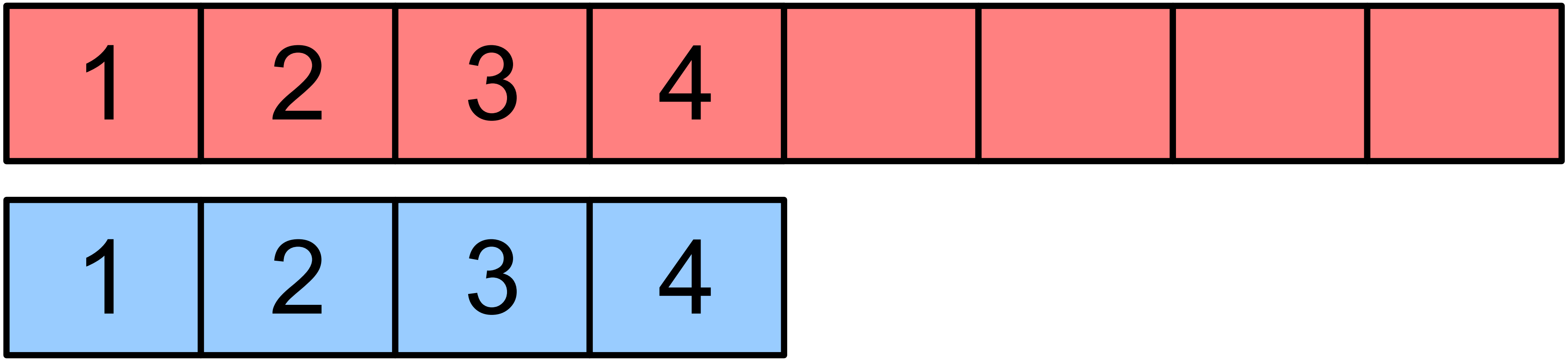
Linked Lists

Part One

Array-Based Allocation

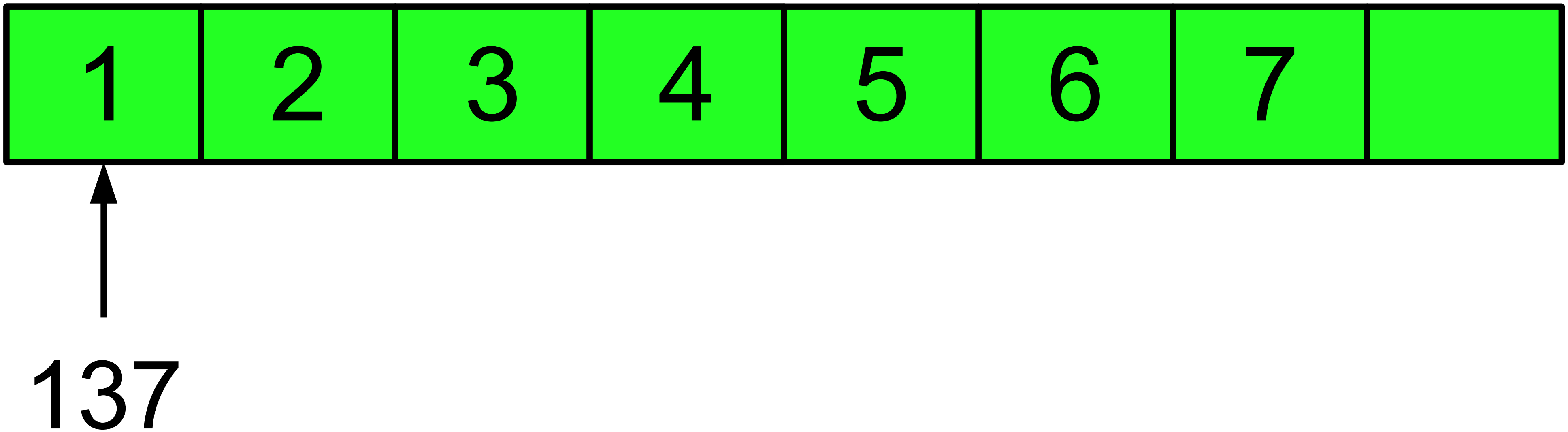
- Our current implementation of `Stack` uses dynamically-allocated arrays.
- To append an element:
  - If there is free space, put the element into that space.
  - Otherwise, get a *huge* new array and move everything over.



A Different Idea

- Instead of reallocating a huge array to get the space we need, why not just get a tiny amount of extra space for the next element?
- Think about how you take notes: when you run out of space on a page, you just get a new page. You don't copy your entire set of notes onto a longer sheet of paper!

Excuse Me, Coming Through...



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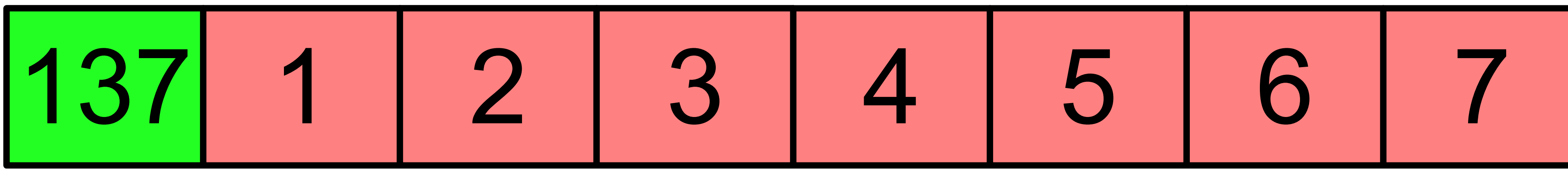
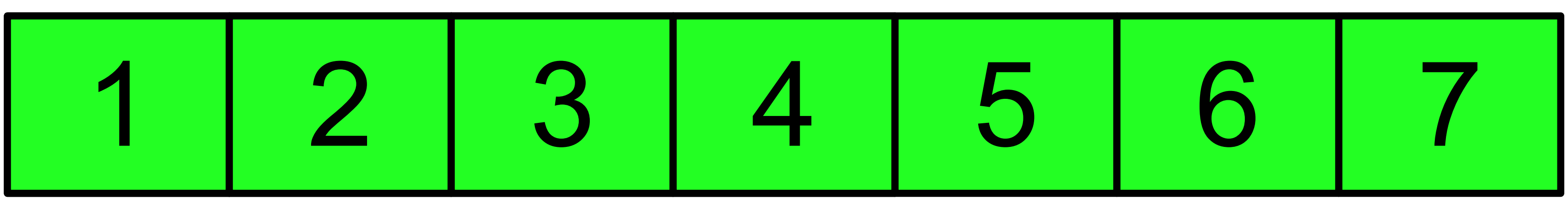


Shoving Things Over

- Right now, inserting an element into a middle of a `Vector` can be very costly.
- Couldn't we just do something like this?



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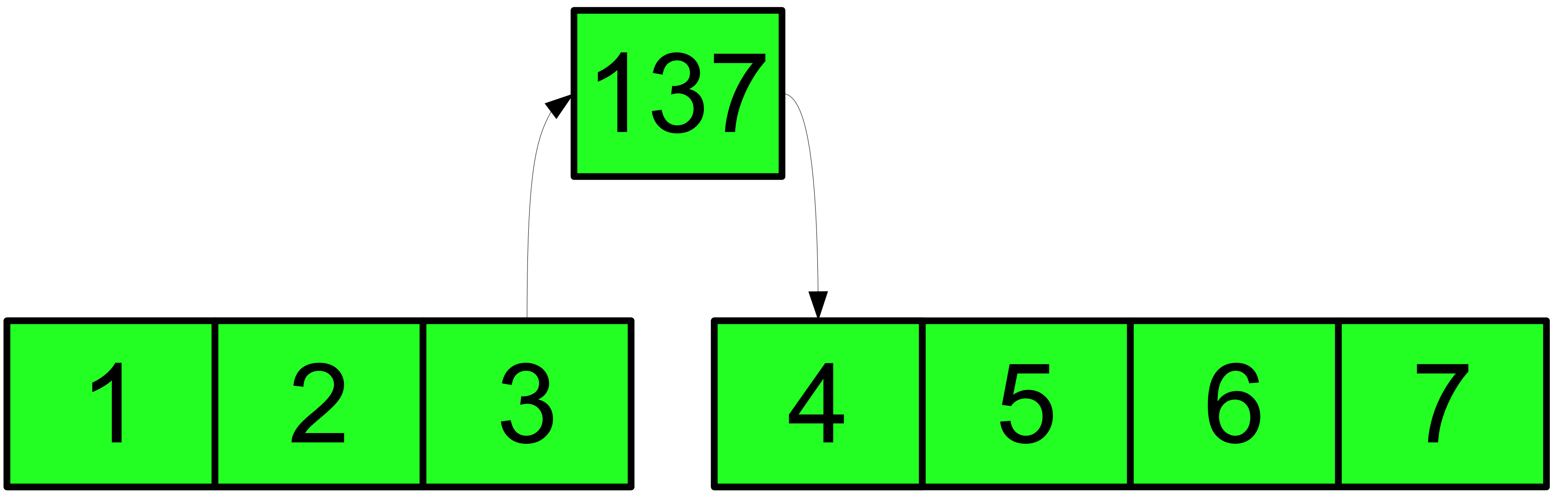
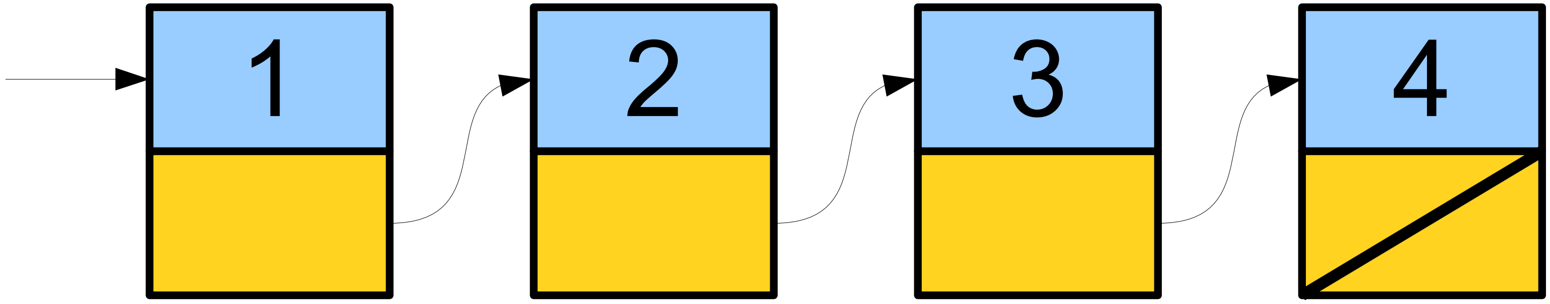


Linked Lists at a Glance

- A ***linked list*** is a data structure for storing a sequence of elements.
- Each element is stored separately from the rest.
- The elements are then chained together into a sequence.



Linked Lists at a Glance

- Can efficiently splice new elements into the list or remove existing elements anywhere in the list.
- Never have to do a massive copy step; insertion is efficient in the worst-case.
- Has some tradeoffs; we'll see this later.

Two Technical Prerequisites

Dynamic Memory Allocation

- We have seen the `new` keyword used to allocate arrays, but it can also be used to allocate single objects.
- The syntax

  `new` ***`T`***`(`***`args`***`)`

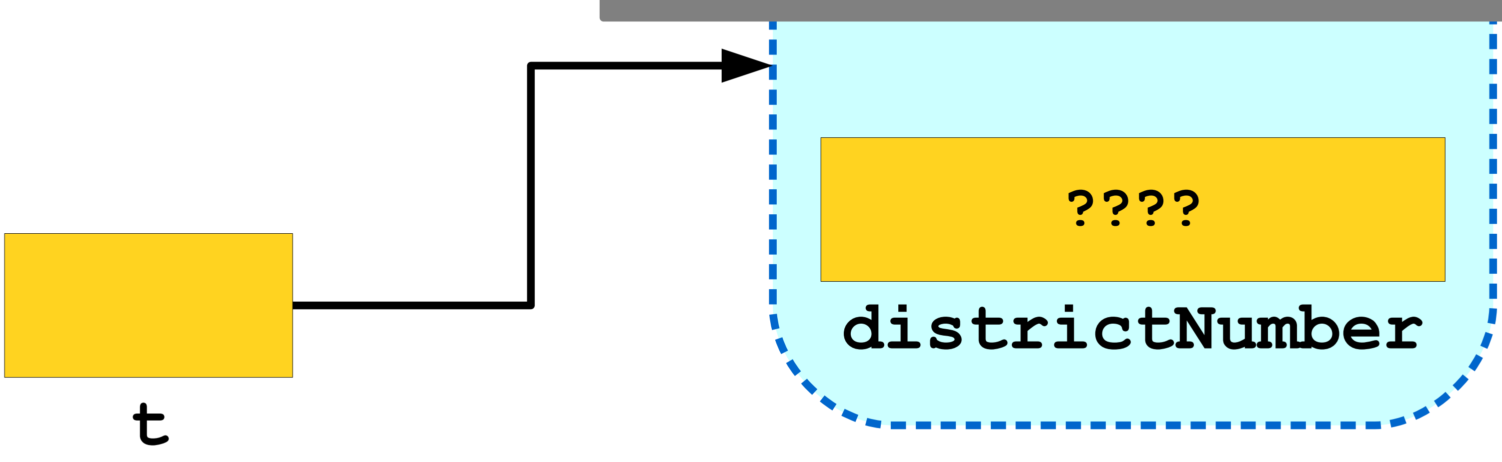
  creates a new object of type ***T*** passing the appropriate arguments to the constructor, then returns a pointer to it.

Dynamic Memory Allocation

```
struct Tribute {
    string name;
    int districtNumber;
};

Tribute* t = new Tribute;
```

A note here: the type `Tribute*` can mean either "an array of `Tributes`" or "a single `Tribute`." It's up to you the programmer to make sure not to mix the two up!

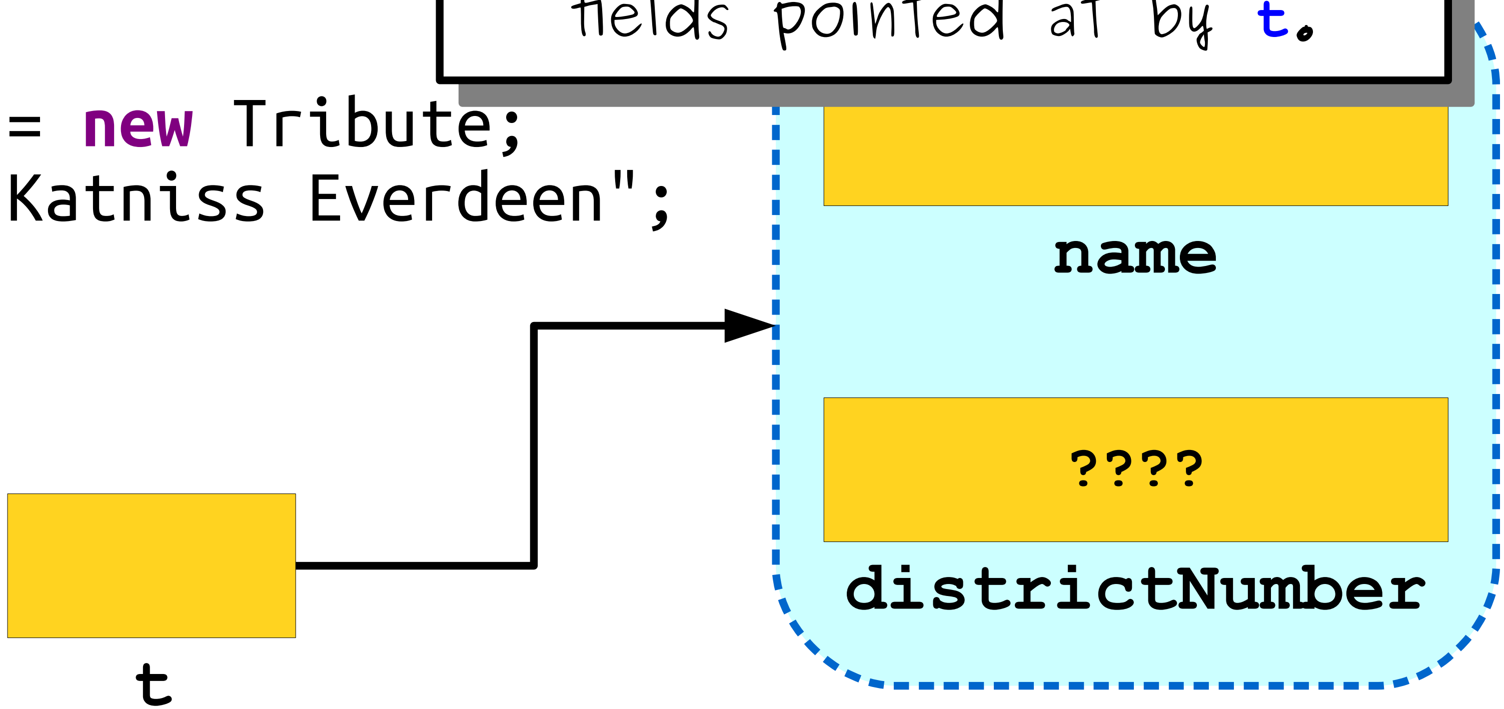


Dynamic Memory Allocation

```
struct Tribute {
    string name;
    int districtNumber;
};

Tribute* t = new Tribute;
t->name = "Katniss Everdeen";
```

Because **t** is a pointer to a **Tribute**, not an actual **Tribute**, we have to use the arrow operator to access the fields pointed at by **t**.

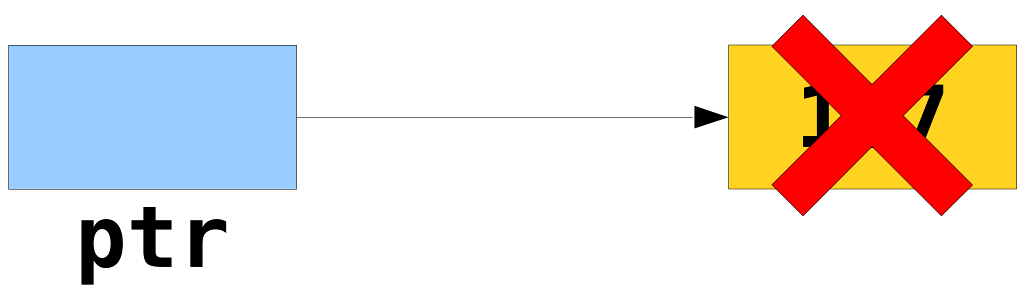


Cleaning Up

- As with dynamic arrays, you are responsible for cleaning up memory allocated with **new**.
- You can deallocate memory with the **delete** keyword:

```
delete ptr;
```

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



Unfortunately...

- In C++, all of the following result in undefined behavior:
  - Deleting an object with **`delete`**`[]` that was allocated with **`new`**.
  - Deleting an object with **`delete`** that was allocated with **`new`**`[]`.
- Although it is not always an error, it is usually a Very Bad Idea to treat an array like a single object or vice-versa.

A Pointless Exercise

- When working with pointers, we sometimes wish to indicate that a pointer is not pointing to anything.
- In C++, you can set a pointer to `nullptr` to indicate that it is not pointing to an object:

```
ptr = nullptr;
```

- This is *not* the default value for pointers; by default, pointers default to a garbage value.
- In older C++ code (and the textbook!), you'll see people use `NULL` instead of `nullptr`. We strongly advise against using `NULL` and recommend you use `nullptr` instead.

And now... linked lists!

But first, some announcements!

Assignment 4

- Assignment 4 was due at the start of class today.
  - Using a late day? You can turn it in by ***Wednesday*** because Monday is a holiday.
  - We ***strongly advise*** against this – the exam expects that you know how to solve all the problems from the assignment and you'll need the time to study.
- Assignment 5 will go out on Wednesday of next week.

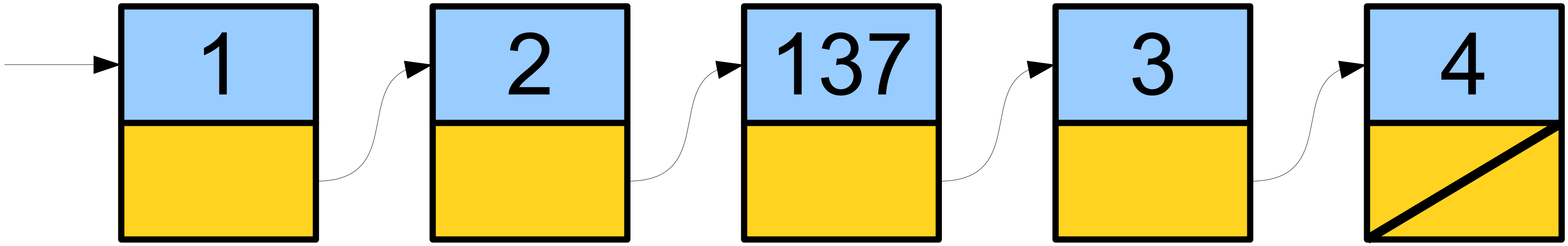
Midterm Logistics

- Midterm is next Tuesday from 7PM – 10PM. Locations are divvied up by last (family) name:
  - **`Abb – Lam`**: Go to Hewlett 200.
  - **`Lee – Nic`**: Go to Hewlett 201.
  - **`Ntu – Zhu`**: Go to Cubberly Auditorium.
- Space is tight, so please go to your assigned exam room.
- You get a double-sided, 8.5” × 11” sheet of notes with you when you take the exam.

Back to CS106B!

Linked List Cells

- A linked list is a chain of ***cells***.
- Each cell contains two pieces of information:
  - Some piece of data that is stored in the sequence, and
  - A ***link*** to the next cell in the list.
- We can traverse the list by starting at the first cell and repeatedly following its link.



Representing a Cell

- For simplicity, let's assume we're building a linked list of `string`s.
- We can represent a cell in the linked list as a structure:

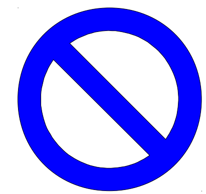
```
struct Cell {
    string value;
    Cell* next;
};
```

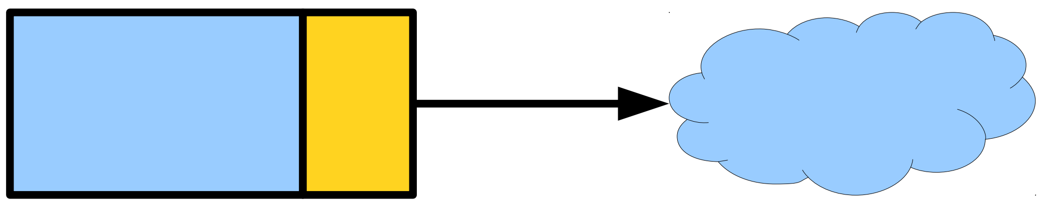
- ***The structure is defined recursively!***

Building Linked Lists

A Linked List is Either…

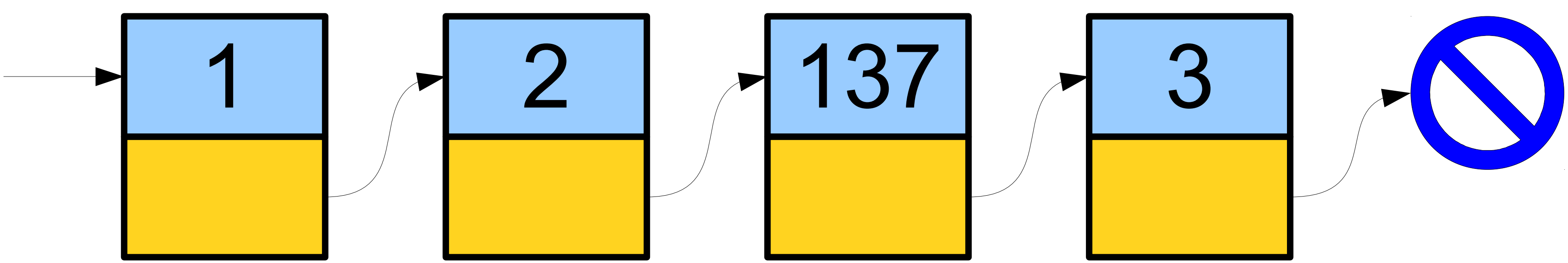
…an empty list, represented by **nullptr**, or…





a single linked list cell that points…

… at another linked list.

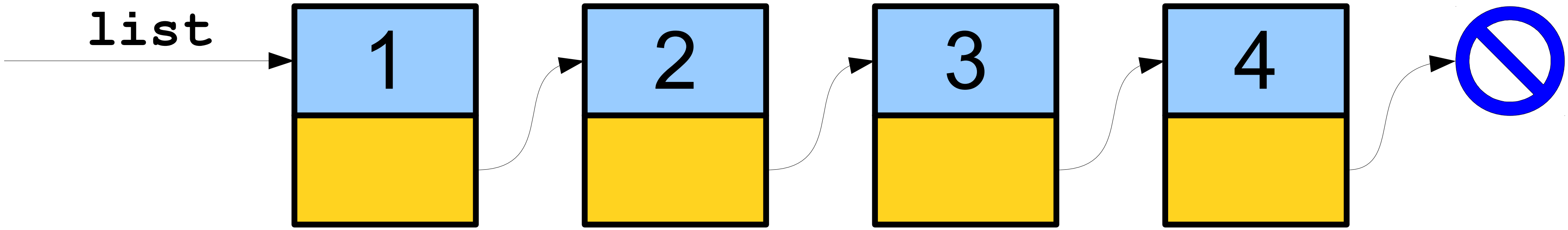


Now that we’ve got the list,
what can we do with it?

Traversing a Linked List

- Once we have a linked list, we can traverse it by following the links one at a time.

```
for (Cell* ptr = list; ptr != nullptr; ptr = ptr->next) {
    /* … use ptr … */
}
```



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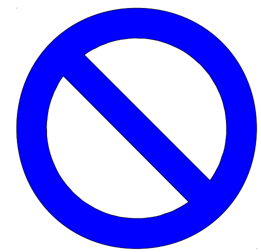

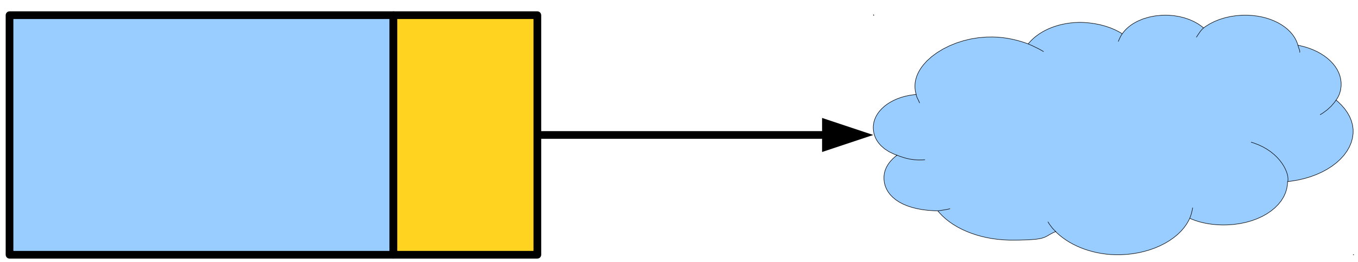

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Next Time

- ***Pointers by Reference***
  - Fun for the whole linked list family!
- ***Reimplementing Stacks and Queues***
  - Worst-case efficiency, at a price!