# Resource allocation in bacterial motility

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## Ribosomes and cell growth



J. Mol. Biol. (1993) 231, 678-688 SCHAECHTER, M., MAALØE, O. & KJELDGAARD, N. O. (1958). J. gen. Microbiol. 19 Dependency on Medium and Temperature of Cell Size ar Synthesis of Proteins in Escherichia coli is Limited by the Chemical Composition during Balanced Growth of Concentration of Free Ribosomes Expression from Reporter Genes does not always Reflect Functional Salmonella typhimurium By M. SCHAECHTER\*, O. MAALØE AND N. O. KJELDGAARD Jesper Vind†, Michael A. Sørensen, Michael D. Rasmussen† and Steen Pedersen‡ State Serum Institute, Copenhagen, Denmark Institute of Microbiology, University of Copenhagen Oster Farimagsgade 2.4 DE Copenhagen, Denma antent 0 Copenhagen, Denmark

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SUMMARY: Cell mass, the and DNA were studied in S growth in different media. functions of the growth rate The size and chemical com fluenced by the temperatu growth, this organism exist states.

The variations in mass/c in mass/nucleus. An incre growth rates could, it ap Calculations indicate that same at all growth rates.

It is a classic observat which precedes cell div again during the perio known that increase i hand (Malmgren & H Folkes, 1953). Previo difference between th the larger forms typi 'resting' or 'expone sidered to be alterna We have studied anced growth in a v 'cell' is used throu colony-forming unit " mtoin more 1

### An Analysis of Bacterial Growth

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### 1. THE SYSTEM

A growing bacterium is a self-contained system whose dominating activity is protein synthesis. Between four-fifths and nine-tenths of the carbon assimilated, and a similarly large fraction of the energy consumed serve this need. As the mediators of protein synthesis the ribosomes play a key role, and it was therefore not surprising to find that mechanisms exist which permit bacteria to adjust the number of ribosomes they produce in accordance with the environment they grow in. But it was both unexpected and gratifying to see that, by and large, this adjustment follows a simple, almost "sensible" rule, namely, in a given environment, no more ribosomes are produced than can be engaged with high efficiency in protein synthesis. This observation allows some of the major syntheses in these cells to be described in relatively simple terms, and the model to be presented is an attempt to account for a mass of data which are suggestive enough, I think, to warrant this exercise.

r plasmids was found to reduce the The reduction depends on the protein galactosidase. It could be observed some cases also during steady-state tion of the free ribosomal subunits competition among the individual reduction in the synthesis rate of was used as an assay to measure e efficiencies were compared to the of specific mRNA species and the 3' ar Shine-Dalgarno sequences, the tion of lacZ and also at very high

rter genes, including the lacZ gene

genes; protein synthesis;

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somal subunits are important parameters egulation; the rates of their respective reactions may determine the size of the tiation-competent polymerase and ribotherefore in turn determine the total requencies of transcription and transen & Pedersen, 1990). Here we argue centration of free ribosomal subunits is miting factor in determining the transfrom a given mRNA, rather than the of initiation factors, charged tRNA or ation yield of an mRNA is determined arameters and can vary 100-fold

Siminovitch, 1971). A particularly rameter here is the ability of the to base-pair to the 3' end of 16S

ns: bp, base-pair; IPTG, isopropul.6.n

### Economy of expensive machines





Sarah Mohammadinejad

### Cost of a flagellum





E.coli: 5-10 flagella per cell ~30 0000 flagellin (FliC) / flagellum ~500 aa/FliC

10<sup>8</sup> aa in flagella

70000 ribosomes/cell ~8000 aa/ribosome

5 10<sup>8</sup> aa in ribosomes

### Growth dependent expression of motility genes



consistent with CRP-cAMP regulation

chemotaxis towards aa source of C, N, aa?

### Nitrogen dependence

different N sources (NH4, single amino acids)

exception: Proline



# Minimal model

R





## Cost of motility: competition experiments



in shaking culture (homog. medium)  $\Delta$ fhIDC outcompetes WT

# Summary

- motility is almost as expensive as ribosomes
  - competition
- growth dependence like carbon catabolism
- role of variability in flagellar number?



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