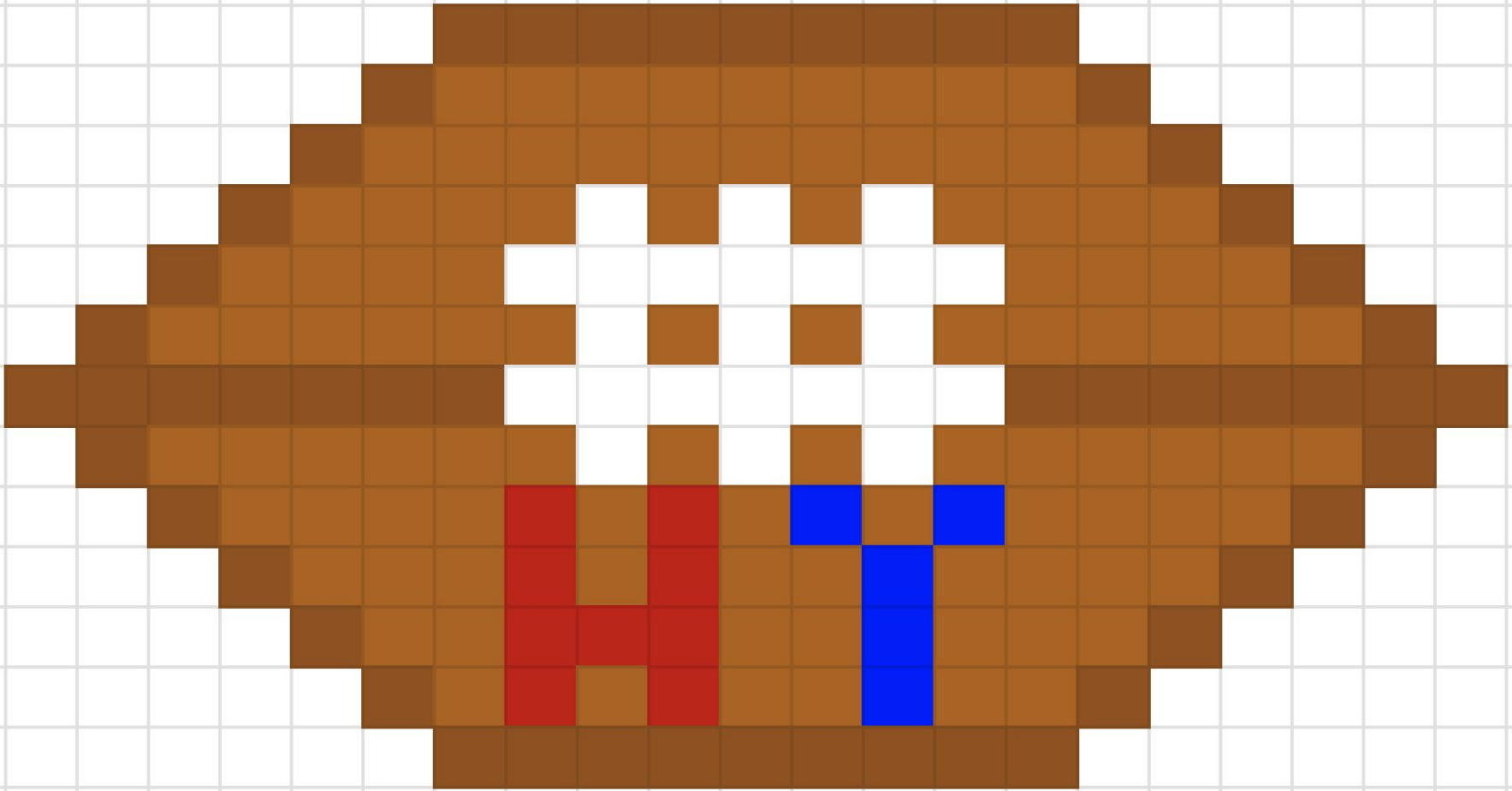
pixel art

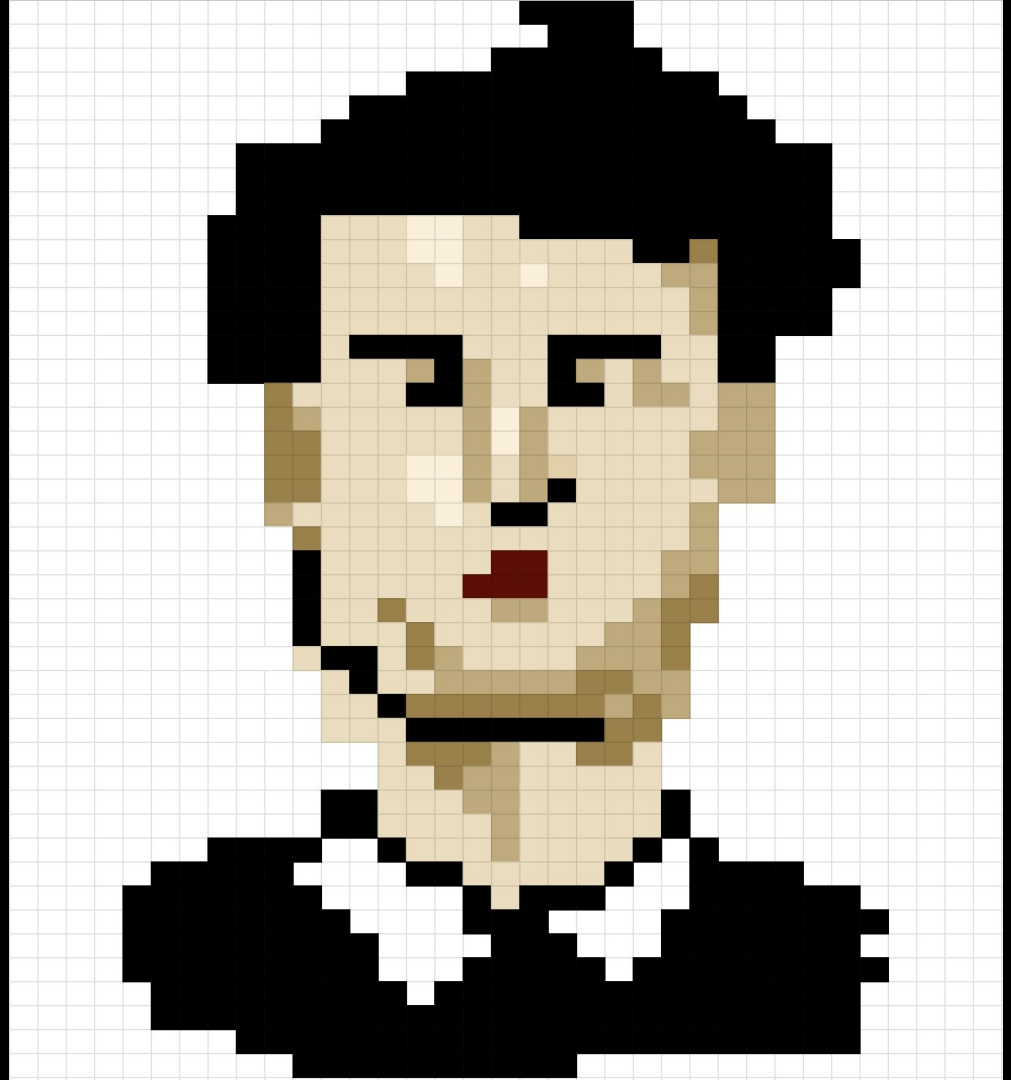

CS50 Pixel Art - Google Sheet
docs.google.com/spreadsheets/d/1u5IFB7e9koG8pxtNdl0v4rN0HWLiBOxrNTkfu4zSc2g/edit#gid=0
CS50 Pixel Art
File Edit View Insert Format Data Tools Extensions Help
Share
AZ2
Type @ to insert
CS50 Pixel Art





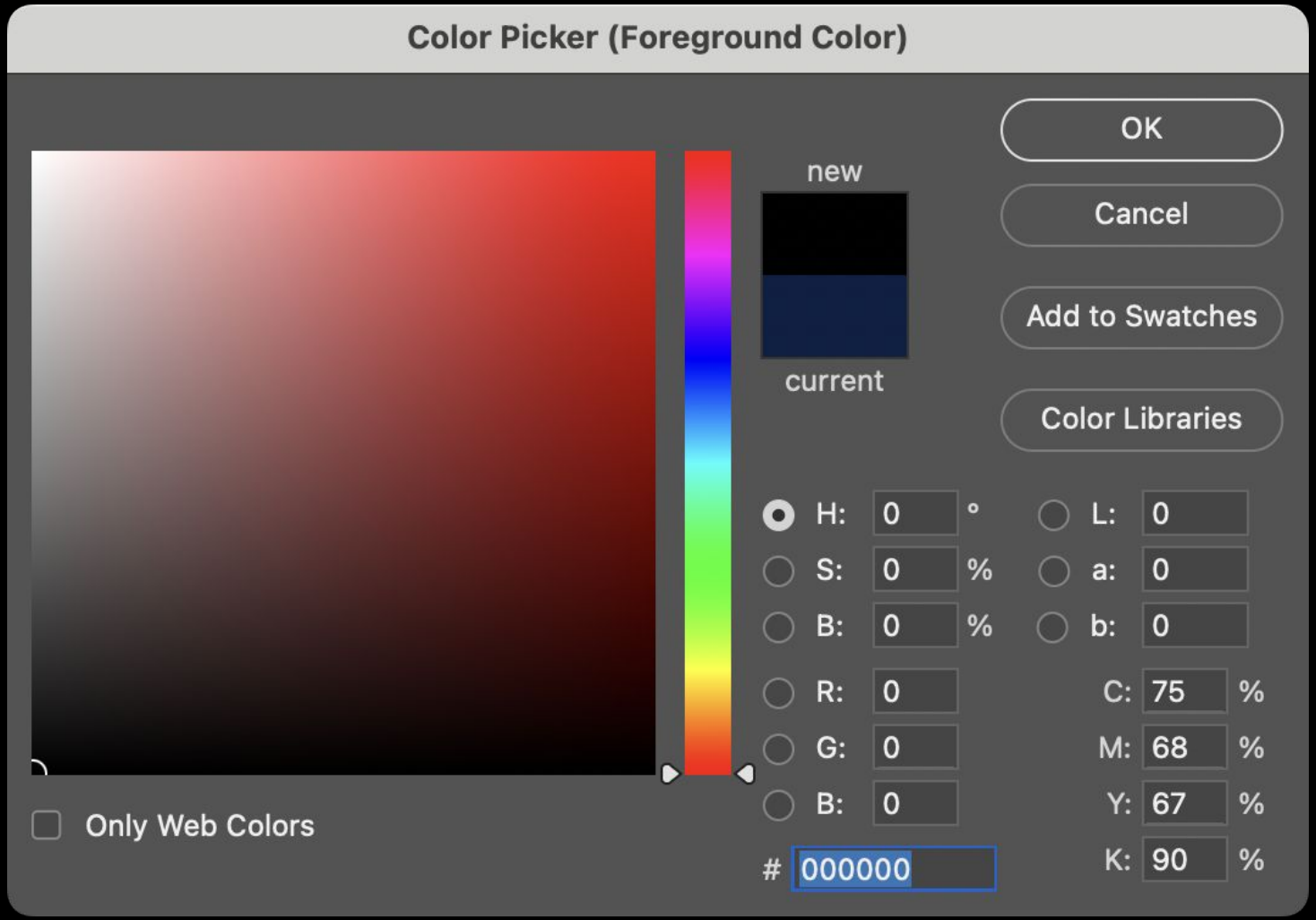
SCRATCH CAT

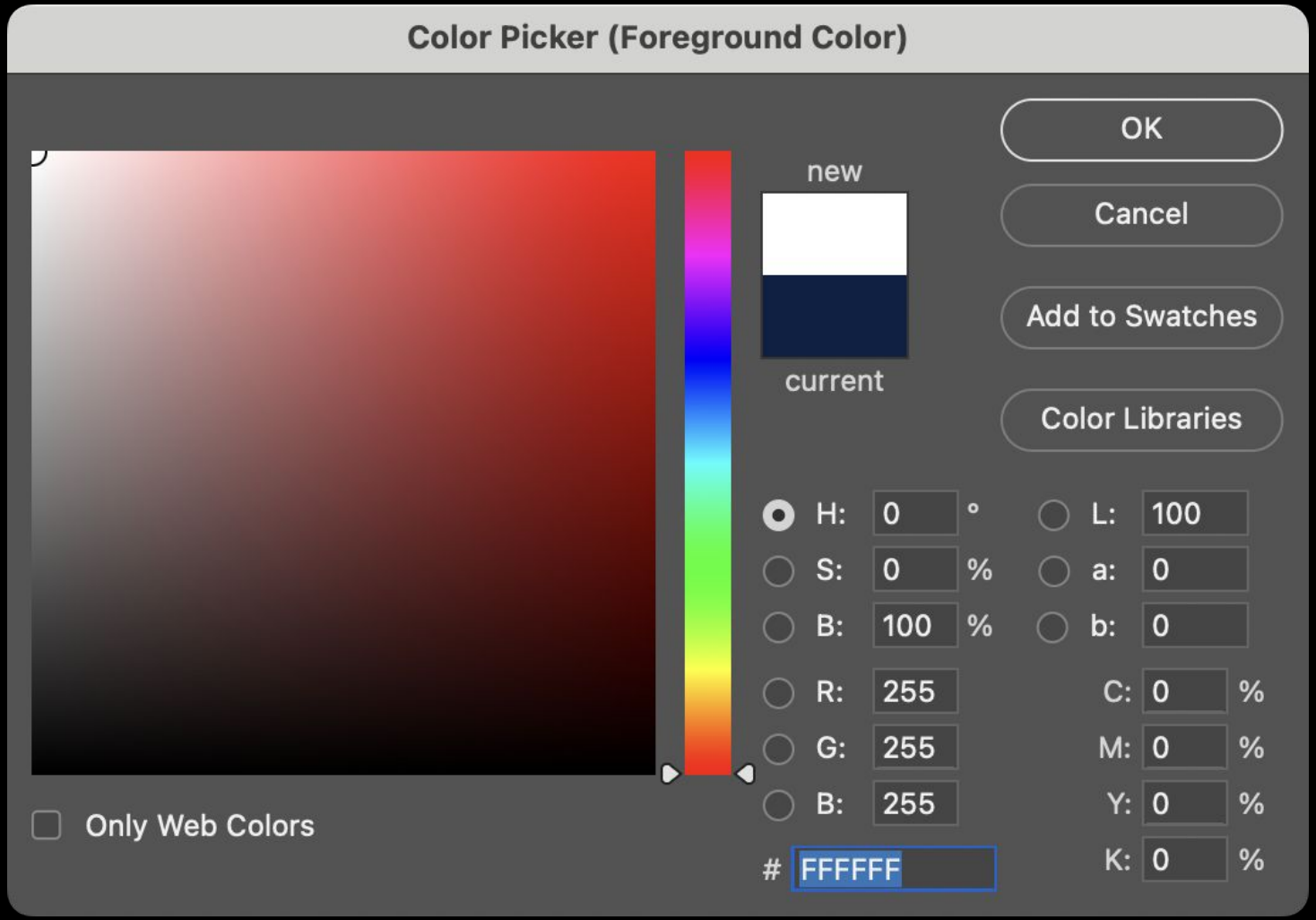




cs50.ly/art

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 °
S: 0 %
B: 100 %
R: 255
G: 255
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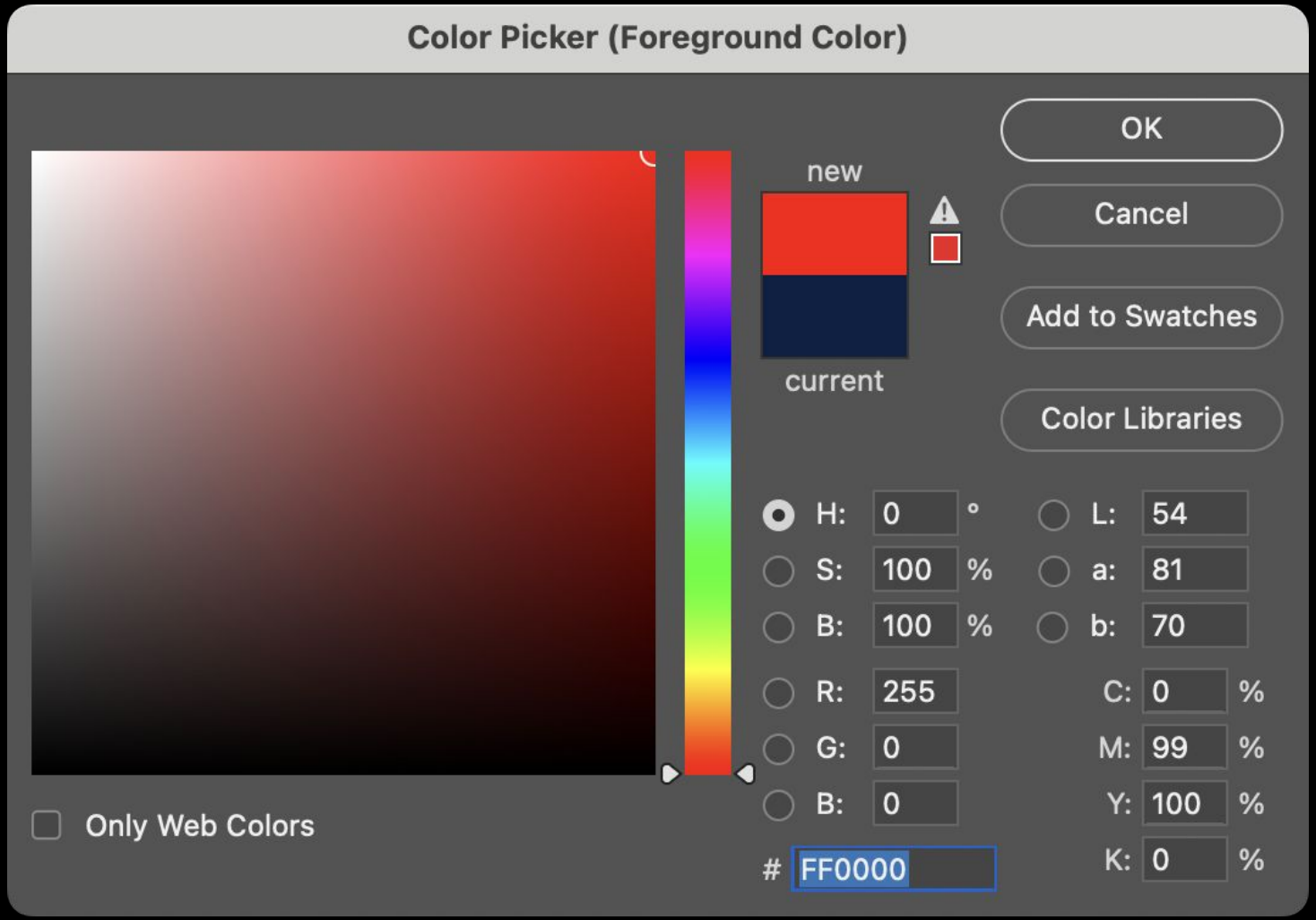
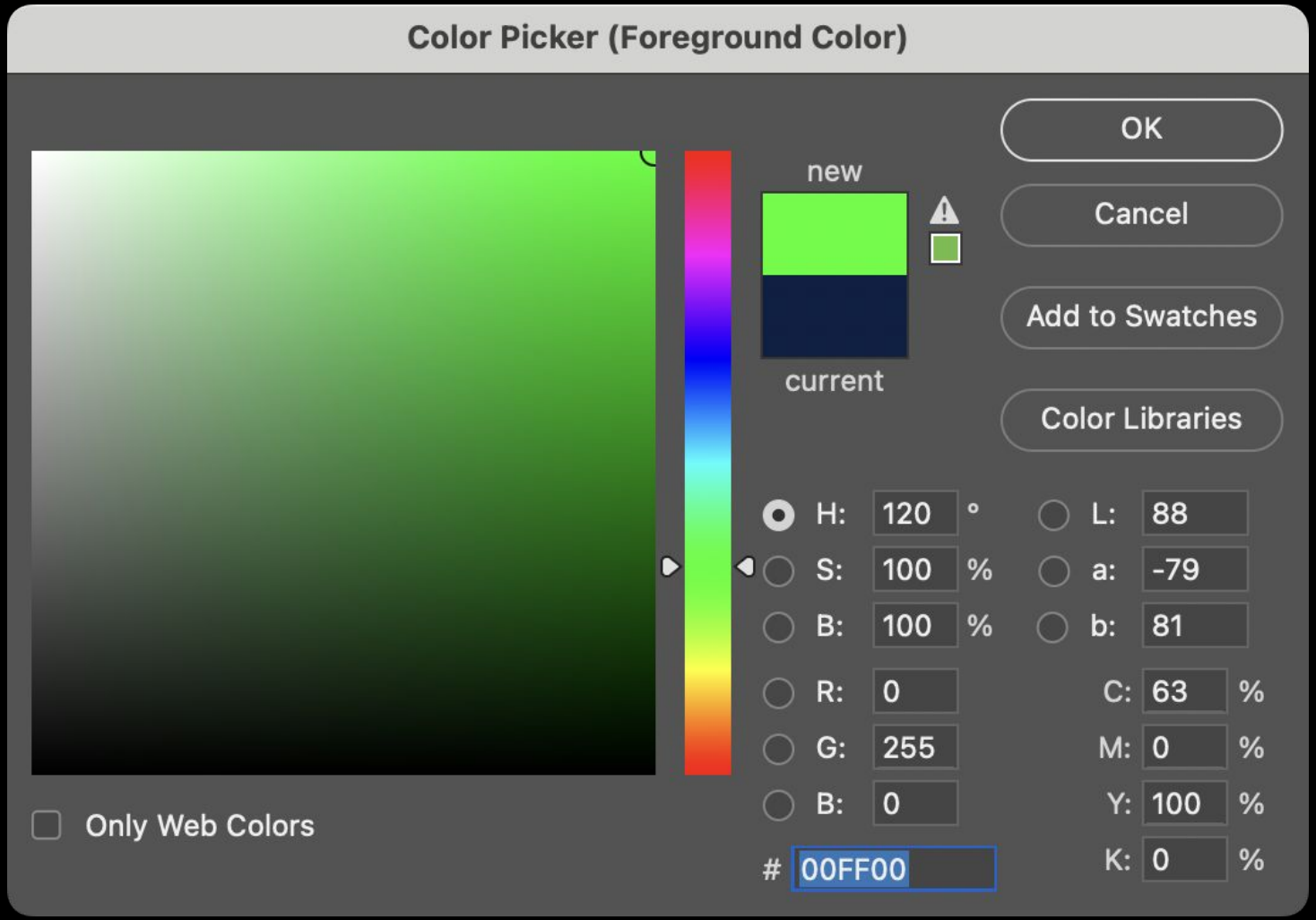
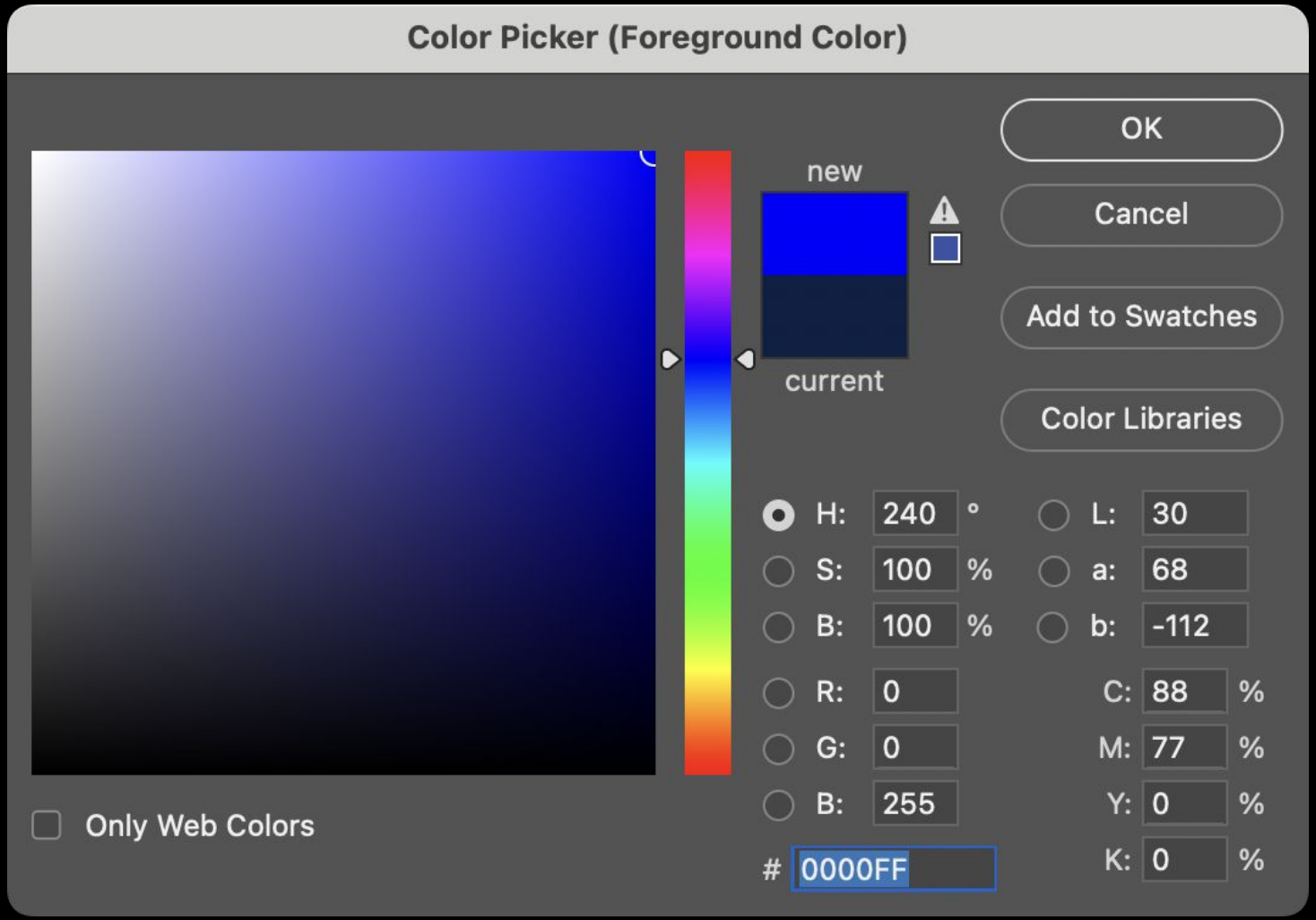
L: 100
a: 0
b: 0
C: 0 %
M: 0 %
Y: 0 %
K: 0 %
FFFFFF
Only Web Colors


Color Picker (Foreground Color)
OK
Cancel
Add to Swatches
Color Libraries
new
current
H: 0 °
S: 100 %
B: 100 %
R: 255
G: 0
B: 0
L: 54
a: 81
b: 70
C: 0 %
M: 99 %
Y: 100 %
K: 0 %
FF0000
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
L: 88
a: -79
b: 81
C: 63 %
M: 0 %
Y: 100 %
K: 0 %
00FF00
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

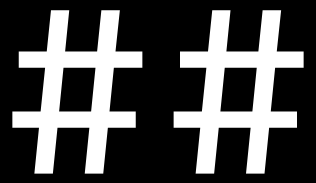
hexadecimal

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

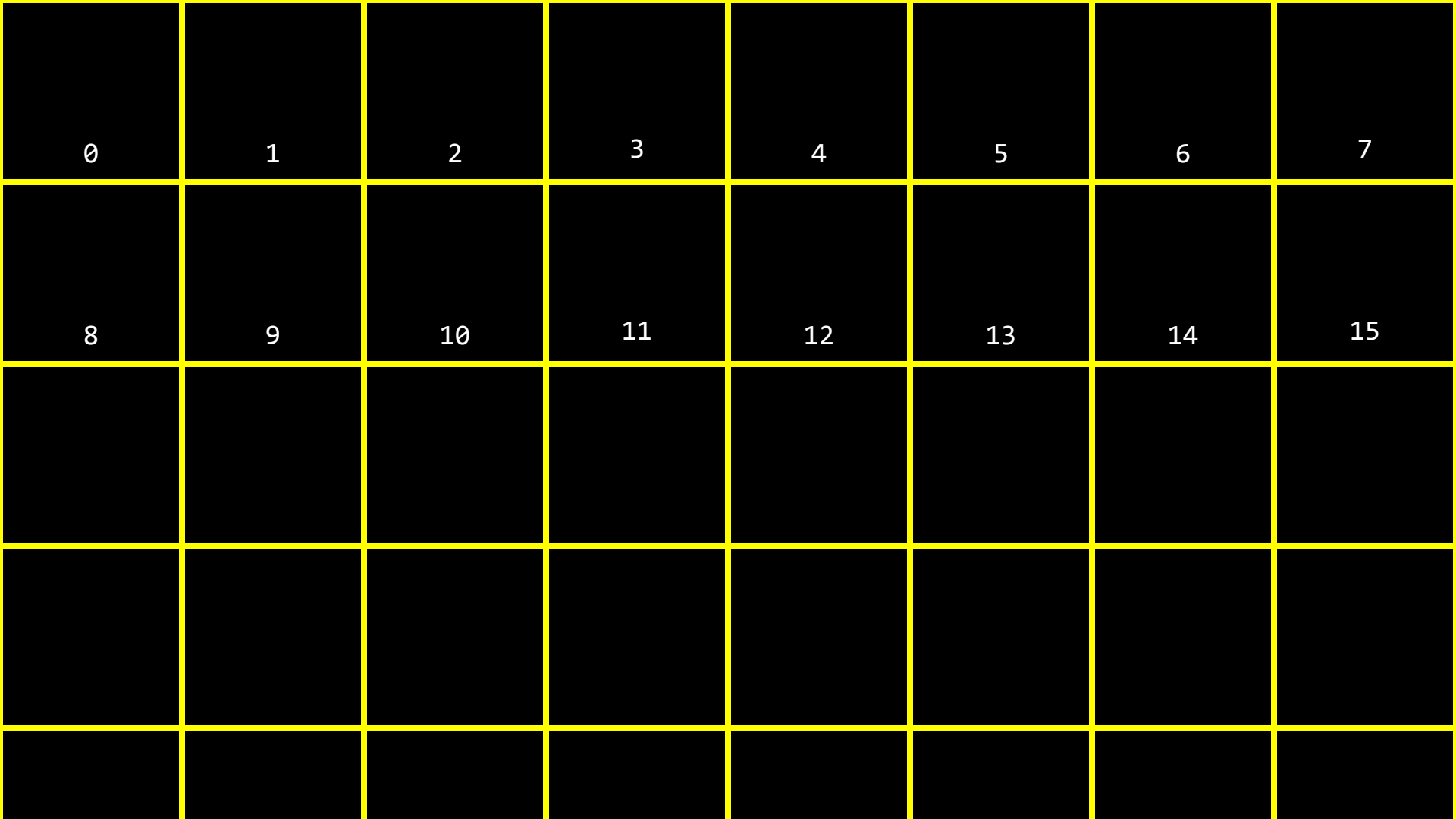
16 1

255

FF

F F

1111 1111


0
1
2
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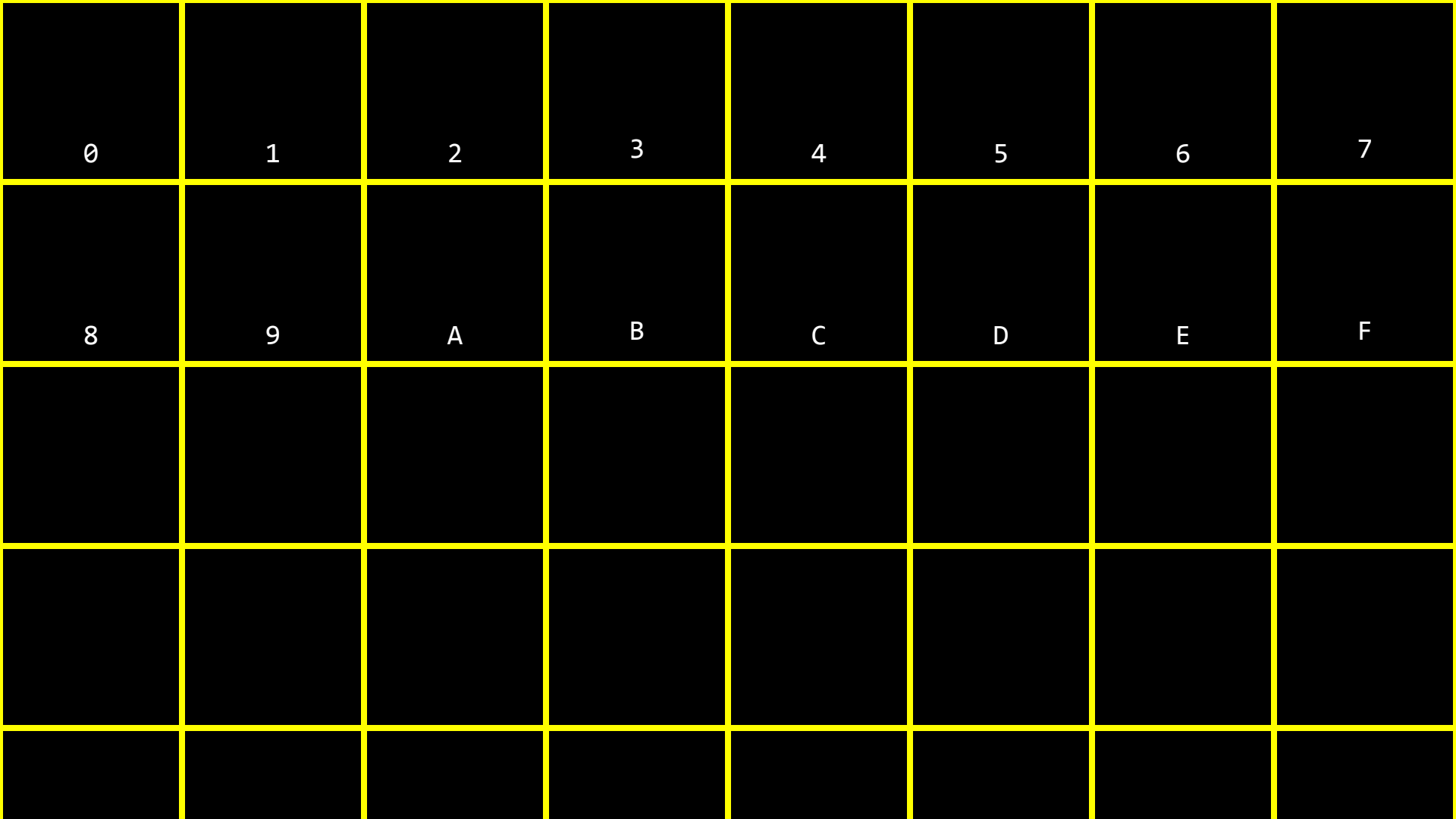
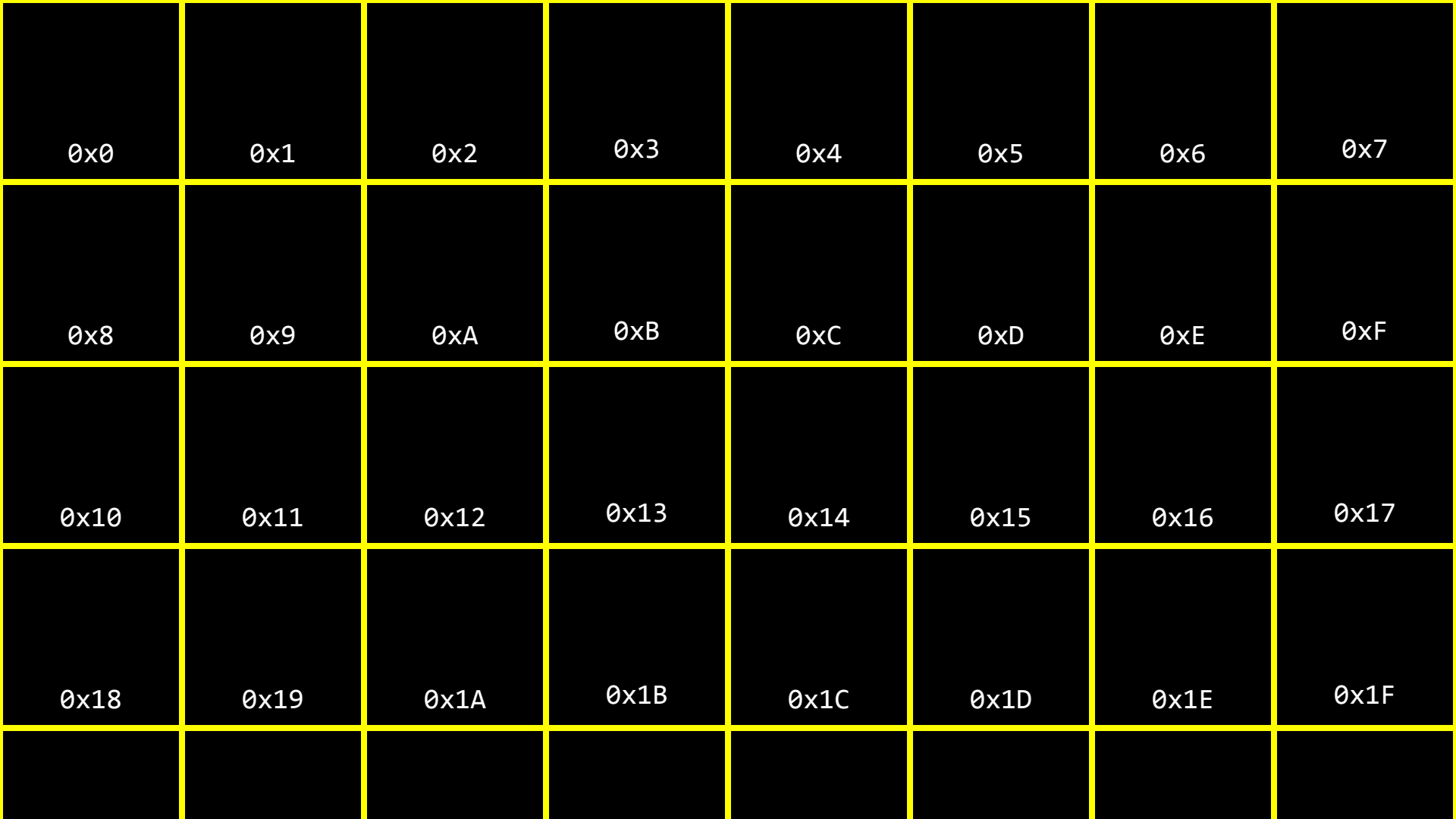
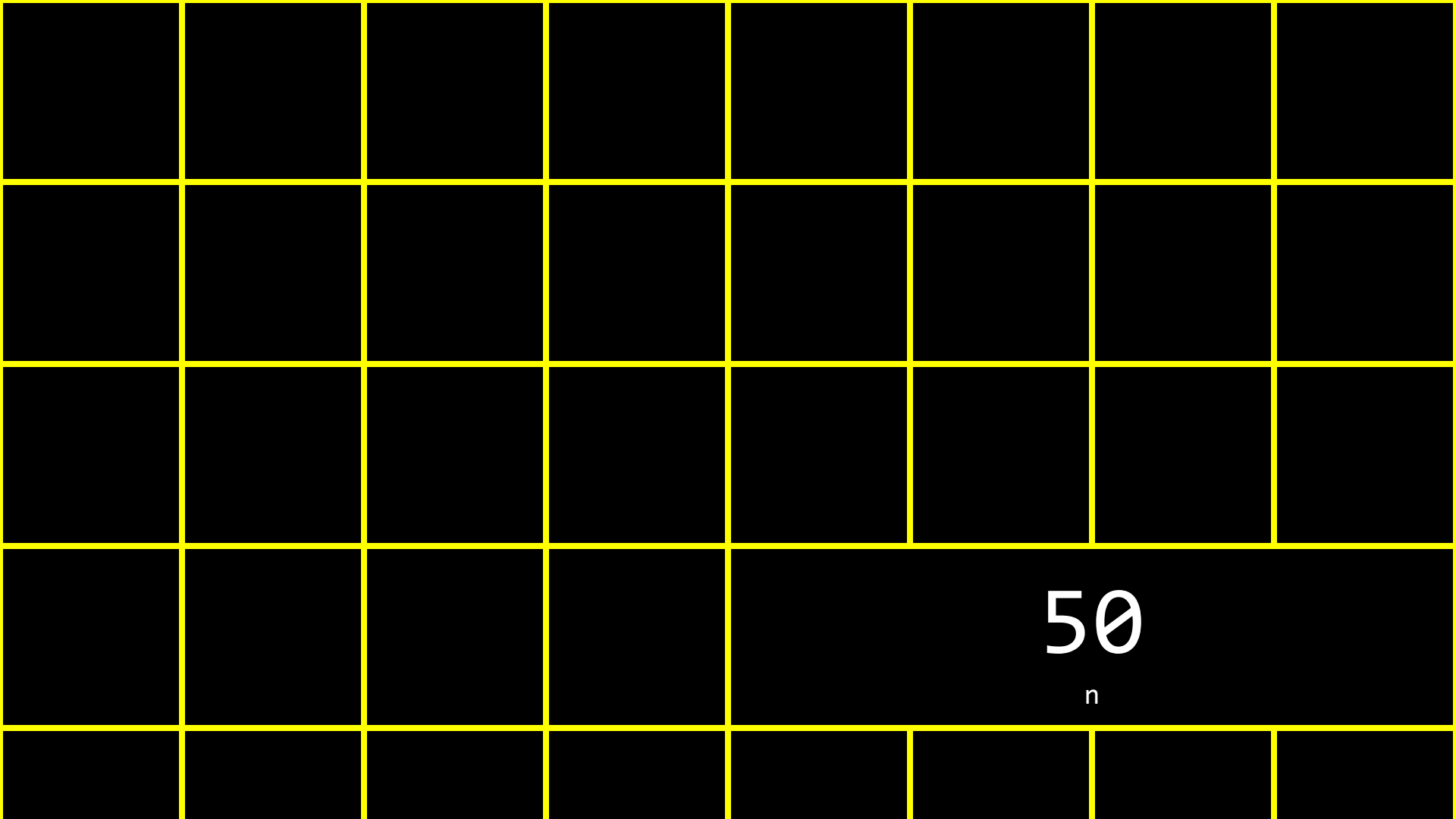
4
5
6
7
8
9
10
11
12
13
14
15

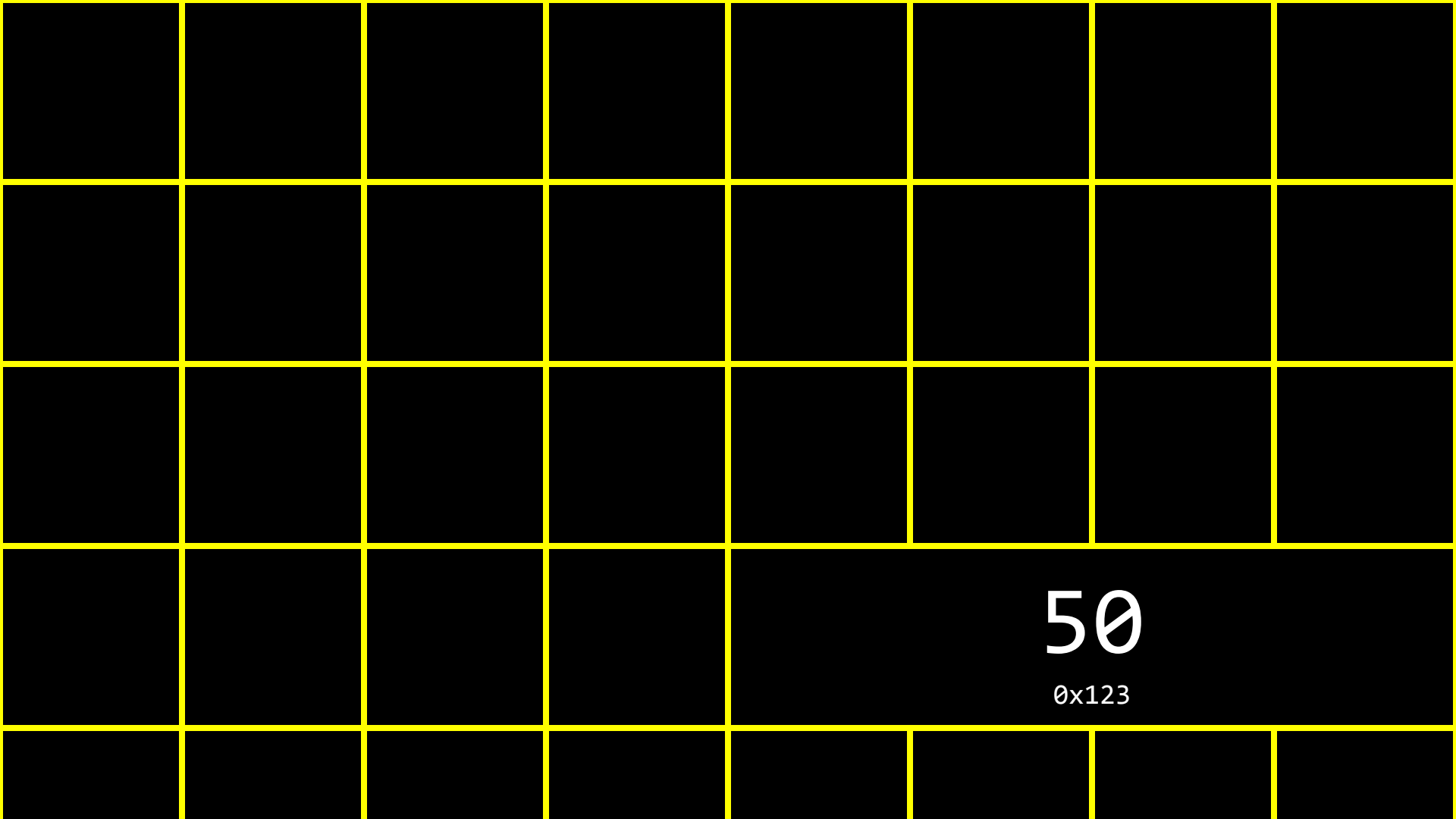

0
1
2
3
4
5
6
7
8
9
A
B
C
D
E
F

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

&

*

%p

pointers

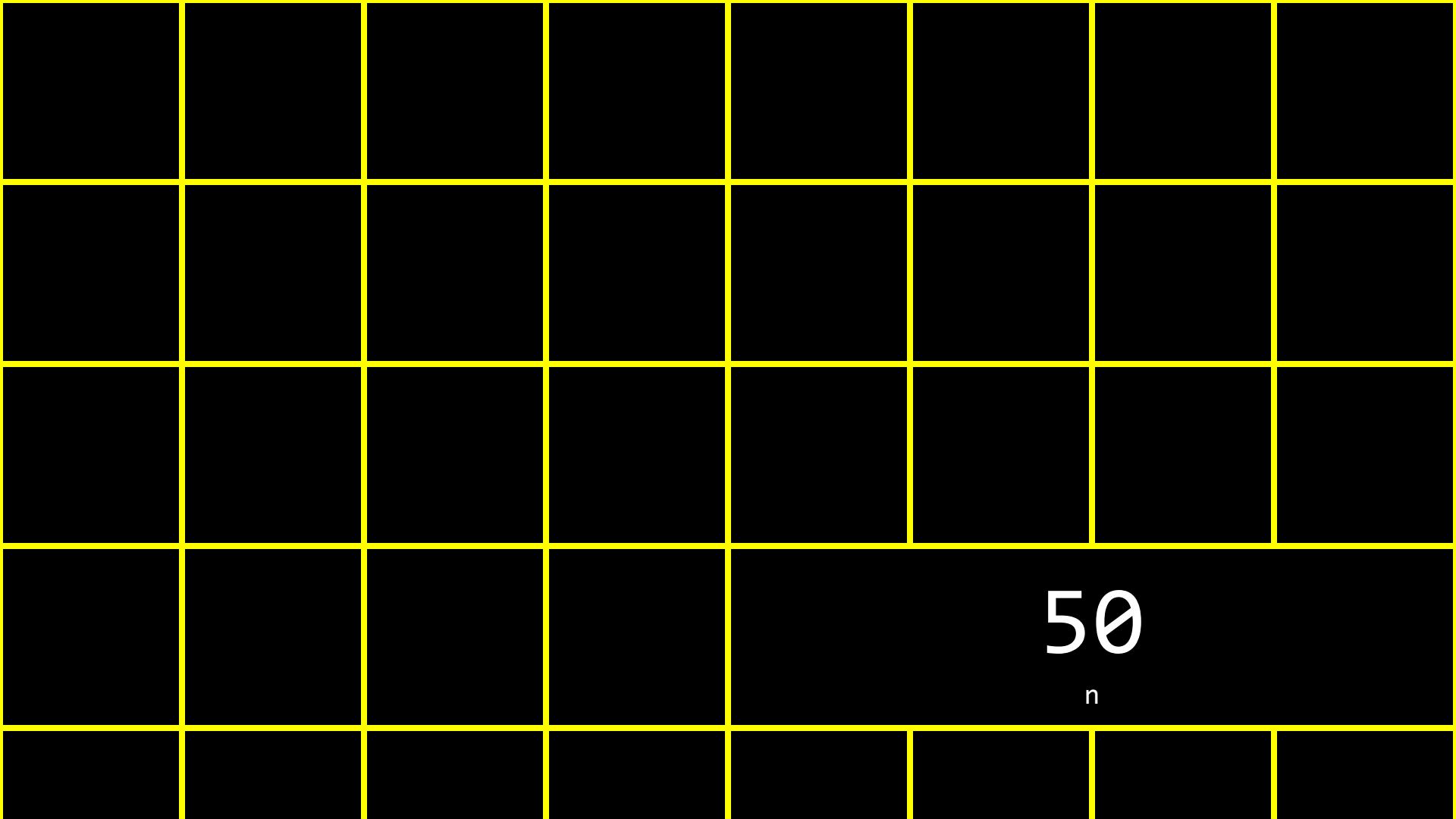
```
int n = 50;

int *p = &n;
```

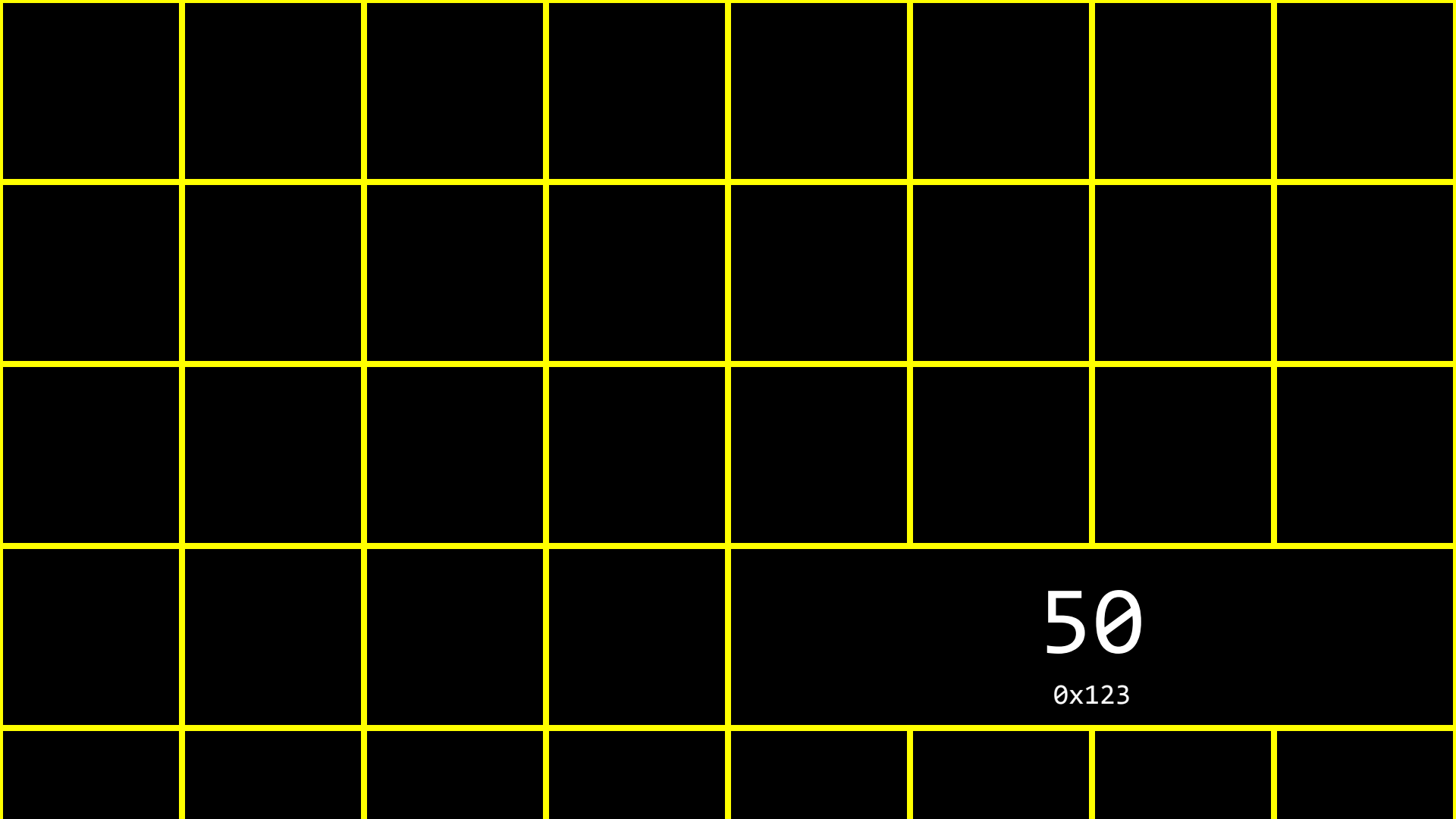
```
int n = 50;

int *p = &n;
```

```
int n = 50;

int* p = &n;
```

```
int n = 50;

int * p = &n;
```

```
int n = 50;

int *p = &n;
```


50
n


50
0x123

0x123

p

50

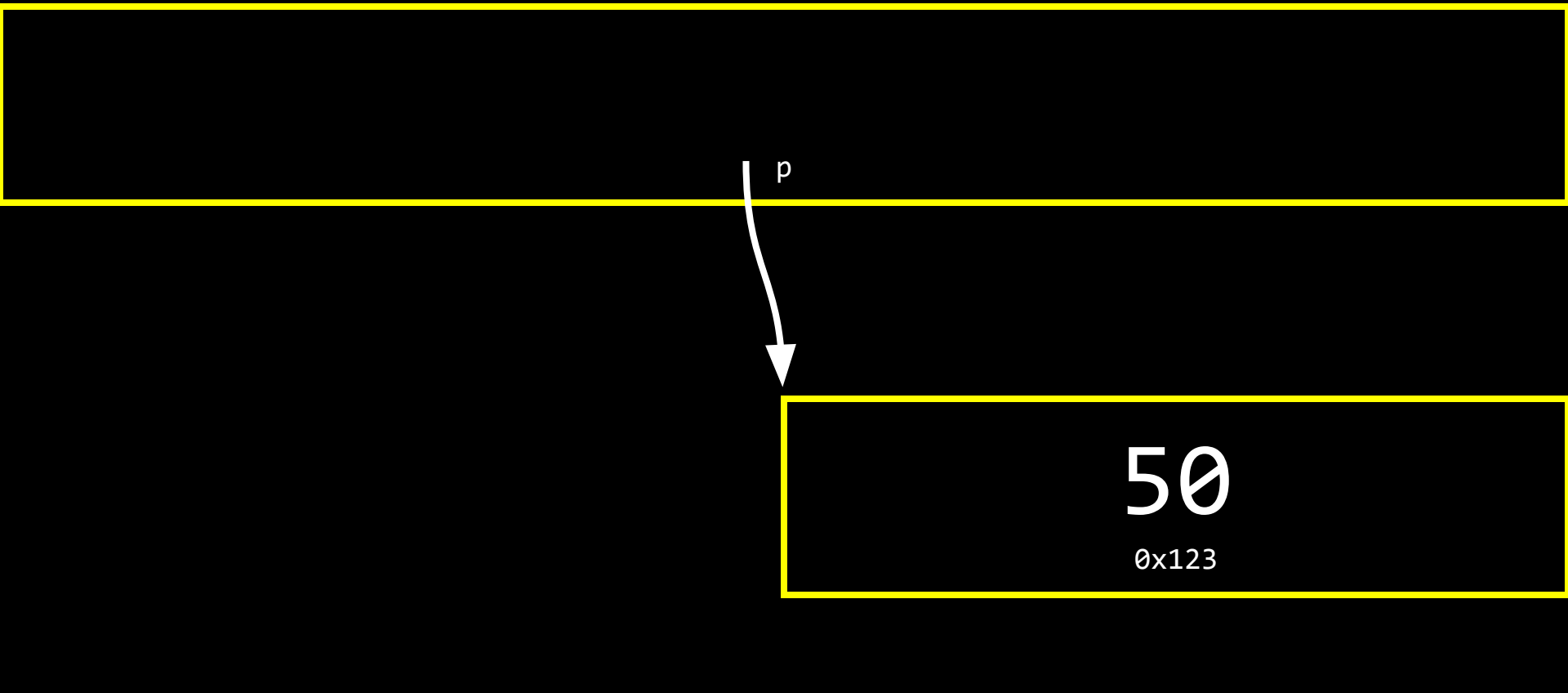
0x123

0x123

p

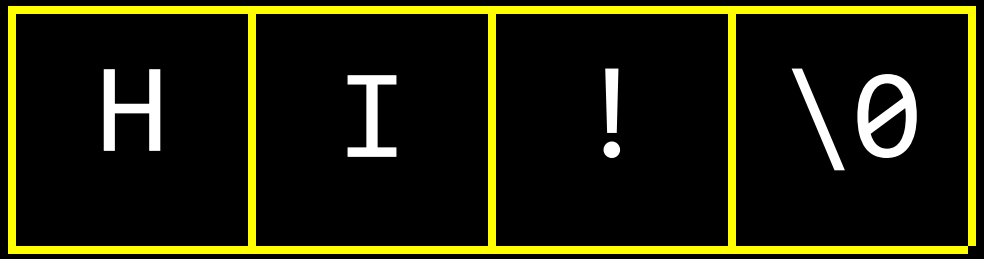
50

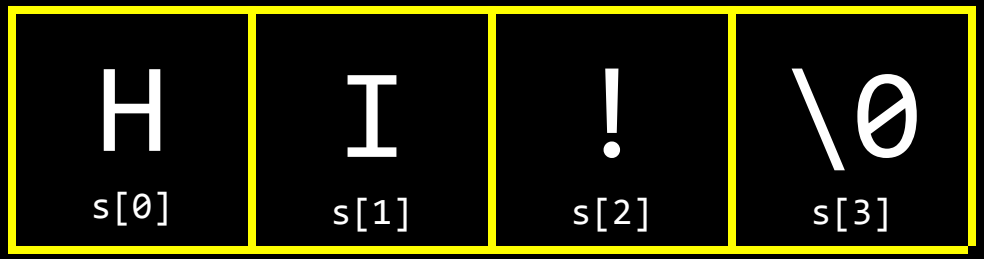
0x123

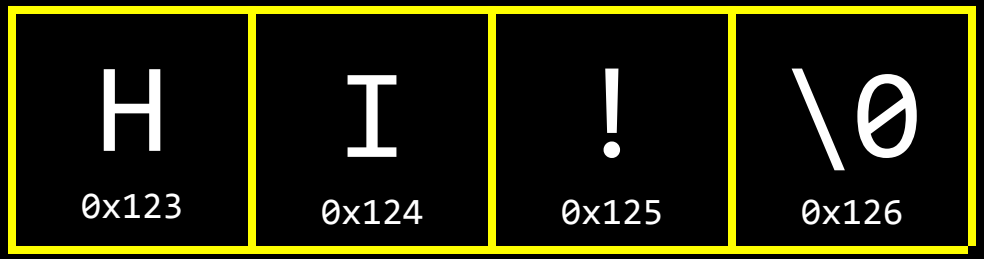

p
50
0x123

string

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


H
I
!
\0

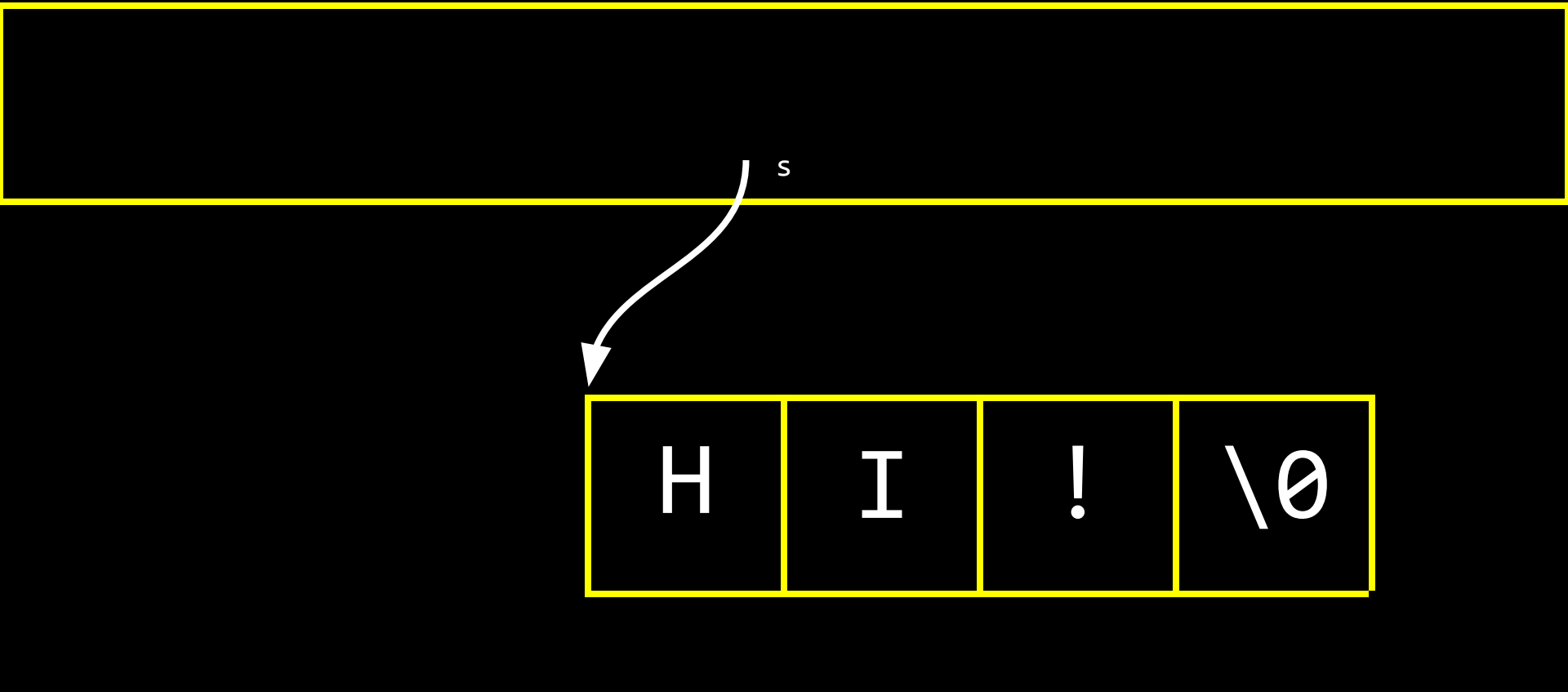

H
s[0]
I
s[1]
!
s[2]
\0
s[3]


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

s

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

```
typedef int
```

```
typedef int integer;
```

typedef

```
typedef char *
```

```
typedef char * string;
```

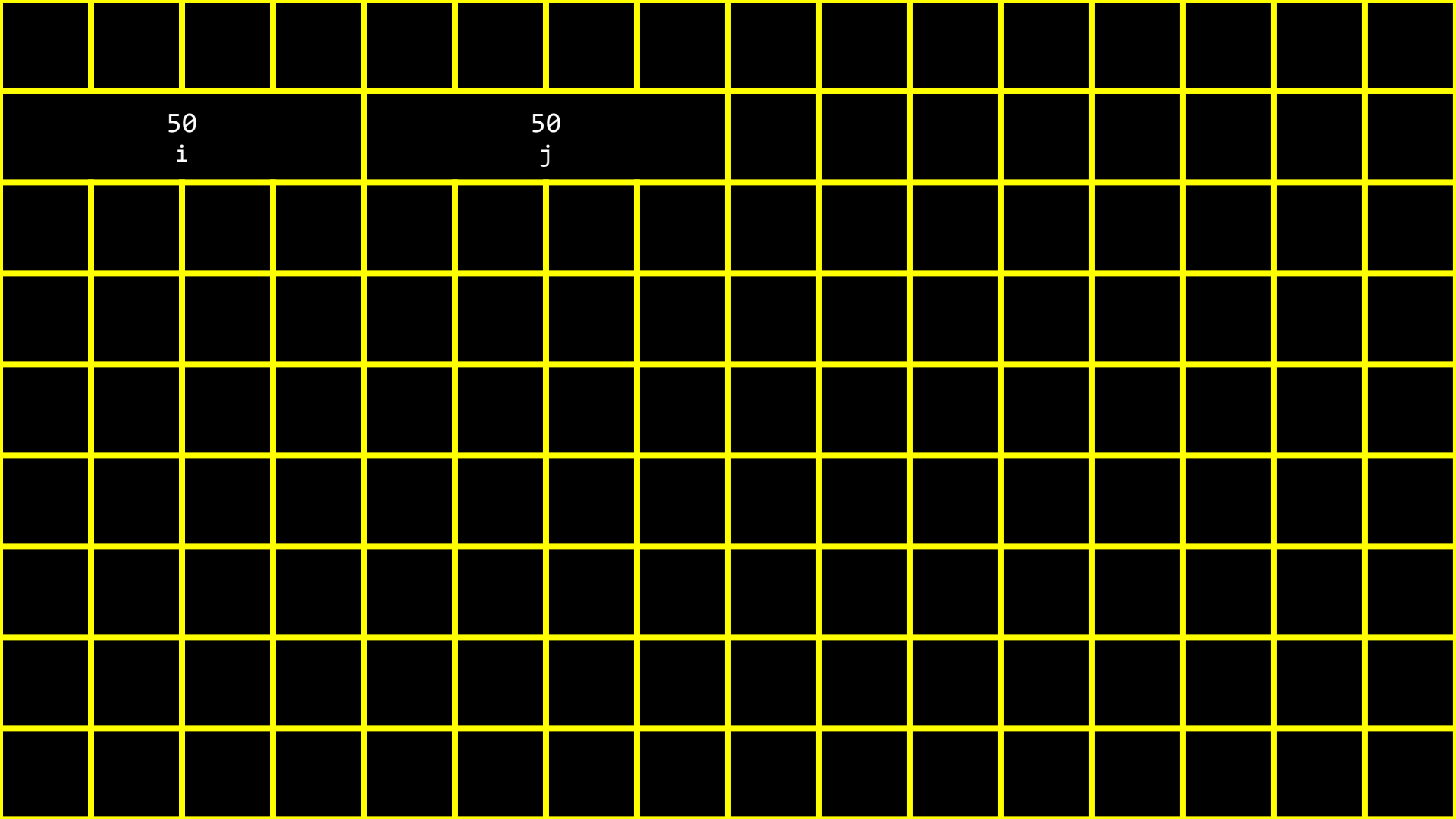
cs50.h

pointer arithmetic


Entenmann's
Little Bites
BLUEBERRY MUFFINS
20 MUFFINS
5 POUCHES
No High Fructose Corn Syrup
No Artificial Colors or Flavors
Made with Real Blueberries
NET WT 8.25 OZ (234g)
PER 1 POUCH SERVING
190 CALORIES
1.5g SAT FAT
200mg SODIUM
15g SUGARS

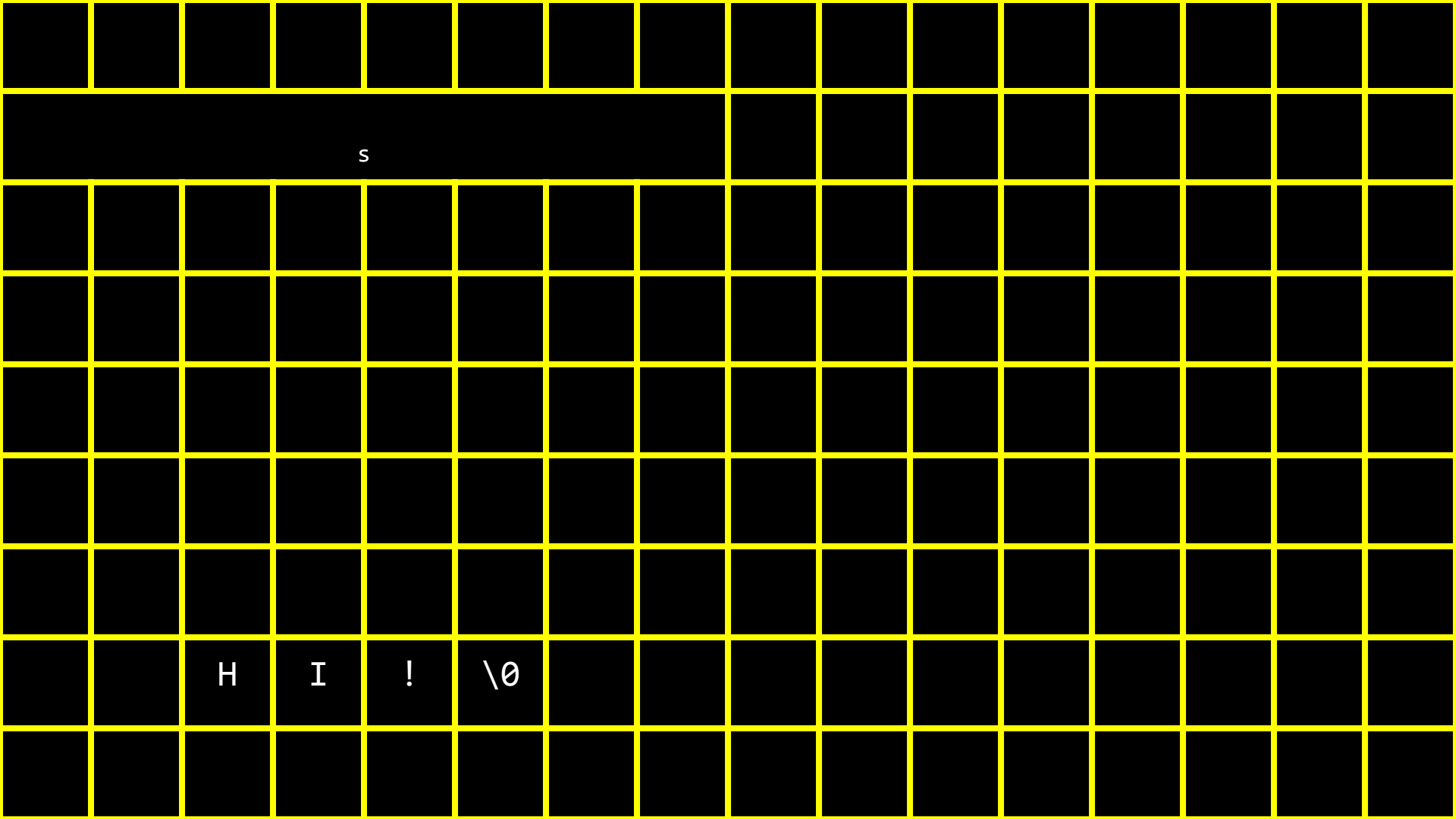
```
typedef char * string;
```

```
typedef char *string;
```

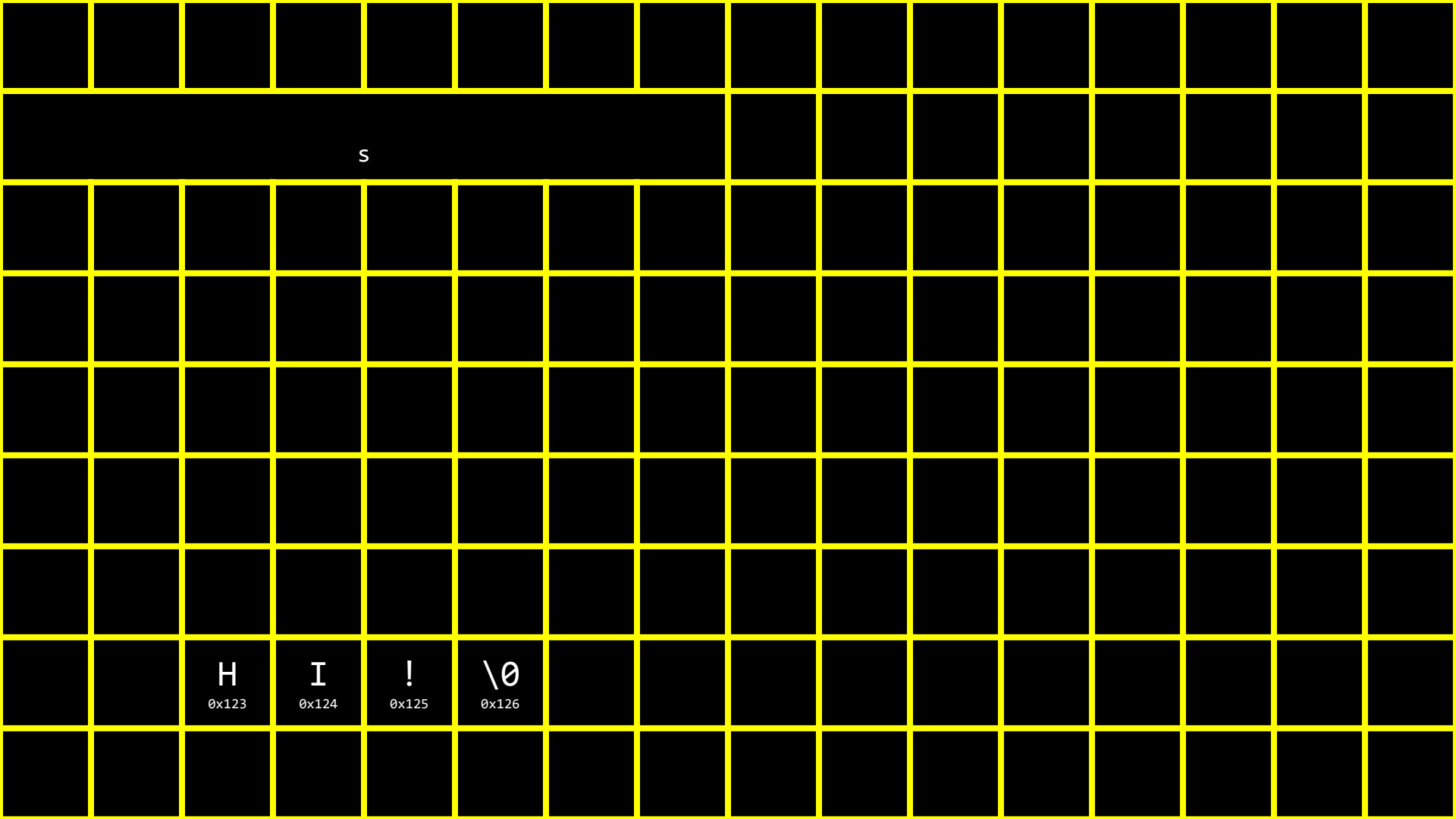

50
i
50
j

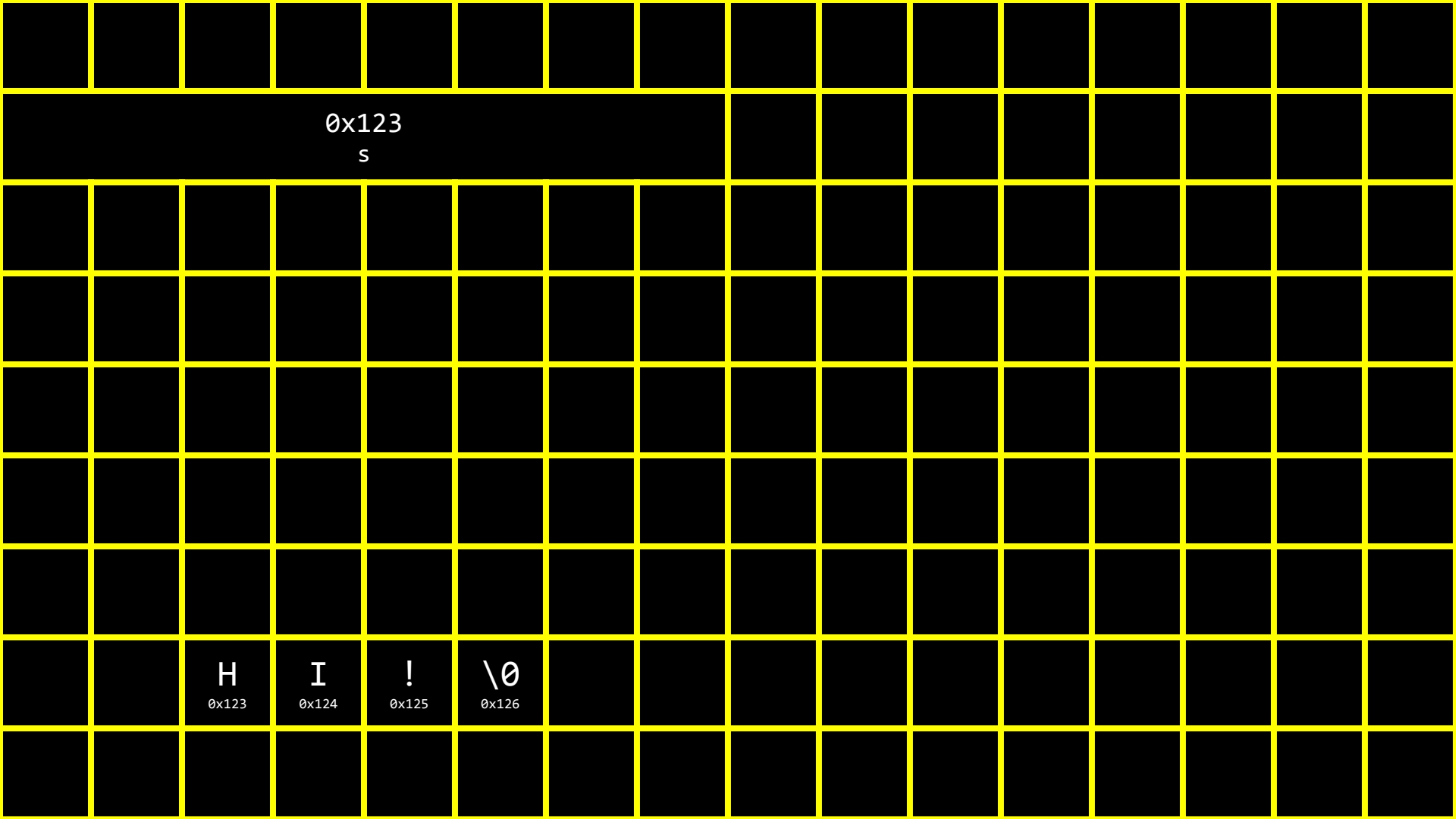
strcmp

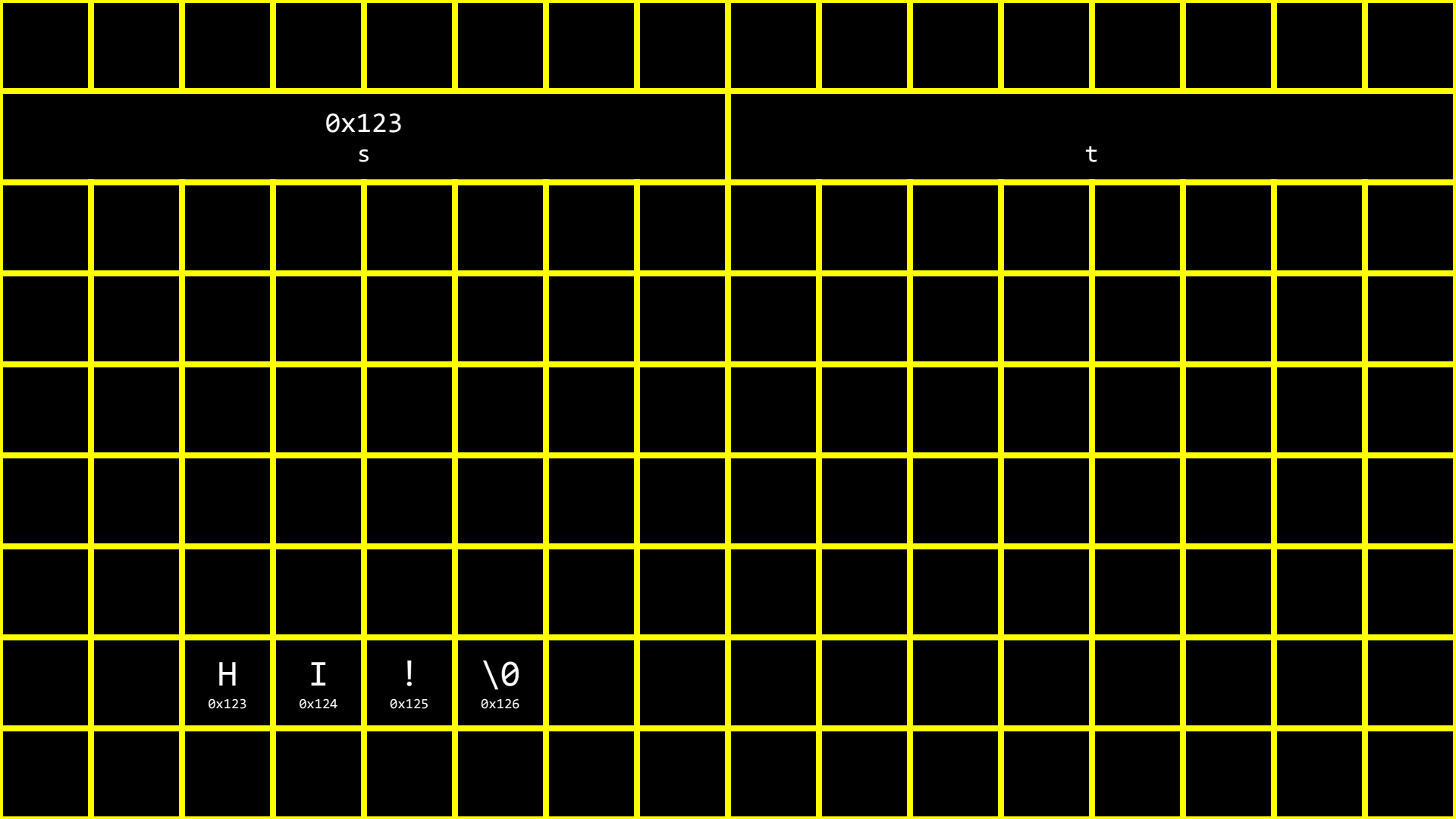
s

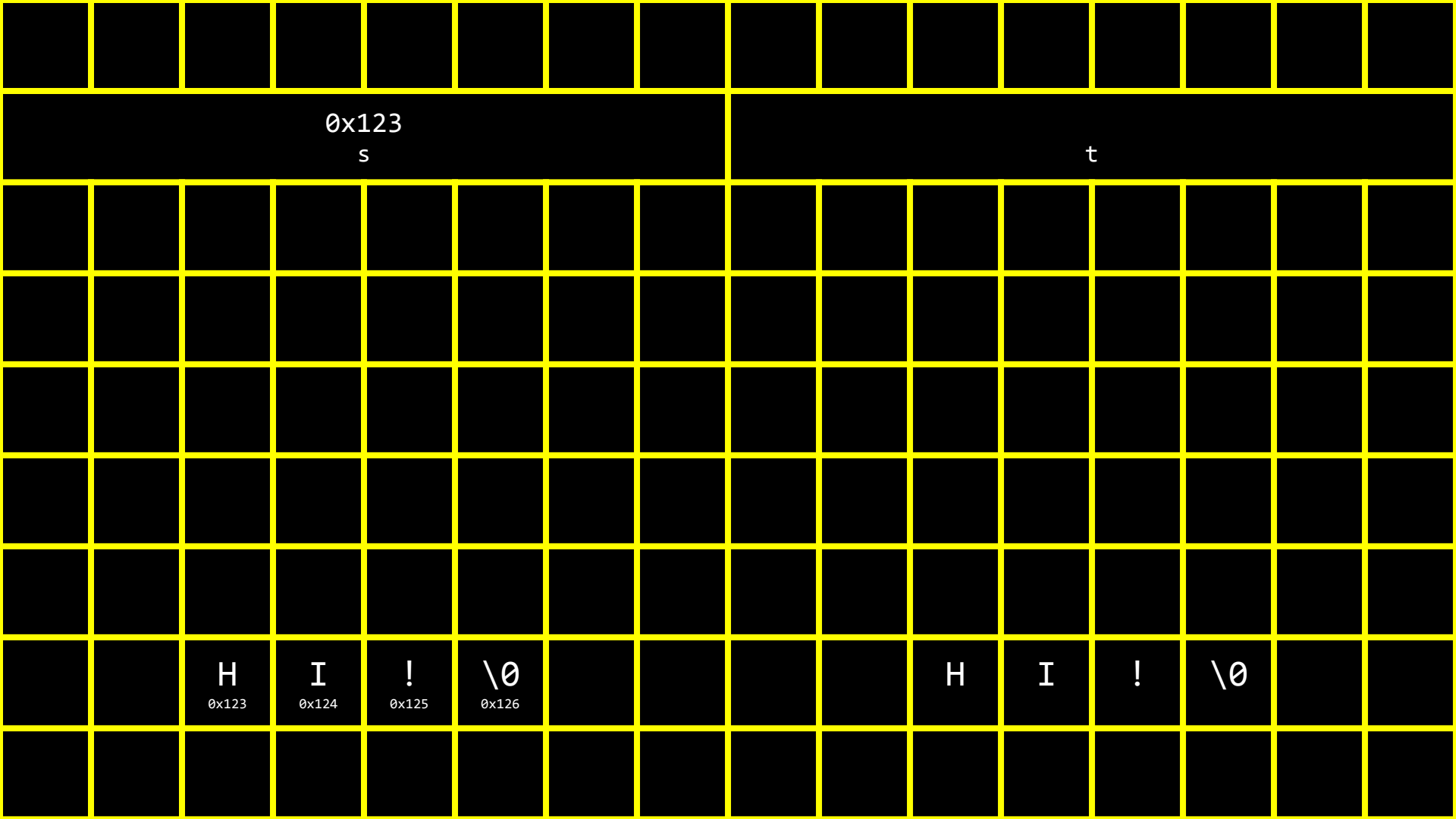

s
H
I
!
\0

s




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


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


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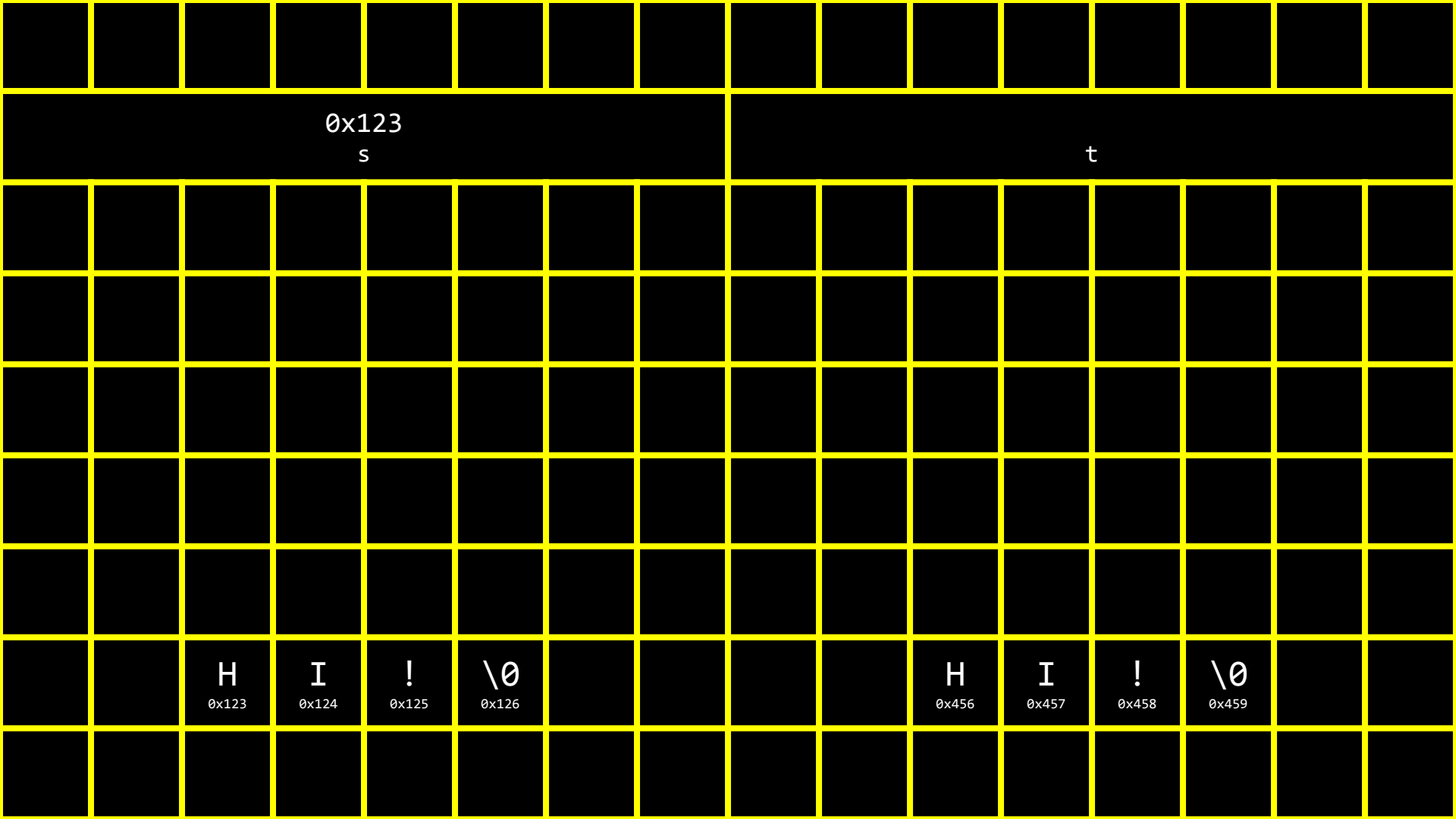
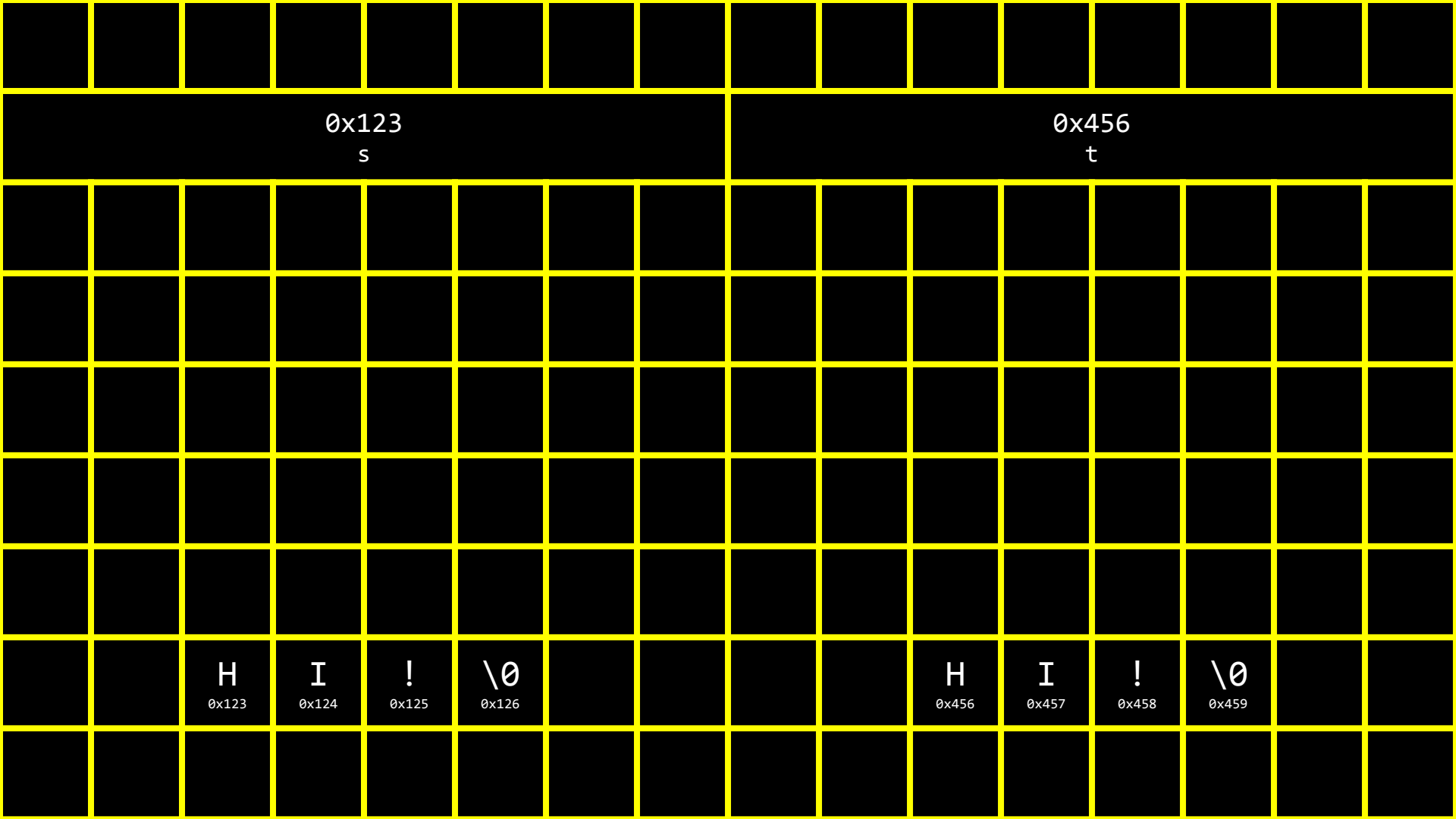
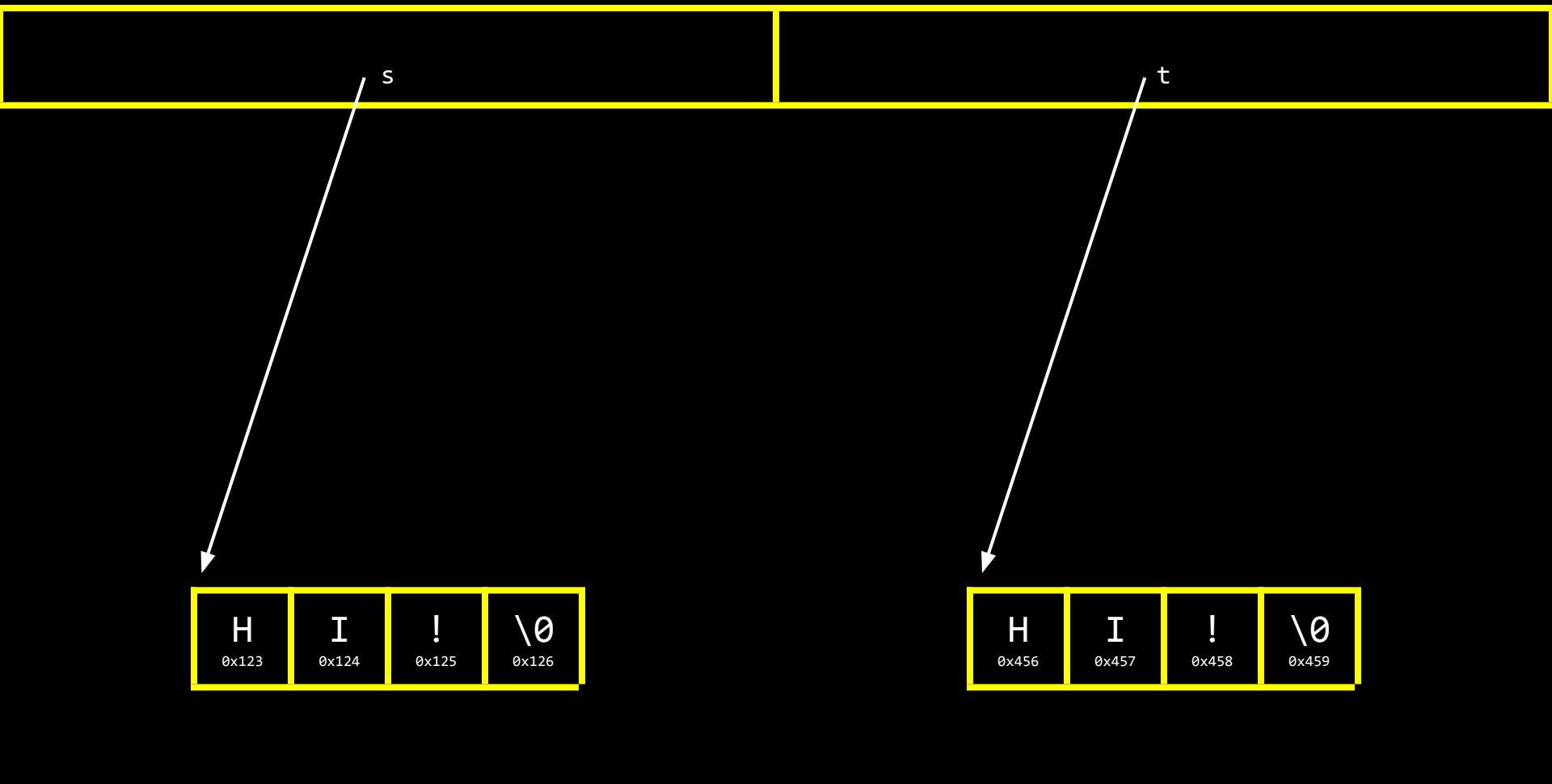
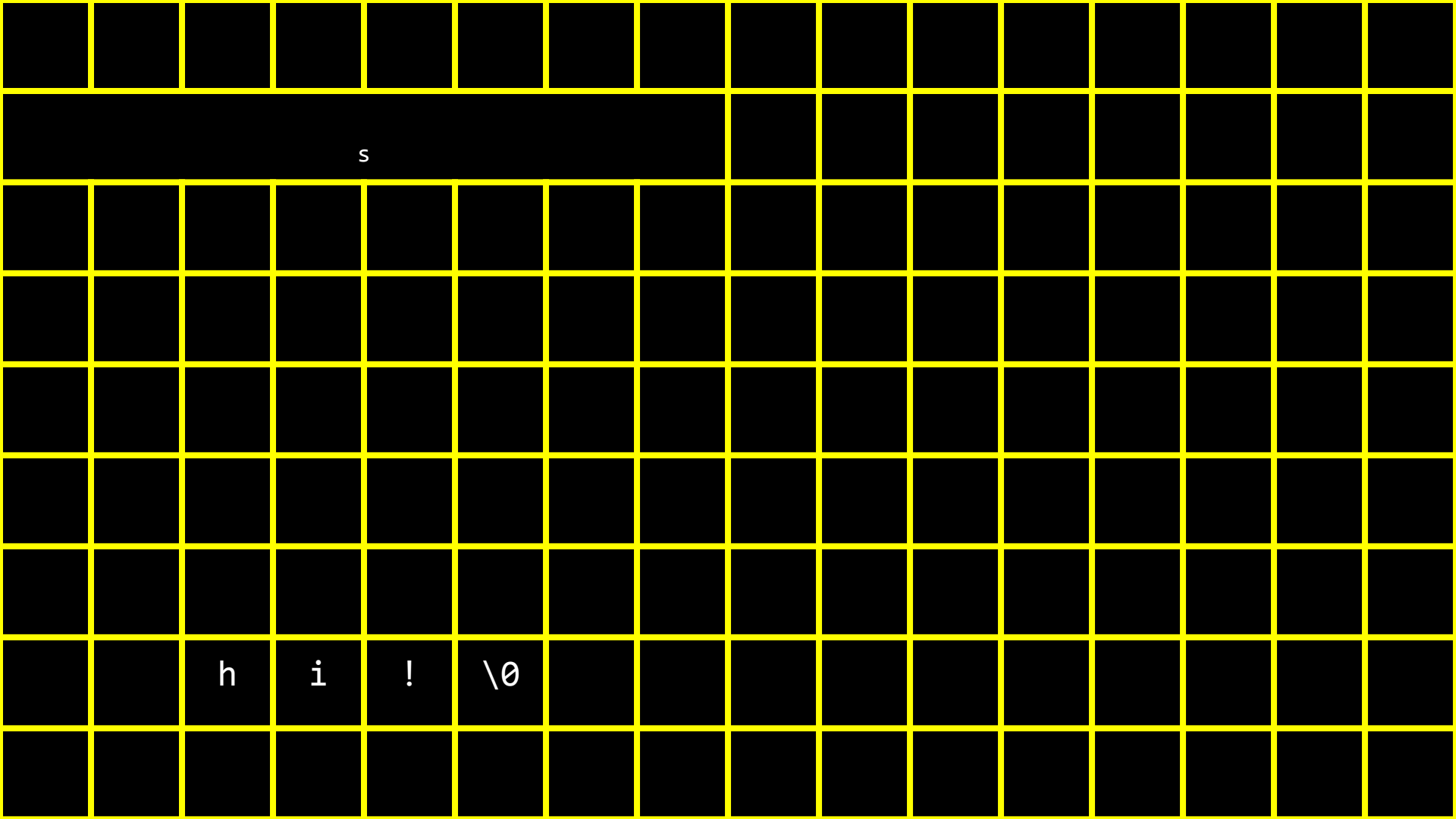

0x123
s
t
H
0x123
I
0x124
!
0x125
\0
0x126
H
0x456
I
0x457
!
0x458
\0
0x459


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

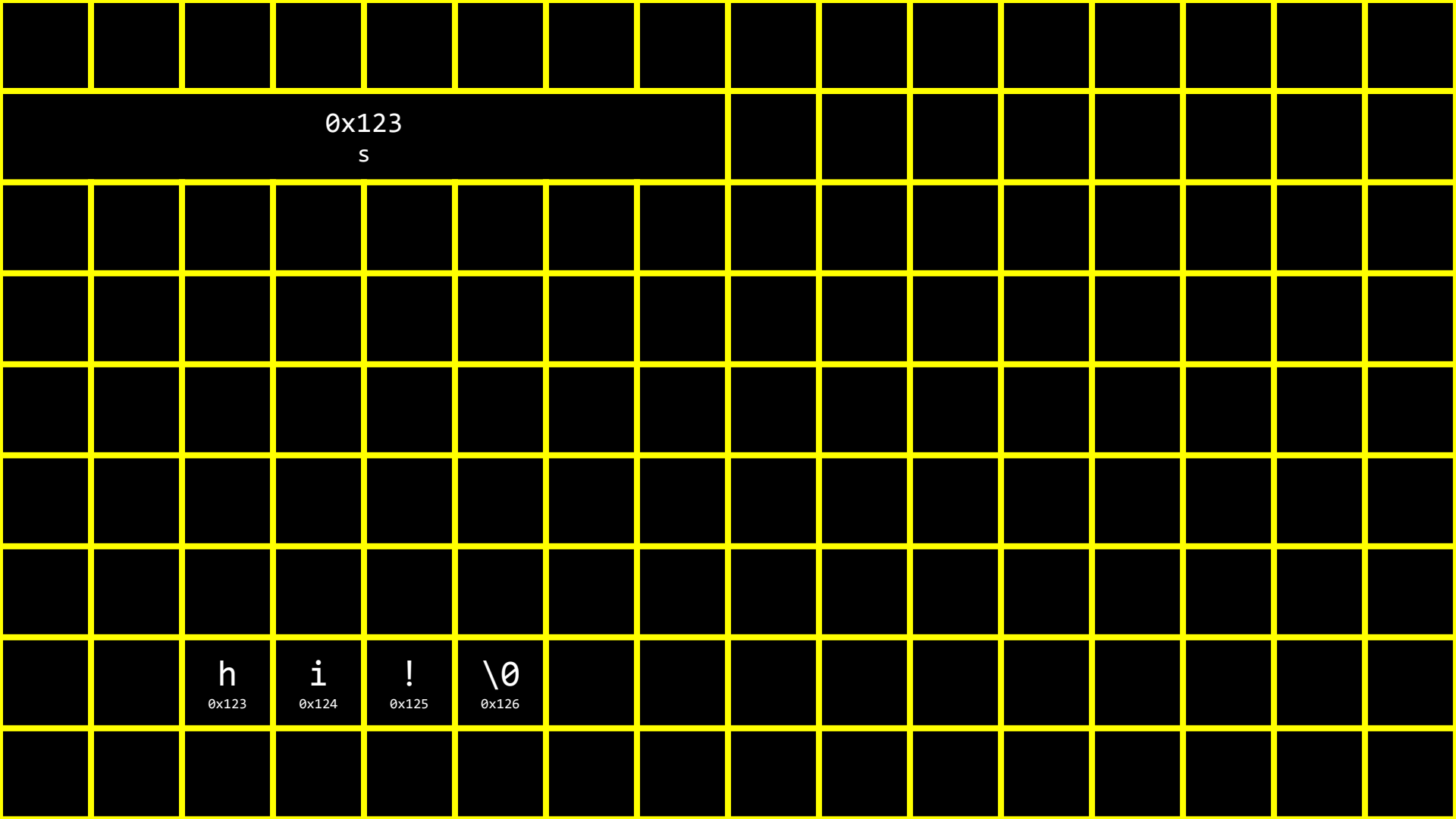

s
t
H
0x123
I
0x124
!
0x125
\0
0x126
H
0x456
I
0x457
!
0x458
\0
0x459

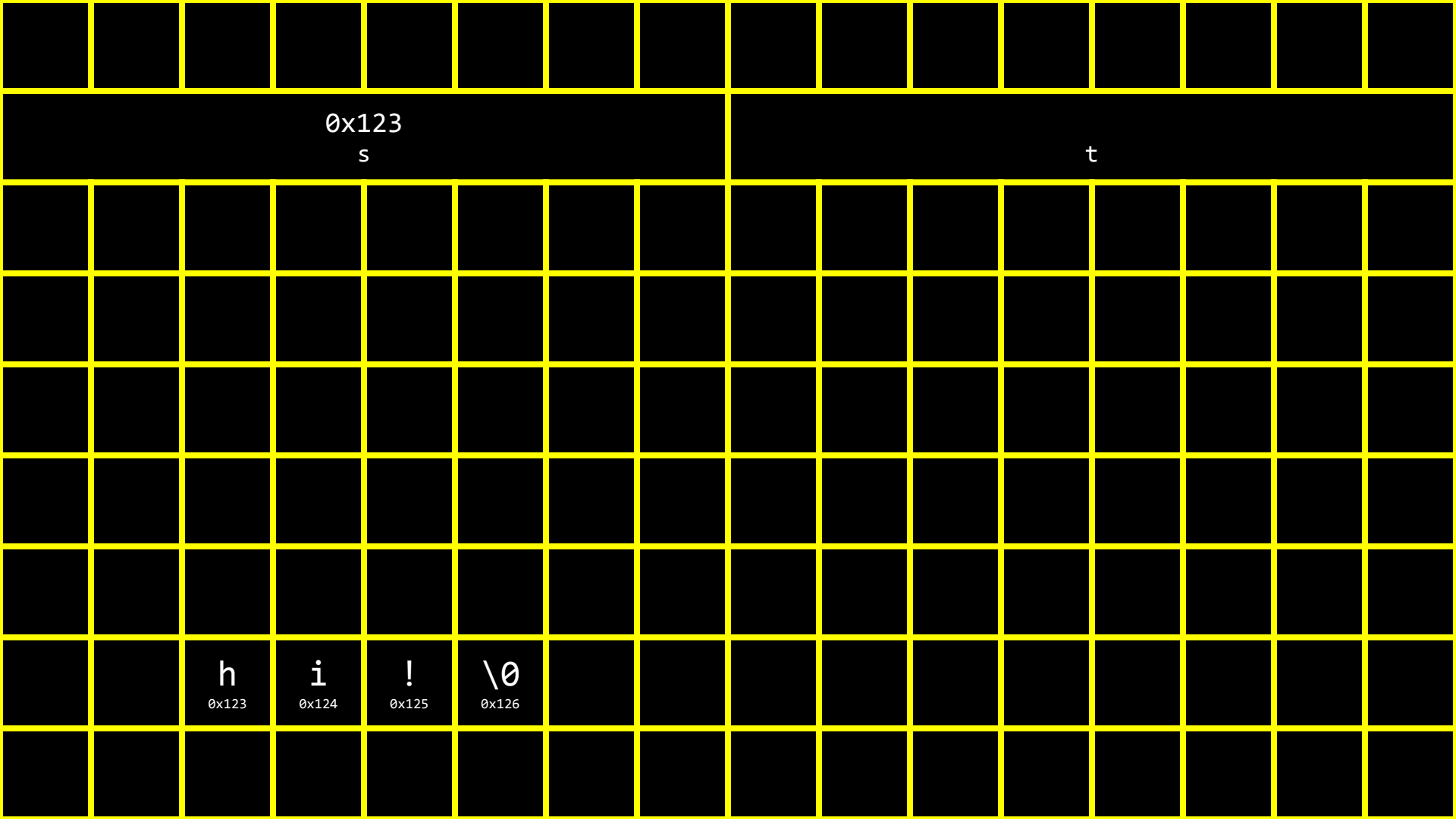
s


s
h
i
!
\0

s

h	i	!	\0
0x123	0x124	0x125	0x126


0x123
s
h
0x123
i
0x124
!
0x125
\0
0x126


0x123
s
t
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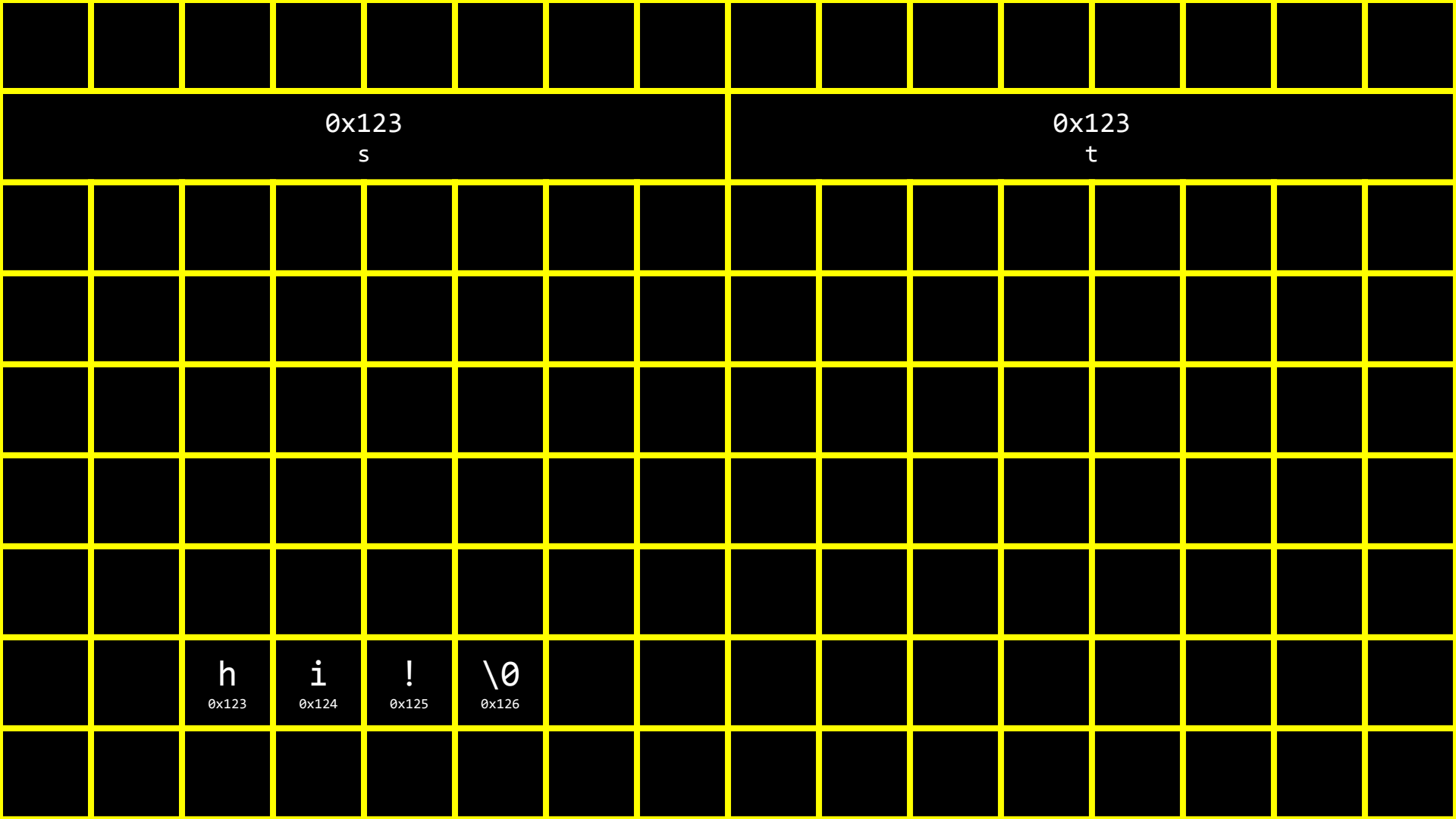
0x123
i
0x124
!
0x125
\0
0x126


0x123
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0x123
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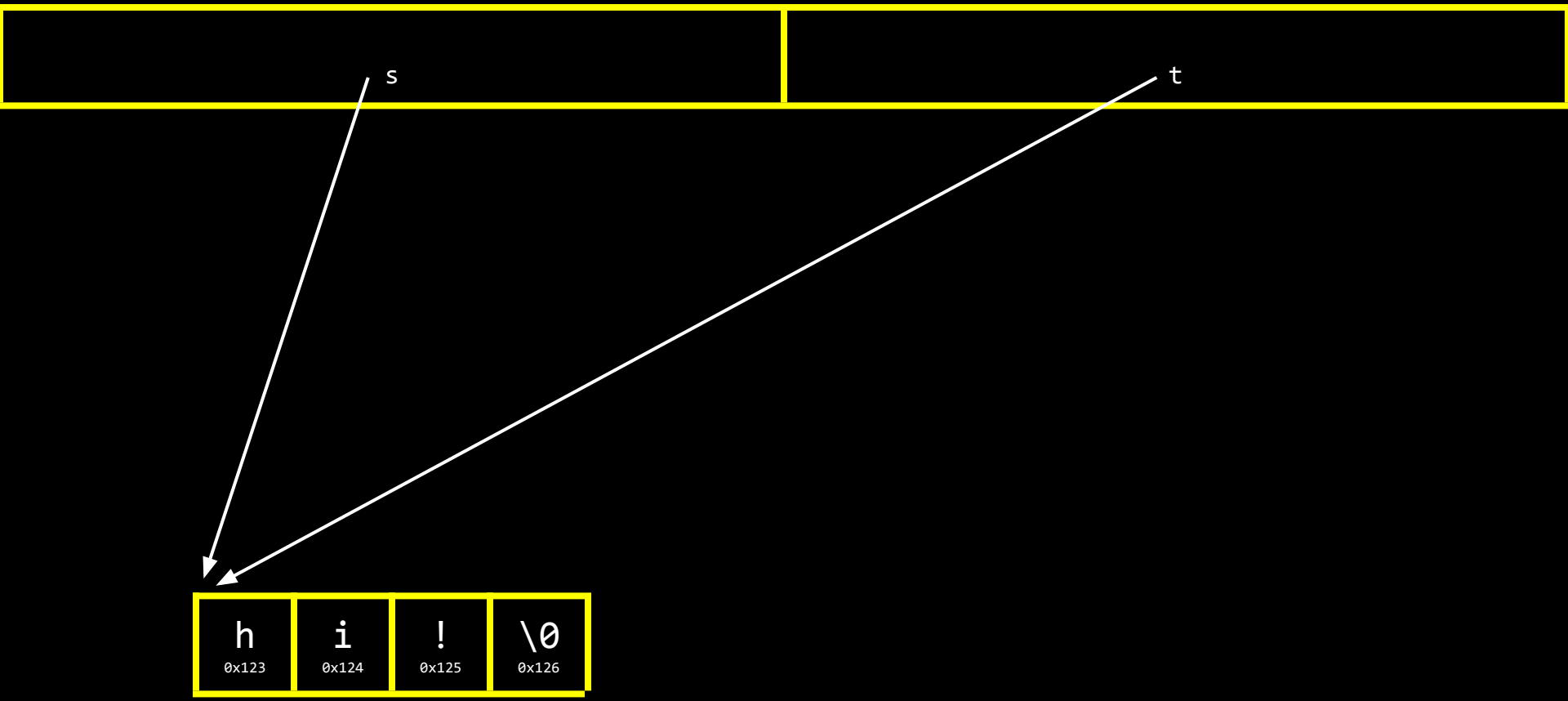
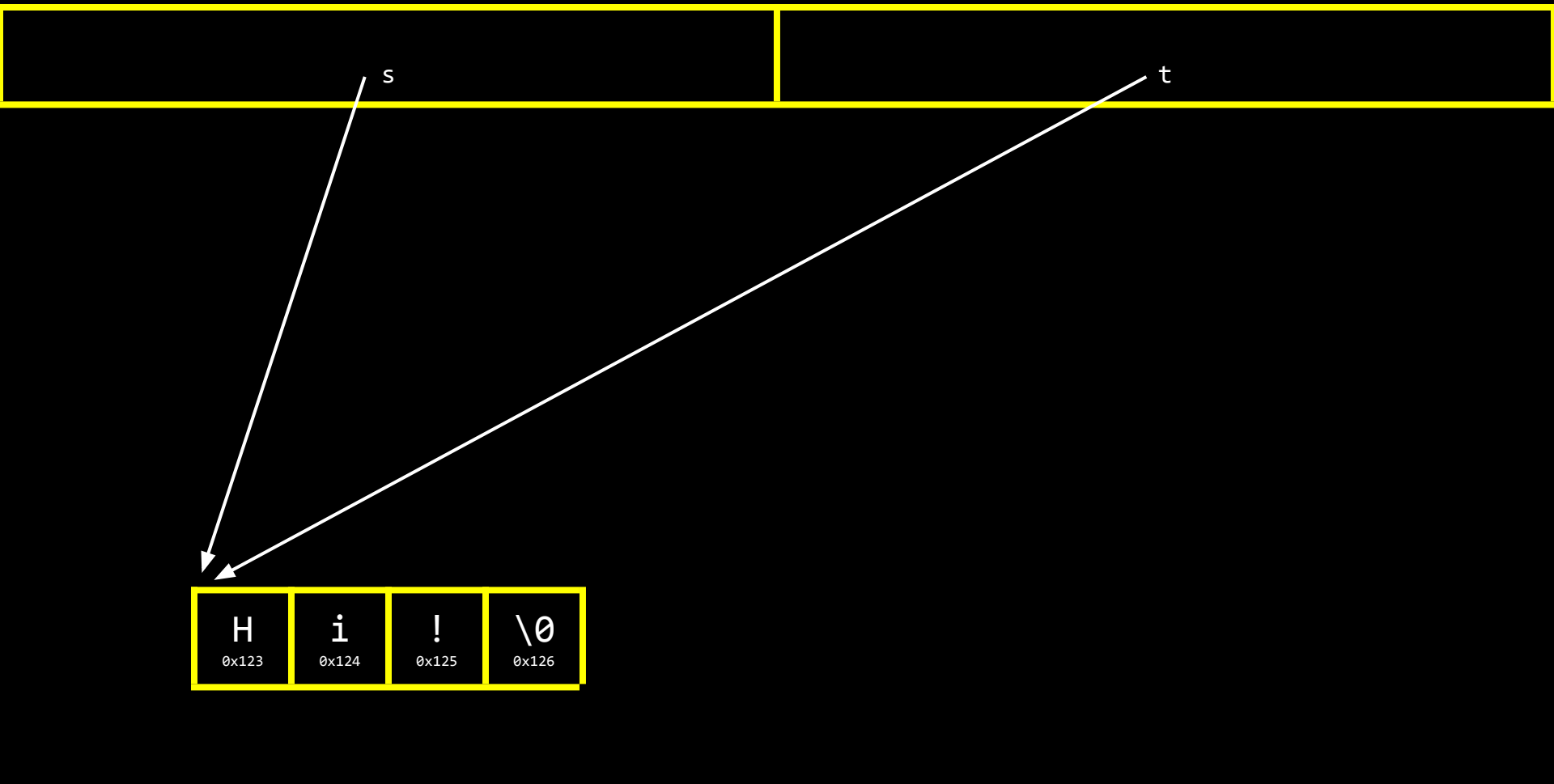
0x123
i
0x124
!
0x125
\0
0x126

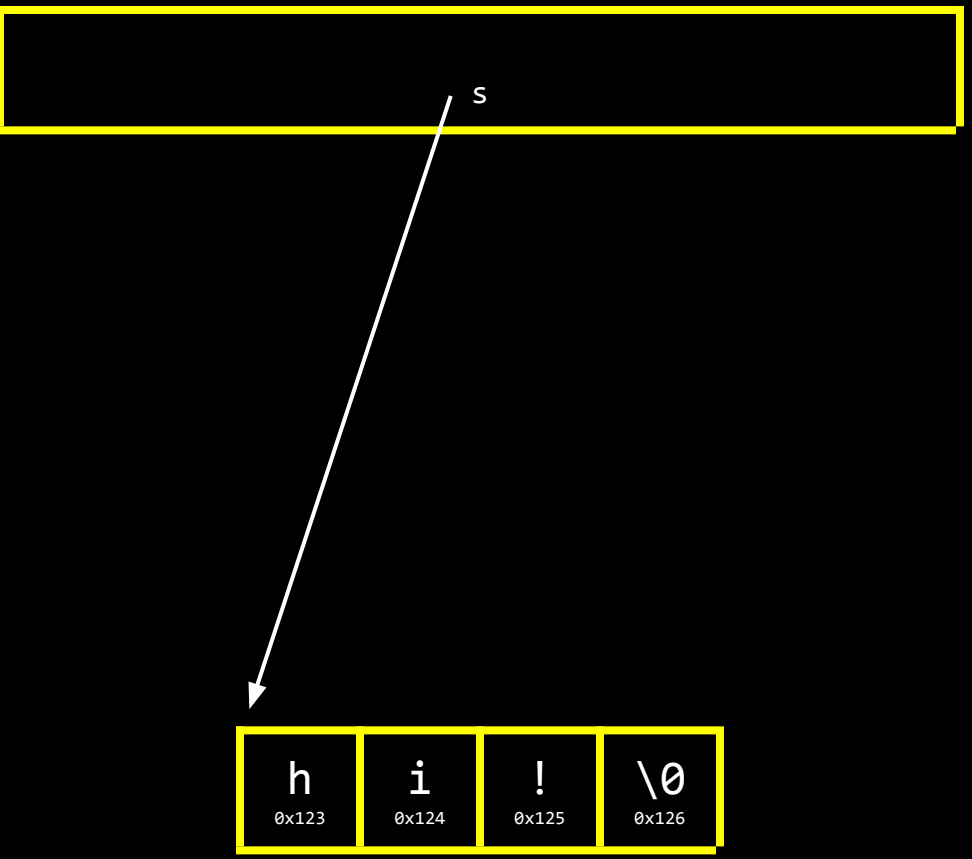

s
t
h
0x123
i
0x124
!
0x125
\0
0x126


s
t
H
0x123
i
0x124
!
0x125
\0
0x126

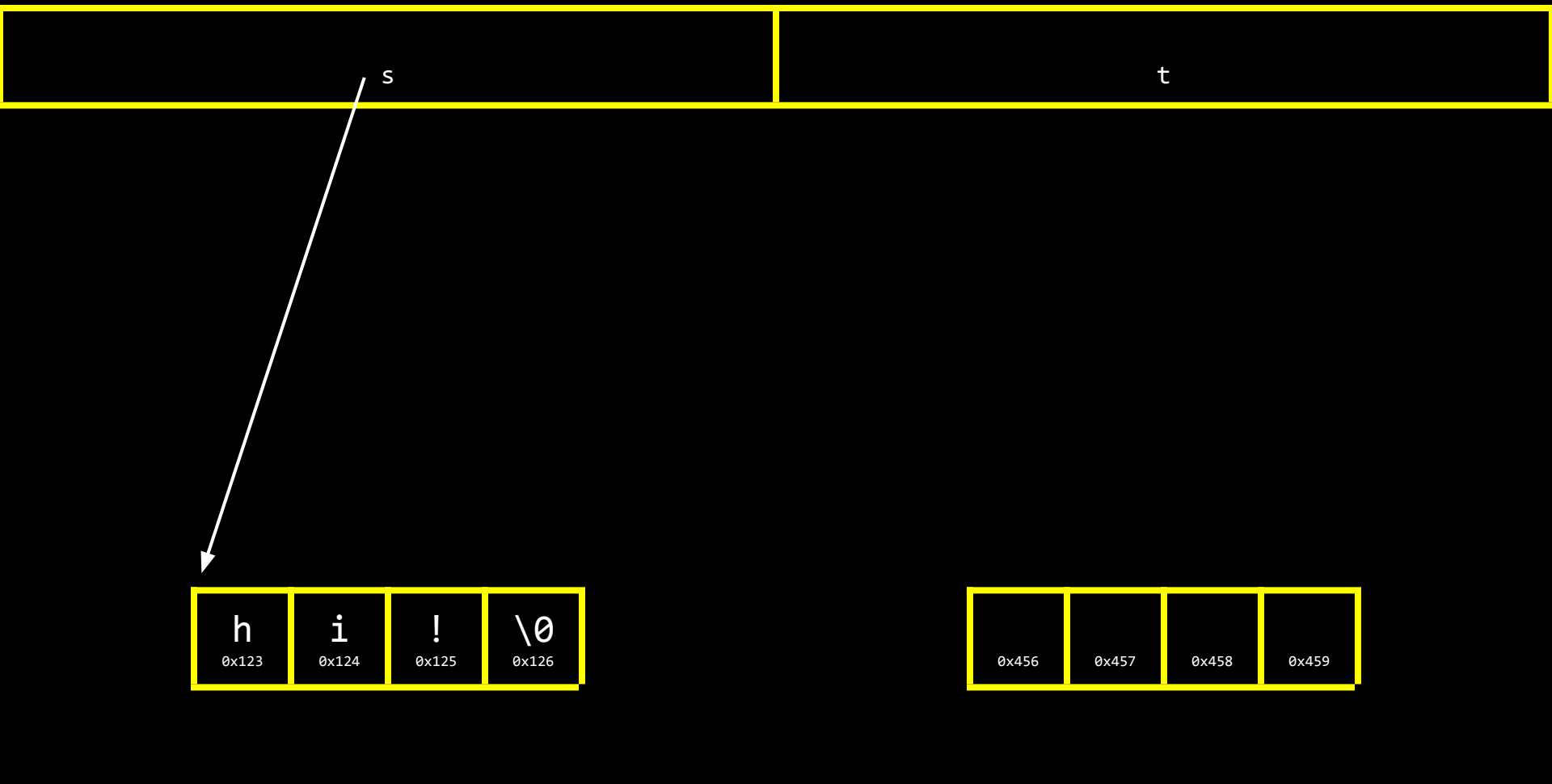
malloc

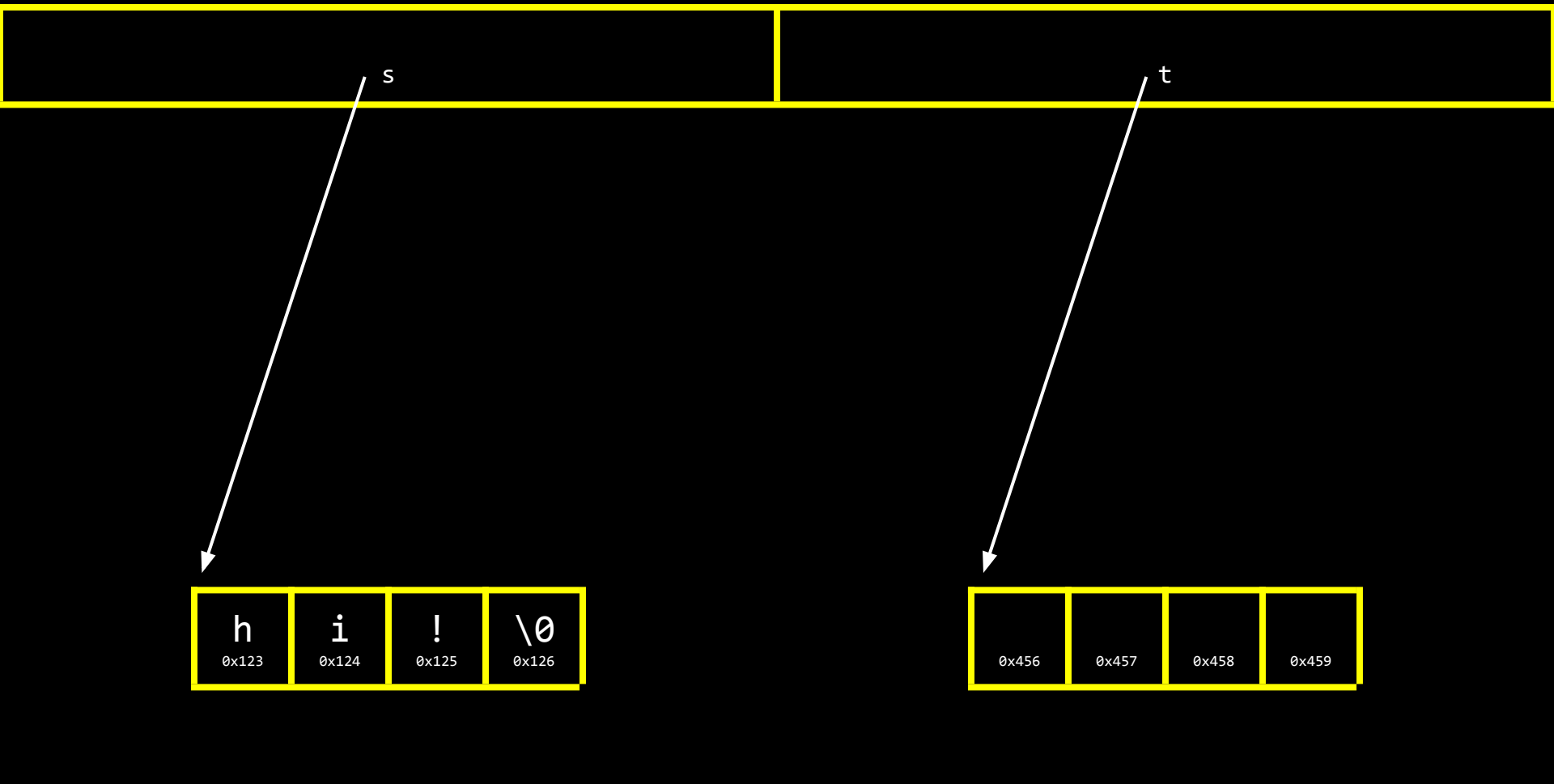
free

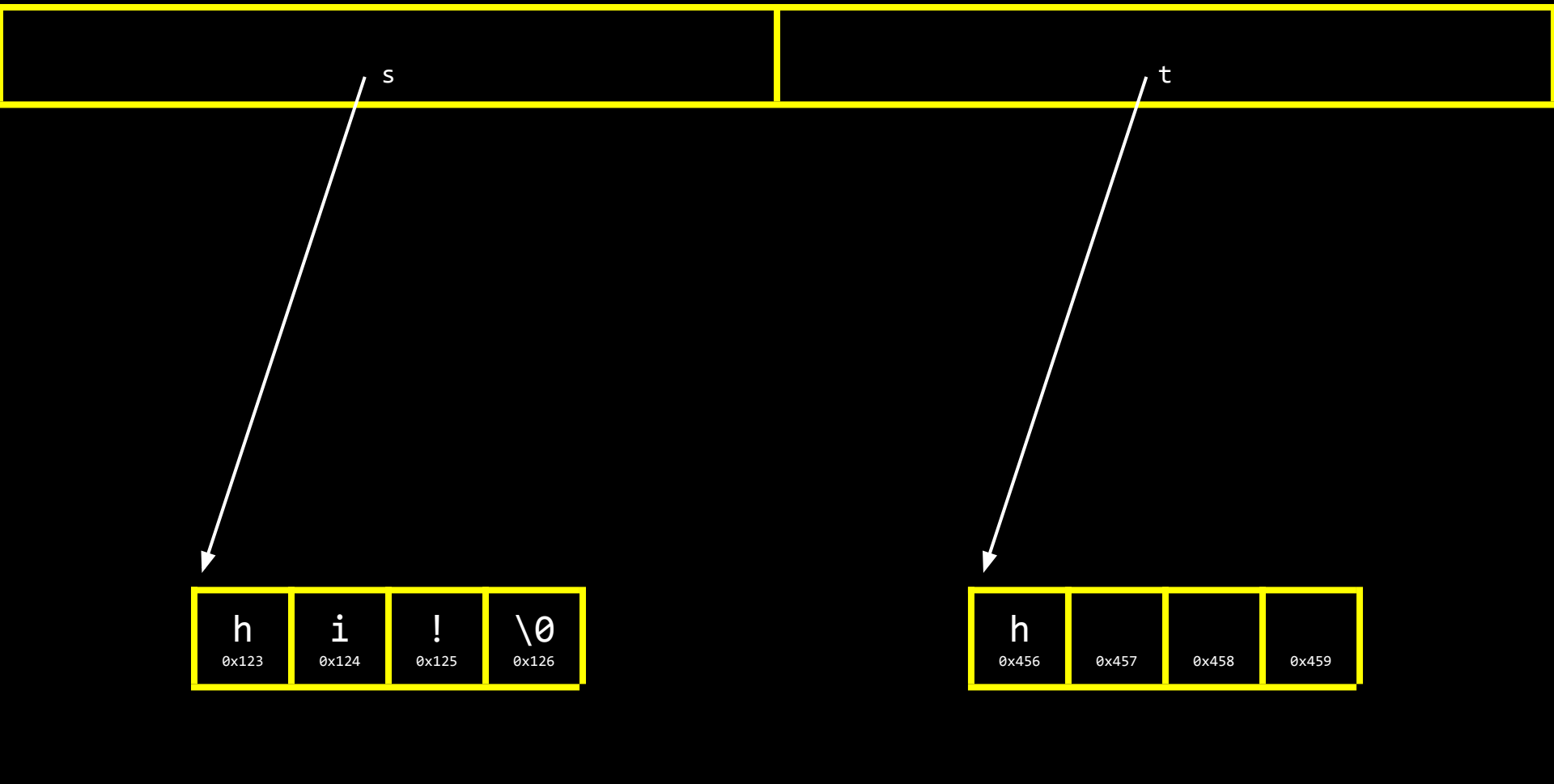
…

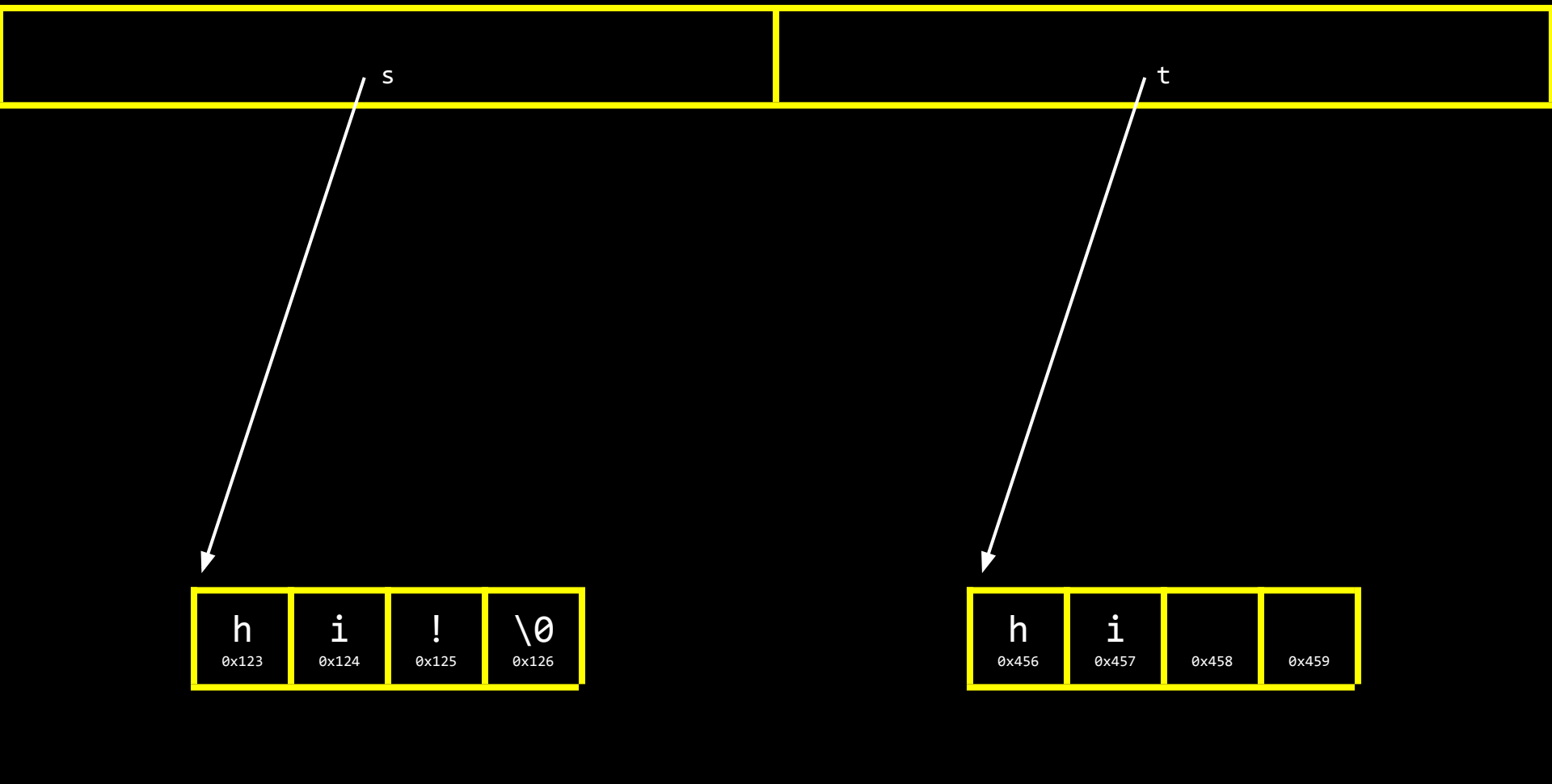

s
h
0x123
i
0x124
!
0x125
\0
0x126

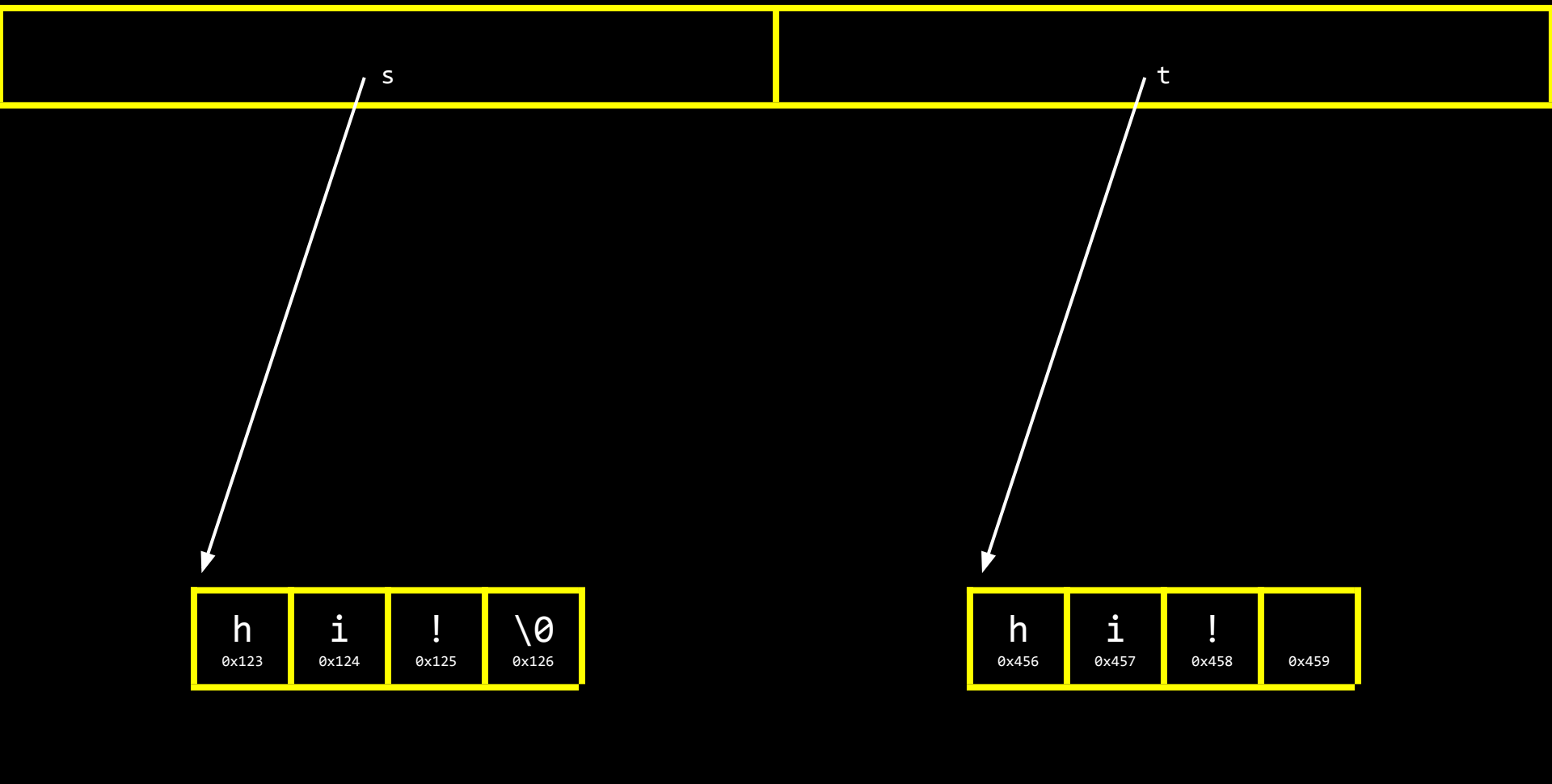

s
t
h
0x123
i
0x124
!
0x125
\0
0x126

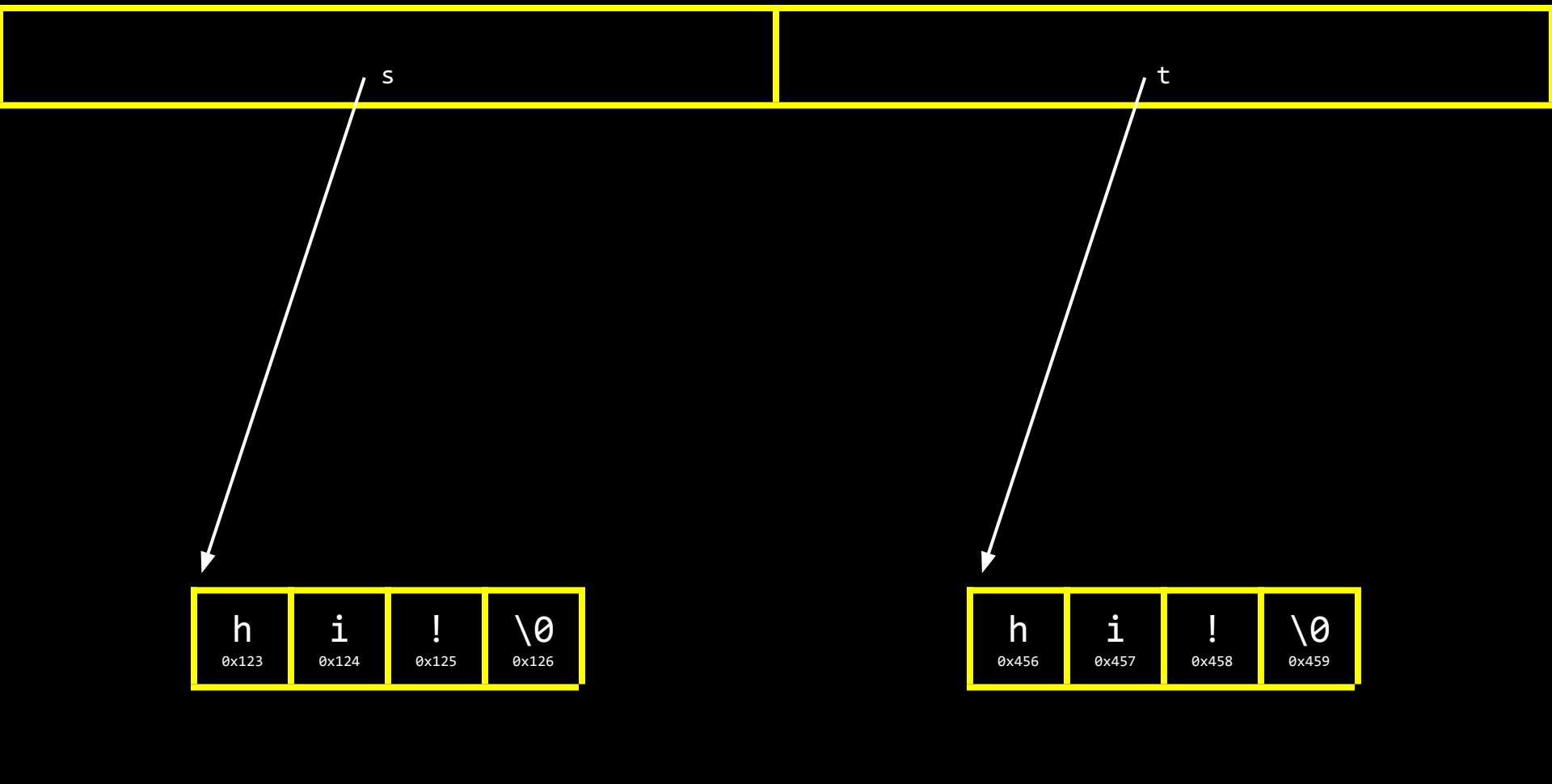

s
t
h
0x123
i
0x124
!
0x125
\0
0x126
0x456
0x457
0x458
0x459

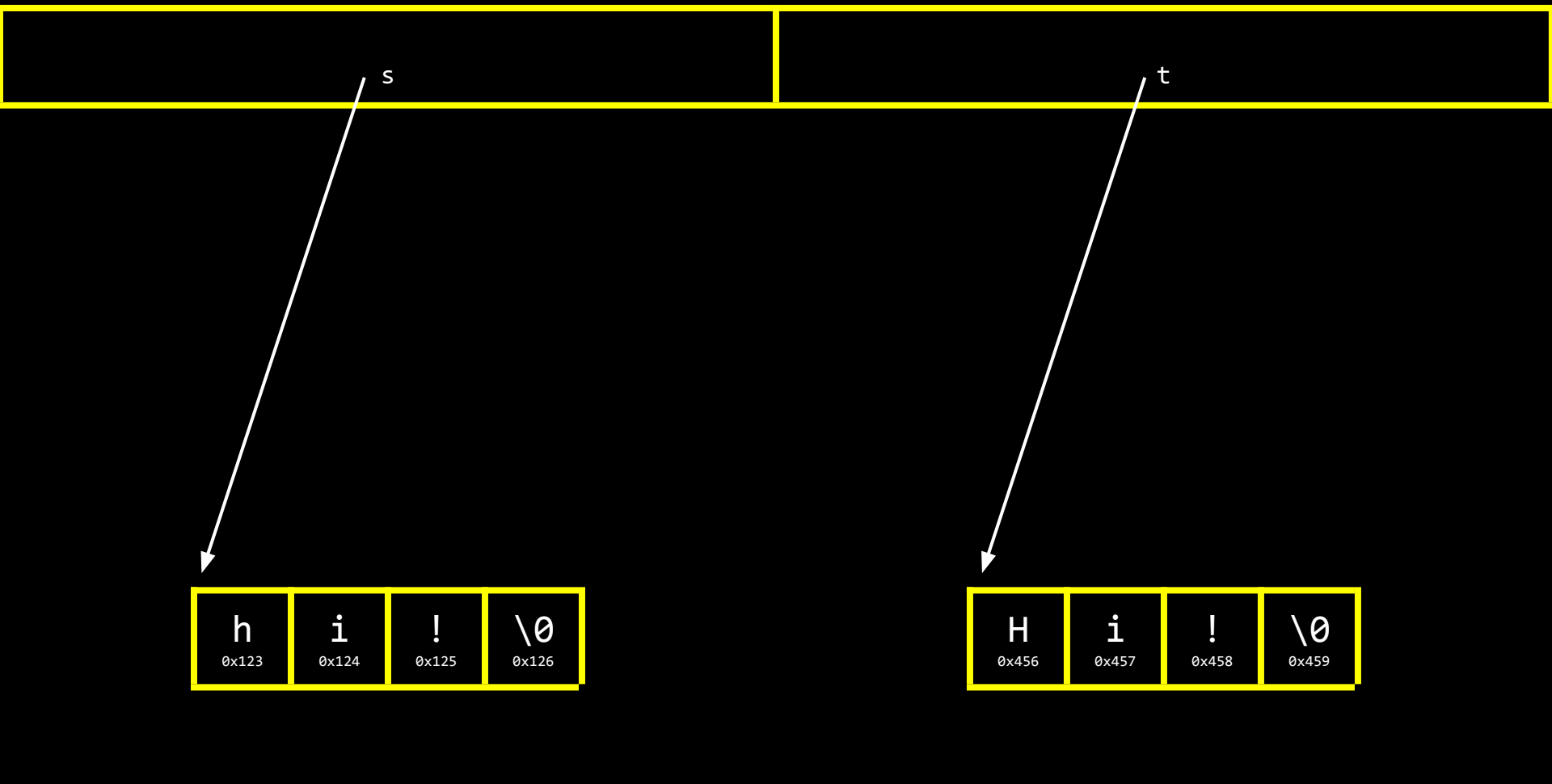

s
t
h
0x123
i
0x124
!
0x125
\0
0x126
0x456
0x457
0x458
0x459


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


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


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


s
t
h
0x123
i
0x124
!
0x125
\0
0x126
h
0x456
i
0x457
!
0x458
\0
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;
}
```

```
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 = 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;
}
```

```
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;
}
```


42

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



}
```

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

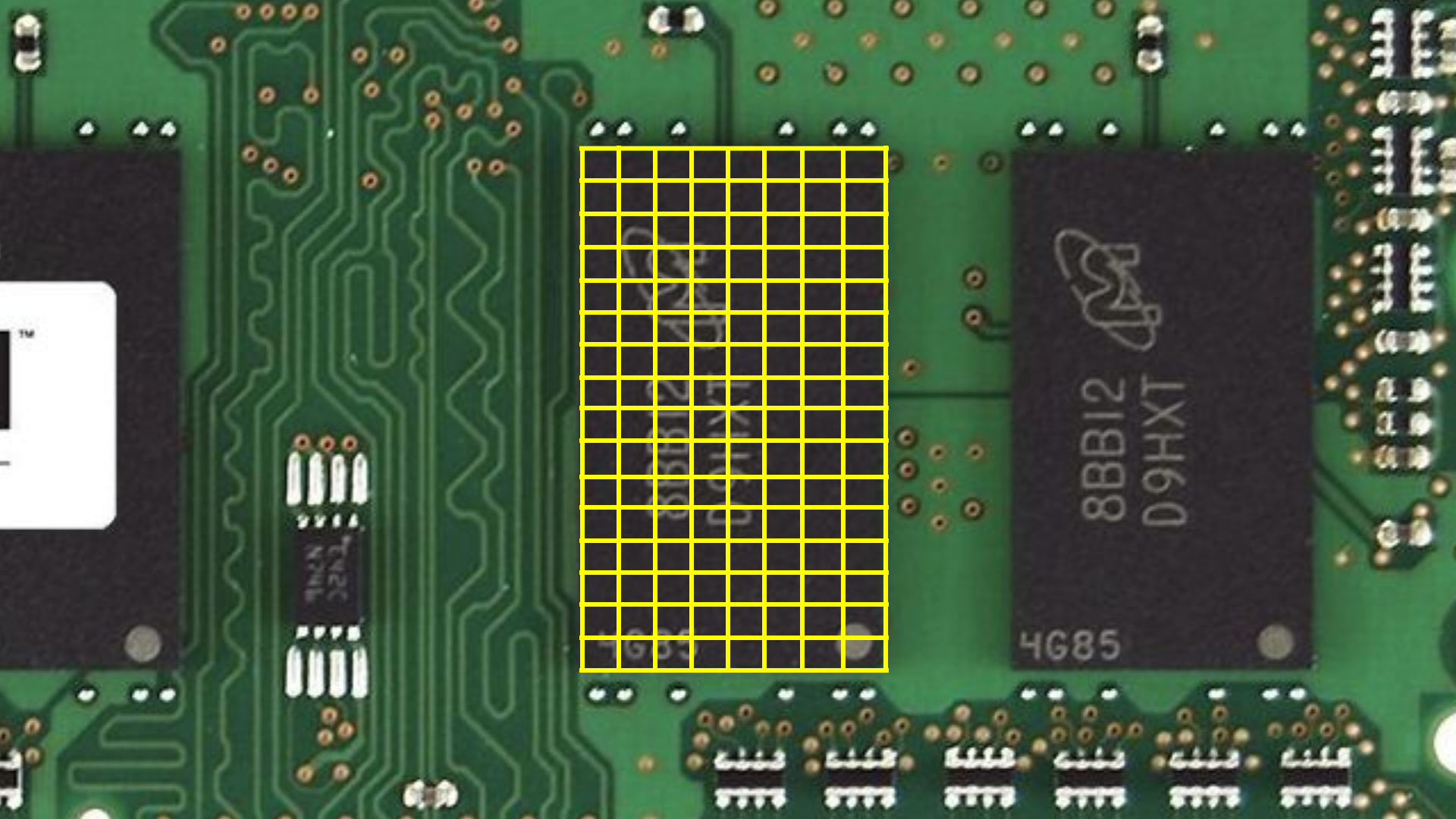
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

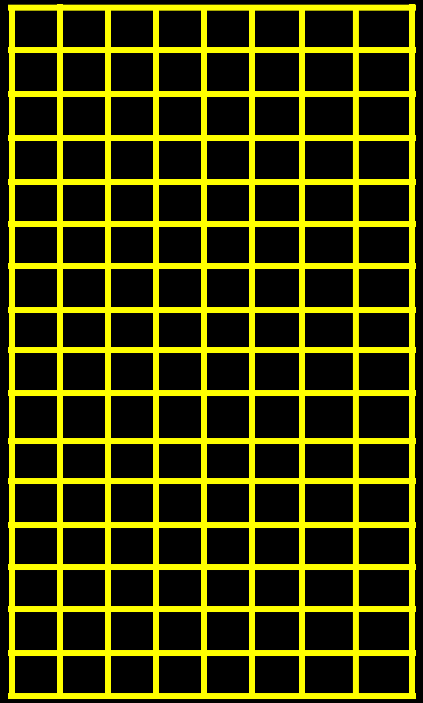
scope

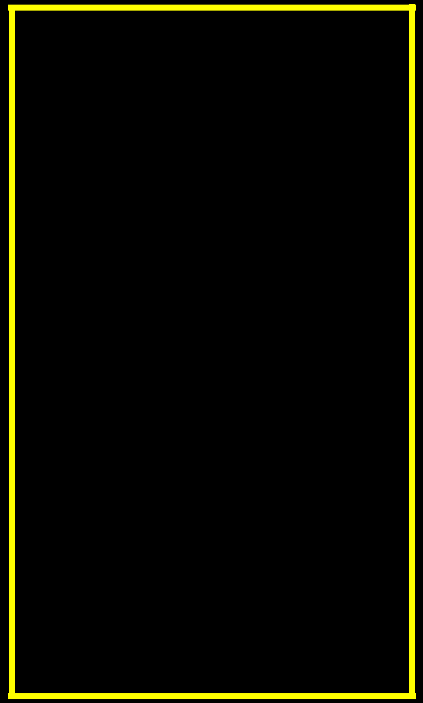
passing by value

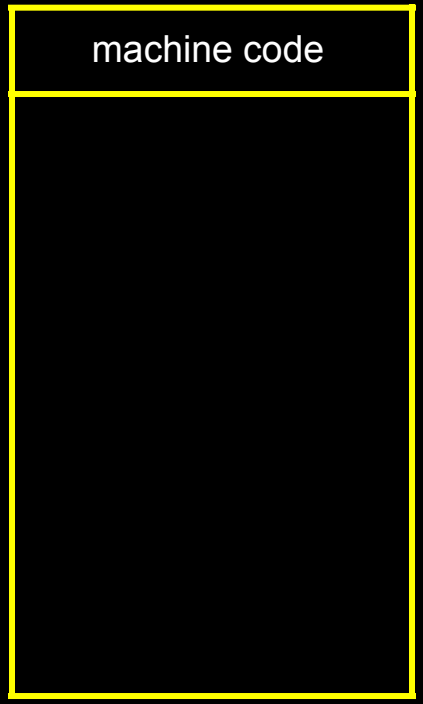

crucial
by Micron
8BBI2
D9HXT
8BBI2
D9HXT
4G85
4G85
4G85
47J6

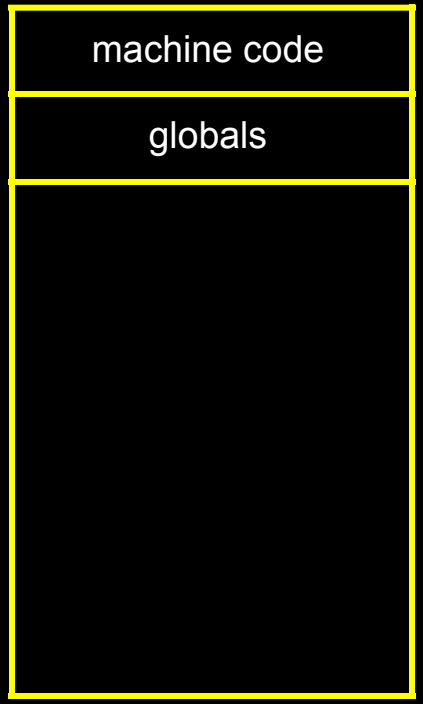

8BBI2
D9HXT
4G85
8BBI2
D9HXT
4G85

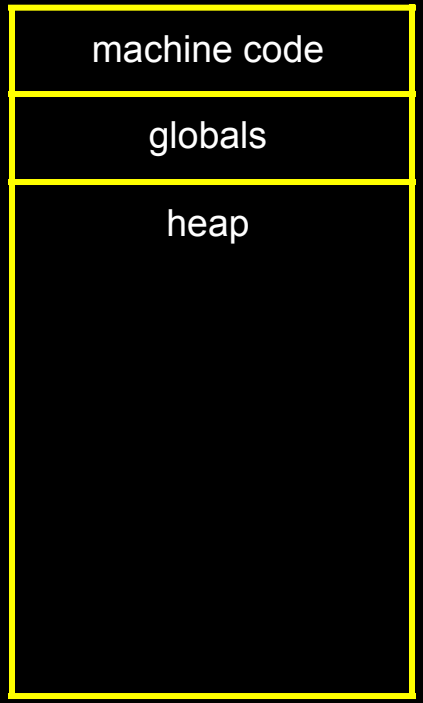

8BBI2
D9HXT
4G85

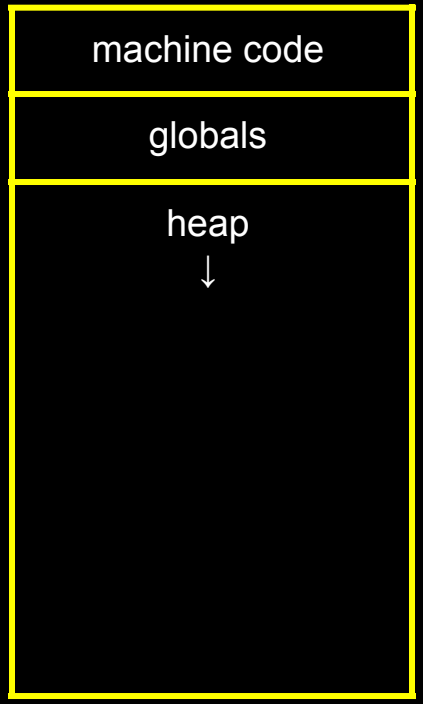


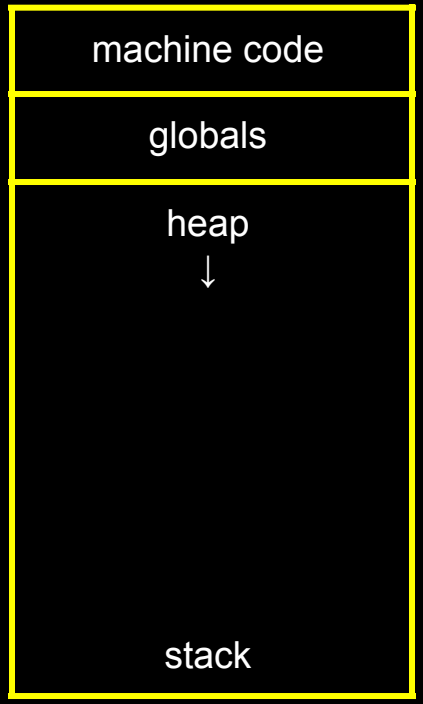


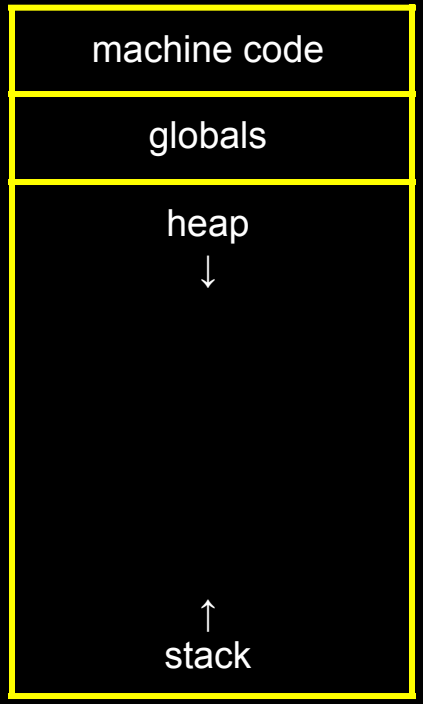

machine code

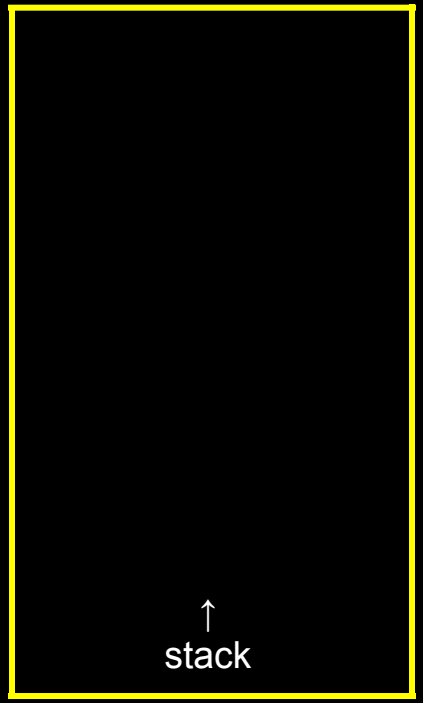

machine code
globals


machine code
globals
heap

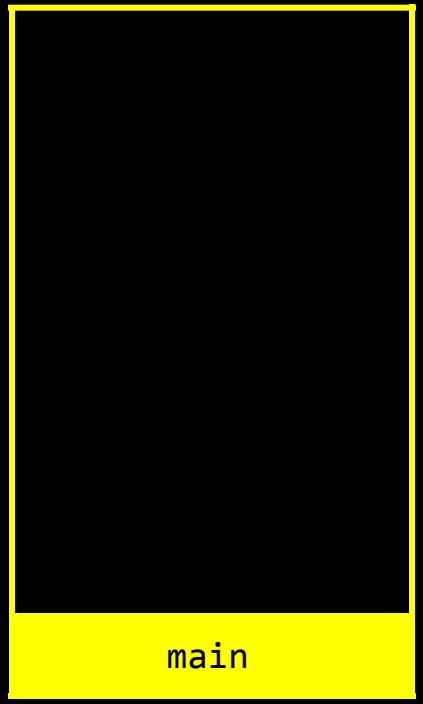

machine code
globals
heap
↓

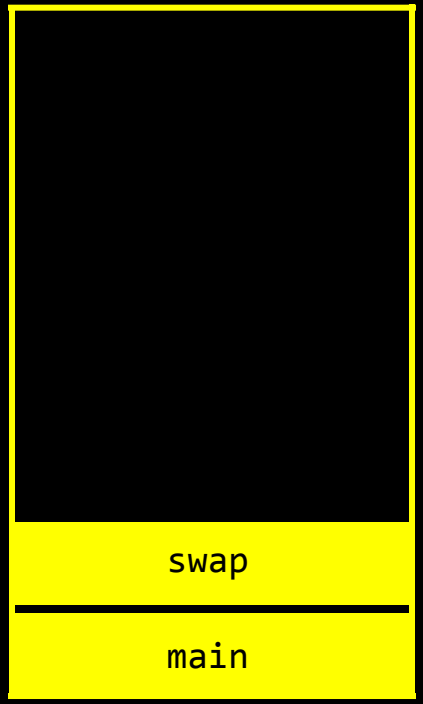

machine code
globals
heap
↓
stack

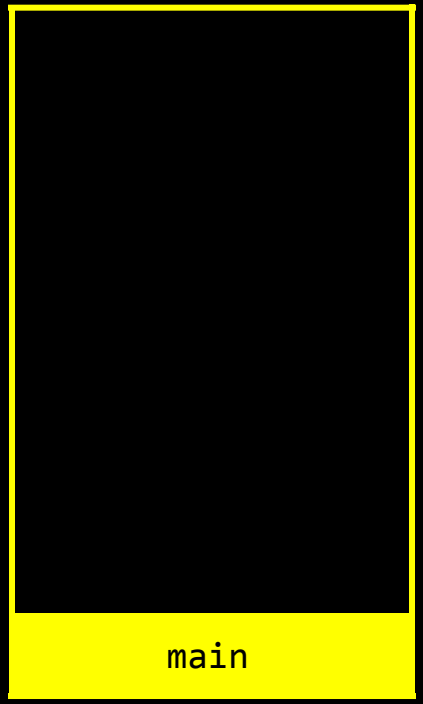

machine code
globals
heap
↓
↑
stack

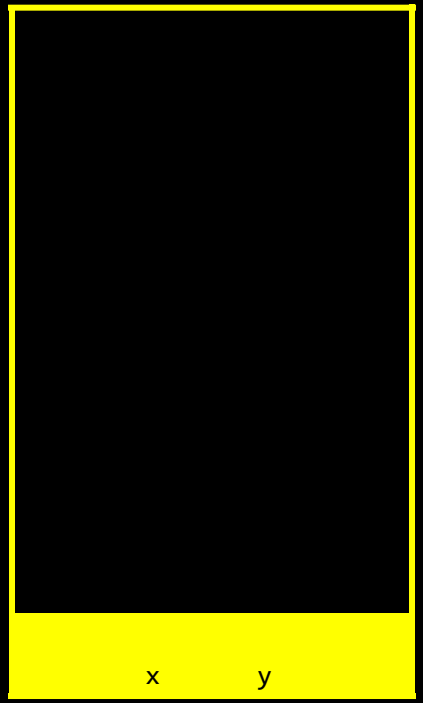

↑
stack

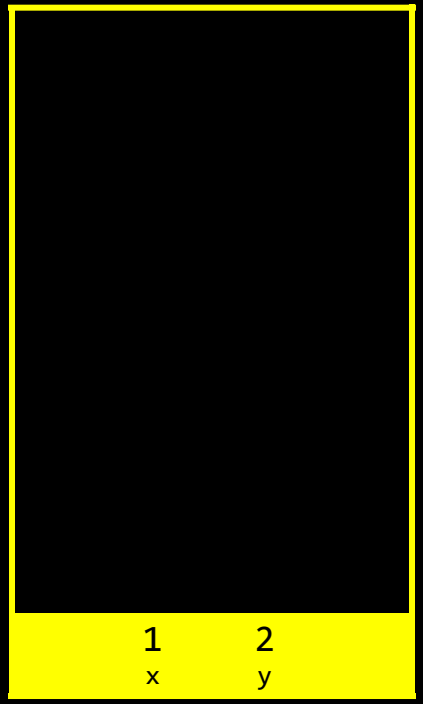
```
void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```

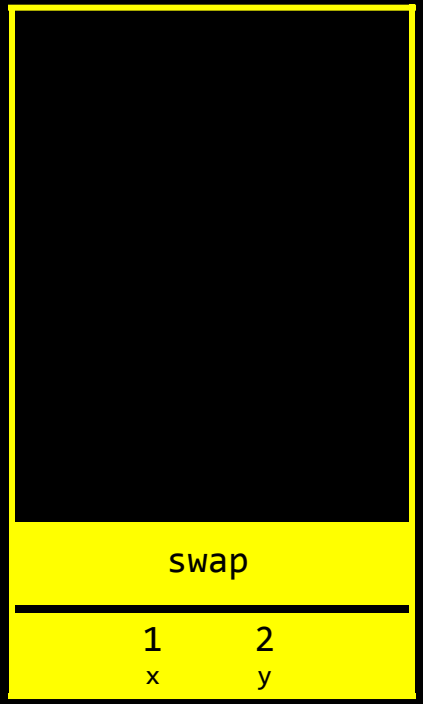

main

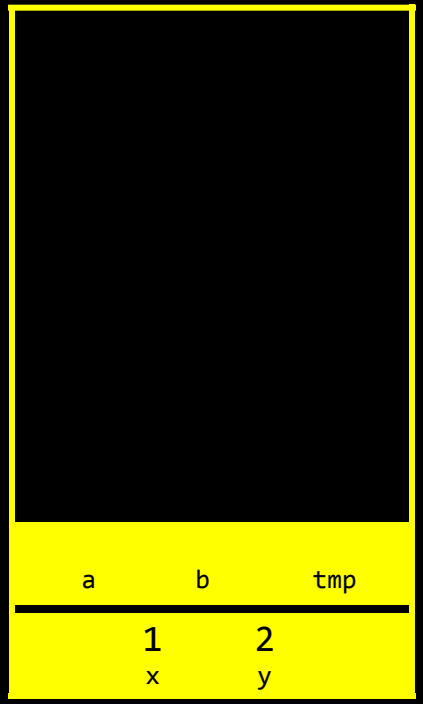

swap
main

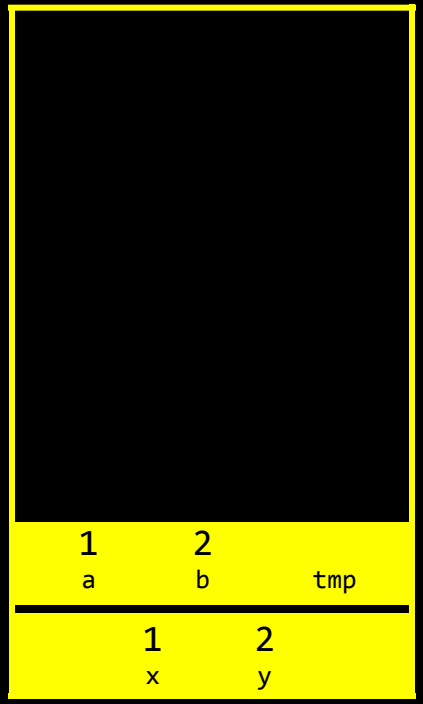

main


x
y

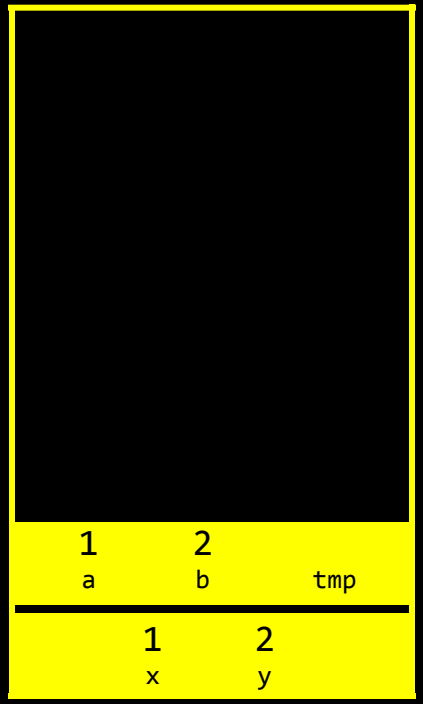

1
x
2
y


swap
1
x
2
y

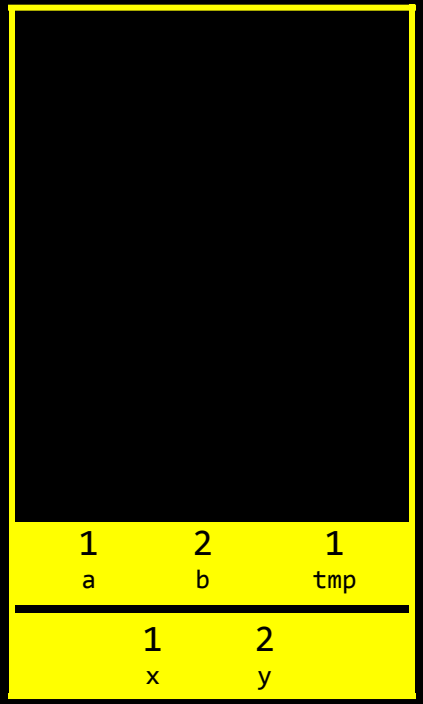

a
b
tmp
1
2
x
y


1
a
2
b
tmp
1
x
2
y

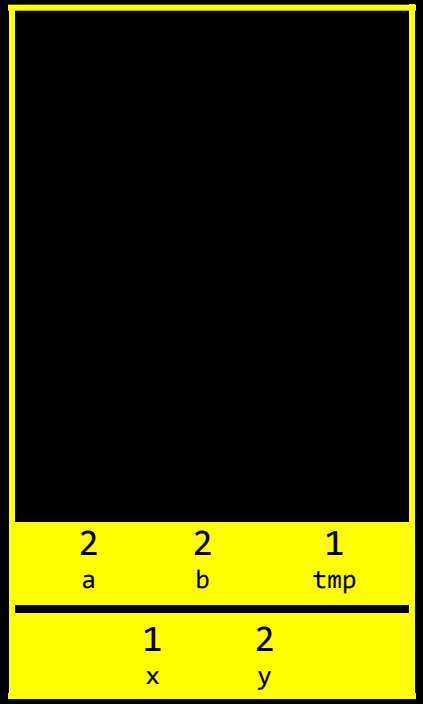
```
int tmp = a;
a = b;
b = tmp;
```



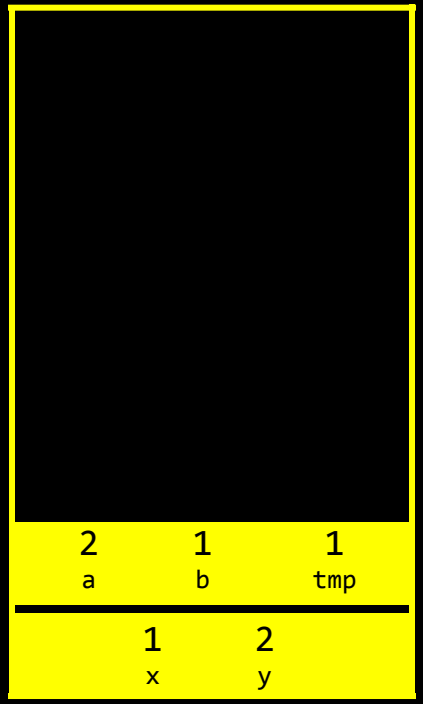
```
int tmp = a;
a = b;
b = tmp;
```

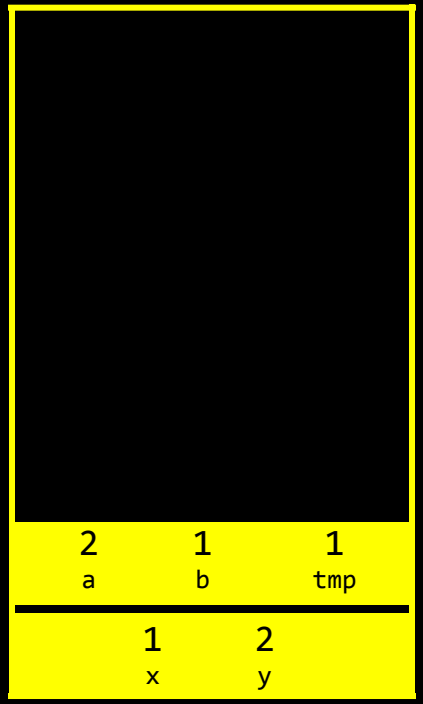


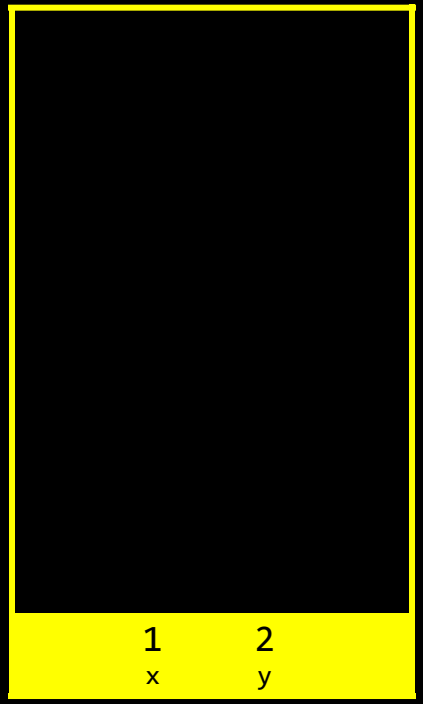
```
int tmp = a;
a = b;
b = tmp;
```



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




2
a
1
b
1
tmp
1
x
2
y

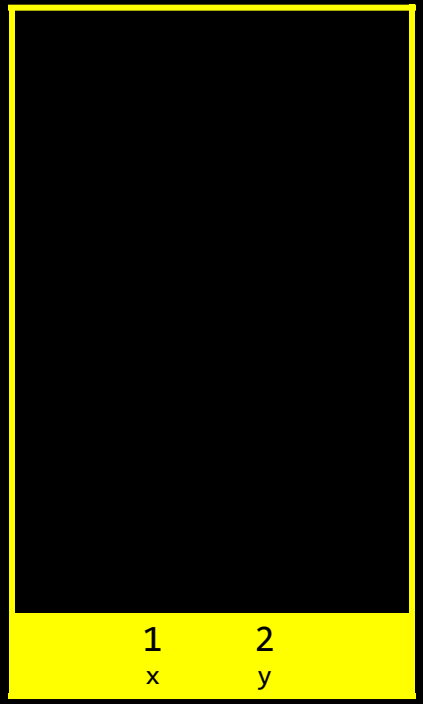

1
x
2
y

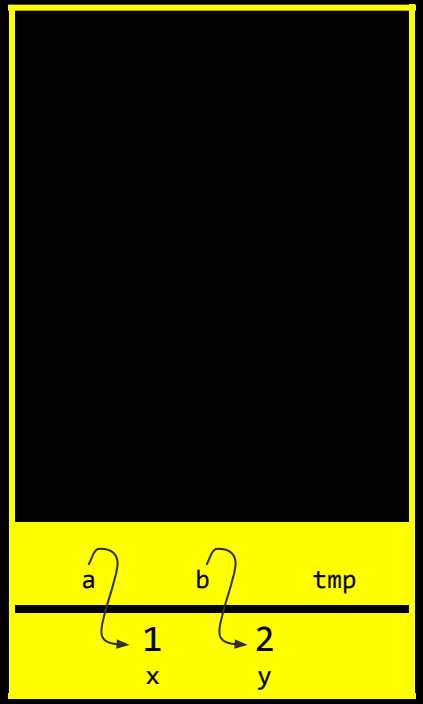
passing by reference

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

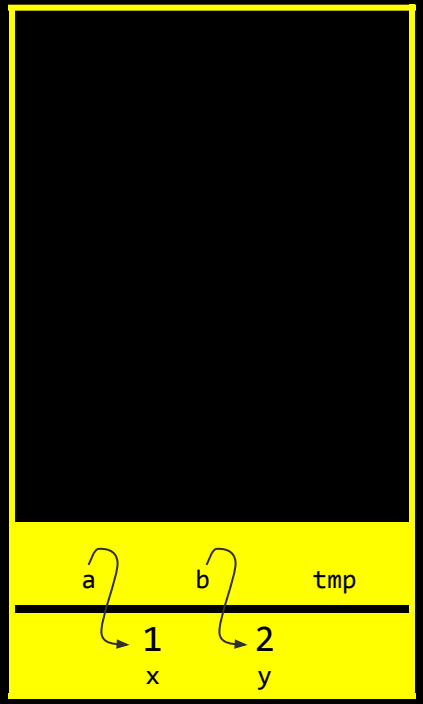
```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```

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

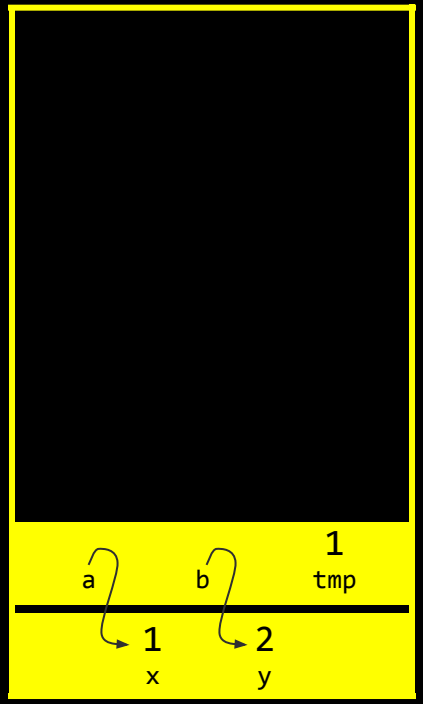

1
x
2
y


a
b
tmp
1
2
x
y

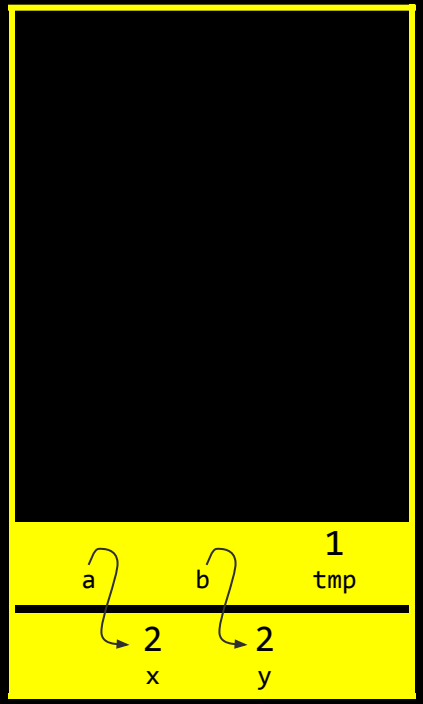
```
int tmp = *a;
*a = *b;
*b = tmp;
```



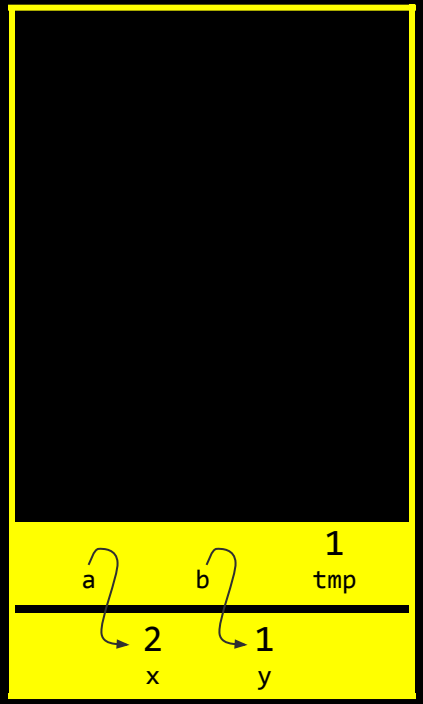
```
int tmp = *a;
*a = *b;
*b = tmp;
```

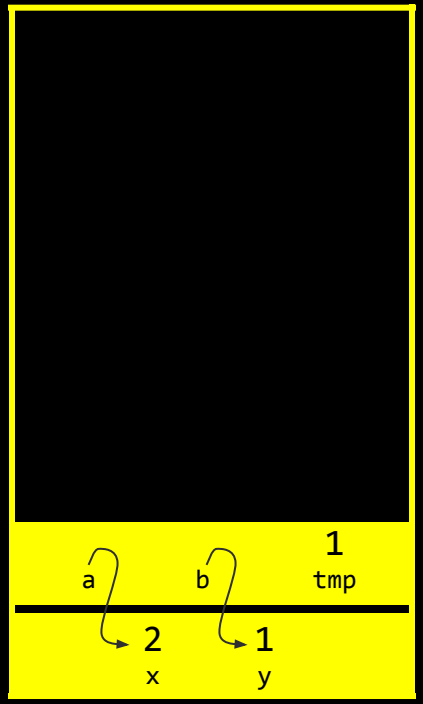


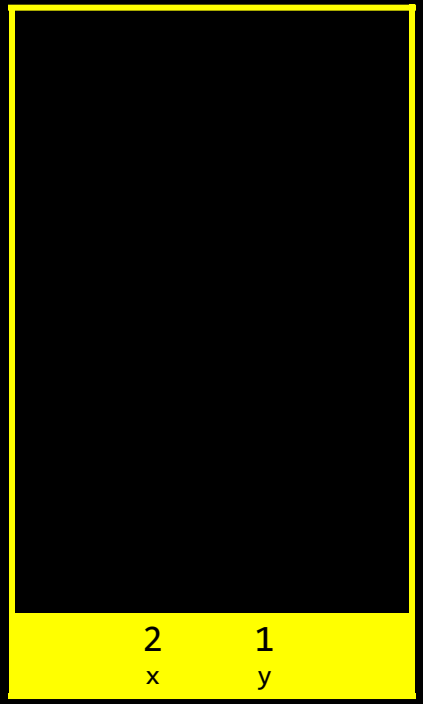
```
int tmp = *a;
*a = *b;
*b = tmp;
```



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

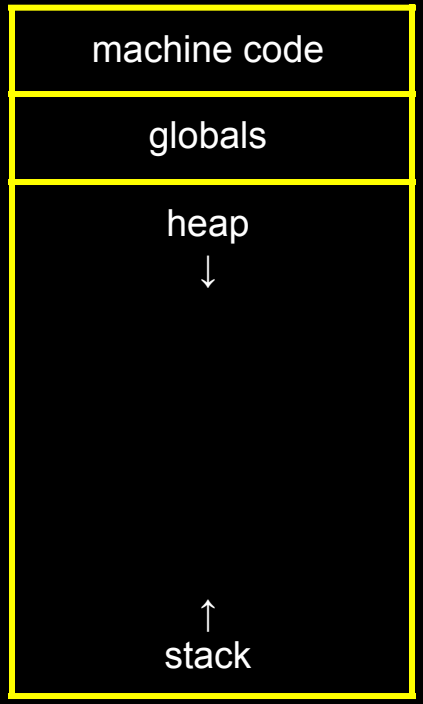


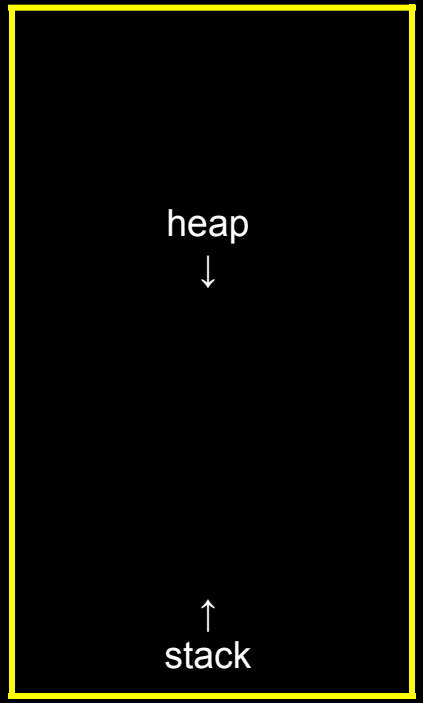

a
b
1
tmp
2
x
1
y


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


CROWDSTRIKE

"Sensors that received the new version of Channel File 291 carrying the problematic content were exposed to a latent out-of-bounds read issue in the Content Interpreter. At the next IPC notification from the operating system, the new IPC Template Instances were evaluated, specifying a comparison against the 21st input value. The Content Interpreter expected only 20 values. Therefore, the attempt to access the 21st value produced an out-of-bounds memory read beyond the end of the input data array and resulted in a system crash."

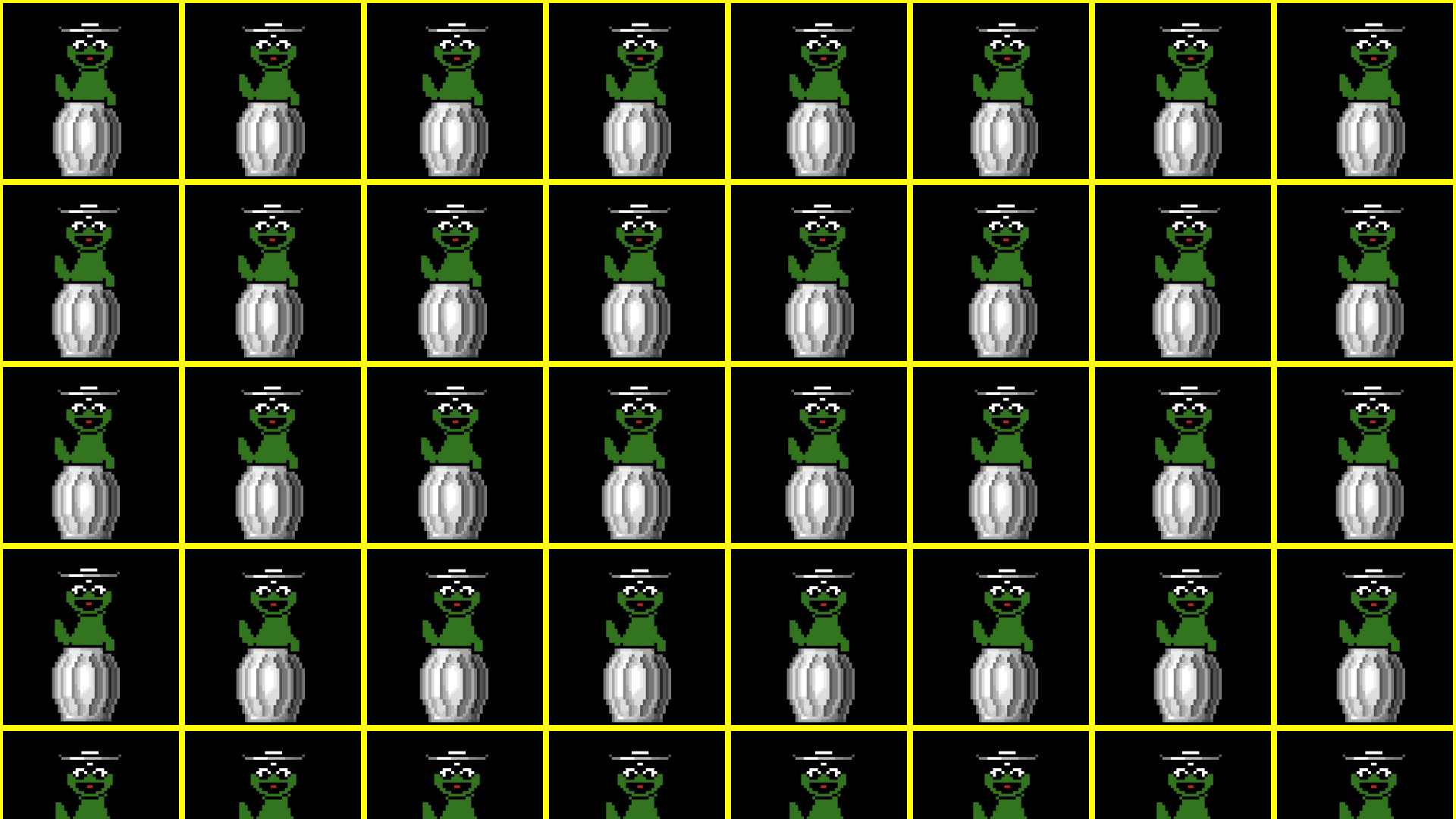
"Sensors that received the new version of Channel File 291 carrying the problematic content were exposed to a latent out-of-bounds read issue in the Content Interpreter. At the next IPC notification from the operating system, the new IPC Template Instances were evaluated, specifying a comparison against the 21st input value. The Content Interpreter expected only 20 values. Therefore, the attempt to access the 21st value produced an out-of-bounds memory read beyond the end of the input data array and resulted in a system crash."

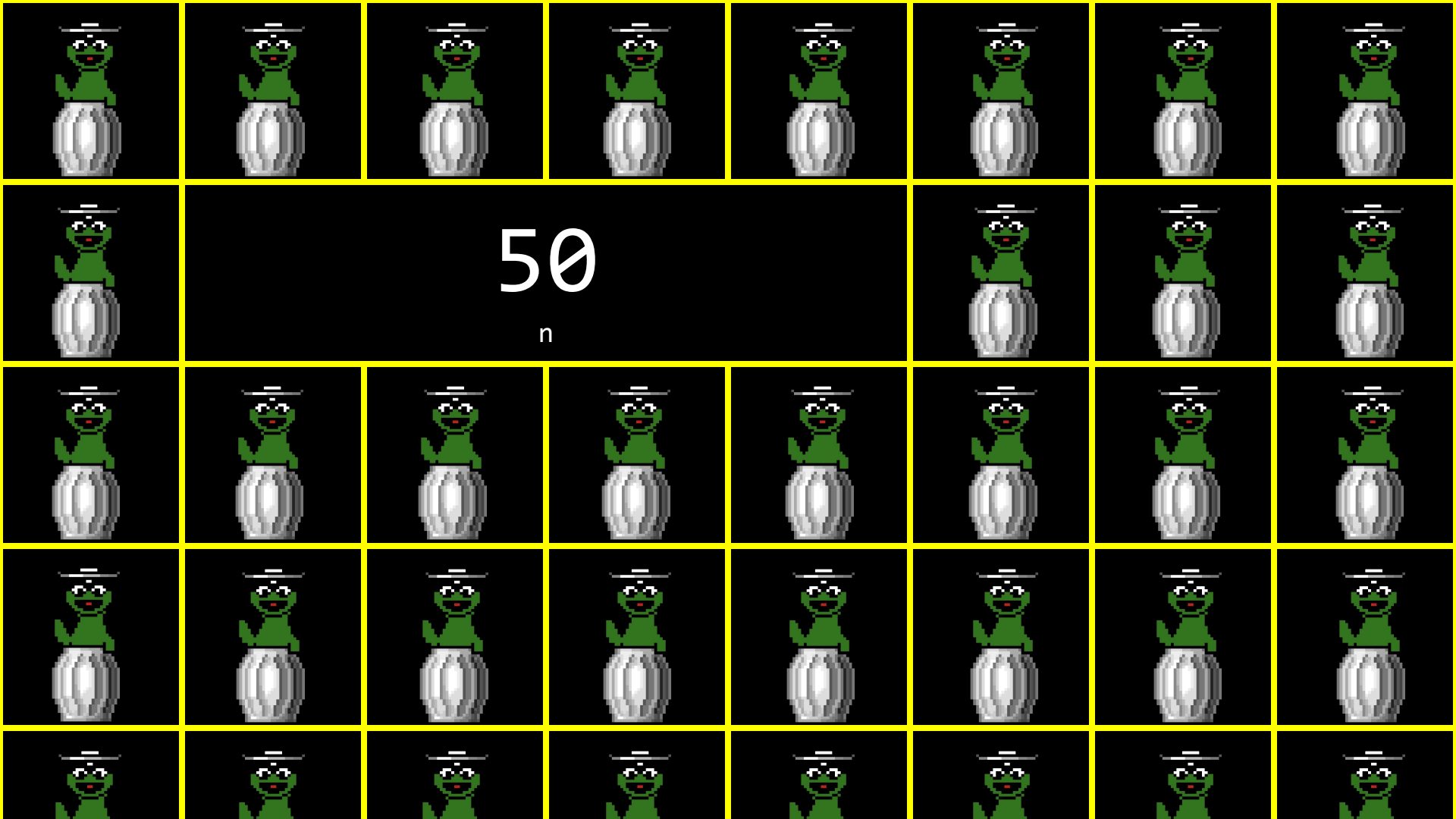
```
get_char

get_double

get_float

get_int

get_long

get_string

...
```

```
get_int
```

scanf

...

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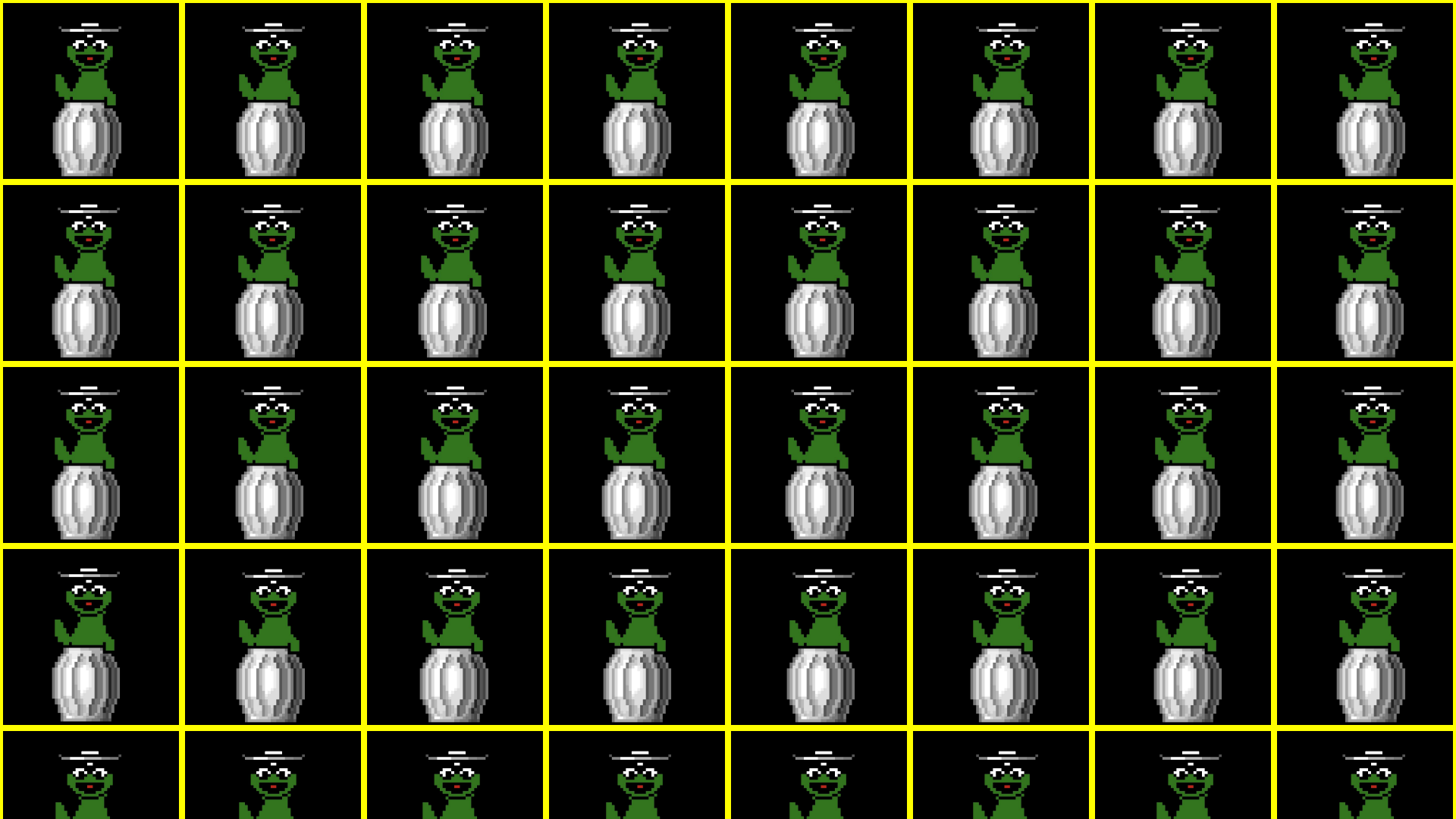

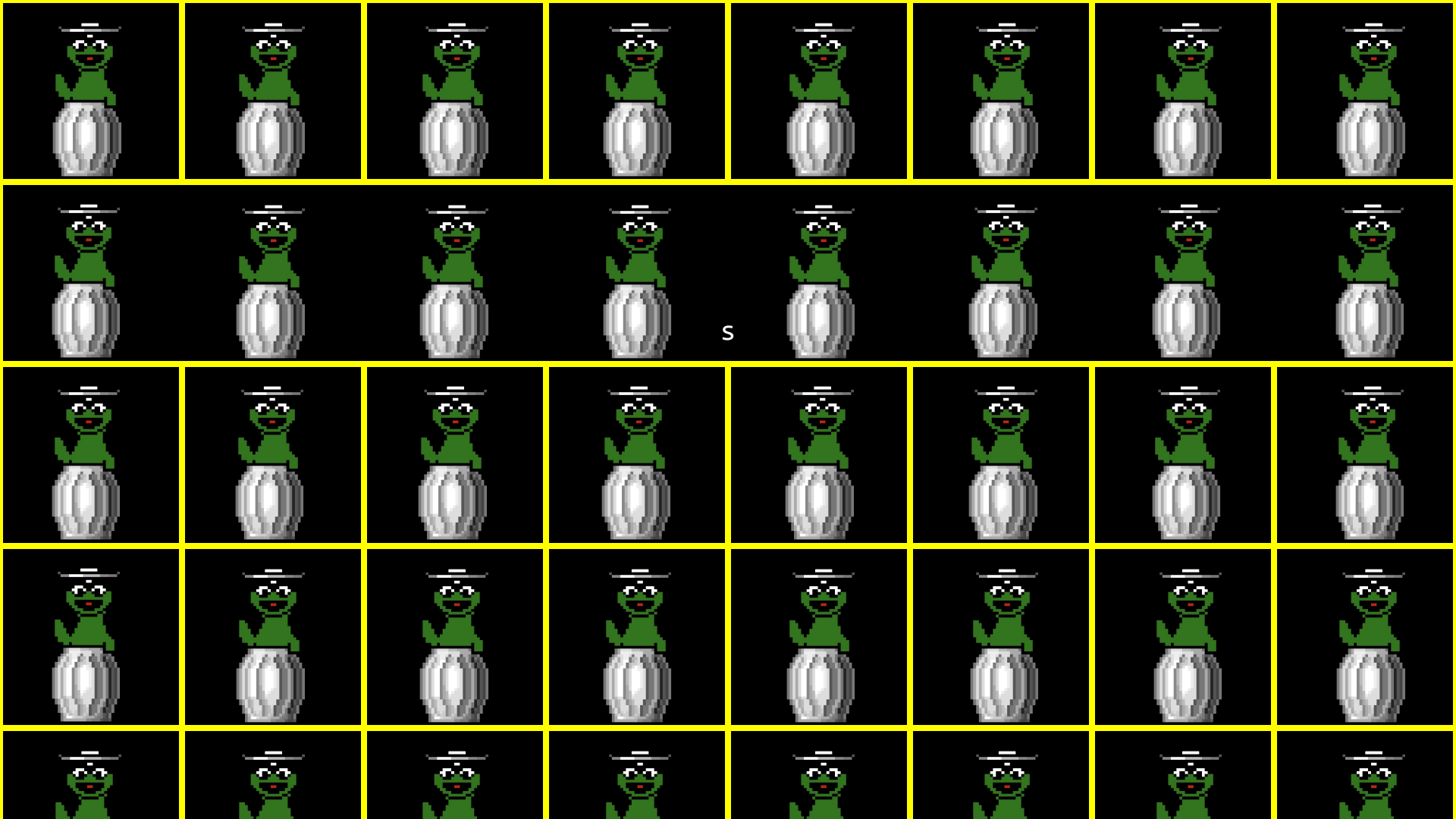
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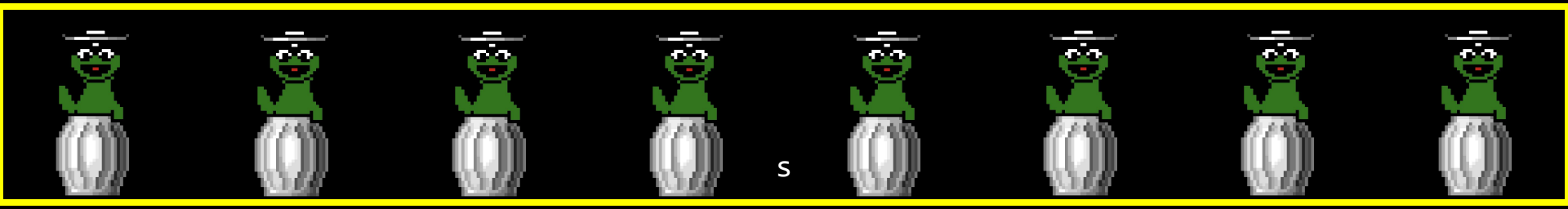
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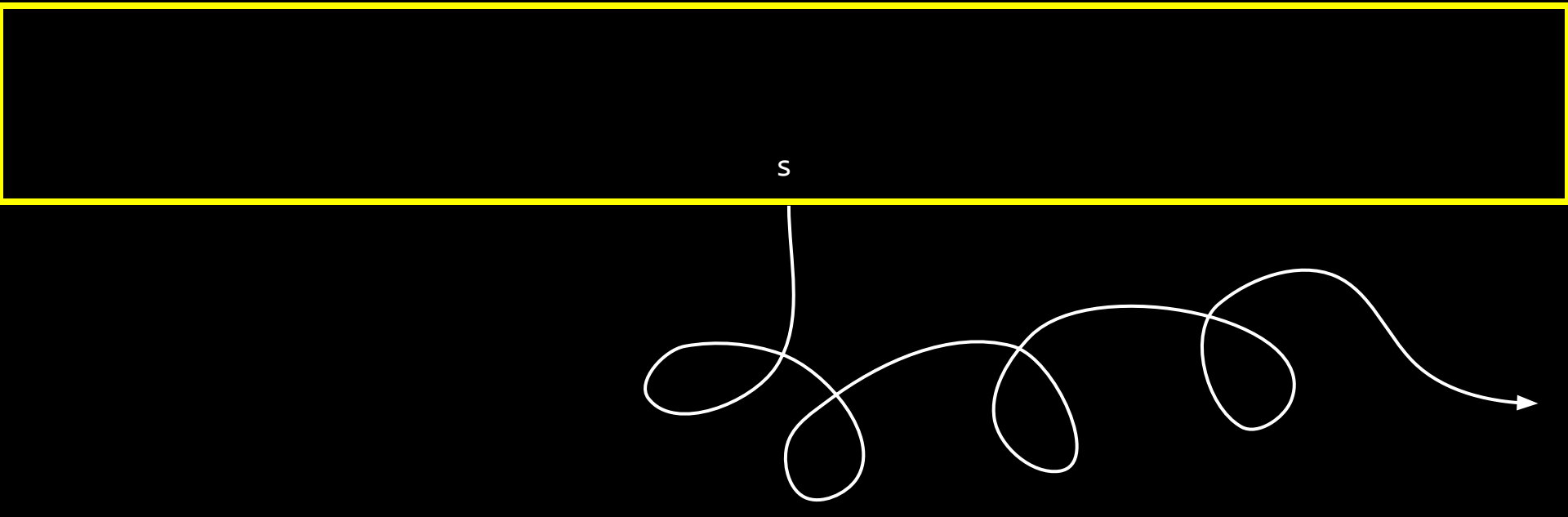
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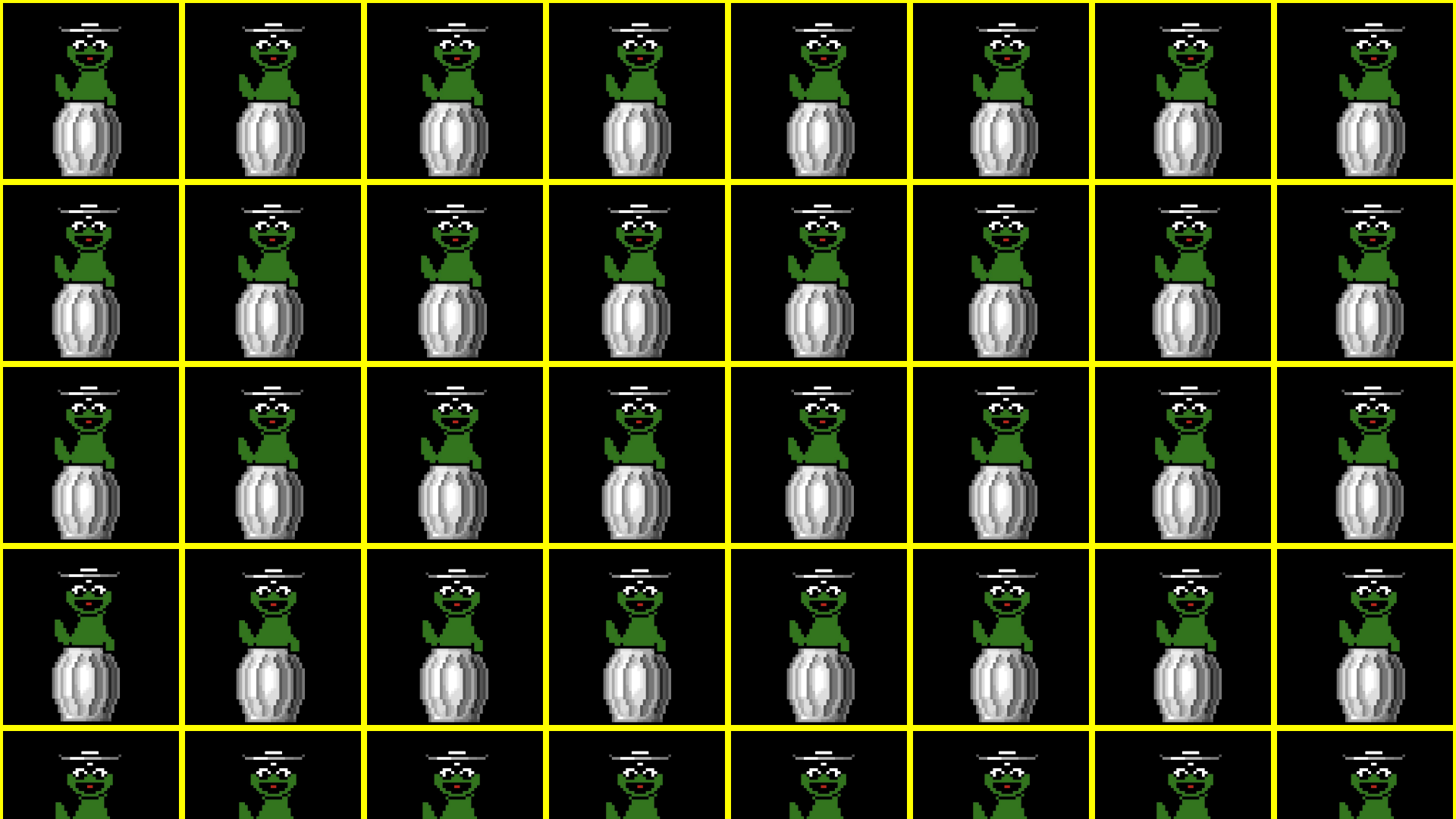

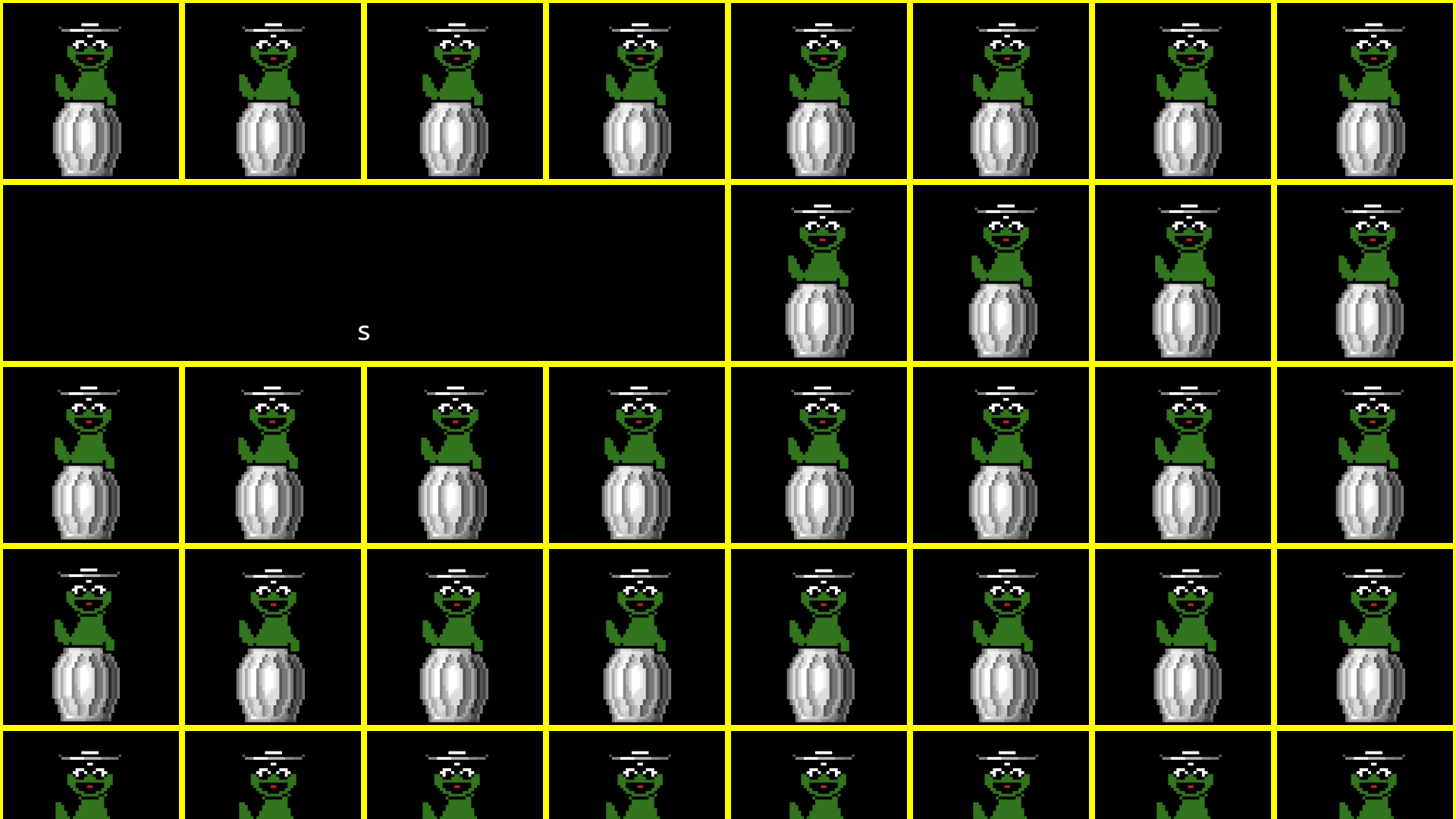
S

file I/O

```
fopen

fclose

fprintf

fscanf

fread

fwrite

fseek

…
```

BMP


MAN, I SUCK AT THIS GAME. CAN YOU GIVE ME A FEW POINTERS?
0x3A28213A
0x6339392C,
0x7363682E.
I HATE YOU.

This is CS50