Dynamic Compartmentalization of Bacteria: Accurate Division in *E. Coli*

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**E. Coli Division**

- Z-ring

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**The min Proteins**

- MinC
- MinD
- MinE

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www.rcsb.org/pdb
Why are they there?

Cell division without the minC or minD proteins

Without minE, cell division is inhibited

http://www.chembio.uoguelph.ca/educmat/chm736/replicat.htm

What do they do?

minC and minD

minC prevents cell division at the poles
• Bound minC prevents FtsZ from forming into a Z-ring
• The Z-ring is needed to initiate septation

http://www.chembio.uoguelph.ca/educmat/chm736/replicat.htm

This is where it gets funky

minC and minD oscillate between the poles

http://www.chembio.uoguelph.ca/educmat/chm736/replicat.htm

minE ejects bound minC/minD into the cytoplasm
• minE forms a band at midcell and moves towards a pole
• Ejected minC/minD rebinds at the other pole
• Once minE reaches the pole, the band reforms at midcell and moves towards the other pole

http://www.chembio.uoguelph.ca/educmat/chm736/replicat.htm
Diffusion of cytoplasmic minD and minE

Spontaneous binding of minD to membrane

Spontaneous unbinding of minE

minD recruits minE to the membrane

minE expels minD into cytoplasm

preventing release of minE

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\begin{align*}
\frac{\partial \rho_D}{\partial t} &= D_D \frac{\partial^2 \rho_D}{\partial x^2} - \frac{\sigma_1 \rho_D}{1 + \sigma'_1 \rho_E} + \frac{\sigma_2 \rho_D \rho_E}{1 + \sigma'_2 \rho_D} \\
\frac{\partial \rho_E}{\partial t} &= D_E \frac{\partial^2 \rho_E}{\partial x^2} - \frac{\sigma_1 \rho_D \rho_E}{1 + \sigma'_1 \rho_D} + \frac{\sigma_3 \rho_E}{1 + \sigma'_3 \rho_D} \\
\frac{\partial \rho_D}{\partial t} &= \sigma_4 \rho_D
\end{align*}
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Math...d'oh!

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D_D = 0.28 \mu m^2 / s \quad \sigma_2 = 0.0063 \mu m/s
\]

\[
D_E = 0.6 \mu m^2 / s \quad \sigma_3 = 0.04 \mu m/s
\]

\[
\sigma_1 = 20 s^{-1} \quad \sigma_4 = 0.8 s^{-1}
\]

\[
\sigma'_1 = 0.028 \mu m \quad \sigma'_4 = 0.027 \mu m
\]

The Model Works!

Space-time plot

Grey scale runs from 0 to 2 times average density

Time increases from top to bottom (ref. bar = 100 s.)

Horizontal scale spans the length of the bacteria (2 \mu m)

The Model Works!

Time-average densities

(relative to respective time-average maxima)
Results of the Model

Period of oscillation increases linearly with minD concentration
Period increases directly with cell length – oscillations are not observed for cells shorter than 1.2 µm

Results of the Model

• For cells longer than 6 µm it is possible for two minE bands to exist for a long time
• For cells longer than 8.4 µm the two band state is stable
• If the minD concentration is increased beyond 2000 µm\(^{-1}\) or decreased beyond 500 µm\(^{-1}\), the system converges to a steady state

Shortcomings of the Model

• minE concentration should affect oscillation period, but doesn’t in this model
• This model does not consider fluctuations due to discrete particles

Thank You

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