Physics International

Original Research Paper

Possible Physical Determination of the Mass, Size, Doubling Time and Density of the Unicellular Organisms Based on the Fundamental Physical Constants

Atanas Todorov Atanasov

Department of Physics and Biophysics, Medical Faculty, Trakia University, Stara Zagora, Bulgaria

Email: atanastod@abv.bg

Abstract: In manuscript the hypothesis 'that the mass, size, doubling time and density of the unicellular organisms (Prokaryotes and Eukaryotes) are determined by the gravitational constant (G, $N \cdot m^2/kg^2$), Planck constant (h, J·s) and growth rate v_{gr} (m/s)' is investigated. By scaling analyses it is indicated that the growth rate of the unicellular organisms ranges in a narrow window of 1.0×10^{-11}–1.0×10^{-10} m/s, in comparison to 10 orders of magnitudes difference between their mass. Dimension analyses demonstrates that the combination between the growth rate of unicellular organisms, gravitational constant and Planck constant provides the equations with dimension of mass $M(v_{gr}) = (h \cdot v_{gr}/G)^{½}$ in kilogram, length $L(v_{gr}) = (h \cdot G/v_{gr}^3)^{½}$ in meter, time $T(v_{gr}) = (h \cdot G/v_{gr}^5)^{½}$ in seconds and density $\rho = v_{gr}^{3.5}/hG^2$ in kg per 1 m^3. For values of growth rate in numerical diapason of 1.0×10^{-11}–$1.0\times10^{-9.5}$ m/s, the calculated numerical values for mass (3.0×10^{-18}–1.0×10^{-16} kg), length (5.0×10^{-8}–1.0×10^{-5} m), time (1.0×10^{2}–1.0×10^{6} s) and density (1.0×10^{-1}–1.0×10^{4} kg/m^3) overlap with diapason of experimentally measured values for cell mass (3.0×10^{-18}–1.0×10^{-15} kg), volume to surface ratio (1.0×10^{-7}–1.0×10^{-4} m), doubling time (1.0×10^{3}–1.0×10^{7} s) and density (1050-1300 kg/m^3) in both bacteria and protozoa.

Keywords: Prokaryotes, Eukaryotes, Planck Constant, Gravitational Constant

Introduction

The origin of the first unicellular organisms on the Earth is one of the enigmas in the life sciences. There are many hypotheses for the origin of bacteria-ranging from astrophysical bases of Universe (Ehrenfreund *et al*., 2002) and self-reproducing coacervates (Oparin, 1973; Colgate *et al*., 2003; Vasas *et al*., 2012) to the first mitotic cells (Sagan, 1967; Ratcliff *et al*., 2012; Montagnes *et al*., 2012). Recently, the quantum-mechanical effects (Patte, 1967; Pati, 2004; Davies, 2008; Tamulis and Grigalavicus, 2010; Fleming *et al*., 2011) and the anthropic principles that implies that Universe must be consistent with the existence of life (Carr and Rees, 1979; Hoyle and Wickramasinghe, 1999; Vidal, 2010; Kamenshchik and Teryaev, 2013) need to be extended into the understanding of life. In the present approach we developed the hypothesis for possible physical determination of the mass, size, doubling time and density parameters of the unicellular organisms on the Earth. The growth rate of unicellular organisms (v_{gr}, *m/s*) is represented as a speed of their volume to surface ratio growth (*V*/*S*, *m*) for corresponding doubling time (T_{dt}, *s*) of organisms (Atanasov, 2007; 2012a; 2014):

$$v_{gr} = V / \left(S \times T_{dt}\right) \quad (1)$$

The diapason growth rate of unicellular Prokaryotes and Eukaryotes ranges in a narrow window between 1.0×10^{-11}-1.0×10^{-10} m s^{-1}, in comparison to 10 orders of magnitudes difference between the cells mass (Atanasov, 2012b). The connection between volume to surface ratio and mean doubling time T_{mean}(*s*) of phages, bacteria and protozoa could be approximated by a linear function:

$$V / S = v_{gr} \times T_{mean} \quad (2)$$

with correlation coefficient near to 1.0 (Atanasov, 2014).

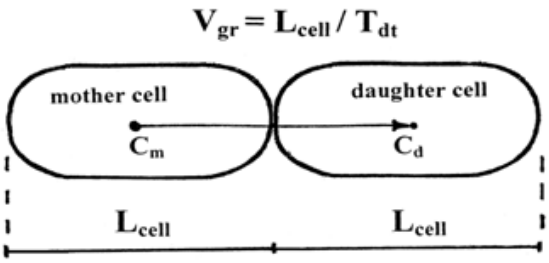

Fig. 1. Schematic presentation of the bacterial cell growth rate 'v_{gr}', represented by length 'L_{cell}' and doubling time 'T_{dt}' of bacteria. *Legend: The symbols C_m and C_d represent the mass-center of mother's and daughter's cell*

The physical analog of Equation 1 and 2 appears to correlate between distance $L(m)$, speed $v(m/s)$ and time $T(s)$ of a given physical object:

$$L(m) = v(m/s) \times T(s) \quad (3)$$

This analogy between Equation 1-3 gives possibilities regarding growth rate of unicellular organisms as physical characteristics (similarly to physical speed) and to combine with different physical constants, using dimensional analyses. The growth rate of unicellular organisms in scientific sours is present by number of cell doublings per day (Alberts *et al*., 1994). The rate of cell elongation during one cell cycle is present by cell length per one doubling time (Cullum and Vicente, 1978). By this fashion the growth rate of a single cell can represents by increases of the linear length of the mother cell for corresponding doubling time (Fig. 1).

The mother's cell divides by binary fission and generates one daughter's cell with approximately the same mass-size-density cellular characteristics. During growth and elongation of the mother cell, the mass-center of the mother's cell (C_m) moves in space with speed equals to the growth rate v_{gr}, up to mass-center (C_d) of the daughter cell (Fig. 1). To eliminate differences between forms of cells, for example the representative length in all calculations is the given volume to surface ratio of the cells. An additional argument in favor of the use volume to surface ratio as representative length is the well known link between this one and metabolic and growth rate of the unicellular organisms (Foy *et al*., 1976; Foy, 1980).

The idea to combine physical and biological constants and parameters is new and is not developed in scientific literature. In this sense, the aim of the study is to test the hypothesis that by dimensional equations we can calculate the numerical values of mass-size-time and density parameters of the unicellular organisms as a function of their growth rate.

Data and Methods

Experimental Data for Mass and Doubling Time and Calculated Data for Volume to Surface Ratio and Growth Rate of the Unicellular Organisms

The experimental data for body mass M(kg), density ρ(kg/m^3), minimum doubling time $T_{min}(s)$ and maximum doubling time $T_{max}(s)$ of unicellular organisms are collected from scientific publications and sources (Lindner, 1978; Holt, 1984; 1986; 1989; Hausmann, 1985; Balows *et al*., 1992; Alberts *et al*., 1994) (data is presented in Table 1). The calculated data for volume to surface ratio V/S (m), mean doubling time $T_{mean}(s)$ and growth rate $v_{gr}(m/s)$ of the cells were taken from previous publication of the author (Atanasov, 2005; 2007; 2012a; 2012b; 2014). Giving in the mind the biological variability of the organismal parameters in all calculations was taken the mean value of the cell mass and doubling time of unicellular organisms. Doubling time of Viruses and Phages was taken as time for synthesis of a particle.

Dimensional Analyses

The dimensional analyses is a conceptual tool often applied in physics and biophysics to understand a tentative possibility for one or another relationship, involving certain physical or biophysical quantities (Bhaskar and Nigam, 1990; Petty, 2001; Valev, 2013). It is routinely used to ascertain the plausibility of the derived equations and computations when it is known. If the form of the given relationship is unknown, a dimensional analysis is used for finding the equations that express these relationships. For example, a quantity F with any dimension (kg, m, s, kg/m^3) is constructed like equations as a function of the fundamental physical constants (gravitational G and Planck h constant) and biological parameter (growth rate v_{gr} of unicellular organisms):

$$F = G^{\alpha} h^{\beta} v_{gr}^{\gamma} \quad (4)$$

The exponents α, β and γ in Equation 4 are determined by matching the dimensions of both sides of the equation. In our study the growth rate of the single organism (v_{gr}) has a dimension of linear speed (meter per second) and can be combined with gravitational constant (G) with dimension (N·m^2/kg^2) and Planck constant (h) with dimension (J·s). These combinations lead to equations with dimensions of mass (in kilogram), length (in meter), time (in second) and density (in kilogram per 1 m^3).

Table 1. Body mass M, volume to surface ratio V/S, doubling time T_{dt} and growth rate v_{gr} in 50 organisms

Unicellular organisms (t, °C of growth)	Cellular mass M (kg)	Volume/Surface V/S (m)	Doubling time (h) T_{min}-T_{max} (T_{mean})	Growth rate V_{gr}(m/s) [V/(S.T_{mean})]
Phages, viruses and cellular organelles				
1. *T7 phage* (35°)	8.6×10^{-20}	7.85×10^{-9}	0.335	6.54×10^{-12}
2. *T1 phage* (35°)	1.4×10^{-19}	9.17×10^{-9}	0.45	5.66×10^{-12}
3. *Lambda phage* (35°)	2.4×10^{-19}	1.10×10^{-8}	0.55	5.66×10^{-12}
4. *T4 phage* (35°)	3.6×10^{-19}	1.26×10^{-8}	0.65	5.38×10^{-12}
5. *T2 phage* (35°)	4.6×10^{-19}	1.36×10^{-8}	0.75	5.04×10^{-12}
6. *Tobacco mosaic* (20°)	5.0×10^{-19}	1.40×10^{-8}	0.75	5.19×10^{-12}
7. *Cow pox virus* (37°)	5.0×10^{-19}	1.40×10^{-8}	0.75	5.19×10^{-12}
8. *Virus influenza* (37°)	6.4×10^{-19}	1.60×10^{-8}	0.78	5.70×10^{-12}
9. *Mitochondria* (37°)	4.0×10^{-18}	3.04×10^{-8}	3.17	1.6×10^{-12}
Prokaryotes (Mycoplasmatales, Bacteria, Rickettsiales, Chlamydiae, Cocci)				
10. *Mycoplasma mycoides* (37°)	1.0×10^{-17}	3.78×10^{-8}	0.335-1.22(0.77)	7.02×10^{-12}
11. *Hemophilus influenzae* (37°)	3.0×10^{-17}	5.42×10^{-8}	0.43-0.75 (0.59)	1.41×10^{-11}
12. *Listeria monocytogenes* (37°)	3.0×10^{-17}	5.42×10^{-8}	0.33-1(0.67)	1.245×10^{-11}
13.*Chlamydia trachomatis* (37°)	3.0×10^{-17}	5.91×10^{-8}	2-3 (2.5)	6.57×10^{-12}
14. *Mycoplasma arthritidis* (35°)	4.0×10^{-17}	6.50×10^{-8}	0.33-2 (1.15)	1.57×10^{-11}
15. *Bdelovibrio bacteriovorus* (35°)	5.0×10^{-17}	6.51×10^{-8}	0.33-3.5 (1.94)	1.146×10^{-11}
16. *Haemobartonella muris* (35°)	6.0×10^{-17}	7.45×10^{-8}	0.33-4.5 (2.44)	8.4×10^{-12}
17. *Wolbachiawelophagi* (35°)	6.0×10^{-17}	7.45×10^{-8}	0.42-5 (2.71)	9.0×10^{-12}
18. *Mycroccoci* (37°)	1.0×10^{-16}	8.8×10^{-8}	0.48-3 (1.74)	1.405×1^{-11}
19. *Ehrlichia canis* (30°)	2.0×10^{-16}	1.1×10^{-7}	0.48-3 (1.74)	1.76×10^{-11}
20. *Diplococcus pneumoniae* (37°)	3.8×10^{-16}	1.37×10^{-7}	0.42-5 (2.71)	1.40×10^{-11}
21. *Nitrobacter* (30°)	5.0×10^{-16}	1.5×10^{-7}	1-5 (3)	1.36×10^{-11}
22. *Nitrosomonas* (25°)	5.0×10^{-16}	1.5×10^{-7}	1-5 (3)	1.36×10^{-11}
23. *Shigella flexneri* (37°)	7.1×10^{-16}	1.68×10^{-7}	0.66-3 (1.83)	2.50×10^{-11}
24. *Staphylococcus aureus* (37°)	7.8×10^{-16}	3.7×10^{-7}	0.38-2 (1.2)	8.56×10^{-11}
25. *Psychrobacter immobilis* sp.(21°)	3.0×10^{-16}	1.26×10^{-7}	2-5 (3.5)	1.0×10^{-11}
26. *Escherichiacoli* (37°)	3.9×10^{-16}	1.38×10^{-7}	0.33-3 (3)	2.3×10^{-11}
27. *Ricketsia prowazeki* (37°)	5.0×10^{-16}	1.7×10^{-7}	8-10 (9)	1.0×10^{-11}
28. *Thiobacillus thioparus* (37°)	5.0×10^{-16}	1.7×10^{-7}	0.33-5 (3.5)	2.6×10^{-11}
29. *Methanosarcina barkeri* (35°)	9.7×10^{-16}	1.86×10^{-7}	2-66 (33)	2.97×10^{-12}
30. *Sulfolobus acidocaldarius* (80°)	1.5×10^{-15}	2.15×10^{-7}	2.9-20 (11.45)	5.2×10^{-12}
31. *Azotobactervinelandii* (35°)	2.0×10^{-15}	2.37×10^{-7}	1-3 (2)	3.28×10^{-11}
32.*Thermotoga maritima* (80°)	4.0×10^{-15}	3.0×10^{-7}	0.33-4.33 (2.33)	3.57×10^{-11}
33. *Bacillus stearothermophilus* (60°)	4.3×10^{-15}	3.1×10^{-7}	0.42-4.33 (2.35)	3.66×10^{-11}
34. *Halobacterium salinarium* (37°)	8.6×10^{-15}	3.82×10^{-7}	4-8 (6)	1.77×10^{-11}
Eukaryotes				
35. *Chlorella sorociniana* (38°)	2.0×10^{-14}	5.06×10^{-7}	2.5-14 (8.25)	1.7×10^{-11}
36. *Saccharomyces cereviseae* (30°)	2.0×10^{-14}	5.06×10^{-7}	1.7-12 (6.85)	2.04×10^{-11}
37.*Tetraselmis viridis* (20°)	3.0×10^{-13}	1.24×10^{-6}	5-24 (14.5)	2.37×10^{-11}
38. *Dunaliella heterosigma* (20°)	3.0×10^{-13}	1.24×10^{-6}	5-24 (14.5)	2.37×10^{-11}
39. *Olisthodiscus luteus* (16°)	3.0×10^{-13}	1.24×10^{-6}	5-24 (14.5)	2.37×10^{-11}
40. *Dictyostelium discoideum* (22°)	4.3×10^{-13}	2.5×10^{-6}	7-12 (9.5)	7.3×10^{-11}
41. *Euglena* (25°)	8.0×10^{-12}	3.65×10^{-6}	6-13 (9.5)	1.07×10^{-10}
42. *Chlamydomonas* (25°)	4.0×10^{-12}	2.9×10^{-6}	6-14 (10)	8.06×10^{-11}
43. *Tetrahymena* (25°)	2.0×10^{-11}	4.94×10^{-6}	6-30 (18)	1.62×10^{-11}
44. *Paramecium* (25°)	4.0×10^{-10}	8.41×10^{-6}	8-40 (24)	1.54×10^{-10}
45. *Pelomyxa* (25°)	1.0×10^{-9}	1.8×10^{-5}	6-50 (28)	1.80×10^{-10}
46. *Amoeba proteus* (25°)	2.0×10^{-8}	4.80×10^{-4}	72-120 (96)	1.4×10^{-11}
47. *Amoeba (Chaos chaos)* (25°)	3.7×10^{-8}	5.90×10^{-4}	72-168 (120)	4.63×10^{-10}
48. *Stentor* (25°)	8.0×10^{-8}	7.62×10^{-4}	96-192 (144)	1.47×10^{-10}
49. Fucus egg (Brown Algae) (25°)	1.87×10^{-10}	1.03×10^{-5}	24	1.79×10^{-10}
50. Pelvetia egg (Brown Algae) (25°)	4.40×10^{-10}	1.37×10^{-5}	24	1.79×10^{-10}

Results

The Numerical Diapasons of the Cell Mass, Volume to Surface Ratio, Doubling Time and Growth Rate in the Unicellular Organisms

Table 1 provides data for 50 unicellular organisms Prokaryotes (viruses, phages and Bacteria) and Eukaryotes (protozoa). The difference between the body mass of studied unicellular organisms is 10^{12} folds (from 8.6×10^{-20} kg in T7 phage to 8.0×10^{-8} kg in Stentor). The difference between the volume to surface ratio is 10^6 folds (from 7.8×10^{-9} m in T7 phage to the 7.64×10^{-4} m in Stentor) and the difference between the mean doubling time of cells is 10^5 folds (from 0.335h in T7 phage to 144h in Stentor). The growth rate of single unicellular organisms v_{gr} appears as a relatively constant parameter, changing 2 orders of magnitude only (from 1.0×10^{-12} to 1.0×10^{-10} m/s), in comparison to 12 orders of magnitude difference between the body mass of organisms. Growth rate of viruses and phages changes in diapason of 1.6×10^{-12}-6.5×10^{-12} m/s with mean value (± SD) of $4.05\pm0.223\times10^{-12}$ m/s. Growth rate of cellular structure such as mitochondria is 1.6×10^{-12} m/s. The growth rate of Prokaryotes (bacterial cells) changes in diapason of 3.0×10^{-12}-8.56×10^{-11} m/s with mean value (± SD) of $1.87\pm0.319\times10^{-11}$ m/s. The growth rate of Eukaryotes changes in diapason of 1.7×10^{-11}-1.8×10^{-10} m/s with mean value (± SD) of $1.063\pm0.288\times10^{-10}$ m/s. On Fig. 2 a schematically is presented the diapasons of growth rate for all studied organisms (viruses, phages, bacteria and protozoa).

The shown on Fig. 2 diapason (1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s) is used in calculations. It is taken to contain the common numerical values of growth rate for Prokaryotes and Eukaryotes. The values of 1.0×10^{-11} and 1.0×10^{-10} m/s are placed symmetrically on the left and on the right of this diapason (with middle point 5.0×10^{-11} m/s). The value of $1.0\times10^{-9.5}$ m/s is equivalent to value 3.16×10^{-10} m/s. The used in calculations common diapason contained the mean values (± SD) of growth rate in Prokaryotes and Eukaryotes.

Basic Dimensionless Equations between Growth Rate, Gravitational and Planck Constant

The purpose of the study is to answer the hypothesis-do unicellular organisms obtain mass-size-time and density characteristics by combination between growth rate of unicellular organisms, gravitational constant and Planck constant. The scheme of the possible dimensional combination is presented on Fig. 3.

The empirically received equations between gravitational constant (G) with dimension of $N\cdot m^2/kg^2$, Planck's constant (h) with dimension of J·s and growth rate (v_{gr}) with dimension of m/s are given on Table 2.

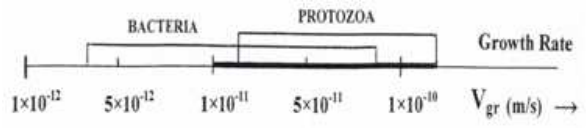

Fig. 2. Growth rate in Prokaryotes and Eukaryotes, according to data on Table 1. *All Prokaryotes are named 'bacteria' and all Eukaryotes are named 'protozoa'. The common diapason of growth rate (1.0×10^{-11}-$1.0\times10^{-9.5}$m/s) represented with a black line is taken in calculations*

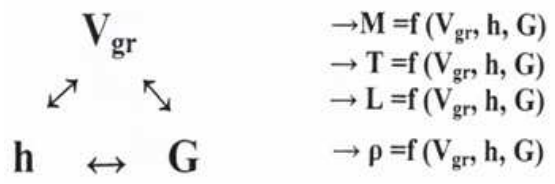

Fig. 3. The sceme of combination between growth rate (v_{gr}) of unicellular organisms, gravitational (G) and Planck (h) constant

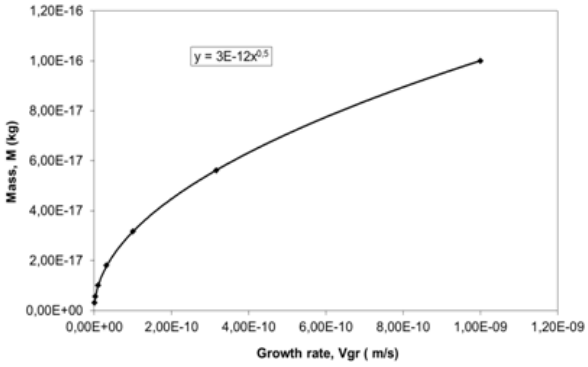

Fig. 4. Calculated by equation $M(v_{gr}) = (h\cdot v_{gr}/G)^{1/2}$ values for mass as a function of the growth rate v_{gr} in diapason of 1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s in log-log plots

Table 2. The dimensional derived equations for mass M, length L, time T and density ρ based on combinations between the gravitational G and Planck constant h and growth rate v_{gr}

Equation (N)	Combinations	Dimensions	Equation
1.	G, h, v_{gr}	kg	$M(v_{gr}) = (h\cdot v_{gr}/G)^{1/2}$
2.	G, h, v_{gr}	m	$L(v_{gr}) = (h\cdot G/v_{gr}^3)^{1/2}$
3.	G, h, v_{gr}	s	$T(v_{gr}) = (h\cdot G/v_{gr}^5)^{1/2}$
4.	G, h, v_{gr}	kg/m^3	$\rho(v_{gr}) = v_{gr}^{3.5}/h\,G^2$

The dimensional equations are presented as a function of growth rate v_{gr} of the unicallular organisms.

Analyses of the Dimensional Equation for Mass M $(v_{gr}) = (h\cdot v_{gr}/G)^{1/2}$

Figure 4 presents the graphical form of equation M $(v_{gr}) = (h\cdot v_{gr}/G)^{1/2}$ for mass in 'kg' as a function of the growth rate v_{gr} in 'meter per second'.

Keeping in mind the numerical values of gravitational constant G = 6.67×10^{-11} N·m^2/kg^2 and Planck constant h = 6.626×10^{-34} J·s, the dimensional Equation 1 on Table 2 takes the form of mathematical function:

$$M = 3.15\times10^{-12} v_{gr}^{0.5} \quad (5)$$

For growth rate v_{gr} in diapason of 1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s the calculated values for mass fall in diapason of 3.0×10^{-18}-1.0×10^{-16} kg. Figure 5 shows the compared, calculated and experimental diapasons of data for mass of Viruses, Phages, Prokaryotic and Eukaryotic cells. The calculated diapason of mass corresponds to the mass of Phages and bacteria (*Mycoplasma, Haemophilus, Chlamydia, Bdelovibrio, Welbachia, Micrococci*), according to experimental data for unicellular organisms in Table 1.

For minimum growth rate (1.0×10^{-12}-7.0×10^{-12} m/s) typical for Viruses and Phages, the calculated mass correspond to the mass of Viruses and Phages (1.0×10^{-19}-1.0×10^{-18} kg). For maximum growth rate (5.0×10^{-10} m/s) the calculated mass (7.0×10^{-17} kg) falls again in the diapason of the bacterial mass. Thus, for the growth rate in full diapason of 1.0×10^{-12}-5.0×10^{-10} m/s the calculated values for mass overlap with mass of the microorganisms (Viruses, Phages and unicellular Prokaryotes).

Analyses of the Dimensional Equation for Length $L(v_{gr}) = (h\cdot G/v_{gr}^3)^{½}$

Figure 6 shows the graphical form of equation $L(v_{gr}) = (h\cdot G/v_{gr}^3)^{1/2}$ for length in 'meter' as a function of growth rate v_{gr} in 'meter per second'.

The calculated on Fig. 6 length is a decreasing function of the growth rate. Giving in the mind the numerical values of gravitational and Planck constant the dimensional Equation 2 on Table 2 takes the form of mathematical function:

$$L = 2.1\times10^{-22} v_{gr}^{-1.5} \quad (6)$$

For numerical values of growth rate in diapason of 1.0×10^{-11}–$1.0\times10^{-9.5}$ m/s, the calculated numerical values for length fall in diapason of 5.0×10^{-8} – 1.0×10^{-5} m. Figure 7 present the comparison between the diapason of the calculated and experimental data, for volume to surface ratio in Prokaryotes and Eukaryotes. The comparison shows that the calculated diapason (from 5.0×10^{-8} to 1.0×10^{-5} m) overlaps with experimental diapason of value for volume to surface ratio in Prokaryotic and Eukaryotic (from 1.0×10^{-7} to 5.0×10^{-4} m).

For example, for prokaryotic *E. coli* the volume to surface ratio is 1.38×10^{-7} m, for growth rate 2.3×10^{-11} m/s. For eukaryotic Pelomyxa the volume to surface ratio is 1.8×10^{-5} m, for growth rate rate 1.8×10^{-10} m/s.

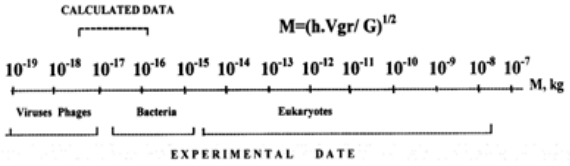

Fig. 5. Diapason of calculated by equation $M(v_{gr}) = (h\cdot v_{gr}/G)^{1/2}$ values for mass and the experimental data for the cell mass presented in Table 1

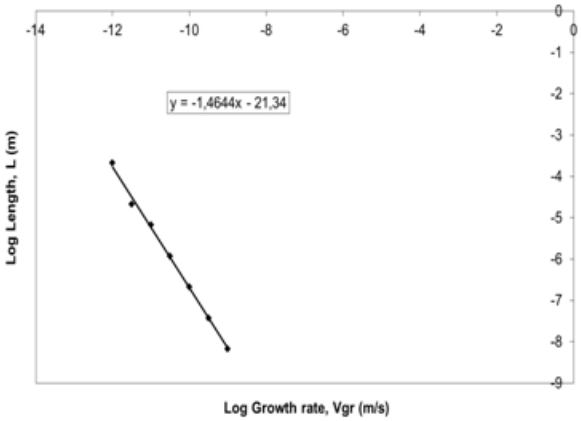

Fig. 6. Calculated by equation $L(v_{gr}) = (h\cdot G/v_{gr}^3)^{1/2}$ values for length as a function of the growth rate v_{gr} in diapason of 1.0×10^{-11} –$1.0\times10^{-9.5}$ m/s

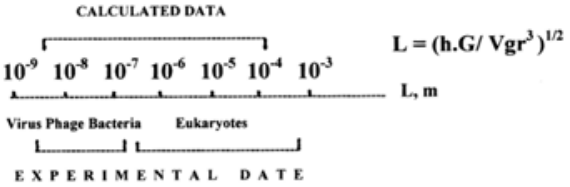

Fig. 7. Comparison between the diapason of length, calculated by equation $L(v_{gr}) = (h\cdot G/v_{gr}^3)^{1/2}$ and the experimental data for cell volume to surface ratio, according to data on Table 1

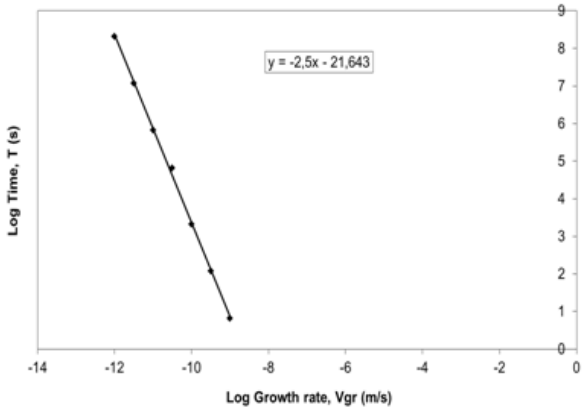

Fig. 8. Calculated by equation $T = (h\cdot G/v_{gr}^5)^{1/2}$ values for time-intervals as a function of the growth rate v_{gr} in diapason of 1.0×10^{-11} –$1.0\times10^{-9.5}$ m/s

The two values fall in the calculated diapason for length, independently of 10^7 folds difference between the cell mass of *E. coli* and *Pelomyxa*. Not only the volume to surface ratio but the cell size of unicellular organisms (length and width) overlaps with the calculated data for length on Fig. 7. For example the linear size of smallest *Mycoplasma* range in diapason of 0.15-0.6 μm (Morowitz, 1966). The size of small *Rickettsia* and *Chlamydia* is in diapason of 0.1-2.0 μm. The size of Bacteria is in diapason of 0.5-3.0 μm and the size of the big Eukaryotes range up to 1.0×10^{-4} m (Lindner, 1978; Gusev and Mineeva, 1985; Holt, 1984; 1986; 1989).

Analyses of the Dimensional Equation for Time $T(v_{gr}) = (h\cdot G/v_{gr}^5)^{1/2}$

Figure 8 provides the graphical form of the equation $T = (h\cdot G/v_{gr}^5)^{½}$ for doubling time in '*s*' as a function of the growth rate v_{gr} in 'meter per second'.

Keeping in mind the numerical values of gravitational and Planck constant the dimensional Equation 3 on Table 2 takes the form of mathematical function:

$$T = 2.2875\times10^{-22} Vgr^{-2.5} \quad (7)$$

For numerical values of growth rate in diapason of 1.0×10^{-11} – $1.0\times10^{-9.5}$ m/s, the calculated diapason for time-intervals fall in the diapason of 1.0×10^2-1.0×10^6 s. Experimental data presented in Table 1, for the cell doubling time show that the calculated diapason overlaps with the experimental diapason of doubling time for prokaryotic Phages and bacteria (5.0×10^2-5.0×10^4 s) and the doubling time for Eukaryotes (5.0×10^4-5.0×10^7 s). Figure 9 presents the comparison between the calculated and experimental diapason of data.

Analyses of the Dimensional Equation for Density $\rho = M/L^3 = v_{gr}^{3.5}/hG^2$

Figure 10 presents the graphical form of equation $\rho=M/L^3$ for density in 'kg/m^3' as a function of growth rate v_{gr} in 'meter per second'.

On Figure 10 the calculated density is an increasing function of growth rate. Keeping in mind the numerical values of gravitational and Planck constants, the dimensional Equation 4 on Table 2 take the form of mathematical function:

$$\rho = 3.4\times10^{53} v_{gr}^{5} \quad (8)$$

For growth rate in diapason of 1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s, the calculated numerical values for density fall in diapason of 1.0×10^{-1}-1.0×10^4 kg/m^3. According to experimental data presented in Table 1, the calculated diapason of density contains the experimental values of density (1100-1300 kg/m^3) in Prokaryotes and Eukaryotes (Günter, 1975; Metzler, 1977). Figure 11 shows a comparison between the calculated and the experimental diapason.

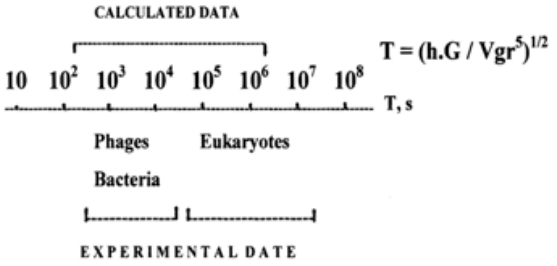

Fig. 9. Comparison between the calculated by equation $T = (h\cdot G/v_{gr}^5)^{1/2}$ time-intervals and the experimental cell doubling time, presented in Table 1. Data are present in log-scale

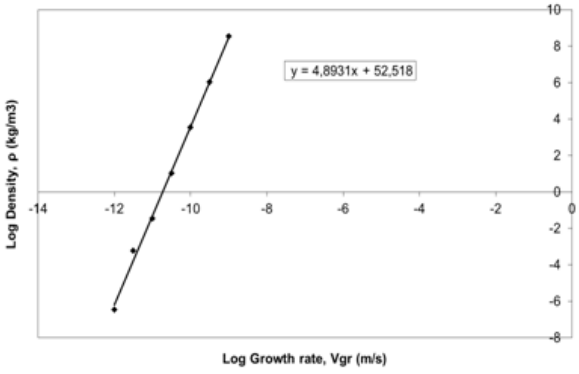

Fig. 10. Calculated by equation $\rho = M/L^3 = v_{gr}^{3.5}/h\ G^2$ density as a function of growth rate v_{gr} in diapason of 1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s

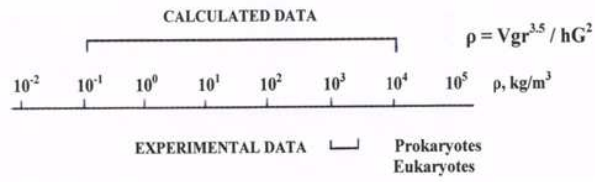

Fig. 11. Comparison between the diapason of calculated by equation $\rho = v_{gr}^{3.5}/h.G^2$ densities and the experimental data for cell density presented in Table 1. Data are present in log-scale

Figure 11 demonstrates that the calculated diapason of density ranges about 5 orders of magnitudes (from 10^{-1} to 10^4 kg/m^3) in comparison to a very small window of density in living organisms (from 1050 kg/m^3 in multicellular to 1100-1300 kg/m^3 in unicellular organisms) m^3 (Günter, 1975; Metzler, 1977; Cantor and Schimmel, 1980). However, the density of living organisms appears relatively constant parameter near to water density~1000 kg/m^3, because of about 70% of the cell body mass consists of water. For example, the calculated density for the smallest spherical Mycoplasma

with mass 2.5×10^{-17} kg and diameter 0.33 μm is 1300 kg/m^3. The density of viruses and phages falls in diapason of 1350-1370 kg/m^3. The proteins have a density about 1400 kg/m^3 and the ribosome density is about 1600 kg/m^3 (Metzler, 1977; Cantor and Schimmel, 1980). The multicellular organisms (Poikilotherms, Mammals and Aves) have a density ~ 1050 kg/m^3 (Günter, 1975) i.e., very near to the water density.

Discussion

The study demonstrates that the combination between growth rate (biological parameter of the unicellular organisms) and two physical constants (Planck and gravitational constant) leads to dimensional equations for mass, length, time and density. From these dimensional equations it can calculate the numerical values for mass, length, doubling time and density in the unicellular organisms. As confirmation of made hypothesis we can give some arguments from the theoretical physics. The arguments correspond to Planck's equation (Edington, 1948; Blochincev, 1970; Barrow, 2002) obtained by dimensional combination between the gravitational constant 'G', Planck constant 'h' and speed of light 'c'(in meter per second). The combination between these constant gives the Planck's equations for mass (M_{Pl}), length (L_{Pl}), time (T_{Pl}) and density (ρ_{Pl}):

$$M_{Pl} = \left(\left(h{\cdot}c / G\right)^{½} = 2.176\times10^{-8} kg\right. \tag{9}$$

$$L_{Pl} = \left(h{\cdot}G / c^3\right)^{½} = 1.616\times10^{-35} m \tag{10}$$

$$T_{Pl} = \left(h{\cdot}G / c^5\right)^{½} = 5.389\times10^{-44} s \tag{11}$$

$$\rho_{Pl} = M_{Pl} / L^3 = 1.0\times10^{97} kg / m^3 \tag{12}$$

The obtained by us dimensional equations are similar to Planck's equations but in them appear the growth rate (v_{gr}) of the unicellular organisms. The Planck's 'mass-length-time-density' parameters are calculated for speed of light $c = 2.9979\times10^8$ m/s, while the parameters of the unicellular organisms are calculated for growth rate in diapason of 1.0×10^{-11}-$1.0\times10^{-9.5}$ m/s. The find similarities support non-random character of dimensional equations for unicellular organisms.

The participation of the gravitational and the Planck constant in received equations shows possible quantum-mechanical and gravitational nature of the events playing role in determination of physical parameters of microorganisms. In the most general cases the participation of the Planck's constant in given physical equation is connected to quantization of parameters. The comparison between Planck's and cell mass show that they are places in the area of classical physics.

The mass of the unicellular organisms (M) is placed between Planck's (M_{Pl} = 2.176×10^{-8} kg) and proton mass (M_{p+} = 1.672×10^{-27} kg) i.e., on the boundary between classical and quantum physical areas:

$$\left(M_{Pl}\times M_{Pl}\right)^{0.5} \geq M \geq \left(M_{Pl}\times M_{p+}\right)^{0.5} \tag{13}$$

where, $(M_{Pl}\times M_{Pl})^{0.5} = 2\times10^{-8}$ and $(M_{Pl}\times M_{p+})^{0.5} = 6\times10^{-17}$ kg. The Planck length L_{Pl} = 1.616×10^{-35}m falls in quantum spatial area, while the characteristics cell length (from 1.0×10^{-7} to 1.0×10^{-4} m) falls in the area of the classical physics. Curiously, but the momentum ($M\times v_{gr}$) between bacterial mass M (from 10^{-15} to 10^{-17} kg) and bacterial growth rate v_{gr} (from 10^{-11} to 10^{-10} m/s) satisfied the Broglie's like equation:

$$L_B = h / \left(M \times v_{gr}\right) \tag{14}$$

where, L_B is the characteristic Broglie's wavelength corresponding to momentum $M\times v_{gr}$. As example, for bacterial mass (10^{-15}-10^{-17} kg) and growth rate (10^{-11}-10^{-10} m/s) the calculated Broglie's wavelength lies in interval from 10^{-8} to 10^{-6} m. This length overlaps with volume to surface ratio in bacterial cells (Atanasov, 2014) (Table 1). The cell generation times (10^3-10^7s) lies in the area of the classical physics. Curiously, but the ratio between the Planck constant (h) and the bacterial kinetic energy ($M\times v_{gr}^2/2$) gives time from 10^2 sec to 10^4 seconds:

$$Time = 2h / \left(M \times v_{gr}^{\ 2}\right) \tag{15}$$

This time-interval overlaps with generation time of bacterial cells (from 10^3 to 10^4 s). Interesting is the fact, that growth rate of microorganisms has the same order of magnitudes ($\sim10^{-11}$) as gravitational constant. In this sense, the growth rate appears the smallest speed on cellular level (about 0.1-1.0 atoms length per second). For comparison, the maximum speed of synthesis of polypeptide and polynucleotide chain in living cells is about 10^{-6} m/s (Cantor and Schimmel, 1980; Atanasov, 2007; Davies, 2008). Possible, such low speed on cellular level can leads to quantization of mass-energy and space-time characteristics of the unicellular organisms.

The independence of Planck and gravitational constant on temperature, physical and chemical factors can explain the stability of the bacterial forms of life during biological evolution. The bacterial cells have appeared and live milliards years ago on the Earth. They changed their genome and biochemical pathways but always keep constantly (and independently of evolutionary time) their mass, size, doubling time and density. This fact can be explained by mutually

connection between physical bacterial characteristics and the fundamental physical constants of the Universe.

Conclusion

Dimensional analyses shows that combination between the growth rate of the unicellular organisms, gravitational and Planck constants give the dimensional equations for mass, length, time and density. The calculated by these equations numerical values correspond to cell mass, cell length, doubling time and cell density of unicellular Prokaryotes and Eukaryotes. This shows possible non-random and based on the fundamental physical constants determination of the physical parameters of the first living organisms.

Funding Information

The authors have no support or funding to report.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues involved.

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