Data Structures
Chapter 4

1. Singly Linked List
   - Pointer & Linking
   - **Singly Linked List (SLL)**
   - SLL Basic Operations
   - SLL Advanced Operations
2. Doubly Linked List

Prof. Youngsup Kim, idebtor@gmail.com, CSEE Dept., Grace School Rm204 Handong Global University
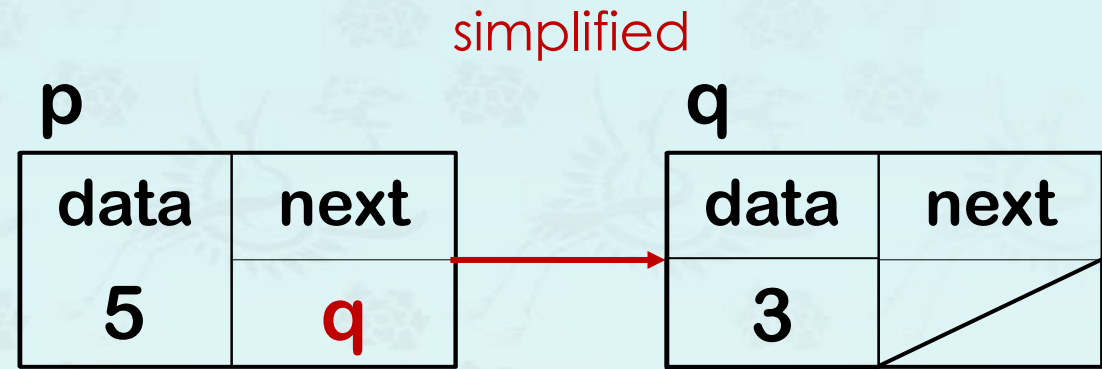
내 아들들을 먼 곳에서 이끌며 내 딸들을 땅 끝에서 오게 하며 내 이름으로 불려지는 모든 자 곧 내가
내 영광을 위하여 창조한 자를 오게 하라 그를 내가 지었고 그를 내가 만들었노라 (사43:6-7)

수고하고 무거운 짐 진 자들아 다 내게로 오라 내가 너희를 쉬게 하리라 나는 마음이 온유하고
겸손하니 나의 멍에를 메고 내게 배우라 그리하면 너희 마음이 쉼을 얻으리니 이는 내 멍에는 쉽고 내
짐은 가벼움이라 하시니라 (마11:28-30)

Pointers Linked

```cpp
class Node {
public:
  int   data;
  Node* next;
};

int main( ) {
  Node* q = new Node{3, nullptr};
  Node* p = new Node{5, q};
}
```

simplified

p	
data	**next**
5	**q**

q	
data	**next**
3	

Pointers Linked

```
class Node {
public:
  int   data;
  Node* next;
};                      ⬅ constructor, destructor


int main( ) {
  Node* p = new Node;
  ...

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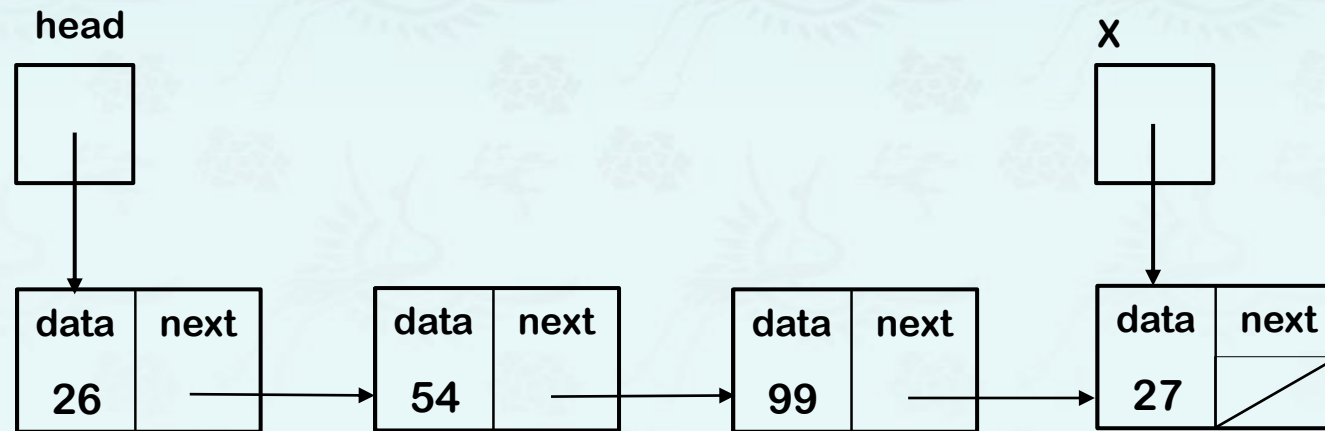
```
struct Node {
  int   data;
  Node* next;

constructor ⮕  Node(int i=0, Node* n=nullptr){
    data = i, next = n;
  }
destructor ⮕  ~Node() {};
};

int main( ) {
  Node* p = new Node;
  ...

}
```

Linked List

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

...

Node* head, *x, *y;
```

basic member functions
- `push_front()`
- `push_back()`
- `pop_front()` ←
- `pop_back()`
- `insert()`
- `remove()`
- `clear()`

head

X

data	next
26	

data	next
54	

data	next
99	

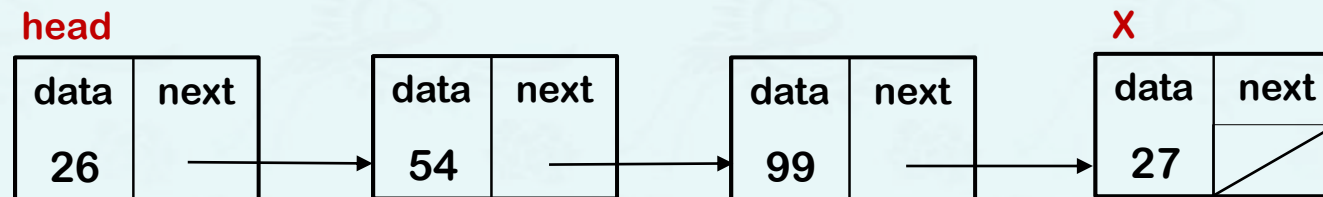| data	next
27	

Linked List

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

...

Node* head, *x, *y;
```

basic member functions
- `push_front()`
- `push_back()`
- `pop_front()`
- `pop_back()`
- `insert()`
- `remove()`
- `clear()`

head   **X**

data	next		data	next		data	next		data	next
26		→	54		→	99		→	27	

Linked List - push_front()

Let us imagine that we have created a linked list, where **head** points to the head of the list and **x** at the last item in the list (i.e. the one with the nullptr pointer) as shown below.

- Add a node (data = 33) at the **head of list**.

Before

head						X	
data	next	data	next	data	next	data	next
26	→	54	→	99	→	27	

After

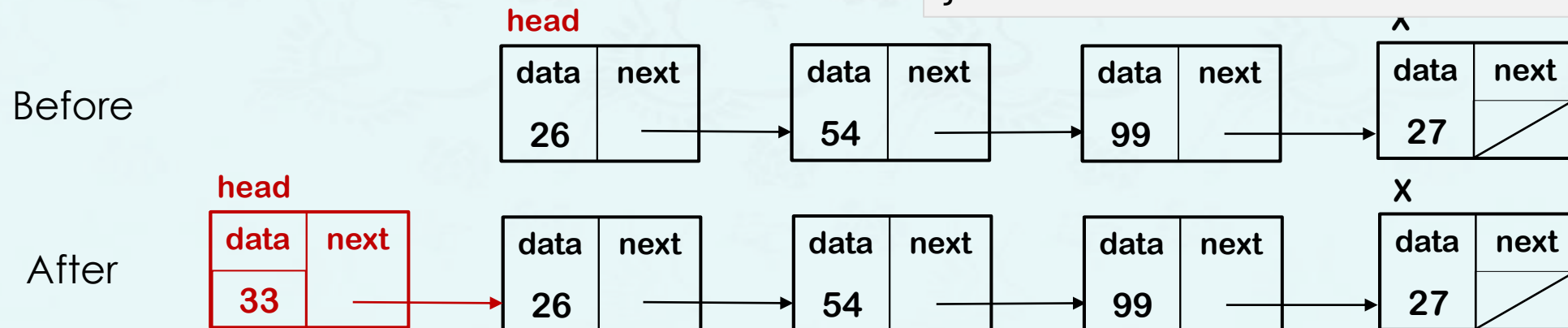| head								X	
data	next	data	next	data	next	data	next	data	next
33	→	26	→	54	→	99	→	27	

Linked List - push_front()

Let us imagine that we have created a linked list, where **head** points to the head of the list and **x** at the last item in the list (i.e. the one with the nullptr pointer) as shown below.

- Add a node (data = 33) at the head of list.

```
Node* push_front(Node* head, int data) {
  Node *y = new Node;
  y->data = data;
  y->next = head;
  return y;
}
```

```
Node* push_front(Node* head, int data) {
  Node *y = new Node {    ,    };
  return y;
}
```

```
Node* push_front(Node* head, int data) {
  return _____
}
```
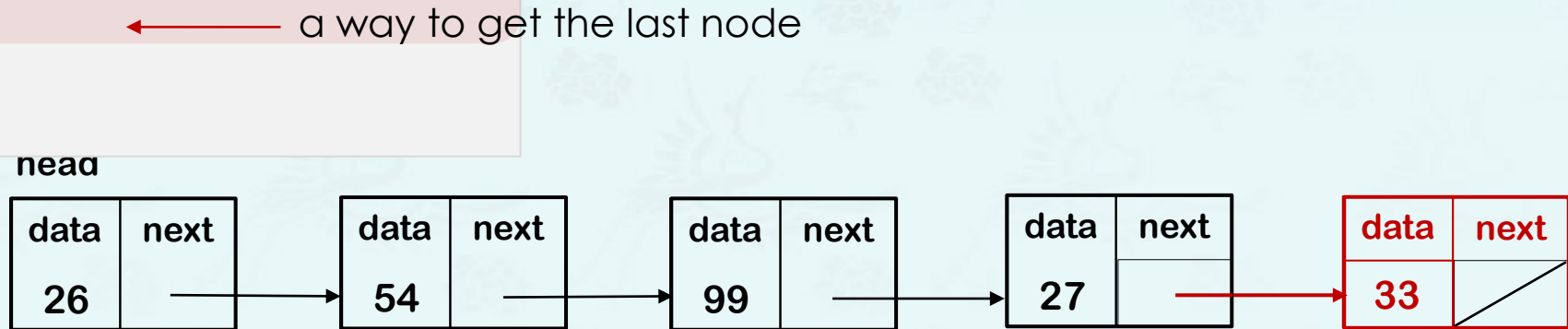
head

Before

data	next		data	next		data	next		data	next
26			54			99			27	/

head

After

data	next		data	next		data	next		data	next		data	next
33			26			54			99			27	/

X

Linked List - push_back()

Let us imagine that we have created a linked list, where **head** points to the head of the list and **x** at the last item in the list (i.e. the one with the nullptr pointer) as shown below.

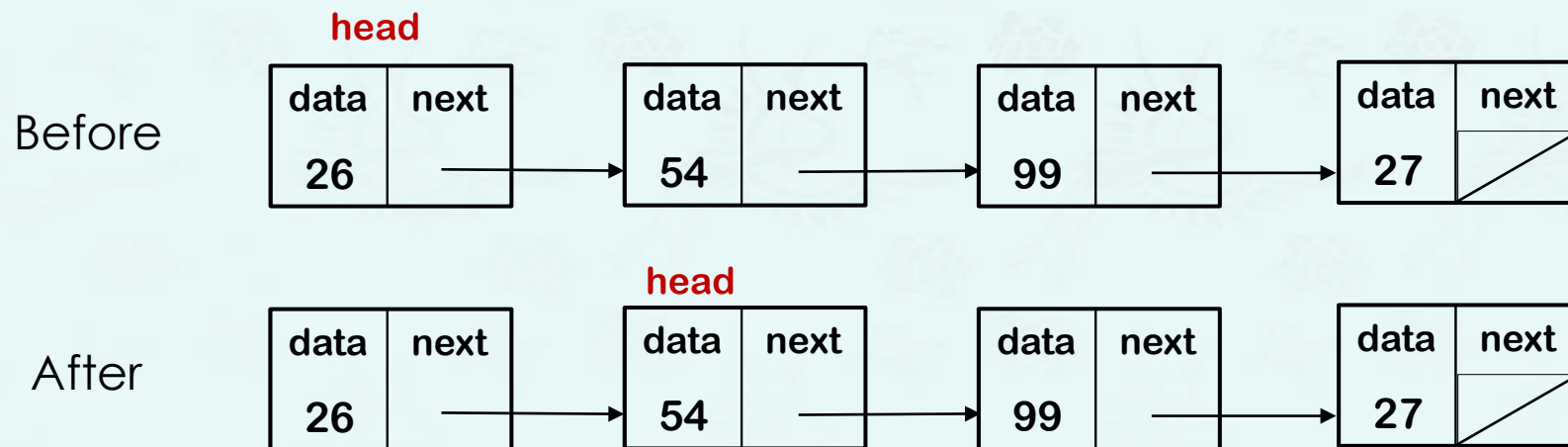- Add a node (data = 33) at the end of list.

- To get to the tail we have to scroll along the list until the end. We want a pointer that will stop while still pointing at the last node. Thus our termination condition is that the node's next field is **nullptr**. Once we have a pointer to the end of the list, we can make it point to the node we want to add:

```
Node* push_back(Node* head, int data) {
  Node *y = new Node {data, nullptr};
  Node *x = head;
  while (x->next != nullptr)
    x = x->next;
  x->next = y;                  ←——— a way to get the last node
  return head;
}
```

Linked List - pop_front()

- Remove the first node or move head to the next node.
  Then what is wrong with the following code?

```
Node* pop_front(Node* head) {
  head = head->next;
  return head;
}
```
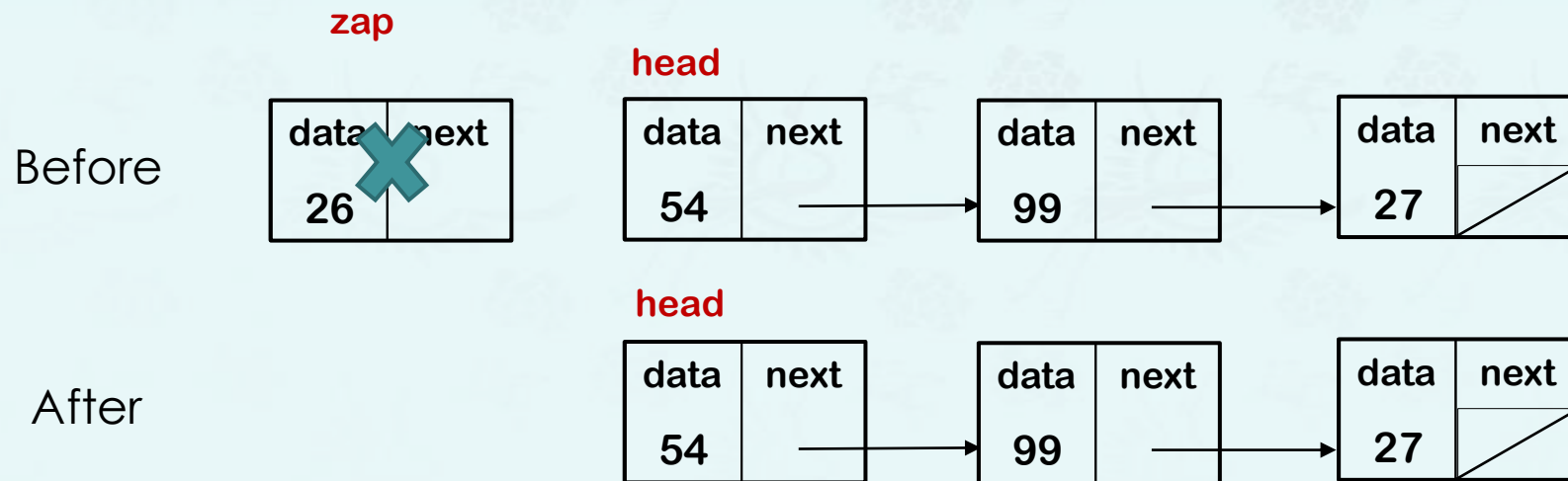
Before

	head			
data	next	data	next	data	next	data	next
26		54		99		27	

After

		head		
data	next	data	next	data	next	data	next
26		54		99		27	

Linked List - pop_front()

- Remove the first node or move head to the next node.
  Then what is wrong with the following code?
- When removing a node, beware of memory leak; remember to give yourself a pointer to the node that is about to be removed before you lose your pointer to it:

```
Node* pop_front(Node* head) {
    Node* zap = head;
    head = head->next;
    delete zap;
    return head;
}
```
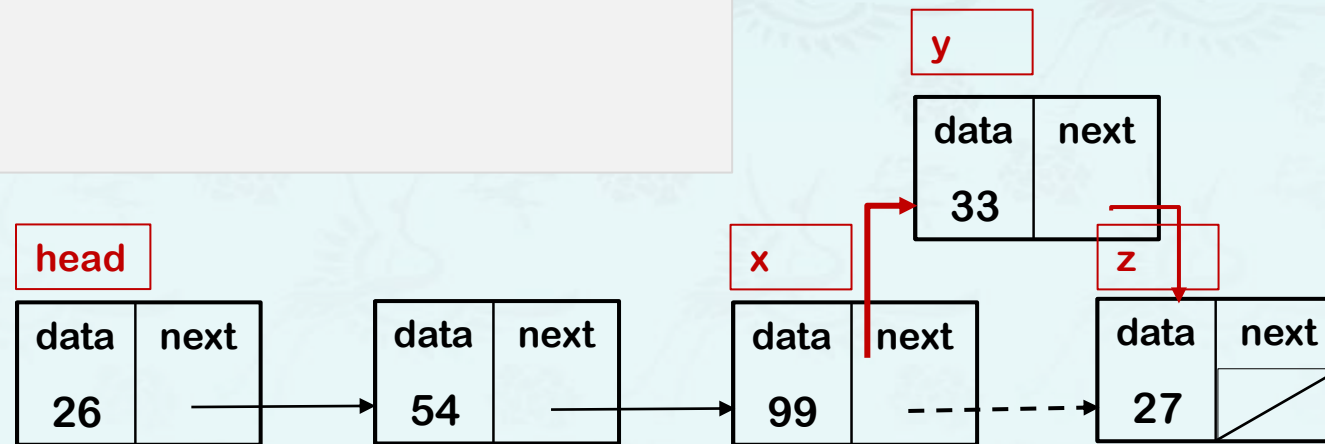
Linked List - insert()

- Insert a new node(data = 33) after the node (key = 99) as shown below.
- Starting from the head node, we have to stop at the node (key = 99) before the insertion point. Remember that a singly-linked list is a one way street!
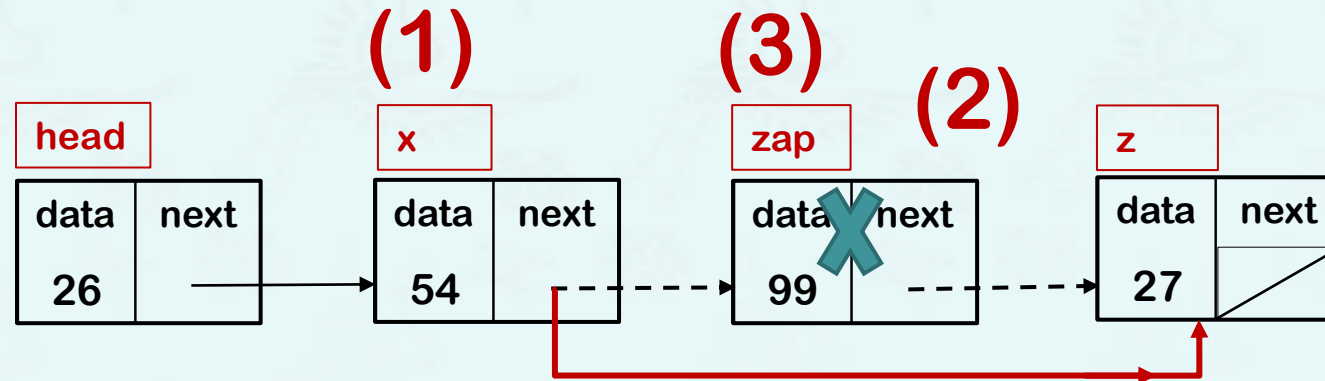
```
Node* insert(Node* head, int key, int data) {
    Node* x = head;
    while (x->data != key)        Where is x pointing after while()?
        x = x->next;
    Node* y = new Node {data, x->next};
    x->next = y;
    return head;
}
```

Linked List - remove()

- Remove a node(key = 99) in the middle of list as shown below.

(1)   **(3)**

(2)

| head			x			zap			z	
data	next		data	next		data	next		data	next
26			54			99			27	

Linked List - remove()

- Remove a node(key = 99) in the middle of list as shown below.
1. use a handle pointer (**zap** here) to keep hold of the unwanted node
2. find the node **before** the unwanted node and make links.
3. delete the unwanted node

```
Node* remove(Node* head, int key) {
    node* pre = head,
    node* zap = head->next;
    while(zap->data!= key) {
        pre = zap;
        zap = zap->next;
    }
    pre->next = zap->next;
    delete zap;
    return head;
}
```
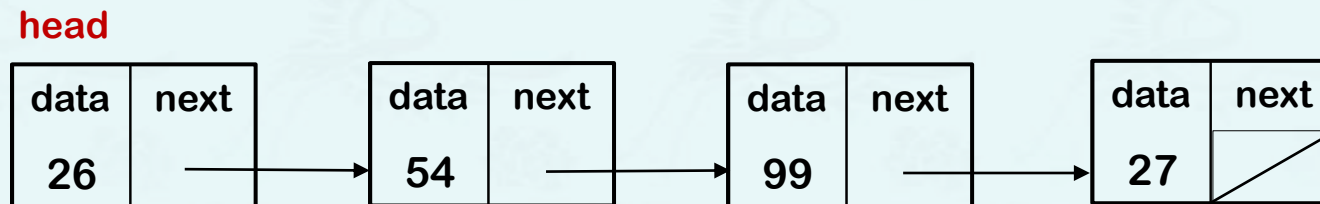
⟶ To find both pre and zap.

Assuming
(1) there are at least two nodes,
(2) the key is not at the head node, and
(3) there is a key node.
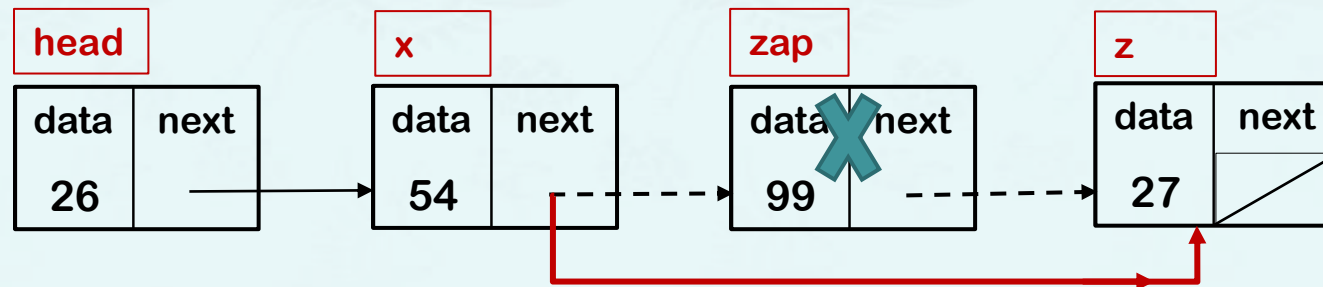
Linked List - clear()

Removes nodes from the list (which are destroyed), and leaving the list with a size of 0.

```
void clear(Node* head) {
    Node *curr = head;
    while(curr != nullptr) {
        ...
        delete ...
    }
}
```

head

Data Structures
Chapter 4

1. Singly Linked List
   - Pointer & Linking
   - **Singly Linked List (1)**
   - Singly Linked List (2)
   - Singly Linked List Operations
2. Doubly Linked List

Summary &
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Prof. Youngsup Kim, idebtor@gmail.com, CSEE Dept., Grace School Rm204 Handong Global University