

# Lecture 20 - Fetch Cycle in Microcode

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## Videos

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<https://youtu.be/lbYE4Jdh0Q> - Lect-20-2150-Fetch-Cycle.mp4

<https://youtu.be/PGa7yS8DC6s> - Lect-20-2150-pt2-compression.mp4

<https://youtu.be/BhRhpSNwA08> - Lect-20-2150-pt3-huffman.mp4

From Amazon S3 - for download (same as youtube videos)

<http://uw-s20-2015.s3.amazonaws.com/Lect-20-2150-Fetch-Cycle.mp4>

<http://uw-s20-2015.s3.amazonaws.com/Lect-20-2150-pt2-compression.mp4>

<http://uw-s20-2015.s3.amazonaws.com/Lect-20-2150-pt3-huffman.mp4>

## LZ Compression

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Please read the section in chapter 7 on LZ compression.

The basic idea behind LZ and LZW compression is to take advantage of repetition in files and replace repeated sections with a "code" that represents the repeated section. This can be beneficial in both time and space. Some kinds of documents like XML and JSON documents that are used for data exchange have a large amount of repeated information in them. By replacing the repeated section with a single code it can make the transmission of the document both faster and take up less CPU time.

Let's take a sample of text:

```
Theophilus Thistle, the unsuccessful Thistle sifter,  
In sifting a sleeve full of un-sifted Thistles,  
Thrust three thousand Thistles through the thick of his thumb.
```

If we replace Thistle with a code 1 and put a dictionary saying this is our replacement at the beginning we end up with:

```
1=Thistle  
Theophilus 1, the unsuccessful 1 sifter,  
In sifting a sleeve full of un-sifted 1s,  
Thrust three thousand 1s through the thick of his thumb.
```

LZ compression implements this in an orderly fashion by starting out with a dictionary of letters and growing each entry in the dictionary as it analyzes the document. Normally the dictionary is 4096 bits using the first 26 for letters and encoding all of the document into 12 bit codes that are in the dictionary. 4096 is 2 to the 12th power so 0b1000\_0000\_0000 or 0x800.

Since the dictionary has to be first to decode the document for small documents this will result in a bigger output. In documents being sent across the web Google has analyzed that any document less than 1721 bytes is better off left un-compressed.

This leaves the question of finding the most frequent text in the book and encoding that with the shortest bit string. To solve that question let's look at Huffman Encoding.

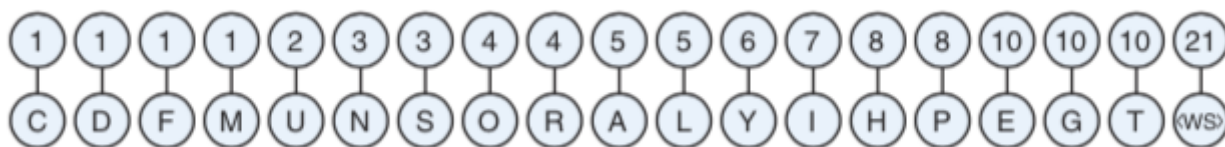
## Huffman Encoding

Let's walk through the example in the book.

First the data is analyzed for the frequency of letters. The reason for this is we will encode the least common letters as the longest patterns. In a real compression system instead of letters this will be the least common strings - but in our example we will just use letters. For the following text:

```
HIGGLETY PIGGLETY POP
THE DOG HAS EATEN THE MOP
THE PIGS IN A HURRY THE CATS IN A FLURRY
HIGGLETY PIGGLETY POP
```

This gives us:

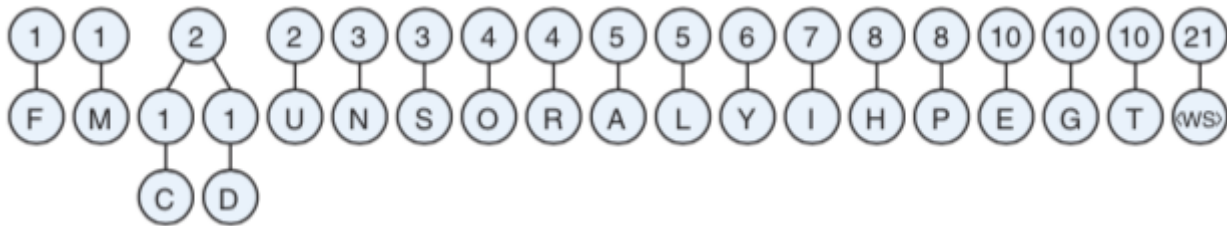


<ws> is the blank (whitespace) in our example. There are 21 blanks in the text. There is only 1 'T'.

The rest of this process is how to group these frequencies into a tree so that traversing the tree in the correct order will result in the letter we want to have.

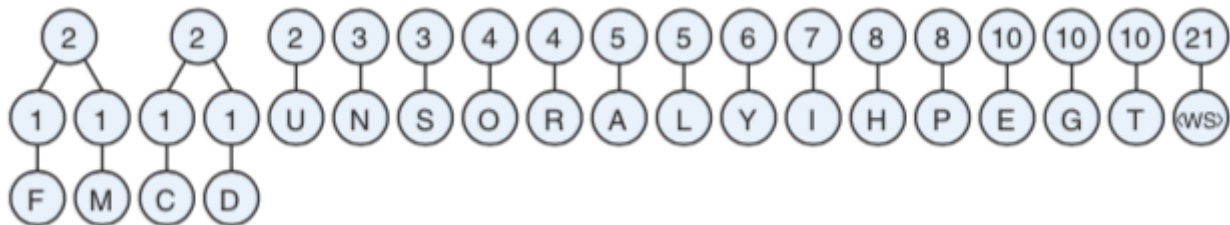
Starting on the left with the least frequent letter. (this will result in the depth of the tree being the deepest for the least used letter in the document)

Group 2 low frequency items together and build a sub-tree.

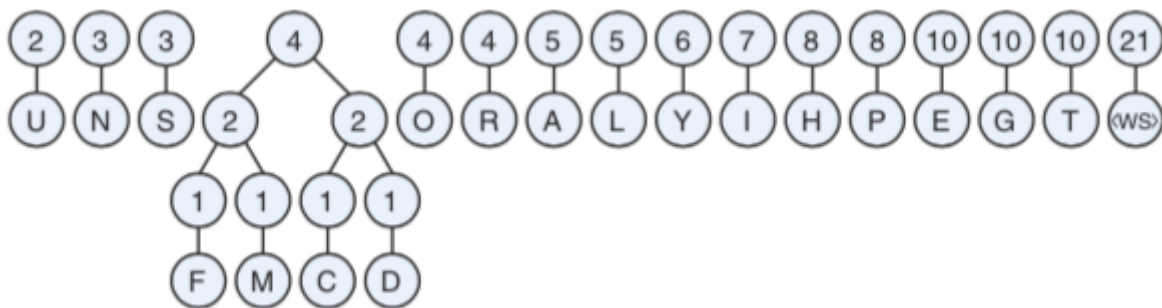


We have a tie for the 1 frequency items so just pick the left most 2 of them "C" and "D" - add the frequency together  $1+1$  is 2 - so insert this back into our list as a 2 frequency with a little tree of C and D. Repeat for "F" and "M".

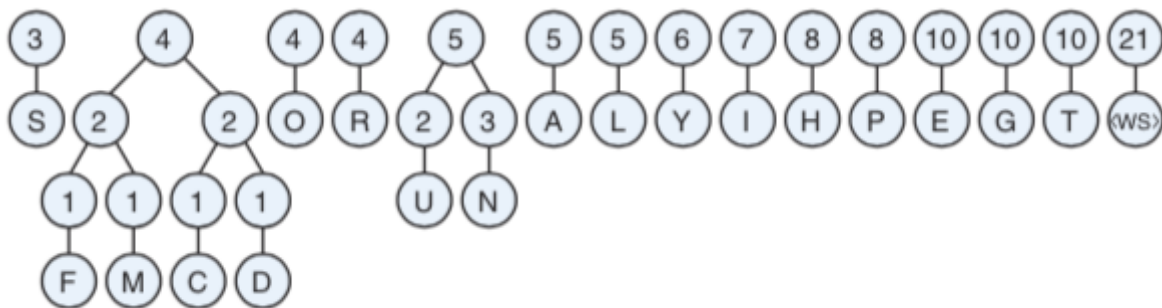
This give us:



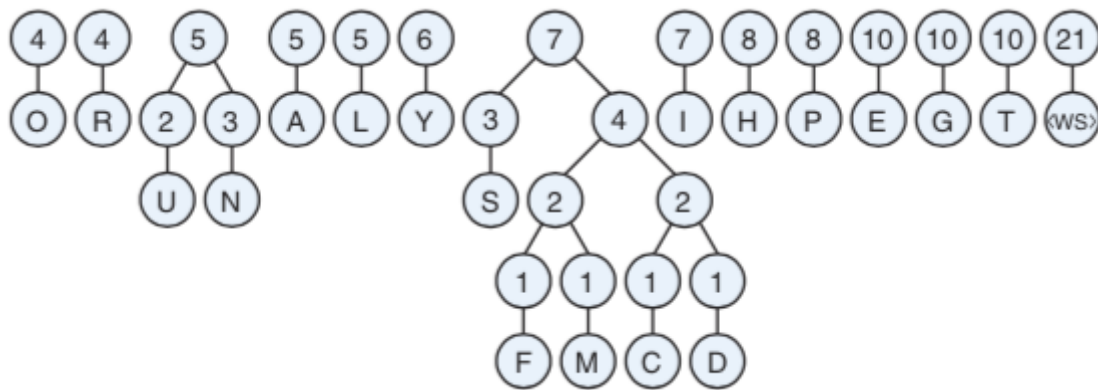
We now have multiple things that are frequency 2. Combining the first 2 of these into a frequency 4 node produces:



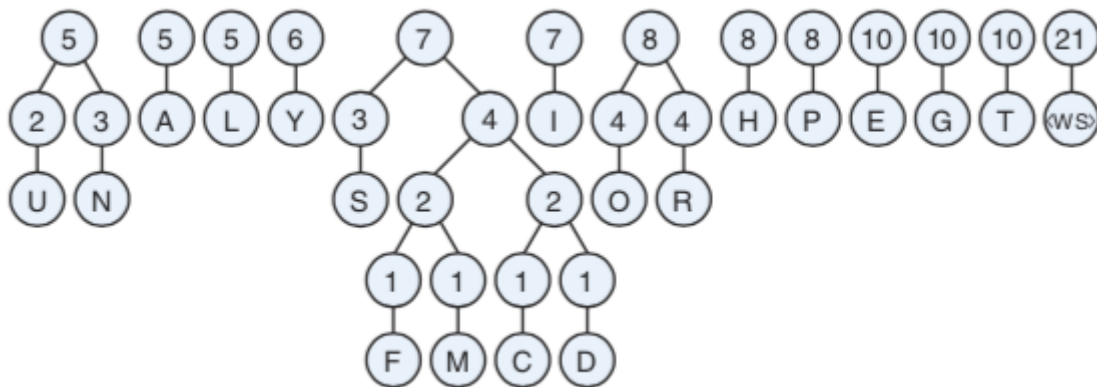
Combining a 2 and a 3 to produce a 5 produces:



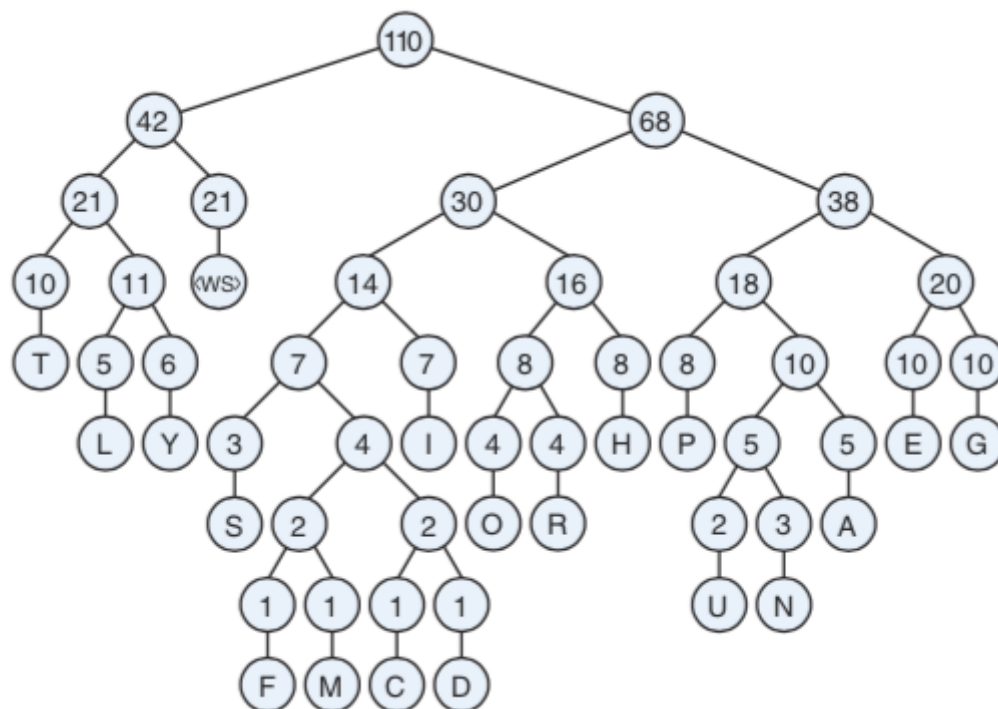
Combining 3 and 4 to produce a 7 results in:



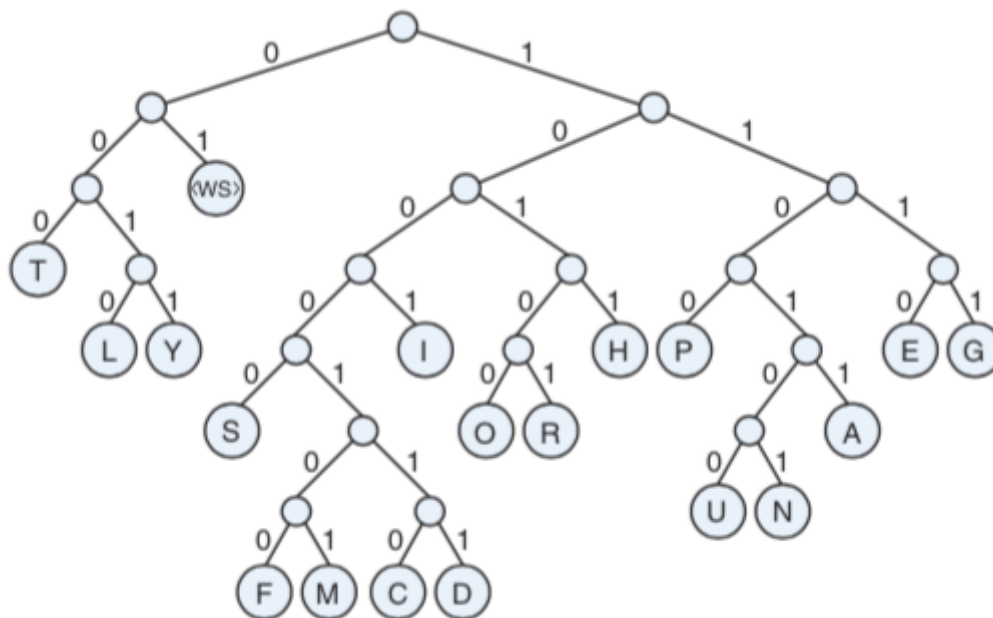
Repeat this process, combining the 5 and other nodes 7 more times:



We end up with the tree:



Mark each left side of a tree with a 0 and each right side with a 1:



From the tree we generate the following encoding table:

Letter	Code	Letter	Code
<WS>	01	O	10100
T	000	R	10101
L	0010	A	11011
Y	0011	U	110100
I	1001	N	110101
H	1011	F	1000100
P	1100	M	1000101
E	1110	C	1000110
G	1111	D	1000111
S	10000		

Now in the document we have an encoding of:

1011  
1001  
1111  
1111  
...

Giving us back the HIGG...

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Images taken from our textbook: The Essentials of Computer Organization and Architecture, 3th edition, Linda Null & Julia Lobur.