Implementing Abstractions

Midterm

- CS106B Midterm Grading party tonight!
- Sorry for how poorly written the bundles question was =(
  - I'll do my best to word things more clearly on the second midterm

From Last Time...

Where are We...

- Course Goal: Develop a strong understanding of basic data structures
- Class so far:
  - Week 1: Basic C++
  - Week 2: Data structures
  - Week 3: Recursion
  - Week 4: Algorithmic Analysis

We are *almost* ready to start implementing and analyzing data structures!

A couple C++ language features we need to cover.

Classes in C++

- Defining a class in C++ (typically) requires two steps:
  - Create a **header file** (typically suffixed with `.h`) describing the class's member functions and data members.
  - Create an **implementation file** (typically suffixed with `.cpp`) that contains the implementation of all the class's member functions.
- Clients of the class can then include the header file to use the class.

Getting Storage Space

- How do the **`Vector`**, **`Stack`**, **`Queue`**, etc. get space to store all the elements that they hold?
- C++ code can request extra storage space as the program is running.
- This is called **dynamic memory allocation**.

What is Memory?

- All variables and objects in C++ need somewhere to live inside the computer's memory.
  - This is RAM, by the way, not disk space.
- Whenever an object is created, space needs to be reserved for it.

Draw Memory
(Board)

New Stuff...

Memory Addresses

- Every object in C++ is physically located somewhere in memory.
- The location is called its **address**.
- Intuitively, think of the address as a link to the object, or a phone number for the object, or a name for the object.
- Given a variable, you can obtain its address by using the **address-of operator** (**&**):

```
cout << &myVariable << endl;
```

Pointers

- A **pointer** is a C++ variable that stores the address of an object.
- Given a pointer to an object, we can get back the original object.
  - Can then read the object's value.
  - Can then write the object's value.
- Think of a pointer as a URL for the object.

Choosing What to Point To

- Pointers store addresses, so if we want our pointer to point at an object, we can assign the pointer to the address of that object.
- For example:

```
int *myPtr = &myVariable;
```

- The object being pointed at is called the **pointee**.

Using a Pointer

- Once we have a pointer that points at some object, we can **dereference** the pointer to read and write that object.
- To dereference a pointer, prefix it with a `*`, as shown here:

```
*ptr = 137;

cout << *ptr << endl;
```

Pointers, Visually

```
int m = 137;
int n = 42;
```

Pointers, Visually

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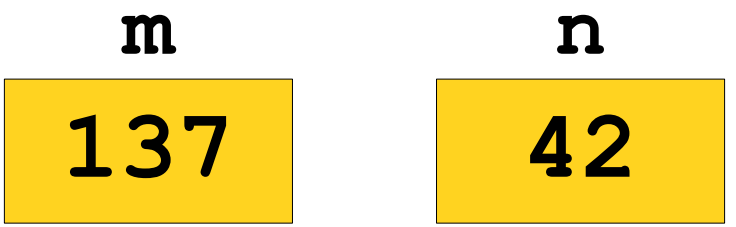

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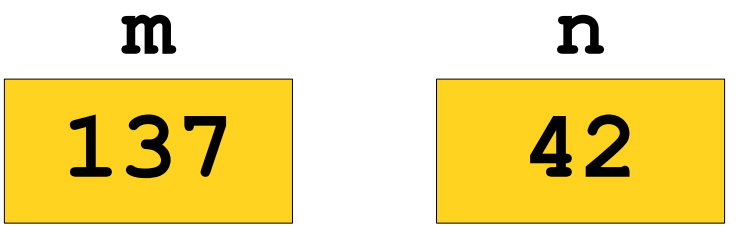

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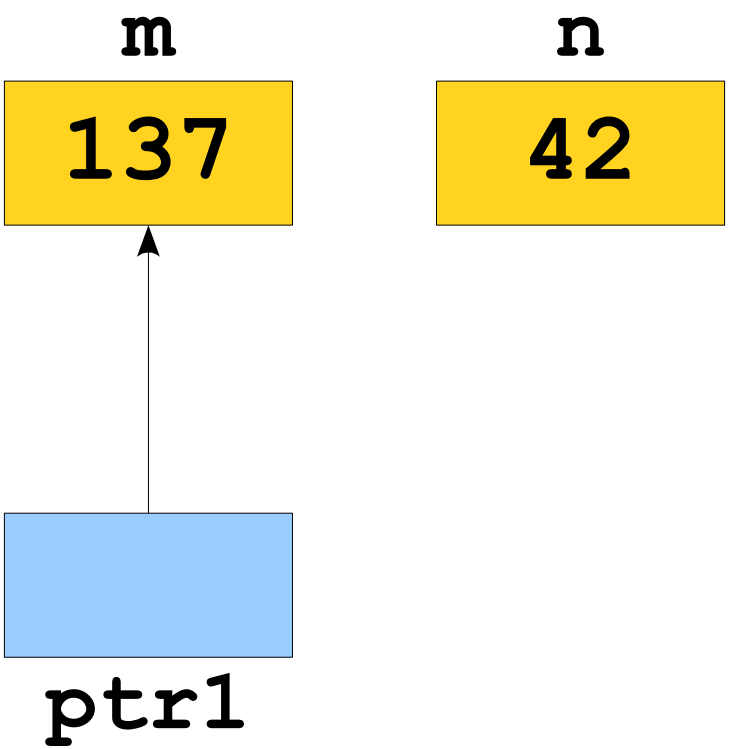

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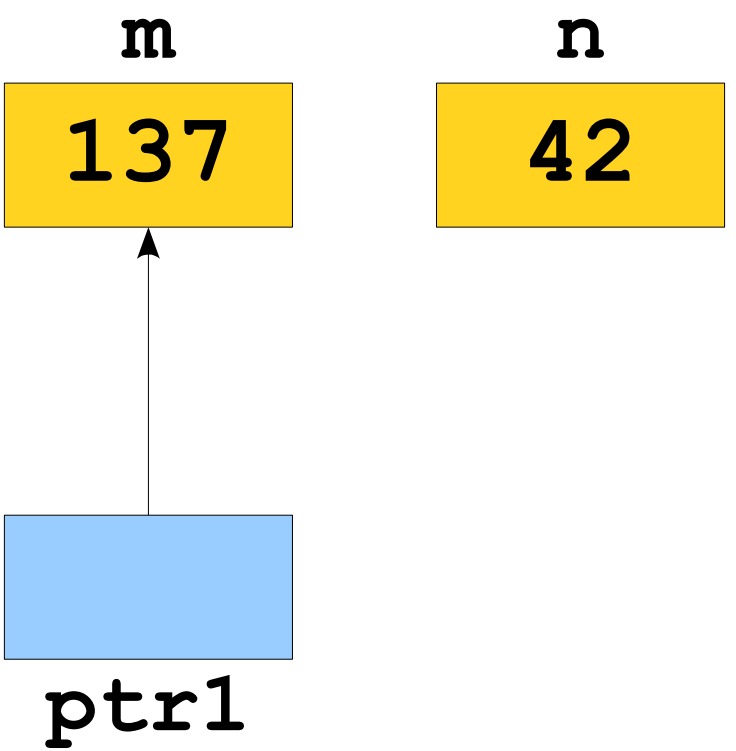

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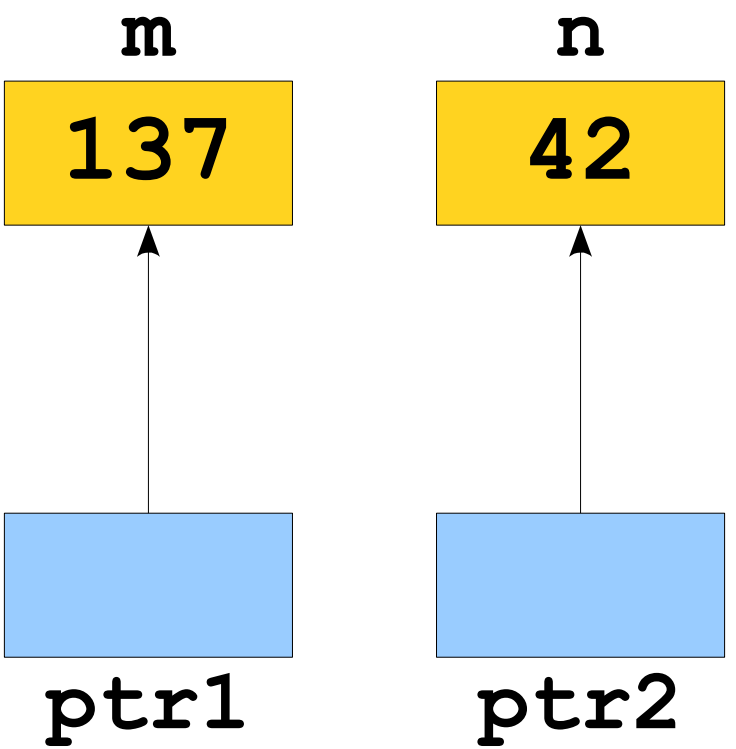

Pointers, Visually

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int m = 137;
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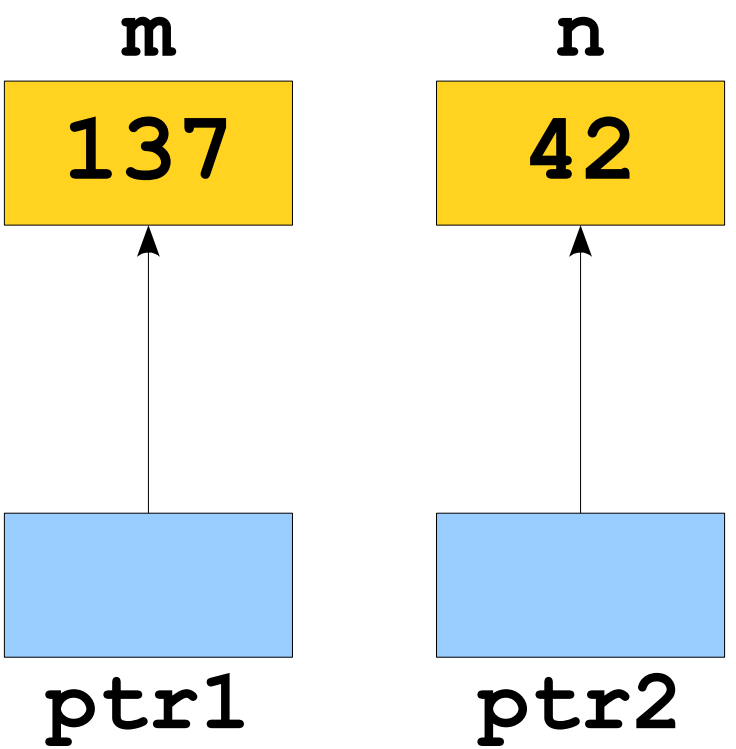
int* ptr1 = &m;
int* ptr2 = &n;

*ptr1 = 2718;
```



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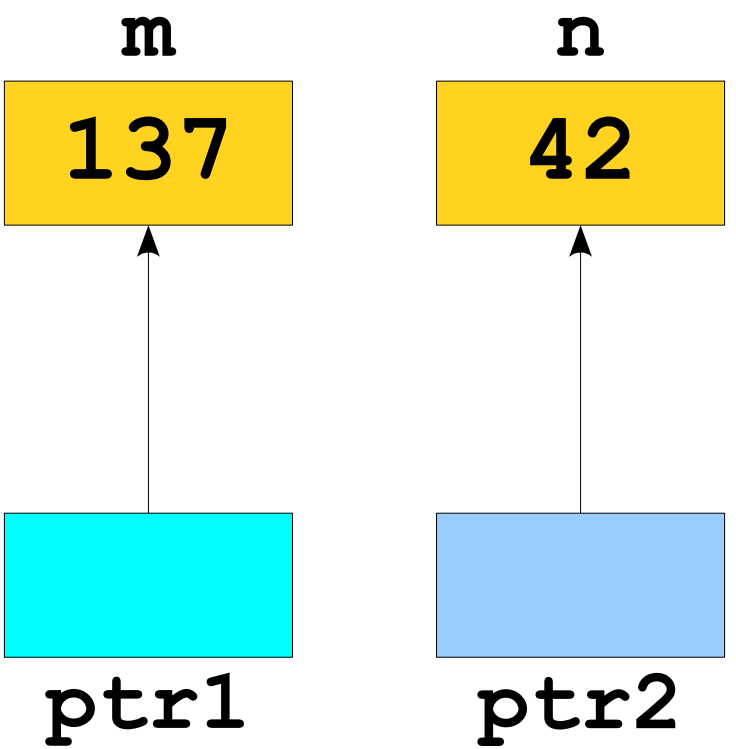

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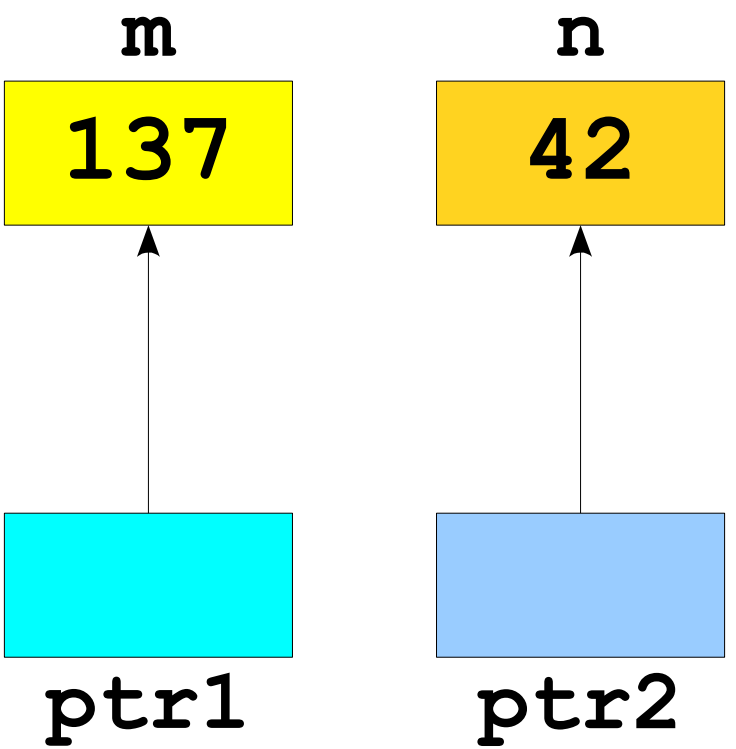

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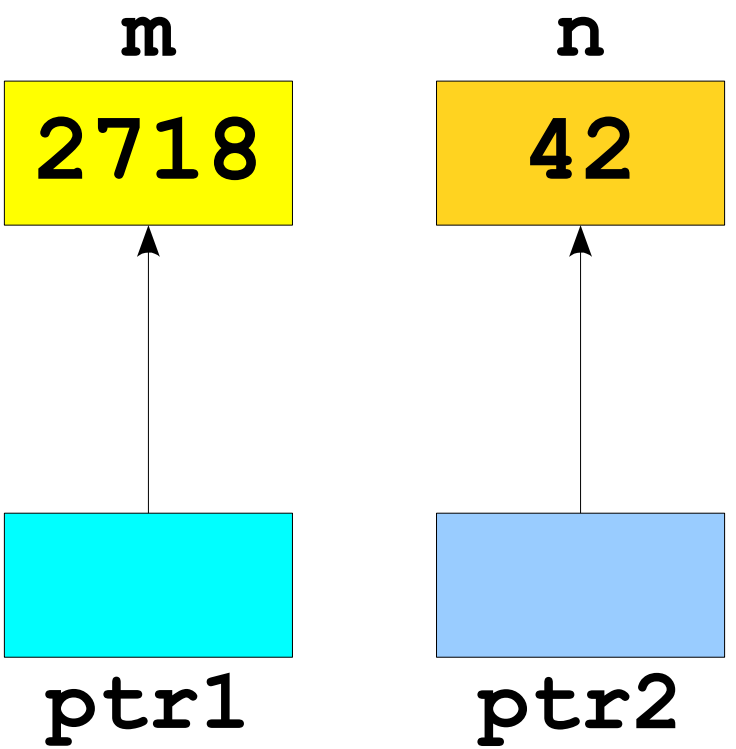

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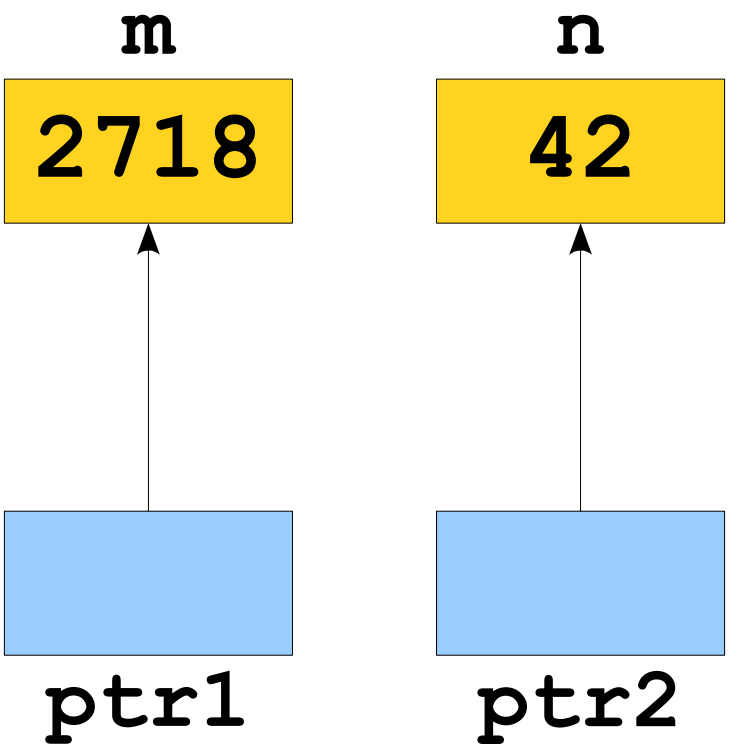

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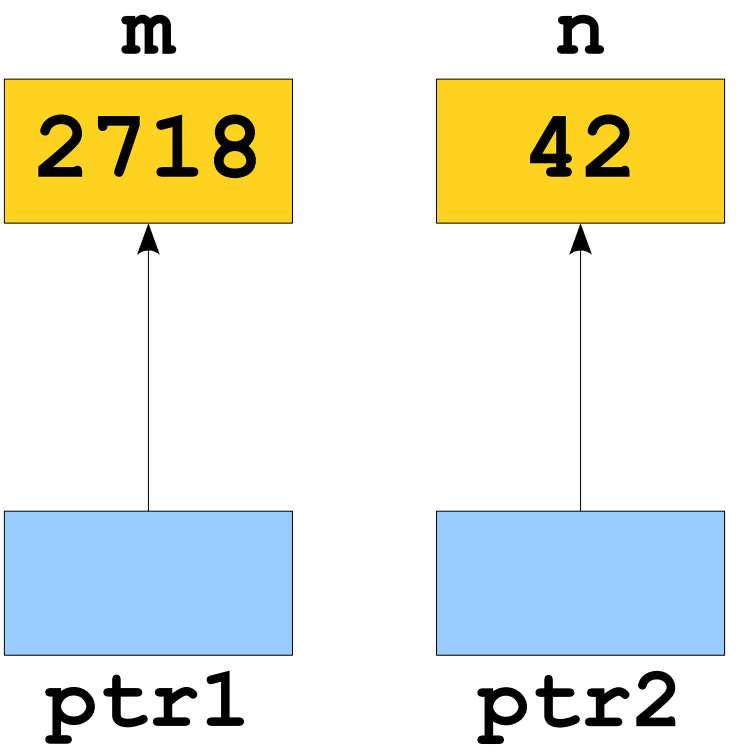

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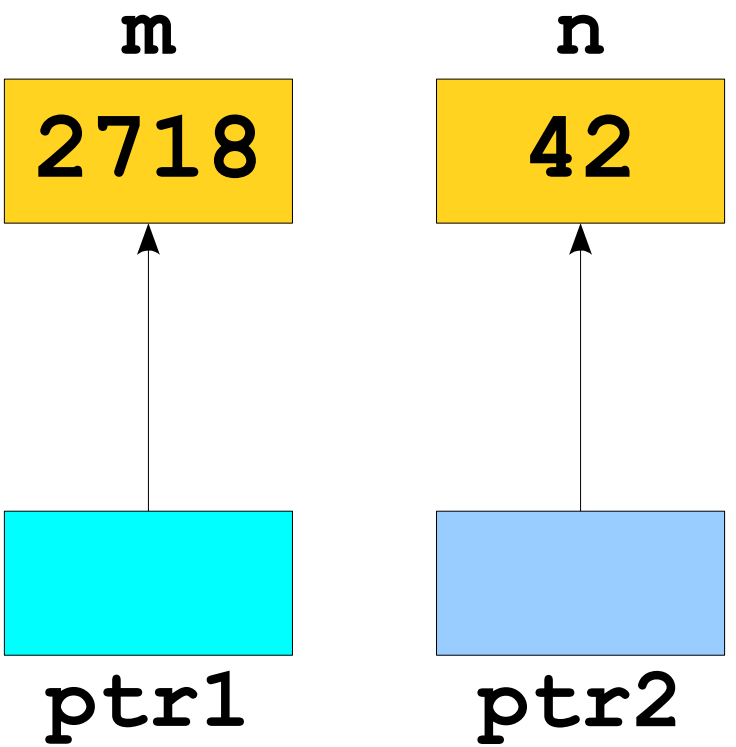

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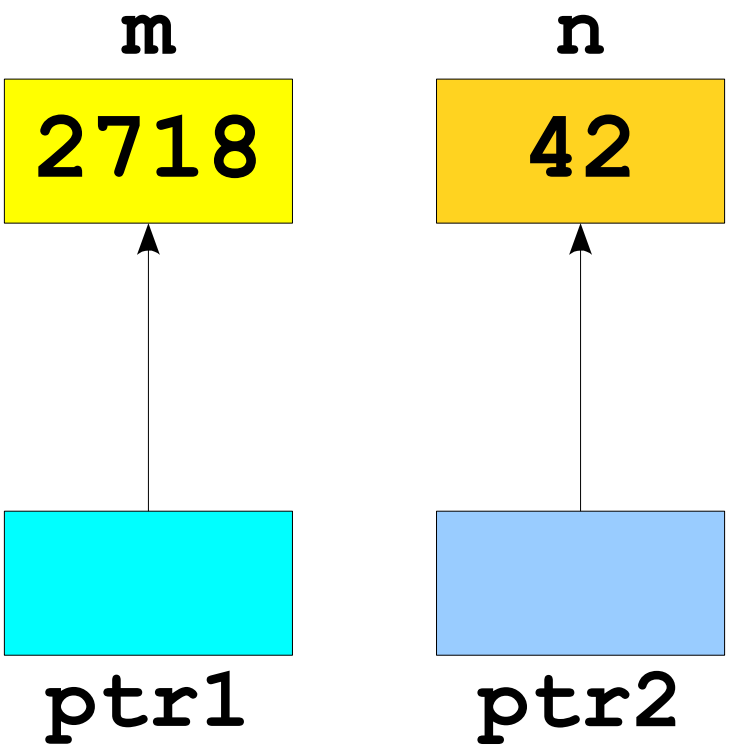

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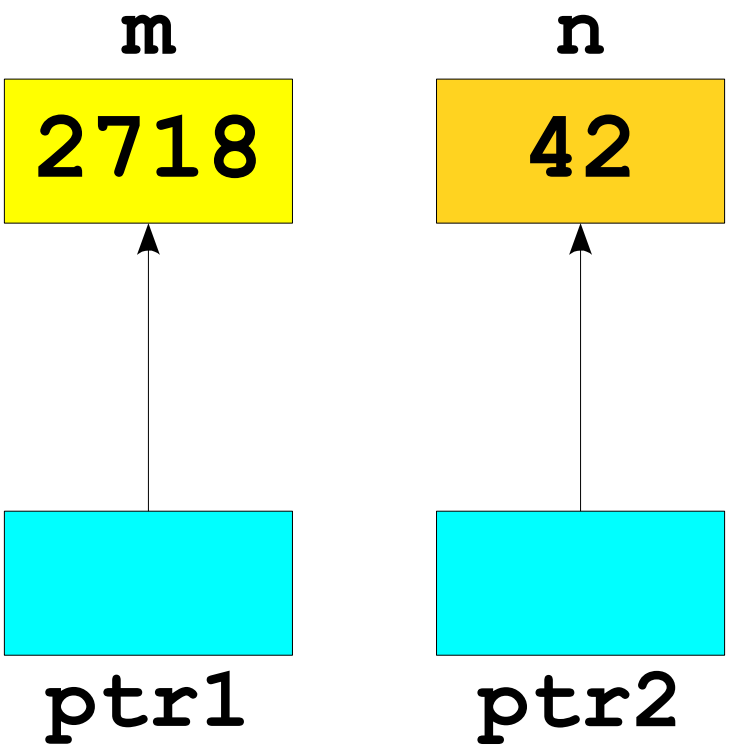

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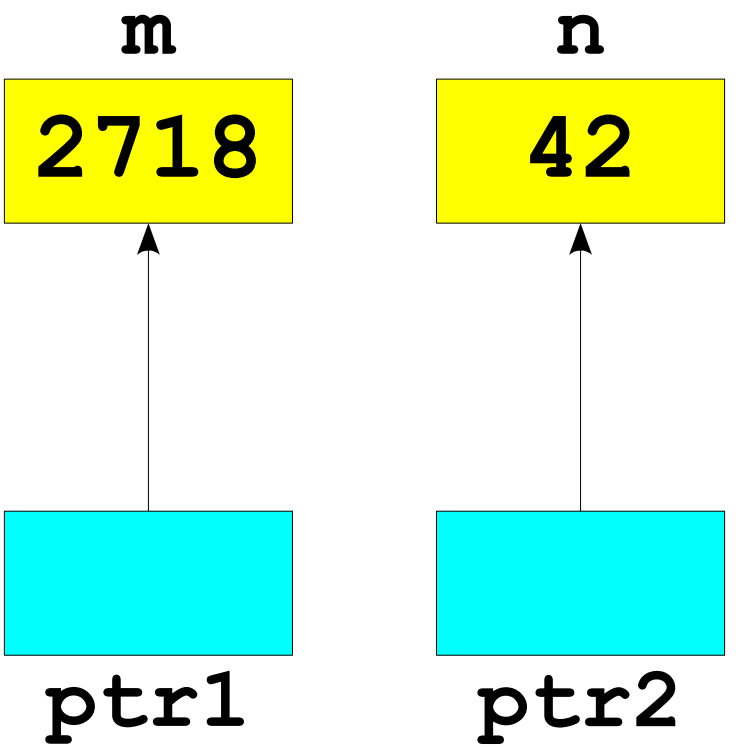

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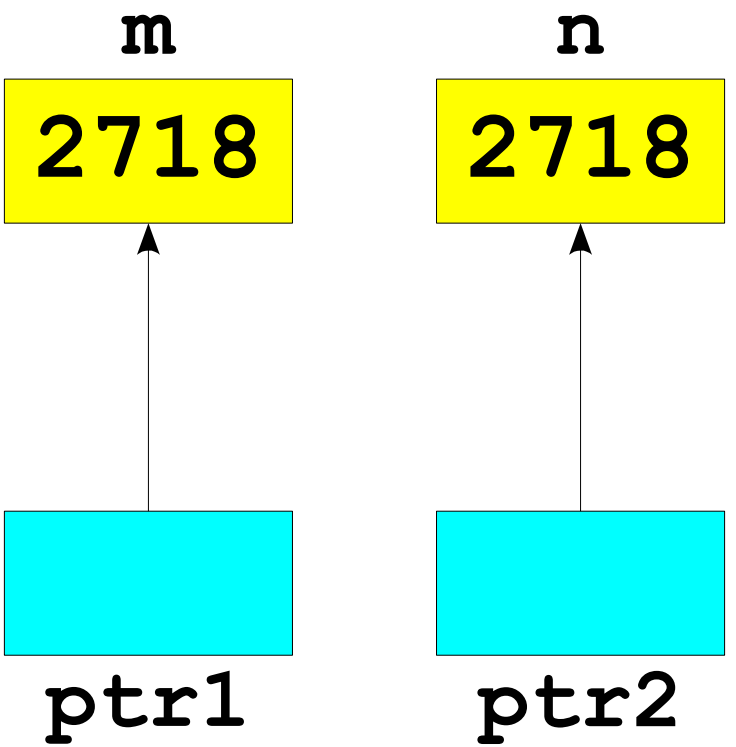

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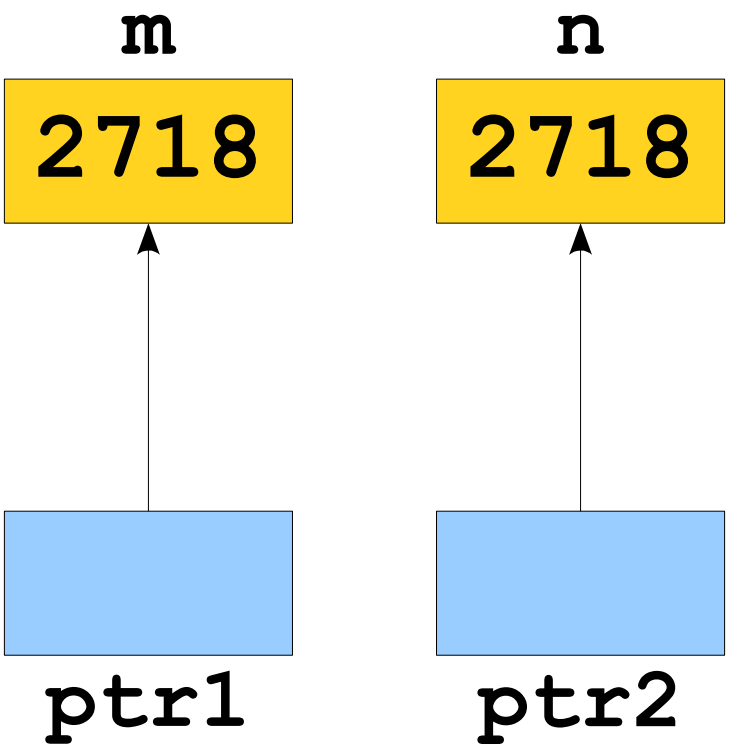
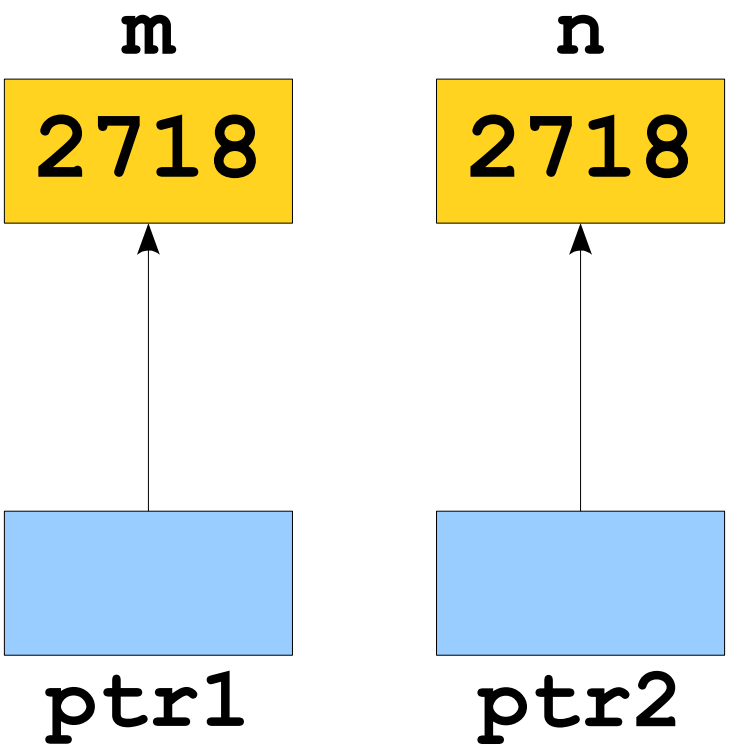


Pointers, Visually

```
int m = 137;
int n = 42;

int* ptr1 = &m;
int* ptr2 = &n;

*ptr1 = 2718;
*ptr2 = *ptr1;
m = 160;
```



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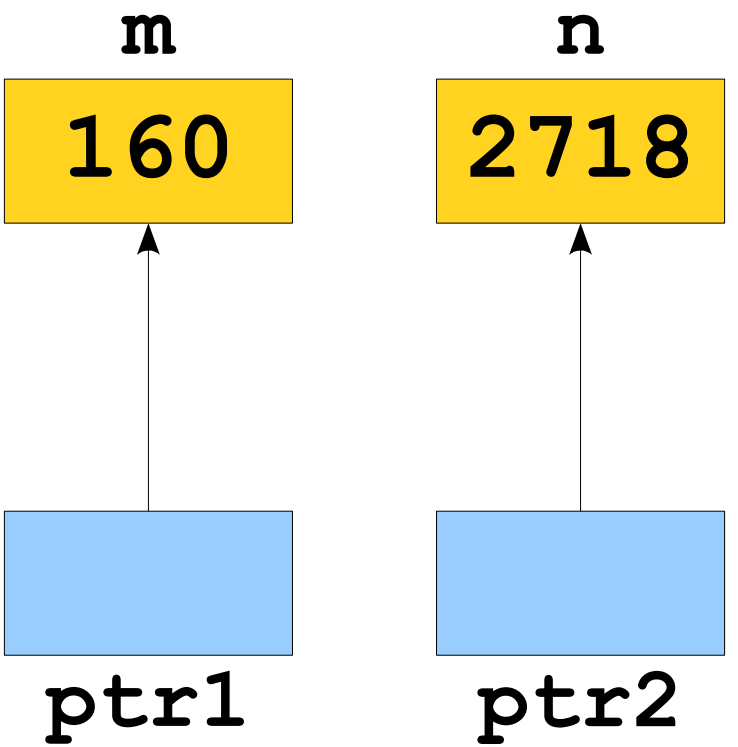

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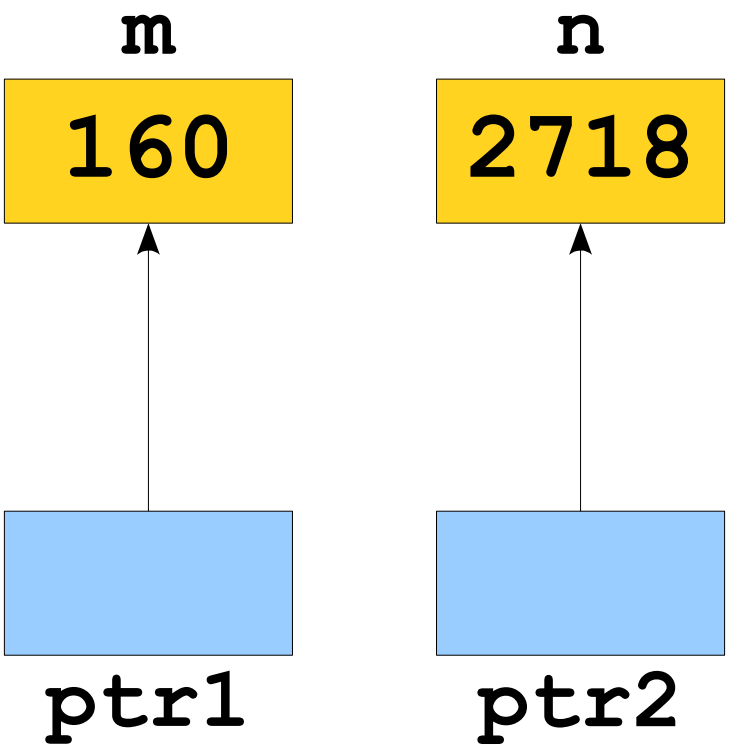

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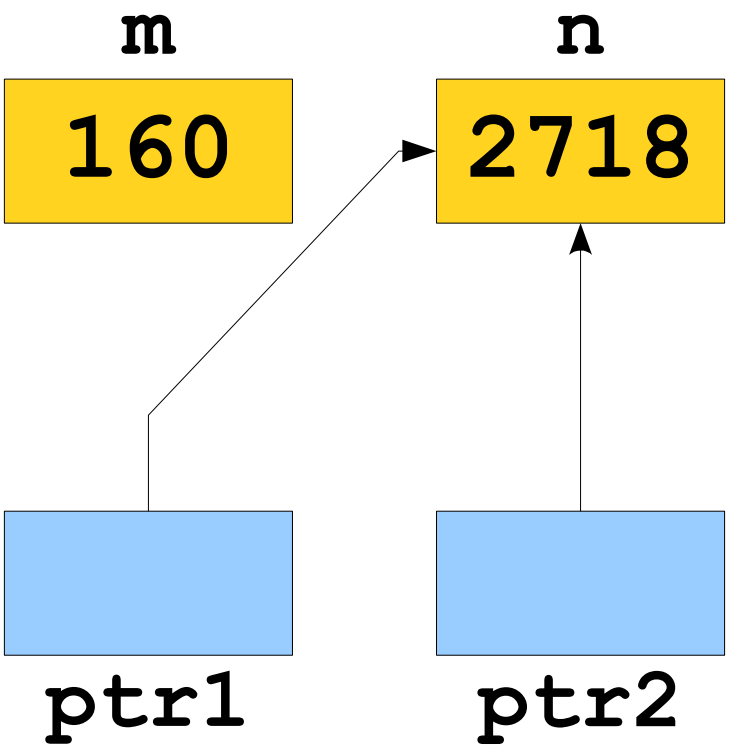

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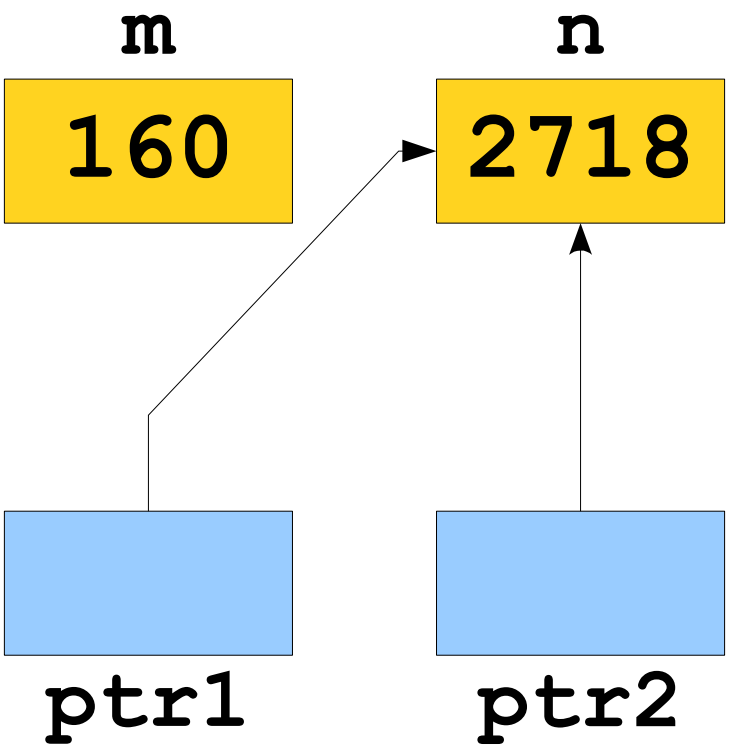

Assigning one pointer to another changes which object is being pointed at. It does not change the value of the pointee.

Pointers, Visually

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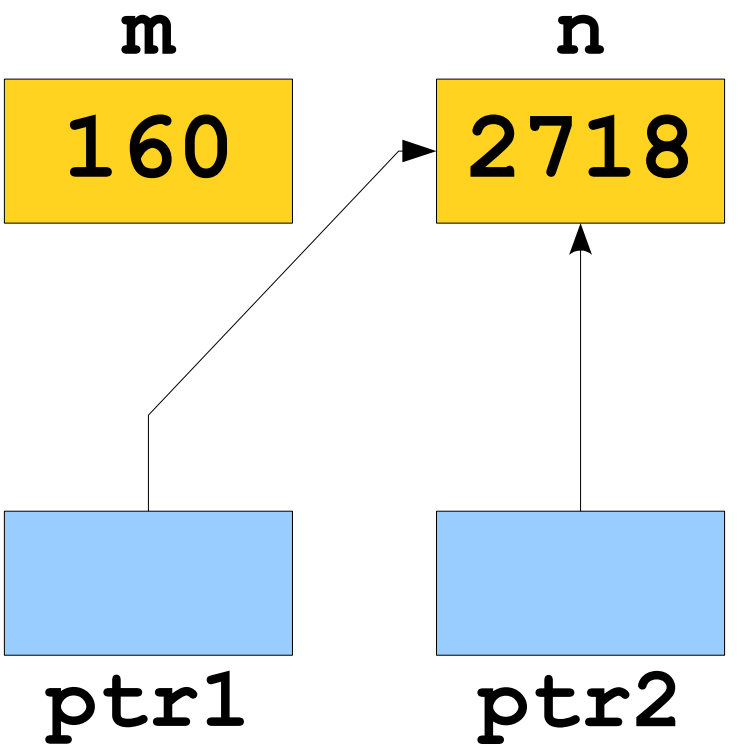

And finally, the reason we care about pointers...

Dynamic Memory Allocation

```
int main() {
   int numValues = getInteger("How many lines? ");

   string* arr = new string[numValues];
   for (int i = 0; i < numValues; i++) {
      arr[i] = getLine();
   }

   for (int i = 0; i < numValues; i++) {
      cout << i << ": " << arr[i] << endl;
   }
}
```

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numValues **7**

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}
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numValues **7** arr

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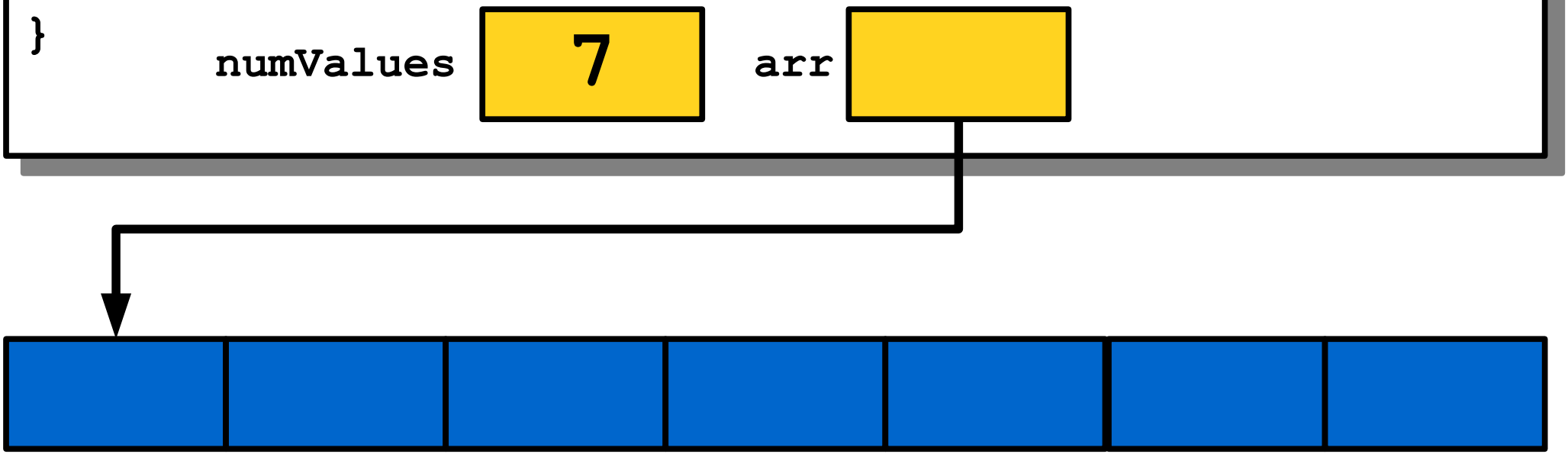

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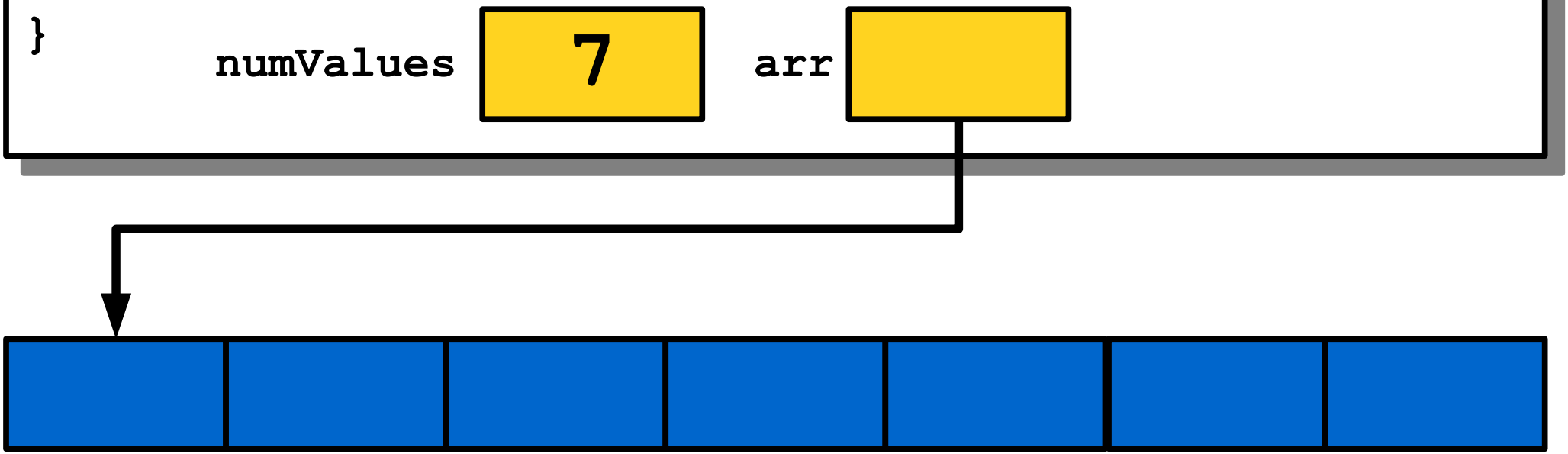

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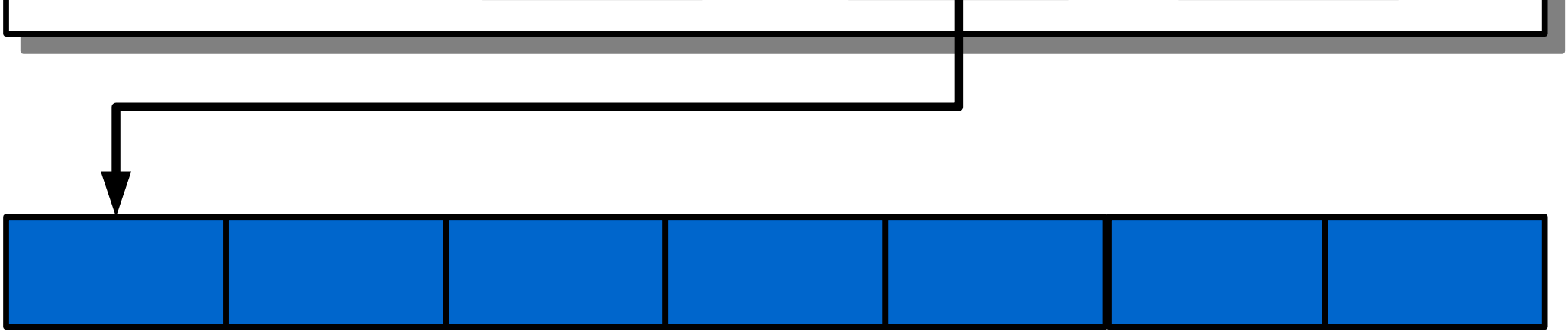

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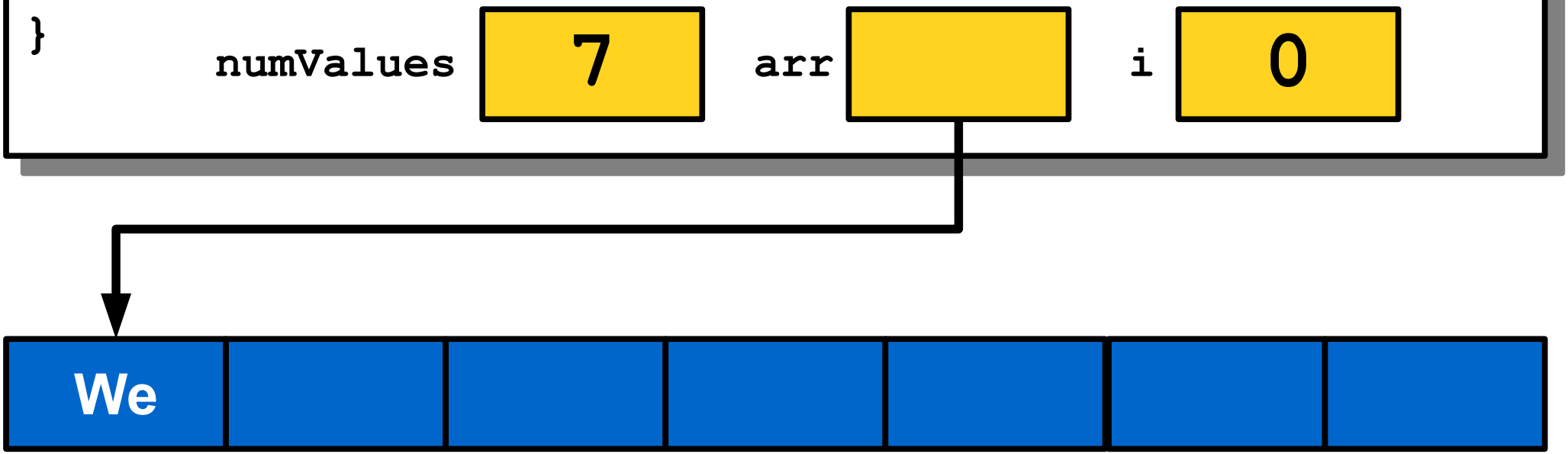

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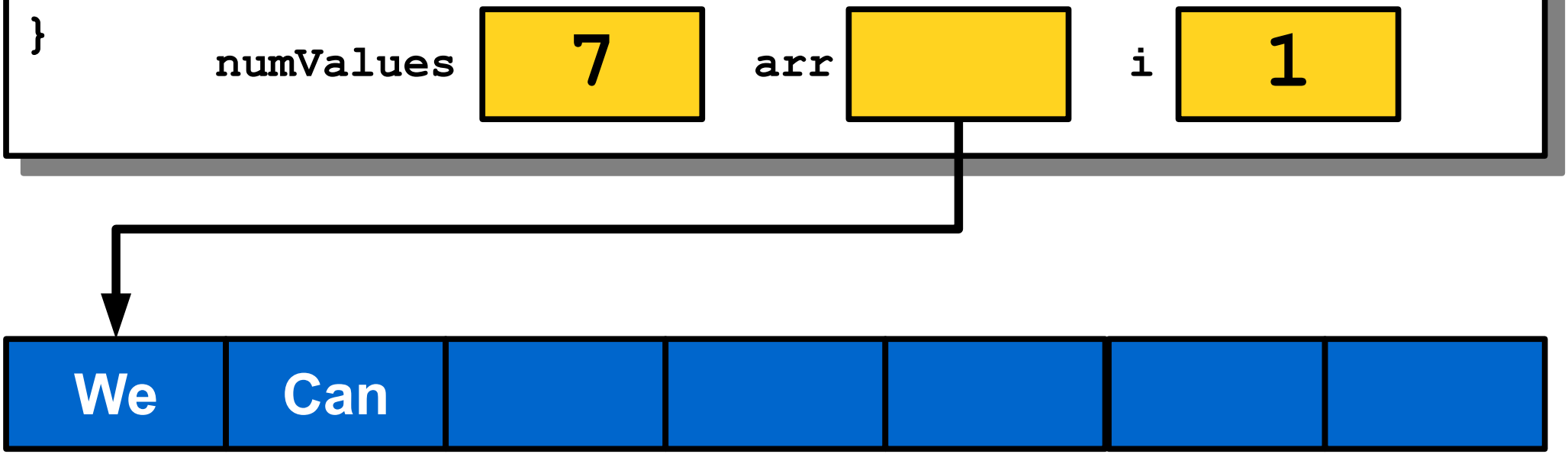

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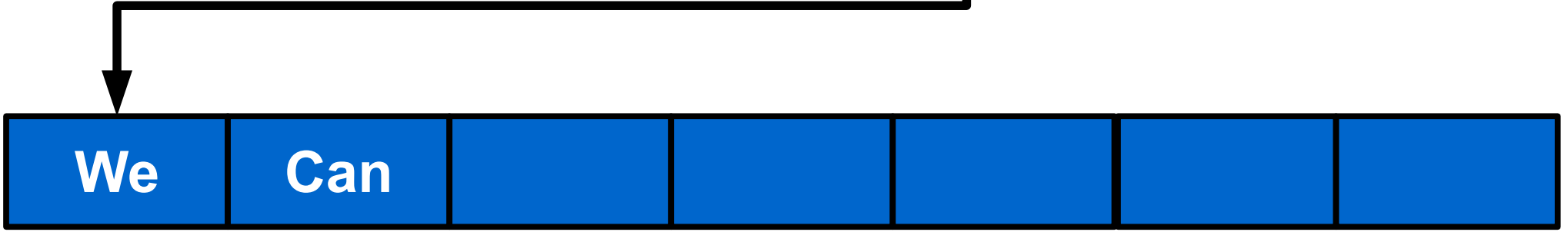
numValues **7** arr i **1**



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numValues 7 arr i 2

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   }
}
```

numValues 7 arr i 2

```
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   string* arr = new string[numValues];
   for (int i = 0; i < numValues; i++) {
      arr[i] = getLine();
   }

   for (int i = 0; i < numValues; i++) {
      cout << i << ": " << arr[i] << endl;
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numValues 7 arr i 3

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   }
}
```

numValues **7** arr i **4**

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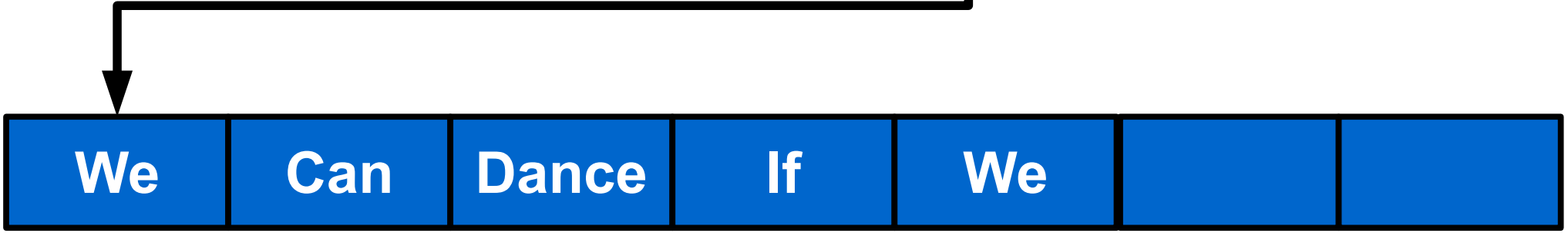
numValues **7** arr i **4**



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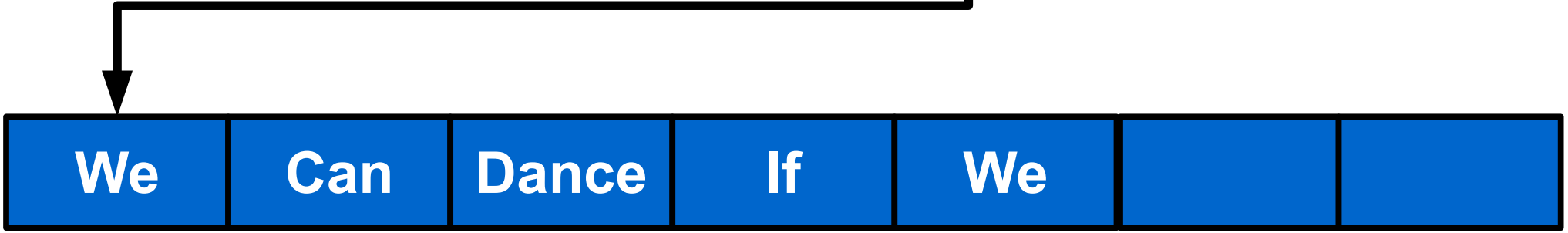
numValues **7** arr i **4**



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numValues 7 arr i 5

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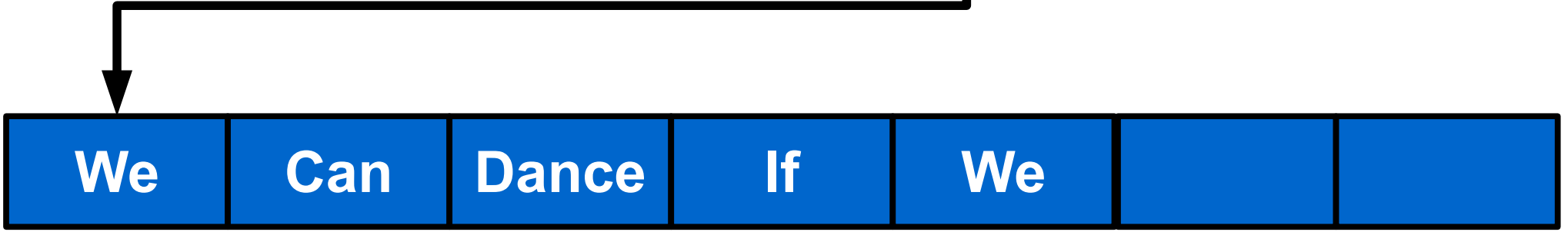
   }

   for (int i = 0; i < numValues; i++) {
      cout << i << ": " << arr[i] << endl;
   }
}
```

numValues 7 arr i 5



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```
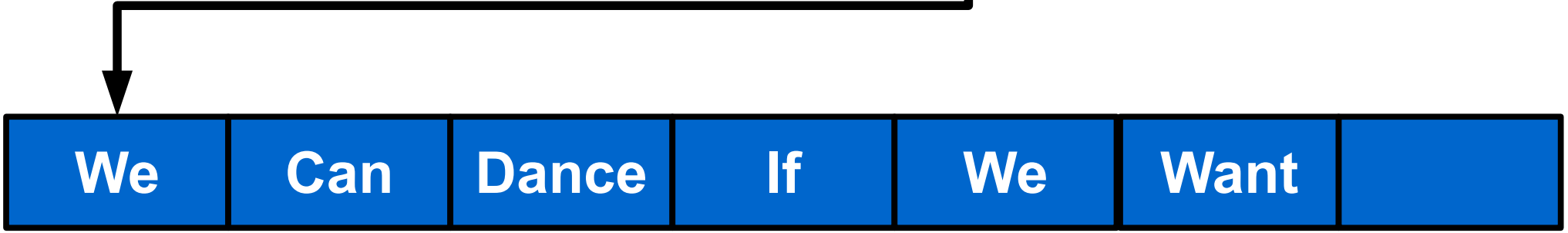

numValues **7** arr i **6**



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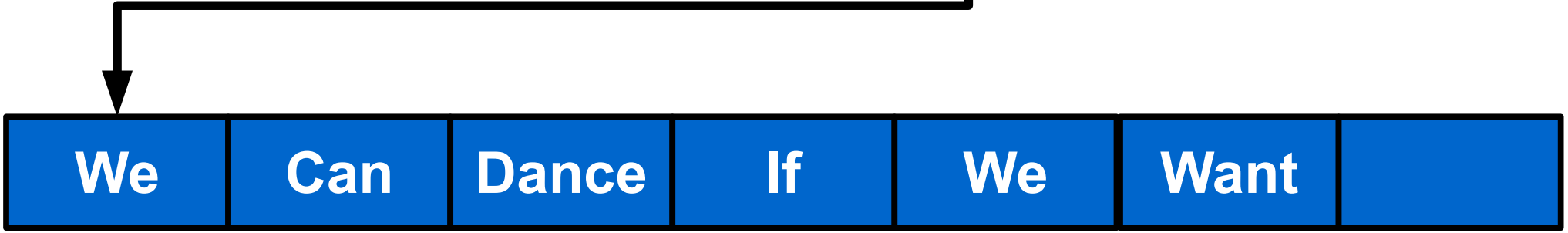
```

numValues **7** arr i **6**



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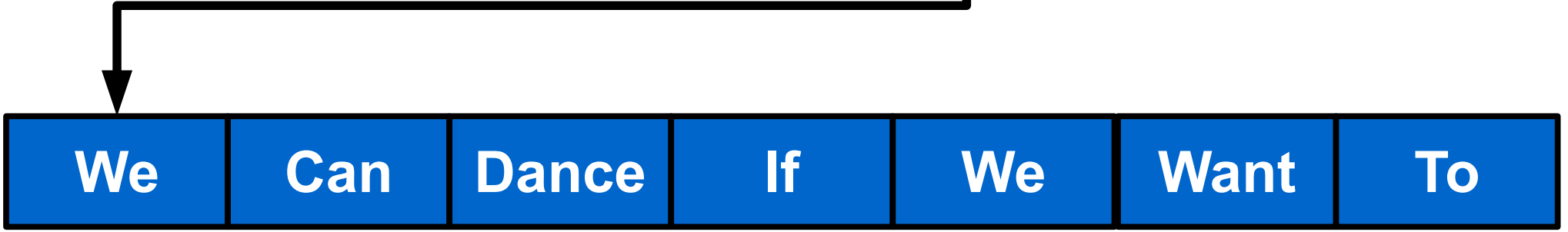
numValues **7** arr i **6**



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```
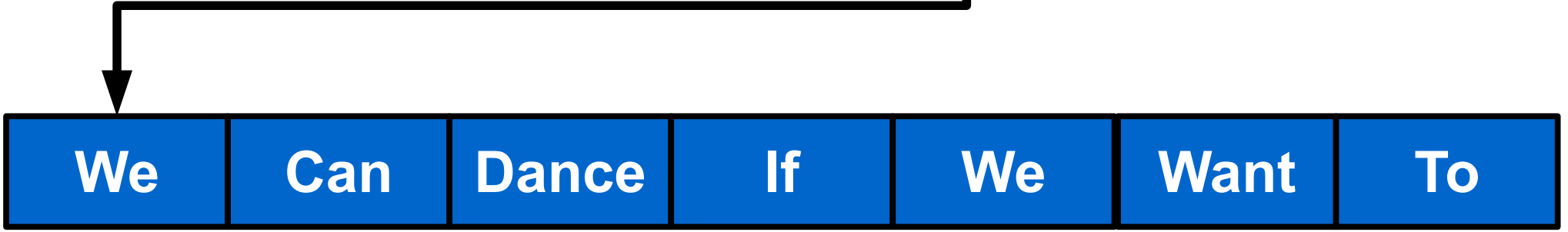

numValues **7** arr i **7**



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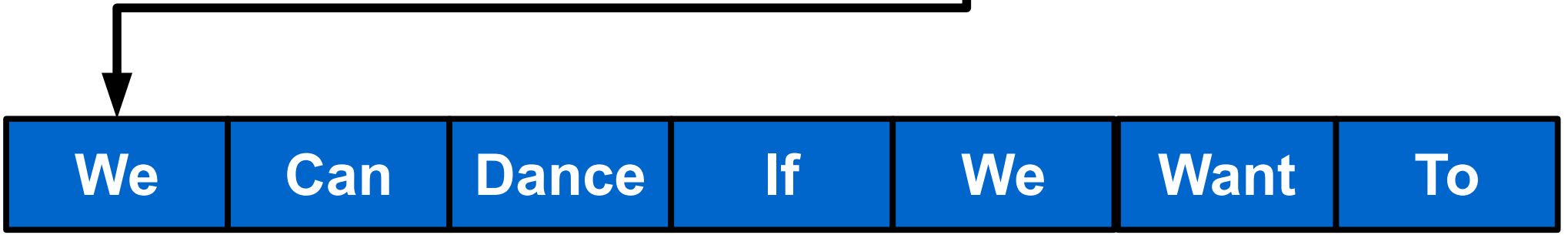
numValues **7** arr



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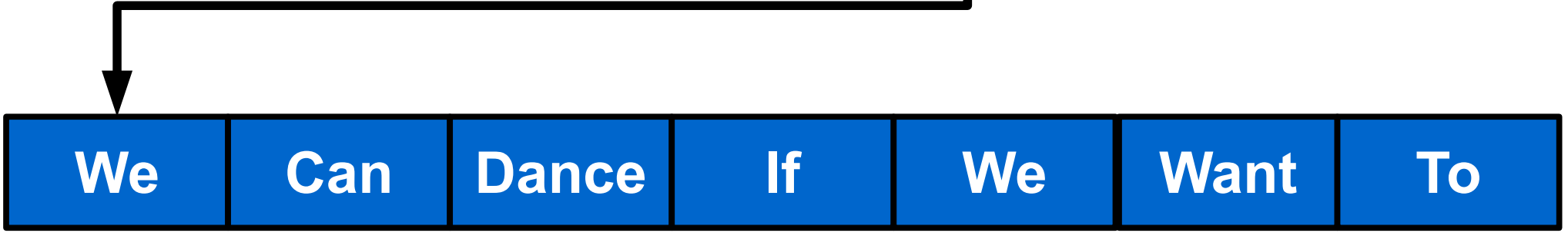
numValues **7** arr



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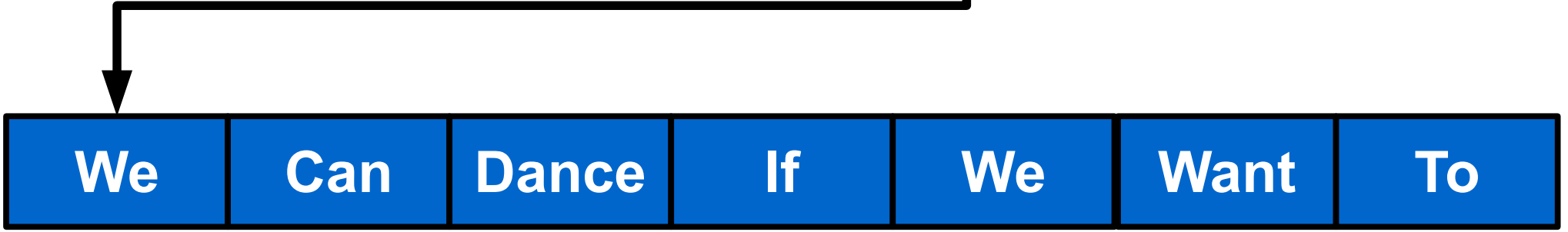

Dynamically Allocating Arrays

- First, declare a variable that will point at the newly-allocated array. If the array elements have type *T*, the pointer will have type *T**.
- Then, create a new array with the `new` keyword and assign the pointer to point to it.
- In two separate steps:

```
T* arr;
arr = new T[size];
```

- Or, in the same line:

```
T* arr = new T[size];
```

Cleaning Up

- When declaring global variables or local variables, C++ will automatically handle memory allocation and deallocation for you.
- When using **`new`**, you are responsible for deallocating the memory you allocate.
- If you don't, you get a **memory leak** and will slowly exhaust all of memory.
- Eventually, the program will crash when you ask for more memory with **`new`**, because the program thinks all of memory is in use.

Memory.cpp
(Memory and Leaking Memory)

Cleaning Up

- You can deallocate memory with the **`delete[]`** operator:

```
delete[] ptr;
```

- This destroys the array pointed at by the given pointer, not the pointer itself.

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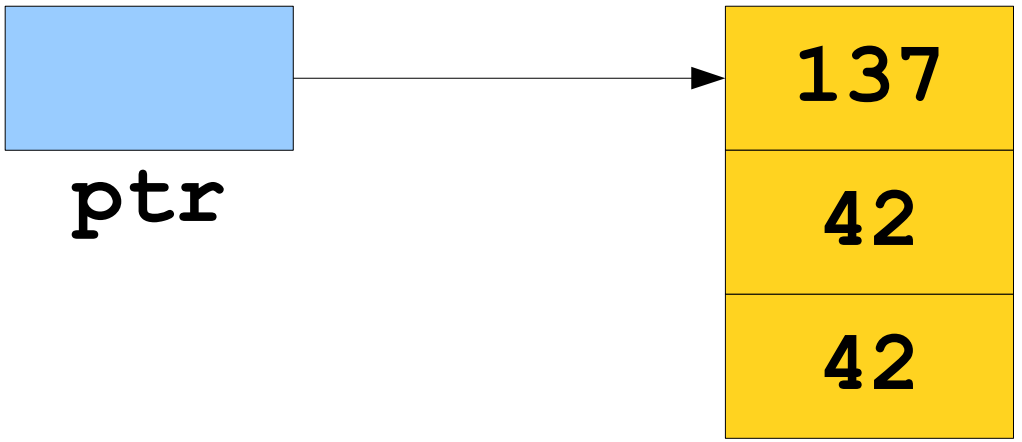

Cleaning Up

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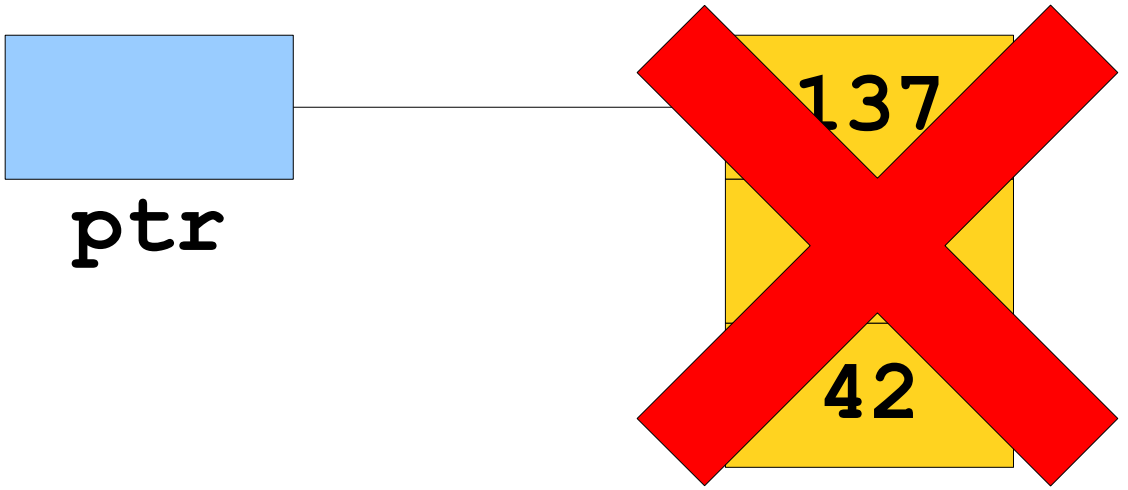


Cleaning Up

- You can deallocate memory with the **`delete[]`** operator:

```
delete[] ptr;
```

- This destroys the array pointed at by the given pointer, not the pointer itself.

Words of Caution

- C++ has few of the safety features present in Java.
- All of the following result in **undefined behavior** in C++:
  - Reading or writing through a pointer that you haven't initialized.
  - Reading or writing through a pointer to an array that you have deallocated.
  - Reading or writing off the end of an array.

Implementing `Stack`

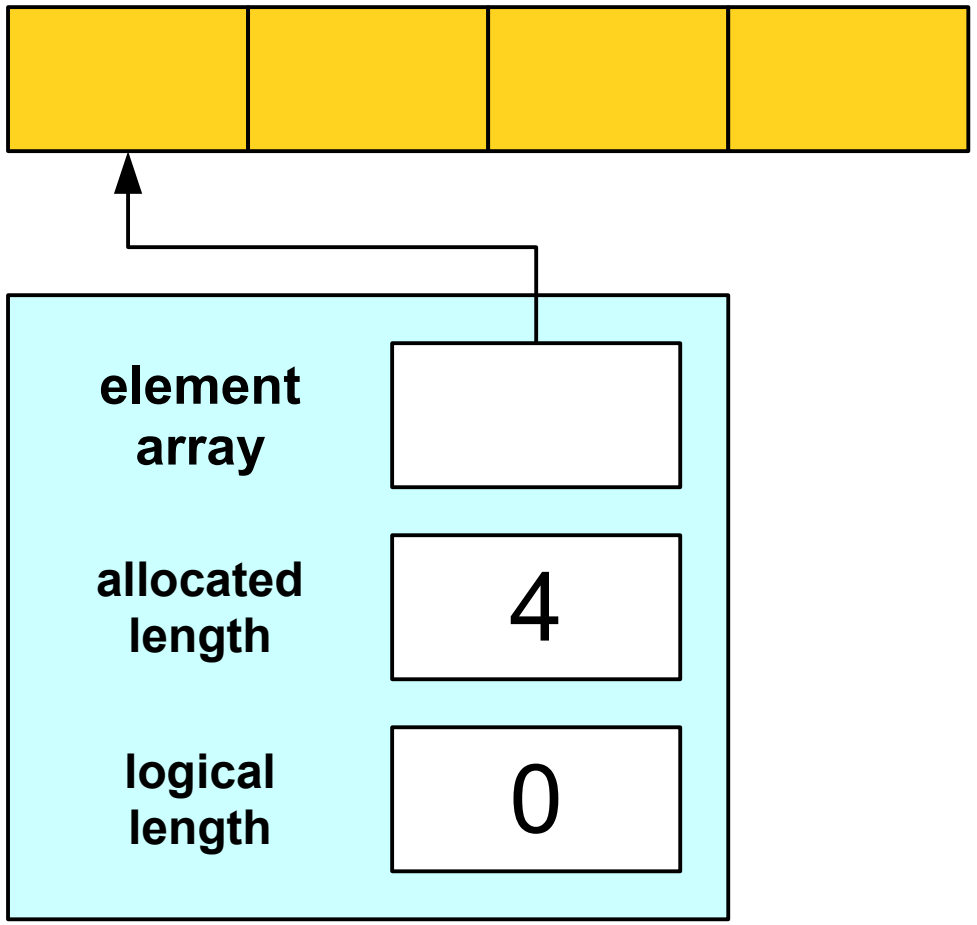
Implementing **`Stack`**

- Last time, we saw how to implement **`RandomBag`** in terms of **`Vector`**.
- We could also implement **`Stack`** in terms of **`Vector`**.
- What if we wanted to implement the **`Stack`** without relying on any other collections?
- Let's build the stack directly!

An Initial Idea

- **A bounded stack.**
- Allocate a fixed-size array for elements.
- Add elements to the array when they're pushed.
- Remove elements from the array when they're popped.
- Report an error if we exceed the size of the array.

An Initial Idea



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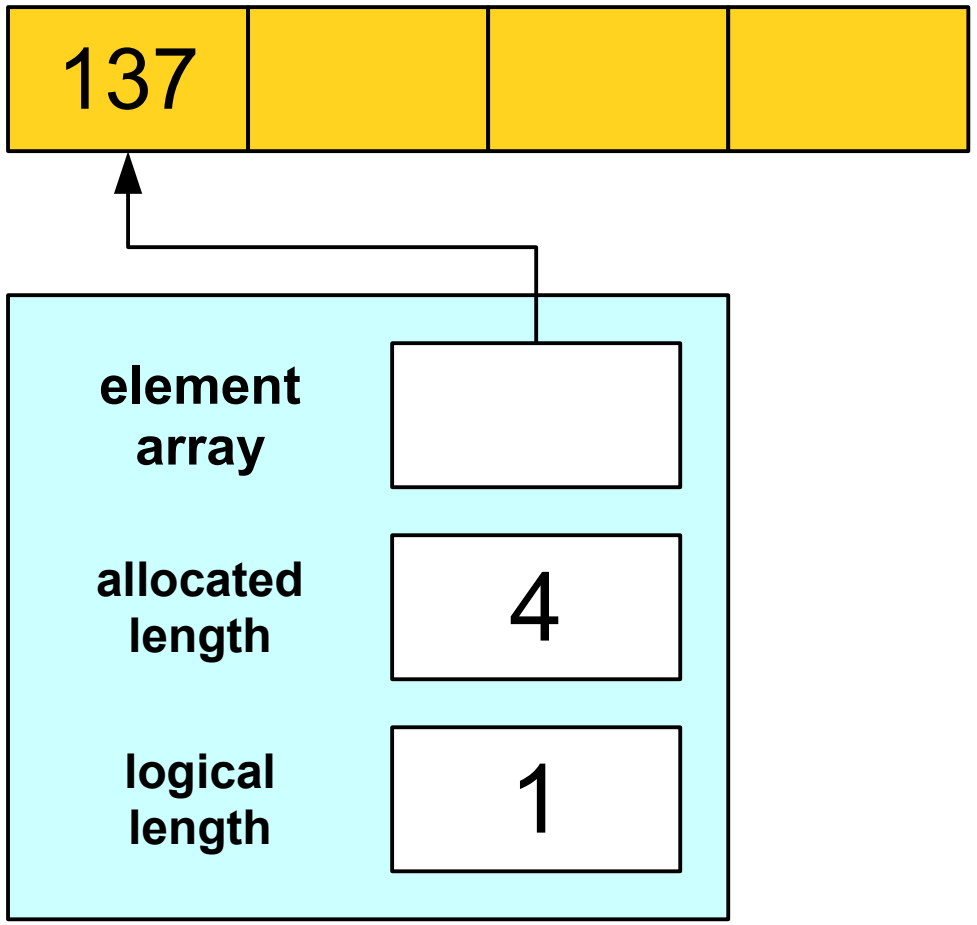

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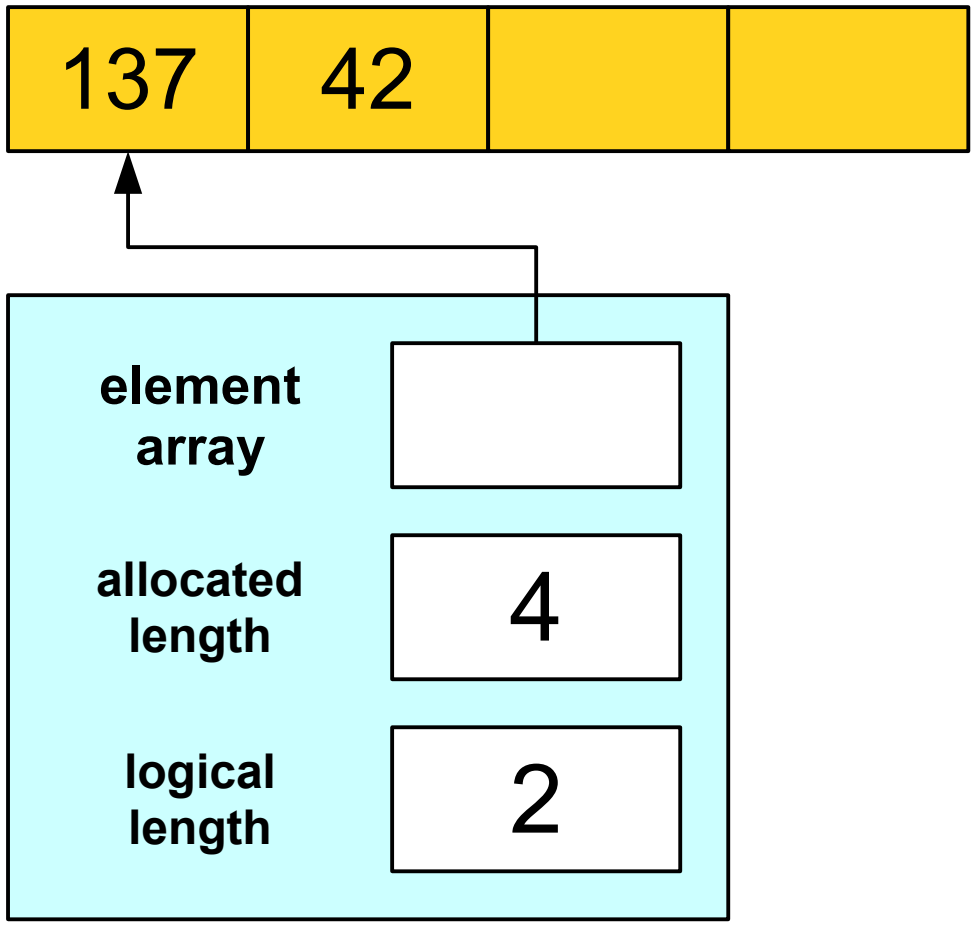

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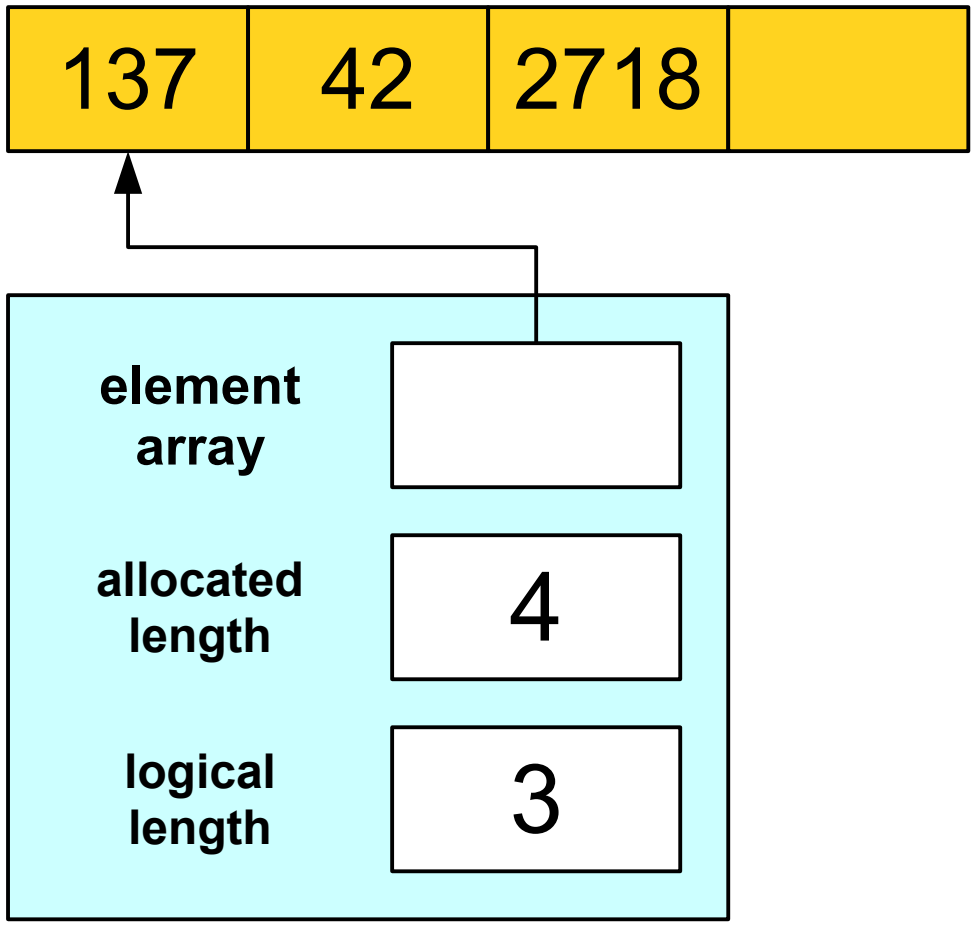

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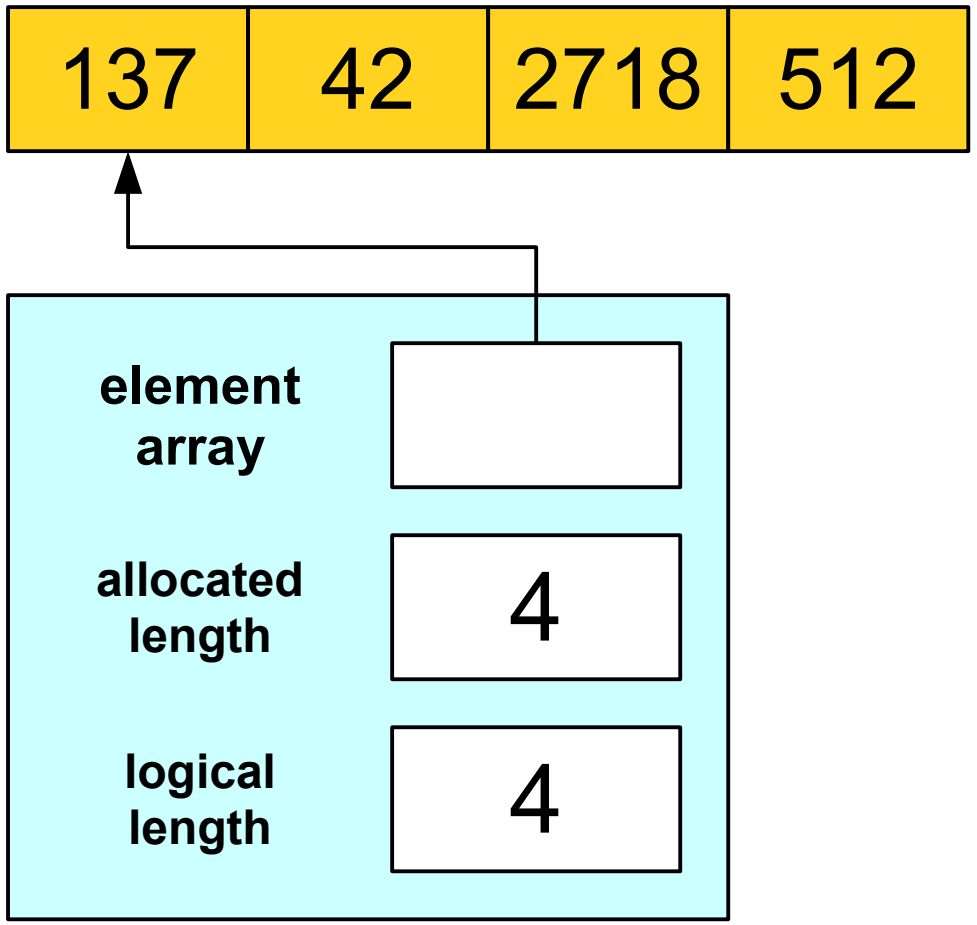

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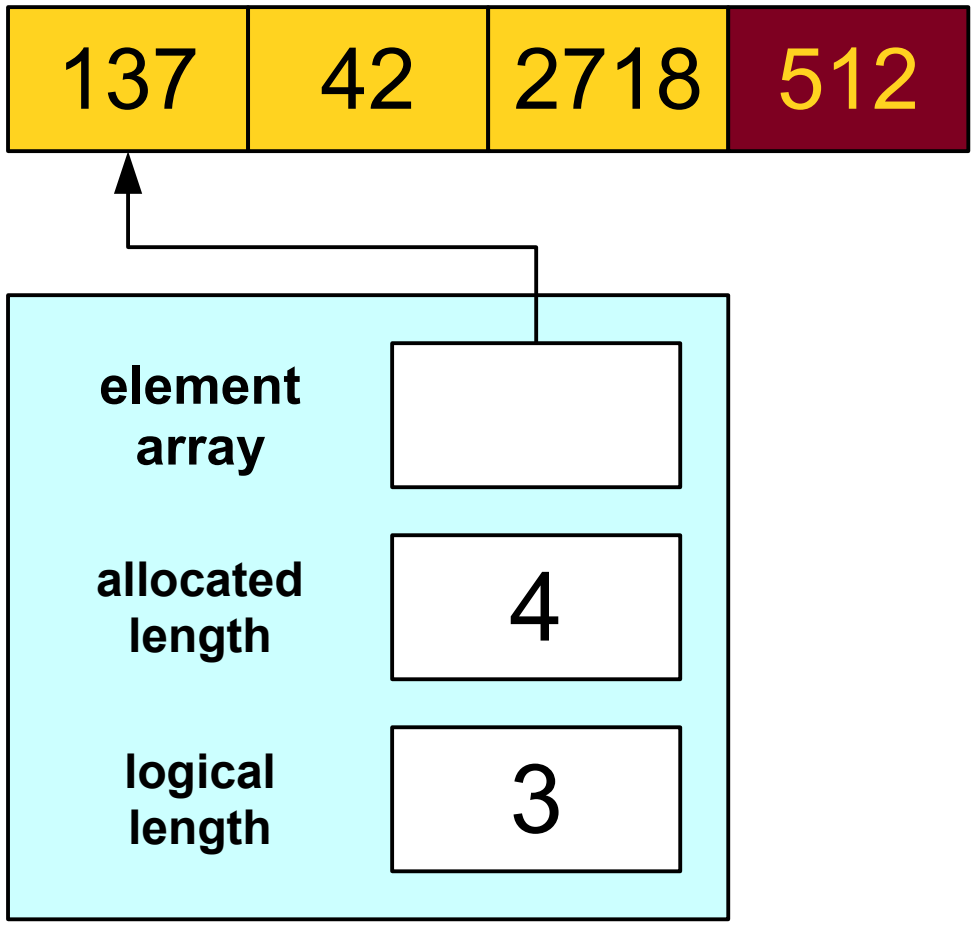

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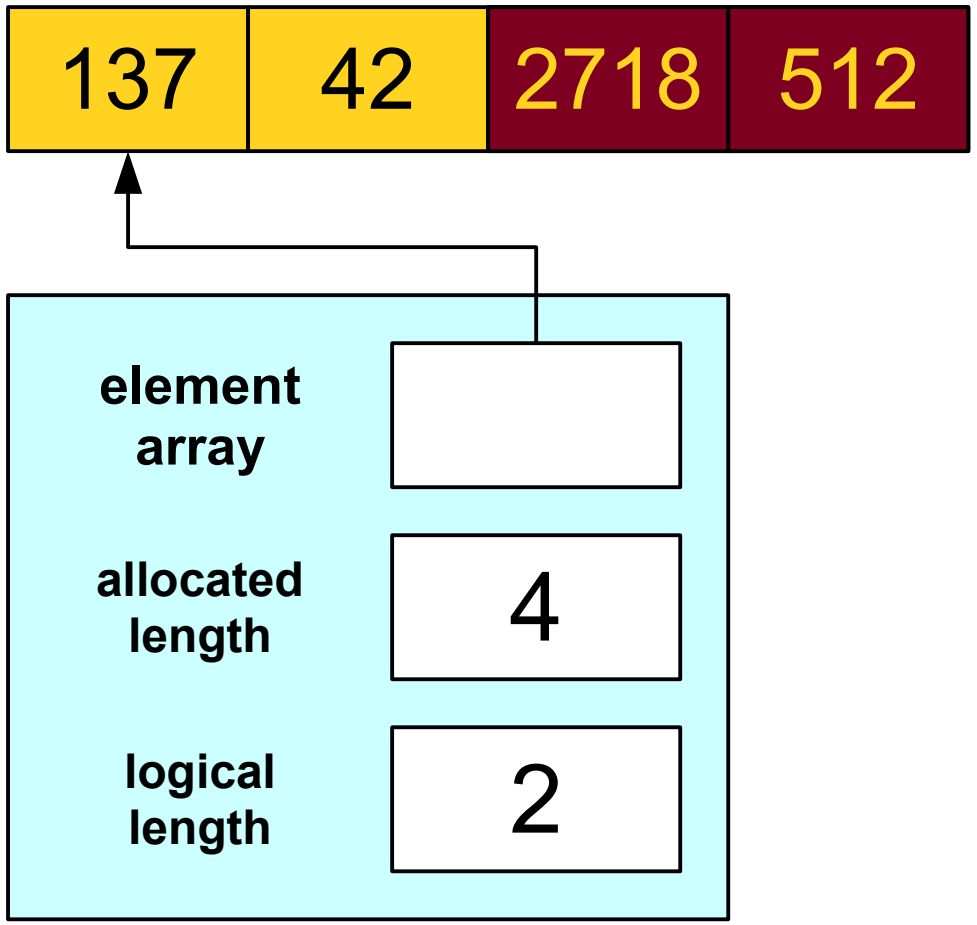

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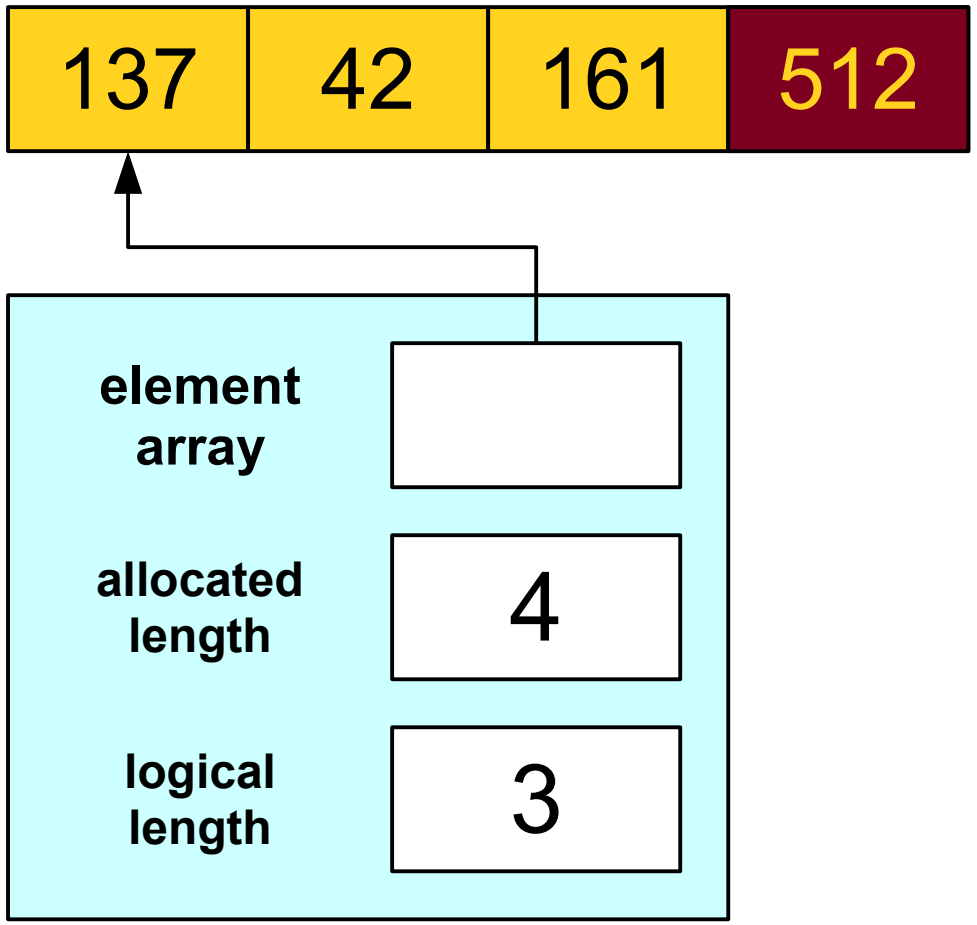

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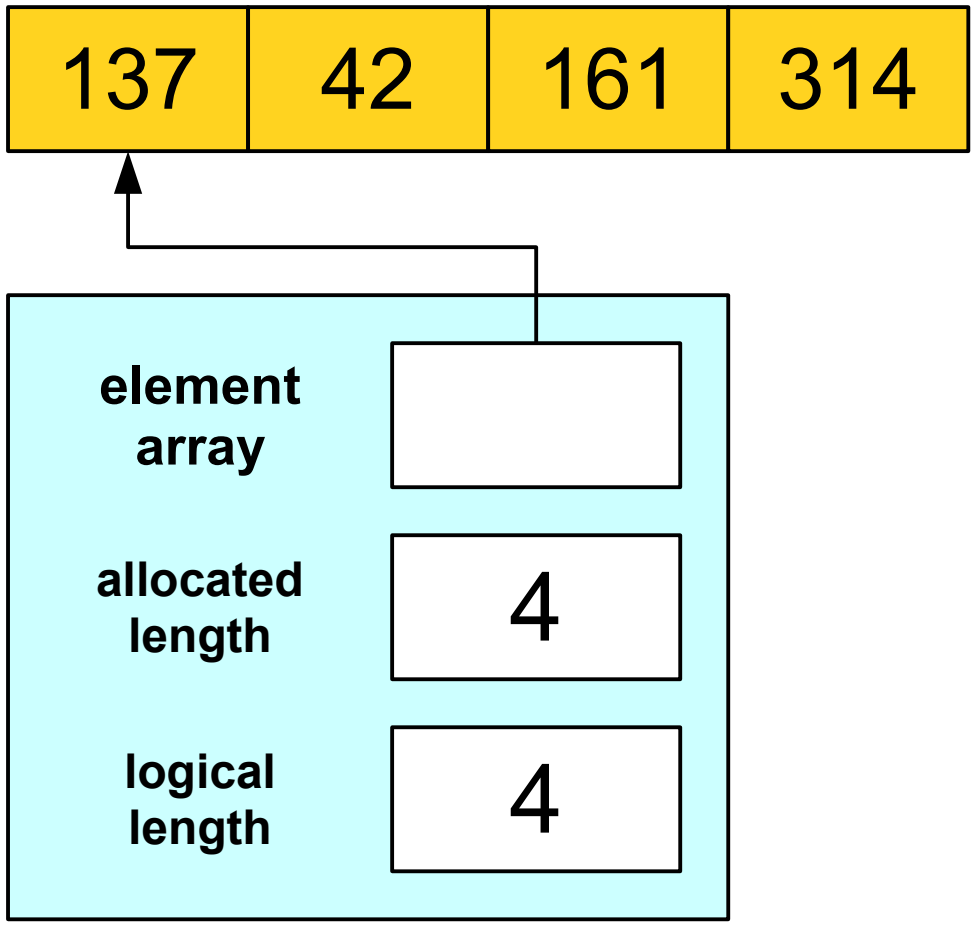

What methods does our Stack need?

What data does our Stack need?

Let's Code it Up!

Constructors

- A **constructor** is a special member function used to set up the class before it is used.
- The constructor is automatically called when the object is created.
- Syntax: The constructor for a class named ***ClassName*** has signature

***ClassName*(*args*);**

Destructors

- A **destructor** is a special member function responsible for cleaning up an object's memory.
- Automatically called when a local variable goes out of scope.
- Automatically called if you `delete` a pointer to an object.
- Syntax: The destructor for a class named ***ClassName*** has signature

`~`*ClassName*`();`

Next Time

- **Making `Stack` Grow!**
  - Different approaches to **`Stack`** growth.
  - Analysis of these approaches.