

Data Structures & Algorithms

Week 2 — Lists, Elements of Complexity

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Recap — Week 1

- Introduction to C++
 - Variables and Basic Types
 - Functions and Selection operator
 - Loops, **Arrays**
 - Scopes — Global, Local and **Block**
 - **C++ Pointers**
 - **Classes**, Access Specifiers (Public, Private, Protected), **Inheritance**
- **Assignment 1 is OUT! Start early and earnestly! Ask questions on Piazza!**

Clarifications - Process Memory

```
#include <iostream>
#include <stdlib.h>

int globalVar; // BSS Segment - Uninitialized Global Variable

int globalVarInit = 10; // Data Segment - Initialized Global Variable

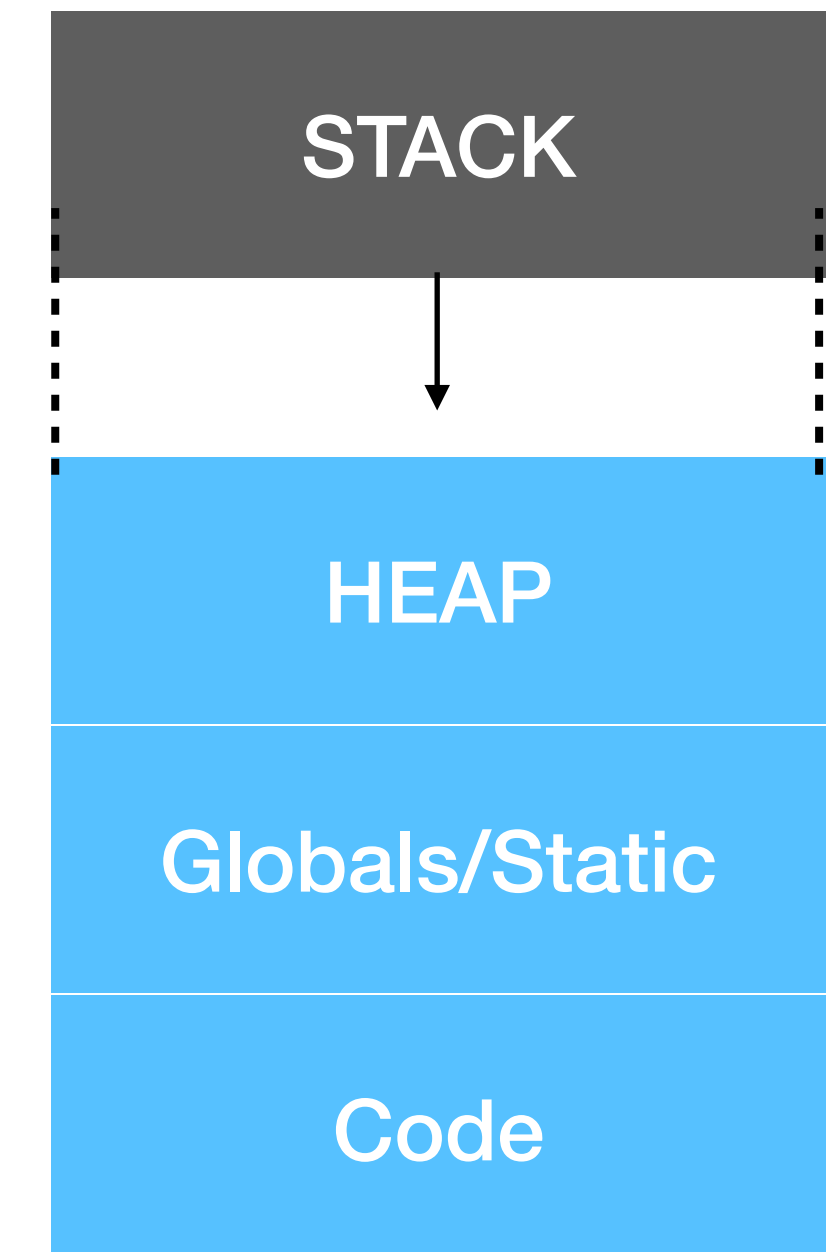
int main() {

    int localVar = 10; // Stack - Local Variable

    int *ptr = new int; // Heap - Dynamically Allocated Variable

    std::cout << "Address of Text Segment: " << (void*)&main << std::endl;
    std::cout << "Address of Data Segment: " << (void*)&globalVarInit << std::endl;
    std::cout << "Address of BSS Segment: " << (void*)&globalVar << std::endl;
    std::cout << "Address of Heap: " << ptr << std::endl;
    std::cout << "Address of Stack: " << (void*)&localVar << std::endl;

    delete ptr; // Remember to free the dynamically allocated memory
    return 0;
}
```



Clarifications - Inheritance Keywords

```
#include<iostream>

class Base {
public:
    virtual void display() {
        std::cout << "Base Display"
                    << std::endl;
    }
};

class Derived : public Base {
private:
    int *pointer;

public:
    Derived(int val) {
        pointer = new int(val);
    }

    void display() {
        std::cout << "Derived Display, Value: "
                    << *pointer << std::endl;
    }
};
```

- **Public Inheritance:**
 - Public members of Base → Public members of Derived
 - Protected members of Base → Protected members of Derived
- **Protected Inheritance:**
 - Public and Protected members of Base → Protected members of Derived
- **Private Inheritance:**
 - All derived members become private

```
int cols);
```

Clarifications - Pointers & Arrays

```
int main() {  
    int rows = 3, cols = 4;  
  
    // Dynamically allocate memory for a 2D array  
    int **arr = new int*[rows];  
    for(int i = 0; i < rows; i++) {  
        arr[i] = new int[cols];  
    }  
  
    // Initialize the 2D array  
    ...  
  
    foo(arr, rows, cols);  
  
    // Don't forget to free the memory  
    for(int i = 0; i < rows; i++) {  
        delete [] arr[i];  
    }  
    delete [] arr;  
  
    return 0;  
}
```

Clarifications — Variables escaping scope

- This leads to undefined behaviour
 - Bad programming practice

```
int* dangerousFunction() {  
    int temp = 10;  
    return &temp;  
}
```

- Safe option

```
int* safeFunction() {  
    int* heapVariable = new int(5);  
    return heapVariable;  
}
```

Debug Challenge



Scan ⁷ me!

Debug Challenge

```
#include<iostream>

class Base {
public:
    virtual void display() {
        std::cout << "Base Display"
                    << std::endl;
    }
};

class Derived : public Base {
private:
    int *pointer;

public:
    Derived(int val) {
        pointer = new int(val);
    }

    void display() {
        std::cout << "Derived Display, Value: "
                    << *pointer << std::endl;
    }
};

int main() {
    1: Derived *d =
        new Derived(5);

    2: Base *b = d;
    3: b->display();

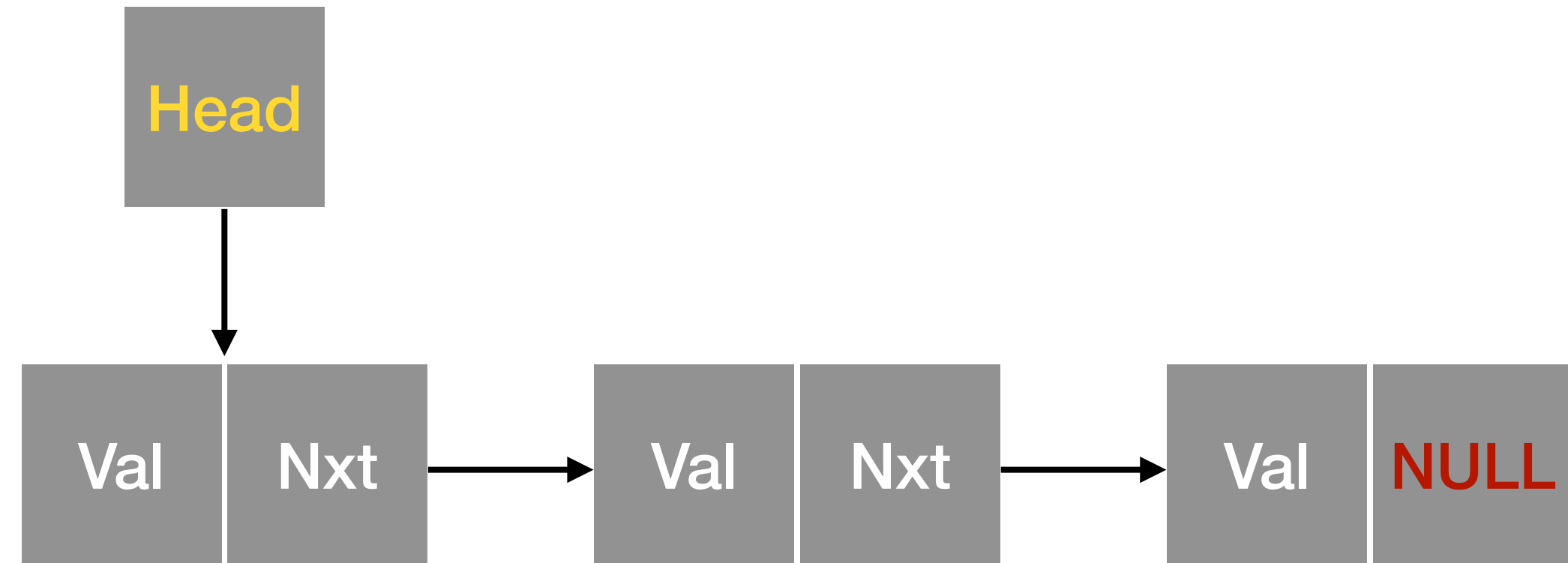
    4: delete b;

    5: d->display();

    return 0;
}
```


Linked Lists

- An abstract data type which represents values in a sequence
- Homogeneous container
- Need not be contiguous
- **Dynamic** data structure:
 - The list can grow and shrink
- Efficient memory utilisation
- Inventors: Allen Newell, Cliff Shaw, Herbert Simon in 1955 (RAND Corp. + CMU)

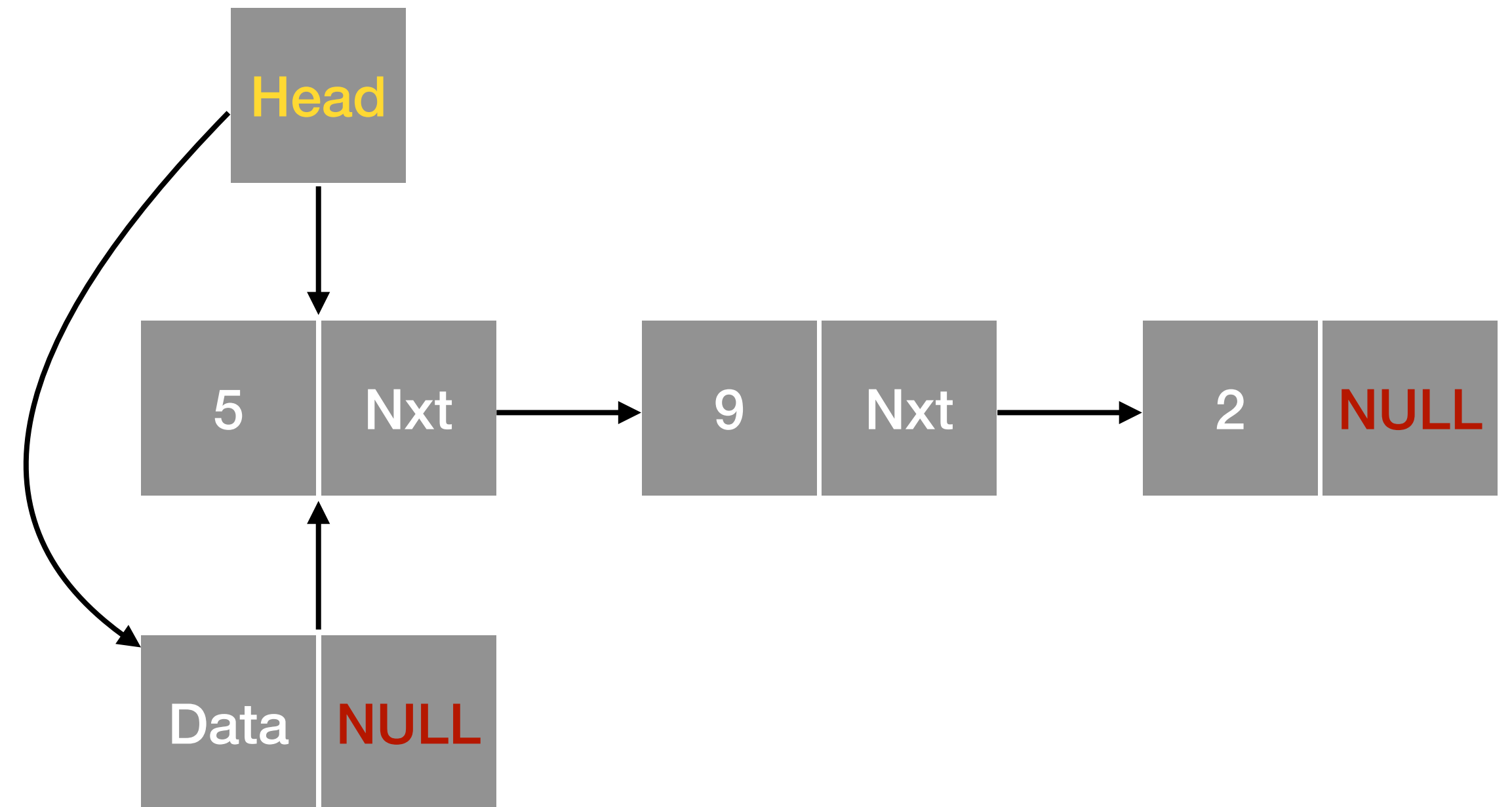


```
class Node {  
    private:  
        int val;  
        Node * next;  
    public:  
        Node(int value, Node *n=nullptr) {  
            val = value;  
            next = n;  
        }  
};
```

Insertion in a Linked List

- Insert @ head

```
void insertAtHead(int data) {  
    Node *newNode = new Node(data);  
    newNode->next = head;  
    head = newNode;  
}
```



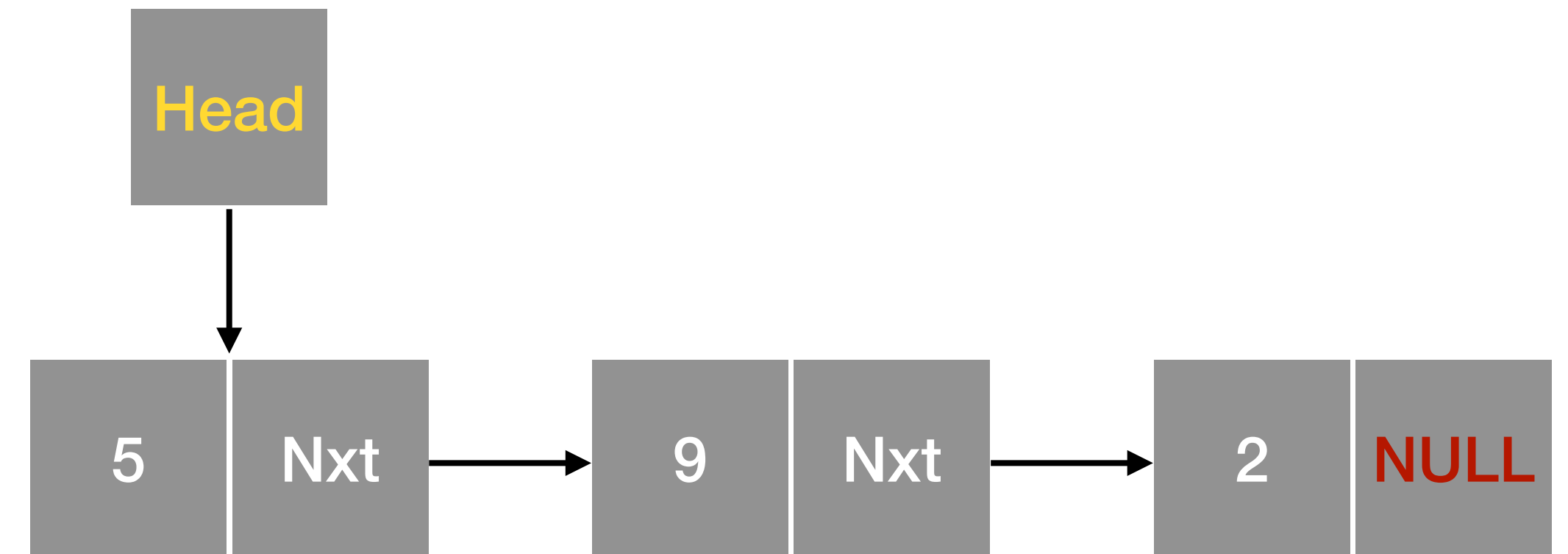
- Similarly, insert after a given node

```
void insertAfter(Node *n, int data) {  
    assert (n != nullptr);  
    Node newNode = new Node(data);  
    newNode->next = n->next;  
    n->next = newNode;  
}
```

- Q: How to insert at the end?

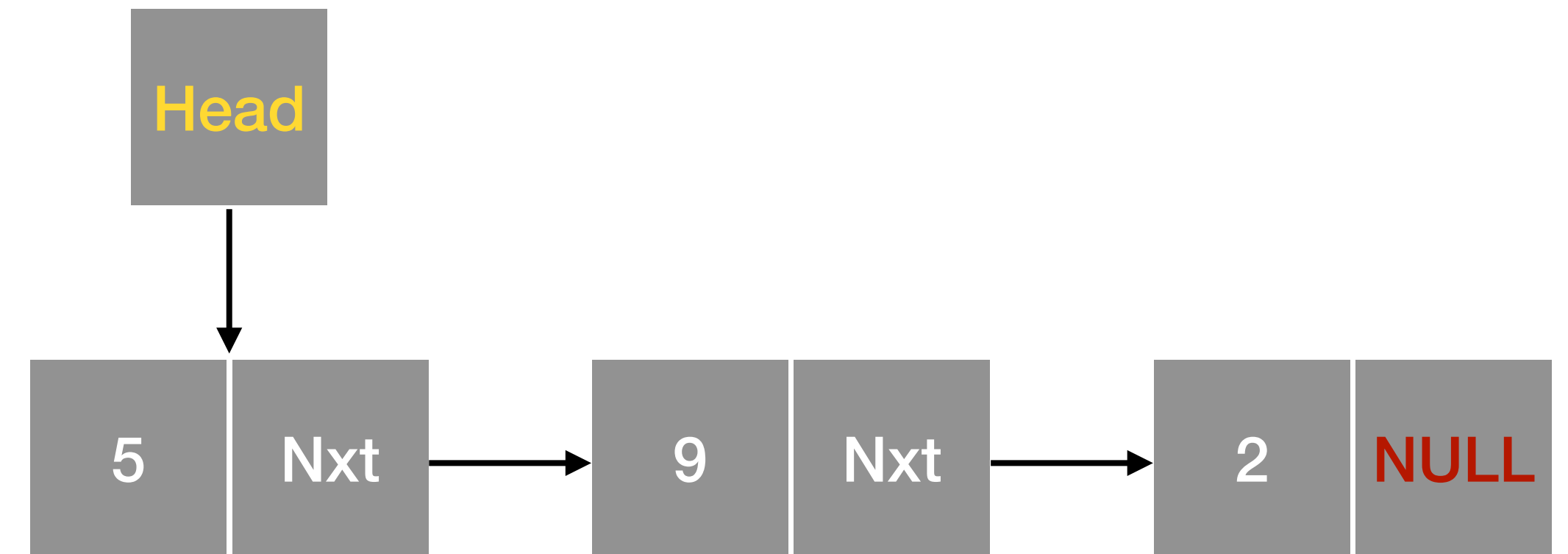
Deletion in a Linked List

- Delete from head:
 - `tmp = head;`
 - `head = head->next;`
 - `delete tmp;`
- Practice Q:
 - Delete after a specified node
 - Delete from the end



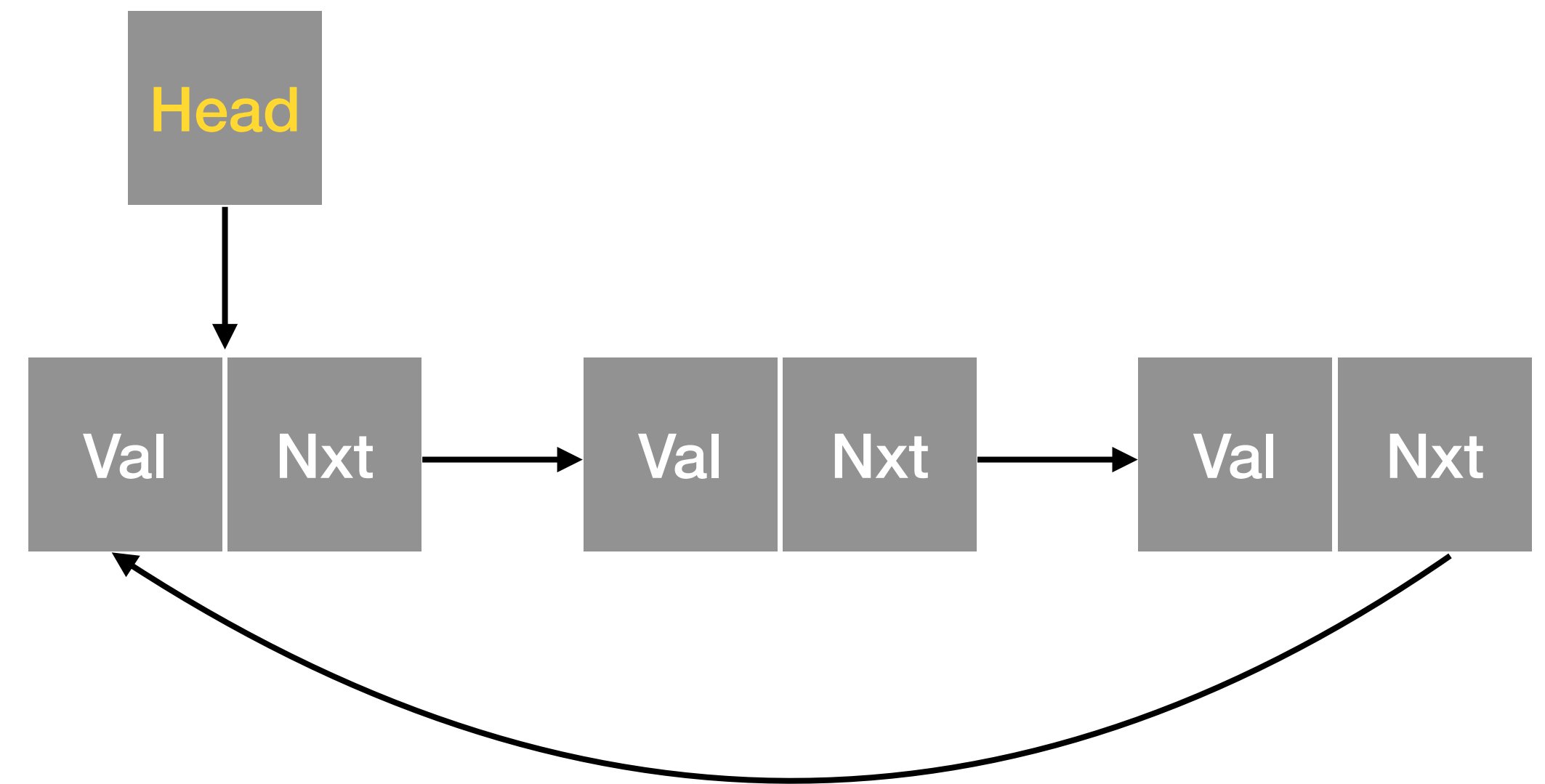
Complexity of Operations in Linked List

- Singly Linked List:
 - Traversal of all elements: $O(n)$
 - Insert/Delete from head: $O(1)$
 - Insert/Delete from end: $O(n)$



Circular Linked List

- The end node is connected to the first node
- Because it is a cycle — no need to maintain a **head ptr**



Doubly Linked List

- Pointers both for next and previous nodes
- Efficient insertions/deletions
- Can retrieve previous node in $O(1)$



Linked List: Applications

- In implementing Operating Systems:
 - Round-robin scheduling requires runnable processes to be kept in a linked list.
 - Scheduled process is removed from the head and added to the tail
 - Eg: Linux, FreeRTOS, Cisco IOS for pkt management
- Web Browsers:
 - Eg: Implementing the back button!
- Computer Networks:
 - Implementation of Routers: Pat management, Route planning etc.
- Memory Management: Keeping track of allocated and deallocated mem blocks.