Recitation 4:

Recursion, Binary Trees, Huff Encoding

CIT 5940
February 16, 2023

Attendance

ENTER CODE:

874589

Announcements

1. HW3 due **February 28th @ 11:59PM ET**
   - GET STARTED EARLY
2. HW3 Group OH TBD. Details on ED
3. HW1 grades (ReadMe) posted
4. Recitation Assignment due 2/17 @ 11:45 PM ET

Recursion Review

Recursion

Definition: a technique of making a function call itself. It often times breaks complicated problems down into simple problems which are easier to solve

Important Steps:

1. Base Case
2. Recursive Step

Popular Recursive Programs:

1. Fibonacci
2. Factorial
3. Tree traversals

Recursion Example: Factorial

How would you write a recursive method to calculate the nth iteration of a **factorial?**

Recursion Example: Factorial

```
static int factorial(int n)
{

    // Handling base case
    // if value of n=1 or n=0, it returns 1
    if (n == 0 || n == 1)
        return 1;

    // Generic case
    // Otherwise we do n*(n-1)!
    return n * factorial(n - 1);
}
```

Recursion Example: Fibonacci

How would you write a recursive method to calculate the nth iteration of **Fibonacci**?

Recursion Example: Fibonacci

```
static int fib(int n)
  {
      if (n <= 1)
            return n;
      return fib(n - 1) + fib(n - 2);
  }
```

Binary Trees

Binary Trees

Definition: A finite set of nodes containing a root node with two disjoint children nodes (which also can be binary trees)

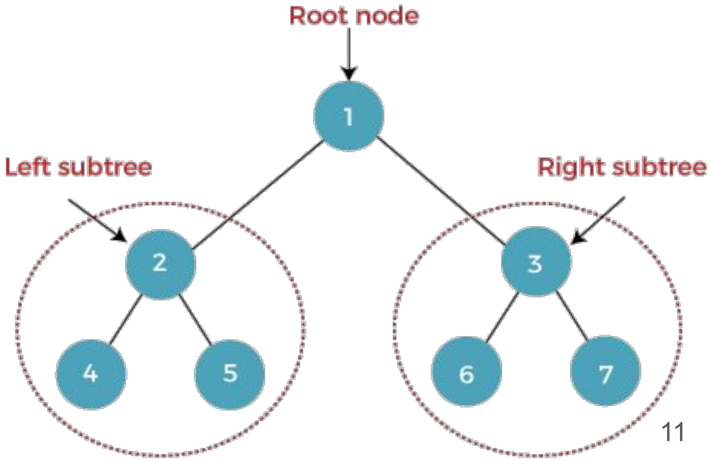
Key Properties:

1. Each node contains a value, a reference to the left child, and a reference to a right child
2. Internal nodes at least one non empty child
3. Leaf nodes have two empty children

Definitions:

1. **depth:** # of edges from root to a particular node
2. **height (h):** depth of the deepest node
3. **size:** total number of nodes -> *2^(h+1)-1*

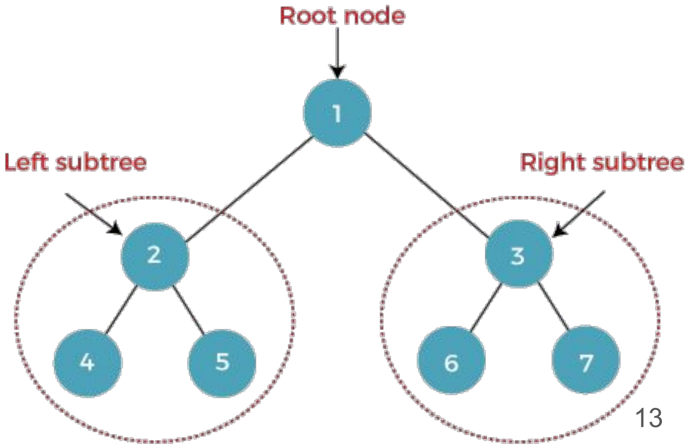
** Traversal is almost always done by **recursion****



Q: Given a binary tree, find the largest Node value

Binary Tree Example: Find Largest Node

```
public int largestNode(Node root) {
    if (root == null) return 0;
    else {
        int leftMax = max(root.value(), largestNode(root.left()));
        int rightMax = max(root.value(), largestNode(root.right()));
        return max(leftMax, rightMax);
    }
}
```



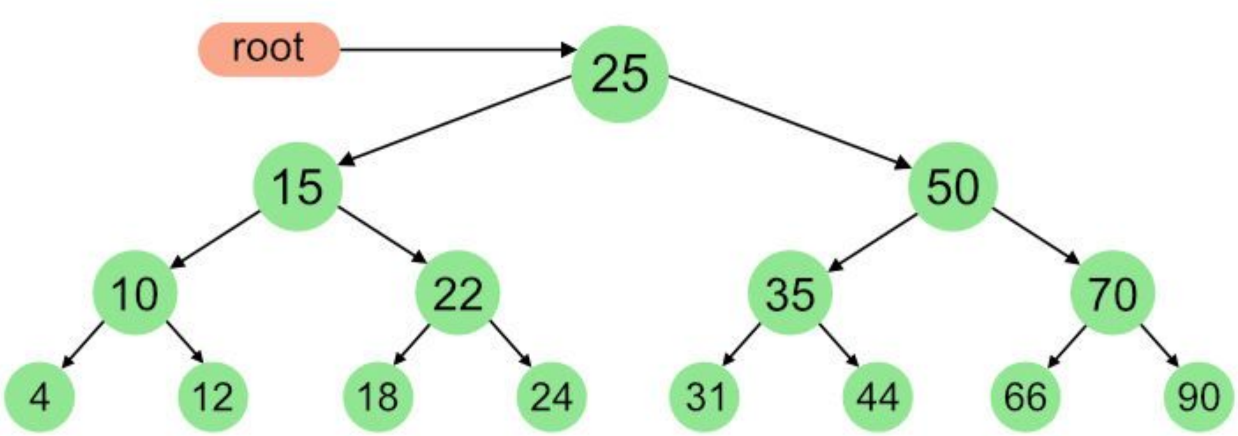
Binary Tree Traversals

Preorder traversal: a traversal that first visits the **root**, then recursively visits the **left** child, then recursively visits the **right** child

Postorder traversal: a traversal that first recursively visits the **left** child, then recursively visits the **right** child, and then visits the **root**

Inorder traversal: a traversal that first recursively visits the **left** child, then visits the **root**, and then recursively visits the **right** child.

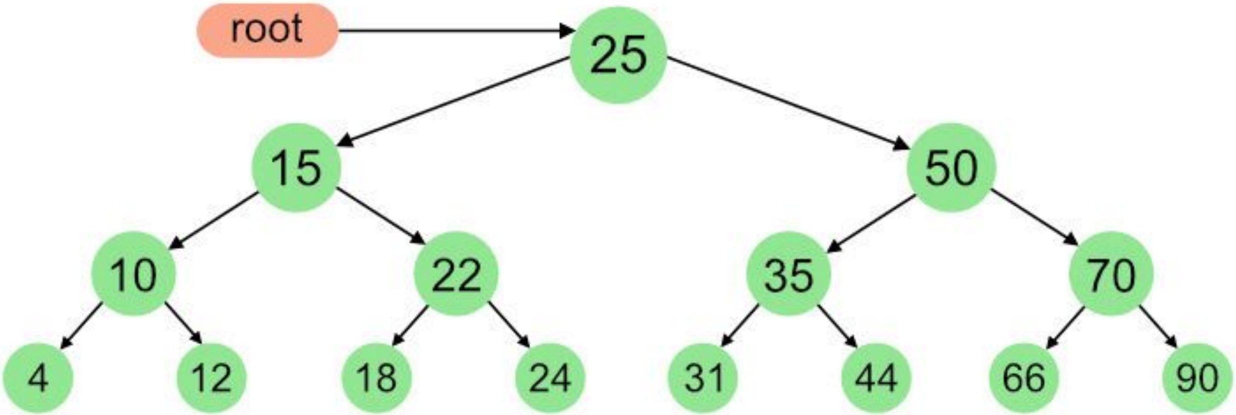
Q: What is the In Order traversal of this tree?



InOrder(root) visits nodes in the following order:

4, 10, 12, 15, 18, 22, 24, 25, 31, 35, 44, 50, 66, 70, 90

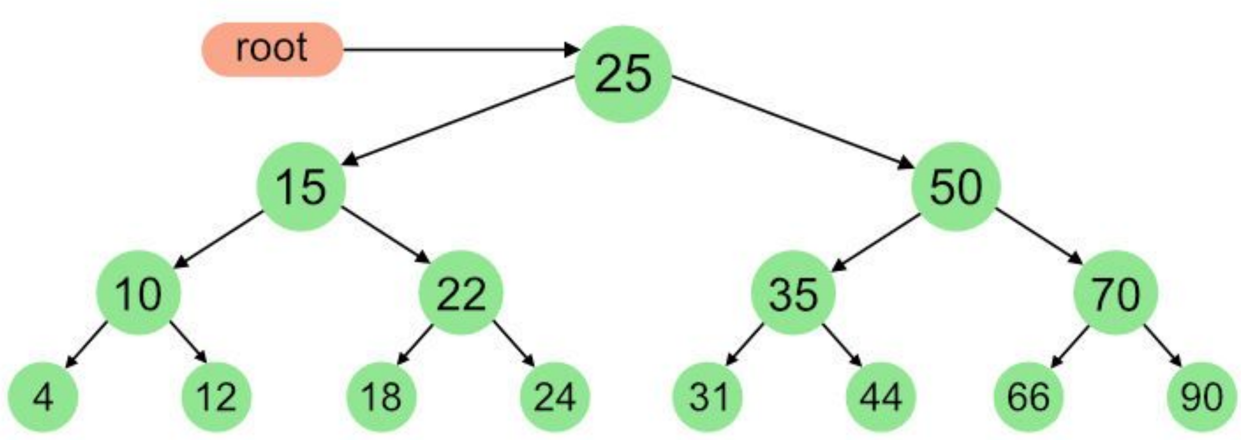
Q: What is the Pre Order traversal of this tree?



A Pre-order traversal visits nodes in the following order:

25, 15, 10, 4, 12, 22, 18, 24, 50, 35, 31, 44, 70, 66, 90

Q: What is the Post Order traversal of this tree?



A Post-order traversal visits nodes in the following order:

4, 12, 10, 18, 24, 22, 15, 31, 44, 35, 66, 90, 70, 50, 25

Huffman Encoding

Huffman Encoding Trees

Used in file compression for variable-length encoding

Steps to encode a string of *n* characters:

1. Create a collection of *n* initial Huffman trees
    a. Each tree is a single leaf node containing one of the letters and its frequency
2. Put the *n* partial trees onto a PriorityQueue *q* organized by weight (frequency)
3. Remove the first two trees (the ones with lowest weight, *a* and *b*) from *q*
4. Join *a* and *b* together to create a new tree *c* whose root has *a* and *b* as children
    a. *w(c) = w(a) + w(b)*
5. Put *c* back into *q*
6. Repeat until all of the partial Huffman trees have been consolidated

Example:

Build a Huffman tree for the following text, including a count for a <PSEUDO_EOF> character:

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Huffman Step 1: Letters & Frequencies

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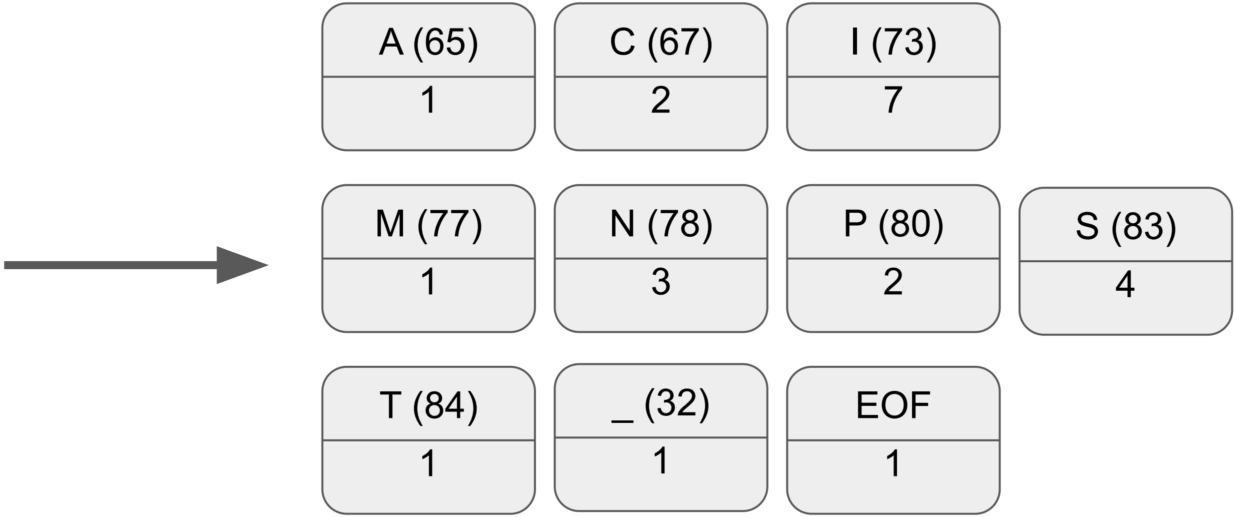
Letter	Frequency
A (65)	1
C (67)	2
I (73)	7
M (77)	1
N (78)	3
P (80)	2
S (83)	4
T (84)	1
_ (32)	1
EOF (26)	1



A (65)
1

C (67)
2

I (73)
7

M (77)
1

N (78)
3

P (80)
2

S (83)
4

T (84)
1

_ (32)
1

EOF
1

* characters in this HW will be represented by their ASCII ints (https://www.asciitable.com/)

Huffman Step 2: Priority Queue by Freq.

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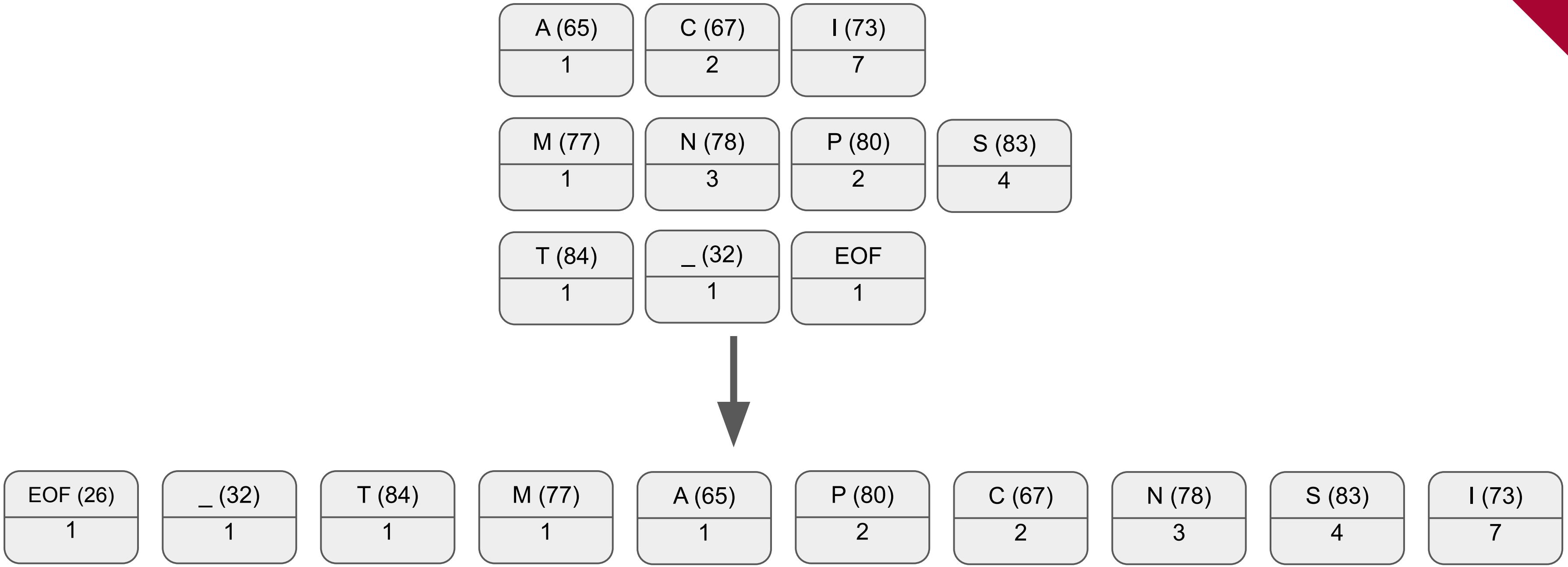

A (65) 1	C (67) 2	I (73) 7	
M (77) 1	N (78) 3	P (80) 2	S (83) 4
T (84) 1	_ (32) 1	EOF 1	

EOF (26)	_ (32)	T (84)	M (77)	A (65)	P (80)	C (67)	N (78)	S (83)	I (73)
1	1	1	1	1	2	2	3	4	7

Pay attention to the order!

Huffman Step 3-6: Joining Trees

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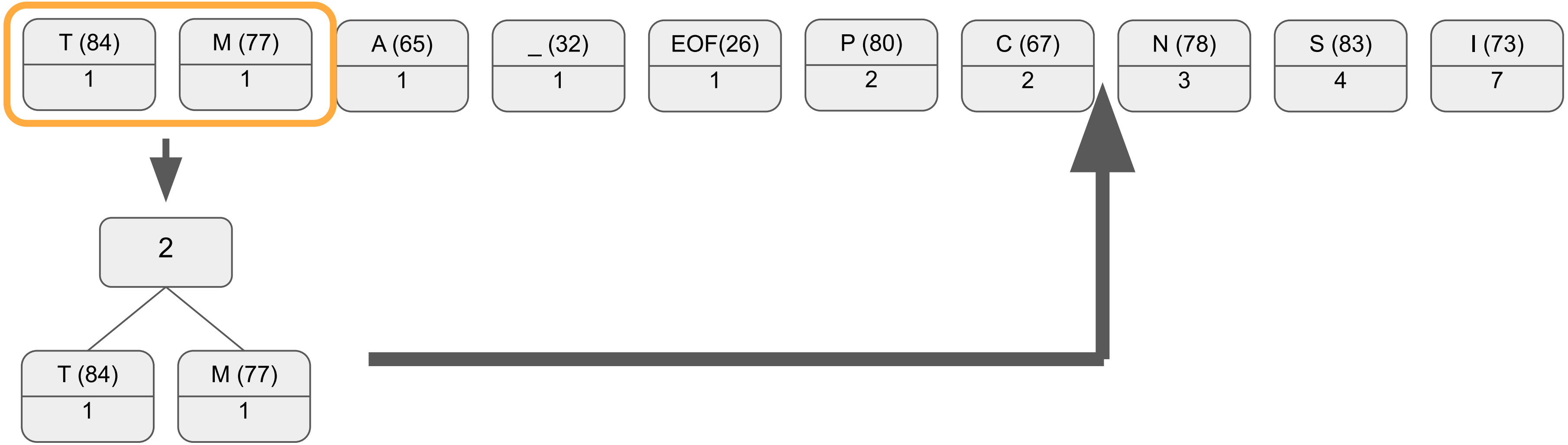

Huffman Step 3-6: Joining Trees

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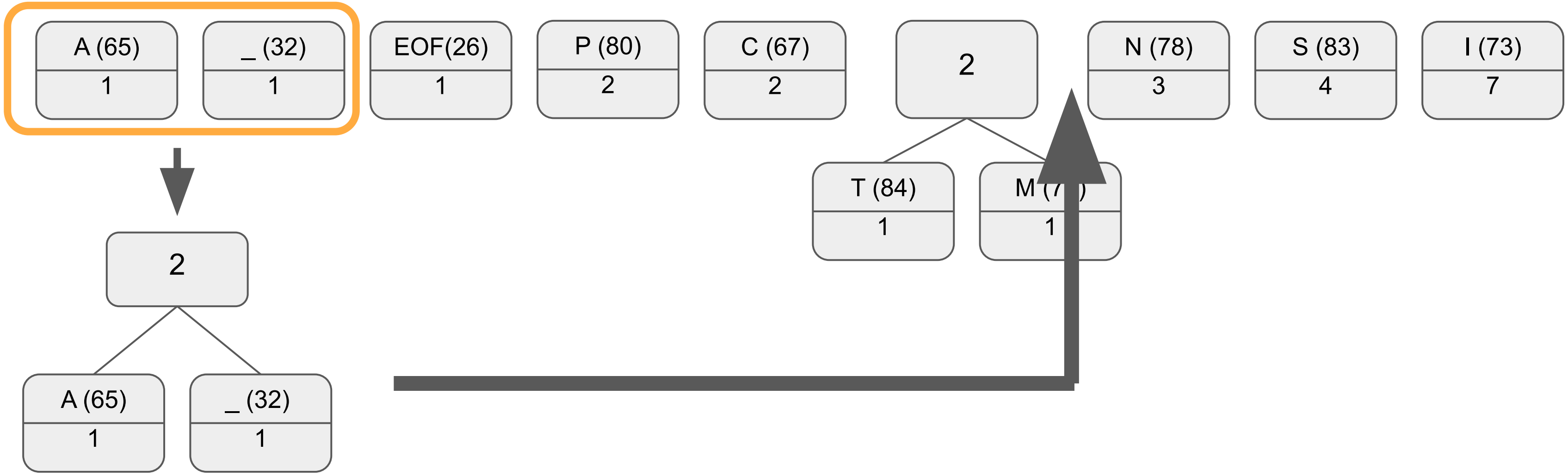

Huffman Step 3-6: Joining Trees

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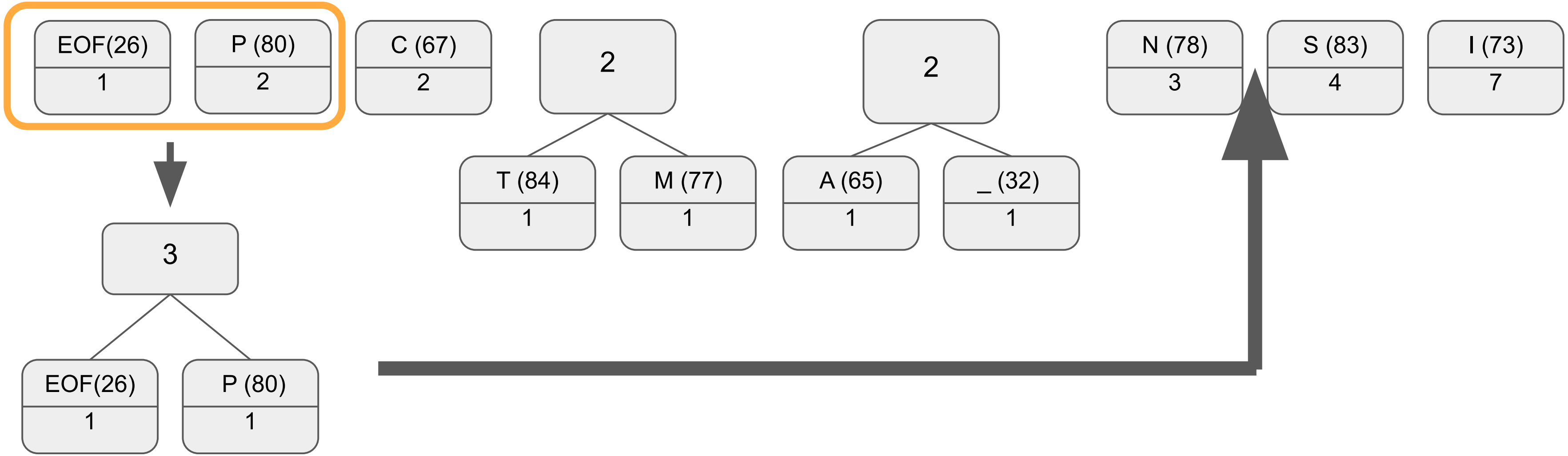

Huffman Step 3-6: Joining Trees

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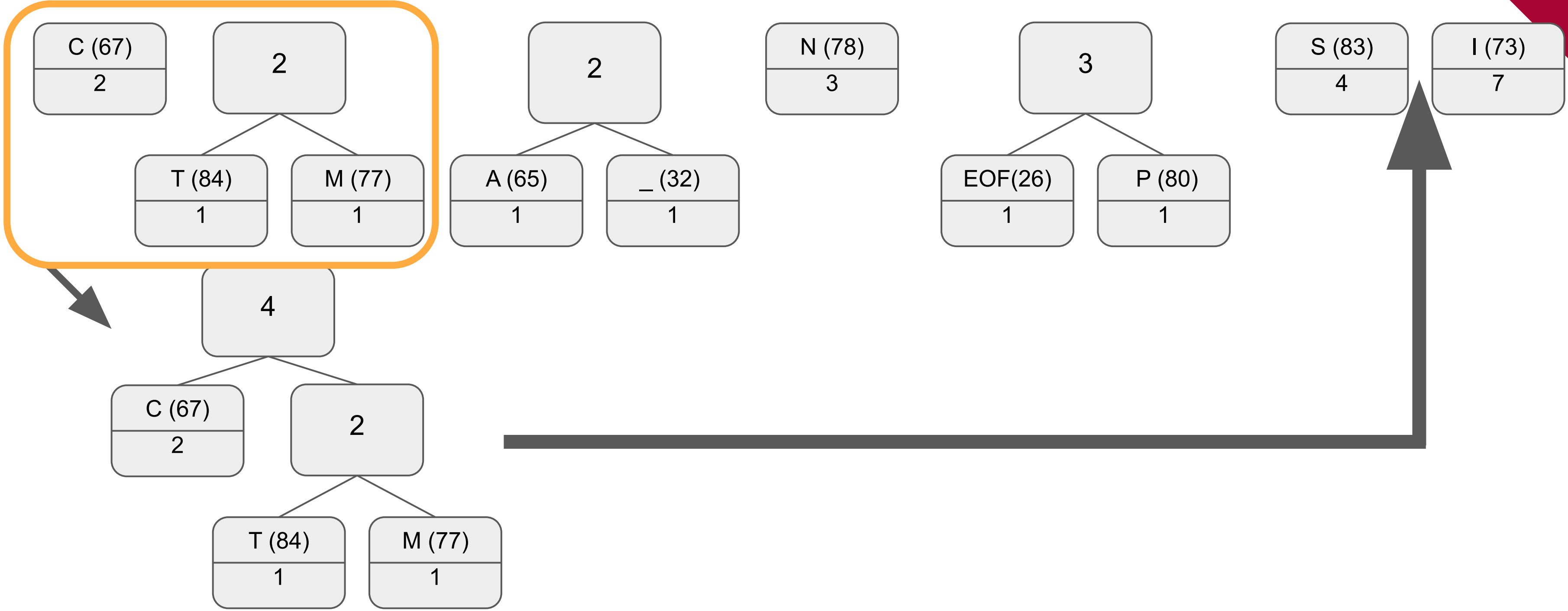

Huffman Step 3-6: Joining Trees

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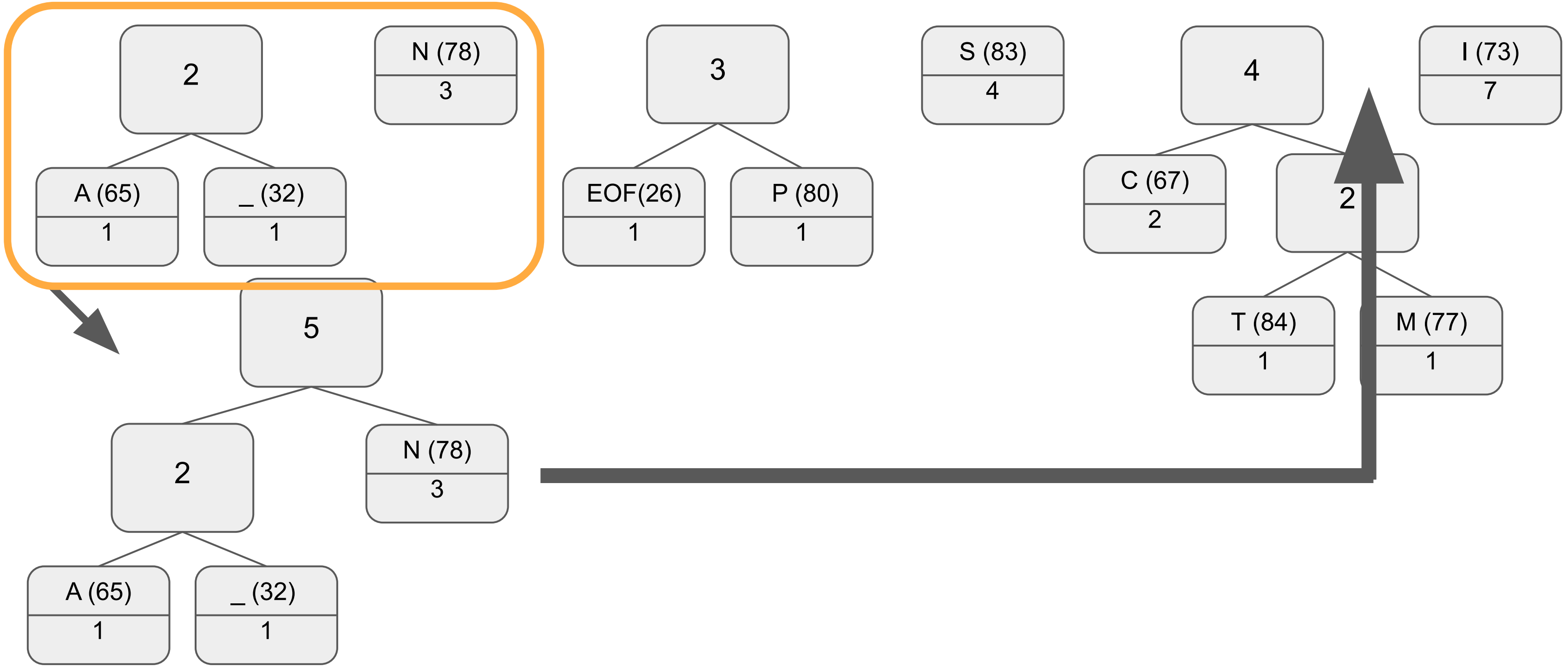

Huffman Step 3-6: Joining Trees

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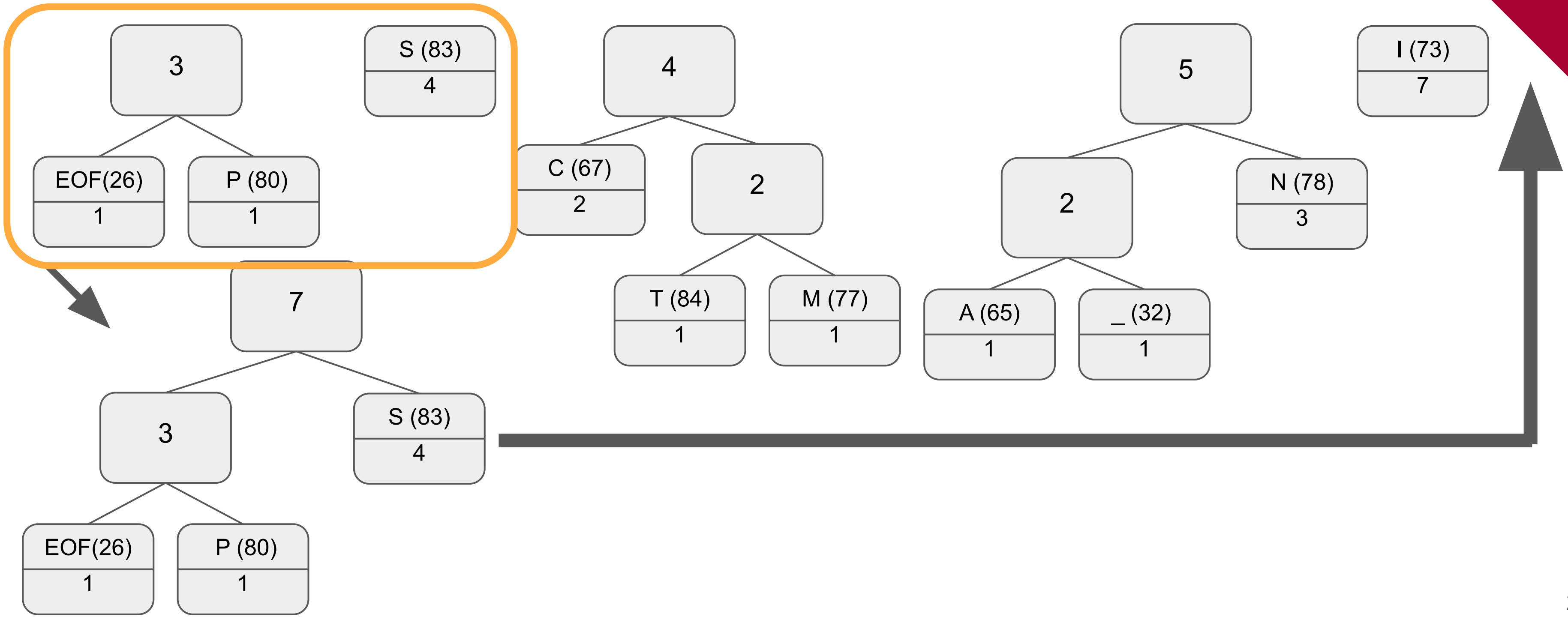

Huffman Step 3-6: Joining Trees

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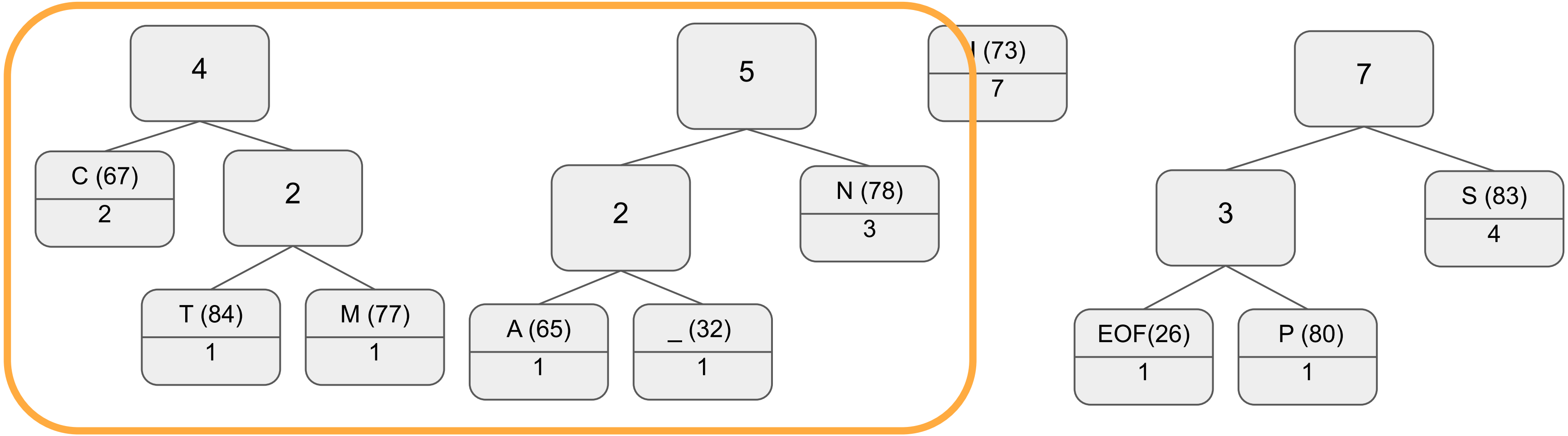

Huffman Step 3-6: Joining Trees

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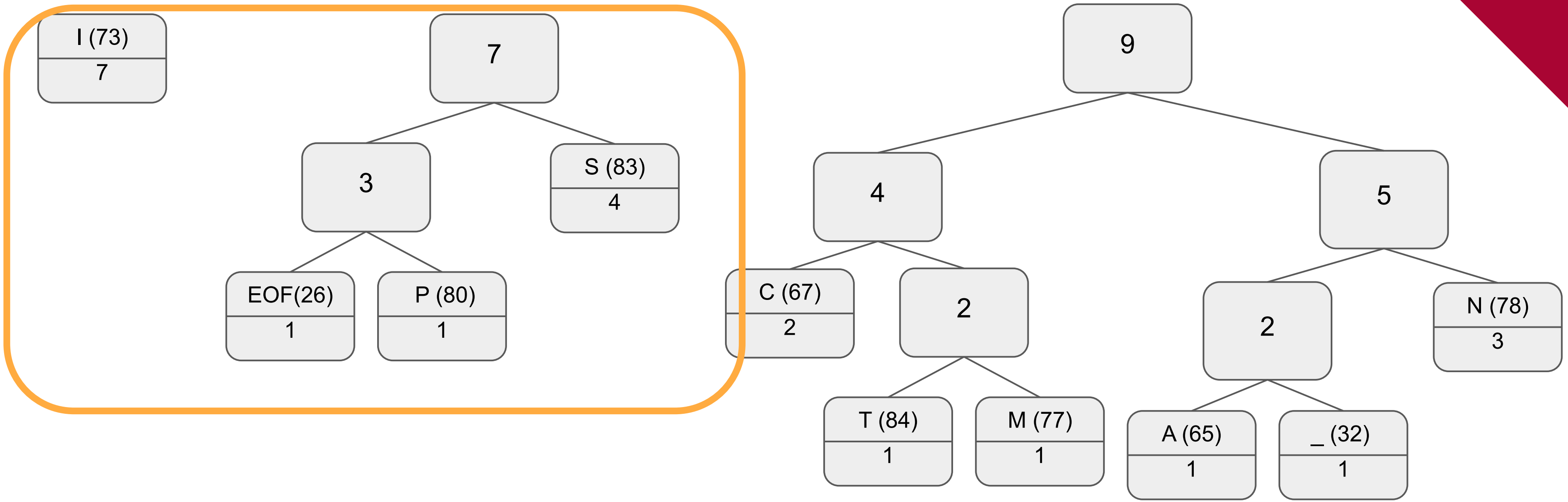

Huffman Step 3-6: Joining Trees

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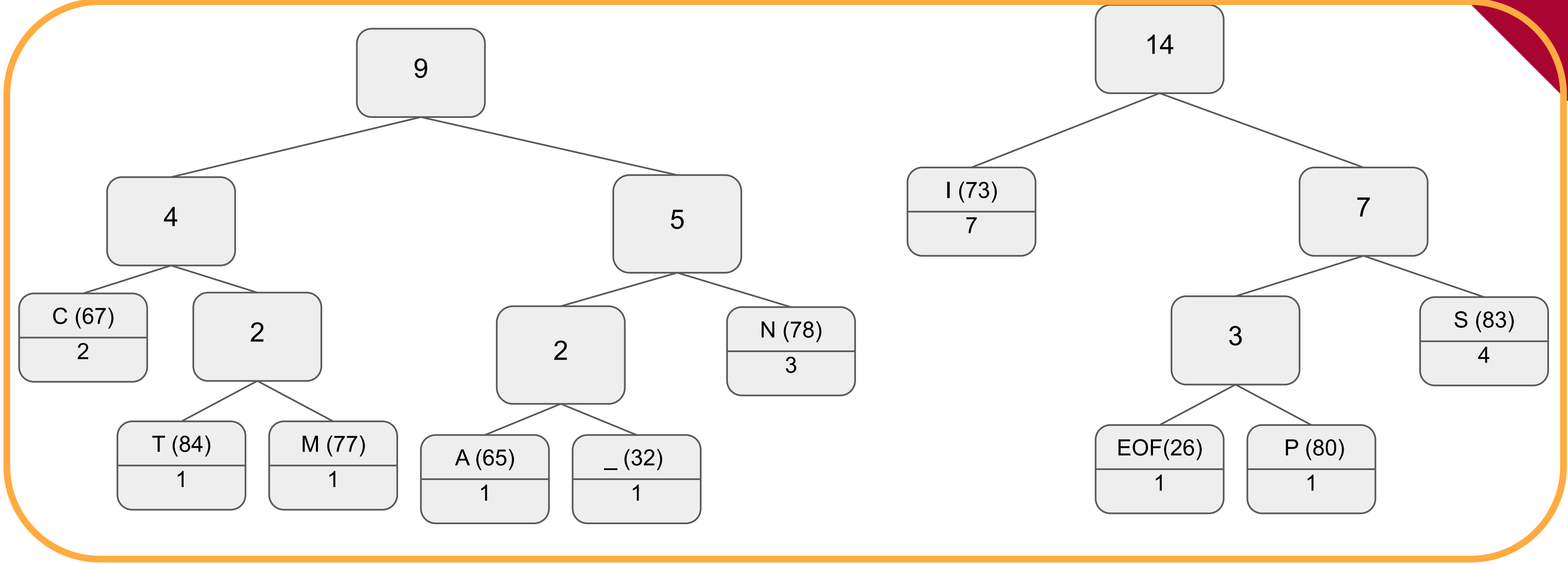

Huffman Step 3-6: Joining Trees

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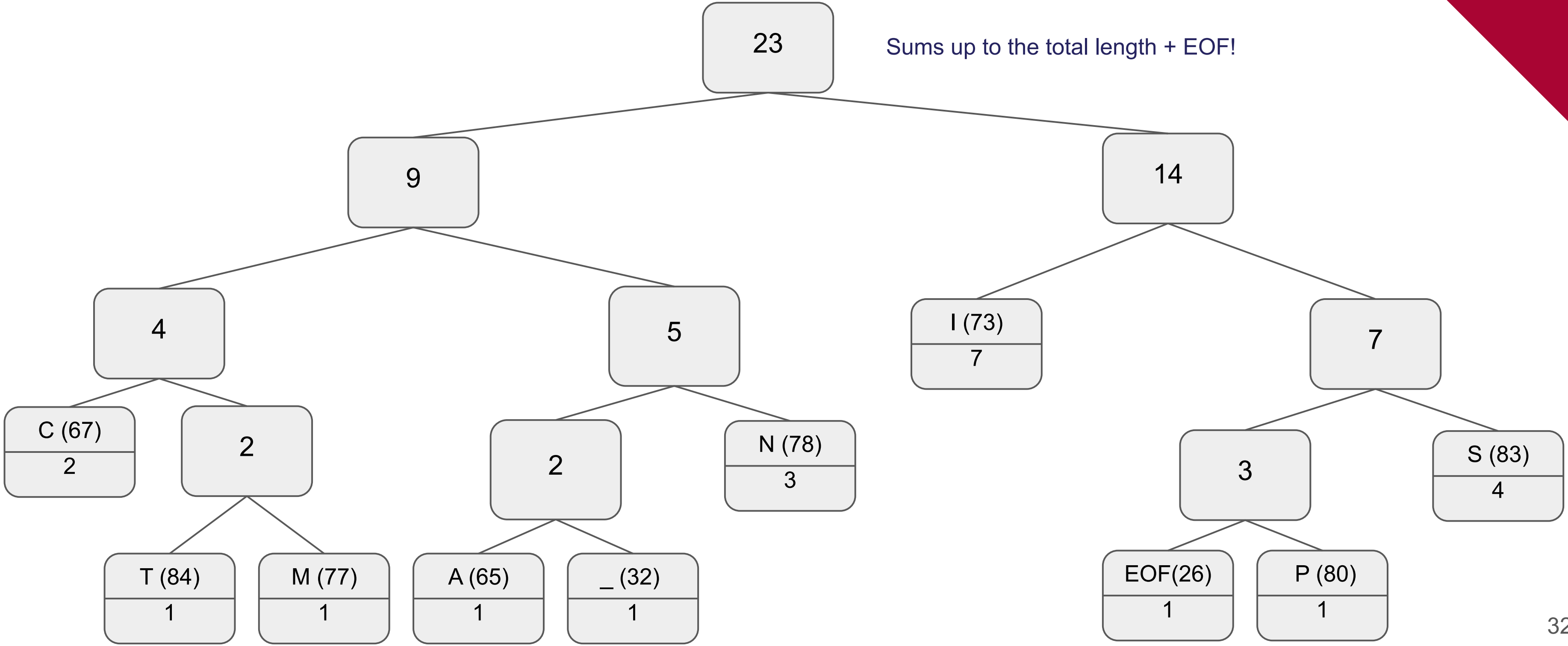
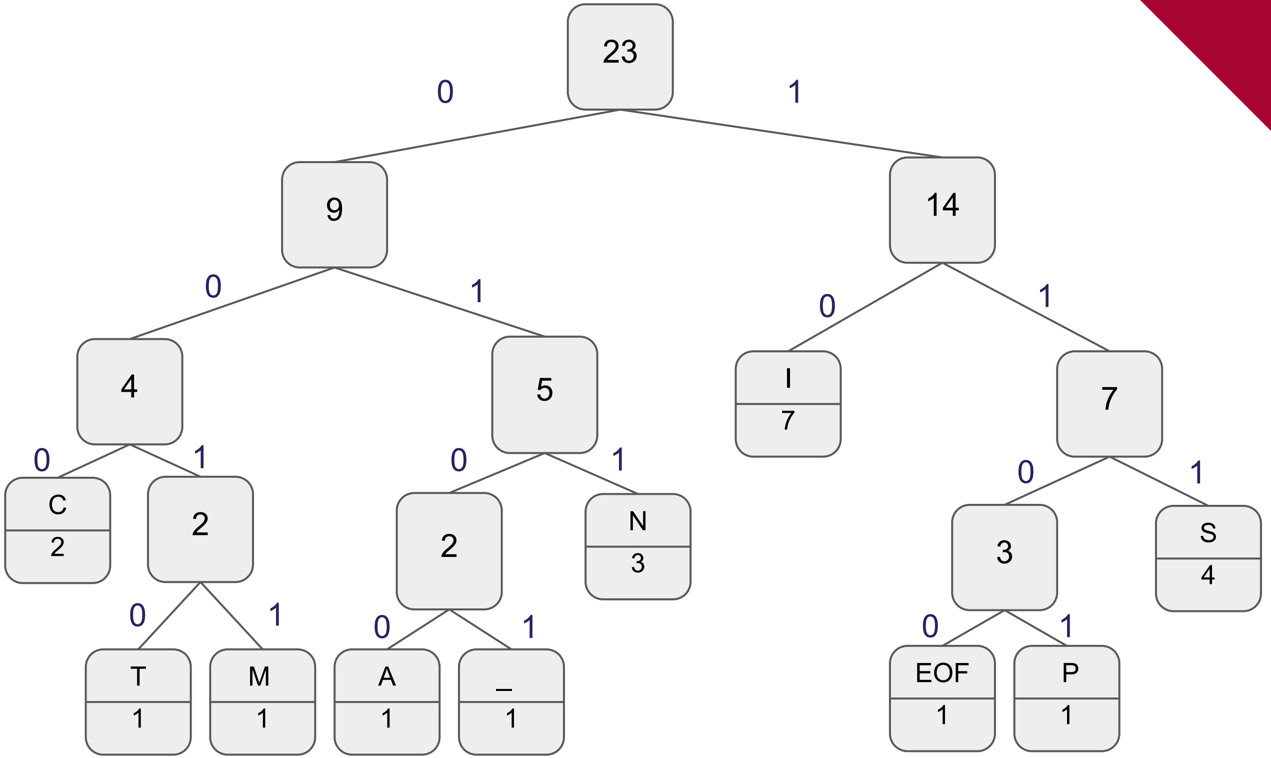


Sums up to the total length + EOF!

Huffman Codes

Letter	Code
C	000
T	0010
M	0011
A	0100
_	0101
N	011
I	10
EOF	1100
P	1101
S	111



Huffman Decoding

Letter	Code
C	000
T	0010
M	0011
A	0100
_	0101
N	011
I	10
EOF	1100
P	1101
S	111

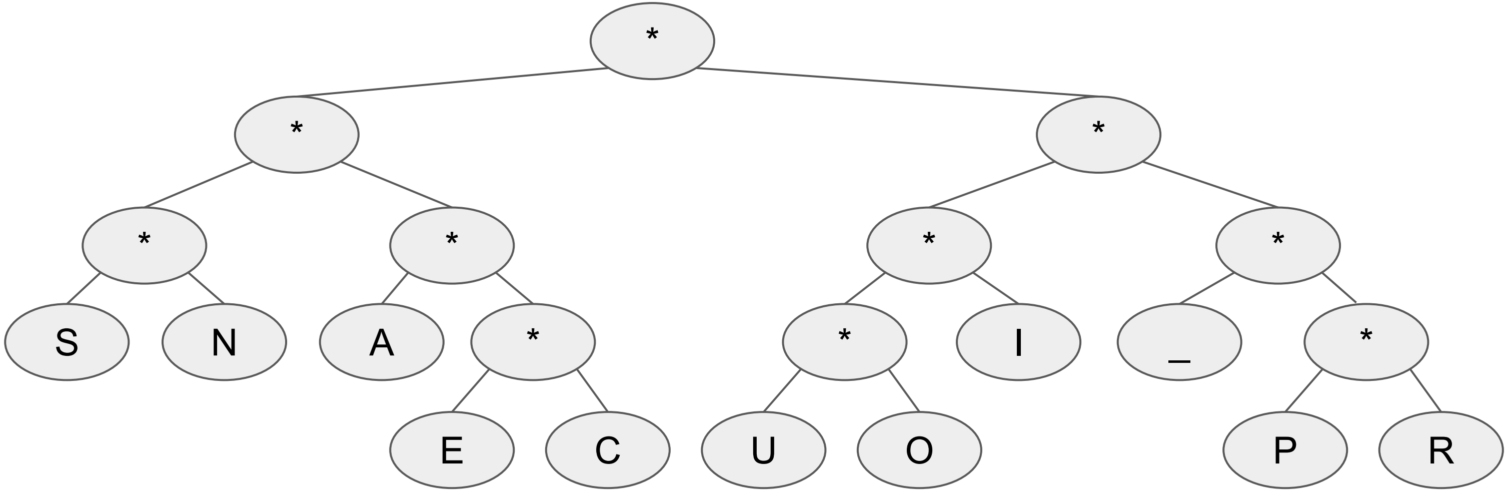
Given this table (that we just built) and the following file contents, what does the file decode to?

0000100001001110110111100

000 0100 0010 011 10 1101 1100

Huffman Code Example (cont.)

Letter	Code
A	010
C	0111
E	0110
I	101
N	001
O	1001
P	1110
R	1111
S	000
U	1000
_	110



What would the order of letters be if retrieved through pre-order traversal?

S, N, A, E, C, U, O, I, _, P, R

Recitation Activity:
Binary Tree Traversals

Attendance

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