Assignment 1

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1 Problem 1

In what follows, r is the radius of the hemispherical caps,l the length and m of the cell. It is given that,

$$r = 0.5\mu\text{m}$$

$$l = 2\mu\text{m}$$

(a) Volume is given by

$$V = \pi r^2 l + \frac{4}{3}\pi r^3 = 2.094\mu\text{m}^3$$

Typical cell volume is $0.6 - 0.7\mu\text{m}^3$
`https://en.wikipedia.org/wiki/Escherichia_coli`

(b) m is the sum of the mass of water contained and that of the other substances. Since, density of water is

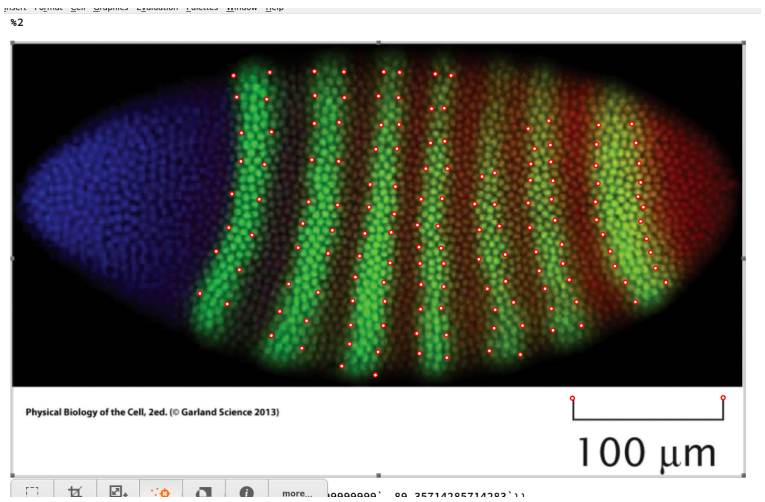
$$10^3 \frac{\text{kg}}{\text{m}^3} = 10^{-6} \frac{\text{pg}}{\mu\text{m}^3}$$

We have

$$m = 10^{-6} \cdot \left(\frac{2}{3} + 1.3 \cdot \frac{1}{3}\right) \cdot V\text{pg} = 2.304 \cdot 10^{-3}\text{pg}$$

Typical cell weight is $1 \cdot 10^{-3}$pg
`https://ecmdb.ca/e_coli_stats)`

It is evident from the above calculations, that the it is the assumed shape of *E. coli* which deviates greatly from what is true.



2 Problem 2

Let at the end of 9^{th} cycle there be N nuclei at the surface. At the end of 13^{th} cycle, therefore there are $16N$ nuclei, which is given as ≈ 6000. Hence,

$$N \approx 375$$

Since, every embryo must start from a single fertilized nucleus, at the end of 9^{th} cycle, there must be $2^9 = 512$ nuclei in total. Therefore, the fraction of nuclei which migrated to the surface is

$$\frac{375}{512} \approx 0.7324$$

Following the notation of Problem 1, surface area of the spherocylinder is

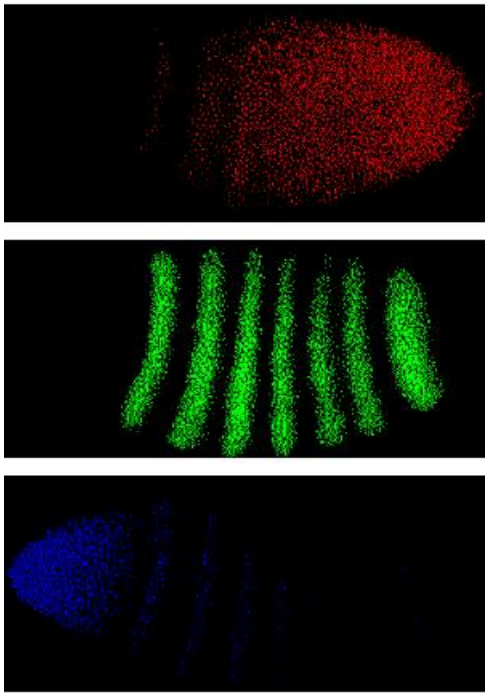
$$A = 4\pi r^2 + 2\pi r l = 4.3982 \cdot 10^{-7}\text{m}^2$$

Therefore, the areal density is

$$1.3642 \cdot 10^{10} \frac{\text{nuclei}}{\text{m}^2}$$

(For the next part, I have used Mathematica.) To calculate the length of the green strips, I marked the ends of widths along the lenghts of each strip, and then used the given scale.
Length of the green strip is: $18.37 \pm 4.99\mu$m To evaluate the number of nuclei in each strip, I isolated the colors, and counted the number of pixels.
Therefore, the number of nuclei corresponding to each dye(I'm considering only a single surface)

- Red: 148
- Green: 210
- Blue: 58



3 Problem 3

3.1 E. coli

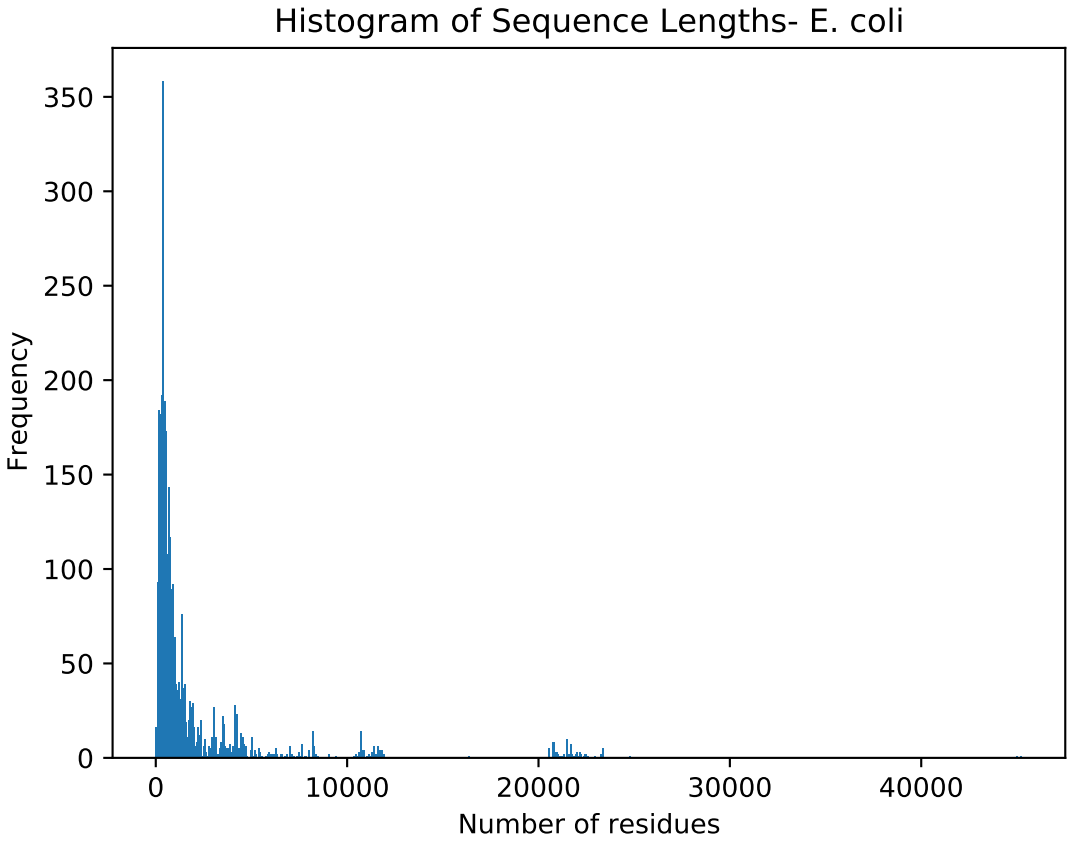
Mean of sequence length: 1892.00
Standard deviation of sequence length: 3872.73
Mean of molecular mass: 289.03
Standard deviation of molecular mass: 775.76

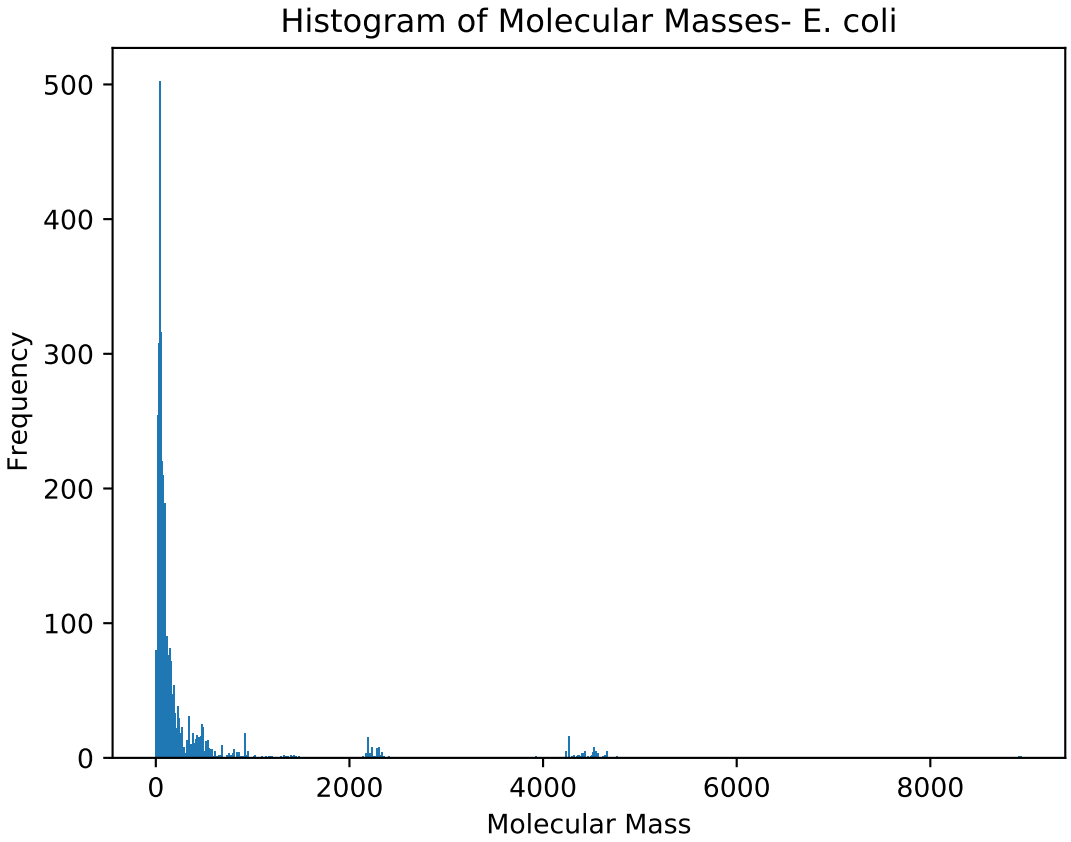
3.2 S. cerevisiae

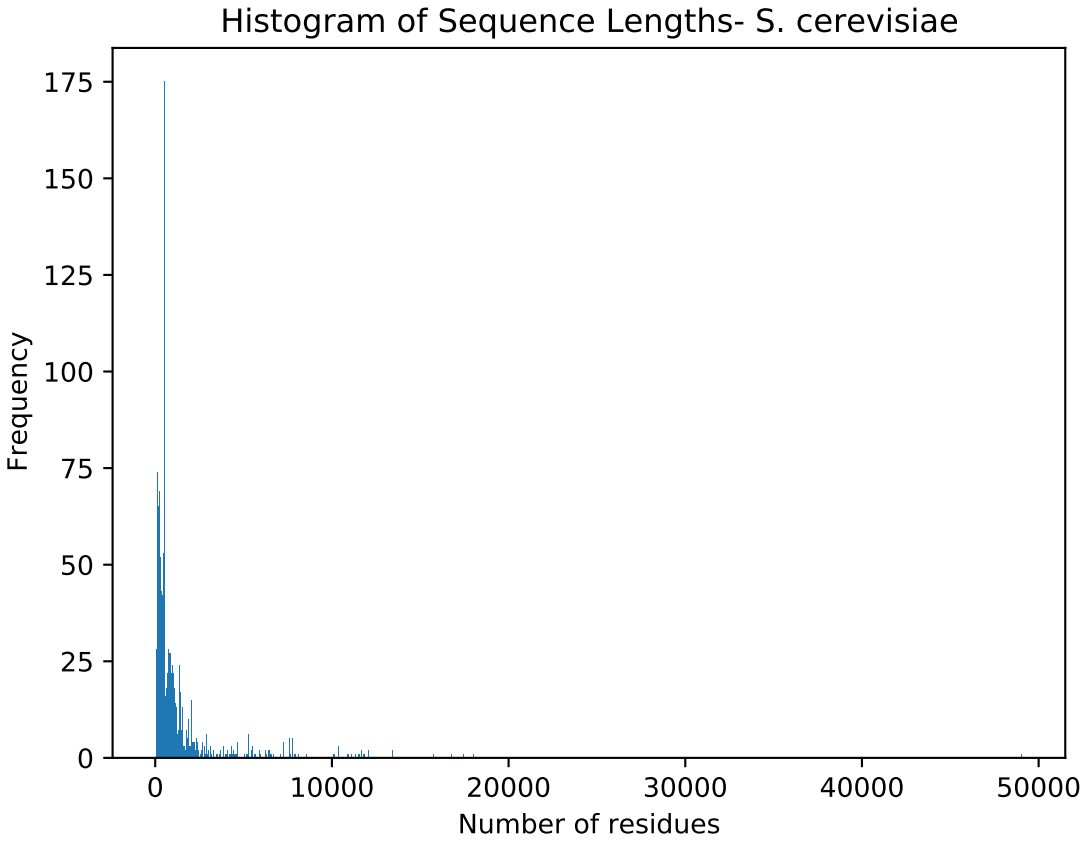
Mean of sequence length: 1287.90
Standard deviation of sequence length: 2444.49
Mean of molecular mass: 154.78
Standard deviation of molecular mass: 313.31

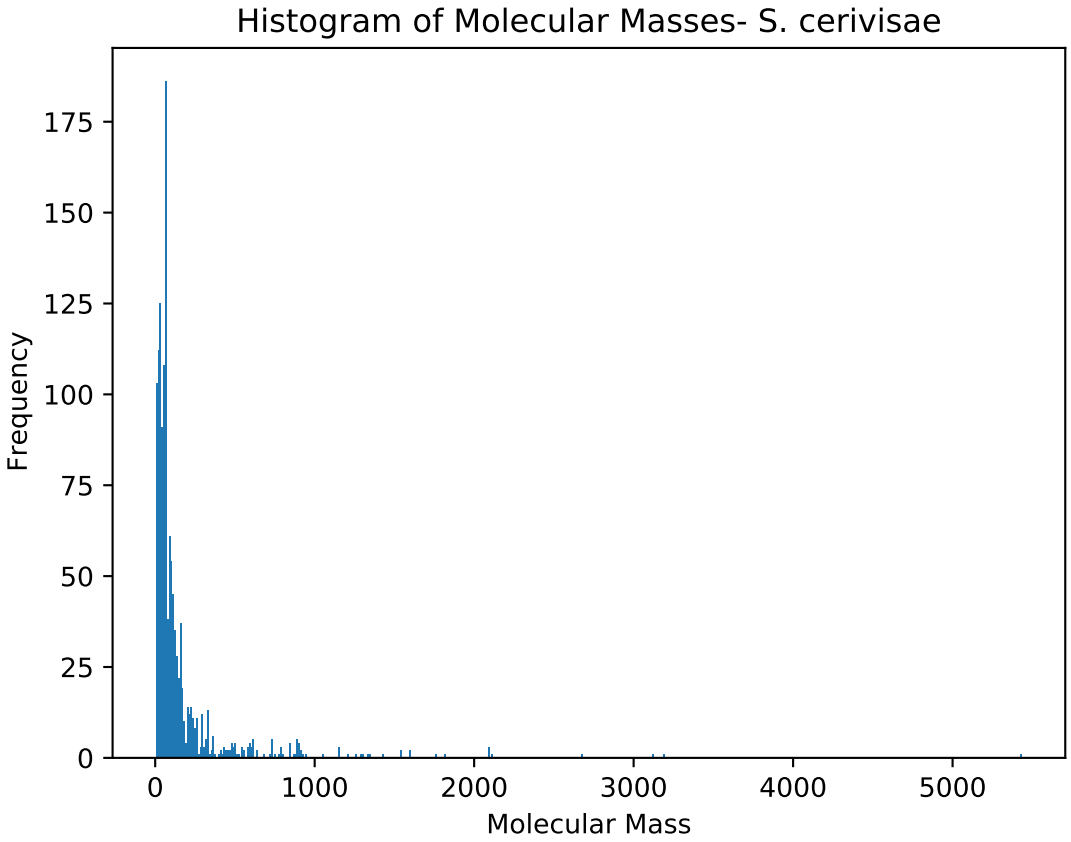
3.3 Humans

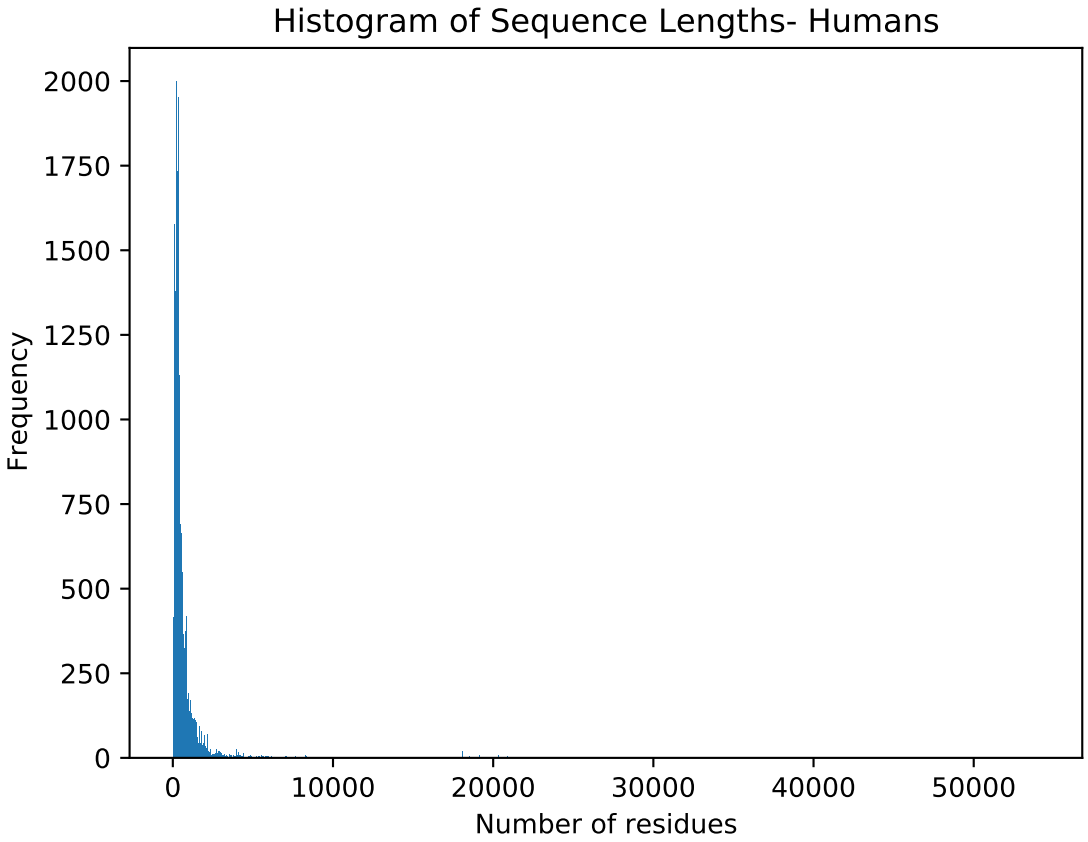
Mean of sequence length: 630.74
Standard deviation of sequence length: 1263.08
Mean of molecular mass: 74.21
Standard deviation of molecular mass:181.93

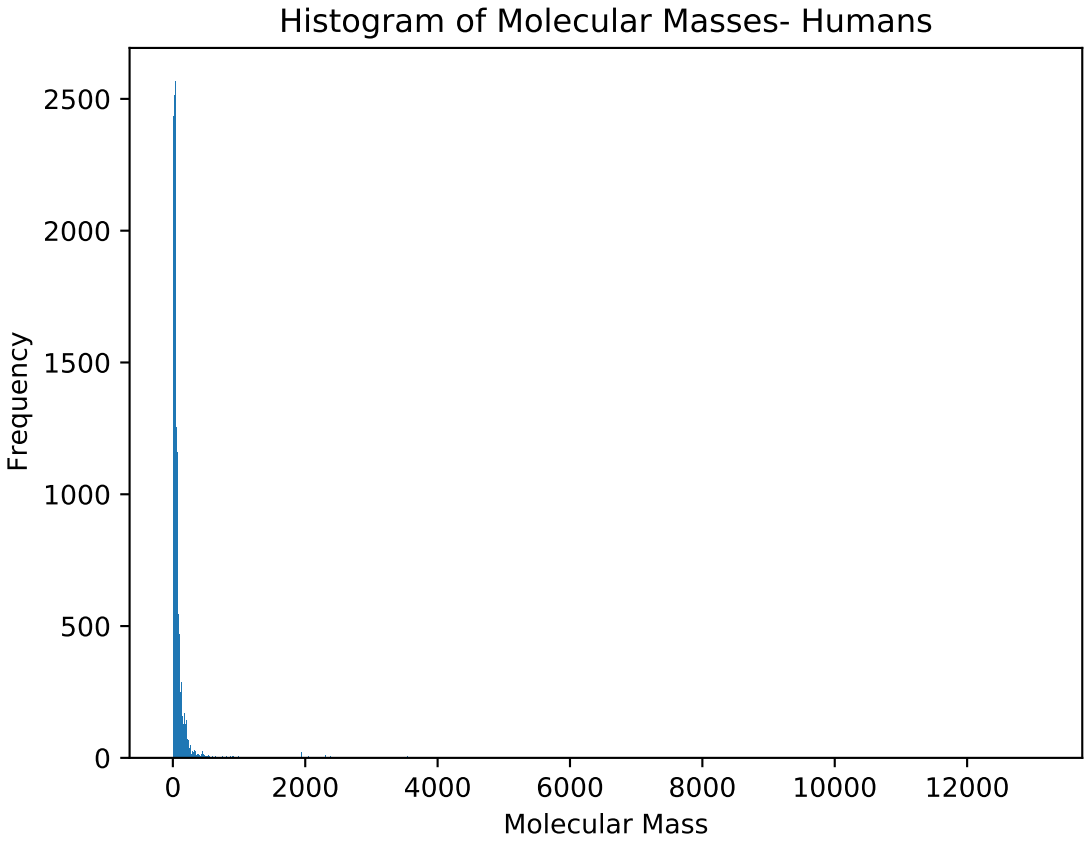

Histogram of Sequence Lengths- E. coli
Frequency
Number of residues
0
50
100
150
200
250
300
350
0
10000
20000
30000
40000


Histogram of Molecular Masses- E. coli
Frequency
Molecular Mass
0
100
200
300
400
500
0
2000
4000
6000
8000


Histogram of Sequence Lengths- S. cerevisiae
Frequency
175
150
125
100
75
50
25
0
0
10000
20000
30000
40000
50000
Number of residues


Histogram of Molecular Masses- S. cerivisae
Frequency
175
150
125
100
75
50
25
0
0
1000
2000
3000
4000
5000
Molecular Mass


Histogram of Sequence Lengths- Humans
Frequency
2000
1750
1500
1250
1000
750
500
250
0
0
10000
20000
30000
40000
50000
Number of residues


Histogram of Molecular Masses- Humans
Frequency
2500
2000
1500
1000
500
0
0
2000
4000
6000
8000
10000
12000
Molecular Mass

4 Problem 4

The probability of having 0 and 6 is

$$p^3q^3$$

. The probability of having 1 and 5 is

$$\binom{3}{1}p^4q^2 + \binom{3}{1}p^2q^4$$

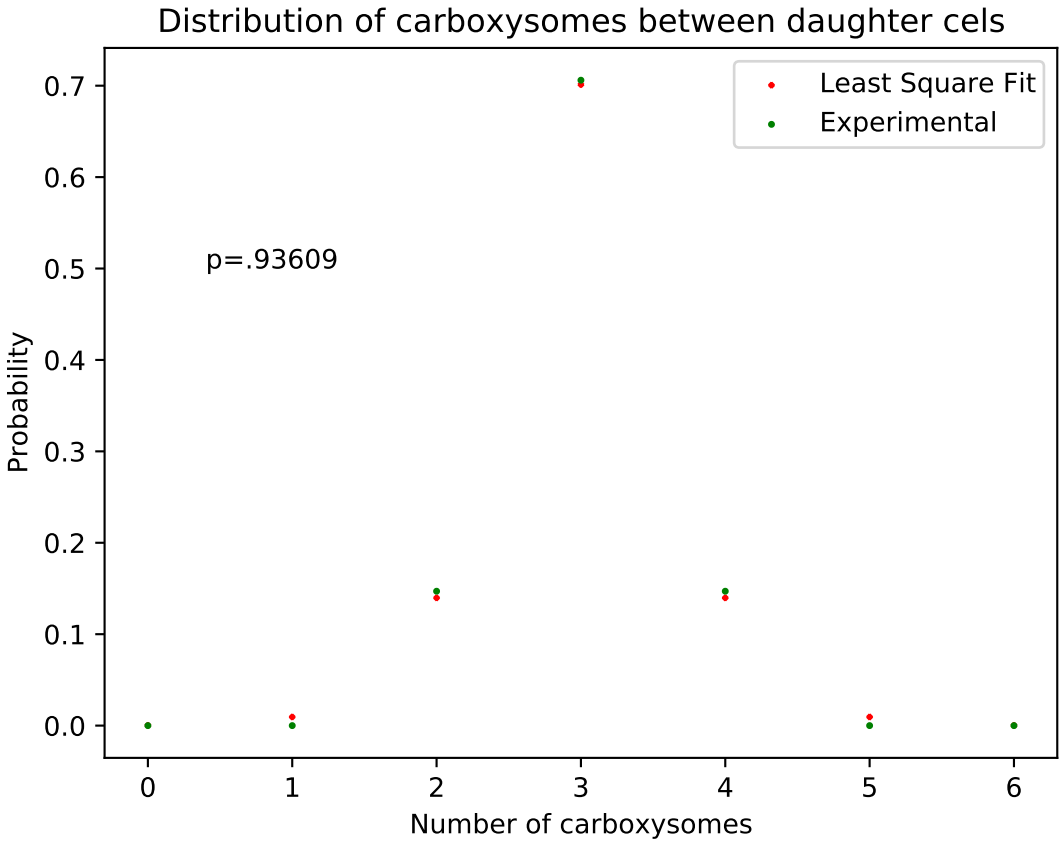
The probability of having 2 and 4 in one cell is

$$\binom{3}{2}p^5q^1 + \binom{3}{2}p^1q^5 + \binom{3}{1}\binom{3}{1}p^3q^3$$

The probability of having 3 in one cell is

$$p^6 + q^6 + \binom{3}{1}\binom{3}{2}p^2q^4 + \binom{3}{2}\binom{3}{1}p^4q^2$$

By substituting $p = 0.5 + x$, and minimizing using the least-squares method with respect to the experimental distribution, obtained value for p is 0.936093. Attached, is a scatter plot showing the deviation. Given that, there are only 6 molecules, and the error is about 0.007 ± 0.001 (for the non-zero values), I believe it's a good model.


Distribution of carboxysomes between daughter cels
Least Square Fit
Experimental
p=.93609
Probability
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
1
2
3
4
5
6
Number of carboxysomes

5 Problem 5

(a) There are 4^3 possible ways of choosing the bases to form a triplet, each with the same probability. Therefore,

$$p_s = \frac{3}{64}$$

(b) There are 64 possible codons. Three of these are not allowed(The stop codons), to form an ORF.Therefore, the number of acceptable possibilities is $(64-3)^N$.
Required probability is $\left(\frac{61}{64}\right)^N$.

(c) Codons are of length 3 bases. Since, the DNA is circular, let us pick an arbitray base and call it the starting point, and label the bases as

$$\ldots x_{N-1}x_N x_0 x_1 x_2 \ldots$$

Looking at the above sequence, we can see that the codons containing x_0 are

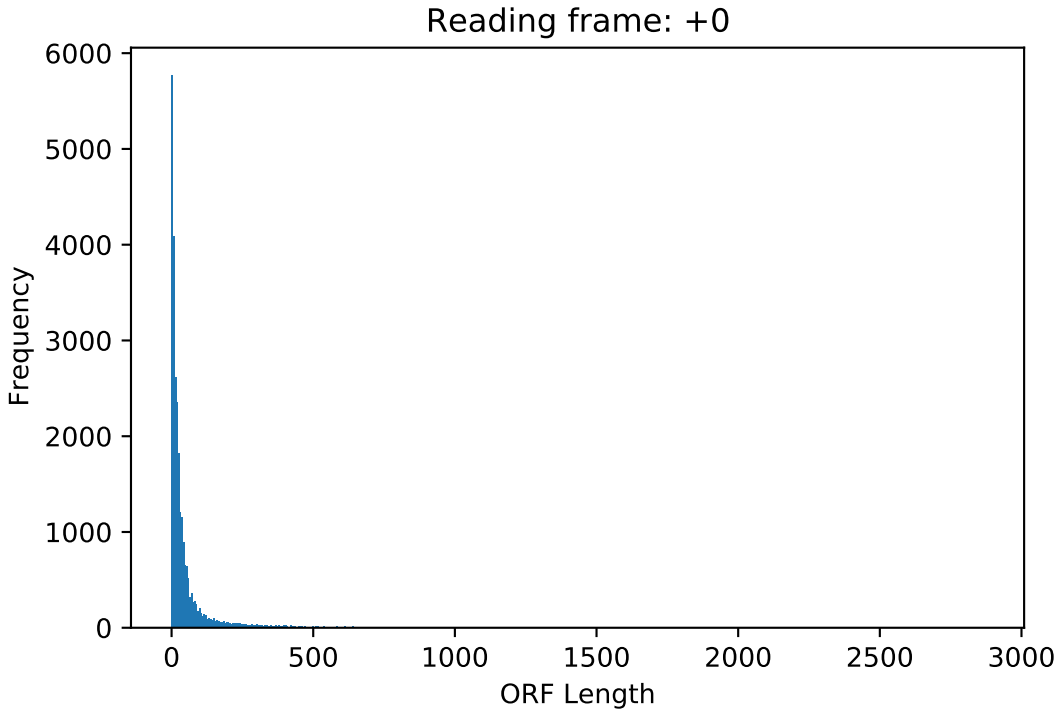
$$x_{N-1}x_N x_0$$
$$x_N x_0 x_1$$
$$x_0 x_1 x_2$$

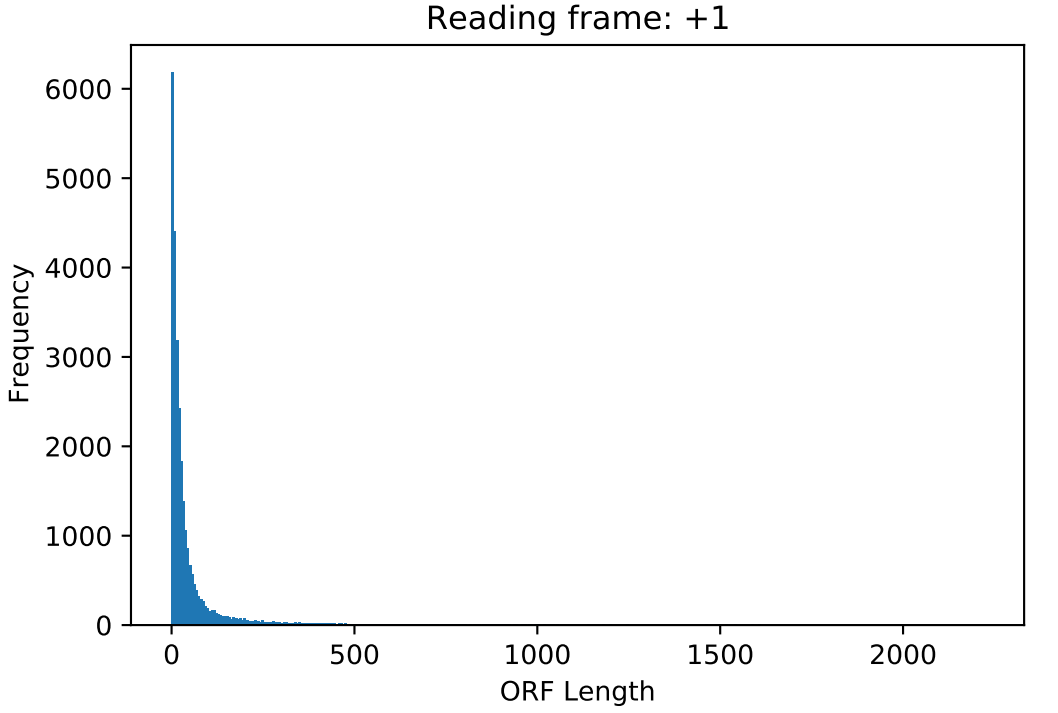
and their reverse(corresponding to either a clockwise read or an anti-clockwise read – Also respectively, each codon corresponds to reading frames: +2,+1 and +0). Therefore, there are 6 reading frames in total.

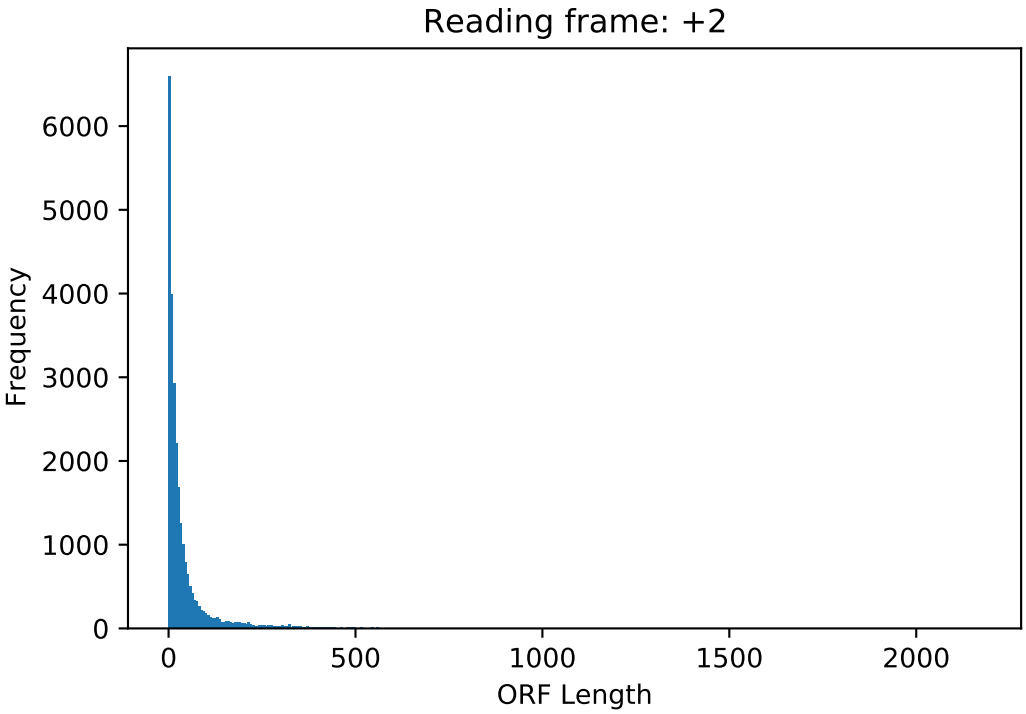
(d) skip

(e) Take a look at the attached ipython notebook.

(f)


Reading frame: +0
Frequency
ORF Length
0
1000
2000
3000
4000
5000
6000
0
500
1000
1500
2000
2500
3000


Reading frame: +1
Frequency
ORF Length
0
1000
2000
3000
4000
5000
6000
0
500
1000
1500
2000


Reading frame: +2
Frequency
6000
5000
4000
3000
2000
1000
0
0
500
1000
1500
2000
ORF Length