This is CS50.

cs50.brianyu.me

Week 4

- Hexadecimal
- Pointers
- Dynamic Memory
- Memory Layout
- File I/O

What questions do you have?

Today

Pointers

Files and Dynamic Memory

Lab

Part One

Pointers

Types

`int`	Integer
`char`	Character

Types

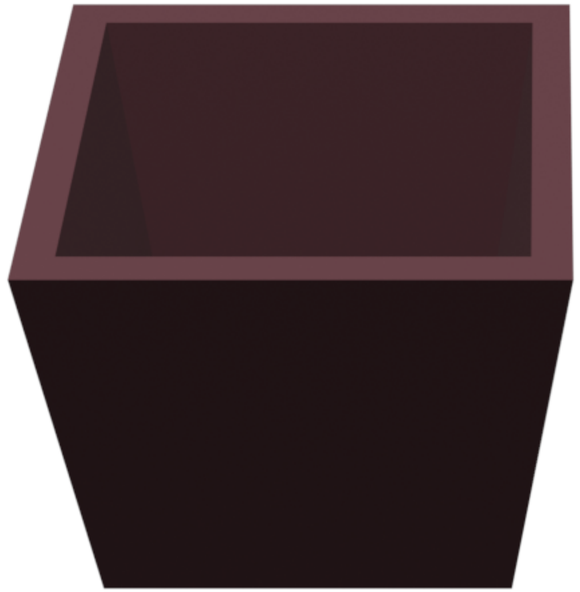
`int *`	Address of an Integer
`char *`	Address of a Character

Pointers

- `type *` is a pointer that stores the address of a `type`
- `*x` takes a pointer `x` and goes to that address
- `&x` takes `x` and gets its address

```
int a = 28;
```

```
int a = 28;
```



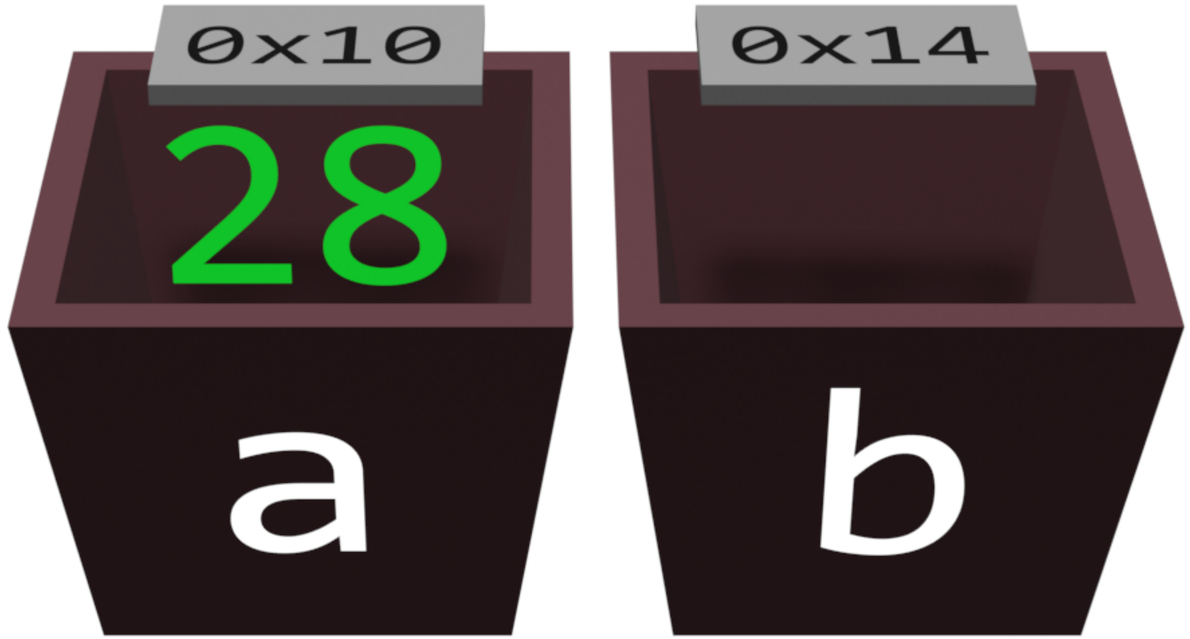
```
int a = 28;
```

```
int a = 28;
```

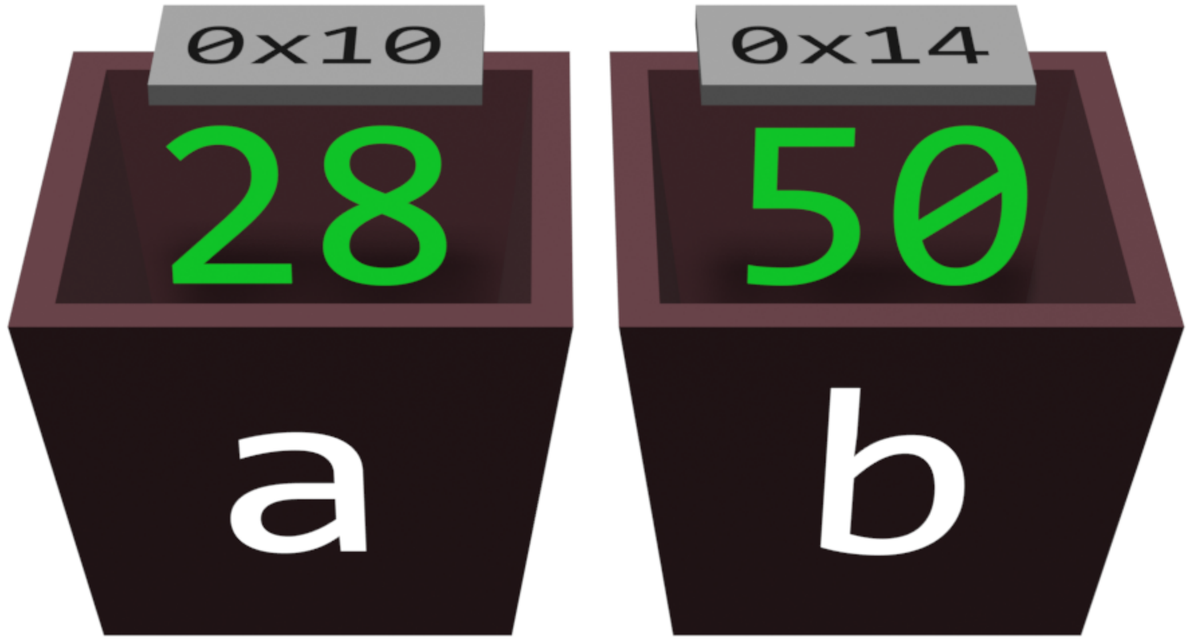
```
int a = 28;
```

```
int a = 28;

int b = 50;
```

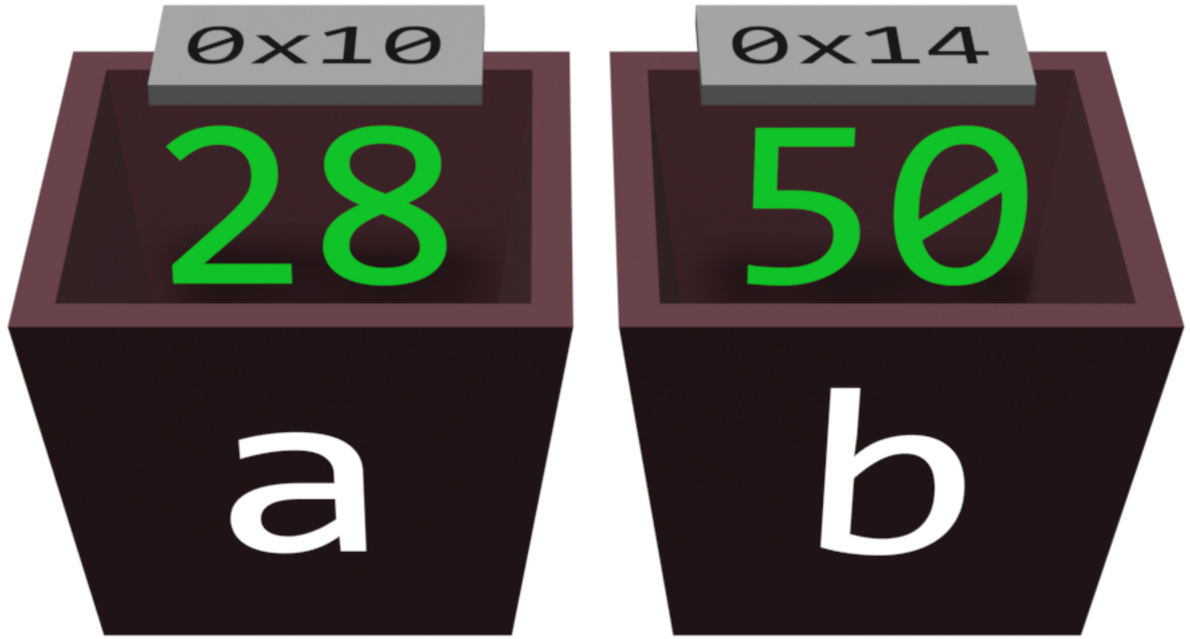
```
int a = 28;

int b = 50;
```



```
int a = 28;

int b = 50;
```



```
int a = 28;

int b = 50;

int *c = &a;
```



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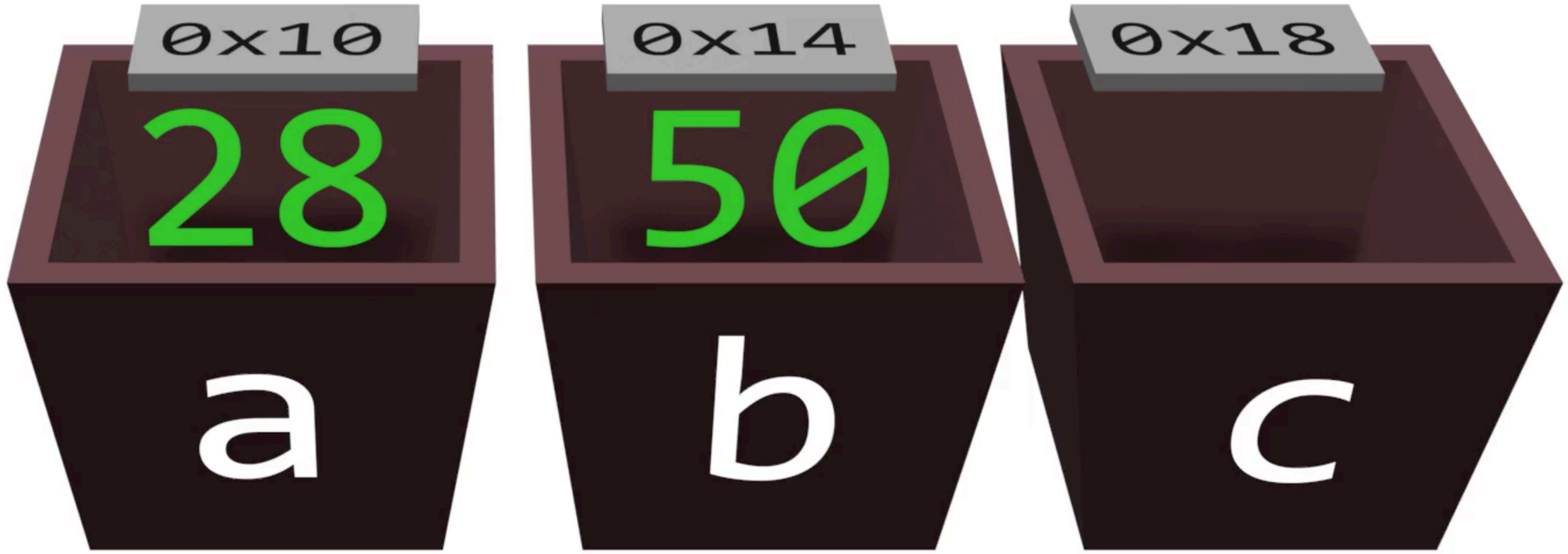
int b = 50;

int *c = &a;
```

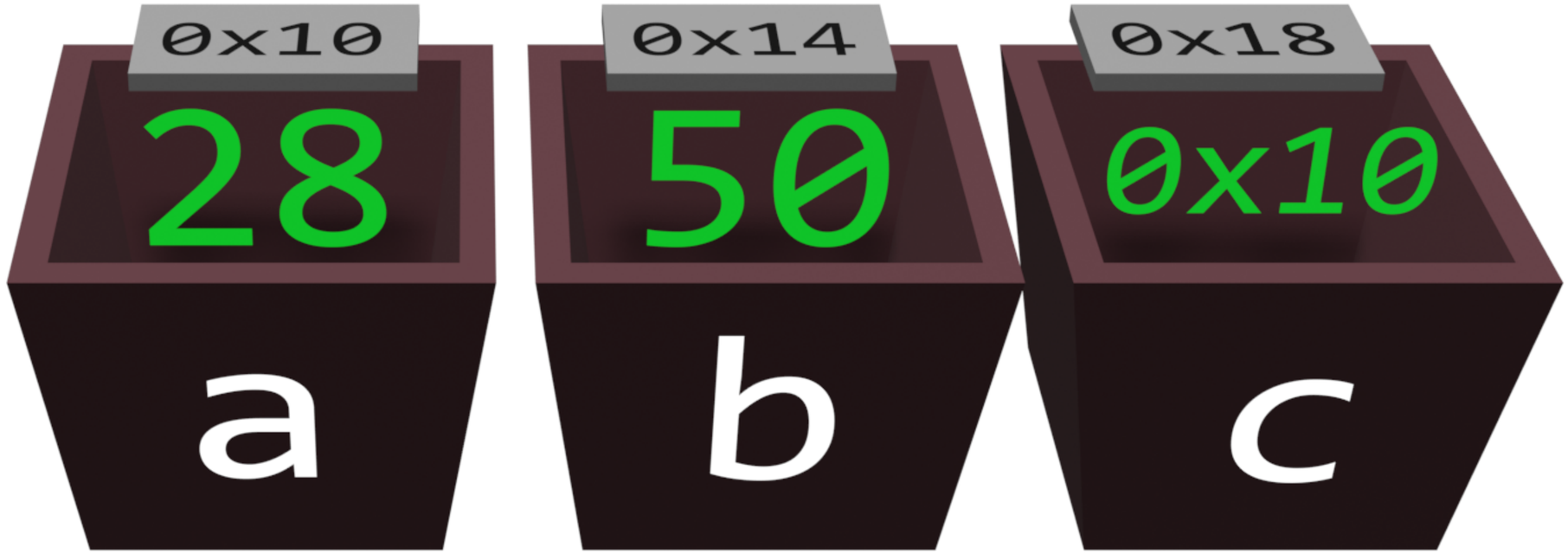


```
int a = 28;

int b = 50;

int *c = &a;

*c = 14;
```

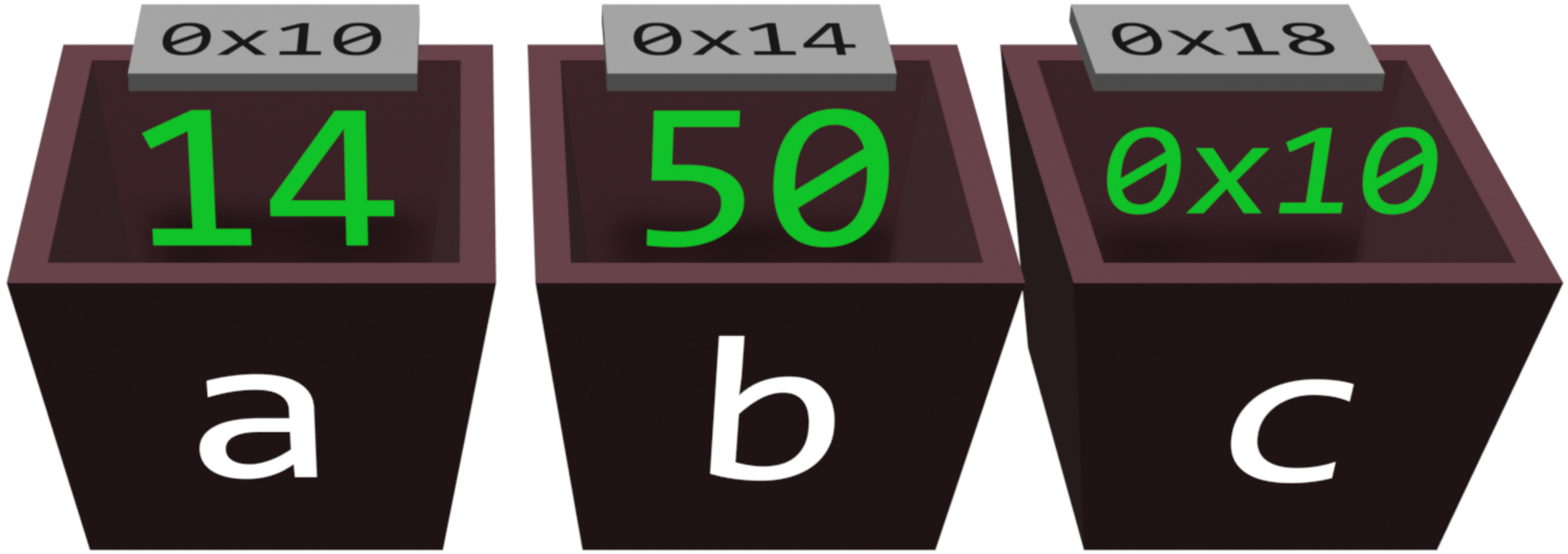


```
int a = 28;

int b = 50;

int *c = &a;

*c = 14;
```



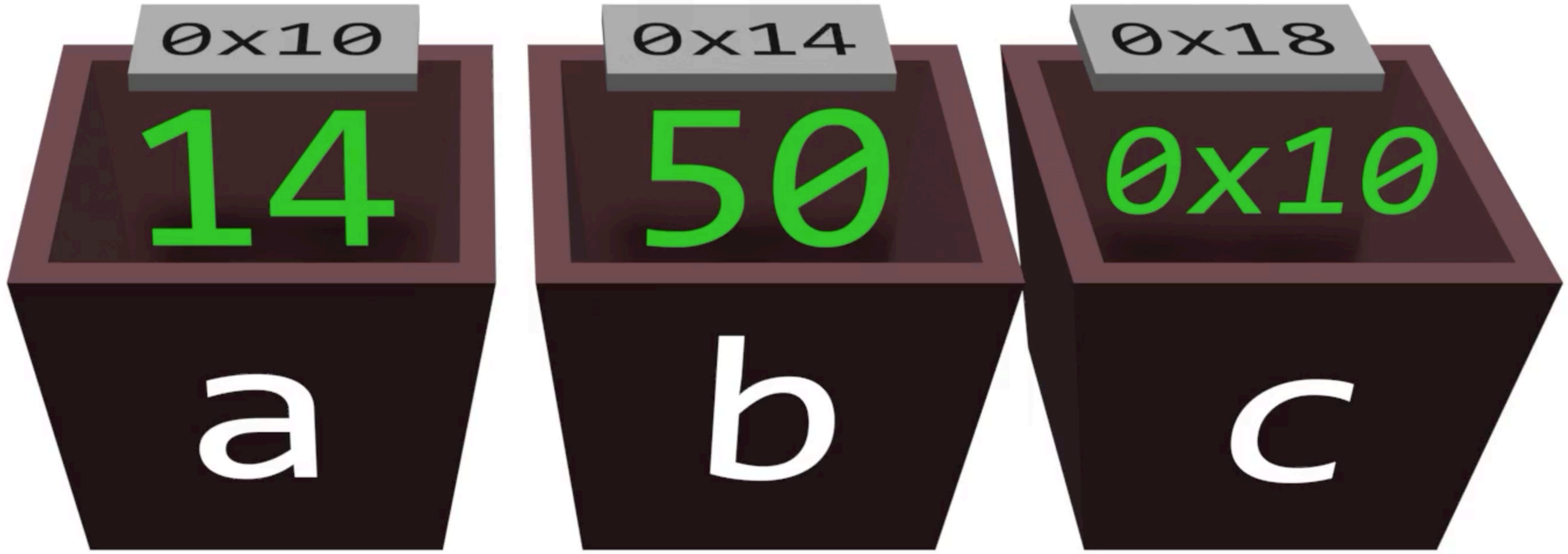
```
int a = 28;

int b = 50;

int *c = &a;

*c = 14;

c = &b;
```



```
int a = 28;

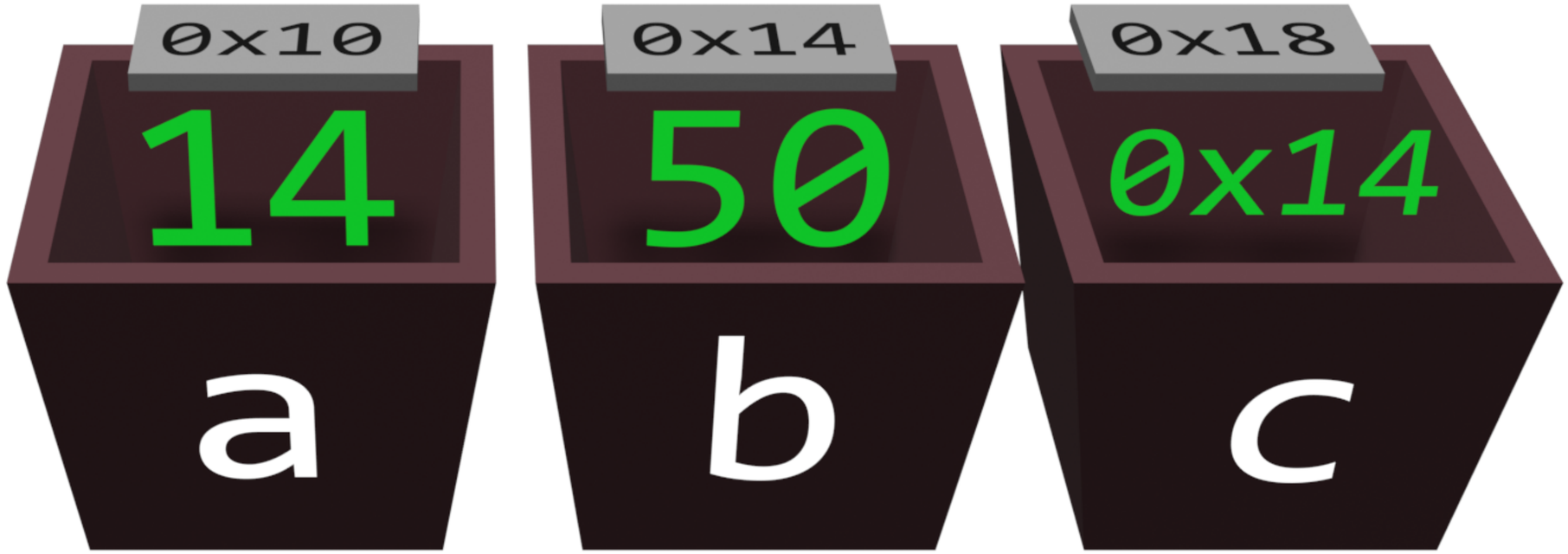
int b = 50;

int *c = &a;

*c = 14;

c = &b;

*c = 20;
```



```
int a = 28;

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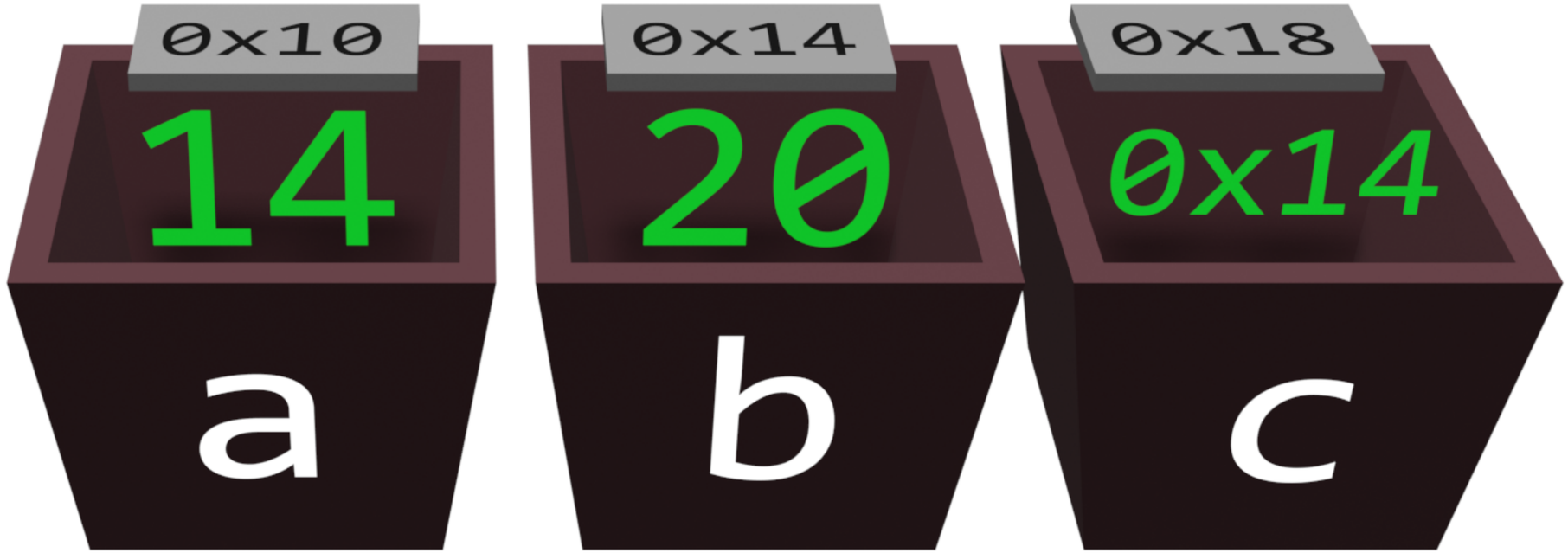
int *c = &a;

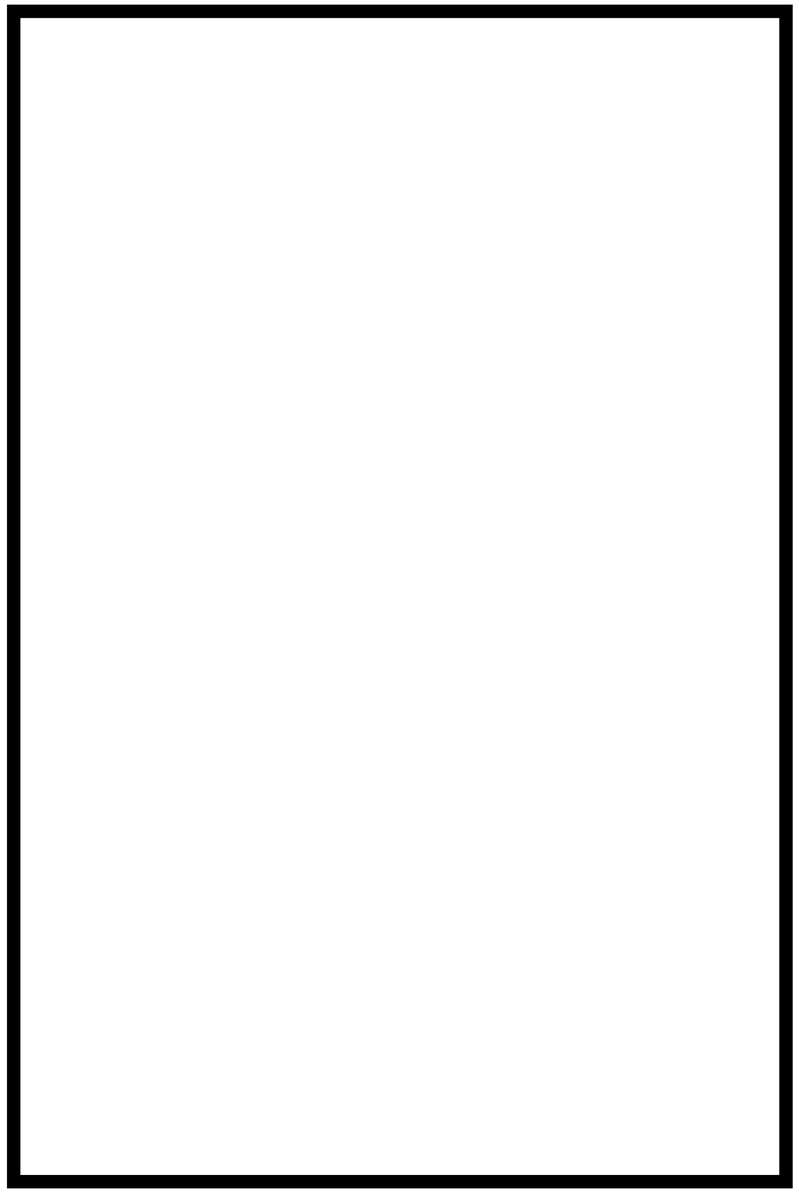
*c = 14;

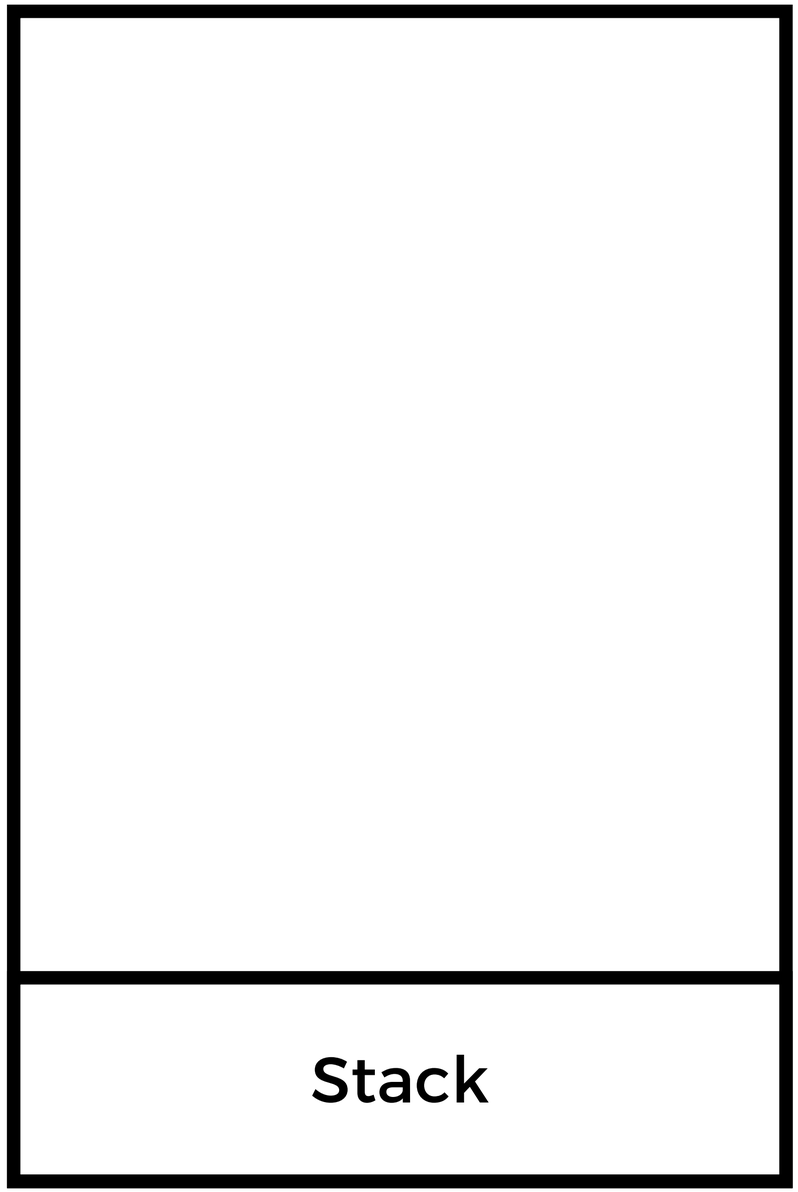
c = &b;

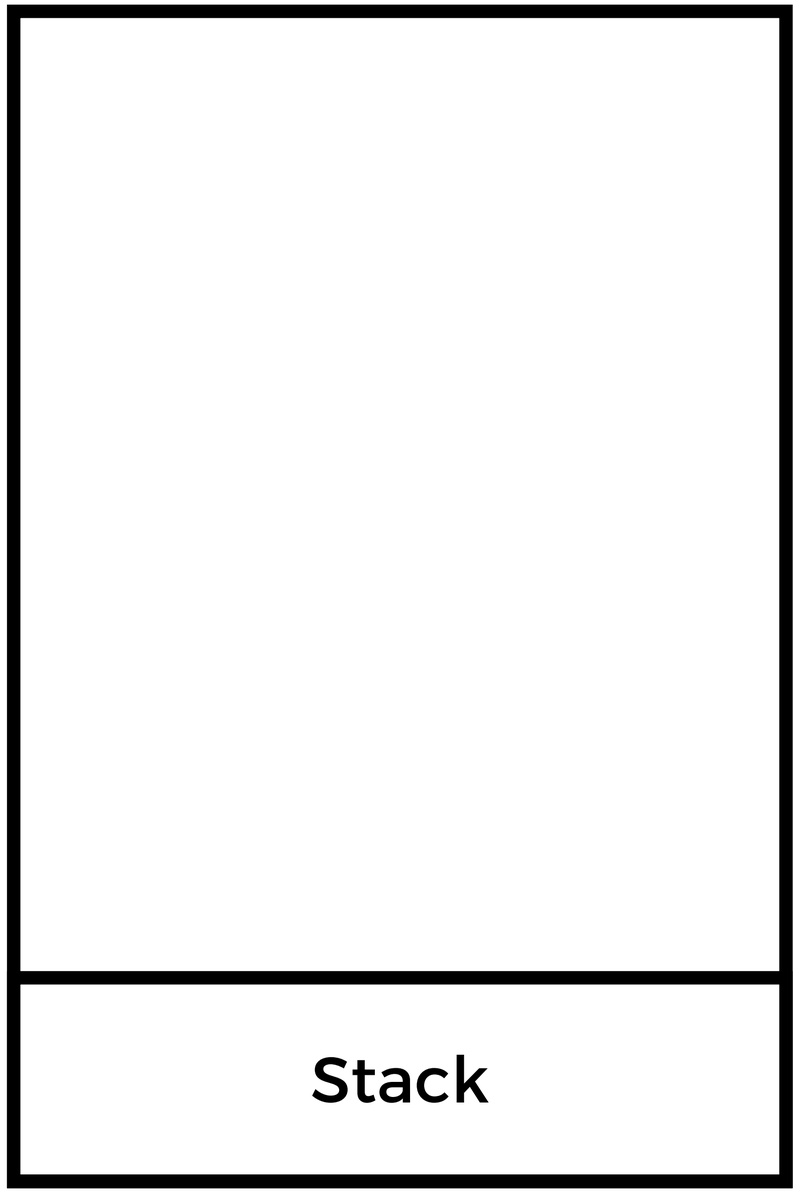
*c = 20;
```



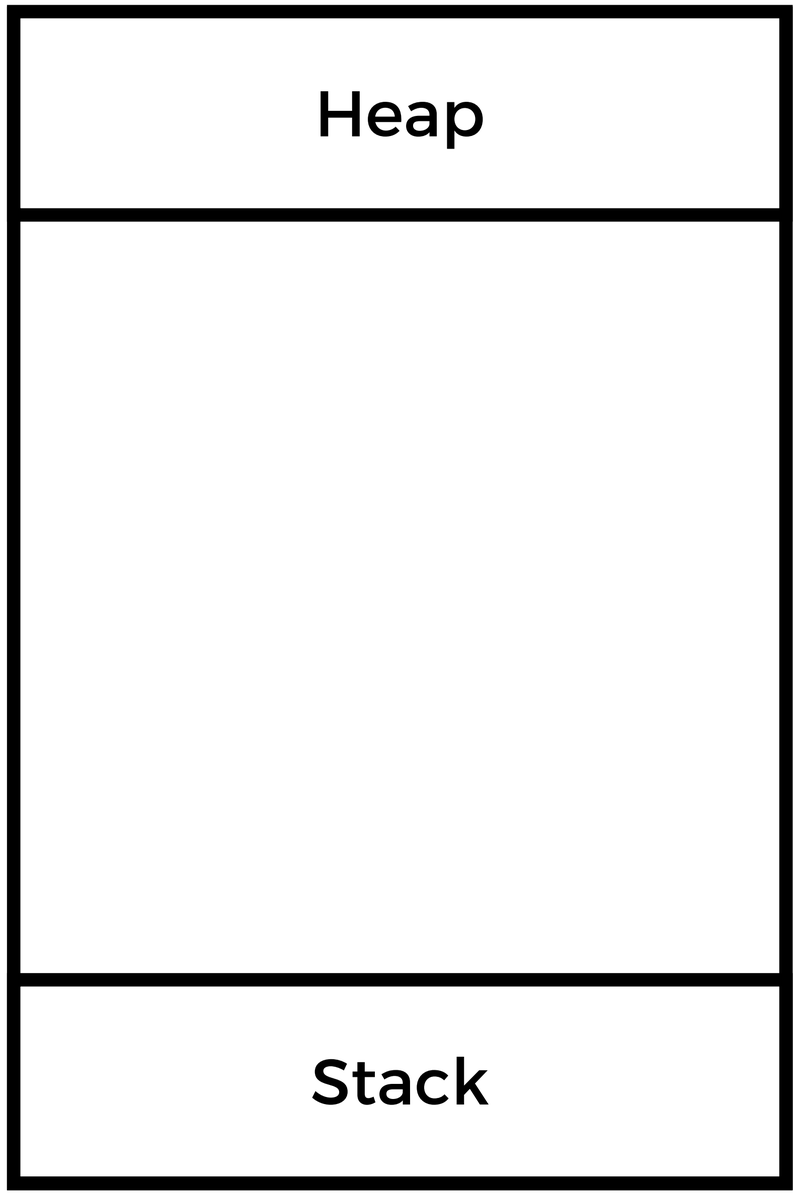
Memory Layout



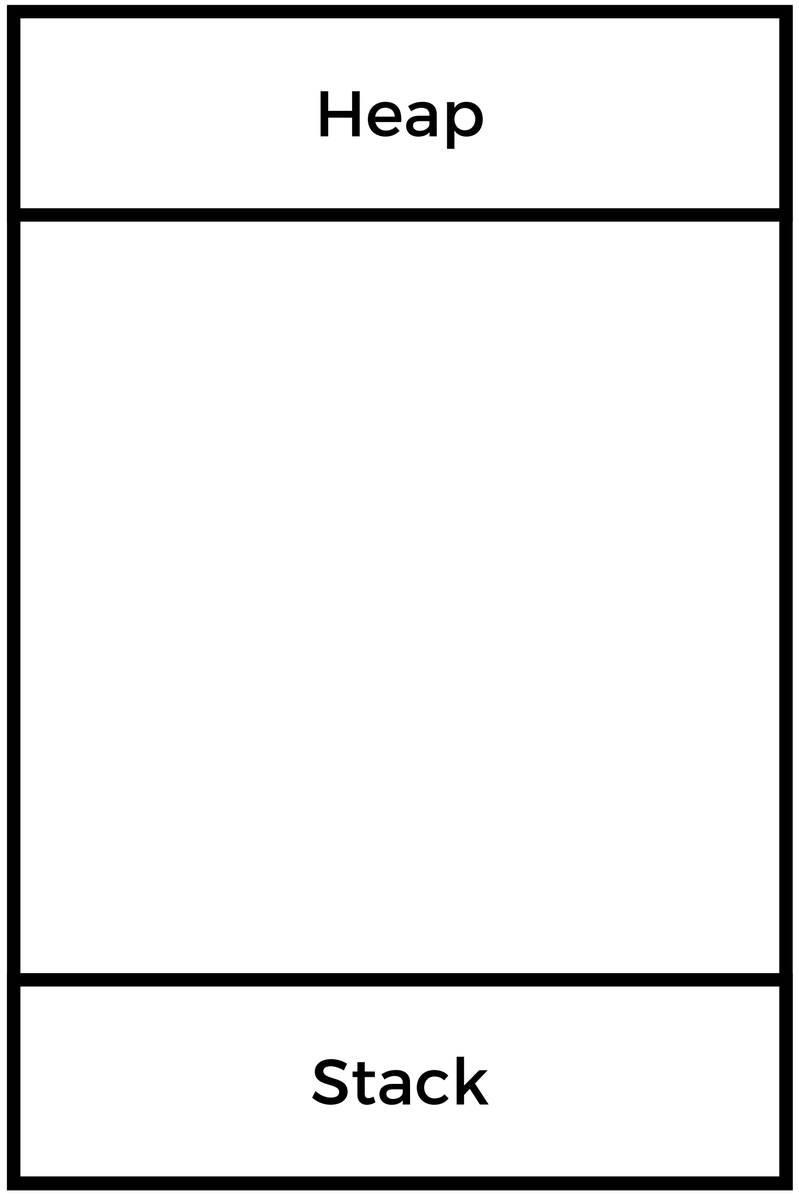

Stack



local variables and functions

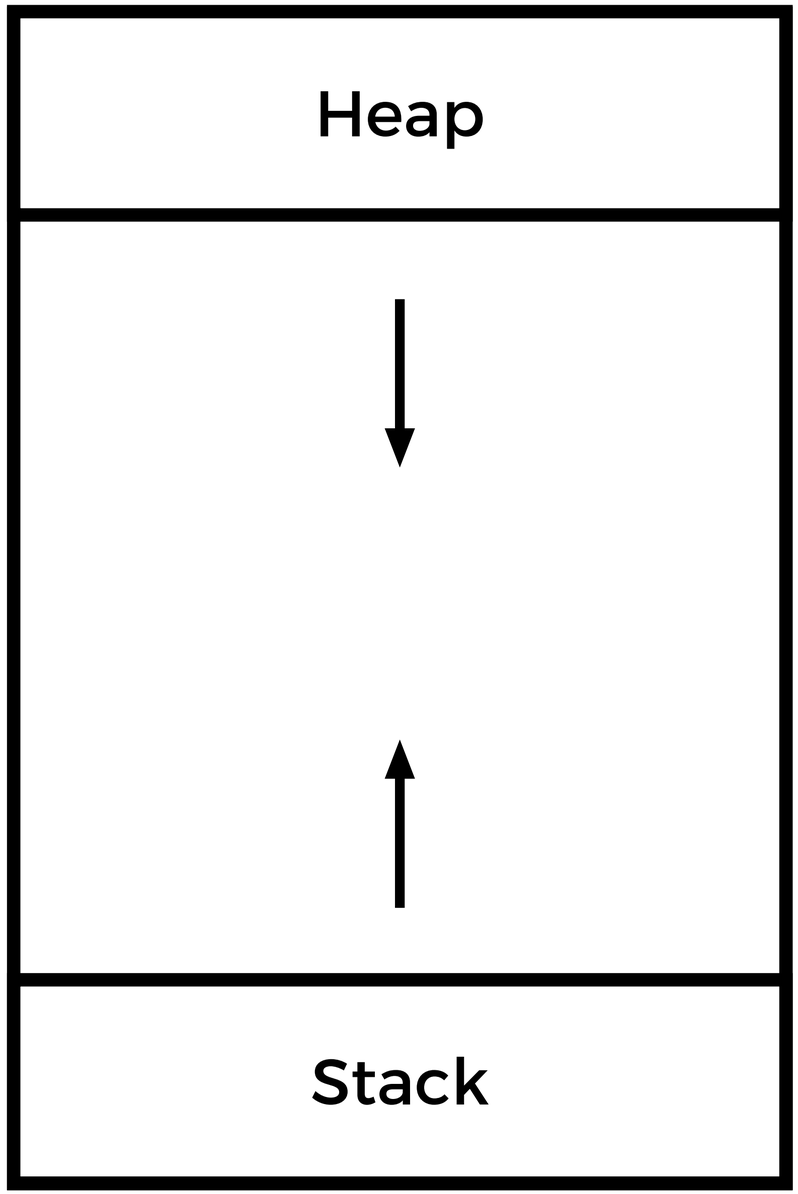


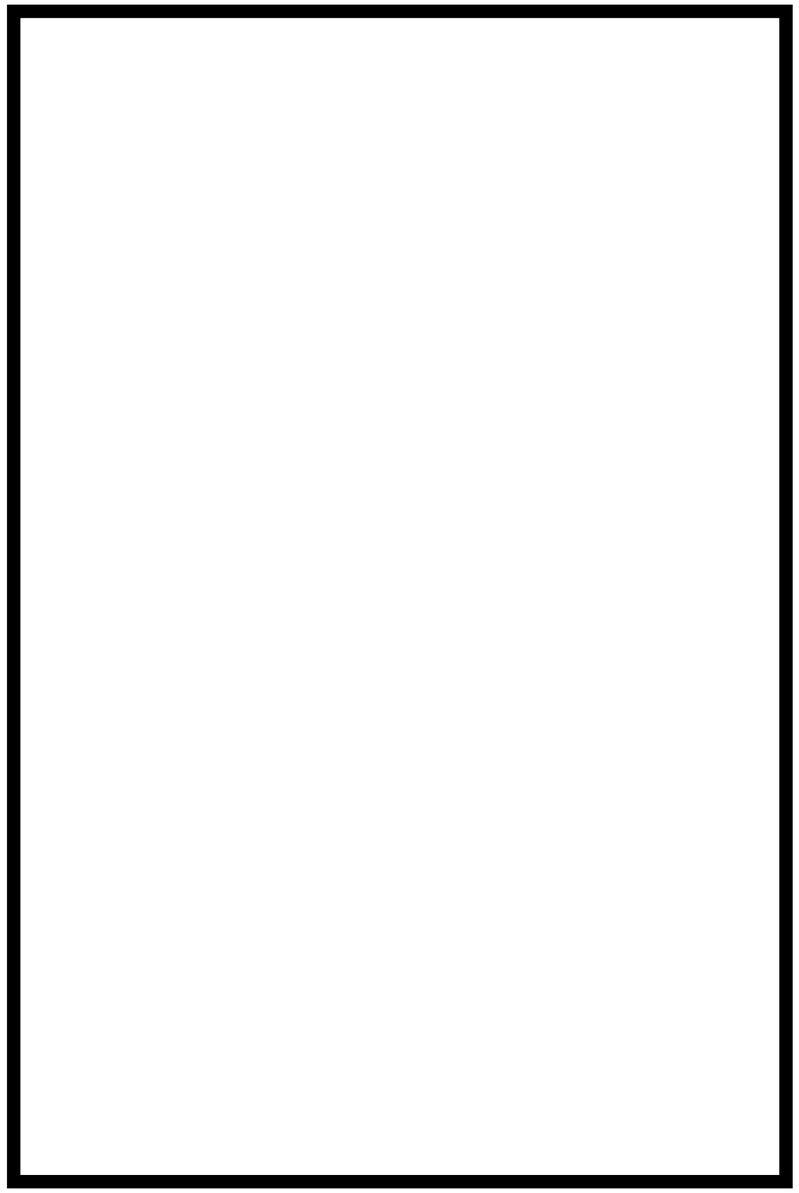
local variables and functions

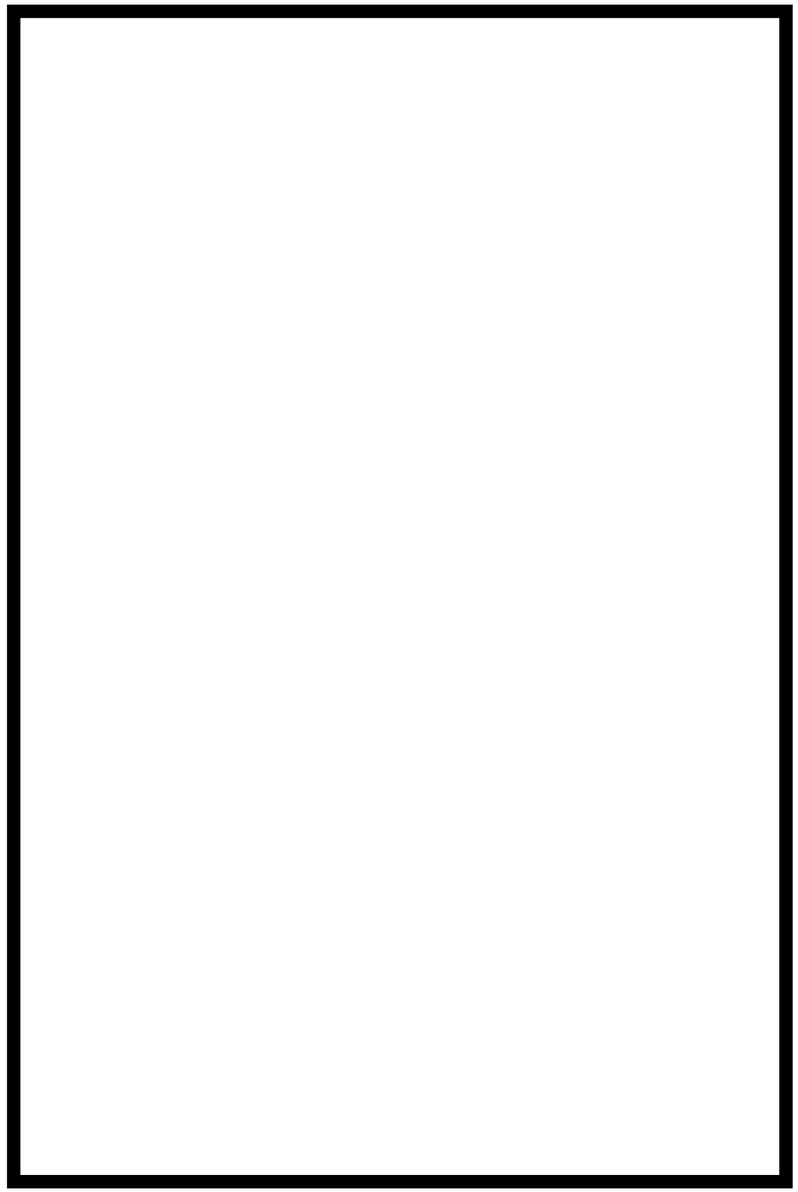


dynamically allocated memory

local variables and functions

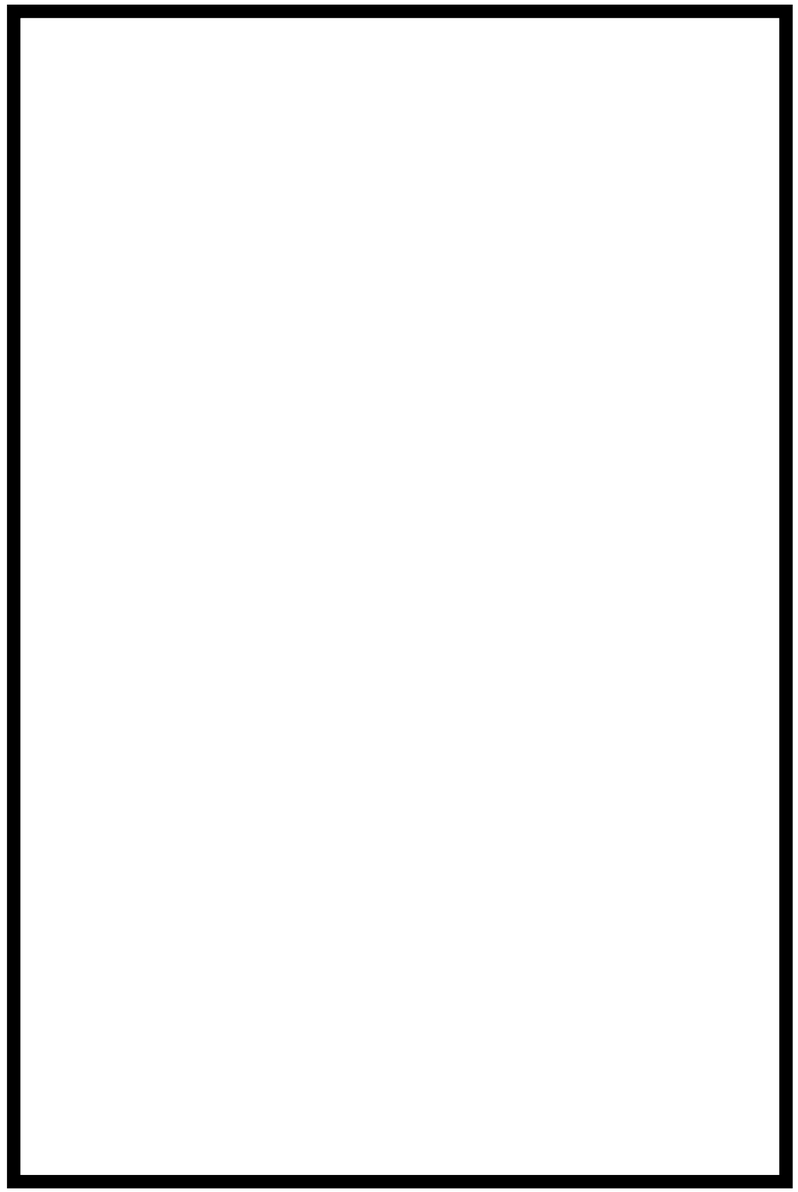

Heap
Stack





```
int main(void)
{
    f();
}

void f(void)
{
    g();
    h();
}
```



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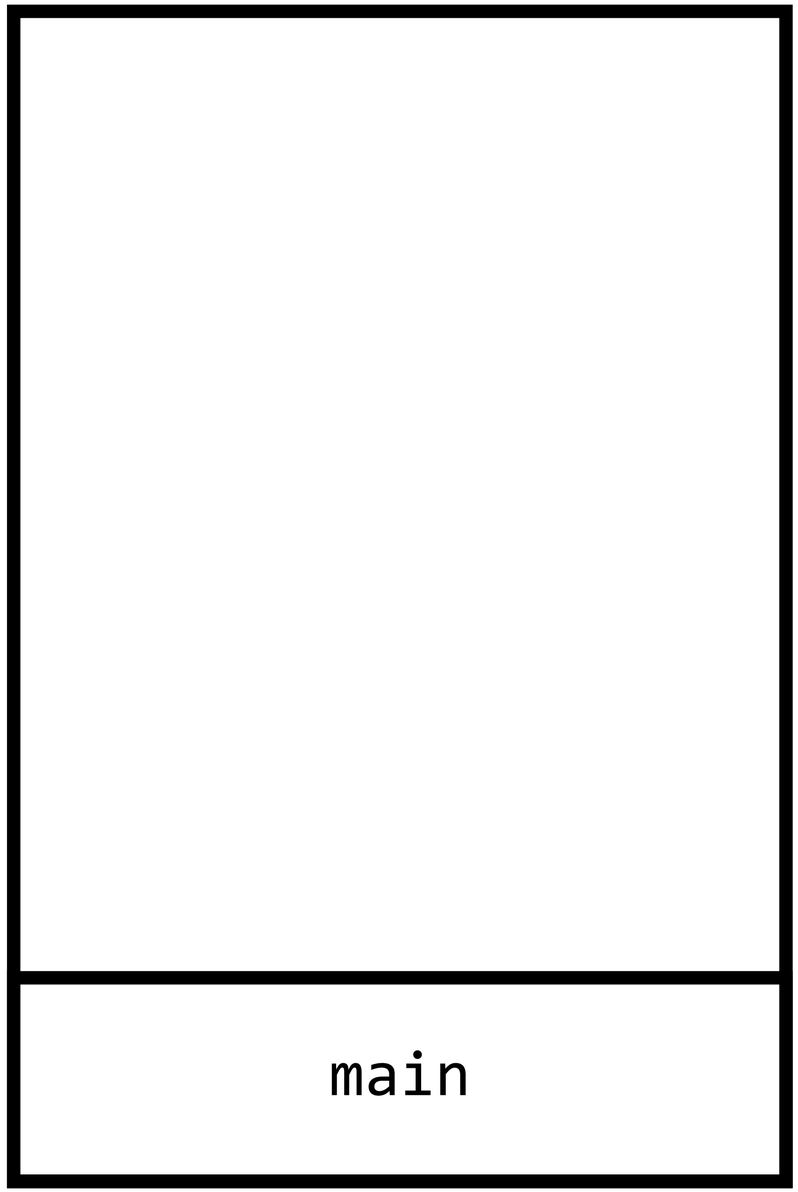


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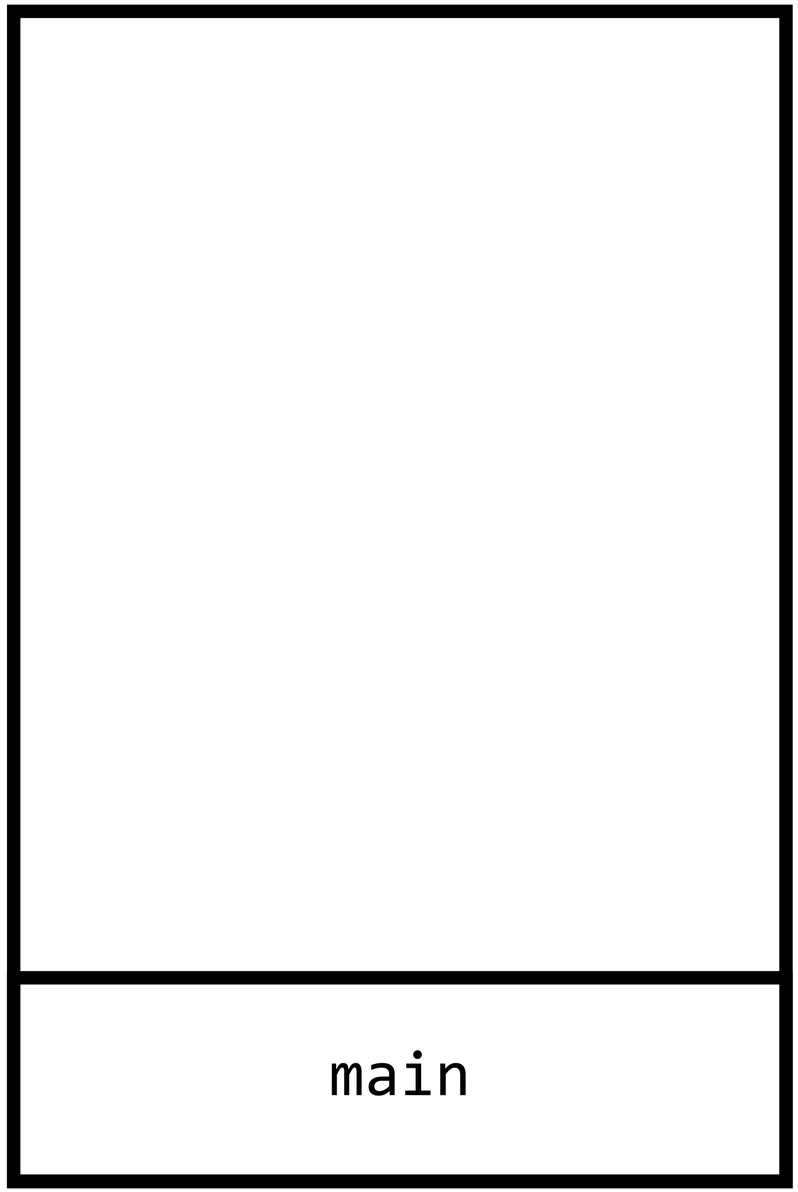


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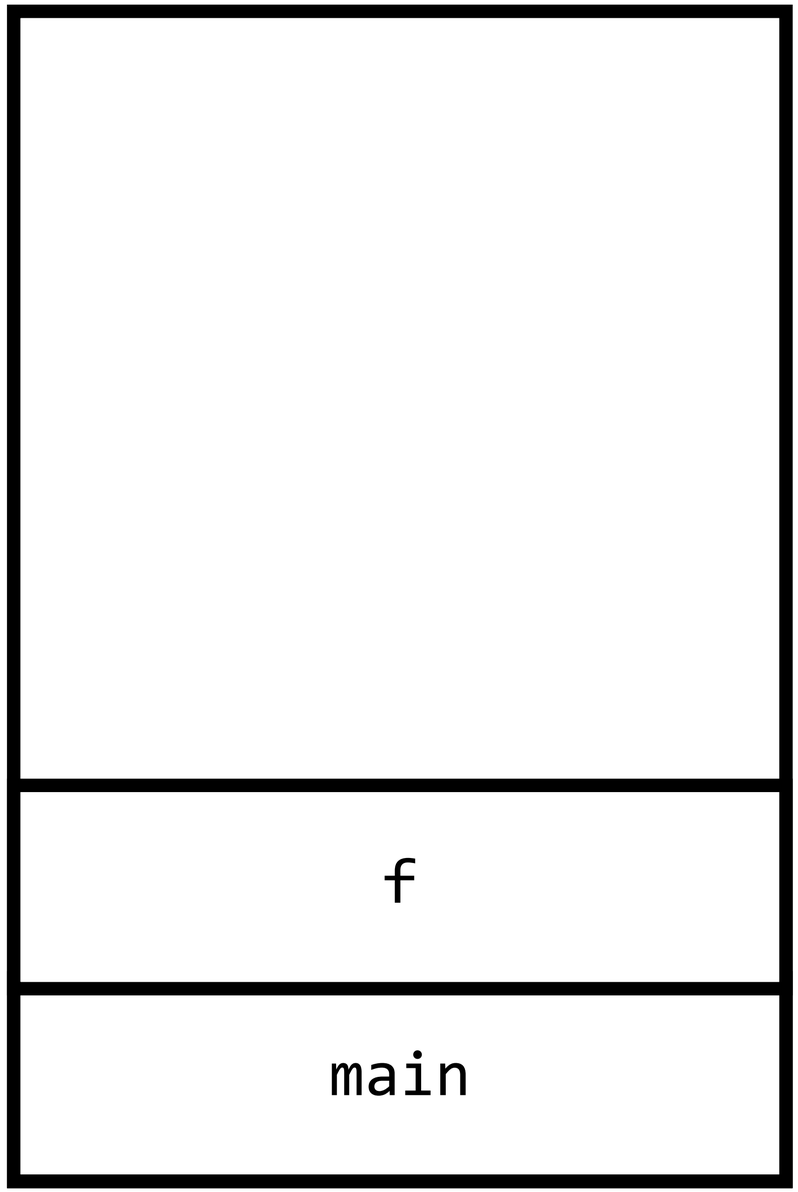


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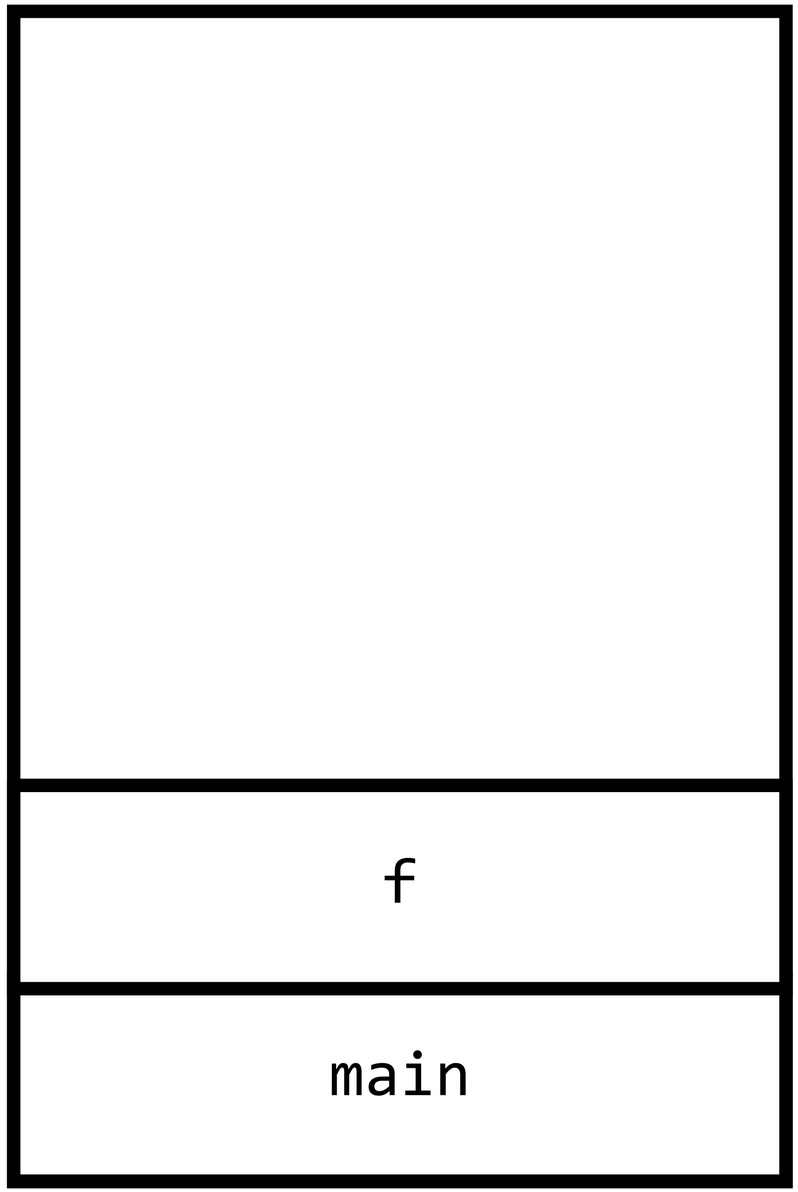


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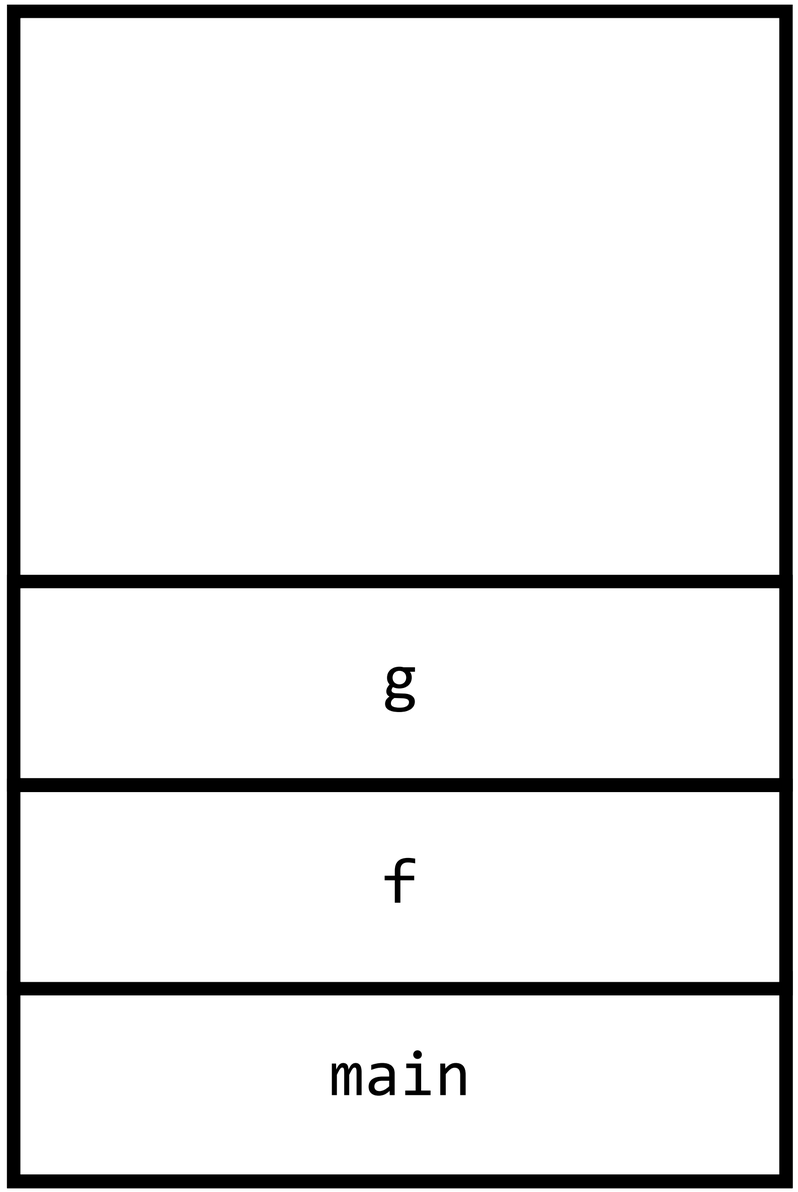


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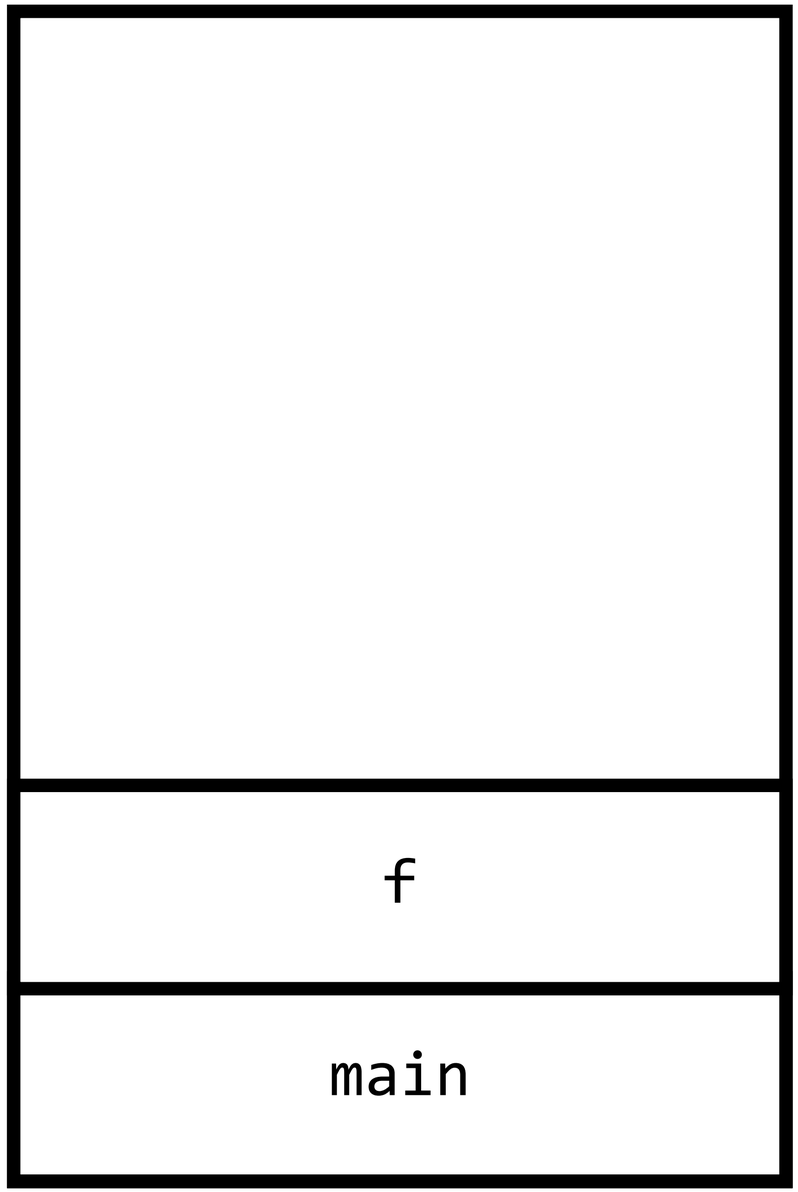


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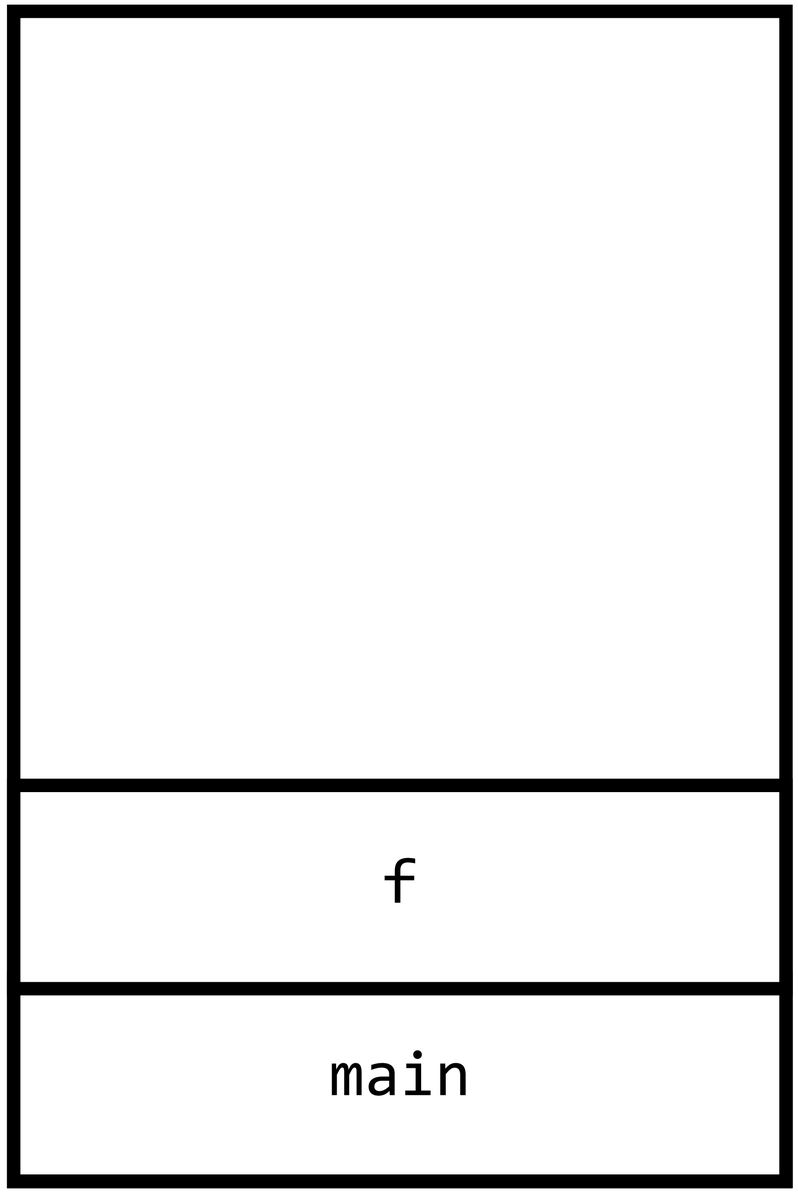


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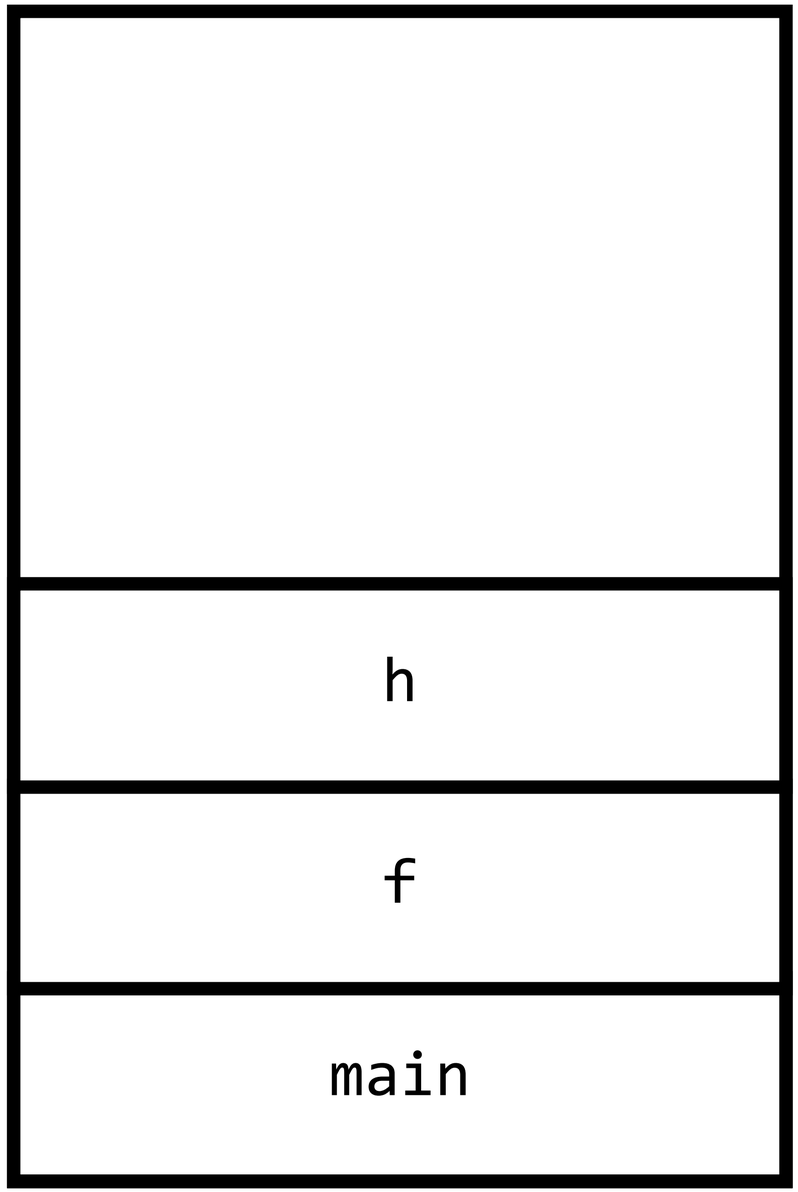


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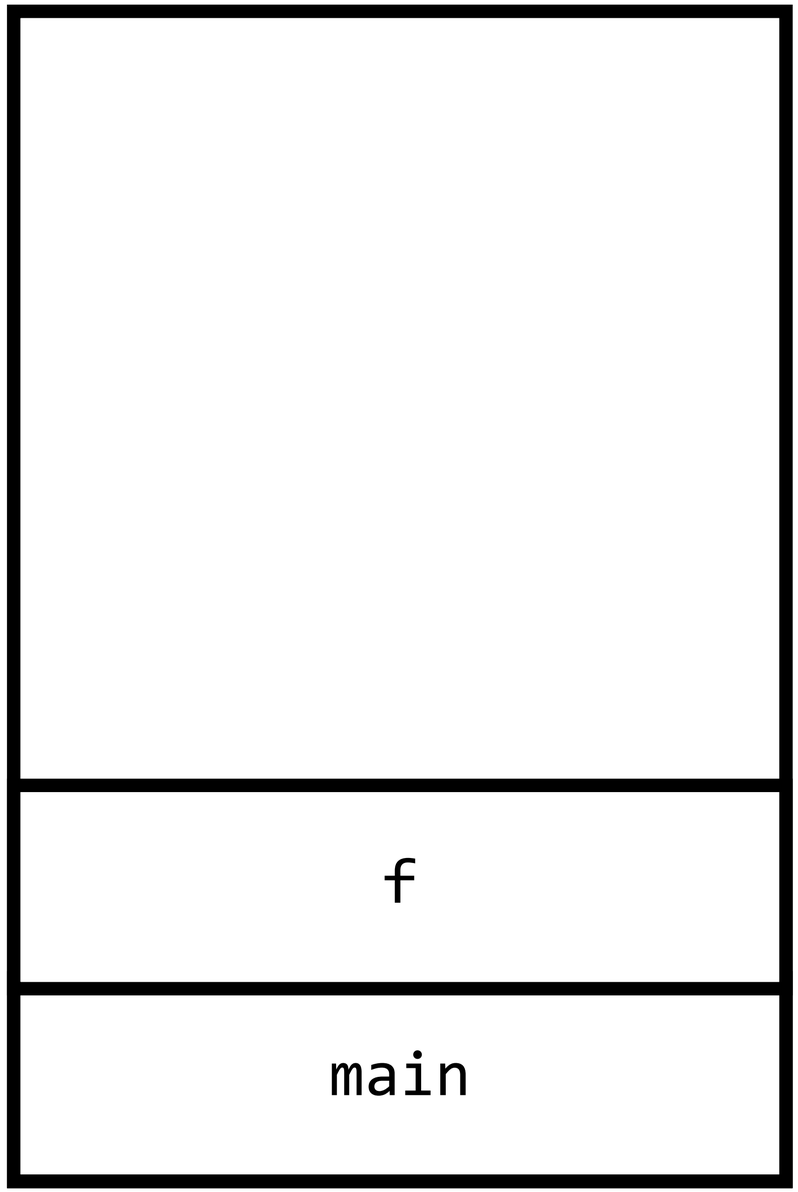


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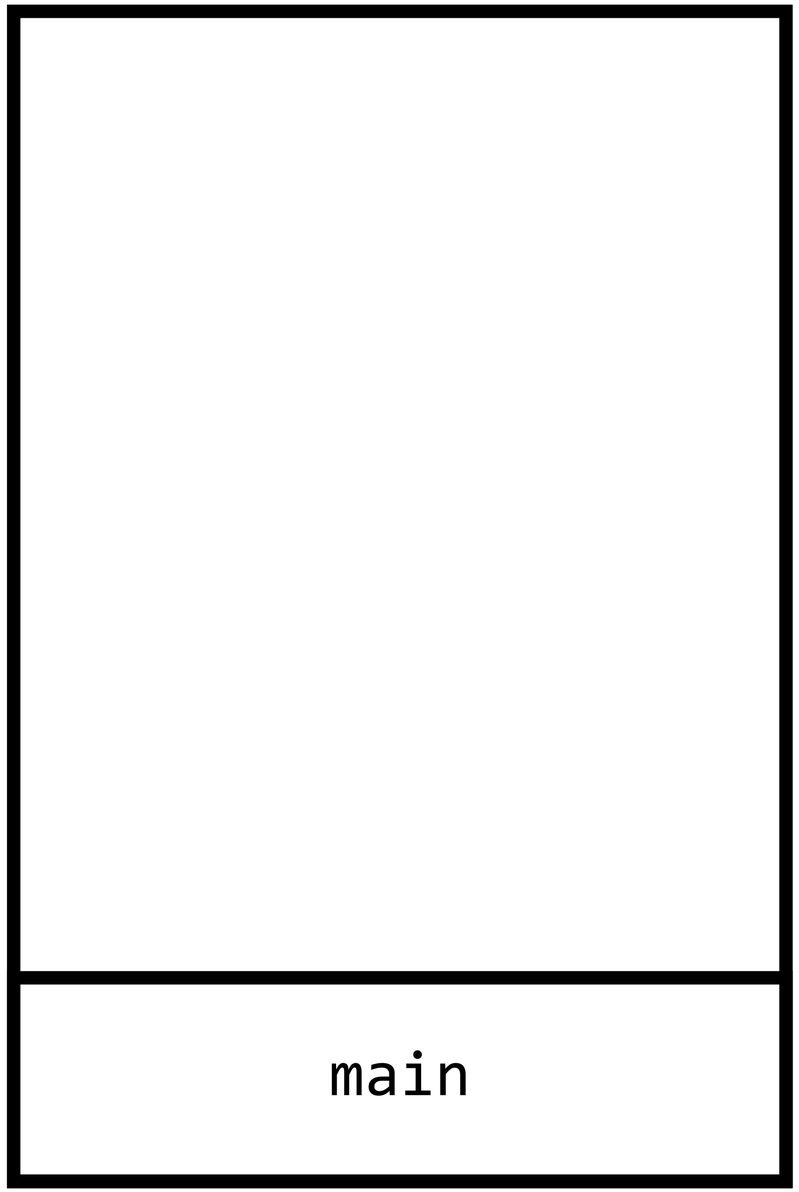


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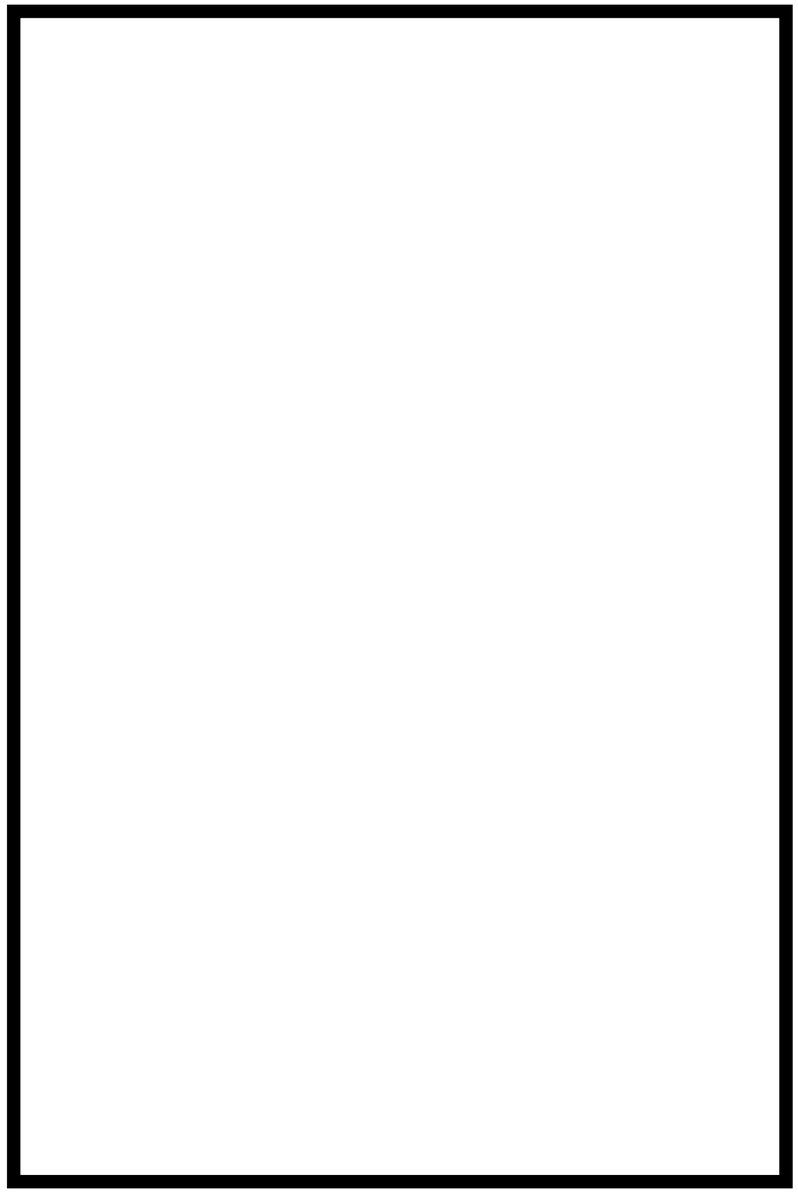

```
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{
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}

void f(void)
{
    g();
    h();
}
```

```
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;
}
```

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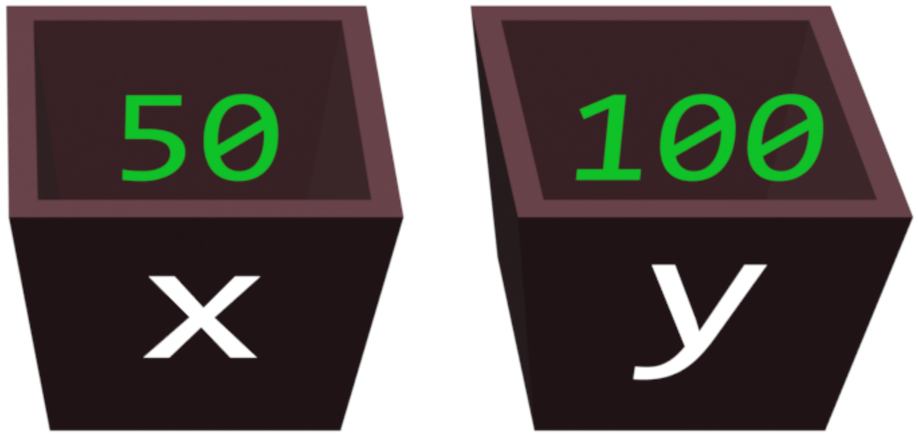
```
swap(x, y)
```



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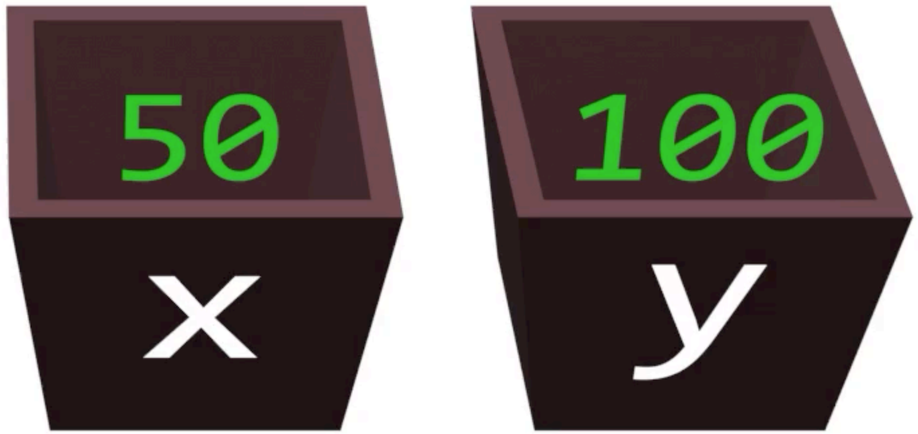

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{
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}
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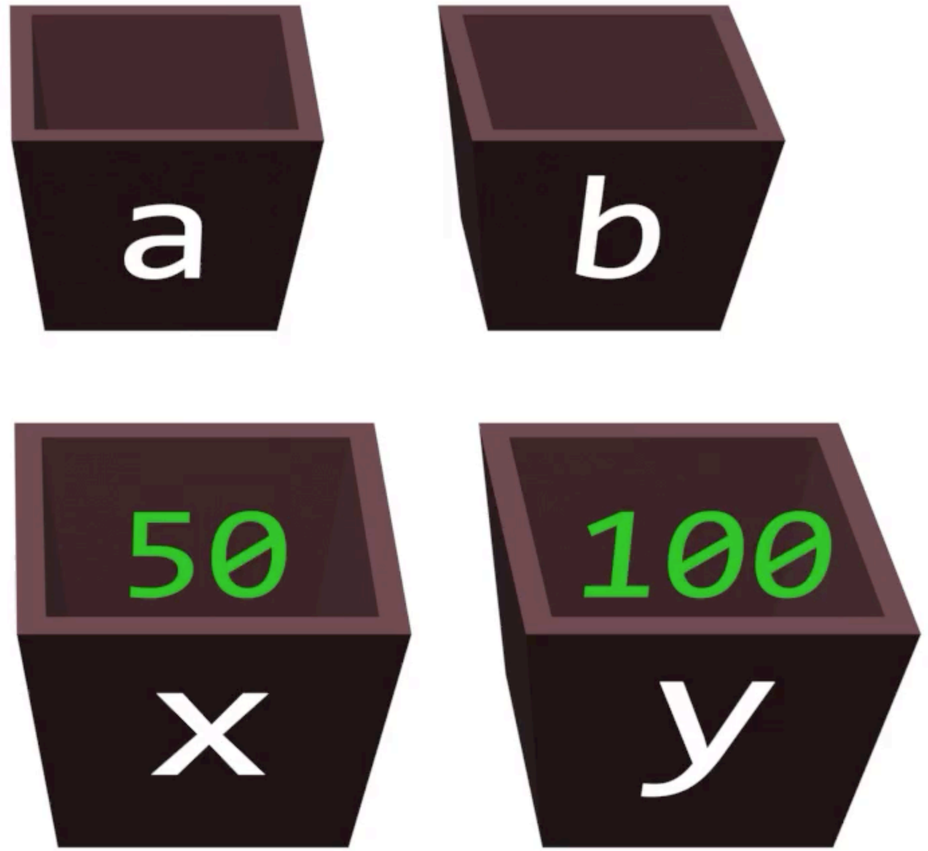

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    int tmp = a;
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}
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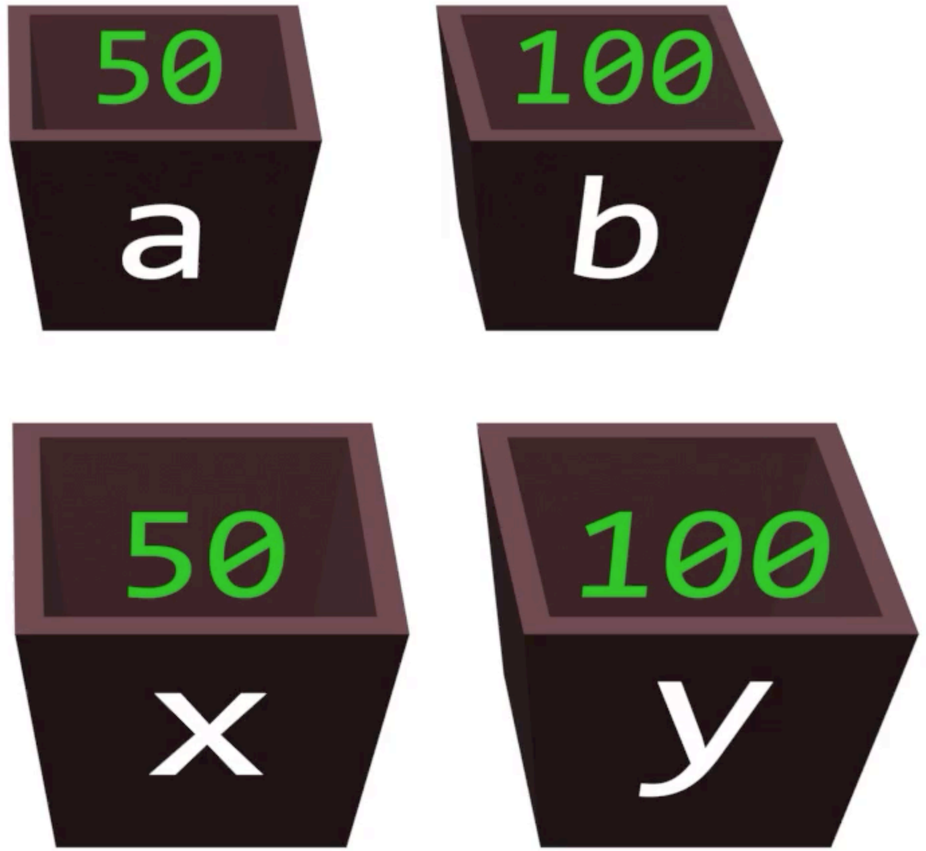

```
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    int tmp = a;
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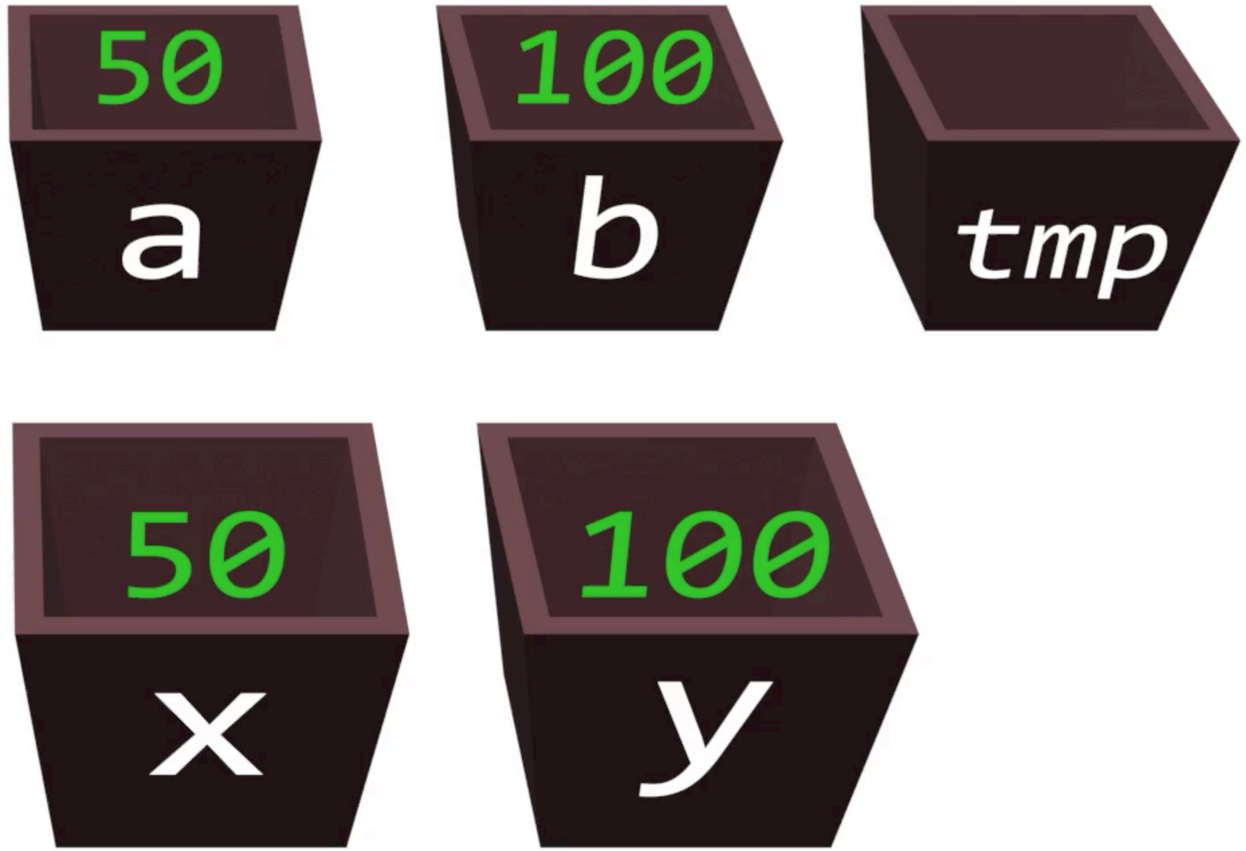

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void swap(int a, int b)
{
    int tmp = a;
    a = b;
    b = tmp;
}
```
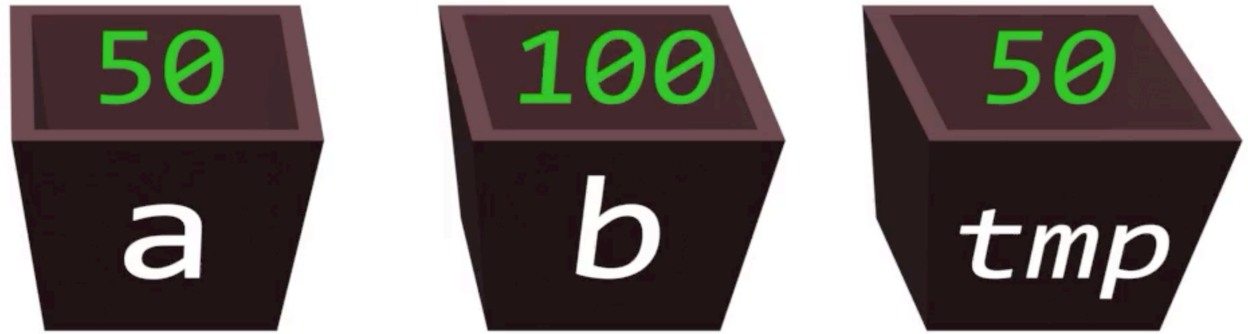
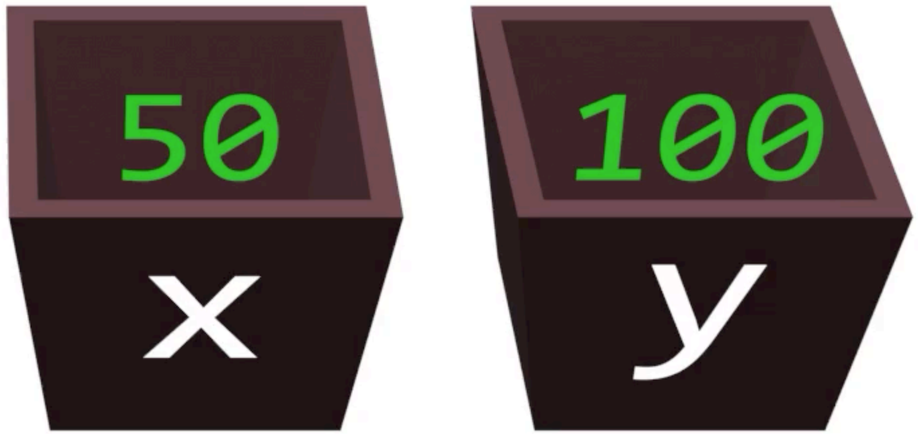




```
swap(x, y)
```



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


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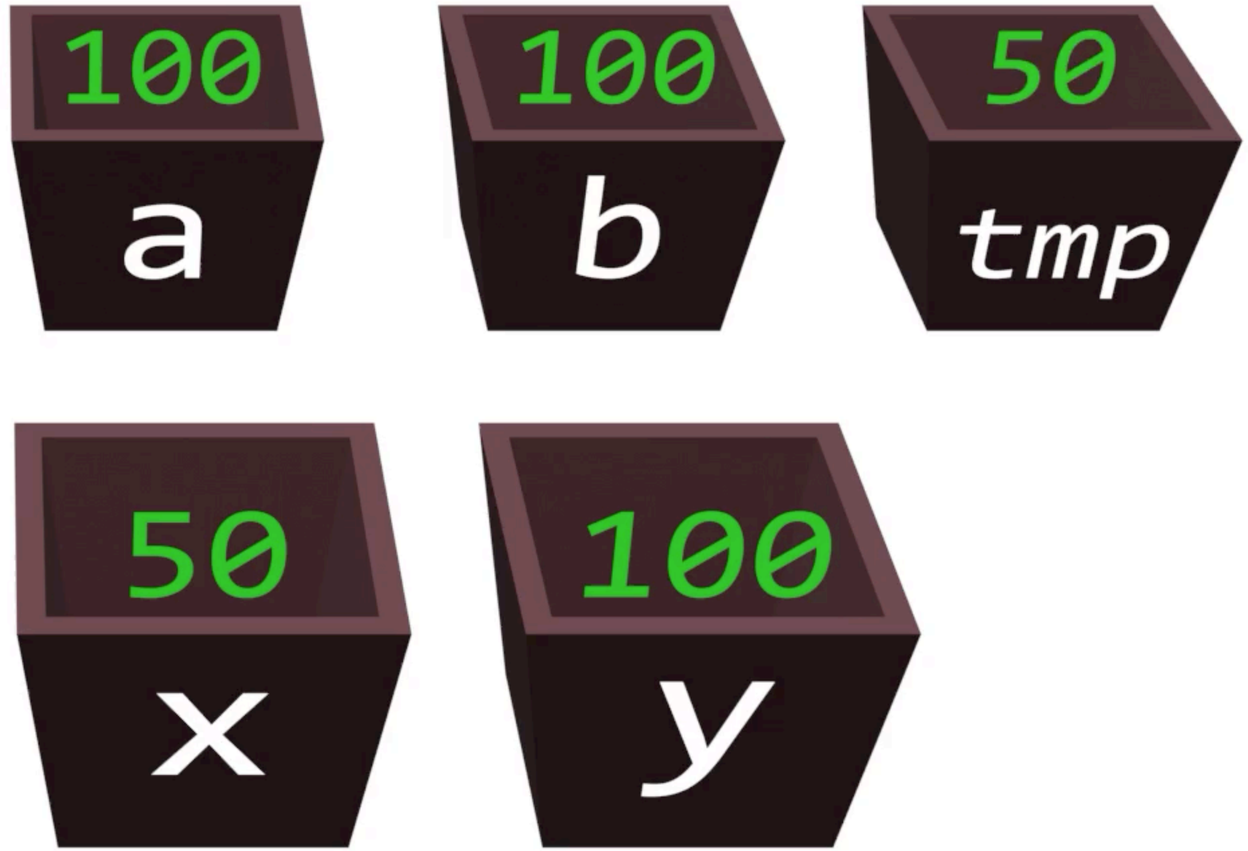
```



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{
    int tmp = a;
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}
```
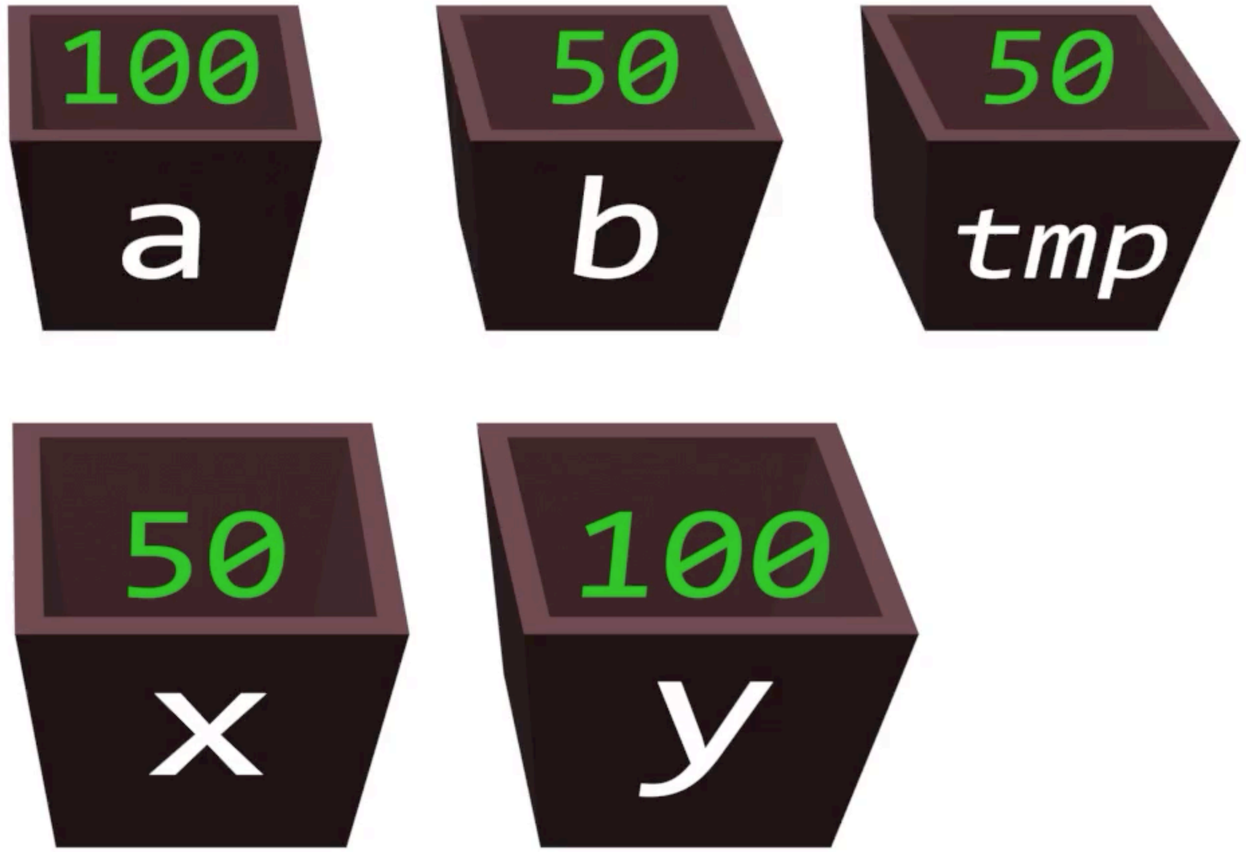

```
swap(x, y)
```



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

```
swap(x, y)
```

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

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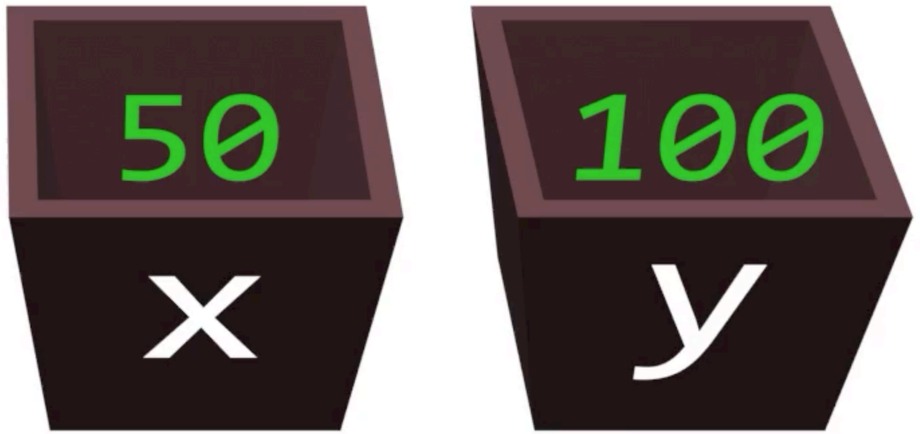
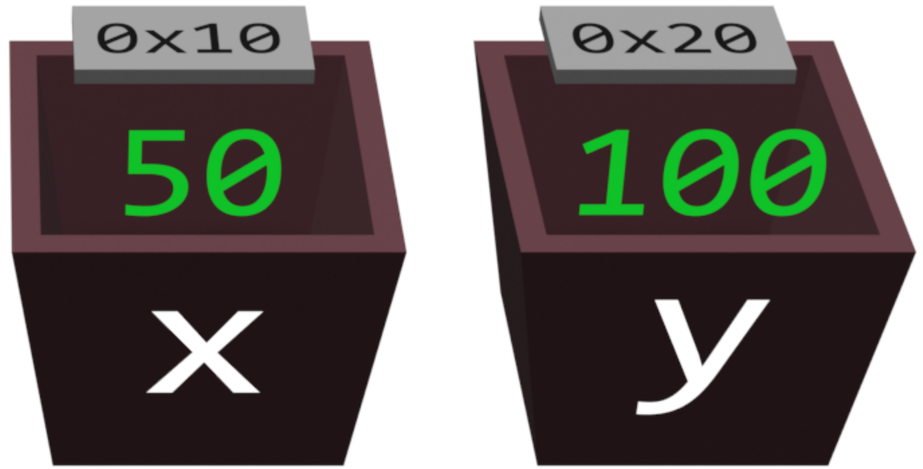


```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}
```

```
swap(&x, &y)
```



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void swap(int *a, int *b)
{
    int tmp = *a;
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    *b = tmp;
}
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swap(&x, &y)
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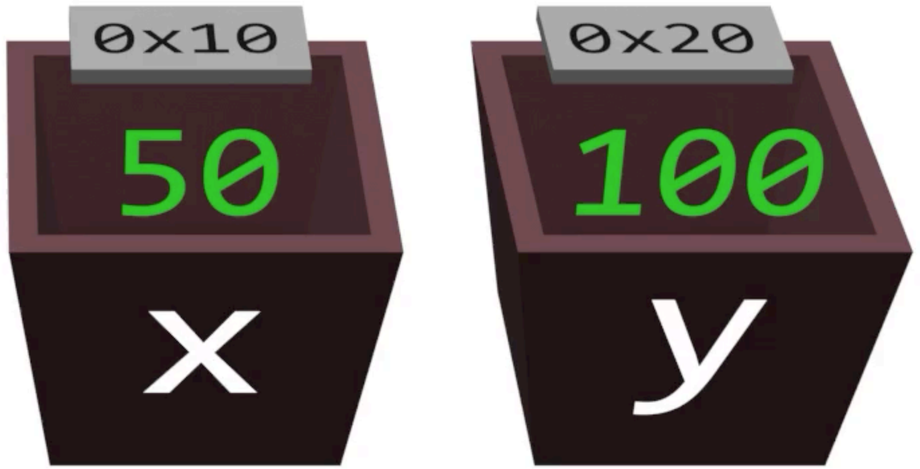

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{
     int tmp = *a;
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     *b = tmp;
}


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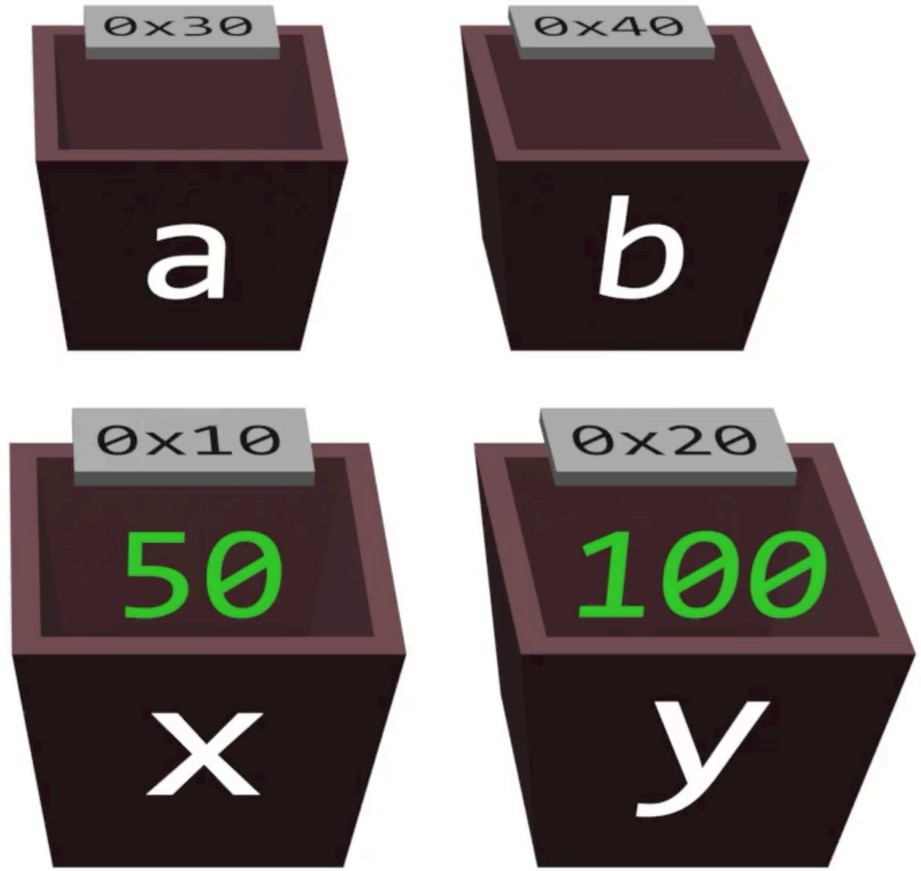
```



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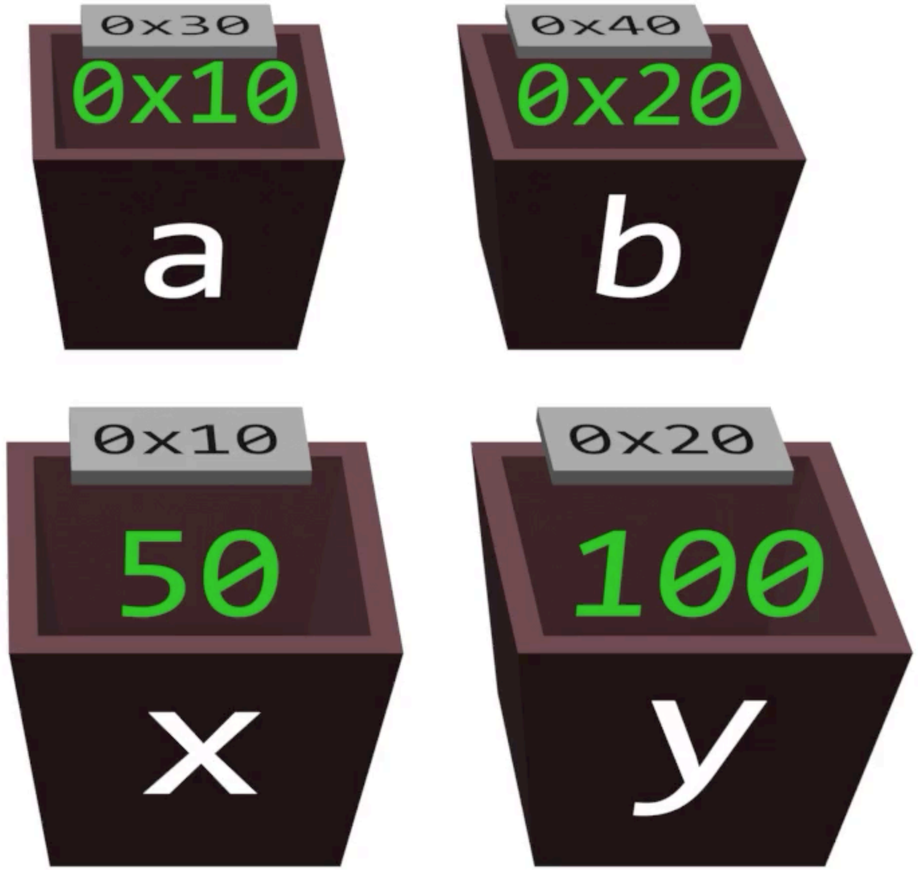

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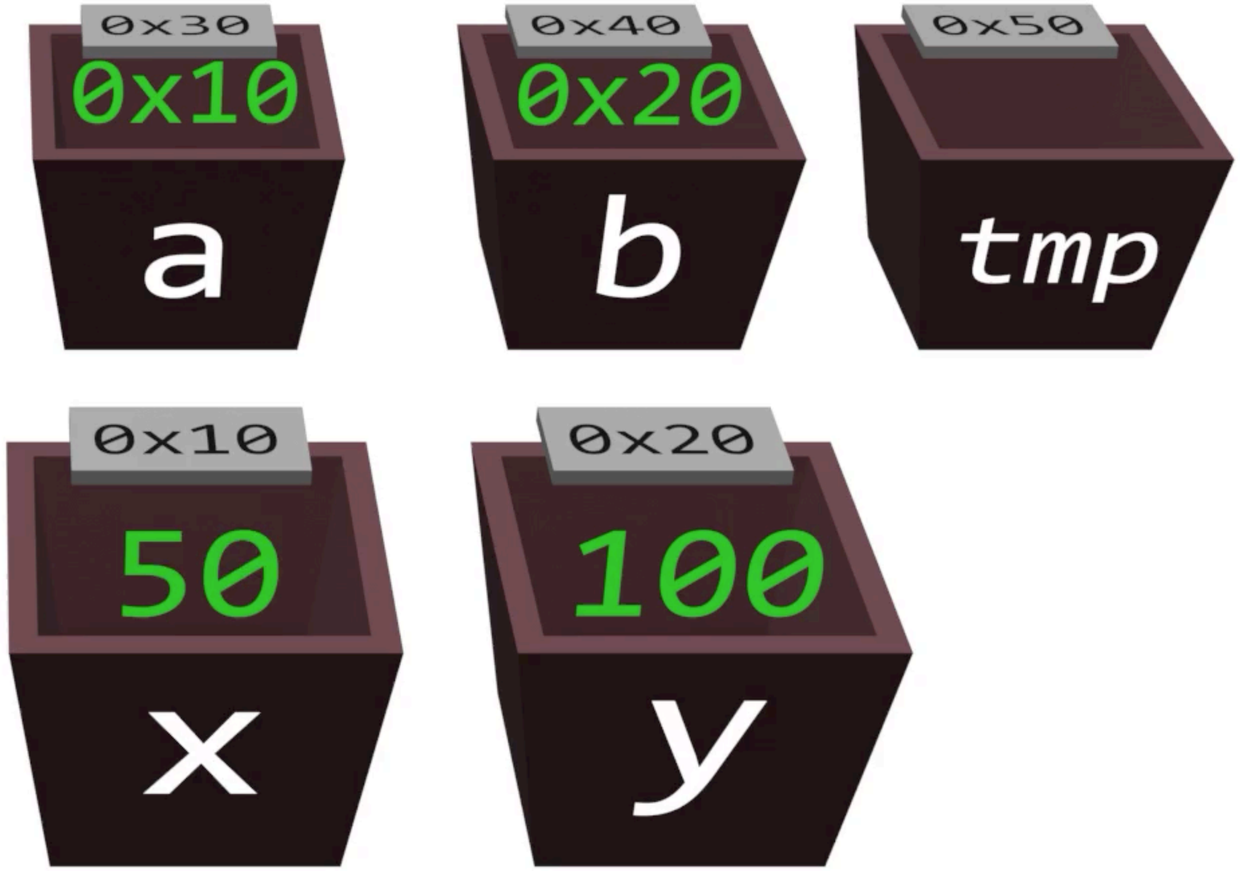

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swap(&x, &y)
```
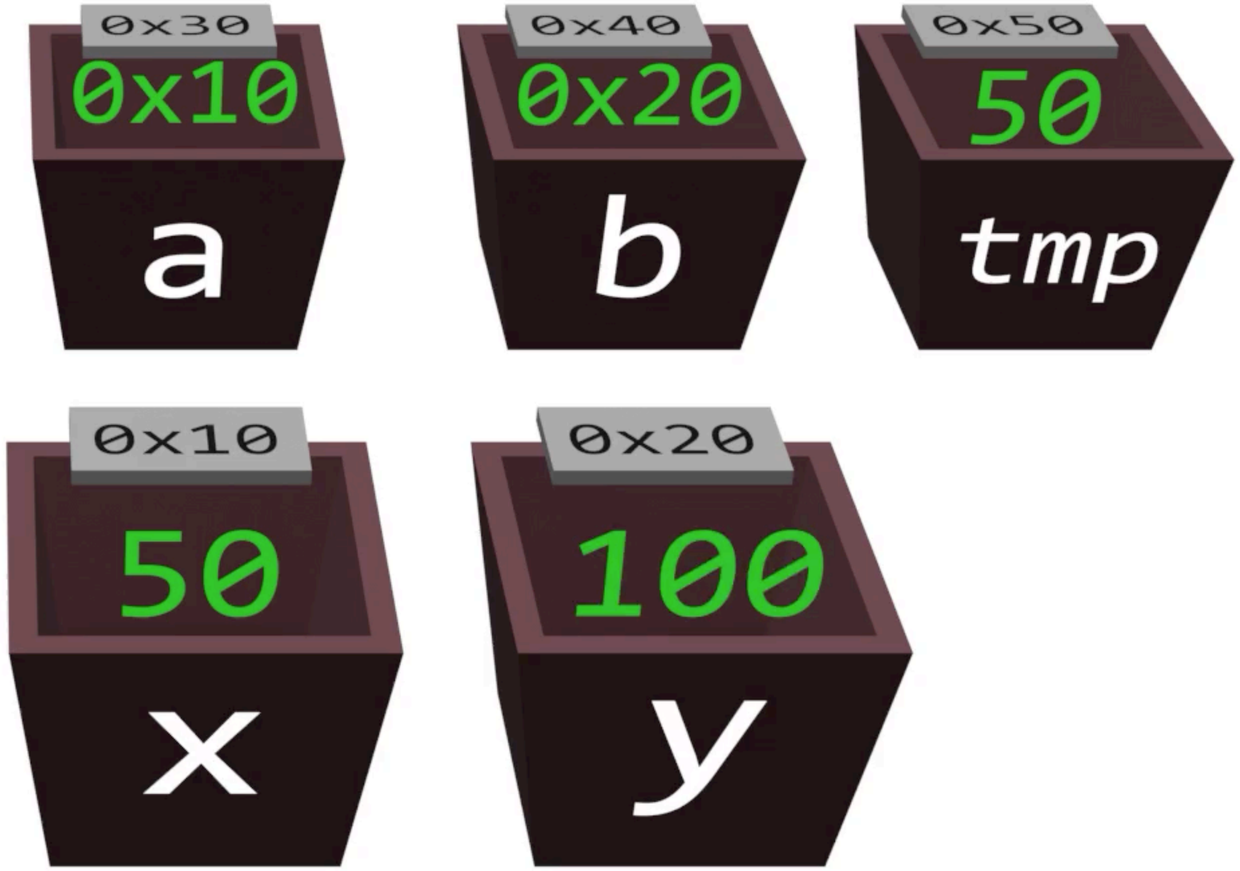
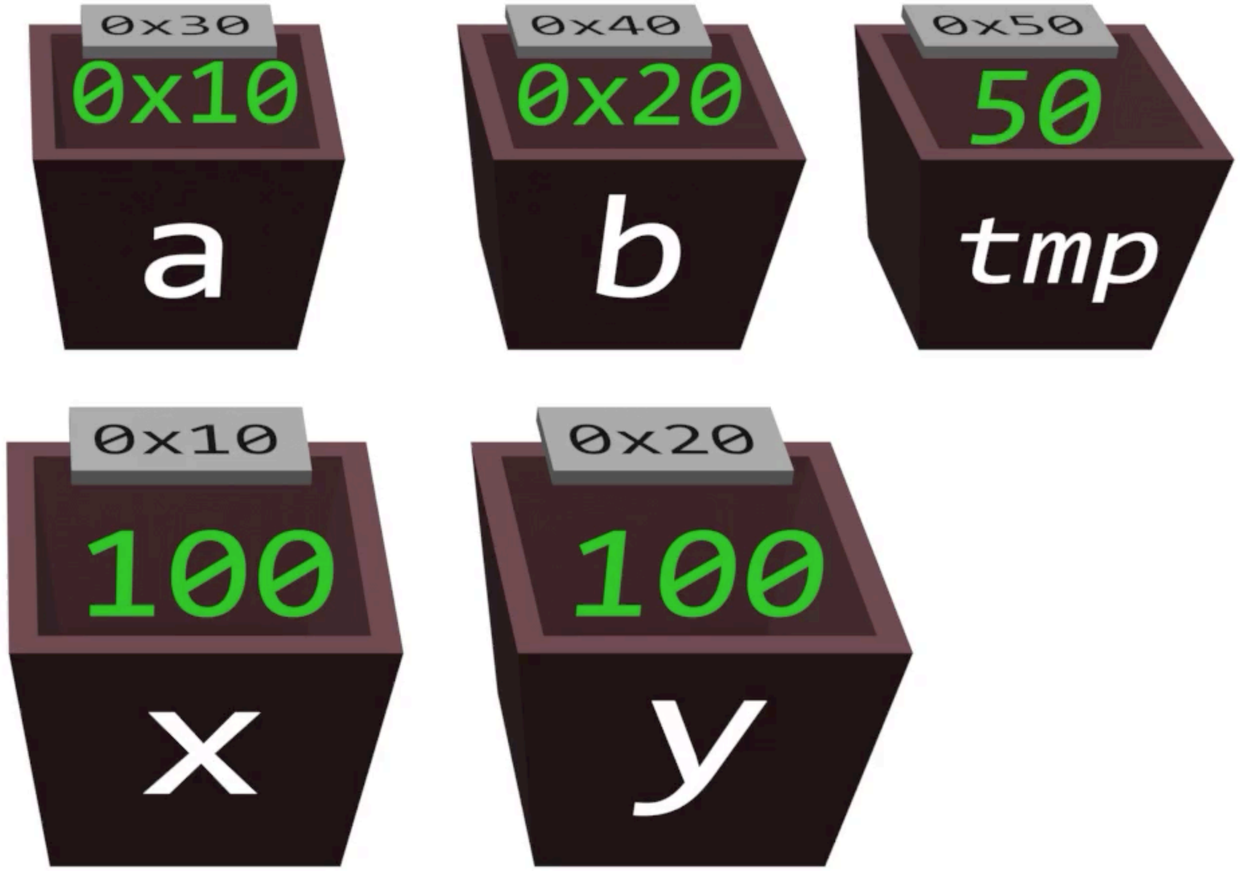
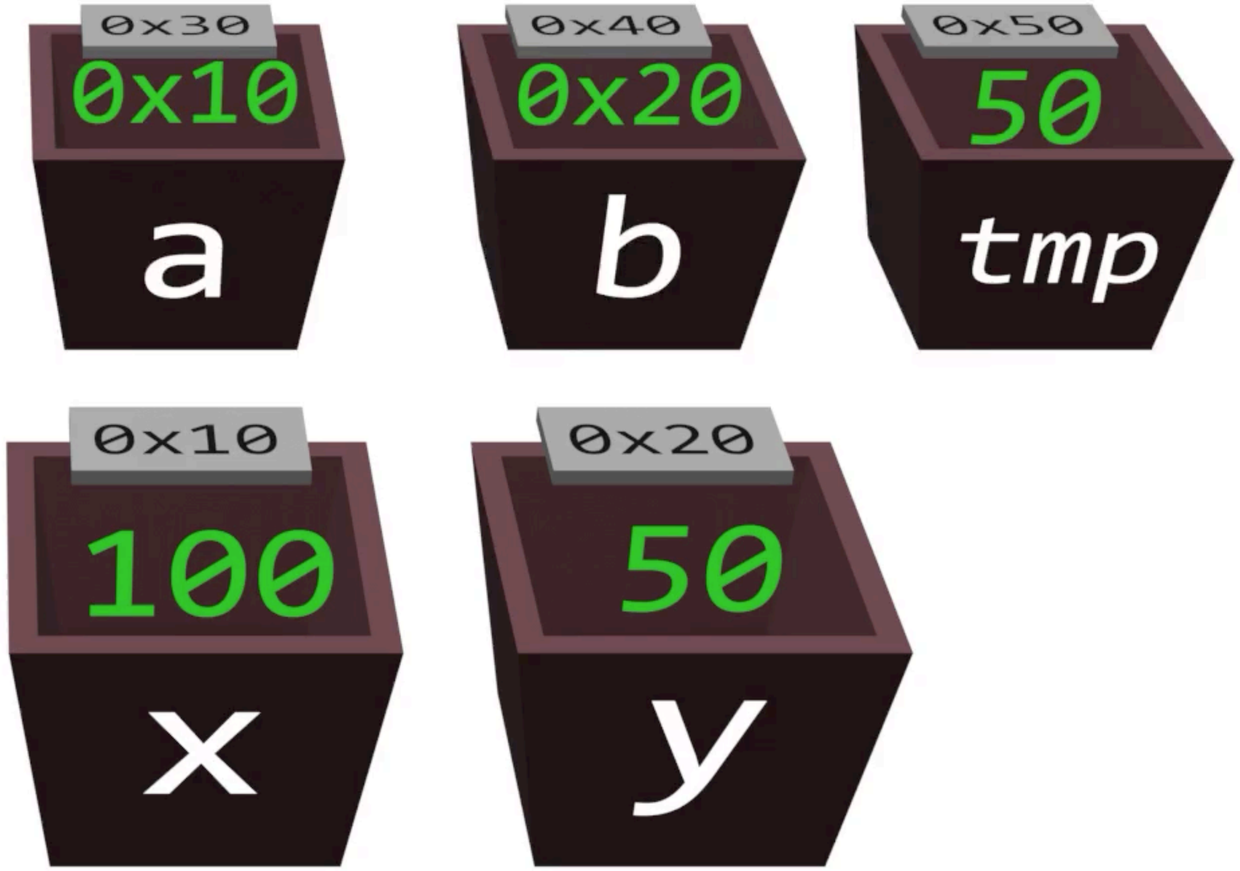



```
void swap(int *a, int *b)
{
    int tmp = *a;
    *a = *b;
    *b = tmp;
}


swap(&x, &y)
```



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


swap(&x, &y)
```



Part Two

Files and Dynamic Memory

File I/O

Open a File

```
FILE *f = fopen("filename.txt", "r");
```

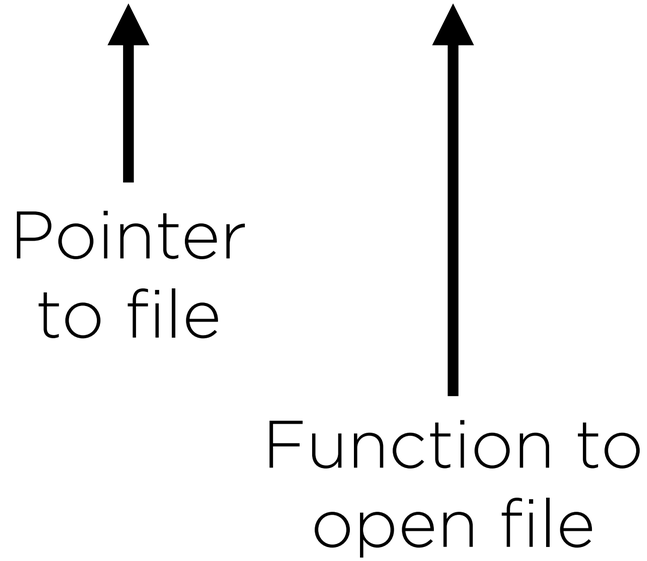
Open a File

```
FILE *f = fopen("filename.txt", "r");
```

Pointer
to file

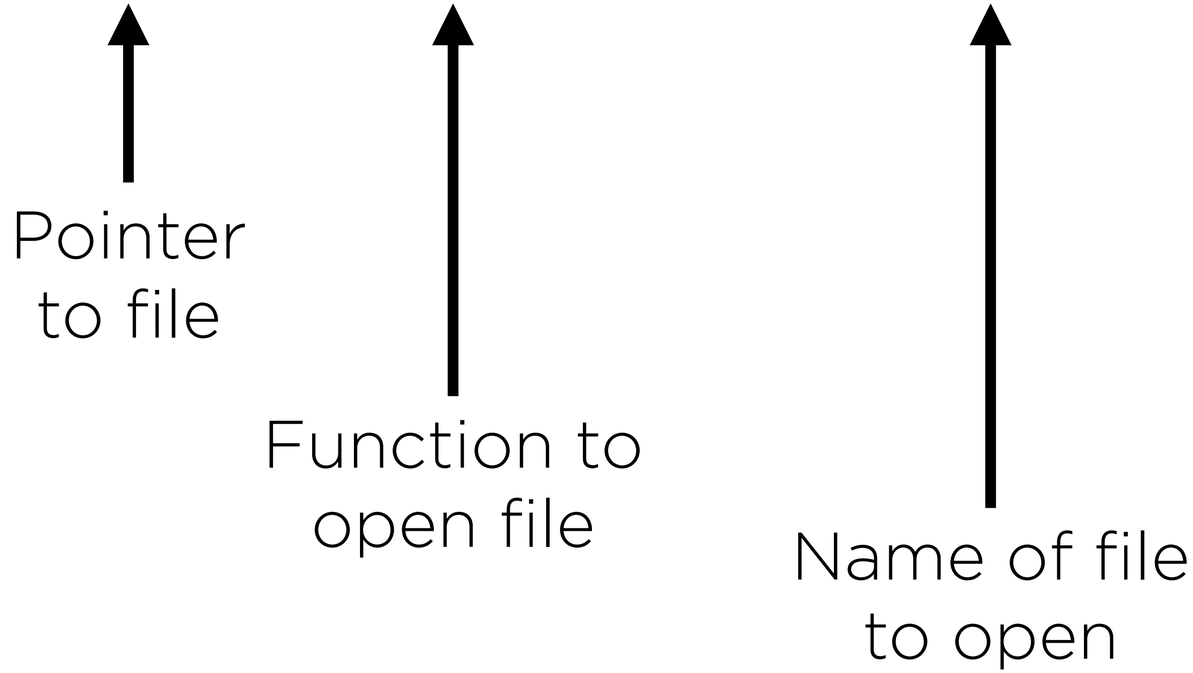
Open a File

```
FILE *f = fopen("filename.txt", "r");
```



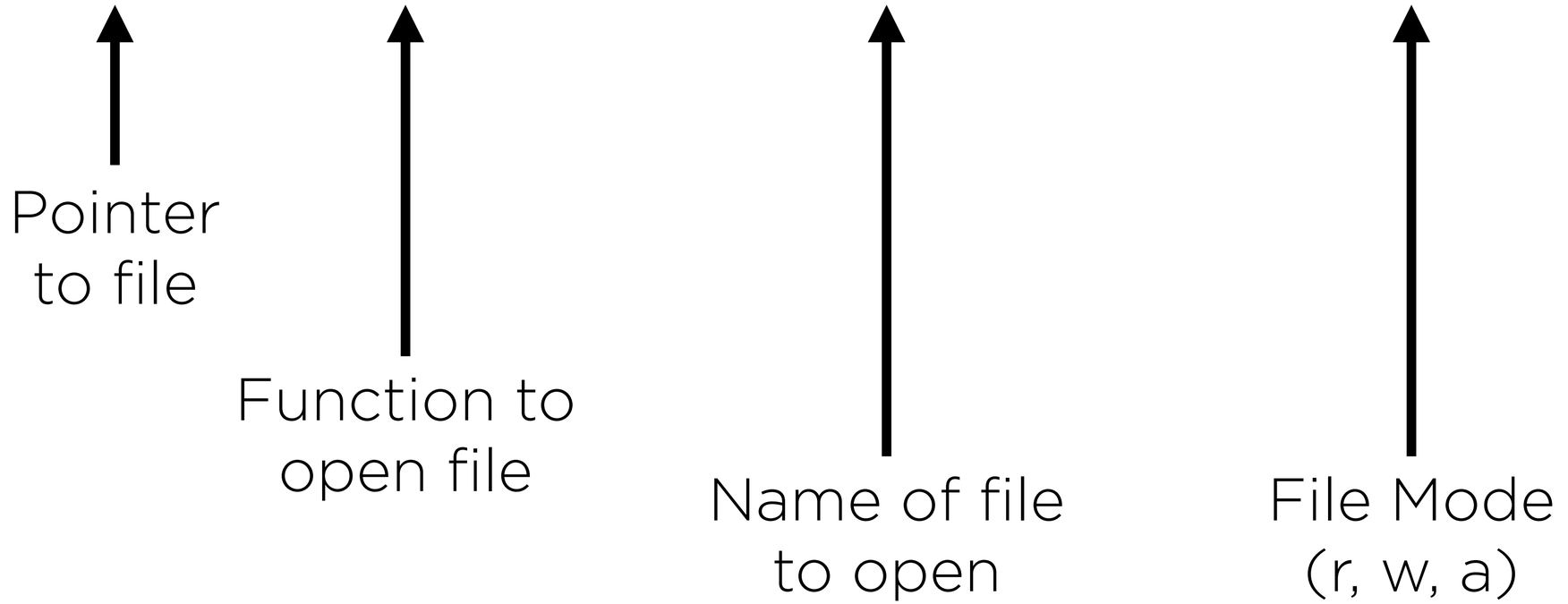
Open a File

```
FILE *f = fopen("filename.txt", "r");
```



Open a File

```
FILE *f = fopen("filename.txt", "r");
```

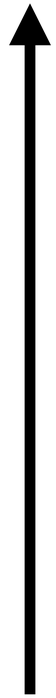


Reading from a File

```
fread(ptr, size, blocks, fp)
```

Reading from a File

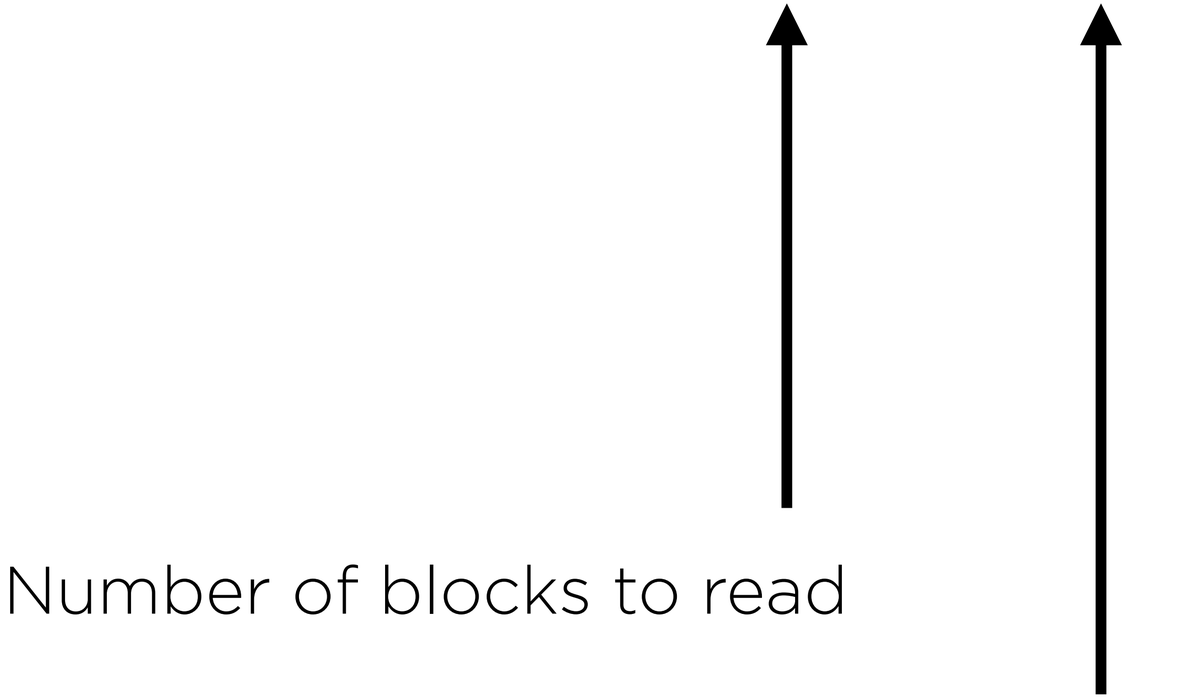
```
fread(ptr, size, blocks, fp)
```



Pointer to file to read from

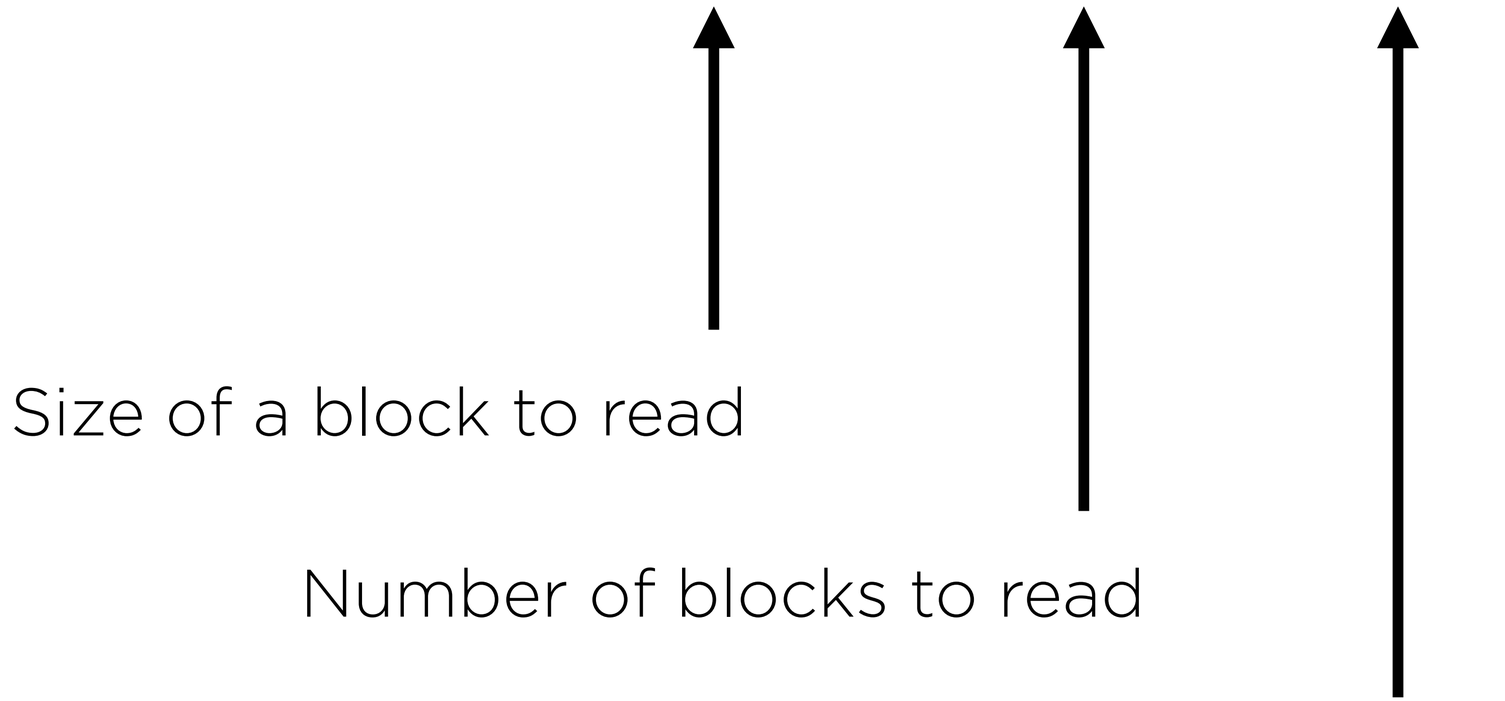
Reading from a File

```
fread(ptr, size, blocks, fp)
```



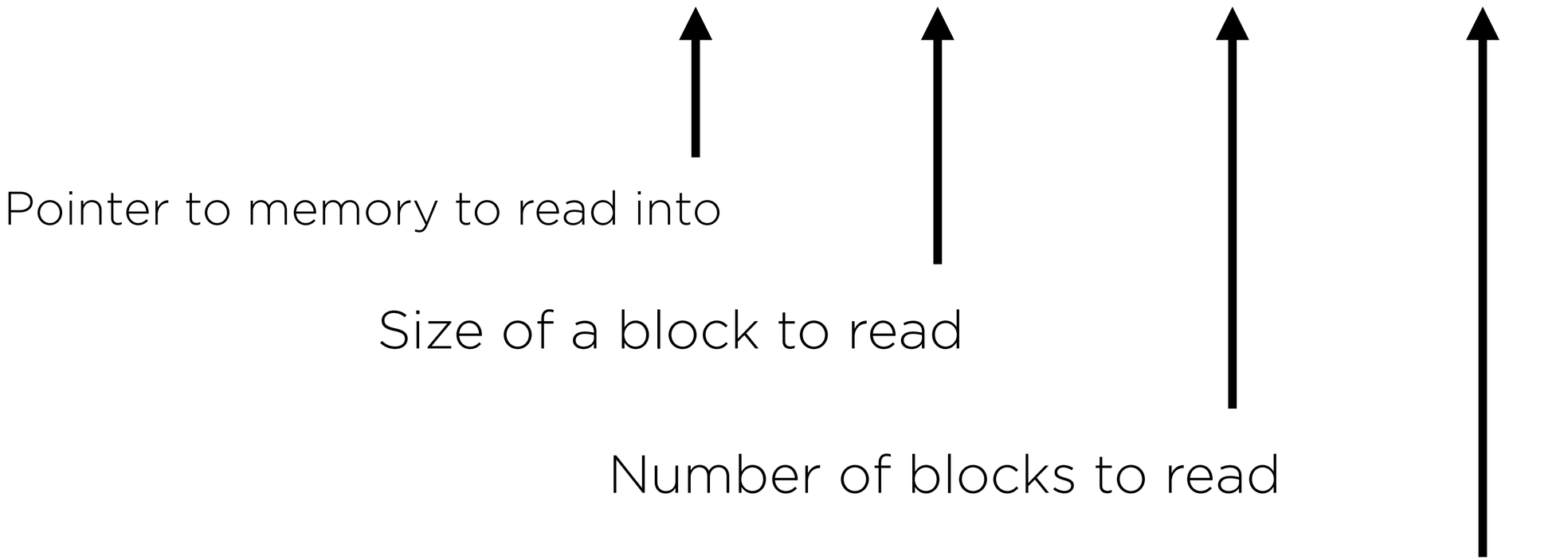
Reading from a File

```
fread(ptr, size, blocks, fp)
```

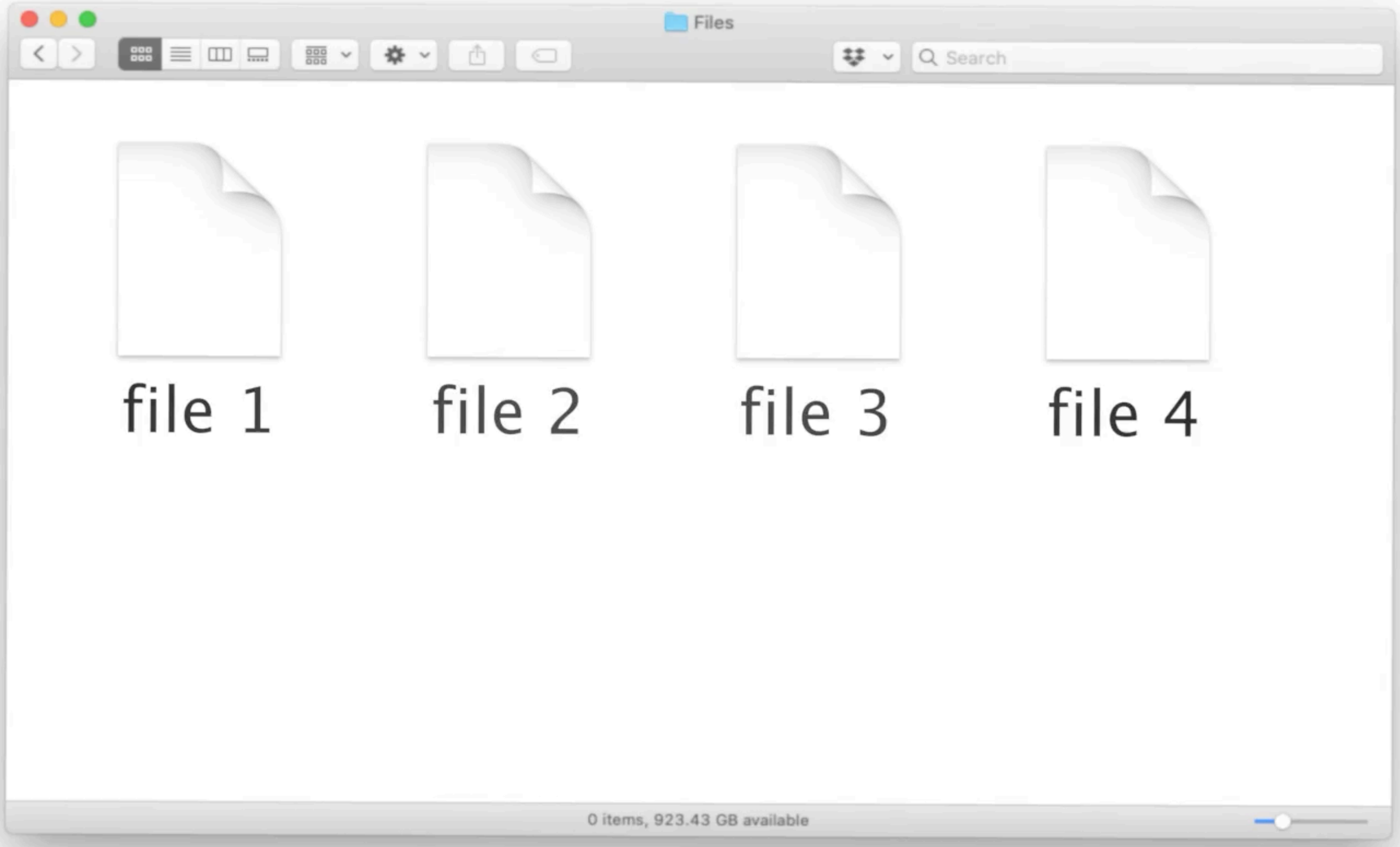


Reading from a File

```
fread(ptr, size, blocks, fp)
```



```
FILE *f = fopen("file 1", "r");
```



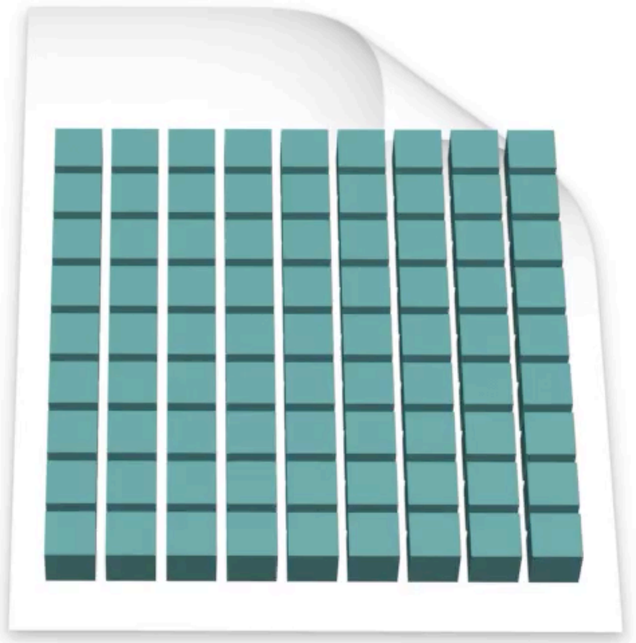
f

file 1

file

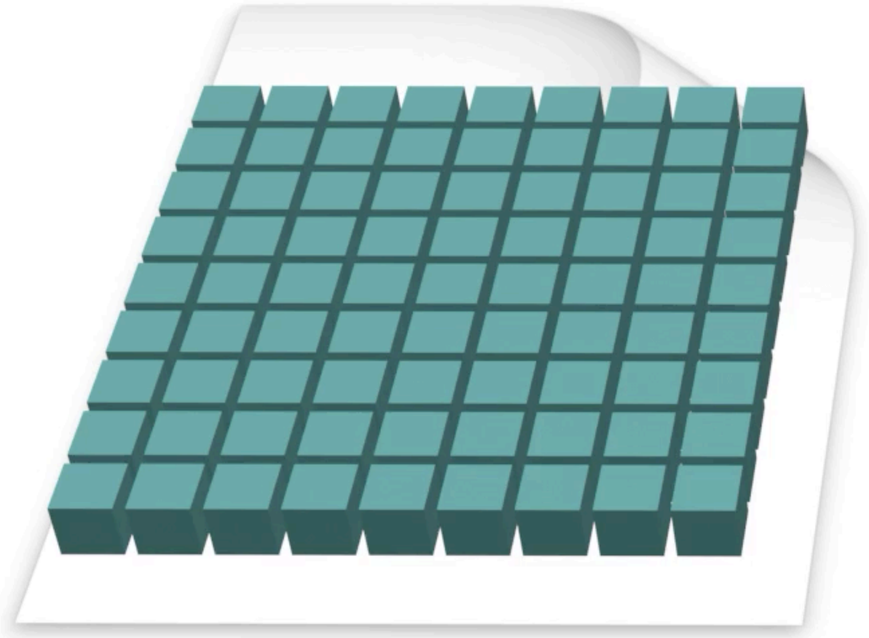
f

f



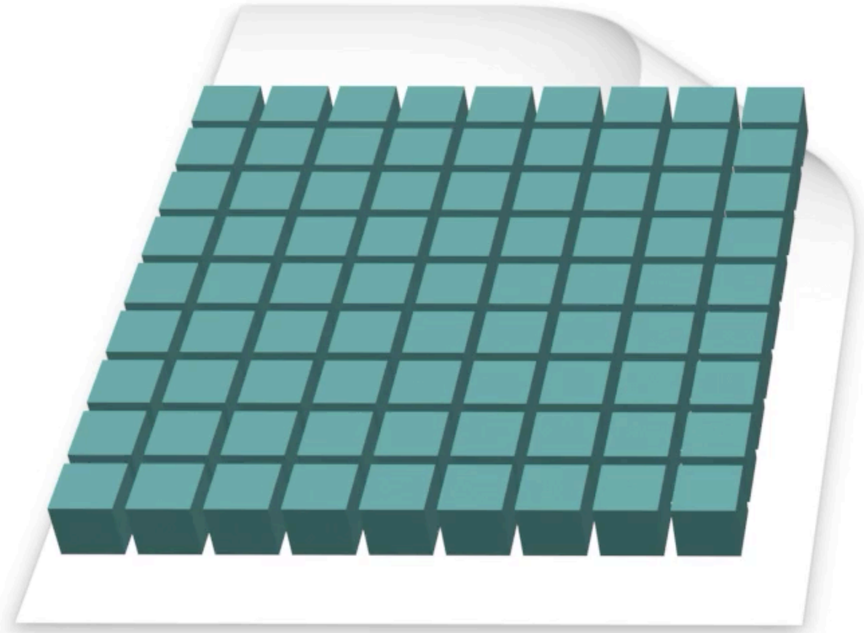
```
uint8_t buffer[4];
```

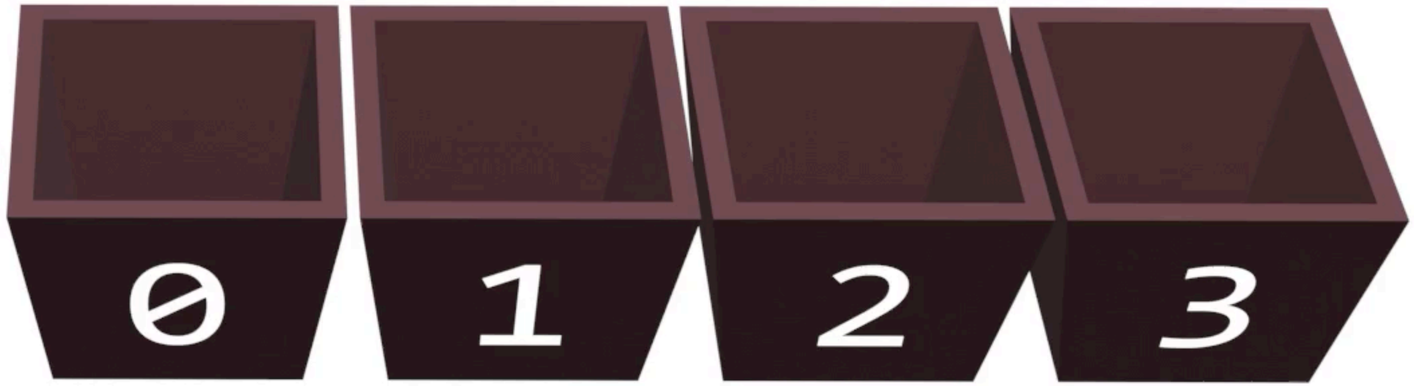
f



```
fread(buffer, 1, 4, f);
```

f

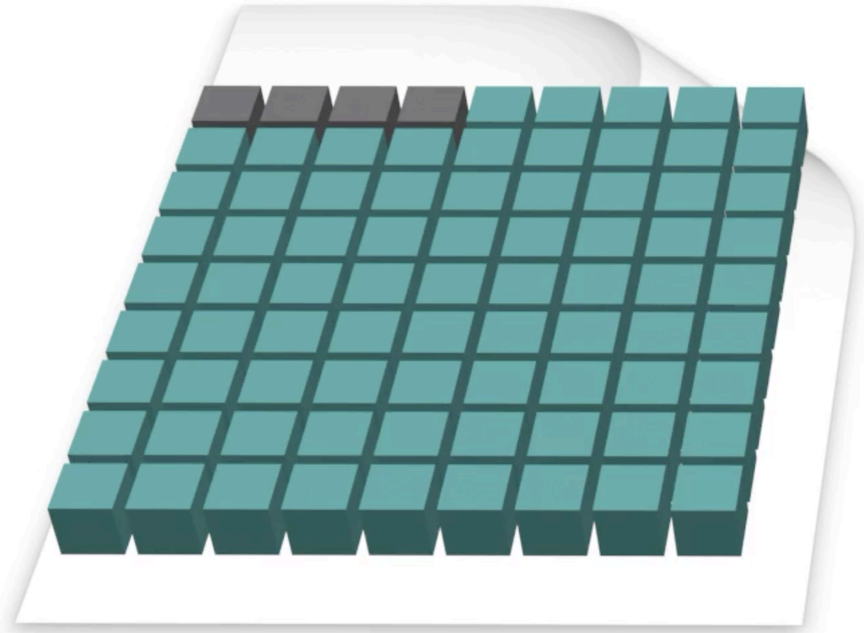


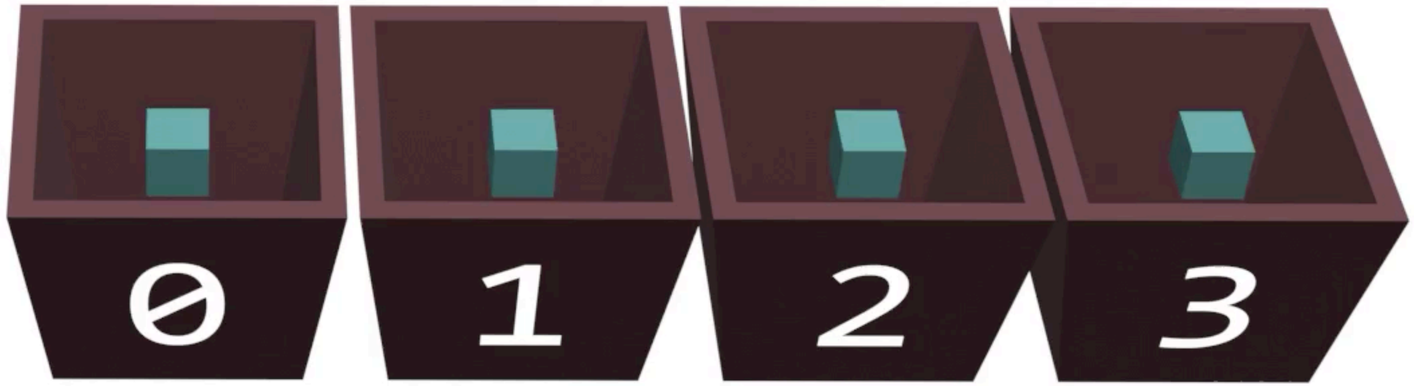


buffer

```
fread(buffer, 1, 4, f);
```

f

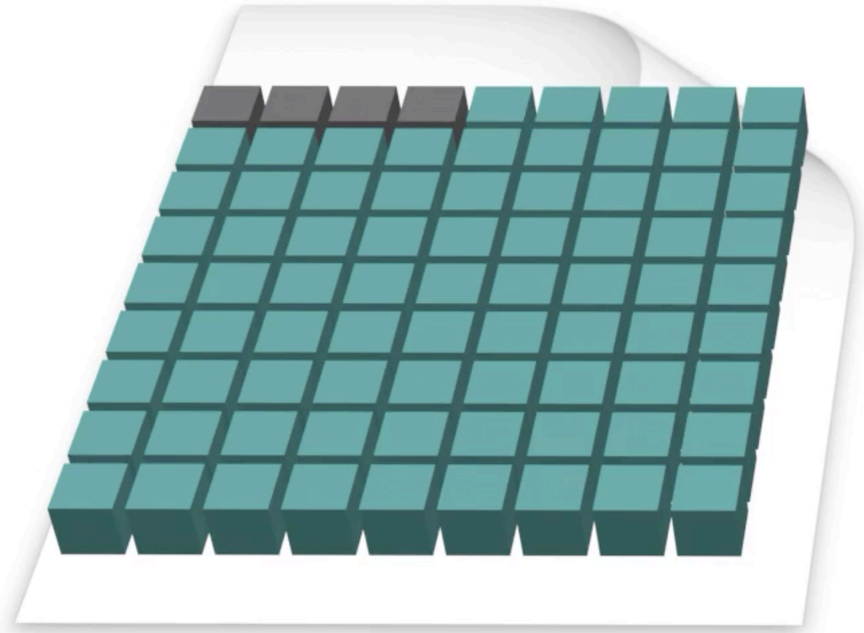


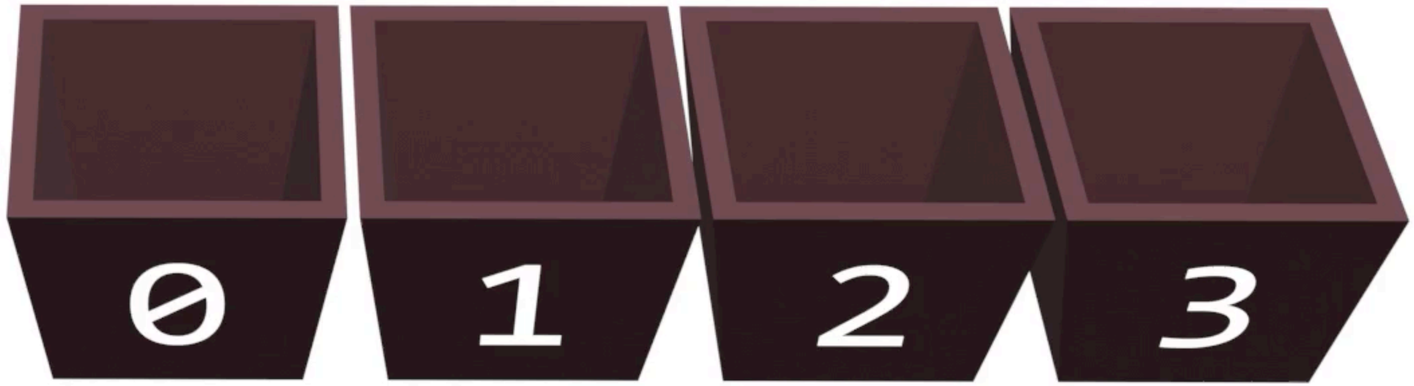


buffer

```
fread(buffer, 1, 4, f);
```

f

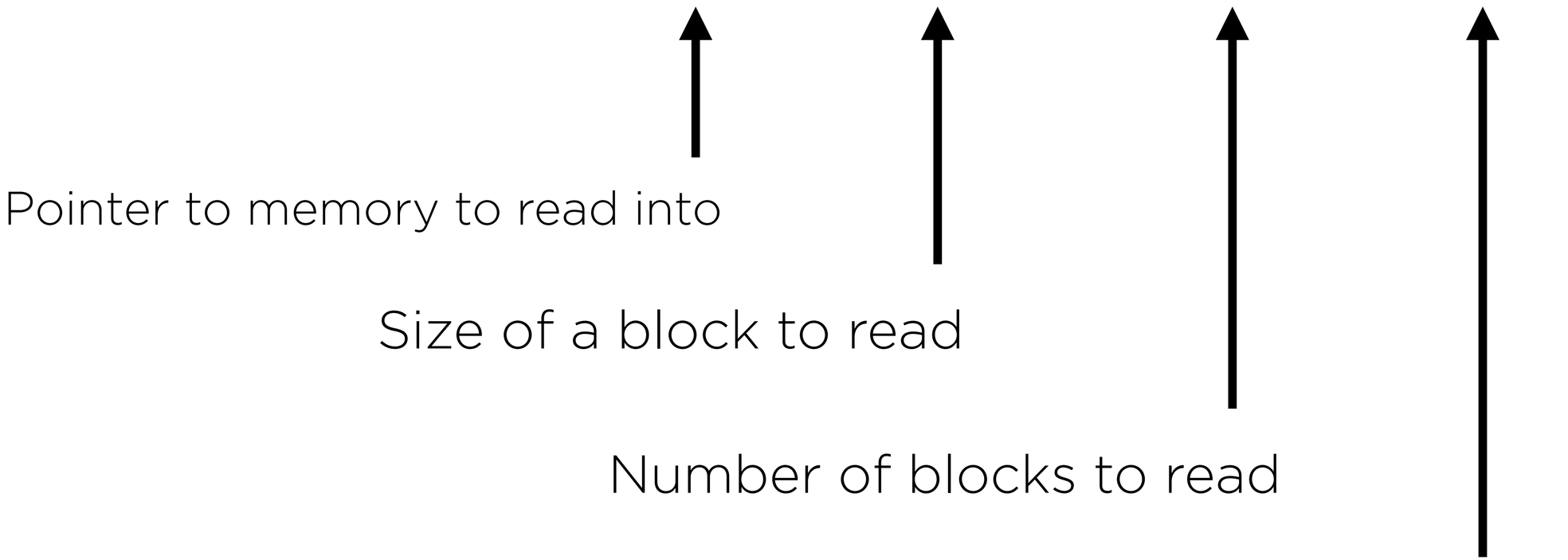




buffer

Reading from a File

```
fread(ptr, size, blocks, fp)
```

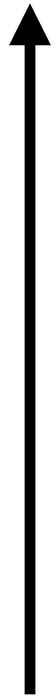


Writing to a File

```
fwrite(ptr, size, blocks, fp)
```

Writing to a File

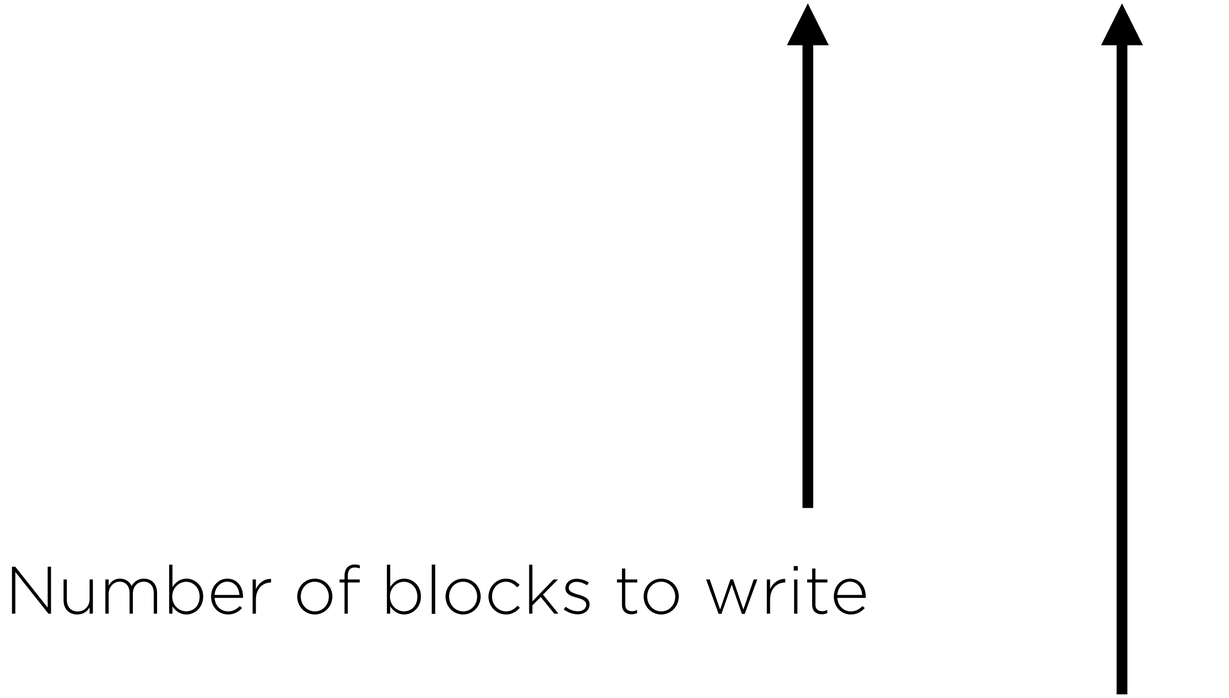
```
fwrite(ptr, size, blocks, fp)
```



Pointer to file to write to

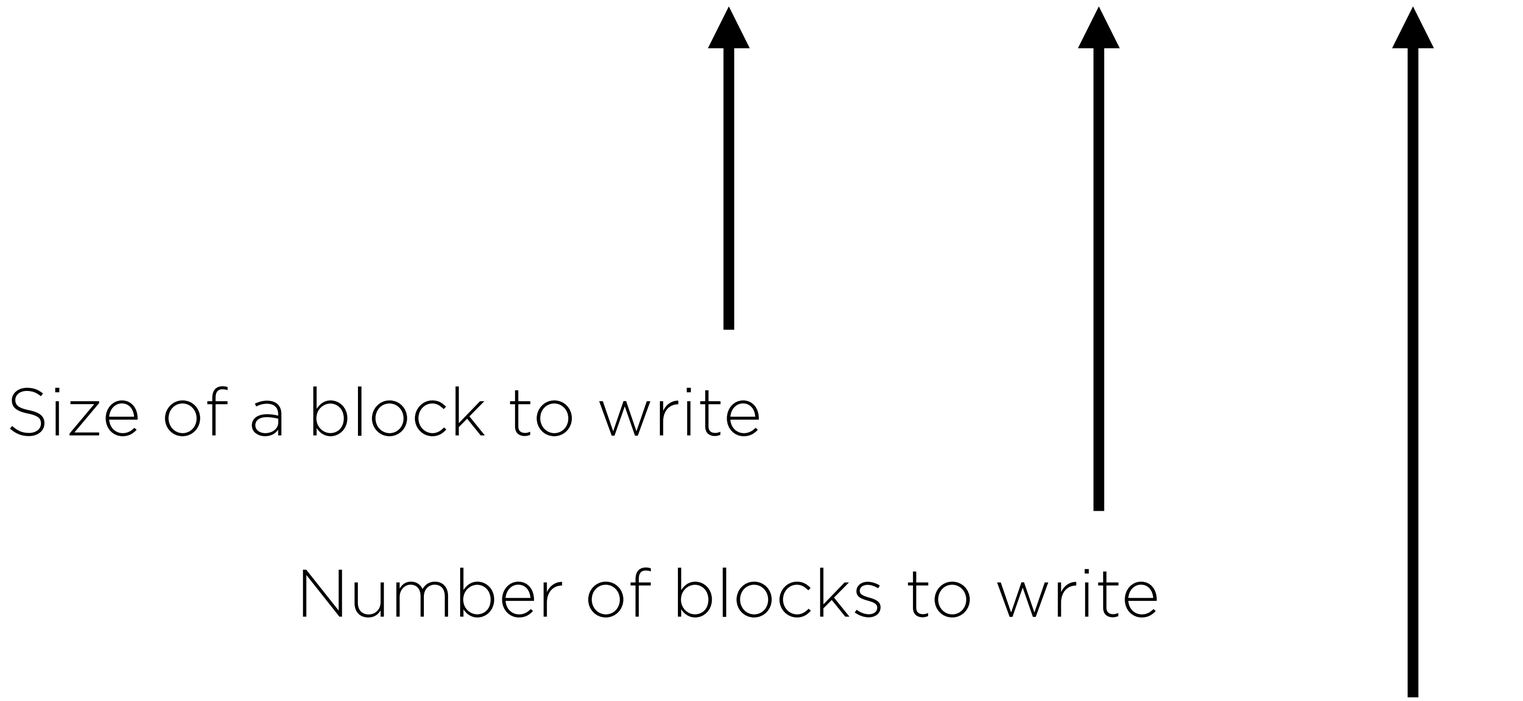
Writing to a File

```
fwrite(ptr, size, blocks, fp)
```



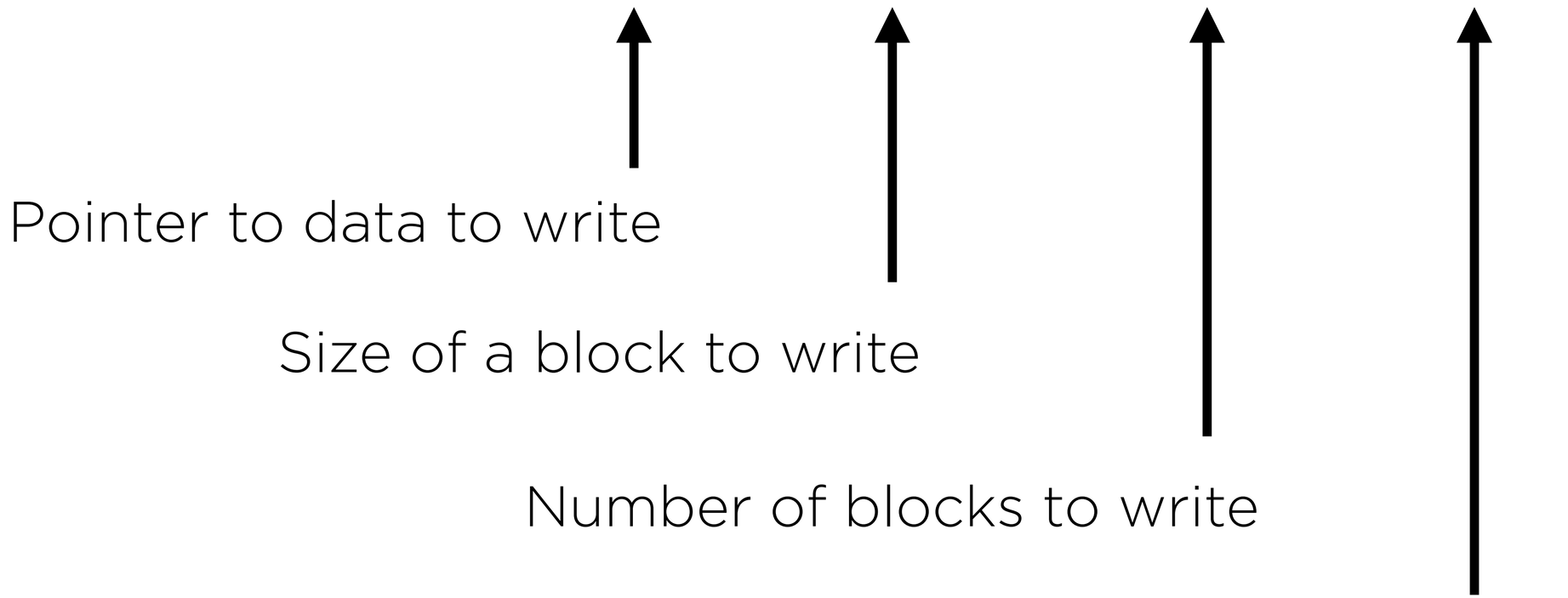
Writing to a File

```
fwrite(ptr, size, blocks, fp)
```



Writing to a File

```
fwrite(ptr, size, blocks, fp)
```



Closing a File

```
fclose(fp)
```

Closing a File

```
fclose(fp)
```

Pointer to file to close

Exercise

Write a program `pdf.c` that checks if a file is a PDF.

Every PDF begins with the first five bytes: `0x25 0x50 0x44 0x46 0x2d`

```
$ ./pdf file.pdf
YES
$ ./pdf picture.jpg
NO
```

Dynamic Memory

Dynamic Memory

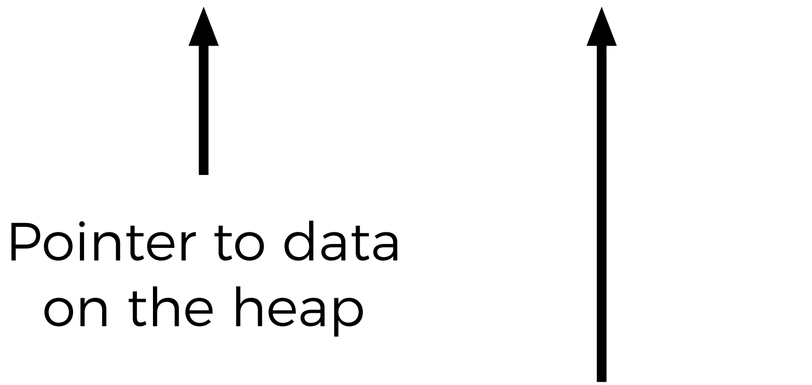
- Memory that lives on the heap, outside of the stack
- Memory that can be requested at runtime

```
int *x = malloc(sizeof(int));
```

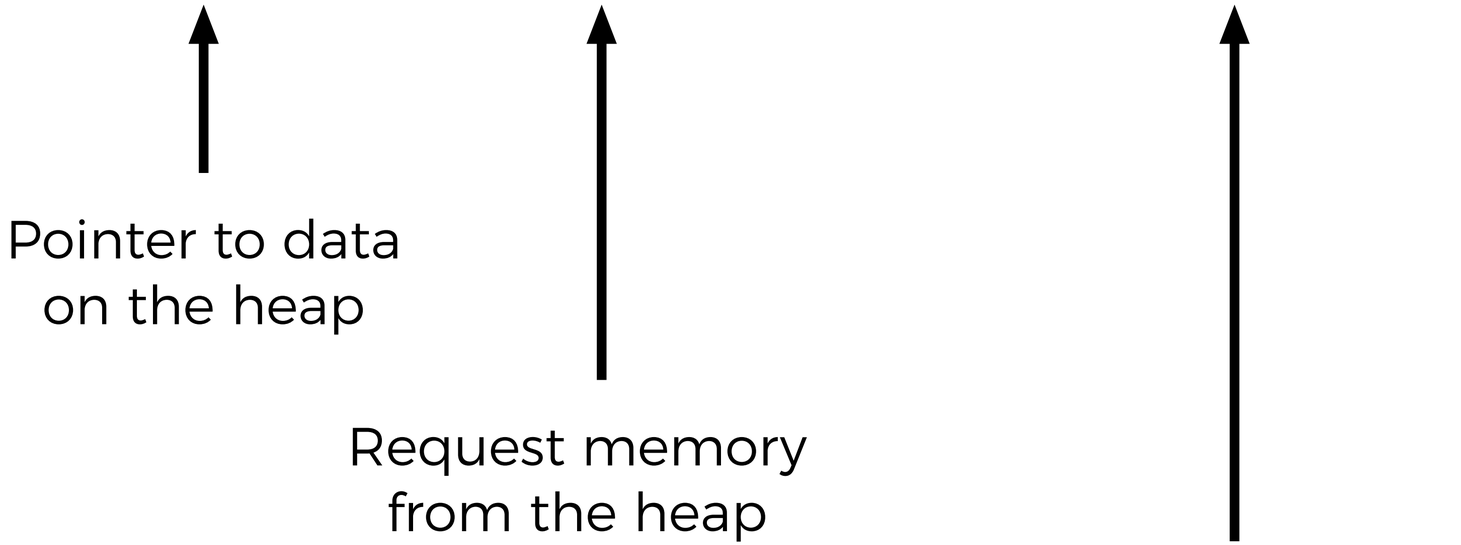
```
int *x = malloc(sizeof(int));
```

Pointer to data
on the heap

```
int *x = malloc(sizeof(int));
```

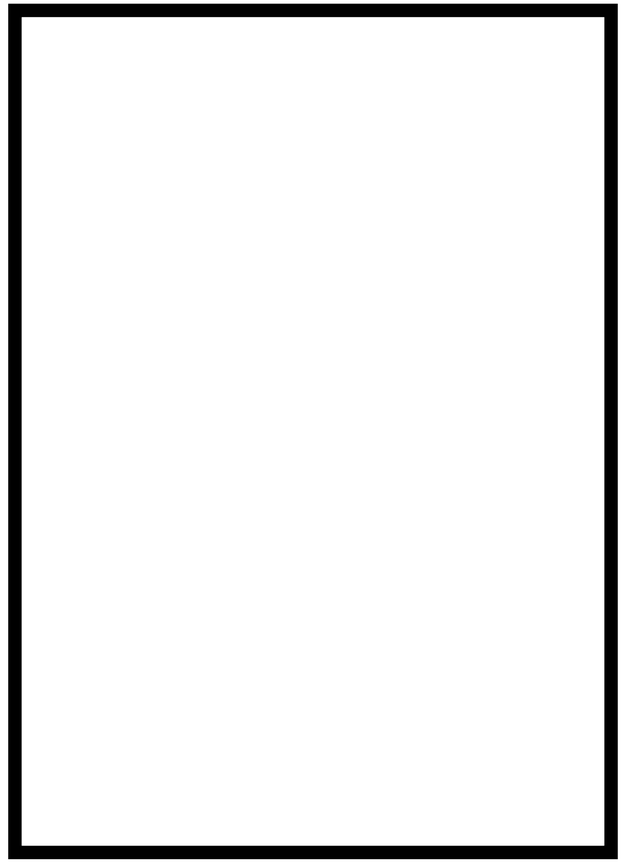


```
int *x = malloc(sizeof(int));
```

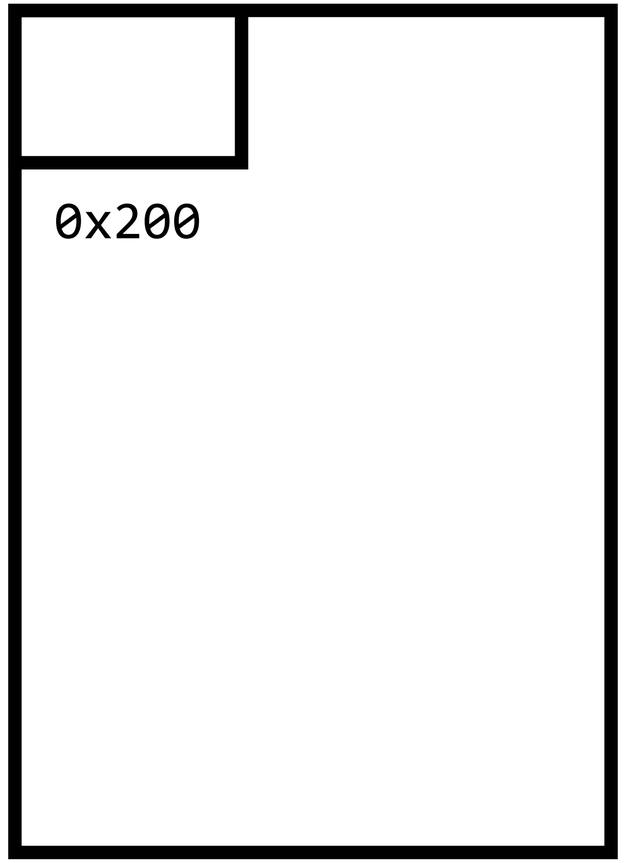


```
int *x = malloc(sizeof(int));
```

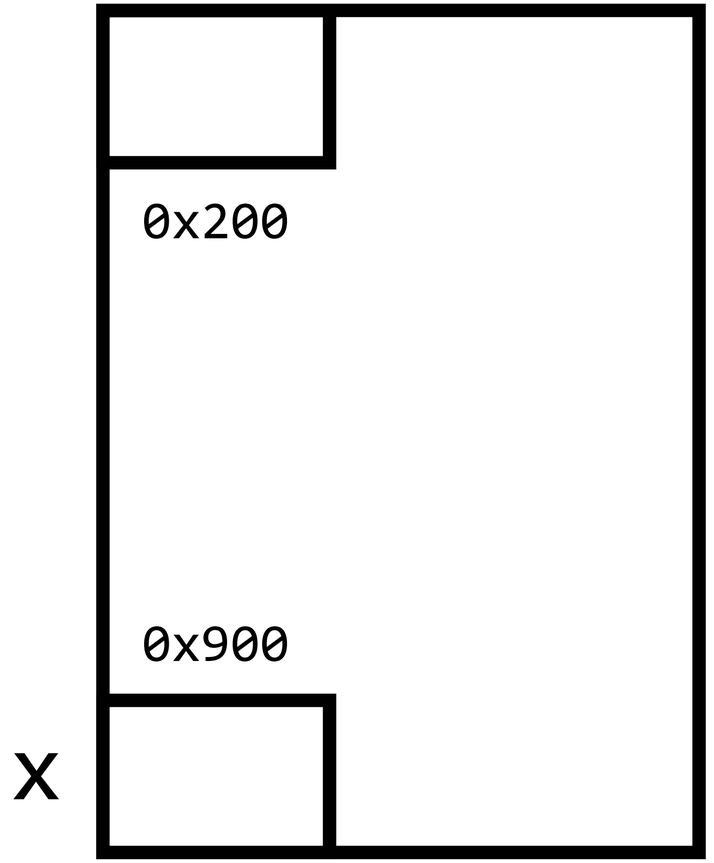
```
int *x = malloc(sizeof(int));
```



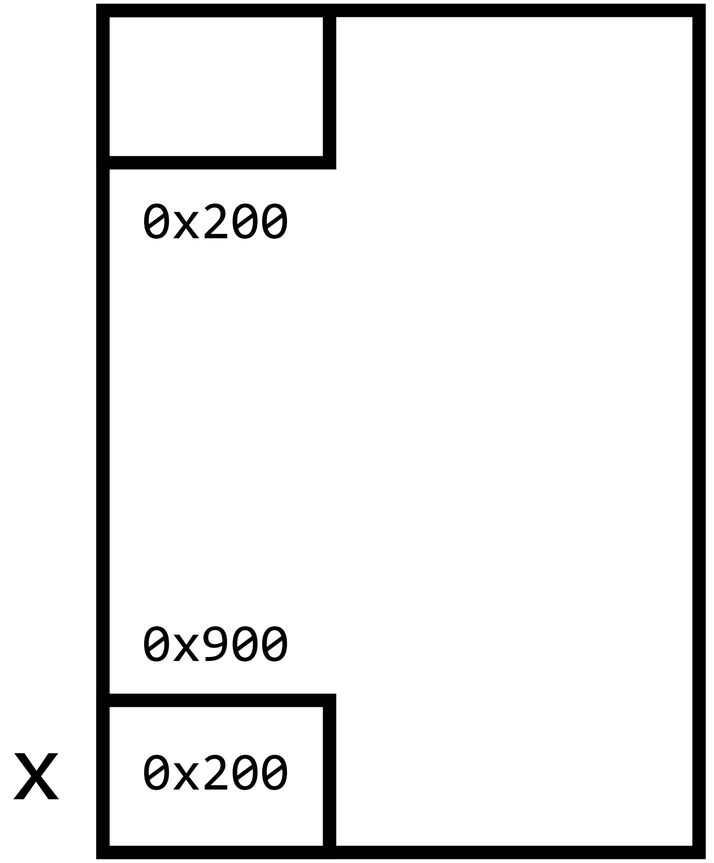
```
int *x = malloc(sizeof(int));
```



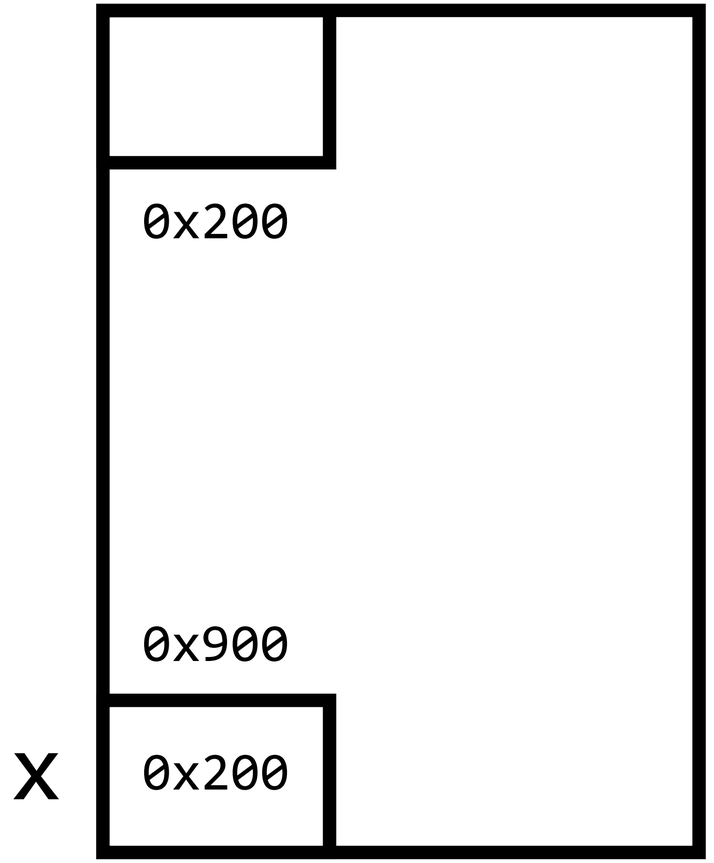
```
int *x = malloc(sizeof(int));
```



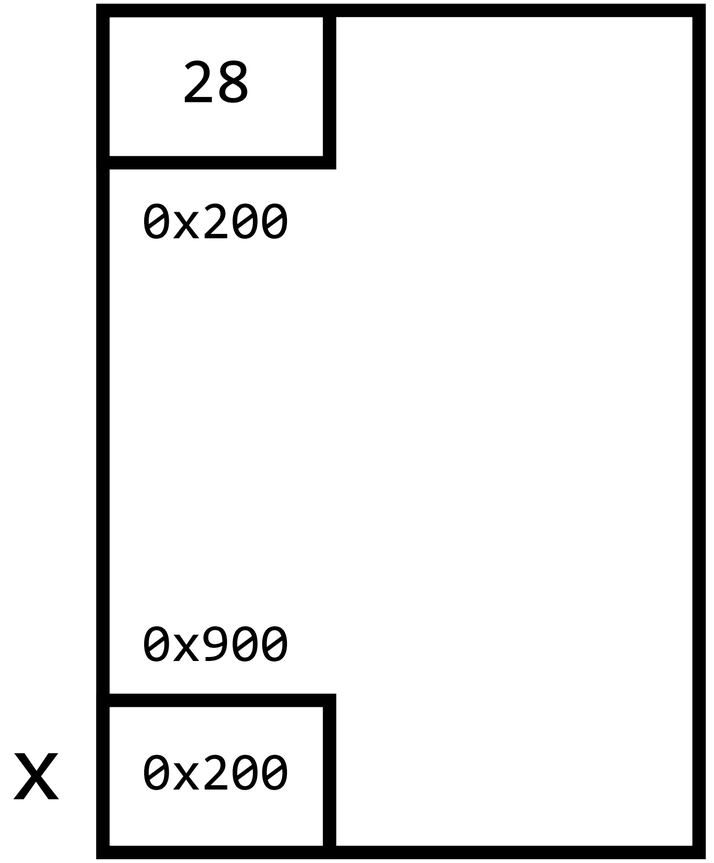
```
int *x = malloc(sizeof(int));
```



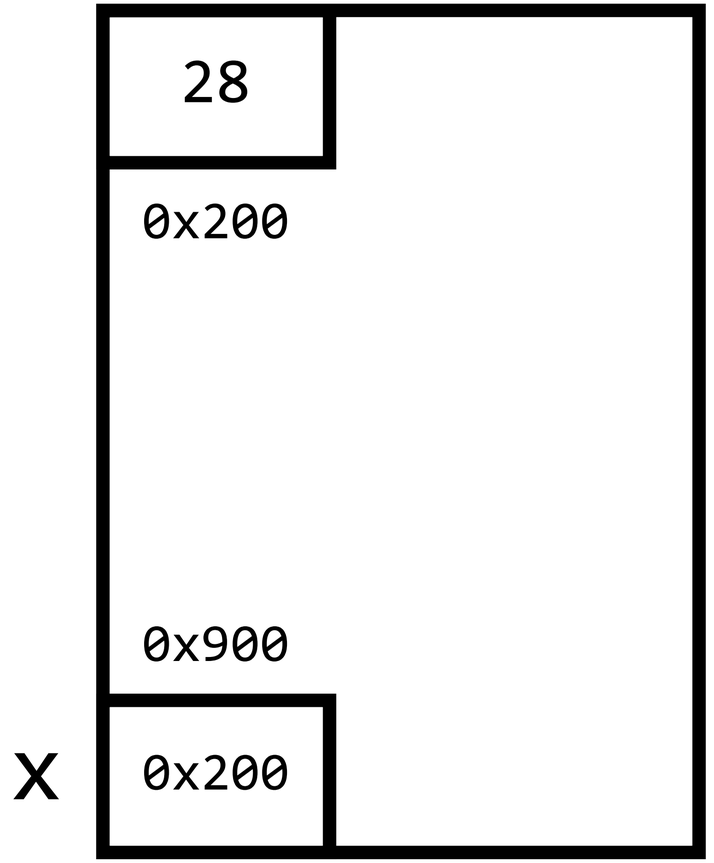
```
int *x = malloc(sizeof(int));

*x = 28;
```



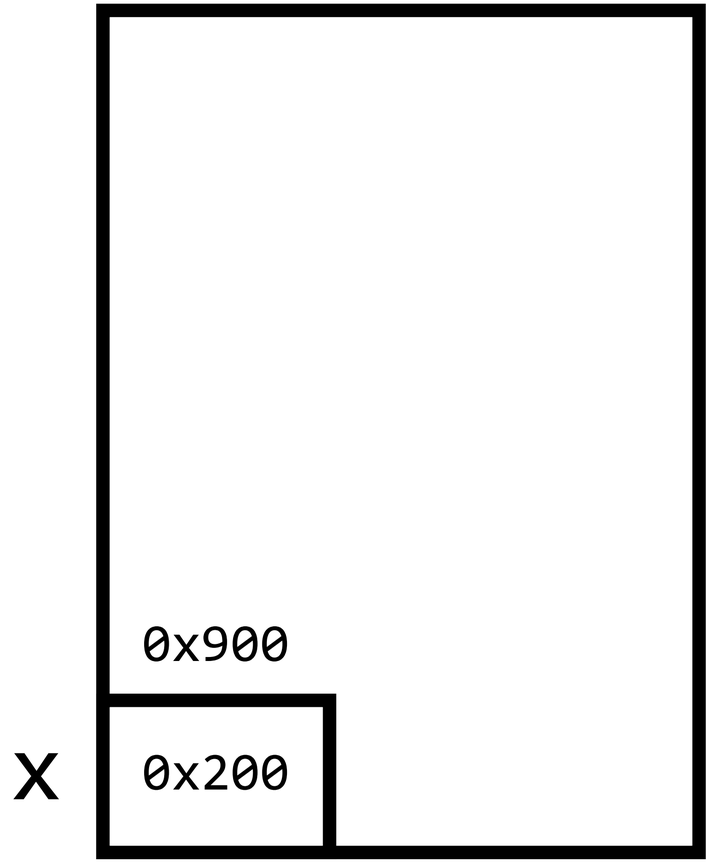
```
int *x = malloc(sizeof(int));

*x = 28;
```



```
int *x = malloc(sizeof(int));

*x = 28;

free(x);
```



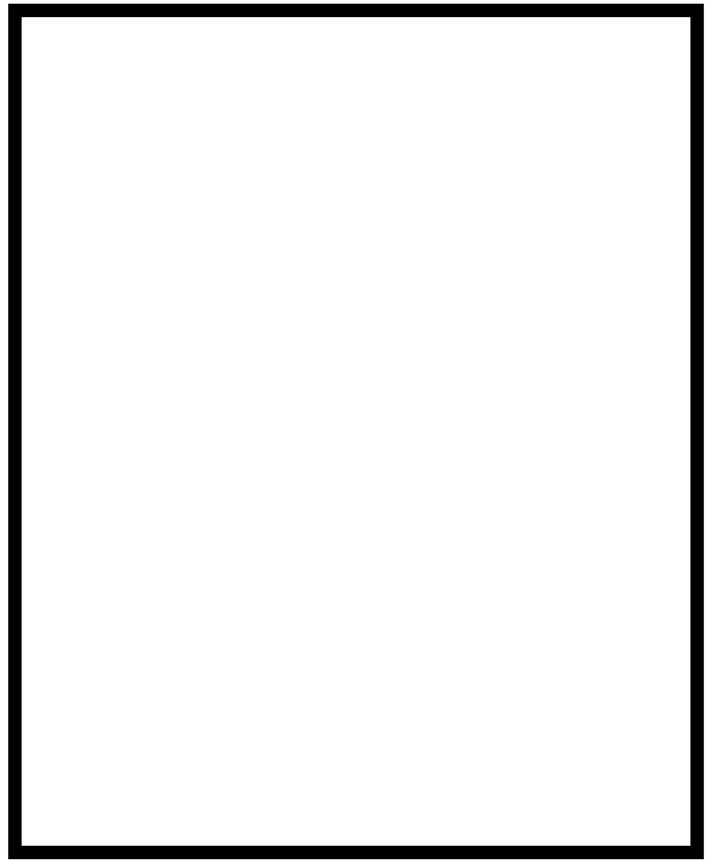
```
int *x = malloc(sizeof(int));

*x = 28;

free(x);
```



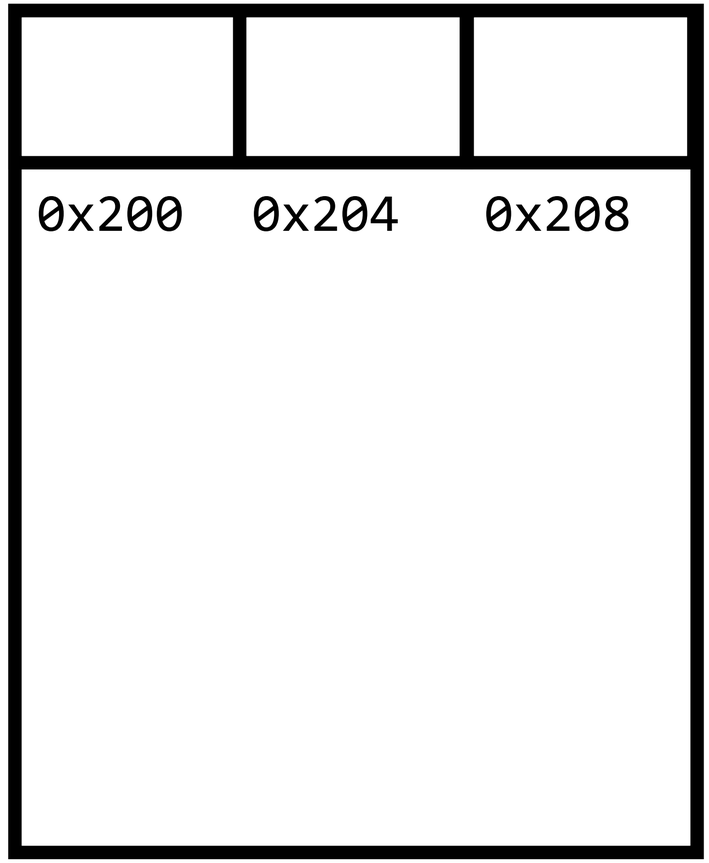
```
int *x = malloc(sizeof(int));
```

```
int *x = malloc(3 * sizeof(int));
```

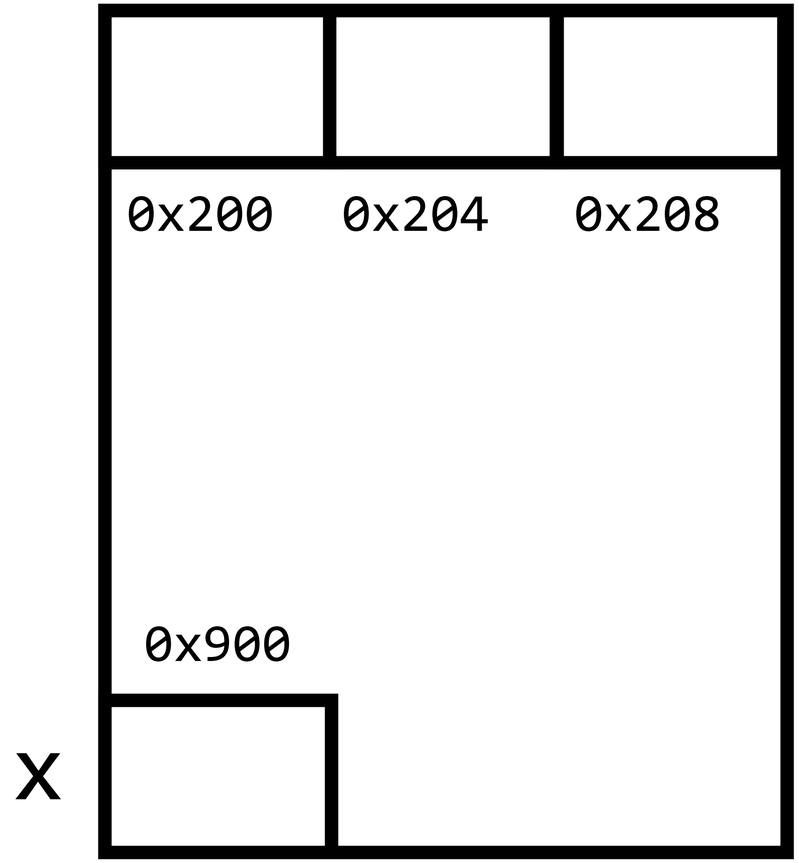
```
int *x = malloc(3 * sizeof(int));
```



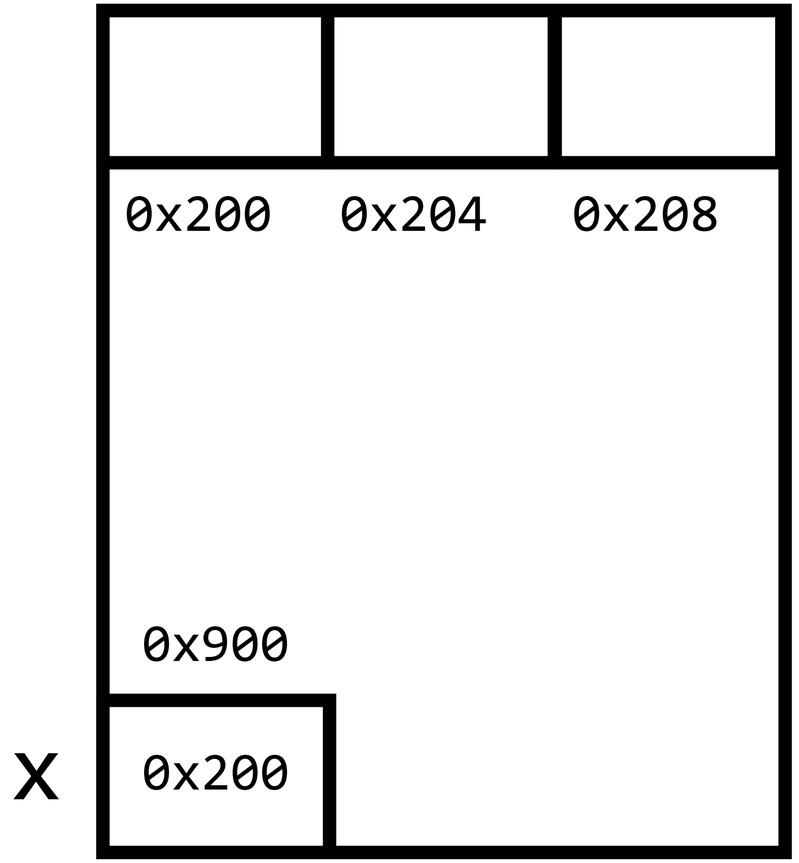
```
int *x = malloc(3 * sizeof(int));
```



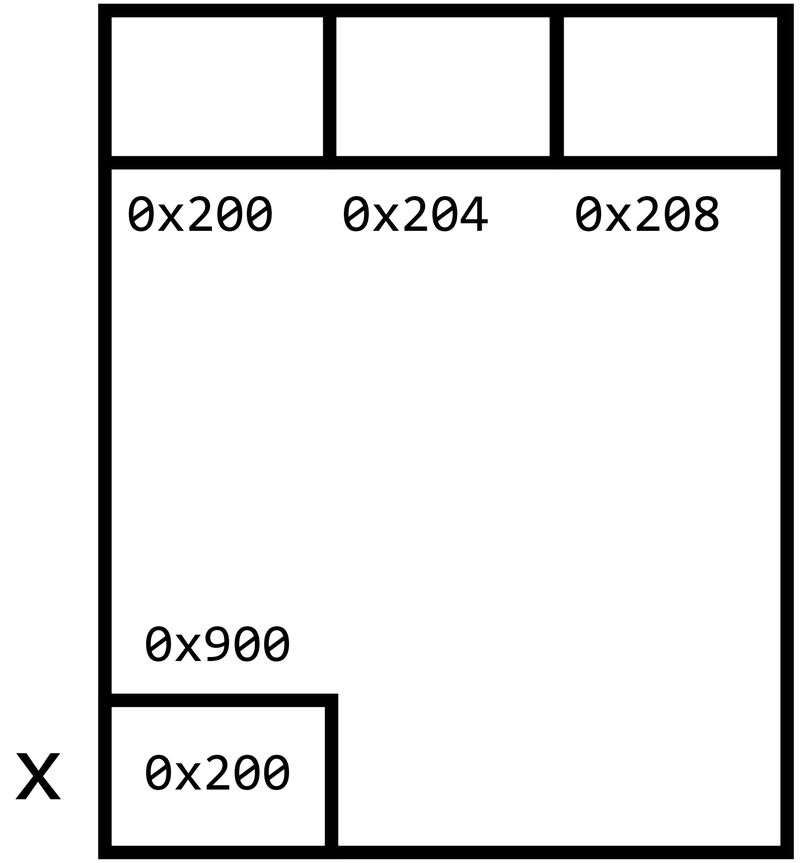
```
int *x = malloc(3 * sizeof(int));
```



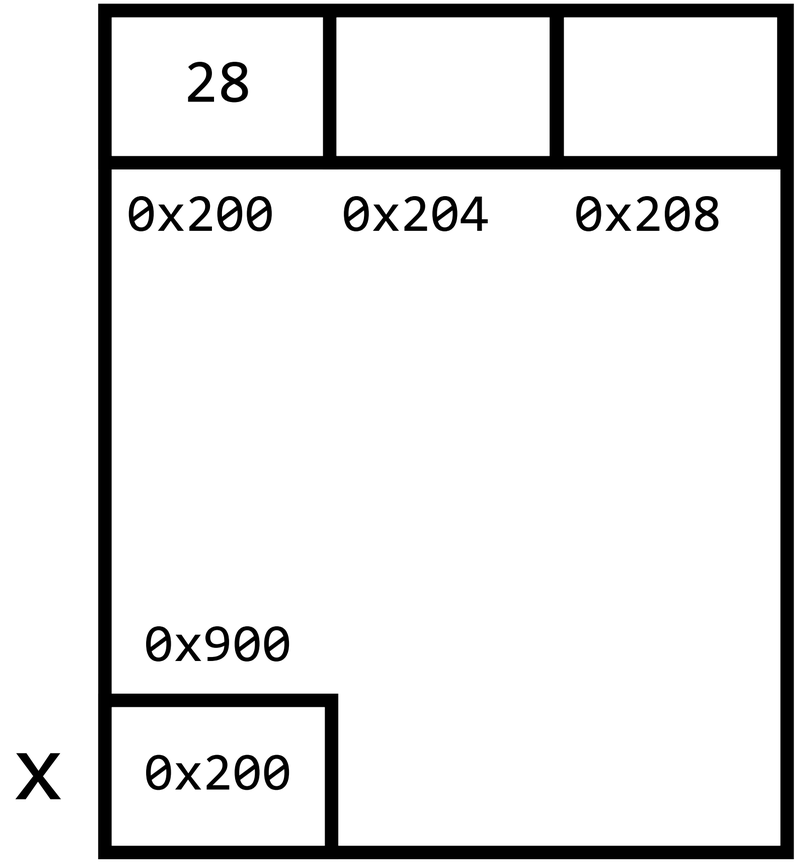
```
int *x = malloc(3 * sizeof(int));
```



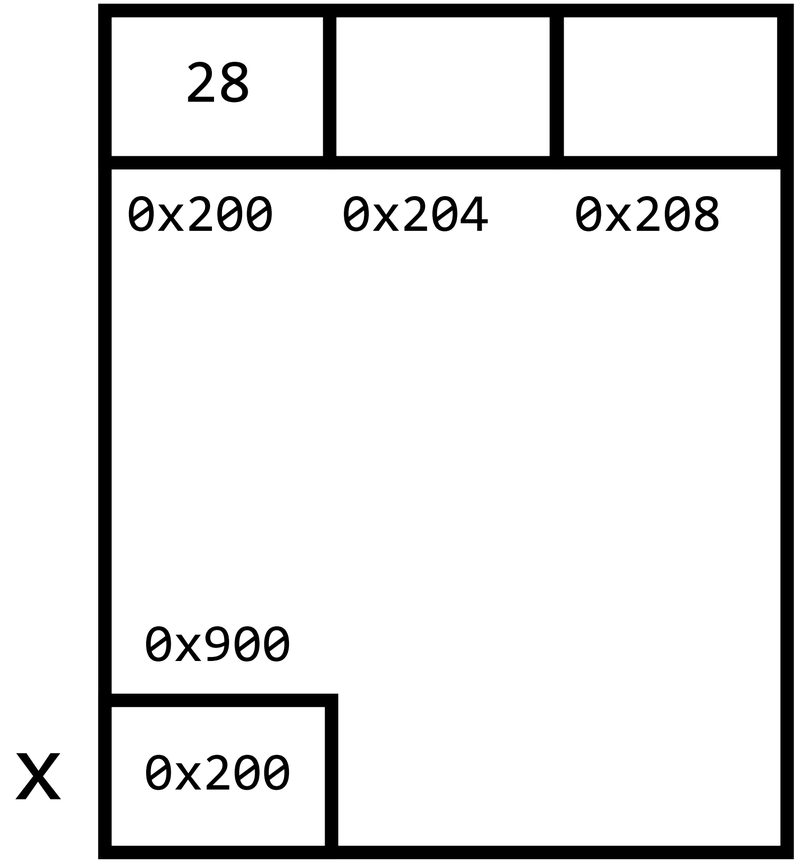
```
int *x = malloc(3 * sizeof(int));

*x = 28;
```



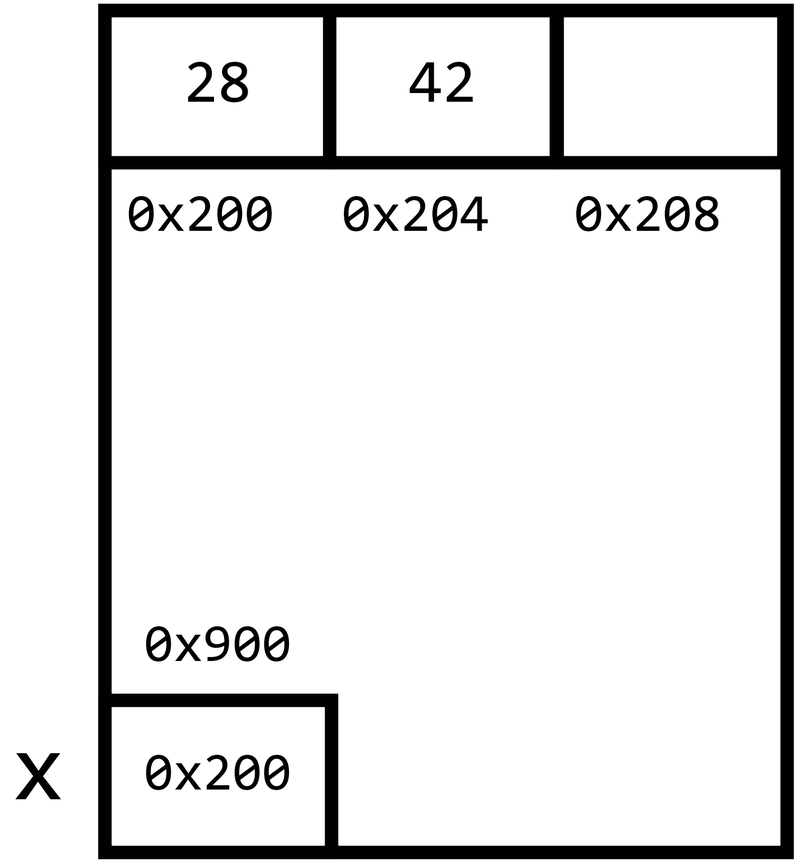
```
int *x = malloc(3 * sizeof(int));

*x = 28;
```



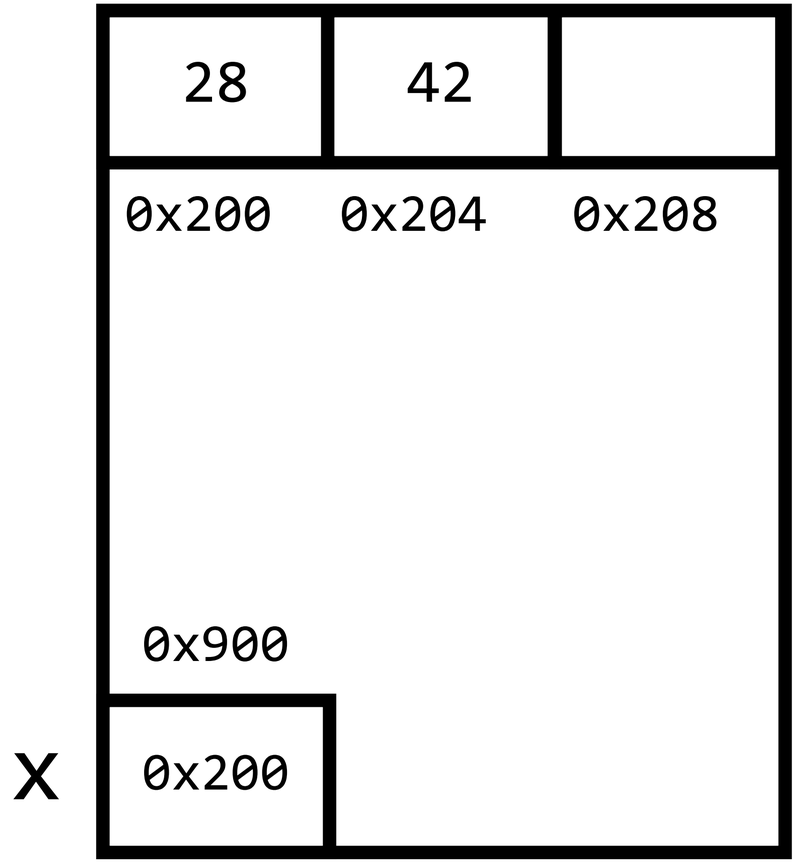
```
int *x = malloc(3 * sizeof(int));

*x = 28;

*(x + 1) = 42;
```



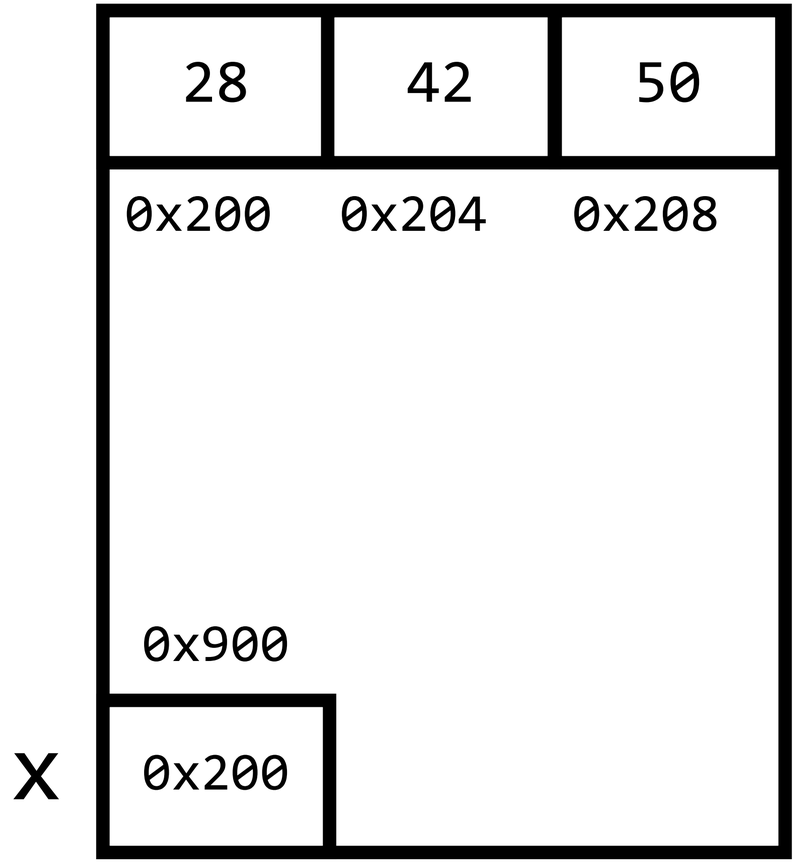
```
int *x = malloc(3 * sizeof(int));

*x = 28;

*(x + 1) = 42;
```



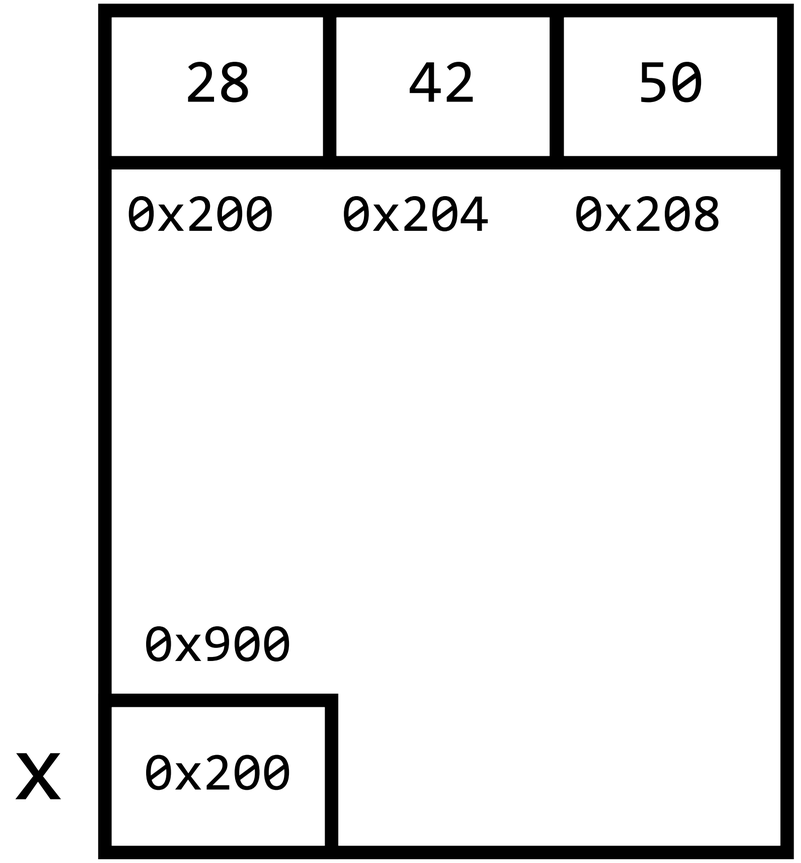
```
int *x = malloc(3 * sizeof(int));

*x = 28;

*(x + 1) = 42;

*(x + 2) = 50;
```



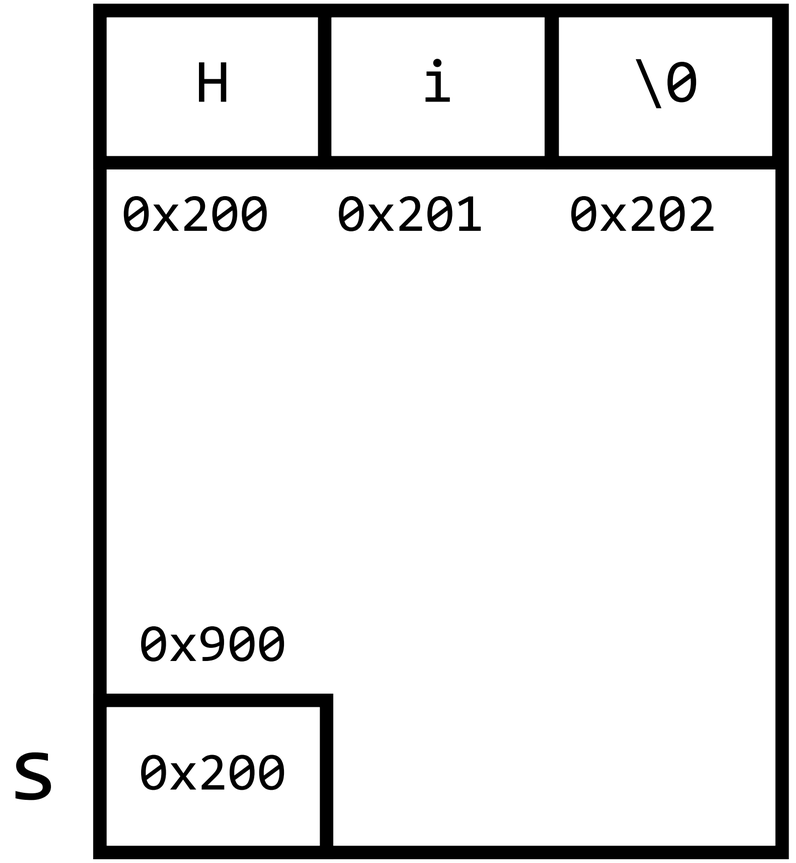
```
int *x = malloc(3 * sizeof(int));

*x = 28;

*(x + 1) = 42;

*(x + 2) = 50;
```



```
int *x = malloc(3 * sizeof(int));

x[0] = 28;

x[1] = 42;

x[2] = 50;
```



```
char *s = malloc(3 * sizeof(char));
s[0] = 'H';
s[1] = 'i';
s[2] = '\0';
```



Memory Errors

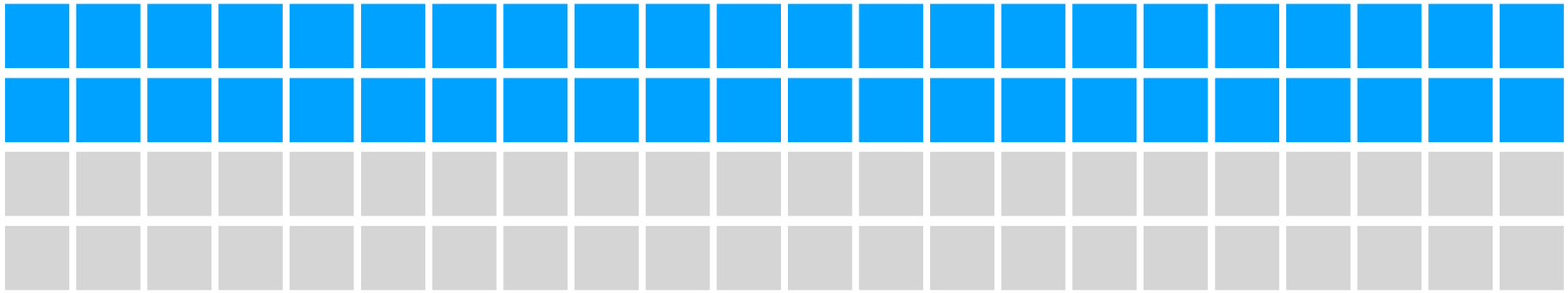
- Always **`free`** memory after done with it
- Use **`valgrind`** to check for memory errors

Part Three

Lab

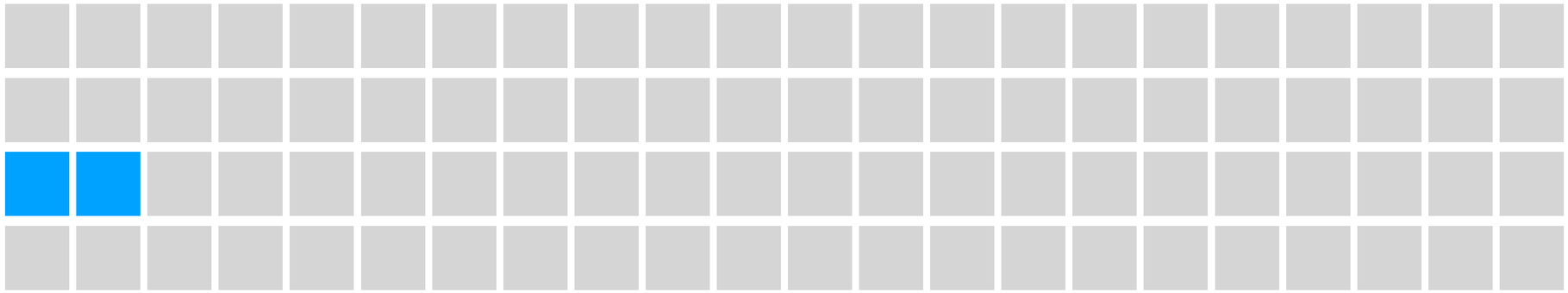
WAV File

WAV File



44 bytes - Header

WAV File

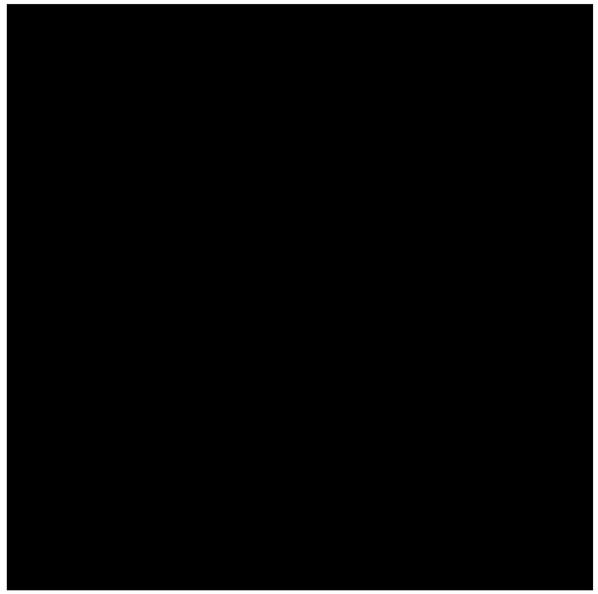


2 bytes each - samples

Problem Set 4

Problem Set 4

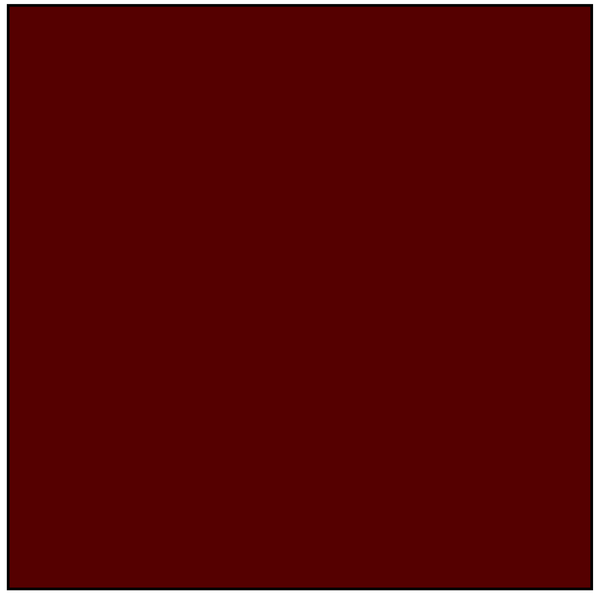
- Filter
  - Grayscale
  - Sepia (less comfortable)
  - Reflect
  - Blur
  - Edges (more comfortable)
- Recover



Red 0 255

Green 0 255

Blue 0 255



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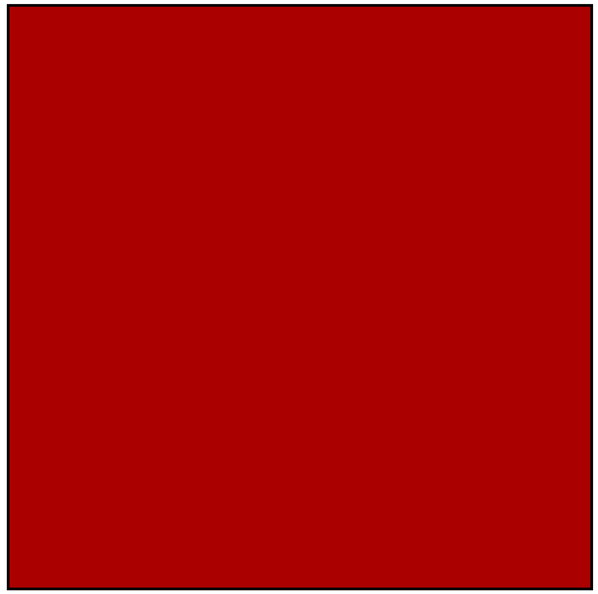

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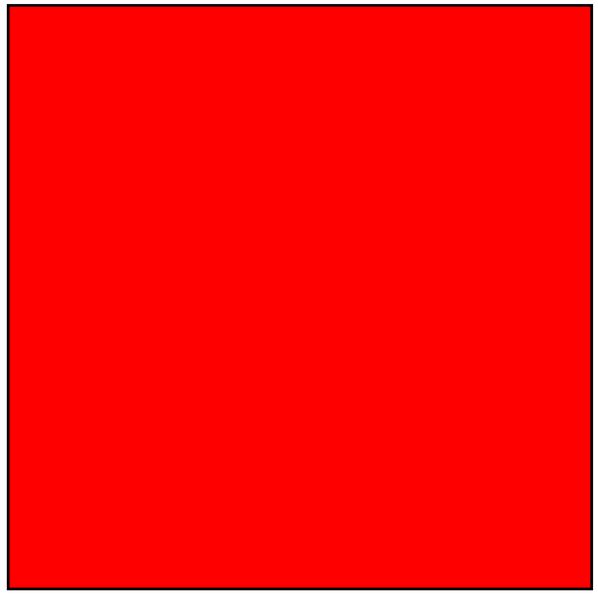

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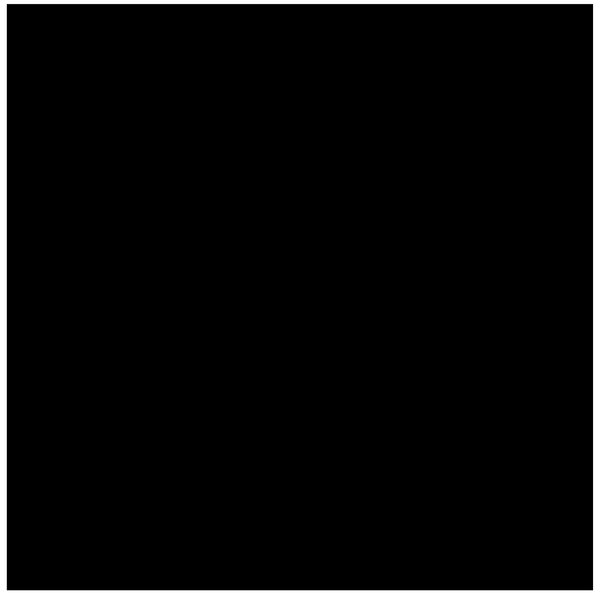

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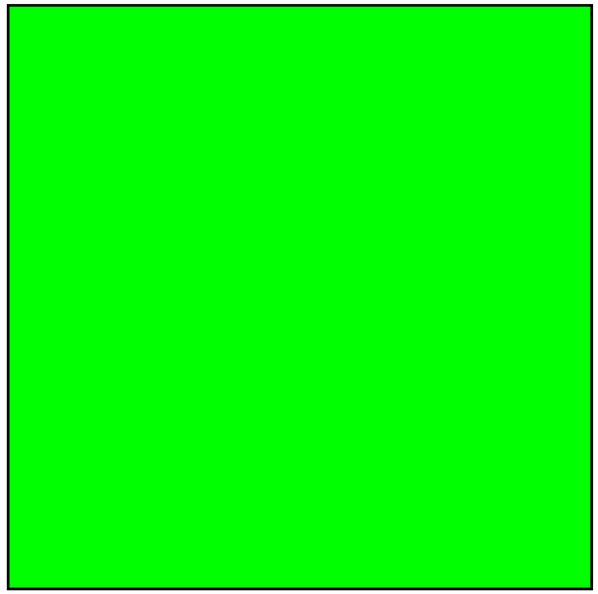

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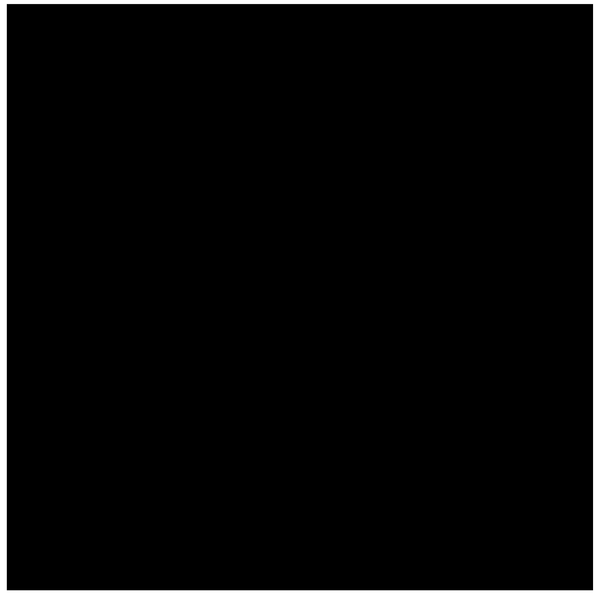

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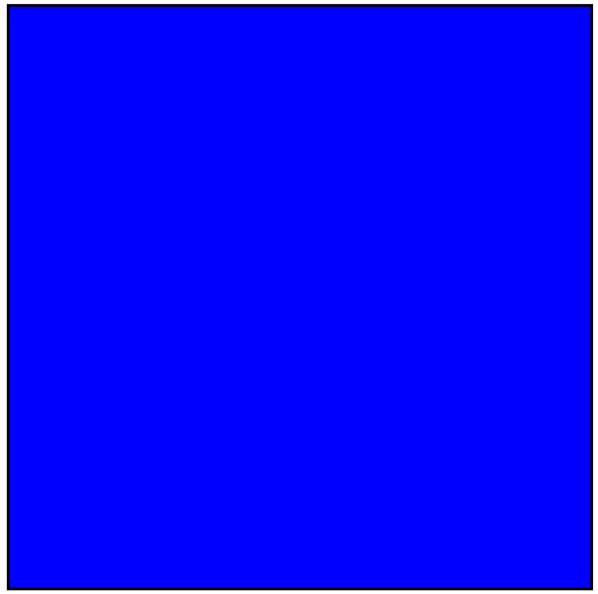

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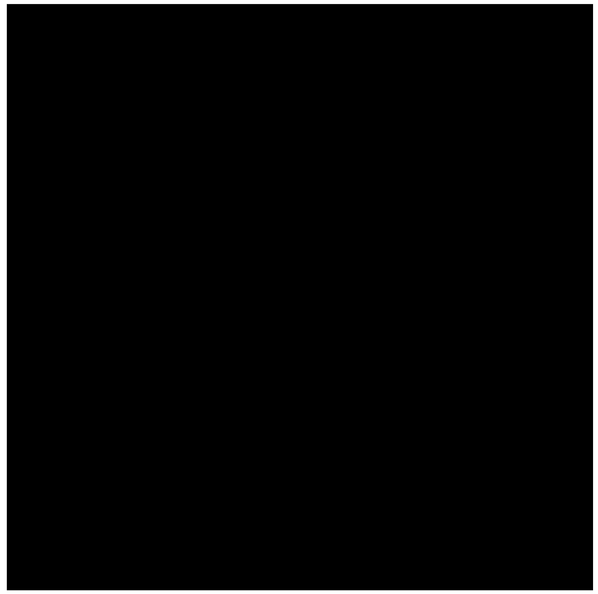

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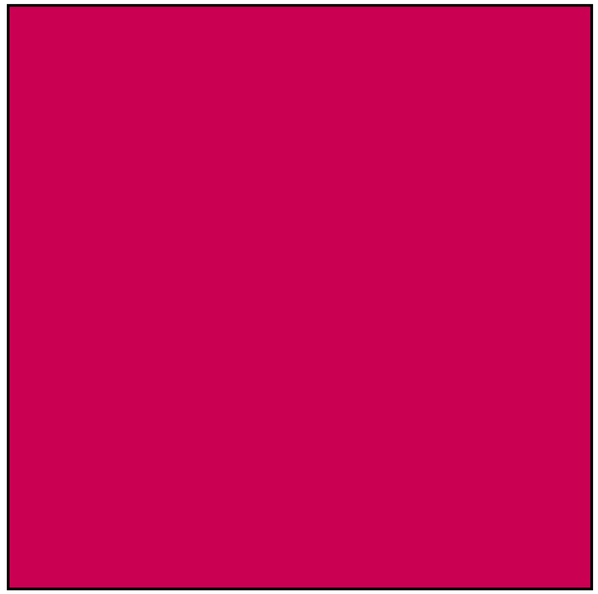

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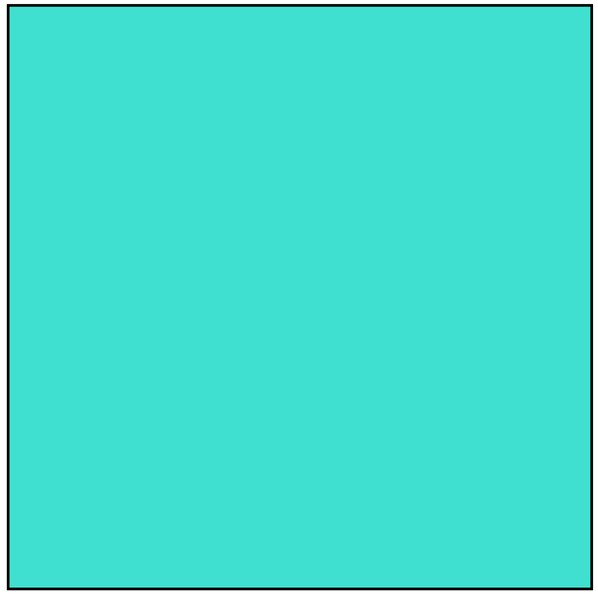

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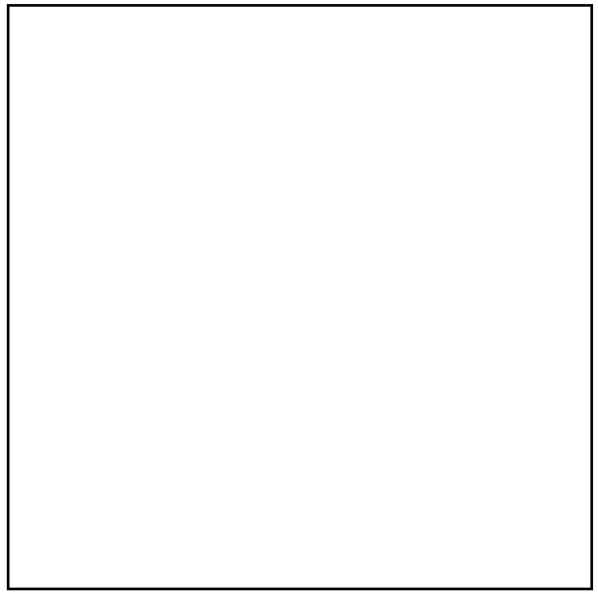

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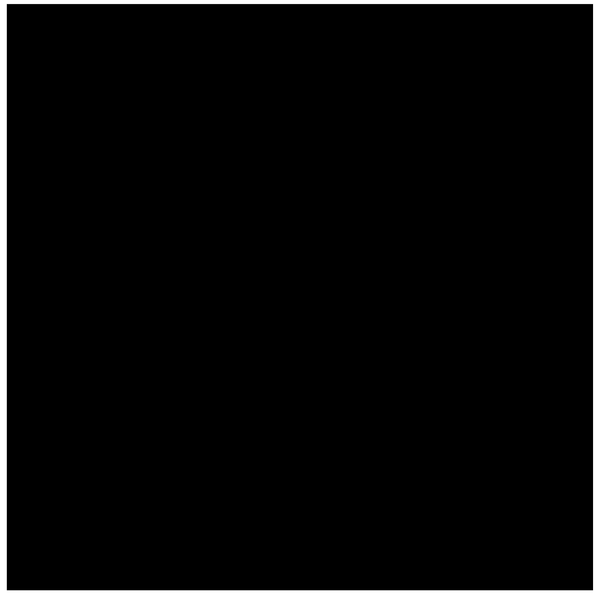

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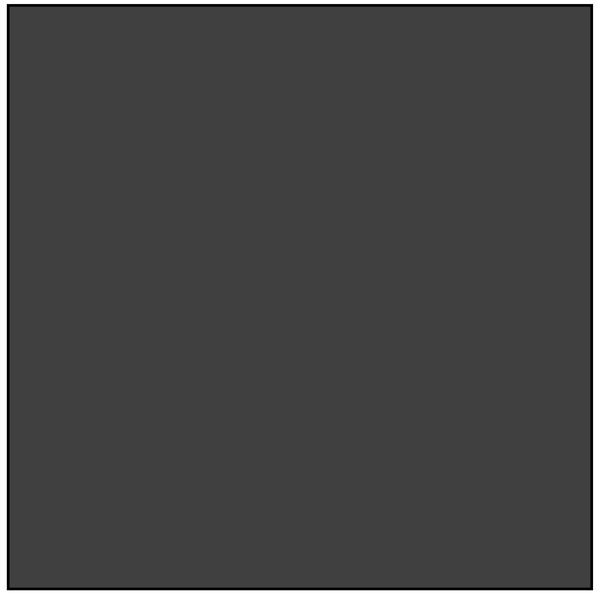

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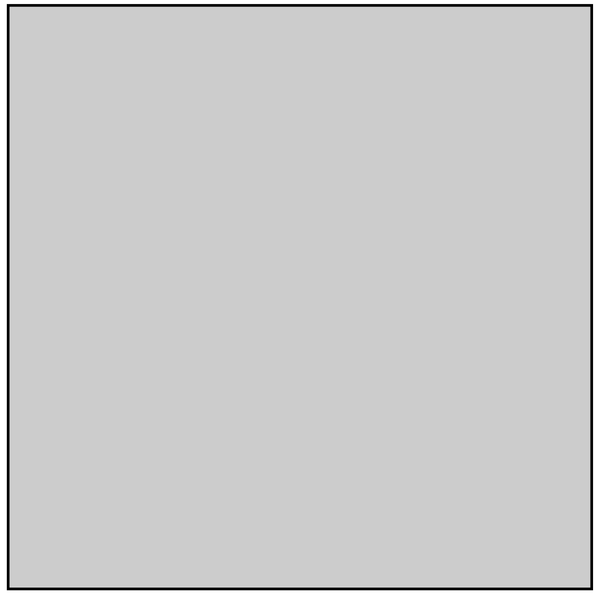

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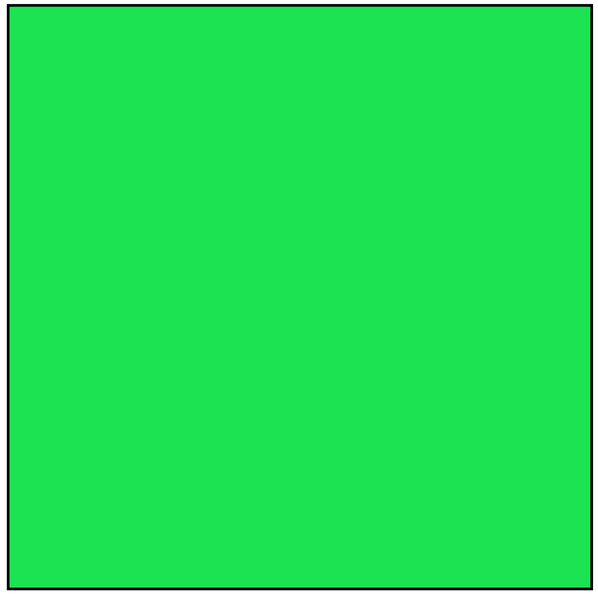

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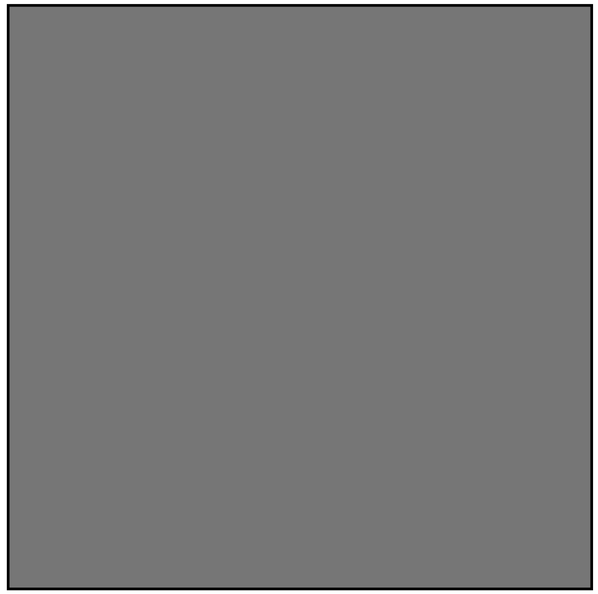

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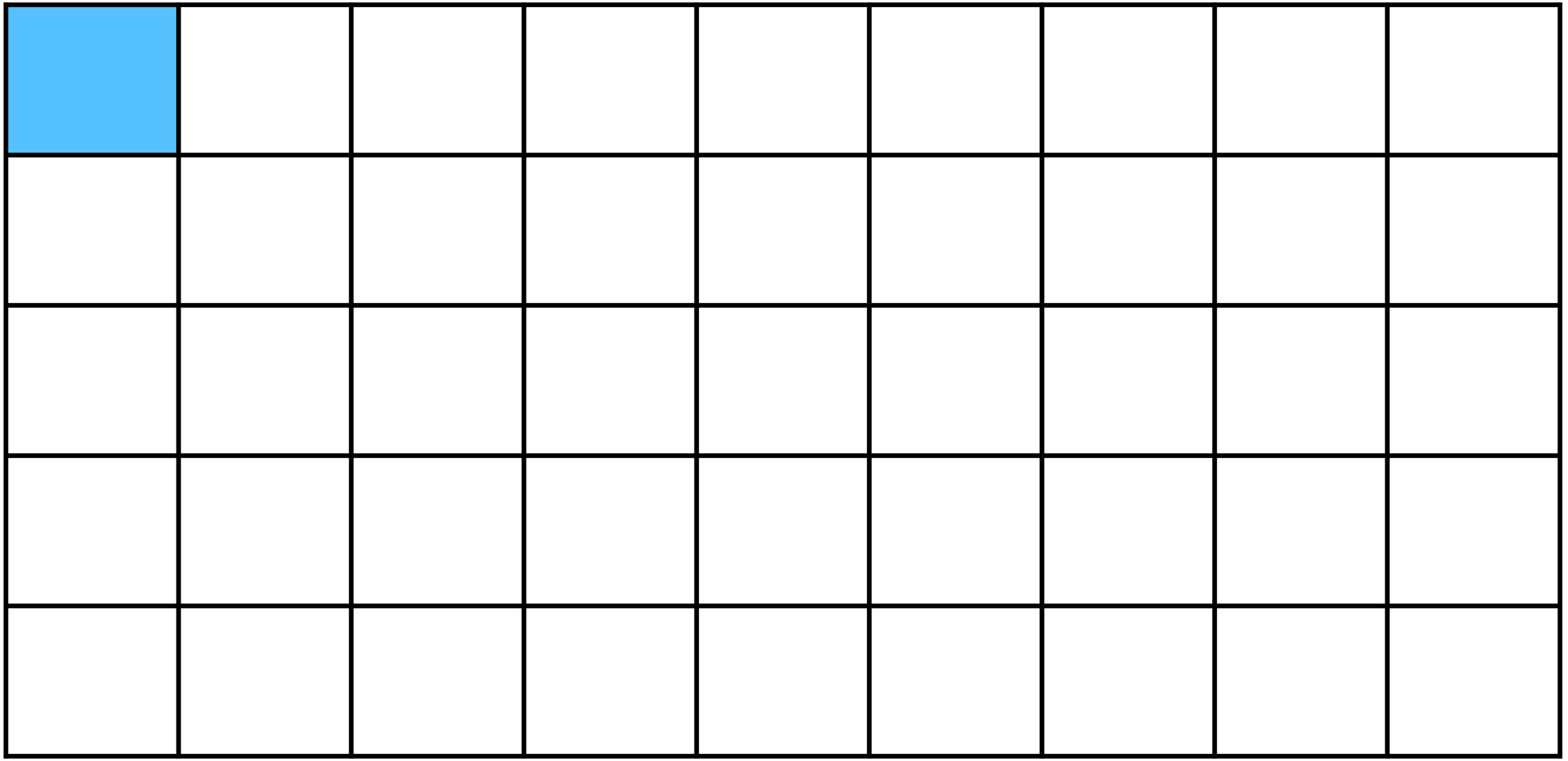

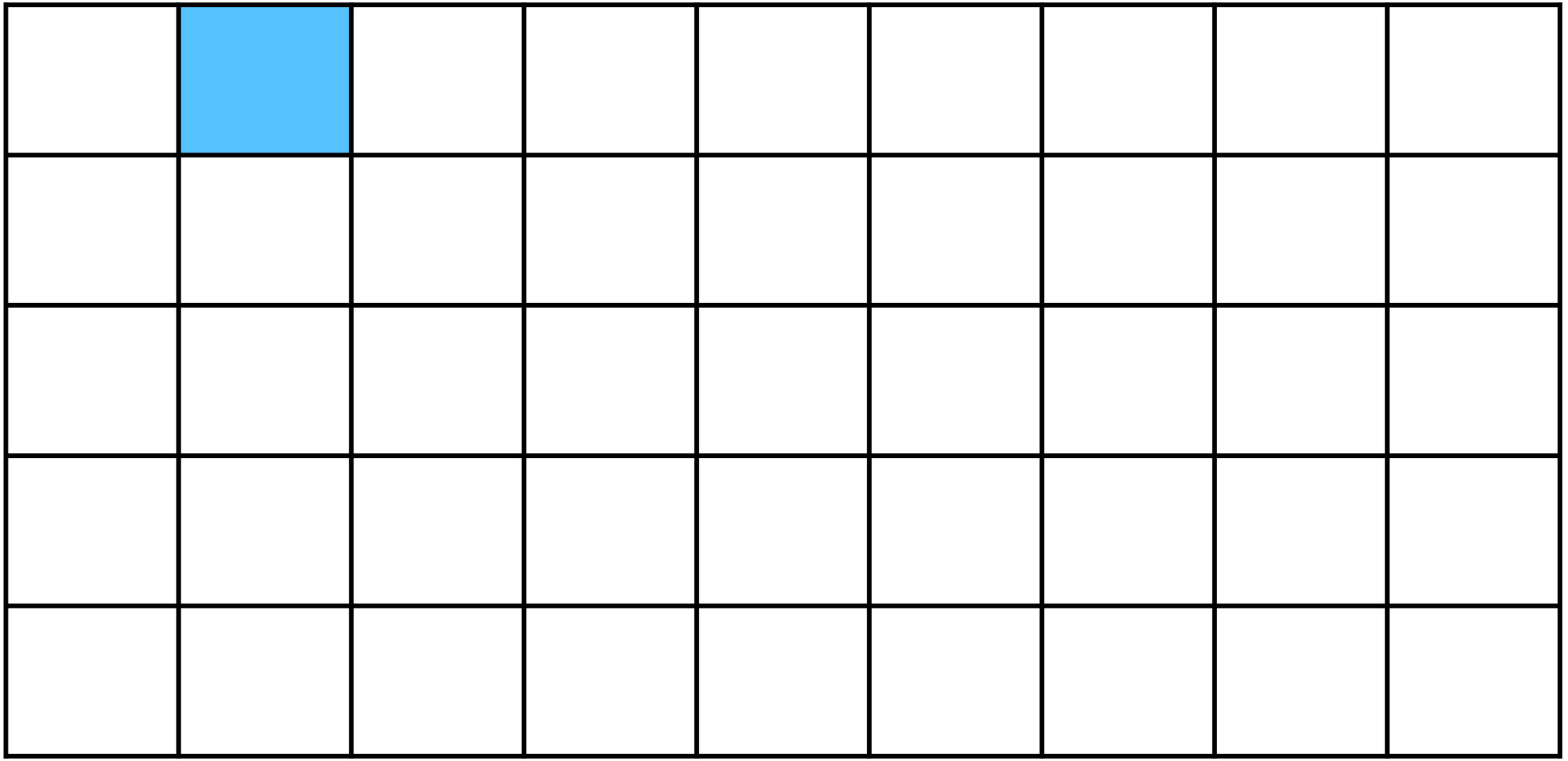

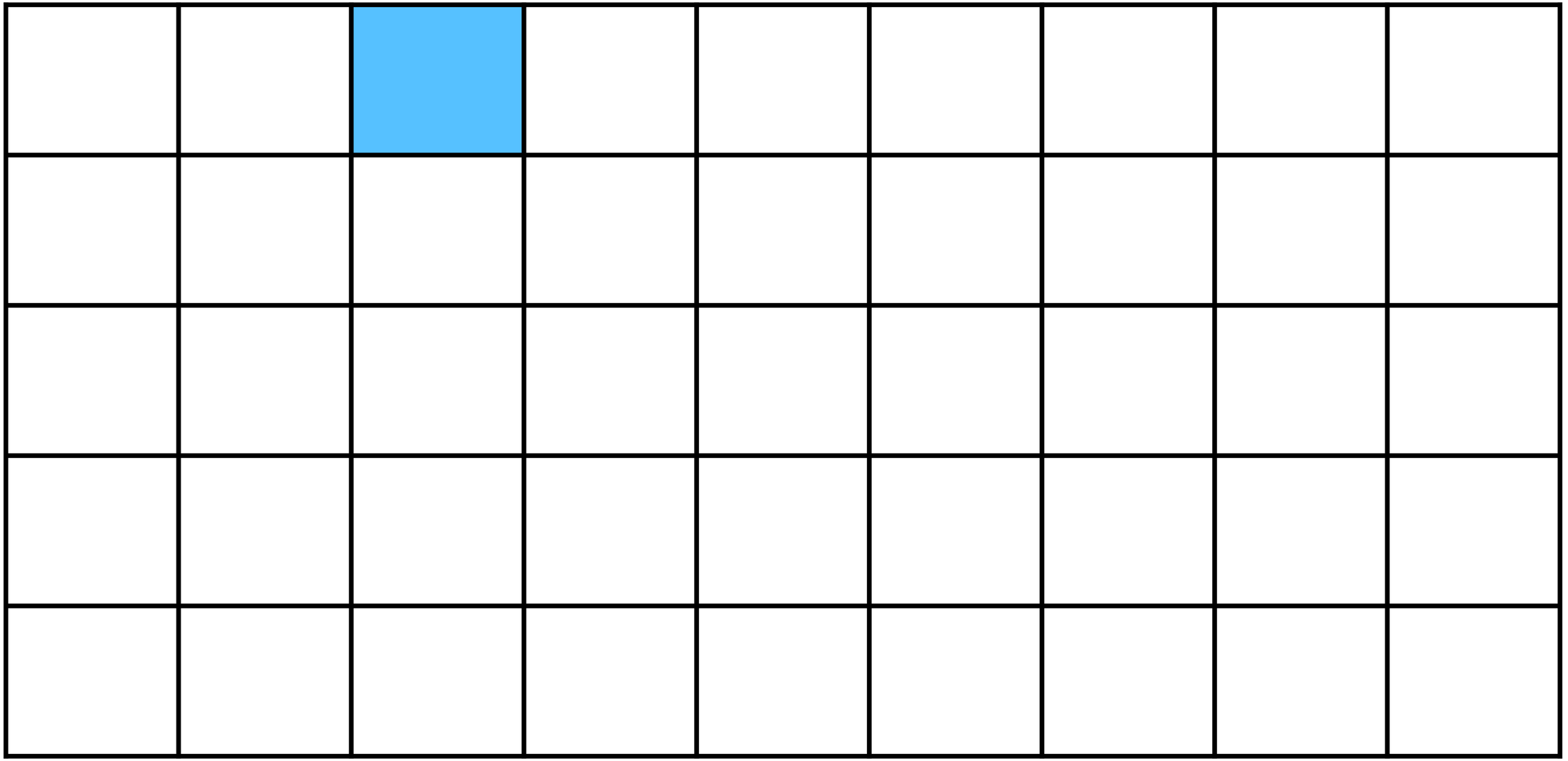

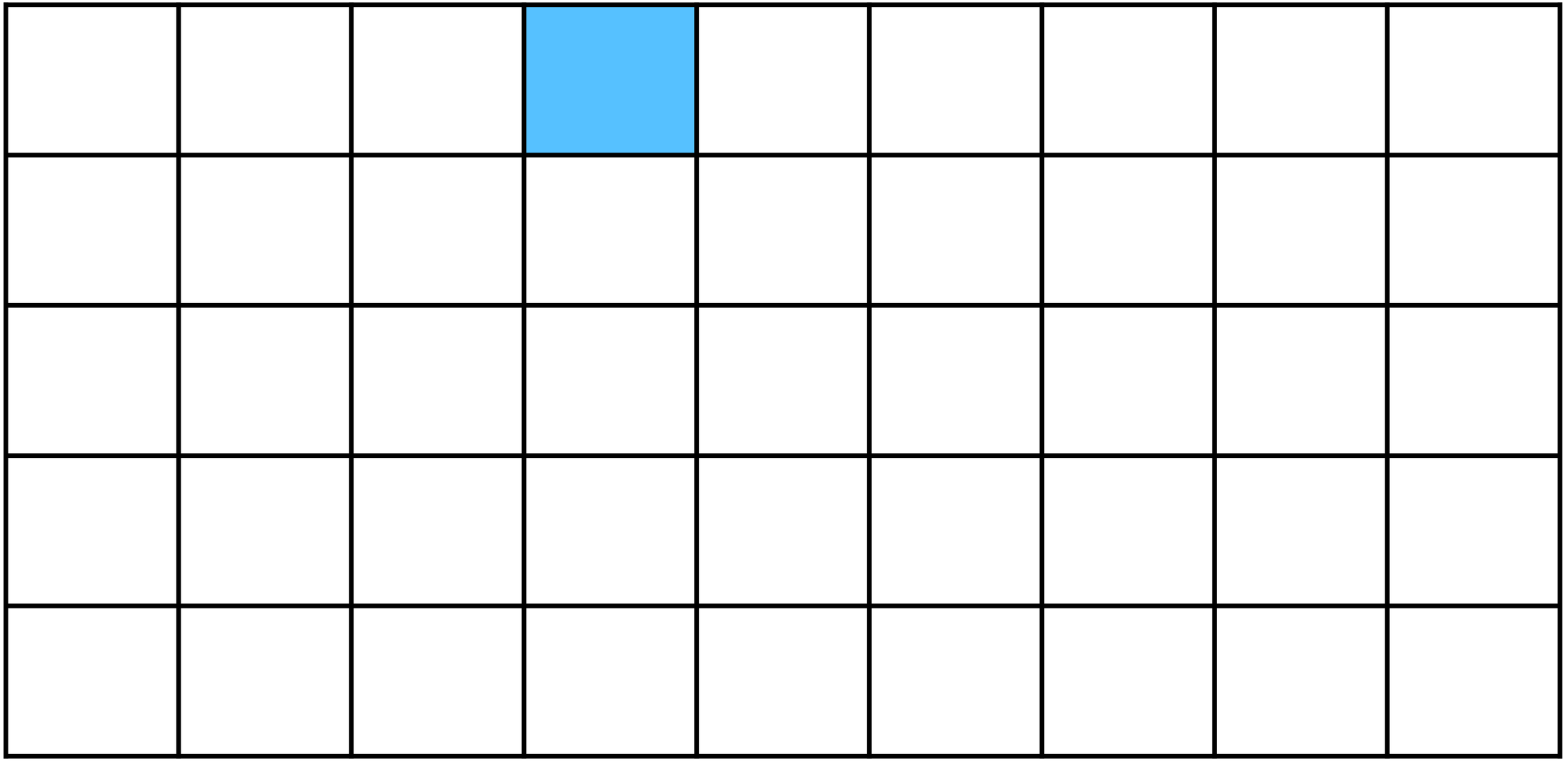

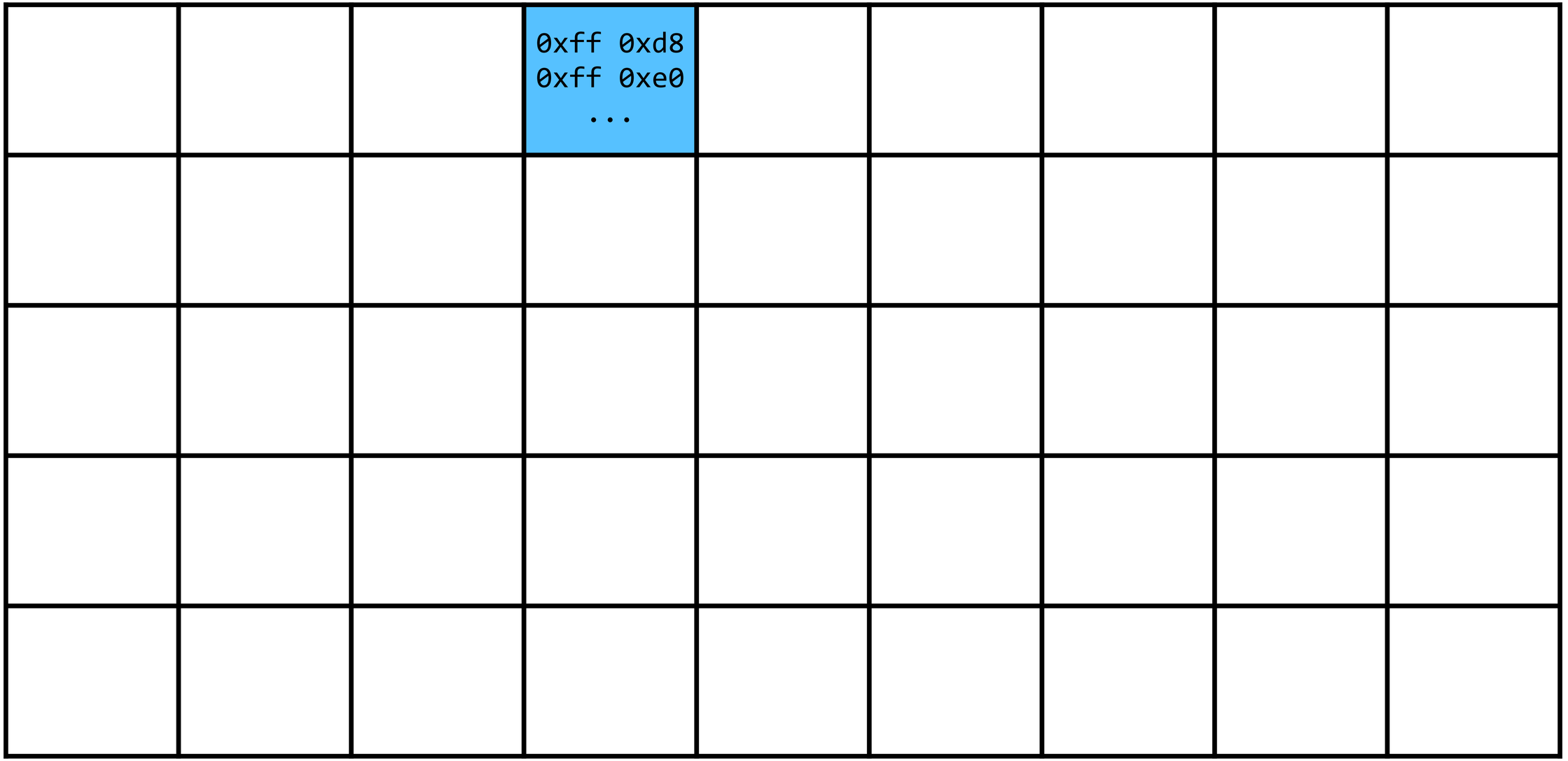
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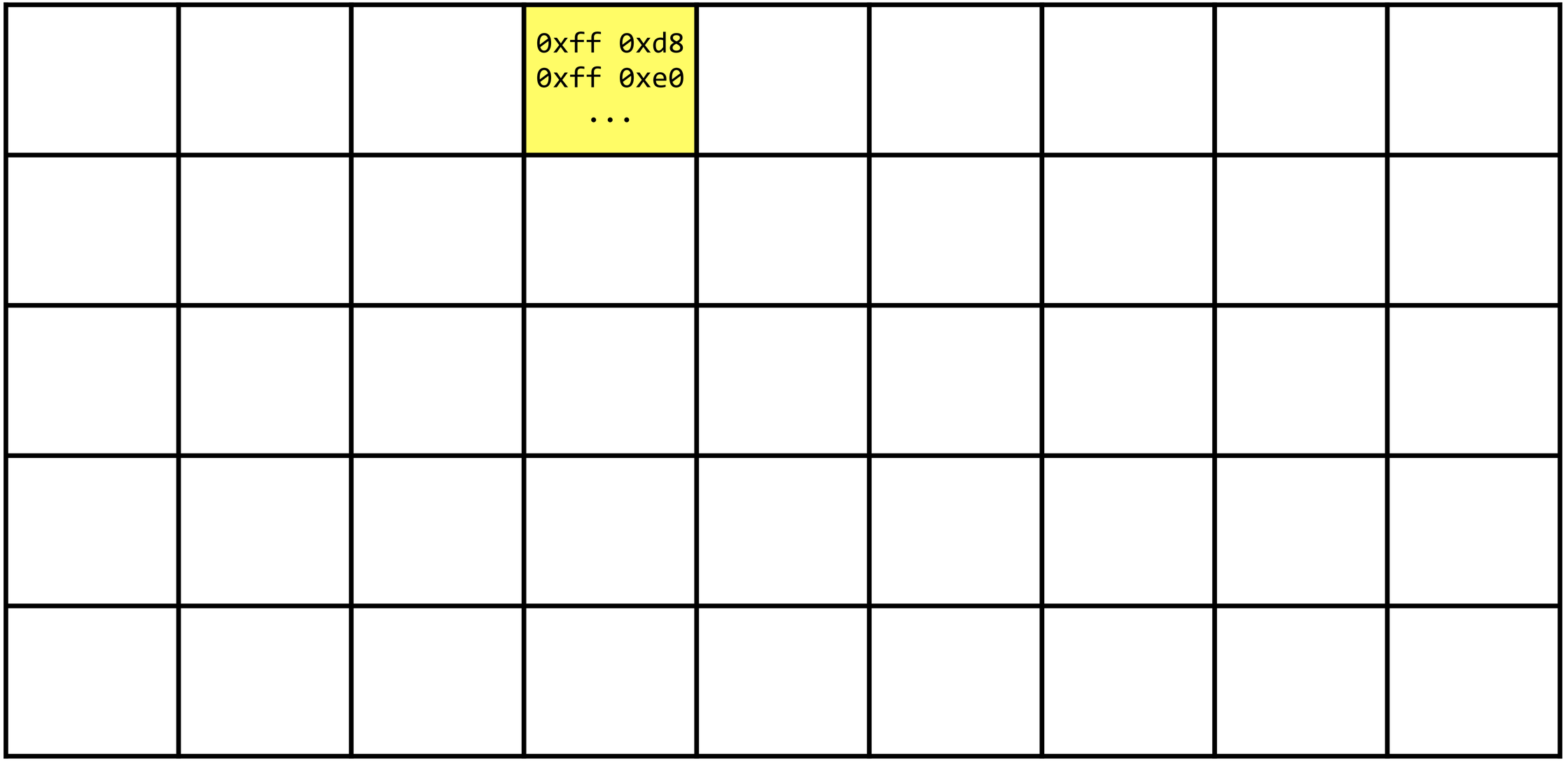
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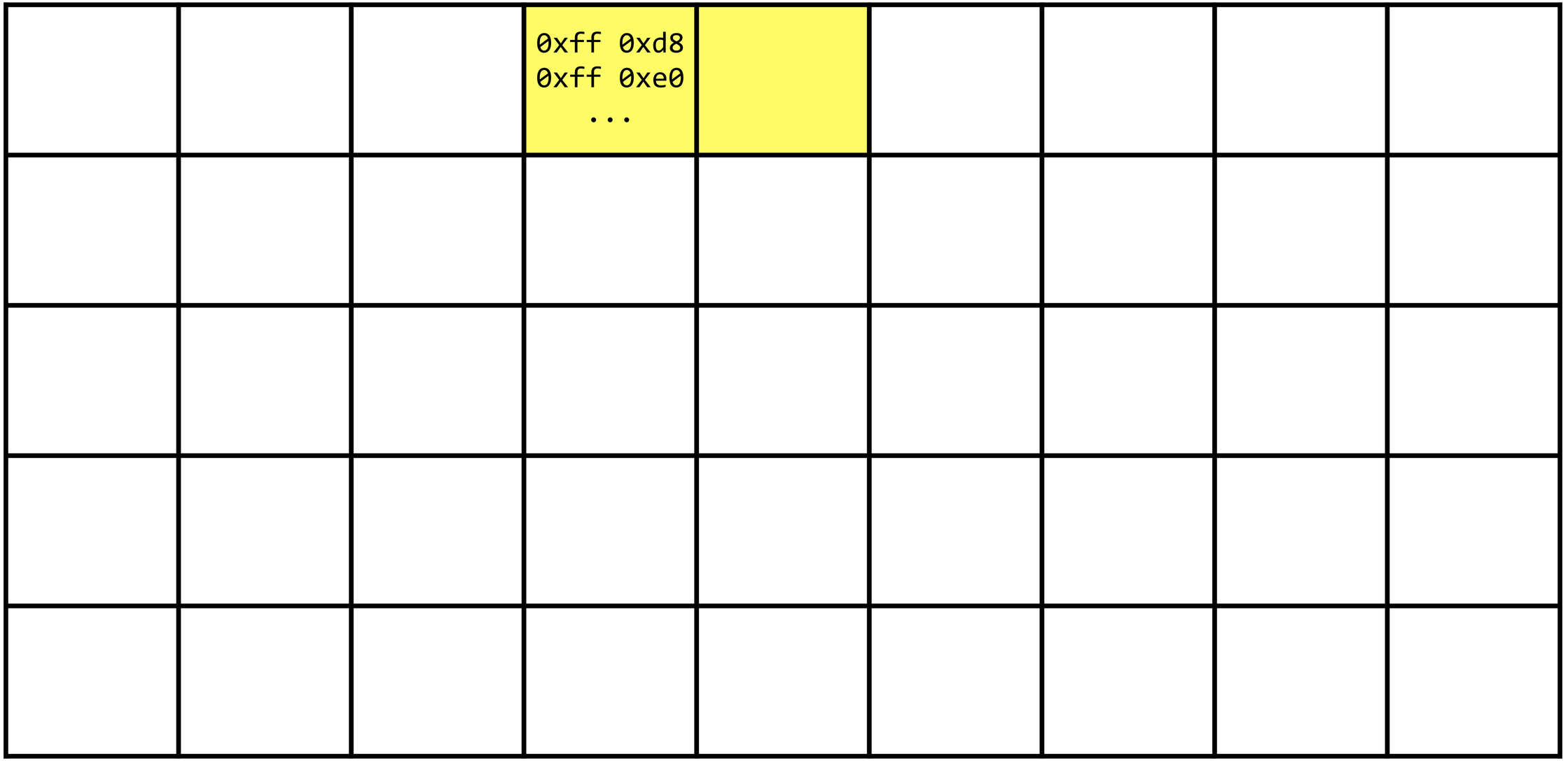
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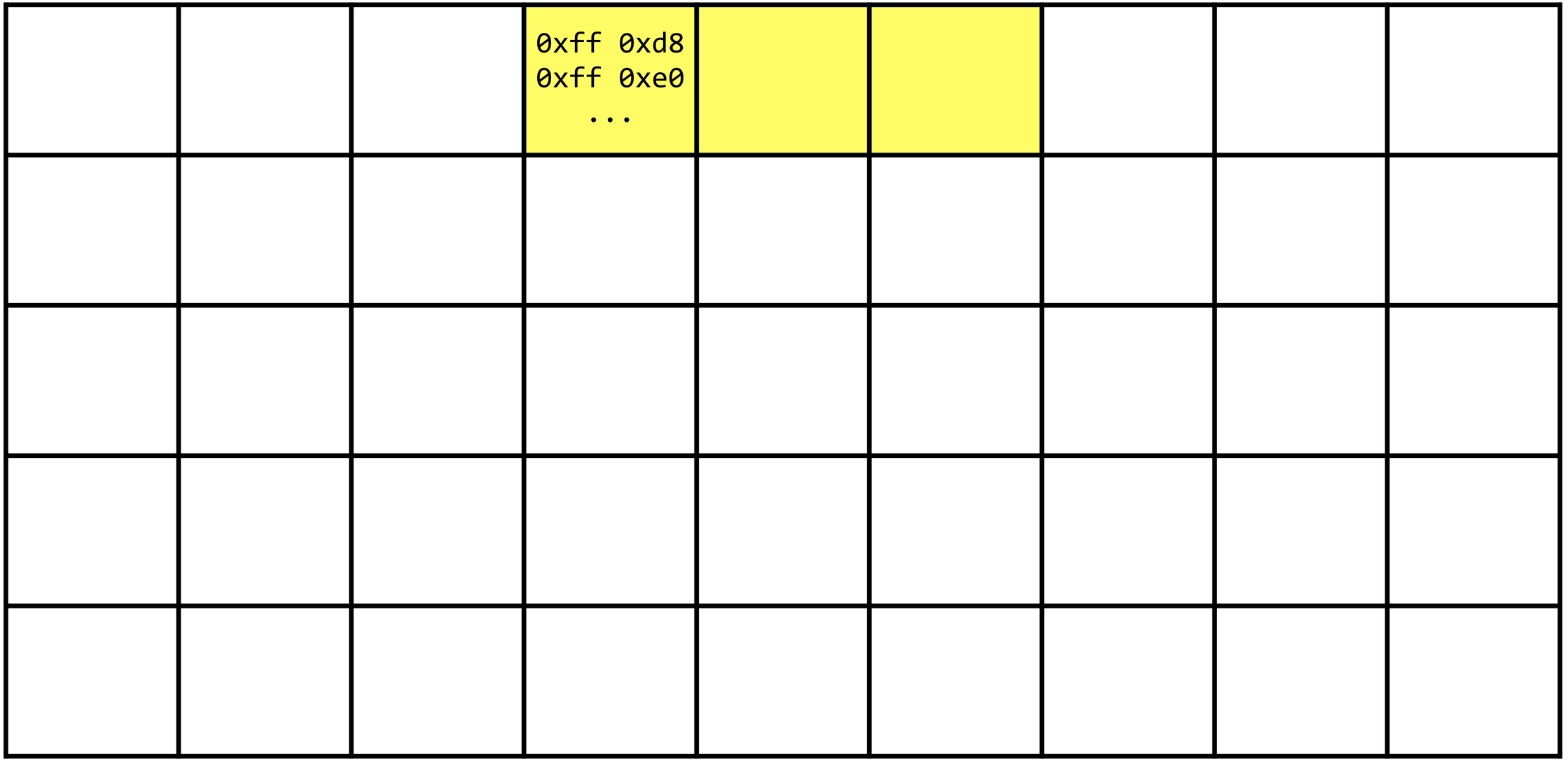
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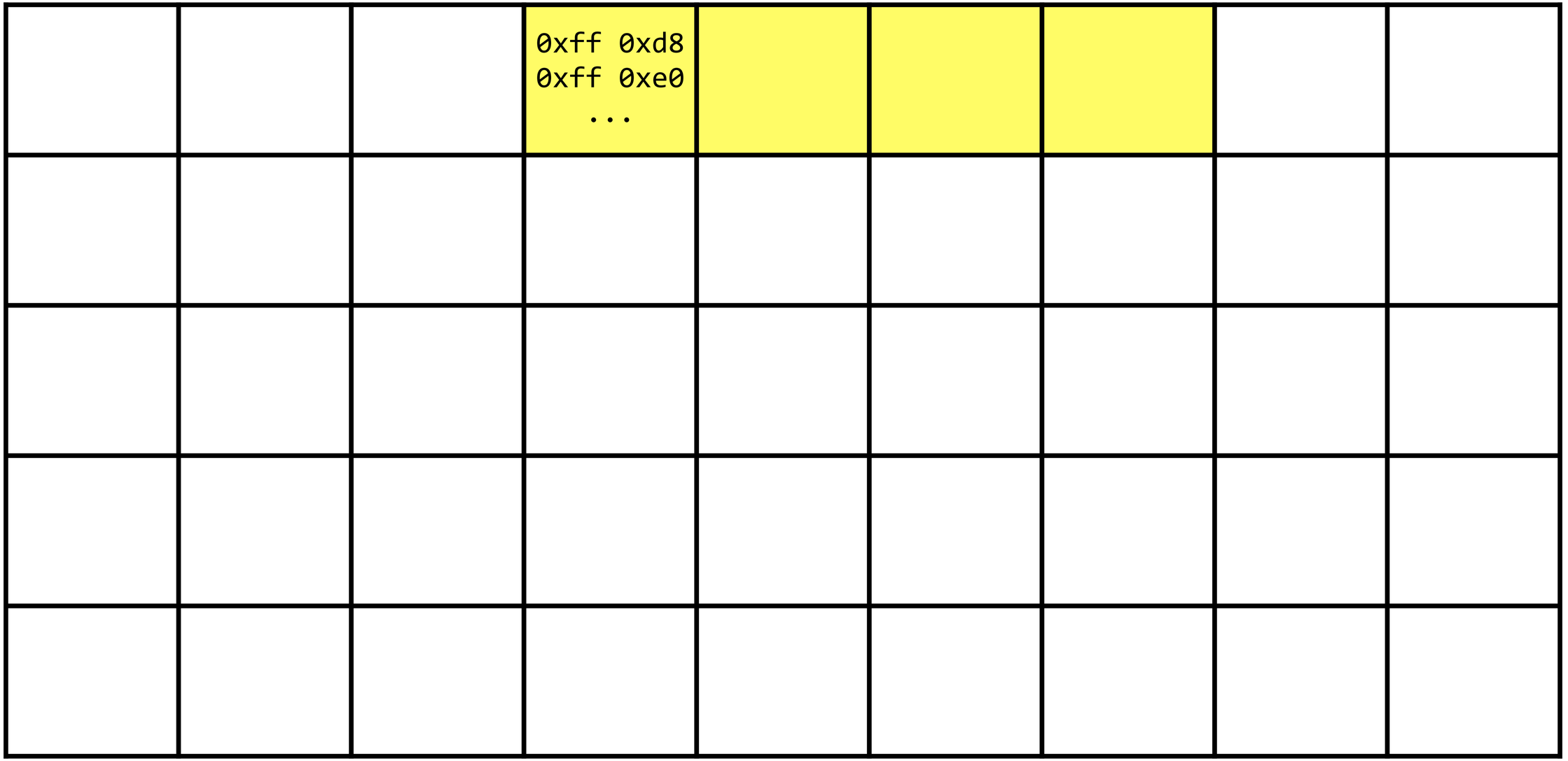
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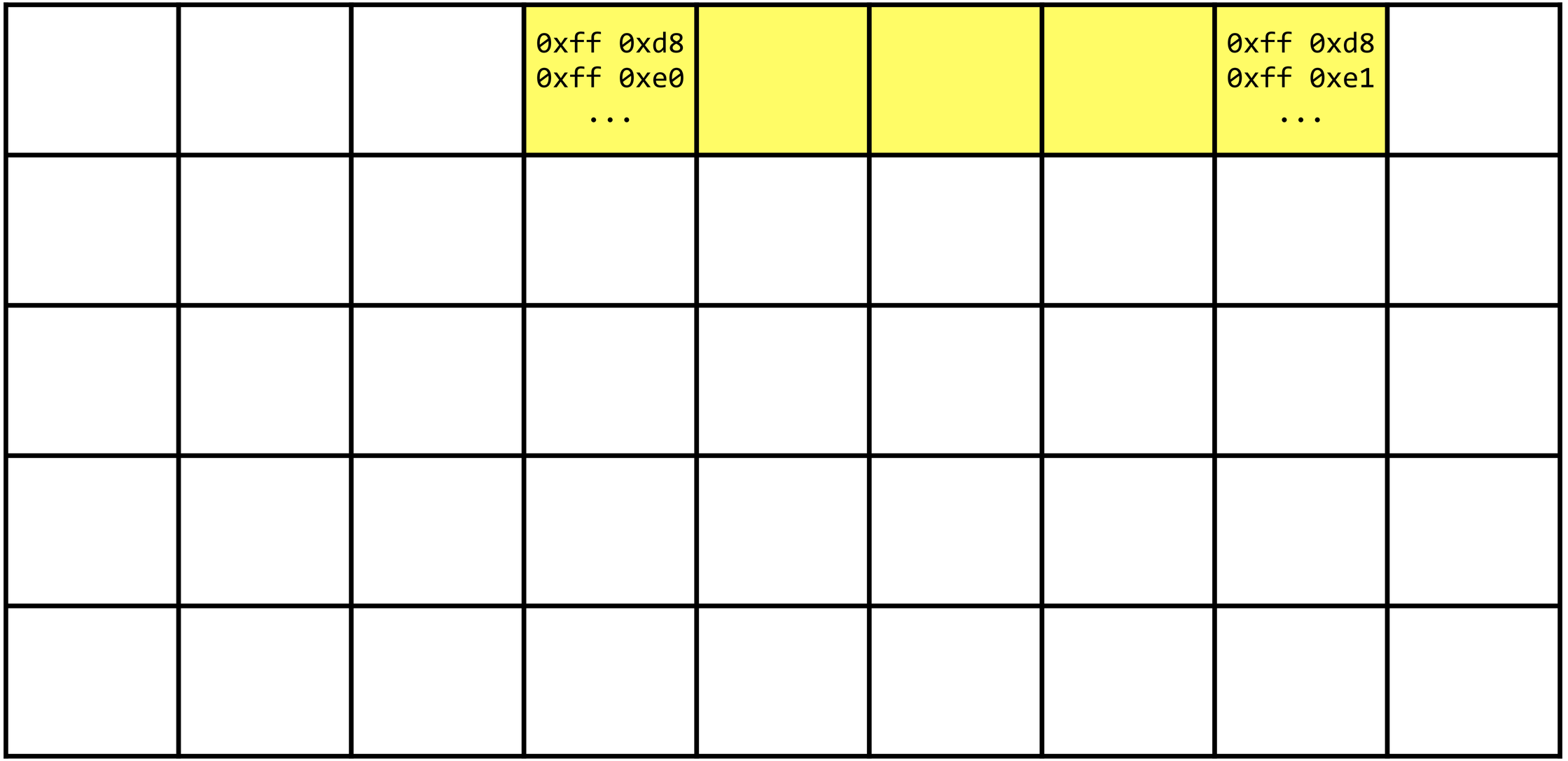
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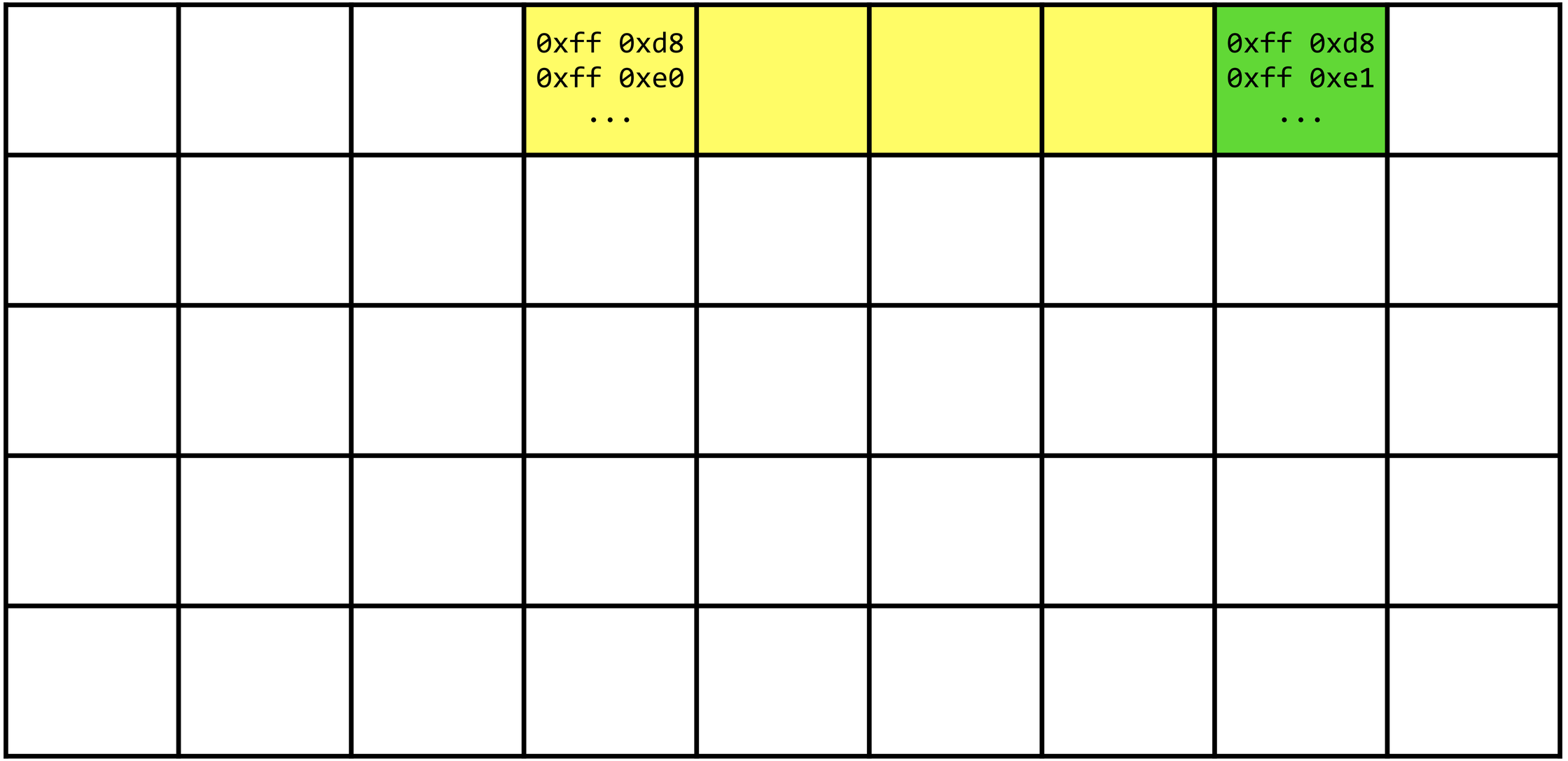
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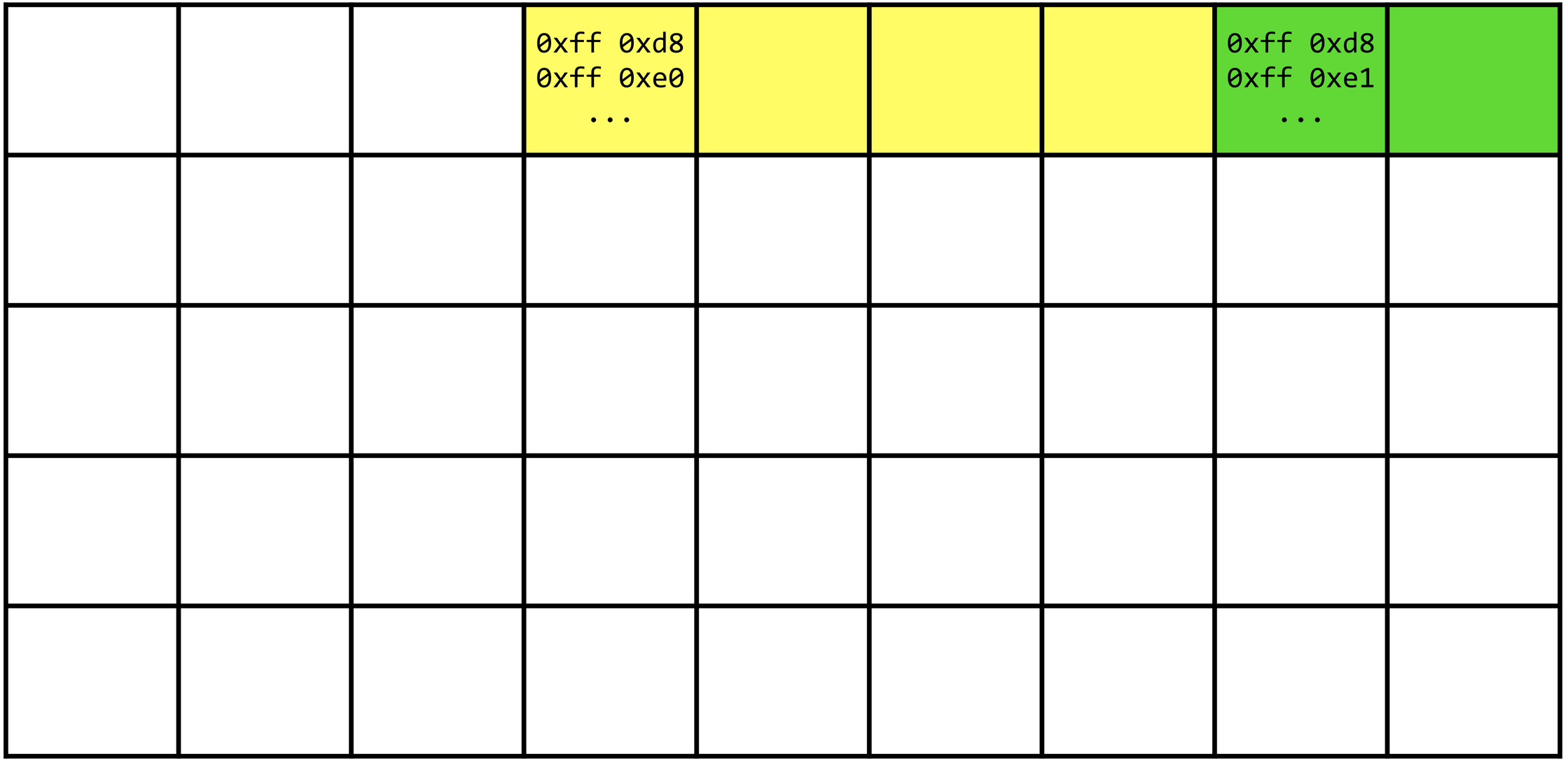
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This is CS50.