On the Molecular Mechanisms of Adaptability of Organism to Temperature

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The earliest (cellular) life on Earth appeared about 3.5 billion years ago. There are evidences that for this eon (Archean) of the young Earth the environmental temperature was extremely high. With reducing of the temperature of the surface of the Earth the organisms (thermo- and hyperthermophilic archaea and bacteria) adopted to this change evolving to mesophilic organisms. Latter lost their ability to survive at high temperatures. The fossils of this organisms cannot give an answer of the question what made thermo- and hyperthermophilic organisms live at temperatures at which life seems to be impossible. The answer came with the surprising discovery of life in the hot springs in Yellowstone Park: the thermo- and hyperthermophilic organisms have proteins with unexpectedly high thermal stability.

Thermal stability of proteins is defined as the temperature, T_m, at which the unfolding free energy equals to zero, $\Delta G(T_m)$. Though there are no properties of matter of lesser or larger importance, T_m is among protein features that deserve some special attention, at least because of its correlation with the temperature limit of the known forms of life. The temperature interval where life can exist is determined by the temperature of cold denaturation, T_c, and by T_m. Beyond these temperatures organisms cannot survive just because proteins unfold. Whilst T_c are temperatures at which other phenomena prohibit life, T_m can be considered as the upper temperature boundary of living matter. The vast majority of proteins undergo unfolding at around 60° C suggesting the earlier common opinion that at higher temperatures no living organisms can be found. This conclusion “ceased to be true” after the discovery of organisms the growth temperature of which may reach 121° C. Hence, these organisms must have a mechanism making their proteoms maintain stability and functionality at high temperature. Unfolding experiments with proteins from thermo extremophilic organisms have clearly proved that this mechanism goes via elevating of T_m. The physical factors for thermal stabilisation, and hence survival of organisms and their adaptability are not completely clear. Electrostatic interactions and molecular packing are believed to be among the most important ones. About latter however controversial observations are reported. A possible reason for this is that these two factors are considered separately, thus their interrelation being omitted. Also, the properties of the unfolded (denatured) state are often not taken into account which leads to an incomplete phenomenological analysis. The role of the mentioned factors in protein thermal stabilisation can by roughly summarised as follows:

1. Due to deamidation of the glutamines and asparagines, these side chains are often coded glutamic and aspartic acid.

2. The charge balance is maintained by the increase of the number of basic side chains.

3. The increase of the number charged groups stabilises enthalpically and

4. Contributes to the compactness of unfolded state (reducing of unfolding).

5. The packing density of the protein interior of thermo- and hyperthermostable protein is lower than that of their mesostable counterparts resulting in reduction of of unfolding (hypothesis).

Prof. Dr. Andrey Karshikoff defended his Ph.D. in Chemistry, at the Institute of Organic Chemistry of the Bulgarian Academy of Sciences in 1985. In the period 1987 - 1991 he is a Postdoc as Alexander-von-Humboldt fellow and later as Max-Planck fellow, in the Max-Planck institute for Biochemistry, Martinsried, Germany. Between 1992 and 2011 he kept the position of associate professor at the Department of Bioscience of the Karolinska Institutet, Sweden. Presently he is Director of the Institute of Molecular Biology of the Bulgarian Academy of Sciences. He is author of about 70 publications in the field of computational biophysics and molecular biology.