

BINARY SEARCH TREES (CONTD)

Problem Solving with Computers-II

C++

```
#include <iostream>
using namespace std;

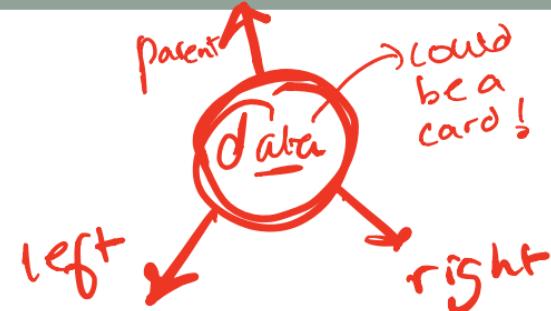
int main(){
    cout<<"Hola Facebook\n";
    return 0;
}
```

A node in a BST

```
class BSTNode {
public:
    BSTNode* left;
    BSTNode* right;
    BSTNode* parent;
    int const data;
    BSTNode( const int & d ) : data(d) {
        left = right = parent = 0;
    }
};
```

I type of data

```
struct Card {
    char suit;
    int value;
};
```



```
class BST {
```

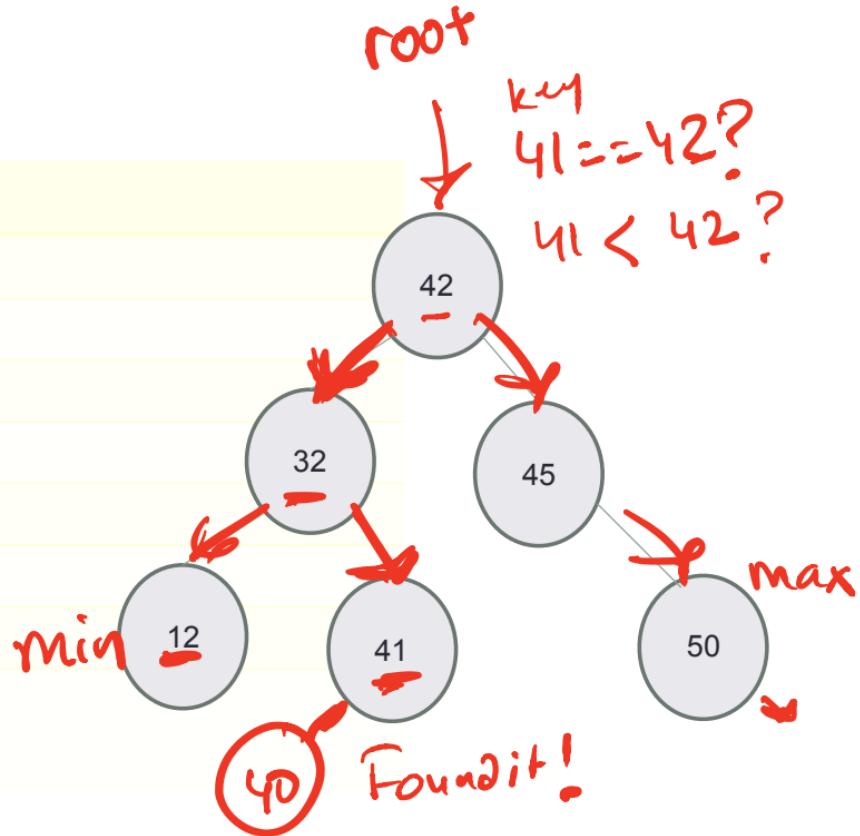
private:
BSTNode* root;

};

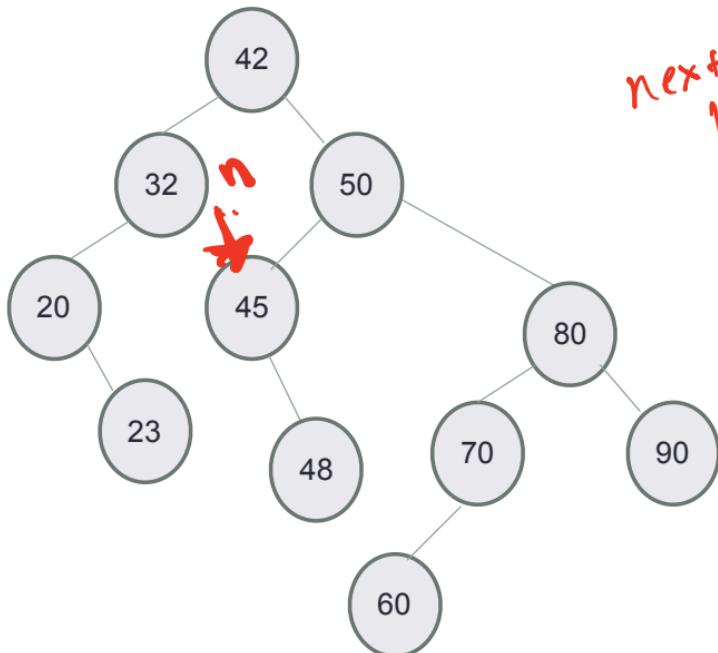
*The data stored in any BST node could be of any type
e.g. Card. as long as the operations ==, < and >
are defined on that type*

Define the BST ADT

Operations
Search ✓
Insert ✓
Min ✓
Max ✓
Successor ↙
Predecessor
Delete
Print elements in order



Successor: Next largest element



next largest
key

int

successor (int value);

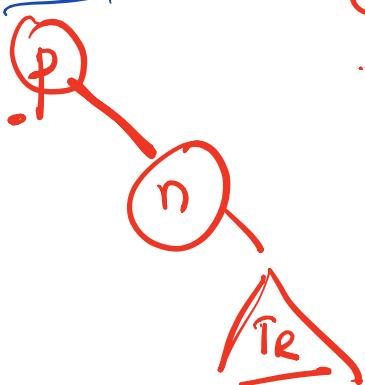
Our algorithm will be for a private version
of this function that takes a pointer to a node
as input and returns a pointer to
the node with the next largest value.

Node* successor_Private (Node* n);

key

Case 1: n has a right subtree T_R

Case 1a



$$\text{key}(n) < \text{key}(T_R) \dots \textcircled{1}$$

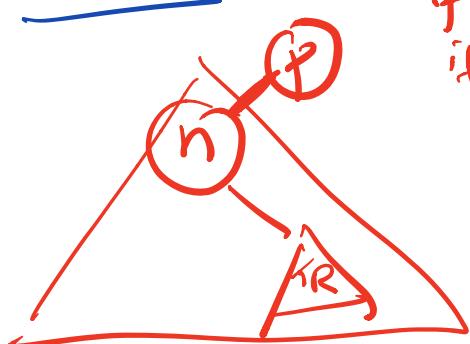
if n is parent's right child:

$$\text{key}(p) < \text{key}(n) \dots \textcircled{2}$$

From ① & ②

$$\text{key}(p) < \text{key}(n) < \text{key}(T_R)$$

Case 1b



if n is its parent's left child
if ($n \rightarrow \text{parent} \rightarrow \text{left} = n$):

$$\text{key}(n) < \text{key}(p) \dots \textcircled{3}$$

$$\text{key}(n) < \text{key}(T_R) \dots \textcircled{4}$$

How does $\text{key}(p)$ compare with $\text{key}(T_R)$

- A.
- B.
- C.

$$\text{key}(p) < \text{key}(T_R)$$

$$\text{key}(p) > \text{key}(T_R)$$

Can't say

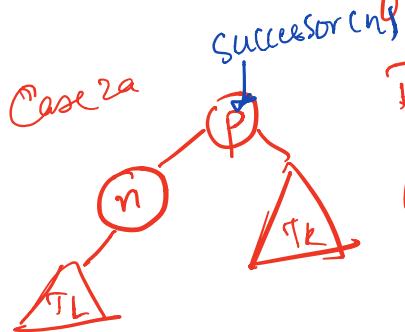
-
-
-
-
-
-
-
-
-

from (3) (4) (5)

$$\text{key}(n) < \text{keys}(T_n) < \text{key}(p)$$

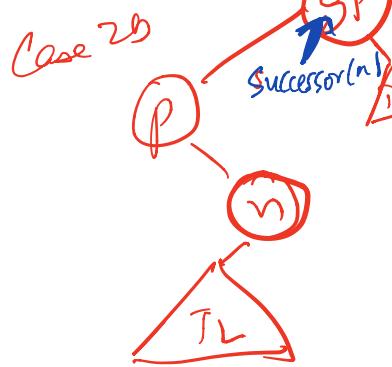
Therefore successor⁽ⁿ⁾ must be in T_2

Case 2: n has no right subtree (this was left as an assignment) but now that you know about the Inorder Traversal, the proof might be easier to follow



n is left child of parent

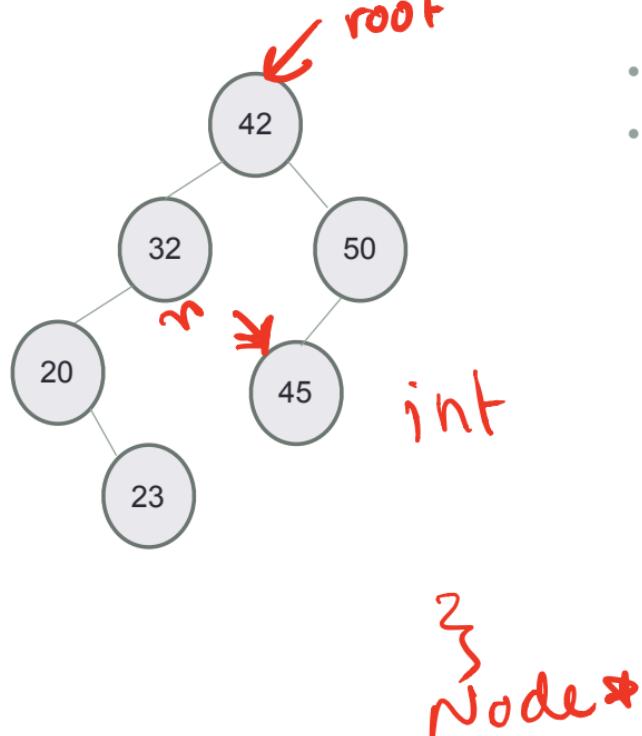
If n is the left child of its parent (as shown on the figure to the left), an inorder traversal of the tree would print the parent's key after printing n. Therefore p is the successor of n



n is right child of parent

If n is the right child of its parent(p) then, the parent's recursive call is done after n's key is printed and we proceed to the grandparent's recursive call OR more generally proceed all the way up the tree until we find a node that is the left child of its parent, and terminate there.

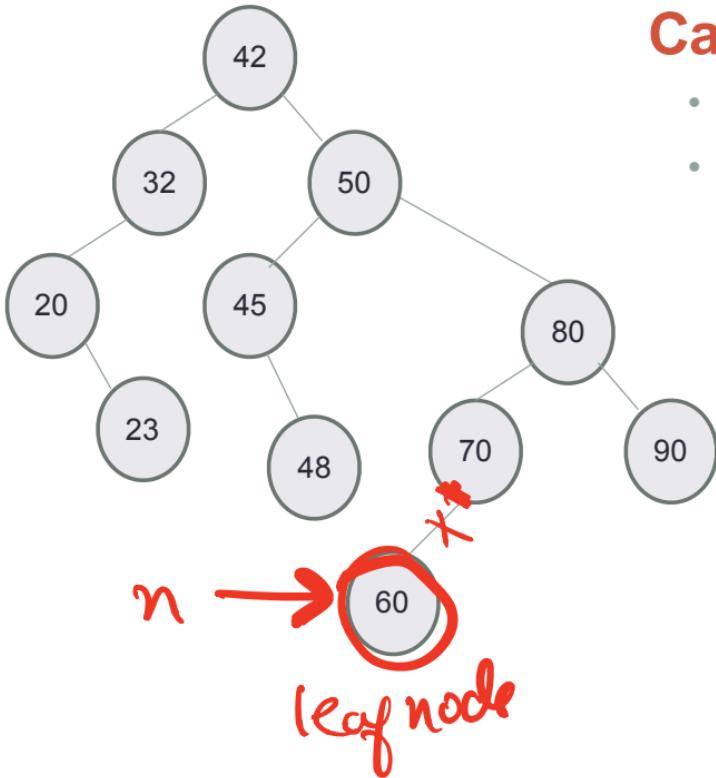
Predecessor: Next smallest element



- What is the predecessor of 32?
- What is the predecessor of 45?

```
predecessor ( int value ) {  
    Node * n = findH( value );  
    return predecessorH( n )->data;  
}  
predecessorH ( Node * n ) {
```

Delete: Case 1

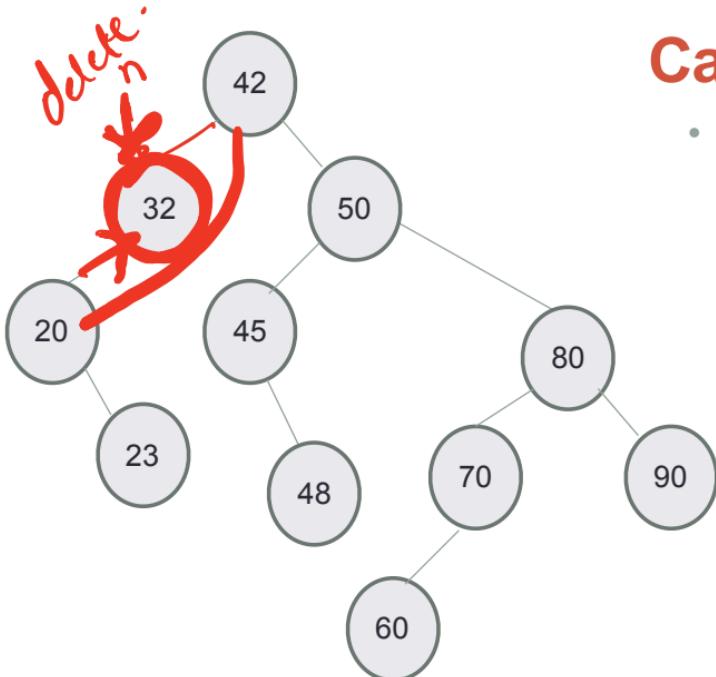


Case 1: Node is a leaf node

- Set parent's (left/right) child pointer to null
- Delete the node

```
if (n->left == !n->right) {  
    // leaf node  
    if (n == n->parent->left)  
        n->parent->left = 0;  
    else  
        n->parent->right = 0;  
    delete n;
```

Delete: Case 2

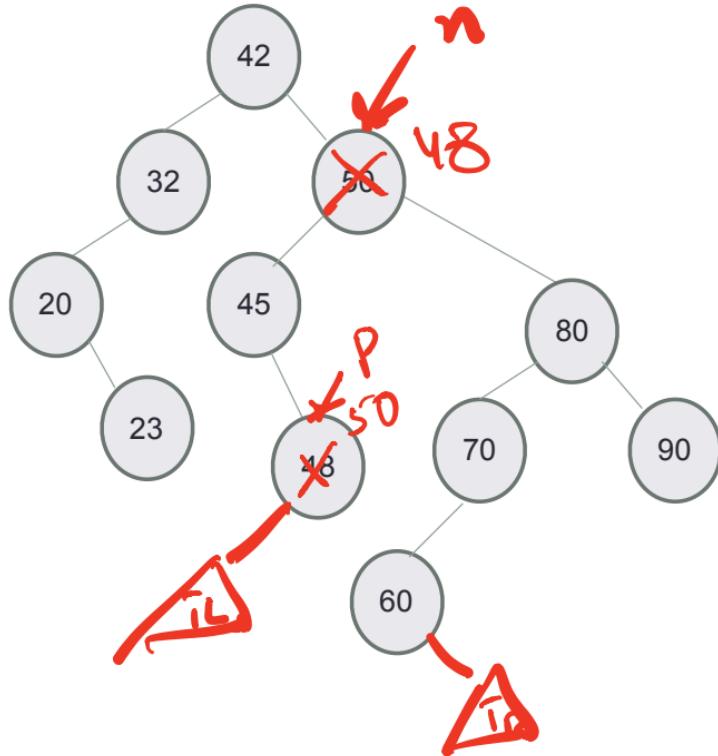


Case 2 Node has only one child

- Replace the node by its only child

```
if ( !n->right && n->parent )
    // connect n's left child to n's parent
    n->left->parent = n->parent;
    if ( n == n->parent->left ) {
        n->parent->left = n->left;
    } else
        n->parent->right = n->left;
    }
    // otherwise
    delete n;
```

Delete: Case 3

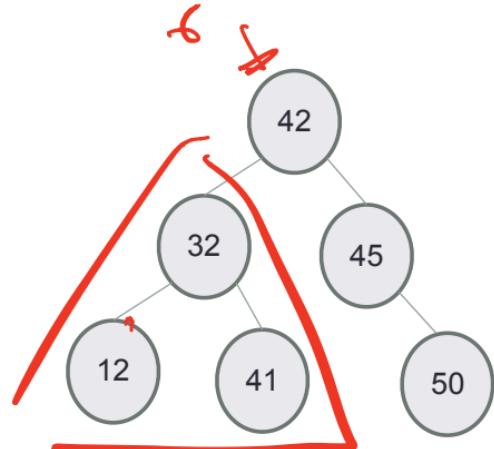


Case 3 Node has two children

- Can we still replace the node by one of its children? Why or Why not?

// Swap n->data with
its predecessor OR
its successor
// delete the predecessor
// Default to either case 1
or case 2

In order traversal: print elements in sorted order



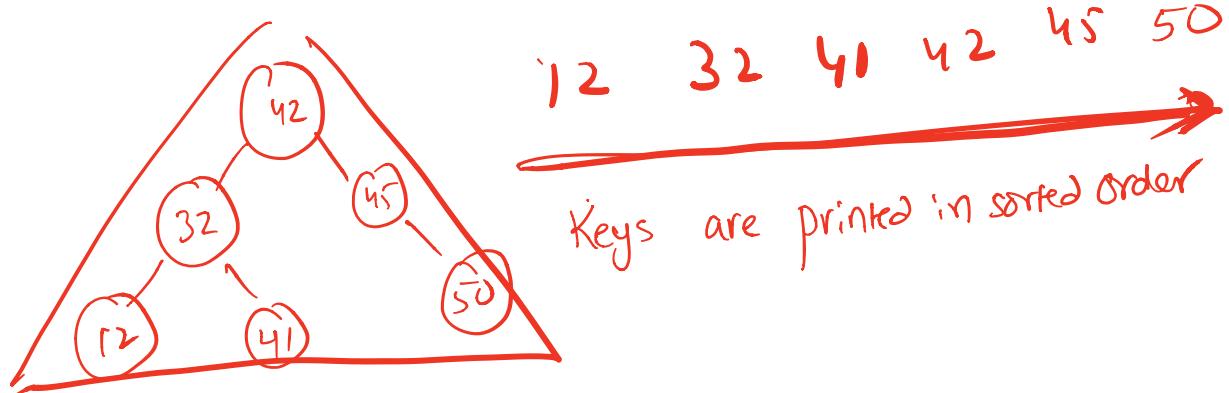
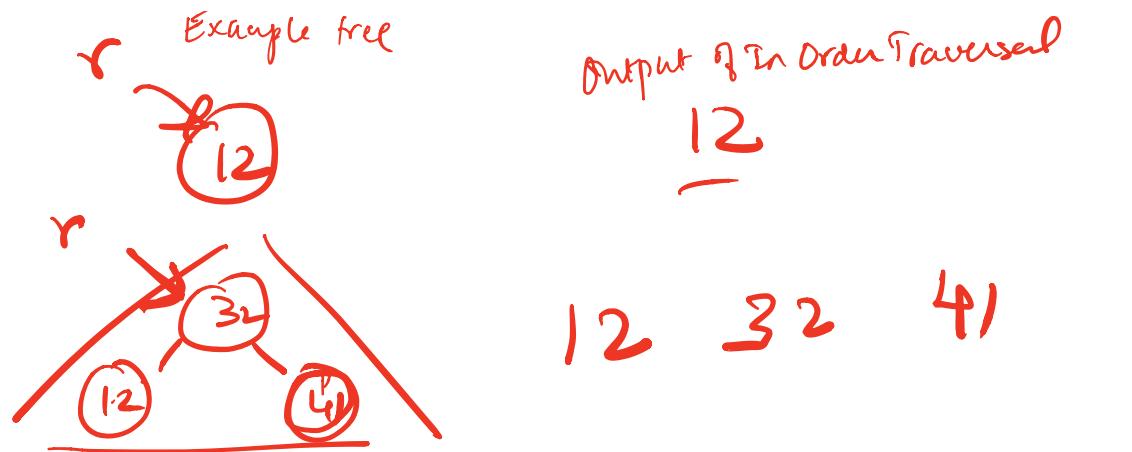
What is the output of doing an in order traversal on the above tree

- A. 32 12 41 42 45 50
- B. 12 32 41 42 45 50
- C. 12 32 42 45 41 50
- D. None of the above

Algorithm Inorder(tree)

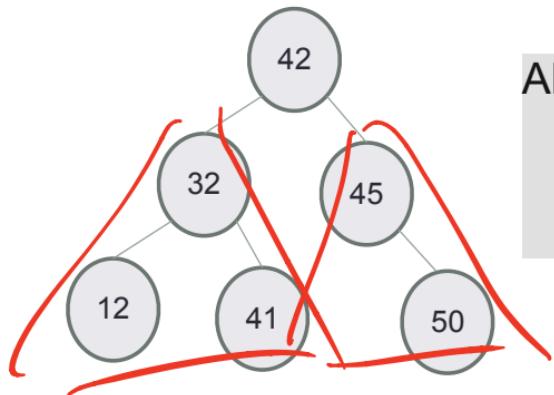
1. Traverse the left subtree, i.e., call Inorder(left-subtree)
2. Visit the root.
3. Traverse the right subtree, i.e., call Inorder(right-subtree)

```
void InOrder(Node* r){  
    if(!r) return;  
    InOrder(r->left);  
    cout<<r->data;  
    InOrder(r->right);  
}
```



12.

Pre-order traversal: nice way to linearize your tree!



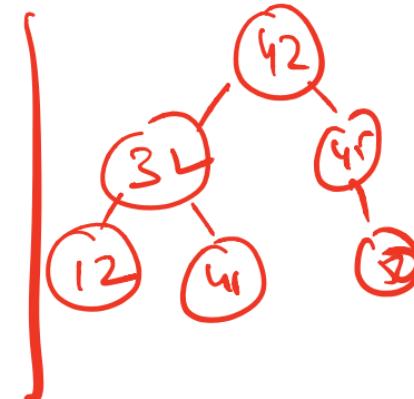
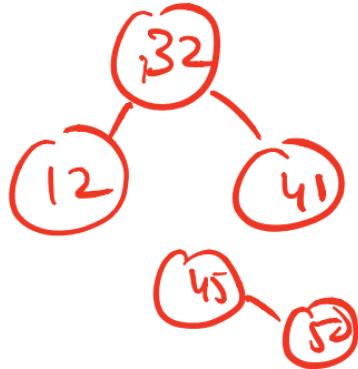
Algorithm Preorder(tree)

1. Visit the root.
2. Traverse the left subtree, i.e., call Preorder(left-subtree)
3. Traverse the right subtree, i.e., call Preorder(right-subtree)

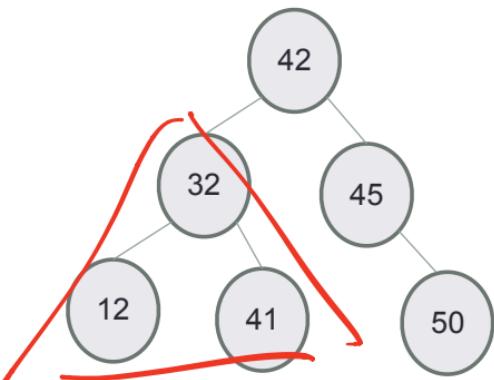
42 32 12 41 45 50

32 12 41

45 50



Post-order traversal: use in recursive destructors!



12 41 32

Algorithm Postorder(tree)

1. Traverse the left subtree, i.e., call Postorder(left-subtree)
2. Traverse the right subtree, i.e., call Postorder(right-subtree)
3. Visit the root.

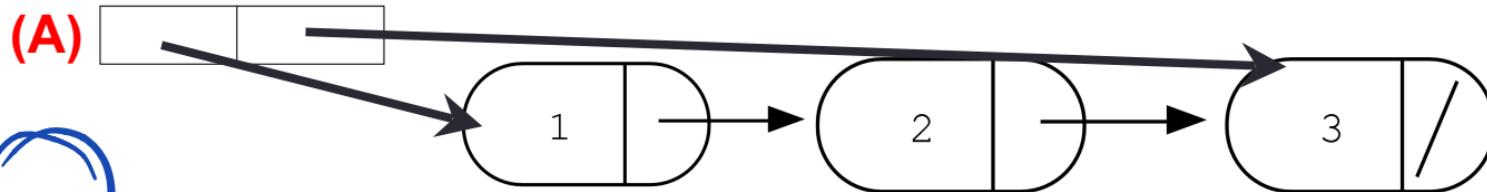
Concept Question

```
LinkedList::~LinkedList(){
    delete head;
}
```

```
class Node {
public:
    int info;
    Node *next;
};
```

Which of the following objects are deleted when the destructor of Linked-list is called?

head tail



(B). only the first node

(C): A and B

(D): All the nodes of the linked list

(E): A and D

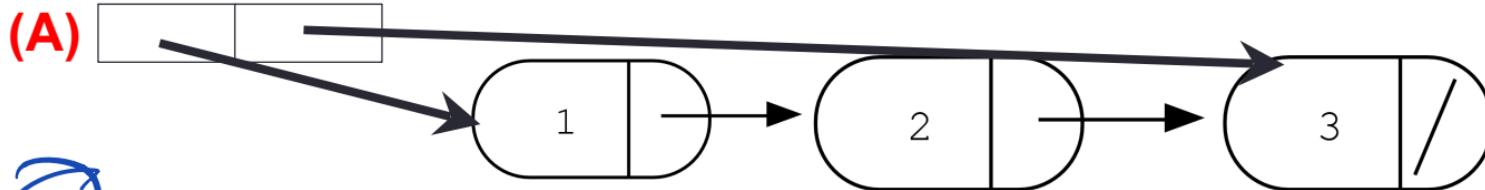
Concept Question

```
LinkedList::~LinkedList(){  
    delete head;  
}
```

```
Node::~Node(){  
    delete next;  
}
```

Which of the following objects are deleted when the destructor of Linked-list is called?

head tail



(B): All the nodes in the linked-list

(C): A and B

(D): Program crashes with a segmentation fault

(E): None of the above

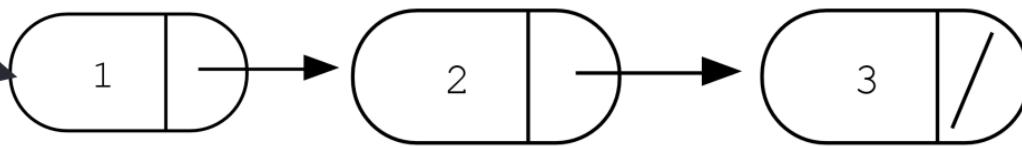
```
LinkedList::~LinkedList(){
    delete head; // calls the first node's
                  destructor
}
```

DL
head tail



delete head

① delete next → ② delete next → ③ delete 0



↑
does not
segfault

call to destructor completes

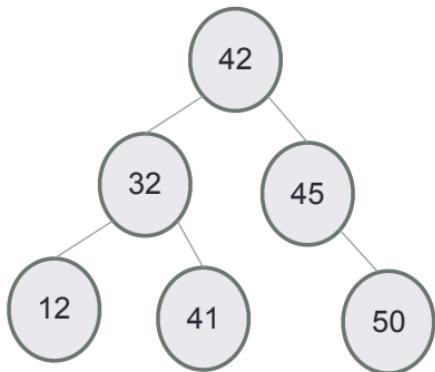
Node -3 is deleted

Call to destructor of 2 completes

Node 2 is deleted

Call to destructor of node 1 completes,
Node 1 is deleted

Post-order traversal: use in recursive destructors!



Algorithm Postorder(tree)

1. Traverse the left subtree, i.e., call Postorder(left-subtree)
2. Traverse the right subtree, i.e., call Postorder(right-subtree)
3. Visit the root.

in BSTNode () {
 delete left;
 delete right;
}