Quantum-Chemical Calculations for the Quantitative Estimations of the Processes in DNA

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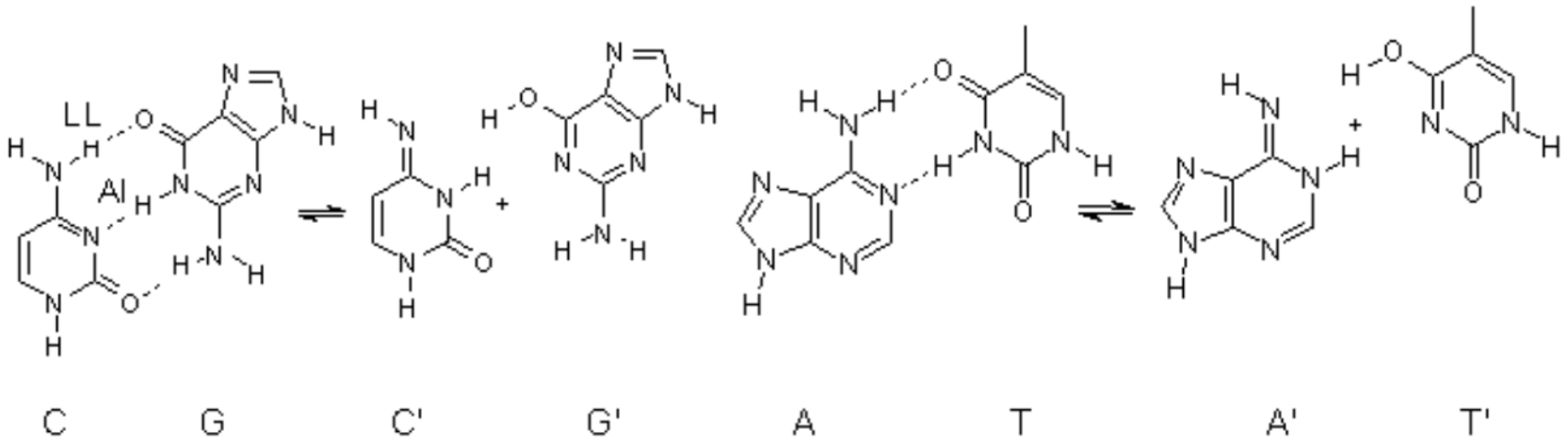
Problem

- DNA tendency to denaturation is stipulated by the elevation of ethanol's concentration in the ambient. The proton transfer between nucleobases of DNA (Adenine-Thimine, Guanine-Cytosine) causes rare tautomeric transformation of the nucleobases pair, which in turn increases both probability of denaturation and frequency of mutation.

- We can estimate the frequency of mutation using constants of equilibrium of Lactam-Lactim and Amine-Imine tautomeric pairs:

- $\nu_m = (K_T(LL)\ \ (K_T(AI) \qquad (1)$



- The above mentioned constants of equilibrium – K_T can be estimated using weakened P_{ij} and enhanced P_{kl} chemical bonds orders

$$K_T = f(P_{ij}, P_{kl}) \qquad (2)$$

Tools and solutions

- For the reason we use the quantum chemical program suite PRIRODA-04, elaborated in the Moscow State University by Laikov D. N. and et al. The software based on DFT (Density Functional Theory) is applicable to the wide class of molecular structures [1]. The application is written on C language and uses MPI.

Porting to HPC clusters

- The High Performance computing cluster of the Politehnica University of Bucharest (NCIT) was the first HPC facility we used to run the program. Application was ported to the HPC (NCIT-Cluster) infrastructure in June 2011. We estimated proton transfer possibilities for the variety of molecular structures on the cluster based on the six-core AMD Opteron 2435 Processors with Infiniband internal communication system. We are grateful to Mr. Dobre Razvan and Mr. Alexandru Herisanu for that help, they have rendered to us during the working process.

- After that (on August 2012) we launched the application on the Hungarian HPC clusters (Debrecen supercomputer and Szeged supercomputer). And we are also grateful to Mr. Rőczei Gábor for this help.
- Scalability studies: Tests on 8, 12, 16, 24, 32 and 64 cores.
- Storage space during a single run: 200 - 500 MB.

Results

- We investigated different molecular structures (>12): imidazole 5-membered new ring, nitrogen-bearing heterocycle (4-Pyridon, Imidazol, p-aminopiridine) – the main duty for the last one was the checking of new stacking mechanism for the proton transfer, …

- For all the investigated structures we calculated constants of equilibrium, probability of proton transfer and frequency of point mutations [2-4]. We received the following important scientific results: we established DNA denaturation mechanism based on the ethanol presence in aquatic ambient, when the aquatic polarity is decreased, distance between DNA helixes is also decreased, which in turn increase tendency to denaturation.
- In the next runs we will increase number of nucleobases (from 4 to 8) in the molecular structures.

Gratitudes and references

- This work was supported by European Commission project "High-Performance Computing Infrastructure for South East Europe’s Research Communities".

- We grateful to the Commission, also hope to get the same support from them in the future.

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- Preparation of another publication based on results of simulations on HP-SEE infrastructure is in progress.