Building and Modeling a Chaotic Gene Regulatory Network in *E. coli*

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Research question: Can a Gene Regulatory Network (GRN) Act Chaotically?

Introduction and Inspiration

Theory: "Chaos Theory" is a field exploring deterministic dynamical systems which are highly sensitive to initial conditions and whose outputs/variables form unique, and seemingly unpredictable patterns.

BZ reaction (A Chemical Example): Complex chemical reaction which shows that chaotic chemical regimes can lie between oscillatory parameter states

[2] *Uncovering life's operating code.*

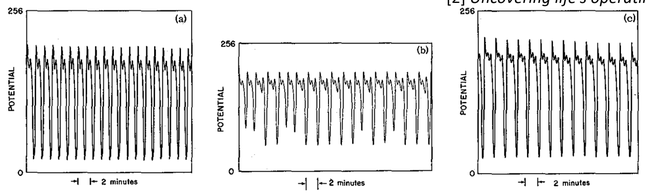
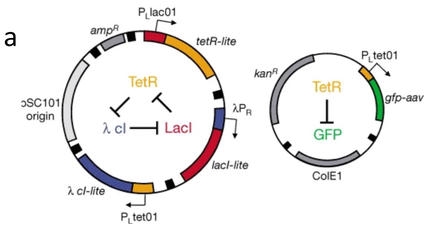


Figure 1: A-periodic state shown between 2 periodic states from the BZ reaction, a key feature of chaos [1]

Biological Oscillators (Inspiration for Chaos):

-The "repressilator" is a GRN when introduced to *E.Coli* shows steady oscillations[3]

-This is a proof of concept that shows promise for chaos in a biological example



Elowitz, M. B., & Leibler, S. (2000).

Modeling and Proposed Circuit

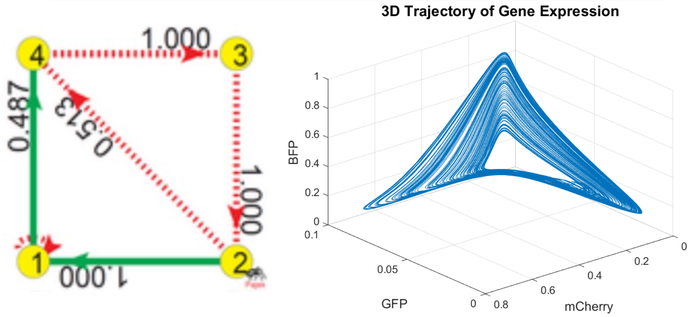


Figure 2: Left: Theoretical chaos GRN, red lines represent genetic repression, green lines represent activation. Right: Chaotic emergence from the chaotic GRN using Matlab modeling. Equations used for modeling are from [4]

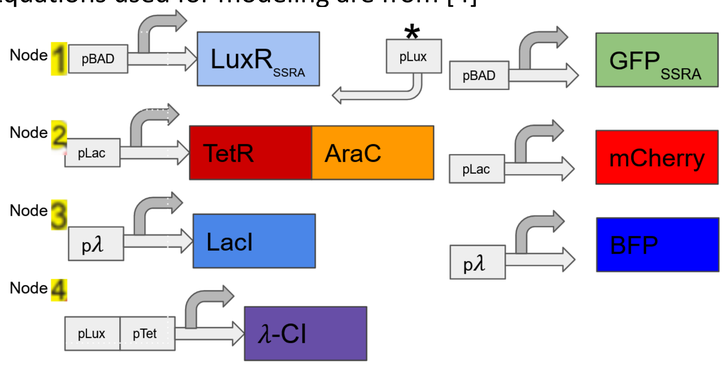
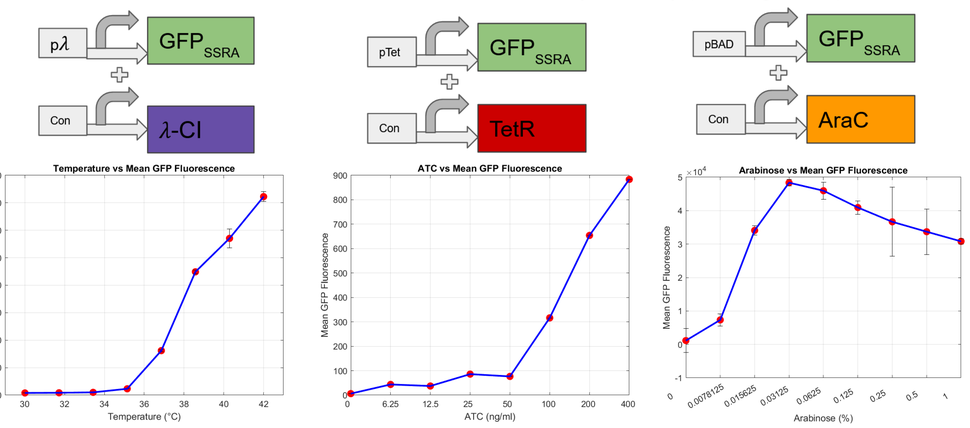


Figure 3: Proposed GRN with genetic parts commonly used in synthetic biology. This circuit will be introduced into *E.Coli* for exploration of biological chaos

Results

Induction curves derived from flow cytometry (Testing Parts)



Discussion and Conclusion

This research is the first technical step to exploring chaotic motifs in GRN's. After the current testing of genetic components is complete, we will assemble a "Chaos Circuit".

If successful, this research could provide insights into chaos within embryogenesis. This may be particularly useful for the development of synthetic organs, organoids, which seek to replicate parts of embryogenesis for the eventual use in regenerative medicine.

References

[1] Zhang, D., Gyorgyi, L., & Peltier, W. R. (1993). Deterministic chaos in the Belousov-Zhabotinsky reaction: Experiments and simulations. *Chaos (Woodbury, N.Y.)*, *3*(4), 723–745. https://doi.org/10.1063/1.165933
[2] *Uncovering life's operating code*. (2024, April 8). Science. https://www.nationalgeographic.com/science/article/uncovering-lifes-operating-code
[3] Elowitz, M. B., & Leibler, S. (2000). A synthetic oscillatory network of transcriptional regulators. *Nature*, *403*(6767), 335–338. https://doi.org/10.1038/35002125
[4] Zhang, Z., Ye, W., Qian, Y., Zheng, Z., Huang, X., & Hu, G. (2012). Chaotic motifs in gene regulatory networks. *PLOS ONE*, *7*(7), e39355. https://doi.org/10.1371/journal.pone.0039355
[5] *Life from chaos*. (n.d.). Retrieved April 4, 2024, from https://seas.harvard.edu/news/2020/05/life-chaos

Acknowledgments: Dr. Kylie Standage-Beier

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