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Quantized States of The Nucleus of a Biological Cell

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Abstract: In this article: a) By the example of the nucleus of a biological cell in a state of interphase, it is shown that the chaotic movement of organelles on average can be ordered and have a discrete set of possible averaged states. These averaged states of the nucleus are described by solutions of the generalized stationary Schrödinger equation; *b*) it is suggested that among the discrete set of excited states of the cell nucleus, there are states that prevent the penetration of genetic material (RNA and/or DNA) of viruses through the nuclear pores into the karyoplasm. Methods of introducing the cell nucleus into an excited state are proposed. It is possible that this method of influencing the nucleus and/or other organelles of the cell will be an effective way to fight viral infection; *c*) the mathematical description of the excited states of the organelles of a biological cell is aimed at the approval of a new "statistical" interpretation of quantum mechanics

Key words: cell nucleus, excited state of organelles of a biological cell, chaotic movement of organelles, viral suppression, interpretation of quantum mechanics.

03.65.−w (Quantum mechanics)
05.30.−d (Quantum statistical mechanics)

Abbreviations

BC is biological cell;

PDF is probability density function;

TME is total mechanical energiality [defined in text; s. Eq. (20)].

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1 Introduction

As is known, organelles inside a biological cell (BC) (see Figure 1*a*) are in constant chaotic movement [16,17,18]. But perhaps there is order in this chaos? The hypotheses expressed in this article offer an answer to this question.

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c)
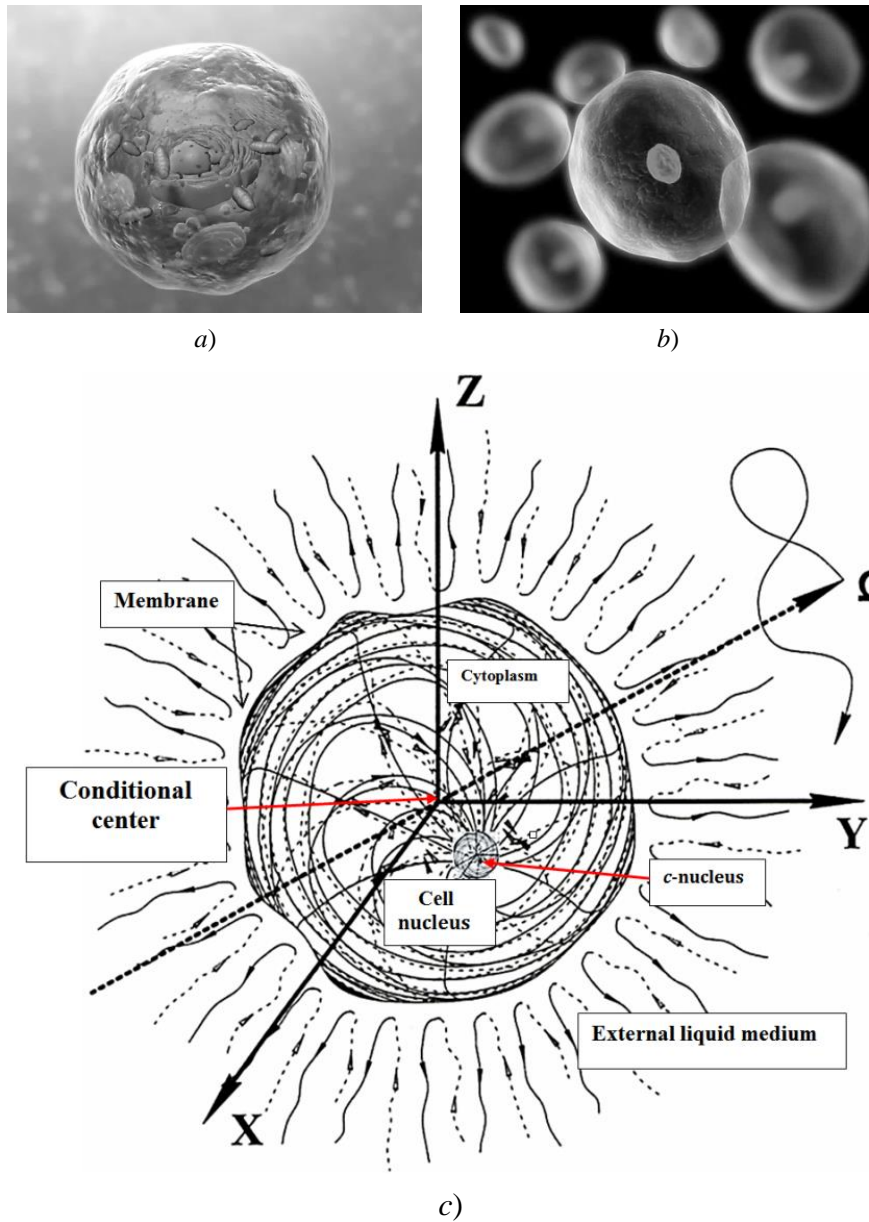
Fig.1: An eukaryotic cell: *a*) chaotically wandering organelles inside a biological cell; *b*) a biological cell with an identified nucleus; *c*) a model of a biological cell with a chaotically wandering nucleus center of mass (which is called the *c*-nucleus) in the vicinity of the conditional center

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Let's focus only on the nucleus of a biological cell (see Figures 1 *b*, *c*), since it is the most visible organelle.

All the conclusions made in this article regarding the cell nucleus concern all other intracellular two-membranous organelles (mitochondria, plasites, etc.) and some one-membrane organelles (lysosomes, vacuoles, secretory vesicles, etc.), which are in similar physical conditions.

2 Model of a biological cell with a chaotically wandering nucleus

Consider a living eukaryotic biological cell in the period between its division (i.e., in a state of interphase).

Let's trace the behavior of the cell nucleus (see Figures 1 *b*, *c* and Figure 2), which has the form of a spherical body with the following parameters:

- radius

$$r_n \approx 3 \ \mu m \approx \ 0.003 \ mm \approx \ 3 \times 10^{-6} \ m, \quad (1)$$

- mass
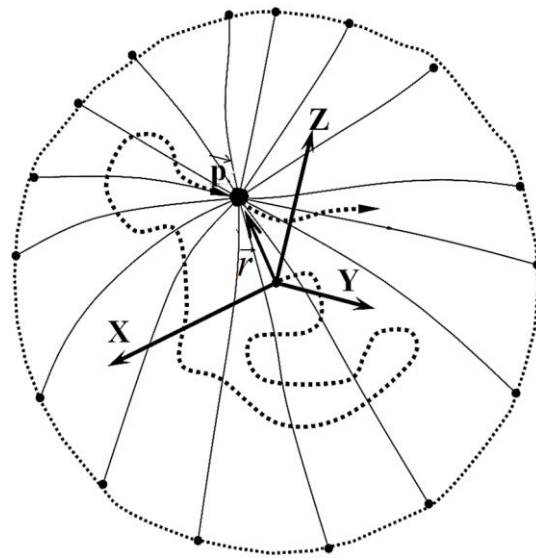
$$m_n \approx 6 \times 10^{-9} \ mg \approx 6 \times 10^{-15} kg, \quad (2)$$

- area of possible appearance, limited by the cell membrane, i.e. dimensions of a BC with a radius

$$r_c \approx 25 \ \mu m \approx 0.025 \ mm \approx 2.5 \times 10^{-5} \ m. \quad (3)$$

The center of mass of the cell nucleus will be denoted by a material point with mass m_n, and we will call this point the "*c*-nucleus " (see Figure 1*c* and Figure 2).

Fig. 2: The center of mass of the cell nucleus (that is, the material point, conventionally called the *c*-nucleus) continuously wanders chaotically in the vicinity of the conditional "center" of the biological cell, so that its total mechanical energy *E* always remains constant ($E = const$)

Let's assume that the state of the interphase of the cell under consideration lasts infinitely long, i.e. we will assume that BC does not change for a long time. In this case, the *c*-nucleus continuously wanders chaotically during the entire observation period in the vicinity of the conditional center (see Figures 1*c* and 2) under the influence of many unconnected force factors.

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In the framework of the model under consideration, this continuous chaotic movement of the c-nucleus is due to the immutability of its total mechanical energy E

$$E = T(x,y,z,t) + U(x,y,z,t) = const, \qquad (4)$$

where $T(x,y,z,t)$ is the kinetic energy of the c-nucleus associated with the speed of its motion;

$U(x,y,z,t)$ is the potential energy of the c-nucleus associated with the elastic properties of the cytoplasm, striving to return the c-nucleus to the conditional center (see Figures 1c and 2).

The energies $T(x,y,z,t)$ and $U(x,y,z,t)$ of the c-nucleus are random functions of time and the place of its position relative to the conventional center, but these energies smoothly flow into each other in such a way, that their sum (i.e., the total mechanical energy of the c-nucleus E) always remains constant ($E = const$).

This condition implies that the chaotic trajectory of the c-nucleus can be considered as a three-dimensional stationary random (stochastic) process.

The speed of the chaotic movement of the c-nucleus is small compared to the speed of light, so every instant it has kinetic energy

$$T(x,y,z,t) = \frac{p_x^2(x,y,z,t) + p_y^2(x,y,z,t) + p_z^2(x,y,z,t)}{2m_n},$$

or briefly

$$T(p_x, p_y, p_z, t) = \frac{p_x^2(t) + p_y^2(t) + p_z^2(t)}{2m_n}, \qquad (5)$$

where $p_x(t)$, $p_y(t)$, $p_z(t)$ are the instantaneous values of the momentum components of the wandering c-nucleus.

The form of the potential energy of the c-nucleus $U(x,y,z,t)$ is specified below.

The action S of the c-nucleus in nonrelativistic mechanics is defined as follows [1]

$$S(t) = \int_{t_1}^{t_2} [T(p_x, p_y, p_z, t) - U(x, y, z, t)]dt + Et.$$

To simplify calculations, consider a one-dimensional version of the action

$$S(t) = \int_{t_1}^{t_2} [T(p_x,t) - U(x,t)]dt + Et, \tag{6}$$

without limiting the generality of the conclusions, since in the case of three dimensions, only the number of integrations increases.

Due to the complexity of the chaotic motion of the c-nucleus, we will be interested not in the action (6) itself, but in its average [2,3]

$$\overline{S} = \int_{t_1}^{t_2} [\overline{T(p_x,t)} - \overline{U(x,t)}]dt + \overline{E}t. \tag{7}$$

Let's represent the averaged kinetic and averaged potential energies of the wandering c - nucleus in the form [2,3]

$$\overline{T(p_x,t)} = \frac{1}{2m_n} \int_{-\infty}^{\infty} \rho(p_x)p_x^2 dp_x, \quad \overline{U(x,t)} = \int_{-\infty}^{\infty} \rho(x)U(x)dx, \tag{8}$$

where $\rho(p_x)$ is the probability density function (PDF) p_x, i.e. the projection of the c-nucleus momentum onto the X-axis;

$\rho(x)$ is the PDF of the location of the projection of the c-nucleus on the X-axis (see Figures 1c and 2).

Substituting (8) into (7), we obtain the averaged action of a constantly randomly wandering c-nucleus [2,3]

$$\overline{S} = \int_{t_1}^{t_2} \left\{ \frac{1}{2m_n} \int_{-\infty}^{\infty} \rho(p_x)p_x^2 dp_x - \int_{-\infty}^{\infty} \rho(x)U(x)dx \right\} dt + \overline{E}t. \tag{9}$$

We note once again that this average action of the c-nucleus was obtained under the condition that the biological cell, on average, remains unchanged during the entire observation period. In this case, all the average characteristics of the chaotic motion of the c-nucleus remain constant.

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3 The generalized Schrödinger equation for a continuously wandering c-kernel

Let's represent the averaged action (9) in coordinate form. To do this, perform the following operations [2,3]:

1] Let's write the PDF $\rho(x)$ in the form of the product of two the probability amplitude $\psi(x)$:

$$\rho(x) = \psi(x)\,\psi(x), \quad \text{given that} \quad \int_{-\infty}^{\infty} \psi(x)\psi(x)dx = 1. \tag{10}$$

In quantum physics, the probability amplitude $\psi(x)$ is called the "wave function".

2] Let's represent the averaged kinetic energy of the c-nucleus in the form [2,3]

$$\overline{T} = \frac{1}{2m_n}\overline{p_x^2} = \frac{1}{2m_n}\int_{-\infty}^{\infty}\rho(p_x)p_x^2 dp_x = \frac{\hbar^2}{2m_n}\int_{-\infty}^{\infty}\psi(x)\frac{\partial^2\psi(x)}{\partial x^2}dx. \tag{11}$$

3] Let's represent the averaged potential energy of the c-nucleus in the form

$$\overline{U} = \int_{-\infty}^{\infty}\rho(x)U(x)dx = \int_{-\infty}^{\infty}\psi(x)U(x)\psi(x)dx. \tag{12}$$

4] Let's represent the total mechanical energy of the c-nucleus in the form [2,3]

$$E = \overline{E} = \int_{-\infty}^{\infty} i\hbar\psi(x)e^{iEt/\hbar}\frac{\partial\psi(x)e^{-iEt/\hbar}}{\partial t}dx = const\ , \tag{13}$$

where $\hbar$ is the reduced Planck's constant ($\hbar = h/2\pi$).

Substituting Expressions (11), (12), and (13) into (9), we obtain a record of the averaged action of a chaotically wandering c-nucleus in the coordinate form [2,3]

$$\overline{S} = \int_{t_1}^{t_2}\left\{\frac{\hbar^2}{2m_n}\int_{-\infty}^{\infty}\psi(x)\frac{\partial^2\psi(x)}{\partial x^2}dx - \int_{-\infty}^{\infty}\psi(x)U(x)\psi(x)dx + \int_{-\infty}^{\infty}i\hbar\psi(x)e^{iEt/\hbar}\frac{\partial\psi(x)e^{-iEt/\hbar}}{\partial t}dx\right\}dt. \tag{14}$$

Changing the order of integration in (14), we obtain the functional of the averaged action

$$\overline{S} = \int_{t_1}^{t_2}\int_{-\infty}^{\infty}\left(\frac{\hbar^2}{2m_n}\psi(x,t)\frac{\partial^2\psi(x,t)}{\partial x^2} + \psi(x,t)^2[E - U(x)] + i\hbar\psi(x,t)\frac{\partial\psi(x,t)}{\partial t}\right)dxdt. \tag{15}$$

The extremal $\psi(x,t)$ of the functional (15) is determined by the Euler-Poisson equation [2,3]

$$i\hbar\frac{\partial\psi(x,t)}{\partial t} = \frac{3\hbar^2}{2m_n}\frac{\partial^2\psi(x,t)}{\partial x^2} + 2[E - U(x)]\psi(x,t). \tag{16}$$

The generalization of Equation (16) to three dimensions has the form [2]

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$$ i\hbar \frac{\partial \psi(x,y,z,t)}{\partial t} = \frac{3\hbar^2}{2m_n}\nabla^2\psi(x,y,z,t) + 2[E - U(x,y,z,t)]\psi(x,y,z,t), \tag{17} $$

where $\nabla^2 = \dfrac{\partial^2}{\partial x^2} + \dfrac{\partial^2}{\partial y^2} + \dfrac{\partial^2}{\partial z^2}$ is the Laplace operator.

In the case when the wave function does not depend on time, i.e. when $\psi(x,y,z,t) = \psi(x,y,z)$, Equation (17) takes the form [2]

$$ -\frac{3}{2}\frac{\hbar^2}{2m_n}\nabla^2\psi(x,y,z) + U(x,y,z)\psi(x,y,z) = E\psi(\vec{r}), \tag{18} $$

which, up to a factor of 3/2, coincides with the stationary (time-independent) Schrödinger equation [4,5,6].

Let's introduce the notation [2]:

$$ \varepsilon_n = E/m_n \tag{19} $$

- let us call this massless quantity the "total mechanical energiality" of the c-nucleus;

$$ u_n(x,y,z) = U(x,y,z)/m_n \tag{20} $$

- let us call this massless quantity the "potential energiality" of the c-nucleus.

Taking into account (19) and (20), Equation (18) can be represented in the form

$$ \frac{3\hbar^2}{4m_n}\nabla^2\psi(x,y,z) + m_n[\varepsilon_n - u_n(x,y,z)]\psi(x,y,z) = 0, \tag{21} $$

We divide both sides of the Equation (21) by $\hbar$

$$ \frac{3\hbar}{4m_n}\nabla^2\psi(x,y,z) + \frac{m_n}{\hbar}[\varepsilon_n - u_n(x,y,z)]\psi(x,y,z) = 0, \tag{22} $$

and take into account that there is a connection between the ratio $\hbar/m_n$ and the main characteristics of a stationary random process (see Figure 3), in which the wandering c-nucleus of the BC takes part [2,3]

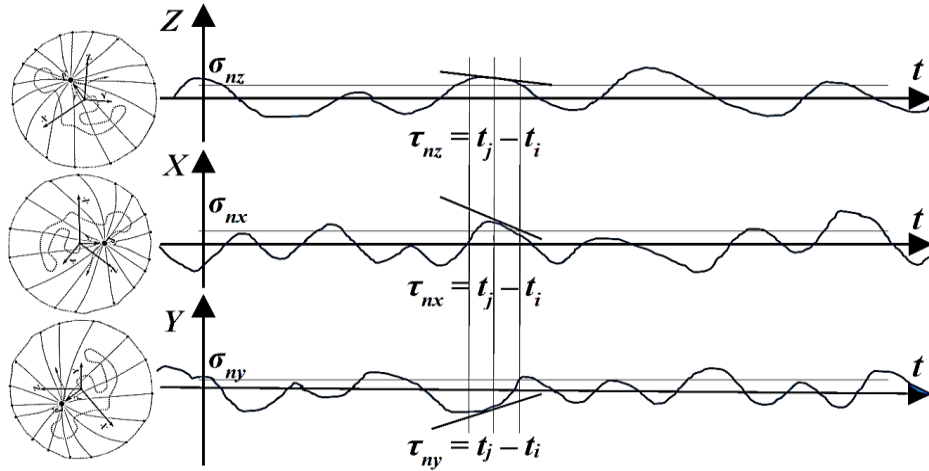$$ \frac{\hbar}{m_n} = \frac{2\sigma_{nr}^2}{\tau_{nr}} = \eta_{nr}, \tag{23} $$

where

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$$\sigma_{nr} = \frac{1}{3}\sqrt{\sigma_{nx}^2 + \sigma_{ny}^2 + \sigma_{nz}^2} \tag{24}$$

is the standard deviation of a chaotically wandering c-nucleus from a conventional center (see Figures 2 and 3);

$$\tau_{nr} = \frac{1}{3}\left(\tau_{nx} + \tau_{ny} + \tau_{nz}\right) \tag{25}$$

is the average autocorrelation interval of the considered stationary random process (Figure 3).

Fig. 3: Stationary random processes of changing the projections on the X, Y and Z axes of the same c-nucleus, randomly wandering in the vicinity of the conditional center; here σ_{ni}, τ_{ni} are the standard deviations and autocorrelation intervals of the corresponding stationary random processes [2,3]

Taking into account (23), Expression (22) takes the form

$$\frac{3}{4}\eta_{nr}\nabla^2\psi(x,y,z) + \frac{1}{\eta_{nr}}[\varepsilon_n - u_n(x,y,z)]\psi(x,y,z) = 0. \tag{26}$$

As a result of simple transformations from Expression (26), we obtain [2]

$$\nabla^2\psi(x,y,z) + \frac{2}{\eta_{nr1}^2}[\varepsilon_n - u_n(x,y,z)]\psi(x,y,z) = 0, \tag{27}$$

where

$$\eta_{nr1} = \sqrt{\frac{3}{2}}\eta_{nr} = \sqrt{\frac{3}{2}\frac{2\sigma_{nr}^2}{\tau_{nr}}} \tag{28}$$

is the scale parameter of the investigated three-dimensional random process.

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Expression (27) will be called the generalized time-independent Schrödinger equation [2].

In the one-dimensional case, Equation (27) takes the form

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{2}{\eta_{nx1}^2}[\varepsilon_n - u_n(x)]\psi(x) = 0. \tag{29}$$

where

$$\eta_{nx1} = \sqrt{\frac{3}{2}}\eta_{nx} = \sqrt{\frac{3}{2}}\frac{2\sigma_{nx}^2}{\tau_{nx}} \tag{30}$$

is the scale parameter of the investigated one-dimensional random process.

Equation (27) makes it possible to determine the averaged stationary states of the chaotically wandering c-nucleus of the BC, provided that the cell does not change during the entire observation time. In this case, the main characteristics of the studied three-dimensional random process remain unchanged: $\sigma_{nr} = $ const, $\tau_{nr} = $ const.

4 The nucleus of a biological cell surrounded by an elastic-tense cytoplasm

Let's consider the case when, as the c-nucleus moves away from the conditional center (see Figures 1c and 2), elastic "tensions" arise in the surrounding cytoplasm, which tend to return the c-nucleus to this center.

Note that the cell cytoplasm is a viscous liquid (i.e., a concentrated aqueous solution of proteins and other substances), in which there is an elastic network of a polymer substance [19].

Let's consider the case when the elastic tensions of the cytoplasm σ_v, on average, increase in proportion to the distance of the c-nucleus from the conditional center

$$\sigma_v(x) \approx k_u x, \tag{31}$$

where $k_u = K_u/m_n$ is the massless coefficient of elastic tension of the cytoplasm;

K_u is the force constant.

In this case, the averaged potential energiality of the c-nucleus can be approximately represented in the form

$$u_n(x) \approx \int k_{ux}\, x dx = \frac{1}{2}k_{ux}x^2. \tag{32}$$

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Substituting (32) into Equation (29), we obtain the equation of the "one-dimensional quantum harmonic oscillator" known in quantum mechanics

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{2}{\eta_{nx1}^2}[\varepsilon_n - \frac{k_{ux}x^2}{2})]\psi(x) = 0. \tag{33}$$

or

$$\varepsilon_n \psi(x) = -\frac{\eta_{nx1}^2}{2}\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{k_{ux}x^2}{2}\psi(x). \tag{34}$$

The study of this well-known equation leads to the following discrete series of the total mechanical energiality eigenvalues of the c-nucleus [7,8,9]:

$$\varepsilon_{nk} = \eta_{n1}\sqrt{k_{ux}}\left(k + \frac{1}{2}\right), \tag{35}$$

where $k = 1, 2, 3, ...$ is the principal where k = 1, 2, 3, ... is the principal quantum number;;

$\sqrt{k_{ux}} = \omega_{n0} = 2\pi f_{n0}$ is the angular frequency of "one-dimensional quantum harmonic oscillator".

Each discrete of the total mechanical energiality eigenvalue ε_{nk} (35) corresponds to an eigenwave function, which is one of the solutions of Equation (34) [7,8]:

$$\psi_{nk}(x) = \frac{1}{\sqrt{k!}}\left(\sqrt{\frac{\sqrt{k_{ux}}}{2\eta_{nx1}}}\right)^k \left(r - \frac{\eta_{nx1}}{\sqrt{k_{ux}}}\frac{d}{dx}\right)^k \left(\frac{\sqrt{k_{ux}}}{\pi\eta_{nx1}}\right)^{1/4} \exp\left\{-\frac{\sqrt{k_{ux}}x^2}{2\eta_{nx1}}\right\}, \tag{36}$$

where according to (23) and (30)

$$\eta_{nx1} = \sqrt{\frac{3}{2}}\frac{\hbar}{m_n} = \sqrt{\frac{3}{2}}\frac{2\sigma_{nx}^2}{\tau_{nx}} \tag{37}$$

is the scale parameter of the investigated stationary random process (see Figure 3).

Let's write out several eigenwave functions (36), describing various averaged states of a constantly randomly wandering c-nucleus, the deviation of which from the conditional center leads to elastic tensions of the surrounding cytoplasm (see Figures 1c and 2), [7,8,9]

$$\psi_{n0}(x) = \frac{1}{\sqrt{a_0\sqrt{\pi}}}\exp\left\{-\frac{x^2}{2a_0^2}\right\}, \quad \text{for } k = 0; \tag{38}$$
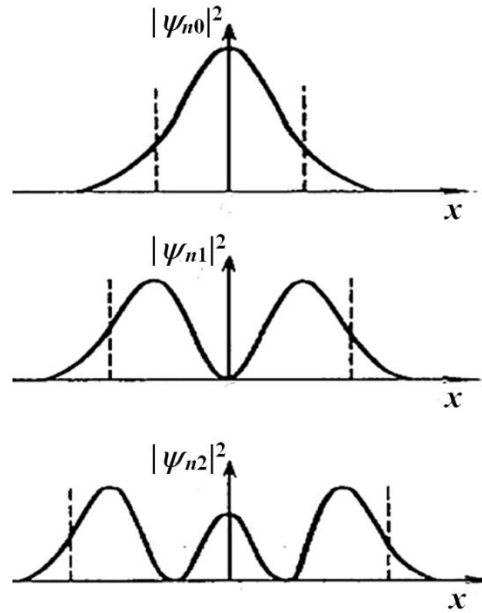
$$\psi_{n1}(x) = \frac{1}{\sqrt{2a_0\sqrt{\pi}}}\frac{2x}{a_0}\exp\left\{-\frac{x^2}{2a_0^2}\right\}, \quad \text{for } k = 1; \tag{39}$$

$$\psi_{n2}(x) = \frac{1}{\sqrt{8a_0\sqrt{\pi}}}\left(\frac{4x^2}{a_0^2} - 2\right)\exp\left\{-\frac{x^2}{2a_0^2}\right\}, \text{ for } k = 2, \tag{40}$$

where

$$a_0 = \sqrt{\frac{\eta_{nx1}}{\sqrt{k_u}}}. \tag{41}$$

The form of the square of the modulus $|\psi_{nk}|^2$ of the eigenwave functions ψ_{nk} (38) – (40) is shown in Figure 5 [7,8,9]

Fig. 5: The probability density functions $|\psi_{nk}|^2$ of the possible location of the c-nucleus in the vicinity of the conditional center [7,8]. The dashed lines mark the possible boundaries of the BC depending on the degree of excitation of the c-nucleus

From the PDFs shown in Figure 5, it follows that for $k = 0$ the most probable location of the c-nucleus coincides with the conditional center. Whereas in the first excited state, i.e. for $k = 1$, the c-nucleus is mainly located in the region of a sphere with a radius of the order of $r_c/2$. In the second excited state, i.e. when $k = 2$, the c-nucleus can be most likely to be located both in the center of a biological cell and in a spherical region close to its periphery.

From Expression (35) it follows that for $k = 0$ the total mechanical energiality of the c - nucleus is not equal to zero

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$$\varepsilon_{n0} = \frac{\eta_{n1}}{2}\sqrt{k_u} \, , \tag{42}$$

in this case, the *c*-nucleus continuously wanders chaotically near the conditional center, so that the PDF to detect it in this region is described by the Gaussian function

$$|\psi_{n0}(x)|^2 = \frac{1}{a_0\sqrt{\pi}} \exp\left\{-\frac{x^2}{a_0^2}\right\} = \frac{1}{\sqrt{2\pi\sigma_{nx}^2}} \exp\left\{-\frac{x^2}{2\sigma_{nx}^2}\right\}. \tag{43}$$

From PDF (43), taking into account (41), it follows

$$\sigma_{nx} = \frac{1}{\sqrt{2}} a_0 = \sqrt{\frac{\eta_{nx1}}{2\sqrt{k_u}}}. \tag{44}$$

Taking into account (30), it follows from (44) that the massless coefficient of elastic tension of the cytoplasm k_u is inversely proportional to the square of the averaged autocorrelation coefficient of the random process under study:

$$k_u = \frac{3}{2}\frac{1}{\tau_{nx}^2}. \tag{45}$$

On the other hand, k_u, as is known [7,8], is proportional to the natural frequency of oscillations of this "one-dimensional quantum harmonic oscillator" $k_u = (2\pi f_{n0})^2$ [see Expression (35)].

Let's assume that for a chaotically wandering *c*-nucleus, the autocorrelation coefficient of a random process is $\tau_{nx} \approx 3\times10^{-3}$ s, then, according to (45) and (35), its natural frequency of oscillations (i.e., jitter) is approximately equal to

$$f_{0x} \approx \sqrt{\frac{3}{2}}\frac{1}{2\pi\tau_{nx}} \approx 64\,Hz \, . \tag{46}$$

This means that external oscillatory processes with a frequency of the order of $f_{rn} \approx f_{0n} \approx 64$ Hz can effectively (resonantly) affect the nucleus of a biological cell.

If we assume that the speed of propagation of sound vibrations in the cell cytoplasm is approximately equal to $v_v \approx 1500$ m/s (this is the average speed of propagation of sound vibrations in the soft tissues of the human body), then the wavelength of sound vibration capable of abruptly changing the average state of the k-nucleus, is approximately equal to

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$$\lambda_{vn} = \frac{v_v}{f_{0n}} \approx \frac{1500}{64} \approx 23,4\,m. \tag{47}$$

Frequency (46) and wavelength (47) are preliminary (a priori) estimates of the characteristics of the effective stimulating effect on the cell nucleus under consideration. More detailed and precise information about disturbances that can effectively influence the averaged states of the nucleus and other similar organelles of a biological cell should be obtained as a result of experiments.

5 Chaotically trembling c-nucleus is the three-dimensional quantum harmonic oscillator

The c-nucleus wanders chaotically in a three-dimensional volume of the cytoplasm surrounded by a membrane (Figures 1c and 2). A quantum three-dimensional harmonic oscillator should be considered as a mathematical model of its behavior. In this case, the generalized Schrödinger equation has the form [7,11]

$$\varepsilon_n \psi(x, y, z) = -\frac{\eta_{nx1}^2}{2} \frac{\partial^2 \psi(x, y, z)}{\partial x^2} + \frac{k_{ux}x^2 + k_{uy}y^2 + k_{uz}x^2}{2} \psi(x, y, z). \tag{48}$$

This equation is solved by the method of separation of variables, i.e. the solution is sought in the following form [7,11]

$$\psi(x, y, z) = \psi(x)\psi(y)\psi(z). \tag{49}$$

In this case, from Equation (48) we obtain the system of equations [7, 11]

$$\frac{\partial^2 \psi(x)}{\partial x^2} + \frac{2}{\eta_{nx1}^2}[\varepsilon_{nx} - \frac{k_{ux}x^2}{2})]\psi(x) = 0, \tag{50}$$

$$\frac{\partial^2 \psi(y)}{\partial y^2} + \frac{2}{\eta_{ny1}^2}[\varepsilon_{ny} - \frac{k_{uy}y^2}{2})]\psi(y) = 0, \tag{51}$$

$$\frac{\partial^2 \psi(z)}{\partial z^2} + \frac{2}{\eta_{nz1}^2}[\varepsilon_{nz} - \frac{k_{uz}z^2}{2})]\psi(z) = 0, \tag{52}$$

$$\varepsilon_n = \varepsilon_{nx} + \varepsilon_{ny} + \varepsilon_{nz}. \tag{53}$$

Each of these equations is similar to the equation for a one-dimensional harmonic oscillator (33); therefore, we obtain three sets of discrete values of mechanical energiality [8]

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$$\varepsilon_{nxk} = \eta_{nx1}\sqrt{k_{ux}}\left(k_x + \frac{1}{2}\right), \qquad \varepsilon_{nyk} = \eta_{ny1}\sqrt{k_{uy}}\left(k_y + \frac{1}{2}\right), \qquad \varepsilon_{nzk} = \eta_{nz1}\sqrt{k_{uz}}\left(k_z + \frac{1}{2}\right), \qquad (54)$$

which correspond to eigenwave functions of the form (36) [8]:

$$\psi_{nk}(x) = \frac{1}{\sqrt{k!}}\left(\sqrt{\frac{\sqrt{k_{ux}}}{2\eta_{nx1}}}\right)^k\left(x - \frac{\eta_{nx1}}{\sqrt{k_{ux}}}\frac{d}{dx}\right)^k\left(\frac{\sqrt{k_{ux}}}{\pi\eta_{nx1}}\right)^{1/4}\exp\left\{-\frac{\sqrt{k_{ux}}x^2}{2\eta_{nx1}}\right\}, \qquad (56)$$

$$\psi_{nk}(y) = \frac{1}{\sqrt{k!}}\left(\sqrt{\frac{\sqrt{k_{uy}}}{2\eta_{ny1}}}\right)^k\left(y - \frac{\eta_{ny1}}{\sqrt{k_{uy}}}\frac{d}{dy}\right)^k\left(\frac{\sqrt{k_{uy}}}{\pi\eta_{ny1}}\right)^{1/4}\exp\left\{-\frac{\sqrt{k_{uy}}y^2}{2\eta_{ny1}}\right\}, \qquad (57)$$

$$\psi_{nk}(z) = \frac{1}{\sqrt{k!}}\left(\sqrt{\frac{\sqrt{k_{uz}}}{2\eta_{nz1}}}\right)^k\left(z - \frac{\eta_{nz1}}{\sqrt{k_{uz}}}\frac{d}{dz}\right)^k\left(\frac{\sqrt{k_{uz}}}{\pi\eta_{nz1}}\right)^{1/4}\exp\left\{-\frac{\sqrt{k_{uz}}z^2}{2\eta_{nz1}}\right\}. \qquad (59)$$

In this case, discrete values of the total mechanical energiality

$$\varepsilon_{nk} = \varepsilon_{nxk} + \varepsilon_{nyk} + \varepsilon_{nzk} \qquad (60)$$

correspond to wave functions of the form

$$\psi_{nk}(x, y, z) = \psi_{nk}(x)\psi_{nk}(y)\psi_{nk}(z). \qquad (61)$$

Let's assume that a biological cell is a spherical (i.e., spherically symmetric) formation. This corresponds to an isotropic three-dimensional harmonic oscillator with parameters

$$\eta_{nr1} = \eta_{nx1} = \eta_{ny1} = \eta_{nz1} \text{ and } k_{ur} = k_{ux} = k_{uy} = k_{uz}.$$

Therefore, the total mechanical energiality of the c-nucleus can take on a discrete series of values [7]

$$\varepsilon_{nN} = \eta_{nr1}\sqrt{k_{ur}}\left(N + \frac{3}{2}\right), \qquad (62)$$

where $N = k_x + k_y + k_z$, $N = 1,2,3,...$ is called the degeneracy multiplicity [7] (or single quantum number).

However, multiplying the wave functions (56) – (59), we find that it is impossible to write

$$\psi_{nk}(x)\psi_{nk}(y)\psi_{nk}(z) = \psi_{nk}(r).$$

In quantum mechanics, this means that it is impossible to excite the c-nucleus in all three directions X, Y and Z simultaneously [7]. That is, it should be expected that additional quantum effects

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may arise when trying to transfer the cell nucleus from one averaged state to another more excited averaged state.

6 Averaged *c*-nucleus moment of velocity

Additional effects in the case of an isotropic three-dimensional quantum harmonic oscillator arise due to the fact that during the chaotic motion of the *c*-nucleus in the vicinity of the conditional center, it constantly changes its direction of motion (see Figures 1*c* and 2). Therefore, the *c* - nucleus at each moment of time has the angular momentum

$$\vec{L} = \vec{r} \times \vec{p}, \tag{63}$$

where $\vec{r}$ is the radius vector from the conditional center to the *c*-nucleus (see Figure 2);

$\vec{p} = m_n \vec{v}$ – instantaneous value of the *c*-nucleus momentum.

In this case, the possible average values of the angular momentum of the *c*-nucleus can take only a discrete series of values (i.e., they are quantized), as will be shown below.

Let's represent the vector Equation (63) in the component form

$$L_x = yp_z - zp_y, \quad L_y = zp_x - xp_z, \quad L_z = xp_y - yp_x. \tag{64}$$

Let's average these components

$$\overline{L_x} = y\overline{p_z} - z\overline{p_y}, \quad \overline{L_y} = z\overline{p_x} - x\overline{p_z}, \quad \overline{L_z} = x\overline{p_y} - y\overline{p_x}. \tag{65}$$

We will use the coordinate representation of the averaged pulse components [2,3]

$$\overline{p_x} = \int_{-\infty}^{\infty} \rho(p_x) p_x dp_x = -i\hbar \int_{-\infty}^{\infty} \psi(x) \frac{\partial \psi(x)}{\partial x} dx = \int_{-\infty}^{\infty} \psi(x) \left(-i\hbar \frac{\partial}{\partial x} \right) \psi(x) dx \equiv \left(-i\hbar \frac{\partial}{\partial x} \right) \int_{-\infty}^{\infty} \psi(x)\psi(x) dx, \tag{66}$$

$$\overline{p_y} = \int_{-\infty}^{\infty} \rho(p_y) p_y dp_y = -i\hbar \int_{-\infty}^{\infty} \psi(y) \frac{\partial \psi(y)}{\partial y} dy = \int_{-\infty}^{\infty} \psi(y) \left(-i\hbar \frac{\partial}{\partial y} \right) \psi(y) dy \equiv \left(-i\hbar \frac{\partial}{\partial y} \right) \int_{-\infty}^{\infty} \psi(y)\psi(y) dy, \tag{67}$$

$$\overline{p_z} = \int_{-\infty}^{\infty} \rho(p_z) p_z dp_z = -i\hbar \int_{-\infty}^{\infty} \psi(z) \frac{\partial \psi(z)}{\partial z} dz = \int_{-\infty}^{\infty} \psi(z) \left(-i\hbar \frac{\partial}{\partial z} \right) \psi(z) dz \equiv \left(-i\hbar \frac{\partial}{\partial z} \right) \int_{-\infty}^{\infty} \psi(z)\psi(z) dz. \tag{68}$$

Substituting (66) – (68) into (65), and taking into account (10), we obtain quantum mechanical operators [8]

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$$\hat{L}_x = \frac{\hbar}{i}\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right), \quad \hat{L}_y = \frac{\hbar}{i}\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right), \quad \hat{L}_z = \frac{\hbar}{i}\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right). \tag{69}$$

We divide both sides of Expressions (69) by m_n

$$\frac{\hat{L}_x}{m_n} = \frac{\hbar}{m_n i}\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right), \quad \frac{\hat{L}_y}{m_n} = \frac{\hbar}{m_n i}\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right), \quad \frac{\hat{L}_z}{m_n} = \frac{\hbar}{m_n i}\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right). \tag{70}$$

Taking into account (23), we have

$$\hat{l}_x = \frac{\eta_n}{i}\left(y\frac{\partial}{\partial z} - z\frac{\partial}{\partial y}\right), \quad \hat{l}_y = \frac{\eta_n}{i}\left(z\frac{\partial}{\partial x} - x\frac{\partial}{\partial z}\right), \quad \hat{l}_z = \frac{\eta_n}{i}\left(x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x}\right), \tag{71}$$

where $\hat{l}_x$, $\hat{l}_y$, $\hat{l}_z$ are the components of the c-nucleus velocity moment operator, since

$$\vec{l} = \frac{\vec{L}}{m_p} = \vec{r} \times \vec{v}. \tag{72}$$

In a spherical coordinate system, massless operators (71) have the form [8]

$$\hat{l}_x = \frac{\eta_n}{i}\left(\sin\varphi\frac{\partial}{\partial\theta} - ctg\theta\cos\varphi\frac{\partial}{\partial\varphi}\right),$$

$$\hat{l}_y = \frac{\eta_n}{i}\left(\cos\varphi\frac{\partial}{\partial\theta} - ctg\theta\sin\varphi\frac{\partial}{\partial\varphi}\right), \tag{73}$$

$$\hat{l}_z = \frac{\eta_n}{i}\frac{\partial}{\partial\varphi}.$$

The operator of the square of the modulus of the c-nucleus velocity moment operator is [8]

$$\hat{l}^2 = \hat{l}_x^2 + \hat{l}_y^2 + \hat{l}_z^2 = -\eta_n^2\nabla_{\theta,\varphi}^2, \tag{74}$$

where $$\nabla_{\theta,\varphi}^2 = \frac{1}{\sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{\sin^2\theta}\frac{\partial^2}{\partial\varphi^2}. \tag{75}$$

This operator will be used below.

7 Isotropic 3D harmonic oscillator

The generalized Schrödinger Equation (48) for an isotropic three-dimensional harmonic oscillator can be represented as [8]

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$$\nabla^2 \psi(r) + \frac{2}{\eta_{nr1}^2}[\varepsilon_n - \frac{k_u r^2}{2}]\psi(r) = 0, \tag{76}$$

where $r = \sqrt{x^2 + y^2 + z^2}$ is the distance from the conventional center to the c-nucleus (Figure 2);

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2 \frac{\partial}{\partial r}\right) + \frac{\nabla_{\theta,\varphi}^2}{r^2} \tag{77}$$

is the Laplace operator in spherical coordinates, while the operator $\nabla_{\theta,\varphi}^2$ is given by Expression (75). When substituting (77) into Equation (76) and dividing variables

$$\psi(r,\theta,\varphi) = R(r)Y(\theta,\varphi), \tag{78}$$

we obtain the equation [8.9]

$$\frac{1}{R(r)}\frac{\partial}{\partial r}\left(r^2 \frac{\partial R(r)}{\partial r}\right) + \frac{2}{\eta_{n1}^2}r^2\left[\varepsilon_n - \frac{k_u r^2}{2}\right] = -\frac{1}{Y(\theta,\varphi)}\nabla_{\theta,\varphi}^2 Y(\theta,\varphi). \tag{79}$$

The solutions to this equation are wave functions [12]

$$\tag{80}$$

$$\psi_{klm}(r,\theta,\varphi) = R_k(r)Y_{lm}(\theta,\varphi) = \sqrt{\sqrt{\frac{2}{\pi}\left(\frac{\sqrt{k_u}}{2\eta_{n1}}\right)^3} \frac{2^{k+2l+3}k!}{(2k+2l+1)!!}\left(\frac{\sqrt{k_u}}{2\eta_{n1}}\right)^l} \; r^l \exp\left\{-\frac{\sqrt{k_u}r^2}{2\eta_{n1}}\right\} L_l^{(l+1/2)}\left(2\sqrt{\frac{\sqrt{k_u}}{2\eta_{nx1}}}r^2\right) Y_{lm}(\theta,\varphi),$$

where $L_l^{(l+1/2)}\left(2\sqrt{\frac{\sqrt{k_u}}{2\eta_{nx1}}}r^2\right)$ are a generalized Laguerre polynomials $\tag{81}$

$$Y_{lm}(\theta,\varphi) = (-1)^m\left[\frac{(2l+1)(l-m)!}{4\pi(l+m)!}\right]^{\frac{1}{2}} e^{im\varphi} P_{lm}(\cos\theta) \quad \text{are a spherical harmonic functions;} \tag{82}$$

$$P_{lm}(\cos\theta) = \frac{d}{2^l l!}\left(1-\xi^2\right)^{m/2}\frac{d^{l+m}}{d\xi^{l+m}} + \left(\xi^2-1\right)^l \quad \text{are associated Legendre functions} \tag{83}$$

$\xi = \cos\theta$;

l is the azimuthal quantum number;

m is the peripheral quantum number.

In atomic quantum physics, the number m is called the "magnetic quantum number", but this name is not suitable for the quantum physics of a biological cell and other similar objects of
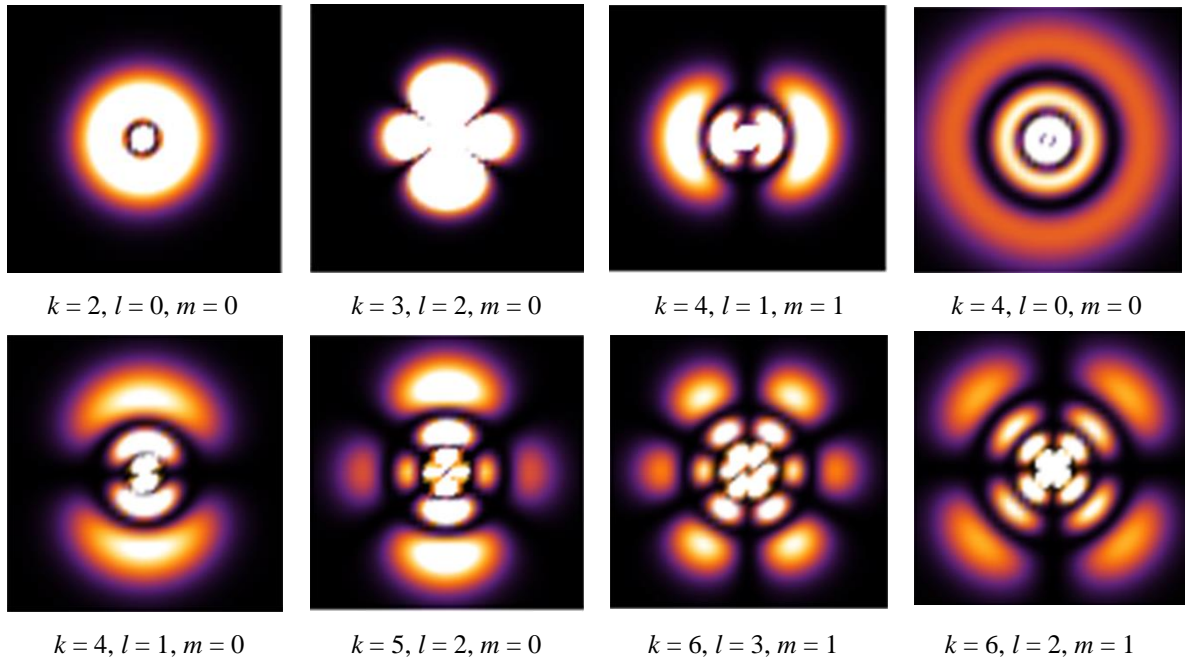
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micro- and macroworlds. Therefore, in this article, the number m is proposed to be called "peripheral quantum number".

Wave functions (80) correspond to the eigenvalues of the total mechanical energy of the *c*-nucleus [12]

The wave functions (80) correspond to the eigenvalues of the total mechanical energiality of the *c*-nucleus [12]

$$\varepsilon_{nkl} = \eta_{nr1} \sqrt{k_{ur}} \left(2k + l + \frac{3}{2} \right) = \eta_{nr1} \sqrt{k_{ur}} \left(N + \frac{3}{2} \right) \quad \text{где} \quad N = 2k + l. \tag{84}$$

The squares of the modulus of wave functions (80) $|\psi_{klm}(r,\theta,\varphi)|^2$ (i.e., the PDF of the possible location of the *c*-nucleus inside the BC) at $\varphi = 0$ and different values of the quantum numbers *k*, *l*, and *m* are shown in Figure 6.

| $k=2, l=0, m=0$ | $k=3, l=2, m=0$ | $k=4, l=1, m=1$ | $k=4, l=0, m=0$ |
| $k=4, l=1, m=0$ | $k=5, l=2, m=0$ | $k=6, l=3, m=1$ | $k=6, l=2, m=1$ |

Fig. 6: The probability density function (PDF) $|\psi_{klm}(r,\theta,\varphi)|^2$ possible locations of the *c*-nucleus at $\varphi = 0$ and different values of the quantum numbers *k*, *l* and *m*. The lighter the spot, the more likely a *c*-nucleus will appear in this area. Calculations were performed using Expression (80) [12] and presented on the web page:
https://upload.wikimedia.org/wikipedia/commons/b/b3/2D_Spherical_Harmonic_Orbitals.png

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Figure 6 shows that each set of three quantum numbers k, l, and m corresponds to a unique spatial configuration of the average state of chaotic wandering (trembling) of the c-nucleus (i.e., the PDF of the place of appearance of the c-nucleus inside the biological cell).

As is known, there is also a fourth spin quantum number s [5,6,7], which in the case under consideration, seemingly, is associated with one of the two possible directions of rotation of the cytoplasm inside the biological cell. However, this process is not covered in this article.

To experimentally fix one of the spatial configurations shown in Figure 6, it is necessary:

- to ensure the absence of a tangible influence of external and internal force factors on the biological cell for the entire period of observation of the cell nucleus.

- make a video recording of the chaotic behavior of the nucleus for a long period of time;

- take into account that the cell as a whole can participate in complex Brownian and/or thermal motion; these movements must be eliminated physically or excluded by software;

- take into account that the cell nucleus can change its shape, and its internal content (karyoplasm, chromatin etc.) can change over time; this leads to blurring of the boundaries of the spatial configuration of the averaged state of trembling of the given organelle. Therefore, it is necessary to monitor not the behavior of the entire cell nucleus, but the chaotic movement of only its center of mass, which in this article is conditionally called the c-nucleus. In other words, it is needful to programmatically identify the center of mass of the cell nucleus (i.e., the c-nucleus) and monitor only it's motion.

- digitized, software-cleaned and mathematically processed video recording of the chaotic behavior of the c-nucleus (i.e., the center of mass of the BC) need to reproduce at high speed, with the display of this highly accelerated process on the computer monitor. The speed of reproduction of the motion of the c-nucleus should be so fast that this point is "smeared" over the entire observation area.

- if all the above actions can be performed with a sufficiently high resolution of the video equipment, as cleanly as possible and with the exclusion of various interfering factors, then in accordance with the hypothesis set out in this article, the configuration of dark and light spots should be revealed on the monitor screen (similar to one of the spot configurations shown in Figure 7). In

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this case, a dark spot on the monitor screen should mean that the c-nucleus appeared in this place more often than in the place where the light spot was formed.

It is possible that the configuration of these dark-light spots will to correspond to one of the eigenwave functions $\psi_{klm}(r,\theta,\varphi)$ (more precisely, PDF $|\psi_{klm}(r,\theta,\varphi)|^2$) of the isotropic three-dimensional quantum harmonic oscillator (see light-dark spots shown in Figure 6).

Fig. 7: Examples of possible configurations of dark-light spots that can be revealed as a result of averaging the chaotic movement (tremor) of the c-nucleus inside a biological cell. These spot configurations can correspond to eigenwave functions $\psi_{klm}(r,\theta,\varphi)$ (80) with different sets of three quantum numbers k, l, and m

Using sound vibrations with a resonant frequency (i.e., with a frequency close to the natural frequency of vibrations of the considered isotropic three-dimensional quantum harmonic oscillator) to influence the cell nucleus, thereby changing the average state of the chaotic wandering of its center of mass (i.e. c-nucleus). After that, all the above steps should be repeated to identify a different configuration of dark-light spots, corresponding to a more excited state of the c-nucleus.

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It is possible that these oscillations must be excited simultaneously from two opposite ends of each of the three mutually perpendicular directions. This will make it possible to exclude the possibility of translational displacement of the c-nucleus due to unilateral action.

If the fundamentals of the quantum physics of the organelles of a biological cell, described in this article, turn out to be correct, then the quantum transition of the c-nucleus from one averaged state to its other state (i.e., an abrupt change in the configuration of dark-light spots on the monitor screen) should occur at transfer to this c-nucleus of additional portion of the total mechanical energiality

$$\Delta\varepsilon_n = \varepsilon_{nk} - \varepsilon_{nk+j}, \tag{85}$$

where ε_{nk} is the total mechanical energiality of the c-nucleus in the state k;

ε_{nk+j} is the total mechanical energiality of the c-nucleus in the state $k + j$ (here $j = 1,2,3, ...$).

In this respect, quantum biophysics ($\sim 10^{-3}$cm) should not differ in any way from the quantum physics of elementary particles ($\sim 10^{-13}$cm). The difference lies only in the scales of the processes under consideration, which differ from each other by about 10 orders of magnitude. Meanwhile, there is no doubt in the modern scientific community that quantum mechanics is applicable to describe processes on intermediate scales, i.e. at the molecular level ($\sim 10^{-8}$cm) [13,14,15]. For example, quantum-mechanical methods describe oscillations of the atomic lattice (phonons), molecular vibrations, etc.

8 Features of the transfer of the c-nucleus into an excited state

As it was said in the previous paragraph, in order for the c-nucleus to pass from one stable state to another, it is necessary to exert a force on it that gives it an additional total mechanical energeticity $\Delta\varepsilon_n$ (85). However, this effect should not change the state of chaotic movement of the entire biological cell as a whole.

Everything that has been written above regarding the chaotic behavior of the cell nucleus also applies to the biological cell itself (separated from the external environment by the cell membrane). A cell can also be represented as a material point and called it the BC-core. This BC-core also continuously wanders (trembles) chaotically in the vicinity of some conditional cent (see Figure 8).

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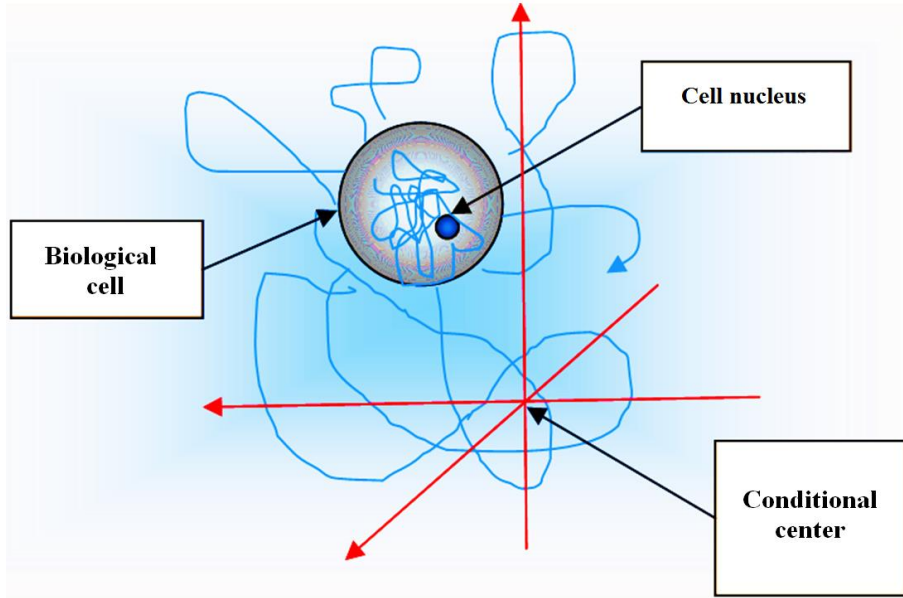
Fig. 8: Chaotically wandering center of mass of a biological cell (i.e., BC-nucleus), inside which the center of mass of its nucleus (i.e., the *c*-nucleus) wanders chaotically

Therefore, the averaged behavior of the BC-core can be described in the same way by a discrete set of solutions of the generalized Schrödinger equation of the form (27), but in this case, instead of the scale parameter (23), we substitute into Equation (27) the scale parameter

$$\eta_c = \frac{2\sigma_{cr}^2}{\tau_{cr}}, \qquad (86)$$

where

$$\sigma_{cr} = \frac{1}{3}\sqrt{\sigma_{cx}^2 + \sigma_{cy}^2 + \sigma_{cz}^2} \qquad (87)$$

is the standard deviation of a chaotically wandering BC-core (i.e., the center of mass of the entire biological cell) from the conditional center of location of this biological cell (see Figure 8);

$$\tau_{cr} = \frac{1}{3}\left(\tau_{cx} + \tau_{cy} + \tau_{cz}\right) \tag{88}$$

is the averaged interval of autocorrelation of a stationary random process, in which the chaotically wandering center of mass of a biological cell is continuously involved (see Figure 8).

Let's suppose that the averaged characteristics of a given stationary random process are of the order of

$$\sigma_c \approx 2{,}3 \times 10^{-5}\,\text{m} \quad \text{and} \quad \tau_c \approx 4 \times 10^{-2}\,\text{s.} \tag{89}$$

As in the case of the k-core, the natural frequency of oscillations of such a quantum harmonic oscillator is approximately equal to

$$f_{0c} \approx \sqrt{\frac{3}{2}}\,\frac{1}{2\pi\tau_{nc}} \approx 4{,}8\,\text{Hz.} \tag{90}$$

This also means that the BC-core can be effectively affected by sound harmonic vibrations of the liquid medium surrounding the biological cell with a wavelength approximately equal to

$$\lambda_{vc} = \frac{v_v}{f_{0c}} \approx \frac{1500}{4{,}8} \approx 312{,}5\,\text{m.} \tag{91}$$

When comparing the obtained estimates of the resonance frequencies (46) and (90), as well as the wavelengths of the disturbing oscillations (47) and (91), we find the following. To change the averaged state of only the c-nucleus, while leaving the BC-core in the same state, it is recommended to excite sound vibrations in the surrounding aqueous medium in a narrow frequency range $\Delta f_{rn} \sim 10 - 15$ Hz with a carrier wavelength of the order of $\lambda_{vn} \sim 23.4$ m.

These a priori characteristics of the exciting effect on the nucleus (or on any other organelle) of BC can be refined as a result of experiments.

9 Results

This article hypothesizes that during the interphase (i.e. when a living biological cell remains in an unchanged, stable state), some particle-like cell organelles, although they move along complex (chaotic) trajectories, but their complete mechanical energy and the average motion configuration remains unchanged. In this case, the discrete set of possible values of the total mechanical ener-

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giality (TME) of the organelle ε_{nk} (in particular, the cell nucleus) and the corresponding averaged states $|\psi_{nk}|^2$, corresponds to the solutions of the generalized Schrödinger equation (27).

The transition from one averaged state of the organelle $|\psi_{nk}|^2$ to its other averaged state $|\psi_{nk+j}|^2$ should occur when a quantum (i.e., portion) is transferred to this organelle by the TME $\Delta\varepsilon_n = \varepsilon_{nk} - \varepsilon_{nk+j}$. This TME quantum can be transmitted to the organelle by using of wave (in particular, sound) disturbances of the surrounding liquid medium with a resonant frequency f_{rn} approximately equal to the natural vibration frequency of this organelle ($f_{rn} \approx f_{0n}$). In order to excite only the required organelle (in particular, the cell nucleus), it is necessary that the wave (sound) disturbance be narrowly directed and with a small frequency range. For example, to excite the cell nucleus (i.e., to transfer it to another average state), a priori estimates of the resonant disturbance frequency $f_{rn} \sim 64$ Hz and the range of disturbing frequencies $\Delta f_{rn} \sim 10 - 15$ Hz.

After the resonant frequency f_{rn} and the range of disturbing frequencies Δf_{rn} are refined as a result of the experimental verification of the effectiveness of their effect on the cell nucleus, sound radiation with these a posteriori characteristics can be directed to the whole organism or to one organ, which can lead to additional collective quantum effects.

When the organelle returns from the excited state $|\psi_{nk+j}|^2$ to the state with a smaller TME $|\psi_{nk}|^2$, it must emit a wave disturbance to the surrounding liquid medium with an energy of the order $\Delta\varepsilon_n \approx |\varepsilon_{nk+j} - \varepsilon_{nk}|$. In other words, this article suggests that quantum biophysics is in many ways similar to quantum subatomic, atomic, and molecular physics.

10 Conclusions

Artificial translation of the organelle (in particular, the cell nucleus) into an excited state can be of practical importance. For example, it is possible that the genetic material (DNA and/or RNA) of viruses will find it more difficult to penetrate into the cell nucleus through its pores if it is in one of the excited states (see Figure 7). Therefore, it is possible that the method of sound or other mechanical action on the cell nucleus and/or other organelles will be an effective way to fight viral infection, including COVID-19.

The second no less important aspect touched upon in this article is the further substantiation and confirmation of the "statistical interpretation of quantum mechanics", the foundations of which were set forth in the author's articles [2,3,20], and is as follows:

1] if any particle (regardless of its scale, be it: an electron in a hydrogen atom, a nucleus of a biological cell, a yolk in an egg, a fly in a glass jar, the tip of a tree branch, an embryo in the womb, a nucleus in the interior of a star or planet, and etc.) constantly randomly wanders (trembles) in the vicinity of the conditional center, so that its total mechanical energy (more precisely, the energiality) remains unchanged, then the averaged behavior of the center of mass of such a particle is described by the generalized Schrödinger equation (27) with a scale parameter of the form (28);

2] in order to detect the averaged state of a wandering particle, it is necessary to record its chaotic behavior for a long period of time, and then reproduce this record at high speed. In this case, not the moving center of mass of such a particle will be visible on the monitor screen, but an area of blurred dark-light spots corresponding to the probability density function of finding a particle in different parts of this area.

This method of detecting the averaged configuration of a particular discrete state of a wandering particle corresponds to long-term data collection and statistical processing of experimental observations; therefore, this approach is called "statistical interpretation of quantum mechanics".

It should be noted that the name "statistical" interpretation of quantum mechanics was proposed by Academician of the Russian Academy of Natural Sciences G.I. Shipov.

This approach to the interpretation of quantum phenomena is devoid of many of the shortcomings of Copenhagen, Many Worlds, Quantum Bayesianism and many other interpretations of quantum mechanics.

At the same time, it is no less important to state that quantum effects are inherent not only in the microworld, but also in the macroworld; only to obtain the averaged characteristics of the chaotic behavior of macroscopic objects, much more observation time is required.

If the hypothesis stated in this article about the subordination of the chaotically wandering of the cell nucleus to the laws of quantum physics is confirmed experimentally, then this will be a significant contribution to the approval of a new "statistical interpretation of quantum mechanics."

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11 Acknowledgements

12 Abbreviations

BC is biological cell

PDF is probability density function

TME is total mechanical energiality;

13 Competing Interests

The author states that there are no competing interests.

14 Consent to publication

There is permission from the Moscow Aviation Institute for publication.

15 Ethics approval and consent to participate

Not applicable.

16 Funding

17 Data Availability

Data confirming the results of this study can be obtained from the author of this article upon request at: alsignat@yandex.ru and at http://metraphysics.ru/.

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