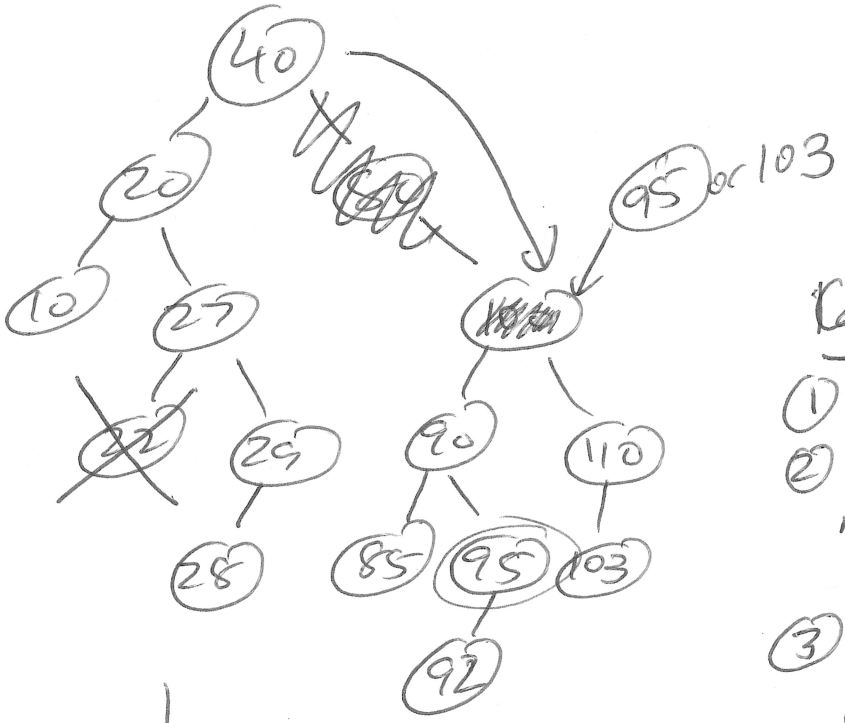
COP 3502 - 10/26/23

1. BST Delete
   - paper
   - code
2. Practice BST problems



Leaf Node

Case 1: Delete 22

free (node)
reset 27's left NULL

1. ID parent
2. save ptr to node free node
3. set parent ptr NULL

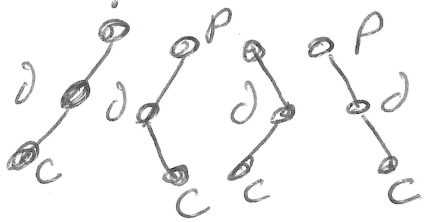
One Child Case

Case 2: Delete 80

ID par
ID child
ID node → free
link appropriate parent link to child node } 4 cases

Case 3: Delete 100

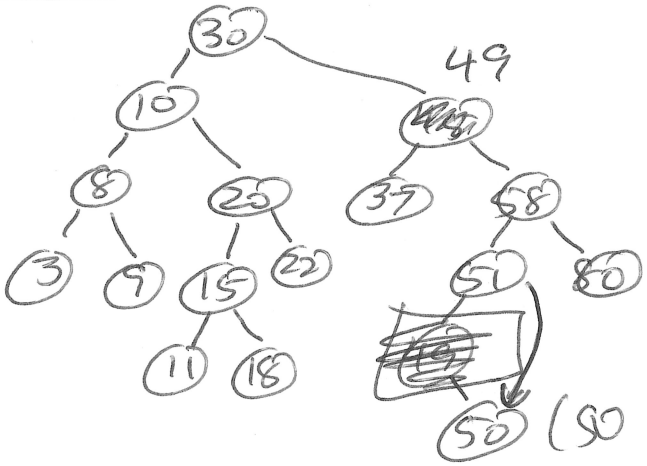
1. remove item
2. replace it with max left sub tree min right sub tree
3. delete the old physical node that left max or right min was in



→ guaranteed this is case 1 or case 2

(1) Delete 60
max left

(2) Delete ~~45~~ 45
min right



Delete 45
min right
(1) replace 45 w/ 49
(2) delete old 45

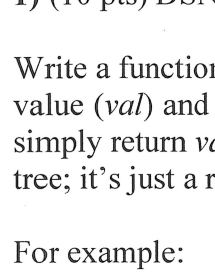
(50 becomes 51's left child)

Name: _____
UCFID: _____
NID: _____

1) (10 pts) DSN (Binary Trees)

Write a function named *find_below*() that takes a pointer to the root of a binary tree (*root*) and an integer value (*val*) and returns the greatest value in the tree that is strictly less than *val*. If no such value exists, simply return *val* itself. Note that the tree passed to your function will **not** necessarily be a binary **search** tree; it's just a regular binary tree.

For example:




```
find_below(root, 196) would return 22
find_below(root, 1) would return 1
find_below(root, 4) would return 1
find_below(root, 22) would return 18
find_below(root, 20) would return 18
find_below(root, 8) would return 7
find_below(root, -23) would return -23
```

→ nothing smaller than 1 so it is returned itself.

You must write your solution in a **single** function. You cannot write any helper functions.

The function signature and node struct are given below.

```
typedef struct node
{
   int data;
   struct node *left;
   struct node *right;
} node;

int find_below(node *root, int val)
{
    if (root == NULL) return val;
    if (root->data < val)
        val = root->data;
    // updating based on root.

    int leftV = find_below(root->left, val);
    int rightV = find_below(root->right, val);
    if (root->data >= val && leftV >= val && rightV >= val) return val;
    int flag = 0; int newV = val
    if (root->data < val) { newV = root->data; flag = 1; }
    if (leftV < val && leftV > newV)
        newV = leftV
    if (rightV < val && rightV > newV) newV = rightV;
    return newV;
}
```

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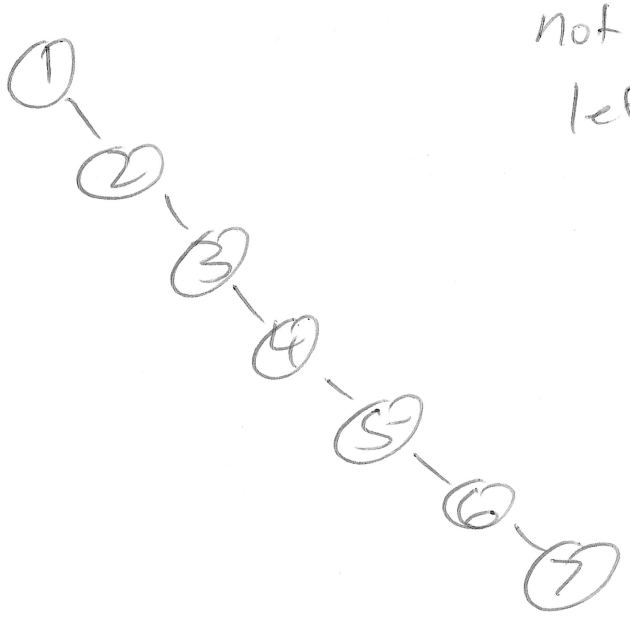
UCFID: _____
NID: _____

1) (5 pts) ALG (Binary Trees)

Draw a single **binary search tree** that meets all the following conditions:

- The tree contains 7 nodes.
- The tree's pre-order traversal is the same as its in-order traversal.
- The tree does not contain any duplicate values.

If it is not possible to draw such a tree, say so and explain why not.



not allowed a left child

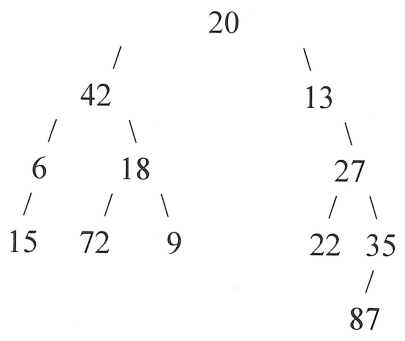
1) (10 pts) ALG (Binary Trees)

Consider a function that takes in a pointer to a binary tree node and returns a pointer to a binary tree node defined below:

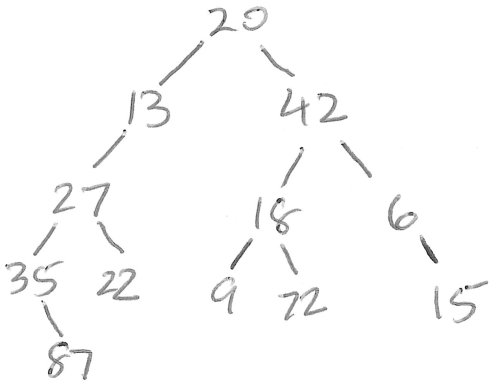
```
typedef struct bintreenode {
    int data;
    struct bintreenode* left;
    struct bintreenode* right;
} btreenode;

btreenode* somefunction(btreenode* root) {
    if (root == NULL) return NULL;
    somefunction(root->left);
    somefunction(root->right);
    btreenode* tmp = root->left;
    root->left = root->right;
    root->right = tmp;
    return root;
}
```

Let the pointer tree point to the root node of the tree depicted below:

root



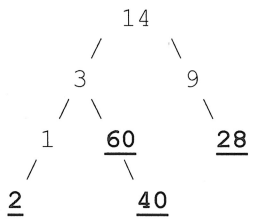
If the line of code `tree = somefunction(tree)` were executed, draw a picture of the resulting binary tree that the pointer tree would point to.



mirror flip
aka "vertical axis"

1) (10 pts) DSN (Binary Trees)

The goal of a function named *legacyCount()* is to take the root of a binary tree (*root*) and return the number of nodes that contain a value greater than at least one of their ancestors. For example, this function would return **4** for the following tree, since **60** is greater than both of its ancestors (3 and 14), **40** is greater than two of its ancestors (3 and 14) (even though 40 isn't greater than its parent!), **28** is greater than both of its ancestors (9 and 14), and **2** is greater than one of its ancestors (1).



Our node struct is as follows:

```
typedef struct node {
   int data;
   struct node *left;
   struct node *right;
} node;
```

To make the code work, *legacyCount*() is a wrapper function for a recursive function called *legacyHelper*(). Included below is the code for legacyCount() as well as the function signature for *legacyHelper*(). Write all of the code for the *legacyHelper*() function. Note: If *root* is NULL, you should return 0.

```
int legacyCount(node *root) {
    if (root == NULL) return 0;
    return legacyHelper(root->left, root->data) +
           legacyHelper(root->right, root->data);
}

int legacyHelper(node* root, int minAncestor) {
    if (root == NULL) return 0;
    int ans = 0;
    if ( root->data > minAncestor )
        ans = 1;
    else
        minAncestor = root->data;

    return ans + legacyHelper(root->left, minAncestor) +
                 legacyHelper(root->right, minAncestor);
}
```

1) (10 pts) DSN (Binary Trees)

Demonstrate your understanding of recursion by rewriting the following recursive function, which operates on a binary tree, as an **iterative** function. In doing so, you must abide by the following restrictions:

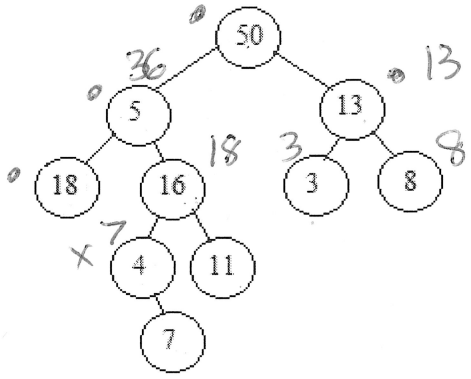
1. Do not write any helper functions in your solution.
2. Do not make any recursive calls in your solution.

```
int foo(node *root) {
    if (root == NULL) return 1;
    if (root->left == NULL && root->right == NULL) return 2;
    if (root->left == NULL) return 3 * foo(root->right);
    if (root->right == NULL) return 4 * foo(root->left);
    if (root->right->data > root->left->data) return 5 * foo(root->right);
    return 6 * foo(root->left);
}

int iterative_foo(node *root) {
```

```
int res = 1;
while (root != NULL) {
    if (root->left == NULL && root->right == NULL) {
        res *= 2;        //return 2*res;
        break;
    }
    else if (root->left == NULL) {
        res *= 3;
        root = root->right;
    }
    else if (root->right == NULL) {
        res *= 4;
        root = root->left;
    }
    else if (root->right->data > root->left->data) {
        res *= 5;
        root = root->right;
    }
    else {
        res *= 6; root = root->left;
    }
}
return res;
```

1) (10 pts) ALG (Binary Trees)

What does the function call `solve(root)` print out if root is pointing to the node storing 50 in the tree shown below? The necessary struct and function are provided below as well. Please fill in the blanks shown below. (Note: the left pointer of the node storing 50 points to the node storing 5, and all of the pointers shown correspond to the direction they are drawn in the picture below.)

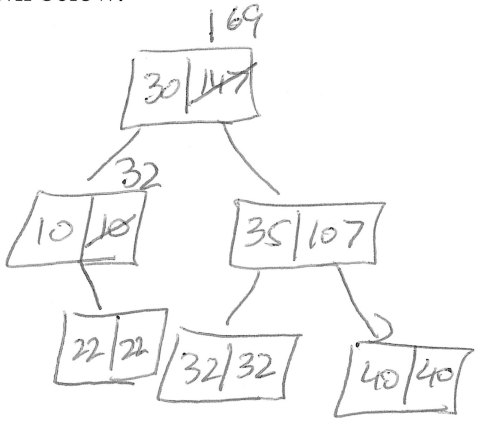



```
typedef struct bstNode {
    int data;
    struct bstNode *left;
    struct bstNode *right;
} bstNode;

int solve(bstNode* root) {

    if (root == NULL) return 0;

    int res = root->data;
    int left = solve(root->left);
    int right = solve(root->right);

    if (left+right > res)
        res = left+right;

    printf("%d, ", res);
    return res;
}
```

18, 7, 7, 11, 18, 36, 3, 8, 13, 50,

1) (10 pts) DSN (Binary Search Trees)

A modified BST node stores the `sum` of the `data` values in its sub-tree. **Complete** writing the insert function shown below ***recursively***, so that it takes in a pointer to the root of a binary search tree, *root*, and an integer, *value*, inserts a node storing value in it into the tree and returns a pointer to the root of the resulting tree. Notice that this task is more difficult than a usual binary tree insert since the sum values in several nodes must be updated as well. The struct used to store a node is shown below.




```
typedef struct bstNode {
   struct bstNode * left, * right;
   int data;
   int sum;
} bstNode;

bstNode* insert(bstNode * root, int value){


    if (root == NULL) {
        bstNode* res = malloc(sizeof(bstNode));

        res->data = value ;

        res->sum = value ;

        res->left = NULL ;

        res->right = NULL ;
        return res;
    }

    if (value <= root->data)
        root->left = insert(root->left, value);
    else
        root->right = insert(root->right, value);
    root->sum += value ;

    return root;
}
```

30 169
10 32
22 22
35 107
32 32
40 40