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The Electric Potential of the Tissue Fluids of Living Organisms as a Possible Epigenetic Factor

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Abstract: It is shown that the state and properties of aqueous DNA depend on the electric potential of the surrounding water. It is particularly shown that water with a positive potential much more actively hydrates DNA than water with negative potential. Since the electric potential of tissue fluids determines the degree of hydration of DNA, i.e. its state, it can be considered as an epigenetic factor.

Keywords: DNA, UV Spectra, UV Absorbance, Epigenetic

1. Introduction

Molecules of DNA have hydration shells both *in vivo* and *in vitro*. However, images of DNA traditionally been deprived of this component. This tradition creates misconceptions about the structure of DNA, and the effect of hydration shells on its structure and functional state. So, as is known, A↔B-DNA conformational transitions cause a change in relative humidity of its fibers from 75 to 92 % or vice versa [1]. But images such DNA crossings do not reflect the effect of humidity, because does not show the linked water DNA-transitions (Figure 1). Moreover, based on these figures, we can conclude that A↔B-conformational transitions of DNA occur spontaneous, without causes.

This tradition has formed a certain style of thinking, which ignores the existence of DNA hydration shells. Moreover, this tradition had formed a representation that the DNA exist and interact in a high vacuum. It is through such representations was possible the appearance of the model of intercalation [1, 2].

As is accepted [1], DNA molecules have two hydration shells, internal and external. Also it is considered that the spaces between the bases of DNA are filled with water molecules that are part of the inner hydration shell of DNA. Thus, the spaces between any two adjacent DNA bases are not empty. For this reason, such spaces cannot be occupied "intercalators" as trying to convince us some authors [1-3]; the proposed intercalation is possible only if you use pictures of dehydrated DNA (Figure 2).

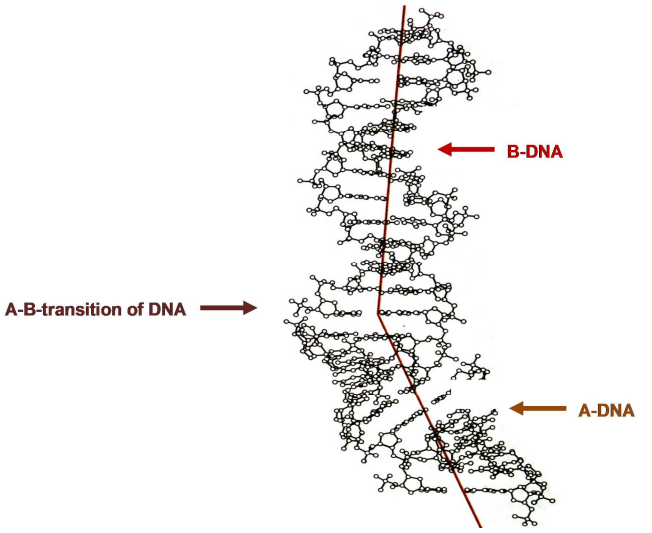

Figure 1. *This is the demonstration of A↔B-conformational transition of DNA [1].*

Furthermore, such intercalation is impossible because the inner hydrate shell of DNA is impermeable to cations, which are typical "intercalators" (proflavine, acridine orange, ethidium bromide) [1-3].

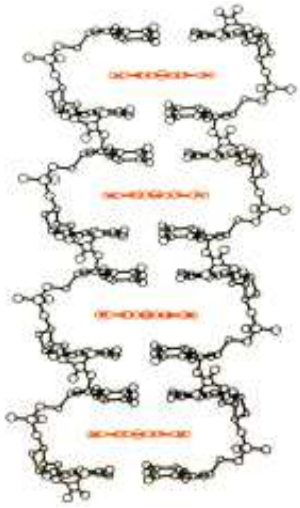

Figure 2. *This is a typical scheme used to demonstrate the intercalation of aromatic dyes in DNA [1].*

In fact, this intercalation is not possible because the spaces between the bases of DNA are occupied by ordered structures formed by water molecules [1].

Thus, it should be recognized that the model of intercalation is a product of the imagination Lerman, who used images of dehydrated DNA, made in accordance with the existing graphic tradition. This is discouraging, since the model of intercalation still used to explain the mechanism of action of several antibiotics. Taking this into account, it should be recognized that hydration of DNA is not only of theoretical but also of practical importance. I personally came to this conclusion when studying the interactions between DNA and cationic phenazine [4]. Moreover, in the process of studying such interactions, I have come to the conclusion that the ability of water to hydrate the DNA depends on its electric potential. Here I offer to your attention the results of my experiments that demonstrate how electric potential of the water determines its ability to hydrate the DNA.

2. Material and Methods

It is known that the interaction between phenazines and substances of biological origin depends on the electrical potential of the environment: an environment with a negative electrical potential contributes to the occurrence of these interactions, and the environment with a positive electric potential to prevent their occurrence [5, 6]. It is clear that in the process of research interaction involving phenazines, I had to use water with a different electric potential.

First, it is necessary to define the terminology used in this article. The term "uncharged water" used to refer to water that was used to control: it was assumed that the electric potential of this water is 0 mV. Uncharged water was obtained during storage of distilled water in a closed aluminum containers: It is considered that in such circumstances, the electric charges of water are concentrated on the outer surface of the container [7].

Water with a positive electric potential was obtained in two ways:

(a) By passing through uncharged water of gaseous oxygen.

(b) By filtration of uncharged water through the silica gel.

It is known that when in contact with water, oxygen gas exhibits the properties of a sorbent of aqueous electrons, and the silica gel exhibits the properties of a sorbent of aqueous hydroxyl ions [8].

Water with a negative electric potential was also obtained in two ways:

(a) By passing through uncharged water of gaseous hydrogen.

(b) By filtration of uncharged water through the activated carbon.

It is known that when in contact with water, hydrogen gas is the electron donor, and activated carbon exhibits the properties of a sorbent of aqueous hydrogen ions [8].

Water with the desired value of the electric potential was obtained in two ways:

(a) By varying the depth of the layer of sorbent through which filtered water is discharged.

(b) Varying the time during which the gas passed through the uncharged water.

The electric potential of the electrically charged water, we measured relative to the uncharged water, the potential of which we have conventionally taken to be 0 mV. In fact, the electric potential of a charged water was measured as a potential of flow or as a potential of filter [9].

3. Results and Discussion

3.1. Potential Dependent Hydration of DNA

In the study of the potential-sensitive interactions between DNA and phenazines, unwittingly had to explore the properties of water with a different electric potential. So, it was found that the surface tension of water clearly depends on its electrical potential. This dependence can be formulated in the following way: the surface tension of water having a positive electrical potential is always greater than the surface tension of water having a negative electrical potential. The existence of such dependence can be demonstrated with simple but illustrative experiments.

So, if you pour 5 ml of water (exactly!) with a negative potential in a standard Petri dish (with a diameter of ~10 cm) and mix, you can see that a thin layer of water covers the bottom of a Petri dish (Figure 3, left). On the other hand, if you pour 5 ml of water (exactly!) with a positive potential in a standard Petri dish and mix, you can see that such water will not cover all the bottom of a Petri dish (Figure 3, right); in this case, the layer of water looks noticeably thicker [10].

This clear difference evidently shows that water with a positive potential has a considerably greater surface tension than water with negative potential. It can be argued that the force field that exists on the surface of positively charged water contributes to its structuring.

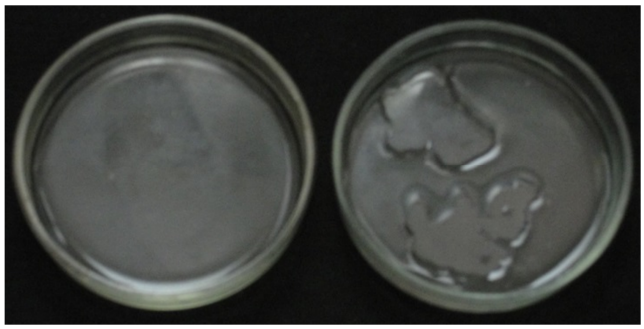

Figure 3. *Left: 5 ml of water with an electric potential of –200 mV cover all the bottom of a Petri dish. Right: 5 ml of water with an electric potential of +200 mV do not cover the bottom of a Petri dish; the surface of such water decreases rapidly after mixing [10].*

These potential-dependent differences in surface tension can be simply demonstrated by powder starch deposited on the surface of charged water. You can see that the forces acting on the surface of positively charged water quickly (for 1 – 2 seconds) distribute the starch on the surface of water (Figure 4, left). You can also see that the surface forces of the negatively charged water do not distribute the starch on the water surface (Figure 4, right). Moreover it can be observed that the starch powder sinks into negatively charged water [10].

In our opinion, the results of the last experiment, demonstrate how the surface tension of water with a positive potential greater than the surface tension of water with negative potential.

In the previous experiment, the powder of starch was used because of the potential clearly, but inexpensive to demonstrate the discussed dependence. In experiments with DNA this is not possible. Particularly impressive is the transformation of the fibres of the sodium salt of DNA deposited on the surface of the positively charged water. It is easy to see how such fibers are initially fast (1 to 2 seconds after application) form a transparent film, which soon dissolves. In my opinion, such transformations clearly indicate that water with a positive potential intensively hydrates DNA. It is clear that the pictures of such a film are difficult to obtain; anyway, I failed it.

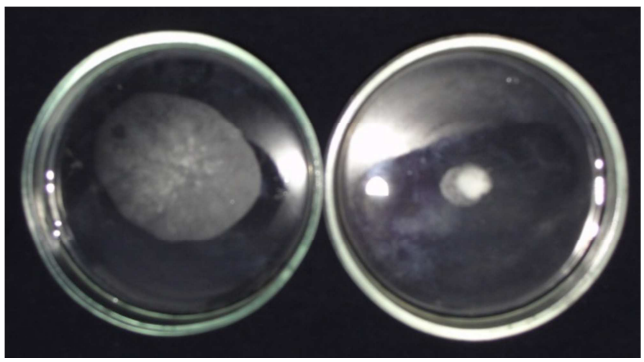

Figure 4. *Left: the starch powder covers the surface of the water with potential +250 mV practically wholly Right: powder starch remains in the same place where it was put in water potential –200 mV [10].*

At the same time, it's easy to visualize DNA precipitation of salts formed in the water with negative potential. It is easy to verify that such water does not dissolve salt DNA, i.e. not hydrating them (Figure 5).

Figure 5. *This precipitation of sodium (left) and potassium (right) salts of DNA, which is formed in solutions prepared with water with the potential of -300 MV. Solutions contain phenazinium dye, which is added for contrast. [4].*

To experimentally observe the dependence of the hydrating ability of water from its electrical potential can also use starch. For this experiment required two transparent vessels. The first vessel to fill with water with a potential of +500 mV (~ 20°C) and the second vessel to fill with water with a potential of –500 mV (~ 20°C). After that, you must stir both vessels 100 mg starch powder. After 30 min. it was seen that the starch did not swell in a bottle containing water with negative potential (Figure 6, left), but swelled in a bottle filled with water with a positive potential (Figure 6, right) [10].

In my opinion, this result gives a clear idea of what the hydrating ability of water with positive and negative potentials are very different. The result of the last experiment, I also explained that the surface tension of water with a positive potential is much greater than the surface tension of water with negative potential.

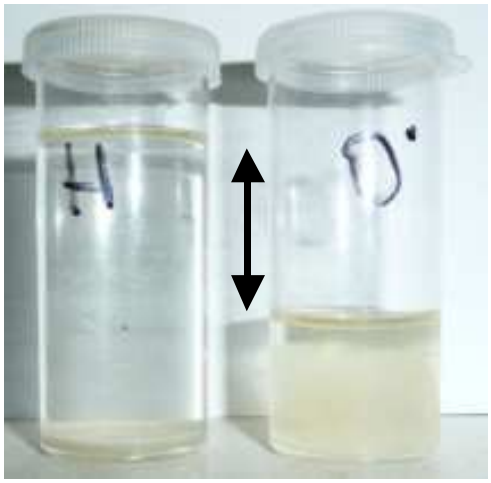

Figure 6. *There is a swelling of starch in water with a different electric potential. Starch does not swell in water with the potential of –500 (left) and swells in water with a potential of +500 mV (right) [10].*

Water with negative potential was obtained by bubbling

hydrogen (left); water with a positive potential was obtained by bubbling oxygen (right).

Water with a positive potential can evaporate even from a closed plastic dishes: the arrow shows how during the day decreased the water level to the positive potential.

Obviously, this experiment also demonstrated that the positive potential of water contribute to its structuring. It should be noted that this tendency of the water with a positive electric potential to the structure is probably general in nature. In any case, it was shown that ice (a variety of structured water) always has a positive potential relative to water, on the surface of which it is formed; the magnitude of this potential is +5 – +10 V [11].

The ability of the water with a positive potential to form hydration shells allowed us earlier to explain why the DNA does not interact with cationic phenazines in the water: such interactions do not occur due to the large hydrate shell of DNA, which eliminates contacts between DNA and phenazines. However, the interaction between DNA and cationic phenazines in water with negative potential is explained by dehydration of DNA, which allows phenazines to contact with DNA [4]. It is natural to expect that the same approach will hold true in interactions between DNA and other substances, such as enzymes. Also, this approach can be applied to explain the physical reasons of A↔B-conformational transitions of DNA (Figure 1). In other words, the electric potential of the medium can be considered as a factor determining the state of hydration shells of DNA, its conformation, and availability for interactions. For this reason, the electric potential of the internal environment of a living organism can be considered as an additional epigenetic factor [12]. In favor of this assumption is evidenced by different values of the electric potential of biological fluids of the female body during the menstrual cycle, in particular the negative potential of such liquids at the stage of ovulation [13].

The last experiment allowed us to observe another amazing property of water with positive potential. As you can see (Figure 6, right), this water is able to penetrate through the plastic and evaporate from a closed polyethylene bottle. This increase in the permeability of polyethylene to water vapor described previously: this phenomenon was observed earlier in the oxidation of polyethylene ROS induced by ionizing radiation [14]. (Recently, I offered a detailed analysis of the physical force which causes this phenomenon [15].)

It is hoped that the obtained results convincingly showed that the properties of the water depend on its electrical potential. This dependence is so obvious, that allows considering water with positive and negative potentials as different liquids. Not surprisingly, this difference is also seen in the spectra of oppositely charged water and DNA solutions prepared with water from the opposite electric potential.

3.2. Potential Dependent UV Absorption of the Aqueous DNA

Previously it was shown that uncharged water does not absorb in the range from 180 to 300 nm; in any case, the water has no distinct peaks in this range. At the same time, it was found that the UV absorption spectra of water with negative potential have a sharp peak with a maximum at ~ 195 nm, and the UV absorption spectra of water with a positive potential have a wide peak with a maximum in the range of 200 – 220 nm [16, 17].

It was also found that the UV absorption spectra of aqueous DNA strongly depend on the electric potential of the water used. It is noteworthy that the sign of the electric potential of aqueous solutions of DNA affects not only the absorption in the range 190 – 220 nm, but at ~ 260 nm (Figure 7) [16, 17].

Because A_{260} of aqueous solutions of DNA depends strongly on the electrical potential of such solutions, it should be recognized: A_{260} cannot be used to accurately determine the concentration of DNA. Therefore, the exact DNA concentration should be determined by the concentration of products color reactions for phosphates, as in [18].

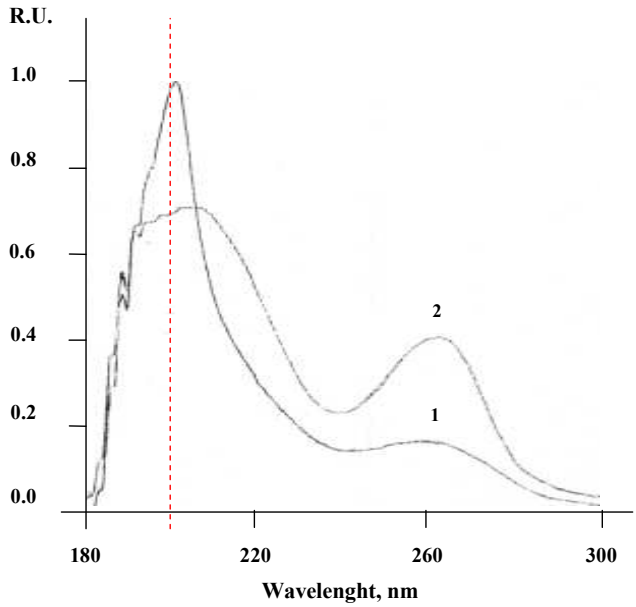

Figure 7. *UV absorption spectra of the aqueous DNA (~20 μg/ml): 1 – DNA dissolved in water, filtered through activated carbon, i.e. having a negative potential; 2 – DNA, dissolved in water, filtered through silica gel, i.e. having a positive potential [16, 17].*

Of course, these spectral differences could be perceived as an interesting phenomenon. But, we are not inclined to think so. That they may have biological significance, we saw when comparing the UV absorption spectra of lymphocytes of healthy people and patients with a form of leukemia (Figure 8) [19]. Comparing the spectra shown (Figures 7, 8), we can assume that the nuclei of the lymphocytes of healthy people have a negative potential, and the nuclei of the lymphocytes of sick people have positive potential. Accordingly, DNA contained in the lymphocytes of healthy people is in a medium with a negative potential, and the DNA contained in the lymphocytes of sick people, is in a medium with a positive potential.

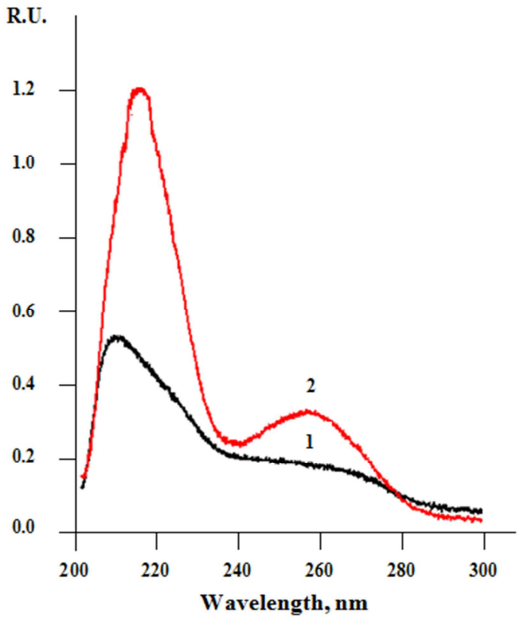

Figure 8. *UV absorption spectra of lymphocytes. 1 – lymphocytes of healthy subjects: 2 – lymphocytes of patients with B-CCL (B-cell chronic lymphocytic leukemia) [18].*

Note: increase A_{260} of aqueous solutions of DNA that occurs when their oxygenation should be considered as the manifestation of (special case: see this) positive electrification of such solutions, and not as a result of the oxidation of DNA [20, 21]. In this regard, it can be assumed that not only the oxidation of DNA can cause a range of diseases, but also the concomitant positive electrification of the intracellular environment [22].

3.3. Some Sources of Electric Potential in Vivo and in Vitro

As shown, the sign of the electric potential of female body liquids varies during the menstrual cycle [13]. These changes cause a natural question: what can be their source of electric potential in the human body? The search for the answer led to the conclusion that such sources may be several. It is advisable to allocate two of them: gases of the air and intestines. First of all it is necessary to highlight two of them: the gases from the air and gases of the intestine. It is known that air consists mostly of nitrogen (~75%) and oxygen (21-22%) [8], and intestinal gases consist mainly of nitrogen (~75%) and hydrogen (21-22%); the maximum was the hydrogen content in the intestinal gas was 37% [23]. It is also known that aqueous solutions receive a negative potential when in contact with hydrogen, and the positive potential when in contact with oxygen [8]. For this reason, it can be assumed that the degree of hydration of DNA in cells, for example, intestines and lung. Accordingly, it is possible to assume that the conformation of such DNA will also be different, with all the ensuing consequences.

When working with objects *in vitro*, it is reasonable to consider positive charge of water solutions occurring under the action of visible light [13], and negative charge occurring during evaporation [15]. For this reason, it is advisable to distinguish the state of the aqueous DNA in the dark and in the light. (When choosing the studied DNA, it should also be noted that DNA inside of the human body is in the dark.)

In the end, it should be noted that the authors describing the process of hydration of DNA, until recently, did not take into account electric potential of water, which forms the hydration shell of DNA [24, 25].

4. Conclusion

DNA conformation depends on the degree of hydration. The ability of water to hydrate the DNA depends on its electric potential. The electric potential of the medium can be considered as a factor determining the state of hydration shells of DNA, its conformation, and availability for interactions. For this reason, the electric potential of the internal environment of a living organism can act as an epigenetic factor.

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