CPSC 213 Lab 3

Dynamic Arrays & C Pointers

Slides available at randyzhu.com/cpsc213

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Course Updates

Quiz 1; A3 due Friday

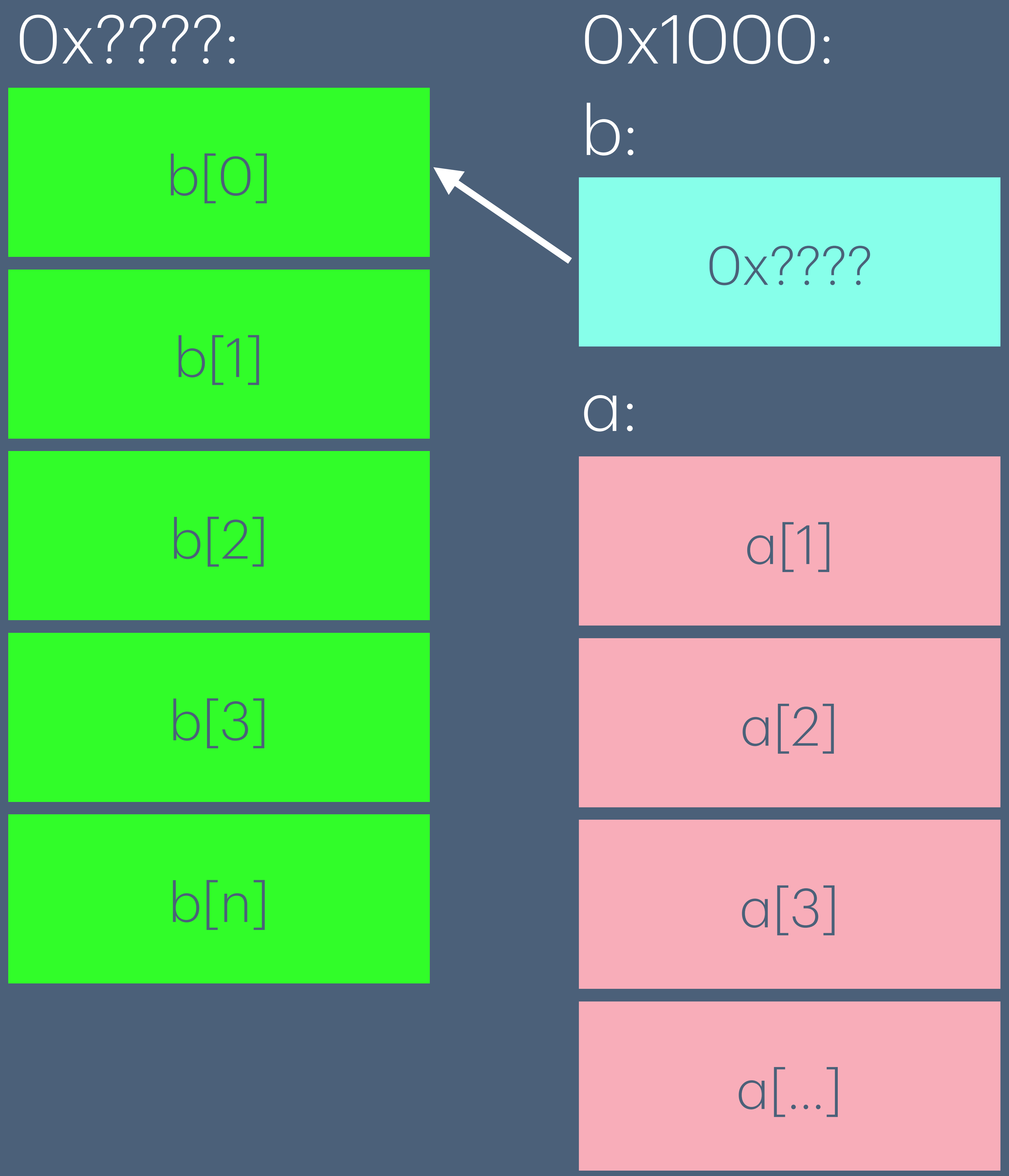
- Assignment 3 is due on Friday, January 30th
- Quiz 1 is running today and tomorrow
  - No questions *about* quizzes

Pointer Review

What is a pointer?

- A variable that contains a memory address
- Syntax examples:
  - `int* ptr;`
  - `unsigned char* m;`
  - `int** matrix;`
- in general: `<type>* ptr;`
- Pointers can point to any type, *including pointers*

```
int* b;
int a[10];
```

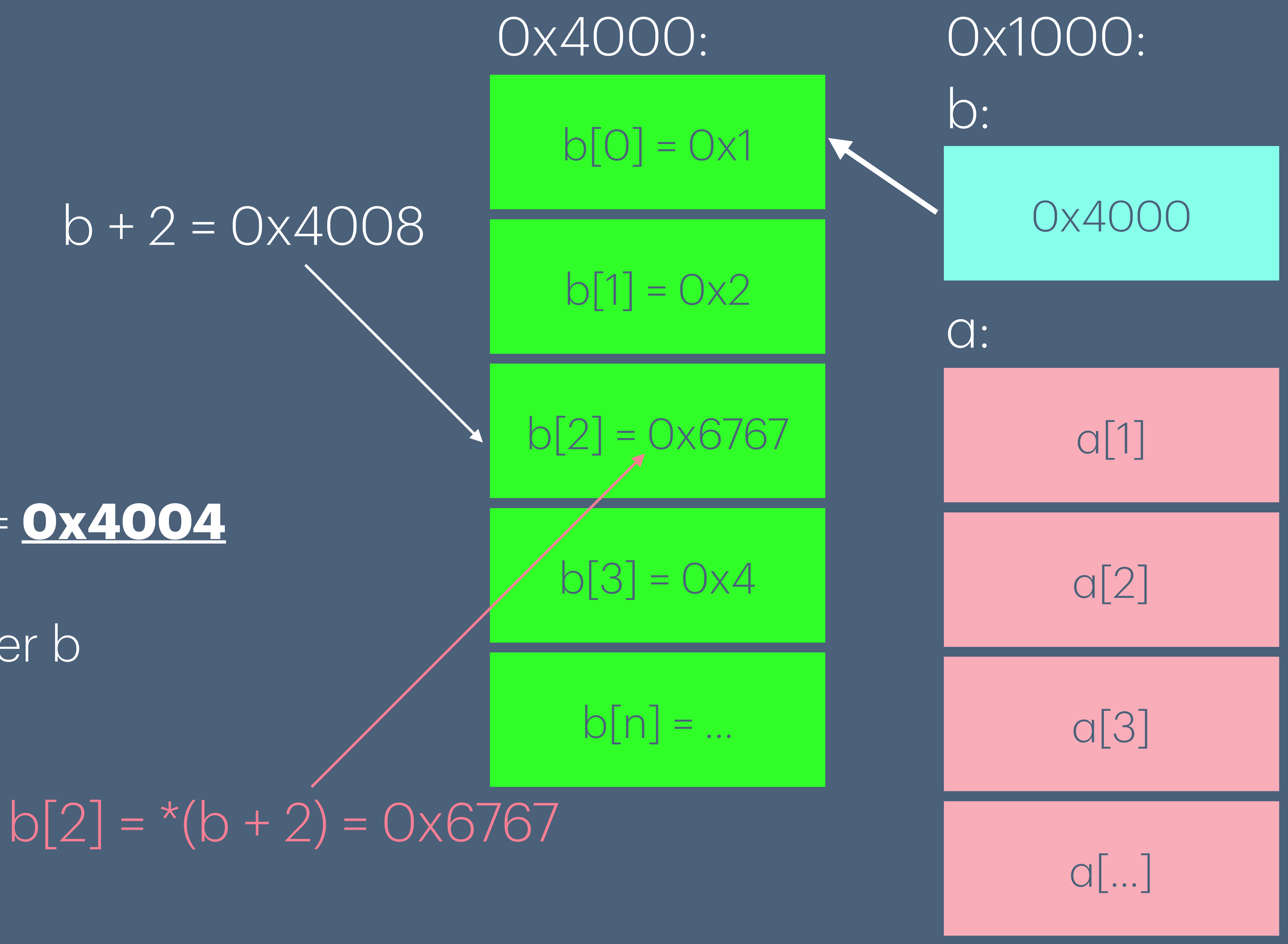


Pointer Review

Array-like; pointer arithmetic

- `*b` gets the value a pointer points to
- Here, `*b` → `0x1`
- `b + 1`
  - Gets the <u>address</u> of "next" int after b
    - 0x4000 + sizeof(int) * 1 = 0x4000 + 4 = <u>**0x4004**</u>
  - `*(b + 1)` gets the <u>value</u> of next int after b
    - Equivalent to `b[1]`
    - In general `*(b + n) = b[n]`

```
int* b;
int a[10];
```



0x4000:

b[0] = 0x1

b[1] = 0x2

b[2] = 0x6767

b[3] = 0x4

b[n] = ...

0x1000:

b:

0x4000

a:

a[1]

a[2]

a[3]

a[...]

b + 2 = 0x4008

b[2] = *(b + 2) = 0x6767

Approaches to counting memory reads

Q1: Static & Dynamic Arrays

- Translate C to ASM
  - Pros
    - Reliable
    - Good practice
  - Cons
    - Slower
    - ASM has to be correct

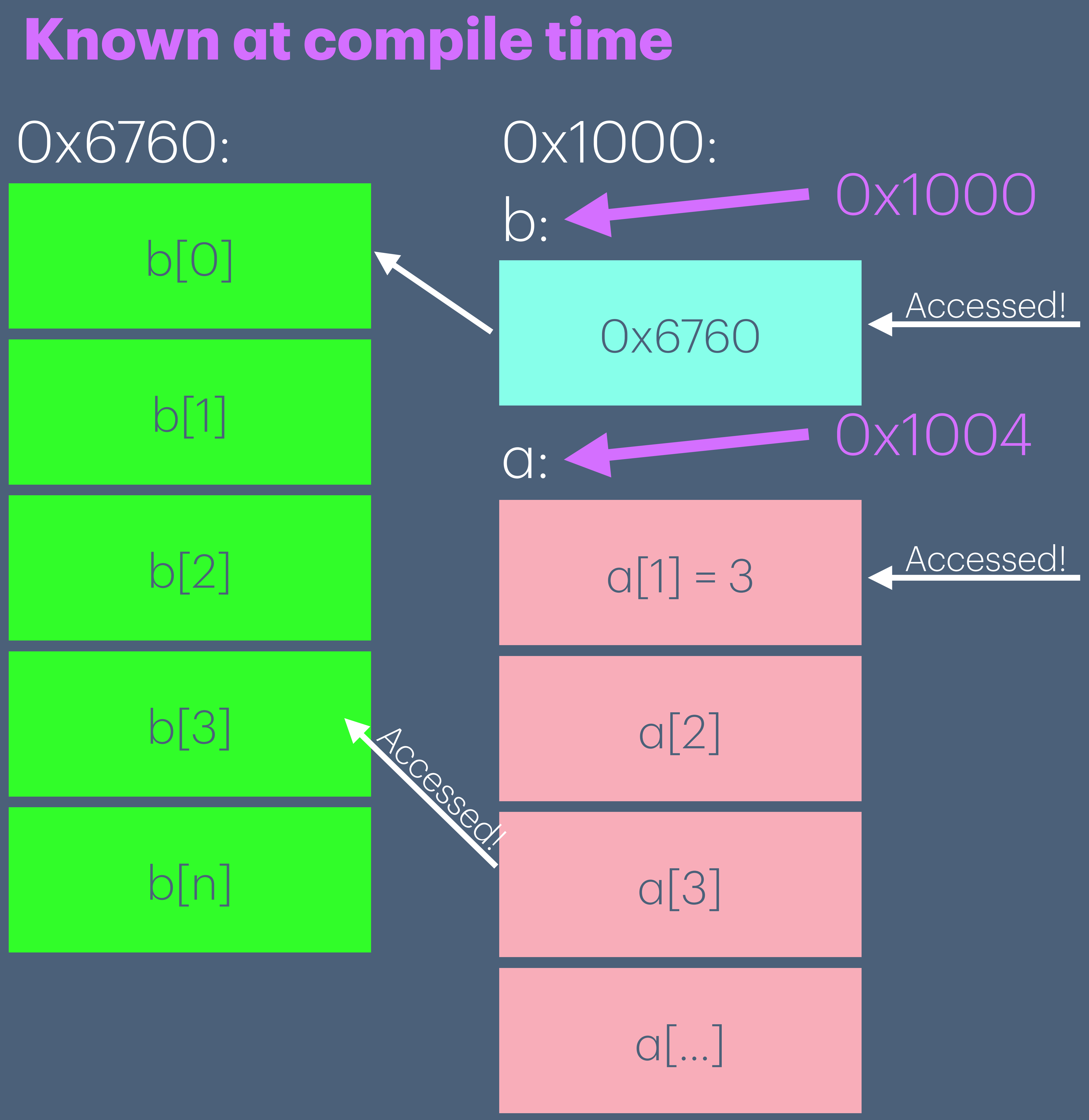
- Analyze the C code
  - Pros
    - Faster
    - Better understanding of C
  - Cons
    - Less flexible

b[b[a[1]]] = b[1] + b[a[1]]

Dynamic vs Static Arrays

- Analysis approach
  - What do I need?
    - **Address** of LHS
    - **Value** of RHS
  - Values can be shared between RHS and LHS

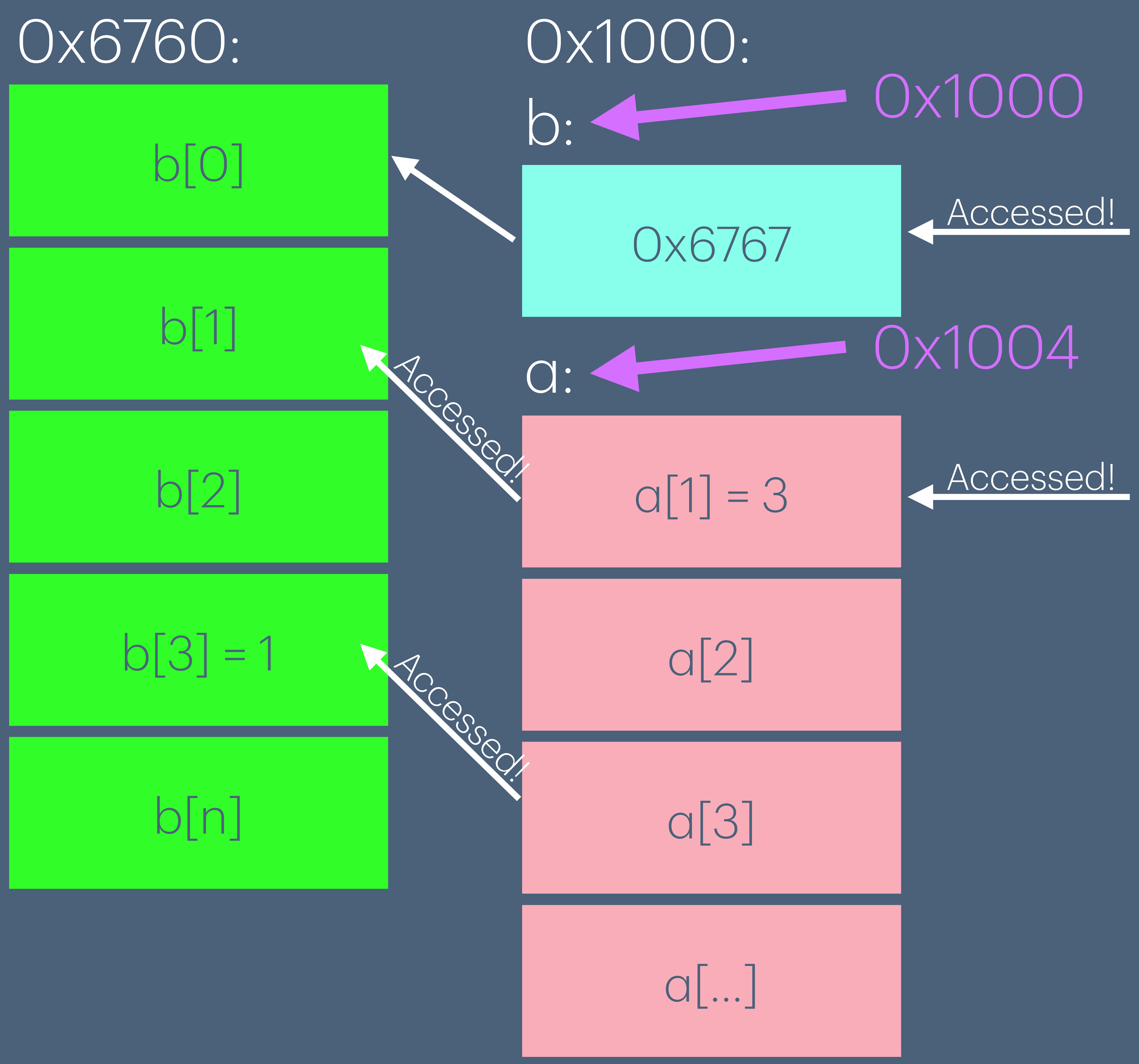
b[b[a[1]]] = b[1] + b[a[1]]



- Address of b[b[a[1]]]
  - Value of b[a[1]]
    - Need a[1]
      - a[1] known at compile time
        - 1 memory read to get a[1]
    - Need value of b (where does b point to?)
      - 1 memory read
    - Finally, b[a[1]], 1 more memory read

b[b[a[1]]] = b[1] + b[a[1]]

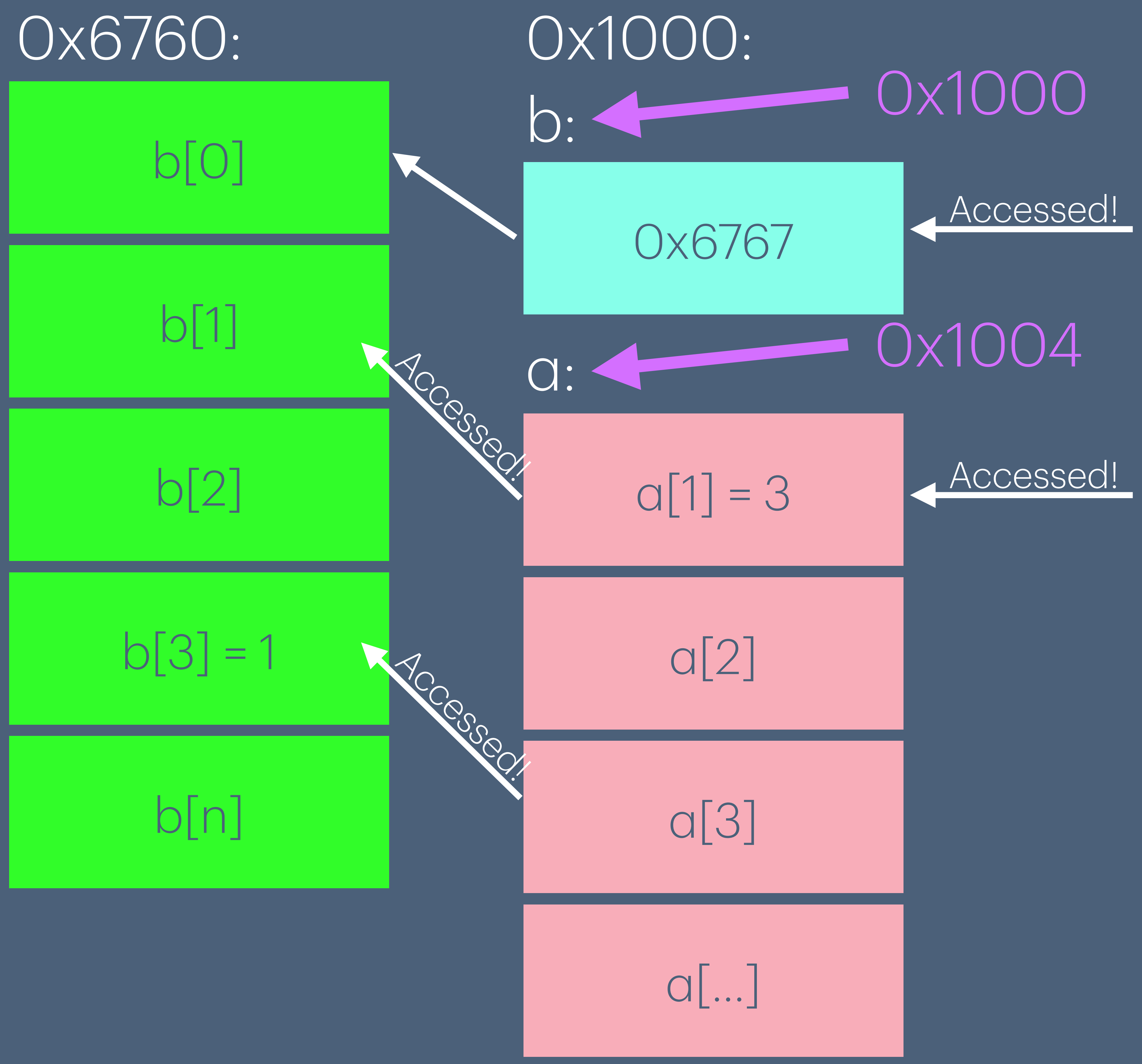
Known at compile time



- What we know from before
  - a[1], b[a[1]], b
  - Need to find where b[b[a[1]]] is still
    - Easy, add b to b[a[1]] * 4, no memory needs needed. b[b[a[1]] = 0x6760 + 1 * 4 = 0x6764.
- Calculate b[1] + b[a[1]]
  - We need b[1], which is 1 memory read

b[b[a[1]]] = b[1] + b[a[1]]

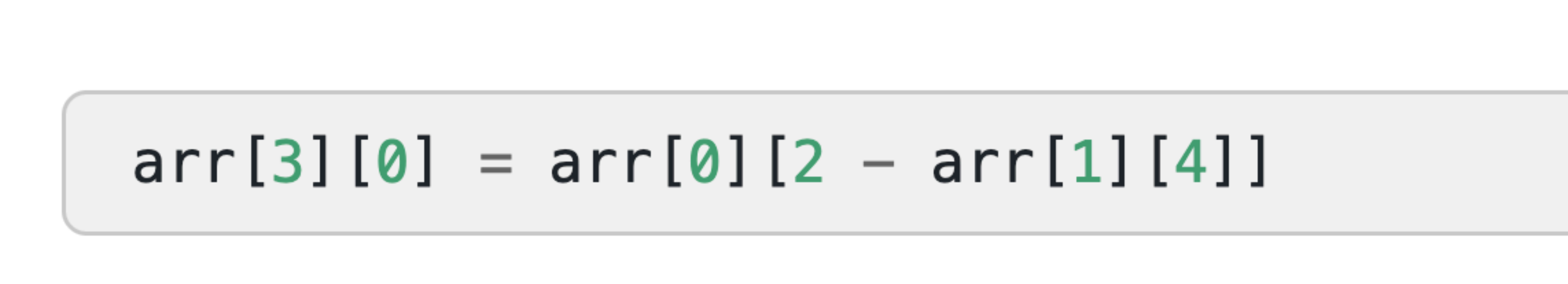
Known at compile time



- Total memory reads
  - 4
- Write assembly approach is probably much slower
  - Count number of instructions in ISA that read from memory

Q2: Pointers

WTF?



```
arr[3][0] = arr[0][2 - arr[1][4]]
```

Q2: Pointers

An algorithm

- Apply this rule:
- `*(a + i) = a[i]`
- Work from right to left
- Simplest first
- Let's start with RHS

- `arr[0][2 - arr[1][4]]`
  - `arr[0][2 - *(arr[1]  + 4)]`
- `arr[0][2 - *(arr[1]  + 4)]`
  - `arr[0][2 - *(*(arr + 1) + 4)]`

Q2: Pointers

RHS continued

- `arr[0][2 - *(*(arr + 1) + 4)]`
  - `*(arr[0] + 2 - *(*(arr + 1) + 4))`
- `*(arr[0] + 2 - *(*(arr + 1) + 4))`
  - `*(*(arr + 0) + 2 - *(*(arr + 1) + 4))`
  - `*(*arr + 2 - *(*(arr + 1) + 4))`
- DONE!

Q2: Pointers

LHS

- Our original expression: `arr[3][0] = arr[0][2 - arr[1][4]]`
- Convert `arr[3][0]`
  - `arr[3][0]`
    - `*(arr[3] + 0)`
    - `*(arr[3])`
    - `*(*(arr + 3))`
    - `**(arr + 3)`

Q2: Pointers

Grand finale

- `**(arr + 3) = *(*arr + 2 - *(*(arr + 1) + 4))`
- Part 2
  - Find a way to apply this "algorithm" in reverse