Double-headed nucleotides in DNA-zipper structures; base-base interactions and UV-induced cross-coupling in the minor groove

Charlotte S. Madsen, Lise J. Nielsen, Nikolai S. Pedersen, Anne Lauritsen and Poul Nielsen*

Supporting information

Index

1. MALDI-data for oligonucleotides S2
2. Exact T_m-values S3-S4
3. HPLC chromatograms of the T-T dimer S5
4. Selected 1D and 2D NMR-spectra for the compounds 2-14 S6-S28
MALDI-data for oligonucleotides

Table S1. MALDI-MS of synthesized oligonucleotides containing monomer T\(^\circ\), T\(^\circ\), T\(^\prime\).

| Sequence           | MW calculated | MW found  |
|--------------------|---------------|-----------|
| 5′-GCG AAT\(^\circ\)ATG CG | 3528.4        | 3528.3    |
| 5′-GCG AAT AT\(^\circ\)G CG | 3528.4        | 3527.4    |
| 5′-CGC ATA TT\(^\circ\)T GC | 3439.3        | 3435.4    |
| 5′-CGC ATA T\(^\circ\)TC GC | 3439.3        | 3441.5    |
| 5′-CGC AT\(^\circ\)A T\(^\circ\)TC GC | 3586.4        | 3586.4    |
| 5′-GCG AAT\(^\prime\)AT\(^\prime\)G CG | 3675.5        | 3675.2    |
| 5′-GCG AAT\(^\circ\)ATG CG | 3504.3        | 3499.9    |
| 5′-GCG AAT AT\(^\circ\)G CG | 3504.3        | 3509.1    |
| 5′-CGC ATA TT\(^\circ\)T GC | 3504.3        | 3503.0    |
| 5′-CGC ATA T\(^\circ\)TC GC | 3413.6        | 3418.1    |
| 5′-CGC AT\(^\circ\)A T\(^\prime\)TC GC | 3413.6        | 3415.9    |
| 5′-GCG AAT\(^\prime\)AT\(^\prime\)G CG | 3536.7        | 3538.9    |
| 5′-GCG AAT\(^\prime\)AT\(^\prime\)G CG | 3491.7        | 3490.9    |
| 5′-GCG AAT AT\(^\prime\)G CG | 3402.7        | 3401.5    |
| 5′-CGC ATA TT\(^\prime\)T GC | 3402.7        | 3402.9    |
| 5′-CGC ATA T\(^\prime\)TC GC | 3514.8        | 3515.7    |
| 5′-CGC AT\(^\prime\)A T\(^\prime\)TC GC | 3491.7        | 3592.4    |
| 5′-GCG AAT\(^\prime\)AT\(^\prime\)G CG | 3605.5        | 3604.7    |
Exact \( T_m \)-values

| Entry | Zipper | ON | Duplex | \( \Delta T_m^a/°C \) | \( \Delta \Delta T_m^a/°C \) |
|-------|--------|----|--------|----------------|-----------------|
| 0     | T1: T2 | 5′-d(CGC ATA TTC GC) | 5′-d(GCG TAT AAG CG) | 46.2 | 46.2 |
| 1     | T1: X1 | 5′-d(CGC ATA TTC GC) | 5′-d(GCG XAT AAG CG) | 42.0 | 39.3 | 45.2 |
| 2     | T1: X2 | 5′-d(CGC ATA TTC GC) | 5′-d(GCG TAC AAG CG) | 40.6 | 39.3 | 45.7 |
| 3     | T1: X3 | 5′-d(CGC ATA TTC GC) | 3′-d(GCG XAC AAG CG) | 35.8 | 30.7 | 44.7 |
| 4     | X4: T2 | 5′-d(CGC ATA TXC GC) | 3′-d(GCG TAT AAG CG) | 43.0 | 39.2 | 44.7 |
| 5     | X5: T2 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG TAT AAG CG) | 41.2 | 39.6 | 44.2 |
| 6     | X6: T2 | 5′-d(CGC AXA XTC GC) | 3′-d(GCG TAT AAG CG) | 35.2 | 30.2 | 43.0 |
| 7     | X5: X2 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG TAT AAG CG) | 36.8 | 33.1 | 43.2 |
| 8     | X5: X1 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG TAT AAG CG) | 37.7 | 35.7 | 44.3 |
| 9     | X5: X1 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG TAT AAG CG) | 38.9 | 37.3 | 42.2 |
| 10    | X4: X1 | 5′-d(CGC ATA TXC GC) | 3′-d(GCG XAT AAG CG) | 37.8 | 30.6 | 43.1 |
| 11    | X4: X3 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG XAC AAG CG) | 32.0 | 25.1 | 43.0 |
| 12    | X5: X3 | 5′-d(CGC ATA XTC GC) | 3′-d(GCG XAC AAG CG) | 34.2 | 29.3 | 42.1 |
| 13    | X5: X1 | 5′-d(CGC AXA XTC GC) | 3′-d(GCG XAT AAG CG) | 31.9 | 29.3 | 41.1 |
| 14    | X6: X2 | 5′-d(CGC AXA XTC GC) | 3′-d(GCG TAT AAG CG) | 27.6 | 26.2 | 43.2 |

\( \Delta T_m \) values are obtained from the maxima of the first derivatives of the melting curves (\( A_{260} vs. \) temperature) recorded in a medium salt buffer (Na\( _2 \)HPO\( _4 \) (2.5 mM), NaH\( _2 \)PO\( _4 \) (5 mM), NaCl (100 mM), EDTA (0.1 mM), pH 7.0) using 1.0 \( \mu \)M concentrations of each strand. Differences in melting temperatures as compared to singly modified duplexes; \( \Delta \Delta T_m = \Delta T_m(x/y) - (\Delta T_m(x/z) + \Delta T_m(y/z)) \).
Table S3. Mixed (−3) zipper motifs (corresponding to Table 2).

| XY | $T_\text{mp}$ | $T_\text{Ph}$ | $T_\text{T}$ | $T_\text{c}$ | $T_\text{a}$ | $T_\text{m}$ | $T_\text{p}$ |
|----|--------------|--------------|-------------|-------------|-------------|-------------|-------------|
| T  | 46.2         | ref          | 41.2        | 39.6        | 44.2        | ref         |
|    | -5.0         | -5.6         | -2.0        |             |             |             |
| T' | ref          | ref          | 41.7        | 38.3        | 39.1        |             |             |
|    | -4.5 [+5.8]  | -6.9 [+4.3]  | -7.0 [+0.2] |             |             |             |
| Tc | 42.0         | 40.3         | 38.9        | 34.9        | 40.2        | 42.7        |
|    | -4.2         | -5.9 [+3.7]  | -7.3 [+1.9] | -10.3 [-0.2]| -5.9 [+0.2] | -3.5 [+5.2] |
| T' | 39.3         | 37.6         | 35.2        | 37.3        | 37.0        | 38.7        |
|    | -5.9         | -7.6 [+3.7]  | -10.0 [+0.6]| -7.9 [+3.6] | -9.1 [-1.2] | -6.5 [+3.9] |
| Tm | 45.2         | 40.1         | 40.3        | 38.1        | 42.2        | 40.5        |
|    | -1.0         | -6.1 [+0.3]  | -5.8 [-1.7] | -8.1 [-1.2] | -4.0 [-1.0] | -5.6 [-0.2] |
| Tp | ref          | ref          | 43.8        | 41.2        | 40.7        |             |
|    | -2.4 [+5.8]  | -4.0 [+4.8]  | -5.4 [-0.3] |             |             |             |

$\Delta T_m$/°C [\(\Delta \Delta T_m\)]/°C

$^a,b$ See Table S2. “ref” corresponds to data taken from ref. 8.
HPLC chromatograms of T-T dimer

**Figure S1.** IC-HPLC profiles (60°C) of the (−3) T₃/T₃ zipper duplex before (left) and after (right) irradiation (254 nm, 15 min.).

**Table S4.** Tₘ measurements before and after UV irradiation (254 nm).

| Sequence                             | Tₘ(before) | Tₘ(after) | ΔTₘ | ΔTₘ a |
|--------------------------------------|------------|-----------|------|-------|
| 5′-d(CGC ATA TTC GC) 3′-d(GCG TAT AAG CG) | 45.8       | 45.5      | −0.3 |       |
| 5′-d(CGC ATA T₃T₃ GC) 3′-d(GCG T₃T₃ AT AAG CG) | 42.1       | 39.5      | −2.6 |       |

*Melting temperatures (Tₘ values/°C) was obtained from the maxima of the first derivatives of the melting curves (A₂₆₀ vs. temperature) recorded in a medium salt buffer (Na₂HPO₄ (7.5 mM), NaCl (100 mM), EDTA (0.1 mM), pH 7.0) using 1.0 µM concentrations of each strand. ΔTₘ = Tₘ(after) − Tₘ(before).*
