New Mathematical Model Evaluates Efficiency of E. Coli

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The bacterium *Escherichia coli*, one of the best-studied single-celled organisms around, is a master of industrial efficiency. This bacterium can be thought of as a factory with just one product: itself. It exists to make copies of itself, and its business model is to make them at the lowest possible cost, with the greatest possible efficiency. Efficiency, in the case of a bacterium, can be defined by the energy and resources it uses to maintain its plant and produce new cells, versus the time it expends on the task.

Dr. Tsvi Tlusty and research student Arbel Tadmor of the Weizmann Institute of Science's Physics of Complex Systems Department developed a mathematical model for evaluating the efficiency of these microscopic production plants. Their model, which appeared in the online journal *PLoS Computational Biology*, uses only five remarkably simple equations to check the efficiency of these complex factory systems.

The equations look at two components of the protein production process: ribosomes (the machinery in which proteins are produced) and RNA polymerase (an enzyme that copies the genetic code for protein production onto strands of messenger RNA for further translation into proteins). RNA polymerase is thus a sort of work "supervisor" that keeps protein production running smoothly, checks the specs, and sets the pace. The first equation assesses the production rate of the ribosomes themselves; the second, the protein output of the ribosomes; the third, the production of RNA polymerase. The last two equations deal with how the cell assigns the available ribosomes and polymerases to the various tasks of creating other proteins, more ribosomes, or more polymerases.

The theoretical model was tested in real bacteria. Do bacteria "weigh" the costs of constructing and maintaining their protein production machinery against the gains to be had from being able to produce more proteins in less time? What happens when a critical piece of equipment is in short supply - say, a main ribosome protein? Tlusty and Tadmor found that their model was able to accurately predict how an *E. coli* would change its production strategy to maximize efficiency following disruptions in the work flow caused by experimental changes to genes with important cellular functions.

What's the optimum? The model predicts that a bacterium, for instance, should have seven genes for ribosome production. It turns out that that's exactly the number an average *E. coli* cell has. Bacteria having five or nine get a much lower efficiency rating. Evolution, in other words, is a master efficiency expert for living factories, meeting any challenges that arise as production conditions change.

For the scientific paper, please see: www.ploscompbiol.org/article/info%3Adoi%2F10.1371%2Fjournal.pcbi.1000038

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