operate only at a regional scale, whereas the stratospheric effects are global.

All this equivocation arises because of our current failure to measure the changes in UV-B irradiation directly. What is needed is a worldwide network of UV-B monitoring stations with suitable spectral resolution to complement the ozone-monitoring Dobson network, as is being discussed at a meeting this week*. Indeed, as raised ultraviolet fluxes affect atmospheric chemistry[7] (by generating hydroxyl radicals which remove many atmospheric trace gases, such as industrial methylchloroform[8]), such a network would have scientific as well as health applications. □

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* *UV-B Monitoring*, Washington DC, 10–12 March 1992.

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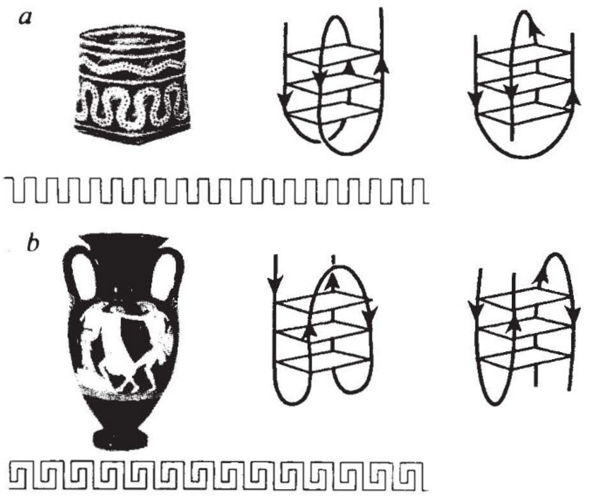
DNA STRUCTURE

The quadruplex and the vase

Maxim Frank-Kamenetskii

SINCE Jane Richardson first proposed the 'vase ornament' classification of protein-folding patterns[1], the notion of the 'Greek key' has become common in the field of protein structure. The first X-ray data on the quadruplex folding of the *Oxytricha* telomeric sequence, presented by Kang *et al.* on page 126 of this issue[2], indicate that the same notion may become equally popular among those interested in unusual DNA structures. In accordance with the previously accepted model of the quadruplex structure in telomeres[3,4], the *Oxytricha* telomeric sequence folds in the Greek-key manner (see figure) with a potassium ion situated axially within the channel formed by the G-quartets. There is a 'but', however, for NMR data, reported by Smith and Feigon also in this issue[5] (page 164), show that in the presence of sodium ions the *Oxytricha* telomeric sequence adopts a different, 'Indian key' topology.



a, Indian and, *b*, Greek vase ornamentation, with examples of the corresponding intra- and intermolecular folding of telomeric sequences forming quadruplexes.

Telomeres are the ends of chromosomes, and are highly unusual in both their mode of synthesis and their structure. The very ends of telomeres carry single-stranded DNA tails. DNA quadruplexes are attracting increasing attention because they readily form from single-stranded DNA molecules with telomeric sequences (general motif $(T/A)_mG_n$, where m is 1–4 and n is 1–8). In the quadruplex, four guanines cohere through Hoogsteen pairing. Until very recently, evidence of quadruplex formation was based on the data from gel mobility or from chemical probing[3,4] (see also my previous News and Views article on the subject[6]). Although these results left few doubts, if any, that the quadruplexes were actually formed, they could not be used to elucidate the detailed geometry. All conjectures as to geometry (reviewed in ref. 7) were based on model building, symmetry considerations and conventional wisdom.

The proposed structure which emerged from this work corresponded to the Greek-key topology. In it, all adjacent strands in the quadruplex were thought to be antiparallel. The nucleotide conformation alternated in the *syn–anti–syn–anti* manner within the G-quartet, and was assumed to be the same along the strands.

The X-ray data now obtained[2] for the intermolecular quadruplex formed by two *Oxytricha* telomeric sequences $G_4T_4G_4$ confirm most of these features and provide us with a detailed view of the structure. The stacked guanine tetrads form a right-handed helix which, if extended, would give about 13 tetrads for each turn. The *syn* and *anti* conformations indeed alternate within tetrads, but in contrast to the early model the *syn–anti* alternation occurs along the strands. Such alternations follow also from the NMR data[5,8], though the reason for them remains obscure. Again, as expected, the potassium ion was found to be situated axially within the channel formed by the stacked tetrads[2].

Surprisingly, however, in their NMR study Smith and Feigon[5] arrive at quite a different conclusion. Instead of the Greek key, they claim to identify Indian-key topology because the Overhauser interaction between the H8 atoms of guanines they observe is inconsistent with antiparallel orientation of all adjacent strands. In the case of the Indian key, the adjacent strands are both parallel and antiparallel (see figure). The nucleotide conformation in the G-quartet is *anti–anti–syn–syn*, not *anti–syn–anti–syn*, in the case of the Indian key.

Why should the X-ray and NMR data point to such different conclusions? The X-ray data are solid, and the arguments based on the NMR results, though much less direct, also look pretty convincing. So the most likely and most interesting possibility is that both groups are right. That would mean that quadruplexes are able to adopt a different topology and geometry under different ambient conditions. The most obvious difference between the two sets of experiments is that Kang *et al.* used potassium, magnesium and spermine as the counter-ions, whereas Smith and Feigon used only sodium. Support for the notion that different quadruplex structures may be adopted by the same telomeric sequences in the presence of different ions follows from the spectroscopic and photochemical data from Cech's group[3,9].

The new findings emphasize how quickly unveiling of the variety of DNA structures is showing that they approach protein structures in versatility — another example is the 'eclectic' structure proposed by myself and colleagues, in which a highly unusual DNA triplex and quadruplex coexist[10]. □

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