

# Stochastic Mechanisms of Cell-Size Regulation in Bacteria

Hamid Teimouri, Rupsha Mukherjee, and Anatoly B. Kolomeisky\*



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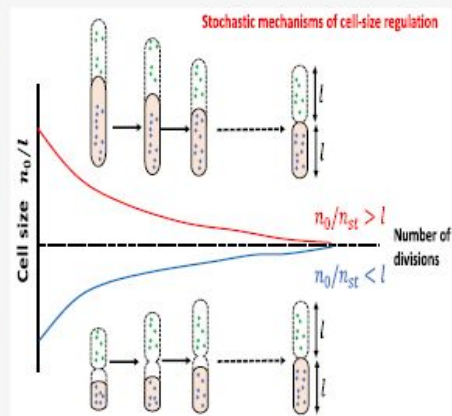


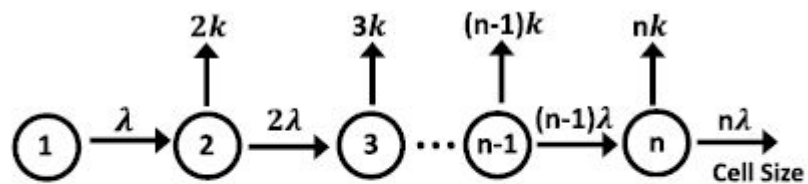
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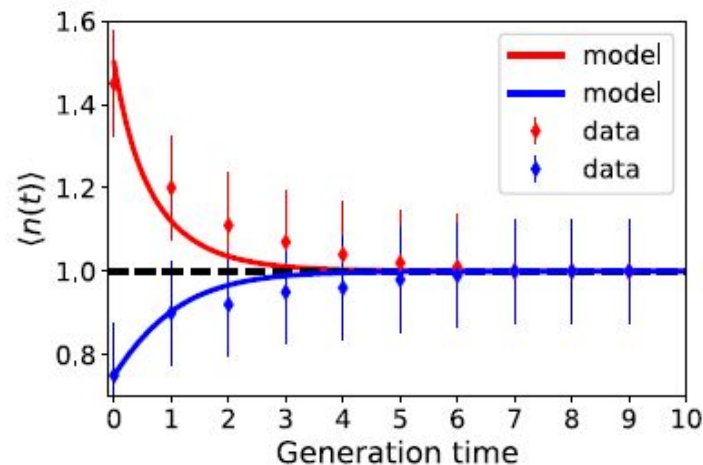
Supporting Information

**ABSTRACT:** How bacteria are able to maintain their sizes remains an open question. It is believed that cells have narrow distributions of sizes as a consequence of a homeostasis that allows bacteria to function at the optimal conditions. Several phenomenological approaches to explain these observations have been presented, but the microscopic origins of the cell-size regulation are still not understood. Here, we propose a new stochastic approach to investigate the molecular mechanisms of maintaining the cell sizes in bacteria. It is argued that the cell-size regulation is a result of coupling of two stochastic processes, cell growth and division, which eliminates the need for introducing the thresholds. Dynamic properties of the system are explicitly evaluated, and it is shown that the model is consistent with the experimentally supported adder principle of the cell-size regulation. In addition, theoretical predictions agree with experimental observations on *E. coli* bacteria. Theoretical analysis clarifies some important features of bacterial cell growth.





**Figure 1.** Schematic view of a discrete-state stochastic model of the cell-size regulation. The cell size is described by a discrete variable  $n$  that corresponds to the number of proteins responsible for growth.

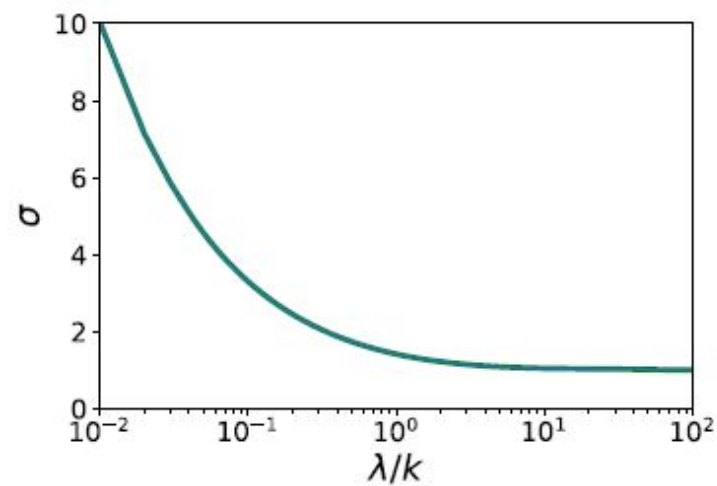


**Figure 2.** Normalized cell length as a function of the time in units of interdivision generation time. Solid lines are theoretical predictions (without fitting parameters) from eq 3, and symbols are from experimental observations for *E. coli* bacteria as given in ref 2.

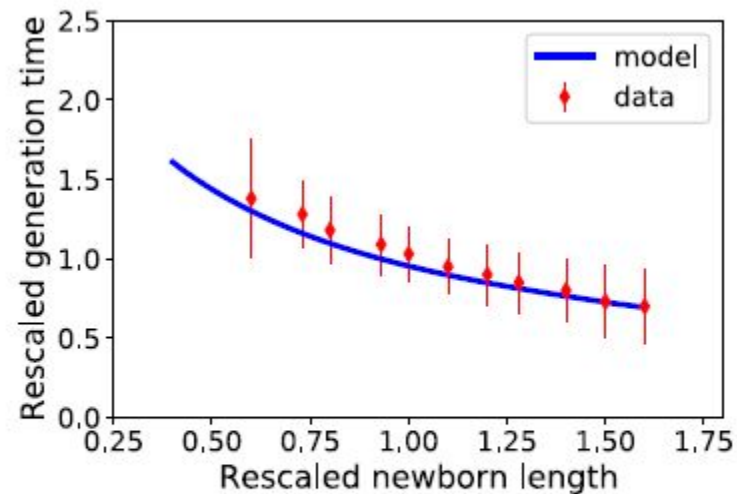
$$\frac{d\langle n \rangle}{dt} = \lambda \langle n \rangle - 2k \langle n \rangle \frac{\langle n \rangle}{2}$$

$$\langle n(t) \rangle = \frac{c\lambda e^{\lambda t}}{1 + kce^{\lambda t}}$$

In this equation, the first term on the right side describes the increase in the cell length due to the growth, while the second term corresponds to the shortening due to the cell division. In this shortening process, every division removes the  $\langle n \rangle / 2$  length from the original average cell length, and it happens with the rate  $k \langle n \rangle$ . The coefficient 2 in the rate reflects the fact that for every single cell of the size  $\langle n \rangle$  two shorter cells of the size  $\langle n \rangle / 2$  are created after division.



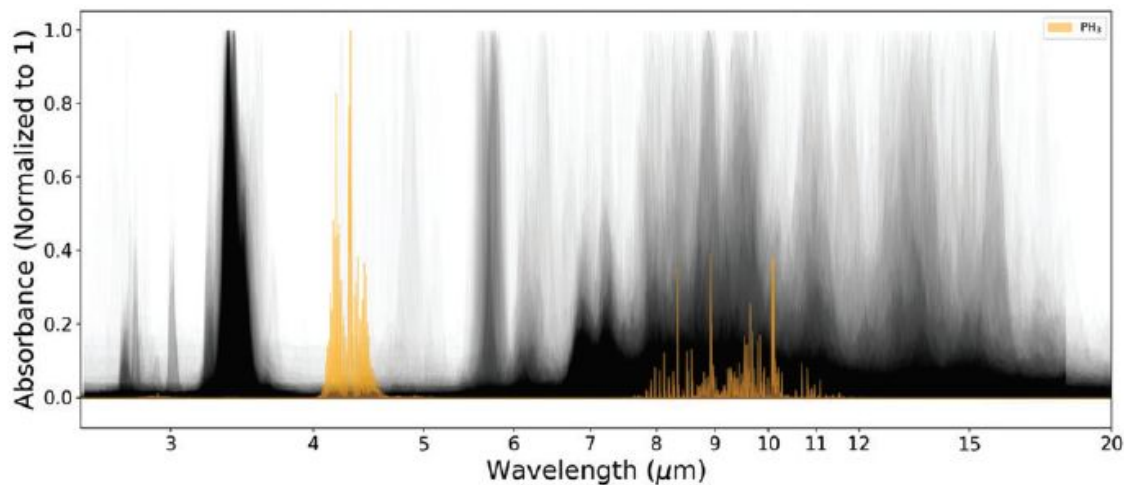
**Figure 4.** Normalized variance  $\bar{\sigma}$  of the added average cell size as a function of  $\lambda/k$ .



**Figure 5.** Rescaled mean generation times between consecutive divisions as a function of the rescaled starting cell size. The details of calculations are presented in the text, and data are from ref 2.

## Phosphine as a Biosignature Gas in Exoplanet Atmospheres

Clara Sousa-Silva,<sup>1,2</sup> Sara Seager,<sup>1,3</sup> Sukrit Ranjan,<sup>1,4</sup> Janusz Jurand Petkowski,<sup>1</sup> Zhuchang Zhan,<sup>1</sup>  
Renyu Hu,<sup>5,6</sup> and William Bains<sup>7</sup>



## Abstract

A long-term goal of exoplanet studies is the identification and detection of biosignature gases. Beyond the most discussed biosignature gas  $O_2$ , only a handful of gases have been considered in detail. In this study, we evaluate phosphine ( $PH_3$ ). On Earth,  $PH_3$  is associated with anaerobic ecosystems, and as such, it is a potential biosignature gas in anoxic exoplanets. We simulate the atmospheres of habitable terrestrial planets with  $CO_2$ - and  $H_2$ -dominated atmospheres and find that  $PH_3$  can accumulate to detectable concentrations on planets with surface production fluxes of  $10^{10}$  to  $10^{14} \text{ cm}^{-2} \text{ s}^{-1}$  (corresponding to surface concentrations of 10s of ppb to 100s of ppm), depending on atmospheric composition and ultraviolet (UV) irradiation. While high, the surface flux values are comparable to the global terrestrial production rate of methane or  $CH_4$  ( $10^{11} \text{ cm}^{-2} \text{ s}^{-1}$ ) and below the maximum local terrestrial  $PH_3$  production rate ( $10^{14} \text{ cm}^{-2} \text{ s}^{-1}$ ). As with other gases,  $PH_3$  can more readily accumulate on low-UV planets, for example, planets orbiting quiet M dwarfs or with a photochemically generated UV shield.  $PH_3$  has three strong spectral features such that in any atmosphere scenario one of the three will be unique compared with other dominant spectroscopic molecules. Phosphine's weakness as a biosignature gas is its high reactivity, requiring high outgassing rates for detectability. We calculate that tens of hours of JWST (James Webb Space Telescope) time are required for a potential detection of  $PH_3$ . Yet, because  $PH_3$  is spectrally active in the same wavelength regions as other atmospherically important molecules (such as  $H_2O$  and  $CH_4$ ), searches for  $PH_3$  can be carried out at no additional observational cost to searches for other molecular species relevant to characterizing exoplanet habitability. Phosphine is a promising biosignature gas, as it has no known abiotic false positives on terrestrial planets from any source that could generate the high fluxes required for detection. Key Words: Phosphine—Biosignature—Exoplanet—Atmospheric gases—Spectroscopy—Anoxic environments. Astrobiology 20, xxx–xxx.

# Narcissism in Political Participation

Zoltán Fazekas<sup>1</sup> and Peter K. Hatemi<sup>2</sup> 

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## Abstract

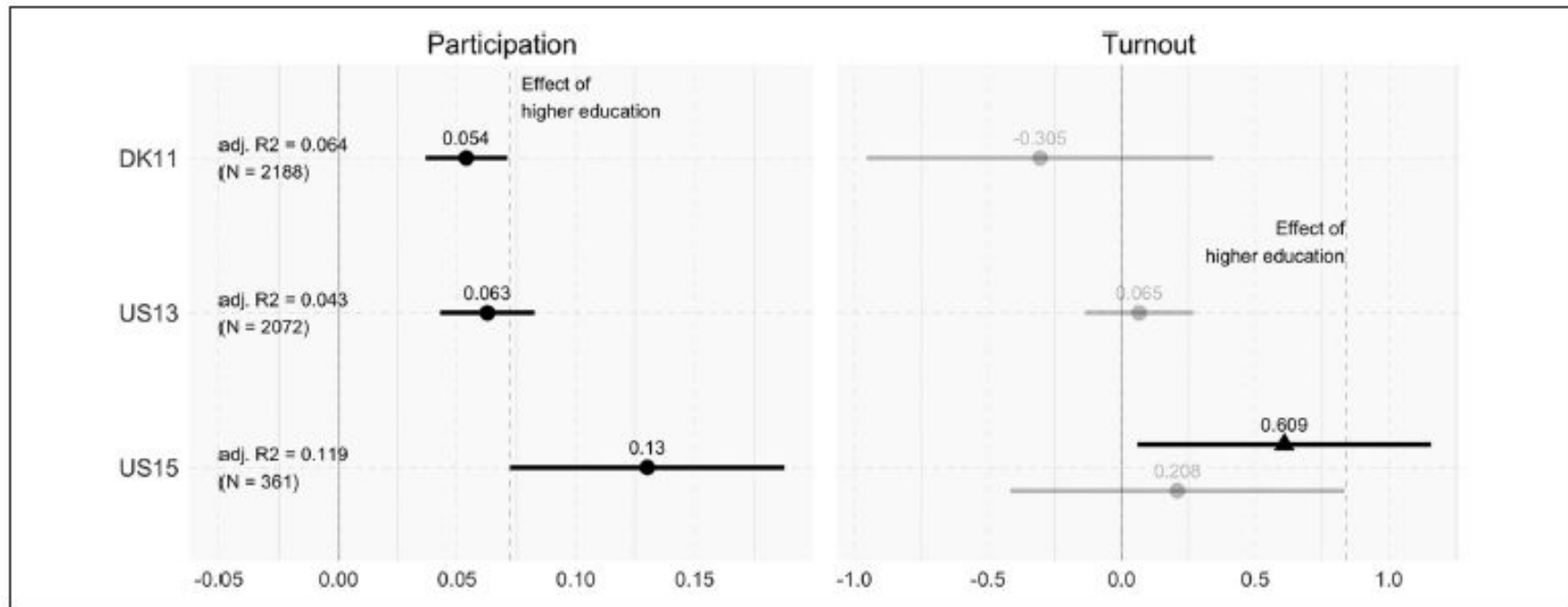
Much attention has focused on the social, institutional, and mobilization factors that influence political participation, with a renewed interest in psychological motivations. One trait that has a deep theoretical connection to participation, but remains underexplored, is narcissism. Relying on three studies in the United States and Denmark, two nationally representative, we find that those scoring higher in narcissism, as measured by the Narcissistic Personality Inventory–40 (NPI-40), participate more in politics, including contacting politicians, signing petitions, joining demonstrations, donating money, and voting in midterm elections. Both agentic and antagonistic components of narcissism were positively and negatively related to different types of political participation when exploring the subfactors independently. Superiority and Authority/Leadership were positively related to participation, while Self Sufficiency was negatively related to participation. In addition, the combined Entitlement/Exploitativeness factor was negatively related to turnout, but only in midterm elections. Overall, the findings support a view of participation that arises in part from instrumental motivations.

## Narcissism measurement

One of the most commonly used measures to capture grandiose narcissism in the general population is the Narcissistic Personality Inventory (NPI; Raskin & Hall, 1979). In its original framework, a single overall narcissism score is derived from the multidimensional 40-item NPI questionnaire that combines (a) Leadership/Authority (self-perception of leadership skills and desire for power), (b) Entitlement (the expectation and amount of entitlement a person has, including favorable treatment and compliance with one's wishes), (c) Exhibitionism (the desire and willingness to be the center of attention), (d) Exploitativeness (how willing one is to exploit others in order to achieve their own desires), (e) Self-Sufficiency (how much one is willing to rely upon on others versus their own abilities to meet their needs and goals), (f) Superiority (how much a person feels they are better than those around them), and (g) Vanity (view of self and desire for others to see one as superior and attractive). The combinations of these traits form a narcissism score that is unimodal with a positive skew.

## Political activity measurement

In all studies, participatory behaviors are measured by eight items through the widely used cross-national ISSP Questionnaire on Citizenship (Verba et al., 1995). The measure includes signing a petition, boycotting, or buying products for political reasons, participating in a demonstration, attending political meetings, contacting politicians, donating money, contacting the media, and taking part in political forums and discussion groups, including those online (for details see Supplemental Information SI3). The average across the eight items serves as a full participation index.



**Figure 1.** The relationship between overall Narcissism and Political Participation.

Note. Lines are 95% confidence intervals. Coefficient plot (2 SD in narcissism). Continuous outcome on [0, 1] range for participation, and dichotomous outcome for turnout. Triangle for 2014 Midterm Vote (available only in US15). Full model results are reported in Supplemental Information SI6.

So far, we have established a consistent relationship between overall Narcissism and Political Participation, but not Turnout in national elections.