CIS 190: C/C++ Programming

Lecture 5

Linked Lists

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

Memory and Functions

- how do different types of variables get passed to and returned from functions?

- passing by value
- passing by reference
  - implicit: arrays, strings
  - explicit: pointers

Memory and Functions

- some simple examples:

```
int Add(int x, int y);
   int answer = Add(1, 2);
void PrintMenu(void);
   PrintMenu();
int GetAsciiValue(char c);
   int ascii = GetAsciiValue ('m');
```

- all passed by value

Memory and Functions

- passing arrays to functions

```
void TimesTwo(int array[], int size);

int arr [ARR_SIZE];
/* set values of arr */

TimesTwo(arr, ARR_SIZE);
```

- arrays of any type are passed by reference
  - changes made in-function persist

Memory and Functions

- passing arrays to functions

```
void TimesTwo(int array[], int size);
void TimesTwo(int * array, int size);
```

- both of these behave the same way
  - they take a pointer to:
    - the beginning of an array
    - an int – that we (can) treat like an array

Memory and Functions

- passing strings to functions

```
void PrintName(char  name[]);
void PrintName(char *name  );

char myName [NAME_SIZE] = "Alice";
PrintName(myName);
```

- strings are arrays (of characters)
  – implicitly passed by reference

Memory and Functions

- passing pointers to int to functions

```
void Square(int *n);

int x = 9;
Square(&x);
```

- pass address of an integer (in this case, x)

Memory and Functions

- passing int pointers to function

```
void Square(int *n);

int x = 9;
int *xPtr = &x;
Square(???);
```

- pass **???**

Memory and Functions

- passing int pointers to function

```
void Square(int *n);

int x = 9;
int *xPtr = &x;
Square(xPtr);
```

- pass xPtr, which is an address to an integer (x)

Memory and Functions

- returning pointers from functions

```
CAR* MakeCar(void) {
   CAR temp;

   return &temp;  }
```

- temp is on the stack – so what happens?

Memory and Functions

- returning pointers from functions

```
CAR* MakeCar(void) {
   CAR temp;

   return &temp;  }
```

- temp is on the stack – so it will be returned to ***the process*** when MakeCar() returns!

Memory and Functions

- returning pointers from functions

```
CAR* MakeCar(void) {
    CAR* temp;
    temp = (CAR*) malloc (sizeof(CAR));
    return  temp;  }
```

- temp is on the heap – so what happens?

Memory and Functions

- returning pointers from functions

```
CAR* MakeCar(void) {
   CAR* temp;
   temp = (CAR*) malloc (sizeof(CAR));
   return  temp;   }
```

- temp is on the heap – so it belongs to ***you*** and will remain on the heap until you free() it

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

What is a Linked List?

What is a Linked List?

- data structure
- dynamic
  - allow easy insertion and deletion

- uses nodes that contain
  - data
  - pointer to next node in the list
    - this is called singly linked, and is what we'll be using

Question

- What are some disadvantages of arrays?

- not dynamic
  - size is fixed once created
  - you can resize it, but you have to do it by hand
  - same for insertion & deletion; it's possible, but it's difficult and there's no built-in function for it
- require contiguous block of memory

Question

- Can we fix these with linked lists? How?

- not dynamic
  - linked lists can change size constantly
  - can add nodes anywhere in a linked lists
  - elements can be removed with no empty spaces
- require contiguous block of memory
  - only one node needs to be held contiguously

Question

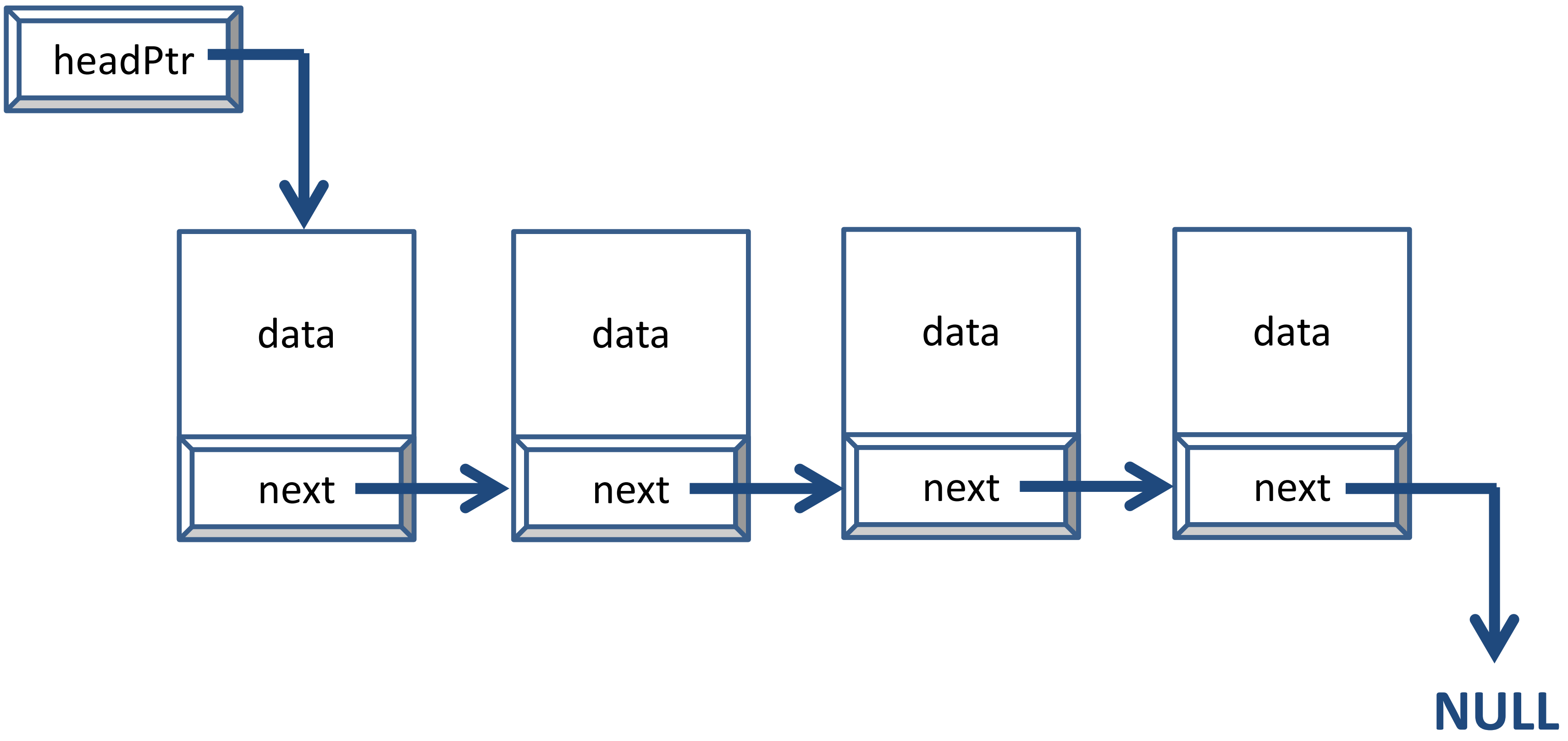
- Are there any disadvantages to linked lists?

- harder to search/access than arrayz
- need to manage size/counter for size
- harder to manage memory
  - in-list cycles, segfaults, etc.
- pointer to next node takes up more memory

Outline

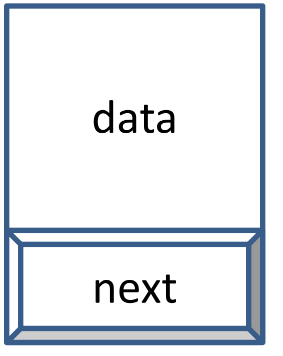
- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

Linked List Anatomy



Nodes

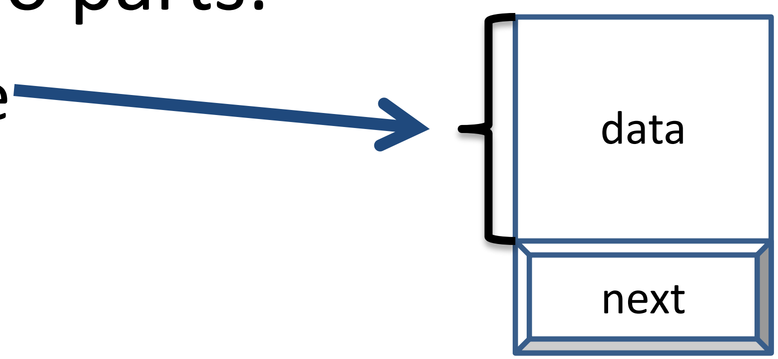
- a “node” is one element of a linked list
- nodes consist of two parts:



- typically represented as structs

Nodes

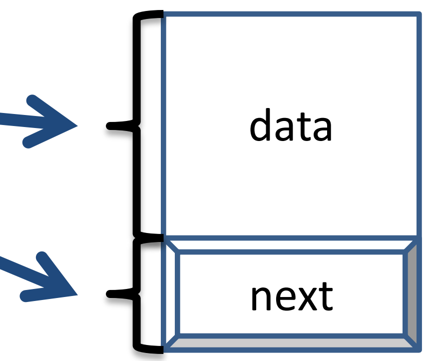
- a “node” is one element of a linked list
- nodes consist of two parts:
  – data stored in node



- typically represented as structs

Nodes

- a “node” is one element of a linked list
- nodes consist of two parts:
  - data stored in node
  - pointer to next node in list



- typically represented as structs

Node Definition

- nodes are typically represented as structs

```
typedef struct node {
    int     data;
    NODEPTR next;
} NODE;
```

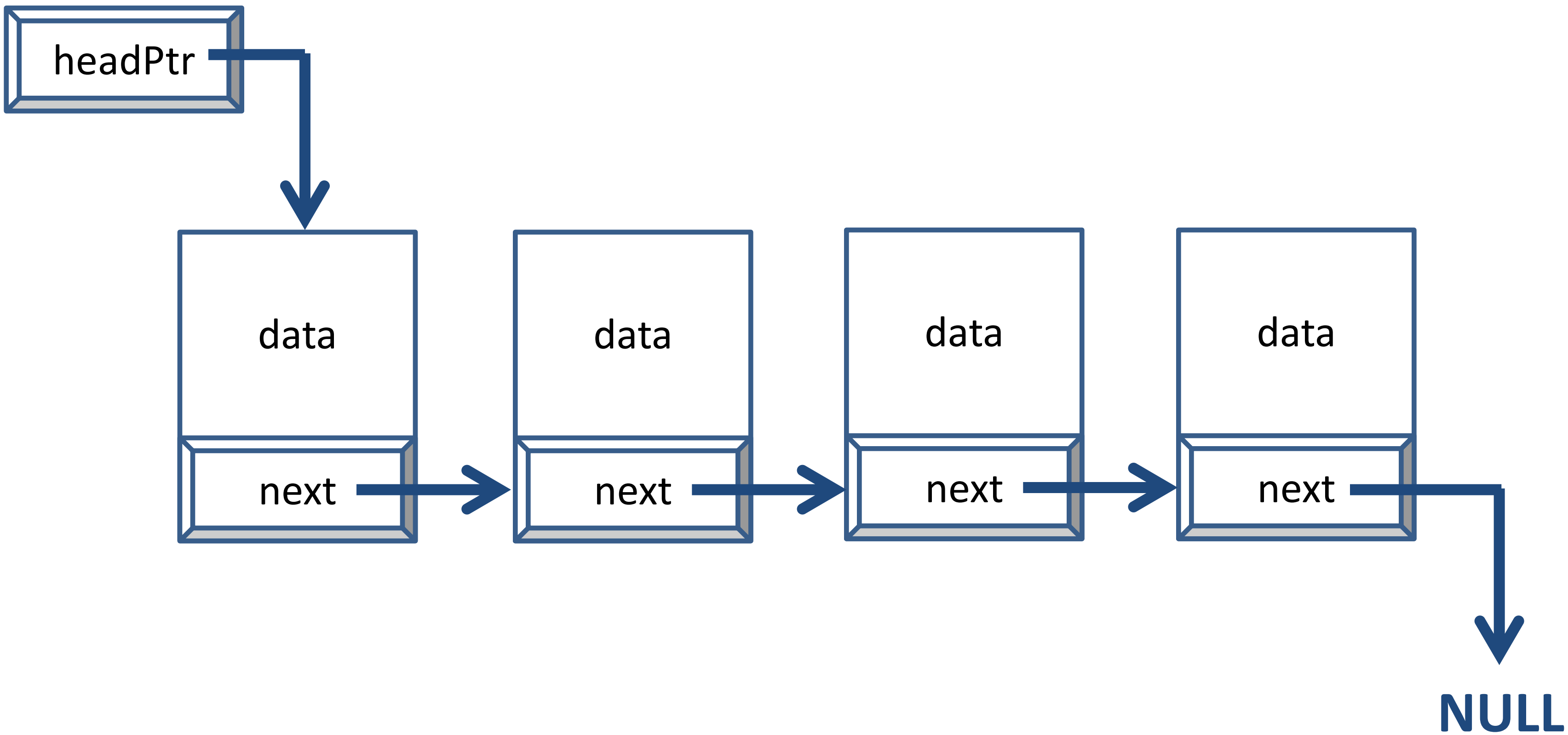
Node Definition

- nodes are typically represented as structs

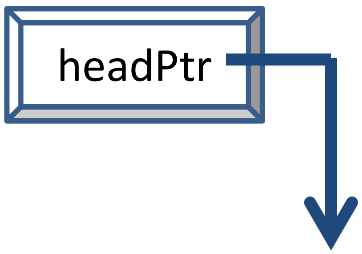
```
typedef struct node * NODEPTR;
typedef struct node {
    int     data;
    NODEPTR next;
} NODE;
```

- typedef NODEPTR beforehand so that it can be used in the definition of the NODE structure

Linked List Anatomy

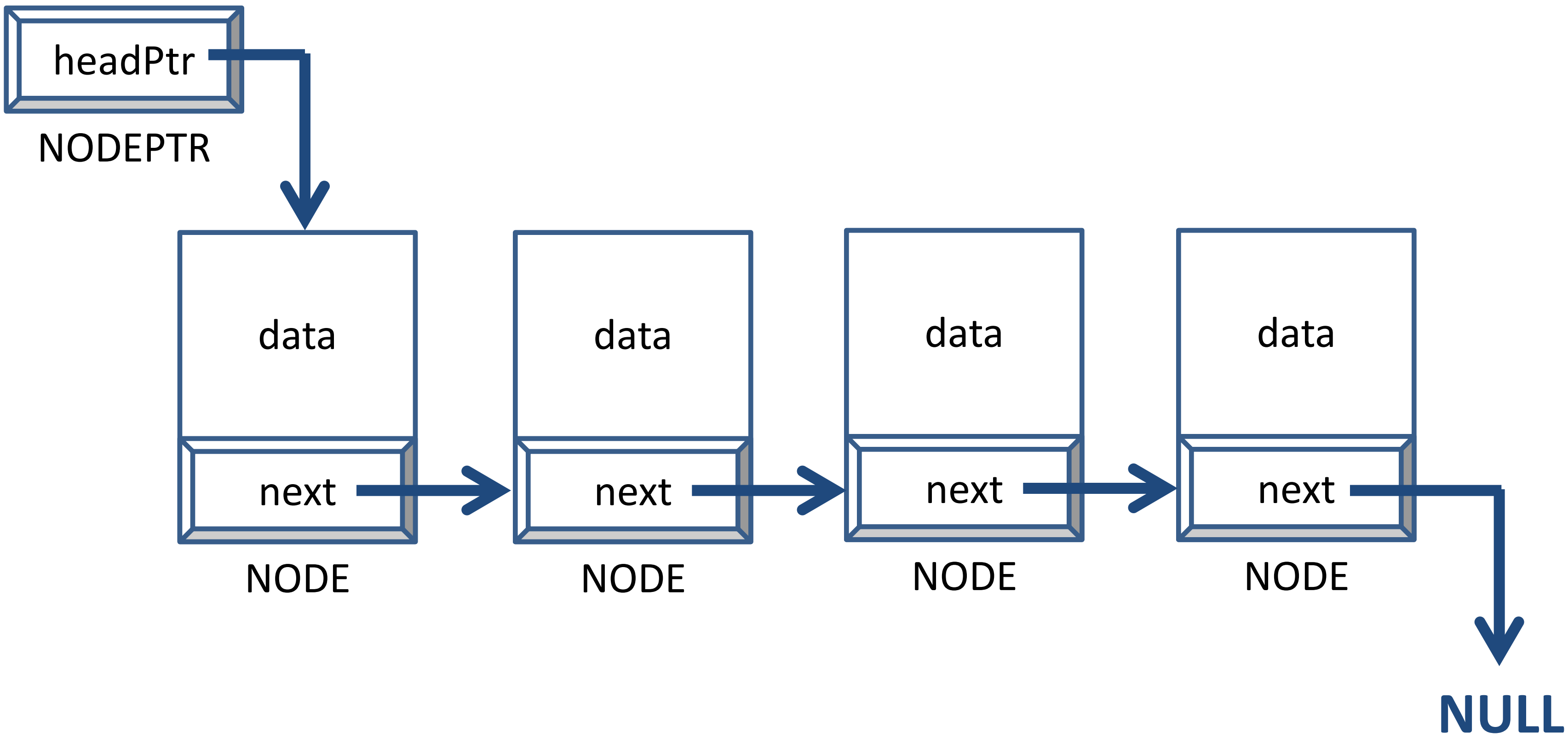


List Head

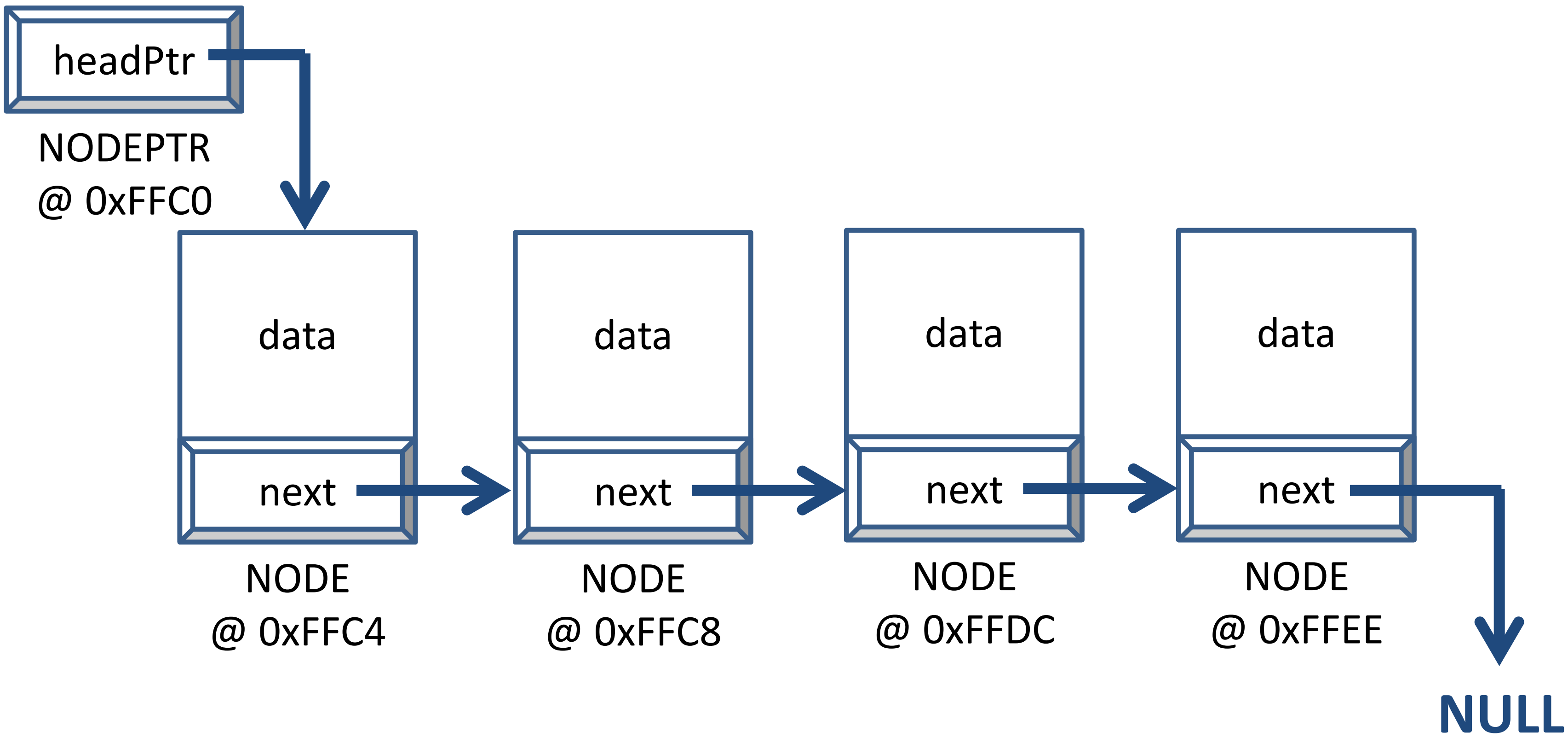


- points to the first NODE in the list
  - if there is no list, points to NULL
- headPtr does not contain any data of its own
  - only a pointer to a NODE

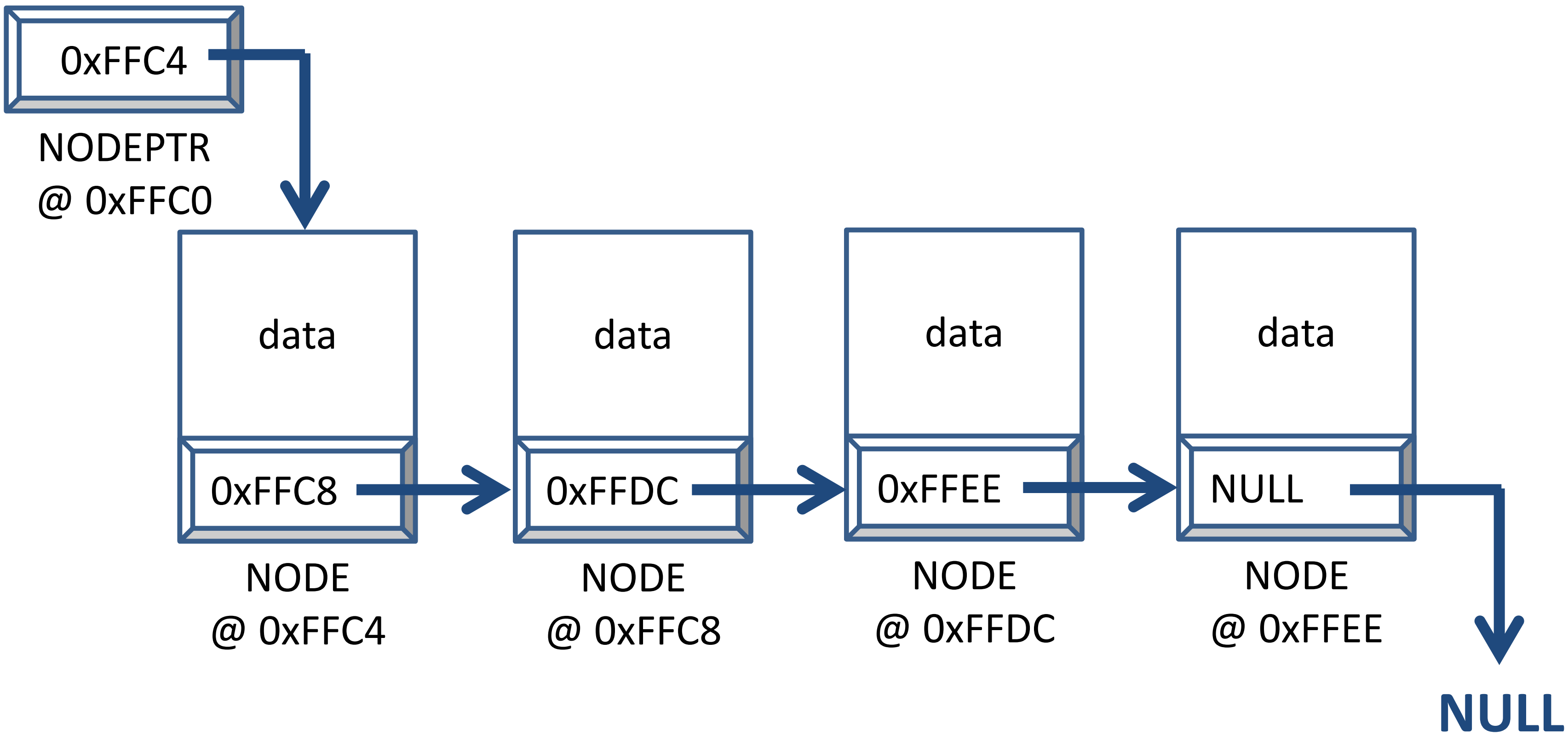
Linked Lists



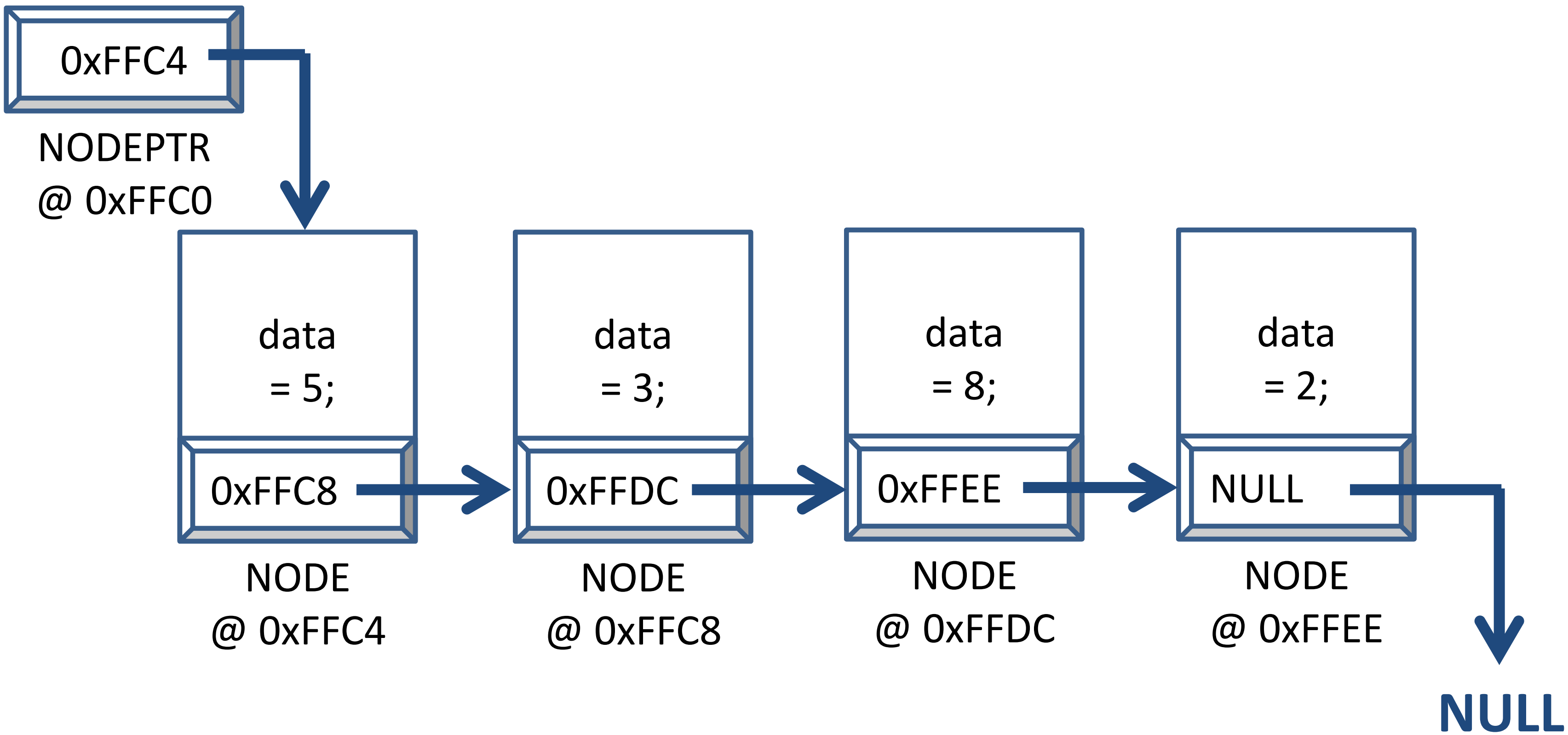
Linked Lists



Linked Lists



Linked Lists



Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

More About headPtr

- headPtr is a pointer to a NODE
  - it has a place where it's stored in memory
  - and it has where it points to in memory

More About headPtr

- headPtr is a pointer to a NODE
  - it has a place where it's stored in memory
  - and it has where it points to in memory

&headPtr	headPtr
0xFFC4	0xDC44
~~address~~ **where it's stored in memory**	**~~value~~** **where it points to in memory**

Passing Pointers

- when we pass a pointer by value, we pass where it points to in memory

- so we can change the value(s) stored in the memory location to which it points
  - but we can’t alter the pointer itself

Passing Pointers by Value Example

```
void SquareNum (int *intPtr) {
    (*intPtr) = (*intPtr) *
                (*intPtr);
}
```

Passing Pointers by Value Example

```
void SquareNum (int *intPtr) {
  (*intPtr) = (*intPtr) *
              (*intPtr);
}
int x = 4;
int *xPtr = &x;
```

Passing Pointers by Value Example

```
void SquareNum (int *intPtr) {
   (*intPtr) = (*intPtr) *
               (*intPtr);
}
int x = 4;
int *xPtr = &x;
SquareNum (xPtr);
/* value of x is now 16 */
```

Passing Pointers

- when we pass a pointer by reference, we are passing where it is stored in memory

- so we can change both
  – where it points to in memory

  and

  – the values that are stored there

Passing Pointers by Reference Example

```
void Reassign (int **ptr,
               int *newAddress) {
  *ptr = newAddress;
}
```

Passing Pointers by Reference Example

```
void Reassign (int **ptr,
                int *newAddress) {
   *ptr = newAddress;
}
int x = 3, y = 5;
int *intPtr = &x;
```

Passing Pointers by Reference Example

```
void Reassign (int **ptr,
               int *newAddress) {
  *ptr = newAddress;
}
int x = 3, y = 5;
int *intPtr = &x;
ReassignPointer (&intPtr, &y);
/* intPtr now points to y */
```

headPtr Naming Conventions

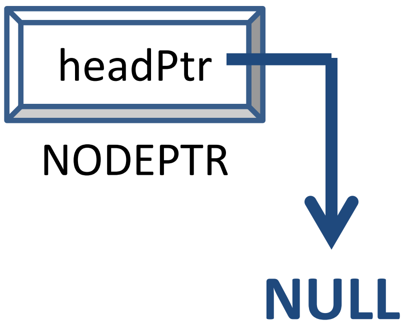
- two variable names for headPtr inside functions
- when we pass headPtr by value
  - we pass where it points to in memory
  - `NODEPTR head` = address of first node
- when we pass headPtr by reference
  - we pass where it's stored in memory
  - `NODEPTR *headPtr` = where headPtr is stored

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

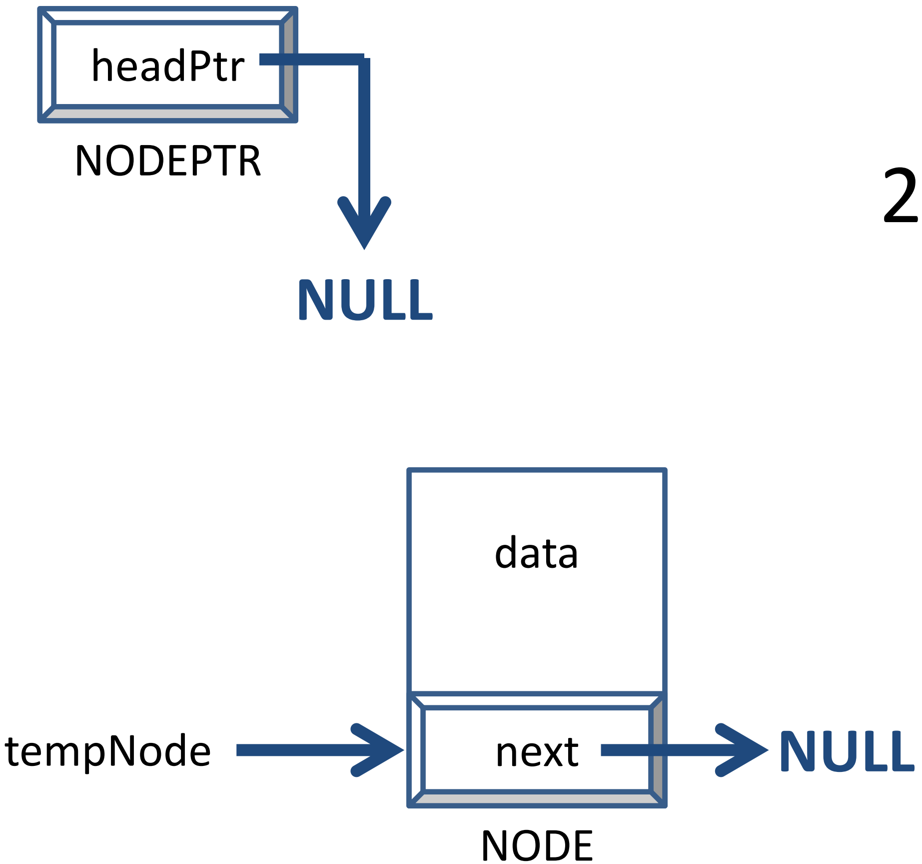
Building a Linked List from Scratch

Building a Linked List from Scratch



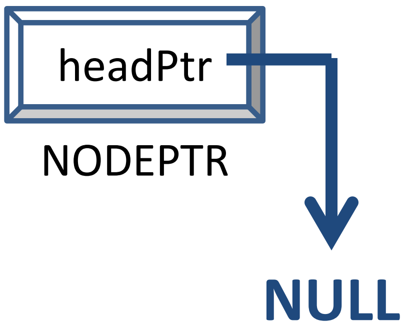
1. declare a headPtr, and set equal to NULL

Building a Linked List from Scratch

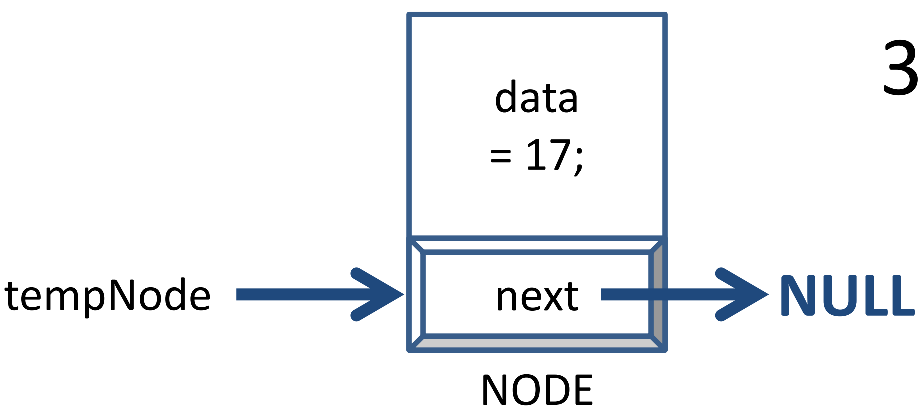


1. declare a headPtr, and set equal to NULL
2. allocate space for a node and set to a temporary variable

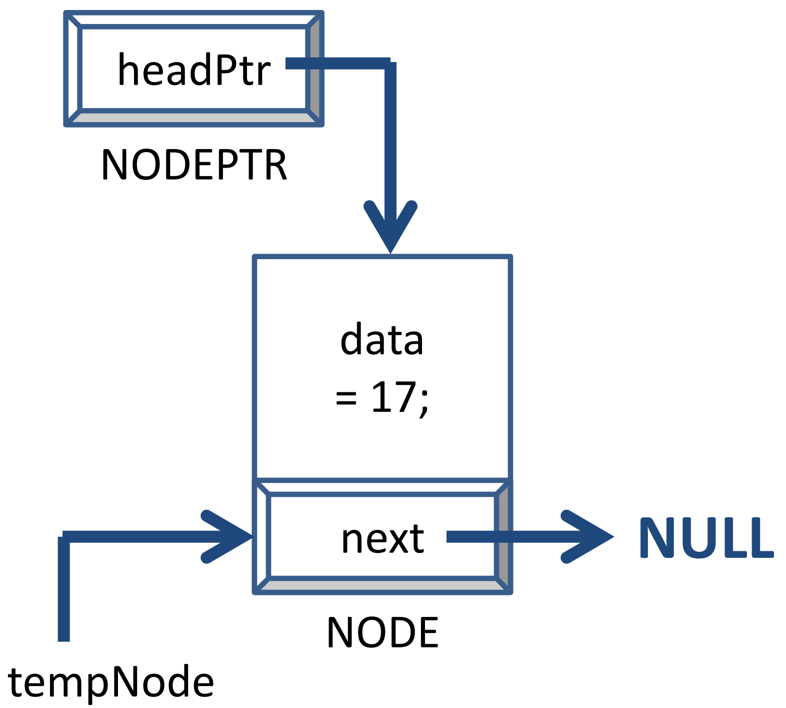
Building a Linked List from Scratch



1. declare a headPtr, and set equal to NULL
2. allocate space for a node and set to a temporary variable
3. initialize node's data



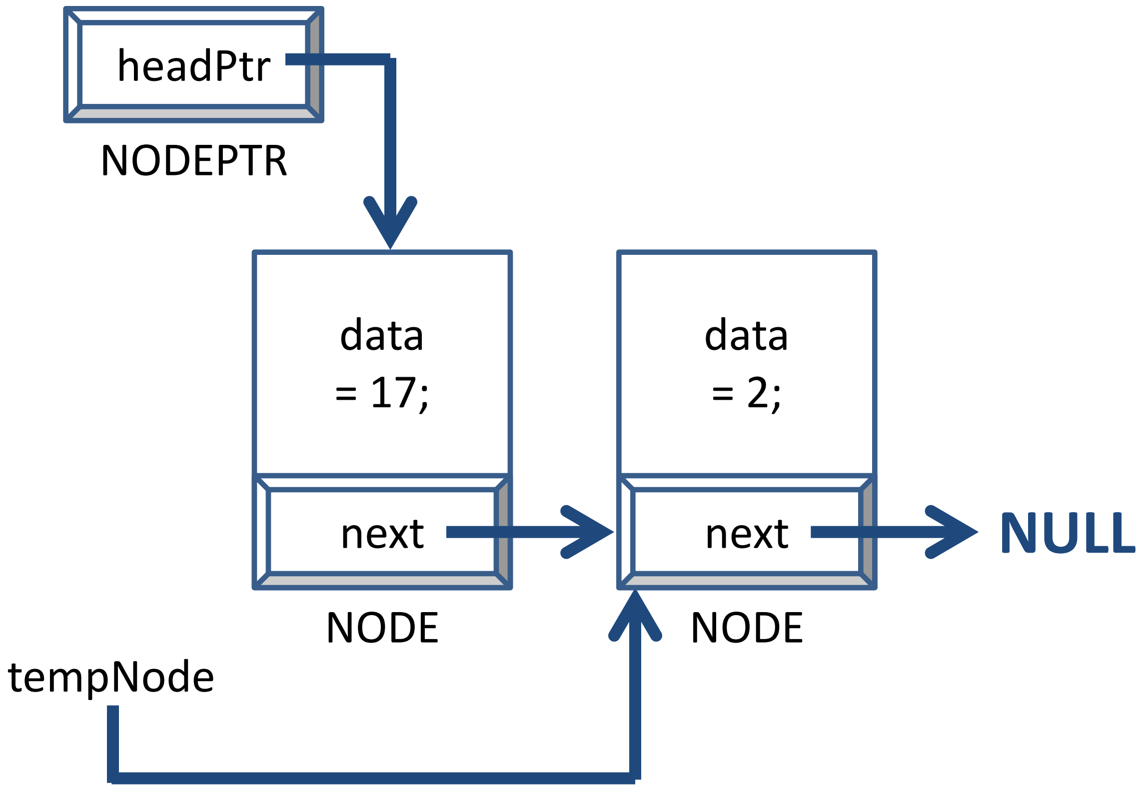
Building a Linked List from Scratch



1. declare a headPtr, and set equal to NULL
2. allocate space for a node and set to a temporary variable
3. initialize node's data
4. insert node in list

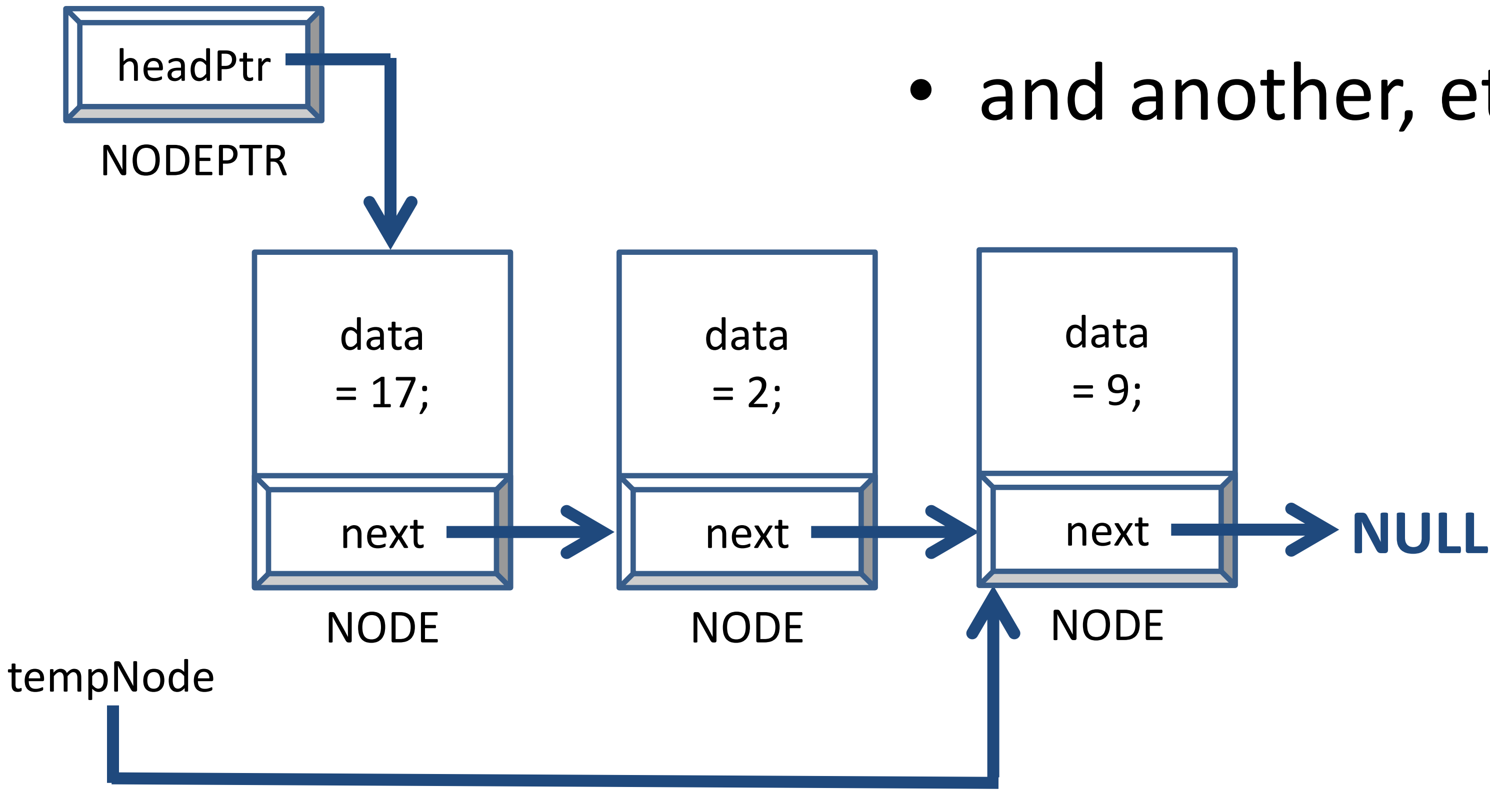
Building a Linked List from Scratch

- insert another node



Building a Linked List from Scratch

- insert another node
- and another, etc.



Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

Creating a Node

```
NODEPTR CreateNode (void)
```

1. create and allocate memory for a node

```
newNode = (NODEPTR) malloc (sizeof(NODE));
```

Creating a Node

```
NODEPTR CreateNode (void)
```

1. create and allocate memory for a node

```
newNode = (NODEPTR) malloc (sizeof(NODE));
```

– cast as NODEPTR, but space for NODE – why?

Creating a Node

```
NODEPTR CreateNode (void)
```

1. create and allocate memory for a node

```
newNode = (NODEPTR) malloc (sizeof(NODE));
```

– cast as NODEPTR, but space for NODE – why?

2. ensure that memory was allocated
3. initialize data

Setting a Node's Data

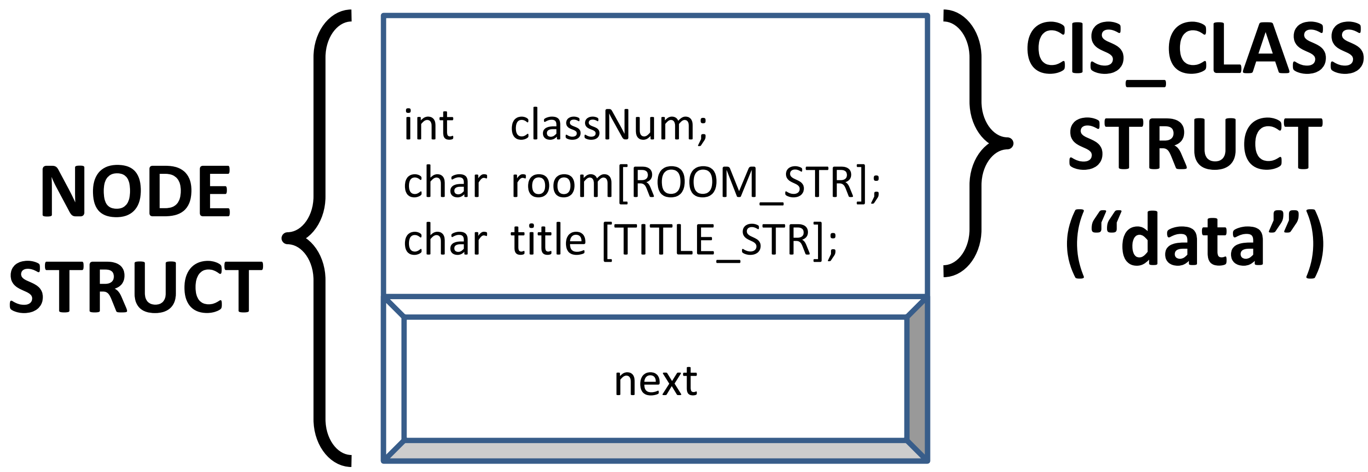
```
void SetData (NODEPTR temp,
              int data)
```

- temp is a pointer, but it points to a struct
  - use arrow notation to access elements
    - or dot star notation

```
  temp->data = data;
(*temp).data = data;
```

When “data” Itself is a Struct

```
typedef struct node {
    CIS_CLASS class;
    NODEPTR   next;
} NODE;
```



Setting Data when “data” is a Struct

```
void SetData (NODEPTR temp, int classNum,
              char room  [ROOM_STR],
              char title [TITLE_STR])

temp->class.classNum = classNum;
strcpy(temp->class.room,  room);
strcpy(temp->class.title, title);
```

- the `class` struct is not a pointer,
  so we can use just dot notation

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

Traversing a Linked List

- used for many linked list operations

- check to see if list is empty

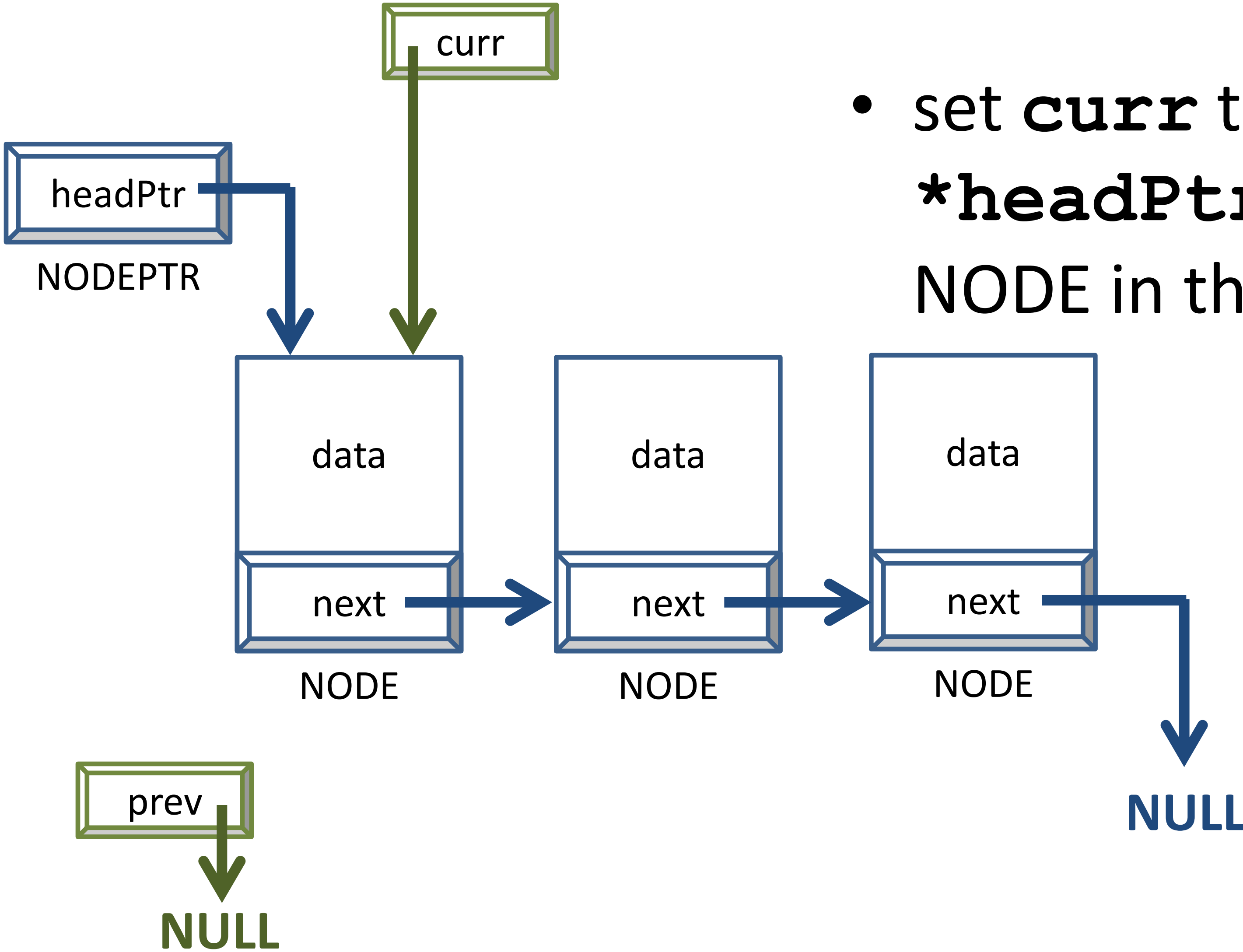
- use two temporary pointers to keep track of current and previous nodes (**`prev`** and **`curr`**)
- move through list, setting **`prev`** to **`curr`** and **`curr`** to the next element of the list
  - continue until you hit the end (or conditions met)

Special Cases with Linked Lists

- always a separate rule when dealing with the first element in the list (where headPtr points)
  - and a separate rule for when the list is empty

- laid out in the code available online, but keep it in mind whenever working with linked lists
  - make sure you understand the code before you start using it in your programs

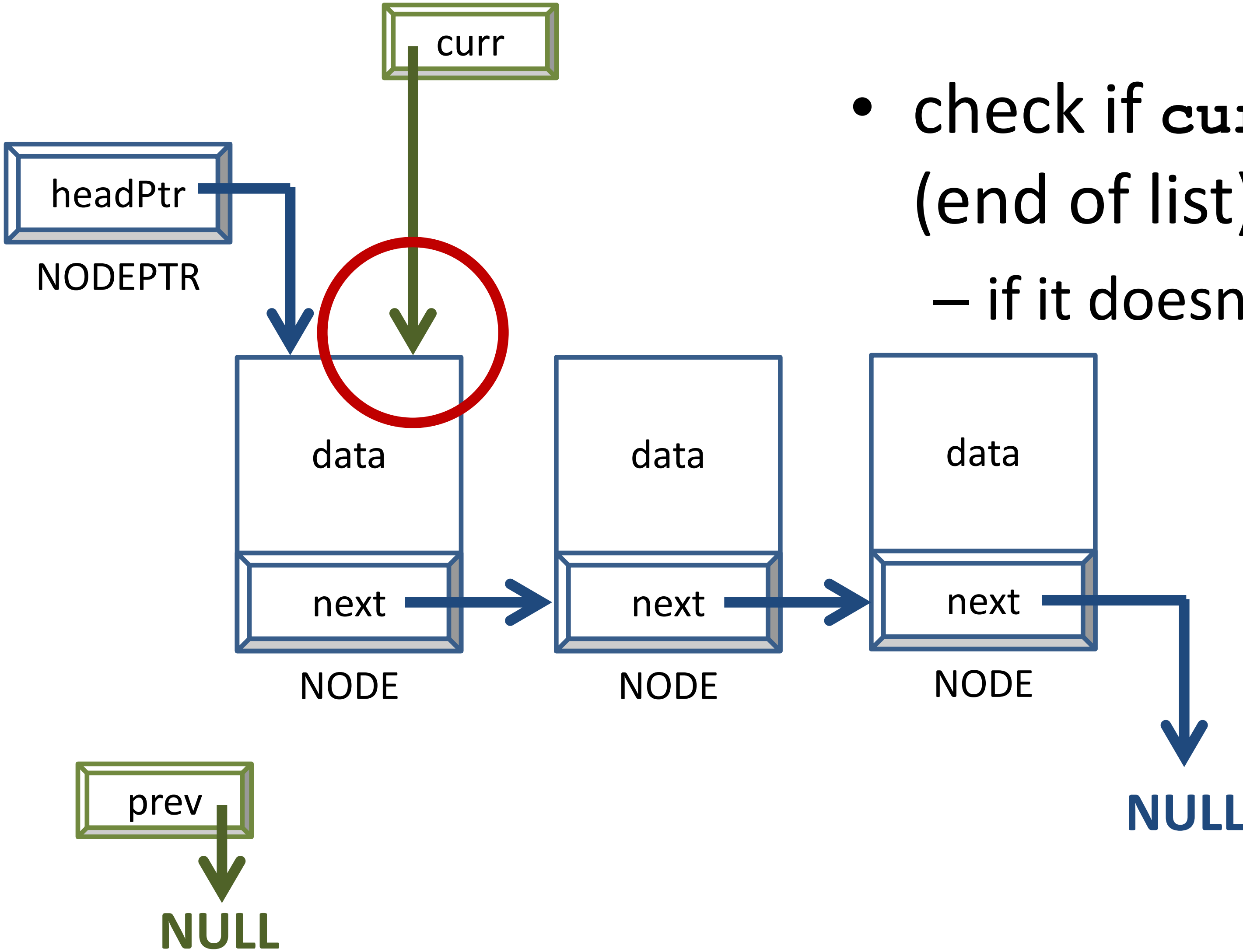
Traversing a Linked List – Step 1



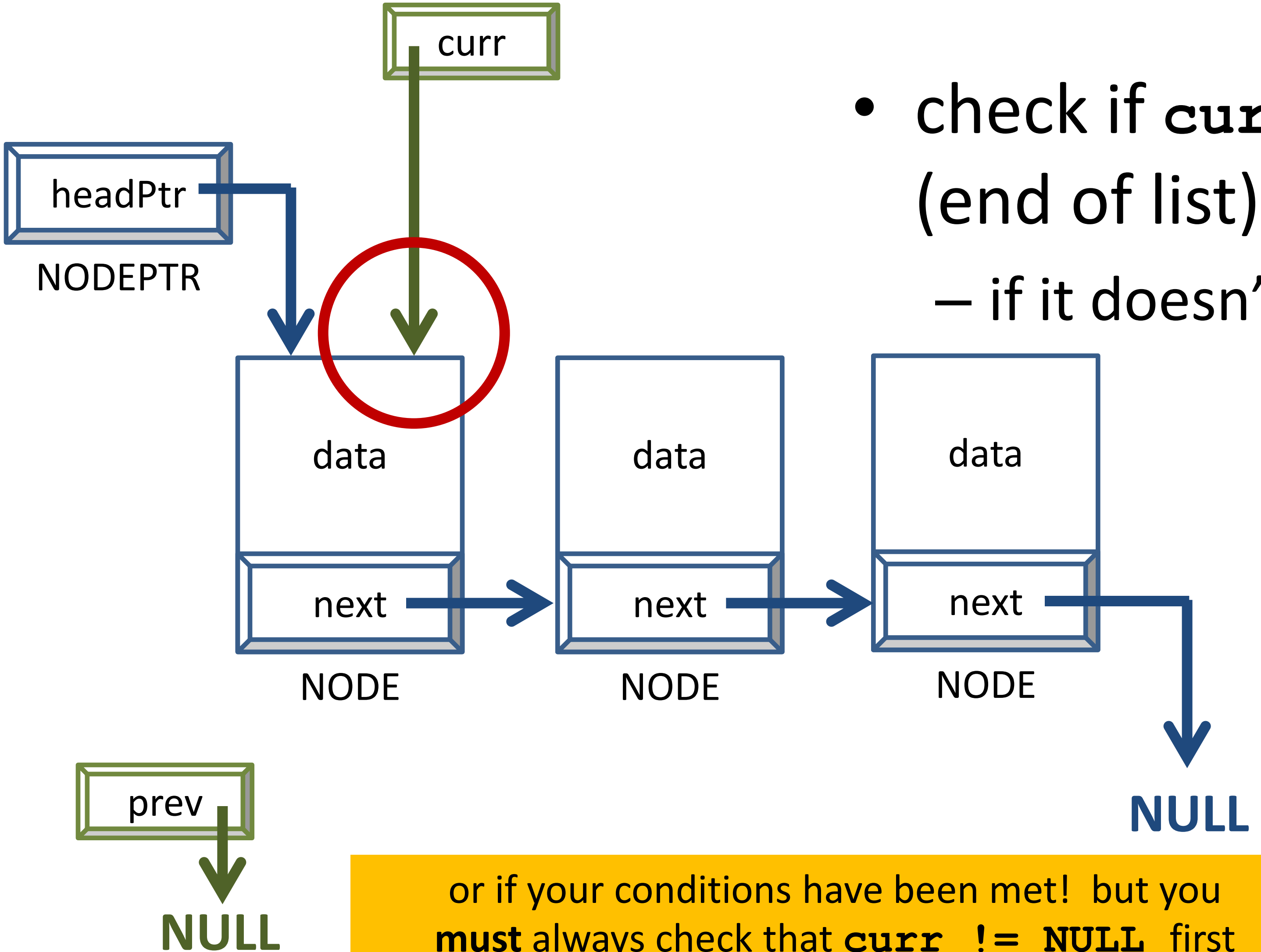
- set **`curr`** to **`*headPtr`**, the first NODE in the list

Traversing a Linked List – Step 2

- check if `curr == NULL` (end of list)
  - if it doesn't, continue



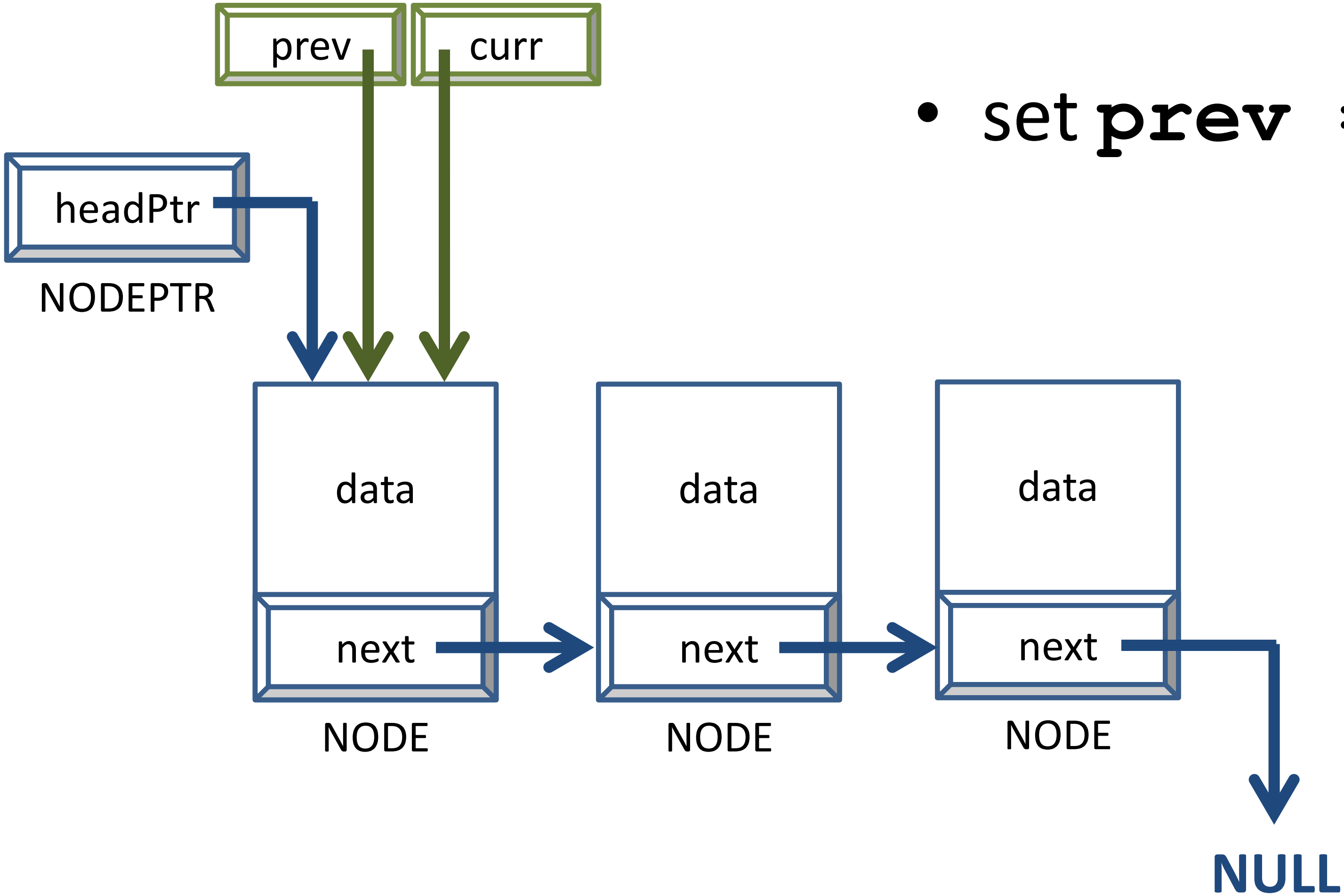
Traversing a Linked List – Step 2



- check if **`curr == NULL`** (end of list)
  - if it doesn't, continue

or if your conditions have been met! but you **must** always check that **`curr != NULL`** first

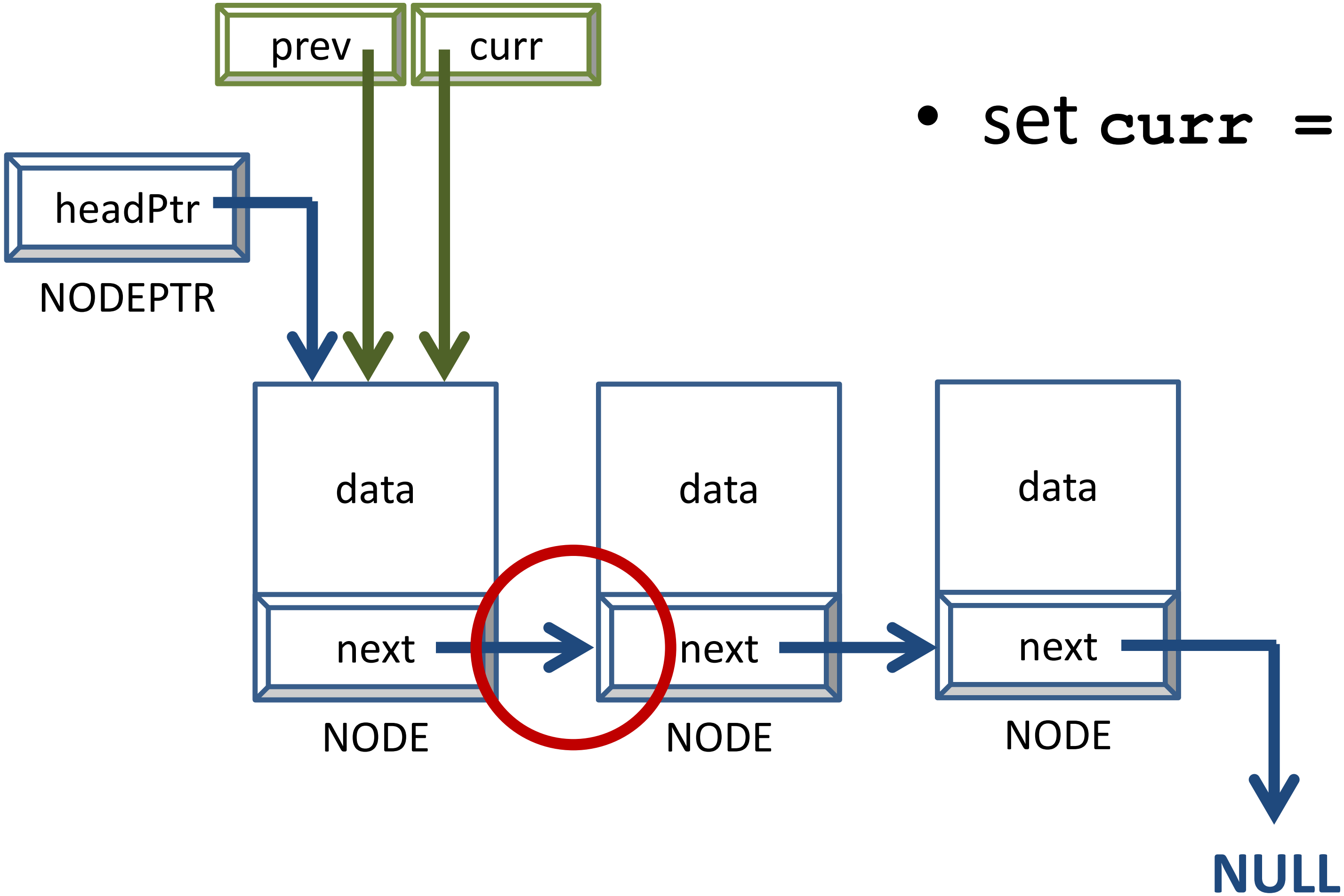
Traversing a Linked List – Step 3



- set `prev = curr`

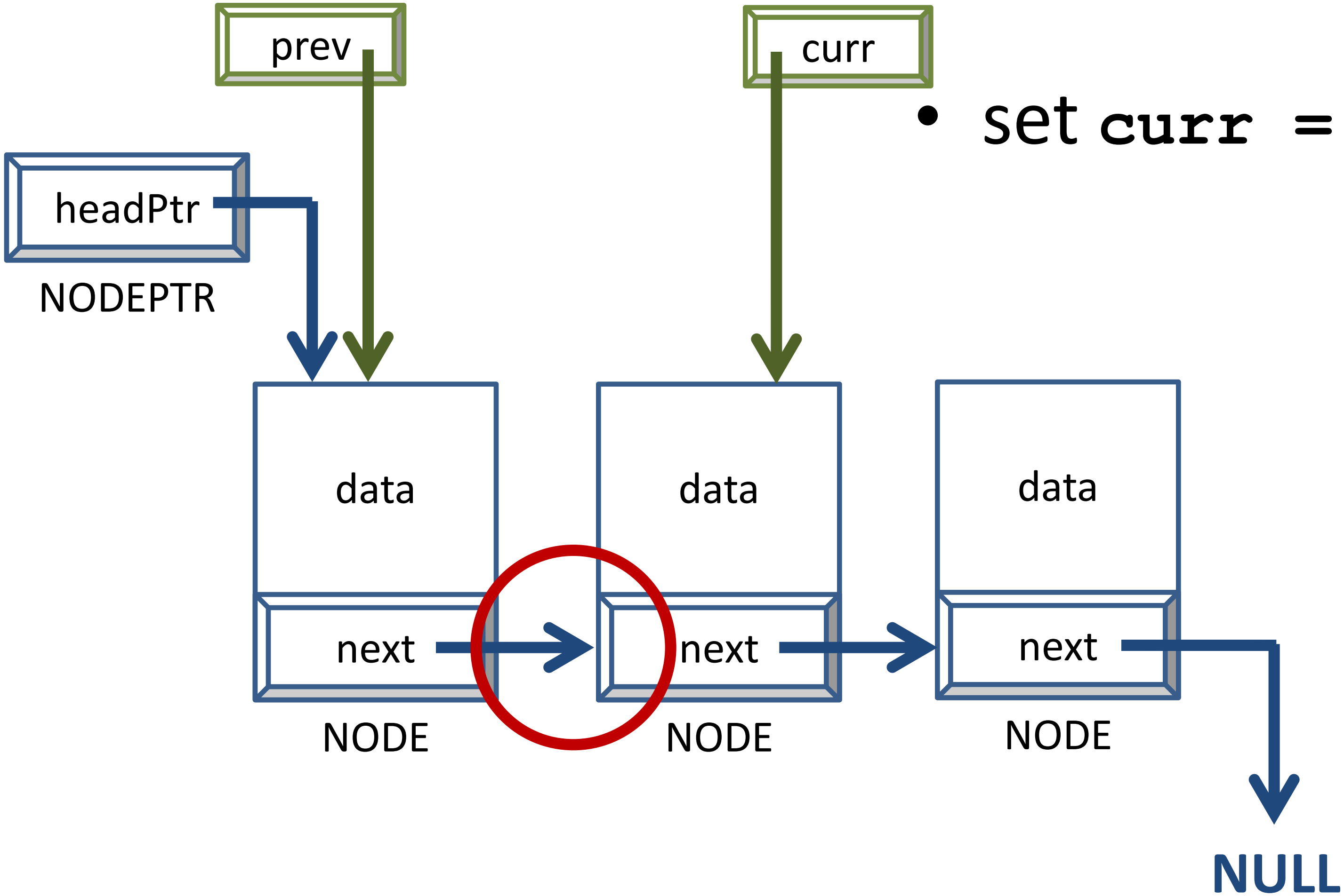
Traversing a Linked List – Step 4

- set `curr = curr->next`

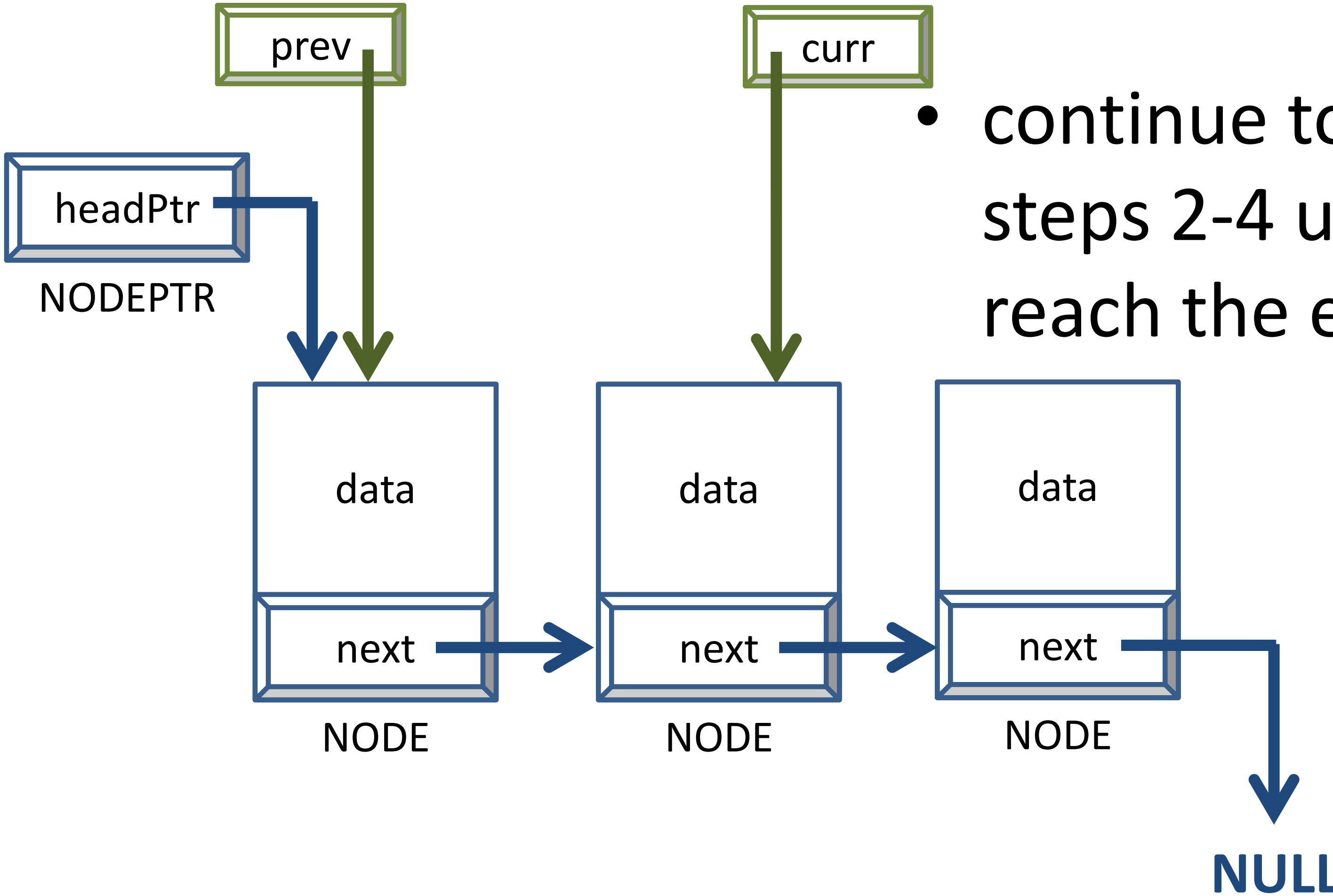


Traversing a Linked List – Step 4

- set `curr = curr->next`

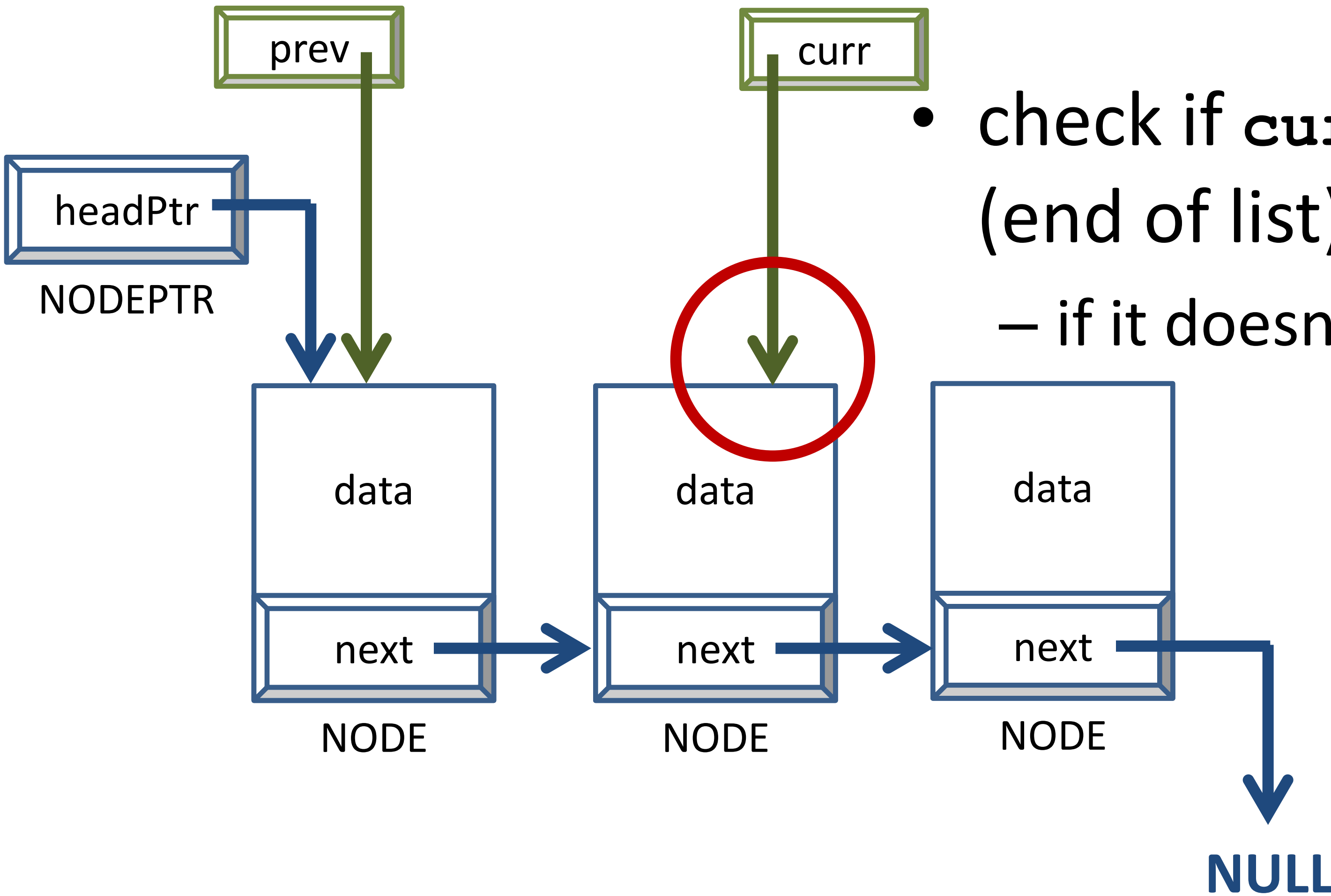


Traversing a Linked List – Step 5



- continue to repeat steps 2-4 until you reach the end

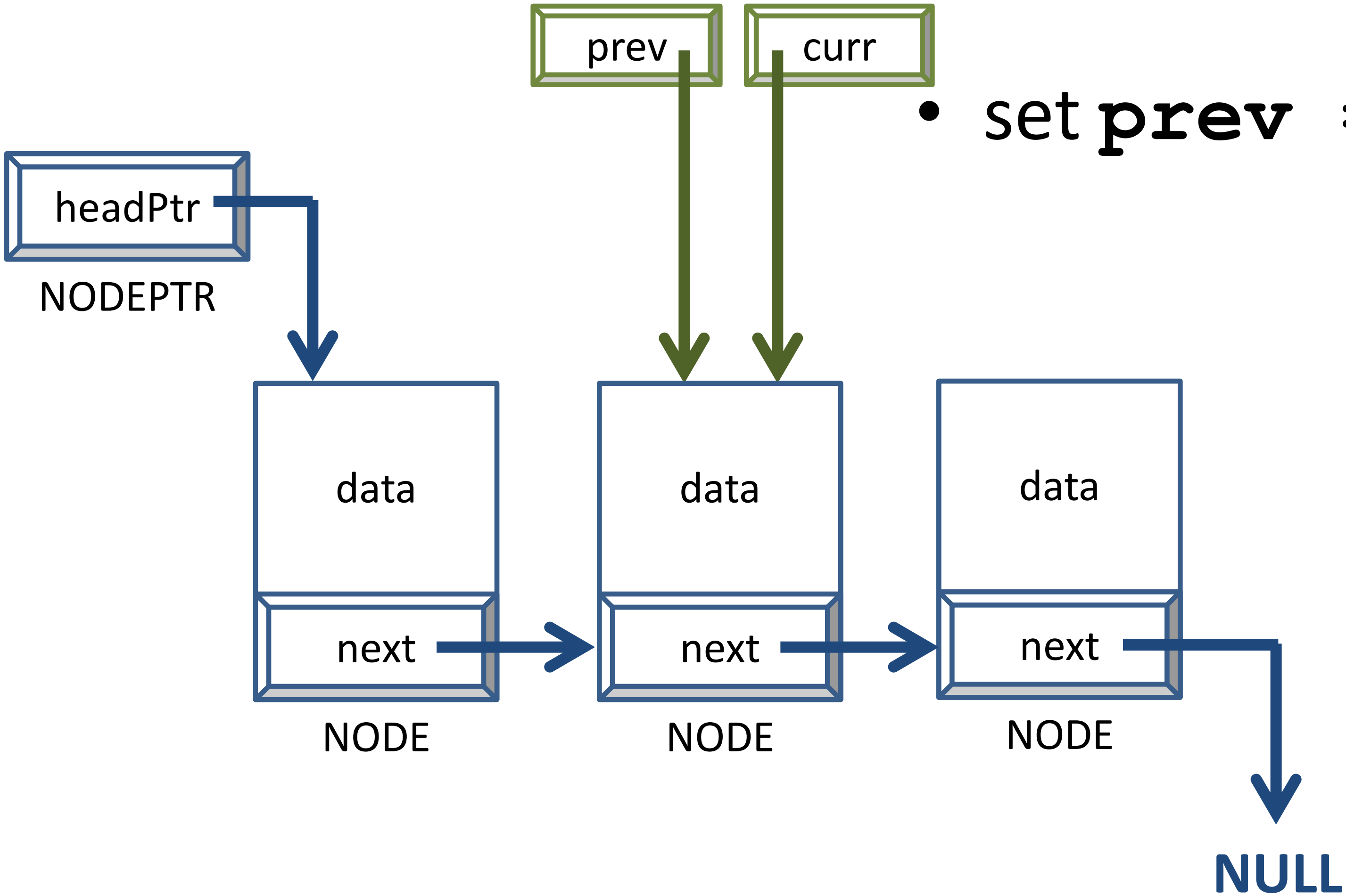
Traversing a Linked List – Step 5…



- check if **`curr == NULL`** (end of list)
  - if it doesn't, continue

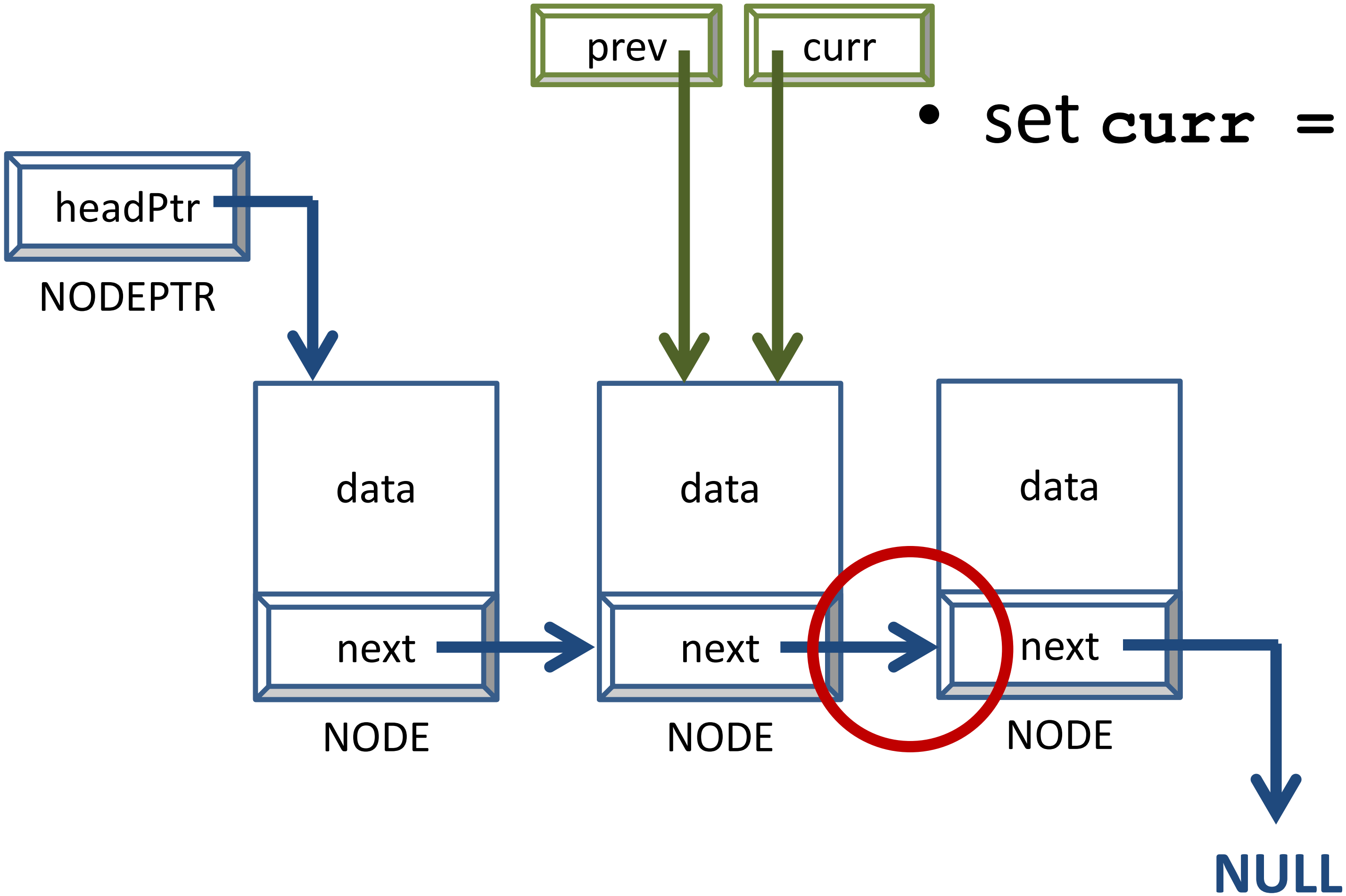
Traversing a Linked List – Step 5...

- set **`prev = curr`**



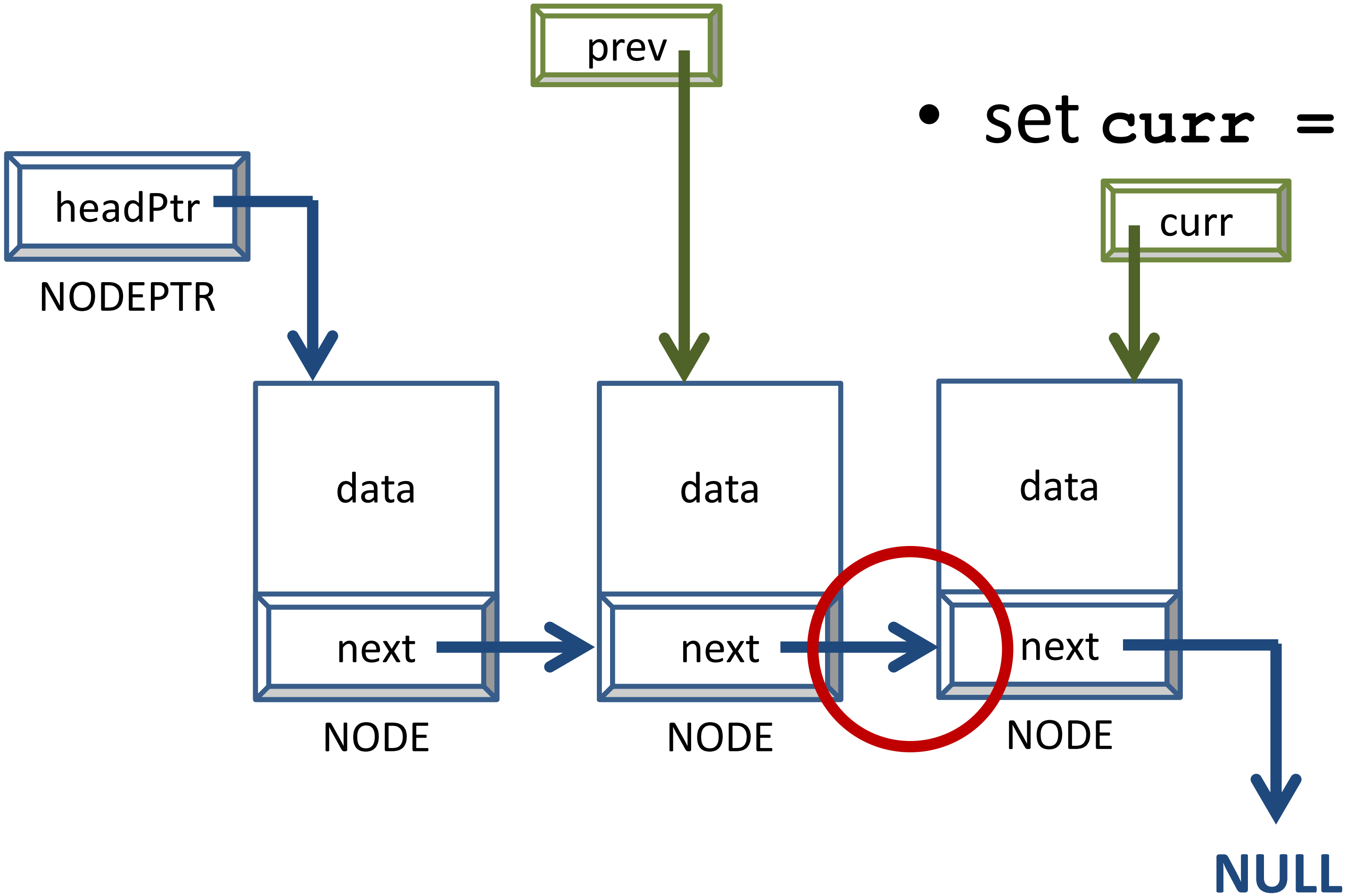
Traversing a Linked List – Step 5...

- set `curr = curr->next`



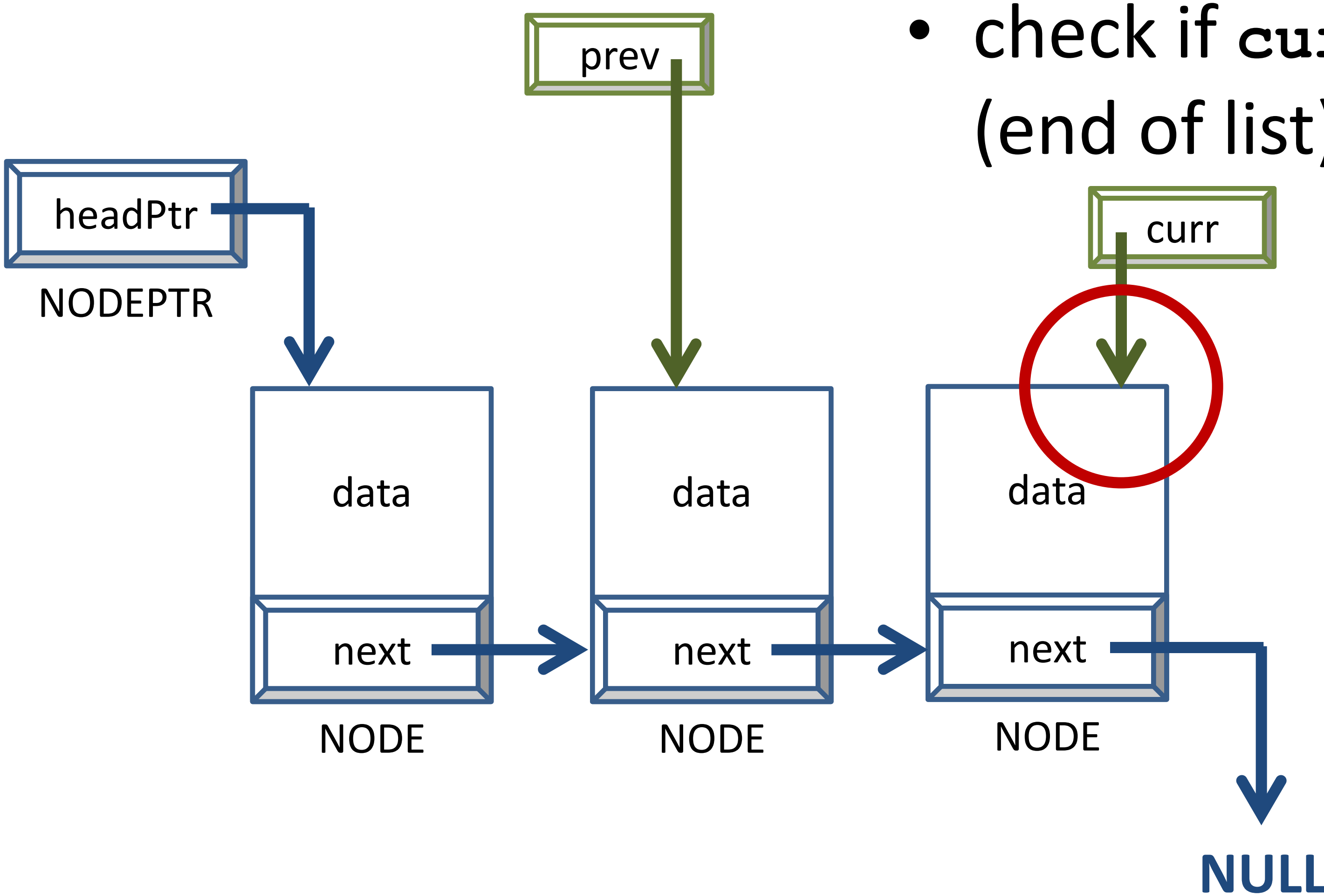
Traversing a Linked List – Step 5…

- set **`curr = curr->next`**



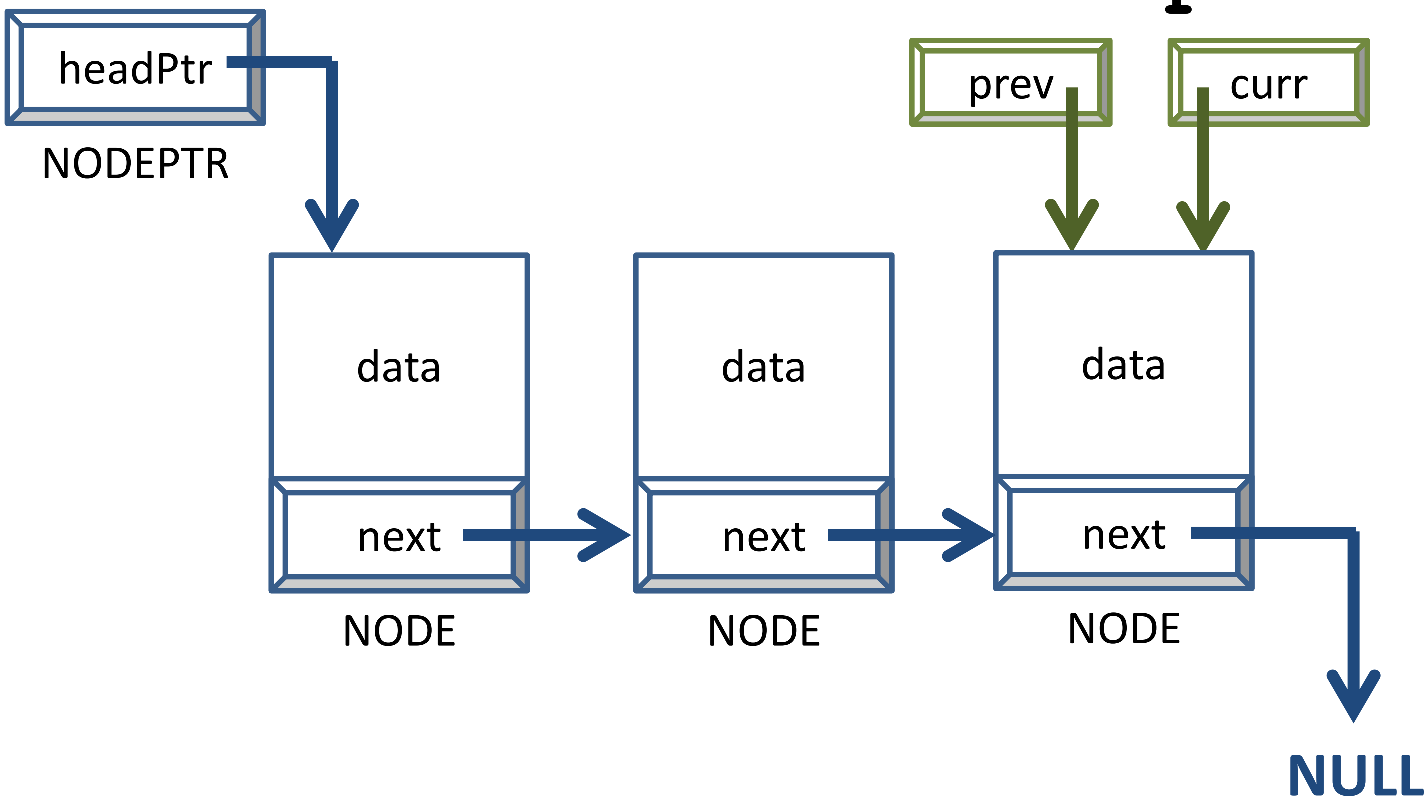
Traversing a Linked List – Step 5…

- check if **`curr == NULL`** (end of list)
  - if it doesn't, continue



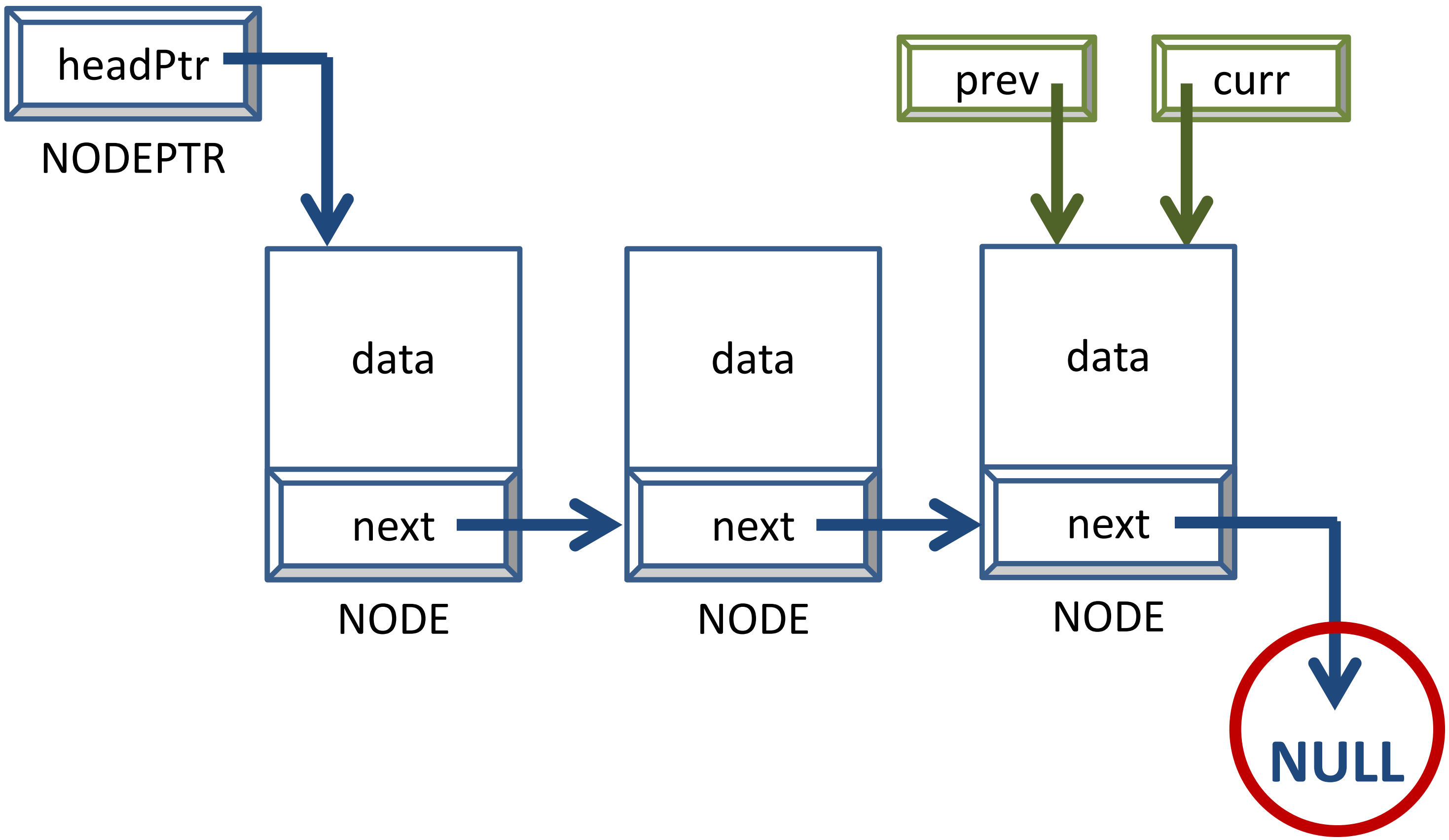
Traversing a Linked List – Step 5...

- set **`prev = curr`**



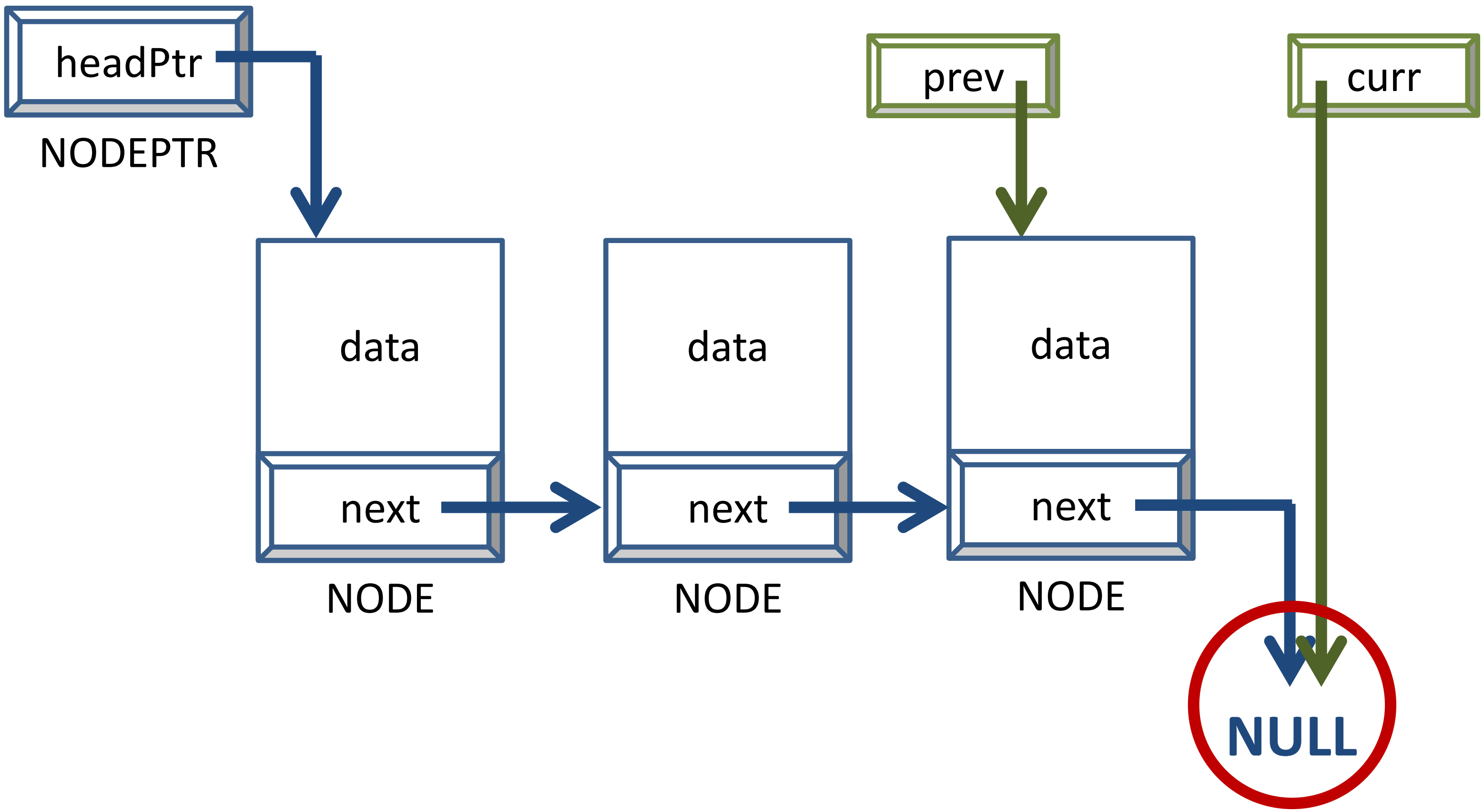
Traversing a Linked List – Step 5...

- set `curr = curr->next`



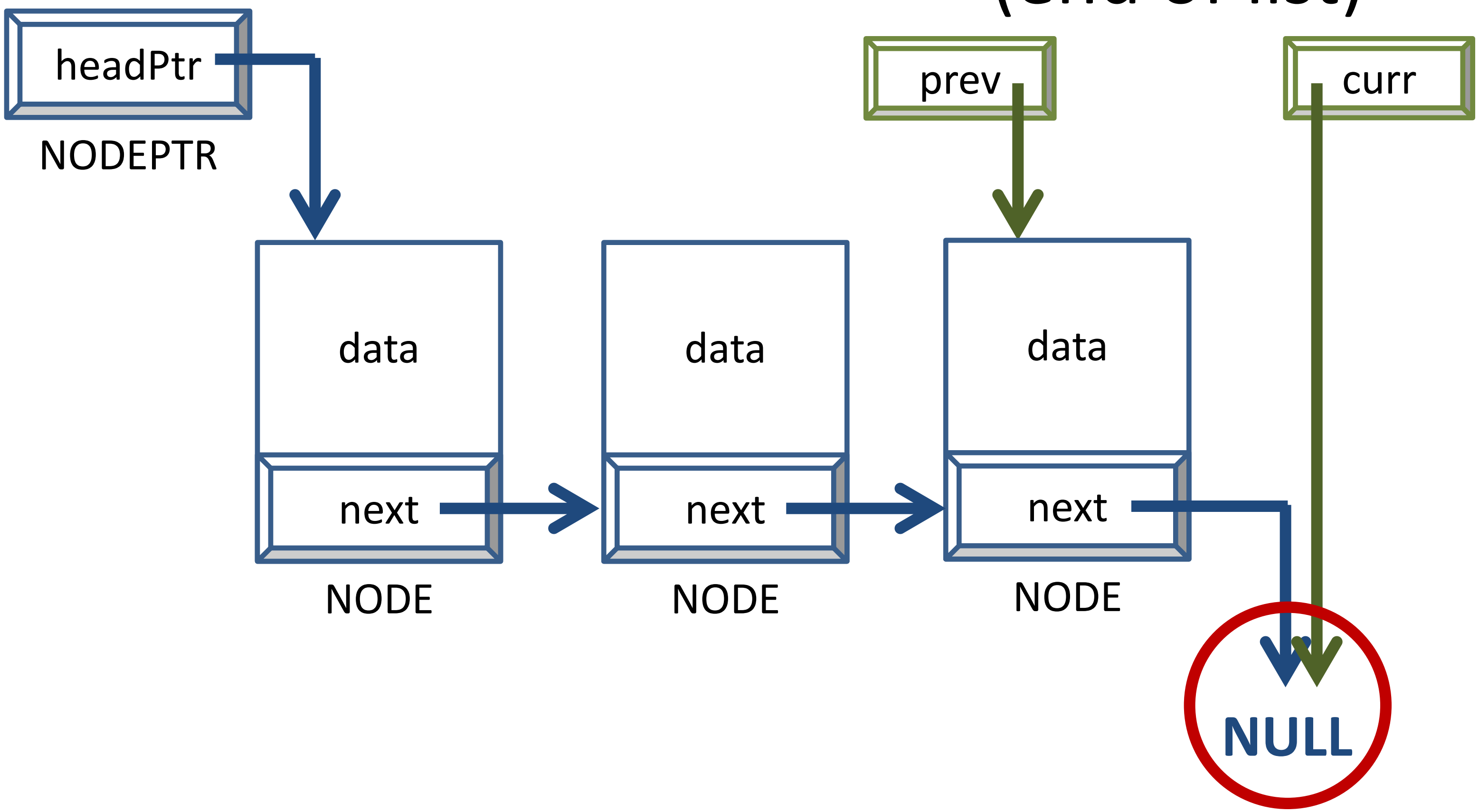
Traversing a Linked List – Step 5…

- set `curr = curr->next`



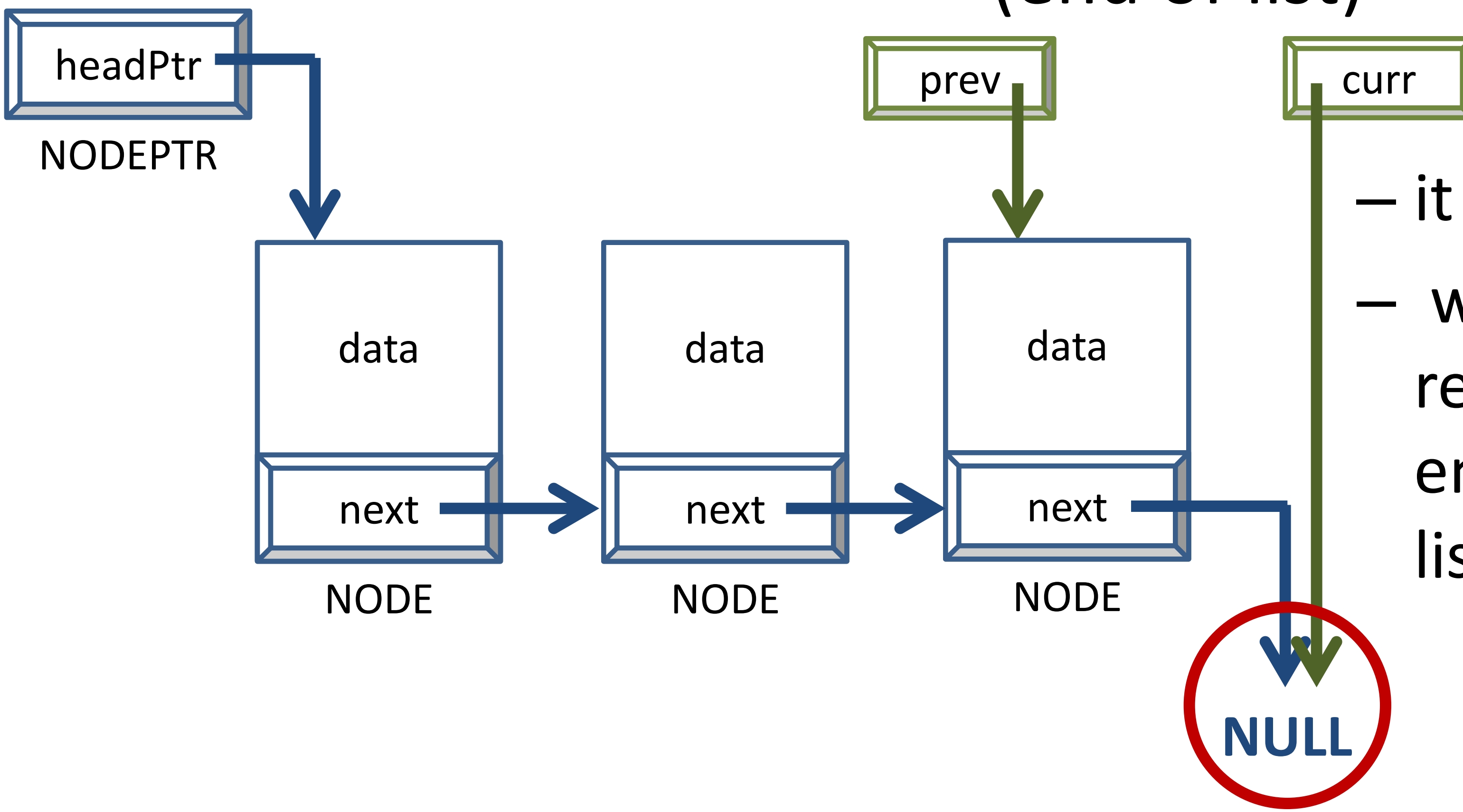
Traversing a Linked List – Step 5…

- check if **`curr == NULL`** (end of list)



Traversing a Linked List – Step 5…

- check if **`curr == NULL`** (end of list)



  - it does!
  - we've reached the end of the list

Printing the Entire Linked List

```
void PrintList (NODEPTR head)
```

- check to see if list is empty
  - if so, print out a message
- if not, traverse the linked list
  - print out the data of each node

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

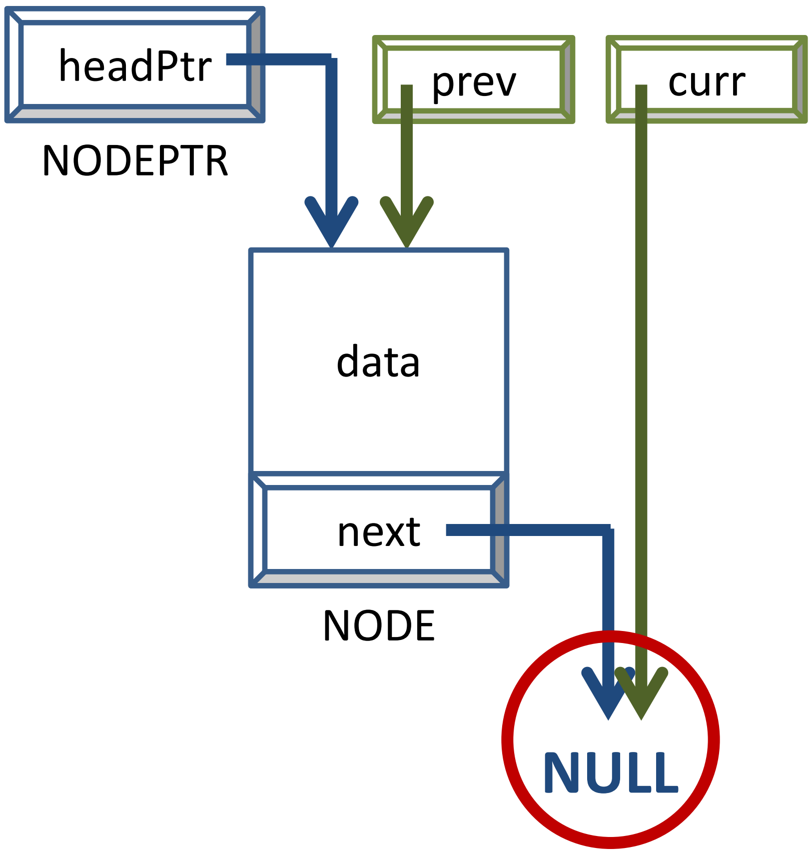
Inserting a Node

```
void Insert (NODEPTR *headPtr,
             NODEPTR  temp)
```

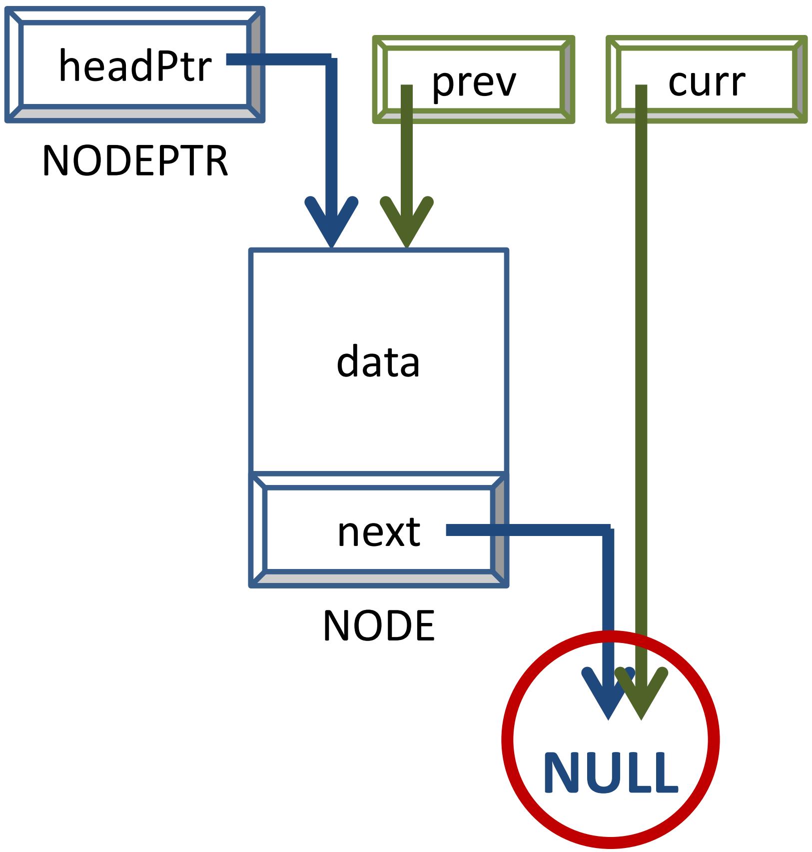
- check if list is empty
  - if so, temp becomes the first node
- if list is not empty
  - traverse the list and insert temp at the end

Inserting a Node

- check if **`curr == NULL`** (end of list)

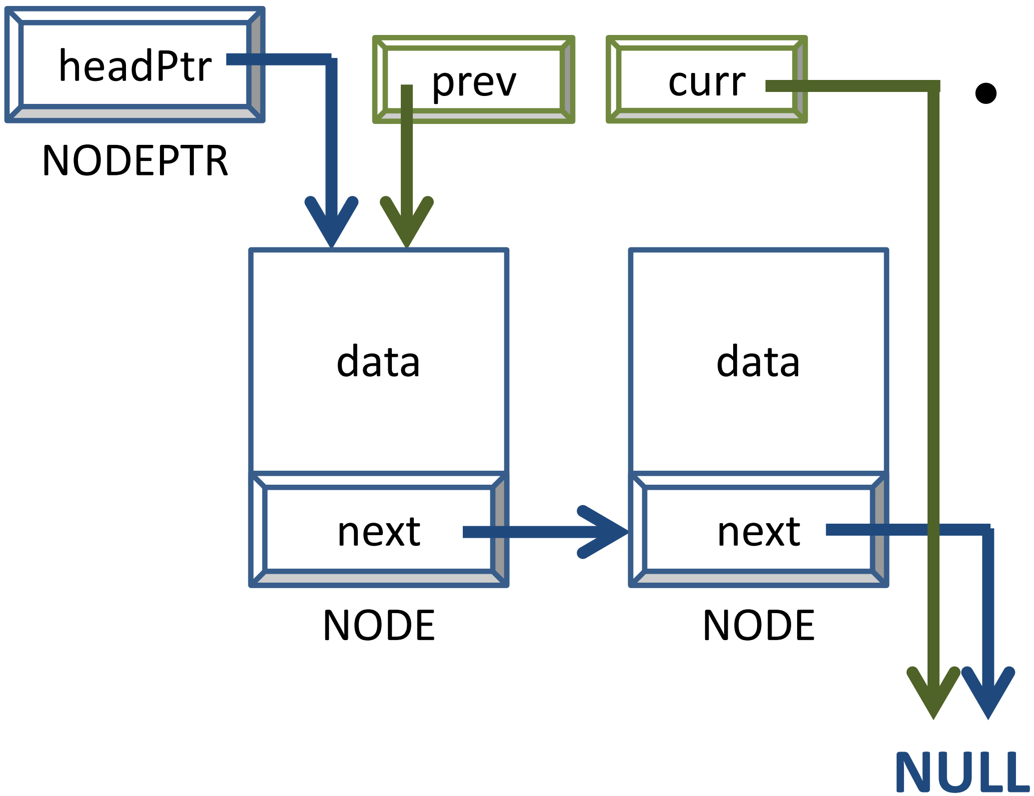


Inserting a Node



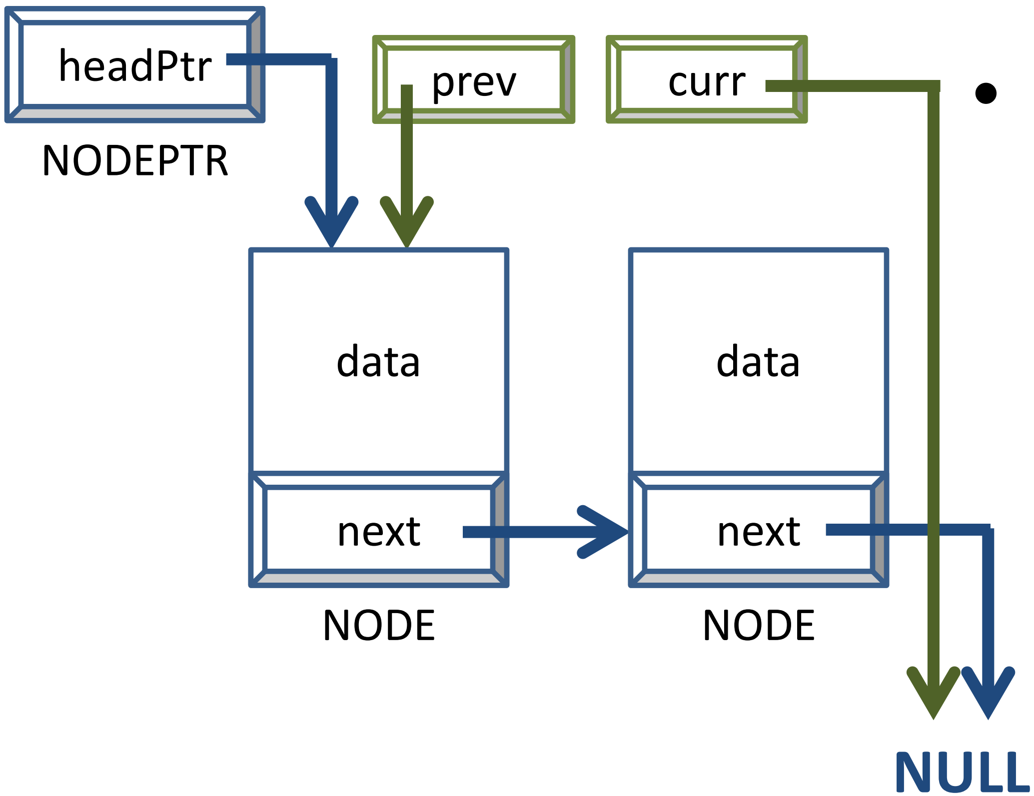
- check if **`curr == NULL`** (end of list)
- insert the new node by changing where **`prev->next`** points to

Inserting a Node



- check if `curr == NULL` (end of list)
- insert the new node by changing where `prev->next` points to
  - address of new node

Inserting a Node



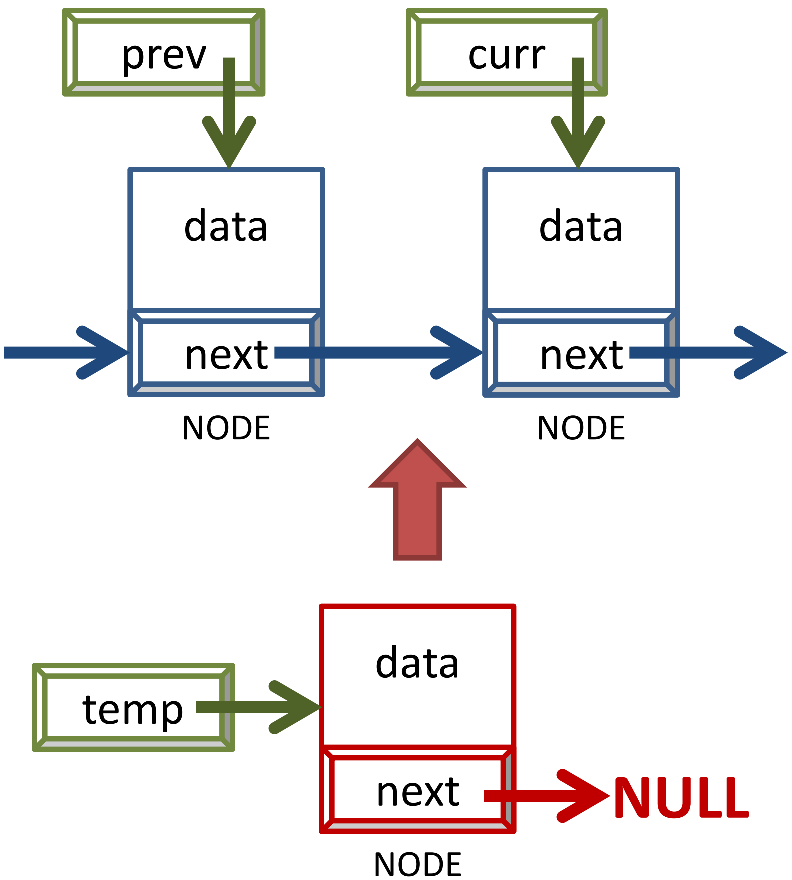
- check if `curr == NULL` (end of list)
- insert the new node by changing where `prev->next` points to
  - address of new node
- new node is successfully inserted at end of the list!

Inserting a Node in the Middle

```
int  Insert (NODEPTR *headPtr,
             NODEPTR  temp,
             int where)
```

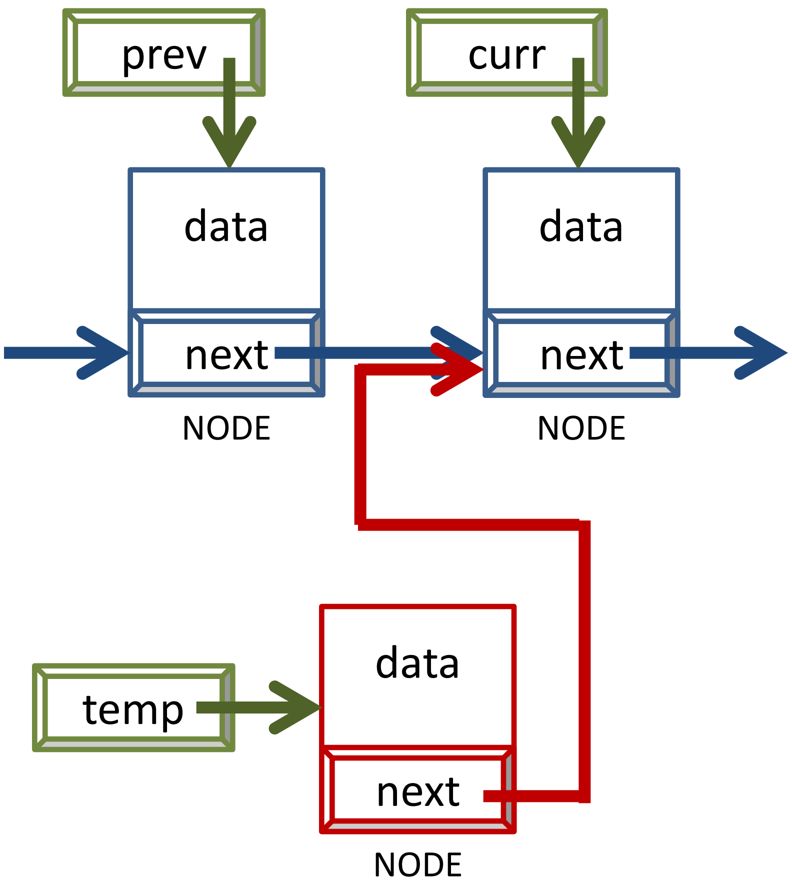
- traverse list until you come to place to insert
  - CAUTION: don't go past the end of the list!
- insert temp at appropriate spot
  - CAUTION: don't "lose" any pointers!
- return an integer to convey success/failure

Inserting a Node – Step 1



- traverse the list until you find where you want to insert temp

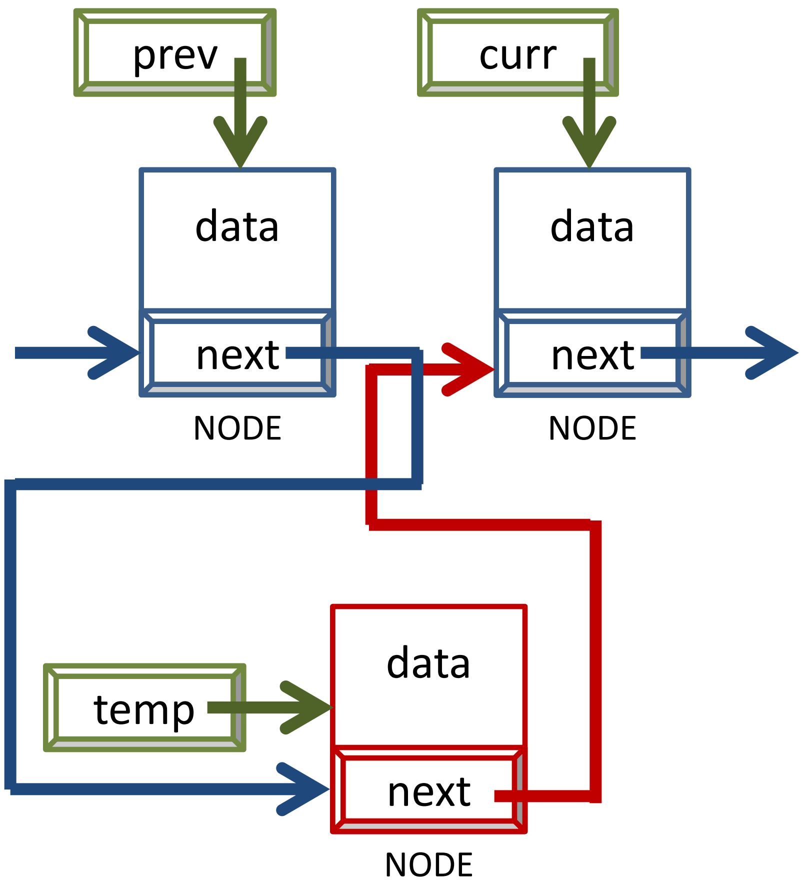
Inserting a Node – Step 2



- first have **`temp->next`** point to what will be the node following it in the list (**`curr`**)

```
temp->next = curr;
```

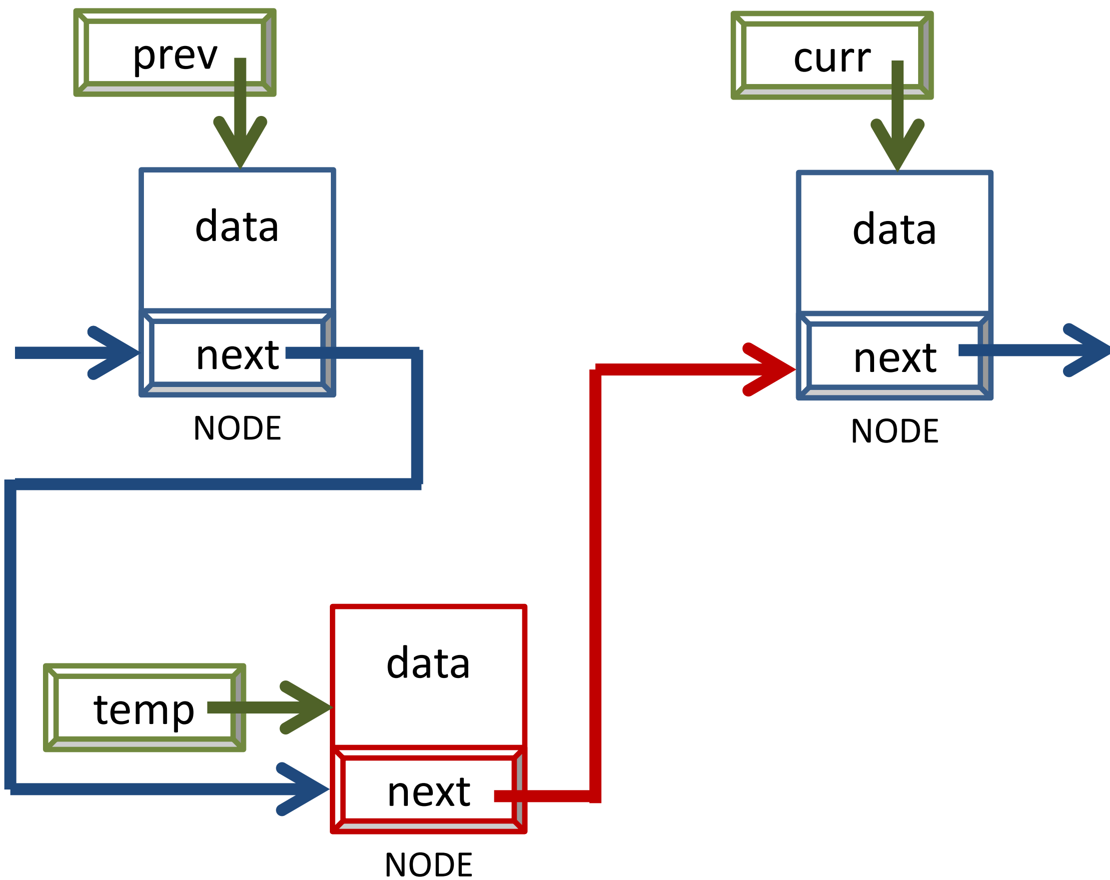
Inserting a Node – Step 3



- then you can have **`prev->next`** point to **`temp`** as the new next node in the list

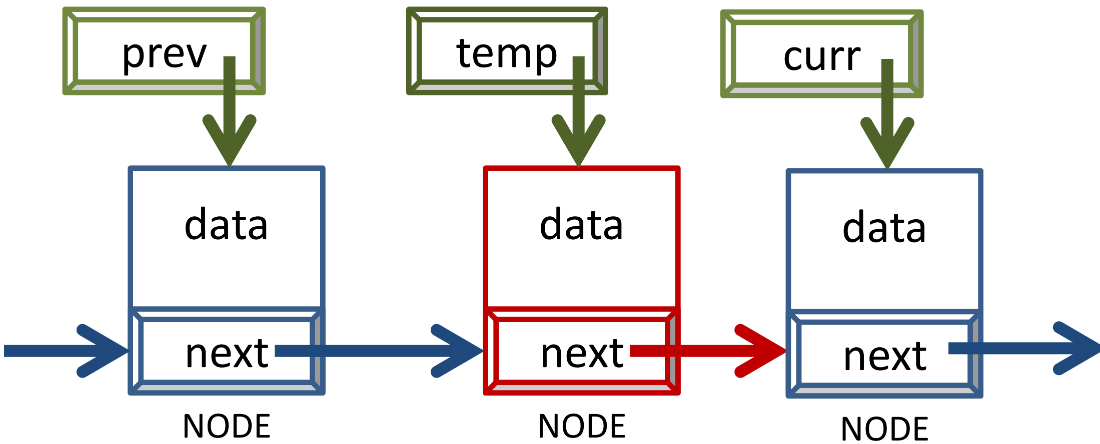
```
prev->next = temp;
```

Inserting a Node – Done



- **`temp`** is now stored in the list between **`prev`** and **`curr`**

Inserting a Node – Done



- **`temp`** is now stored in the list between **`prev`** and **`curr`**
  - return a successful code (insert worked)

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

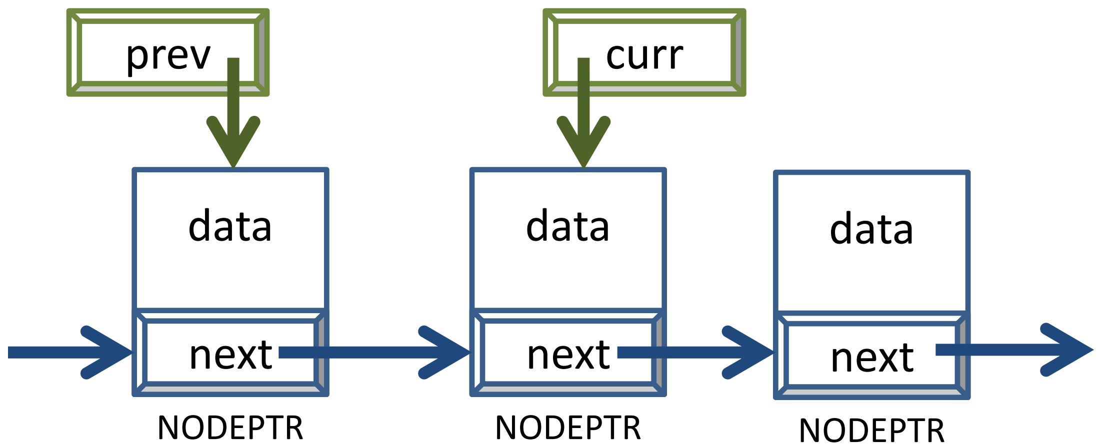
Deleting a Node

```
int Delete (NODEPTR *headPtr,
                  int target)
```

- code is similar to insert
- pass in a way to find the node you want to delete
  - traverse list until you find the correct node:

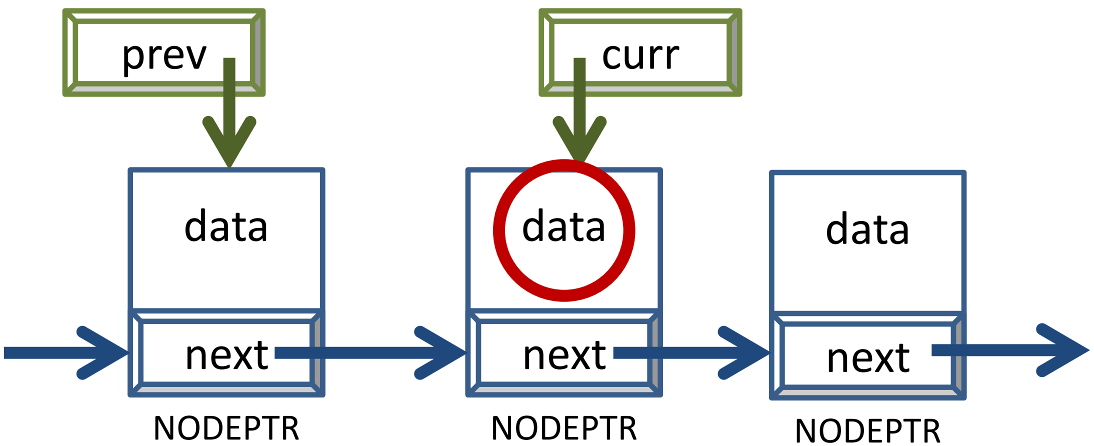
    ```
    curr->data == target
    ```
- return an integer to convey success/failure

Deleting a Node – Step 1



- traverse the list, searching until **`curr->data`** matches **`target`**

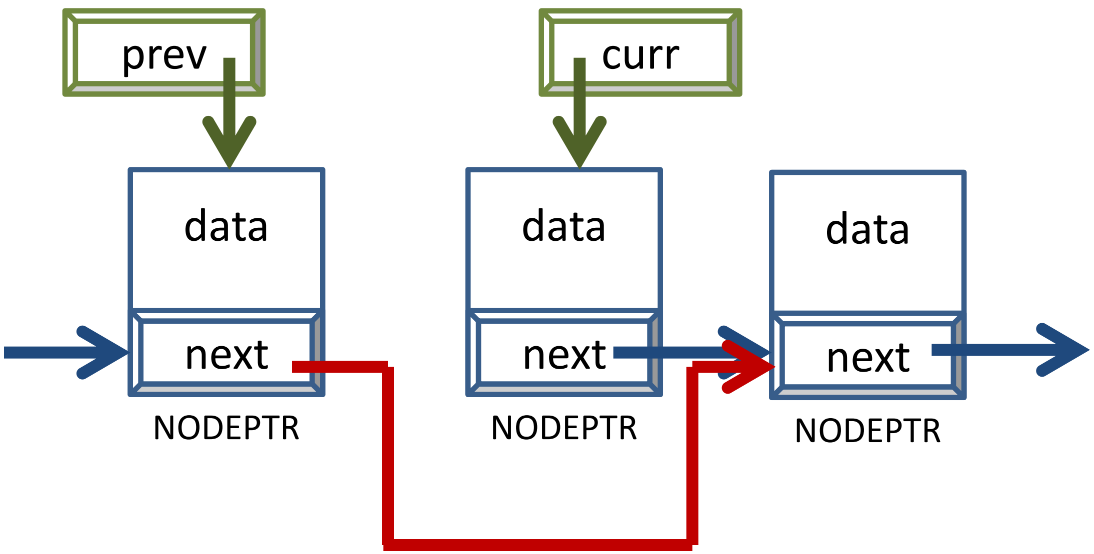
Deleting a Node – Step 1



- traverse the list, searching until **`curr->data`** matches **`target`**

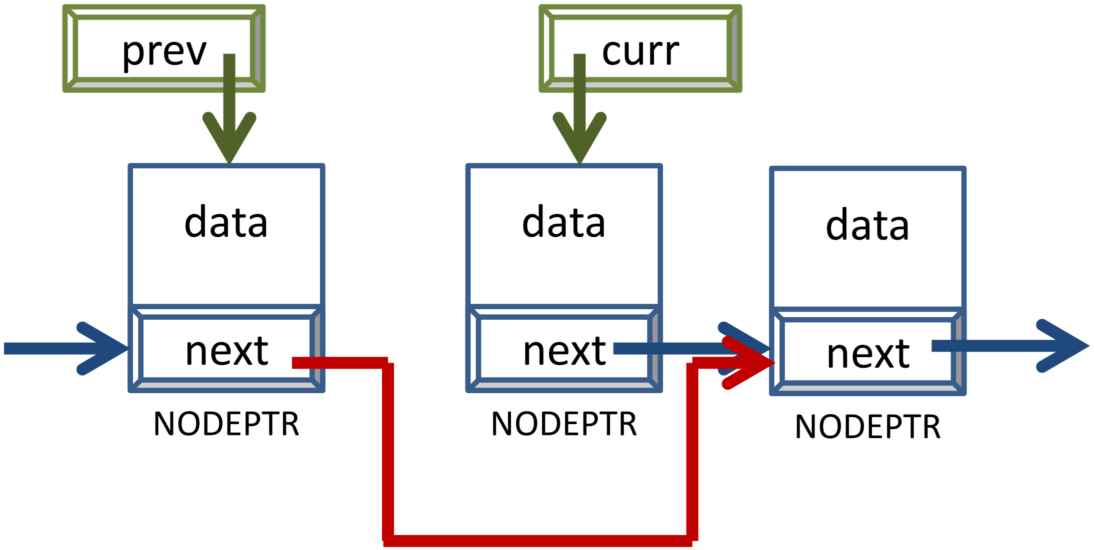
but don't forget, you **must** always check that **`curr != NULL`** first

Deleting a Node – Step 2



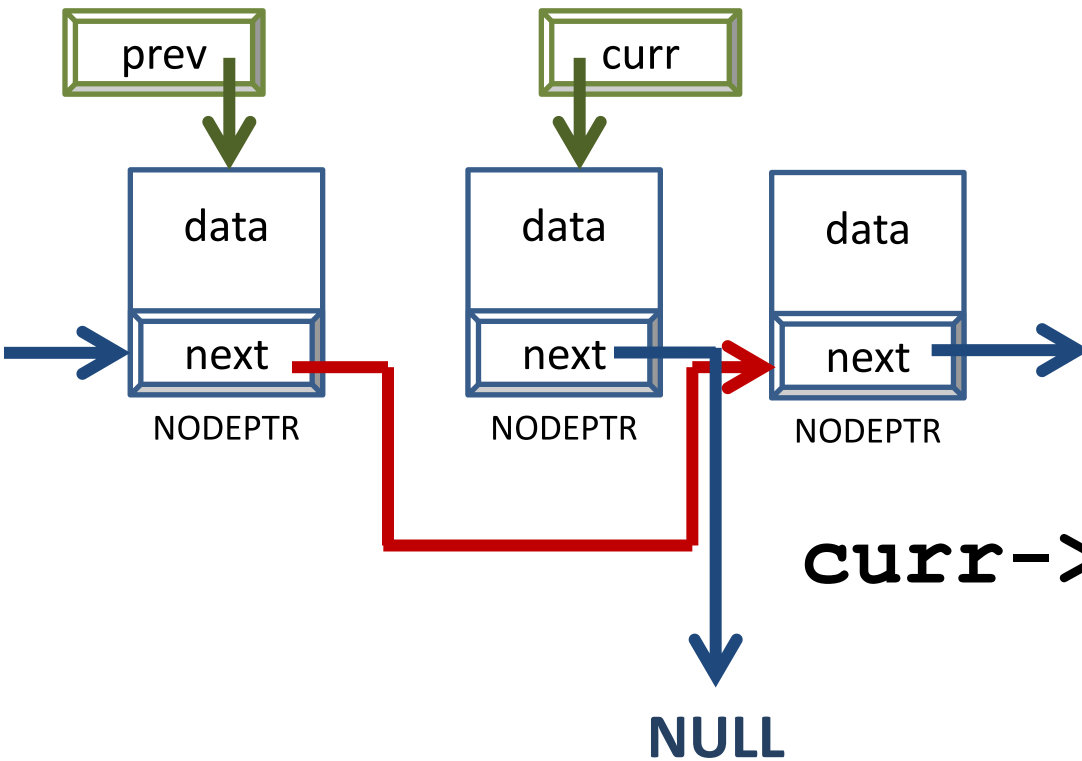
- "remove" **`curr`** from the list by setting **`prev->next`** to **`curr->next`**

Deleting a Node – Step 3



- free the memory used by **`curr`** and set pointers to NULL

Deleting a Node – Step 3

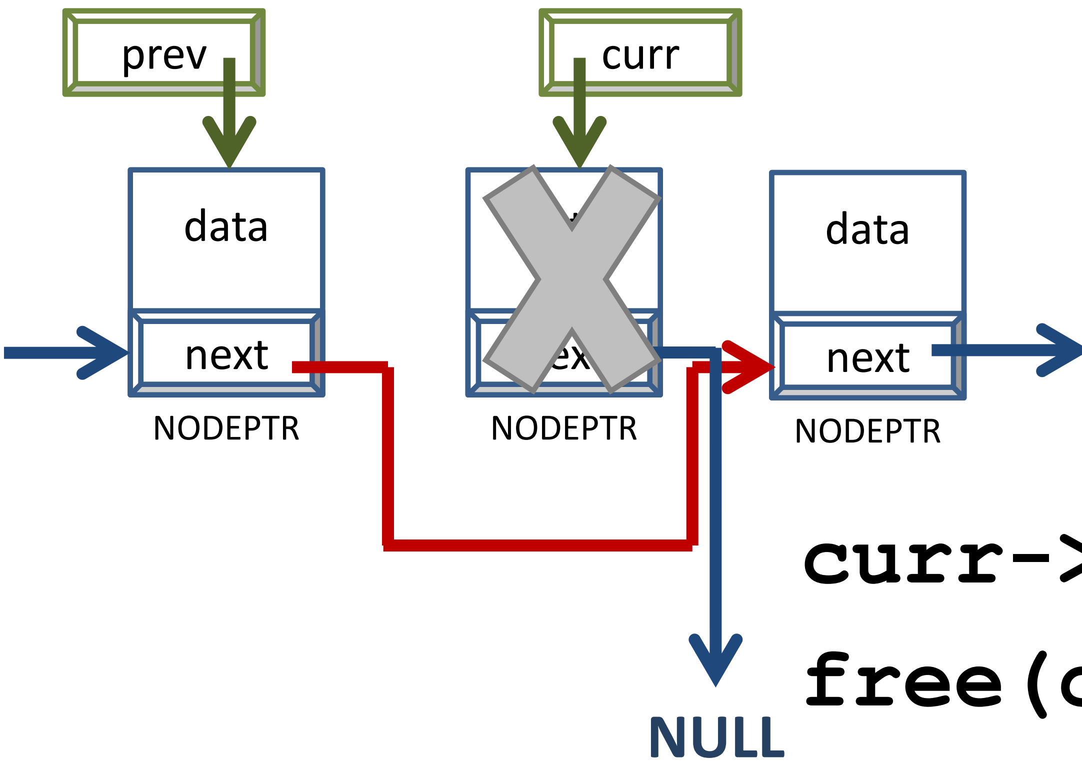


- free the memory used by **`curr`** and set pointers to NULL

```
curr->next = NULL;
```

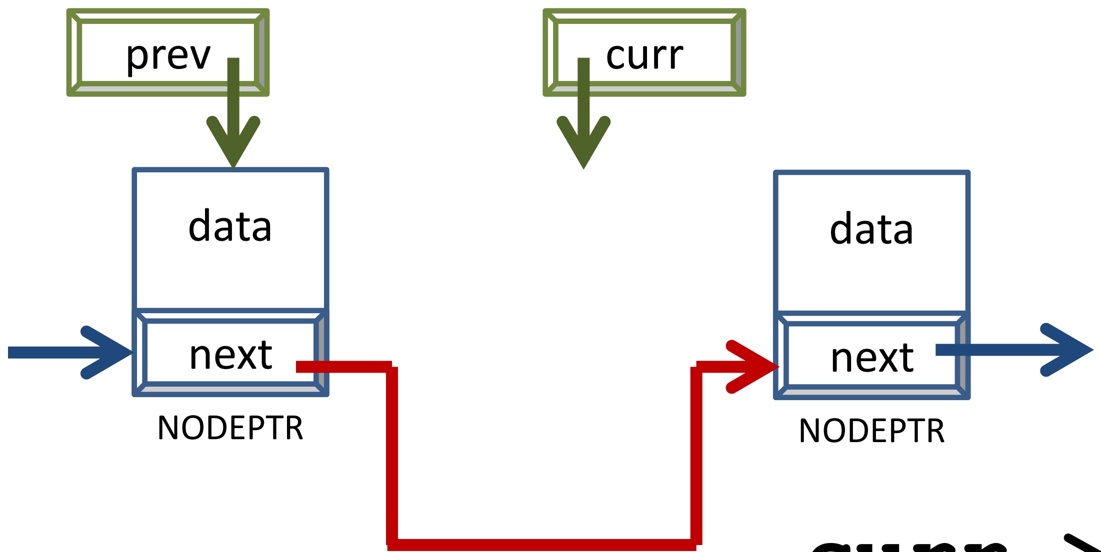
Deleting a Node – Step 3

- free the memory used by **`curr`** and set pointers to NULL




```
curr->next = NULL;
free(curr);
```

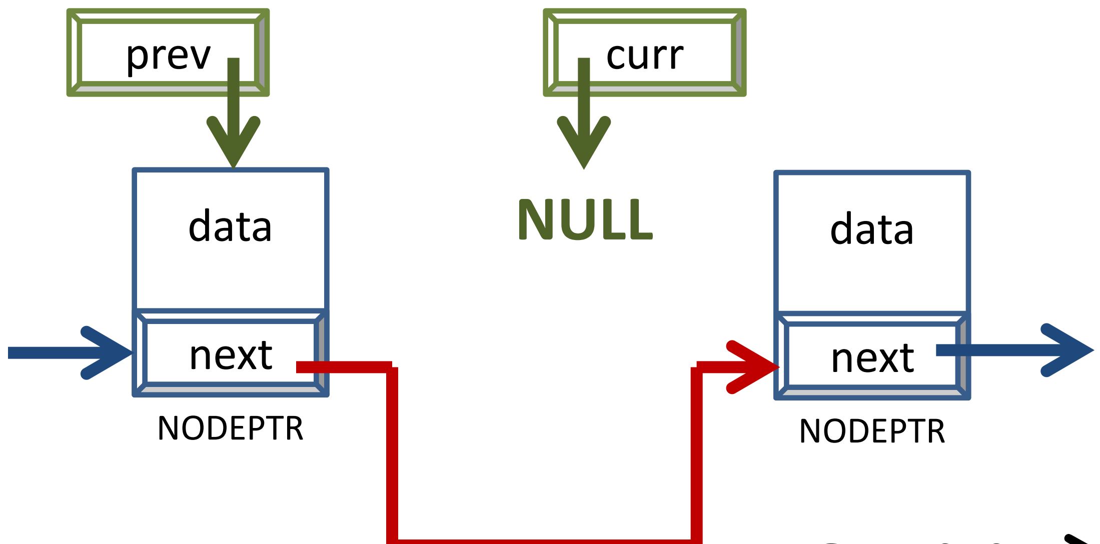
Deleting a Node – Step 3



- free the memory used by **`curr`** and set pointers to NULL

```
curr->next = NULL;
free(curr);
```

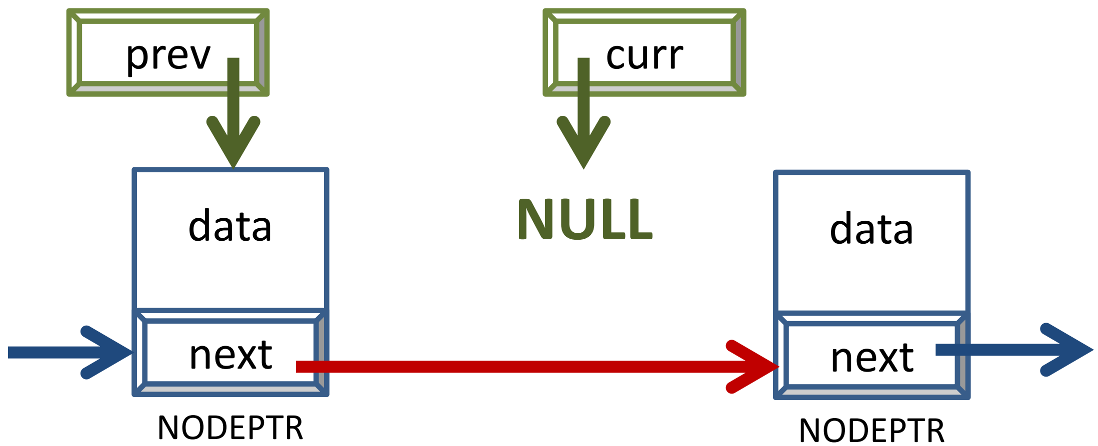
Deleting a Node – Step 3



- free the memory used by **`curr`** and set pointers to NULL

```
curr->next = NULL;
free(curr);
curr = NULL;
```

Deleting a Node – Step 3



- free the memory used by **`curr`** and set pointers to NULL

```
curr->next = NULL;
free(curr);
curr = NULL;
```

Outline

- (from last class) Memory and Functions
- Linked Lists & Arrays
- Anatomy of a Linked List
  - Details On Handling headPtr
- Using Linked Lists
  - Creation
  - Traversal
  - Inserting a Node
  - Deleting a Node
- Homework 4B

Homework 4B

- Karaoke

- heavy on pointers and memory management
- think before you attack

- start early
- test often (don’t forget edge cases)
- use a debugger when needed

Linked List Code for HW4B

- code for all of these functions is available on the Lectures page
- comments explain each step
- you can use this code in your Homework 4B, or as the basis for similar functions