Coupled Resonant Straws (Snack version of Wave Exhibit)

We are now moving from gravity-driven resonant systems (pendula) to resonant systems that do not depend on gravity, but on torsion.

Materials: (per pair)

Masking tape
15 plastic straws (not the bendable kind)
30 large paper clips
at least 4 small paper clips
Two tables
Stop watch
Metric ruler/measuring tape
Sharpie
Calculator

To Do and Notice:

1. Stretch a long piece of masking tape between 2 tables that are about 85 cm apart, sticky side up. It should be very taut and level and stuck to the edges of the tables. Use smaller lengths of tape to make the long piece very taut and level.
2. Mark center of straws with Sharpie.
3. Add one large and one small paper clip weights to each of the ends of 2 plastic straws.
4. Place 2 straws on tape so that each one is 20 cm from the edge of one of the tables.

5. Measure period of each of the two normal modes: Straws in opposition, straws together. Time 10 periods, then divide by 10. Do this several times for each mode, as this can be challenging. You may want to take the mean of several reasonable trials.
6. Recall that the period is the reciprocal of the frequency. To find the frequency of each mode, find the reciprocal of the period (T).

$f = 1/T$ and $T = 1/f$

Our data:

In opposition	Together
$f_1 = 1.71$ cycles/sec	$f_2 = 1.255$ cycles/sec

7. Find the difference in these two frequencies to predict the beat frequency.
Difference: $f_1 - f_2 = \Delta f = .46$ cycles/sec (beat frequency)

Lori Lambertson and Thomas Humphrey
Exploratorium Teacher Institute

8. To get the beat period T_b, find the reciprocal of the beat frequency.

$1/f = T_b$ 1/.46 cycles/sec = 2.17 sec
(time it takes for one beat period when straws are coupled)

9. Start one straw, observe coupled behavior, time several beat periods, and divide by the total number you timed. Compare to predicted beat period.

10. Add weighted straws (one large paper clip at each end) at the half way points between existing straws. Add a straw, then push one end straw. What shapes do you notice?

11. Keep adding straws, and testing to see what happens when you push one at the end.

12. After you have attached all your straws, what do you notice when you push one at the end? What does the motion look like? Can you "drive" this multiple coupled masses system at a resonant frequency?

Exhibit: Wave

Notice the similarities between this exhibit and the snack you just built. We can identify the normal modes in multiple masses by "hump counting".
If there are ~30 masses, then there will be 30 normal modes.
Notice that you cannot "drive" it at any frequency.
Let's revisit the Giant Slinky, and develop some more scientific language for "hump counting".

Lori Lambertson and Thomas Humphrey
Exploratorium Teacher Institute