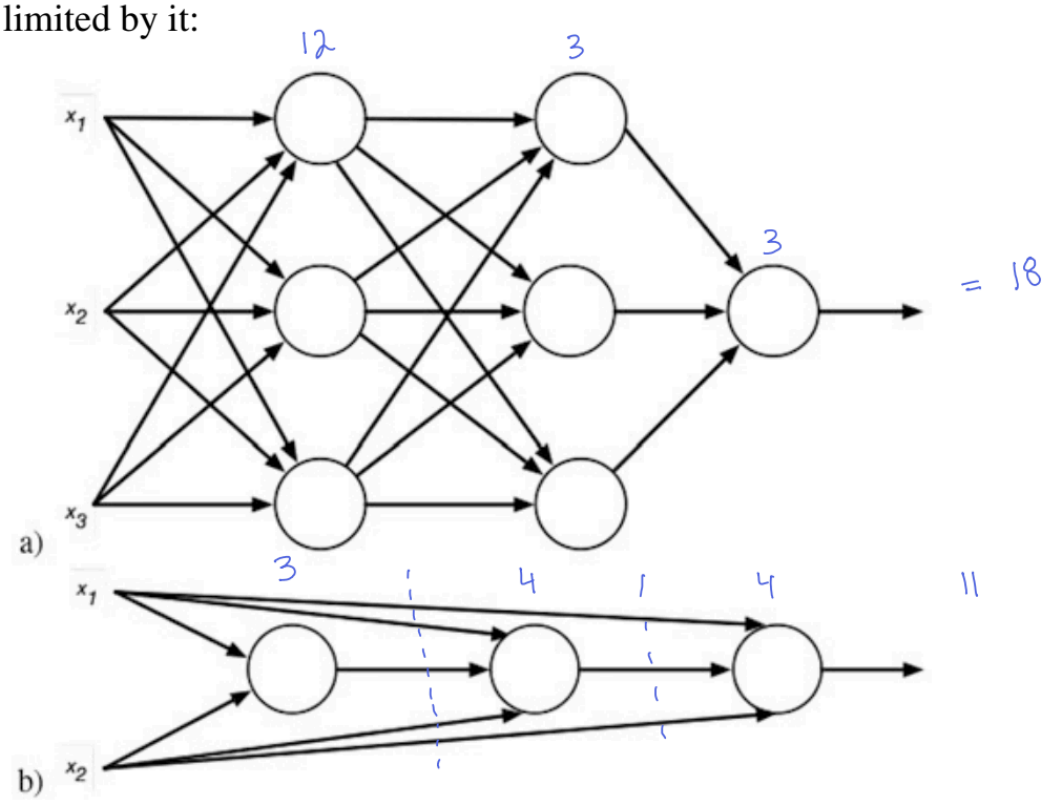
# Section 8

## Question 1

have biases. There is enough information in the input that the first layer is not limited by it:




### 1a

18 bits

### 1b

11 bits

### 1c

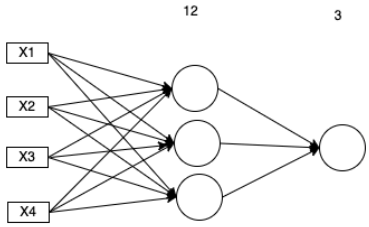
1a can memorize 18 rows of data with 1 bit of output for each row.
1b can memorize 11 rows of data with 1 bit of output for each row.

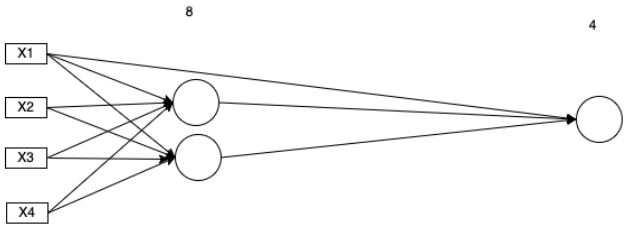
### 1d

1a can memorize 9 floor(18/2) rows of data with 2 bits of output for each row
1b can memorize 5 floor(11/2) rows of data with 2 bits of output for each row

## Question 2

MEC required is 12 bits because we have to memorize 12 rows with 1 bit for each row since it's a binary classification. The two systems below produce an MEC >= 12 bits so they should be able to memorize the data mentioned.




## Question 4

### 4a

- MEC for brain is $10^{11}$ (number of neurons) * 1000 (number of synapses per neuron) = $10^{14}$
- It is hard to say what I have memorized but I can try to figure out how much information I have received as an upper bound since I can't memorize more than that. For that information, maybe I'll only consider visual information for now.
- The human eye has 120 million rods and 6 million cones. Since we have 2 eyes, that is 240 million rods and 12 million cones. Rods don't fire in bright daylight and we'll assume that we are asleep when it's dark so we only really care about cones here. Assuming there are multiple cones for colors in RGB, we multiple 12 million by 3 to get to 36 million.
- Due to the persistence of vision, the human brain can only process 10-12 images per second. So, how many seconds have I been alive? 28 years * 365 days per year * 16 hours awake per day * 60 minutes per hour * 60 seconds per day equals to 5.88 * $10^8$ seconds. We'll multiply this by 10 to figure out total number of images I've processed in my life = 5.88 * $10^9$
- To calculate how much information is produced for a single image, perhaps a simplification would be that a cone either fires or doesn't. So, if there are 3.6 * $10^7$ cones

that fire per image and I have seen 5.88 * $10^9$ images, in total the number of cones and rods that have fired are 2.12 * $10^{18}$.

- So, just the visual information alone of just the cones has 2.12 * $10^{18}$ information and our brain can only store $10^{14}$ bits. Does this mean the brain is full? Probably not because the brain responds to changes in stimulus. So, if we stare at a blue sky for 12 hours straight, the brain recognizes that this is the same information already received so it stops storing it. Additionally, even when receiving totally different stimuli, the brain is probably still removing a bunch of the information and that's perhaps why when we remember images of sceneries, we tend to remember parts of them that were more appealing to us, and don't really have a high fidelity recall of the whole scenery that we saw.

## 4b

What is the information content in the works of Shakespeare? 8 bits to store a letter. According to some online sources, Shakespeare wrote 884,647 words (https://www.opensourceshakespeare.org/statistics/). Assuming each word is on average 5 characters, that makes a total of 3.54 * $10^7$ bits. The capacity of the brain is larger than this so we should be able to store his works in the brain completely. There are people who can probably recite all his works verbatim so that's a little anecdotal evidence that the capacity of the brain is larger than his works. You could also argue that his works were created by the brain and so by the information processing inequality, his works can't have more bits than that of the brain.