COMSW 1003-1

Introduction to Computer Programming in C

Lecture 19

Spring 2011

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http://www1.cs.columbia.edu/~mmerler/comsw1003-1.html

Basic Data Structures

Basic Data Structures

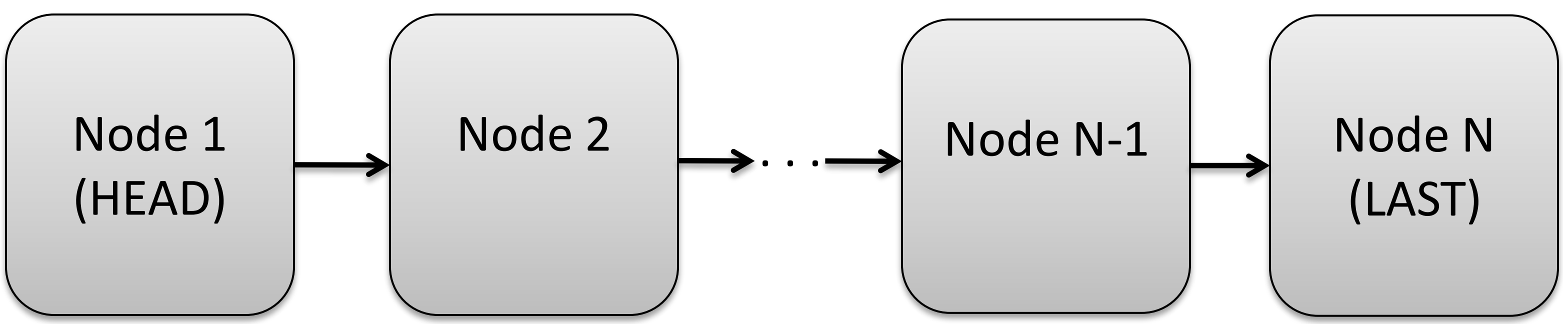
- So far, the only data structures we have seen to store data have been arrays (and structs)

- There are other (and potentially more useful) data structures that can be used
  - Lists
  - Trees

- Benefits:
  - Dynamically grow and shrink is easy
  - Search is faster

Linked Lists

- A chain of elements
- First element is called HEAD
- Each element (called NODE) points to the next
- The last node does not point to anything
- Like a treasure hunt with clues leading one to another



structPoint.c

Pointers to structs

- Pointers can point to any type, including structs
- There is a particular way of accessing fields in a struct through a pointer: the **->** operator

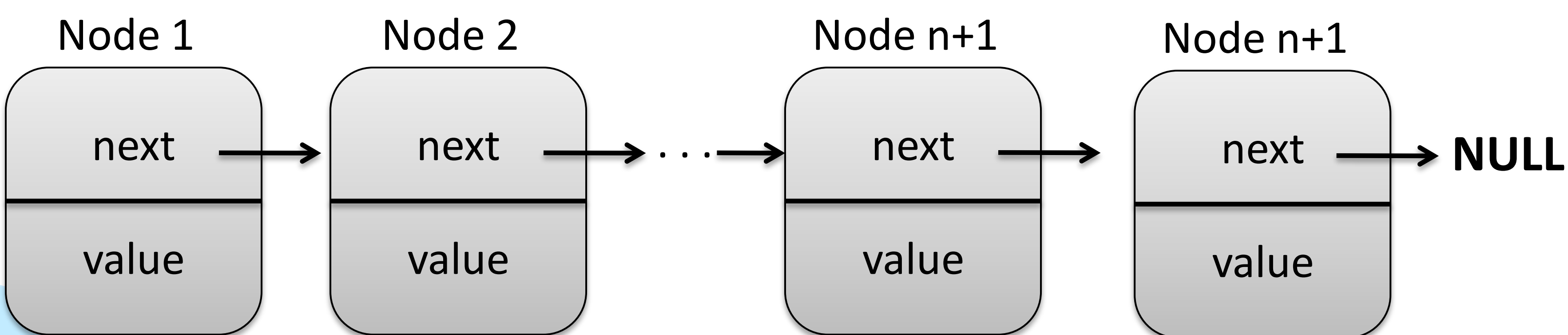
```
struct person {
        int age;
        char *name;
}

struct person p1 = {15, "Luke"};
struct person *ptr = &p1;
ptr->age = 20;            // (*ptr).age = 20;
printf("%s\n", ptr->name);
```

linkedList.c

Linked Lists

- Structure declaration for a node of a linked list

```
struct ll_node {
        int value;
        struct ll_node *next;
};
typedef struct ll_node node;
```



Linked Lists Initialization

```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

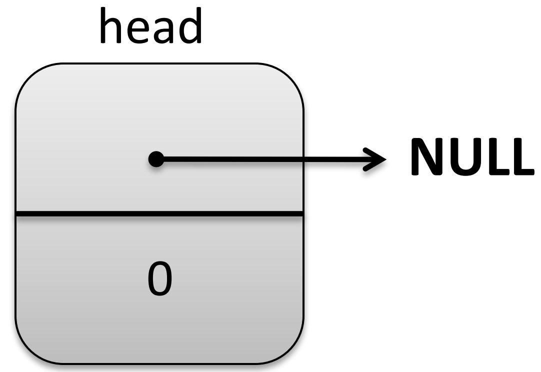
```
node *head = (node *) malloc(sizeof(node));
head->value = 0;
head->next = NULL;
```

- First node (HEAD) of the list is just a pointer to the list, it not counted as an actual node in the list

- Value set to 0 (could be any number, maybe a counter)

- The list is still empty, there is only HEAD, so next is NULL (end of the list)

Linked Lists Initialization




```
node *head = (node *) malloc(sizeof(node));
head->value = 0;
head->next = NULL;
```

- First node (HEAD) of the list is just a pointer to the list, it not counted as an actual node in the list
- Value set to 0 (could be any number, maybe a counter)
- The list is still empty, there is only HEAD, so next is NULL (end of the list)

Linked Lists
Insert node in front

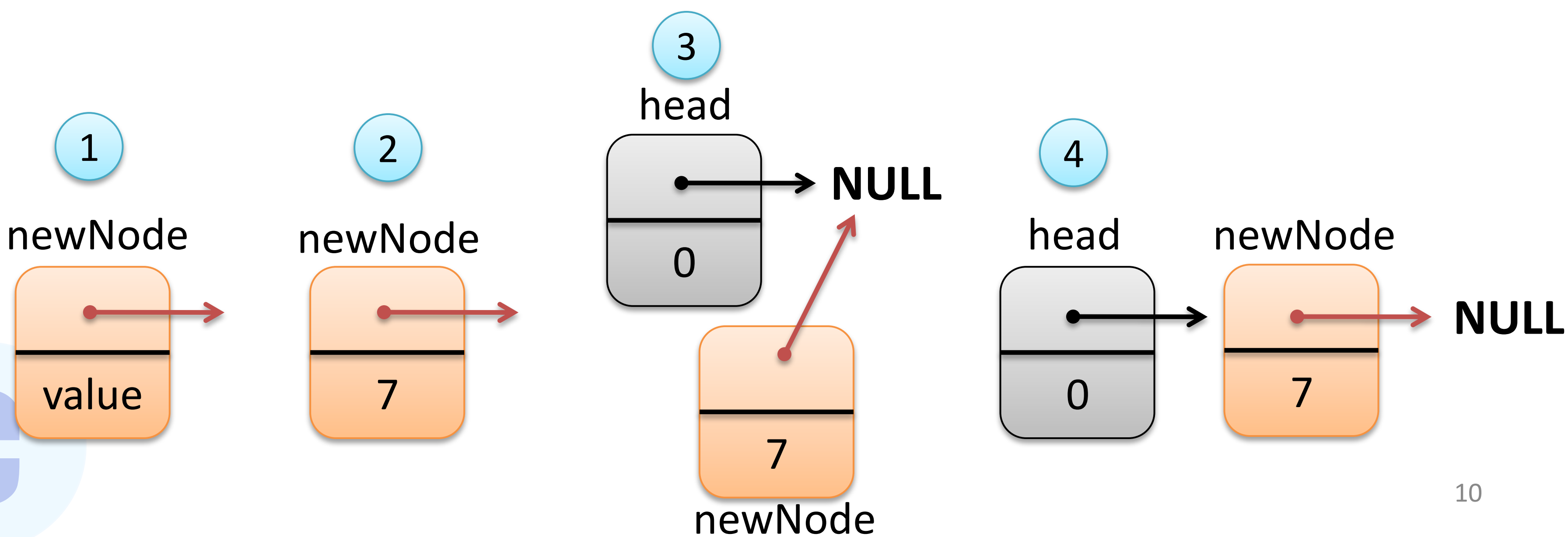
```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

```
int addNodeFront( int val, node *head ){
    node *newNode = (node *) malloc(sizeof(node));
    newNode->value = val;
    newNode->next = head->next;
    head->next = newNode;
    return 0;
}
```

Linked Lists - Insert node in front

```
int addNodeFront( int val, node *head ){
  1) node *newNode = (node *) malloc(sizeof(node));
  2) newNode->value = val;
  3) newNode->next = head->next;
  4) head->next = newNode;
     return 0;
}
```

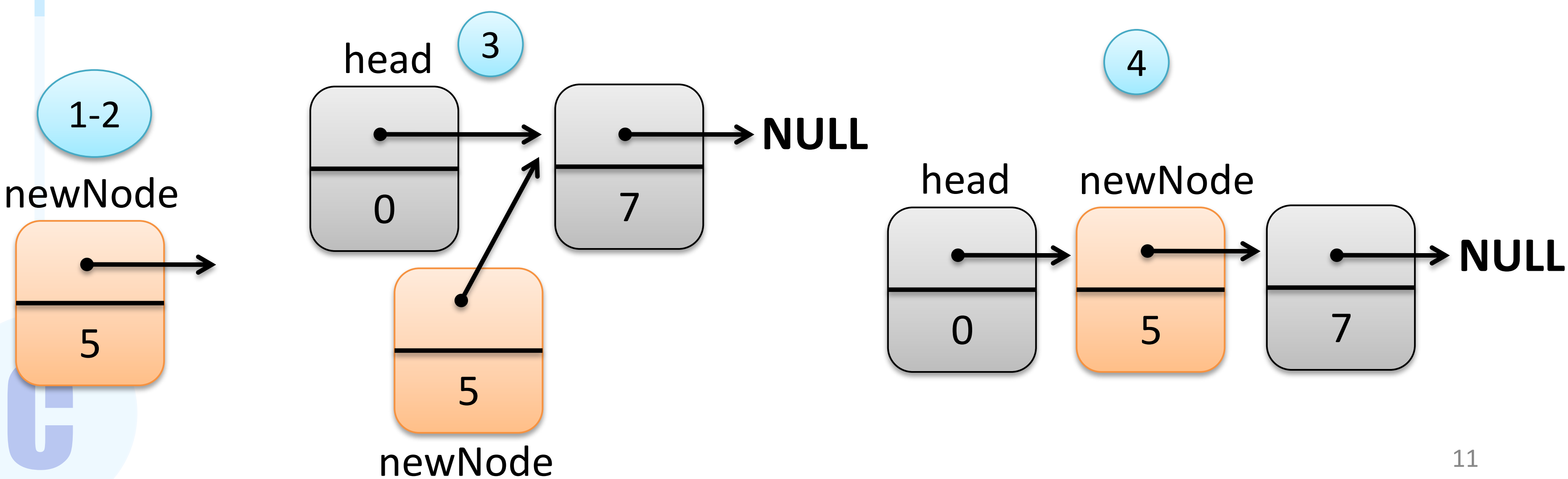
```
addNodeFront( 7, head );
```



Linked Lists - Insert node in front

```
int addNodeFront( int val, node *head ){
   1) node *newNode = (node *) malloc(sizeof(node));
   2) newNode->value = val;
   3) newNode->next = head->next;
   4) head->next = newNode;    return 0;
}
```

```
addNodeFront( 7, head );
addNodeFront( 5, head );
```



Linked Lists
Insert node at position N

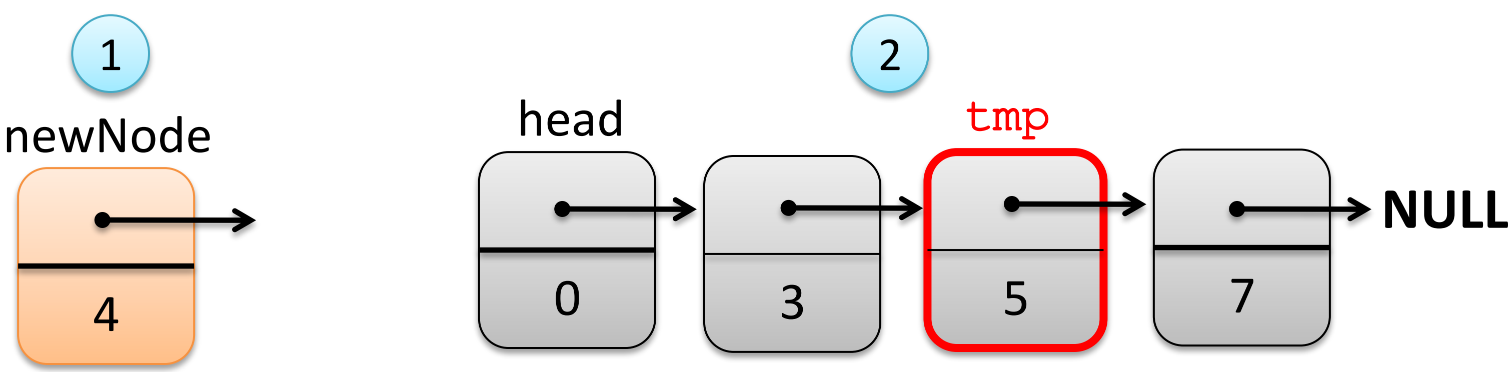
```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

```
int addNode( int val, node *head, int pos ){
   node *newNode = (node*) malloc( sizeof(node) );
   newNode->value = val;
   int i;
   node *tmp = head;
   for(i=0 ; i<pos; i++)
         tmp = tmp->next;
   newNode->next = tmp->next;
   tmp->next = newNode;
   return 0;
}
```

Linked Lists - Insert node at position N

```
int addNode( int val, node *head, int pos ){
 1)  node *newNode = (node*) malloc( sizeof(node) );
     newNode->value = val;
 2)  node *tmp = head;
     for(i=0 ; i<pos; i++)
         tmp = tmp->next;
 3)  newNode->next = tmp->next;
 4)  tmp->next = newNode;
     return 0;
}
```

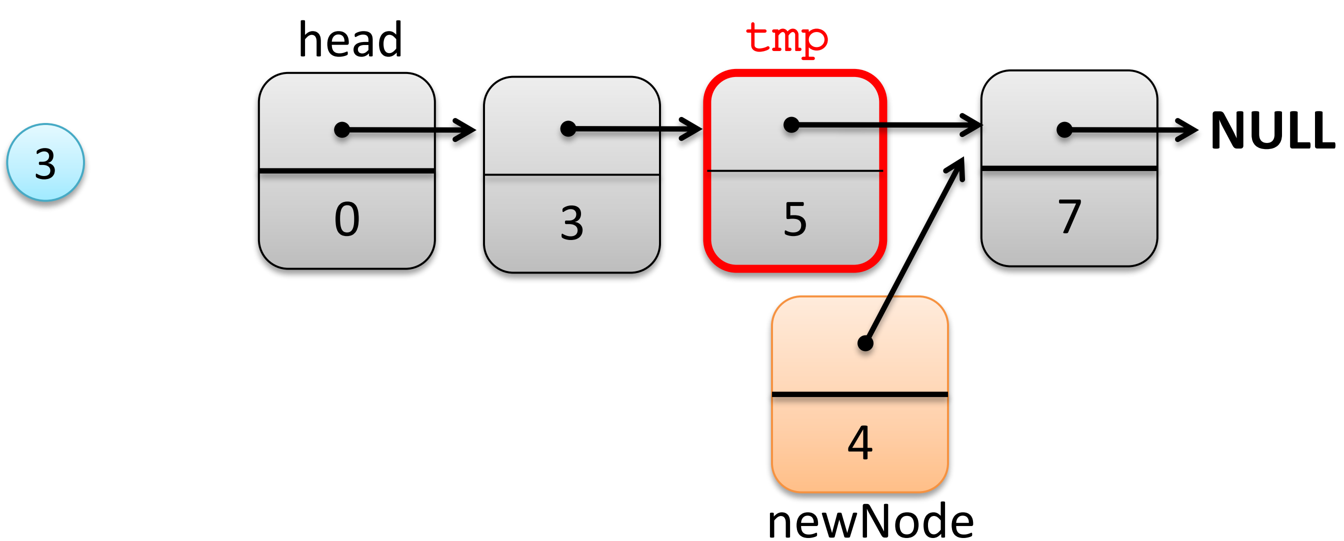
```
addNode( 4, head, 2 );
```



Linked Lists - Insert node at position N

```
int addNode( int val, node *head, int pos ){
 2)   node *tmp = head;
      for(i=0 ; i<pos; i++)
          tmp = tmp->next;
 3)   newNode->next = tmp->next;
 4)   tmp->next = newNode;
      return 0;
}
```

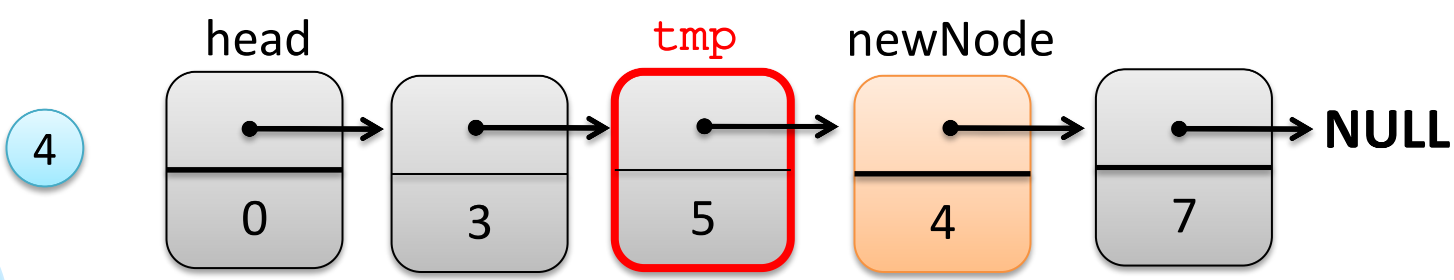
```
addNode( 4, head, 2 );
```



Linked Lists - Insert node at position N

```
int addNode( int val, node *head, int pos ){
     node *tmp = head;
 2)  for(i=0 ; i<pos; i++)
         tmp = tmp->next;
 3)  newNode->next = tmp->next;
 4)  tmp->next = newNode;
     return 0;
}
```

```
addNode( 4, head, 2 );
```



Linked Lists
Delete Node

```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

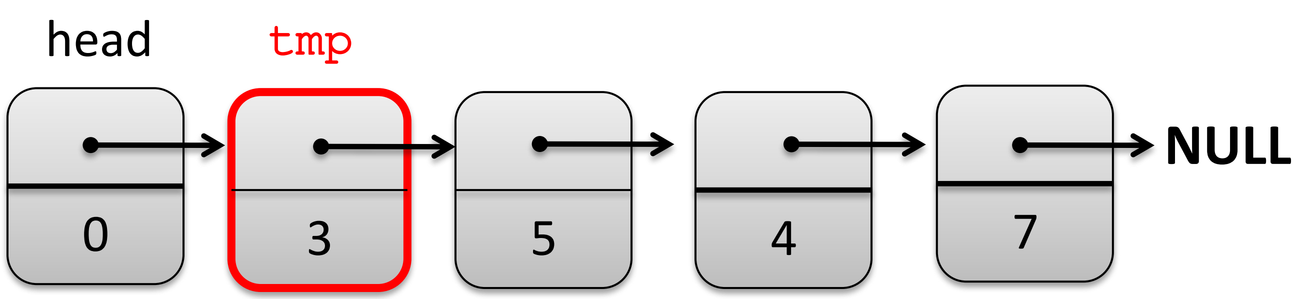
```
int removeNodePosition( node *head, int pos ){
    int i;
    node *tmp = head;
    for(i=0 ; i<pos; i++)
        tmp = tmp->next;
    node* tmp2 = tmp->next;
    tmp->next = tmp->next->next;
    free(tmp2);
    return 0;
}
```

Linked Lists - Delete Node

```
int removeNodePosition( node *head, int pos ){
        int i;
 1)     node *tmp = head;
        for(i=0 ; i<pos; i++)
            tmp = tmp->next;
 2)     node* tmp2 = tmp->next;
        tmp->next = tmp->next->next;
 3)     free(tmp2);
        return 0;
}
```

```
removeNode( head, 1 );
```

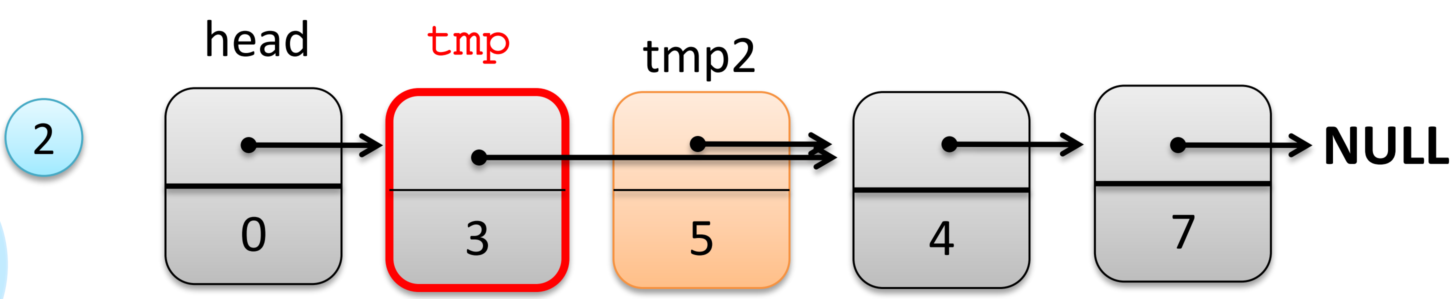
1



Linked Lists - Delete Node

```
int removeNode( node *head, int pos ){
        int i;
 1)     node *tmp = head;
        for(i=0 ; i<pos; i++)
            tmp = tmp->next;
 2)     node* tmp2 = tmp->next;
        tmp->next = tmp->next->next;
 3)     free(tmp2);
        return 0;
}
```

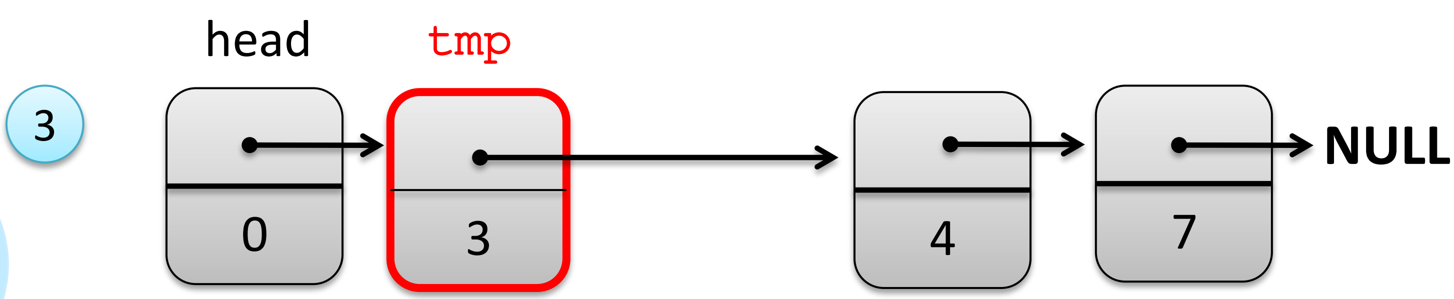
```
removeNode( head, 1 );
```



Linked Lists - Delete Node

```
int removeNode( node *head, int pos ){
        int i;
  1)    node *tmp = head;
        for(i=0 ; i<pos; i++)
            tmp = tmp->next;
  2)    node* tmp2 = tmp->next;
        tmp->next = tmp->next->next;
  3)    free(tmp2);
        return 0;
}
```

```
removeNode( head, 1 );
```



Linked Lists
Delete Whole List

```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

```
int destroyList( node **head ){
   node *tmp;
   while( (*head)->next != NULL ){
        tmp = (*head);
        (*head) = (*head)->next;
        free(tmp);
    }
    return 0;
}
```

```
destroyList( &head );
```

Linked Lists
Delete Whole List

```
struct ll_node {
    int value;
    struct ll_node *next;
};
```

```
int destroyList( node **head ){
   node *tmp;
   while( (*head)->next != NULL ){
        tmp = (*head);
        (*head) = (*head)->next;
        free(tmp);
    }
    return 0;
}
```

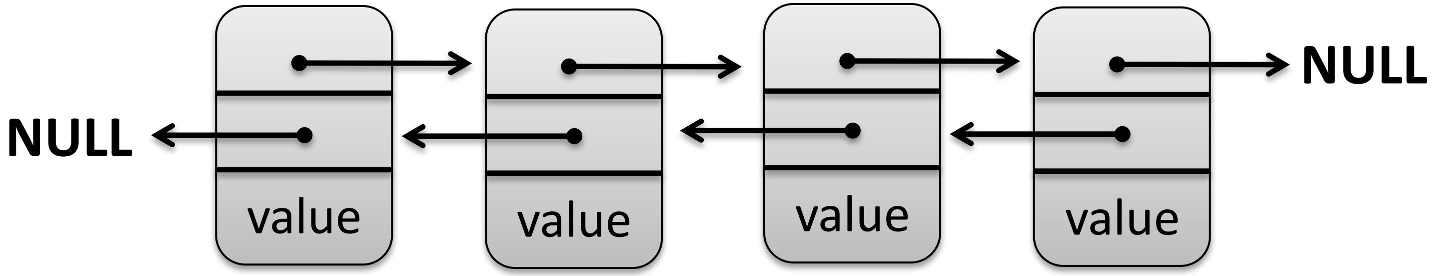
I need to pass head by reference,
because I am changing it within the function

```
destroyList( &head );
```

Doubly linked lists

- Pointer to next AND previous node
- Faster backtracking

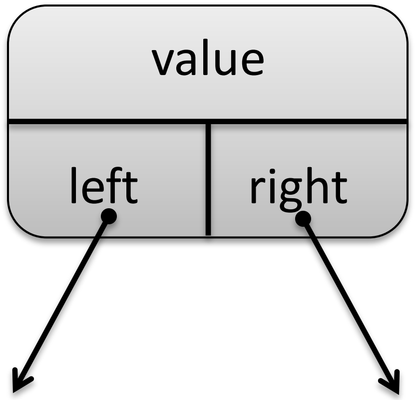
```
struct dll_node {
    int value;
    struct dll_node *prev;
    struct dll_node *next;
};
```



Binary Trees

- Like lists, but each node has a pointer to two elements:
  - Left has a value < current node
  - Right has a value > current node
- First node is called ROOT

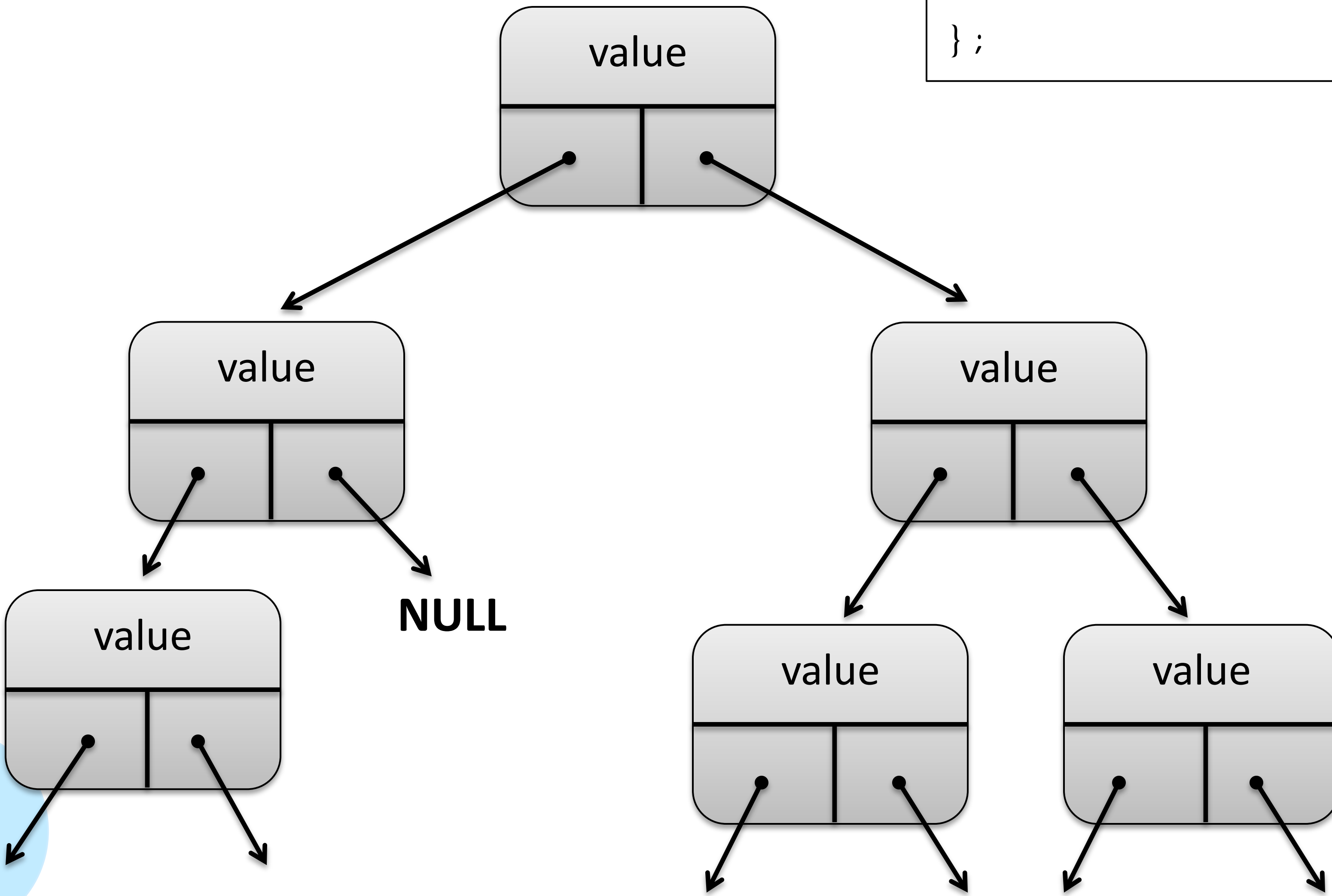
```
struct t_node {
    int value;
    struct t_node *left;
    struct t_node *right;
};
```



Binary Trees

- Left has a value < current node
- Right has a value > current node

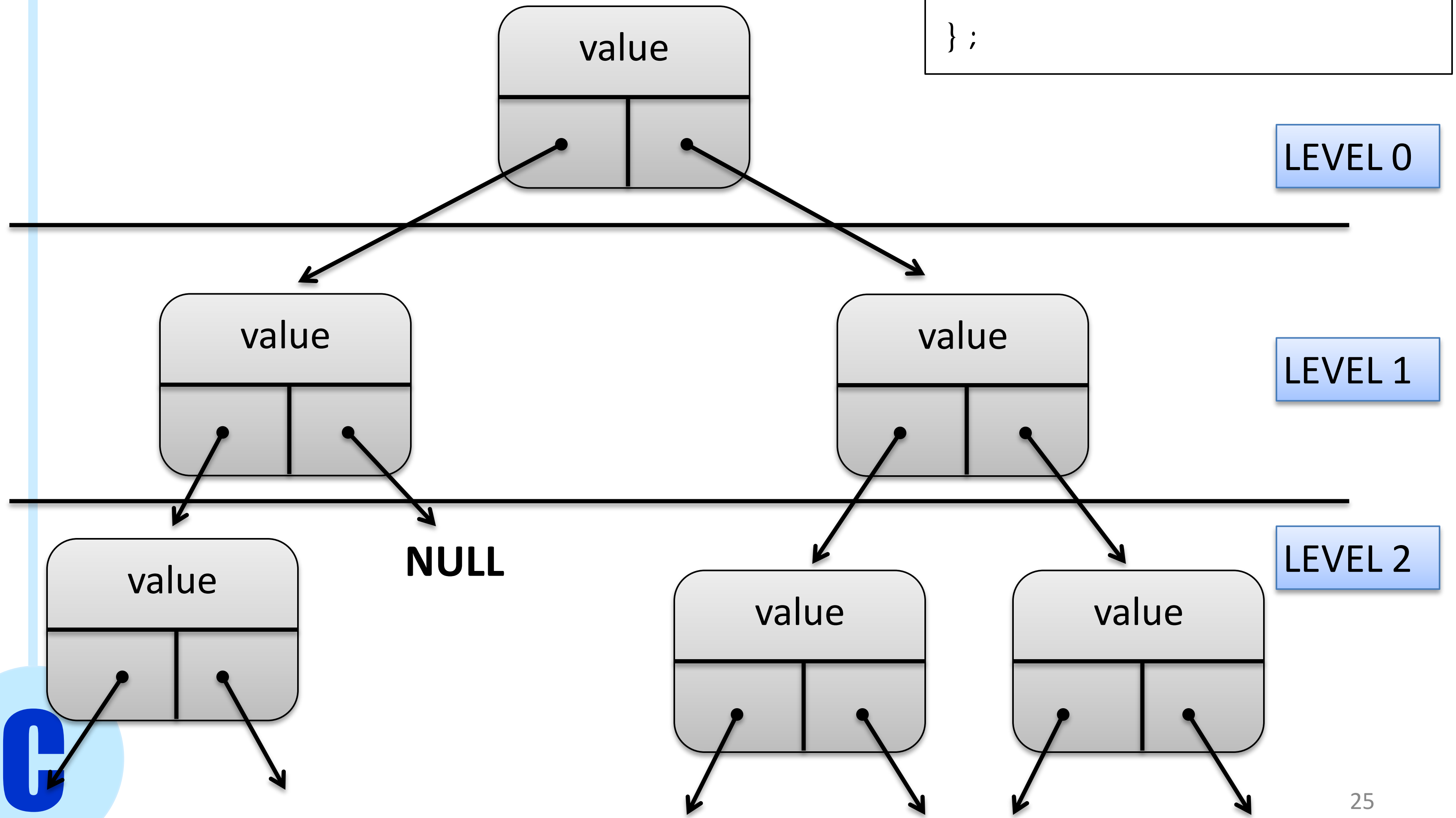
```c
struct t_node {
  int value;
  struct t_node *left;
  struct t_node *right;
};
```



Binary Trees

- Left has a value < current node
- Right has a value > current node

```
struct t_node {
  int value;
  struct t_node *left;
  struct t_node *right;
};
```



Binary Trees

– Left has a value < current node
– Right has a value > current node

```
struct t_node {
   int value;
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};
```
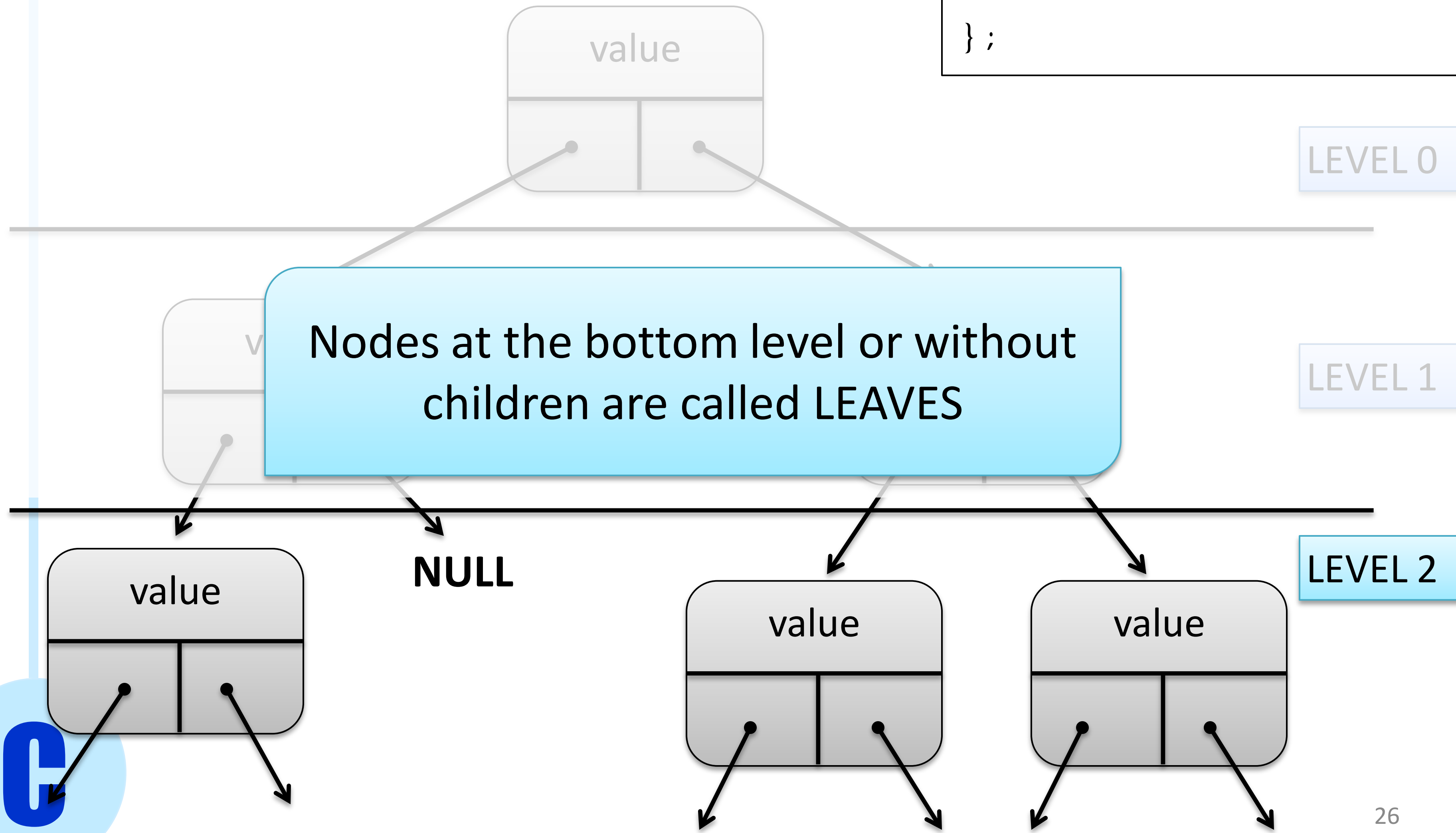



Binary Trees

Inserting number **x into a Binary Tree:**

1. Start at root

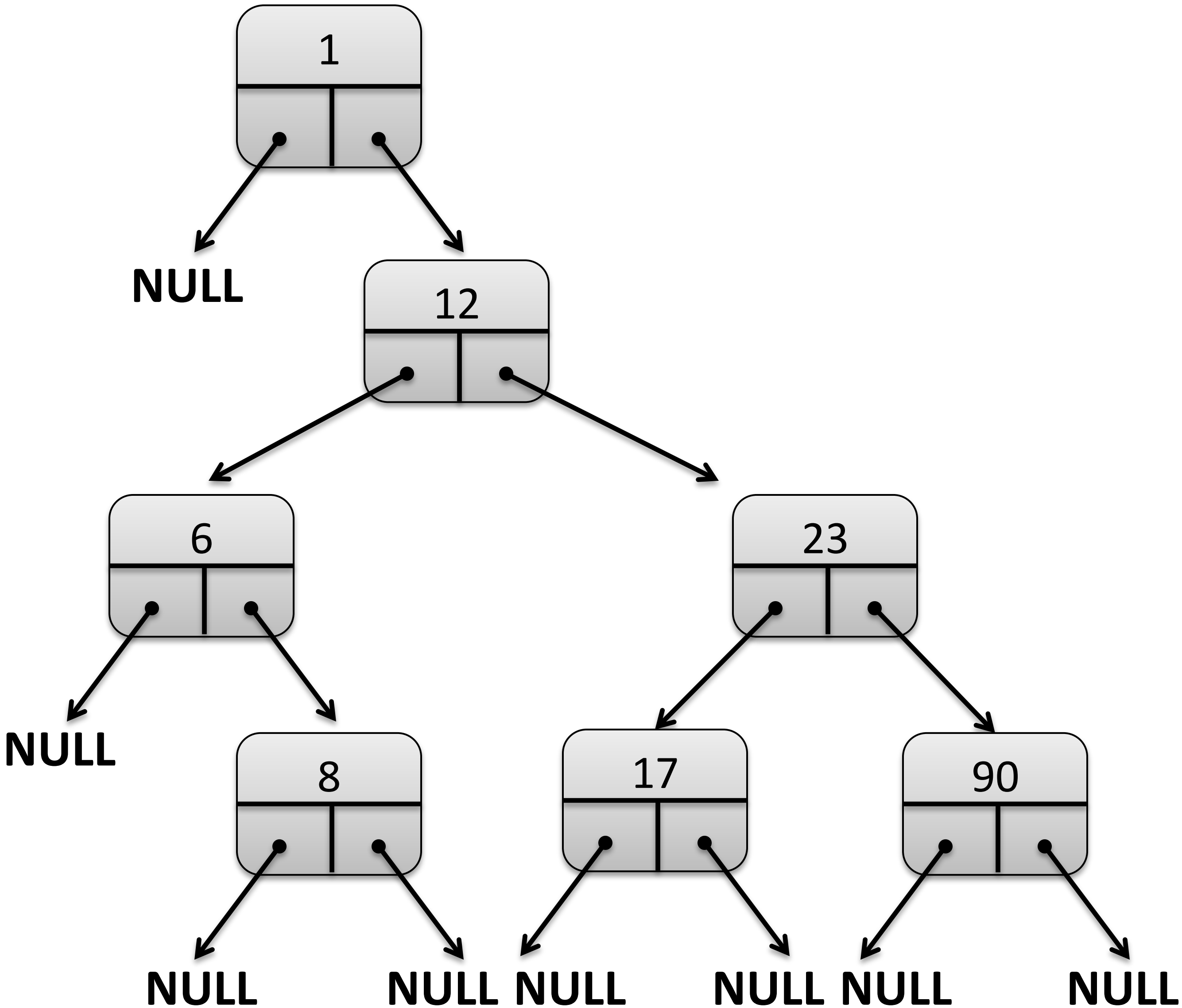
2. if (current node is NULL)
   create new node and set node’s value to **x**
3. else

   if (x >= current node’s value)
      follow right pointer
   else
      follow left pointer

   Go to 1

Binary Trees

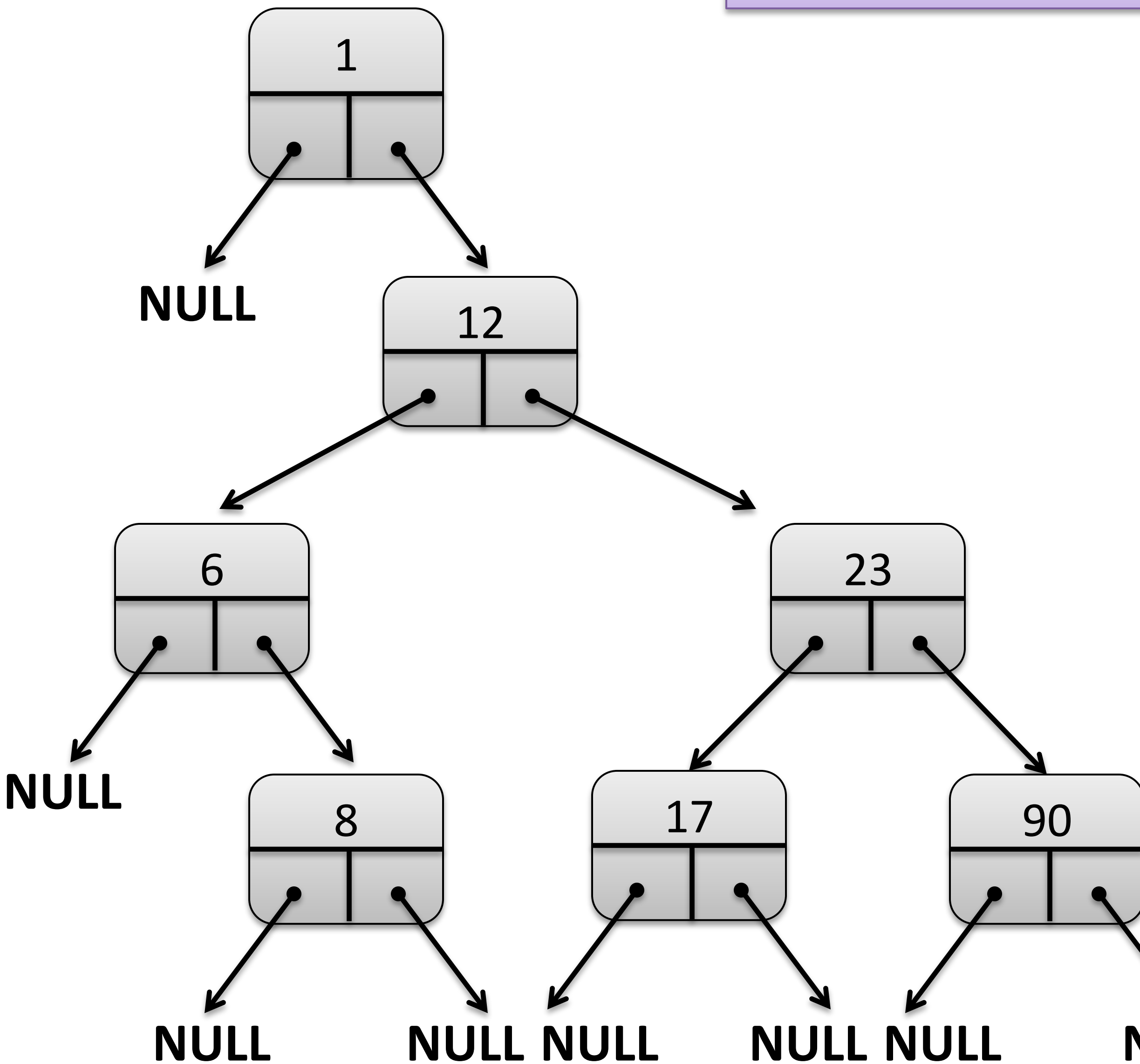
Example: [1 12 6 23 17 90 8]



Binary Trees

Example: [1 12 6 23 17 90 8]

Find all elements < 10

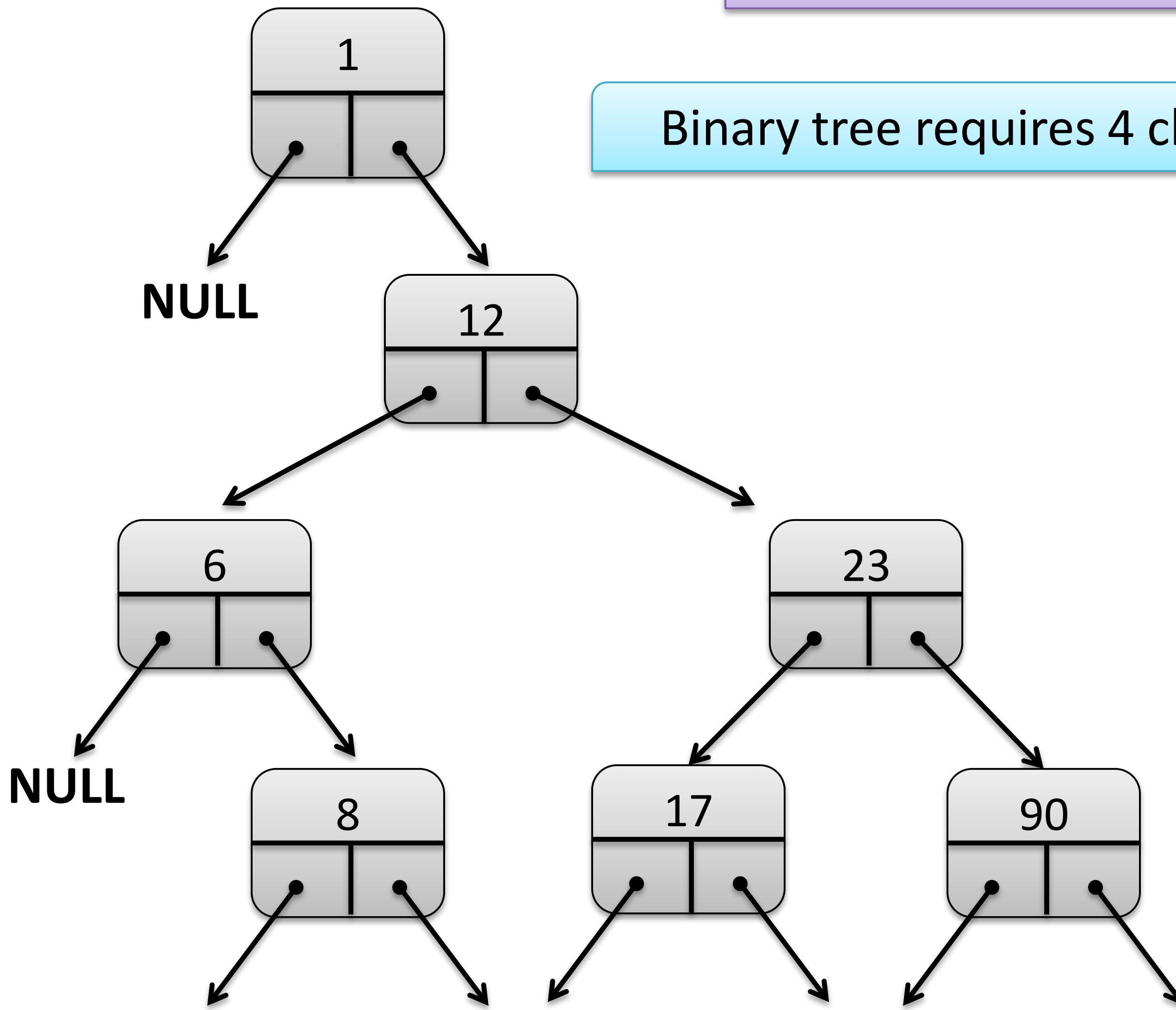


Binary Trees

Example: [1 12 6 23 17 90 8]

Find all elements < 10

Binary tree requires 4 checks



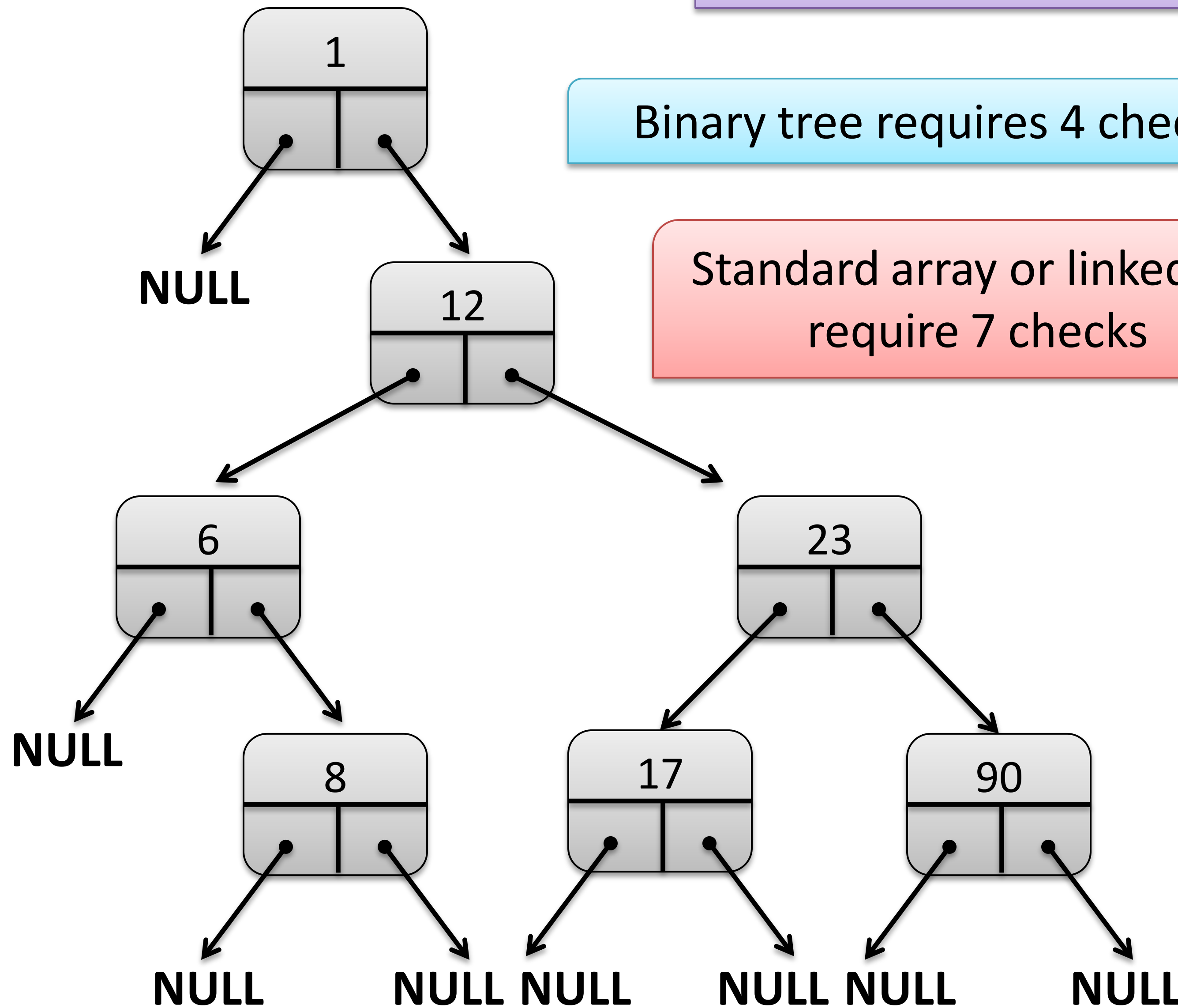
Binary Trees

Example: [1 12 6 23 17 90 8]

Find all elements < 10

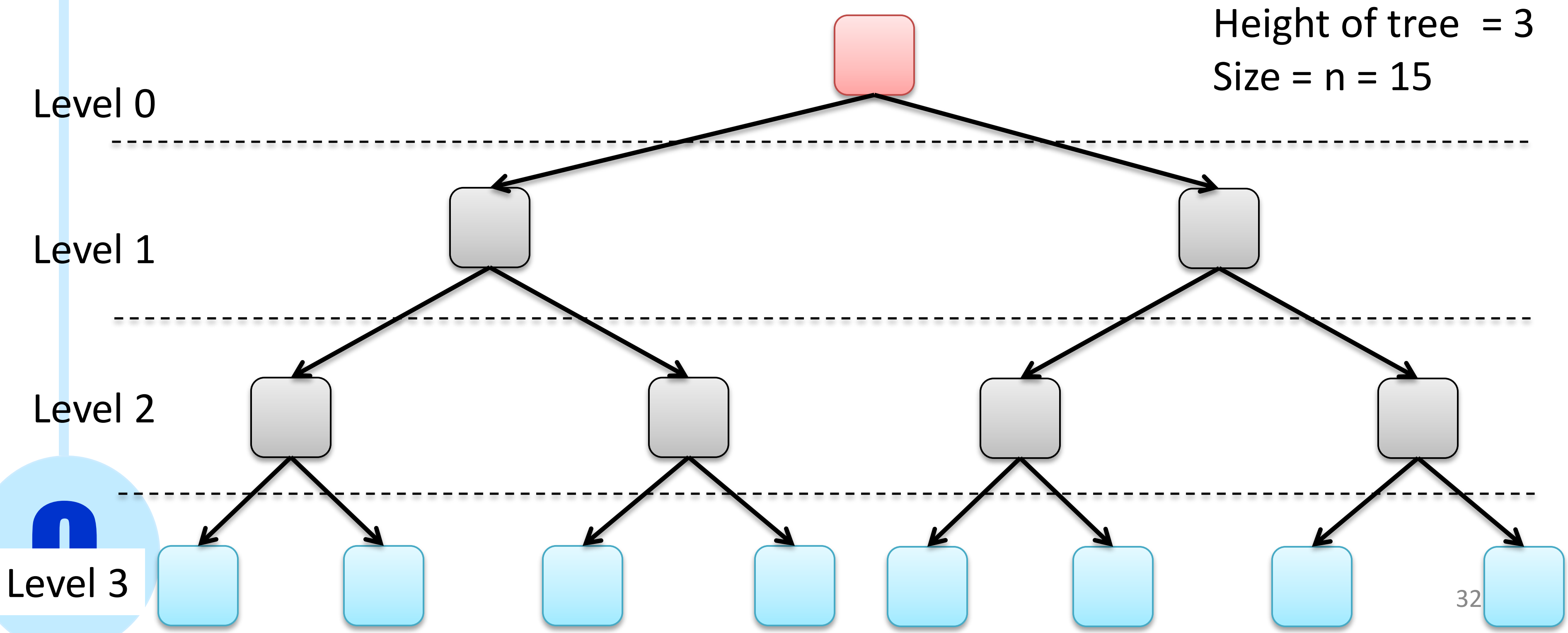
Binary tree requires 4 checks

Standard array or linked list require 7 checks



Trees Definitions

- Root : node with no parents. Leaf : node with no children
- Depth (of a node) : path from root to node
- Level: set of nodes with same depth
- Height or depth (of a tree) : maximum depth
- Size (of a tree) : total number of nodes
- Balanced binary tree : depth of all the leaves differs by at most 1.



Read PCP Chapter 17