# COHERENT VIBRATION INTERACTION AMONG CELLS IN BIOLOGICAL SYSTEMS

Coherent electric vibrations are excited in biological systems through metabolic energy supply. The process of coherent vibrating states formation is similar to that of Einstein condensation of a Bose gas /1,2/. It follows from the theory in /1/ and /2/ that the mode with the lowest frequency is very strongly excited and that the vibrating energy concentrated in this mode is predominating if the energy supply is large enough. Coherent vibration interaction among large systems (cells) results in the change of the frequency or even may result in the change of the energy distribution in the vibrating modes. The free energy of the interacting systems is, therefore, changed. The free energy change determines the energy of interaction. The interaction forces among cells depend on the energy of coherent vibrations /2-4/. In this short paper the numerical values of the interaction energy are computed to assess the role and importance of the assumed interaction forces for the behaviour of cells in biological systems.

We adopt a model of two identical cells (Fig.1) the membranes of which are sources of coherent dipole oscillations with frequency $\frac{\omega}{2\pi}$ (the frequency of a very strongly excited mode). The adjacent parts of both cells are substituted by two parallel circular dipole layers $S_1$ and $S_2$. We assume that the circular layers $S_1$ and $S_2$ are composed of elementary oscillating electric dipoles the axes of which are perpendicular to the circular surfaces of $S_1$ and $S_2$ and that the elementary dipoles have the same properties. We compute the interaction energy of the circular dipole layers along the x axis. Using normal

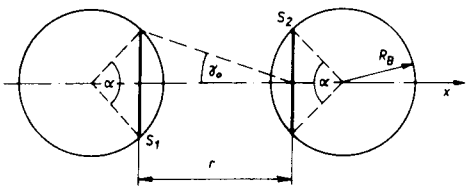



Fig.1. Model of two interacting cells ($R_B$ - the radius of the spherical cell; $S_1$, $S_2$ - the circular effective interaction layers; r - the distance between $S_1$ and $S_2$).

co-ordinates the normal modes of the vibrational Hamiltonian are found. The frequencies of the normal modes of two interacting circular layers are given by

$$\omega_{\pm}^2 = \omega^2 \pm \frac{q^2}{S_e M} \frac{\cos\gamma_0 - \cos^3\gamma_0}{2\varepsilon r} , \tag{1}$$

where $S_e$ and $q$ are the cross-section and the charge of the elementary dipoles, respectively, $M$ is the mass of the oscillating charge and $\varepsilon = \varepsilon'\varepsilon_0$ is permittivity. The meaning of $\gamma_0$, $r$ in Eq.(1) follows from Fig.1.

If the vibrating energy in the lowest frequency mode is predominating, it holds for the interaction energy of an elementary dipole

$$I_F = \hbar(N_- \omega_- - N\omega) , \tag{2}$$

where $N_-$, $N$ are the numbers of quanta. It follows from (2) that if $N_- \approx N$, then $I_F < 0$ and the forces of the Fröhlich interaction are attractive.

If the energy of the mode with frequency $\omega_+$ cannot be neglected, it holds

$$I_W = \hbar(N_+ \omega_+ + N_- \omega_- - N\omega) . \tag{3}$$

Eq.(3) coincides with the expression for the Van der Waals interaction energy if $N_+ = N_- = \frac{1}{2} N$. If the coherent vibrating excitation allowed under some circumstances reaching $N_+ = N_- = N$, then according to (3) the interaction energy would satisfy the condition $I_W > 0$ and the forces of interaction would be repulsive. This condition, however, has not theoretical justification. Both repulsive and attractive interaction forces may exist as a consequence of the permittivity dispersion in the relevant frequency region /3/.

The Fröhlich and Van der Waals interaction energy curves are computed from (2) and (3) using (1) for the relative permittivity in the range $5 \leq \varepsilon' \leq 50$. The interaction energy as a function of the distance $r$ is plotted for $q = 0.1\,e$ in Fig.2a and for $q = 0.5\,e$ in Fig.2b ($e$ is the elementary charge). The interaction energy is negative. The full line curves show the Fröhlich interaction energy ($N_- = N = 1$). The dashed line curves show the Van der Waals interaction energy ($2N_+ = 2N_- = N = 1$).

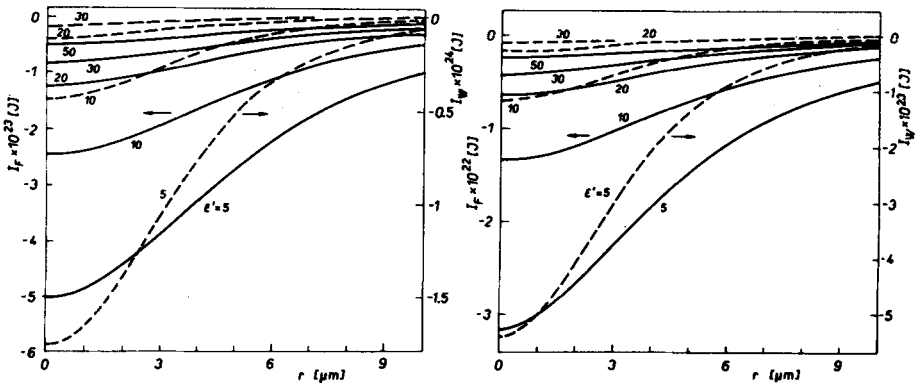



Fig.2. Fröhlich and Van der Waals interaction energy curves for q = 0.1 e (a) and q = 0.5 e (b). The curves are computed for $\nu = \frac{\omega}{2\pi} = 10^{12}$ Hz, $M = q\frac{m}{e}$, where m is the electron mass, $\alpha = \frac{\pi}{2}$, the diameter of the elementary dipole cross-section 1 nm and the membrane thickness (the thickness of $S_1$ and $S_2$) 10 nm.

The interaction forces among cells in biological systems are important if $|I_F| \geq kT$. The value of kT for $T \approx 310$ K is about $5\times10^{-21}$ J. The numbers of quanta $N_-$ and N must achieve at least values of the order $10^1$ for q = 0.5 e and $10^2$ for q = 0.1 e, which coincides with the condition of coherent states far from thermal-equilibrium.

It follows from the above that the coherent vibration interaction forces among cells may have an important and decisive effect on cells behaviour within the distance of about 10 μm from the outer surface of the membrane. This conclusion is supported by the observation of the blood cells behaviour in the time course of the LAI tests and control tests based on a nonspecific adherence of cells to the surfaces of various materials /5/. The blood cells are placed in liquid PBS and the time course of their behaviour and motion is recorded on a film. Their mutual distance being from about 5 to 15 μm the cells change their motion as if the interaction forces started to operate. In some cases the resulting effect is attraction and in other cases repulsion of cells. This observation suggests a possible way of the experimental proof of the coherent vibration interaction forces.

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## References

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