Simulation of *Escherichia coli (E. Coli)* Growth in Presence of Various Carbon Sources

Modelling and Simulation

Group - 19

Swastik Satyanarayan Nayak, Siddharth B

November 8, 2019

1 Introduction

The *E. Coli* is one of the most common anaerobic bacteria found in the large intestines of warm-blooded animals and the bacteria plays an important role in digesting food. Everyday around 10billion *E. Coli* bacteria is ejected out of the animal body through organic wastes.

They predominantly feed on the Glucose and other sugars like Galactose, lactose etc. Other sugar molecules are only metabolized once the Glucose reserve is completely exhausted. The bacteria tends to divide rapidly when under the influence of Glucose but slows down while consuming other carbon sources[1].

The *E. Coli* adapts to its environment, and when there is an absence of Glucose or Galactose. The *E. Coli* bacteria with a specific enzyme beta-galactosidase will convert available lactose into Glucose and Galactose. But over a period of time if the bacteria colony is provided with rich Glucose supply the number of enzyme produced by the *E. Coli* cell diminishes drastically. A lack of Glucose will cause the bacterial growth to slow down and possible death of few cells due to starvation. The *E. Coli* colony will start synthesizing the beta-galactosidase enzyme under the presence of lactose molecules, and the *E. Coli* adapts to the new environment[2].

2 Project Goals

- Simulate the division of the *E. Coli* bacteria under the presence and absence of carbon sources and observe the impact. The simulation will take into consideration that the bacteria will divide at 20min intervals (relative or absolute scaling can be used).

- Simulate the *E. Coli* cells when there is depletion of other carbon sources and when lactose is the only energy source available. To process Lactose as its unique source of energy in the absence of Glucose, the *E. Coli* needs several thousand copies of the beta-galactosidase enzyme in-order to live on lactose. In the presence of Glucose the enzyme beta-galactosidase in the *E. Coli* cell will diminish to a very low count of approximately 10. The beta-glactosidase is an inducible enzyme, it is only synthesized by the *E. Coli* in the presence of lactose molecules[2].
- Simulate a stable cells that does not go extinct.

3 Equation modelling

The concept and the equations to simulate this project are currently in an early stage and will be subject to change as the research on the topic progresses.

The differential equations to simulate the cells under the influence of Glucose and Galactose are relatively straight forward as shown below,

Calculate the resource available after the *E. Coli* cells consumes the resource

$$R = R - Ec * Rc \tag{1}$$

```
where, R - Resource/Available Resource
       Ec - \textit{E. coli} Count
       Rc - Resource Consumption
```

Equation to check for shortage of Resources, when RS $\neq 0$

$$Rs = min(0, R - (Ec * Rc)) \tag{2}$$

```
where, Rs - Resource Shortage
       Rc - Resource Consumption
```

Equation to calculate partial starvation and partial division of the cells under shortage of food, but not Zero

$$Ps = Rs/Rc \tag{3}$$

```
where, Ps - Partial starvation/starvation at abs(Rs) = E * DR
```

Partial cell division equation, when there is resource shortage

$$Pd = (Ec - Ps) * Dr \tag{4}$$

```
where, Pd - Partial division
```

Population growth restriction equation, due to death of the cell and ejection from the host.

$$Pgr = 2 * r * Ec^2 \tag{5}$$

```
where, Pgr - Population growth restriction
```

Complete starvation equation where there is zero resources available,

$$Cs = Ec * Df \tag{6}$$

```
where, Df - Death factor (percentage)
       Cs - Complete starvation
```

Ecoli cells cell division equation

$$Ec = (Ec * Dr) - Ps - Cs - Pgr \tag{7}$$

```
where, Ec - Ecoli Count
       Dr - Division Rate
       Ps - Partial Starvation
       Cs - Complete Starvation
       Pgr - Population growth restriction
```

Total Resources

$$R = Gl + Ga \tag{8}$$

```
where, Gl - Glucose count
       Ga - Galactose count
```

Glucose consumption equation

$$Gl = Gl - Ec * Rc \tag{9}$$

```
where, Rc - Resource consumption
```

Galactose consumption equation

$$Ga = Ga + min(Gl, 0) \tag{10}$$

The beta-galactosidase is a enzyme that diminishes in a Glucose rich environment and will be abundantly present in a Glucose deficient environment but the presence of lactose. The probability of the enzyme existing in the cells/*E. Coli* bacteria will increase or decrease based on the current environment. A differential equation has to be crafted to simulate this scenario. A probability factor will also be introduced to the equations to simulate the randomness of the death of the *E. Coli*, especially during the absence of desired carbon source (Glucose).

4 Project Planning

- Model and Refine the equations to simulate the cells under the influence of Glucose and Galactose.

- Simulate the growth of the bacteria in a Glucose deficient environment and simulate what happens when lactose is introduced. Model and refine the equations to support this simulation scenario.
- Attempt to stabilize the bacterial culture that does not go extinct.
- Work on the project report alongside the research and development of the project.

5 References

1 Glucose becomes one of the worst carbon sources for E.coli on poor nitrogen sources due to suboptimal levels of cAMP Anat Bren,1 Junyoung O. Park,2,3 Benjamin D. Towbin,1 Erez Dekel,1 Joshua D. Rabinowitz,2,4 and Uri Alona,1 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4843011/

2 Molecules, Dynamics Life: An Introduction To Self-Organization of Matter, by A.BABLOYANTZ

3 Wikipedia: https://nl.wikipedia.org/wiki/Escherichia$_c oli$