File Edit View Help

File Edit View Help

Foundational Data Structures

Arrays

- Fixed, Contiguous Blocks of Memory of the same type
- Pros
  - Random Access
- Cons
  - Cannot Resize
  - Not great if the size is not known or fixed

Array of Size 10 In Memory

Identifier	Contents	Byte Address
…	…	…
a[]	36	28
…	….	…
a[0]	256	36
a[1]		42
a[2]		48
…		
a[9]	NULL	90

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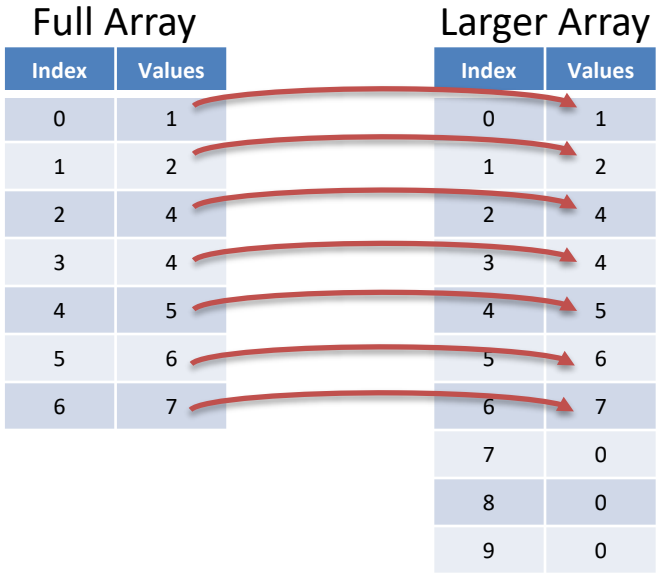
Growable Arrays

- Array Lists
  - Strings
- Growing
  - Create a new array with a larger size
  - Transfer all the data from the original array to the new array
  - Remove the original Array
- Pros
  - Semi-Random Access
  - Growable Structure
- Cons
  - Lots of Overhead
  - Does not Shrink
  - Not Great for Large Amounts of Data
  - Not Great Performance

Growing Concept



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IS THERE A BETTER WAY!?

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Linking Structures

Linking Structures

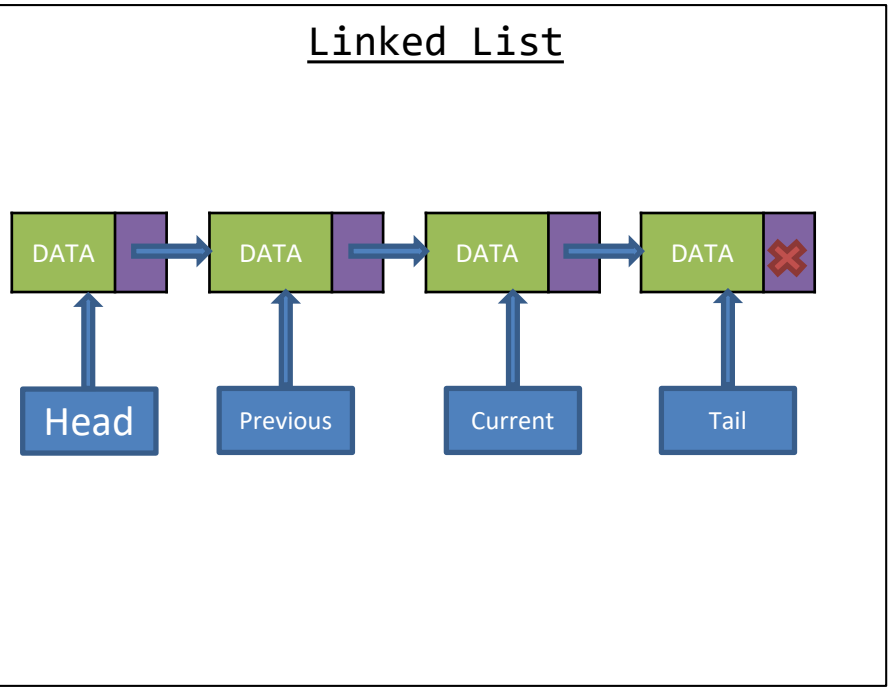
- Groups Together
  - Data
  - Link(s) / Reference(s) / Pointer(s)
  - "Node"
- Pros
  - Growable
  - Shrinkable
- Cons
  - No Random Access

Node

List of Nodes

Linked Lists

- Nodes Contain
  - Data
  - Link
- Special Nodes
  - Head: Always points to the first element of the list
  - Tail: Always points to the last element of the list
  - Current: Movable pointer used to Access and Modify Data in the List
  - Previous: Always stays on node behind Current
- Certain Linked Lists may omit some of these Nodes



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Linked List Set Up

Internal Classes

- Class within Classes
- Aids in grouping together like-information that is only used within a class
- Other Programmers do not need access to these classes

Syntax

```
public <<class identifier>>
{
        private <<internal class identifier>>
        {
                //Body of Internal Class
        }
}
```

Example

```
public class IntLL
{
      private class ListNode
      {

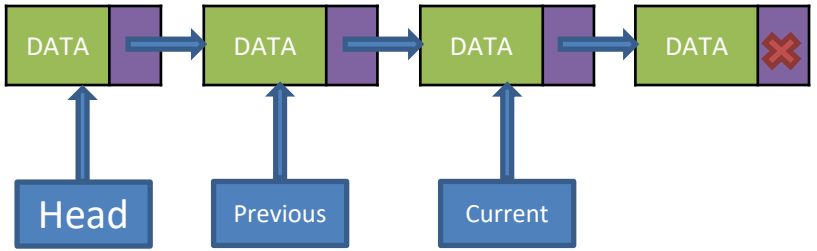
      }
}
```

File Edit View Help

Adding

- Create a new Node with the given Data
- Start from the Head and find the Node with the first Null Link
- Point that Node to the newly Created Node

Concept



Adding

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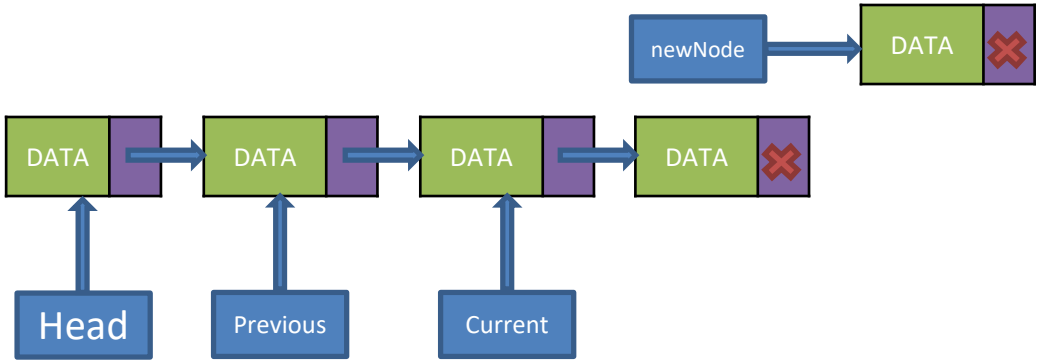

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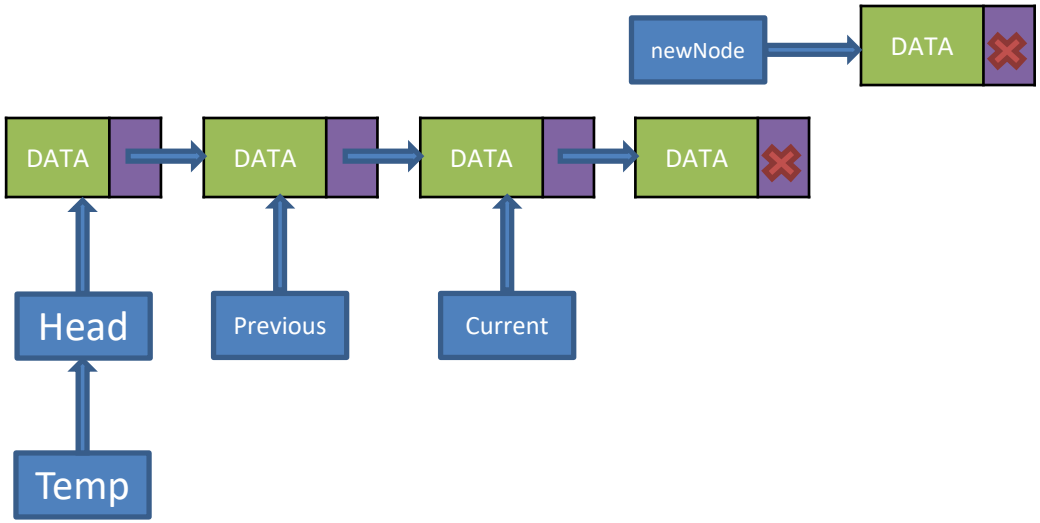

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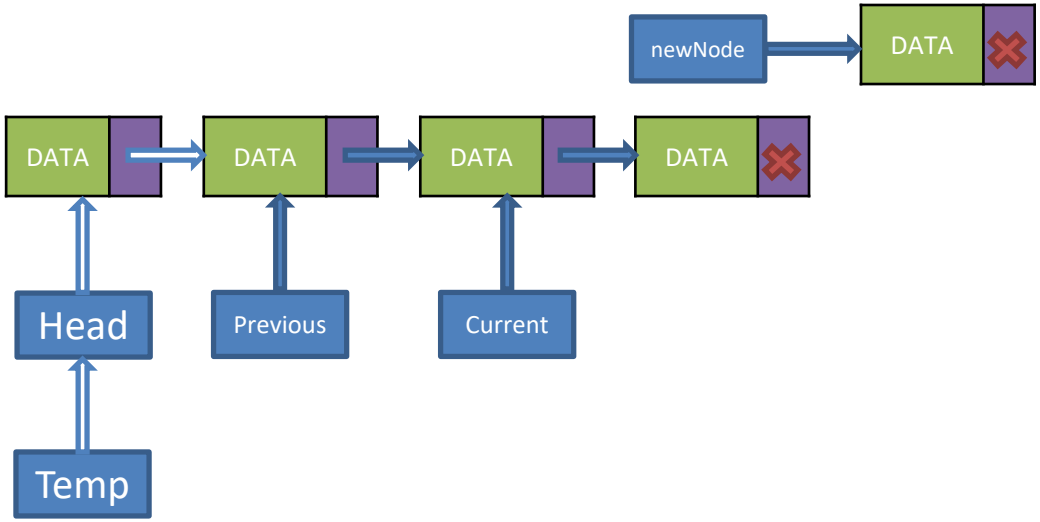

File Edit View Help

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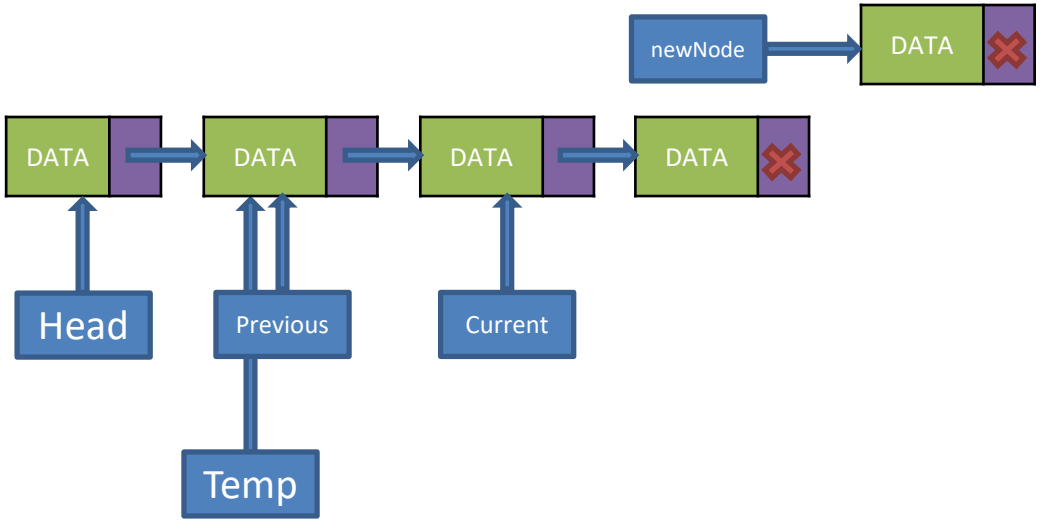

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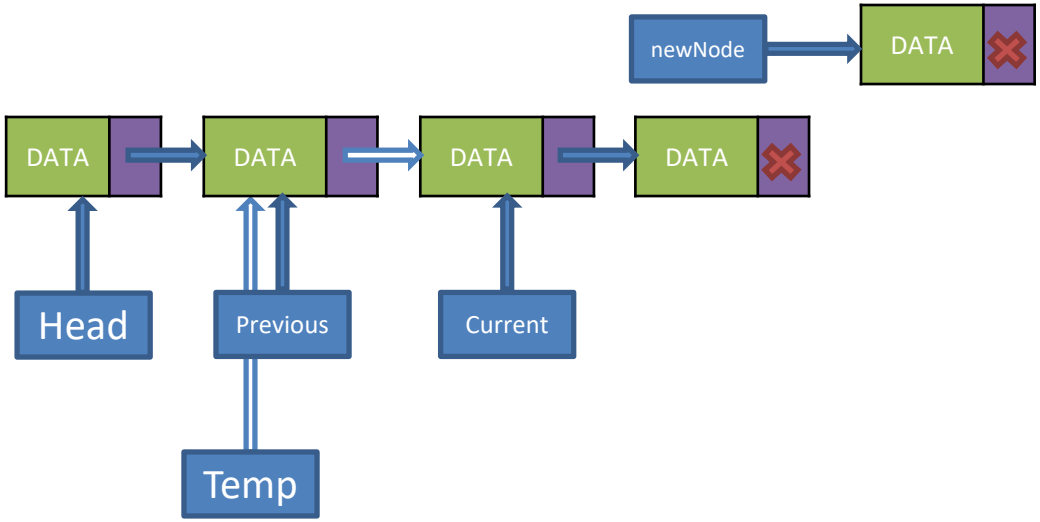

Adding

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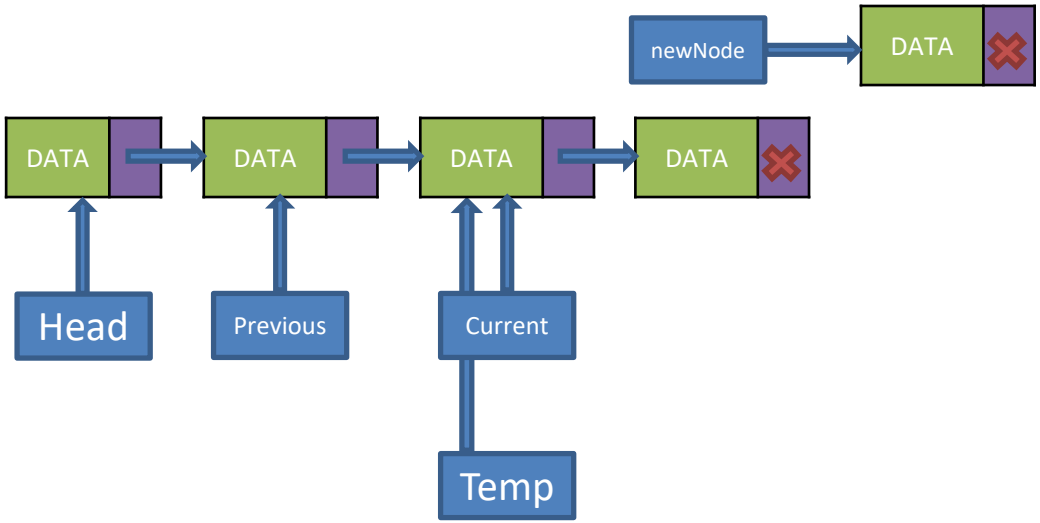

Adding

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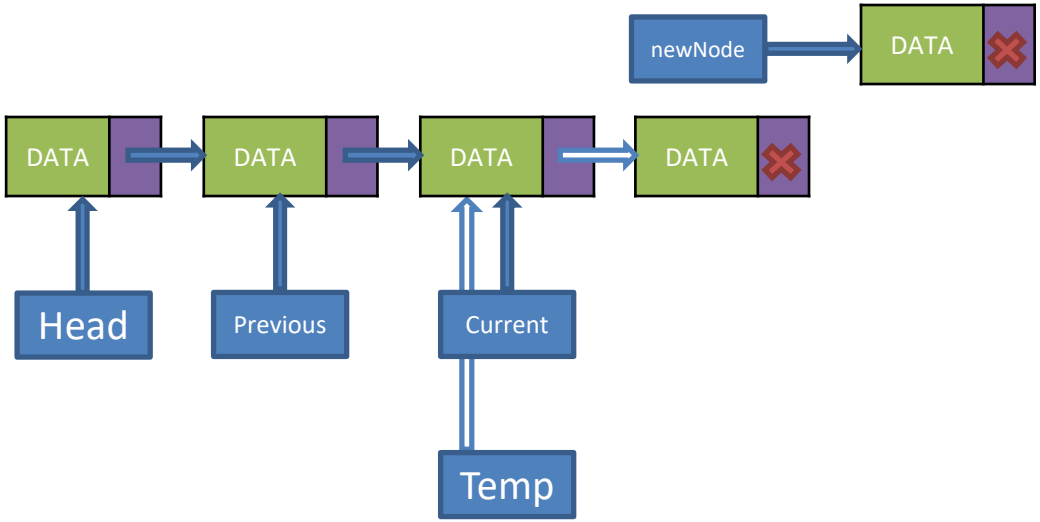

File Edit View Help

Adding

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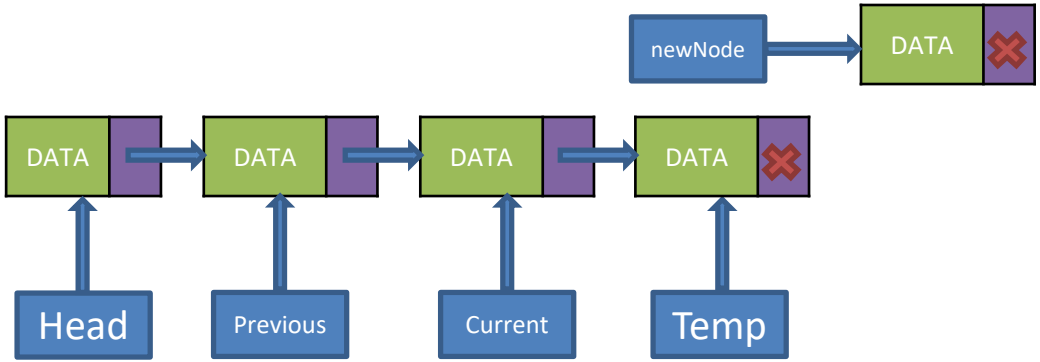

File Edit View Help

Adding

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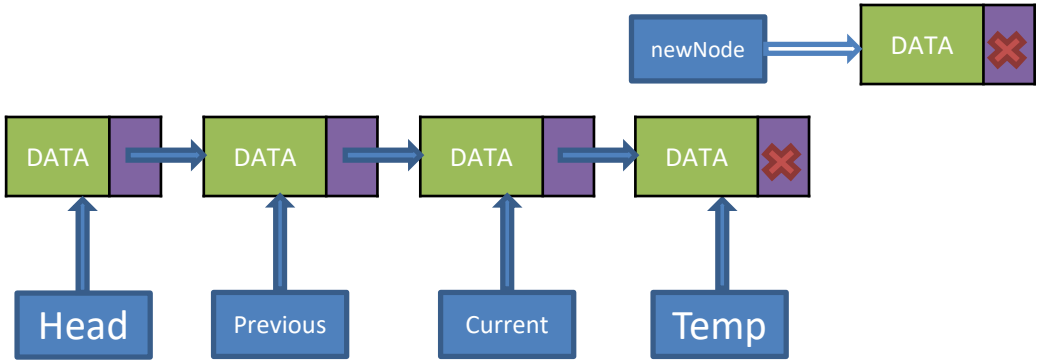

File Edit View Help

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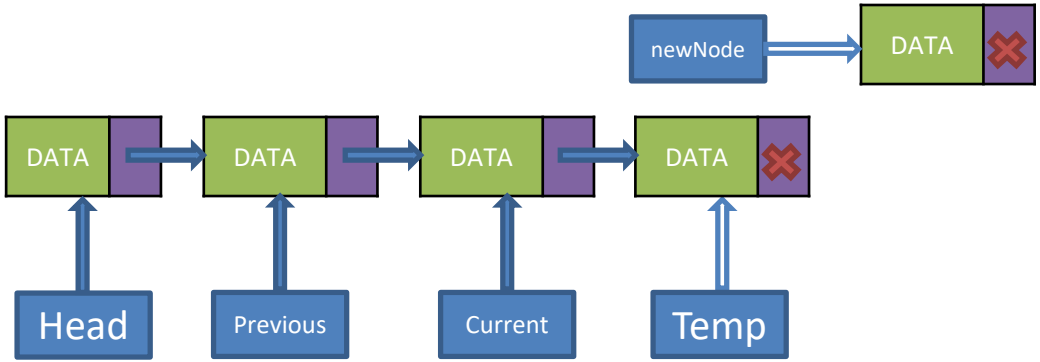

File Edit View Help

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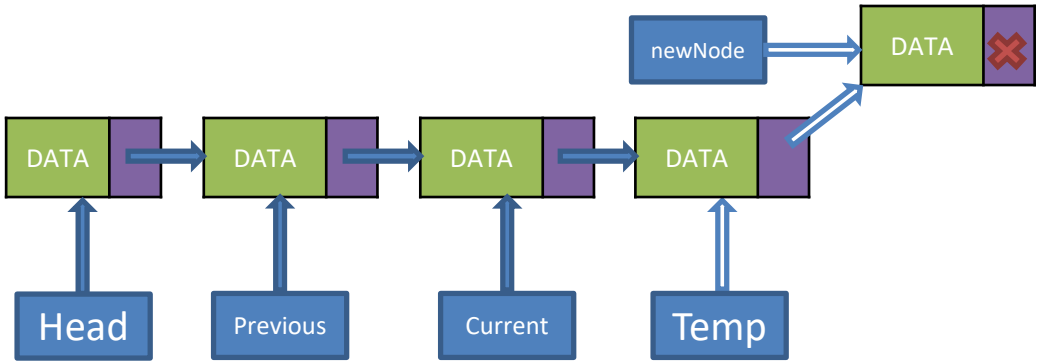

File Edit View Help

Adding

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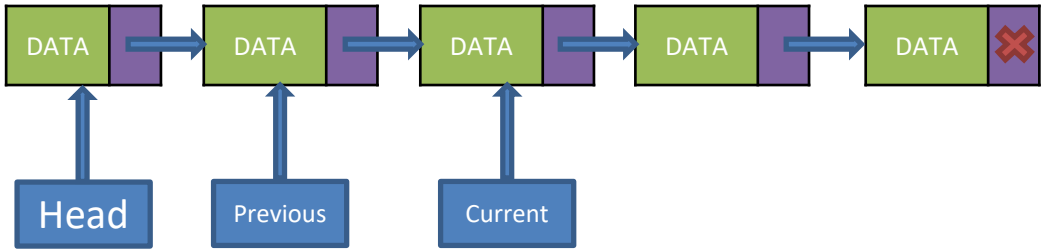

File Edit View Help

Adding in Memory

```
public void add(int aData)
{
    ListNode newNode = new ListNode(aData,null);
    if(head == null)
    {
        head = current = newNode;
        return;
    }
    ListNode temp = head;
    while(temp.link != null)
    {
        temp = temp.link;
    }
    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
…	…	…
iLinkedList	NULL	28
…	….	…

More Memory

Identifier	Contents	Byte Address
…	…	…
…	…	…

File Edit View Help

Adding in Memory

```
public void add(int aData)
{
    ListNode newNode = new ListNode(aData,null);
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    {
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        return;
    }
    ListNode temp = head;
    while(temp.link != null)
    {
        temp = temp.link;
    }
    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
…	…	…
iLinkedList	NULL	28
…	….	…
IntLL	-	50
head	NULL	64
current	NULL	70
previous	NULL	76
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
…	…	…

File Edit View Help

Adding in Memory

```
public void add(int aData)
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    {
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    }
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}
```

Memory

Identifier	Contents	Byte Address
…	…	…
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…	….	…
IntLL	-	50
head	NULL	64
current	NULL	70
previous	NULL	76
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
…	…	…

File Edit View Help

Adding in Memory

4

```
public void add(int aData)
{
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    while(temp.link != null)
    {
        temp = temp.link;
    }
    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
…	…	…
iLinkedList	50	28
…	….	…
IntLL	-	50
head	NULL	64
current	NULL	70
previous	NULL	76
…	…	…
aData	4	96
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…

Adding in Memory

4

```
public void add(int aData)
{
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Memory

Identifier	Contents	Byte Address
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More Memory

Identifier	Contents	Byte Address
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Adding in Memory

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Memory

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previous	NULL	76
…	…	…
aData	4	96
…	…	…
newNode	NULL	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…

Adding in Memory

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```
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…	…	…
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…	…	…
newNode	NULL	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…

Adding in Memory

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More Memory

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Adding in Memory

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…	…	…
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…	…	…
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…	…	…

More Memory

Identifier	Contents	Byte Address
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File Edit View Help

Adding in Memory

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More Memory

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File Edit View Help

Adding in Memory

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…	…	…
newNode	128	104
…	…	…

More Memory

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File Edit View Help

Adding in Memory

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More Memory

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Adding in Memory

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More Memory

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More Memory

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Adding in Memory

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More Memory

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Adding in Memory

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More Memory

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File Edit View Help

Adding in Memory

3

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public void add(int aData)
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previous	NULL	76
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
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data	4	130
link	NULL	134
…	…	…

Adding in Memory

3

```
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    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
…	…	…
iLinkedList	50	28
…	….	…
IntLL	-	50
head	**128**	64
current	**128**	70
previous	NULL	76
…	…	…
aData	3	96
…	…	…
newNode	265	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274

Adding in Memory

3

```
public void add(int aData)
{
    ListNode newNode = new ListNode(aData,null);
    if(head == null)
    {
        head = current = newNode;
        return;
    }
    ListNode temp = head;
    while(temp.link != null)
    {
        temp = temp.link;
    }
    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
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…	….	…
IntLL	-	50
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…	…	…
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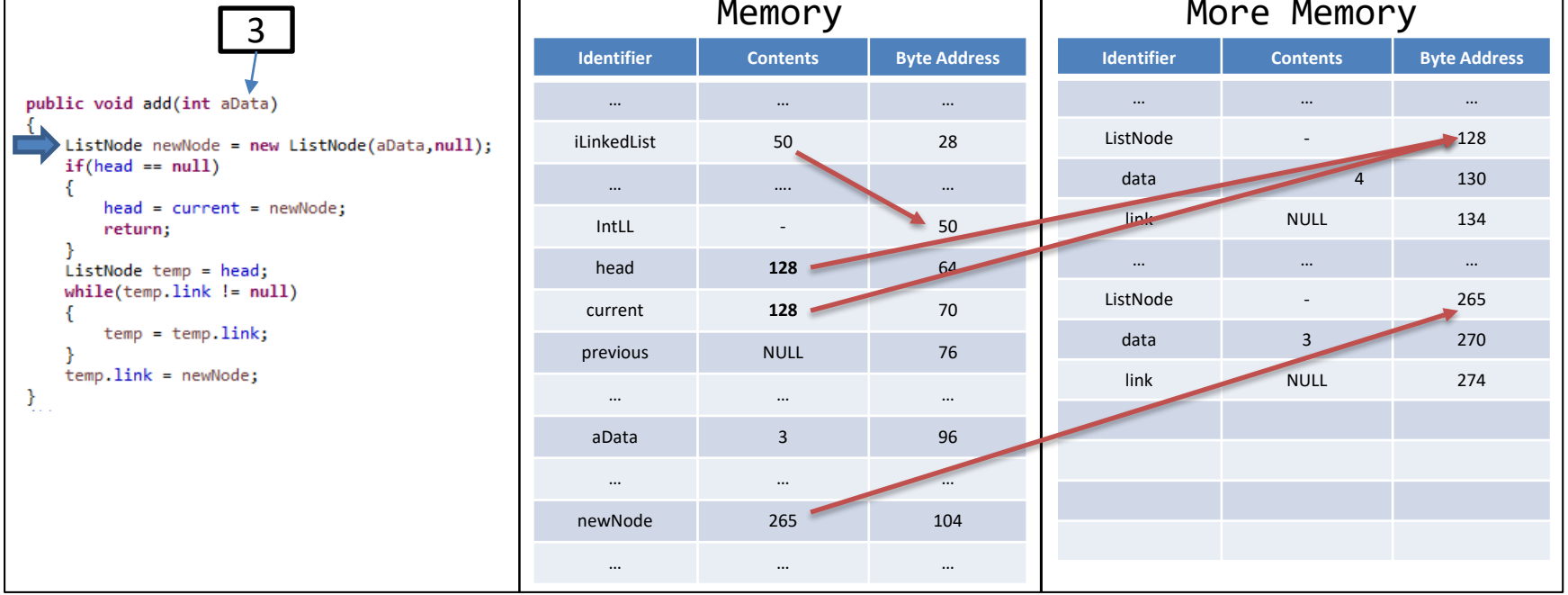
More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274



File Edit View Help

Adding in Memory

3

```
public void add(int aData)
{
    ListNode newNode = new ListNode(aData,null);
    if(head == null)
    {
        head = current = newNode;
        return;
    }
    ListNode temp = head;
    while(temp.link != null)
    {
        temp = temp.link;
    }
    temp.link = newNode;
}
```

Memory

Identifier	Contents	Byte Address
…	…	…
iLinkedList	50	28
…	….	…
IntLL	-	50
head	**128**	64
current	**128**	70
previous	NULL	76
…	…	…
aData	3	96
…	…	…
newNode	265	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274

Adding in Memory

3

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public void add(int aData)
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    ListNode newNode = new ListNode(aData,null);
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More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	NULL	355

Adding in Memory

3

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public void add(int aData)
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…	…	…
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newNode	265	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	NULL	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	**128**	355

Adding in Memory

3

```
public void add(int aData)
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newNode	265	104
…	…	…

More Memory

Identifier	Contents	Byte Address
…	…	…
ListNode	-	128
data	4	130
link	**NULL**	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	**128**	355

File Edit View Help

Adding in Memory

3

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More Memory

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ListNode	-	128
data	4	130
link	**NULL**	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	**128**	355

Adding in Memory

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More Memory

Identifier	Contents	Byte Address
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ListNode	-	128
data	4	130
link	**265**	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	**128**	355

Adding in Memory

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More Memory

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data	4	130
link	**265**	134
…	…	…
ListNode	-	265
data	3	270
link	NULL	274
…	…	…
temp	**128**	355

File Edit View Help

Adding in Memory

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More Memory

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ListNode	-	128
data	4	130
link	**265**	134
…	…	…
ListNode	-	265
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File Edit View Help

Adding in Memory

2

```
public void add(int aData)
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    }
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File Edit View Help

Adding in Memory

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More Memory

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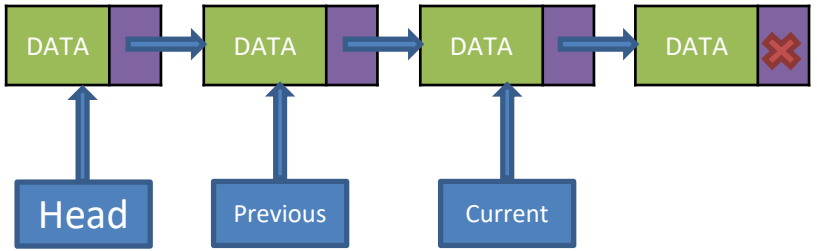
…	…	…
ListNode	-	128
data	4	130
link	**265**	134
…	…	…
ListNode	-	265
data	3	270
link	**374**	274
…	…	…
ListNode	-	374
data	2	380
link	NULL	384

Adding After Current

- Create a new Node with the given Data
- Set new Node's Link to Current's Link
- Point Current's Link to the new Node

Concept



Adding After Current

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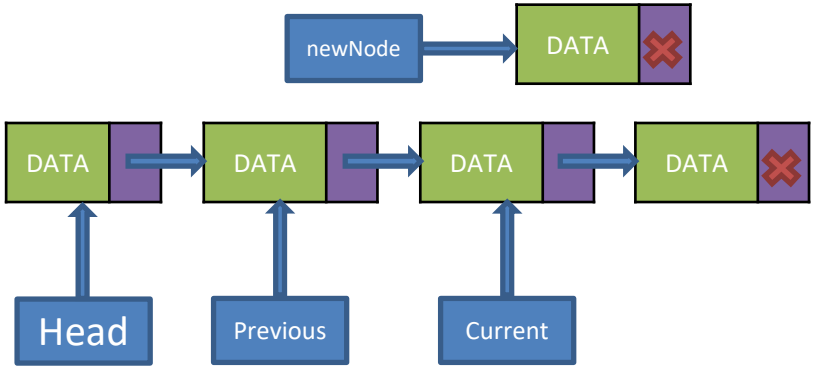

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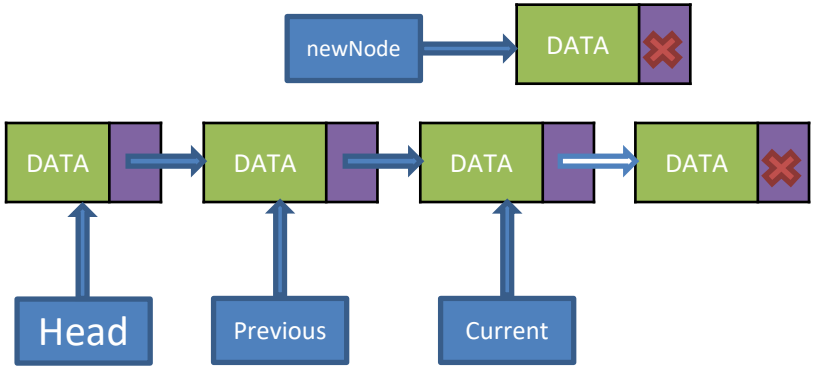

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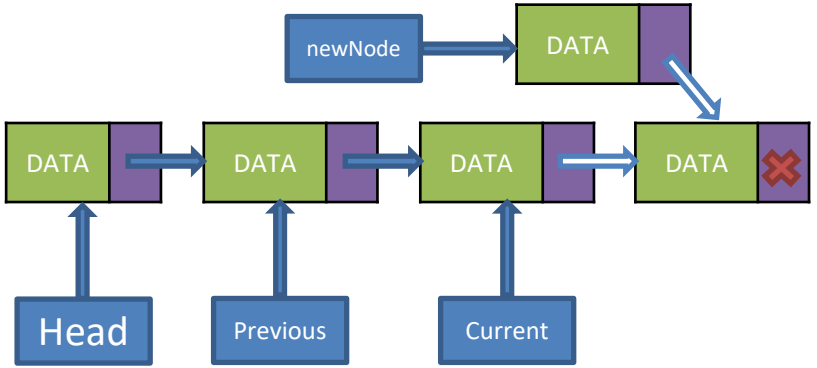

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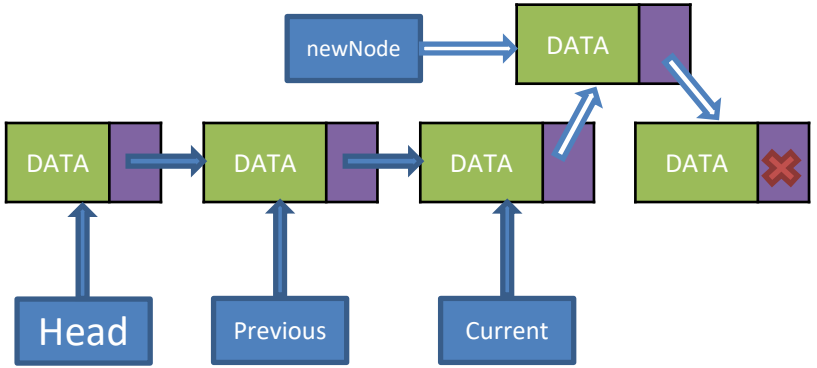

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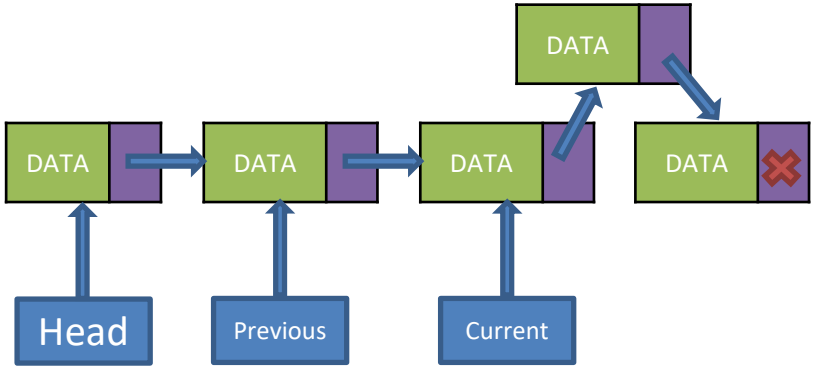
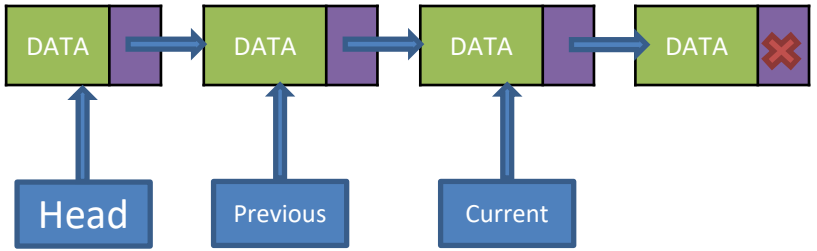


Removing Current

- If the Current is referencing the Head
  - Move Head and Current forward one node
- Set the Previous' Link to Current's Link
- Move Current Forward

Concept



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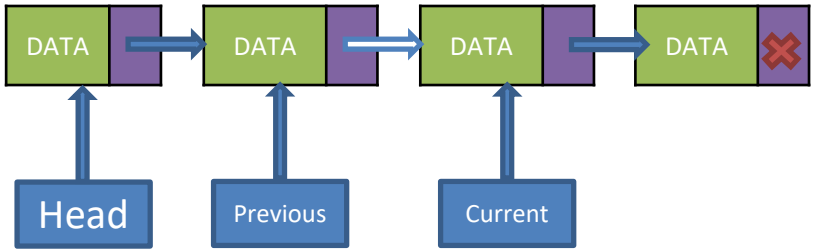

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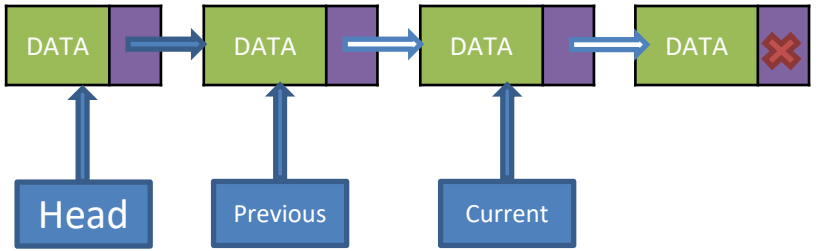

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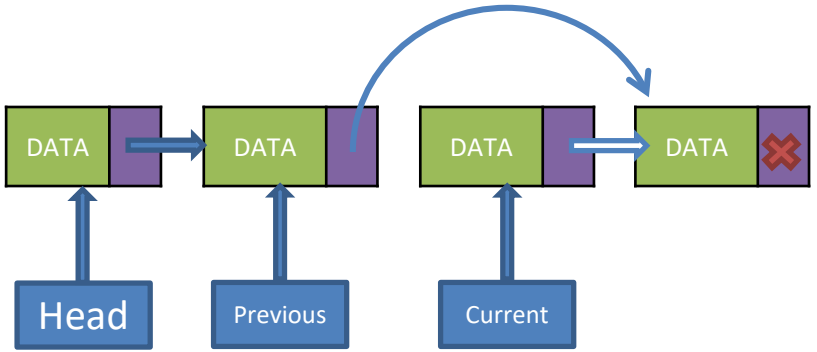

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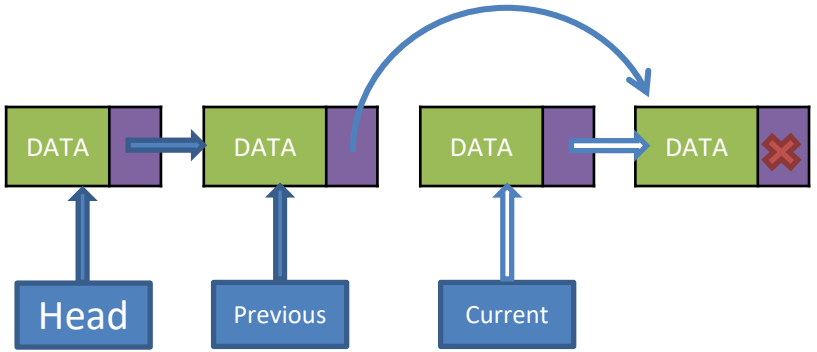

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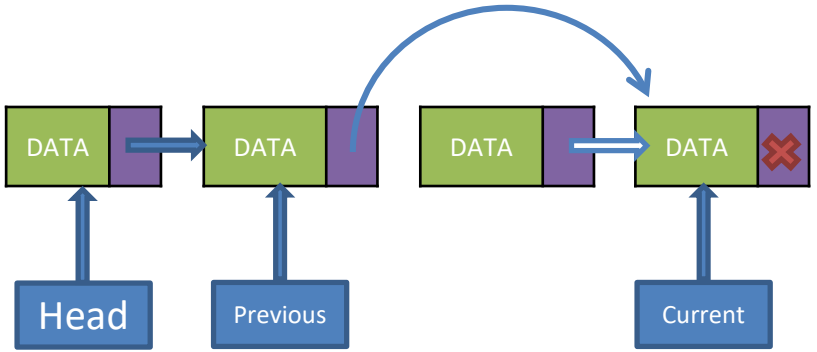

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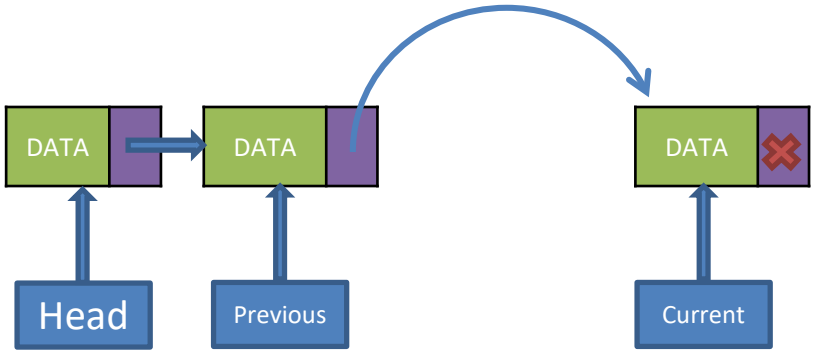

Removing Current in Memory

```
public void removeCurrent()
{
    if ((current != null) && (previous != null))
    {
        previous.link = current.link;
        current = current.link;
    }
    else if ((current != null) && (previous == null))
    {//At head node
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Memory

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head	128	64
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...	...	...

More Memory

Identifier	Contents	Byte Address
...	...	...
ListNode	-	128
data	4	130
link	265	134
...	...	...
ListNode		265
data	3	270
link	374	274
...	...	...
ListNode	-	374
data	2	380
link	NULL	384

File Edit View Help

Removing Current in Memory

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public void removeCurrent()
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Problems

- This is only a Linked List of Integers
- How can we make this same structure without having to rewrite the code for every type?

File Edit View Help

Linking Structures