Vibrational modes within HEAT Repeats: a mechanism for interaction at a distance within cells?

Nigel Dyer
September 2006

Abstract

In recent years a growing number of protein and protein complexes containing HEAT repeats have been discovered. HEAT repeats consist of a sequence of repeated helix pairs with a relatively loose consensus pattern. Many of these proteins are involved with chromosome and microtubule dynamics, and include condensin, delangins (in association with cohesin), importin beta, and the TOGp/XMAP215 family of microtubule associated proteins. However it has not been clear how the HEAT repeat motif contributes to the function of these proteins.

Recent experimental evidence suggests that the structure associated with HEAT repeats has evolved to support a vibrational mode that allows interaction at a distance between proteins that contain this motif. The principles of such an interaction were originally suggested by Professor Herbert Fröhlich who investigated the quantum mechanical properties of such a collection of vibrating particles within biological systems. He proposed that such a collection can exhibit collective behaviour similar to that of a Bose Einstein Condensate when certain criteria are met. This can then give rise to an attractive force between components of such a system, which Fröhlich believed provides an explanation for some interactions that are seen within cells.

Whereas Fröhlich's original proposal relied on a dipole-dipole interaction between vibrating components, recent experimental evidence from biological systems may indicate that this is not the case, and that an alternative non-dipole based interaction occurs within cells. Fröhlich's original proposal only considered the possibility of a simple attractive force. The same experimental evidence indicates that the interaction can also give rise to a force that can align vibrating components, and that this is the basis for the way that HEAT repeats are able to provide an alignment mechanism within cells.

It is possible to trace how such a mechanism evolved, with the earliest example of such an attractive force probably being between coiled-coil components of bacterial condensins. This then evolved to a more advanced interaction between the HEAT repeat domains of eukaryotic condensins. This is able to provide the attractive and aligning force demonstrated by condensins during the process of chromosome condensation, and also during mitosis and meiosis.

Evidence is also beginning to emerge for a similar interacion between the HEAT repeats in delangins, where it provides a subtle interaction between distributed components of the chromosome which is key to some types of gene expression control.

A further examples of such an attractive interaction is the attractive force between the HEAT repeats in condensin and importin beta which is used to by importins to draw themselves and their cargo towards, and into the nucleus.

A final example involves the HEAT repeats found in the TOG family of proteins which are associated with the growing ends of microtubules when they are forming the mitotic spindle. The HEAT repeats would provide an attractive force to guide the growing ends of the microtubules towards the kinetichores within the chromsomes.