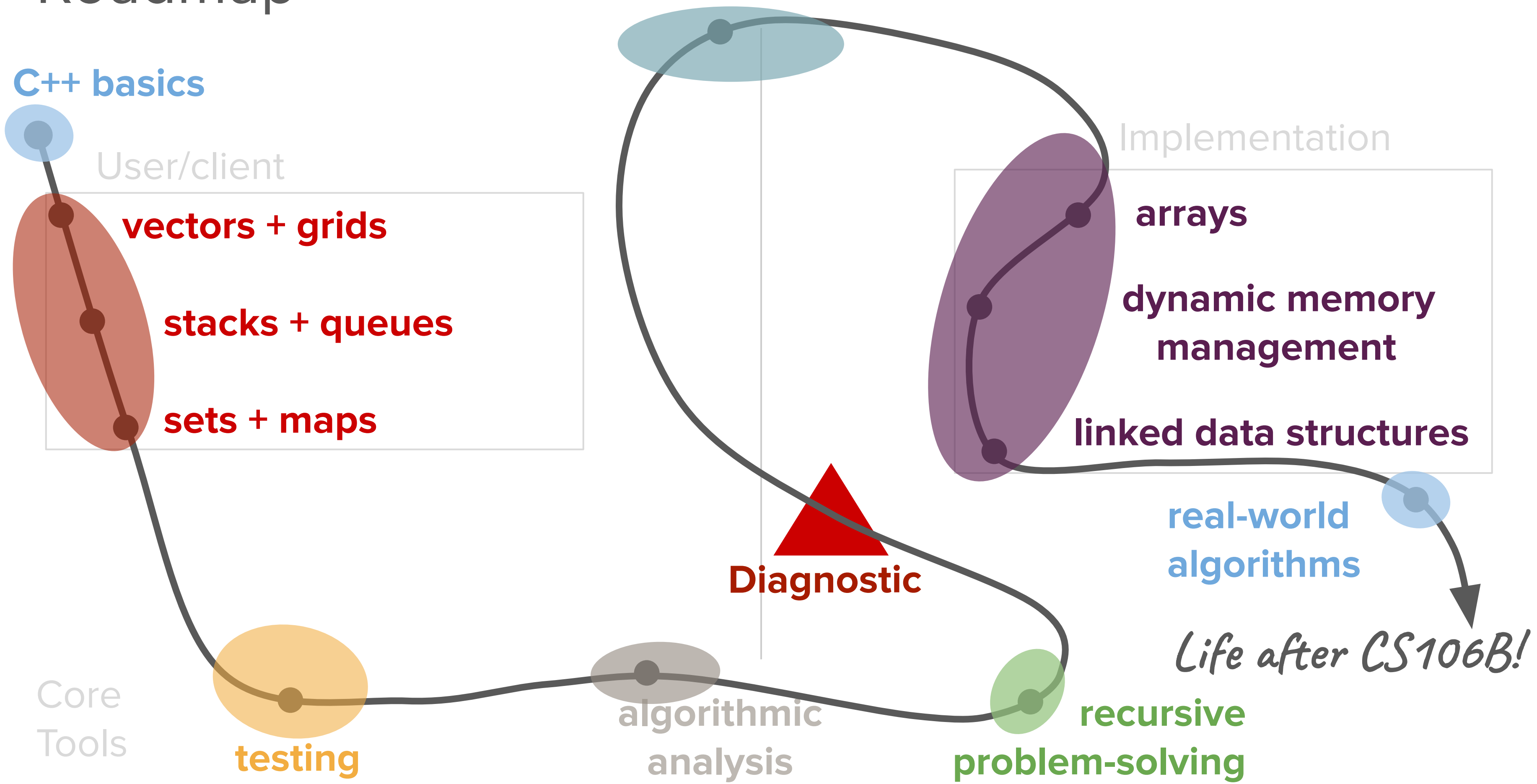
Linked Lists

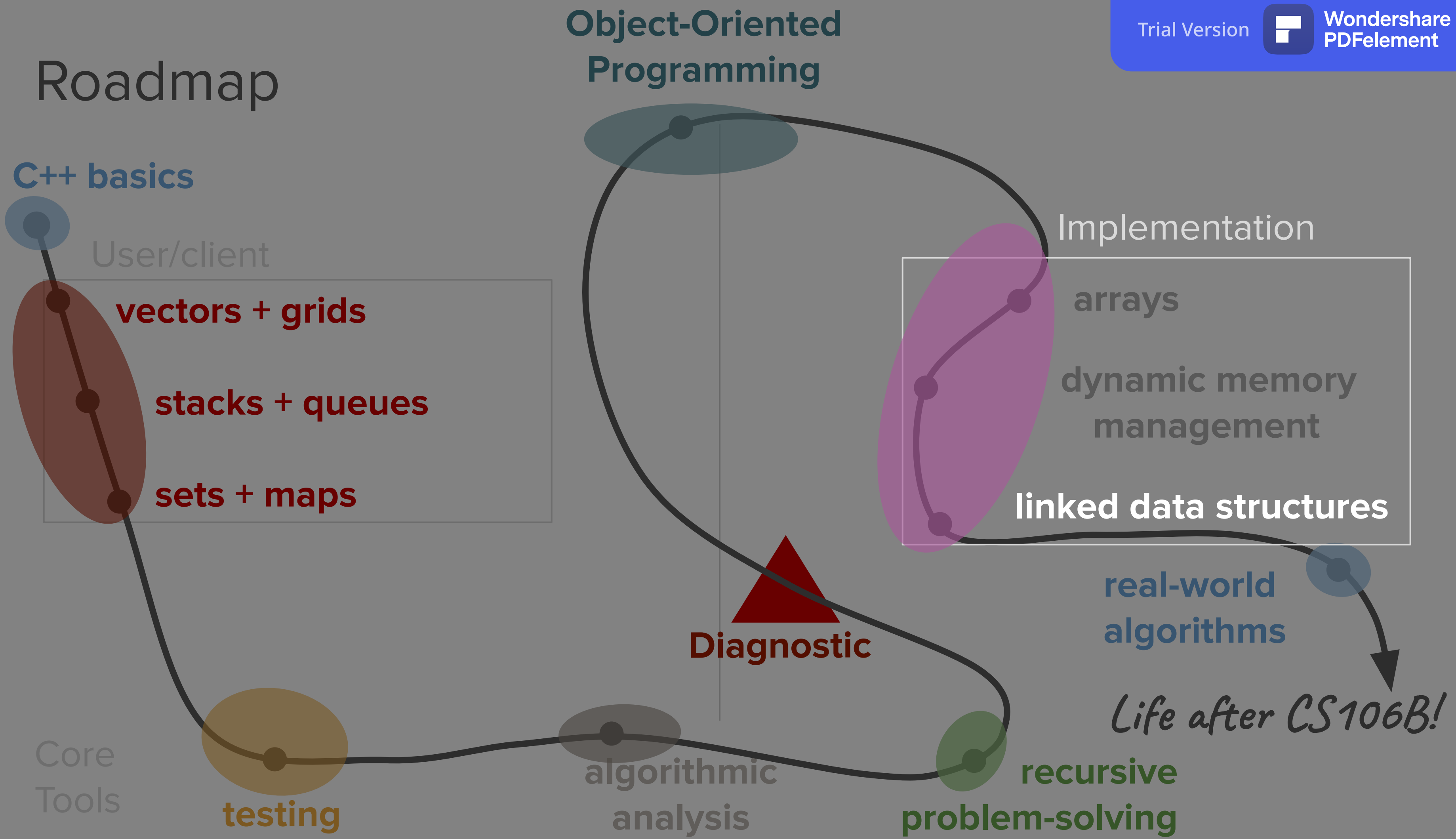
Is there a topic you'd like us to dive more in depth into in the last week of the class?

(put your answers the chat)

Roadmap


Object-Oriented Programming
C++ basics
User/client
vectors + grids
stacks + queues
sets + maps
Implementation
arrays
dynamic memory management
linked data structures
real-world algorithms
Diagnostic
Life after CS106B!
Core Tools
testing
algorithmic analysis
recursive problem-solving

Roadmap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Today's question

How can we use pointers to organize non-contiguous memory on the heap?

Today's topics

1. Review
2. What is a linked list?
3. How do we manipulate linked lists?

Review

[memory and pointers]

Levels of abstraction

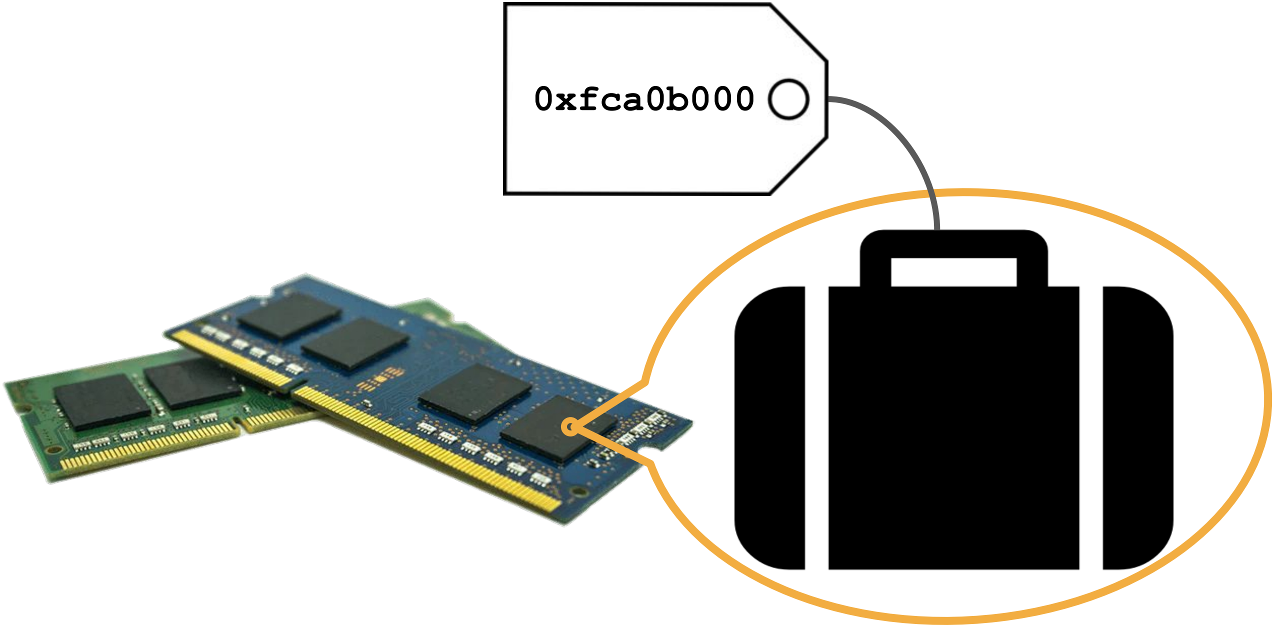
Abstract Data Structures

Data Organization Strategies

Fundamental C++ Data Storage

Computer Hardware

How is computer memory organized?



Pointers and Memory

- Every variable you create has an address in memory on your computer (either on the stack or the heap).

- A pointer is just a type of variable that stores a memory address!
  - You specify the type of the variable that it points to so that C++ knows how much space the value its pointing to is taking up (e.g. **`string*`** or **`int*`** or **`Vector*`**).
  - But remember that pointers and what they point to (e.g. **`string`** vs. **`string*`**) are two completely different data types!

Pointers and Memory

- Every variable you create has an address in memory on your computer (either on the stack or the heap)
- A pointer is just a type of variable that stores a memory address!
- When you **dynamically allocate** variables on the heap, you must use the keyword **`new`** (or **`new[]`** for arrays) and must store the address in a pointer to keep track of it.
  - E.g. `int* number = new int;`

Dynamically allocated variables are the only reason we'll use pointers in this class!

Pointers and Memory

- Every variable you create has an address in memory on your computer (either on the stack or the heap)

- A pointer is just a type of variable that stores a memory address!

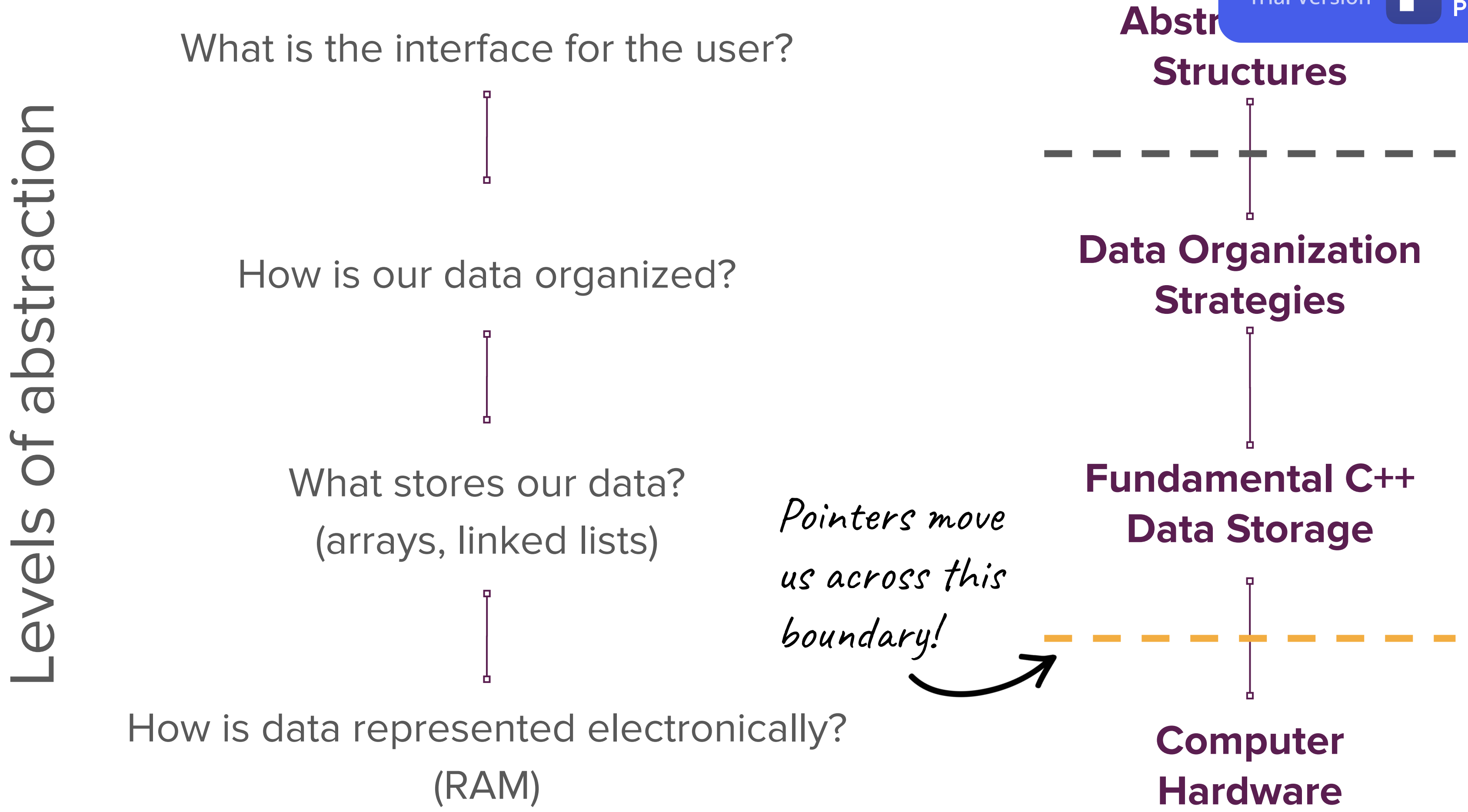
- When you **dynamically allocate** variables on the heap, you must use the keyword **`new`** (or **`new[]`** for arrays) and must store the address in a pointer to keep track of it.

- To get the value located at the memory address stored in a pointer, you must **dereference** the pointer using the **`*`** operator (e.g. **`cout << *number << endl;`**).

Today: Using pointers in practice

How can we use pointers to organize non-contiguous memory on the heap?

Not arrays!


Levels of abstraction
What is the interface for the user?
How is our data organized?
What stores our data?
(arrays, linked lists)
How is data represented electronically?
(RAM)
Abstr
Structures
Data Organization
Strategies
Fundamental C++
Data Storage
Computer
Hardware
Pointers move
us across this
boundary!

Levels of abstraction

What is the interface for the user?

Abstr… Structures

How is our data organized?

Data Organization Strategies

What stores our data?
(**arrays**, **linked lists**)

These are built on top of pointers!

Fundamental C++ Data Storage

How is data represented electronically?
(RAM)

Computer Hardware

Levels of abstraction

What is the interface for the user?

Abstr
Structures

How is our data organized?

Data Organization Strategies

What stores our data?
(arrays, **linked lists**)

Our focus for today!

Fundamental C++ Data Storage

How is data represented electronically?
(RAM)

Computer Hardware

What is a linked list?

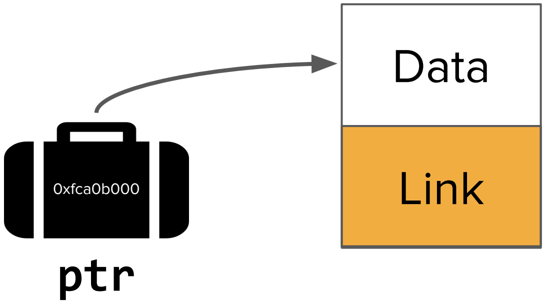
What is a linked list?

- A linked list is a **chain of nodes**.

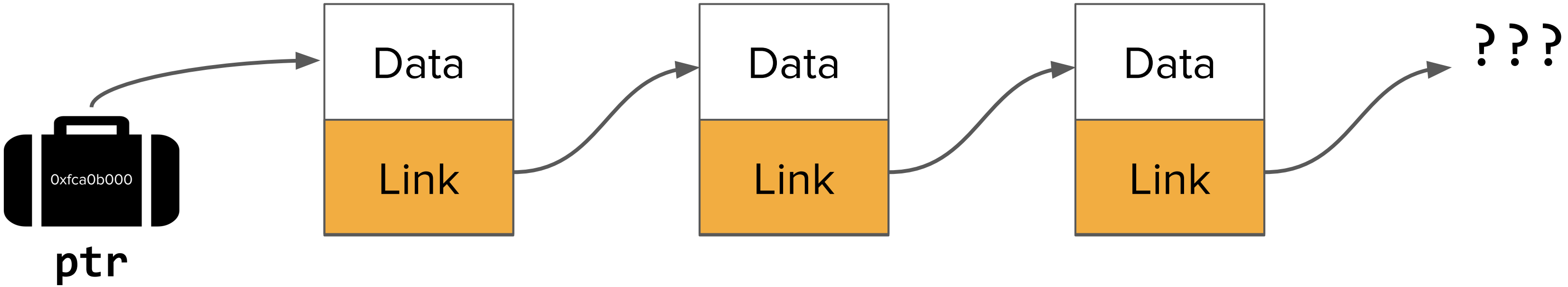
- Each **node** contains two pieces of information:
  - Some piece of data that is stored in the sequence
  - A link to the next node in the list

- We can traverse 遍历 the list by starting at the first node and repeatedly following its link.

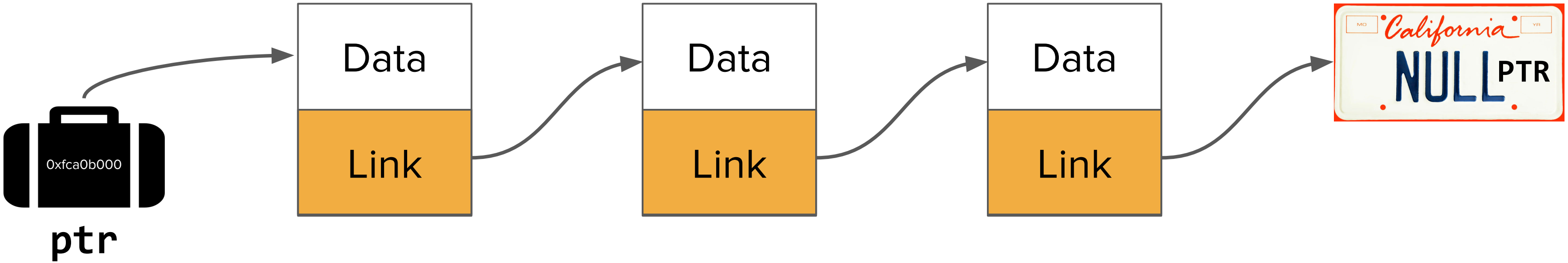
Pointer to a node



Pointer to a node that points to a node that points to a node



A linked list!



A link


0xfca0b000
ptr


r/todayilearned
Posted by u/shaka_sulu • 8h
TIL a California man got 'NULL' as a personalized license plate hoping that 'NULL' would confuse the computer system. Instead, when cops left the plate number info empty on a ticket or citation, the fine went to him. He got over $12k fines sent to him his first year.
arstechnica.com
15.8k
355
Share


California
NULL
PTR

Why use linked lists?

- More flexible than arrays!
  - Since they're not contiguous, they're easier to rearrange.

拼接

- We can efficiently splice new elements into the list or remove existing elements anywhere in the list. (We'll see how shortly!)

- We never have to do a massive copy step.

- Linked lists have many tradeoffs, and are not often the best data structure!

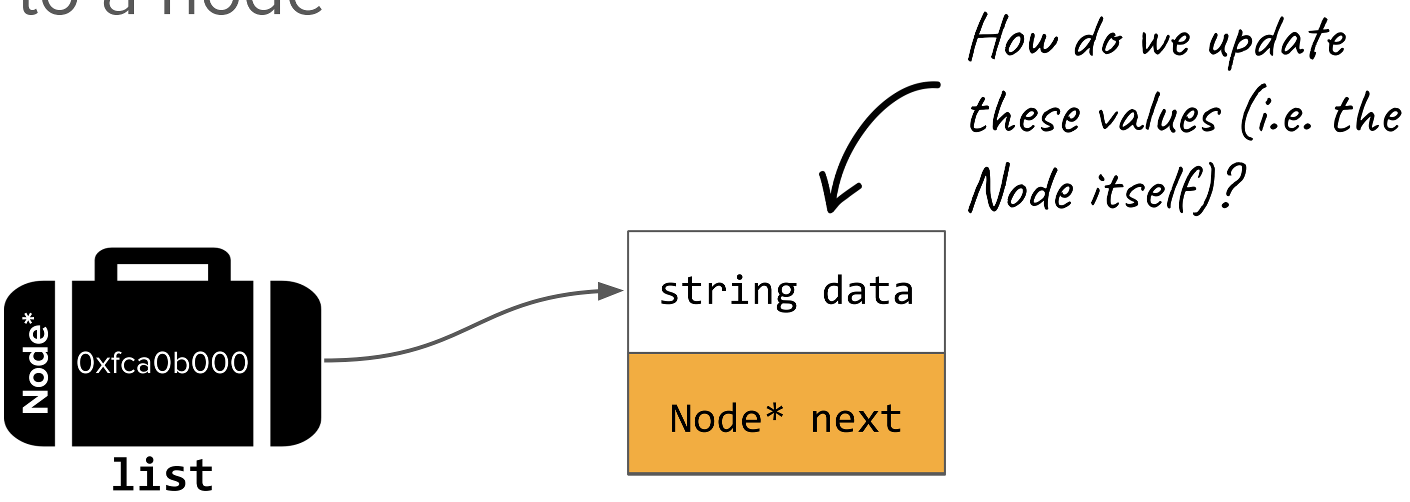
Linked lists in C++

The **Node** struct

```
struct Node {
    string data;
    Node* next;
}
```

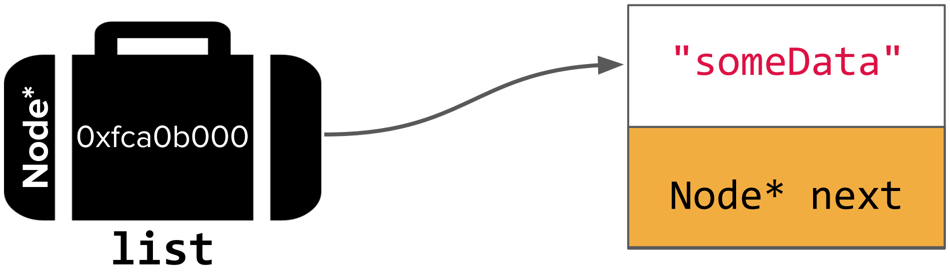
- The structure is defined recursively! (both the Node and the linked list itself)
- The compiler can handle the fact that in the definition of the **Node** there is a **Node*** because it knows it is simply a pointer.
  - (It would be impossible to recursively define the **Node** with an actual **Node** object inside the struct.)

Pointer to a node




```
Node* list = new Node;
```

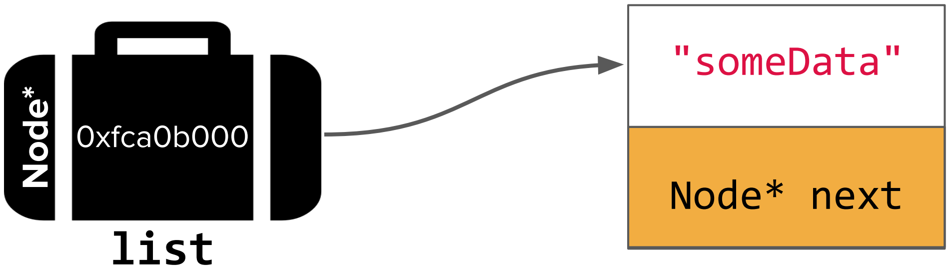
Pointer to a node




```
Node* list = new Node;
(*list).data = "someData";
```

Use * to dereference the pointer to get the Node struct.

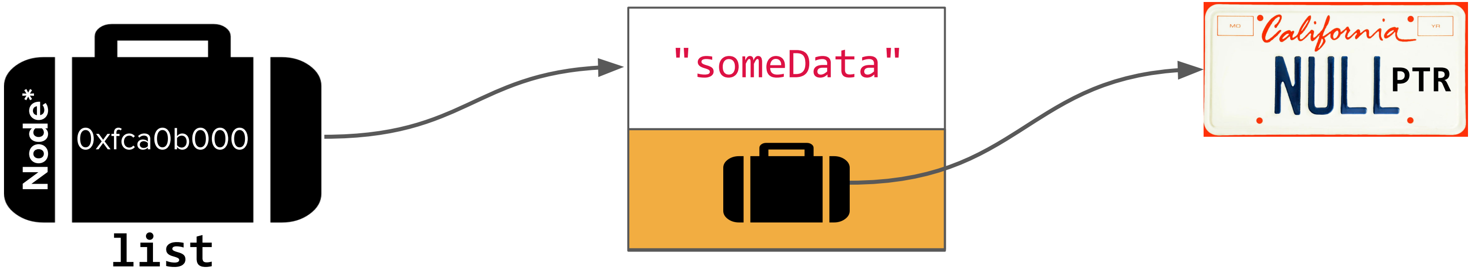
Pointer to a node




```
Node* list = new Node;
(*list).data = "someData";
```

Use dot (.) notation to update the data field of the struct.

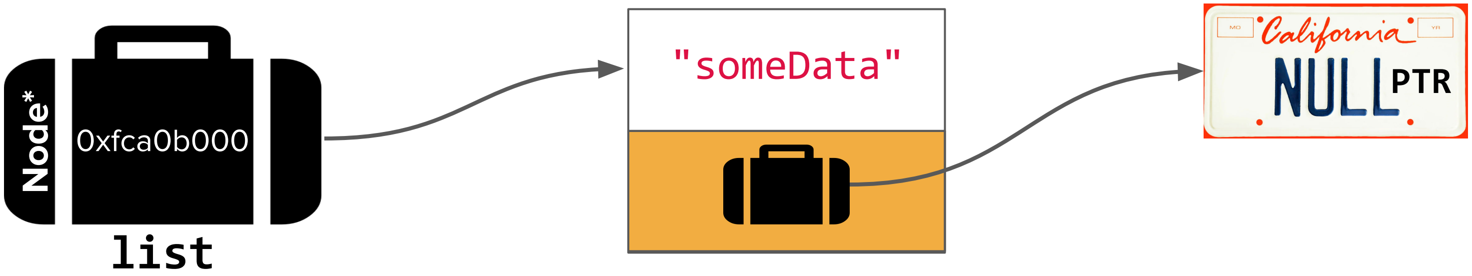
Pointer to a node




```
Node* list = new Node;
(*list).data = "someData";
(*list).next = nullptr;
```

There's an easier way!

Pointer to a node




```
Node* list = new Node;
list->data = "someData";
list->next = nullptr;
```

The arrow notation (->) dereferences AND accesses the field for pointers that point to structs specifically.

Announcements

Announcements

- Assignment 4 is due this upcoming **Monday, July 27 at 11:59pm PDT.**

- Make sure to get started on reading through the final project guidelines and brainstorming what you might want to do your project on!
  - If you're interested in exploring a topic that we haven't yet covered in the class, come by our OHs and we can help you scope the problem!

How do we manipulate linked lists?

Common linked lists operations

- **Traversal**
  - How do we walk through all elements in the linked list?
- **Rewiring**
  - How do we rearrange the elements in a linked list?
- **Insertion**
  - How do we add an element to a linked list?
- **Deletion**
  - How do we remove an element from a linked list?

Implementing a Stack

Note: You could do this with an array! This is just for the sake of getting practice with linked lists.

Stack as a linked list

- We'll keep a pointer **`Node* top`** that points to the "top" element in our stack.
  - This member var will get initialized to **`nullptr`** when our stack is empty!

- Our linked list nodes will be connected from the top to the bottom of our stack.

- Our stack will specifically hold integers, so our **`Node`** struct will hold an **`int`** type for our **`data`** field:

```
struct Node {
    int data;
    Node* next;
}
```

Three Stack operations

- **`push()`**
- **`pop()`**
- Destructor

Common linked lists operations

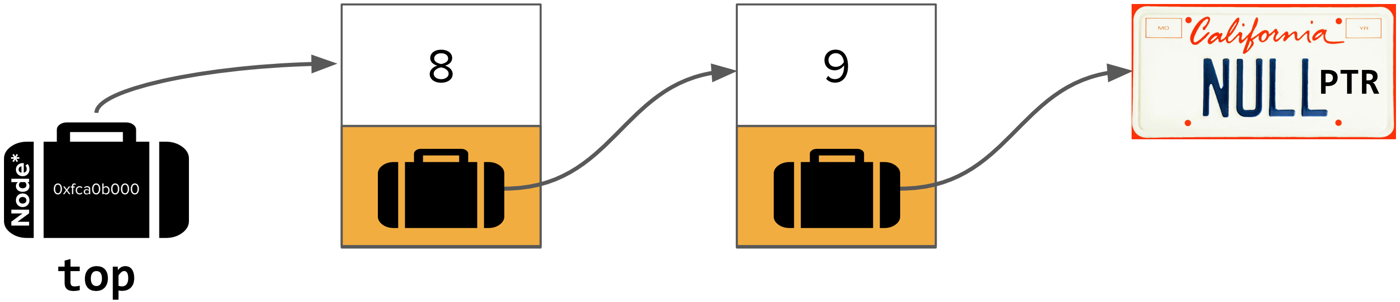
- **Traversal**
  - How do we walk through all elements in the linked list?
- **Rewiring**
  - How do we rearrange the elements in a linked list?
- **Insertion (at the front)**
  - How do we add an element to a linked list?
- **Deletion**
  - How do we remove an element from a linked list?

push()

- Suppose we have the following Stack we want to push to:

```
Stack myStack = {9, 8}; // 8 is at the "top" of the stack
myStack.push(7); // we want the result to be {9, 8, 7}
```

How our linked list starts:



push()

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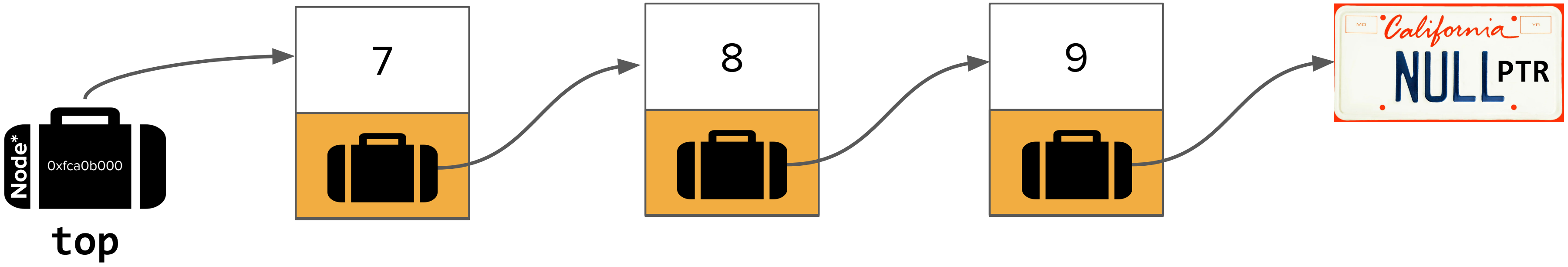
Goal:

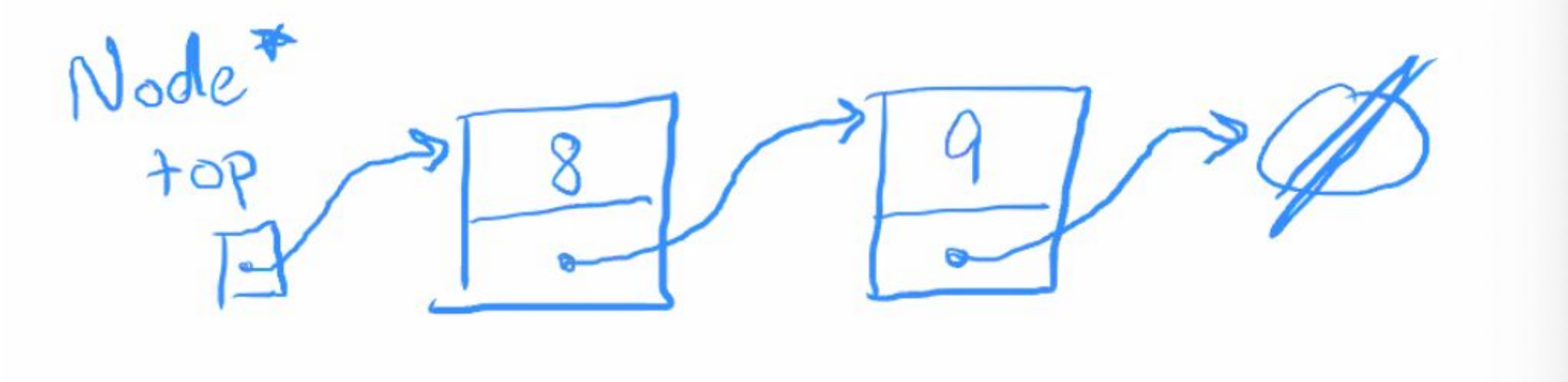


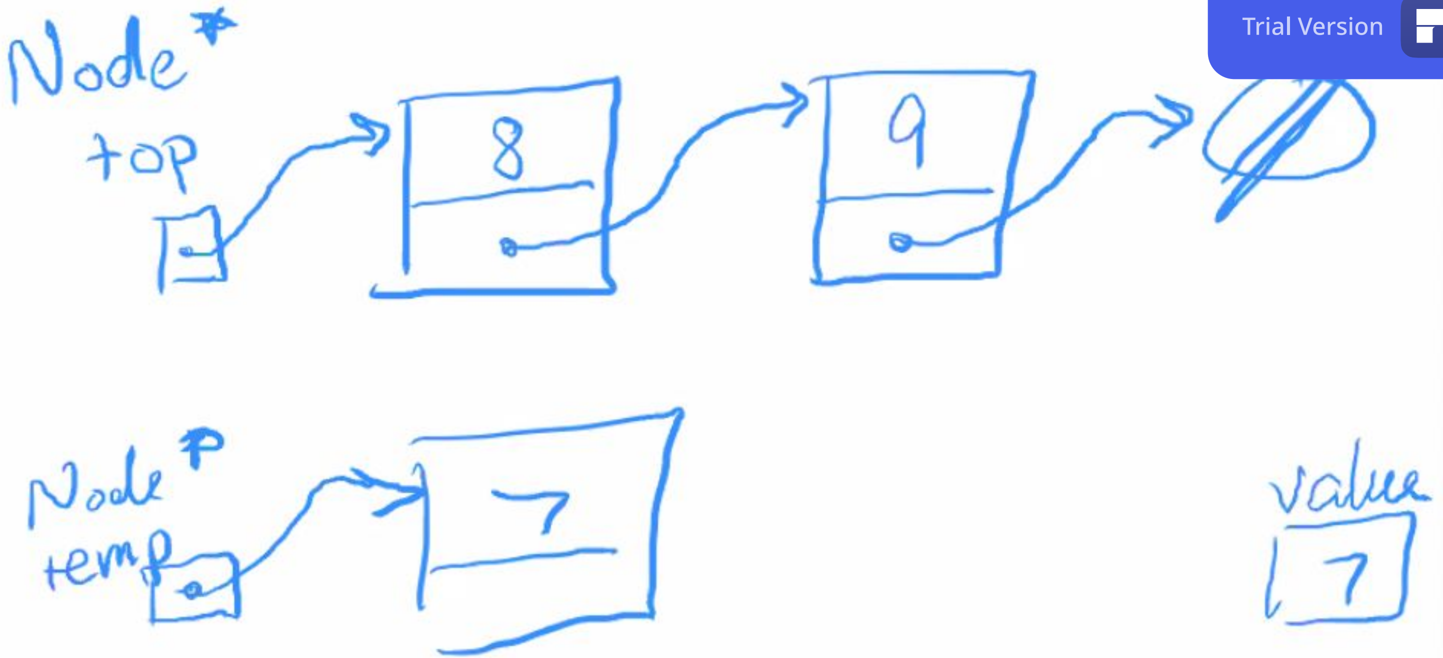
Let's code **push()**!

Live Activity Summary

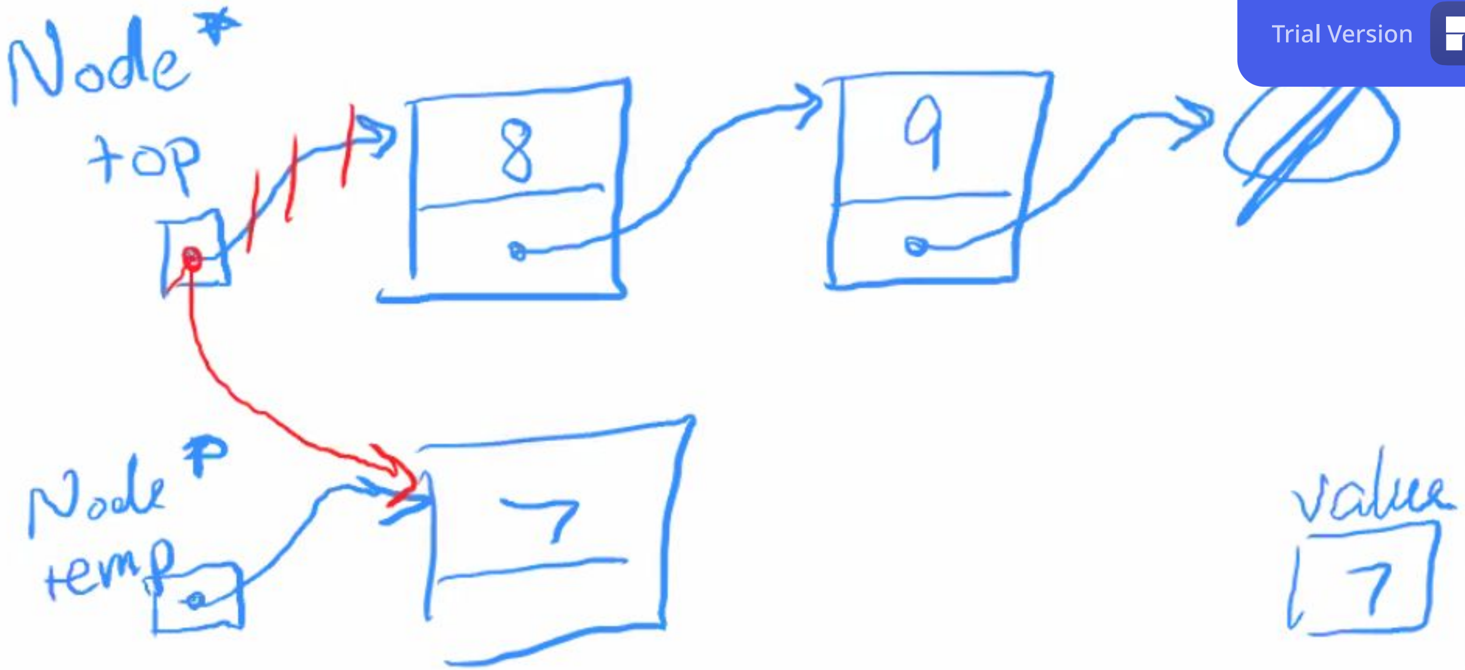
- We strongly recommend watching the live recording of the coding activity, as the code and explanations contextualize the following diagrams

Initial State (beginning of **push()** function)

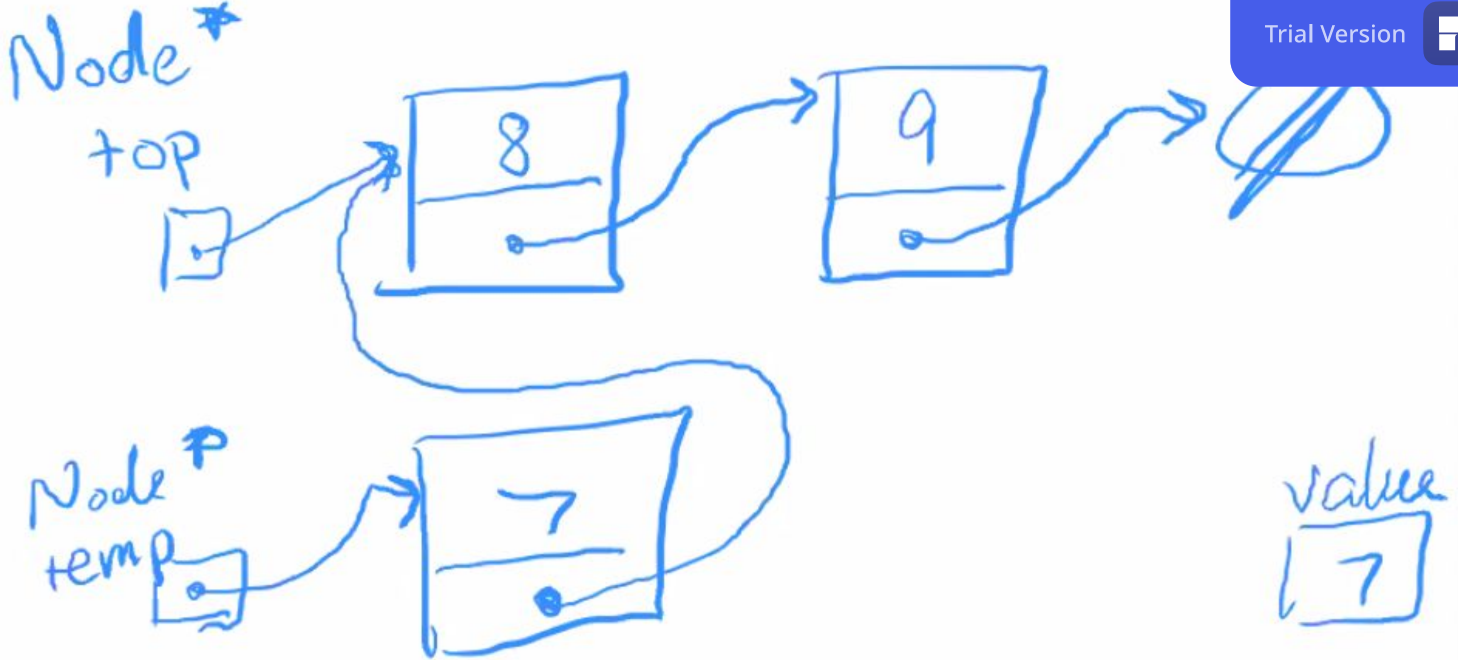




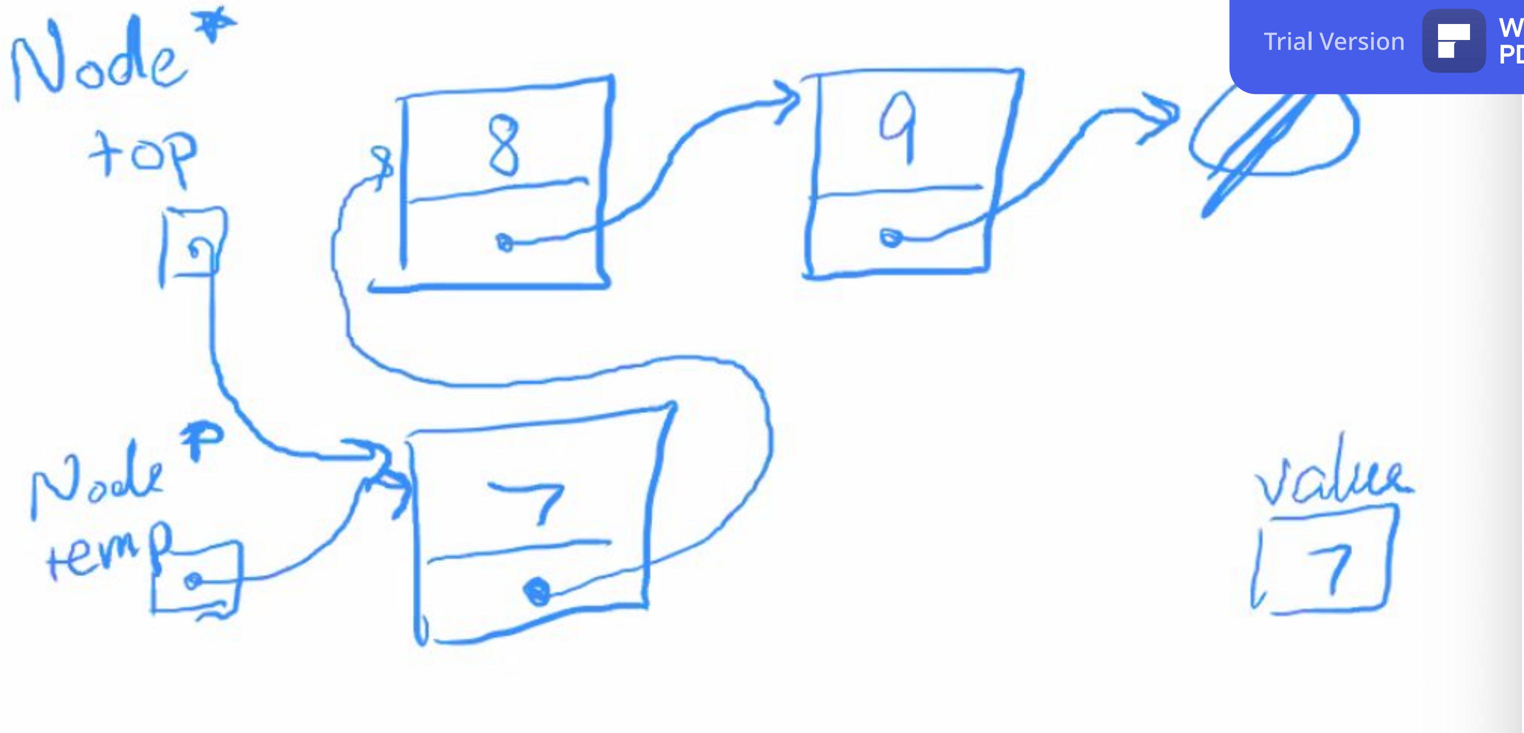

```
Node *temp = new Node;
temp->data = 7;
```




```
Node *temp = new Node;
temp->data = 7;
top = temp; // INCORRECT
```




```
Node *temp = new Node;
temp->data = 7;
temp->next = top;
```

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temp->data = 7;
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top = temp;
```

Three Stack operations

- `push()`
- `pop()`
- Destructor

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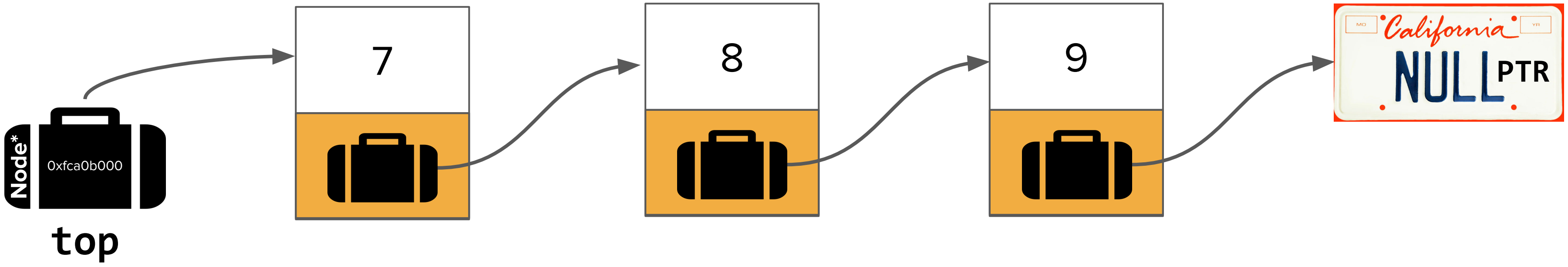
pop()

- Now we want to remove the top value:

```
...
myStack.pop(); // we want the result to be {9, 8}
```

Starting state of the list:

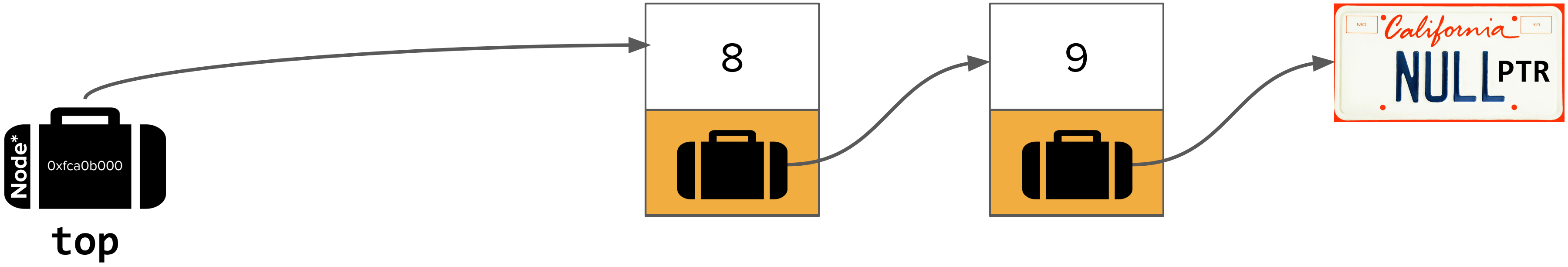


pop()

- Now we want to remove the top value:

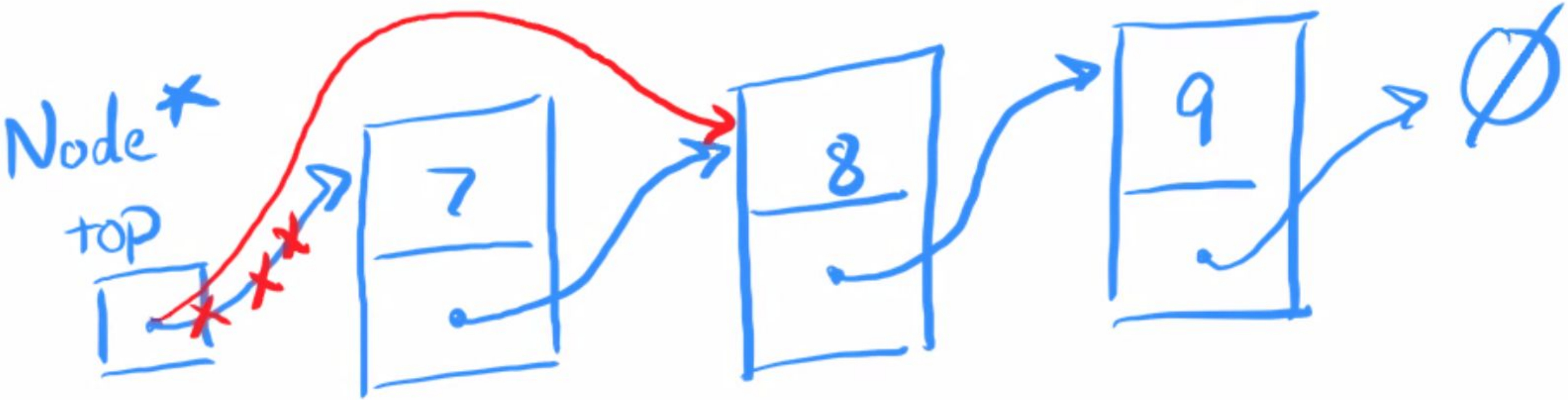
```
...
myStack.pop(); // we want the result to be {9, 8}
```

Goal:

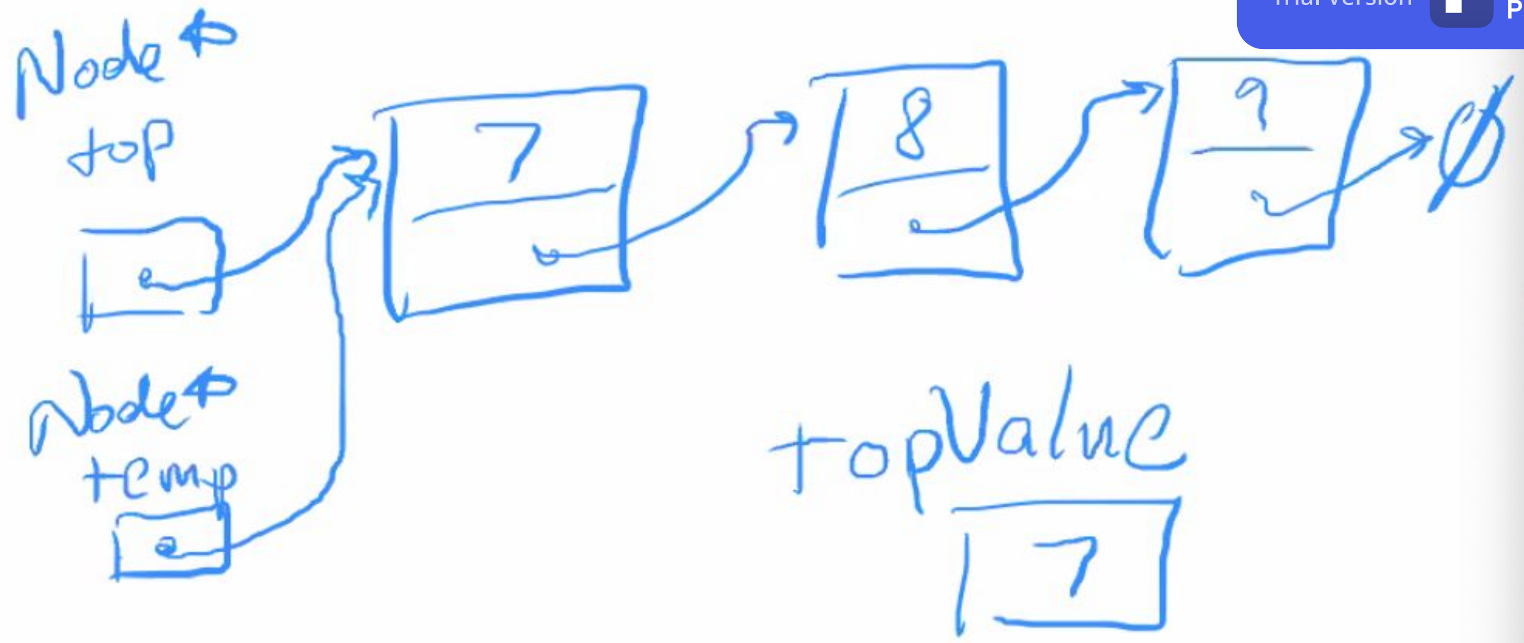


Let's code **pop()**!

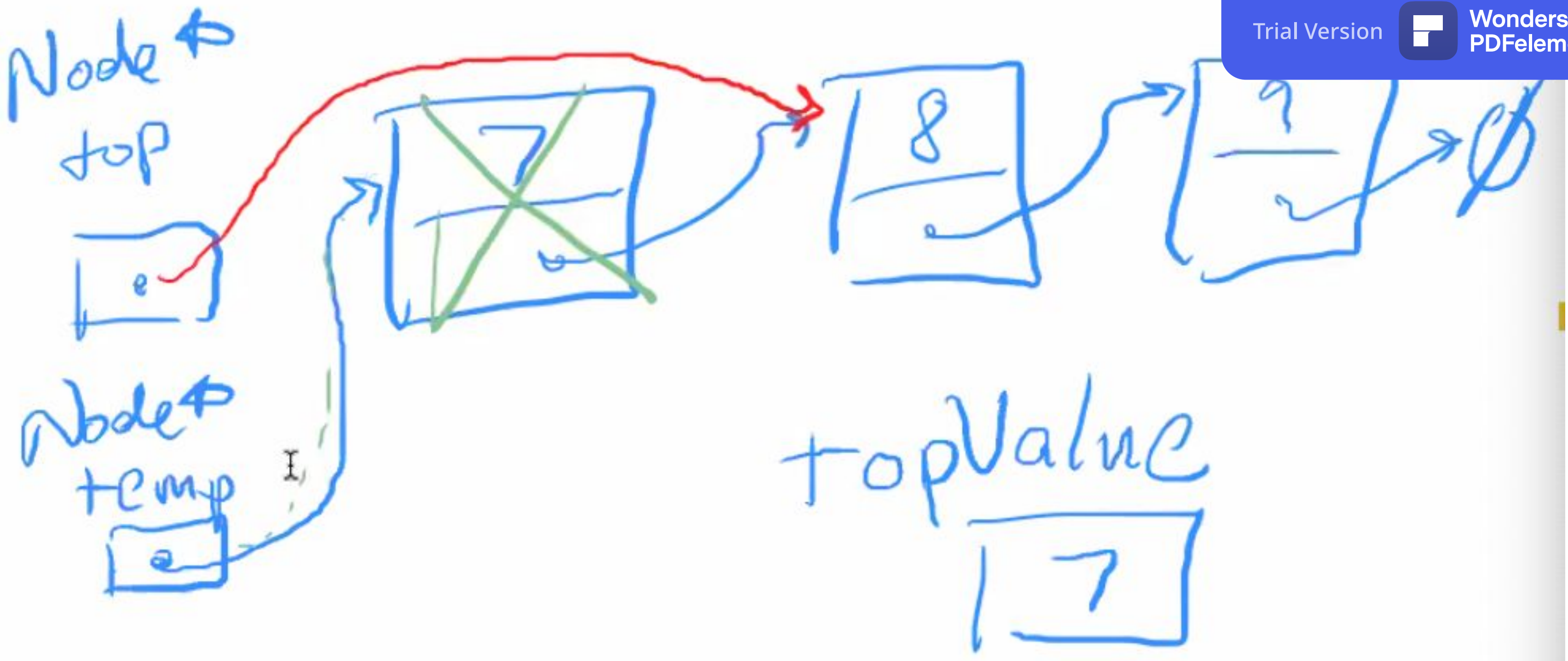
Initial State (beginning of **pop( )** function)




```
top = top->next; // INCORRECT
```




```
Node* temp = top;
```




```
Node* temp = top;
top = top->next;
delete temp;
```

Three Stack operations

- `push()`
- `pop()`
- **Destructor**

Common linked lists operations

- **Traversal**
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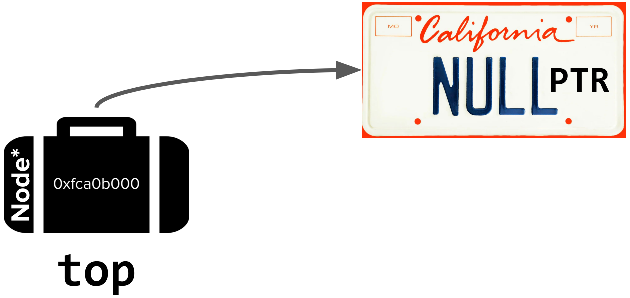
  - How do we remove an element from a linked list?

Destructor

- We have to make sure we delete all of the **`Node`**s.
- The **`top`** pointer should be **`nullptr`** when we're done.



Let’s code the destructor!

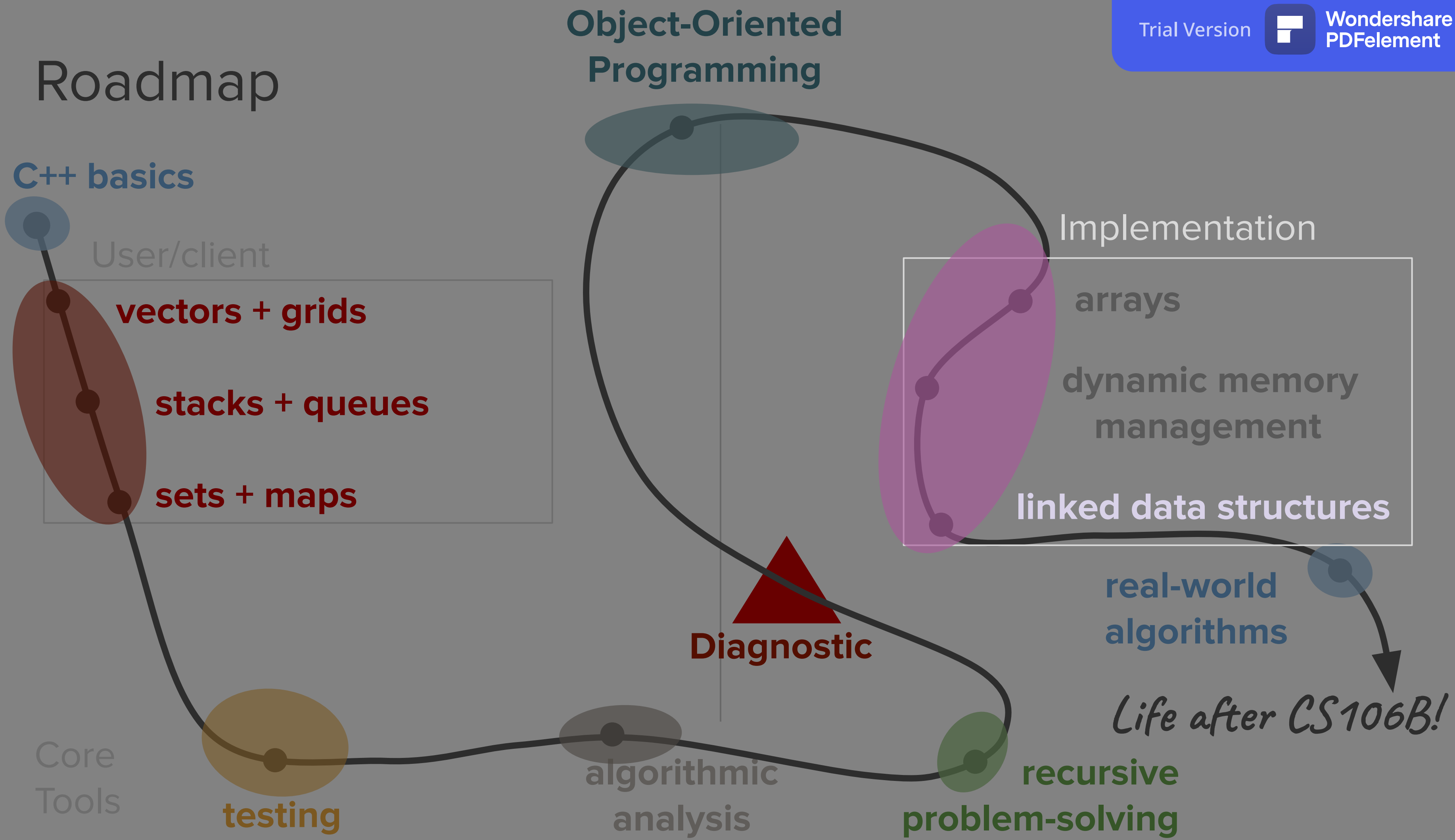
Summary

Linked lists summary

- Linked lists are chains of Node structs, which are connected by pointers.
    - Since the memory is not contiguous, they allow for fast rewiring between nodes (without moving all the other Nodes like an array might).
- Common traversal strategy
    - While loop with a pointer that starts at the front of your list
    - Inside the while loop, reassign the pointer to the next node
- Common bugs
    - Be careful about the order in which you delete and rewire pointers!
    - It's easy to end up with dangling pointers or memory leaks (memory that hasn't been deallocated but that you not longer have a pointer to)

What’s next?

Roadmap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More on linked lists!