Scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the Academy of Sciences of the USSR (28–29 May 1986)

Usp. Fiz. Nauk **150**, 625–635 (December 1986)

A joint scientific session of the Division of General Physics and Astronomy and the Division of Nuclear Physics of the USSR Academy of Sciences was held on May 28 and 29, 1986 in the conference hall of the S. I. Vavilov Institute of Physical Problems of the USSR Academy of Sciences. The following reports were presented at the session:

May 28

1. *É. L. Andronikashvili and G. M. Mrevlishvili.* Low-temperature heat capacity of DNA.

2. *N. N. Gor'kavyĭ and A. M. Fridman.* Resonance nature of the rings of Uranus and prediction of new satellites of Uranus.

May 29

3. *S. P. Mikheev and A. Yu. Smirnov.* Neutrino oscillations in a medium with variable density.

4. *V. L. Ginzburg and V. P. Frolov.* Quantum effects in accelerated systems, anomalous Doppler effect, and the principle of equivalence.[1)]

Summaries of three of the reports are presented below.

É. L. Andronikashvili and G. M. Mrevlishvili. *Low-temperature heat capacity of DNA.* In this report we examine the problem of the physical characteristics of the "native state" of a biologically very important material—the carrier of genetic information—the DNA molecule, i.e., the characteristics of the functionally important and unique structural state of this biopolymer. We note that this problem was first studied from the physical viewpoint at the beginning of the 1940s by E. Schroedinger, who characterized the "genes" in a living cell as an "aperiodic crystal." [1] For example, what are the main physical differences between the native, ordered (though aperiodic) structure of DNA and the properties of other aperiodic and amorphous structures of biological and nonbiological origin? How should the boundary between the "native" (living) and biologically inactive ("dead") matter be characterized? At what level of the hierarchical structure of biological material are the physically measured differences between these states manifested?

The answers to these questions could be obtained (together with well-known approaches; see, for example, Refs. 2–5) by studying the thermal properties of biological macromolecules, assuming different conformations, near 0 K (É.

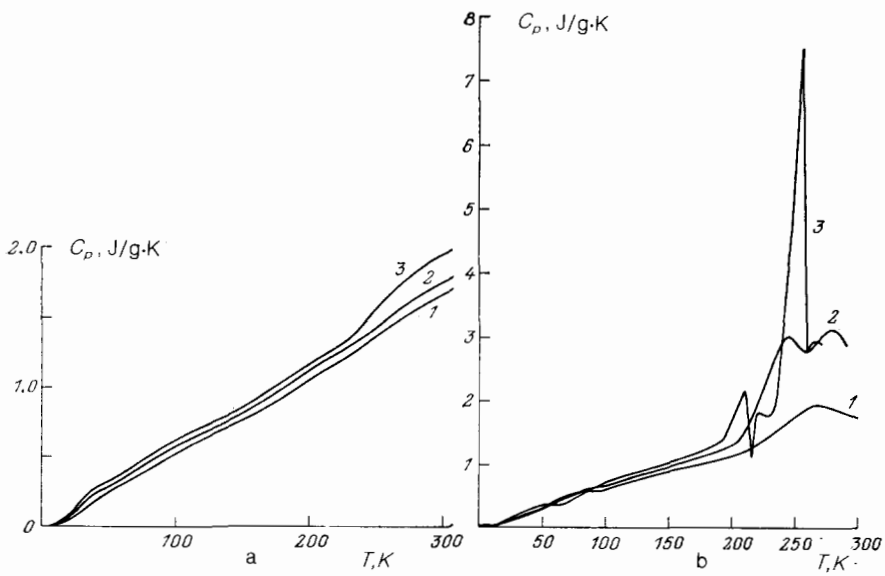

FIG. 1. Temperature dependence of the heat capacity of native strands of Na-DNA of salmon sperm (a) and mechanical mixture of nucleotides [Na_2-d (AMP), Na_2-d (TMP), Na_2-d (GMP), Na_2-d (CMP)] (b) with different water content: 1) $n = 0$–2; 2) $n = 8$–10; 3) $n = 23$ mole H_2O/MBP. The concentration of "base pairs" in the mechanical mixture of nucleotides corresponds to the molar ratio of base pairs in native DNA and equals 41% GC.

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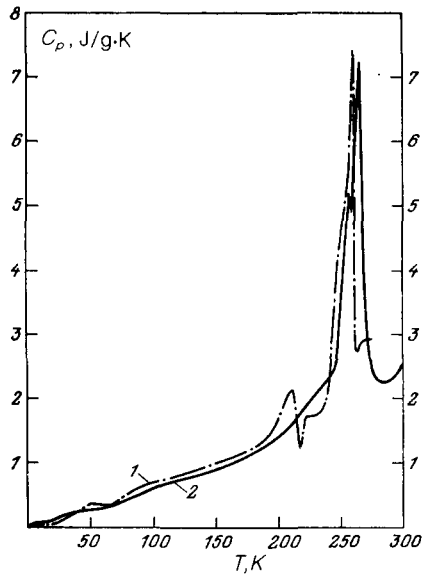

FIG. 2. Temperature dependence of the heat capacity of a mechanical mixture of nucleotides (1) and single strands of DNA in the state of statistical balls (2) with $n = 23$ mole H_2O/MBP.

L. Andronikashvili, 1956; see Ref. 6). We were able to approach the solution of the problems indicated above with the help of the high-sensitivity low-temperature microcalorimetry developed at the Institute of Physics of the Georgian SSR Academy of Sciences.[7,8]

It has been established that the critical value of the amount of water of crystallization (water which does not participate in the ice-water phase transition when solutions of biopolymers are heated and cooled), without which DNA is no longer "ordered" and loses its biological activity, is determined by the chemical compositions of DNA and depends linearly on the GC content according to the law $n = [28.0–0.12\ (\%\ \mathrm{GC})]$ moles of H_2O/MBP.[8,9]

The thermal effects at low temperatures (10, 50, 100, 200 K), discovered in a chaotic-amorphous mixture of nucleotides (which are the building blocks of the native DNA molecule), sharply distinguish this state from the aperiodic structure of DNA (Fig. 1). The character of $C_p = f(T)$ for single polynucleotide chains in the state of statistical balls also differs from $C_p = f(T)$ for native DNA, but is the same as the temperature dependence of the heat capacity (including phase transitions in the solvent) for a mechanical mixture of nucleotides over the entire temperature range (Fig. 2). Thus a qualitative jump in the properties characterizing the "native" biopolymer arises not at the level of creation of the unique linear sequence of nucleotides (which remains in single chains of DNA), but rather after the complete formation of the double helix. In addition, as is evident from the data presented, the role of the solvent (water) turned out to be decisive in determining the physical properties of this—"self-organizing from chaos"—macromolecular structure. Taken as a whole, the studies performed showed that the formation of the native structure of DNA (i.e., ready for the functioning of the genome) is a result of the coalescence of two substructures, one of which is aperiodic (polynucleotide chains of DNA), while the other is a lattice of hydrogen bonds, created between the water molecules built into the double helix. This lattice is not completely ordered (topologically disordered). (The geometry of the water "framework" of the hydrate shell of DNA in different ordered forms was recently determined in detail by the method of x-ray structural analysis.[10,11]) Thus native DNA must be regarded as an aperiodic crystal, "penetrating" the bulk of the solvent, approximating a glassy state, and therefore we are dealing with a special type of state of condensed matter ("aperiodic solid"). Further studies of the physical characteristics of such macromolecular structures at low and superlow (< 1 K) temperatures taking into account the effect of the water medium could substantially change our ideas about the dynamic properties of biopolymers.

[11]The material in this report will be published later in a separate paper. (Editors).

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