

Supplementary information

Designer DNA nanostructures for viral inhibition

In the format provided by the authors and unedited

Supplementary Information

Designer DNA nanostructures for viral inhibition

Shaokang Ren^{1,2,#}, Keith Fraser^{3,#}, Lili Kuo^{4,#}, Neha Chauhan^{1,2,5}, Addison T. Adrian^{1,2,5}, Fuming Zhang⁶, Robert J. Linhardt^{3,6,7}, Paul S. Kwon¹ and Xing Wang^{1,2,5,8,*}

¹ Nick Holonyak Jr. Micro and Nanotechnology Laboratory (HMNTL), University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

² Department of Chemistry, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

³ Department of Biological Science, Center for Biotechnology and Interdisciplinary Studies, Rensselaer Polytechnic Institute, Troy, NY 12047, USA

⁴ Wadsworth Center, New York State Department of Health, Albany, NY 12201, USA

⁵ Centre for Pathogen Diagnostics, DREMES at the University of Illinois at Urbana-Champaign and the Zhejiang University-University of Illinois at Urbana-Champaign Institute, Urbana, IL, USA

⁶ Department of Chemical and Biological Engineering, Center for Biotechnology and Interdisciplinary Studies, Rensselaer Polytechnic Institute, Troy, NY 12047, USA

⁷ Department of Chemistry and Chemical Biology, Center for Biotechnology and Interdisciplinary Studies, Rensselaer Polytechnic Institute, Troy, NY 12047, USA

⁸ Carl R. Woese Institute for Genomic Biology (IGB), University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

These authors contributed equally

*Corresponding author email: xingw@illinois.edu

Supplementary Table 1 | DNA sequences for 5-point DNA star.

Strand Name	DNA sequence (5'-3')	Length	Molar equivalents
Scaffold-1	CTC AGC TGT CGG CAA CAG TCG CCG ATC AGG GCG ACT CAC GAC CAG ACT GTG CTT CCT CTA CCA CCT A	67	1
Scaffold-2	GAG TCC TGT CGG TCT CAG TCG CCG ATC AGG GCG ACT CGT CTG TCA TGC CGT CTT CCT CTA CCA CCT A	67	1
Scaffold-3	CCT ACG ATC TCA CGC CAG TCG CCG ATC AGG GCG ACT CCA CAC GAT GCA TGC CTT CCT CTA CCA CCT A	67	1
Scaffold-4	CTG CAC GAC TGA GGT CAG TCG CCG ATC AGG GCG ACT GGC GTT CGC ATT TGG CTT CCT CTA CCA CCT A	67	1
Scaffold-5	GCA TCA GGT AGC CAG GAG TCG CCG ATC AGG GCG ACT GCT TCA GCT GAG AGG CTT CCT CTA CCA CCT A	67	1
Edge-1	GTT GCC GAC AGC TGA GTT TTT TTG AAA TCT TAT ACG CCT CCG GCC ATT GGC TGG CGC AGC GCT CTT TCC TCT ACC ACC TA	80	1
Edge-2	AAG CTG TAC ATC GTT TGA GAT GAA GCC TAC GAT ACA TGC CCG TTT TTT TGC ACA GTC TGG TCG TG	65	1
Edge-3	GAG ACC GAC AGG ACT CTT TTT TTC AGC AGG GCA TGA GTT AGA TCC AAG TCA ACT CAT GCA GAG ACT TCC TCT ACC ACC TA	80	1
Edge-4	TTG CTC ACC AGA ACG AGT AGT TCC TAA CGT ACC AAC GCA CGG TTT TTT TGA CGG CAT GAC AGA CG	65	1
Edge-5	GGC GTG AGA TCG TAG GTT TTT TTT CTG CCC TGA CTT CTA TGC CCG CAT GAA CTA TAG ACT GCG TCT	80	1

	TCC TCT ACC ACC TA		
Edge-6	GAG CAC ACT AGC ACA CTC ATC CAG AGG ACA ACT TCC TAC GTA TTT TTT TGG CAT GCA TCG TGT GG	65	1
Edge-7	GAC CTC AGT CGT GCA GTT TTT TTT GGT CGG ATT CTC AAC TCG TCG ATG AAT AAG GCT TGC CCG GTT TCC TCT ACC ACC TA	80	1
Edge-8	GAT GAA TAA GGC TTG CCC TGT TAA GAT GAA GAT AGG CCA CCC TTT TTT TGC CAA ATG CGA ACG CC	65	1
Edge-9	CCT GGC TAC CTG ATG CTT TTT TTC TCT TTC AAC GGC GTA TTA AGA CGG CTA CAG AGG CTT TGA GGT TCC TCT ACC ACC TA	80	1
Edge-10	CTA TTT TTG CGG ATG GCT TAG TTC GTC TGC ATG AGT GAT GTC TTT TTT TGC CTC TCA GCT GAA GC	65	1
Fix-1	GAT CTA ACT CAT GCC CTG CTG TTT CGG GCA TGT ATC GTA GGC TTC	45	1
Fix-2	GGG CAT AGA AGT CAG GGC AGA TTT CCG TGC GTT GGT ACG TTA GGA	45	1
Fix-3	GAC GAG TTG AGA ATC CGA CCA TTT TAC GTA GGA AGT TGT CCT CTG	45	1
Fix-4	CTT AAT ACG CCG TTG AAA GAG TTT GGG TGG CCT ATC TTC ATC TTA	45	1
Fix-5	GCC GGA GGC GTA TAA GAT TTC TTT GAC ATC ACT CAT GCA GAC GAA	45	1
Close-1	ATC TCA AAC GAT GTA CAG CTT TTT TTT TAG AGC GCT GCG CCA GCC AAT G	49	1
Close-2	ACT ACT CGT TCT GGT GAG CAA TTT TTT TGT CTC TGC ATG AGT TGA CTT G	49	1
Close-3	GAT GAG TGT GCT AGT GTG CTC TTT TTT TGA CGC AGT CTA TAG TTC ATG C	49	1
Close-4	ACA GGG CAA GCC TTA TTC ATC TTT TTT TAC CGG	49	1

	GCAAGC CTT ATT CAT C		
Close-5	CTAAGC CAT CCG CAA AAA TAG TTT TTT TCC TCA AAG CCT CTG TAG CCG T	49	1
Aptamer	GCA CCG GGA GGG AGG GAG GGC TTT TTA GGT GGT AGA GGAA	40	10

Supplementary Table 2 | DNA sequences for 6-point DNA star.

Strand Name	DNA sequence (5'-3')	Length	Molar equivalents
Scaffold-1	CTC AGC TGT CGG CAA CAG TCG CCG ATC AGG GCG ACT CAC GAC CAG ACT GTG CTT CCT CTA CCA CCT A	67	1
Scaffold-2	GAG TCC TGT CGG TCT CAG TCG CCG ATC AGG GCG ACT CGT CTG TCA TGC CGT CTT CCT CTA CCA CCT A	67	1
Scaffold-3	CCT ACG ATC TCA CGC CAG TCG CCG ATC AGG GCG ACT CCA CAC GAT GCA TGC CTT CCT CTA CCA CCT A	67	1
Scaffold-4	CTG CAC GAC TGA GGT CAG TCG CCG ATC AGG GCG ACT GGC GTT CGC ATT TGG CTT CCT CTA CCA CCT A	67	1
Scaffold-5	GCA TCA GGT AGC CAG GAG TCG CCG ATC AGG GCG ACT GCT TCA GCT GAG AGG CTT CCT CTA CCA CCT A	67	1
Scaffold-6	CTG GCT CGAAA TGC CAG TCG CCG ATC AGG GCG ACT CCA ACC TAA GCC GGA GTT CCT CTA CCA CCT A	67	1
Edge-1	GTT GCC GAC AGC TGA GTT TTT TTG AAA TCT TAT ACG CCT CCG GCC ATT GGC TGG CGC AGC GCT CT	65	1
Edge-2	AAG CTG TAC ATC GTT TGA GAT GAA GCC TAC GAT ACA TGC CCG TTT TTT TGC ACA GTC TGG TCG TG	65	1
Edge-3	GAG ACC GAC AGG ACT CTT TTT TTC AGC AGG GCA TGA GTT AGA TCC AAG TCA ACT CAT GCA GAG AC	65	1
Edge-4	TTG CTC ACC AGA ACG AGT AGT TCC TAA CGT ACC AAC GCA CGG TTT TTT TGA CGG CAT GAC AGA CG	65	1
Edge-5	GGC GTG AGA TCG TAG GTT TTT TTT CTG CCC TGA	65	1

	CTT CTA TGC CCG CAT GAA CTA TAG ACT GCG TC		
Edge-6	GAG CAC ACT AGC ACA CTC ATC CAG AGG ACA ACT TCC TAC GTA TTT TTT TGG CAT GCA TCG TGT GG	65	1
Edge-7	GAC CTC AGT CGT GCA GTT TTT TTT GGT CGG ATT CTC AAC TCG TCG ATG AAT AAG GCT TGC CCG GT	65	1
Edge-8	GAT GAA TAA GGC TTG CCC TGT TAA GAT GAA GAT AGG CCA CCC TTT TTT TGC CAA ATG CGA ACG CC	65	1
Edge-9	CCT GGC TAC CTG ATG CTT TTT TTC TCT TTC AAC GGC GTA TTA AGA CGG CTA CAG AGG CTT TGA GG	65	1
Edge-10	CTA TTT TTG CGG ATG GCT TAG TTC GTC TGC ATG AGT GAT GTC TTT TTT TGC CTC TCA GCT GAA GC	65	1
Edge-11	GGC ATT TTC GAG CCA GTT TTT TTC GGA TCG TAC TAT GGT TGC CTT AGC ATC GGA ACG AGG GTA AG	65	1
Edge-12	TCG ACT GTA CCA AGA GCC ATC CTT GAA CCA CCA CAG CTT ACG TTT TTT TCT CCG GCT TAG GTT GG	65	1
Fix-1	GAT CTA ACT CAT GCC CTG CTG TTT CGG GCA TGT ATC GTA GGC TTC	45	1
Fix-2	GGG CAT AGA AGT CAG GGC AGA TTT CCG TGC GTT GGT ACG TTA GGA	45	1
Fix-3	GAC GAG TTG AGA ATC CGA CCA TTT TAC GTA GGA AGT TGT CCT CTG	45	1
Fix-4	CTT AAT ACG CCG TTG AAA GAG TTT GGG TGG CCT ATC TTC ATC TTA	45	1
Fix-5	AGG CAA CCA TAG TAC GAT CCG TTT GAC ATC ACT CAT GCA GAC GAA	45	1
Fix-6	GCC GGA GGC GTA TAA GAT TTC TTT CGT AAG CTG TGG TGG TTC AAG	45	1
Close-1	ATC TCAAAC GAT GTA CAG CTT TTT TTT TAG AGC GCT GCG CCA GCC AAT G	49	1
Close-2	ACT ACT CGT TCT GGT GAG CAA TTT TTT TGT CTC	49	1

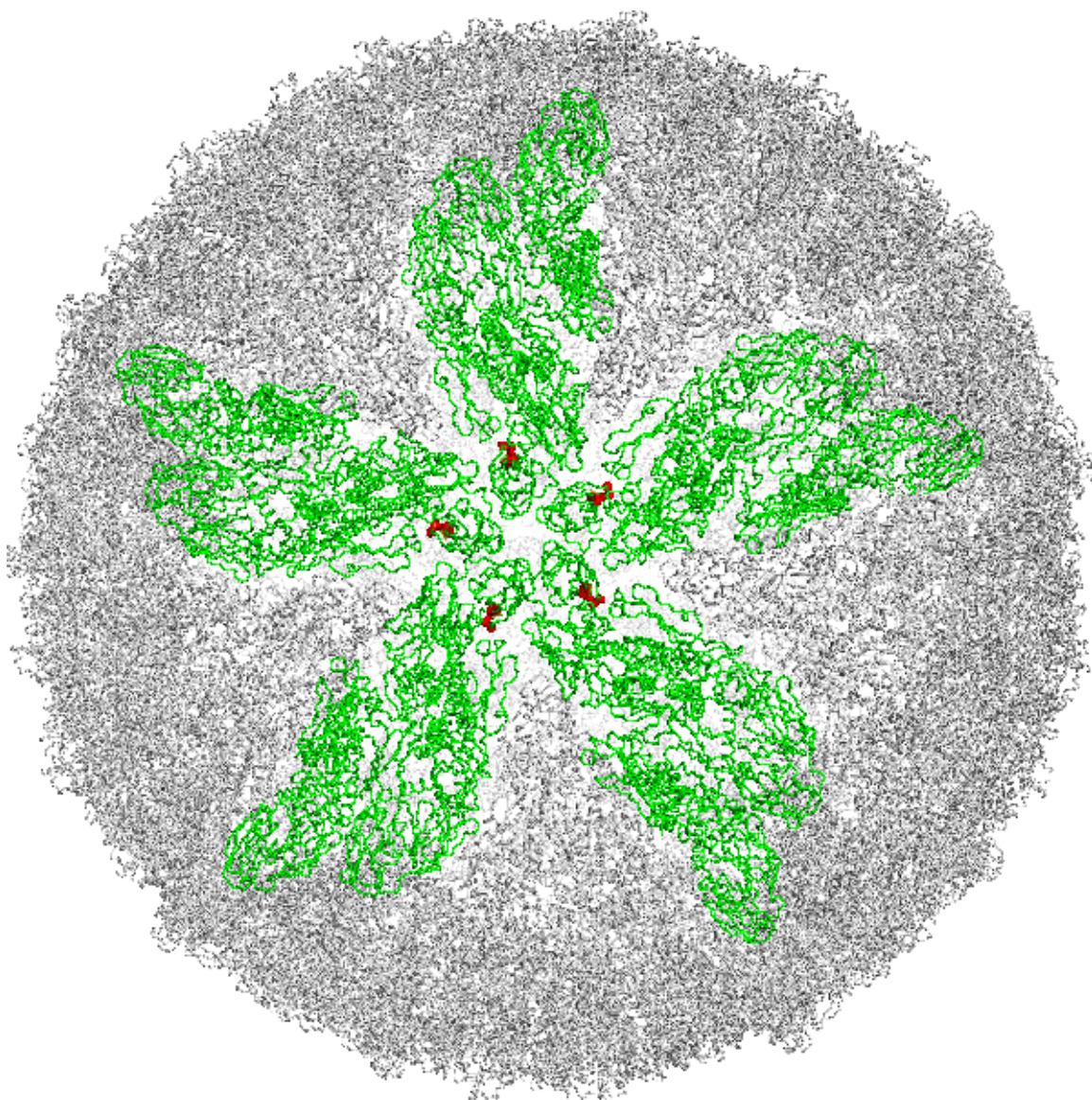
	TGC ATG AGT TGA CTT G		
Close-3	GAT GAG TGT GCT AGT GTG CTC TTT TTT TGA CGC AGT CTA TAG TTC ATG C	49	1
Close-4	ACA GGG CAA GCC TTA TTC ATC TTT TTT TAC CGG GCAAGC CTT ATT CAT C	49	1
Close-5	CTAAGC CAT CCG CAA AAA TAG TTT TTT TCC TCA AAG CCT CTG TAG CCG T	49	1
Close-6	GAT GGC TCT TGG TAC AGT CGA TTT TTT TCT TAC CCT CGT TCC GAT GCT A	49	1
Aptamer	GCA CCG GGA GGG AGG GAG GGC TTT TTA GGT GGT AGA GGAA	40	6

Supplementary Table 3 | DNA sequences for 7-point DNA star.

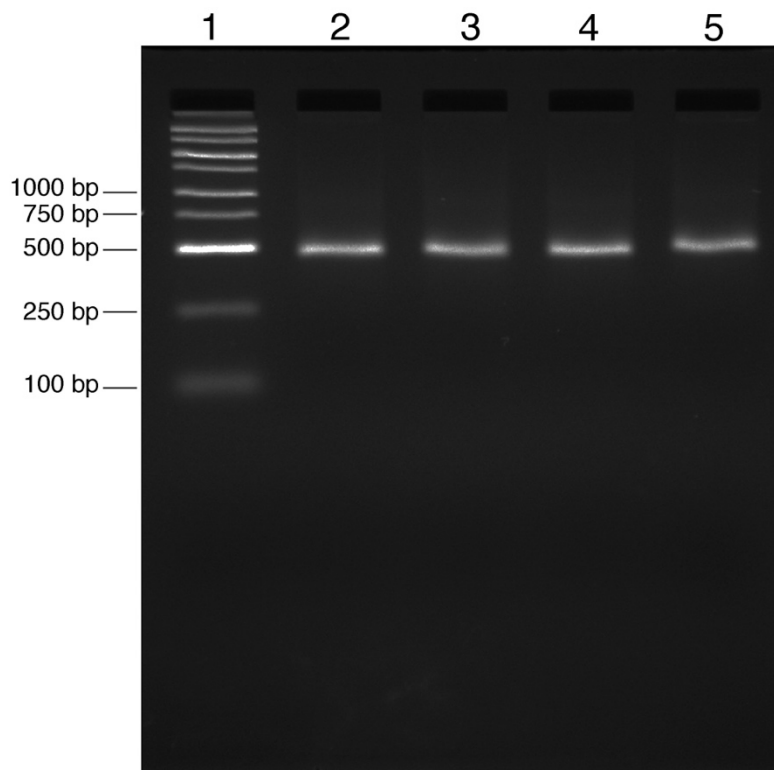
Strand Name	DNA sequence (5'-3')	Length	Molar equivalents
Scaffold-1	CTC AGC TGT CGG CAA CAG TCG CCG ATC AGG GCG ACT CAC GAC CAG ACT GTG CTT CCT CTA CCA CCT A	67	1
Scaffold-2	GAG TCC TGT CGG TCT CAG TCG CCG ATC AGG GCG ACT CGT CTG TCA TGC CGT CTT CCT CTA CCA CCT A	67	1
Scaffold-3	CCT ACG ATC TCA CGC CAG TCG CCG ATC AGG GCG ACT CCA CAC GAT GCA TGC CTT CCT CTA CCA CCT A	67	1
Scaffold-4	CTG CAC GAC TGA GGT CAG TCG CCG ATC AGG GCG ACT GGC GTT CGC ATT TGG CTT CCT CTA CCA CCT A	67	1
Scaffold-5	GCA TCA GGT AGC CAG GAG TCG CCG ATC AGG GCG ACT GCT TCA GCT GAG AGG CTT CCT CTA CCA CCT A	67	1
Scaffold-6	CTG GCT CGAAAA TGC CAG TCG CCG ATC AGG GCG ACT CCA ACC TAA GCC GGA GTT CCT CTA CCA CCT A	67	1
Scaffold-7	CGC TAT GTT CAA GGT CAG TCG CCG ATC AGG GCG ACT CAT CTG ACG TTA CCT GTT CCT CTA CCA CCT A	67	1
Edge-1	GTT GCC GAC AGC TGA GTT TTT TTG AAA TCT TAT ACG CCT CCG GCC ATT GGC TGG CGC AGC GCT CT	65	1
Edge-2	AAG CTG TAC ATC GTT TGA GAT GAA GCC TAC GAT ACA TGC CCG TTT TTT TGC ACA GTC TGG TCG TG	65	1
Edge-3	GAG ACC GAC AGG ACT CTT TTT TTC AGC AGG GCA TGA GTT AGA TCC AAG TCA ACT CAT GCA GAG AC	65	1

Edge-4	TTG CTC ACC AGA ACG AGT AGT TCC TAA CGT ACC AAC GCA CGG TTT TTT TGA CGG CAT GAC AGA CG	65	1
Edge-5	GGC GTG AGA TCG TAG GTT TTT TTT CTG CCC TGA CTT CTA TGC CCG CAT GAA CTA TAG ACT GCG TC	65	1
Edge-6	GAG CAC ACT AGC ACA CTC ATC CAG AGG ACA ACT TCC TAC GTA TTT TTT TGG CAT GCA TCG TGT GG	65	1
Edge-7	GAC CTC AGT CGT GCA GTT TTT TTT GGT CGG ATT CTC AAC TCG TCG ATG AAT AAG GCT TGC CCG GT	65	1
Edge-8	GAT GAA TAA GGC TTG CCC TGT TAA GAT GAA GAT AGG CCA CCC TTT TTT TGC CAAATG CGAACG CC	65	1
Edge-9	CCT GGC TAC CTG ATG CTT TTT TTC TCT TTC AAC GGC GTA TTAAGA CGG CTA CAG AGG CTT TGA GG	65	1
Edge-10	CTA TTT TTG CGG ATG GCT TAG TTC GTC TGC ATG AGT GAT GTC TTT TTT TGC CTC TCA GCT GAA GC	65	1
Edge-11	GGC ATT TTC GAG CCA GTT TTT TTC GGA TCG TAC TAT GGT TGC CTT AGC ATC GGA ACG AGG GTAAG	65	1
Edge-12	TCG ACT GTA CCA AGA GCC ATC CTT GAA CCA CCA CAG CTT ACG TTT TTT TCT CCG GCT TAG GTT GG	65	1
Edge-13	GAC CTT GAA CAT AGC GTT TTT TTC TGG AGG TGG CAT CCT ACT GTT GCG CCG ACAATG ACAACT AC	65	1
Edge-14	CGA TTG TAG CTG AGG CTT GCT AGT ACG GTG TCT GGAAGT TTC TTT TTT TCA GGT AAC GTC AGA TG	65	1
Fix-1	GAT CTA ACT CAT GCC CTG CTG TTT CGG GCA TGT ATC GTA GGC TTC	45	1
Fix-2	GGG CAT AGA AGT CAG GGC AGA TTT CCG TGC GTT GGT ACG TTA GGA	45	1
Fix-3	GAC GAG TTG AGA ATC CGA CCA TTT TAC GTA GGA AGT TGT CCT CTG	45	1
Fix-4	CTT AAT ACG CCG TTG AAA GAG TTT GGG TGG CCT ATC TTC ATC TTA	45	1

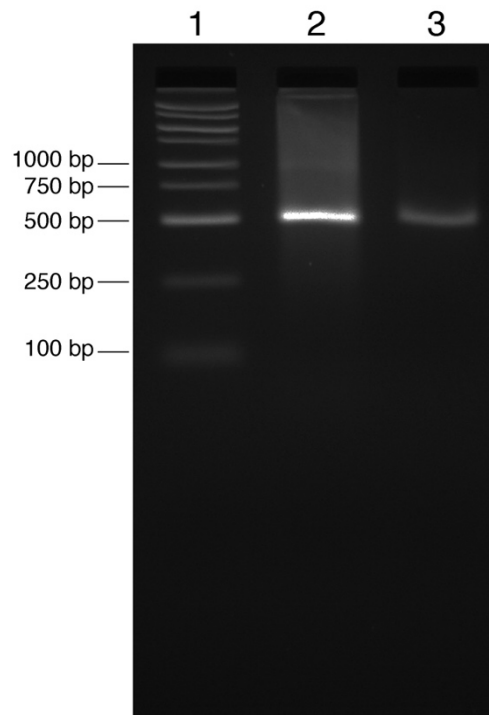
Fix-5	AGG CAA CCA TAG TAC GAT CCG TTT GAC ATC ACT CAT GCA GAC GAA	45	1
Fix-6	ACA GTA GGA TGC CAC CTC CAG TTT CGT AAG CTG TGG TGG TTC AAG	45	1
Fix-7	GCC GGA GGC GTA TAA GAT TTC TTT GAA ACT TCC AGA CAC CGT ACT	45	1
Close-1	ATC TCAAAC GAT GTA CAG CTT TTT TTT TAG AGC GCT GCG CCA GCC AAT G	49	1
Close-2	ACT ACT CGT TCT GGT GAG CAA TTT TTT TGT CTC TGC ATG AGT TGA CTT G	49	1
Close-3	GAT GAG TGT GCT AGT GTG CTC TTT TTT TGA CGC AGT CTA TAG TTC ATG C	49	1
Close-4	ACA GGG CAA GCC TTA TTC ATC TTT TTT TAC CGG GCAAGC CTT ATT CAT C	49	1
Close-5	CTA AGC CAT CCG CAA AAA TAG TTT TTT TCC TCA AAG CCT CTG TAG CCG T	49	1
Close-6	GAT GGC TCT TGG TAC AGT CGA TTT TTT TCT TAC CCT CGT TCC GAT GCT A	49	1
Close-7	AGC AAG CCT CAG CTA CAA TCG TTT TTT TGT AGT TGT CAT TGT CGG CGC A	49	1
Aptamer	GCA CCG GGA GGG AGG GAG GGC TTT TTA GGT GGT AGA GGAA	40	7



Supplementary Figure 1 | Illustration of the distribution of E proteins in the dengue viral particle. The particle consists of 12 of the represented 5-point star structures (green) with each leaf/node on the star representative of three monomers of the E protein (for illustrative purposes only one of these is shown). The QHGTI sequence motif (red) that functions as the antigen binding site is present in domain III of the E protein and is displayed in a defined geometric pattern that repeats across the surface of the viral particle.



Supplementary Figure 3 | DNA star stability through freeze-thaw cycles. DNA star complex before and after one, two or three freeze-thaw cycles (-20 °C to 23 °C) were characterized on a 3% AGE. Lane-1: DNA ladder; Lane-2: DNA star (before freeze-thaw cycle); Lane-3: DNA star (after one freeze-thaw cycle); Lane-4: DNA star (after two freeze-thaw cycles); Lane-5: DNA star (after three freeze-thaw cycles).



Supplementary Figure 4 | Purification of DNA star complex using AGE. DNA star complex before and after gel purification. Lane-1: DNA ladder; Lane-2: DNA star (before gel purification); Lane-3: DNA star (after gel purification).