

HYDRATION OF STRUCTURAL PROTEINS AND MODEL OF CELLULAR PULSATIONS

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Abstract

The turn-to-turn hydration of protein molecules of cytoskeleton, which depends on the temperature, and the concentration of water molecules in a cell is of great importance. The application of hydration increases the volume of a cell. The pressure difference assists in the arrival of sodium ions together with water molecules, oxygen, and nutrients into the cell. However, these substances disturb the homeostasis of the cell. ATP hydrolysis brings about weaker hydration and returns the cell to a point of departure. Therefore, the changes of turn-to-turn hydration are the basis for cell pulsations and other important cell processes. At the same time, the changes of turn-to-turn hydration explain the conversion of heat energy into work.

Keywords: Protein molecules, hydration, hydrolysis, heat, work, pulsation, cytoskeleton

Introduction

The hydrated protein as a whole, consists of parts of protein molecule and water molecules. The whole [as F. Capra considers (Capra, 2003)] possess properties which its components do not possess. However, an important property of the hydrated protein molecule as a whole will be the ability to change the length of the degree of hydration. We will understand the turn-to-turn hydration where the degree is defined by a fraction of protein flights linked with water molecules as protein hydration. The more this fraction is, the longer the protein molecule. It belongs to globular proteins of a cytoskeleton, such as G-actin because a globule also represents the coiled helix. The known high reactivity of water molecules is important for turn-to-turn hydration of proteins. The turn-to-turn hydration moves with the release of heat (enthalpy change $\Delta H < 0$) and a decrease in entropy, $\Delta S < 0$.

$$\Delta G = \Delta H - T \cdot \Delta S \quad (1)$$

The process goes spontaneously at a negative value of the Gibbs potential shift of $\Delta G < 0$. From (1), it seems that at a well-defined temperature (T_k), the Gibbs potential shift goes to zero. Thus, this signifies the

equilibrium processes of hydration and dehydration for this protein molecule. At temperature below T_k , there is a spontaneous hydration, and at temperatures over T_k , there is spontaneous dehydration. It is approximately possible to decide the value of T_k by the results of A.A. Ukhtomsky experiences (Ukhtomsky, 1952). He placed myofibrils into heated water and myofibrils were reduced at a temperature of 44° C. Thus, it is possible to consider that the value of T_k is in the interval of $42-43^{\circ}$ C.

Taking into account changes in the turn-to-turn hydration, it is possible to suggest the model of the mechanism of cellular pulsations. We will consider cellular pulsations as a combination of two cycles: thermal cycle and pressure cycle. Both cycles are based on the equilibrating feedback coupling principle. The hydration raises temperature, increases the cell volume, reduces the number of particles in it, and decompresses a cell. According to the Le Chatelier principle, the process begins in a cell reducing impact of hydration. However, this process is known as dehydration. The dehydration goes with heat absorption. It lowers the temperature, shortens protein molecules of a cytoskeleton – reducing a cell volume, and increases the number of particles in it. The pressure is raised in a cell. All this creates conditions for the transition from dehydration to hydration. The interchange of hydration and dehydration would have to lead to long auto oscillation – to cellular pulsations. However, the part of hydration heat diffuses. Therefore, the cell has to have an independent heat source. This source, as a rule, is ATP hydrolysis. However, the addition of an independent heat source (ATP hydrolysis) provides a cellular pulsation – this infinite auto oscillation.

Further, we will emphasize that the use of exothermic reactions heat in cell becomes possible as a result of unique water property – its abnormal high thermal capacity. However, to explain water thermal capacity is a very interesting and ambitious problem. The thermal capacity at the constant volume (C_v) is equal to the derivative of the potential energy of water molecules (U) at temperature, T .

$$C_v = dU/dT \quad (2)$$

For ice, the potential energy U is equal to 2ε ; where ε is the binding energy between molecules, and the coefficient (2) considers that 2 bindings fall at one molecule. In water, 2 bindings fall at one molecule too, but we considered that each binding exists in water for a time; and for a time, it is broken. Therefore, the potential energy for water should be written down as:

$$U=2P\varepsilon, \quad (3)$$

Where P – probability to find existing binding. Both values depend on temperature, and for the thermal capacity after differentiation, we will receive:

$$C_v = 2[\varepsilon \cdot (dP/dT) + P \cdot (d\varepsilon/dT)] \quad (4)$$

In the received equation, the thermal capacity depends not only on $d\varepsilon/dT$, but also on the energy of hydrogen bond ε , on its probability P , and also on its derivative at temperature. By the equation, the values of a thermal capacity were calculated, already acceptable being in line with the values received experimentally (Yashkichev, Shilin, 2014)).

After that important digression, we will return to the turn-to-turn hydration and cellular pulsations. We will give some experiences confirming the mechanism of pulsations, and the cases of pulsations occurring in nature. Pulsations are shown both in plant and animal cells. For instance, it was shown by the V.N. Zholkevich experiment with “aerial roots”. The separated dried roots were placed into hermetic empty test tubes. At the same time of water evaporation from the root (inside bottom of a test tube “wept”), they were exudation of droplets on the root section: evaporation reduced the concentration of water in root cells, and decreased the turn-to-turn hydration. As a result, cells on a section were contractive and striped due to exudation (Zholkevich, 2001). The important fact is that the self-oscillatory water which moves in plants is experimentally established. In addition, experiment showed that both rhythmical change of cell volumes and the water movement (more usually aqueous solutions) in living cells of a plant consists of two series phases. The first phase is the water entrance into a cell (relaxation phase), while the second phase is water pushing out in the direction of xylem vessels (contraction phase) (Zholkevich, 2001).

Therefore, not only plant cells carries the property to pulse, but self-oscillatory processes are described as well for animal cells. It is revealed, for example, that work of asynchronous muscles of insects belongs to self-oscillatory processes. Self-oscillations of asynchronous muscles can be caused, regulating the load on muscles or stimulating them with electric current. The ability of these muscles to work self-paced in lack of nervous impulses is confirmed in experiences with model muscular fibers. In solutions with ATP and ions of Ca^{2+} , such myofibrils passes to rhythmic variations which can run on for hours (Tyshchenko, 1977). It is well-known that fetal heart pulses when its conduction system is not built yet.

The direct experiment indicating the turn-to-turn hydration is described in the study of rhodopsin protein. The method using X-rays was applied. The X-ray radiation forms water molecules hydroxyl radicals, which then chemically modify the amino acids, which are the components of protein. Mass spectrometry and the molecular maps shows where there is water molecules inside rhodopsin. However, the position of water molecules in the rhodopsin when it was activated by light and when it was not activated by light defined chemical modifications. The maps showed that in response to activation, the water molecules change the position in protein, and protein changes the form (Angel, Gupta et al., 2009). Thus, we will note that only

those water molecules could stay close by the amino acids composing protein, which take part in turn-to-turn hydration. At the same time, only the change of the turn-to-turn hydration could change the position of water molecules in protein, and however changes the protein form.

Homeostasis is a condition of the dynamic balance of natural system in particular cells. A cell is vitally important for preserving homeostasis. In this study, we will consider an important component of homeostasis – a balance between the content of sodium ions and potassium ions. At the same time, it will be an illustration of a model of the mechanism of cellular pulsation. The cell contains potassium ions and sodium ions which are outside. At the first phase by increasing the cell volume, the pressure drops in a cell. The arisen pressure gradient directs to a cell of water molecules, nutrients and oxygen. Sodium ions except for a pressure gradient are affected by a negative charge in a cell and concentration gradient. However, sodium ions are directed into a cell together with water molecules, oxygen, and nutrients. The cell will take up oxygen and nutrients, and the sodium ions which have come to the cell, and the accumulated metabolic products will disrupt homeostasis. It is necessary to take the second phase of a pulsation – cell shrinkage. The hydration heat is not enough. ATP hydrolysis helps in places where the inclusion of sodium ions is necessary. While achieving a certain concentration of sodium ions, an enzyme of sodium adenosine triphosphatase is activated, as ATP hydrolysis starts. Dehydration squeezes the cell, and sodium ions together with surplus of water molecules and metabolic products are put out of the cell. Thus, removing sodium ions from a cell stops ATP hydrolysis. The homeostasis is restored, and cell begins the first phase of the following pulsation. Rhythmical heat release and absorption in a nerve are established experimentally, and the quantity of waste heat is by 20% which is then absorbed (Leonteva, 1972). Hence, it will be coordinated by a suggested model of pulsations.

Therefore, we pay attention that within the put-forward model, the issue of conversation of heat to mechanical energy in a cell is simply resolved. The heat of hydration and the heat of ATP hydrolysis together conduct the dehydration of molecules of cytoskeleton. Molecules of cytoskeleton are shortened, and as such, the cell contracts. Spontaneous cell contraction is a demonstration of mechanical forces (Yashkichev, 2012).

Conclusion

Cell processes with the participation of water molecules are not studied sufficiently. A managed hydration of proteins is a clue for understanding cell pulsation including nervous cells, and the transition of heat energy into work. Thus, it is possible to understand the mechanism of

motion F-actin in Huxley theory (Huxley, 1957). In our next article, we will provide further information on this study.

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