# Implementing Abstractions

Part One

# Turtles All the Way Down?

- Last time, we implemented a `RandomBag` on top of our library `Vector` type.
- But the `Vector` type is itself a library – what is it layered on top of?
- ***Question:*** What are the fundamental building blocks provided by the language, and how do we use them to build our own custom classes?

# Getting Storage Space

- The `Vector`, `Stack`, `Queue`, etc. all need storage space to put the elements that they store.
- That storage space is allocated using ***dynamic memory allocation***.
- Essentially:
  - You can, at runtime, ask for extra storage space, which C++ will give to you.
  - You can use that storage space however you'd like.
  - You have to explicitly tell the language when you're done using the memory.

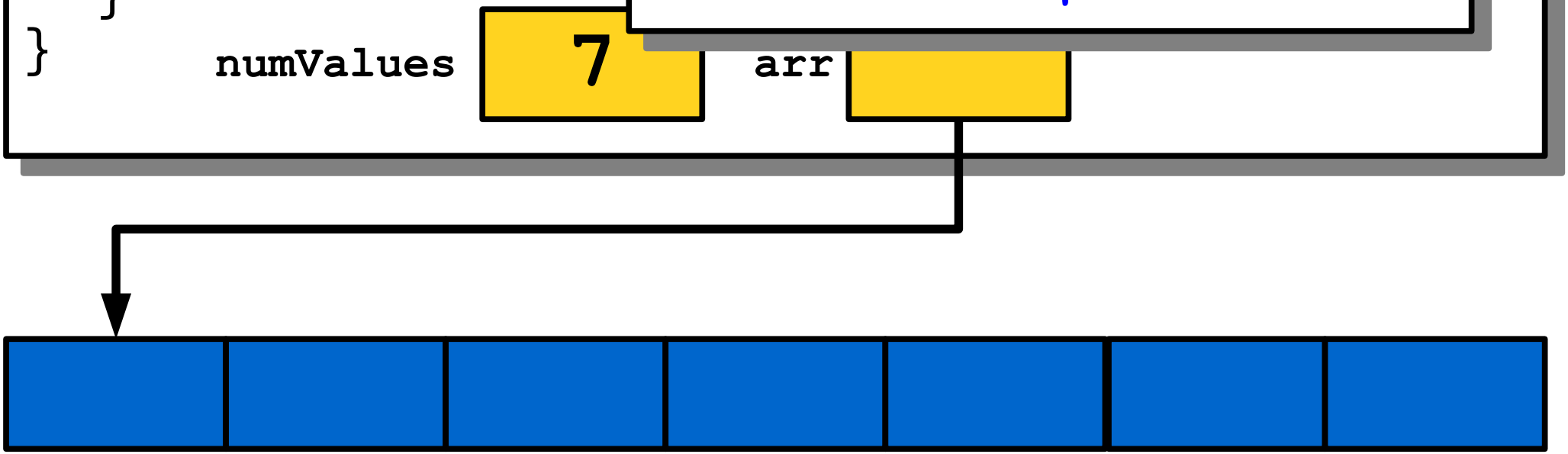
# Dynamic Allocation Demo

```
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 <
      cout << i << ":
   }
}
```

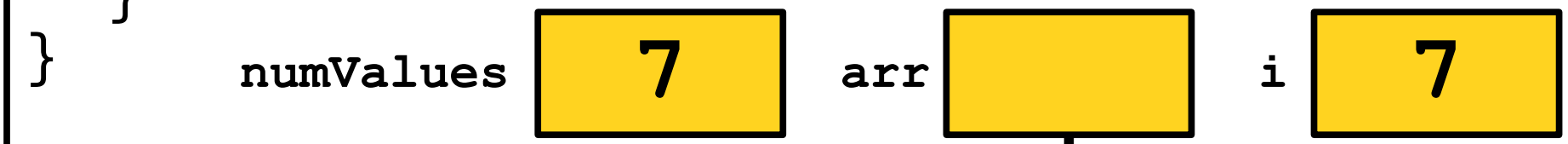
Because the variable **arr** points to the array, it is called a *pointer*.



```
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;
   }
}
```




# 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****.
  - e.g. `int*`, `string*`, `Vector<double>*`
- 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];
```

# Dynamically Allocating Arrays

- C++'s language philosophy prioritizes speed over safety and simplicity.
- The array you get from `new[]` is ***fixed-size***: it can neither grow nor shrink once it's created.
  - The programmer's version of "conservation of mass."
- The array you get from `new[]` has ***no bounds-checking***. Walking off the beginning or end of an array triggers *undefined behavior*.
  - Literally anything can happen: you read back garbage, you crash your program, or you let a hacker take over your computer. Do a search for "buffer overflow" for more details.

# Cleaning Up

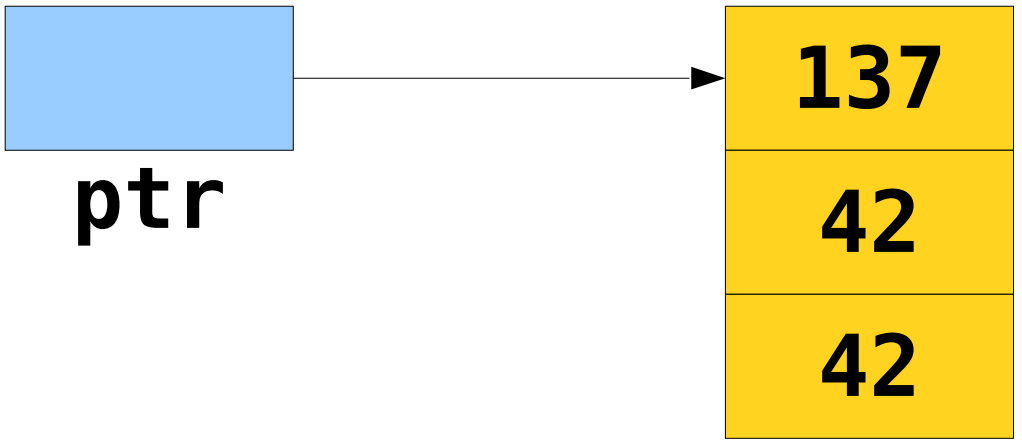
- When declaring local variables or parameters, C++ will automatically handle memory allocation and deallocation for you.
- When using `new`, you are responsible for deallocating the memory you allocate.
- If you don't, you get a ***memory leak***. Your program will never be able to use that memory again.
  - Too many leaks can cause a program to crash – it’s important to not leak 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.



# 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.


`ptr` is now a ***dangling pointer***. We can reassign it to point somewhere else, but if we try to read from it, it'll do Cruel and Unusual Things!

Time-Out for Announcements!

# Midterm Exam

- The midterm exam is next Tuesday, February 21 from 7:00PM – 10:00PM.
  - Location TBA
- Covers topics up through and including big-O notation, plus Assignments 0 – 4.
- Closed-book, closed-computer, limited-note. You get one double-sided sheet of 8.5” × 11” notes when you take the exam. We also provide a library reference sheet.
- We’re holding a practice exam ***tonight, right here*** from 7:00PM – 10:00PM.
  - ***You should plan to attend the practice exam unless you have a hard conflict***. The actual exam should not be the first time you write code on paper under time pressure.
- Can’t make the exam time? You ***must*** contact Anton by 5:00PM today.

# Assignment 4

- Assignment 4 is due on Friday.
- If you're following our timetable, you should aim to complete Doctors Without Orders, Disaster Planning, and DNA Detective by this evening.
- You should aim to complete the Winning the Presidency part of the assignment by Wednesday evening.
- Please ask questions on Piazza, stop by Keith's or Anton's office hours, or drop by the LaIR if you have questions!

# A Humble Plea

- Please feel free to ask questions on Piazza.
- However, if you do, please make sure that the question you're asking hasn't already been answered before – we're getting a lot of duplicate questions.
- That's all!

```
continue;
```

# Implementing `Stack`

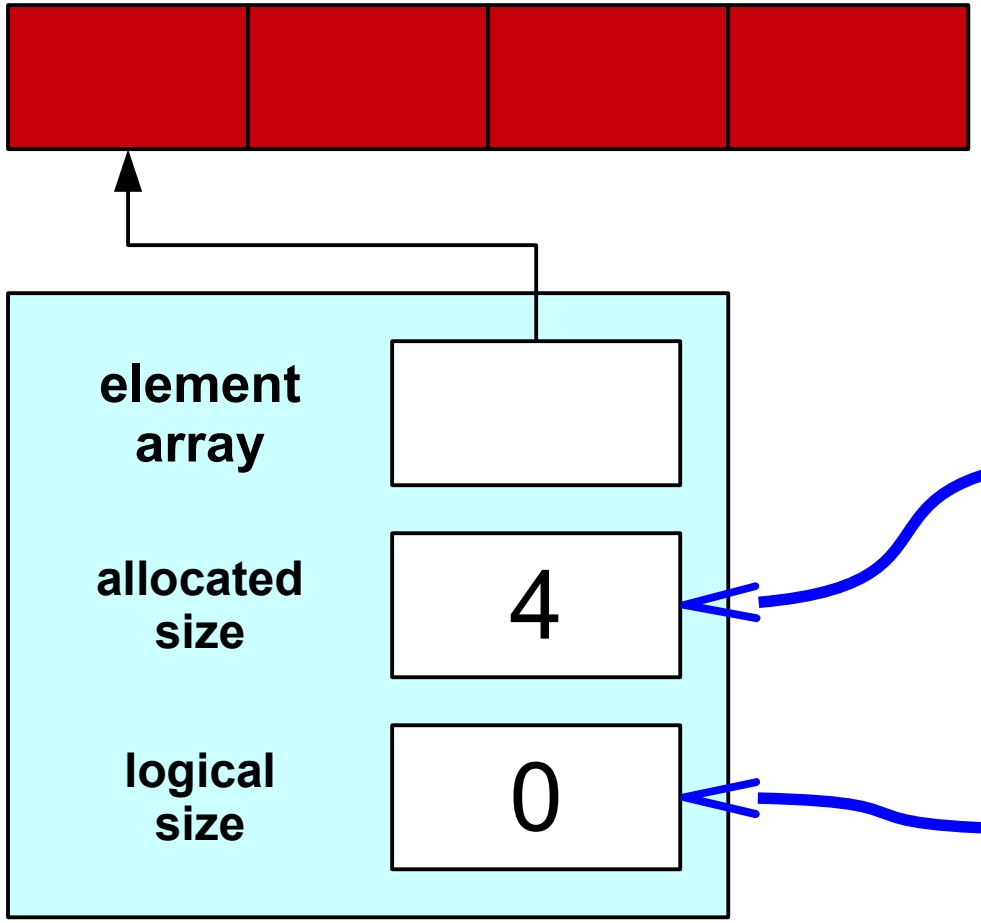
# Implementing `Stack`

- 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!

# You Gotta Start Somewhere

- Our initial implementation of the stack will be a *bounded* stack with a maximum capacity.
- We'll allocate a fixed amount of storage space for the elements, then write them into the array as they're pushed.
- If we run out of space, we'll report an error.
- Next time, we'll update this code so that we can have a stack without any fixed maximum capacity.

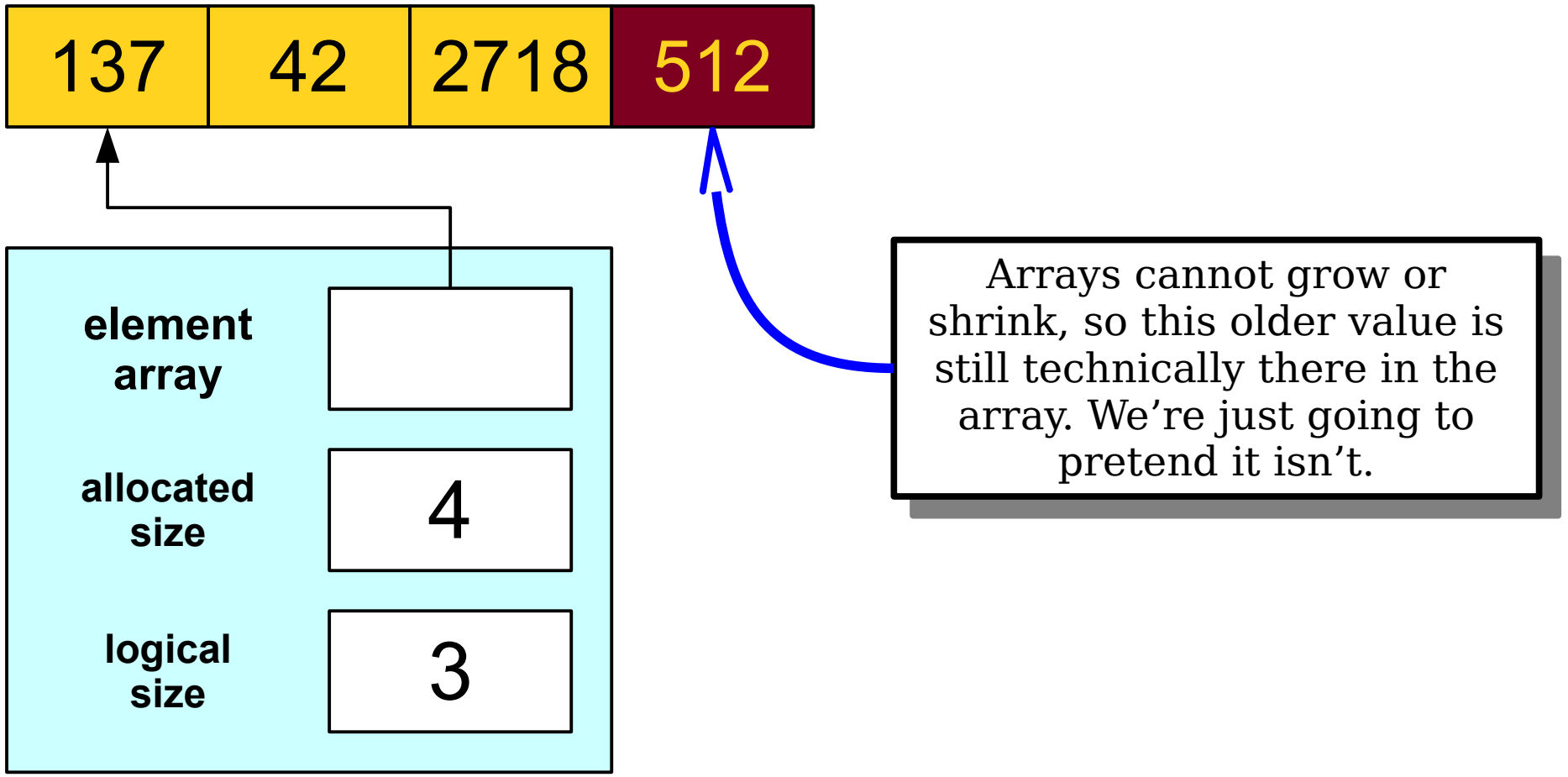
# An Initial Idea



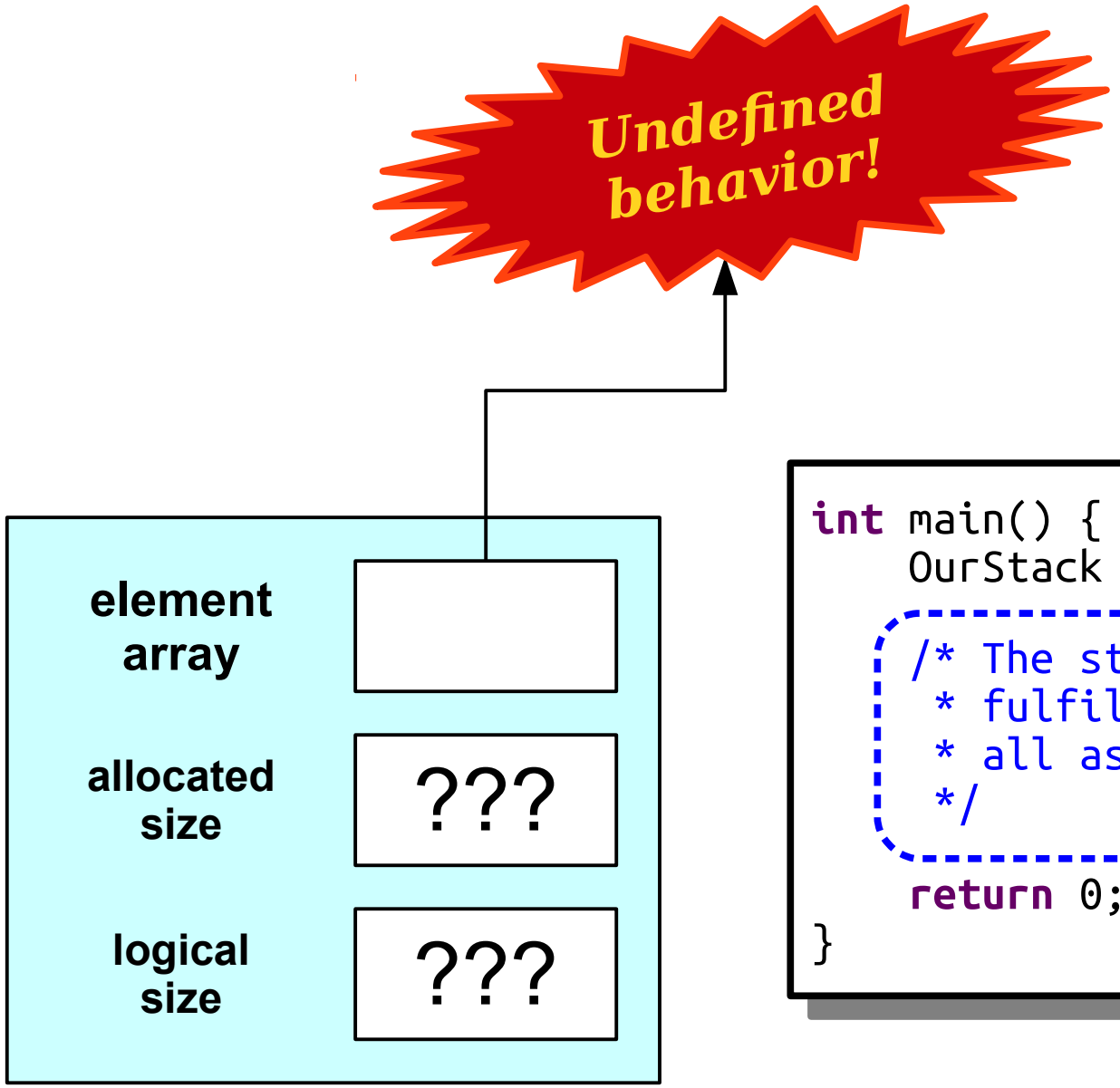

The stack's ***allocated size*** is the number of slots in the array. Remember – arrays in C++ cannot grow or shrink.

The stack's ***logical size*** is the number of elements actually stored in the stack. This lets us track how much space we're actually using.

# An Initial Idea



# Cradle to Grave




```
int main() {
    OurStack stack;

    /* The stack lives a rich, happy,
     * fulfilling life, the kind we
     * all aspire to.
     */

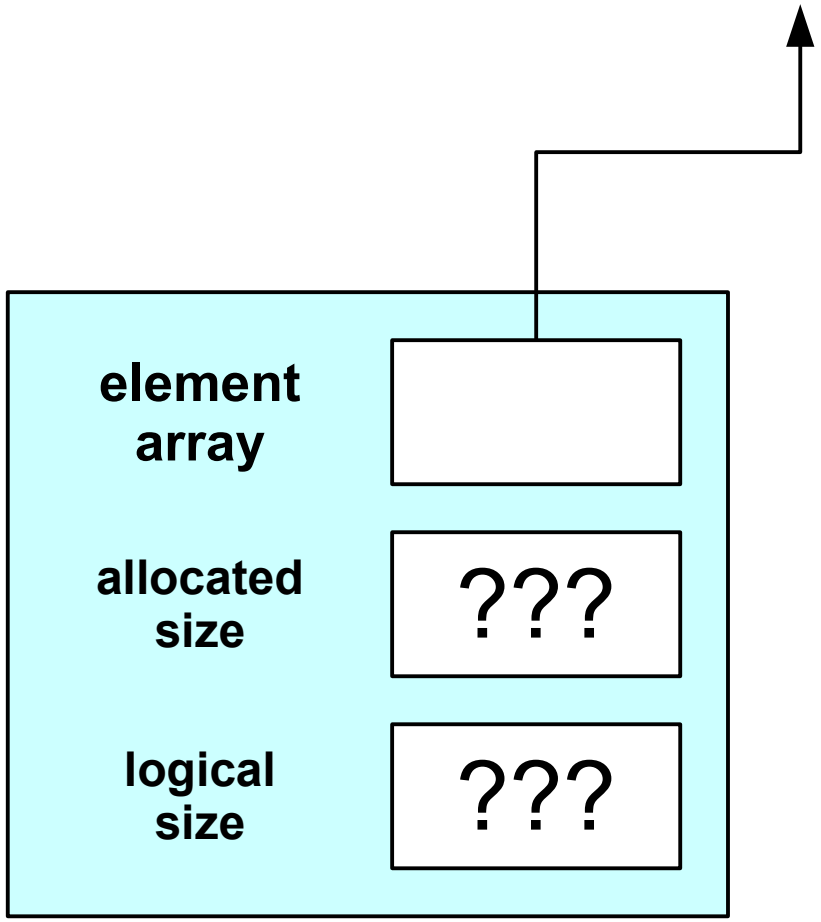
    return 0;
}
```

# 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.
- The constructor for a class named ***ClassName*** has signature

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

# Cradle to Grave, Take II

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int main() {
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   /* The stack lives a rich, happy,
    * fulfilling life, the kind we
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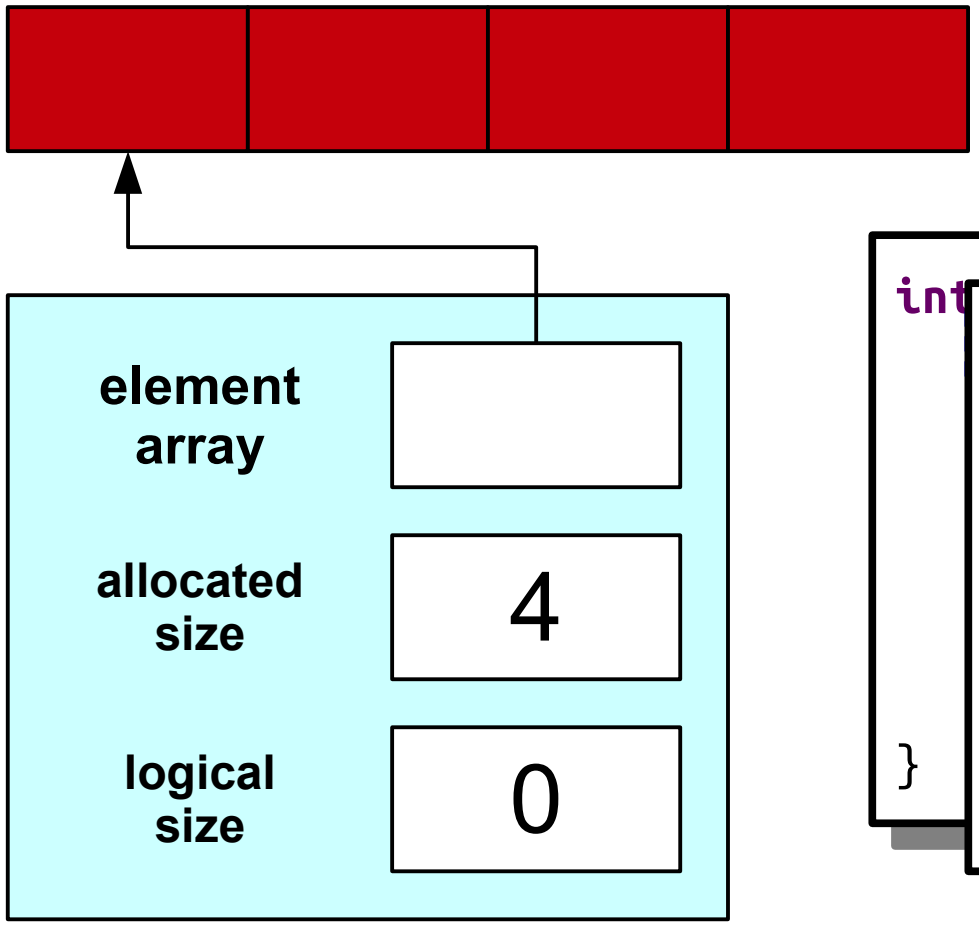
    */

   return 0;
}
```

# Cradle to Grave, Take II

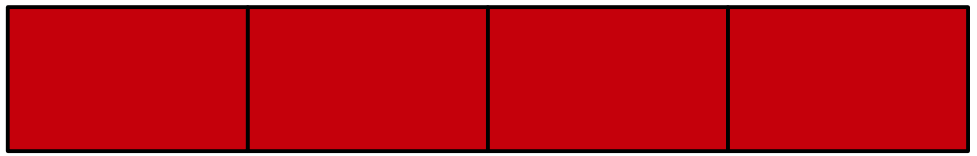



```
int

OurStack::OurStack() {
    logicalSize = 0;
    allocatedSize = kInitialSize;
    elems = new int[allocatedSize];
}

}
```

# Cradle to Grave, Take II



I am adrift, alone, condemned to forever wander meaninglessly.

```
int main() {
    OurStack stack;

    /* The stack lives a rich, happy,
     * fulfilling life, the kind we
     * all aspire to.
     */

    return 0;
}
```

# Destructors

- A ***destructor*** is a special member function responsible for cleaning up an object's memory.
- It’s automatically called whenever an object’s lifetime ends (for example, if it’s a local variable that goes out of scope.)
- The destructor for a class named ***ClassName*** has signature

```
~ClassName();
```

# To Summarize

- You can create arrays of a fixed size at runtime by using `new[]`.
- You are responsible for freeing any memory you explicitly allocate by calling `delete[]`.
- Constructors are used to set up a class's internal state so that it's in a good place.
- Destructors are used to free resource that a class allocates.

# Next Time

- ***Making Stack Grow!***
  - Different approaches to `Stack` growth.
  - Analysis of these approaches.
  - The reality: *everything is a tradeoff!*
- ***Implementing the `Queue`***
  - … is not too hard when you have a stack!