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Neutron scattering confirms DNA is as stretchy as nylon

September 8 2011

(PhysOrg.com) -- Neutron scientists at the Institut Laue-Langevin (ILL, France) have measured how fast sound travels along DNA to determine its 'stiffness'. These findings help to explain how DNA folds, coils and denatures.

Researchers at the Institut Laue-Langevin have used neutron scattering to determine the structural elasticity of DNA and account for the wide variety of values obtained from previous measurements. Their results, published in *Physical Review Letters*, help explain how DNA can bend and split in order to establish traits in all living organisms and pass these traits on from one generation to the next.

The double helix structure of DNA is constantly twisted, bent and stretched inside the cell. It is DNA's response to this pressure, based on its fundamental structural properties, that allows it to carry out two of its primary biological functions.

• Replication – how DNA makes copies of itself that is the basis for passing on traits from one generation to the next

• Transcription – the process by which genetic information is copied from DNA to RNA that represents the first step towards gene expression, where information in a gene is used to develop the molecular tools needed for life

Measurements of DNA elasticity in man-made solutions that attempt to recreate conditions inside a cell have been made before and have delivered results that indicate a flexible DNA structure. However these results vary by an order of magnitude, between 0.3 to 3 N/m. They are also two orders of magnitude lower than earlier figures determined from sound velocity measurements.

At ILL, the team used neutron scattering to measure the structural flexibility of the molecule and determined a force constant of 83 N/m that is consistent with the 'stiffer' sound velocity measurements. This value is roughly equivalent to that of the nylon, commonly used in textiles.

These latest measurements were made on 'wet-spun' samples of DNA, wound onto a bobbin. The samples were then placed in the Institute's brand new IN5 neutron scattering spectrometer. IN5 uses a 30m^2 detector while ILL's exceptionally high neutron flux offers an energy resolution an order of magnitude better than in previous X-ray measurements.

With the DNA inside the instrument, the team measured how the frequency of sound waves running along the double helix structure changed with their wavelength. "We are essentially measuring the speed of sound in DNA which gives you a direct measurement of its structural flexibility", explains Professor Mark Johnson, a physicist at ILL.

Using computer simulations of DNA stretching, Johnson and his team were also able to account for the wide range of previously reported values, both within the solution based measurements, and between these values and their own.

The team point to the influence of the solution itself, composed of charged ions like lithium and sodium in water, which mimics the conditions inside the cell. The ions, alongside the water molecules are able to get between the DNA atoms and influence its stiffness.

In the solution based measurements, the solvent molecules and ions can adapt to the DNA structure as it is stretched, making it seem softer. In the neutron scattering measurements, the time available for the water based solution to get in amongst the DNA atoms and lessen the stiffness is reduced. This therefore produces a higher force constant value than if the DNA is stretched slowly.

"Quantifying the molecular elasticity of DNA is fundamental to our understanding of its biological functions," says Johnson. "With some debate in biological circles as to the exact wetness of the inside of the cell, we have established an upper limit on how stretchy DNA can be before it denatures and comes apart."

The high force constant determined at ILL backs up recent work on the overstretching of DNA. The double helix structure has been shown to readily unwind and unzip in response to tension inside the cell because its inbuilt structural stiffness prevents the double-strand DNA molecule from extending.

Dr Lambert van Eijck, one of the lead authors, from Delft University of Technology, The Netherlands: "Our findings support increasing evidence that suggests DNA's stiffness is an important factor in how it is stored in cells and then unzips, starting the replication process that drives genetic inheritance. The experiments and calculations performed in this work determine the intrinsic stiffness of DNA and highlight the influence of solvent molecules and ions in making the DNA softer.

Provided by Institut Laue-Langevin