LESSON 10: 5-LOOP TENNIS NETS

Weaving a 5-loop tennis net requires tremendous concentration since every finger is utilized in its formation. A loop made from a 4-span string is essential. One would think that the presence of a fifth loop would exponentially increase the number of interesting patterns one can form. But because 5-loop looms have an odd number of loops, many of the symmetrical operations commonly employed in the weaving of 4-loop tennis nets do not have obvious counterparts in a 5-loop environment (for example, index loop up through middle finger loop followed by middle finger loop up through index loop). In my mind, string figures made from 2- and 4-loop looms constitute one family while figures made from 3- and 5-loop looms constitute another.

A prototypical 5-loop tennis net is not easy to define. One attempt is illustrated in chart 22 (fig. 42). The first few loop passages of the 4-loop tennis net are easy to mimic in a 5-loop environment since only the outermost loops are involved. But subsequent passages, in which the inner loops are manipulated, are more difficult to copy. In chart 22, the index and ring finger loops are passed up through the middle finger loop followed by middle up through index and middle up through ring.

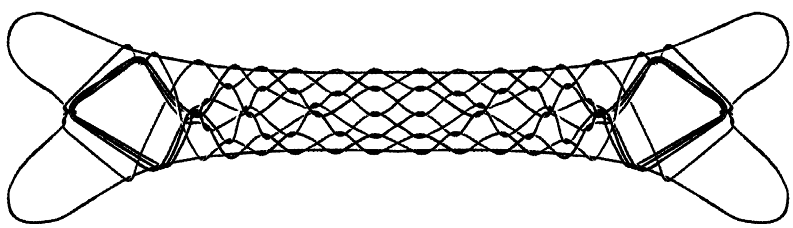


Fig. 42 - *5-loop Tennis Net Prototype*

Other early attempts which i recently found in some of my older notebooks are shown in charts 23-26. In Variation 1 (chart 23, fig. 43), doubled strings emanate from the central diamond and wind their way through the figure. Doubled strings also coil around the frame lines like snakes. Variation 2 (chart 24, fig. 44) is similar but lacks doubled strings. Variation 3 (chart 25, fig. 45) features a central rod-shaped knot surrounded by four large holes. A pleasing octagon occupies the center of Variation 4 (chart 26, fig. 46).

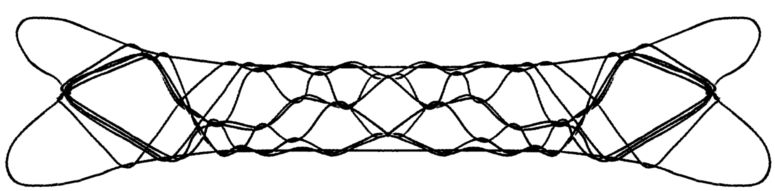


Fig. 43 - *5-loop Tennis Net, Variation 1*

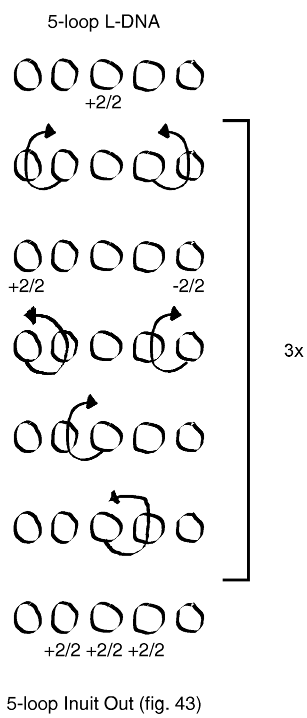


Chart 23

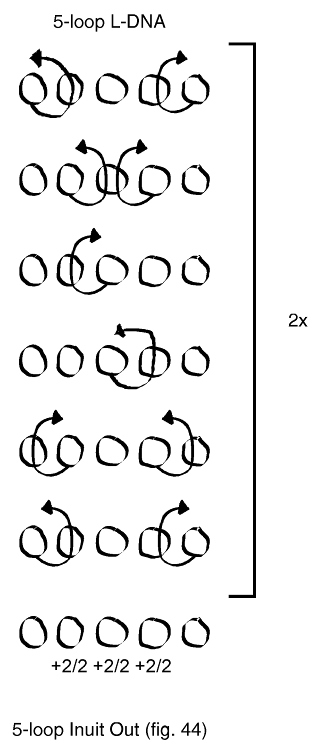


Chart 24

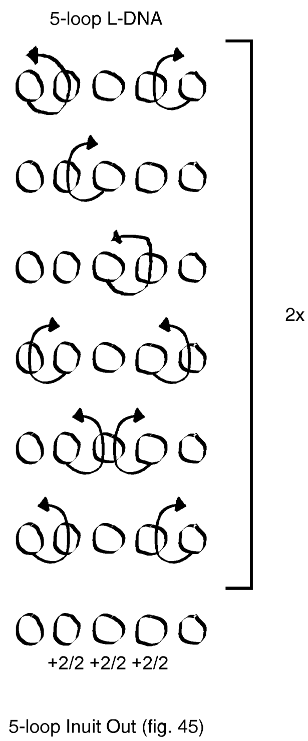


Chart 25

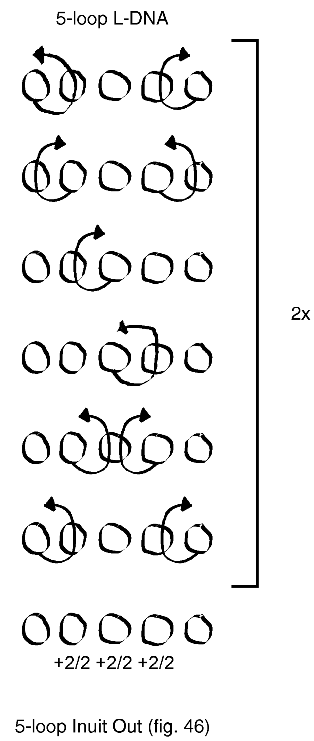


Chart 26

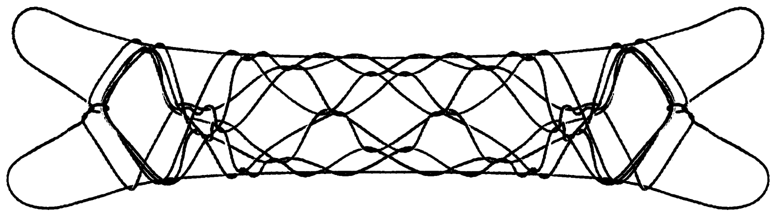


Fig. 44 - *5-loop Tennis Net, Variation 2*

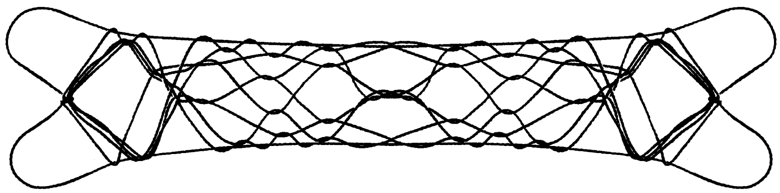


Fig. 45 - *5-loop Tennis Net, Variation 3*

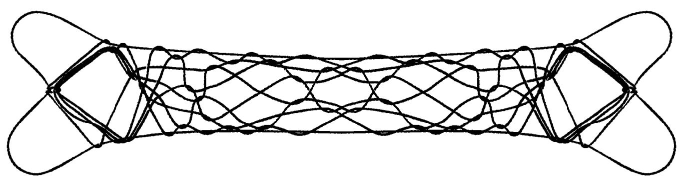


Fig. 46 - *5-loop Tennis Net, Variation 4*

Also impressive is the 5-loop analog of fig. 31 (chart 9). See fig. 47 (chart 27). Like its 4-loop counterpart, this figure features "towers" embedded in the web. This effect is created by passing each loop up through its adjacent loop, rolling the figure, then passing each loop down through its adjacent loop and rolling again.

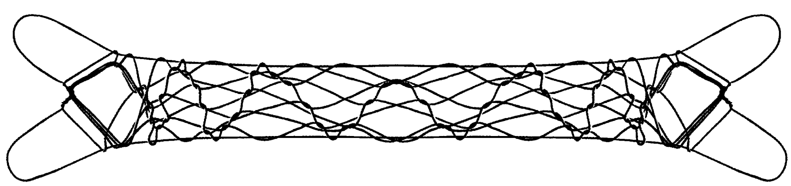


Fig. 47 - *5-loop Tennis Net, Variation 5 (towers)*

As in the 4-loop system, there are a multitude of finishing moves that one can apply after the iterative phase of any 5-loop tennis net. These include:

(1) thumb loop up through index loop; little finger loop up through ring finger loop.
(2) thumb loop up through index loop; little finger loop up through ring finger loop; index loop up through middle finger loop; ring finger loop up through middle finger loop.
(3) (1) or (2) followed by +2/2 rotation of middle finger loop
(4) (1) or (2) followed by +2/2 rotation of index, middle, and ring finger loops.
(5) rotation of thumb loop +2/2 and little finger loop –2/2 followed by (1) or (2) or (3).
(6) (2) followed by middle finger loop up through index loop; middle finger loop up through ring finger loop.

Inner loop rotations (rotations of the index, middle, or ring finger loops) add complexity to the final design. These can be confined to the initial loom alone, or repeated with each iteration of the main weaving sequence as illustrated by Variation 6 (fig. 48, chart 28) and Variation 7 (fig. 49, chart 29).

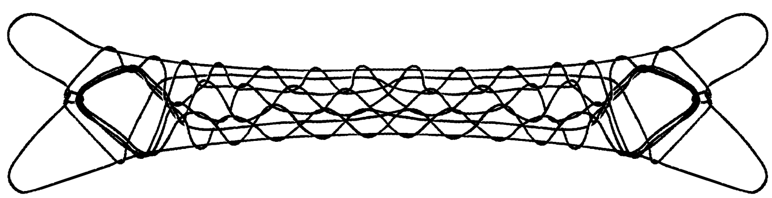


Fig. 48 - *5-loop Tennis Net, Variation 6*

The weaving sequence of Variation 6 is remarkably simple, yet a complex design results because of the repetitive loop rotations. A new type of symmetry is apparent in the chart for Variation 7. The outermost loop passages are of opposite direction (thumb loop *up* through index loop, but little finger *down* through ring finger loop). The same is true of the innermost loop passages (index loop *up* through middle finger loop; ring finger loop *down* through middle finger loop).

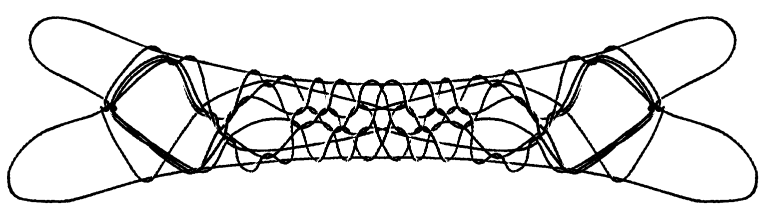


Fig. 49 - *5-loop Tennis Net, Variation 7*

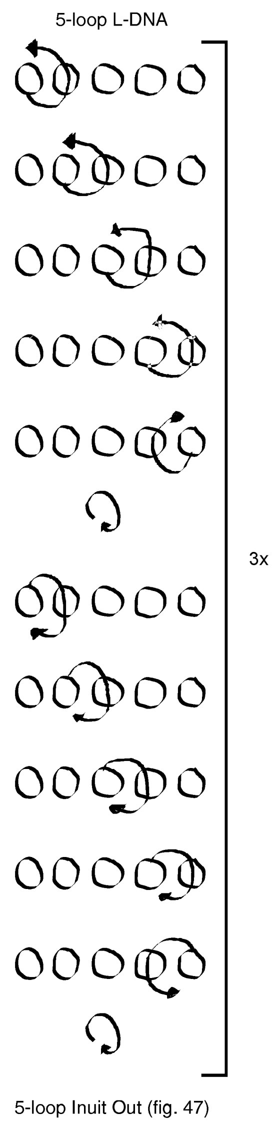


Chart 27

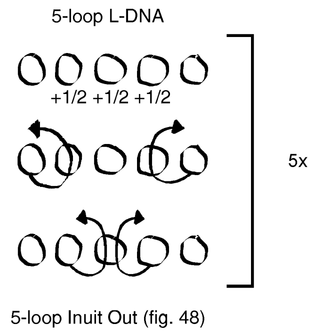


Chart 28

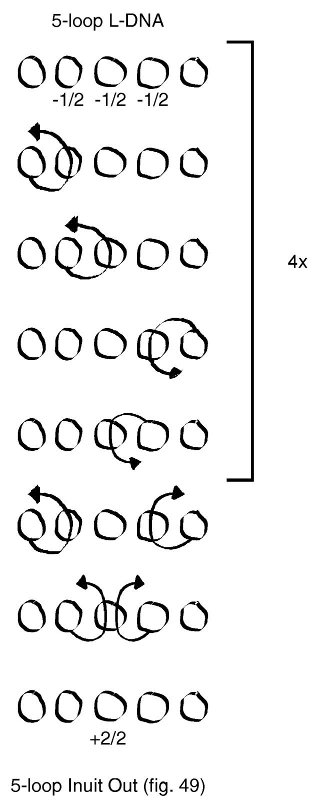


Chart 29

However, when half-rotations are introduced into the thumb and/or little finger loops, an even number of iterations must take place before finishing moves are applied so that the near thumb and far little finger strings, which are transverse in the initial loom, are once again transverse. Examples can be found in charts 30-32. Note that in each example, half-rotations of the outermost loops are done a total of four times. In Variation 8 (fig. 50, chart 30), the four outermost loops all receive half rotations whereas the innermost loop (the middle finger loop) receives a full rotation. In Variation 9 (fig. 51, chart 31), all five loops receive a half rotation with each iteration. In Variation 10 (fig. 52, chart 32), the first iteration differs from the subsequent three iterations, yet a total of four are performed in order to restore the positions of the frame strings.

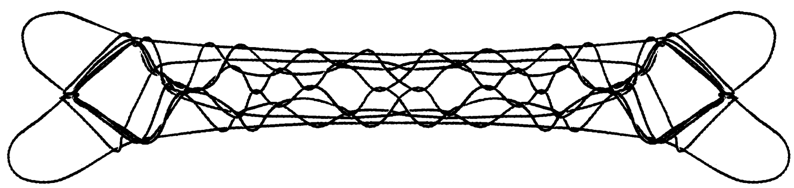


Fig. 50 - *5-loop Tennis Net, Variation 8*

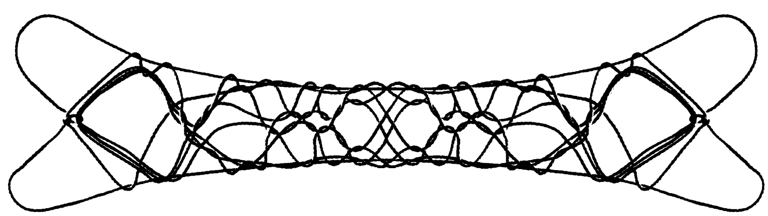


Fig. 51 - *5-loop Tennis Net, Variation 9*

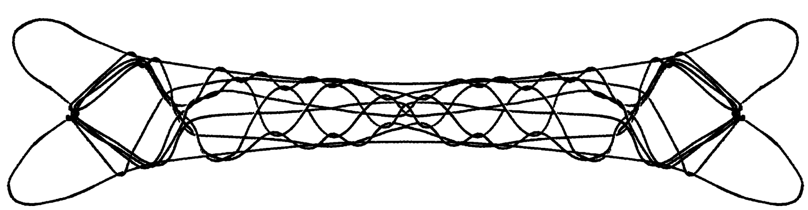
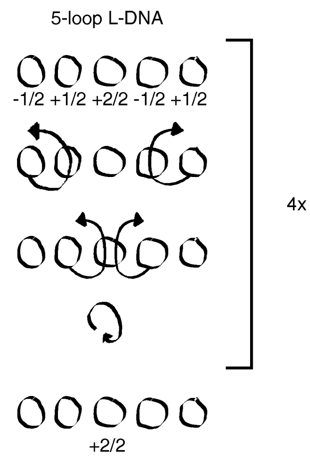
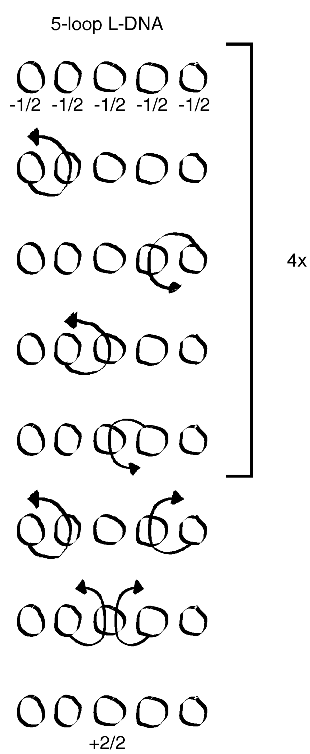


Fig. 52 - *5-loop Tennis Net, Variation 10*



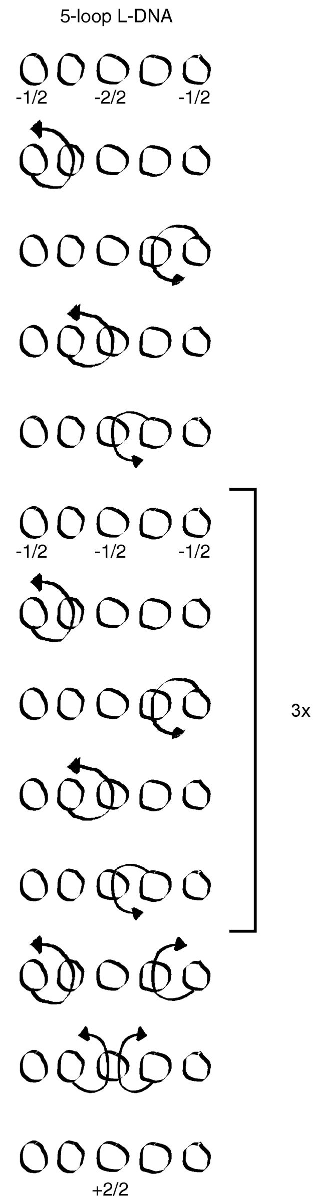
5-loop Inuit Out (fig. 50)

Chart 30



5-loop Inuit Out (fig. 51)

Chart 31



5-loop Inuit Out (fig. 52)

Chart 32

LESSON 11: CHEROKEE SEVEN STARS IN A 5-LOOP ENVIRONMENT

The classic 3-loop weaves (I-1 and I-1') of the ‘Cherokee Seven Stars’ sequence can be mimicked in a 5-loop environment by simply adding two more circles to the 3-loop circle notation chart. The new weaves are labeled (I-1)5 and (I-1')5 (charts 33 and 34):

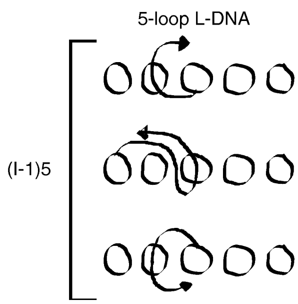


Chart 33

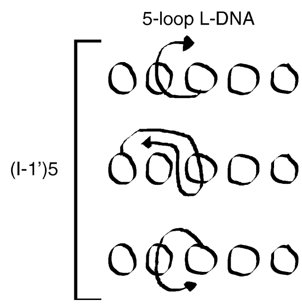


Chart 34

‘Cherokee Seven Stars in a 5-loop environment’ results when these two weaves replace I-1 and I-1' in chart 3. In this interesting design (fig. 53, chart 35) the internal transverse strings that weave in and out of the diamonds are tripled. Many variations are possible. Although not illustrated here, a simple variation would be to start with a 5-loop loom in which the middle finger loop has been rotated +2/2.

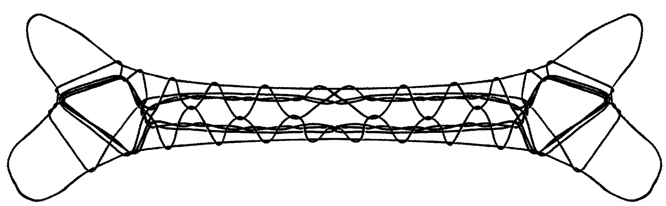


Fig. 53 - *5-loop Cherokee Seven Stars*

One can also replace (I-1')5 with (I-1)5 and add extra loop rotations. In Variation 1 (‘Jewish Stars’) +1/2 rotations of the index, middle, and ring finger loops are introduced before each pair of (I-1)5 weaves (fig. 54, chart 36). After the first two diamonds in the center, the figure settles down to a gorgeous series of six-pointed stars that overlap.

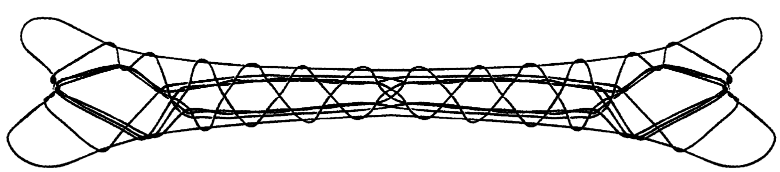


Fig. 54 - *5-loop Cherokee Seven Stars, Variation 1 (Jewish Stars)*

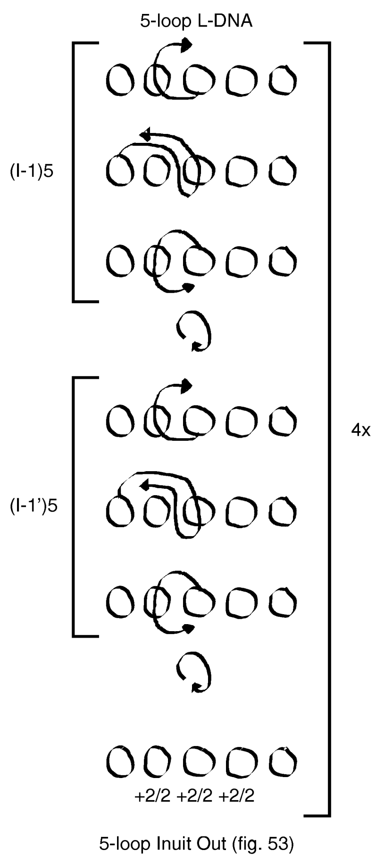


Chart 35

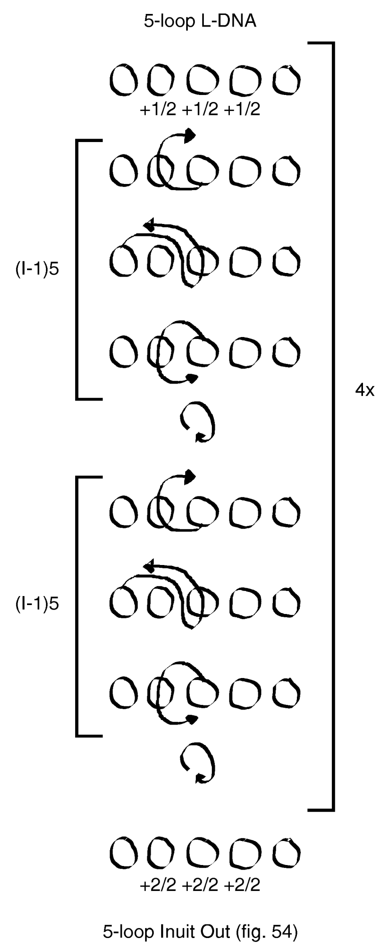


Chart 36

One can also experiment with adding a +2/2 thumb loop rotation and a –2/2 little finger loop rotation in line 2 of chart 36. This modification wraps the loose interior transversal around the adjacent frame line, thus improving the figure's extension (Variation 2, fig. 55).

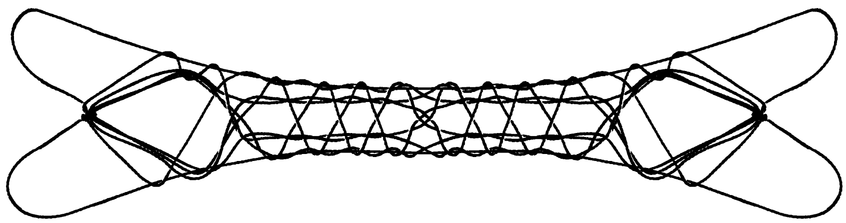


Fig. 55 - *5-loop Cherokee Seven Stars, Variation 2 (Jewish Stars with frame wraps)*

The 5-loop analog of fig. 41 (chart 21) is also quite interesting. In chart 21, the roll at the end of each iteration is omitted. In a 4-loop environment this alters the internal transversal. But the effect of omitting a roll in a 5-loop environment is completely different: the internal transversals remain parallel as in 'Jewish Stars' (see Variation 3, fig. 56, chart 37).

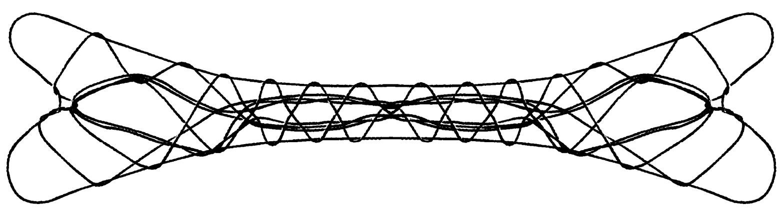
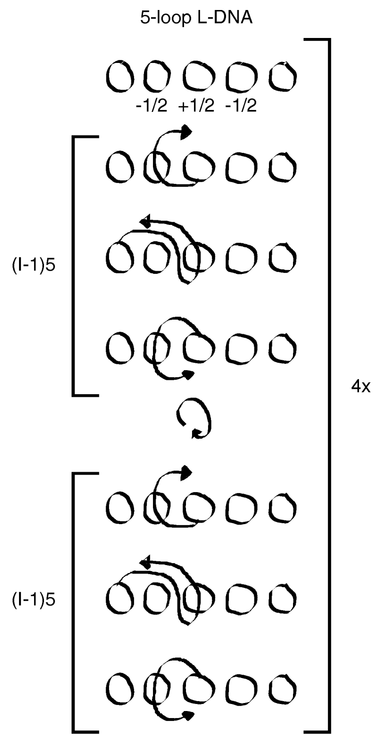


Fig. 56 - *5-loop Cherokee Seven Stars, Variation 3 (Jewish Stars, roll omitted)*

LESSON 12: TENNIS NET/VERTICAL NET HYBRIDS

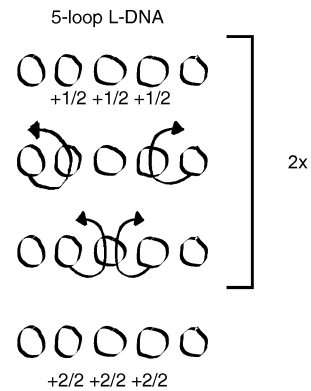
Since 4- and 5-loop figures are difficult to extend, i usually reduce the number of loops to two using an 'Inuit Out' sequence and apply the Power Lift or Caroline Extension to display the final design. But lately i've also been experimenting with the Vertical Net sequence as a finishing move for 5-loop tennis nets. After completing the iterative sequence the internal loops are rotated a full turn to seal off the complexity, then the loops are rearranged to form a Vertical Loom configuration:

- Transfer the middle finger loop to the top of the ring finger; transfer the index loop to the top of the ring finger; transfer the thumb loop to the top of the ring finger; finally, transfer all four ring finger loops to the index finger, maintaining their order. Fingers are inserted from below during these transfers.



5-loop Inuit Out (fig. 56)

Chart 37



Vertical Net Out (fig. 57)

Chart 38

- Pass the thumb under the index loops, transfer the little finger loop to the thumb, inserting the thumb from below, then immediately retransfer this loop to the middle-ring-little fingers, inserting them from above and pressing their tips against the palm.

Now do the first and second Vertical Weaves (V-1 and V-2) followed by the Vertical Net Finishing Move (V-finish) and apply the Power Lift or Caroline Extension. i call this ending ‘Vertical Net Out’. Fig. 57 (chart 38) serves as an example.

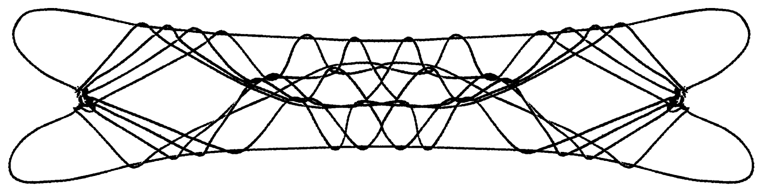


Fig. 57 - *5-loop Tennis Net with Vertical Net ending applied*

Lesson 13: Dominant Switches

Loop exchanges are often used to modify looms and add richness to designs. The figure described on page 244 is a good example. After forming the loom (Opening A), the right and left index loops are exchanged. As a result, the near (and far) index strings of the loom interlock rather than merely cross (fig. 58). In loop exchanges order is important. If one starts with Opening A (right palmar string picked up first), the left index loop must pass over the right index loop during the exchange (i call this a *left-dominant exchange*). If done vice-versa, the loom dissolves.

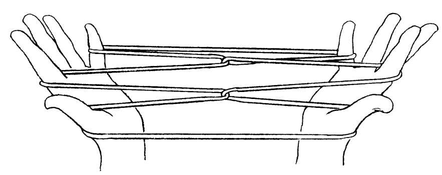


Fig. 58 - *Left-dominant index exchange applied to Opening A.*

Traditional loop exchanges (fingers inserted from above during the transfers) cannot be applied to DNA looms: the looms will partially dissolve, regardless of the order in which the loops are exchanged. For this reason i invented a new type of exchange, which i call a *switch*. In a switch exchange, the fingers are inserted *from below* during the loop transfers. Again, order is important. One can define two types of switches: a *left-dominant switch* (left loop passes over right loop) and a *right-dominant switch* (right loop passes over left loop). To practice, set up a 3-loop L-DNA loom and proceed as follows:

Left-Dominant Index Switch

- Transfer the left index loop to the top of the right index, inserting the right index from below and from the near side; pass the left index down through the right upper index loop, then insert it, from below and from the near side, into the right lower index loop; lift this loop off the right index, drawing it up through the right upper index loop as you return the left index to its original position.

The result is shown in fig. 59. The effect of applying a left-dominant index switch to an L-DNA loom is magical: the far thumb-far index string of one hand interlocks with the near index-near little finger string of the opposite hand, As a result, a small hole forms in the center of the loom. One can immediately design a simple figure that show-cases this feature:

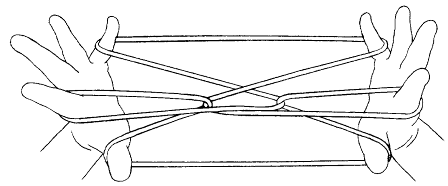


Fig. 59 - *Left-dominant index switch applied to a 3-loop L-DNA loom*

- 3-loop L-DNA loom
- Left-dominant index switch
- Inuit Out, Power Lift (fig. 60).

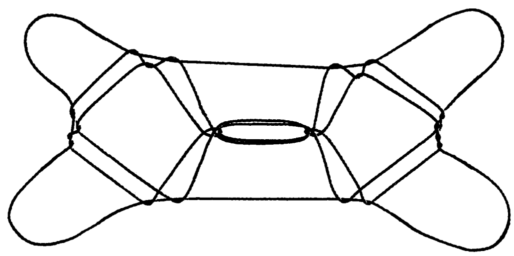


Fig. 60 - *Dominant switch test pattern ('Inuit Hole')*

A right dominant index switch is similarly defined. To practice, set up a 3-loop R-DNA loom and proceed as follows:

Right Dominant Index Switch

- Transfer the right index loop to the top of the left index, inserting the left index from below and from the near side; pass the right index down through the left upper index loop, then insert it, from below and from the near side, into the left lower index loop; lift this loop off the left index, drawing it up through the left upper index loop as you return the right index to its original position.

The result is shown in fig. 61. One should note that a left dominant switch should only be applied to a left DNA loom. Likewise, a right dominant switch should only be applied to a right DNA loom. Going "against the grain" of a loom (applying a left dominant switch to a right DNA loom) destroys the symmetry of the central design motif and often results in a tangled mass of strings.

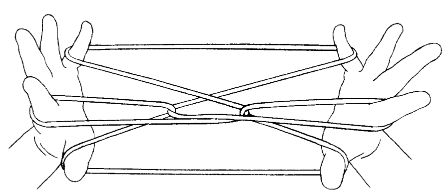


Fig. 61 - *Right-dominant index switch applied to a 3-loop R-DNA loom*

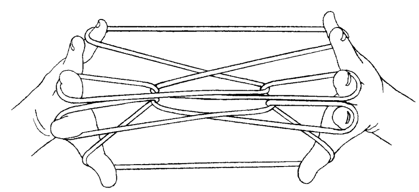


Fig. 62 - *Left-dominant index and middle switches applied to a 4-loop L-DNA loom*

Dominant switches can also be applied to 4- and 5-loop DNA looms. In a 4-loop DNA loom both the index and middle finger loops can be switched to give two nested holes in the center of the loom (fig. 62). In a 5-loop DNA loom, the index, middle, and ring finger loops can all be switched to give three nested holes.

To investigate the effects of introducing dominant switches into the looms of 4- and 5-loop tennis nets, i devised two simple test patterns (fig 63, chart 39, and fig. 64, chart 40). In my circle notation charts, an “LS” placed under a circle indicates that a left-dominant switch should be applied to the corresponding loop (“RS” stands for right-dominant switch):

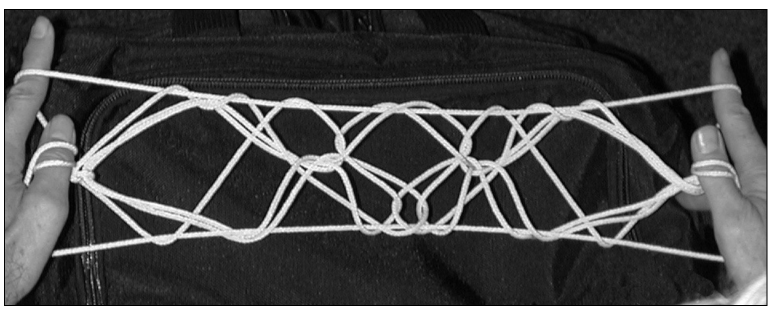


Fig. 63 - *Simple left-dominant switched 4-loop tennis net*

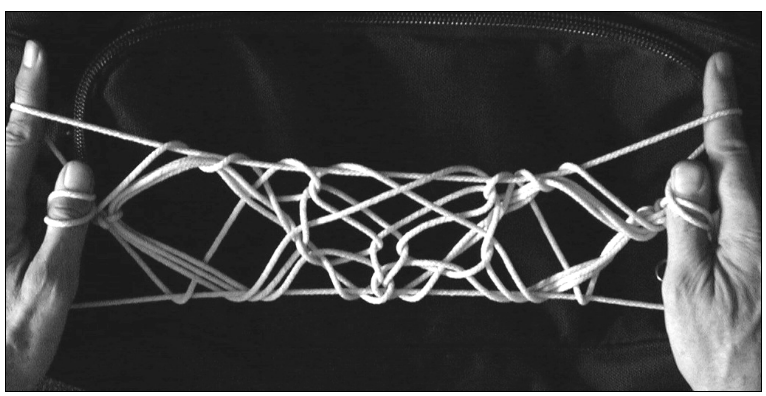


Fig. 64 - *Simple left-dominant switched 5-loop tennis net*

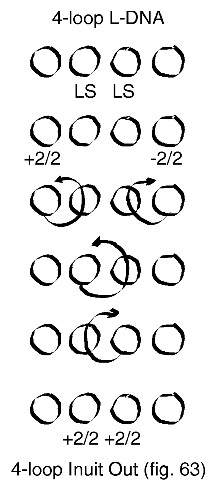


Chart 39

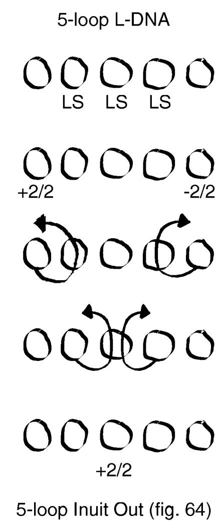


Chart 40

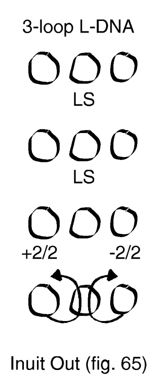


Chart 41

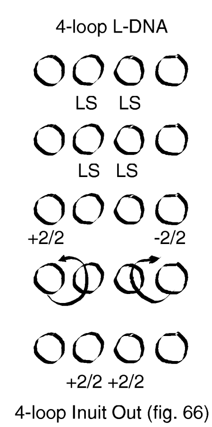


Chart 42

Some interesting design motifs arise from applying dominant switches twice to simple loop passage figures. Simple test patterns are shown in fig. 65 (chart 41) and fig. 66 (chart 42).

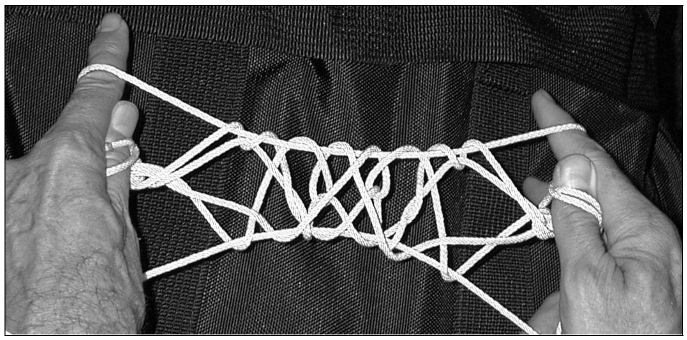


Fig. 65 - *Two left-dominant switches applied to a simple 3-loop L-DNA figure*

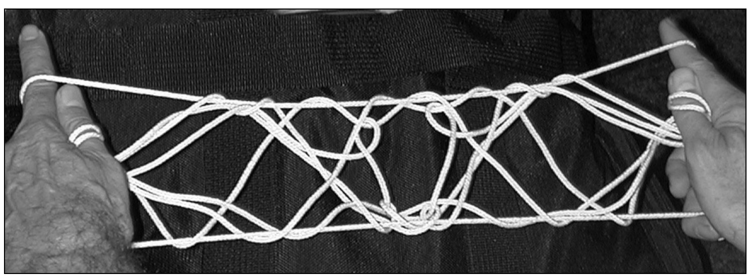


Fig. 66 - *Two left-dominant switches applied to a simple 4-loop L-DNA figure*

Right and left dominant switches can occur in the same figure and still result in a symmetrical design, provided a "mixed" DNA loom is used. In a mixed loom, some of the loops are created using the left thumb and others are created using the right thumb. A standard 4-loop L-DNA loom is actually an LLL-DNA loom (the left thumb is used three times to add loops to the loom). In forming an RRL-DNA loom, the first loop sits on the little fingers, then the *right* thumb is used to create the second loop (which is then transferred to the middle fingers); the *right* thumb likewise creates the third loop (which is then transferred to the index fingers); but the *left* thumb is used to create the final loop (which remains on the thumbs). As an exercise, try making the figure illustrated in chart 43 (see fig. 67). This combination results in two interlocking loops in the center of the design. If the same figure is now made using an LRL 4-loop DNA loom (chart 44), the locking loops separate and are asymmetrically placed (fig. 68). To make the mirror image of this figure (chart 45), simply reverse right and left (fig. 69).

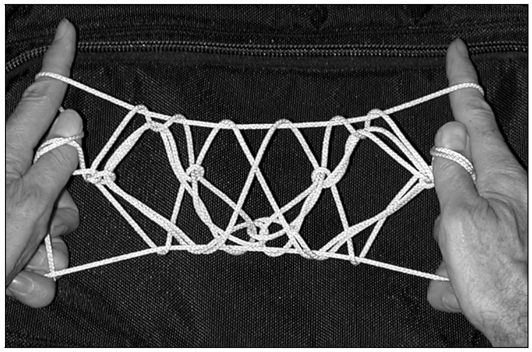


Fig. 67 - *Dominant-switches applied to a simple RRL-DNA loom figure*

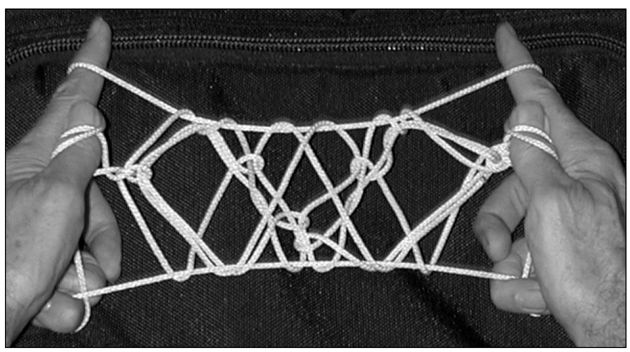


Fig. 68 - *Dominant-switches applied to a simple LRL-DNA loom figure*

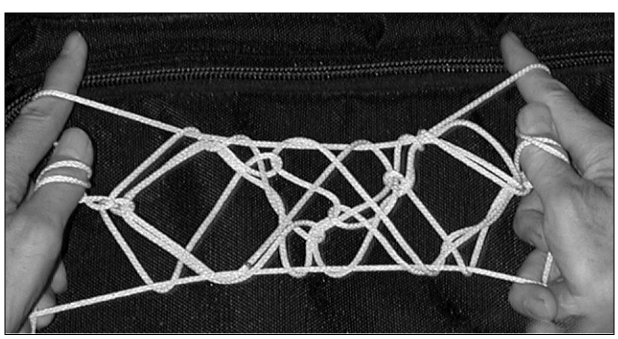
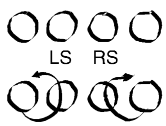


Fig. 69 - *Dominant-switches applied to a simple RLR-DNA loom figure*

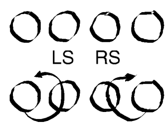
4-loop RRL-DNA



4-loop Inuit Out (fig. 67)

Chart 43

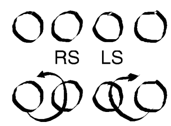
4-loop LRL-DNA



4-loop Inuit Out (fig. 68)

Chart 44

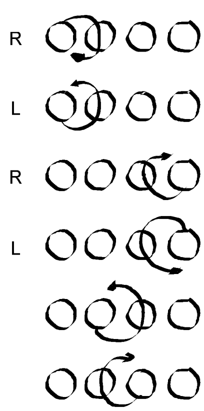
4-loop RLR-DNA



4-loop Inuit Out (fig. 69)

Chart 45

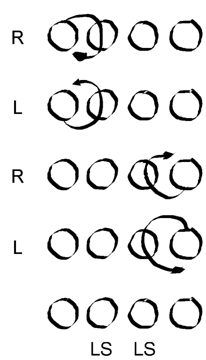
4-loop L-DNA



4-loop Inuit Out (fig. 70)

Chart 46

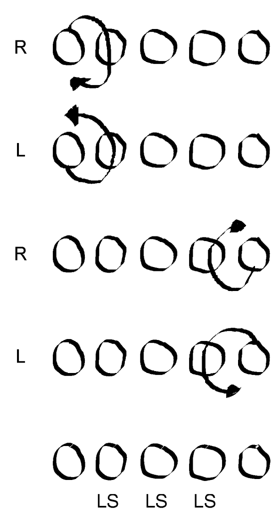
4-loop L-DNA



4-loop Inuit Out (fig. 71)

Chart 47

5-loop L-DNA



5-loop Inuit Out (fig. 72)

Chart 48

LESSON 14: MIXED LOOP PASSAGES

Several favorite designs of mine arise from doing different loop passages on each hand. In my circle notation charts i place an R or an L before a row to indicate that the loop passage should only be done on the right or the left hand. The first design in this series (fig. 70, chart 46) is called 'Koi Fish' because of the two protruding "eyes" that pop out of the center on the back side of the figure.

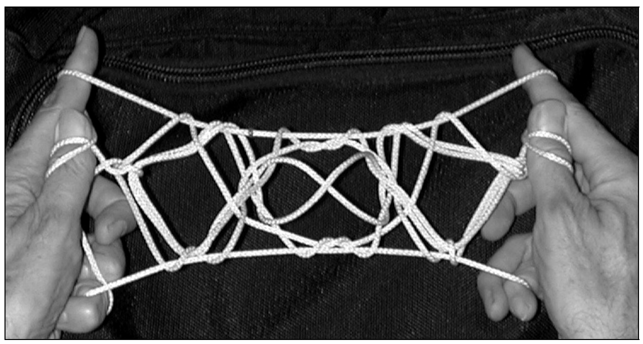


Fig. 70 - *'Koi Fish.' The finished figure was rolled once before applying the Power Lift so that the protruding eyes would face the camera.*

The second design is called 'American Eagle' (fig. 71, chart 47). This eagle has a realistic head, two feet, a prominent feathered breast, and two fully extended wings, much like the eagle seen on numerous U.S. coins and government emblems. In this figure i combine mixed loop passages with dominant switches. The corresponding 5-loop figure (index, middle, and ring left-dominant switched) is likewise impressive (fig. 72, chart 48).

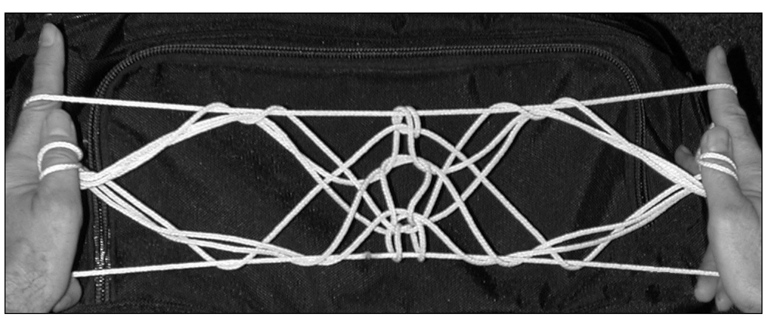


Fig. 71 - *'American Eagle' (4-loop version)*

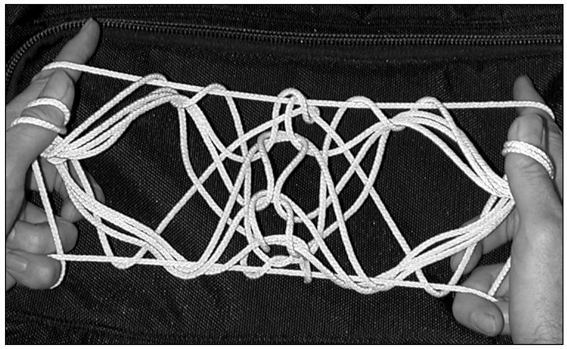


Fig. 72 - *'American Eagle' (5-loop version)*

EPILOGUE

Throughout my series of four articles outlining my approach to teaching math skills using string figures, methods for making several hundred intricate new designs have been provided, and if one includes the figures mentioned in matrices the number approaches a million or more. But the system i use for teaching these figures to students requires very little memorization. This is because all these wonderful figures derive from just three simple patterns gleaned from the literature: 'Two Diamonds,' 'Ten Men,' and the 'Inuit Net.' What i teach is how to break down their methods of construction into comprehensible units which can then be shuffled, iterated, transplanted, and hybridized. In doing so my students learn to think in a whole new way, a way that fosters the type of analytical thinking required for tackling advanced math problems.

One of the basic ideas of my system of learning string figures was suggested to me by one of my high school students when he was challenged to describe how he would change the formation of a figure in order to make a new figure *if he had to.* Early on my high school string figures class was devoted largely to the learning of string figures described in the classic literature. During my second or third year of teaching there was a shy young man who always sat in the back of the class and was shunned by all the other students because of his smell and his appearance. He was always in rumpled clothes and his teeth were very uneven and rather hideous looking. While he didn't talk to or interact with the other students, he did try to learn string figures by watching the other students from a distance.

After about six weeks, and after all the students could form the simple diamond figures and all were accomplished at making 'Ten Men', i walked to the back of the room and sat in one of the empty chairs surrounding this young man. He bristled and then shrunk in on himself. In a soft conversational tone he was asked how he would change something in making the figure in order to make a new figure. He didn't answer and the conversational tone continued, as i explained that it wasn't an idle question being asked but one of vital importance for his passing the class. i further confided that the instructor was blocked in his attempts at coming up with new figures, and that the Cherokee grandmother who had taught him his first figure always said that one could make up one's own figures if one tried hard enough and was smart enough.

"You need help?" he said.

"Yes," i said.

"Then I would spin the little finger strings before picking them up," he smiled, and his face was transformed.

And that was the beginning of my fascination with the results of rotating the loops while performing clearly defined operations. By careful observation of the resulting figures, a string figure system began to form in my mind. And it started with a frightened young man who was put on a hot seat and asked respectfully what he had surmised during his solitary play with the thin torus of string, his sole textbook for the course.

* * *

In closing i offer the following poem:

the sounds of work grow dim
my fingers never rest
i shape a string outlining
a mirror of my mind

the work grows dim in sound
my rhythmic fingers move
the strings are strum in meaning
a mirror of my soul

i pick the strings in tandem
i pick a melody
the sounds are grim in echo
my mind outlines my soul

i work in tension’s molding
i flex my muscled arm
i hold fast to my meaning
and mean nobody harm

i flex to form a window
of geometric form
to look through as i am singing
the gladness in the storm

alone with finger’s wander
alone here in my home
i make a soul with fingers
i stroke a rhyming love

inoli

LITERATURE CITED

Firth, R. and Maude, H.C. (1970) "Tikopia String Figures." *Royal Anthropological Institute Occasional Paper* 29.

Jayne, C.F. (1962) *String Figures and How to Make Them*. New York: Dover.

Murphy, J. (1997) "Using String Figures to Teach Math Skills: Part 1 — The Diamonds System." *Bulletin of the International String Figure Association* 4:56-74.

Murphy, J. (1998) "Using String Figures to Teach Math Skills: Part 2 — The Ten Men System." *Bulletin of the International String Figure Association* 5:159-209.

Murphy, J. (1999) "Using String Figures to Teach Math Skills: Part 3 — The North American Net System." *Bulletin of the International String Figure Association* 6:160-211.

ACKNOWLEDGMENT

Thanks go to Mark Sherman for the line drawings. Figures 17, 18, 73, and the cover page photo are by Jeff Wang. Figures 29 and 30 are by Greg W. Knight.

APPENDIX

Murphy's Mesh (Tikopian Net variation)

Form the Loom

- Begin with Opening A.

First Weave

- Pass each thumb away from you over the near index string and under the far index string, then pick up the near little finger string and return.
- Pass each index down through the upper thumb loop, then pick up the lower far thumb string and return.
- Drop both thumb loops and extend.

Second Weave

- Pass each thumb away from you over the lower near index string and under all other strings, then pick up the near little finger string and return.
- Drop the little finger loop and extend.

Fix the Bottom

- Pass each little finger down through the upper index loop, then toward you under both strings of the lower index loop, pick up the far thumb string and return through the upper index loop.
- Drop the thumb loop and extend.

Clean the Top

- Pass each thumb between the lower and upper near index strings, pick up the lower and upper far index strings (maintain their relative order), and return.
- Navaho the thumb loops.
- Drop the upper index loop.

Reset the Loom

- Transfer the thumb loop to the top of the index, inserting the index from below, then retransfer this loop to the thumb, inserting the thumb *from above* (this accomplishes a -1/2 rotation of the thumb loop).

Repeat the entire weaving sequence four more times (omit "Form the Loom") then make the 3-loop Inuit Net from the beginning, as if you had Opening A on your hands, and finish with the Power Lift or Caroline Extension (Murphy 1999:188-189). See figure 73. The formula for this figure is:

Opening A, [first weave, second weave, fix the bottom, clean the top, reset the loom]^5, Inuit Out, Power Lift or Caroline Extension.

Fig. 73 - *Murphy's Mesh*