Folding DNA to create nanoscale shapes and patterns
Supplementary Notes 1–11

Paul W. K. Rothemund

Computation and Neural Systems, and Computer Science, California Institute of Technology, Pasadena, California, United States of America

Supplementary Note S1: Design of DNA origami

The program used for designing DNA origami, `multishapes.m`, may be downloaded from:

`http://www.dna.caltch.edu/SupplementaryMaterial/`

Below is a description of how design proceeds using this program. It is not meant to be a manual but rather to show the level of abstraction at which the origami are designed, and to show the various types of diagrams that the program can draw to aid in design. If scaffolded DNA origami becomes widely used, a better CAD design tool will have to be written. Given a desired shape (for example the red outline in Fig. 1a) design of a DNA origami to approximate it proceeds in five phases (two manual design steps and three passes of the program):

1. **Generation of a block diagram**. By hand, a rough geometric model is generated. It is comprised of rectangular blocks in which each block is taken to be one turn of DNA wide and one DNA helix plus the inter-helix gap in height. (Such a block diagram sloppily overestimates the height of a structure by one inter-helix gap.) An example block diagram is in Supplementary Fig. S1 step 1.

   This step is performed with an eye towards the next step (generation of a folding path), in some cases the block diagram is conceived almost simultaneously with the folding path. The phase of the underlying periodic crossover lattice is chosen as well; generally this phasing is chosen so that seams and long edges of the shape align with columns of periodic crossovers. For blocks on the edge of the diagram, it is useful to keep track of the relationship of such blocks to the underlying crossover lattice. For an origami with 1.5-turn spacing between crossovers there are 3 possible offsets that an edge may have with respect to the underlying lattice—call them 0, +1 and -1 (Origami with 2.5 turn spacing have 5 possible offsets). For designs with a central seam, blocks on edges of offset 0 are colored red and blocks on edges of offset +1 and -1 are colored yellow and orange, depending on whether they occur to the left or right of the central seam. At this point the placement of seams may already be apparent; if so, half-blocks are used along seams. Adjacent half-blocks involved in the same scaffold crossover are colored the same (one of either green or purple) but adjacent half-blocks that participate in different crossovers are given different colors.

2. **Generation of a folding path**, by raster fill, through the block diagram. For a given shape there are many compatible raster fill patterns; currently the raster fill pattern must be hand-designed. For any helical domain in which the scaffold is to start and end on the same side of the helix (top or bottom), an integral number of turns (blocks) is traversed. For any helical domain in which the scaffold starts and ends on opposite sides sides of the helix, the scaffold traverses an odd number of half-turns (half-blocks). An example folding path is in Supplementary Fig. S1 step 2.

3. **Generation of a first pass design** based on the block diagram and folding path. The lengths of various helical domains, in units of DNA turns, are implied by the block diagram and folding paths; these are what is input to the computer program. For every design with seams presented here *except* the 3-hole disk, a single vertical seam was used in the design and so a simple matrix respresentation of the domain lengths could be used. Supplementary Fig. S1 step 3 shows a matrix (`design_turns`) of these domain lengths that is input to the program. (The equilateral and sharp triangle have a single seam *in each domain* that could be similarly specified by a single matrix. For the 3-hole disk, the position of seams was entered as a separate matrix and the routing of the scaffold between these seams as a matrix slightly more complicated than the `design_turns` matrix.) Column C0 gives the total number of turns in a particular row of the design. Column C1 and C4 give the total number of turns to the left and right of the seam, respectively. (Column C0, the sum of C1 and C4, was thus redundant and was used for checking the design.) Columns C2 and C3, unused for this design, give the offset (in number of turns) from the seam of the left and right helical domains, respectively; this feature is not used for the house design here, but is used for the bottom "legs" of the star design. The program converts lengths given (by the user) in turns to numbers of bases (matrix `design_lengths`) and outputs a first-pass design.

The first pass design can be output either as a line diagram (as in Supplementary Fig. S1 step 3) or as a detailed diagram showing the sequence of the scaffold layed out along the folding path, and the sequence of the staples where they appear in the final folded structure (Supplementary Fig. S2). In the detailed design diagram staple strands are indexed by xy position of the adjacent crossover and the designation 'a' or 'b' depending on whether the staple falls to the left or right of the crossover, respectively. Here names are of the form `sXtYP` where `X` is the x position, `Y` is the y position, and `P` the position with respect to the adjacent crossover.

4. **Refinement of the helical domain lengths** to minimize strain in the design. In a third sort of diagram (Supplementary Fig. S3), the computer program displays the predicted twist at each base position as a color (assuming the spacing of crossovers represents an exact number of half turns). Red indicates that the base at a particular position is pointing up, blue that it is pointing down. At crossover points, strand backbone positions should fall at the tangent point between helices; thus bases from the helix above a crossover should be blue and those from the helix below a crossover should be red. (More specifically, the color of bases at the crossover should be spaced equally clockwise and counterclockwise of the colors blue and red, that themselves should occur exactly at the tangent point.) All of the crossovers internal to the design are spaced 16 bases apart and related by a glide symmetry that should balance strain. This can be observed for the two types of crossovers ('+', major-groove up and '-' major-groove down) that occur internally in a shape, shown in both the boxed regions and at the lower left of Supplementary Fig. S3. (A naive view is that the bases of the crossover will actually be centered around the tangent point between helices. In reality, twist strain might be relieved by distortion of the crossover but the idea is that if so, such a distortion will be balanced by that of neighboring symmetrically-placed crossovers.)

   Ideally, at all other crossovers in the design, the orientation of bases would be similar to that desired for the balanced internal crossovers. However, because of the non-integral number of bases in a single turn, and the major-minor groove angle, it is not possible to put all crossovers in this optimal orientation. Crossovers along the edges of the shape, in particular, must be adjusted to minimize strain. The program computes a "strain energy" along the edges of the design, and so positions of predicted high strain can be identified. (For a given strand passing through a crossover, the computed strain energy is just the sum of the squared angular deviation from the tangent point for the base before and the base after the crossover.)

   By hand, helical domain lengths are changed by single bases until the strain energy is minimized. The map of twists aids in this process. For example, high twist strain occurs in a couple scaffold crossovers in the first pass design (marked by 's' labels inside ovals in Supplementary Fig. S3). These crossovers were initially designed to be 5 bases away from the nearest internal crossover (a '-' crossover). At bottom right, the situation for one such crossover may be compared to that which would occur if the distance to the nearest internal crossover were changed to 6 bases, as well as the 'ideal' situation for this type of crossover, that of a '+' type crossover. The 6-base distance creates the least strain.

   Once the appropriate adjustments are decided, a matrix of adjustments is input to the design program, with the original design (Supplementary Fig. S4, `design{ADJUSTMENTS}`, top). The matrix gives adjustments for the left and right edges of each helical domain in the design, columns C1 and C2 for domains to the left of the seam and columns C3 and C4 for columns to the right of the seam. The program updates `design_lengths` (Supplementary Fig. S4, bottom) accordingly and a second pass diagram is generated (Supplementary Fig. S5).

5. **Breaking and merging of strands.** The merging of strands is specified by giving a pairwise list of the names to be merged (i.e. `s-2t9b` and `s-1t8a`) along with the name of the new strand (i.e. `s-1t8e`). The program checks to see that all strands to be merged have adjacent 3' and 5' bases. The position of strands to be broken is specified by the name of a strand and the position along its length at which it is to be broken. The pattern of merges is not unique. Supplementary Fig. S6, Supplementary Fig. S8, and Supplementary Fig. S10 show three different diagrams (full sequence, line drawing, and crossover map) of a design that features bridging staple strands across the seam. Supplementary Fig. S7, Supplementary Fig. S9, and Supplementary Fig. S11 show three different diagrams (full sequence, line drawing, and crossover map) of a design that has no bridging staples. Diagrams are interleaved to allow comparison of the differences between these two designs. Using a PDF viewer, flip back and forth between two diagrams of the same type to see the effect of different merge patterns. Particularly interesting are the crossover maps, Supplementary Fig. S10 and Supplementary Fig. S11. The addition of bridging staples creates a characteristic pattern of "bars" down the center of the design which is observed in experiments that using bridging staples (and not observed in experiments that don't use bridging staples.) Supplementary Fig. S12 highlights the the basic type of grid underlying each merge pattern and the implications for applying pixels to the pattern.

The design method given here is a generalization of that developed by Nadrian Seeman for creating rigid molecules out of parallel helical domains (here helices are technically 'antiparallel' in the standard terminology), which was first elaborated for the creation of double-crossover molecules (molecules with two parallel helices, ref. 16) and later extended to triple crossover molecules (molecules with three parallel helices,[24]). The main principle used in these works is that **crossovers may be used to hold helices rigidly in a parallel orientation**. More specifically, **wherever the twist of two parallel helices bring the backbones of the two helices sufficiently close, reciprocal strand exchange can be used to incorporate a crossover.** Further, an amazing aspect of the principle is that such a crossover does not disturb base pairing in either helix; the crossover appears to contain only single phosphate from each strand. The basic principle can be extended to many general schemes with a variety of crossover spacings and crossover types (parallel or antiparallel), as was mentioned in ref. 16. Here I explore a scheme that uses a regular grid of antiparallel crossovers (spaced an odd number of half-turns apart) in the bulk of a shape but on the edges and seams of a shape admits the placement of a crossovers with arbitrary offsets (in integral numbers of turns) from the underlying crossover grid.

The composition of double crossovers into periodic two dimensional crystals[25] showed that, through the use of sticky-end interactions, arbitrary numbers of helices could be held in a parallel arrangement by crossovers. Because the natural equilibrium length for a single turn of DNA appears to be close to 10.5 base pairs[26, 27], and because DNA backbones are not symmetrically spaced around the helix (there is a major and minor groove), designs of such two dimensional DNA nanostructures (which must use integral numbers of DNA bases) invariably incorporate features that should cause strain. That is, the design assumes a DNA geometry slightly different than that of a single isolated helix with 10.5 bases per turn with 'normal' major/minor groove angles. This difficulty appears to have manifested itself experimentally. A number of 2D DNA nanostructures form tubes rather than sheets[15,22].

The solution to this problem was first articulated to me by Erik Winfree, and was implicit in the design of DAO-E double crossover lattices[25]: **crossovers (and nicks) in extended structures of parallel helices should be placed so that they have symmetries which balance strain.** This principle is described at length in ref. 15 and its supplemental materials; it is also often described as 'corrugation'[22]. The principle has demonstrably inhibited tube formation in at least one system[22].

For DNA origami this criterion was used in the placement of crossovers; after merging it does not hold true for nicks in some designs. The use of 16 bases to represent 1.5 turns of DNA (in the 1.5-turn crossover spacing structures) or 26 bases to represent 2.5 turns of DNA (in the 2.5-turn crossover spacing structures) means that the helical domains between crossovers are slightly overtwisted or undertwisted, respectively. To balance this strain, alternating columns of staple crossovers are related by a glide symmetry—the local configuration of crossovers in one column is identical to that of crossovers in the next column over after a translation and a 'flip' (a rotation about one of the crossovers in-plane axes). Cross-section 1 of Fig. 1d shows the presumed orientation of backbones through one column of crossovers in the lattice, and the top two helices of cross-section 2, the presumed orientation of crossovers in an adjacent column 1.5 turns away (alternatively the diagrams for '+' and '-' crossovers in Supplementary Fig. S3). This symmetry should tend to balance strain in the origami and cause them to be, on average, flat. (So far, no experimental evidence has demonstrated that the origami are flat, however).

The use of a glide symmetry means that large regions of a DNA origami should have balanced strain. However, at seams and edges this is not necessarily true, even where a seam or edge lines up with the underlying crossover lattice. At seams or edges, because DNA has a major and minor groove, a crossover involving staple strands is in tension with an adjacent crossover involving the scaffold strand. Such a configuration of crossovers in tension has never before been used in DNA nanostructures. For example, in Fig. 1d the cross-section through a seam (cross-section 2) has been drawn so that the staple crossover is relaxed (top two helices of three) and the scaffold crossover (bottom two helices of three) is highly strained. Perhaps both crossovers assume some intermediate conformation.

How the strain is actually relieved is unknown, the final base pairs of each helix may be distorted. Strain at seams or edges does not appear to cause any gross defects in the origami; bases at the end of the helices are highly available for stacking against other DNA origami which suggests that the last base pair does form and assumes a planar configuration. If, in the future, strain associated defects should be detected at edges, then one or two scaffold bases could be left unpaired and allowed to form a hairpin that should relax the crossover.

Another place that the design of scaffolded DNA origami currently breaks with normal DNA nanotechnology is in its use of a wide range of sequences for its antiparallel crossovers. Customarily, crossover sequences are drawn from one of a few sequences that both form an immobile branched junction[28] and have well-characterized geometry. Such junctions have been designed with minimal symmetry so that the junction cannot branch migrate back and forth. Because the crossover sequences in the DNA origami demonstrated here are determined by the M13mp18 DNA sequence, and hundreds of them are used, a few probably have symmetries that would allow them to branch migrate a few bases; the crossover sequences have not been inspected for such properties. Further, different crossover sequences show a varying tendency to assume one of two different stacked-X conformers[29, 30], one of which is incompatible with the DNA origami's intended structure at every crossover.

It is hoped that the juxtaposition of multiple crossovers in DNA origami inhibits both branch migrations and conformer isomerizations; isomerization or migration to an undesired form at one junction would tend to increase strain between adjacent junctions. A study of a pair of symmetric antiparallel junctions juxtaposed with an asymmetric antiparallel junction has shown that the asymmetric junction can prevent the adjacent symmetric junctions from branch migrating[31]. But the same study showed that two symmetric antiparallel junctions juxtaposed next to eachother *can* branch migrate. Thus it seems possible that several symmetric junctions near eachother might conspire and migrate. Indeed it seems likely that some local rearrangements of junctions in origami happen; since they are likely to be smaller than a few nanometers, they cannot be observed by AFM. Eventually higher resolution structural information on DNA origami will determine if such isomerizations occur. Importantly, I note that there is no reason why better characterized, well-behaved junction sequences should not be incorporated into DNA origami designs if it helps to create more precise structure. The incorporation of specific crossover sequences will require the use of a synthetic scaffold rather than a natural one, a practical incovenience for very long scaffolds.

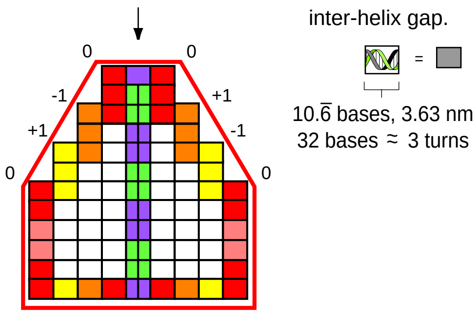
A note on seams: while most seams presented here are vertically aligned (for simplicity and convenience in design), and this necessitates the use of bridges to strengthen seams, it is in possible to create staggered seams (as E. Winfree has suggested) so that staple strands naturally cross and bridge the seam vertically (between two adjacent helices) and no creation of horizontal bridges would be required. In these cases the addition of horizontal bridges across some parts of the seam might still add addtional strength. A small instance of staggered seams occurs in the smiley face design. Above the right hand eye a small 2-helix seam appears that, because it is not aligned with other seams would not necessarily need bridges. An experiment in which the staples at this position were rearranged to remove horizontal bridging gave smileys of (not surprisingly) similar quality.

A note on folding paths and arbitrary shapes: there may be additional constraints on DNA origami that limit the family of shapes that can be approximated a little. In particular, shapes with lots of long thin projections or thin "waists" connecting two different parts of the shape may not form very well. As presented here, the minimum allowable width of a vertically oriented structure (such as a tall thin rectangle), if the scaffold rasters progesses in one direction vertically, is 1.5 turns, or about 5.4 nm wide. I have not tested the formation of such a narrow structure. The narrowest equivalent structure occurs at the jaw hinge of the smiley, 4.5 turns wide, about 16 nm wide. While most smileys are well formed, a significant number have dislocations along these 4.5 turn waists and it appears to be a weak spot.

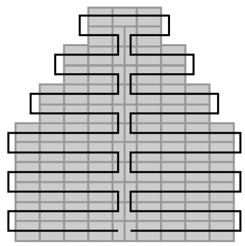
In some shapes it is desired that a strand pass both back and forth through a narrow waist so that it may access different portions of the shape. For example, consider a vertically oriented hourglass shape. If it is desired that a circular scaffold be used, then the scaffold must pass both up and down the narrow waist of the hourglass. As presented here, the minimal allowable width of the waist, which would accomodate the scaffold going up and down, would be 3 turns or about 11 nm. This width is the width of the top 4 helices of the star and because they do not image well, it seems that such a narrow waist may be floppy (in isolation). Clearly the analogous waist down the center of the smiley, which is 6 turns or 22 nm wide forms well and is mechanically stable in the context of the larger structure. Note that it is asymmetric an is composed of 1.5 turn and 4.5 turn wide vertical rasters.

Similarly, consider a horizontally oriented hourglass. For a circular scaffold to pass both left and right through the waist of the hourglass would require two helices, and so in principle the waist could be about 5 nm wide. However, I am unsure how well such a skinny waist would form. Again the smiley gives the best example of the smallest such waist so far. Below each eye is a four helix waist, about 11 nm wide which forms well and is stable.

1. Block diagram



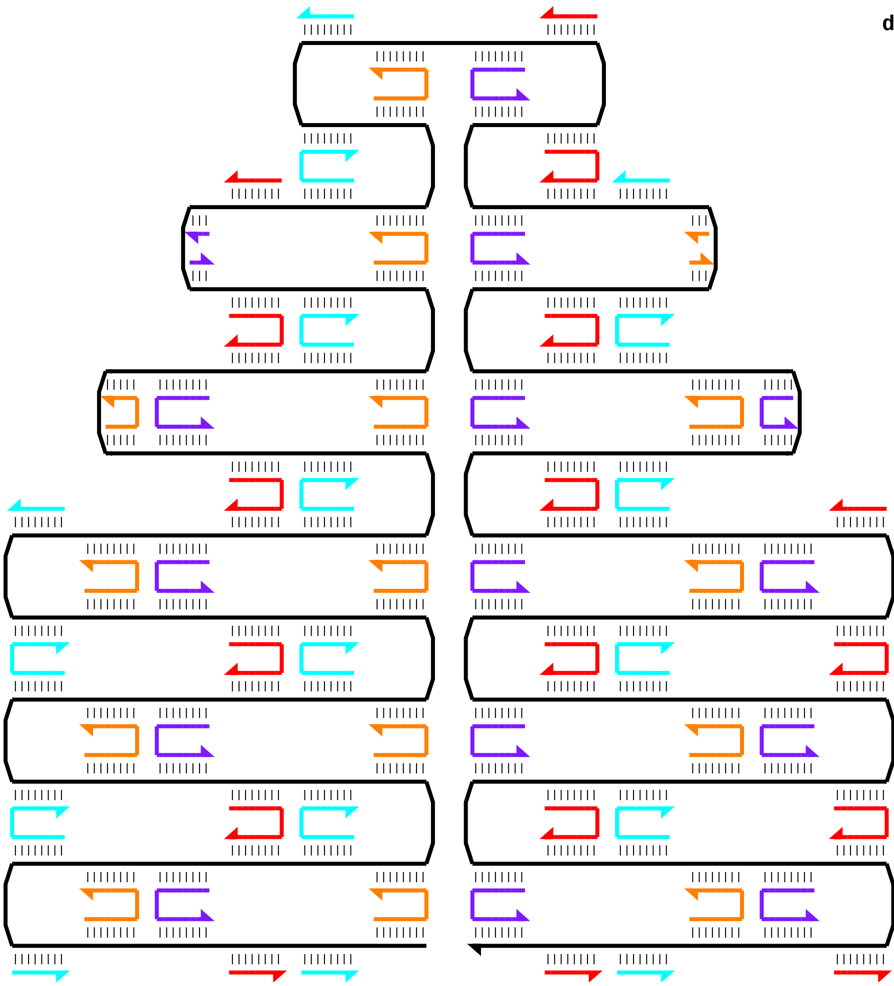
2. Folding path



3. First pass design

```
%  C0  C1   C2  C3 C4
design_turns = [
   [3  1.5  0   0  1.5]; %H1
   [3  1.5  0   0  1.5]; %H2
   [5  2.5  0   0  2.5]; %H3
   [5  2.5  0   0  2.5]; %H4
   [7  3.5  0   0  3.5]; %H5
   [7  3.5  0   0  3.5]; %H6
   [9  4.5  0   0  4.5]; %H7
   [9  4.5  0   0  4.5]; %H8
   [9  4.5  0   0  4.5]; %H9
   [9  4.5  0   0  4.5]; %H10
   [9  4.5  0   0  4.5]; %H11
   [9  4.5  0   0  4.5]; %H12
];
```

Program outputs first pass design:

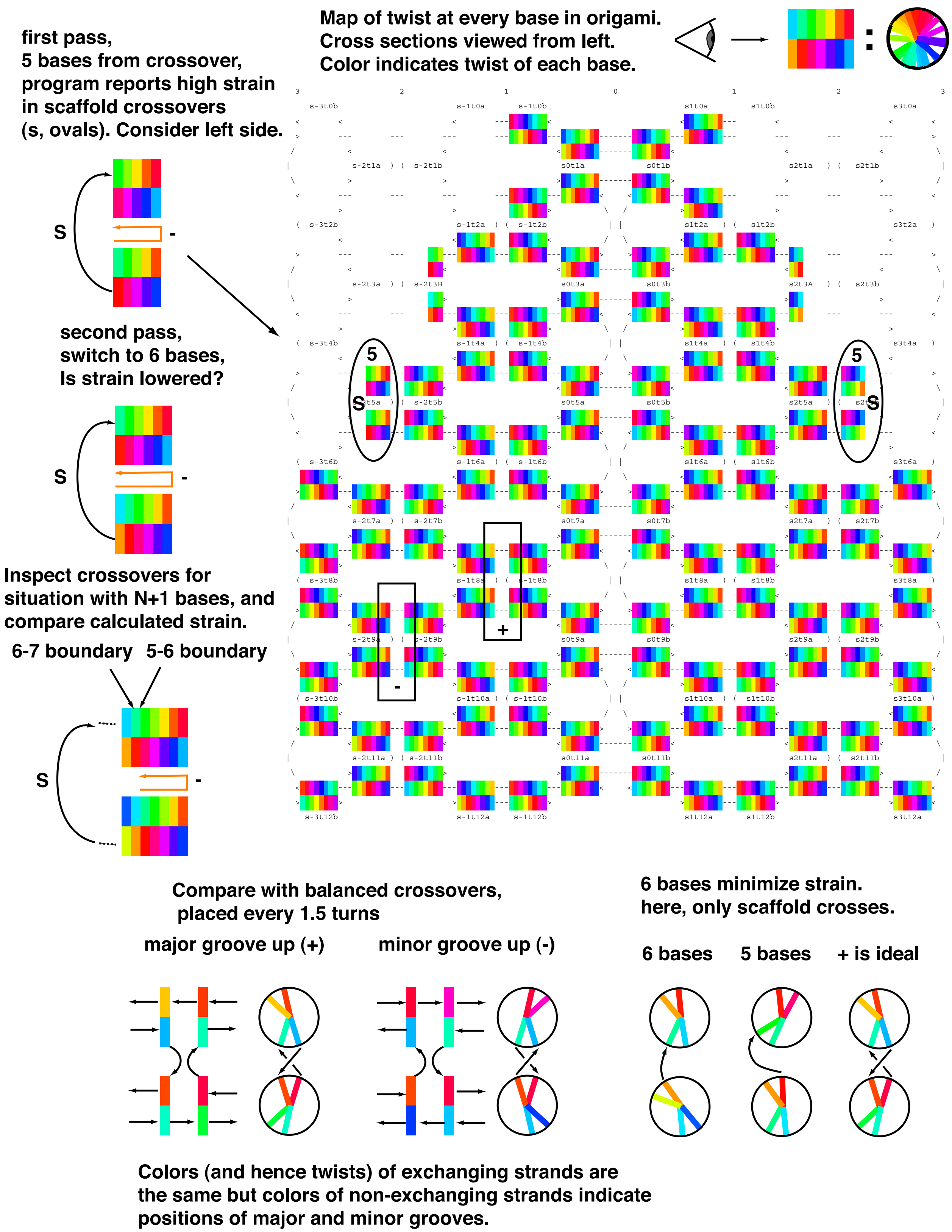


```
design_lengths =
   C0    C1    C2    C3    C4
   32    16    0     0     16   %H1
   32    16    0     0     16   %H2
   54    27    0     0     27   %H3
   54    27    0     0     27   %H4
   74    37    0     0     37   %H5
   74    37    0     0     37   %H6
   96    48    0     0     48   %H7
   96    48    0     0     48   %H8
   96    48    0     0     48   %H9
   96    48    0     0     48   %H10
   96    48    0     0     48   %H11
   96    48    0     0     48   %H12
```

Supplementary Figure S1: First three steps of origami design.

```
 3                     2                     1                      0                        1                     2                     3
    s-3t0b                         s-1t0a       s-1t0b                             s1t0a         s1t0b                         s3t0a
 <        <                       <        ---GGAGAGGG<                           <GTAATTAC---        <                       <        <
 >        ---        ---        ---        ---CCTCTCCC---CGCGCGTT-------GGCCGATT---CATTAATG---        ---        ---        ---        >
/           <                   <                       <GCGCGCAA-------CCGGCTAA<                       <                   <           \
|            s-2t1a  ) (  s-2t1b                         s0t1a             s0t1b                         s2t1a   ) (   s2t1b             |
\           >                   >                       >GTATTGGG-------CCTGTCGT>                       >                   >           /
 <        ---        ---        ---        ---GCCAAACG---CATAACCC<     <GGACAGCA---CGGTCGAC---        ---        ---        ---        <
          >                       >           CGGTTTGC>           \   /           >GCCAGCTG           >                       >
 (  s-3t2b                         s-1t2a  ) (  s-1t2b             | |             s1t2a   )  (  s1t2b                         s3t2a   )
          <                       <CACTTTTC  TTTTTGGT<           /   \           <GACCTTTC   GCCCGTCA<                       <
 >        ---        ---     CTG---GTGAAAAG---AAAAACCA---CCCTGGCG>     >TTTCCCGA---CTGGAAAG---CGGGCAGT---GAG     ---        ---        >
/           <                GAC<                       <GGGACCGC-------AAAGGGCT<                       <CTC                <           \
|            s-2t3a  ) (  s-2t3B                         s0t3a             s0t3b                         s2t3A   ) (   s2t3b             |
\           >                TGA>                       >TTGCCCTT-------GAGCTAAC>                       >GCG                >           /
 <        ---        ---     ACT---CTGCCCGT---TGTCGACT---AACGGGAA<     <CTCGATTG---AGTGTAAT---TAACGCAA---CGC     ---        ---        <
          >                       >GACGGGCA  ACAGCTGA>           \   /           >TCACATTA   ATTGCGTT>                       >
 (  s-3t4b                         s-1t4a  ) (  s-1t4b             | |             s1t4a   )  (  s1t4b                         s3t4a   )
          <                       <GTTGAGAG  AGTCCCGG<           /   \           <CCGTGGGG   TCCGAAAT<                       <
 >        ---   GGACC---GCTTGCTG---CAACTCTC---TCAGGGCC---AGGCGGTG>     >ACTCATTA---GGCACCCC---AGGCTTTA---CACTTTAT---GCTTC   ---        >
/           <   CCTGG   CGAACGAC<                       <TCCGCCAC-------TGAGTAAT<                       <GTGAAATA   CGAAG   <           \
|            s-2t5a  ) (  s-2t5b                         s0t5a             s0t5b                         s2t5a   ) (   s2t5b             |
\           >   ACGCT   GGTTTGCC>                       >CTGTTTGA-------TGTTATCC>                       >AACATACG   AGCCG   >           /
 <        ---   TGCGA---CCAAACGG---GGTCGTCC---GCTTTTAG---GACAAACT<     <ACAATAGG---CGAGTGTT---AAGGTGTG---TTGTATGC---TCGGC   ---        <
          >                       >CCAGCAGG  CGAAAATC>           \   /           >GCTCACAA   TTCCACAC>                       >
 (  s-3t6b                         s-1t6a  ) (  s-1t6b             | |             s1t6a   )  (  s1t6b                         s3t6a   )
  CCGATAAG<                       <TAAAACGG  CTAAAGCC<           /   \           <GTCCTTTG   TCGATACT<                       <CTCGAGCC
 >GGCTATTC---TTTTGATT---TATAAGGG---ATTTGCCC---GATTTCGG---AACCACCA>     >ATTTCACA---CAGGAAAC---AGCTATGA---CCATGATT---ACGAATTC---GAGCTCGG>
/           <AAAACTAA   ATATTCCC<                       <TTGGTGGT-------TAAAGTGT<                       <GGTACTAA   TGCTTAAG<           \
|            s-2t7a  ) (  s-2t7b                         s0t7a             s0t7b                         s2t7a   ) (   s2t7b             |
\           >GGTTGAGT   GTTGTTCC>                       >CCACTATT-------GTGCCAAG>                       >TCGACTCT   AGAGGATC>           /
 <GCTCTATC---CCAACTCA---CAACAAGG---TCAAACCT---TGTTCTCA---GGTGATAA<     <CACGGTTC---GAACGTAC---GGACGTCC---AGCTGAGA---TCTCCTAG---GGGCCCAT<
  CGAGATAG>                       >AGTTTGGA  ACAAGAGT>           \   /           >CTTGCATG   CCTGCAGG>                       >CCCGGGTA
 (  s-3t8b                         s-1t8a  ) (  s-1t8b             | |             s1t8a   )  (  s1t8b                         s3t8a   )
  GGGACTAT<                       <AACTGCAA  CCTCAGGT<           /   \           <CAAAATGT   TGCAGCAC<                       <GCAATGGG
 >CCCTGATA---GACGGTTT---TTCGCCCT---TTGACGTT---GGAGTCCA---CGTTCTTT>     >TGGCCGTC---GTTTTACA---ACGTCGTG---ACTGGGAA---AACCCTGG---CGTTACCC>
/           <CTGCCAAA   AAGCGGGA<                       <GCAAGAAA-------ACCGGCAG<                       <TGACCCTT   TTGGGACC<           \
|            s-2t9a  ) (  s-2t9b                         s0t9a             s0t9b                         s2t9a   ) (   s2t9b             |
\           >CACTACGT   GAACCATC>                       >TTGGGGTC-------TATTACGC>                       >GATGTGCT   GCAAGGCG>           /
 <GCTACCGG---GTGATGCA---CTTGGTAG---TGGGTTTA---GTTCAAAA---AACCCCAG<     <ATAATGCG---GTCGACCG---CTTTCCCC---CTACACGA---CGTTCCGC---TAATTCAA<
  CGATGGCC>                       >ACCCAAAT  CAAGTTTT>           \   /           >CAGCTGGC   GAAAGGGG>                       >ATTAAGTT
 ( s-3t10b                         s-1t10a ) ( s-1t10b             | |             s1t10a  )  (  s1t10b                        s3t10a  )
  TTAGCCCC<                       <GCTAAATC  ACGAAATG<           /   \           <CGGGCGTG   GCTAGCGG<                       <GTCGGACT
 >AATCGGGG---GCTCCCTT---TAGGGTTC---CGATTTAG---TGCTTTAC---GGCACCTC>     >GCGAAGAG---GCCCGCAC---CGATCGCC---CTTCCCAA---CAGTTGCG---CAGCCTGA>
/           <CGAGGGAA   ATCCCAAG<                       <CCGTGGAG-------CGCTTCTC<                       <GAAGGGTT   GTCAACGC<           \
|            s-2t11a ) ( s-2t11b                         s0t11a           s0t11b                         s2t11a  ) (  s2t11b             |
\           >GACGGGGA   AAGCCGGC>                       >GAAGGGAA-------CCGGCACC>                       >ACCAGGCA   AAGCGCCA>           /
 <ATCTCGAA---CTGCCCCT---TTCGGCCG---CTTGCACC---GCTCTTTC---CTTCCCTT<     <GGCCGTGG---CGAAGACC---ACGGCCTT---TGGTCCGT---TTCGCGGT---AAGCGGTA<
 >TAGAGCTT>                       >GAACGTGG---CGAGAAAG>                           >GCTTCTGG---TGCCGGAA>                       >TTCGCCAT<
   s-3t12b                         s-1t12a     s-1t12b                             s1t12a       s1t12b                         s3t12a
```

Supplementary Figure S2: First pass diagram, staple strands with xy labels and explicit bases.



Supplementary Figure S3: First pass diagram, twists displayed as colors for examination of strain.

In the second pass a matrix of adjustments (in nucleotides) is defined:

```
%      C1   C2   C3   C4
design{ADJUSTMENTS} = [
     [0    0    0    0];      % H1
     [0    0    0    0];      % H2
     [0    0    0    0];      % H3
     [0    0    0    0];      % H4
     [1    0    0    1];      % H5
     [1    0    0    1];      % H6
     [0    0    0    0];      % H7
     [0    0    0    0];      % H8
     [0    0    0    0];      % H9
     [0    0    0    0];      % H10
     [0    0    0    0];      % H11
     [0    0    0    0];      % H12
];
```

And the design lengths are updated accordingly.

```
design_lengths =
     C0     C1     C2     C3     C4
     32     16      0      0     16
     32     16      0      0     16
     54     27      0      0     27
     54     27      0      0     27
     76     38      0      0     38
     76     38      0      0     38
     96     48      0      0     48
     96     48      0      0     48
     96     48      0      0     48
     96     48      0      0     48
     96     48      0      0     48
     96     48      0      0     48
```

Supplementary Figure S4: Adjustments to applied during the second pass.

```
 -3                    -2                    -1                      0                       +1                    +2                    +3
     s-3t0b                         s-1t0a       s-1t0b                             s1t0a         s1t0b                         s3t0a
  <        <                       <        ---AGAGGGGC<                           <AATTACGT---        <                        <        <
  >        ---        ---        ---        ---TCTCCCCG---CGCGTTGG-------CCGATTCA---TTAATGCA---        ---        ---         >
 /           <                   <                       <GCGCAACC-------GGCTAAGT<                       <                    <           \
|             s-2t1a  ) (  s-2t1b                         s0t1a             s0t1b                         s2t1a    ) (  s2t1b              |
 \           >                   >                       >GCGTATTG-------AACCTGTC>                       >                    >           /
  <        ---        ---        ---        ---CCGCCAAA---CGCATAAC<     <TTGGACAG---CACGGTCG---        ---        ---         <
           >                       >           GGCGGTTT>           \   /           >GTGCCAGC           >                        >
  (  s-3t2b                         s-1t2a  ) (  s-1t2b             | |             s1t2a   ) (   s1t2b                         s3t2a    )
           <                       <CTTTTCTT   TTTGGTGG<           /   \           <CCTTTCGC   CCGTCACT<                        <
  >        ---        ---     GGT---GAAAAGAA---AAACCACC---CTGGCGCC>     >TCCCGACT---GGAAAGCG---GGCAGTGA---GCG     ---         ---        >
 /           <                CCA<                       <GACCGCGG-------AGGGCTGA<                       <CGC                 <           \
|             s-2t3a  ) (  s-2t3B                         s0t3a             s0t3b                         s2t3A    ) (  s2t3b              |
 \           >                AGT>                       >GATTGCCC-------GTGAGCTA>                       >TTG                 >           /
  <        ---        ---     TCA---CTCTGCCC---GTTGTCGA---CTAACGGG<     <CACTCGAT---TGAGTGTA---ATTAACGC---AAC     ---         ---        <
           >                       >GAGACGGG   CAACAGCT>           \   /           >ACTCACAT   TAATTGCG>                        >
  (  s-3t4b                         s-1t4a  ) (  s-1t4b             | |             s1t4a   ) (   s1t4b                         s3t4a    )
           <                       <TGAGAGAG   TCCCGGTC<           /   \           <GTGGGGTC   CGAAATGT<                        <
  >        ---  GACCGC---TTGCTGCA---ACTCTCTC---AGGGCCAG---GCGGTGAA>     >TCATTAGG---CACCCCAG---GCTTTACA---CTTTATGC---TTCCGG  ---         >
 /           <  CTGGCG   AACGACGT<                       <CGCCACTT-------AGTAATCC<                       <GAAATACG   AAGGCC   <           \
|             s-2t5a  ) (  s-2t5b                         s0t5a             s0t5b                         s2t5a    ) (  s2t5b              |
 \           >  CACGCT   GGTTTGCC>                       >CTGTTTGA-------AAATTGTT>                       >ACACAACA   TACGAG   >           /
  <        ---  GTGCGA---CCAAACGG---GGTCGTCC---GCTTTTAG---GACAAACT<     <TTTAACAA---TAGGCGAG---TGTTAAGG---TGTGTTGT---ATGCTC  ---         <
           >                       >CCAGCAGG   CGAAAATC>           \   /           >ATCCGCTC   ACAATTCC>                        >
  (  s-3t6b                         s-1t6a  ) (  s-1t6b             | |             s1t6a   ) (   s1t6b                         s3t6a    )
   CCGATAAG<                       <TAAAACGG   CTAAAGCC<           /   \           <TTTGTCGA   TACTGGTA<                        <AGCCATGG
  >GGCTATTC---TTTTGATT---TATAAGGG---ATTTTGCC---GATTTCGG---AACCACCA>     >CACACAGG---AAACAGCT---ATGACCAT---GATTACGA---ATTCGAGC---TCGGTACC>
 /           <AAAACTAA   ATATTCCC<                       <TTGGTGGT-------GTGTGTCC<                       <CTAATGCT   TAAGCTCG<            \
|             s-2t7a  ) (  s-2t7b                         s0t7a             s0t7b                         s2t7a    ) (  s2t7b              |
 \           >GGTTGAGT   GTTGTTCC>                       >CCACTATT-------GCCAGTGC>                       >CAGGTCGA   CTCTAGAG>            /
  <GCTCTATC---CCAACTCA---CAACAAGG---TCAAACCT---TGTTCTCA---GGTGATAA<     <CGGTCACG---GTTCGAAC---GTACGGAC---GTCCAGCT---GAGATCTC---CTAGGGGC<
   CGAGATAG>                       >AGTTTGGA   ACAAGAGT>           \   /           >CAAGCTTG   CATGCCTG>                        >GATCCCCG
  (  s-3t8b                         s-1t8a  ) (  s-1t8b             | |             s1t8a   ) (   s1t8b                         s3t8a    )
   GGGACTAT<                       <AACTGCAA   CCTCAGGT<           /   \           <ATGTTGCA   GCACTGAC<                        <TGGGTTGA
  >CCCTGATA---GACGGTTT---TTCGCCCT---TTGACGTT---GGAGTCCA---CGTTCTTT>     >CGTCGTTT---TACAACGT---CGTGACTG---GGAAAACC---CTGGCGTT---ACCCAACT>
 /           <CTGCCAAA   AAGCGGGA<                       <GCAAGAAA-------GCAGCAAA<                       <CCTTTTGG   GACCGCAA<            \
|             s-2t9a  ) (  s-2t9b                         s0t9a             s0t9b                         s2t9a    ) (  s2t9b              |
 \           >CACTACGT   GAACCATC>                       >TTGGGGTC-------TCGCTATT>                       >GGGGGATG   TGCTGCAA>            /
  <GCTACCGG---GTGATGCA---CTTGGTAG---TGGGTTTA---GTTCAAAA---AACCCCAG<     <AGCGATAA---TGCGGTCG---ACCGCTTT---CCCCCTAC---ACGACGTT---CCGCTAAT<
   CGATGGCC>                       >ACCCAAAT   CAAGTTTT>           \   /           >ACGCCAGC   TGGCGAAA>                        >GGCGATTA
  ( s-3t10b                         s-1t10a ) ( s-1t10b             | |             s1t10a  ) (  s1t10b                         s3t10a   )
   TTAGCCCC<                       <GCTAAATC   ACGAAATG<           /   \           <CGTGGCTA   GCGGGAAG<                        <GACTTACC
  >AATCGGGG---GCTCCCTT---TAGGGTTC---CGATTTAG---TGCTTTAC---GGCACCTC>     >AGAGGCCC---GCACCGAT---CGCCCTTC---CCAACAGT---TGCGCAGC---CTGAATGG>
 /           <CGAGGGAA   ATCCCAAG<                       <CCGTGGAG-------TCTCCGGG<                       <GGTTGTCA   ACGCGTCG<            \
|             s-2t11a ) ( s-2t11b                         s0t11a           s0t11b                         s2t11a   ) ( s2t11b              |
 \           >GACGGGGA   AAGCCGGC>                       >GAAGGGAA-------CTTTCCGG>                       >GGAAACCA   GGCAAAGC>            /
  <ATCTCGAA---CTGCCCCT---TTCGGCCG---CTTGCACC---GCTCTTTC---CTTCCCTT<     <GAAAGGCC---GTGGCGAA---GACCACGG---CCTTTGGT---CCGTTTCG---CGGTAAGC<
  >TAGAGCTT>                       >GAACGTGG---CGAGAAAG>                           >CACCGCTT---CTGGTGCC>                        >GCCATTCG<
    s-3t12b                         s-1t12a     s-1t12b                             s1t12a       s1t12b                         s3t12a
```

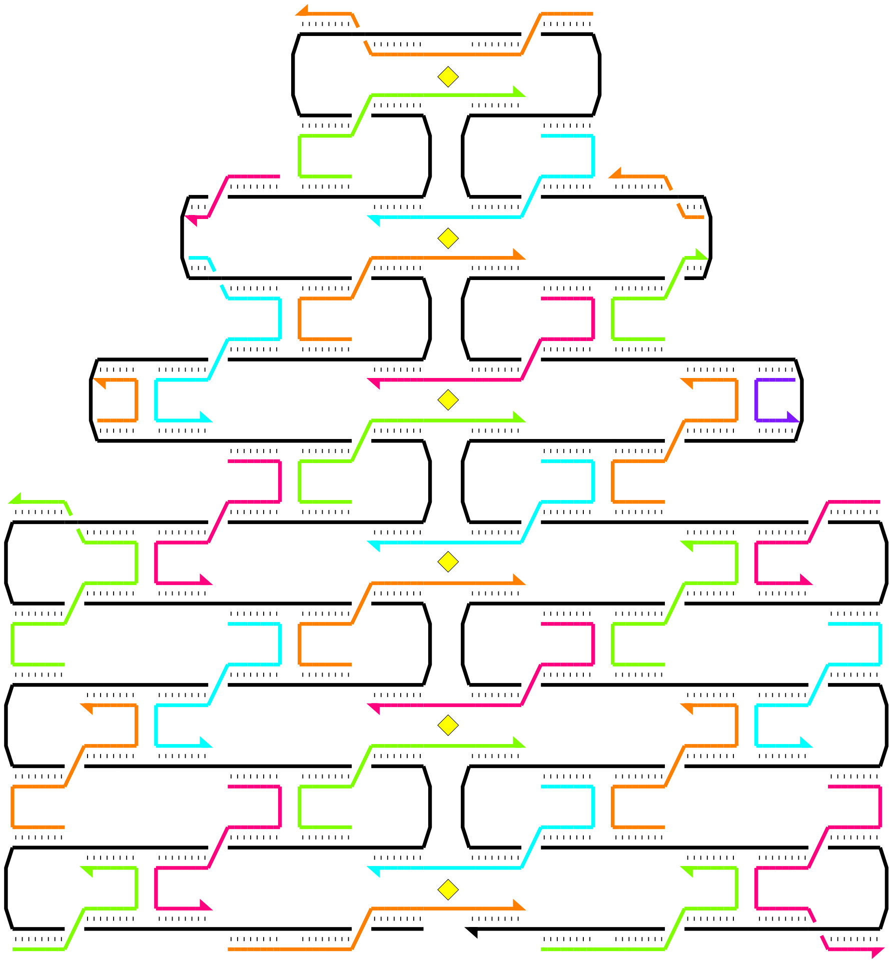
Supplementary Figure S5: Second pass diagram with staple strands before merge.

```
 -3                    -2                    -1                      0                       +1                    +2                    +3
     s-3t0b                         s-1t0a                                          s1t0g         s1t0b                         s3t0a
  <        <                       <        ---AGAGGGGC<                           <AATTACGT---        <                       <        <
  >        ---        ---        ---        ---TCTCCCCG---CGCGTTGG-------CCGATTCA---TTAATGCA---        ---        ---        ---        >
 /           <                   <                       <GCGCAACC-------GGCTAAGT<                       <                   <           \
|             s-2t1a  ) (  s-2t1b                                                                         s2t1a   ) (  s2t1b             |
 \           >                   >                       >GCGTATTG-------AACCTGTC>                       >                   >           /
  <        ---        ---        ---        ---CCGCCAAA---CGCATAAC<     <TTGGACAG---CACGGTCG---        ---        ---        ---        <
           >                       >           GGCGGTTT>           \   /           >GTGCCAGC           >                       >
  (  s-3t2b                         s-1t2e  ) (  s-1t2i             | |             s1t2i   ) (                                 s3t2a   )
           <                       <CTTTTCTT   TTTGGTGG<           /   \           <CCTTTCGC   CCGTCACT<                       <
  >        ---        ---     GGT---GAAAAGAA---AAACCACC---CTGGCGCC>     >TCCCGACT---GGAAAGCG---GGCAGTGA---GCG     ---        ---        >
 /           <                CCA<                       <GACCGCGG-------AGGGCTGA<                       <CGC                <           \
|             s-2t3a  ) (  s-2t3g                                                                         s2t3c   ) (  s2t3b             |
 \           >                AGT>                       >GATTGCCC-------GTGAGCTA>                       >TTG                >           /
  <        ---        ---     TCA---CTCTGCCC---GTTGTCGA---CTAACGGG<     <CACTCGAT---TGAGTGTA---ATTAACGC---AAC     ---        ---        <
           >                       >GAGACGGG   CAACAGCT>           \   /           >ACTCACAT   TAATTGCG>                       >
  (  s-3t4b                                 ) (  s-1t4i             | |             s1t4i   ) (   s1t4f                         s3t4a   )
           <                       <TGAGAGAG   TCCCGGTC<           /   \           <GTGGGGTC   CGAAATGT<                       <
  >        ---  GACCGC---TTGCTGCA---ACTCTCTC---AGGGCCAG---GCGGTGAA>     >TCATTAGG---CACCCCAG---GCTTTACA---CTTTATGC---TTCCGG  ---        >
 /           <  CTGGCG   AACGACGT<                       <CGCCACTT-------AGTAATCC<                       <GAAATACG   AAGGCC  <           \
|             s-2t5a  ) (                                                                                                 ) (  s2t5b             |
 \           >  CACGCT   GGTTTGCC>                       >CTGTTTGA-------AAATTGTT>                       >ACACAACA   TACGAG  >           /
  <        ---  GTGCGA---CCAAACGG---GGTCGTCC---GCTTTTAG---GACAAACT<     <TTTAACAA---TAGGCGAG---TGTTAAGG---TGTGTTGT---ATGCTC  ---        <
           >                       >CCAGCAGG   CGAAAATC>           \   /           >ATCCGCTC   ACAATTCC>                       >
  (                                 s-1t6e  ) (  s-1t6i             | |             s1t6i   ) (   s1t6f                         s3t6e   )
   CCGATAAG<                       <TAAAACGG   CTAAAGCC<           /   \           <TTTGTCGA   TACTGGTA<                       <AGCCATGG
  >GGCTATTC---TTTTGATT---TATAAGGG---ATTTTGCC---GATTTCGG---AACCACCA>     >CACACAGG---AAACAGCT---ATGACCAT---GATTACGA---ATTCGAGC---TCGGTACC>
 /           <AAAACTAA   ATATTCCC<                       <TTGGTGGT-------GTGTGTCC<                       <CTAATGCT   TAAGCTCG<           \
|                     ) (                                                                                         ) (                    |
 \           >GGTTGAGT   GTTGTTCC>                       >CCACTATT-------GCCAGTGC>                       >CAGGTCGA   CTCTAGAG>           /
  <GCTCTATC---CCAACTCA---CAACAAGG---TCAAACCT---TGTTCTCA---GGTGATAA<     <CGGTCACG---GTTCGAAC---GTACGGAC---GTCCAGCT---GAGATCTC---CTAGGGGC<
   CGAGATAG>                       >AGTTTGGA   ACAAGAGT>           \   /           >CAAGCTTG   CATGCCTG>                       >GATCCCCG
  (  s-3t8g                         s-1t8e  ) (  s-1t8i             | |             s1t8i   ) (   s1t8f                         s3t8e   )
   GGGACTAT<                       <AACTGCAA   CCTCAGGT<           /   \           <ATGTTGCA   GCACTGAC<                       <TGGGTTGA
  >CCCTGATA---GACGGTTT---TTCGCCCT---TTGACGTT---GGAGTCCA---CGTTCTTT>     >CGTCGTTT---TACAACGT---CGTGACTG---GGAAAACC---CTGGCGTT---ACCCAACT>
 /           <CTGCCAAA   AAGCGGGA<                       <GCAAGAAA-------GCAGCAAA<                       <CCTTTTGG   GACCGCAA<           \
|                     ) (                                                                                         ) (                    |
 \           >CACTACGT   GAACCATC>                       >TTGGGGTC-------TCGCTATT>                       >GGGGGATG   TGCTGCAA>           /
  <GCTACCGG---GTGATGCA---CTTGGTAG---TGGGTTTA---GTTCAAAA---AACCCCAG<     <AGCGATAA---TGCGGTCG---ACCGCTTT---CCCCCTAC---ACGACGTT---CCGCTAAT<
   CGATGGCC>                       >ACCCAAAT   CAAGTTTT>           \   /           >ACGCCAGC   TGGCGAAA>                       >GGCGATTA
  ( s-3t10f                         s-1t10e ) ( s-1t10i             | |             s1t10i  ) (  s1t10f                         s3t10g  )
   TTAGCCCC<                       <GCTAAATC   ACGAAATG<           /   \           <CGTGGCTA   GCGGGAAG<                       <GACTTACC
  >AATCGGGG---GCTCCCTT---TAGGGTTC---CGATTTAG---TGCTTTAC---GGCACCTC>     >AGAGGCCC---GCACCGAT---CGCCCTTC---CCAACAGT---TGCGCAGC---CTGAATGG>
 /           <CGAGGGAA   ATCCCAAG<                       <CCGTGGAG-------TCTCCGGG<                       <GGTTGTCA   ACGCGTCG<           \
|                     ) (                                                                                         ) (                    |
 \           >GACGGGGA   AAGCCGGC>                       >GAAGGGAA-------CTTTCCGG>                       >GGAAACCA   GGCAAAGC>           /
  <ATCTCGAA---CTGCCCCT---TTCGGCCG---CTTGCACC---GCTCTTTC---CTTCCCTT<     <GAAAGGCC---GTGGCGAA---GACCACGG---CCTTTGGT---CCGTTTCG---CGGTAAGC<
  >TAGAGCTT>                       >GAACGTGG---CGAGAAAG>                           >CACCGCTT---CTGGTGCC>                       >GCCATTCG<
    s-3t12f                         s-1t12j                                         s1t12g
```

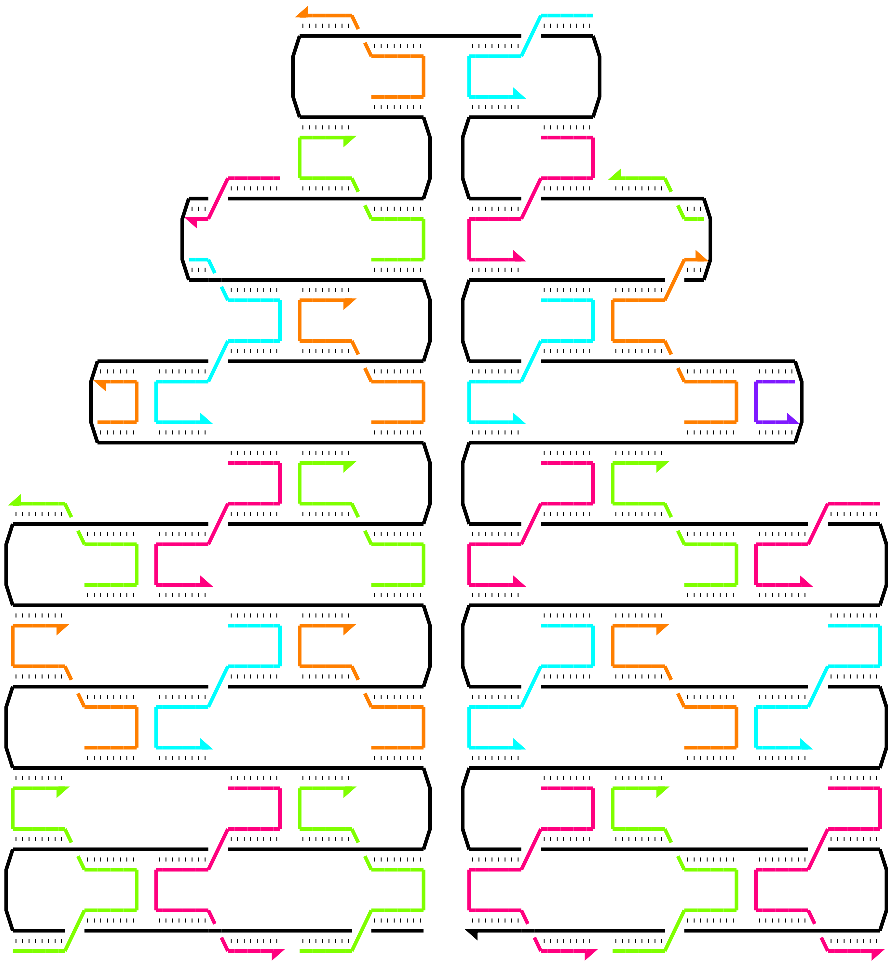
Supplementary Figure S6: Third pass diagram with staple strands after merge (bridged seam).

```
 3                     2                      1                      0                        1                     2                     3
    s-3t0b                         s-1t0a                                           s1t0e         s1t0b                         s3t0a
 <        <                        <       ---AGAGGGGC<                            <AATTACGT---        <                       <        <
 >        ---        ---        ---        ---TCTCCCCG---CGCGTTGG-------CCGATTCA---TTAATGCA---         ---        ---        ---        >
/           <                   <                       <GCGCAACC-------GGCTAAGT<                        <                   <           \
|            s-2t1a  ) (  s-2t1b                         s0t1f                                            s2t1a   ) (   s2t1b             |
\           >                   >                       >GCGTATTG-------AACCTGTC>                        >                   >           /
 <        ---        ---        ---        ---CCGCCAAA---CGCATAAC<      <TTGGACAG---CACGGTCG---        ---        ---        ---        <
          >                        >          GGCGGTTT>            \   /           >GTGCCAGC           >                       >
 (  s-3t2b                         s-1t2e  ) (                      | |             s1t2e   ) (                                 s3t2a   )
          <                        <CTTTTCTT   TTTGGTGG<           /   \           <CCTTTCGC   CCGTCACT<                       <
 >        ---        ---     GGT---GAAAAGAA---AAACCACC---CTGGCGCC>      >TCCCGACT---GGAAAGCG---GGCAGTGA---GCG     ---        ---        >
/           <                CCA<                       <GACCGCGG-------AGGGCTGA<                        <CGC                <           \
|            s-2t3a  ) (  s-2t3g                         s0t3f                                            s2t3c   ) (   s2t3b             |
\           >                AGT>                       >GATTGCCC-------GTGAGCTA>                        >TTG                >           /
 <        ---        ---     TCA---CTCTGCCC---GTTGTCGA---CTAACGGG<      <CACTCGAT---TGAGTGTA---ATTAACGC---AAC     ---        ---        <
          >                        >GAGACGGG   CAACAGCT>           \   /           >ACTCACAT   TAATTGCG>                       >
 (  s-3t4b                                 ) (                      | |             s1t4e   ) (                                 s3t4a   )
          <                        <TGAGAGAG   TCCCGGTC<           /   \           <GTGGGGTC   CGAAATGT<                       <
 >        ---  GACCGC---TTGCTGCA---ACTCTCTC---AGGGCCAG---GCGGTGAA>      >TCATTAGG---CACCCCAG---GCTTTACA---CTTTATGC---TTCCGG  ---        >
/           <  CTGGCG   AACGACGT<                       <CGCCACTT-------AGTAATCC<                        <GAAATACG   AAGGCC  <           \
|            s-2t5a  ) (                                 s0t5f                                            s2t5g   ) (   s2t5b             |
\           >  CACGCT   GGTTTGCC>                       >CTGTTTGA-------AAATTGTT>                        >ACACAACA   TACGAG  >           /
 <        ---  GTGCGA---CCAAACGG---GGTCGTCC---GCTTTTAG---GACAAACT<      <TTTAACAA---TAGGCGAG---TGTTAAGG---TGTGTTGT---ATGCTC  ---        <
          >                        >CCAGCAGG   CGAAAATC>           \   /           >ATCCGCTC   ACAATTCC>                       >
 (                                 s-1t6e  ) (                      | |             s1t6e   ) (                                 s3t6e   )
  CCGATAAG<                        <TAAAACGG   CTAAAGCC<           /   \           <TTTGTCGA   TACTGGTA<                       <AGCCATGG
 >GGCTATTC---TTTTGATT---TATAAGGG---ATTTTGCC---GATTTCGG---AACCACCA>      >CACACAGG---AAACAGCT---ATGACCAT---GATTACGA---ATTCGAGC---TCGGTACC>
/           <AAAACTAA   ATATTCCC<                       <TTGGTGGT-------GTGTGTCC<                        <CTAATGCT   TAAGCTCG<           \
|            s-2t7f  ) (                                 s0t7f                                            s2t7f   ) (                     |
\           >GGTTGAGT   GTTGTTCC>                       >CCACTATT-------GCCAGTGC>                        >CAGGTCGA   CTCTAGAG>           /
 <GCTCTATC---CCAACTCA---CAACAAGG---TCAAACCT---TGTTCTCA---GGTGATAA<      <CGGTCACG---GTTCGAAC---GTACGGAC---GTCCAGCT---GAGATCTC---CTAGGGGC<
  CGAGATAG>                        >AGTTTGGA   ACAAGAGT>           \   /           >CAAGCTTG   CATGCCTG>                       >GATCCCCG
 (                                 s-1t8e  ) (                      | |             s1t8e   ) (                                 s3t8e   )
  GGGACTAT<                        <AACTGCAA   CCTCAGGT<           /   \           <ATGTTGCA   GCACTGAC<                       <TGGGTTGA
 >CCCTGATA---GACGGTTT---TTCGCCCT---TTGACGTT---GGAGTCCA---CGTTCTTT>      >CGTCGTTT---TACAACGT---CGTGACTG---GGAAAACC---CTGGCGTT---ACCCAACT>
/           <CTGCCAAA   AAGCGGGA<                       <GCAAGAAA-------GCAGCAAA<                        <CCTTTTGG   GACCGCAA<           \
|            s-2t9f  ) (                                 s0t9f                                            s2t9f   ) (                     |
\           >CACTACGT   GAACCATC>                       >TTGGGGTC-------TCGCTATT>                        >GGGGGATG   TGCTGCAA>           /
 <GCTACCGG---GTGATGCA---CTTGGTAG---TGGGTTTA---GTTCAAAA---AACCCCAG<      <AGCGATAA---TGCGGTCG---ACCGCTTT---CCCCCTAC---ACGACGTT---CCGCTAAT<
  CGATGGCC>                        >ACCCAAAT   CAAGTTTT>           \   /           >ACGCCAGC   TGGCGAAA>                       >GGCGATTA
 (                                 s-1t10f ) (                      | |             s1t10g  ) (                                 s3t10g  )
  TTAGCCCC<                        <GCTAAATC   ACGAAATG<           /   \           <CGTGGCTA   GCGGGAAG<                       <GACTTACC
 >AATCGGGG---GCTCCCTT---TAGGGTTC---CGATTTAG---TGCTTTAC---GGCACCTC>      >AGAGGCCC---GCACCGAT---CGCCCTTC---CCAACAGT---TGCGCAGC---CTGAATGG>
/           <CGAGGGAA   ATCCCAAG<                       <CCGTGGAG-------TCTCCGGG<                        <GGTTGTCA   ACGCGTCG<           \
|                    ) (                                                                                          ) (                     |
\           >GACGGGGA   AAGCCGGC>                       >GAAGGGAA-------CTTTCCGG>                        >GGAAACCA   GGCAAAGC>           /
 <ATCTCGAA---CTGCCCCT---TTCGGCCG---CTTGCACC---GCTCTTTC---CTTCCCTT<      <GAAAGGCC---GTGGCGAA---GACCACGG---CCTTTGGT---CCGTTTCG---CGGTAAGC<
 >TAGAGCTT>                        >GAACGTGG---CGAGAAAG>                           >CACCGCTT---CTGGTGCC>                       >GCCATTCG<
   s-3t12g                                     s-1t12g                                           s1t12g
```

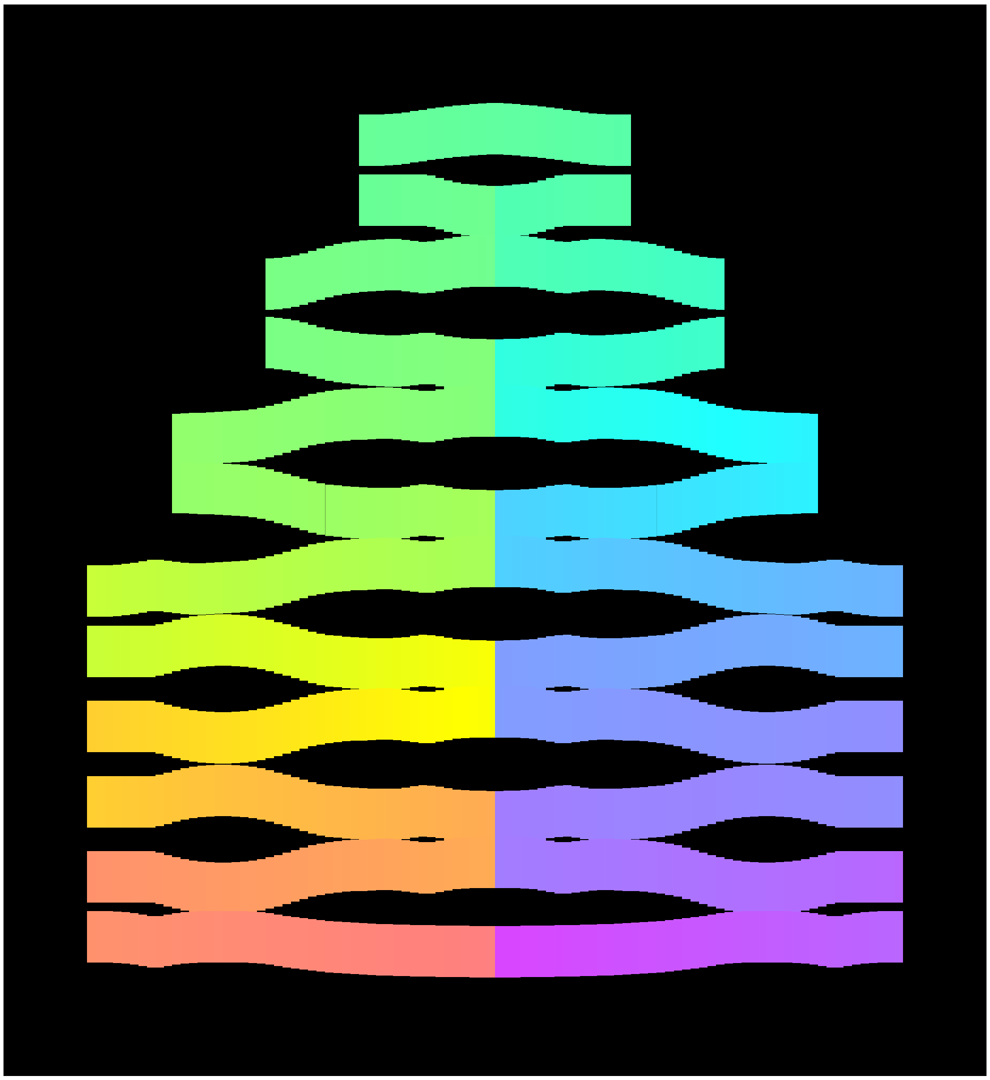
Supplementary Figure S7: Third pass diagram with staple strands after merge (unbridged seam).



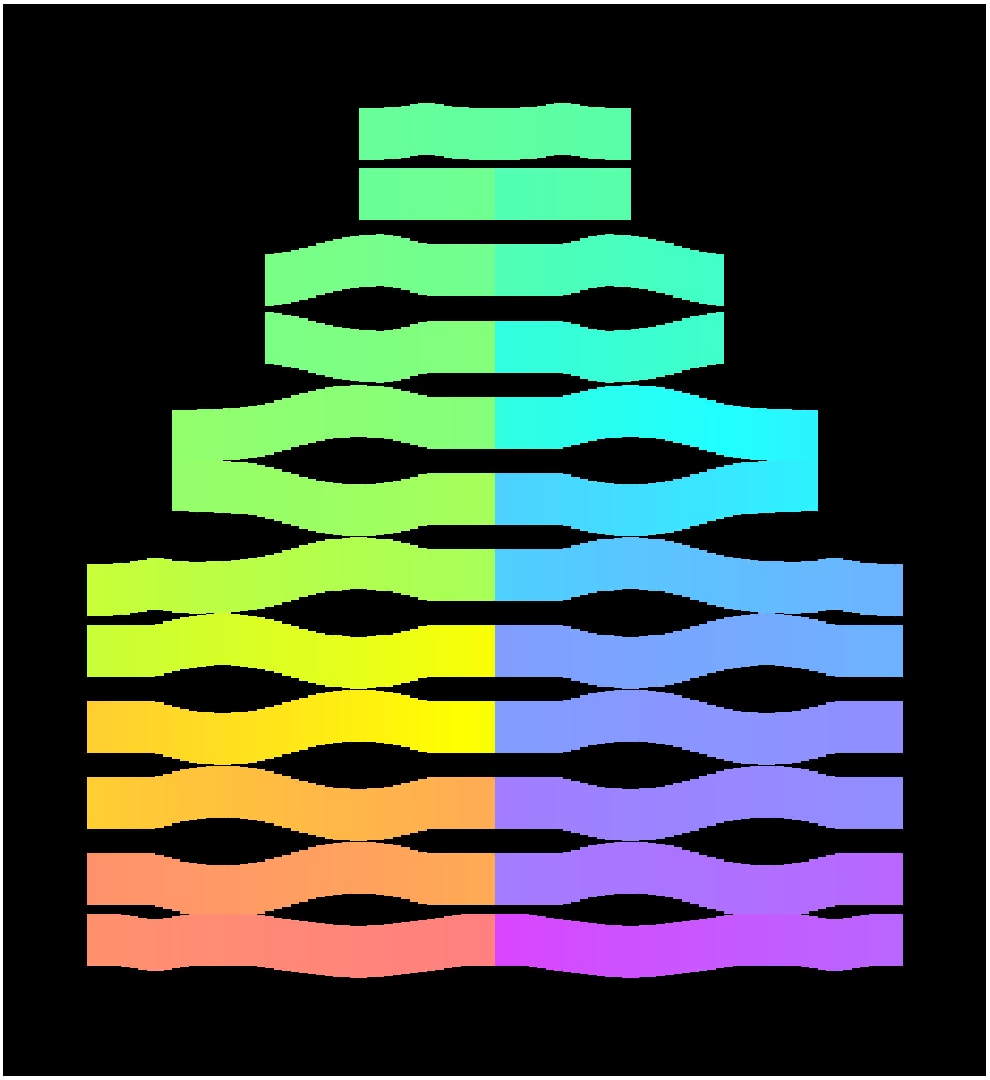
Supplementary Figure S8: Third pass diagram with staple strands after staggered merge.



Supplementary Figure S9: Third pass diagram with staple strands after rectilinear merge.

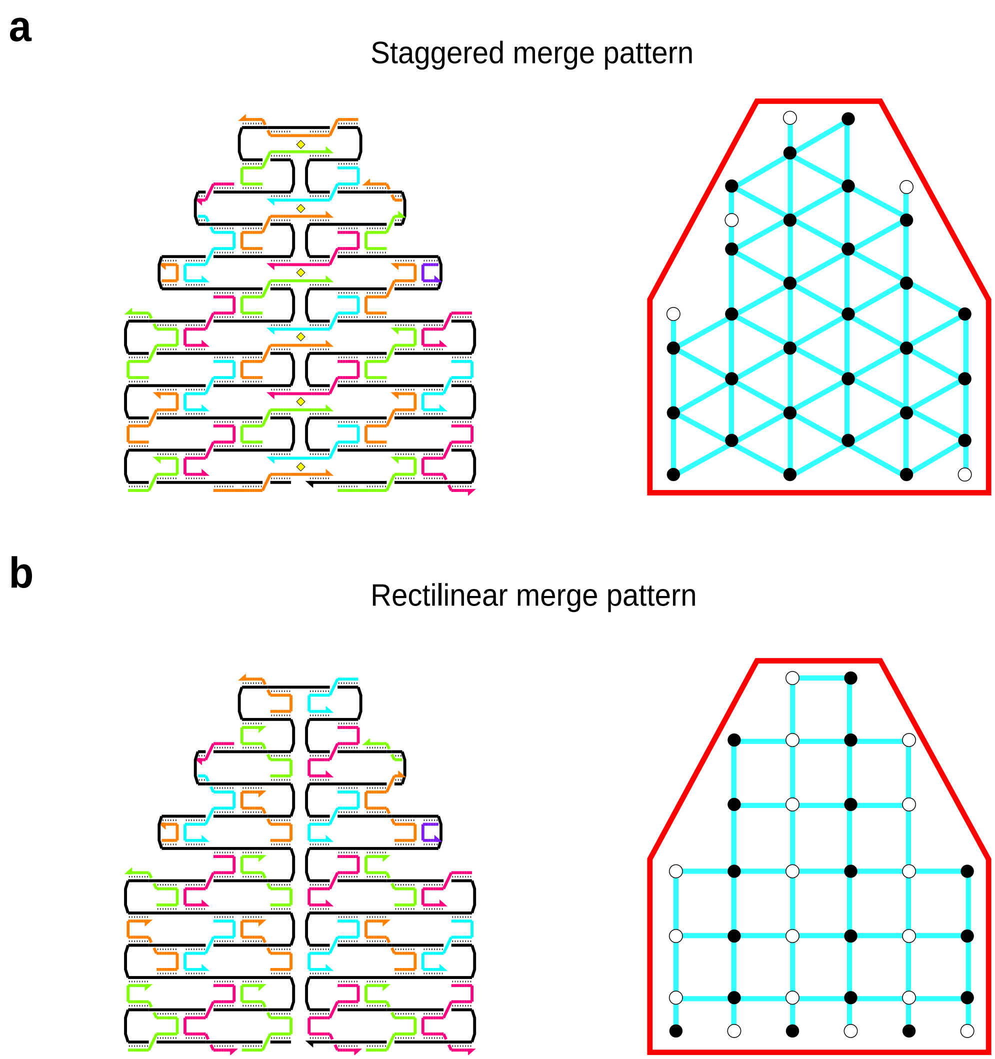


Supplementary Figure S10: Crossover diagram of bridged design.



Supplementary Figure S11: Crossover diagram of unbridged design.

a



Supplementary Figure S12: Different patterns of merges yield different types of grids for any pixel pattern. Black dots indicate merges made on the top face of the structure, white dots indicate merges made on the bottom face. To create a '1' pixel a hairpin is added at the position of one of the merges. Special cases on the edge of the shape are not normally used for pixels. **a** A staggered pattern of merges. In this case all modifications made to the middle of a staple strand fall on the same face of the lattice. **b** A rectilinear pattern of merges. In this case a modifications made to the middle of a staple strand fall on alternating faces of the lattice, depending on the column in which they occur. While the structure in **a** has a bridged seam, and the structure in **b** has an unbridged seam, the basic pattern of merges is independent of whether or not the seam is bridged.

Supplementary Note S2: Effects of inter-helix gaps and DNA bending on the length and width of DNA nanostructures

When the first planar DNA nanostructures based on parallel double helical domains were made (DNA tile lattices based on double-crossover molecules[25]) a few assumptions were made about their structure. It was assumed (1) that the helices would be lie close-packed and (2) that the helices would be be without bends. Implicit in these assumptions were two more: (3) the length of DNA nanostructures with parallel helices (measured perpendicular to the helices) was assumed to be given by $2h$ nanometers where h is the number of helices and (4) the width was assumed to be $.34n$ nanometers where n was the number of nucleotides in the structure. Here I review what has been learned about these assumptions. (1) turns out to be incorrect, at least for structures imaged by AFM on mica under buffer. Because of this, (2) appears to be incorrect and (3) is not a good approximation for the length (top to bottom) of a DNA nanostructure. While (4) is probably inexact it turns out to remain a useful approximation for the width of a DNA nanostructure.

When a DNA nanostructure with parallel helices bound by together crossovers is imaged by AFM, the result does not model a series of close-packed cylinders. Instead, AFM seems to reveal gaps between helices, typically 1-2 nm wide, whose position and length follow the pattern of crossovers in the underlying structure. Wherever two helices have a crossover, no gap is observed; a few nanometers away from a crossover, an inter-helix gap is observed.

The source of the inter-helix gap is unknown, it may be electrostatic repulsion between helices (as first, to my knowledge, suggested by Rizal Hariadi), or detailed geometry of the crossovers (free crossovers, when not constrained by adjacent crossovers in a multi-crossover molecule, assume an angle of approximately 60 degrees[32, 33]). It remains for the gap to be measured on different substrates, or in solution, or by a different imaging technique such as TEM, or for it to be measured as a function of salt concentration which might be expected to change the gap by changing the screening of electrostatic interactions.

Whatever the source, the width of the gap appears to depend on the spacing of crossovers: here origami with 16 nt spacing (about 1.5 turns) between crossovers have a $\sim$1 nm gap, origami with 26 nt spacing (about 2.5 turns) appear to have a $\sim$1.5 nm gap. I note that the relationship between crossover spacing and gap width is not yet proven. Here, all structures with 2.5-turn spacing have one pattern of nicks—that of Fig. 1c—that yields staples that connect only 2 helical domains; on the other hand, all structures with 1.5 turn spacing have a pattern of nicks—that of Fig. 1e that connect 3 helical domains. Thus it is possible that 2.5-turn spacing structure with a nick pattern like that of Fig. 1e might have a different spacing than the 2.5-turn structures explored here. To test whether the pattern of nicks has an effect one could re-render the 2.5-turn spacing square with 3-helix spanning staple strands as in Fig. 1e.

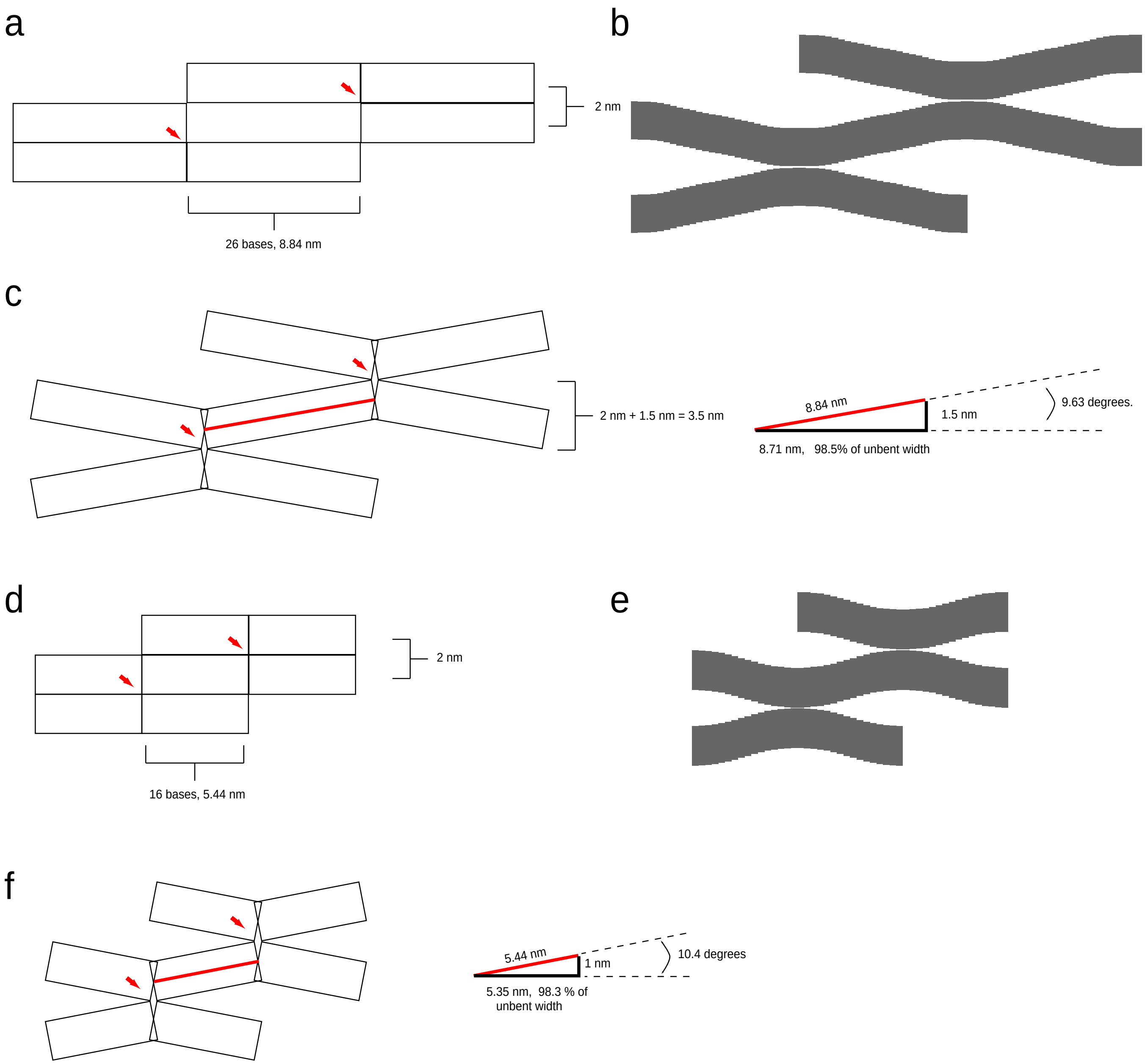
Because the interhelix gap appears to set the aspect ratio of DNA nanostructures constructed from parallel helices, we can use it to attempt to engineer the length and width of DNA origami. With an estimate of the gap in hand, it is simple to design DNA origami with a desired *length* (if a roughly periodic pattern of crossovers is used): the length of the structure should be $2h + (h-1)g$ nm where h is the number of 2 nm wide helices and g is the inter-helix gap. Lengths measured by AFM are typically within 5% of the predicted length by this formula; it assumed that this error is caused by AFM drift or miscalibration. Note that the formula predicts lengths roughly 50% and 75% greater than those that would be predicted assuming close-packed helices.

Given an estimate of the inter-helix gap, it would seem *a priori* more difficult to estimate or design the *width* of a DNA origami. To create the inter-helix gap it appears the DNA helices must bend back and forth between the crossovers in which they participate. If one assumes that the contour length of a helix of DNA does not change as it bends and follows a curve, then the end to end distance of a DNA helix following such a curve must be shorter than the end to end distance of a straight helix of the same number of nucleotides. That is, to get a correct estimate for the width of an origami, one must take the bend into account.

However, very little is known about the nature of the bending. So far, few AFM images of DNA have a resolution high enough for the contour of the helix to be traced explicity and so it seems there is not enough data to model it accurately. Exactly what curve is followed by the helix is probably affected by electrostatic repulsion between the DNA backbones, mechanics of DNA bending, the amount of supercoiling between crossovers, and detailed geometry of the junctions. In the schematic drawing of DNA origami (row 2, Fig. 2) I give a cartoon version of the bending that seeks to reproduce structures seen in AFM images based on the pattern of crossovers in the design. Zooms of the curve used, (based on the sums of exponentials that decay away from crossovers) are giving in Supplementary Fig. S13b and e. There is no reason to believe that these curves are physically accurate.

As a very rough estimate of the change in width due to helix bending, close-packed versions of the 2.5 turn spacing and 1.5 turn spacing lattices (Supplementary Fig. S13 a and d) were deformed by bending the helical domains between crossovers an amount appropriate to create the inter-helix gap ($\approx$10 degrees). The projection of these bent domains on the x-axis was then calculated and taken as the new width between crossover. The width between crossovers changed less than -2% in both cases (Supplementary Fig. S13 c and f), because of the small angles involved. I note that because I use 32 nt to cover 3 helical turns in the 1.5 turn spacing designs, the DNA in most designs is overtwisted (relative to 10.5 bases/turn) by 1.5%. Thus it is possible that relaxation of supercoiling might have a compensatory effect (relative to the effect of bending) on the width of DNA origami. (On the other hand, 52 bases are used to cover 5 turns in the 2.5 turn spacing designs and they are 1% undertwisted with respect to 10.5 bases/turn.)

Finally, the experimental widths of DNA origami are typically within 10% of that predicted using the $.34n$ nanometers approximation. Thus while helix bending appears to happen to accomodate the inter-helix gap, the width of structures is predicted by the formula $.34n$ nanometers to within AFM error.

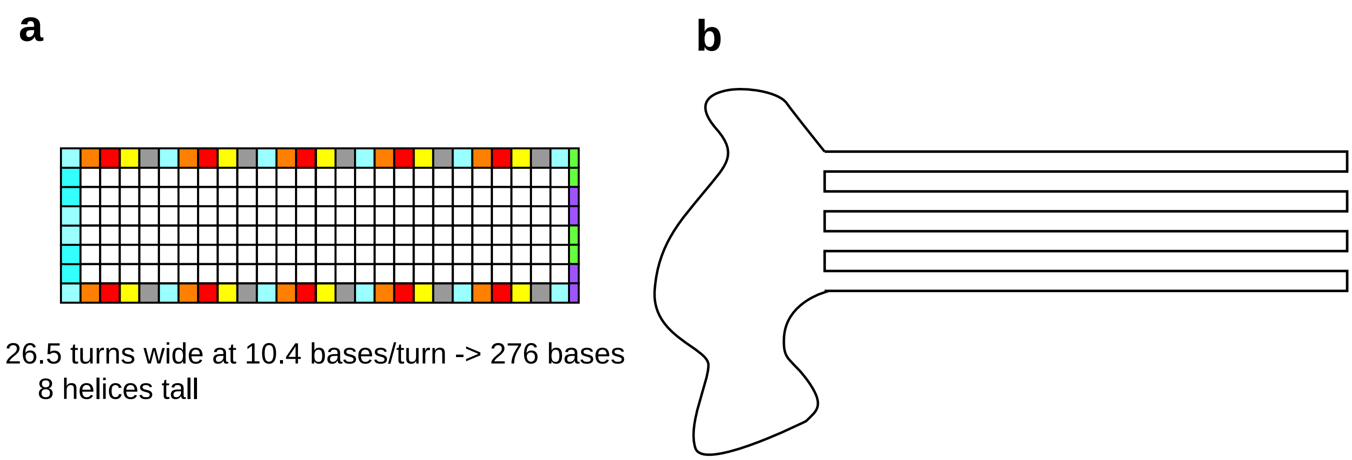


Supplementary Figure S13: A figure that suggests that the effect of helix bending between crossovers contributes little to the width of a DNA origami.

Supplementary Note S3: Designs and sequences

In this note, for all large designs I include: (1) a block diagram and reproduction of the folding path (2) an enlargement of the schematics used to diagram the effects of crossover position on helix bending as in Fig. 2, row 2 and (3) the list of sequences used. A few comments:

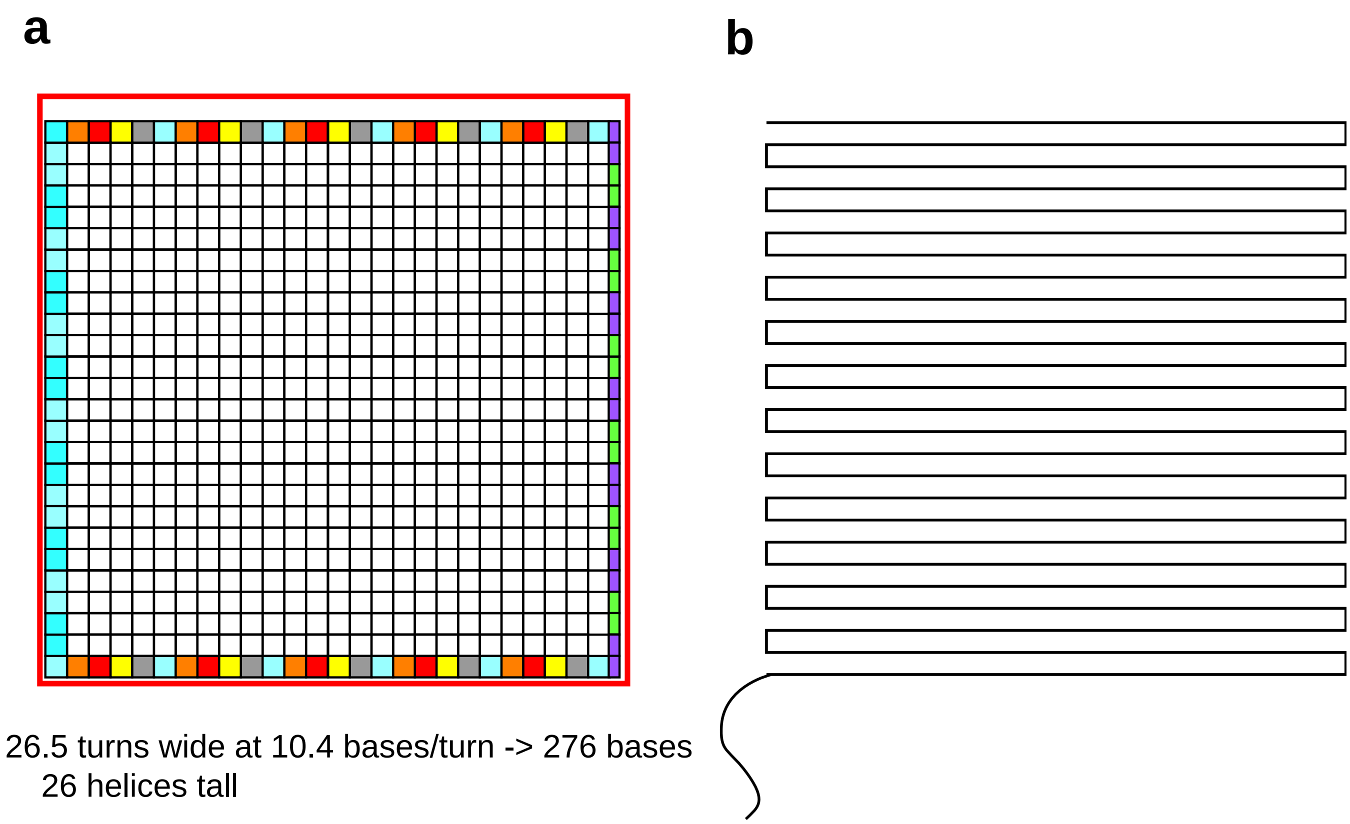
1. **Because they are very large and do not print well, the full designs with staple and scaffold sequences explicitly written out appear in a separate file as Supplementary Note 12, not here.**
2. For the 1/3 square, the crossover diagram is not included but is similar to that for the full square.
3. For the smiley and star I include high-resolution AFM that correponds well to the crossover models for comparison. For the smiley I inlude a model of how smileys can maximize stacking interactions.
4. For the tall rectangle, two different crossover diagrams are given, one for a bridged seam, and one for the unbridged seam (as used in Fig. 3e–i).
5. At the end of this note the full sequence of the New England Biolabs clone of M13mp18 used in this paper is included (Supplementary Fig. S39). The sequence is unpublished and appears to be available only from the NEB web site.



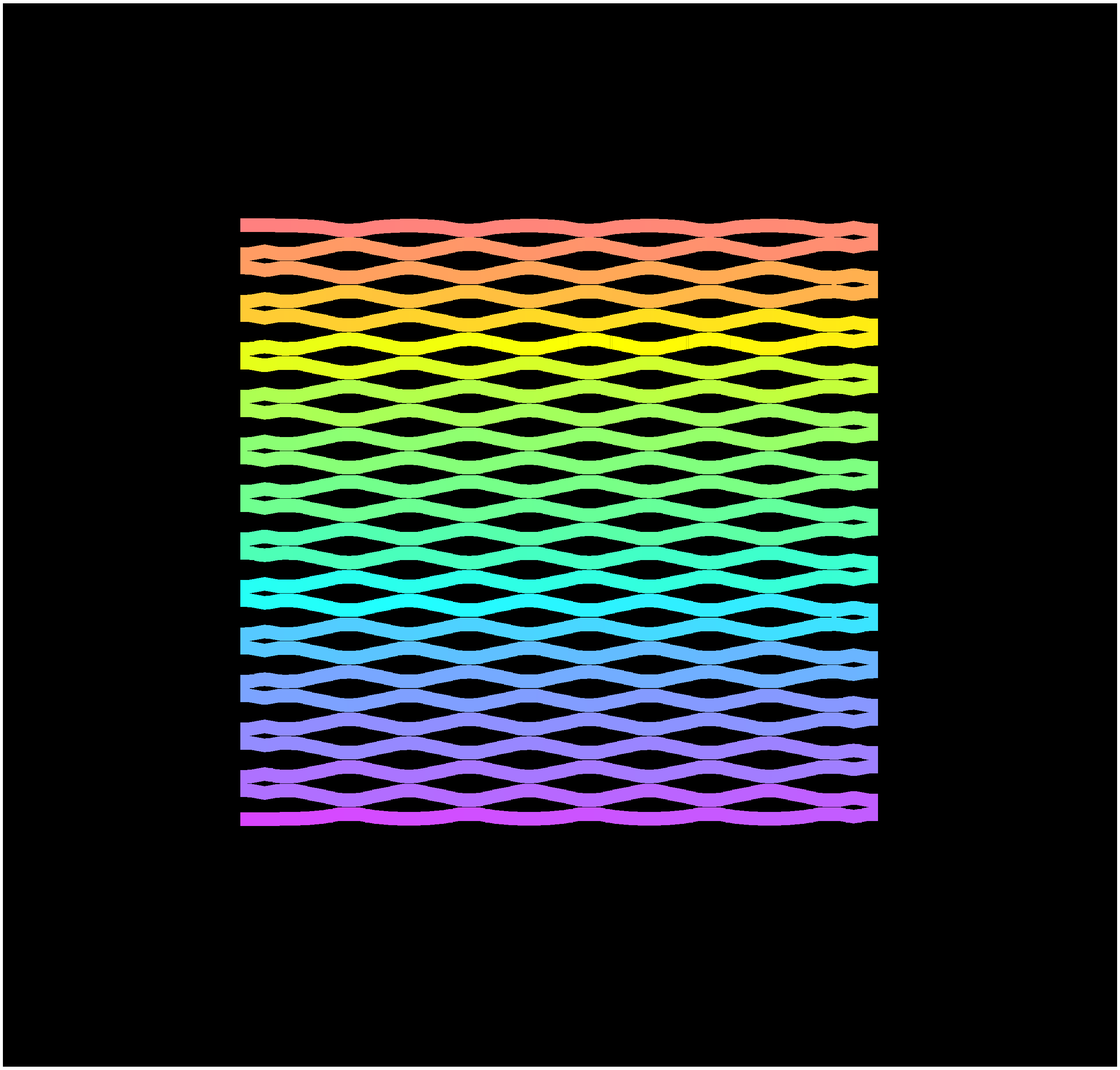
Supplementary Figure S14: Schematics for $\sim 1/3$ of the square (8 helices) in Fig. 2a used in the first origami experiments (Supplemental Note S5.3). **a** Block diagram. Designed for 2.5-turn spacing blocks have 5 different offsets with respect to the underlying lattice of crossovers, hence the 5 different hues of blocks in different columns. As in other block diagrams, orange block/red block boundaries have an offset of 0 turns with respect to the underlying lattice of crossovers. **b** Folding path. A circular scaffold is used.

```
1y_1C; GAGCCCCCGATTTAGAGCTTGACGGG
x3y_1C; CAAGTTTTTTGGGGTCGAGGTGCCGT
x5y_1C; CGAAAAACCGTCTATCAGGGCGATGG
x7y_1C; AGTTTGGAACAAGAGTCCACTATTAA
x9y_1C; AATCGGCAAAATCCCTTATAAATCAAAAGAATAG

x0y0A; CTGGGGTGCCTAATGAGTGAGCGTGGCGAGAAAGGAAGGGAA
x0y0B; GAAAGCCGGCGAACTAACTCACATTA
x2y0A; CCAGTCGGGAAACGGAACCCTAAAGG
x2y0B; AAAGCACTAAATCCTGTCGTGCCAGC
x4y0A; GGGAGAGGCGGTTCCATCACCCAAAT
x4y0B; CCCACTACGTGAATGCGTATTGGGCG
x6y0A; GAGACGGGCAACACAACGTCAAAGGG
x6y0B; AGAACGTGGACTCGCTGATTGCCCTT
x8y0A; GCAAGCGGTCCACTGAGTGTTGTTCC
x8y0B; CCCGAGATAGGGTGCTGGTTTGCCCC

x1y1A; ATTGCGTTGCGCTCTCACAATTCCAC
x1y1B; AAATTGTTATCCGCACTGCCCGCTTT
x3y1A; TGCATTAATGAATCTCGAATTCGTAA
x3y1B; CCCGGGTACCGAGCGGCCAACGCGCG
x5y1A; CCAGGGTGGTTTTTGCCAAGCTTGCA
x5y1B; AAACGACGGCCAGTCTTTTCACCAGT
x7y1A; CACCGCCTGGCCCGTTGGGTAACGCC
x7y1B; GCAAGGCGATTAATGAGAGAGTTGCA
x9y1A; AGCAGGCGAAAATTCTTCGCTATTAC
x9y1B; GAAGGGCGATCGGTGCGGGCCCCTGTTTGATGGTGGTTCCGA

x0y2A; CGCGTCTGGCCTTCCTGTAGCCGGAAGCATAAAGTGTAAAGC
x0y2B; ACAACATACGAGCCAGCTTTCATCAA
x2y2A; GTCGGATTCTCCGTGTTTCCTGTGTG
x2y2B; TCATGGTCATAGCTGGGAACAAACGG
x4y2A; CGTTGGTGTAGATACTCTAGAGGATC
x4y2B; TGCCTGCAGGTCGGGGCGCATCGTAA
x6y2A; GACGACAGTATCGTCACGACGTTGTA
x6y2B; AGGGTTTTCCCAGGCCTCAGGAAGAT
x8y2A; GCTTCTGGTGCCGAGGGGGATGTGCT
x8y2B; GCCAGCTGGCGAAGAAACCAGGCAAA

x1y3A; CATTAAATGTGAGTAAATCAGCTCAT
x1y3B; ATTAAATTTTTGTCGAGTAACAACCC
x3y3A; CGGATTGACCGTATATTTAAATTGTA
x3y3B; TTGTATAAGCAAAATGGGATAGGTCA
x5y3A; CCGTGCATCTGCCCCCCGGTTGATAA
x5y3B; TCAATCATATGTAAGTTTGAGGGGAC
x7y3A; CGCACTCCAGCCAACAAGAGAATCGA
x7y3B; GAGTCTGGAGCAAGCTTTCCGGCACC
x9y3A; GCGCCATTCGCCATTTTGAGAGATCT
x9y3B; AATGCCGGAGAGGGTAGCTATTTCAGGCTGCGCAACTGTTGG

x0y4A; CAATAAATCATACAGGCAAGGGGAACGCCATCAAAAATAATT
x0y4B; TTTTTAACCAATACAAAGAATTAGCA
x2y4A; TAAAGCTAAATCGTGTTAAAATTCGC
x2y4B; AACGTTAATATTTGTTGTACCAAAAA
x4y4A; GGAGAAGCCTTTAAAAAACAGGAAGA
x4y4B; TCAGAAAAGCCCCTTTCAACGCAAGG
x6y4A; TTTTAAATGCAATTAAAACTAGCATG
x6y4B; TGAACGGTAATCGGCCTGAGTAATGT
x8y4A; AAGGCCGGAGACAGGTCATTGCCTGA
x8y4B; ACAAAGGCTATCAGTCAAATCACCAT

x1y5A; AAATTAAGCAATAGCTGAAAAGGTGG
x1y5B; ATTTGGGGCGCGAAAGCCTCAGAGCA
x3y5A; CATTATGACCCTGATTTCGCAAATGG
x3y5B; GACCATTAGATACTAATACTTTTGCG
x5y5A; ATAAAAATTTTTACAGTTGATTCCCA
x5y5B; TCATTCCATATAAGAACCCTCATATA
x7y5A; GTAGGTAAAGATTTGTTTTAAATATG
x7y5B; CTGTAGCTCAACACAAAAGGGTGAGA
x9y5A; CAATATGATATTCTTTTGCGGATGGC
x9y5B; CTCCTTTTGATAAGAGGTCATAACCGTTCTAGCTGATAAATT

x0y6A; ATGTTTAGACTGGATAGCGTCAATAGTAGTAGCATTAACATC
x0y6B; CATCAATTCTACTCAATACTGCGGAA
x2y6A; CTCAAATGCTTTATAGCTATATTTTC
x2y6B; TCAATAACCTGTTAACAGTTCAGAAA
x4y6A; AGGTCTTTACCCTGTAGATTTAGTTT
x4y6B; ATTCTGCGAACGAGACTATTATAGTC
x6y6A; GATTAAGAGGAAGGTGTCTGGAAGTT
x6y6B; CAACTAAAGTACGCCCGAAAGACTTC
x8y6A; AAAGCGAACCAGAGCTGAATATAATG
x8y6B; TTAGAGCTTAATTCCGGAAGCAAACT

x1y7C; TCGTCATAAATATTCATTGAATCCCC
x3y7C; ACGAGAATGACCATAAATCAAAAATC
x5y7C; AGAAGCAAAGCGGATTGCATCAAAAA
x7y7C; AAATATCGCGTTTTAATTCGAGCTTC
x9y7C; CCAACAGGTCAGGATTAGAGAGTACCTTTAATTG
```

Supplementary Figure S15: Strands used to create $\sim 1/3$ of a square.



Supplementary Figure S16: Schematics for the square in Fig. 2a. **a** Block diagram. Designed for 2.5-turn spacing, blocks have 5 different offsets with respect to the underlying lattice of crossovers, hence the five different hues of blocks in different columns. As in other block diagrams, orange block/red block boundaries have an offset of 0 turns with respect to the underlying lattice of crossovers. The red square highlights our prediction for how well the design is expected to approximate a square. **b** Folding path.



Supplementary Figure S17: Crossover induced structure of square.

1y_1C; GAGCCCCCGATTTAGAGCTTGACGGG
x3y_1C; CAAGTTTTTTGGGGTCGAGGTGCCGT
x5y_1C; CGAAAAACCGTCTATCAGGGCGATGG
x7y_1C; AGTTTGGAACAAGAGTCCACTATTAA
x9y_1C; AATCGGCAAAATCCCTTATAAATCAAAAGAATAG

x0y0A; CTGGGGTGCCTAATGAGTGAGCGTGGCGAGAAAGGAAGGGAA
x0y0B; GAAAGCCGGCGAACTAACTCACATTA
x2y0A; CCAGTCGGGAAACGGAACCCTAAAGG
x2y0B; AAAGCACTAAATCCTGTCGTGCCAGC
x4y0A; GGGAGAGGCGGTTCCATCACCCAAAT
x4y0B; CCCACTACGTGAATGCGTATTGGGCG
x6y0A; GAGACGGGCAACACAACGTCAAAGGG
x6y0B; AGAACGTGGACTCGCTGATTGCCCTT
x8y0A; GCAAGCGGTCCACTGAGTGTTGTTCC
x8y0B; CCCGAGATAGGGTGCTGGTTTGCCCC

x1y1A; ATTGCGTTGCGCTCTCACAATTCCAC
x1y1B; AAATTGTTATCCGCACTGCCCGCTTT
x3y1A; TGCATTAATGAATCTCGAATTCGTAA
x3y1B; CCCGGGTACCGAGCGGCCAACGCGCG
x5y1A; CCAGGGTGGTTTTTGCCAAGCTTGCA
x5y1B; AAACGACGGCCAGTCTTTTCACCAGT
x7y1A; CACCGCCTGGCCCGTTGGGTAACGCC
x7y1B; GCAAGGCGATTAATGAGAGAGTTGCA
x9y1A; AGCAGGCGAAAATTCTTCGCTATTAC
x9y1B; GAAGGGCGATCGGTGCGGGCCCCTGTTTGATGGTGGTTCCGA

x0y2A; CGCGTCTGGCCTTCCTGTAGCCGGAAGCATAAAGTGTAAAGC
x0y2B; ACAACATACGAGCCAGCTTTCATCAA
x2y2A; GTCGGATTCTCCGTGTTTCCTGTGTG
x2y2B; TCATGGTCATAGCTGGGAACAAACGG
x4y2A; CGTTGGTGTAGATACTCTAGAGGATC
x4y2B; TGCCTGCAGGTCGGGGCGCATCGTAA
x6y2A; GACGACAGTATCGTCACGACGTTGTA
x6y2B; AGGGTTTTCCCAGGCCTCAGGAAGAT
x8y2A; GCTTCTGGTGCCGAGGGGGATGTGCT
x8y2B; GCCAGCTGGCGAAGAAACCAGGCAAA

x1y3A; CATTAAATGTGAGTAAATCAGCTCAT
x1y3B; ATTAAATTTTTGTCGAGTAACAACCC
x3y3A; CGGATTGACCGTATATTTAAATTGTA
x3y3B; TTGTATAAGCAAAATGGGATAGGTCA
x5y3A; CCGTGCATCTGCCCCCCGGTTGATAA
x5y3B; TCAATCATATGTAAGTTTGAGGGGAC
x7y3A; CGCACTCCAGCCAACAAGAGAATCGA
x7y3B; GAGTCTGGAGCAAGCTTTCCGGCACC
x9y3A; GCGCCATTCGCCATTTTGAGAGATCT
x9y3B; AATGCCGGAGAGGGTAGCTATTTCAGGCTGCGCAACTGTTGG

x0y4A; CAATAAATCATACAGGCAAGGGGAACGCCATCAAAAATAATT
x0y4B; TTTTTAACCAATACAAAGAATTAGCA
x2y4A; TAAAGCTAAATCGTGTTAAAATTCGC
x2y4B; AACGTTAATATTTGTTGTACCAAAAA
x4y4A; GGAGAAGCCTTTAAAAAACAGGAAGA
x4y4B; TCAGAAAAGCCCCTTTCAACGCAAGG
x6y4A; TTTTAAATGCAATTAAAACTAGCATG
x6y4B; TGAACGGTAATCGGCCTGAGTAATGT
x8y4A; AAGGCCGGAGACAGGTCATTGCCTGA
x8y4B; ACAAAGGCTATCAGTCAAATCACCAT

x1y5A; AAATTAAGCAATAGCTGAAAAGGTGG
x1y5B; ATTTGGGGCGCGAAAGCCTCAGAGCA
x3y5A; CATTATGACCCTGATTTCGCAAATGG
x3y5B; GACCATTAGATACTAATACTTTTGCG
x5y5A; ATAAAAATTTTTACAGTTGATTCCCA
x5y5B; TCATTCCATATAAGAACCCTCATATA
x7y5A; GTAGGTAAAGATTTGTTTTAAATATG
x7y5B; CTGTAGCTCAACACAAAAGGGTGAGA
x9y5A; CAATATGATATTCTTTTGCGGATGGC
x9y5B; CTCCTTTTGATAAGAGGTCATAACCGTTCTAGCTGATAAATT

x0y6A; ATGTTTAGACTGGATAGCGTCAATAGTAGTAGCATTAACATC
x0y6B; CATCAATTCTACTCAATACTGCGGAA
x2y6A; CTCAAATGCTTTATAGCTATATTTTC
x2y6B; TCAATAACCTGTTAACAGTTCAGAAA
x4y6A; AGGTCTTTACCCTGTAGATTTAGTTT
x4y6B; ATTCTGCGAACGAGACTATTATAGTC
x6y6A; GATTAAGAGGAAGGTGTCTGGAAGTT
x6y6B; CAACTAAAGTACGCCCGAAAGACTTC
x8y6A; AAAGCGAACCAGAGCTGAATATAATG
x8y6B; TTAGAGCTTAATTCCGGAAGCAAACT

x1y7A; TCGTCATAAATATCGAGAGGCTTTTG
x1y7B; AAAACCAAAATAGTCATTGAATCCCC
x3y7A; ACGAGAATGACCAAGCAACACTATCA
x3y7B; GAGGCATAGTAAGTAAATCAAAAATC
x5y7A; AGAAGCAAAGCGGATTCAACTAATGC
x5y7B; TTAGGAATACCACATTGCATCAAAAA
x7y7A; AAATATCGCGTTTACAACATTATTAC
x7y7B; ACGAACTAACGGATAATTCGAGCTTC
x9y7A; CCAACAGGTCAGGCCAGTCAGGACGT
x9y7B; TTTAAGAACTGGCTCATTATAATTAGAGAGTACCTTTAATTG

x0y8A; CCGGAACGAGGCGCAGACGGTGCCAGAGGGGGTAATAGTAAA
x0y8B; CAAAAGAAGTTTTCAATCATAAGGGA
x2y8A; ACAGATGAACGGTCCAGACGACGATA
x2y8B; TAACCCTCGTTTAGTACAGACCAGGC
x4y8A; AGTAATCTTGACACAAAAGGAATTAC
x4y8B; AGATACATAACGCAGAACCGGATATT
x6y8A; TGCTCATTCAGTGCATCAGTTGAGAT
x6y8B; AGGTAGAAAGATTAATAAGGCTTGCC
x8y8A; TAAATTGGGCTTGCTACGTTAATAAA
x8y8B; TGGGAAGAAAAATAGATGGTTTAATT

x1y9A; ACCGAACTGACCAGCCTGATAAATTG
x1y9B; GATTTGTATCATCACTTTGAAAGAGG
x3y9A; GCATAGGCTGGCTCCCAGCGATTATA
x3y9B; CTCATCTTTGACCGACCTTCATCAAG
x5y9A; CATTACCCAAATCCAACCTAAAACGA
x5y9B; ACTACGAAGGCACAACGTAACAAAGC
x7y9A; CTGACGAGAAACATGAGGAAGTTTCC
x7y9B; AAAGACTTTTTCACCAGAACGAGTAG
x9y9A; TCAACTTTAATCAGGAACGAGGGTAG
x9y9B; TCAGCAGCGAAAGACAGCATCTTGTGAATTACCTTATGCGAT

x0y10A; AACTTTCAACAGTTTCAGCGGGACCTGCTCCATGTTACTTAG
x0y10B; TGTCGAAATCCGCAGTGAGAATAGAA
x2y10A; ATAATTTTTTCACAAAGTACAACGGA
x2y10B; CCAAGCGCGAAACGTTGAAAATCTCC
x4y10A; TAATTGTATCGGTATACACTAAAACA
x4y10B; AAGAGGCAAAAGATTATCAGCTTGCT
x6y10A; GATACCGATAGTTAATACGTAATGCC
x6y10B; ATTAAACGGGTAAGCGCCGACAATGA
x8y10A; ATATATTCGGTCGGGCTTTGAGGACT
x8y10B; CAACGGCTACAGACTGAGGCTTGCAG

x1y11A; AGGAACAACTAAATTTCCAGACGTTA
x1y11B; AAGTTTTGTCGTCGGAATTGCGAATA
x3y11A; AAAAAAAAGGCTCCATTCCACAGACA
x3y11B; ACAACGCCTGTAGCAAAAGGAGCCTT
x5y11A; TTCGAGGTGAATTCATGTACCGTAAC
x5y11B; CCCAATAGGAACCTCTTAAACAGCTT
x7y11A; CAACAACCATCGCACCCTCAGAGCCA
x7y11B; CCTCAGAACCGCCCCACGCATAACCG
x9y11A; GGAGTTAAAGGCCACTCAGGAGGTTT
x9y11B; CCGGAATAGGTGTATCACCGTGCTTTTGCGGGATCGTCACCC

x0y12A; GGAAAGCGCAGTCTCTGAATTCTGTATGGGATTTTGCTAAAC
x0y12B; GTAAATGAATTTTTACCGTTCCAGTA
x2y12A; CAGGAGTGTACTGGCGTAACGATCTA
x2y12B; GCCCTCATAGTTAGTAATAAGTTTTA
x4y12A; GCCCGTATAAACAACCAGTACAAACT
x4y12B; ACTGAGTTTCGTCGTTAATGCCCCCT
x6y12A; AACATGAAAGTATCAGGGATAGCAAG
x6y12B; CCACCCTCATTTTTAAGAGGCTGAGA
x8y12A; CGGGGTTTTGCTCTCAGAACCGCCAC
x8y12B; AGTACCGCCACCCAGTACCAGGCGGA

x1y13A; AGCGTCATACATGTTGGCCTTGATAT
x1y13B; GCAGGTCAGACGAGCTTTTGATGATA
x3y13A; ACGGGGTCAGTGCCACCACCAGAGCC
x3y13B; CCGCCACCAGAACCTTGAGTAACAGT
x5y13A; GCCTATTTCGGAACCCTCAGAACCGC
x5y13B; CTCAGAGCCGCCACCTATTATTCTGA
x7y13A; CTCCTCAAGAGAAAAAATCACCGGAA
x7y13B; TCTTTTCATAATCGGATTAGGATTAG
x9y13A; TAAGTGCCGTCGACGGCATTTTCGGT
x9y13B; CAGACTGTAGCGCGTTTTCATGAGGGTTGATATAAGTATAGC

x0y14A; TTATTTTGTCACAATCAATAGAATCCTCATTAAAGCCAGAAT
x0y14B; TCACAAACAAATAAAAATTCATATGG
x2y14A; GACATTCAACCGAACAGGAGGTTGAG
x2y14B; GCCGCCAGCATTGTTGAGGGAGGGAA
x4y14A; TAAAGGTGAATTAACCACCCTCAGAG
x4y14B; CACCCTCAGAGCCTCACCGTCACCGA
x6y14A; GCAAAATCACCAGCGGAACCGCCTCC
x6y14B; CCAGAGCCACCACTAGCACCATTACC
x8y14A; TGAAACCATCGATTTAGCGTTTGCCA
x8y14B; CATAGCCCCCTTAAGCAGCACCGTAA

x1y15A; TTTACCAGCGCCAAAAGGTGGCAACA
x1y15B; AAAATACATACATAAGACAAAAGGGC
x3y15A; GGTAAATATTGACATTAAGACTCCTT
x3y15B; AAGAACTGGCATGGGAAATTATTCAT
x5y15A; CTTGAGCCATTTGAAGGAAACCGAGG
x5y15B; ACAAAGTTACCAGGGAATTAGAGCCA
x7y15A; ATTAGCAAGGCCGTACCGAAGCCCTT
x7y15B; GCAATAGCTATCTGAAACGTCACCAA
x9y15A; TCAGTAGCGACAGGAGTTAAGCCCAA
x9y15B; GAGAGATAACCCACAAGAATTAATCAAGTTTGCCTTTAGCGT

x0y16A; AATCAAGATTAGTTGCTATTTCAAAGACACCACGGAATAAGT
x0y16B; TATAAAAGAAACGTGCACCCAGCTAC
x2y16A; TAACGAGCGTCTTTTAGCAAACGTAG
x2y16B; ATTACGCAGTATGTCCAGAGCCTAAT
x4y16A; ATTATTTATCCCAACGGAATACCCAA
x4y16B; AAACGCAATAATAATCCAAATAAGAA
x6y16A; GAAAATAGCAGCCAGCAGATAGCCGA
x6y16B; TTTAAGAAAAGTATTTACAGAGAGAA
x8y16A; GACGGGAGAATTAAAACAATGAAATA
x8y16B; TAATAAGAGCAAGACTGAACACCCTG

x1y17A; AATTTTATCCTGAAGGCGTTTTAGCG
x1y17B; TTCTAAGAACGCGATCTTACCAACGC
x3y17A; TTGCCAGTTACAACAATAGCAAGCAA
x3y17B; TCATTACCGCGCCAATAAACAGCCAT
x5y17A; ACGATTTTTTGTTTCGAGAACAAGCA
x5y17B; AGTACCGCACTCATAACGTCAAAAAT
x7y17A; TAACATAAAAACACTGTCTTTCCTTA
x7y17B; AATCAATAATCGGGGGAAGCGCATTA
x9y17A; AACAAAGTCAGAGAAATAATATCCCA
x9y17B; TAGATAAGTCCTGAACAAGAAGGTAATTGAGCGCTAATATCA

x0y18A; AATAAGAATAAACACCGGAATGCGGGAGGTTTTGAAGCCTTA
x0y18B; AACCTCCCGACTTCATAATTACTAGA
x2y18A; TATACAAATTCTTGGCTTATCCGGTA
x2y18B; ATCAGATATAGAAACCAGTATAAAGC
x4y18A; AGAATCGCCATATTTCATCGTAGGAA
x4y18B; AGCCGTTTTTATTTTAACAACGCCAA
x6y18A; GAGCCAGTAATAAGGGTATTAAACCA
x6y18B; TCATTCCAAGAACGAGAATATAAAGT
x8y18A; CCAGACGACGACAGCATGTAGAAACC
x8y18B; TCCTAATTTACGAATAAACAACATGT

x1y19A; AAAAGCCTGTTTATAAATTTAATGGT
x1y19B; TCATCTTCTGACCGTATCATATGCGT
x3y19A; CAACGCTCAACAGGAACGCGAGAAAA
x3y19B; ATCGCAAGACAAATAGGGCTTAATTG
x5y19A; CATGTAATTTAGGTGGGTTATATAAC
x5y19B; CTCCGGCTTAGGTCAGAGGCATTTTC
x7y19A; ACCGACAAAAGGTTTTATCAAAATCA
x7y19B; AGTCAATAGTGAAAAAGTAATTCTGT
x9y19A; TCAGCTAATGCAGTGAAAACATAGCG
x9y19B; TTAATTTTCCCTTAGAATCCTAACGCGCCTGTTTATCAACAA

x0y20A; TTTAACGTCAGATGAATATACCGTGTGATAAATAAGGCGTTA
x0y20B; TTGAAATACCGACAGTAACAGTACCT
x2y20A; TTCGCCTGATTGCATTTTAGTTAATT
x2y20B; CTTTTTCAAATATTTTGAATACCAAG
x4y20A; TTCATTTCAATTATGATGCAAATCCA
x4y20B; TATATGTAAATGCCCTGAGCAAAAGA
x6y20A; CAAAATTAATTACCTACCTTTTTAAC
x6y20B; TAGGTCTGAGAGAATTTAACAATTTC
x8y20A; CAGTACATAAATCAGACGCTGAGAAG
x8y20B; ATAGCTTAGATTAAATATATGTGAGT

x1y21A; TTTACATCGGGAGTTATTTGCACGTA
x1y21B; TACCATATCAAAAAAACAATAACGGA
x3y21A; TTACAAAATCGCGGTTTGGATTATAC
x3y21B; TATAATCCTGATTCAGAGGCGAATTA
x5y21A; AGATGATGAAACACATCATATTCCTG
x5y21B; GGAGCGGAATTATAACATCAAGAAAA
x7y21A; ATTTGAATTACCTGTAACATTATCAT
x7y21B; TTTAAAAGTTTGATTTTTAATGGAAA
x9y21A; GAATAACCTTGCTGACAACTCGTATT
x9y21B; ATTAGACTTTACAAACAATTCTCTGTAAATCGTCGCTATTAA

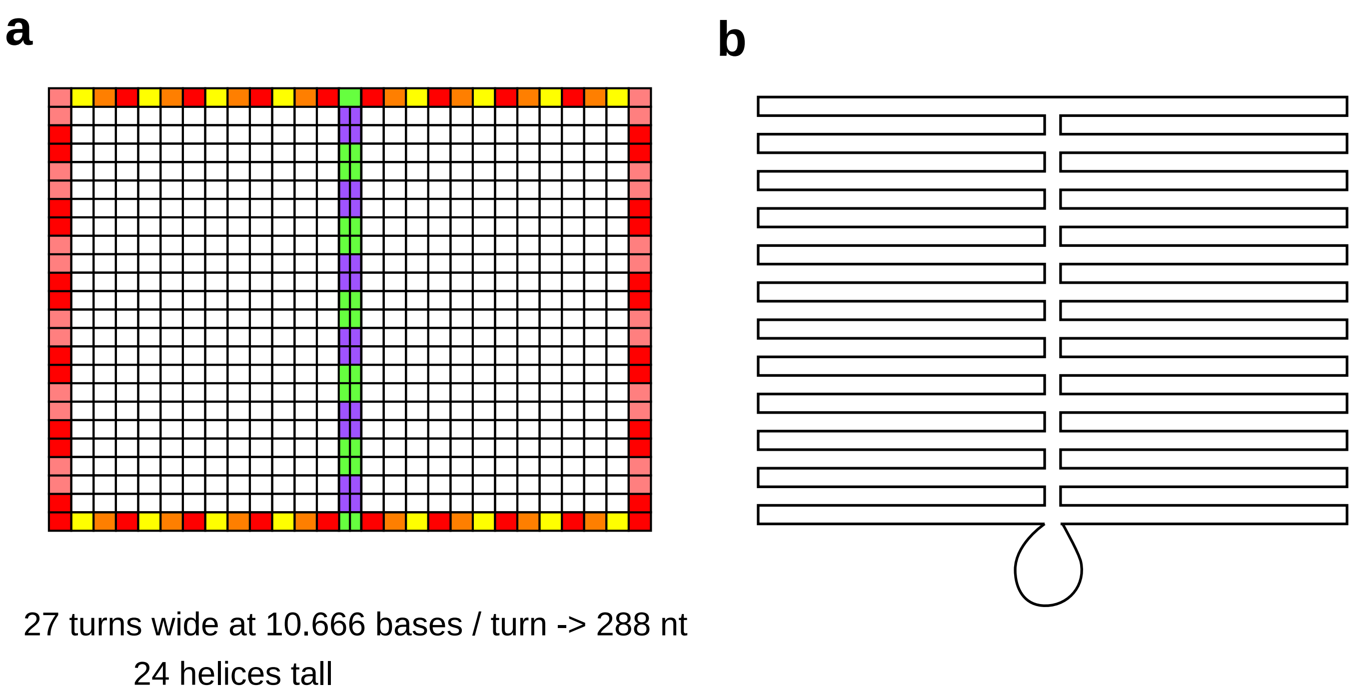
x0y22A; AATACCGAACGAACCACCAGCGAAATTGCGTAGATTTTCAGG
x0y22B; AAACAGAAATAAAAGAAGATAAAACA
x2y22A; GCCTGCAACAGTGAAGGGTTAGAACC
x2y22B; TTCTGAATAATGGCCACGCTGAGAGC
x4y22A; TCACCTTGCTGAAGGCAATTCATCAA
x4y22B; ATTATCAGATGATCCTCAAATATCAA
x6y22A; GCAAATCAACAGTGAAACCACCAGAA
x6y22B; TTTGCGGAACAAATGAAAGGAATTGA
x8y22A; AGCACTAACAACTGAACGTTATTAAT
x8y22B; AAATCCTTTGCCCAATAGATTAGAGC

x1y23A; GAGGTGAGGCGGTTTAGTCTTTAATG
x1y23B; TTTTGAATGGCTACAGTATTAACACC
x3y23A; CAGCAGCAAATGACTGACCTGAAAGC
x3y23B; AGATAGAACCCTTAAAATCTAAAGCA
x5y23A; ACCCTCAATCAATTCACACGACCAGT
x5y23B; GCAGATTCACCAGATCTGGTCAGTTG
x7y23A; GGAAGGTTATCTATTTTGACGCTCAA
x7y23B; GGAAATACCTACAAAATATCTTTAGG
x9y23A; CGTCAATAGATAAAATATTACCGCCA
x9y23B; CTTGCTGGTAATATCCAGAACTACATTTGAGGATTTAGAAGT

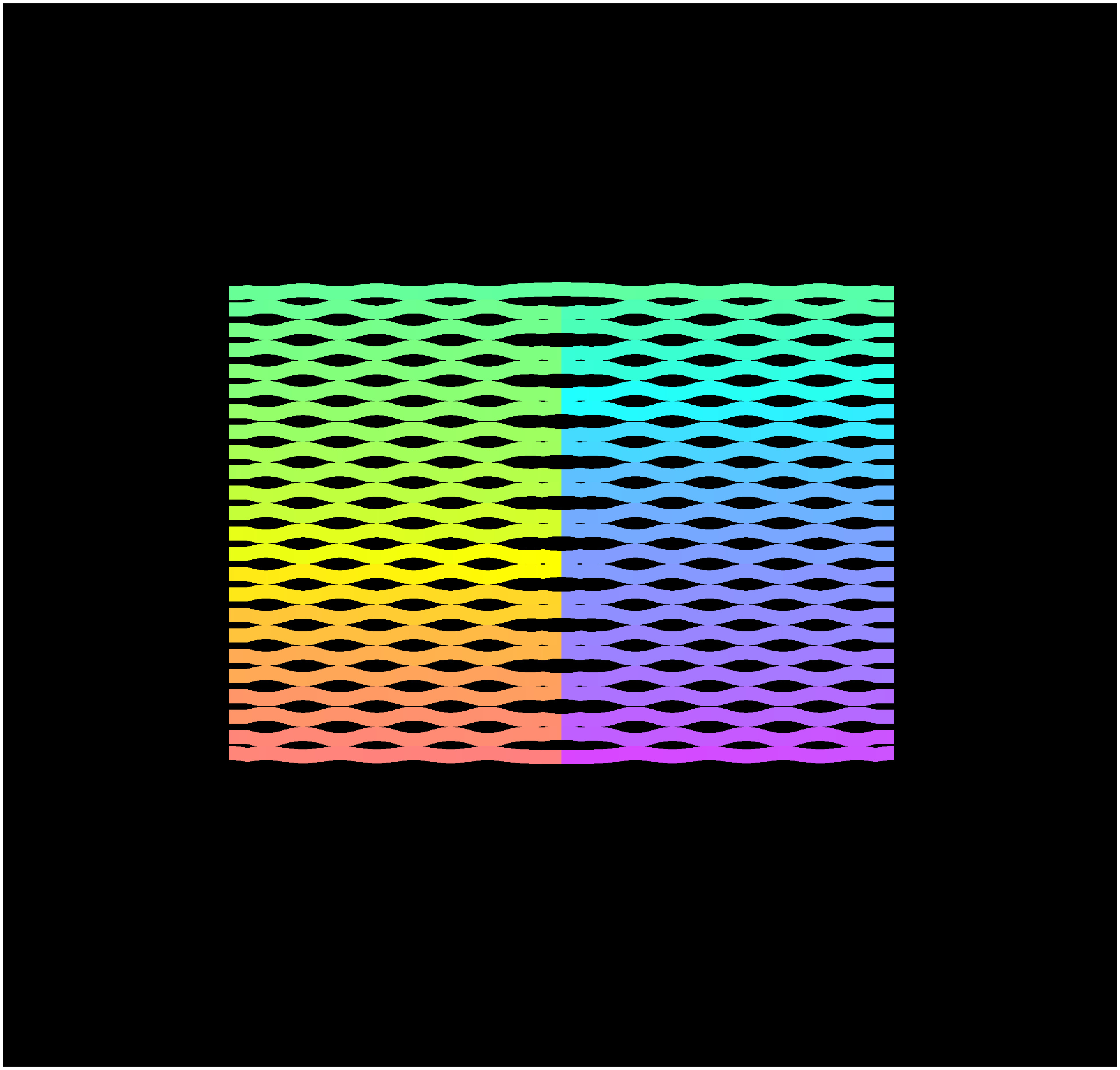
x0y24A; GCGCTTAATGCGCCGCTACAGCCCTAAAACATCGCCATTAAA
x0y24B; CGCGAACTGATAGGGCGCGTACTATG
x2y24A; GCTTTCCTCGTTAGCACAGACAATAT
x2y24B; GTAGAATACGTGGAATCAGAGCGGG
x4y24A; ATTTTAGACAGGATTCTGGCCAACAG
x4y24B; AATAAAAGGGACAACGGTACGCCAGA
x6y24A; TGAGGCCACCGAGATTATTTACATTG
x6y24B; TCGTCTGAAATGGTAAAAGAGTCTGT
x8y24A; AATACTTCTTTGAGAAAAACGCTCAT
x8y24B; GCCATTGCAACAGTTAGTAATAACAT

x1y25C; GTTGCTTTGACGAGCACGTATAACGT
x3y25C; AGCTAAACAGGAGGCCGATTAAAGGG
x5y25C; ATCCTGAGAAGTGTTTTTATAATCAG
x7y25C; CCATCACGCAAATTAACCGTTGTAGC
x9y25C; CACTTGCCTGAGTAGAAGAACTCAAACTATCGGC

Supplementary Figure S18: Sequences for the square.



Supplementary Figure S19: Schematics for the rectangle Fig. 2b. **a** Block diagram. **b** Folding path.



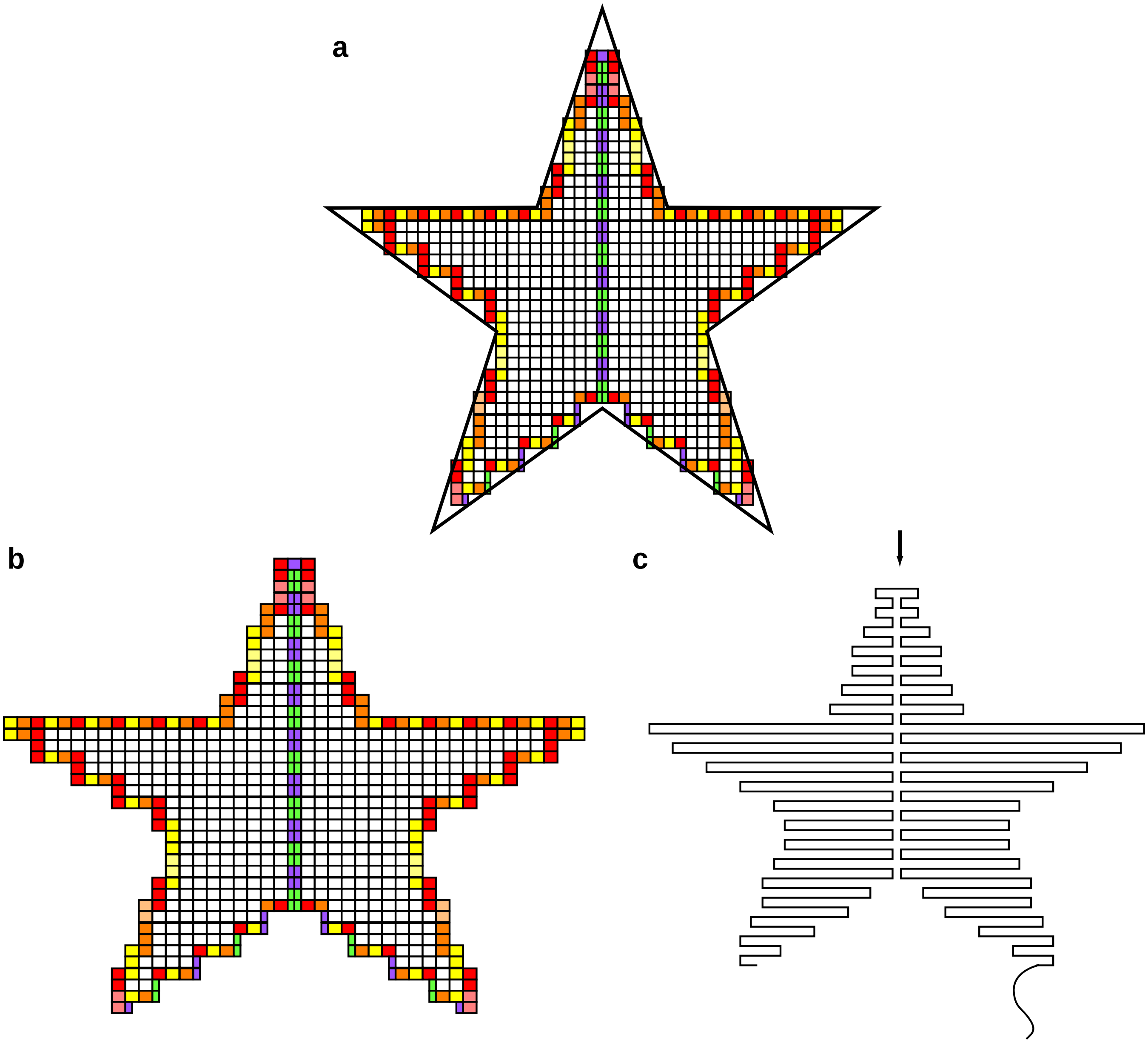
Supplementary Figure S20: Crossover diagram for the rectangle.

```
Plate number: 1
r1t0g,A1,CAAGCCCAATAGGAACCCATGTACCGTAACAC
r1t10e,B1,TCTTACCAGCCAGTTACAAAATAAATGAAATA
r1t10f,C1,CCTAATTTACGCTAACGAGCGTCTATATCGCG
r1t12e,D1,CTAATTTATCTTTCCTTATCATTCATCCTGAA
r1t12f,E1,ATCGGCTGCGAGCATGTAGAAACCAGCTATAT
r1t14e,F1,AATTACTACAAATTCTTACCAGTAATCCCATC
r1t14f,G1,GCGTTATAGAAAAAGCCTGTTTAGAAGGCCGG
r1t16e,H1,TAGAATCCCTGAGAAGAGTCAATAGGAATCAT
r1t16f,A2,TTAAGACGTTGAAAACATAGCGATTTAAATCA
r1t18e,B2,TTTAACGTTCGGGAGAAACAATAATTTTCCCT
r1t18f,C2,CTTTTACACAGATGAATATACAGTAAGCGCCA
r1t20e,D2,GGATTTAGCGTATTAAATCCTTTGTTTTCAGG
r1t20f,E2,CGACAACTAAGTATTAGACTTTACAGCCGGAA
r1t22e,F2,TAGCCCTACCAGCAGAAGATAAAAACATTTGA
r1t22f,G2,ACGAACCAAAACATCGCCATTAAATGGTGGTT
r1t24h,H2,CGGCCTTGCTGGTAATATCCAGAACGAACTGA
r1t2e,A3,TGCCTTGACTGCCTATTTCGGAACAGGGATAG
r1t2f,B3,AATGCCCCGTAACAGTGCCCGTATGTGAATTT
r1t4e,C3,AACCAGAGACCCTCAGAACCGCCAGGGGTCAG
r1t4f,D3,GAGCCGCCCCACCACCGGAACCGCCTAAAACA
r1t6e,E3,ATTGAGGGTAAAGGTGAATTATCAATCACCGG
r1t6f,F3,TTATTCATAGGGAAGGTAAATATTCATTCAGT
r1t8e,G3,GCAATAGCGCAGATAGCCGAACAATTCAACCG
r1t8f,H3,AAAAGTAATATCTTACCGAAGCCCAACACTAT
r3t0g,A4,CTCAGAGCCACCACCCTCATTTTCCTATTATT
r3t10e,B4,TATTTTGCTCCCAATCCAAATAAGTGAGTTAA
r3t10f,C4,ATTATTTAACCCAGCTACAATTTTCAAGAACG
r3t12e,D4,TAAGTCCTACCAAGTACCGCACTCTTAGTTGC
r3t12f,E4,GGTATTAAGAACAAGAAAAATAATTAAAGCCA
r3t14e,F4,AGGCGTTACAGTAGGGCTTAATTGACAATAGA
r3t14f,G4,ACGCTCAAAATAAGAATAAACACCGTGAATTT
r3t16e,H4,CTGTAAATCATAGGTCTGAGAGACGATAAATA
r3t16f,A5,ATCAAAATCGTCGCTATTAATTAACGGATTCG
r3t18e,B5,ACAGAAATCTTTGAATACCAAGTTCCTTGCTT
r3t18f,C5,CCTGATTGAAAGAAATTGCGTAGACCCGAACG
r3t20e,D5,AGATTAGATTTAAAAGTTTGAGTACACGTAAA
r3t20f,E5,TTATTAATGCCGTCAATAGATAATCAGAGGTG
r3t22e,F5,GAATGGCTAGTATTAACACCGCCTCAACTAAT
r3t22f,G5,AGGCGGTCATTAGTCTTTAATGCGCAATATTA
r3t24h,H5,CCGCCAGCCATTGCAACAGGAAAAATATTTTT
r3t2e,A6,AGTGTACTTGAAAGTATTAAGAGGCCGCCACC
r3t2f,B6,CTGAAACAGGTAATAAGTTTTAACCCCTCAGA
r3t4e,C6,GTTTGCCACCTCAGAGCCGCCACCGATACAGG
r3t4f,D6,GCCACCACTCTTTTCATAATCAAACCGTCACC
r3t6e,E6,AGCGCCAACCATTTGGGAATTAGATTATTAGC
r3t6f,F6,GACTTGAGAGACAAAAGGGCGACAAGTTACCA
r3t8e,G6,GCCCAATACCGAGGAAACGCAATAGGTTTACC
r3t8f,H6,GAAGGAAAATAAGAGCAAGAAACAACAGCCAT
r5t0g,A7,CCCTCAGAACCGCCACCCTCAGAACTGAGACT
r5t10e,B7,AGGTTTTGAACGTCAAAAATGAAAGCGCTAAT
r5t10f,C7,TTTTGTTTAAGCCTTAAATCAAGAATCGAGAA
r5t12e,D7,AATGCAGACCGTTTTTATTTTCATCTTGCGGG
r5t12f,E7,CAAGCAAGACGCGCCTGTTTATCAAGAATCGC
r5t14e,F7,AATGGTTTACAACGCCAACATGTAGTTCAGCT
r5t14f,G7,CATATTTAGAAATACCGACCGTGTTACCTTTT
r5t16e,H7,AAATCAATGGCTTAGGTTGGGTTACTAAATTT
r5t16f,A8,TAACCTCCATATGTGAGTGAATAAACAAAATC
r5t18e,B8,AACCTACCGCGAATTATTCATTTCCAGTACAT
r5t18f,C8,GCGCAGAGATATCAAAATTATTTGACATTATC
r5t20e,D8,CTAAAATAGAACAAAGAAACCACCAGGGTTAG
r5t20f,E8,ATTTTGCGTCTTTAGGAGCACTAAGCAACAGT
r5t22e,F8,GCGTAAGAGAGAGCCAGCAGCAAAAAGGTTAT
r5t22f,G8,GCCACGCTATACGTGGCACAGACAACGCTCAT
r5t24h,H8,GGAAATACCTACATTTTGACGCTCACCTGAAA
r5t2e,A9,TAAGCGTCGAAGGATTAGGATTAGTACCGCCA
r5t2f,B9,CCTCAAGAATACATGGCTTTTGATAGAACCAC
r5t4e,C9,TCGGCATTCCGCCGCCAGCATTGACGTTCCAG
r5t4f,D9,CACCAGAGTTCGGTCATAGCCCCCGCCAGCAA
r5t6e,E9,TCACAATCGTAGCACCATTACCATCGTTTTCA
r5t6f,F9,AATCACCAAATAGAAAATTCATATATAACGGA
r5t8e,G9,ATCAGAGAAAGAACTGGCATGATTTTATTTTG
r5t8f,H9,ATACCCAAGATAACCCACAAGAATAAACGATT
r7t0g,A10,TATCACCGTACTCAGGAGGTTTAGCGGGGTTT
r7t10e,B10,GAGGCGTTAGAGAATAACATAAAAGAACACCC
r7t10f,C10,CTTTACAGTTAGCGAACCTCCCGACGTAGGAA
r7t12e,D10,CCAGACGAGCGCCCAATAGCAAGCAAGAACGC
r7t12f,E10,TCATTACCCGACAATAAACAACATATTTAGGC
r7t14e,F10,TTTTAGTTTTTCGAGCCAGTAATAAATTCTGT
r7t14f,G10,AGAGGCATAATTTCATCTTCTGACTATAACTA
r7t16e,H10,TTGAATTATGCTGATGCAAATCCACAAATATA
r7t16f,A11,TATGTAAACCTTTTTTAATGGAAAAATTACCT
r7t18e,B11,TGGATTATGAAGATGATGAAACAAAATTTCAT
r7t18f,C11,GAGCAAAAACTTCTGAATAATGGAAGAAGGAG
r7t20e,D11,ATCAACAGTCATCATATTCCTGATTGATTGTT
r7t20f,E11,CGGAATTATTGAAAGGAATTGAGGTGAAAAAT
r7t22e,F11,GCCAACAGTCACCTTGCTGAACCTGTTGGCAA
r7t22f,G11,CTAAAGCAAGATAGAACCCTTCTGAATCGTCT
r7t24h,H11,GAAATGGATTATTTACATTGGCAGACATTCTG
r7t2e,A12,GGAAAGCGACCAGGCGGATAAGTGAATAGGTG
r7t2f,B12,TGCTCAGTCAGTCTCTGAATTTACCAGGAGGT
r7t4e,C12,TGCCTTTAGTCAGACGATTGGCCTGCCAGAAT
r7t4f,D12,TGAGGCAGGCGTCAGACTGTAGCGTAGCAAGG
r7t6e,E12,ACGCAAAGGTCACCAATGAAACCAATCAAGTT
r7t6f,F12,CCGGAAACACACCACGGAATAAGTAAGACTCC
r7t8e,G12,TGAACAAACAGTATGTTAGCAAACTAAAAGAA
r7t8f,H12,TTATTACGGTCAGAGGGTAATTGAATAGCAGC
```

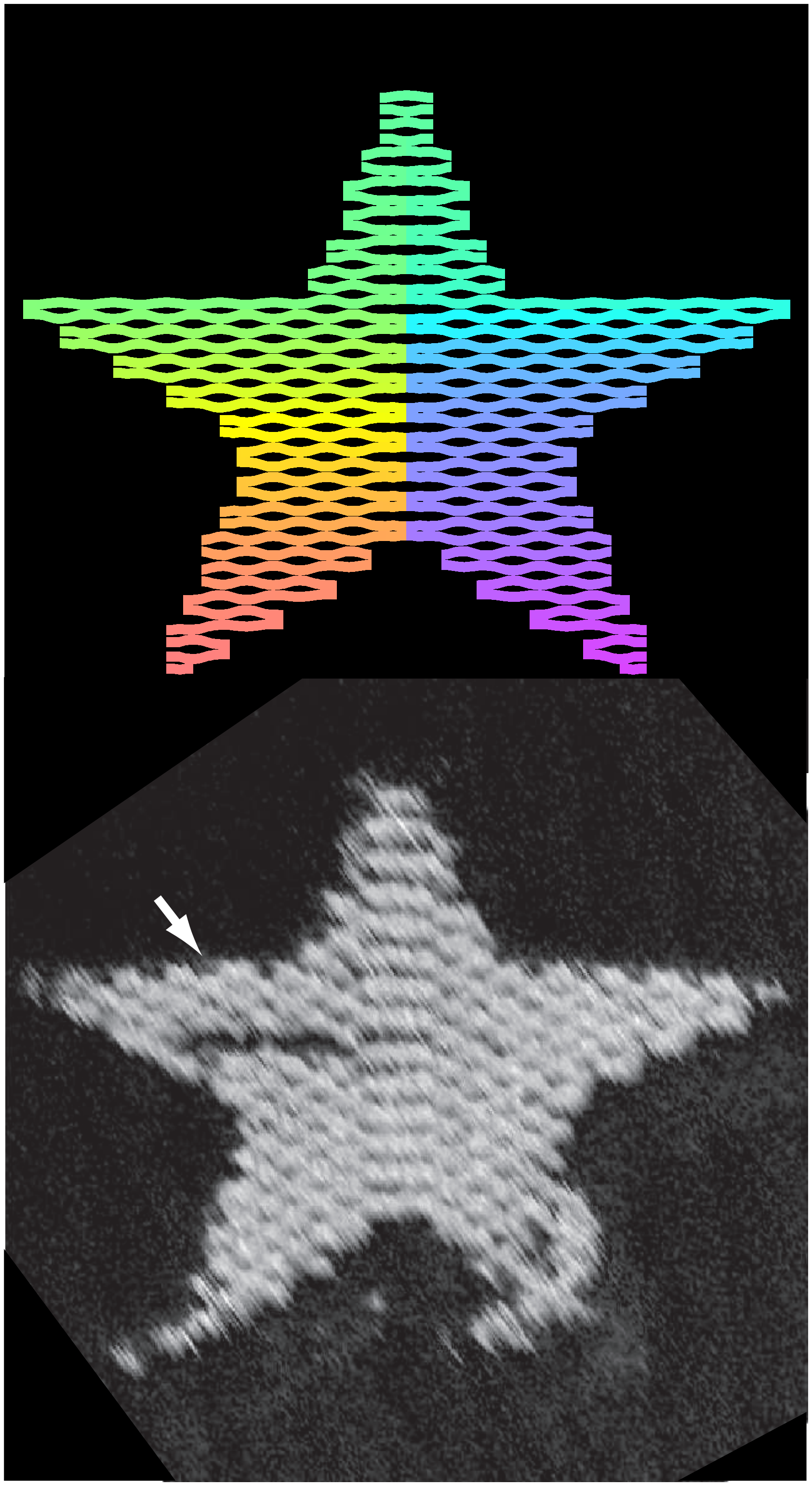
```
Plate number: 2
r9t0f,A1,TATAAGTATAGCCCGGCCGTCGAG
r9t10f,B1,GCGCATTAGCTTATCCGGTATTCTAAATCAGA
r9t12f,C1,TATAGAAGCGACAAAAGGTAAAGTAGAGAATA
r9t14f,D1,TAAAGTACCGCGAGAAAACTTTTTATCGCAAG
r9t16f,E1,ACAAAGAAATTAATTACATTTAACACATCAAG
r9t18f,F1,AAAACAAATTCATCAATATAATCCTATCAGAT
r9t20f,G1,GATGGCAAAATCAATATCTGGTCACAAATATC
r9t22j,H1,AAACCCTCACCAGTAATAAAAGGGATTCACCAGTCACACG
r9t2f,A2,AGGGTTGAATAAATCCTCATTAAATGATATTC
r9t4f,B2,ACAAACAAAATCAGTAGCGACAGATCGATAGC
r9t6f,C2,AGCACCGTTAAAGGTGGCAACATAGTAGAAAA
r9t8f,D2,TACATACAGACGGGAGAATTAACTACAGGGAA
r-1t0g,E2,TGAGTTTCGTCACCAGTACAAACTTAATTGTA
r-1t10e,F2,TTTTAATTGCCCGAAAGACTTCAATTCCAGAG
r-1t10f,G2,AAGAGGAACGAGCTTCAAAGCGAAGATACATT
r-1t12e,H2,TTTCATTTGGTCAATAACCTGTTTAATCAATA
r-1t12f,A3,TCGCAAATGGGGCGCGAGCTGAAATAATGTGT
r-1t14e,B3,AGACAGTCATTCAAAAGGGTGAGATATCATAT
r-1t14f,C3,AGGTAAAGAAATCACCATCAATATAATATTTT
r-1t16e,D3,GCTCATTTTCGCATTAAATTTTTGAGCTTAGA
r-1t16f,E3,GTTAAAATTTTAACCAATAGGAACCCGGCACC
r-1t18e,F3,TTCGCCATTGCCGGAAACCAGGCAAACAGTAC
r-1t18f,G3,GCTTCTGGTCAGGCTGCGCAACTGTGTTATCC
r-1t20e,H3,GCATAAAGTTCCACACAACATACGAAACAATT
r-1t20f,A4,GCTCACAATGTAAAGCCTGGGGTGGGTTTGCC
r-1t22e,B4,CCGAAATCCGAAAATCCTGTTTGAAATACCGA
r-1t22f,C4,CCAGCAGGGGCAAAATCCCTTATAAAGCCGGC
r-1t24h,D4,GAACGTGGCGAGAAAGGAAGGGAACAAACTAT
r-1t2e,E4,CTTAAACATCAGCTTGCTTTCGAGAAACAGTT
r-1t2f,F4,TCGGTTTAGCTTGATACCGATAGTCCAACCTA
r-1t4e,G4,CTCATCTTGAGGCAAAAGAATACACTCCCTCA
r-1t4f,H4,AAACGAAATGACCCCCAGCGATTATTCATTAC
r-1t6e,A5,GAATAAGGACGTAACAAAGCTGCTGACGGAAA
r-1t6f,B5,CCAAATCACTTGCCCTGACGAGAACGCCAAAA
r-1t8e,C5,CATAACCCGAGGCATAGTAAGAGCTTTTTAAG
r-1t8f,D5,GGAATTACTCGTTTACCAGACGACAAAAGATT
r-3t0g,E5,TGTAGCATTCCACAGACAGCCCTCATCTCCAA
r-3t10e,F5,GAAGCAAAAAAGCGGATTGCATCAGATAAAAA
r-3t10f,G5,TCAGAAGCCTCCAACAGGTCAGGATCTGCGAA
r-3t12e,H5,TCAATTCTTTTAGTTTGACCATTACCAGACCG
r-3t12f,A6,CGAGTAGAACTAATAGTAGTAGCAAACCCTCA
r-3t14e,B6,ACCGTTCTAAATGCAATGCCTGAGAGGTGGCA
r-3t14f,C6,TATATTTTAGCTGATAAATTAATGTTGTATAA
r-3t16e,D6,AAATAATTTTAAATTGTAAACGTTGATATTCA
r-3t16f,E6,GCAAATATCGCGTCTGGCCTTCCTGGCCTCAG
r-3t18e,F6,GGCGATCGCACTCCAGCCAGCTTTGCCATCAA
r-3t18f,G6,GAAGATCGGTGCGGGCCTCTTCGCAATCATGG
r-3t20e,H6,GTGAGCTAGTTTCCTGTGTGAAATTTGGGAAG
r-3t20f,A7,TCATAGCTACTCACATTAATTGCGCCCTGAGA
r-3t22e,B7,GAATAGCCGCAAGCGGTCCACGCTCCTAATGA
r-3t22f,C7,GAGTTGCACGAGATAGGGTTGAGTAAGGGAGC
r-3t24h,D7,CCCCGATTTAGAGCTTGACGGGGAAATCAAAA
r-3t2e,E7,CAATGACACTCCAAAAGGAGCCTTACAACGCC
r-3t2f,F7,AAAAAAGGACAACCATCGCCCACGCGGGTAAA
r-3t4e,G7,GCGAAACATGCCACTACGAAGGCATGCGCCGA
r-3t4f,H7,ATACGTAAAAGTACAACGGAGATTTCATCAAG
r-3t6e,A8,ACGAGTAGTGACAAGAACCGGATATACCAAGC
r-3t6f,B8,AGTAATCTTAAATTGGGCTTGAGAGAATACCA
r-3t8e,C8,CCAAAATATAATGCAGATACATAAACACCAGA
r-3t8f,D8,CATTCAACGCGAGAGGCTTTTGCATATTATAG
r-5t0g,E8,CGTAACGATCTAAAGTTTTGTCGTGAATTGCG
r-5t10e,F8,TACCTTTAAGGTCTTTACCCTGACAAAGAAGT
r-5t10f,G8,CAAAAATCATTGCTCCTTTTGATAAGTTTCAT
r-5t12e,H8,CAATAAATACAGTTGATTCCCAATTTAGAGAG
r-5t12f,A9,TCCATATACATACAGGCAAGGCAACTTTATTT
r-5t14e,B9,GGTAGCTAGGATAAAAATTTTTAGTTAACATC
r-5t14f,C9,CAACGCAATTTTTGAGAGATCTACTGATAATC
r-5t16e,D9,CTTTCATCCCCAAAAACAGGAAGACCGGAGAG
r-5t16f,E9,AGAAAAGCAACATTAAATGTGAGCATCTGCCA
r-5t18e,F9,CAGCTGGCGGACGACGACAGTATCGTAGCCAG
r-5t18f,G9,GTTTGAGGGAAAGGGGGATGTGCTAGAGGATC
r-5t20e,H9,ACTGCCCGCCGAGCTCGAATTCGTTATTACGC
r-5t20f,A10,CCCGGGTACTTTCCAGTCGGGAAACGGGCAAC
r-5t22e,B10,AGTTTGGAGCCCTTCACCGCCTGGTTGCGCTC
r-5t22f,C10,AGCTGATTACAAGAGTCCACTATTGAGGTGCC
r-5t24h,D10,GTAAAGCACTAAATCGGAACCCTAGTTGTTCC
r-5t2e,E10,ATATATTCTTTTTTCACGTTGAAAATAGTTAG
r-5t2f,F10,AATAATAAGGTCGCTGAGGCTTGCAAAGACTT
r-5t4e,G10,CGCCTGATGGAAGTTTCCATTAAACATAACCG
r-5t4f,H10,TTTCATGAAAATTGTGTCGAAATCTGTACAGA
r-5t6e,A11,TTTCAACTATAGGCTGGCTGACCTTGTATCAT
r-5t6f,B11,CCAGGCGCTTAATCATTGTGAATTACAGGTAG
r-5t8e,C11,TTTGCCAGATCAGTTGAGATTTAGTGGTTTAA
r-5t8f,D11,AAAGATTCAGGGGGTAATAGTAAACCATAAAT
r-7t0g,E11,ACGTTAGTAAATGAATTTTCTGTAAGCGGAGT
r-7t10e,F11,TTTTTGCGCAGAAAACGAGAATGAATGTTTAG
r-7t10f,G11,AAACAGTTGATGGCTTAGAGCTTATTTAAATA
r-7t12e,H11,CAAAATTAAAGTACGGTGTCTGGAAGAGGTCA
r-7t12f,A12,TGCAACTAAGCAATAAAGCCTCAGTTATGACC
r-7t14e,B12,TCAGGTCACTTTTGCGGGAGAAGCAGAATTAG
r-7t14f,C12,CTGTAATATTGCCTGAGAGTCTGGAAAACTAG
r-7t16e,D12,ACCCGTCGTCATATGTACCCCGGTAAAGGCTA
r-7t16f,E12,CATGTCAAGATTCTCCGTGGGAACCGTTGGTG
r-7t18e,F12,ATTAAGTTCGCATCGTAACCGTGCGAGTAACA
r-7t18f,G12,TAGATGGGGGGTAACGCCAGGGTTGTGCCAAG
r-7t20e,H12,GCCAGCTGCCTGCAGGTCGACTCTGCAAGGCG
```

```
Plate number: 3
r-7t20f,A1,CTTGCATGCATTAATGAATCGGCCCGCCAGGG
r-7t22e,B1,TGGACTCCCTTTTCACCAGTGAGACCTGTCGT
r-7t22f,C1,TGGTTTTTAACGTCAAAGGGCGAAGAACCATC
r-7t24h,D1,ACCCAAATCAAGTTTTTTGGGGTCAAAGAACG
r-7t2e,E1,AAAGGCCGAAAGGAACAACTAAAGCTTTCCAG
r-7t2f,F1,GAGAATAGCTTTTGCGGGATCGTCGGGTAGCA
r-7t4e,G1,GCTCCATGAGAGGCTTTGAGGACTAGGGAGTT
r-7t4f,H1,ACGGCTACTTACTTAGCCGGAACGCTGACCAA
r-7t6e,A2,CGATTTTAGAGGACAGATGAACGGCGCGACCT
r-7t6f,B2,CTTTGAAAAGAACTGGCTCATTATTTAATAAA
r-7t8e,C2,ACTGGATAACGGAACAACATTATTACCTTATG
r-7t8f,D2,ACGAACTAGCGTCCAATACTGCGGAATGCTTT
r-9t10e,E2,ATATAATGCATTGAATCCCCCTCAAATCGTCA
r-9t12e,F2,GCTAAATCCTGTAGCTCAACATGTATTGCTGA
r-9t14e,G2,AGAGAATCGGTTGTACCAAAAACAAGCATAAA
r-9t16e,H2,GATTGACCGATGAACGGTAATCGTAGCAAACA
r-9t18e,A3,CACGACGTGTAATGGGATAGGTCAAAACGGCG
r-9t20e,B3,GGGAGAGGTGTAAAACGACGGCCATTCCCAGT
r-9t22e,C3,TATCAGGGCGGTTTGCGTATTGGGAACGCGCG
r-9t24e,D3,CGATGGCCCACTACGTAAACCGTC
r-9t2i,E3,CAGCGAAAAACTTTCAACAGTTTCTGGGATTTTGCTAAAC
r-9t4e,F3,ACGGTCAAGACAGCATCGGAACGAACCCTCAG
r-9t6e,G3,GGACGTTGTCATAAGGGAACCGAAAGGCGCAG
r-9t8e,H3,TAAATATTGGAAGAAAAATCTACGACCAGTCA
rt-rem1,A4,AACATCACTTGCCTGAGTAGAAGAACT
rt-rem2,B4,TGTAGCAATACTTCTTTGATTAGTAAT
rt-rem3,C4,AGTCTGTCCATCACGCAAATTAACCGT
rt-rem4,D4,ATAATCAGTGAGGCCACCGAGTAAAAG
rt-rem5,E4,ACGCCAGAATCCTGAGAAGTGTTTTT
rt-rem6,F4,TTAAAGGGATTTTAGACAGGAACGGT
rt-rem7,G4,AGAGCGGGAGCTAAACAGGAGGCCGA
rt-rem8,H4,TATAACGTGCTTTCCTCGTTAGAATC
rt-rem9,A5,GTACTATGGTTGCTTTGACGAGCACG
rt-rem10,B5,GCGCTTAATGCGCCGCTACAGGGCGC
```

Supplementary Figure S21: Sequences for the rectangle.



Supplementary Figure S22: More design details for the star **a,** Original block diagram assuming that each block (1 turn of DNA) would have an aspect ration of roughly 1:1 (3.5 nm per turn:3.5 nm per helix) based on the inter-helix gap for 2.5 turn spacing. In reality 1.5-turn spacing appears to have a ratio of roughly 1.2:1 (3.6 nm per turn:3 nm per helix) and so the stars were somewhat squat **b**. **c** reproduces the folding path for reference. In **a**, turns that occur between columns of red blocks and orange blocks have offset 0 with respect to the underlying crossover lattice. Other turns on the left and right outer edges have +1 or -1 offsets depending on which side of the star they occur. Purple and green half-blocks show that turns (in the scaffold) made on the seam or on the interior of the bottom left and right star arms are made an odd number of 1/2 turns (DNA half-turns) away from turns (in the scaffold) on the outer edges.



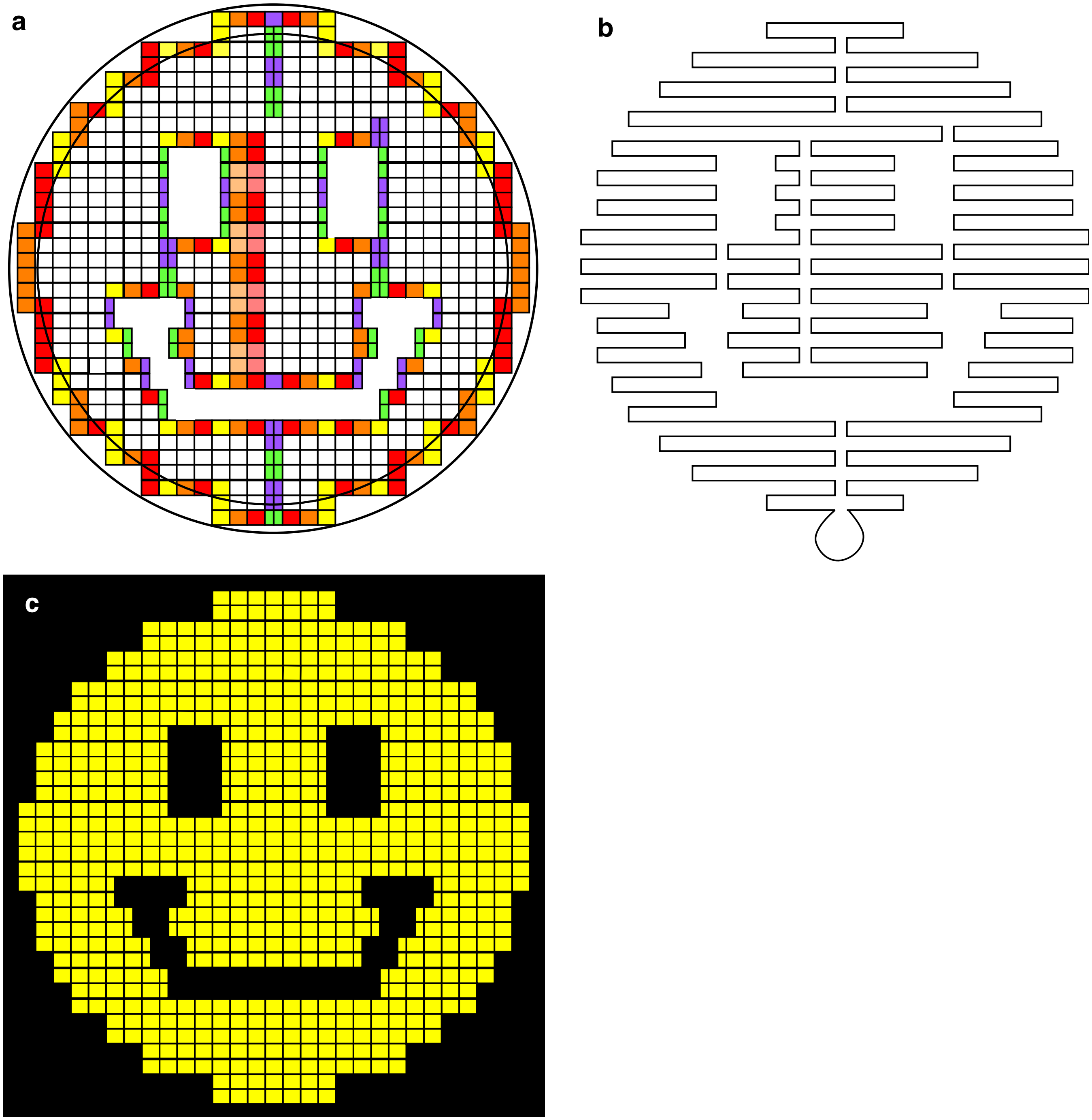
Supplementary Figure S23: Crossover diagram for the star (top) and high resolution AFM (bottom, taken by E. Winfree) which shows the crossover structure in great detail. Defects are probably tip damage. White arrow points to a section of helix that does not image well and appears to be a hole. On edges where helices can move unimpeded by neighbors helices often disappear at high tapping amplitude.

Plate number: 1
s10t15f,A1,AAAGACAAGCAAGGCCGGAAACGT
s10t17f,B1,AGAGAGAACCACAAGAATTGAGTTCCAGCGCC
s11t14e,C1,AGCACCATTACCATTAAAGGGCGA
s11t16e,D1,CATTCAACATATCAGAGAGATAACTAACATAA
s11t18g,E1,AAACAGGGAACAAGCAAGCCGTTTTACCGCACTCATCGAG
s11t18h,F1,AAGCGCATTAGACGGGGGGTAATTGAGCGCTACGATTGAG
s12t15f,G1,GGAGGGAACAGCAAAATCACCAGT
s13t14e,H1,ATTTGGGAATTAGAGCGGTAAATA
s13t16g,A2,TTGACGGACCTGAACAAAGTCAGAAGAATTAACTGAACAC
s13t16h,B2,AATTATTCATTAAAGGGTCACCGACTTGAGCC
s14t15b,C2,ATCACCTGAATT
s1t0h,D2,TATAGCCCGGAATAGGTGTATCACCGTACTCA
s1t10i,E2,CGTTCCAGGGAAAGCGCAGTCTCTTTCAACAG
s1t12i,F2,CAGGAGGTCACCAGAGCCGCCGCCAAAAGGAG
s1t14i,G2,CCAGAGCCTTTTCATAATCAAAATATATTCGG
s1t16i,H2,TTAAGACTGAATACCCAAAAGAACGAACCGGA
s1t18i,A3,TTATCCTGGCTATTTTGCACCCAGTAATAGTA
s1t20i,B3,ATGTTCAGGTCCAGACGACGACAACTCAACAT
s1t22i,C3,ACCTAAATTATTTTAGTTAATTTCACCAAAAA
s1t24i,D3,AATTTTCCTTCTGTAAATCGTCGCAGAGATCT
s1t26i,E3,TTGAATACCAATAACGGATTCGCCAAATCAGC
s1t28i,F3,ATGATGGCTATCATCATATTCCTGGGGGACGA
s1t2i,G3,GATATAAGCGGATAAGTGCCGTCGCACCCTCA
s1t30i,H3,ATCTAAAAAGTTGAAAGGAATTGAGTTGTAAA
s1t32g,A4,GCGCGAACTGACAGTTGGCAAATCAACTATCTTTA
s1t4i,B4,GTACCAGGTTAGGATTAGCGGGGTCCCTCAGA
s1t6i,C4,TTAAGAGGCTATTATTCTGAAACAGTACCGTA
s1t8i,D4,TTGAGTAAATAAGTTTTAACGGGGCGTAACGA
s2t11f,E4,GTCAGACGTCATTAAAGCCAGAATTAAGCGTC
s2t13f,F4,AACCGCCTCCGCCACCAGAACCACTGAGGCAG
s2t15f,G4,CGCAGTATATTAGCGTTTGCCATCACCACCGG
s2t17f,H4,CAACGCTAAAACGCAATAATAACGCCTTATTA
s2t19f,A5,GAACGCGCTAAATCAAGATTAGTTAATCTTAC
s2t21f,B5,TTGAAATAAAGGTAAAGTAATTCTCTAATGCA
s2t23f,C5,CCTTGAAAAAAACTTTTTCAAATATTAATGGT
s2t25f,D5,AAAATCGCGAGTGAATAACCTTGCCTTAGAAT
s2t27f,E5,AATATAATTTTACATCGGGAGAAACAAGTTAC
s2t29f,F5,GGAGCACTCCAGAAGGAGCGGAATAATTCATC
s2t5g,G5,CAAGAGAAGGA
s2t7b,H5,TGCCCCAGTTAA
s2t7g,A6,GTATAAACCTGCCTATTTCGGAACCTGAGACTCCT
s2t9b,B6,ATGATACTTTTG
s2t9f,C6,ATACATGGCAGGAGTGTACTGGTACAGTGCCC
s3t10e,D6,ACAAACAAATAAATCCATTGGCCT
s3t12e,E6,TGATATTCGCCACCACCCTCAGAGCCCTCAGA
s3t14e,F6,GCCGCCACCGGTCATAGCCCCCTTGTTAGCAA
s3t16e,G6,ACGTAGAACAGAAGGAAACCGAGGACGAGCGT
s3t18e,H6,CTTTCCAGGGAGGTTTTGAAGCCTCTGTTTAT
s3t20e,A7,CAACAATATATAAAGTACCGACAACCGACCGT
s3t22e,B7,GTGATAAAAGACAAAGAACGCGAGACATAGCG
s3t24e,C7,ATAGCTTAATAAATCAATATATGTGCAGAGGC
s3t26e,D7,GAATTATTTACAGTAACAGTACCTCCTGATTG
s3t28e,E7,TTTGGATTCGGAACAAAGAAACCAAACAACTA
s3t30e,F7,ATAGATTATCAATCAATATCTGGTTAGCCCTA
s3t32h,G7,AAACATCGATTTTTGAATGGCTATTAGTCTTTAAT
s3t34a,H7,ATGGAAACGCTC
s4t13g,A8,CCACCCTCAGA
s4t15g,B8,CATAAAGGTTTTCATCGGCATTTTCCTCAGAACCG
s4t17f,C8,TTGCCAGTAGCCGAACAAAGTTACAATACATA
s4t19f,D8,CTGAACAAAACCTCCCGACTTGCGAGCCTAAT
s4t21f,E8,TAAATAAGGCCAGTAATAAGAGAAGATAAGTC
s4t23f,F8,CGCTGAGATGCAAATCCAATCGCATAAGGCGT
s4t25f,G8,TTACCTGATTAATGGAAACAGTACGATTAAGA
s4t27f,H8,GAATAATGTAACGTCAGATGAATACATTTCAA
s4t29f,A9,AATAGATATAACATTATCATTTTGATACTTCT
s4t31f,B9,AATACCGACTCAAATATCAAACCCGAGCCGTC
s4t33f,C9,ATTTTGACACGTGGCACAGACAATCCATTAAA
s4t35f,D9,CATTGCAACAGGAAAAATACCTAC
s5t14e,E9,GTCAGACTGTAGCGCGTGGCAACA
s5t16e,F9,TATAAAAGAGAAAAGTAAGCAGATTACAAAAT
s5t18e,G9,AAACAGCCGCGAGGCGTTTTAGCGGAAAAATA
s5t20e,H9,ATATCCCAGCAGAGGCATTTTCGAAATAAACA
s5t22e,A10,CCGGAATCTATATGTAAATGCTGAAGAGTCAA
s5t24e,B10,TAGTGAATATTTGAATTACCTTTTGCAAAAGA
s5t26e,C10,AGATGATGCGTAGATTTTCAGGTTGAAGGGTT
s5t28e,D10,AGAACCTAATTTTAAAAGTTTGAGATACATTT
s5t30e,E10,GAGGATTTCATCACCTTGCTGAACACGAACCA
s5t32e,F10,CCAGCAGACTGAAAGCGTAAGAATGCTCAATC
s5t34e,G10,GTCTGAAACAATATTACCGCCAGC
s5t36a,H10,GAGTCTGTAAAA
s6t15f,A11,AGACACCACAAGTTTGCCTTTAGC
s6t17f,B11,TATCCCAAACCGAAGCCCTTTTTAAAACGCAA
s6t19f,C11,TACGAGCACCGGTATTCTAAGAACATATTATT
s6t21f,D11,TAGAAAAACCAACATGTAATTTAGTCCTAATT
s6t23f,E11,ATCATAGGGGTTGGGTTATATAACATAATTAC
s6t25b,F11,ATTAATAACAAA
s6t25f,G11,ATCAAGAATACATTTAACAATTTCTTATCAAA
s6t27b,H11,TAAAACTGCACG
s6t27f,A12,AAATTATTAGAAATAAAGAAATTGAAACAAAC
s6t29f,B12,TAGACTTTTGCCCGAACGTTATTACCATATCA
s6t31f,C12,CAGAGGTGAATGAAAAATCTAAAGAGAAGTAT
s6t33f,D12,TTACATTGATAGAACCCTTCTGACAGATAAAA
s6t35f,E12,CGCAAATTCTGGTAATATCCAGAATGGATTAT
s6t37f,F12,TCAGTGAGGCCACCGAGTCCATCA
s7t14e,G12,TCAGTAGCGACAGAATCGGAATAA
s7t16e,H12,GTTTATTTTAGCAATAGCTATCTTTCCAAATA

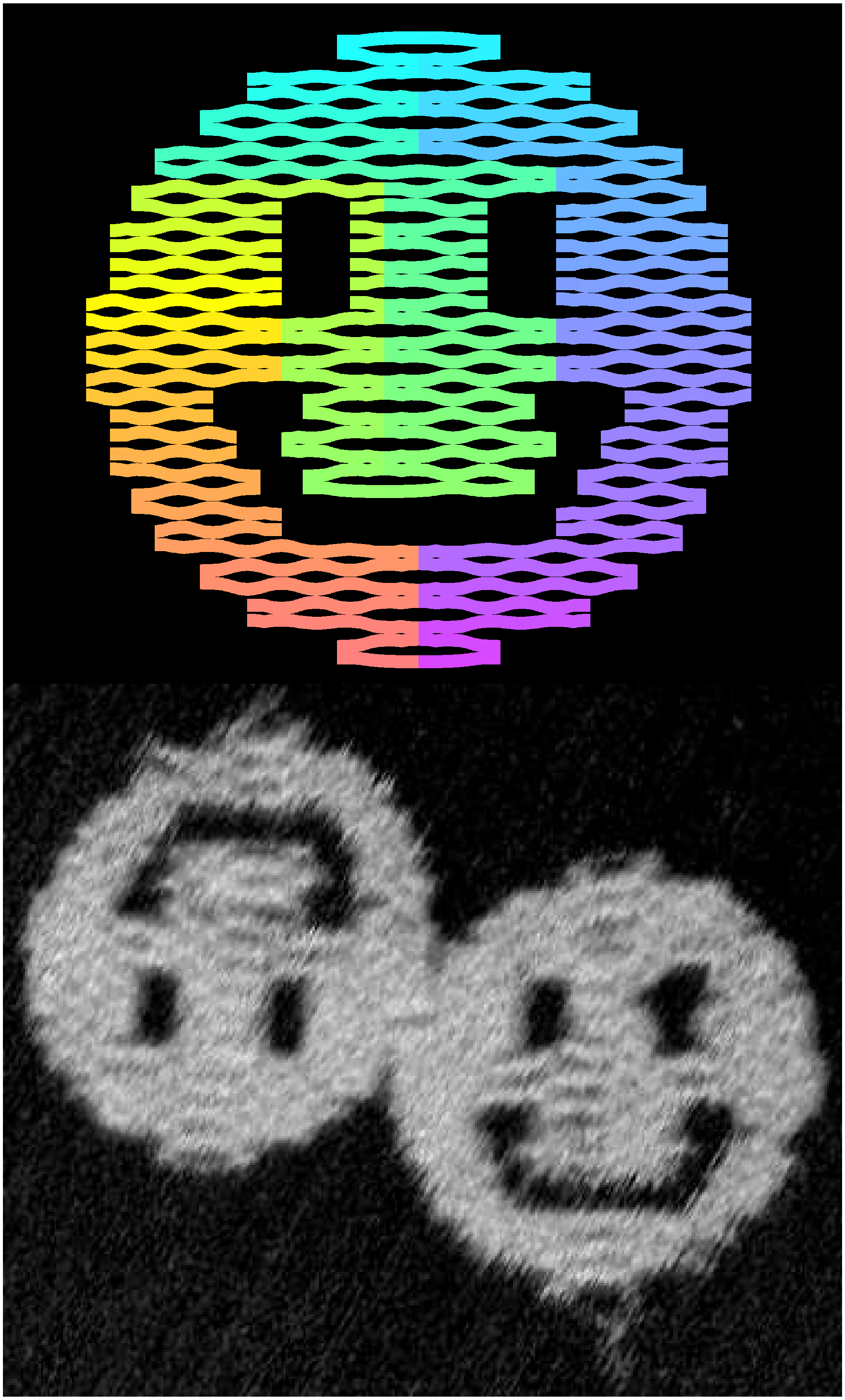
Plate number: 2
s7t18e,A1,AGAAACGAGATATAGAAGGCTTATTGTAGAAA
s7t20e,B1,CCAATCAAGCCATATTTAACAACGGCCTGTTT
s7t22g,C1,AGTATCATTTTAACCTCCGGCTTATCTGAGAGACTACCTT
s7t22h,D1,ATGCGTTATACAAATTGGCTTAATTGAGAATCTAATCGGC
s7t28e,E1,CTCGTATTAAATCCTTACAAACAA
s7t30e,F1,TTCGACAACTGAGAGCCAGCAGCAAGGCGGTC
s7t32e,G1,AGTATTAAATTCTGGCCAACAGAGGCAGATTC
s7t34e,H1,ACCAGTCACAAACTATCGGCCTTGAACCGTTG
s7t36e,A2,TAGCAATAAGAAGTGTTTTTATAA
s7t38a,B2,AATCAGCGTTAG
s8t15f,C2,TCAATAGAGATAGCAGCACCGTAA
s8t17f,D2,TTAACGTCGCAAGAAACAATGAAATGTCACAA
s8t19f,E2,TGTCTTTCAATAGCAAGCAAATCATTTTTTGT
s8t31g,F2,ACAGTGCCACG
s8t33h,G2,ATAAAAGGGACCACCGCCTGCA
s8t35b,H2,CACTTGTAACAT
s8t35g,A3,ATTAGTAACCTGAGTAGAAGAACTCACGACCAGTA
s8t37f,B3,CTAAACAGGTACGCCAGAATCCTGCTTCTTTG
s8t39f,C3,TATAACGTGCTTTCCTAGCGGGAG
s9t14e,D3,CACCAATGAAACCATCAAATTCAT
s9t16e,E3,ATGGTTTAAAGCCCAATAATAAGAAAAAATGA
s9t18e,F3,AAATAGCAAATCATTACCGCGCCCCTTATCAT
s9t20g,G3,TCCAAGAACAACGCTCAACAGTAGCTTACCAGTATAAAGC
s9t20h,H3,CGGGTATTAAACCAAGTTATTTTCATCGTAGGGCCTTTAC
s9t36e,A4,ATTTTAGACAGGAACGGAGGCCGA
s9t38g,B4,TTAAAGGGTGCTTTGACGAGCACGGGGCGCGTACTATGGT
s-10t15f,C4,ATAAATTGACGTAATGCCACTACG
s-10t17f,D4,TCATCAGTGGCTCATTATACCAGTATCGCCTG
s-11t14e,E4,AAGGCACCAACCTAAAAACGGAGA
s-11t16g,F4,TTTGTATCCAGGACGTTGGGAAGACAACATTATTACAGGT
s-11t20g,G4,TTAAGAGGAAGCCCGAGATTGCATCAAAAAGAAGAAAGAT
s-12t15f,H4,CAAAGTACACGAAAGAGGCAAAAG
s-13t14g,A5,AATACACTAAAACACTCCAGCGATTATACCAA
s-13t18g,B5,AAACGAACTAACGGAAAAAATCTACGTTAATAGCGCGAAA
s-14t15a,C5,TGACCCCATCTT
s-1t10e,D5,TGTATGGGGAGTGAGAATAGAAAGTTCACGTT
s-1t10i,E5,TTTCAGCGATTTTGCTAAACAACTGAATTTAC
s-1t12e,F5,GAAAATCTTGTATCGGTTTATCAGATGACAAC
s-1t12i,G5,CCTTTAATCCAAAAAAAAGGCTCCAGCATTGA
s-1t14e,H5,AACCATCGGCTTGCAGGGAGTTAATGGCTGAC
s-1t14i,A6,TCGCTGAGCCCACGCATAACCGATCACCGGAA
s-1t16e,B6,CTTCATCAACCCAAATCAACGTAAGGCTTTTG
s-1t16i,C6,TATTCATTAGAGTAATCTTGACAATGGCATGA
s-1t18e,D6,CAAAAGAAAGACTGGATAGCGTCCTTAGAGCT
s-1t18i,E6,AAATGTTTGTTTTGCCAGAGGGGGCTACAATT
s-1t20e,F6,TAATTGCTTATGCAACTAAAGTACAAAGCCTC
s-1t20i,G6,GTTTTAAAGAATATAATGCTGTAGTAAACAAC
s-1t22e,H6,AGAGCATACCCTGTAATACTTTTGTAAATTAA
s-1t22i,A7,CATTATGAAAGCTAAATCGGTTGTATCTTCTG
s-1t24e,B7,TGCCGGAGTATCAGGTCATTGCCTTATTTTGT
s-1t24i,C7,ACAAAGGCAGGGTAGCTATTTTTGTATTAATT
s-1t26e,D7,TAAAATTCTAACCAATAGGAACGCGGCGCATC
s-1t26i,E7,TCATTTTTGCATTAAATTTTTGTTTGATTGCT
s-1t28e,F7,GTAACCGTTCGGCCTCAGGAAGATTTGGGTAA
s-1t28i,G7,CGACAGTAGCATCTGCCAGTTTGAATTATCAG
s-1t2i,H7,GAACCGCCGGAGGTTTAGTACCGCAGAGGGTT
s-1t30g,A8,CGCCAGGGCAGTGCCAAGCTTGCAGCTCACTGCCC
s-1t30i,B8,ACGACGGCTTTTCCCAGTCACGACGGAAGGTT
s-1t32h,C8,GCTTTCCAGTCGGGAAACCTGTCGTGCACATTAAT
s-1t4g,D8,CCTCATTTTCA
s-1t4i,E8,GCCACCACACCCTCAGAACCGCCATTTGCTCA
s-1t6i,F8,ACACTGAGCCCAATAGGAACCCATTGAAAGTA
s-1t8e,G8,TCCACAGATTTGTCGTCTTTCCAGGAATTTTC
s-1t8i,H8,TCTAAAGTCAGCCCTCATAGTTAGTCAGTGCC
s-2t11f,A9,ATAATTTTGAACAACTAAAGGAAT
s-2t13f,B9,CGCCGACACTTGCTTTCGAGGTGATGCGAATA
s-2t15f,C9,GCATAGGCAGGCCGCTTTTGCGGGGATAGTTG
s-2t17f,D9,TAGCGAGACAAAGCTGCTCATTCAGACCAGGC
s-2t19f,E9,CGGATGGCAATACTGCGGAATCGTAACCAAAA
s-2t21f,F9,TAAGCAATGGTGTCTGGAAGTTTCCATTTTTG
s-2t23f,G9,CTAGCTGACGGGAGAAGCCTTTATAGCAAAAT
s-2t25f,H9,AACGTTAAGAGAGTCTTGGAGCAAACAACCGTT
s-2t27f,A10,TGTAGATGCATCAAAAATAATTCGAAATTGTA
s-2t29f,B10,CGATTAAGCGCACTCCAGCCAGCTCACGTTGG
s-2t31f,C10,TGCGTTGCTGCCTGCAGGTCGACTCTGCAAGG
s-2t5g,D10,GGGATAGCAAGTTTCGTCACCAGTACATGTAGCAT
s-2t7a,E10,AACGCCAACTAC
s-2t9a,F10,GTAAATACGTTA
s-3t12g,G10,ATTTCTTAAAC
s-3t16e,H10,GGTGTACAGTGAATAAGGCTTGCCACCAGACG
s-3t18e,A11,ACGATAAACATAAATATTCATTGACCTTTTGA
s-3t20e,B11,TAAGAGGTATTCCATATAACAGTTGGCAAGGC
s-3t22e,C11,AAAGAATTTTCAACGCAAGGATAACCATCAAT
s-3t24e,D11,ATGATATTCAAGAGAATCGATGAAGTATAAGC
s-3t26e,E11,AAATATTTCGTCTGGCCTTCCTGTCCGTAATG
s-3t28e,F11,GGATAGGTTTCCGGCACCGCTTCTGCGAAAGG
s-3t30e,G11,GGGATGTGCTAGAGGATCCCCGGGATGAGTGA
s-3t32e,H11,GCTAACTCCAGCTGCATTAATGAAGCAAGCGG
s-3t34b,A12,CCCCAGGGTTTG
s-3t34e,B12,TCCACGCTCAGGCGAAAATCCTGT
s-4t13g,C12,AGCTTGATACCATCGTCACCCTCAGCAAGATGAAC
s-4t15f,D12,AAGAGGACGCGAAAGACAGCATCG
s-4t17f,E12,CCTCGTTTCTGACGAGAAACACCAAACTTTGA
s-4t19f,F12,TAATTGCTATCCCCCTCAAATGCTATCATAAC
s-4t21f,G12,ATCATACAGATTCCCAATTCTGCGAGTACCTT
s-4t23f,H12,TCAAATCAAAATTTTTAGAACCCTTCCAATAA

Plate number: 3
s-4t25f,A1,GGAAGATTCGGTAATCGTAAAACTGGAGACAG
s-4t27f,B1,CGGATTGAAGCCAGCTTTCATCAACAAAAACA
s-4t29f,C1,GCCAGCTGGGTGCCGGAAACCAGGACAAACGG
s-4t31f,D1,GGTGCCTATACCGAGCTCGAATTCGCTATTAC
s-4t33f,E1,GAGTTGCATCGGCCAACGCGCGGGAAGCCTGG
s-4t35f,F1,TTGATGGTGGTTCCGACCCTGAGA
s-5t14e,G1,GAACGAGGGTAGCAACGGGAACCG
s-5t16e,H1,AACTGACCGAACGAGTAGTAAATTTAGTAAGA
s-5t18e,A2,GCAACACTTTAAACAGTTCAGAAACAGGTCAG
s-5t20e,B2,GATTAGAGAACGAGTAGATTTAGTAGTAGTAG
s-5t22e,C2,CATTAACACATATATTTTAAATGCAAGGGTGA
s-5t24e,D2,GAAAGGCCAGCATGTCAATCATATATAATCAG
s-5t26e,E2,AAAAGCCCCATTAAATGTGAGCGACGGATTCT
s-5t28e,F2,CCGTGGGACAAAGCGCCATTCGCCCGGTGCGG
s-5t30e,G2,GCCTCTTCGTAATCATGGTCATAGGGAAGCAT
s-5t32e,H2,AAAGTGTAGAGAGGCGGTTTGCGTGCCCTTCA
s-5t34e,A3,CCGCCTGGAATCGGCAAAATCCCTTGGACTCC
s-5t36b,B3,AAAAACAGGGCG
s-5t36e,C3,AACGTCAACGTCTATCAGGGCGAT
s-6t15f,D3,AATCATAAGGCTACAGAGGCTTTG
s-6t17f,E3,ACGAGGCAGGGCTTGAGATGGTTTAGACGGTC
s-6t19f,F3,AACTCCAAACGAGAATGACCATAAAAGGAATT
s-6t21f,G3,CTACTAATTTGACCATTAGATACACGGAAGCA
s-6t25a,H3,CGGTTGGTACCC
s-6t27a,A4,ACCCGTGTAACA
s-6t29f,B4,AGGGCGATATTCAGGCTGCGCAAC
s-6t31f,C4,TACGAGCCCTGTTTCCTGTGTGAATGTTGGGA
s-6t33f,D4,AGCTGATTATTGGGCGCCAGGGTGACACAACA
s-6t35f,E4,AAAGAACGTATAAATCAAAAGAATCGGGCAAC
s-6t37f,F4,GGCCCACTACGTGAACCCACTATT
s-7t14e,G4,AGGACTAAAGACTTTTAGCCGGAA
s-7t16e,H4,CGAGGCGCAATTTCAACTTTAATCAGATACAT
s-7t18e,A5,AACGCCAAATCAAAAATCAGGTCTTCAAAGCG
s-7t20g,B5,AACCAGACTTTCGCAAATGGTCAACGAGCTGAAAAGGTGG
s-7t24g,C5,GTAGGTAAAGATTCAAAATGCCTGAGTAATGTCATCAATT
s-7t30g,D5,ATTGTTATCCG
s-7t36e,E5,ACAAGAGTCATCACCCAAATCAAGATCGGAAC
s-7t38b,F5,CCGATTGAGCCC
s-7t38e,G5,CCTAAAGGTAGAGCTTGACGGGGA
s-8t15f,H5,TGTTACTTTCATGAGGAAGTTTCC
s-8t17f,A6,ACTAATGCATTGTGAATTACCTTACTGCTCCA
s-8t19f,B6,TTCGAGCTTTACCCTGACTATTATCACATTCA
s-8t31h,C6,CTCACAATTCCGTTTTTCTTTT
s-8t33g,D6,CACCAGTGAGAAGCCCGAGATAGGGTTAGTTTGGA
s-8t35a,E6,TGTTCCGAGTGT
s-8t37f,F6,AGCACTAATTTTTTGGGGTCGAGG
s-9t14e,G6,ATTAAACGGGTAAAATTGTCGAAA
s-9t16e,H6,TCCGCGACTGCGATTTTAAGAACTTGAGATTT
s-9t18g,A7,AGGAATACAGTCAGAAGCAAAGCGAAGACTTCAAATATCG
s-9t22g,B7,ATTTTCATTTGGGGCGTAACCTGTTTAGCTATCGTTTTAA
s-9t40g,C7,CGAGAAAGGAAGGGAAAAGCCGGCGAACGTGGTGCCGTAA
st-rem1,D7,GCGCTTAATGCGCCGCTACA

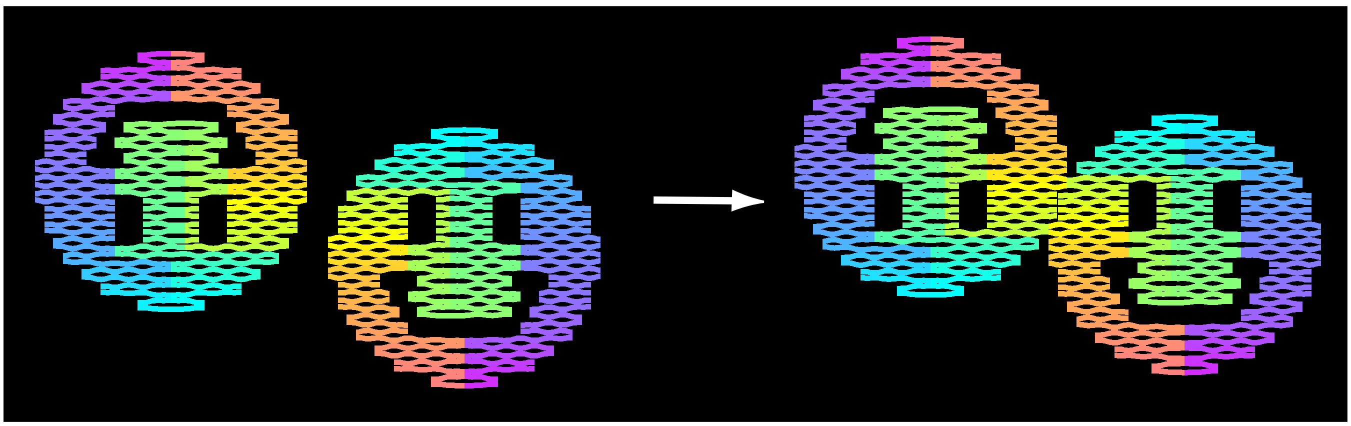
Supplementary Figure S24: Sequences for the star.



Supplementary Figure S25: More design details of the 3-hole disk (smiley). **a,** Block diagram. **b,** Reproduction of the folding path. **c,** Block diagram with all colors and notations removed. In **a**, turns that occur between columns of red blocks and orange blocks have offset 0 with respect to the underlying crossover lattice. Other turns on the left and right outer edges have +1 or -1 offsets depending on which side of the smiley they occur. Purple and green half-blocks show that scaffold turns made at most seams or on the interior of voids are an odd number of 1/2 DNA turns away from scaffold turns on the outer edges. A pair of columns with alternating light and dark orange and red blocks marks a seam of 0 offset, placed 1.5 turns to the left of the central seam.



Supplementary Figure S26: Crossover diagram for the disk with holes (smiley) with a high resolution zoom out of Fig. 2:d_3 for comparison of fine structure. Some tip damage has occurred to the right eye of the righthand smiley.



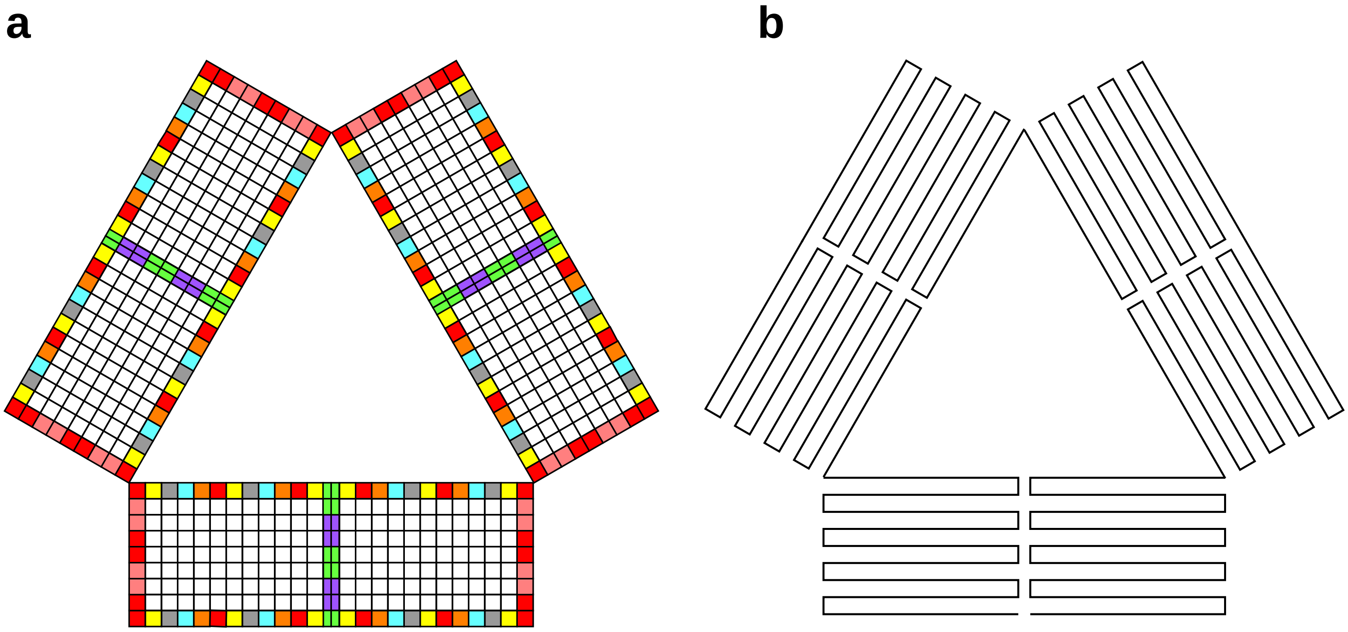
Supplementary Figure S27: Diagram showing how the smileys stick together to maximize the number of blunt end stacking interactions. Compare to previous Supplementary Fig. S26.

```
Plate number: 1
s0m25k,A1,AAACACCAGAACGAGTAGTAAATTGGGCTTGA
s10m15g,B1,ATATATTTTAG
s10m17g,C1,TCCTTGAAAACAACTTTTTCAA
s10m19g,D1,ATTCATTTCAATTCCCTTAGAA
s1m0j,E1,ACGCAAAGACACCACGGAATAAGTTTATTTTG
s1m10e,F1,CGTACTCAACCCTCAGAACCGCCAAGCAAGCC
s1m12e,G1,CAATAGGAAGTACAAACTACAACGAGCGTAAC
s1m14e,H1,GATCTAAAATTTTCTGTATGGGATGTGAGAAT
s1m16e,A2,AGAAAGGATGCTTTCGAGGTGAATGACAATGA
s1m18e,B2,CAACAACCATCGGAACGAGGGTAGTTTTTCAT
s1m20e,C2,GAGGAAGTAAAACACTCATCTTTGGTACAACG
s1m22e,D2,GAGATTTGGACCAACTTTGAAAGAAGGCTGGC
s1m24e,E2,TGACCTTCGGCTTGCCCTGACGAG
s1m28i,F2,GCAACAGTAGGCGGTCAGTATTAAGGGAGAGG
s1m2i,G2,ATGTTAGCGATTAAGACTCCTTATACCGATTG
s1m30i,H2,GTAATAAAGCAGATTCACCAGTCAATAGGGTT
s1m32i,A3,AGTAGAAGATTAGTAATAACATCAATCGGAAC
s1m34g,B3,GTCTGTCCATCACGCATAGCAATACTTCTTTGAACTCAAA
s1m4i,C3,GAGCAAGAGAATTGAGTTAAGCCCTAGCAGCA
s1m6i,D3,ATTATTTAGCCAGTTACAAAATAACCTCAGAG
s1m8e,E3,CCCTGCCTCGGATAAGTGCCGTCGTGTATCAC
s2m11f,F3,ACCGTAACCACCCTCAGAACCGCCGGAGGTTT
s2m13f,G3,GTCTTTCCACTGAGTTTCGTCACCACCCATGT
s2m15f,H3,AGGAATTGAGACGTTAGTAAATGAGTTTTGTC
s2m15g,A4,CGAATAATAATTTTTTAAGGAGCCTTTAATTGCGATATAT
s2m17f,B4,CGCATAACTATCGGTTTATCAGCTACAACTAA
s2m19f,C4,AACGGGTAAGCAGCGAAAGACAGCATCGCCCA
s2m1b,D4,AAGGTGTACATA
s2m1f,E4,AAAATACAGCAACATATAAAAGAA
s2m21f,F4,CCTGATAAGGCAAAAGAATACACTTTCCATTA
s2m23f,G4,TAATCTTGATAAGGGAACCGAACTTATCATCG
s2m25f,H4,CTCATTCAGTGAATAAATCAAGAG
s2m27g,A5,GCAGCAAATGAAAAATACGAACCACCAGCAGAACAGAGAT
s2m29g,B5,TCTGGCCAAGATAAAACAGAGGTGGCCACGCTGAGAGCCA
s2m31f,C5,CTATCGGCTGGATTATTTACATTGAGGGACAT
s2m33b,D5,CCGTTGAATTAA
s2m3f,E5,AATAGCAACCAAAAGAACTGGCATAAACGTAG
s2m5f,F5,CAAATAAGGAGAGATAACCCACAAAACAATGA
s2m7f,G5,ACCTATTATTCCAGAGCCTAATTTTCCCAATC
s2m9f,H5,AGTACCGCTTTGCTCAGTACCAGGATTTCGGA
s3m16i,A6,GGCTCCAACACGTTGAAAATCTCCTAACCTCC
s3m18e,B6,TCGGTCGCCGGGATCGTCACCCTCAAATACGT
s3m18i,C6,CGCTTTTGTGAGGCTTGCAGGGAGTTTTTTAA
s3m20b,D6,GGCACCTACGAA
s3m20e,E6,AATGCCACAACCTAAAACGAAAGAATTGTGTC
s3m22e,F6,GAAATCCGGCGCAGACGGTCAATCACAAGAAC
s3m24b,G6,CCAAATCATTAC
s3m24e,H6,CGGATATTCAACGTAACAAAGCTG
s3m2e,A7,AATAATAACGGAATACTAGCTATC
s3m30g,B7,AGAACCCTGCTCAATCGTCTGAAACTTGCTGGTAATATCC
s3m32g,C7,AGAACAATATTACCGCATACCTACATTTTGACTCTGACCT
s3m4e,D7,TTACCGAATTGAGCGCTAATATCAAAACGATT
s3m6e,E7,TTTTGTTTACGCTAACGAGCGTCTTTCTGAAA
s3m8e,F7,CATGAAAGTTAGGATTAGCGGGGT
s3m8i,G7,GAGAAGGATATTAAGAGGCTGAGATAGAAGGC
s4m23g,H7,ACTTAGCCGGAACGAGCGACCTGCTCCATGTT
s4m25g,A8,GAGCCGTCAATAGATAAACAACTAATAGATTACTGAACCT
s4m29g,B8,GAAAGCGTCCATTAAAAATACCGACTAAAGCATCACCTTG
s4m3f,C8,TAAGAAAAGAAACCGAGGAAACGC
s4m5f,D8,AAATGAAACAAAGTCAGAGGGTAAGCCCTTTT
s4m9g,E8,CCAATCAATAATCGGCTACGAGCATGTAGAAATAAGAGAA
s5m12e,F8,TATAAAGTATTTTCGAGCCAGTAACCGGAATC
s5m14g,G8,ATAATTACTAAATAAGAATAAACA
s5m16i,H8,GGCTTAGGTGAGAGACTACCTTTTAAAAAAAA
s5m18i,A9,TGGAAACATTTCATTTGAATTACCTTAAAGGC
s5m22g,B9,TATCAAAATTA
s5m24a,C9,GAACAATTTGCG
s5m28e,D9,CAAATATCTAGCCCTAAAACATCGAAGAATAC
s5m2e,E9,ACAAAGTTACCAGAAGGTAAGCAG
s5m30g,F9,GTGGCACAAAAAACGCTCATGGAACAGCCATTGCAACAGG
s5m30h,G9,GACAATATTTTTGAATTTAATGCGCGAACTGAAAACCCTC
s5m4e,H9,ATAGCCGAAACTGAACACCCTGAAATAGCAGC
s5m6j,A10,CTTTACAGACCCAGCTACAATTTTATCCTGAATCTTACCAAACGTCAA
s5m8i,B10,TTATCCGGGCAAGCAAATCAGATACTCCTCAA
s6m11f,C10,AAGGTAAAATATCCCATCCTAATTTGTCTTTC
s6m13f,D10,GCCTGTTTTAATTTAGGCAGAGGCACCGACAA
s6m15f,E10,TATAACTAGTGATAAATAAGGCGTTAGAAAAA
s6m17f,F10,ATCAATATATCAAAATCATAGGTCTTGGGTTA
s6m19f,G10,TAATTACATTTAACAAGTACATAA
s6m23f,H10,CCAGAAGGAGAACCTACCA
s6m25f,A11,GAGGATTTTGAGTAACATTATCATAGAAACCA
s6m27f,B11,AATCAATATATCTTTAGGAGCACTATACATTT
s6m29b,C11,TAGTCTGGCTAT
s6m5b,D11,AAGCGCACAGGG
s6m5f,E11,ACATAAAAATTAGACGGGAGAATT
s6m7f,F11,GAACGCGATTAGTTGCTATTTTGCAGAGAATA
s6m9f,G11,CTTATCATATTACCGCGCCCAATATATTCTAA
s7m10e,H11,CGGGTATTCTGAACAAGAAAAATAGTAATTCT
s7m12e,A12,GTCCAGACTAACAACGCCAACATGAGTATCAT
s7m14e,B12,ATGCGTTATTGAAATACCGACCGTTATGTAAA
s7m16e,C12,TGCTGATGAGTCAATAGTGAATTTATGTGAGT
s7m18e,D12,GAATAACCATCAAGAAAACAAAATATAACGGA
s7m20e,E12,TTCGCCTGTACATCGGGAGAAACATTTGCACG
s7m22e,F12,TAAAACAGGAATAATGGAAGGGTTAGCGGAAT
s7m24e,G12,TATCATCAATTAATTTTAAAAGTTAGAAGTAT
s7m26e,H12,TAGACTTTGGAAGGTTATCTAAAATCTGGTCA
```

```
Plate number: 2
s7m28g,A1,GTTGGCAAATCAACAGTTG
s7m8e,B1,AGCGAACCTTTCATCGTAGGAATCTCCAAGAA
s8m11f,C1,TAAACAACCAACAATAGATAAGTCAAACCAAG
s8m13f,D1,CTTACCAGTGAGAATCGCCATATTGACGACAA
s8m15f,E1,ATCGCAAGACCTAAATTTAATGGTTACAAATT
s8m17f,F1,GTAAATCGTTAAGACGCTGAGAAGCAAATCCA
s8m19f,G1,GAATACCAAGATGATGAAACAAACTTGCTTCT
s8m21f,H1,AAATTGCGCAGTAACAGTACCTTTATTGCTTT
s8m23f,A2,ATTATCAGTTTGGATTATACTTCTAAATAAAG
s8m25b,B2,TTAAATCTCGTA
s8m25f,C2,TTCGACAACCTTTGCCCGAACGTTTATTCCTG
s8m27g,D2,AAAGGAATTGAACAAACAA
s8m7g,E2,GGGAGGTTTTGAAGCCTTAAATCAAGAGGCGTTTT
s8m9b,F2,AGAACATCATCG
s8m9g,G2,TACCGCACAGCAAGCCGTTTTTATTCCCGACTTGC
s9m10e,H2,GAACGCGCCTGTTTATATGTTCAG
s9m12e,A3,CTAATGCAAACAGTAGGGCTTAATTATAAAGC
s9m14e,B3,CAACGCTCTTAATTTCATCTTCTGACAAAGAA
s9m16e,C3,CGCGAGAAATAGCGATAGCTTAGATCGCTATT
s9m18e,D3,AATTAATTTTACCTGAGCAAAAGAAGTTACAA
s9m20e,E3,AATCGCGCACGTCAGATGAATATATAGATTTT
s9m20f,F3,AGAGGCGAATT
s9m22g,G3,CAGGTTTAAATATAATCCTGATTGATGATGGCAATTCATC
s-10m15g,H3,TATGATATTCAAGAAAAGCCCC
s-10m17g,A4,AAAAACAGGAAGCGAGTAACAA
s-10m19g,B4,CCCGTCGGATT
s-1m0e,C4,TCACAATCAATAGAAATACCAGCG
s-1m10i,D4,AAATATCGTATAGCCCGGAATAGGAGAGGGTT
s-1m10j,E4,GCCACCACTTAAGAGGAAGCCCGAGATTGCAT
s-1m12i,F4,CAAAAAGACCTCATTTTCAGGGATCCCTCAGA
s-1m12j,G4,ATTCCACAAGTCAGAAGCAAAGCGTTACCCTG
s-1m14i,H4,ACTATTATGACAGCCCTCATAGTTCCTGTAGC
s-1m14j,A5,ACAACTTTATCAAAAATCAGGTCTACGAGAAT
s-1m16i,B5,GACCATAACAACAGTTTCAGCGGATTTGCTAA
s-1m16j,C5,CAGCTTGAAGACTGGATAGCGTCCTAATAGTA
s-1m18i,D5,AAATGTTTTACCGATAGTTGCGCCTTCTTAAA
s-1m18j,E5,ACAGAGGCATCATAACCCTCGTTTTAGTAAGA
s-1m20i,F5,GCAACACTTTTGAGGACTAAAGACCAACGGCT
s-1m20j,G5,CGATTATAATTTAGGAATACCACAAGATTCAT
s-1m22i,H5,CAGTTGAGCCAAGCGCGAAACAAAACCCCCAG
s-1m22j,A6,GAACGGTGCATTATACCAGTCAGGATTTTAAG
s-1m24i,B6,AACTGGCTTACAGACCAGGCGCATGGACAGAT
s-1m28i,C6,CGGTTTGCAATCGGCCAACGCGCGCACCGCCT
s-1m2e,D6,CCAAAGACAAGGTAAATATTGACGAAGGCCGG
s-1m2i,E6,AGGGAGGGAAAAGGGCGACATTCATACGCAGT
s-1m30e,F6,TATAAATCTTCCAGTTTGGAACAATTTTTTGG
s-1m30i,G6,GAGTGTTGAAAAGAATAGCCCGAGCACGACCA
s-1m32g,H6,GGTCGAGGGAGCCCCCGATTTAGAAAGCCGGCGAACGTGG
s-1m32i,A7,CCTAAAGGTGCCGTAAAGCACTAACTTGCCTG
s-1m34j,B7,CGAGAAAGGAAGGGAAGCCACCGAGTAAAAGA
s-1m4e,C7,AAACGTCAAGTAGCGACAGAATCAACCCTCAG
s-1m4i,D7,CCGTAATCCCAATGAAACCATCGAAATAATAA
s-1m6e,E7,AACCGCCAAGAACCACCACCAGAGAGTGCCTT
s-1m6i,F7,CCGCCACCCCCTCAGAGCCACCACACAGCCAT
s-1m8e,G7,GAGTAACACGTTTTAATTCGAGCTAAGACTTC
s-1m8i,H7,GATATAAGGTGCCCGTATAAACAGTTAATGCC
s-2m17g,A8,AGAGGGGGAATACTGCGGAATCGTTTAAACAGTTCAGAAA
s-2m19f,B8,ACGAGGCAACCAGACGACGATAAAGTTTTGCC
s-2m1a,C8,ATGGTTATTCAT
s-2m21f,D8,AGGTAGAATTCAACTAATGCAGATAAGGAATT
s-2m23f,E8,CTTATGCGACGTTGGGAAGAAAAAATTATTAC
s-2m25f,F8,GATGGTTTAATTTCAATGAATTAC
s-2m27g,G8,GCCAGCTGCATTAATGGTATTGGGCGCCAGGGAAATCCCT
s-2m29g,H8,AATCGGCATGGTTTTTCTTTTCACTCGGGAAACCTGTCGT
s-2m33a,A9,CGGGGAGCTTGA
s-2m3f,B9,CCATTAGCGAAATTATTCATTAAA
s-2m5f,C9,GAGCCGCCAGTTTGCCTTTAGCGTCACCATTA
s-2m7f,D9,ACGGGGTCCCGCCGCCAGCATTGACTCCCTCA
s-2m9f,E9,TCAAAGCGAACCAGACAAGTTTTA
s-3m16i,F9,CAAATGCTCATAAATATTCATTGAGAGTCTGG
s-3m18i,G9,CAAAAGAAAACCAAAATAGCGAGATTTTTAAC
s-3m20a,H9,CGCCAAACATAA
s-3m24a,A10,TCATTGCTTTAA
s-3m2e,B10,GGTGAATTATCACCGTGCAAAATC
s-3m30g,C10,TTGATGGTAACGTGGACTCCAACGGGCCCACTACGTGAAC
s-3m32g,D10,CATCACCCAAATCAAGGAGTCCACTATTAAAGGGTTCCGA
s-3m4e,E10,ACCAGTAGCAGACTGTAGCGCGTTCCACCACC
s-3m6e,F10,GGAACCGCCAGGAGGTTGAGGCAGGGAGTGTA
s-3m8e,G10,CTGGTAATCGGAAGCAAACTCCAA
s-4m11f,H10,GTAGCATTTTTCATTCCATATAACGTACGGTG
s-4m13f,A11,TTTTAGAAAACATCCAATAAATCATAATAGTA
s-4m15g,B11,CCCTCATATATTTTAAATAAAAAT
s-4m21g,C11,GAACTAACGGAACAACTCTACGTTAATAAAAC
s-4m27g,D11,TTGCGCTCTTCCTGTGTGAAATTGTCATGGTCATAGCTGT
s-4m27h,E11,ACTGCCCGCTTTCCAGCAGTGAGACGGGCAACAATCCTGT
s-4m29f,F11,CAGGCGAAAGCTGATTGCCCTTCATAATTGCG
s-4m3f,G11,TAGAGCCACACCGACTTGAGCCAT
s-4m5f,H11,AACCAGAGTTCATCGGCATTTTCGTTGGGAAT
s-4m7f,A12,ATGATACAGTCAGACGATTGGCCTATCACCGG
s-4m9f,B12,TCTGGAAGCAGGTCAGGATTAGAGGGCTTTTG
s-5m10e,C12,CAACTAAAAGTTGATTCCCAATTCGTGGCATC
s-5m12e,D12,AATTCTACTACAGGCAAGGCAAAGTTATTTCA
s-5m14e,E12,ACGCAAGGATGCAATGCCTGAGTAAGATCTAC
s-5m16e,F12,AAAGGCTAAGAGAATCGATGAACGATTCGCAT
s-5m16i,G12,AGCAAACATCAGGTCATTGCCTGAATCCCCCT
s-5m18e,H12,TAAATTTTACGCCATCAAAAATAA
```

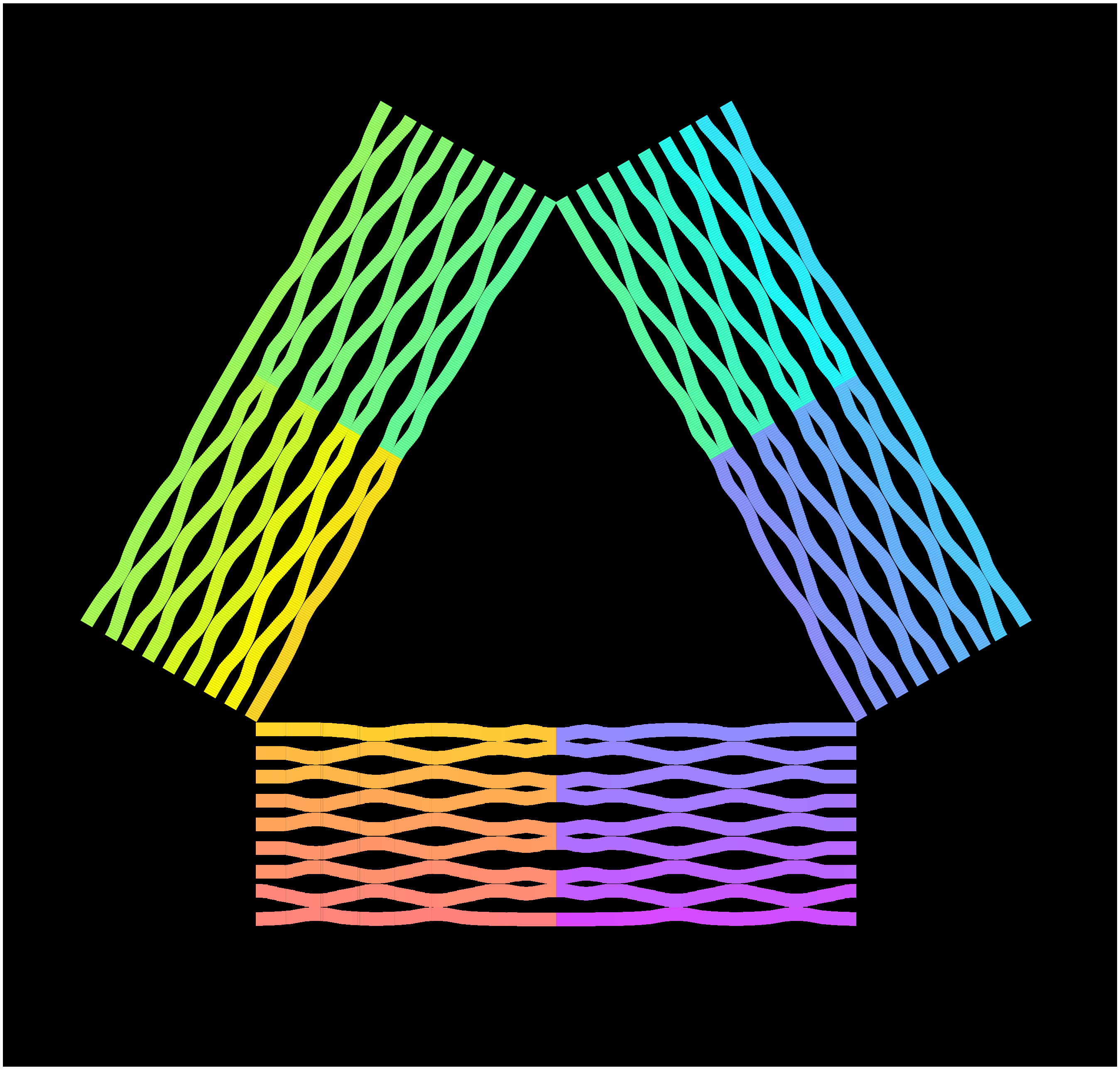
```
Plate number: 3
s-5m18i,A1,CAATAGGATGTTAAATCAGCTCATGGCTTTTG
s-5m22g,B1,GTGCCGGAAACTGTGCTGC
s-5m24b,C1,GGGTAATAAGTT
s-5m24e,D1,AAGGCGATCGCCAGGGTTTTCCCAGAGCTCGA
s-5m26e,E1,ATTCGTAATTATCCGCTCACAATTGTGAGCTA
s-5m28g,F1,ACTCACATCCGCCTGGCCCTGAGAGCGGTCCACGCTGGTT
s-5m32g,G1,CGTCTATCAGGGCGATTCAAAGGGCGAAAAACTGCCCCAG
s-5m4e,H1,GTCATAGCCCCCTTATTCTTTTCA
s-5m6e,A2,TAATCAAATGATATTCACAAACAAAGTAAGCG
s-5m8e,B2,TCATACATAGTACCTTTAATTGCTTAAATATG
s-6m11f,C2,CTGAAAAGTGCGAACGAGTAGATTGTAGCTCA
s-6m13f,D2,AGAAGCCTAATTAGCAAAATTAAGGGCGCGAG
s-6m15f,E2,TTTTTGAGATGTGTAGGTAAAGATTTTGCGGG
s-6m17f,F2,TTGTTAAAGTAATCGTAAAACTAGGGTAGCTA
s-6m19f,G2,GTCACGTTTTCGCGTCTGGCCTTCTTAATATT
s-6m21f,H2,CTTTCCGGGGTGTAGATGGGCGCATGGGATAG
s-6m21g,A3,CACCGCTTCTG
s-6m23f,B3,AAGGGGGACAGGCAAAGCGCCATTCCAGCCAG
s-6m25f,C3,CGGGTACCGTCACGACGTTGTAAAGCTGGCGA
s-6m27f,D3,CCTAATGACCACACAACATACGAGAGGATCCC
s-6m29a,E3,CAGCAAGAGTTG
s-6m5a,F3,TTGCCATAGCGT
s-6m7g,G3,ACCGTTCCATAAATCCTCATTAAAGCCAGAATGGA
s-6m9f,H3,ACATGTTTCCTTTTGATAAGAGGTCTGAATTT
s-7m10e,A4,ATAATGCTTAGTTTGACCATTAGACTATATTT
s-7m12e,B4,TCATTTGGCAATAAAGCCTCAGAGATGACCCT
s-7m14e,C4,GTAATACTTCAAAAGGGTGAGAAAAATTAATG
s-7m16e,D4,CCGGAGAGCATGTCAATCATATGTATTTAAAT
s-7m18e,E4,TGTAAACGCTGTAGCCAGCTTTCAGGCGGATT
s-7m20e,F4,GACCGTAATCGTAACCGTGCATCTTCAGGAAG
s-7m22e,G4,ATCGCACTCGCCATTCAGGCTGCGCTTCGCTA
s-7m24e,H4,TTACGCCAACGACGGCCAGTGCCATGCAGGTC
s-7m26e,A5,GACTCTAGCCGGAAGCATA
s-8m11f,B5,CTGTTTAGTACATTTCGCAAATGG
s-8m13f,C5,AAAACATTCATAAAGCTAAATCGGTCAATAAC
s-8m15f,D5,AGCTGATAGGCCGGAGACAGTCAATTGTACCA
s-8m17f,E5,AAGCAAATACCCCGGTTGATAATCACCGTTCT
s-8m19f,F5,GAACAAACTCAACATTAAATGTGAGATTGTAT
s-8m21f,G5,TATCGGCCGCCAGTTTGAGGGGACCTCCGTGG
s-8m25a,H5,CATGCCAGCTTG
s-8m27g,A6,AAGTGTAAAGCCTGGGGTG
s-8m7g,B6,AAGCGCAGTCTCATTTTTGCGGATGGCTGCTGAAT
s-8m9a,C6,CTTAATTTAGAG
s-9m14e,D6,ATCACCATCAA
s-9m24g,E6,CGATCGGTGCGGGCCTCAACTGTTGGGAAGGGGACGACAG
sm-rem1,F6,CCTGAGAAGTGTTTTTATAATCAGTGAG
sm-rem2,G6,ATTTTAGACAGGAACGGTACGCCAGAAT
sm-rem3,H6,GGAGCTAAACAGGAGGCCGATTAAAGGG
sm-rem4,A7,ACGTGCTTTCCTCGTTAGAATCAGAGCG
sm-rem5,B7,ACTATGGTTGCTTTGACGAGCACGTATA
sm-rem6,C7,GCGCTTAATGCGCCGCTACAGGGCGCGT
```

Supplementary Figure S28: Sequences for the disk with holes (smiley).



25 turns wide at 10.4 bases/turn -> 260 bases
9 helices / domain, 27 helices in alll

Supplementary Figure S29: Schematics for the triangle Fig. 2e. **a** Block diagram. Designed for 2.5-turn spacing blocks have 5 different offsets with respect to the underlying lattice of crossovers, hence the 5 different hues of blocks in different columns. As in other block diagrams, orange block/red block boundaries have an offset of 0 turns with respect to the underlying lattice of crossovers. **b** Folding path.



Supplementary Figure S30: Crossover diagram for the equilateral composed of rectangular domains.

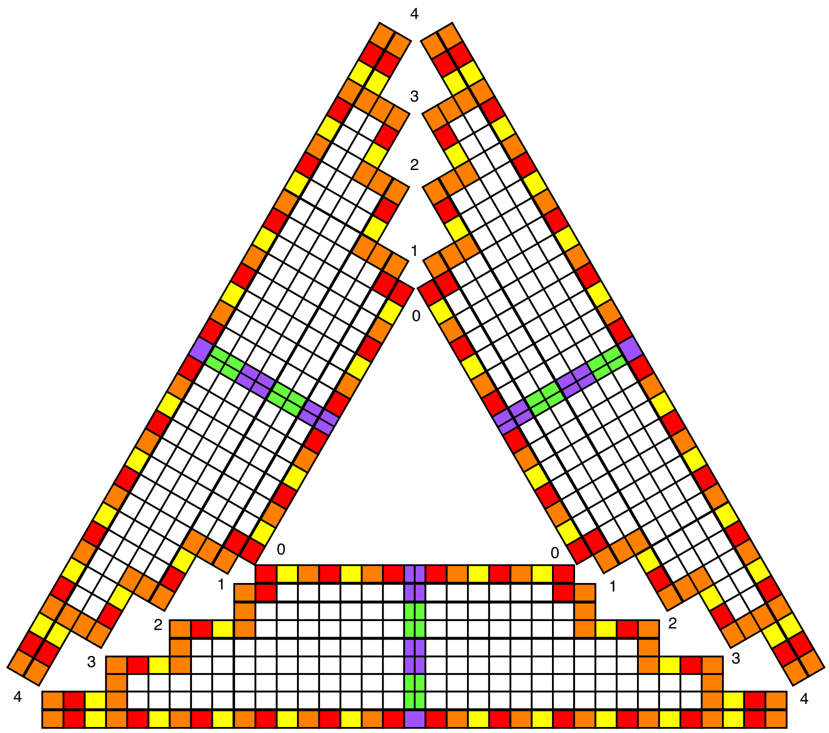
```
Plate number: 1
e0t11d,A1,CATAGTTAGCGTAAATCGATGAACGG
e0t13c,B1,GCCGACAATGACACTGTAATACTTTT
e0t13d,C1,GAGCAAACAAGAGACGATCTAAAGTT
e0t15c,D1,ACTCATCTTTGACTCATTCCATATAA
e0t15d,E1,AAACATTATGACCACAACCATCGCCC
e0t17c,F1,AATCAACGTAACATATTATAGTCAGA
e0t17d,G1,GTGTCTGGAAGTTCCCCAGCGATTAT
e0t19c,H1,CTAATGCAGATACATAACGCCAAAAG
e0t19d,A2,TCTTTACCCTGACAAGCTGCTCATTC
e0t1d,B2,CAATAGTGAATTTTGCTCAGTACCAG
e0t21d,C2,TAACAACCCGTCGAATCGCGCAGAGG
e0t23c,D2,CCAGCTGGCGAAAAGAAGGAGCGGAA
e0t23d,E2,TACCAAGTTACAAGATTCTCCGTGGG
e0t25c,F2,AGCTAACTCACATACCTCAAATATCA
e0t25d,G2,CAAAGAAACCACCGGGGGATGTGCTG
e0t27c,H2,CGGCAAAATCCCTTAAAAGGGACATT
e0t27d,A3,ATCACCTTGCTGATAATTGCGTTGCG
e0t29c,B3,GAAAGGAAGGGAAATAATCAGTGAGG
e0t29d,C3,ACACGACCAGTAATATAAATCAAAAG
e0t3c,D3,GTATCATATGCGTATTCACAAACAAA
e0t3d,E3,ATTAGCGGGGTTTATCAAAATCATAG
e0t5c,F3,CCATCCTAATTTAATCAAGTTTGCCT
e0t5d,G3,GATTGGCCTTGATTATACAAATTCTT
e0t7c,H3,CTATTTTGCACCCAGTTATTTTTGT
e0t7d,A4,CAGTAGCGACAGACGAGCATGTAGAA
e0t9c,B4,AGAGAGATAACCCACAAGAATTGAGT
e0t9d,C4,GACACCACGGAATAGCTACAATTTTA
e1t10e,D4,TAAGCCCAATAATAAGAGCAAGAAAC
e1t12a,E4,TAATCGTAAAACTGCCTGAGAGTCTG
e1t12b,F4,CTATCAGGTCATTAGCATGTCAATCA
e1t14a,G4,GCGGGAGAAGCCTTCGGTTGTACCAA
e1t14b,H4,GCATAAAGCTAAATTATTTCAACGCA
e1t16a,A5,CAGTTGATTCCCACAACTAAAGTACG
e1t16b,B5,TGTTTTAAATATGATTCTGCGAACGA
e1t18a,C5,AGCAAAGCGGATTATCAAAAATCAGG
e1t18b,D5,AGAATGACCATAAGCATCAAAAAGAT
e1t20e,E5,GAATTACGAGGCATAGTAAGAGCAAC
e1t22a,F5,CGAATTATTCATTTGATTGCTTTGAA
e1t22b,G5,TAACGGATTCGCCTCAATTACCTGAG
e1t24a,H5,TTATCATCATATTTCATTTTGCGGAA
e1t24b,A6,TTGAGTAACATTACCTGATTATCAGA
e1t26a,B6,AACCCTCAATCAAAAAAATCTAAAGC
e1t26b,C6,CCAGCAGCAAATGTATCTGGTCAGTT
e1t28a,D6,CTGGCCAACAGAGAGATTCACCAGTC
e1t28b,E6,TATTTACATTGGCATAGAACCCTTCT
e1t2a,F6,GCGGATAAGTGCCGAGAAGGATTAGG
e1t2b,G6,TGAGACTCCTCAAGTCGAGAGGGTTG
e1t30e,H6,CCACCGAGTAAAAGAGTCTGTCCATC
e1t4a,A7,TAAATCCTCATTAAGGCAGGTCAGAC
e1t4b,B7,TGACAGGAGGTTGAAGCCAGAATGGA
e1t6a,C7,TTAGCGTCAGACTGCAGCACCGTAAT
e1t6b,D7,GAAACCATCGATAGTAGCGCGTTTTC
e1t8a,E7,CACAATCAATAGAAAAGAAACGCAAA
e1t8b,F7,GTGGCAACATATAAAATTCATATGGT
e2t11e,G7,TATGTACCCCGGTTGATAATCAGAAA
e2t13a,H7,AGGATAAAAATTTAGATCTACAAAGG
e2t13b,A8,AGCTATTTTTGAGTTAGAACCCTCAT
e2t15a,B8,GTAGATTTAGTTTATAAAGCCTCAGA
e2t15b,C8,GCAAAATTAAGCAGACCATTAGATAC
e2t17a,D8,TAAGAGGAAGCCCTGTAGCTCAACA
e2t17b,E8,GCTGAATATAATGGAAAGACTTCAAA
e2t19a,F8,ACTATCATAACCCAGTTCAGAAAACG
e2t19b,G8,AAATGCTTTAAACTCGTTTACCAGAC
e2t1e,H8,ATATAAGTATAGCCCGGAATAGGTGT
e2t21e,A9,CAAAAGAAGATGATGAAACAAACATC
e2t23a,B9,TGATGGCAATTCATCGGGAGAAACAA
e2t23b,C9,AGTACCTTTTACATCAATATAATCCT
e2t25a,D9,GGCAAATCAACAGTAATTTTAAAAGT
e2t25b,E9,GCCCGAACGTTATTTGAAAGGAATTG
e2t27a,F9,GACCTGAAAGCGTGCCACGCTGAGAG
e2t27b,G9,CGCCTGCAACAGTAGAATACGTGGC
e2t29a,H9,ACGCAAATTAACCGTCTGAAATGGAT
e2t29b,A10,TTGACGCTCAATCGTTGTAGCAATAC
e2t3a,B10,AAGCGCAGTCTCTAGTATTAAGAGGC
e2t3b,C10,TCTGAAACATGAAGAATTTACCGTTC
e2t5a,D10,ATCGGCATTTTCGCCGCCGCCAGCAT
e2t5b,E10,ACCACCACCAGAGGTCATAGCCCCCT
e2t7a,F10,TTACCAGCGCCAAAAACGTCACCAAT
e2t7b,G10,TTAGCAAGGCCGGAGACAAAAGGGCG
e2t9a,H10,AATGAAATAGCAATACATACATAAAG
e2t9b,A11,CAAACGTAGAAAATAGCTATCTTACC
e3t10e,B11,GAAGCCCTTTTTAAGAAAAGTAAGCA
e3t12a,C11,AGCCCCAAAAACATGCCGGAGAGGGT
e3t12b,D11,GCTGATAAATTAAGGAAGATTGTATA
e3t14a,E11,ATATTTTAAATGCAGGCAAAGAATTA
e3t14b,F11,AATCATACAGGCAAATGCCTGAGTAA
e3t16a,G11,ATTTCGCAAATGGTTAGAGCTTAATT
e3t16b,H11,TTTTGCGGATGGCTCAATAACCTGTT
e3t18a,A12,TATCGCGTTTTAATTGAATCCCCCTC
e3t18b,B12,TCATAAATATTCATTCGAGCTTCAAA
e3t20e,C12,GACGATAAAAACCAAAATAGCGAGAG
e3t22a,D12,AAGAAAACAAAATAATATACAGTAAC
e3t22b,E12,TTAACGTCAGATGTAATTACATTTAA
e3t24a,F12,GATTGTTTGGATTTATTAAATCCTTT
e3t24b,G12,ATTCGACAACTCGATACTTCTGAATA
e3t26a,H12,AGGAAGGTTATCTTCAGTATTAACAC
```

```
Plate number: 2
e3t26b,A1,AGAGGTGAGGCGGAAAATATCTTTAG
e3t28a,B1,ACAGACAATATTTAAATACCTACATT
e3t28b,C1,AAAACGCTCATGGTTGAATGGCTATT
e3t2a,D1,ATCACCGTACTCACGGAACCTATTAT
e3t2b,E1,CCCCTGCCTATTTGGAGGTTTAGTAC
e3t30e,F1,TTCTTTGATTAGTAATAACATCACTT
e3t4a,G1,CAGTAAGCGTCATAGCCGCCACCAGA
e3t4b,H1,CCACCACCCTCAGACATGGCTTTTGA
e3t6a,A2,TATTAGCGTTTGCAGCACCATTACCA
e3t6b,B2,CAAAATCACCAGTCATCTTTTCATAA
e3t8a,C2,ACATTCAACCGATCGCAGTATGTTAG
e3t8b,D2,AGACTCCTTATTATGAGGGAGGGAAG
e4t11e,E2,AGCAAATATTTAAATTGTAAACGTTA
e4t13a,F2,TGTGTAGGTAAAGTTCAACCGTTCTA
e4t13b,G2,CATCAATATGATAATTCAAAAGGGTG
e4t15a,H2,TAGCTATATTTTCTTAACATCCAATA
e4t15b,A3,AATAGTAGTAGCAATTTGGGGCGCGA
e4t17a,B3,GCGAACCAGACCGGATAAGAGGTCAT
e4t17b,C3,AATTGCTCCTTTTGAAGCAAACTCCA
e4t19a,D3,GCTTTTGCAAAAGTACTGCGGAATCG
e4t19e,E3,GGATAGCGTCCAAAAGTTTTGCCAGAGGGGGTAATAGTA
e4t1e,F3,CGCCACCCTCAGAACCGCCACCCTCA
e4t21e,G3,CAATTTCATTTGAATTACCTTTTTTA
e4t23a,H3,ATGGAAGGGTTAGTAGATTTTCAGGT
e4t23b,A4,TAAAGAAATTGCGAACCTACCATATC
e4t25a,B4,GAGCACTAACAACGACTTTACAAACA
e4t25b,C4,TTTAGAAGTATTATAATAGATTAGAG
e4t27a,D4,AGTCTTTAATGCGCAGAAGATAAAAC
e4t27b,E4,AACGAACCACCAGCGAACTGATAGCC
e4t29a,F4,GCCTGAGTAGAAGCATTGCAACAGGA
e4t29e,G4,TATTACCGCCAGCAACTCAAACTATCGGCCTTGCTGGTA
e4t3a,H4,TGATACAGGAGTGAAACAGTTAATGC
e4t3b,A5,ACAGTGCCCGTATTACTGGTAATAAG
e4t5a,B5,TCAAAATCACCGGGCCACCCTCAGAG
e4t5b,C5,CACCCTCAGAACCAACCAGAGCCACC
e4t7a,D5,GTAAATATTGACGGAATTAGAGCCAG
e4t7b,E5,TTGAGCCATTTGGGAAATTATTCATT
e4t9a,F5,GATAGCCGAACAAACTGGCATGATTA
e4t9e,G5,AATACCCAAAAGAAGTTACCAGAAGGAAACCGAGGAAAC
e5t12a,H5,ATATTTTGTTAAAACAGTCAAATCAC
e5t14a,A6,AGAAAGGCCGGAGCATCAATTCTACT
e5t16a,B6,GCTGAAAAGGTGGAGAGAGTACCTTT
e5t18a,C6,ACAGGTCAGGATTAAATGTTTAGACT
e5t22a,D6,ATGGAAACAGTACCGTAAAACAGAAA
e5t24a,E6,AAAATTATTTGCAATACATTTGAGGA
e5t26a,F6,CCGTCAATAGATAATTAAAAATACCG
e5t28a,G6,CTAAAACATCGCCATATCCAGAACAA
e5t2a,H6,GAACCGCCACCCTAGTGCCTTGAGTA
e5t4a,A7,TTTTAACGGGGTCCCCTCAGAGCCGC
e5t6a,B7,ACCGGAACCGCCTCACCGTCACCGAC
e5t8a,C7,AAAGGTGAATTATGCAATAATAACGG
e-1t10e,D7,TCAGAGGGTAATTGAGCGCTAATATC
e-1t12a,E7,GCCTGTAGCATTCAGACGTTAGTAAA
e-1t12b,F7,TTGTCGTCTTTCCCACAGACAGCCCT
e-1t14a,G7,TTAAACAGCTTGAATATTCGGTCGCT
e-1t14b,H7,ACGCATAACCGATTACCGATAGTTGC
e-1t16a,A8,AAAGAGGCAAAAGCAAAGTACAACGG
e-1t16b,B8,ACCAAGCGCGAAAAATACACTAAAAC
e-1t18a,C8,GACAAGAACCGGATGCCCTGACGAGA
e-1t18b,D8,AGTGAATAAGGCTTATTCATTACCCA
e-1t20e,E8,TTGAGATTTAGGAATACCACATTCAA
e-1t22a,F8,TTTCATCAACATTTTGACCGTAATGG
e-1t22b,G8,AACAAACGGCGGAAAATGTGAGCGAG
e-1t24a,H8,TCGGTGCGGGCCTTTGGGTAACGCCA
e-1t24b,A9,CAAGGCGATTAAGCTTCGCTATTACG
e-1t26a,B9,GTAAAGCCTGGGGTTCCAGTCGGGAA
e-1t26b,C9,CTCACTGCCCGCTTGCCTAATGAGTG
e-1t28a,D9,ATCCTGTTTGATGAGGGTTGAGTGTT
e-1t28b,E9,AATAGCCCGAGATGTGGTTCCGAAAT
e-1t2a,F9,GCTTAGATTAAGACCTTTTTAACCTC
e-1t2b,G9,GTCTGAGAGACTACGCTGAGAAGAGT
e-1t30e,H9,ACGGGGAAAGCCGGCGAACGTGGCGA
e-1t4a,A10,CATAATTACTAGACAACGCTCAACAG
e-1t4b,B10,ACCAGTATAAAGCAAAAGCCTGTTTA
e-1t6a,C10,AAGTCCTGAACAACGGCTGTCTTTCC
e-1t6b,D10,ACCAATCAATAATGAAAAATAATATC
e-1t8a,E10,TTGAAGCCTTAAACAACGCTAACGAG
e-1t8b,F10,TCCTGAATCTTACTCAAGATTAGTTG
e-2t11e,G10,GTTTCGTCACCAGTACAAACTACAAC
e-2t13a,H10,ATCAGCTTGCTTTTGGGATTTTGCTA
e-2t13b,A11,TGAATTTTCTGTACGAGGTGAATTTC
e-2t15a,B11,CACTACGAAGGCAAGTTAAAGGCCGC
e-2t15b,C11,GAGGCTTGCAGGGCCAACCTAAAACG
e-2t17a,D11,GGCTGACCTTCATCGCCTGATAAATT
e-2t17b,E11,AGATTTGTATCATCAAGAGTAATCTT
e-2t19a,F11,TTATTACAGGTAGGTAGTAAATTGGG
e-2t19b,G11,AACACCAGAACGAAAAGATTCATCAG
e-2t1e,H11,TTAGAATCCTTGAAAACATAGCGATA
e-2t21e,A12,TCGCGTCTGGCCTTCCTGTAGCCAGC
e-2t23a,B12,GGCTGCGCAACTGGGTGTAGATGGGC
e-2t23b,C12,GATAGGTCACGTTTTGGGAAGGGCGA
e-2t25a,D12,CAACATACGAGCCCACGACGTTGTAA
e-2t25b,E12,GGGTTTTCCCAGTGGAAGCATAAAGT
e-2t27a,F12,ACGCTGGTTTGCCGCTGCATTAATGA
e-2t27b,G12,ACCTGTCGTGCCACCAGCAGGCGAAA
e-2t29a,H12,AAAGGGAGCCCCCACAAGAGTCCACT
```

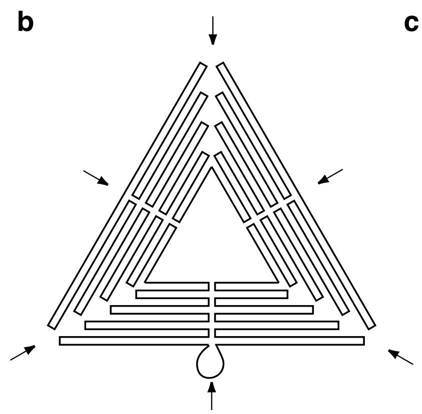
```
Plate number: 3
e-2t29b,A1,GTTCCAGTTTGGAGATTTAGAGCTTG
e-2t3a,B1,CGTTAAATAAGAAGTTATATAACTAT
e-2t3b,C1,CGGCTTAGGTTGGTAAACACCGGAAT
e-2t5a,D1,AACGCGCCTGTTTAGAATCGCCATAT
e-2t5b,E1,TAGGGCTTAATTGATCAACAATAGAT
e-2t7a,F1,GCGAACCTCCCGAAACGGGTATTAAA
e-2t7b,G1,TTATCATTCCAAGCTTGCGGGAGGTT
e-2t9a,H1,GAATTAACTGAACCCTAATTTGCCAG
e-2t9b,A2,CGTCTTTCCAGAGACCCTGAACAAAG
e-3t10e,B2,AAAACAGGGAAGCGCATTAGACGGGA
e-3t12a,C2,TAGGAACCCATGTAGTTTCAGCGGAG
e-3t12b,D2,AACAACTTTCAACACCGTAACACTGA
e-3t14a,E2,AAAGGAGCCTTTATCACCCTCAGCAG
e-3t14b,F2,TTTTGCGGGATCGATTGTATCGGTTT
e-3t16a,G2,CATTAAACGGGTACGACCTGCTCCAT
e-3t16b,H2,GTGTCGAAATCCGAAATACGTAATGC
e-3t18a,A3,CGGTGTACAGACCAATTTCAACTTTA
e-3t18b,B3,CTTGAGATGGTTTAGGCGCATAGGCT
e-3t20e,C3,TAATAAAACGAACTAACGGAACAACA
e-3t22a,D3,CCAATAGGAACGCGCATCTGCCAGTT
e-3t22b,E3,GCATCGTAACCGTCATCAAAAATAAT
e-3t24a,F3,CCAGGCAAAGCGCGCCAAGCTTGCAT
e-3t24b,G3,AACGACGGCCAGTCATTCGCCATTCA
e-3t26a,H3,AATTGTTATCCGCCGGGGAGAGGCGG
e-3t26b,A4,ATCGGCCAACGCGTCACAATTCCACA
e-3t28a,B4,CCTGAGAGAGTTGGACTCCAACGTCA
e-3t28b,C4,ATTAAAGAACGTGCAGCAAGCGGTCC
e-3t2a,D4,AATCGTCGCTATTTGCAAATCCAATC
e-3t2b,E4,ATGTAAATGCTGAAATTAATTTTCCC
e-3t30e,F4,GCCGTAAAGCACTAAATCGGAACCCT
e-3t4a,G4,AAATACCGACCGTCATGTAATTTAGG
e-3t4b,H4,TTAACAACGCCAAGTGATAAATAAGG
e-3t6a,A5,ATAAACAACATGTTCATCGAGAACAA
e-3t6b,B5,CCAAGTACCGCACTCAGCTAATGCAG
e-3t8a,C5,GTATTCTAAGAACAGCCATATTATTT
e-3t8b,D5,TTACAAAATAAACGCGAGGCGTTTTA
e-4t11e,E5,CTCATTTTCAGGGATAGCAAGCCCAA
e-4t13a,F5,TGAAAATCTCCAAGAACAACTAAAGG
e-4t13b,G5,TGAGAATAGAAAGAAAAAAGGCTCCA
e-4t15a,H5,TAAAGACTTTTTCCGGAACGAGGGTA
e-4t15b,A6,CGAAAGACAGCATATGAGGAAGTTTC
e-4t17a,B6,ACCAACTTTGAAAAACGAGGCGCAGA
e-4t17b,C6,GTTACTTAGCCGGGAGGACAGATGAA
e-4t19b,D6,ATCATTGTGAATTGAAAAATCTACGT
e-4t1e,E6,TGTGAGTGAATAACCTTGCTTCTGTA
e-4t21e,F6,TTTTGTTAAATCAGCTCATTTTTTAA
e-4t23a,G6,TCCGGCACCGCTTACAGTATCGGCCT
e-4t23b,H6,TGAGGGGACGACGCTGGTGCCGGAAA
e-4t25a,A7,CATGGTCATAGCTCTCTAGAGGATCC
e-4t25b,B7,GCCTGCAGGTCGAGTTTCCTGTGTGA
e-4t27a,C7,CAGCTGATTGCCCCGCCAGGGTGGTT
e-4t27b,D7,TTTGCGTATTGGGTTCACCGCCTGGC
e-4t29b,E7,AAGGGCGAAAAACTTGGGGTCGAGGT
e-4t3a,F7,TCTTCTGACCTAACGCGAGAAAACTT
e-4t3b,G7,GCAAGACAAAGAAATTTAATGGTTTG
e-4t5a,H7,AAAGTAATTCTGTGAGCCAGTAATAA
e-4t5b,A8,CAGAGGCATTTTCCCAGACGACGACA
e-4t7a,B8,CAAATCAGATATAATTTTCATCGTAG
e-4t7b,C8,GCAAGCCGTTTTTGAAGGCTTATCCG
e-4t9b,D8,ATCCCAATCCAAAAGAGAATAACATA
e-5t10e,E8,AAAAATGAAAATAGCAGCCTTTACAGTAAGAAACGATTT
e-5t12b,F8,AATTGCGAATAATCAGAGCCACCACC
e-5t14b,G8,GCAACGGCTACAGAATTTTTTCACGT
e-5t16b,H8,CGGTCAATCATAAAGGCTTTGAGGAC
e-5t18b,A9,TTAAGAACTGGCTGGGAACCGAACTG
e-5t20e,B9,CATTATACCAGTCAGGACGTTGGGAAACCTTATGCGATT
e-5t22b,C9,CAGGAAGATCGCAATTCGCATTAAAT
e-5t24b,D9,CCGGGTACCGAGCCTCCAGCCAGCTT
e-5t26b,E9,TTTCTTTTCACCATCGAATTCGTAAT
e-5t28b,F9,GATGGCCCACTACGTGAGACGGGCAA
e-5t2b,G9,TTTCAAATATATTATAAATCAATATA
e-5t30e,H9,GTGAACCATCACCCAAATCAAGTTTTCGTCTATCAGGGC
e-5t4b,A10,GAGAATATAAAGTTTAGTTAATTTCA
e-5t6b,B10,GAATCATTACCGCACCGACAAAAGGT
e-5t8b,C10,TTTGTTTAACGTCGCCCAATAGCAAG
et-rem1,D10,ACGCCAGAATCCTGAGAAGTGTTTTT
et-rem2,E10,TTAAAGGGATTTTAGACAGGAACGGT
et-rem3,F10,AGAGCGGGAGCTAAACAGGAGGCCGA
et-rem4,G10,TATAACGTGCTTTCCTCGTTAGAATC
et-rem5,H10,GTACTATGGTTGCTTTGACGAGCACG
et-rem6,A11,GCGCTTAATGCGCCGCTACAGGGCGC
```

Supplementary Figure S31: Sequences for the equilateral composed of rectangular domains.

a



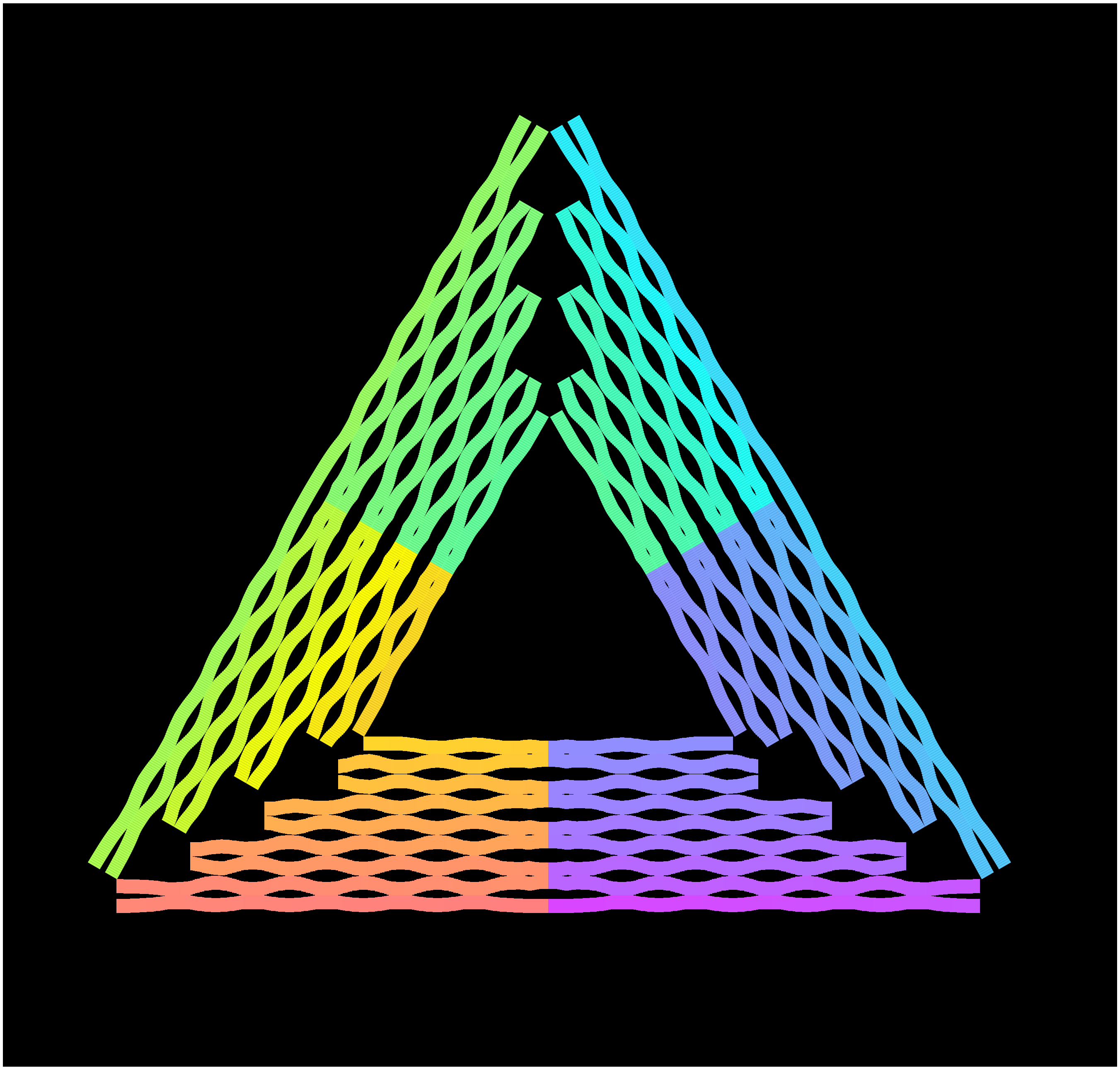
b



c

```
For bridges between trapezoidal slant edges
contact type,  name,  and sequence
1,  t-5s2e-t6s23c-3T,A6,    TTAATTAATTTTTTACCATATCAAA
2,  t-7s4e-t8s25c-2T,B6,    TTAATTTCATCTTAGACTTTACAA
3,  t-9s6e-t10s27c-1T,C6,   CTGTCCAGACGTATACCGAACGA
4,  t-11s8e-t12s29c-0T,D6,  TCAAGATTAGTGTAGCAATACT

1,  t-5s12e-t6s3c-3T,E6,    TGTAGCATTCCTTTTATAAACAGTT
2,  t-7s14e-t8s5c-2T,F6,    TTTAATTGTATTTCCACCAGAGCC
3,  t-9s16e-t10s7c-1T,G6,   ACTACGAAGGCTTAGCACCATTA
4,  t-11s18e-t12s9c-0T,H6,  ATAAGGCTTGCAACAAAGTTAC

1,  t-5s22e-t6s13c-3T,A7,   GTGGGAACAAATTTCTATTTTTGAG
2,  t-7s24e-t8s15c-2T,B7,   CGGTGCGGGCCTTCCAAAAACATT
3,  t-9s26e-t10s17c-1T,C7,  ATGAGTGAGCTTTTAAATATGCA
4,  t-11s28e-t12s19c-0T,D7, ACTATTAAAGAGGATAGCGTCC
```

Supplementary Figure S 32: More details of sharp triangle design. **a** Block design for the sharp triangle composed of trapezoidal domains. Contacts between trapezoids on their slant faces are of type 0, 1, 2, 3, and 4. Contacts of type 0 are bridged by the scaffold strand as shown in the folding path (**b**). Other contacts are bridged by special staples (**c**) that each replace two of the staple strands in the staple sequences (Supplementary Fig. S34), identified by the composite names of the bridging staples. Assuming a 1 nm inter-helix gap and 32 bases/3 turns, I calculated that the contacts would have gaps of width of 1.5696 nm, 1.0822 nm, 0.5944 nm, 0.1070 nm for contact types 1,2,3, and 4. (The gap widths drawn in the block diagram above are not accurate; contact type 4 has essentially no gap given an inter-helix gap of 1 nm.) Assuming that an unpaired thymine can bridge .43 nm (the length per base-pair of single stranded DNA[34]), this would require adding 3.7, 2.5, 1.4, or 0.25 T's in the bridging staple for each contact point. In fact, 4T loops are often used to bridge 2 nm wide double helices to make them into hairpins assuming .5 nm per T. I used 3, 2, 1, and 0 T's for contacts of type 1, 2, 3, and 4 as can be seen inserted into the middle of the sequence in **c**. As in other block diagrams, in **a**, turns that occur between columns of red blocks and orange blocks have offset 0 with respect to the underlying crossover lattice. Other turns on the left and right outer edges have +1 or -1 offsets depending on which side of the trapezoid they occur. Purple and green half-blocks show that scaffold turns made at the central seams are an odd number of DNA 1/2 turns away from scaffold turns on the outer edges.



Supplementary Figure S33: Crossover diagram for the sharp triangle composed of trapezoidal domains.

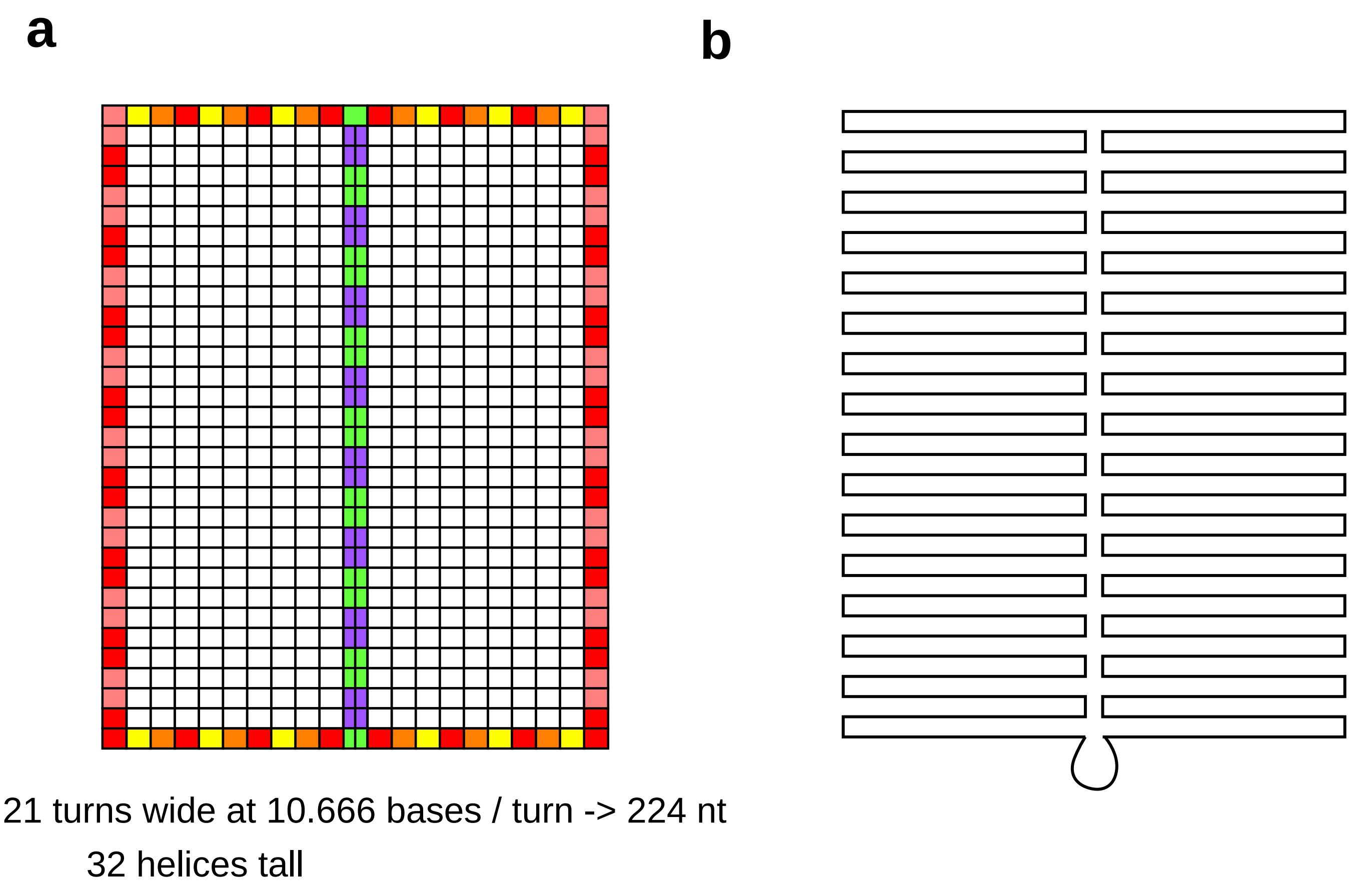
```
Plate number: 1
t10s17c,A1,TTAAATATGCA
t10s27c,B1,ATACCGAACGA
t10s7c,C1,TAGCACCATTA
t11s18h,D1,AATACTGCGGAATCGTAGGGGGTAATAGTAAAATGTTTAGACT
t11s28h,E1,TCTTTGATTAGTAATAGTCTGTCCATCACGCAAATTAACCGTT
t11s8h,F1,CAGAAGGAAACCGAGGTTTTTAAGAAAAGTAAGCAGATAGCCG
t12s19c,G1,GGATAGCGTCC
t12s29c,H1,GTAGCAATACT
t12s9c,A2,AACAAAGTTAC
t1s10g,B2,GACGGGAGAATTAACTCGGAATAAGTTTATTTCCAGCGCC
t1s12i,C2,TCATATGTGTAATCGTAAAACTAGTCATTTTC
t1s14i,D2,GTGAGAAAATGTGTAGGTAAAGATACAACTTT
t1s16i,E2,GGCATCAAATTTGGGGCGCGAGCTAGTTAAAG
t1s18i,F2,TTCGAGCTAAGACTTCAAATATCGGGAACGAG
t1s20g,G2,GAATACCACATTCAACTTAAGAGGAAGCCCGATCAAAGCG
t1s22i,H2,TCGGGAGATATACAGTAACAGTACAAATAATT
t1s24i,A3,CCTGATTAAAGGAGCGGAATTATCTCGGCCTC
t1s26i,B3,GCAAATCACCTCAATCAATATCTGCAGGTCGA
t1s28i,C3,CGACCAGTACATTGGCAGATTCACCTGATTGC
t1s2i,D3,CGGGGTTTCCTCAAGAGAAGGATTTTGAATTA
t1s30g,E3,TTGACGAGCACGTATACTGAAATGGATTATTTAATAAAAG
t1s4i,F3,AGCGTCATGTCTCTGAATTTACCGACTACCTT
t1s6i,G3,TTCATAATCCCCTTATTAGCGTTTTTCTTACC
t1s8i,H3,ATGGTTTATGTCACAATCAATAGATATTAAAC
t2s11g,A4,AGAAAAGCCCCAAAAAGAGTCTGGAGCAAACAATCACCAT
t2s13g,B4,ACAGTCAAAGAGAATCGATGAACGACCCCGGTTGATAATC
t2s15f,C4,ATAGTAGTATGCAATGCCTGAGTAGGCCGGAG
t2s17f,D4,AACCAGACGTTTAGCTATATTTTCTTCTACTA
t2s1g,E4,GATAAGTGCCGTCGAGCTGAAACATGAAAGTATACAGGAG
t2s21g,F4,CCTGATTGCTTTGAATTGCGTAGATTTTCAGGCATCAATA
t2s23g,G4,TGGCAATTTTTAACGTCAGATGAAAACAATAACGGATTCG
t2s25f,H4,AAGGAATTACAAAGAAACCACCAGTCAGATGA
t2s27f,A5,GGACATTCACCTCAAATATCAAACACAGTTGA
t2s3g,B5,TTTGATGATTAAGAGGCTGAGACTTGCTCAGTACCAGGCG
t2s5f,C5,CCGGAACCCAGAATGGAAAGCGCAACATGGCT
t2s7f,D5,AAAGACAACATTTTCGGTCATAGCCAAAATCA
t3s10g,E5,GTCAGAGGGTAATTGATGGCAACATATAAAAGCGATTGAG
t3s14e,F5,CAATATGACCCTCATATATTTTAAAGCATTAA
t3s16e,G5,CATCCAATAAATGGTCAATAACCTCGGAAGCA
t3s18g,H5,AACTCCAAGATTGCATCAAAAAGATAATGCAGATACATAA
t3s20g,A6,CGCCAAAAGGAATTACAGTCAGAAGCAAAGCGCAGGTCAG
t3s24e,B6,TAATCCTGATTATCATTTTGCGGAGAGGAAGG
t3s26e,C6,TTATCTAAAGCATCACCTTGCTGATGGCCAAC
t3s28g,D6,AGAGATAGTTTGACGCTCAATCGTACGTGCTTTCCTCGTT
t3s30g,E6,AGAATCAGAGCGGGAGATGGAAATACCTACATAACCCTTC
t3s4e,F6,TGTACTGGAAATCCTCATTAAAGCAGAGCCAC
t3s6e,G6,CACCGGAAAGCGCGTTTTCATCGGAAGGGCGA
t3s8g,H6,CATTCAACAAACGCAAAGACACCAGAACACCCTGAACAAA
t4s11g,A7,GCAAATATTTAAATTGAGATCTACAAAGGCTACTGATAAA
t4s13g,B7,CGTTCTAGTCAGGTCATTGCCTGACAGGAAGATTGTATAA
t4s15f,C7,CAGGCAAGATAAAAATTTTTAGAATATTCAAC
t4s17f,D7,GATTAGAGATTAGATACATTTCGCAAATCATA
t4s1g,E7,TAGCCCGGAATAGGTGAATGCCCCCTGCCTATGGTCAGTG
t4s21g,F7,GCGCAGAGGCGAATTAATTATTTGCACGTAAATTCTGAAT
t4s23g,G7,GATTATACACAGAAATAAAGAAATACCAAGTTACAAAATC
t4s25f,H7,TAGGAGCATAAAAGTTTGAGTAACATTGTTTG
t4s27f,A8,TGACCTGACAAATGAAAAATCTAAAATATCTT
t4s3g,B8,TTTAACGGTTCGGAACCTATTATTAGGGTTGATATAAGTA
t4s5f,C8,CTCAGAGCATATTCACAAACAAATTAATAAGT
t4s7f,D8,GGAGGGAATTTAGCGTCAGACTGTCCGCCTCC
t5s10g,E8,GATAACCCACAAGAATGTTAGCAAACGTAGAAAATTATTC
t5s14e,F8,TTAATGCCTTATTTCAACGCAAGGGCAAAGAA
t5s16e,G8,TTAGCAAATAGATTTAGTTTGACCAGTACCTT
t5s18g,H8,TAATTGCTTTACCCTGACTATTATGAGGCATAGTAAGAGC
t5s20g,A9,AACACTATCATAACCCATCAAAAATCAGGTCTCCTTTTGA
t5s24e,B9,AATGGAAGCGAACGTTATTAATTTCTAACAAC
t5s26e,C9,TAATAGATCGCTGAGAGCCAGCAGAAGCGTAA
t5s28g,D9,GAATACGTAACAGGAAAAACGCTCCTAAACAGGAGGCCGA
t5s30g,E9,TTAAAGGGATTTTAGATACCGCCAGCCATTGCGGCACAGA
t5s4e,F9,CCTTGAGTCAGACGATTGGCCTTGCGCCACCC
t5s6e,G9,TCAGAACCCAGAATCAAGTTTGCCGGTAAATA
t5s8g,H9,TTGACGGAAATACATACATAAAGGGCGCTAATATCAGAGA
t6s13c,A10,CTATTTTTGAG
t6s15g,B10,ATAAAGCCTTTGCGGGAGAAGCCTGGAGAGGGTAG
t6s17f,C10,TAAGAGGTCAATTCTGCGAACGAGATTAAGCA
t6s23c,D10,ACCATATCAAA
t6s25g,E10,TCAATAGATATTAAATCCTTTGCCGGTTAGAACCT
t6s27f,F10,CAATATTTGCCTGCAACAGTGCCATAGAGCCG
t6s3c,G10,TATAAACAGTT
t6s5g,H10,CAGAGCCAGGAGGTTGAGGCAGGTAACAGTGCCCG
t6s7f,A11,ATTAAAGGCCGTAATCAGTAGCGAGCCACCCT
t7s10g,B11,ATAAGAGCAAGAAACATGGCATGATTAAGACTCCGACTTG
t7s14e,C11,ATGACCCTGTAATACTTCAGAGCA
t7s16e,D11,TAAAGCTATATAACAGTTGATTCCCATTTTTG
t7s18g,E11,CGGATGGCACGAGAATGACCATAATCGTTTACCAGACGAC
t7s20g,F11,GATAAAAACCAAAATATTAAACAGTTCAGAAATTAGAGCT
t7s24e,G11,ACAATTCGACAACTCGTAATACAT
t7s26e,H11,TTGAGGATGGTCAGTATTAACACCTTGAATGG
t7s28g,A12,CTATTAGTATATCCAGAACAATATCAGGAACGGTACGCCA
t7s30g,B12,GAATCCTGAGAAGTGTATCGGCCTTGCTGGTACTTTAATG
t7s4e,C12,GCCGCCAGCATTGACACCACCCTC
t7s6e,D12,AGAGCCGCACCATCGATAGCAGCATGAATTAT
t7s8g,E12,CACCGTCACCTTATTACGCAGTATTGAGTTAAGCCCAATA
t8s15c,F12,CCAAAAACATT
t8s17g,G12,TAATTGCTTGGAAGTTTCATTCCAAATCGGTTGTA
t8s25c,H12,AGACTTTACAA
```

```
Plate number: 2
t8s27g,A1,CGCGAACTAAAACAGAGGTGAGGCTTAGAAGTATT
t8s5c,B1,CCACCAGAGCC
t8s7g,C1,AGCCATTTAAACGTCACCAATGAACACCAGAACCA
t9s10h,D1,TATCTTACCGAAGCCCAAACGCAATAATAACGAAAATCACCAG
t9s16e,E1,ACTAAAGTACGGTGTCGAATATAA
t9s18g,F1,TGCTGTAGATCCCCCTCAAATGCTGCGAGAGGCTTTTGCA
t9s20h,G1,AAAGAAGTTTTGCCAGCATAAATATTCATTGACTCAACATGTT
t9s26e,H1,ACCACCAGCAGAAGATGATAGCCC
t9s28g,A2,TAAAACATTAGAAGAACTCAAACTTTTTATAATCAGTGAG
t9s30h,B2,GCCACCGAGTAAAAGAACATCACTTGCCTGAGCGCCATTAAAA
t9s6e,C2,CCATTAGCAAGGCCGGGGGAATTA
t9s8g,D2,GAGCCAGCGAATACCCAAAAGAACATGAAATAGCAATAGC
t-10s17h,E2,ACCAACCTAAAAAATCAACGTAACAAATAAATTGGGCTTGAGA
t-10s27h,F2,AACTCACATTATTGAGTGTTGTTCCAGAAACCGTCTATCAGGG
t-10s7h,G2,ACGACAATAAATCCCGACTTGCGGGAGATCCTGAATCTTACCA
t-11s18e,H2,ATAAGGCTTGC
t-11s28e,A3,ACTATTAAAGA
t-11s8e,B3,TCAAGATTAGT
t-12s19h,C3,CCTGACGAGAAACACCAGAACGAGTAGGCTGCTCATTCAGTGA
t-12s29h,D3,ACGTGGACTCCAACGTCAAAGGGCGAATTTGGAACAAGAGTCC
t-12s9h,E3,TGCTATTTTGCACCCAGCTACAATTTTGTTTTGAAGCCTTAAA
t-1s10e,F3,AGAGAATAACATAAAAACAGGGAAGCGCATTA
t-1s12i,G3,AGGGATAGCTCAGAGCCACCACCCCATGTCAA
t-1s14e,H3,ATTTTCTGTCAGCGGAGTGAGAATACCGATAT
t-1s14i,A4,CAACAGTTTATGGGATTTTGCTAATCAAAAGG
t-1s16e,B4,ATTCGGTCTGCGGGATCGTCACCCGAAATCCG
t-1s16i,C4,GCCGCTTTGCTGAGGCTTGCAGGGGAAAAGGT
t-1s18g,D4,CGACCTGCGGTCAATCATAAGGGAACGGAACAACATTATT
t-1s18i,E4,GCGCAGACTCCATGTTACTTAGCCCGTTTTAA
t-1s20e,F4,ACAGGTAGAAAGATTCATCAGTTGAGATTTAG
t-1s22i,G4,CGCGTCTGATAGGAACGCCATCAACTTTTACA
t-1s24e,H4,CAGTTTGACGCACTCCAGCCAGCTAAACGACG
t-1s24i,A5,AGGAAGATGGGGACGACGACAGTAATCATATT
t-1s26e,B5,GCCAGTGCGATCCCCGGGTACCGAGTTTTTCT
t-1s26i,C5,CTCTAGAGCAAGCTTGCATGCCTGGTCAGTTG
t-1s28g,D5,TTTCACCAGCCTGGCCCTGAGAGAAAGCCGGCGAACGTGG
t-1s28i,E5,CCTTCACCGTGAGACGGGCAACAGCAGTCACA
t-1s2i,F5,CCTTTTTTCATTTAACAATTTCATAGGATTAG
t-1s30e,G5,CGAGAAAGGAAGGGAAGCGTACTATGGTTGCT
t-1s4e,H5,TTATCAAACCGGCTTAGGTTGGGTAAGCCTGT
t-1s4i,A6,TTTAACCTATCATAGGTCTGAGAGTTCCAGTA
t-1s6e,B6,TTAGTATCGCCAACGCTCAACAGTCGGCTGTC
t-1s6i,C6,AGTATAAAATATGCGTTATACAAAGCCATCTT
t-1s8g,D6,TTTCCTTAGCACTCATCGAGAACAATAGCAGCCTTTACAG
t-1s8i,E6,CAAGTACCTCATTCCAAGAACGGGAAATTCAT
t-2s11g,F6,CCTCAGAACCGCCACCCAAGCCCAATAGGAACGTAAATGA
t-2s13g,G6,AGACGTTACCATGTACCGTAACACCCCTCAGAACCGCCAC
t-2s15f,H6,CACGCATAAGAAAGGAACAACTAAGTCTTTCC
t-2s17f,A7,ATTGTGTCTCAGCAGCGAAAGACACCATCGCC
t-2s1g,B7,AAAACAAAATTAATTAAATGGAAACAGTACATTAGTGAAT
t-2s21g,C7,GCTCATTTTTAACCAGCCTTCCTGTAGCCAGGCATCTGC
t-2s23g,D7,GTAACCGTCTTTCATCAACATTAAAATTTTTGTTAAATCA
t-2s25f,E7,ACGTTGTATTCCGGCACCGCTTCTGGCGCATC
t-2s27f,F7,CCAGGGTGGCTCGAATTCGTAATCCAGTCACG
t-2s3g,G7,AGAGTCAAAAATCAATATATGTGATGAAACAAACATCAAG
t-2s5f,H7,ACTAGAAATATATAACTATATGTACGCTGAGA
t-2s7f,A8,TCAATAATAGGGCTTAATTGAGAATCATAATT
t-3s10g,B8,AACGTCAAAAATGAAAAGCAAGCCGTTTTTATGAAACCAA
t-3s14e,C8,GTTTTGTCAGGAATTGCGAATAATCCGACAAT
t-3s16e,D8,GACAACAAGCATCGGAACGAGGGTGAGATTTG
t-3s18g,E8,TATCATCGTTGAAAGAGGACAGATGGAAGAAAAATCTACG
t-3s20g,F8,TTAATAAAACGAACTAACCGAACTGACCAACTCCTGATAA
t-3s24e,G8,TGTAGATGGGTGCCGGAAACCAGGAACGCCAG
t-3s26e,H8,GGTTTTCCATGGTCATAGCTGTTTGAGAGGCG
t-3s28g,A9,GTTTGCGTCACGCTGGTTTGCCCCAAGGGAGCCCCCGATT
t-3s30g,B9,TAGAGCTTGACGGGGAGTTGCAGCAAGCGGTCATTGGGCG
t-3s4e,C9,GATTAAGAAATGCTGATGCAAATCAGAATAAA
t-3s6e,D9,CACCGGAATCGCCATATTTAACAAAATTTACG
t-3s8g,E9,AGCATGTATTTCATCGTAGGAATCAAACGATTTTTTGTTT
t-4s11g,F9,AGGTTTAGTACCGCCATGAGTTTCGTCACCAGGATCTAAA
t-4s13g,G9,AGCGTAACTACAAACTACAACGCCTATCACCGTACTCAGG
t-4s15f,H9,TAGTTGCGAATTTTTTCACGTTGATCATAGTT
t-4s17f,A10,GTACAACGAGCAACGGCTACAGAGGATACCGA
t-4s1g,B10,GAGCAAAAGAAGATGAGTGAATAACCTTGCTTATAGCTTA
t-4s21g,C10,GTTAAAATTCGCATTAATGTGAGCGAGTAACACACGTTGG
t-4s23g,D10,GGATAGGTACCCGTCGGATTCTCCTAAACGTTAATATTTT
t-4s25f,E10,AGTTGGGTCAAAGCGCCATTCGCCCCGTAATG
t-4s27f,F10,CGCGCGGGCCTGTGTGAAATTGTTGGCGATTA
t-4s3g,G10,ACATAGCGCTGTAAATCGTCGCTATTCATTTCAATTACCT
t-4s5f,H10,GTTAAATACAATCGCAAGACAAAGCCTTGAAA
t-4s7f,A11,CCCATCCTCGCCAACATGTAATTTAATAAGGC
t-5s10g,B11,TCCCAATCCAAATAAGATTACCGCGCCCAATAAATAATAT
t-5s12e,C11,TGTAGCATTCC
t-5s16e,D11,AACAGCTTGCTTTGAGGACTAAAGCGATTATA
t-5s18g,E11,CCAAGCGCAGGCGCATAGGCTGGCAGAACTGGCTCATTAT
t-5s20g,F11,ACCAGTCAGGACGTTGGAACGGTGTACAGACCGAAACAAA
t-5s22e,G11,GTGGGAACAAA
t-5s26e,H11,TGCTGCAAATCCGCTCACAATTCCCAGCTGCA
t-5s28g,A12,TTAATGAAGTTTGATGGTGGTTCCGAGGTGCCGTAAAGCA
t-5s2e,B12,TTAATTAATTT
t-5s30g,C12,CTAAATCGGAACCCTAAGCAGGCGAAAATCCTTCGGCCAA
t-5s6e,D12,GTGTGATAAGGCAGAGGCATTTTCAGTCCTGA
t-5s8g,E12,ACAAGAAAGCAAGCAAATCAGATAACAGCCATATTATTTA
t-6s13f,F12,ACAGACAGCCCAAATCTCCAAAAAAAAATTTCTTA
t-6s15c,G12,CGAGGTGAGGCTCCAAAAGGAGCC
t-6s17f,H12,ACCCCCAGACTTTTTCATGAGGAACTTGCTTT
```

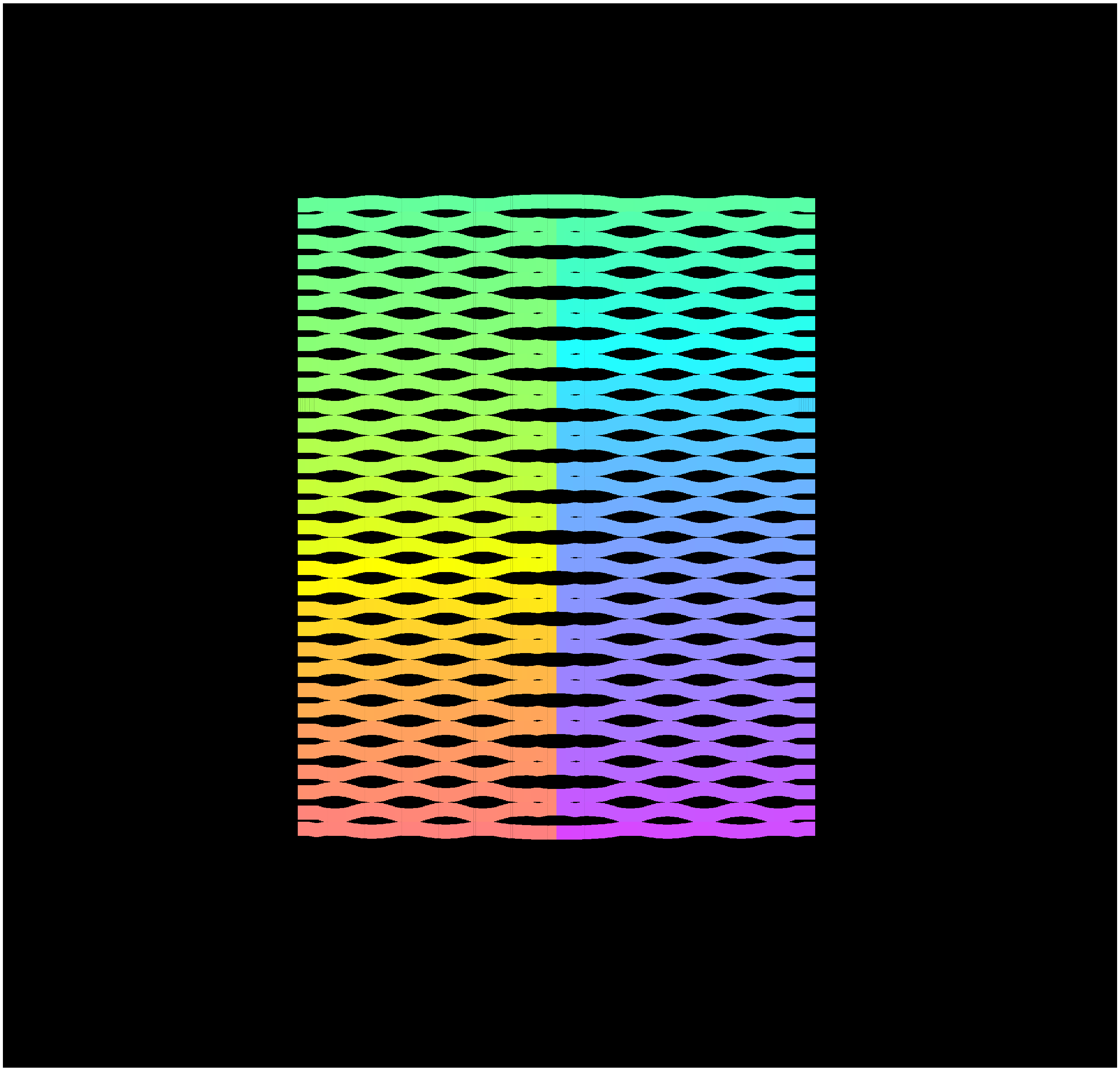
```
Plate number: 3
t-6s23f,A1,CGGCGGATTGAATTCAGGCTGCGCAACGGGGGATG
t-6s25c,B1,TGGCGAAATGTTGGGAAGGGCGAT
t-6s27f,C1,TGTCGTGCACACAACATACGAGCCACGCCAGC
t-6s3f,D1,TCCCTTAGAATAACGCGAGAAAACTTTTACCGACC
t-6s5c,E1,GTTTGAAATTCAAATATATTTTAG
t-6s7f,F1,AATAGATAGAGCCAGTAATAAGAGATTTAATG
t-7s10g,G1,GCCAGTTACAAAATAATAGAAGGCTTATCCGGTTATCAAC
t-7s14e,H1,TTTAATTGTAT
t-7s18g,A2,AAAACACTTAATCTTGACAAGAACTTAATCATTGTGAATT
t-7s20g,B2,ACCTTATGCGATTTTATGACCTTCATCAAGAGCATCTTTG
t-7s24e,C2,CGGTGCGGGCC
t-7s28g,D2,TTCCAGTCCTTATAAATCAAAAGAGAACCATCACCCAAAT
t-7s30g,E2,CAAGTTTTTTGGGGTCGAAATCGGCAAAATCCGGGAAACC
t-7s4e,F2,TTAATTTCATC
t-7s8g,G2,GCGCCTGTTATTCTAAGAACGCGATTCCAGAGCCTAATTT
t-7s8g,G2,GCGCCTGTTATTCTAAGAACGCGATTCCAGAGCCTAATTT
t-8s15f,H2,CGGTTTATCAGGTTTCCATTAAACGGGAATACACT
t-8s17c,A3,GGCAAAAGTAAAATACGTAATGCC
t-8s25f,B3,TCTTCGCTATTGGAAGCATAAAGTGTATGCCCGCT
t-8s27c,C3,GCGCTCACAAGCCTGGGGTGCCTA
t-8s5f,D3,TTCTGACCTAAAATATAAAGTACCGACTGCAGAAC
t-8s7c,E3,TCAGCTAAAAAAGGTAAAGTAATT
t-9s10g,F3,ACGCTAACGAGCGTCTGGCGTTTTAGCGAACCCAACATGT
t-9s16e,G3,ACTACGAAGGC
t-9s20g,H3,TGGTTTAATTTCAACTCGGATATTCATTACCCACGAAAGA
t-9s26e,A4,ATGAGTGAGCT
t-9s30g,B4,CGATGGCCCACTACGTATAGCCCGAGATAGGGATTGCGTT
t-9s6e,C4,CTGTCCAGACG
ts-rem1,D4,GCGCTTAATGCGCCGCTACAGGGC
```

```
Bridges between trapezoids
t-5s2e-t6s23c-3T,A6,   TTAATTAATTTTTTACCATATCAAA
t-7s4e-t8s25c-2T,B6,   TTAATTTCATCTTAGACTTTACAA
t-9s6e-t10s27c-1T,C6,  CTGTCCAGACGTATACCGAACGA
t-11s8e-t12s29c-0T,D6, TCAAGATTAGTGTAGCAATACT

t-5s12e-t6s3c-3T,E6,   TGTAGCATTCCTTTTATAAACAGTT
t-7s14e-t8s5c-2T,F6,   TTTAATTGTATTTCCACCAGAGCC
t-9s16e-t10s7c-1T,G6,  ACTACGAAGGCTTAGCACCATTA
t-11s18e-t12s9c-0T,H6, ATAAGGCTTGCAACAAAGTTAC

t-5s22e-t6s13c-3T,A7,  GTGGGAACAAATTTCTATTTTTGAG
t-7s24e-t8s15c-2T,B7,  CGGTGCGGGCCTTCCAAAAACATT
t-9s26e-t10s17c-1T,C7, ATGAGTGAGCTTTTAAATATGCA
t-11s28e-t12s19c-0T,D7,ACTATTAAAGAGGATAGCGTCC
```

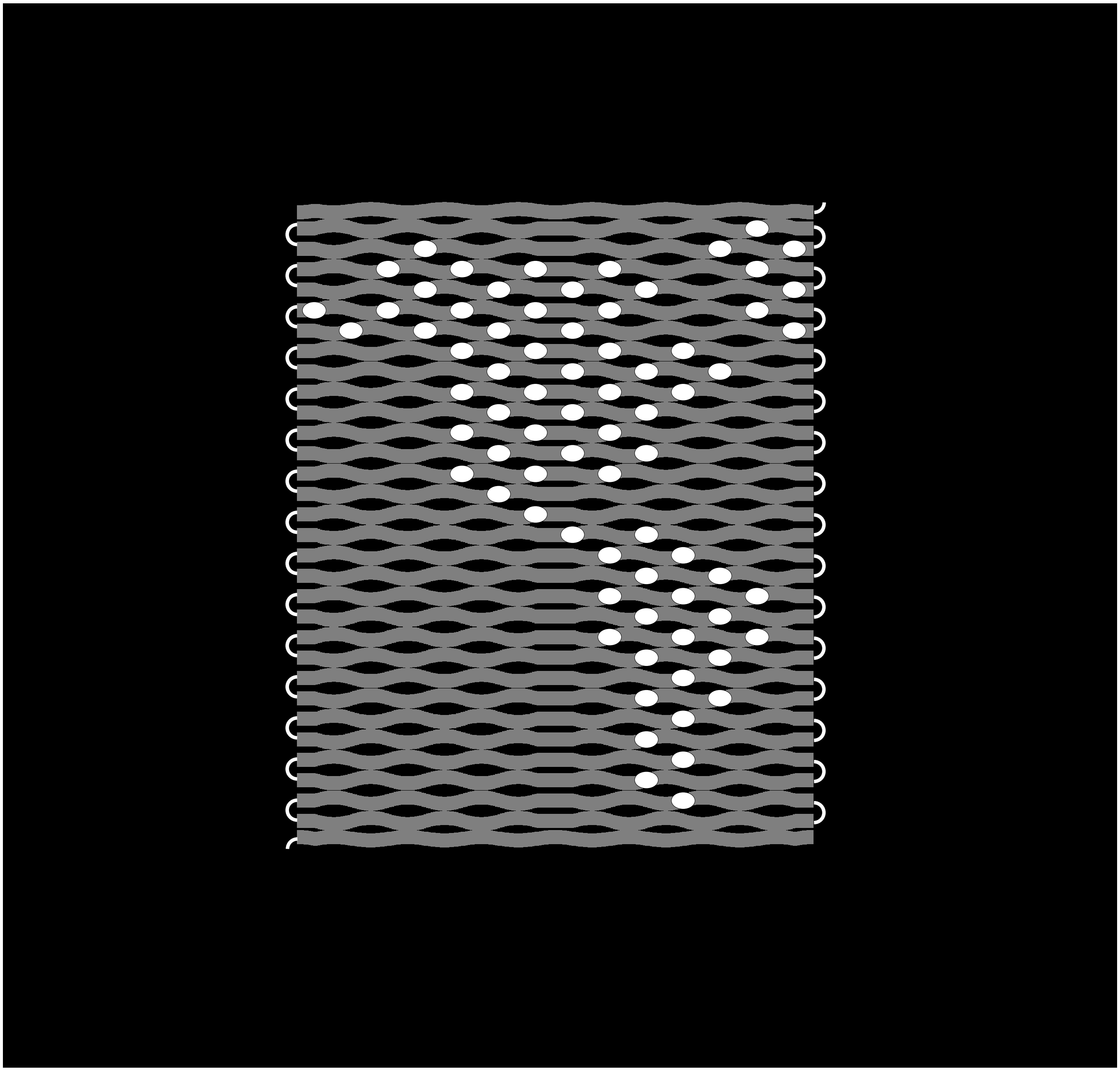
Supplementary Figure S34: Sequences for the sharp triangle composed of trapezoidal domains.



Supplementary Figure S 35: Schematics for the "tall" rectangle used for the map pattern shown in Fig. 4e–i. **a** Block diagram. **b** Folding path.



Supplementary Figure S36: Basic crossover diagram for the "tall" rectangle used for the map pattern shown in Fig. 3e–i. Note, here I show the crossovers at the seam as bridged by staple strands. In the experiments shown in Fig. 3f and g, the seam was unbridged and only stacking interactions held it together, as diagrammed in Fig. 3e. For comparison, Fig. 3e is reproduced in the next figure, Supplementary Fig. S36



Supplementary Figure S37: Actual crossover diagram for the “tall” rectangle used for the map pattern shown in Fig. 3e–i. The seam is unbridged and staple strands with ‘TTTT’ loops have been added to the edges to discourage blunt-end stacking. At two corners 4-T tails have been added.

```
Plate number: 1
t1r0g,A1,AGGGTTGATATAAGTATAGCCCGGAATAGGTG
t1r10e,B1,TGAACAAAGATAACCCACAAGAATAAGACTCC
t1r10f,C1,ATCAGAGAGTCAGAGGGTAATTGAACCAGTCA
t1r12e,D1,TATTTTGCACGCTAACGAGCGTCTGAACACCC
t1r12f,E1,TCTTACCAACCCAGCTACAATTTTAAAGAAGT
t1r14e,F1,ATCGGCTGACCAAGTACCGCACTCTTAGTTGC
t1r14f,G1,GGTATTAATCTTTCCTTATCATTCATATCGCG
t1r16e,H1,CATATTTATTTCGAGCCAGTAATAAATCAATA
t1r16f,A2,AGAGGCATACAACGCCAACATGTATCTGCGAA
t1r18e,B2,ACAAAGAAAATTTCATCTTCTGACAGAATCGC
t1r18f,C2,TTTTAGTTCGCGAGAAAACTTTTTTTATGACC
t1r20e,D2,AAATCAATCGTCGCTATTAATTAAATCGCAAG
t1r20f,E2,CTGTAAATATATGTGAGTGAATAAAAAGGCTA
t1r22e,F2,TTTAACGTTCGGGAGAAACAATAACAGTACAT
t1r22f,G2,CTTTTACACAGATGAATATACAGTGCCATCAA
t1r24e,H2,TTATTAATGAACAAAGAAACCACCTTTTCAGG
t1r24f,A3,ATTTTGCGTTTAAAAGTTTGAGTACCGGCACC
t1r26e,B3,CTAAAGCAAATCAATATCTGGTCACCCGAACG
t1r26f,C3,AAACCCTCTCACCTTGCTGAACCTAGAGGATC
t1r28e,D3,GCCAACAGATACGTGGCACAGACATGAAAAAT
t1r28f,E3,GCGTAAGAAGATAGAACCCTTCTGAACGCGCG
t1r2e,F3,TAAGCGTCGGTAATAAGTTTTAACCCGTCGAG
t1r2f,G3,AGTGTACTATACATGGCTTTTGATCTTTCCAG
t1r30e,H3,GTTGTAGCCCTGAGTAGAAGAACTACATTCTG
t1r30f,A4,ATCACTTGAATACTTCTTTGATTAGTTGTTCC
t1r32h,B4,TACAGGGCGCGTACTATGGTTGCTAATTAACC
t1r4e,C4,AACCAGAGACCCTCAGAACCGCCACGTTCCAG
t1r4f,D4,GAGCCGCCCCACCACCGGAACCGCTGCGCCGA
t1r6e,E4,GACTTGAGGTAGCACCATTACCATATCACCGG
t1r6f,F4,AATCACCACCATTTGGGAATTAGACCAACCTA
t1r8e,G4,TTATTACGTAAAGGTGGCAACATACCGTCACC
t1r8f,H4,TACATACACAGTATGTTAGCAAACTGTACAGA
t3r0g,A5,TGCTCAGTACCAGGCGGATAAGTGGGGGTCAG
t3r10e,B5,GCGCATTAATAAGAGCAAGAAACAATAACGGA
t3r10f,C5,GCCCAATAGACGGGAGAATTAACTTTCCAGAG
t3r12e,D5,AGGTTTTGGCCAGTTACAAAATAAACAGGGAA
t3r12f,E5,CCTAATTTAAGCCTTAAATCAAGAATCGAGAA
t3r14e,F5,CTAATTTACCGTTTTTATTTTCATCTTGCGGG
t3r14f,G5,CAAGCAAGCGAGCATGTAGAAACCAGAGAATA
t3r16e,H5,ACGCTCAACGACAAAAGGTAAAGTATCCCATC
t3r16f,A6,TAAAGTACCAGTAGGGCTTAATTGCTAAATTT
t3r18e,B6,TATGTAAAGAAATACCGACCGTGTTAAAGCCA
t3r18f,C6,AATGGTTTTGCTGATGCAAATCCATTTTCCCT
t3r20e,D6,TTGAATTATTGAAAACATAGCGATTATAACTA
t3r20f,E6,TAGAATCCCCTTTTTTAATGGAAACGGATTCG
t3r22e,F6,ACAGAAATCTTTGAATACCAAGTTAATTTCAT
t3r22f,G6,CCTGATTGAAAGAAATTGCGTAGAAGAAGGAG
t3r24e,H6,CGACAACTTCATCATATTCCTGATCACGTAAA
t3r24f,A7,CGGAATTACGTATTAAATCCTTTGGTTGGCAA
t3r26e,B7,GCCACGCTTTGAAAGGAATTGAGGAAACAATT
t3r26f,C7,ATCAACAGGAGAGCCAGCAGCAAAATATTTTT
t3r28e,D7,GTCACACGATTAGTCTTTAATGCGGCAACAGT
t3r28f,E7,GAATGGCTACCAGTAATAAAAGGGCAAACTAT
t3r2e,F7,GGAAAGCGGTAACAGTGCCCGTATCGGGGTTT
t3r2f,G7,TGCCTTGACAGTCTCTGAATTTACCCCTCAGA
t3r30e,H7,GTAAAAGACTGGTAATATCCAGAAATTCACCA
t3r30f,A8,CGGCCTTGGTCTGTCCATCACGCATTGACGAG
t3r32h,B8,CACGTATAACGTGCTTTCCTCGTTGCCACCGA
t3r4e,C8,GTTTGCCACCTCAGAGCCGCCACCGCCAGAAT
t3r4f,D8,GCCACCACTCTTTTCATAATCAAATAGCAAGG
t3r6e,E8,TTATTCATGTCACCAATGAAACCATTATTAGC
t3r6f,F8,CCGGAAACTAAAGGTGAATTATCATAAAAGAA
t3r8e,G8,ATACCCAAACACCACGGAATAAGTGACGGAAA
t3r8f,H8,ACGCAAAGAAGAACTGGCATGATTTGAGTTAA
t5r0g,A9,CCTCAAGAGAAGGATTAGGATTAGAAACAGTT
t5r10e,B9,CTTTACAGTATCTTACCGAAGCCCAGTTACCA
t5r10f,C9,GCAATAGCAGAGAATAACATAAAAACAGCCAT
t5r12e,D9,GAGGCGTTTCCCAATCCAAATAAGATAGCAGC
t5r12f,E9,ATTATTTATTAGCGAACCTCCCGACGTAGGAA
t5r14e,F9,TAAGTCCTGCGCCCAATAGCAAGCAAGAACGC
t5r14f,G9,TCATTACCGAACAAGAAAAATAATAATTCTGT
t5r16e,H9,GCGTTATACGACAATAAACAACATACAATAGA
t5r16f,A10,CCAGACGACAAATTCTTACCAGTAGATAAATA
t5r18e,B10,TAACCTCCAATAAGAATAAACACCTATCATAT
t5r18f,C10,AGGCGTTAGGCTTAGGTTGGGTTAAGCTTAGA
t5r20e,D10,AAAACAAACTGAGAAGAGTCAATATACCTTTT
t5r20f,E10,TTAAGACGATTAATTACATTTAACACAAAATC
t5r22e,F10,AACCTACCGCGAATTATTCATTTCACATCAAG
t5r22f,G10,GCGCAGAGATATCAAAATTATTTGTATCAGAT
t5r24e,H10,GGATTTAGTTCATCAATATAATCCAGGGTTAG
t5r24f,A11,GATGGCAAAAGTATTAGACTTTACAAGGTTAT
t5r26e,B11,AGGCGGTCTCTTTAGGAGCACTAAACATTTGA
t5r26f,C11,CTAAAATAAGTATTAACACCGCCTCGAACTGA
t5r28e,D11,GAAATGGAAAACATCGCCATTAAACAGAGGTG
t5r28f,E11,TAGCCCTATTATTTACATTGGCAGCAATATTA
t5r2e,F11,ACAAACAACTGCCTATTTCGGAACCTGAGACT
t5r2f,G11,AATGCCCCATAAATCCTCATTAAAAGAACCAC
t5r30e,H11,AGAAGTGTCATTGCAACAGGAAAAAATCGTCT
t5r30f,A12,CCGCCAGCTTTTATAATCAGTGAGAGAATCAG
t5r32h,B12,AGCGGGAGCTAAACAGGAGGCCGAGAATCCTG
t5r4e,C12,TCGGCATTCCGCCGCCAGCATTGATGATATTC
t5r4f,D12,CACCAGAGTTCGGTCATAGCCCCCTCGATAGC
t5r6e,E12,ATTGAGGGAATCAGTAGCGACAGACGTTTTCA
t5r6f,F12,AGCACCGTAGGGAAGGTAAATATTTTATTTTG
t5r8e,G12,GAAGGAAAAATAGAAAATTCATATTTCAACCG
t5r8f,H12,TCACAATCCCGAGGAAACGCAATAATGAAATA
```

```
Plate number: 2
t7r0f,A1,TGAAAGTATTAAGAGGCTATTATT
t7r10f,B1,AAAAGTAAAACGTCAAAAATGAAAAAACGATT
t7r12f,C1,TTTTGTTTGCTTATCCGGTATTCTAAATCAGA
t7r14f,D1,TATAGAAGACGCGCCTGTTTATCAGTTCAGCT
t7r16f,E1,AATGCAGAGAAAAAGCCTGTTTAGGGAATCAT
t7r18f,F1,AATTACTACATAGGTCTGAGAGACGTGAATTT
t7r20f,G1,ATCAAAATGAAGATGATGAAACAAAATTACCT
t7r22f,H1,GAGCAAAAACTTCTGAATAATGGATGATTGTT
t7r24f,A2,TGGATTATGCCGTCAATAGATAATCAACTAAT
t7r26f,B2,AGATTAGACCAGCAGAAGATAAAAAATACCGA
t7r28f,C2,ACGAACCACTACATTTTGACGCTCACGCTCAT
t7r2f,D2,CTGAAACAGTCAGACGATTGGCCTCAGGAGGT
t7r30j,E2,GGAAATACCAGGAACGGTACGCCATTAAAGGGATTTTAGA
t7r4f,F2,TGAGGCAGGCGTCAGACTGTAGCGATCAAGTT
t7r6f,G2,TGCCTTTAAGACAAAAGGGCGACAGGTTTACC
t7r8f,H2,AGCGCCAAGCAGATAGCCGAACAATTTTTAAG
t-1r0g,A3,TATCACCGTACTCAGGAGGTTTAGATAGTTAG
t-1r10e,B3,GGACGTTGAGAACTGGCTCATTATGCGCTAAT
t-1r10f,C3,CGATTTTAGGAAGAAAAATCTACGGATAAAAA
t-1r12e,D3,TTTGCCAGGCGAGAGGCTTTTGCAATCCTGAA
t-1r12f,E3,CCAAAATAAGGGGGTAATAGTAAAAAAAGATT
t-1r14e,F3,TTTTAATTGCCCGAAAGACTTCAACAAGAACG
t-1r14f,G3,AAGAGGAACGAGCTTCAAAGCGAAAGTTTCAT
t-1r16e,H3,CGAGTAGAACAGTTGATTCCCAATATTTAGGC
t-1r16f,A4,TCCATATATTTAGTTTGACCATTAAGCATAAA
t-1r18e,B4,CTGTAATAGGTTGTACCAAAAACACAAATATA
t-1r18f,C4,GCTAAATCCTTTTGCGGGAGAAGCCCGGAGAG
t-1r20e,D4,TCAGGTCATTTTTGAGAGATCTACCCTTGCTT
t-1r20f,E4,GGTAGCTATTGCCTGAGAGTCTGGTTAAATCA
t-1r22e,F4,AAATAATTTTTAACCAATAGGAACAACAGTAC
t-1r22f,G4,GCTCATTTCGCGTCTGGCCTTCCTGGCCTCAG
t-1r24e,H4,GCTTCTGGCACTCCAGCCAGCTTTACATTATC
t-1r24f,A5,GAAGATCGTGCCGGAAACCAGGCAGTGCCAAG
t-1r26e,B5,CCCGGGTACCTGCAGGTCGACTCTCAAATATC
t-1r26f,C5,CTTGCATGCCGAGCTCGAATTCGTCCTGTCGT
t-1r28e,D5,GGGAGAGGCATTAATGAATCGGCCACCTGAAA
t-1r28f,E5,GCCAGCTGCGGTTTGCGTATTGGGAATCAAAA
t-1r2e,F5,ACGTTAGTTCTAAAGTTTTGTCGTGATACAGG
t-1r2f,G5,CGTAACGAAAATGAATTTTCTGTAGTGAATTT
t-1r30e,H5,AGTTTGGACGAGATAGGGTTGAGTGTAATAAC
t-1r30f,A6,GAATAGCCACAAGAGTCCACTATTAAGCCGGC
t-1r32h,B6,GAACGTGGCGAGAAAGGAAGGGAATGCGCCGC
t-1r4e,C6,CAATGACAGCTTGATACCGATAGTCTCCCTCA
t-1r4f,D6,CTTAAACAACAACCATCGCCCACGCGGGTAAA
t-1r6e,E6,AAACGAAATGCCACTACGAAGGCAGCCAGCAA
t-1r6f,F6,ATACGTAAGAGGCAAAAGAATACACTGACCAA
t-1r8e,G6,CCAGGCGCGAGGACAGATGAACGGGTAGAAAA
t-1r8f,H6,CTTTGAAAATAGGCTGGCTGACCTACCTTATG
t-3r0g,A7,CCCTCAGAACCGCCACCCTCAGAAACAACGCC
t-3r10e,B7,ACGAACTATTAATCATTGTGAATTTCATCAAG
t-3r10f,C7,TTTCAACTACGGAACAACATTATTAACACTAT
t-3r12e,D7,ACTGGATATCGTTTACCAGACGACTTAATAAA
t-3r12f,E7,CATAACCCGCGTCCAATACTGCGGTATTATAG
t-3r14e,F7,GAAGCAAAAAAGCGGATTGCATCAATGTTTAG
t-3r14f,G7,TCAGAAGCCTCCAACAGGTCAGGATTTAAATA
t-3r16e,H7,TCGCAAATAAGTACGGTGTCTGGACCAGACCG
t-3r16f,A8,TGCAACTAGGTCAATAACCTGTTTAGAATTAG
t-3r18e,B8,CAACGCAAAGCAATAAAGCCTCAGGATACATT
t-3r18f,C8,CAAAATTAGGATAAAAATTTTTAGGATATTCA
t-3r20e,D8,AGAGAATCAGCTGATAAATTAATGCTTTATTT
t-3r20f,E8,ACCGTTCTGATGAACGGTAATCGTAATATTTT
t-3r22e,F8,CTTTCATCTCGCATTAAATTTTTGAGCAAACA
t-3r22f,G8,GTTAAAATAACATTAAATGTGAGCATCTGCCA
t-3r24e,H8,TTCGCCATGGACGACGACAGTATCGTAGCCAG
t-3r24f,A9,GTTTGAGGTCAGGCTGCGCAACTGTTCCCAGT
t-3r26e,B9,TCATAGCTTGTAAAACGACGGCCAAAGCGCCA
t-3r26f,C9,CACGACGTGTTTCCTGTGTGAAATTTGCGCTC
t-3r28e,D9,TGGTTTTTCTTTCCAGTCGGGAAAAATCATGG
t-3r28f,E9,ACTGCCCGCTTTTCACCAGTGAGATGGTGGTT
t-3r2e,F9,TGCTAAACTCCACAGACAGCCCTCTACCGCCA
t-3r2f,G9,TGTAGCATAACTTTCAACAGTTTCTAATTGTA
t-3r30e,H9,TGGACTCCGGCAAAATCCCTTATACGCCAGGG
t-3r30f,A10,CCGAAATCAACGTCAAAGGGCGAAAAGGGAGC
t-3r32h,B10,CCCCGATTTAGAGCTTGACGGGGAAAAGAACG
t-3r4e,C10,ATATATTCTCAGCTTGCTTTCGAGTGGGATTT
t-3r4f,D10,TCGGTTTAGGTCGCTGAGGCTTGCAAAGACTT
t-3r6e,E10,CTCATCTTGGAAGTTTCCATTAAACATAACCG
t-3r6f,F10,TTTCATGATGACCCCCAGCGATTAAGGCGCAG
t-3r8e,G10,AGTAATCTTCATAAGGGAACCGAACTAAAACA
t-3r8f,H10,ACGGTCAATGACAAGAACCGGATATGGTTTAA
t-5r0g,A11,CTCAGAGCCACCACCCTCATTTTCCGTAACAC
t-5r10e,B11,AAAGATTCTAAATTGGGCTTGAGATTCATTAC
t-5r10f,C11,ACGAGTAGATCAGTTGAGATTTAGCGCCAAAA
t-5r12e,D11,TAAATATTGAGGCATAGTAAGAGCACAGGTAG
t-5r12f,E11,GGAATTACCATTGAATCCCCCTCACCATAAAT
t-5r14e,F11,TACCTTTAAGGTCTTTACCCTGACAATCGTCA
t-5r14f,G11,CAAAAATCATTGCTCCTTTTGATAATTGCTGA
t-5r16e,H11,TTTCATTTCTGTAGCTCAACATGTTTAGAGAG
t-5r16f,A12,ATATAATGGGGGCGCGAGCTGAAATTAACATC
t-5r18e,B12,TATATTTTCATACAGGCAAGGCAAAGCTATAT
t-5r18f,C12,CAATAAATAAATGCAATGCCTGAGAAGGCCGG
t-5r20e,D12,CATGTCAAAAATCACCATCAATATAACCCTCA
t-5r20f,E12,AGACAGTCTCATATGTACCCCGGTTTGTATAA
t-5r22e,F12,ACCCGTCGTTAAATTGTAAACGTTAAAACTAG
t-5r22f,G12,GCAAATATGATTCTCCGTGGGAACCGTTGGTG
t-5r24e,H12,GGCGATCGCGCATCGTAACCGTGCGAGTAACA
```

```
Plate number: 3
t-5r24f,A1,TAGATGGGGTGCGGGCCTCTTCGCGCAAGGCG
t-5r26e,B1,GCTCACAAGGGTAACGCCAGGGTTTTGGGAAG
t-5r26f,C1,ATTAAGTTTTCCACACAACATACGCCTAATGA
t-5r28e,D1,AGCTGATTACTCACATTAATTGCGTGTTATCC
t-5r28f,E1,GTGAGCTAGCCCTTCACCGCCTGGGGTTTGCC
t-5r2e,F1,GAGAATAGGTCACCAGTACAAACTCCGCCACC
t-5r2f,G1,TGAGTTTCAAAGGAACAACTAAAGATCTCCAA
t-5r30e,H1,TATCAGGGCGAAAATCCTGTTTGACGGGCAAC
t-5r30f,A2,CCAGCAGGCGATGGCCCACTACGTGAGGTGCC
t-5r32h,B2,GTAAAGCACTAAATCGGAACCCTAAAACCGTC
t-5r4e,C2,AAAGGCCGCTCCAAAAGGAGCCTTAGCGGAGT
t-5r4f,D2,AAAAAAGGCTTTTGCGGGATCGTCGGGTAGCA
t-5r6e,E2,GCGAAACAAGAGGCTTTGAGGACTAGGGAGTT
t-5r6f,F2,ACGGCTACAAGTACAACGGAGATTCGCGACCT
t-5r8e,G2,CCAAATCATTACTTAGCCGGAACGTACCAAGC
t-5r8f,H2,GCTCCATGACGTAACAAAGCTGCTACACCAGA
t-7r10e,A3,CATTCAACCTTGCCCTGACGAGAACATTCAGT
t-7r12e,B3,AAACAGTTTAATGCAGATACATAAGAATACCA
t-7r14e,C3,TTTTTGCGCAGAAAACGAGAATGAAATGCTTT
t-7r16e,D3,TCAATTCTGATGGCTTAGAGCTTAAGAGGTCA
t-7r18e,E3,AGGTAAAGACTAATAGTAGTAGCAAGGTGGCA
t-7r20e,F3,AGAAAAGCATTCAAAAGGGTGAGATAATGTGT
t-7r22e,G3,GATTGACCCCCAAAAACAGGAAGATGATAATC
t-7r24e,H3,CAGCTGGCGTAATGGGATAGGTCAAAACGGCG
t-7r26e,A4,GCATAAAGGAAAGGGGGATGTGCTTATTACGC
t-7r28e,B4,GAGTTGCATGTAAAGCCTGGGGTGAGCCGGAA
t-7r2i,C4,AATAATAAATAGGAACCCATGTACAGGGATAGCAAGCCCA
t-7r30e,D4,ACCCAAATGCAAGCGGTCCACGCTCCCTGAGA
t-7r32e,E4,CAAGTTTTTTGGGGTCGAACCATC
t-7r4e,F4,CAGCGAAATTTTTTCACGTTGAAAGAATTGCG
t-7r6e,G4,CGCCTGATGACAGCATCGGAACGAACCCTCAG
t-7r8e,H4,GAATAAGGAAATTGTGTCGAAATCTGTATCAT
tr-rem1,A5,GCGCTTAA
```

Supplementary Figure S38: Sequences for the "tall" rectangle used for the map pattern shown in Fig. 3e–i. These sequences are for a bridged seam.