GOOD, GOOD, GOOD VIBRATIONS!!!

Caroline Hulbert
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Background

Have you ever had a car pull up beside yours with the base booming so loud that your car vibrates? When that happened, did you ever think about the effects that those vibrations must be having on you as well as the person in the booming car, or just on matter in general? Normally when we think of vibrations, we think of sound and particularly music. But in truth, vibrations are a much greater part of our lives and through my investigations, I hope to show you that.

Vibrations come from many sources, from the smallest units of light and matter to the largest even including stars. The range of vibrations makes up the electromagnetic spectrum. Although there are many sources, from boats to planes and cell phones to stars, I am most interested in radio sound vibrations, the longest waves in the electromagnetic spectrum. My interest is that under certain conditions, the waves can interact to form interference patterns as illustrated in Figure 1.

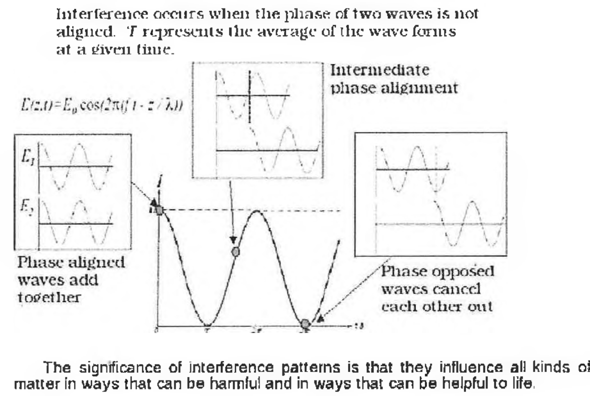


Figure 1. Interference Concept.

Interference occurs when the phases of two interacting waves are not aligned. This happens when there is intermediate phase alignment. When the waves are phase aligned, they add and when they are phase opposed, they cancel each other out. The significance of interference patterns is they influence all kinds of matter in many different ways [4, 5].

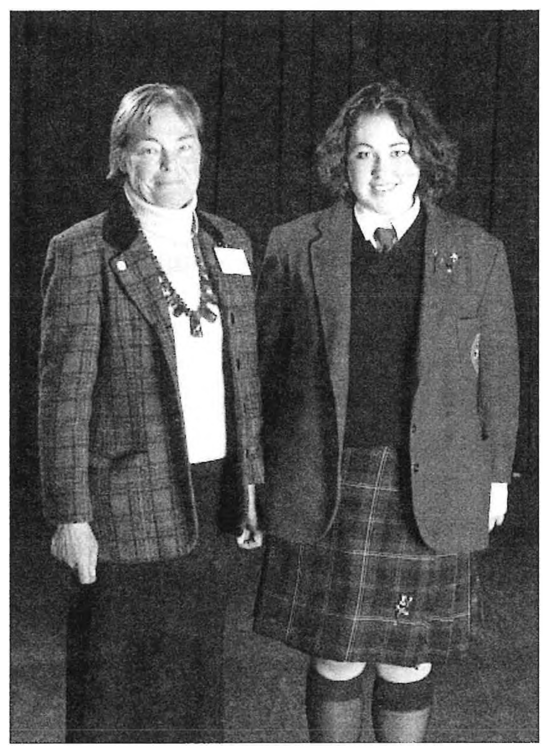
Back in 1787, physicist Earnst Chladni founded the sci-

CANADA WIDE SCIENCE FAIR

From File Reports

Caroline Hulbert, a Grade 10 student at St. Margaret's School in Victoria, BC, won this year's acoustics prize at the Canada Wide Science Fair. Hulbert is currently in Grade 11 at Mount Douglas Secondary. She is the Year book Editor for the Fine Arts. She is also in the School Concert choir and has been surrounded by music through out her life. Because these vibrations always played such a major role in her life, Hulbert started to ask questions, such as: what are the effects of constantly bombarding oneself with all these different vibrations? With her father as her mentor Hulbert set out to find the answer. Along the way she came across the above experiment that could further her knowledge about these vibrations and validate the research that she had done.

Editor's Note: We are very happy to note that Ms. Hulbert submitted a brief summary of her project work that won the prize at the fair. Her full article is reproduced above.



Caroline Hulbert (r) with CAA's Elzbieta Slawinski (l)

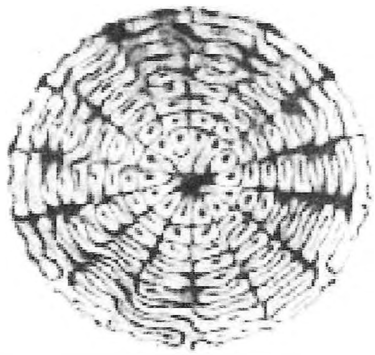


Figure 2. Plant Cell Patterns in Sand.

ence of Cymatics which is the study of how sound affects matter. His work was extended by Dr. Hans Jenny, a Swiss physician [2, 6]. He suspended a metal plate on crystal oscillators connected to a frequency generator. Then he put various media on the plate and observed the patterns formed when he changed the frequencies. He demonstrated that the shapes of various plants, animals and insects could be reproduced in sand patterns in his laboratory just by selecting various frequencies. One example of his findings is shown in Figure 2. This pattern is very similar to the organization of cells in the stem of a plant. So, neat sand patterns are formed because of interference patterns. Now then, what is the relationship between the sand patterns and the interference patterns? Dr. Jenny found that the area in the sand pattern that had no sand was the area of high energy, where the waveforms had added together. Where the waveforms had canceled each other out, there was an area of low energy and that was where the sand had deposited. He showed that sand patterns are negatives of interference patterns.

Purpose

To explore the relationship between frequencies and waveforms that produce defined interference patterns in sand and their effects on biological matter - bacteria growth and plant seed germination and growth.

Hypotheses

1) different waveforms at a given frequency will produce different interference patterns, and
2) sounds that cause different interference patterns in sand to form will affect the rate of *E. coli* bacteria colony growth and the rates of Alfalfa seed germination and growth.

Procedure

I. Frequency Generator Setup Holes (1/8" diameter) were drilled into the bottom of a 1 Kilo size coffee can and a speaker was mounted over the holes. A rubber sheet was carefully stretched across the top of the coffee can and secured with an elastic band. A paper retainer was placed around the rim of the can to contain the sand on top of the rubber sheet. Leads were connected from the Circuitmate frequency generator to the speaker. The maximum amplitude was used for all frequencies tested. The experimental set-up is shown in Figure 3.

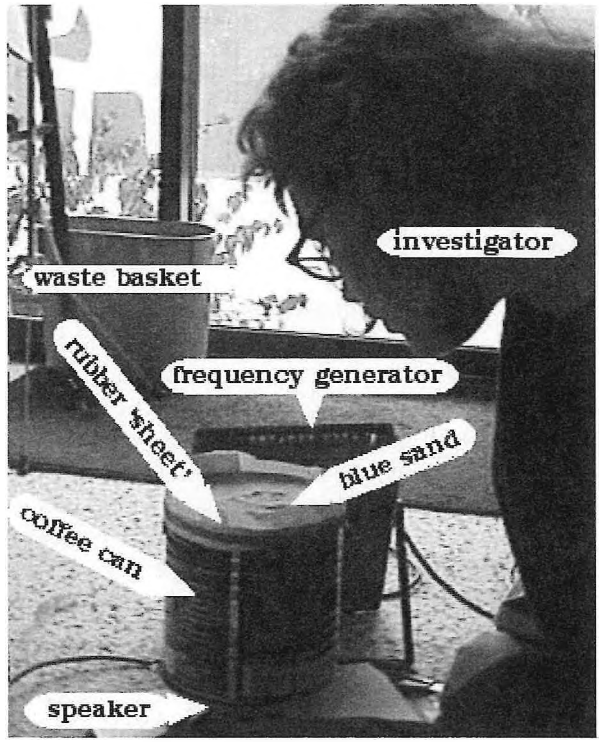


Figure 3. Experimental Set-Up.

II. Sand Procedure

a) Multi-waveform patterns Three frequencies, 200 Hz, 3000 Hz, and 8500 Hz were selected for testing. The waveform output of the frequency generator was swiitched from sine wave to square wave to triangular wave and the patterns generated were recorded with a digital camera.

b) Experimental waveforms for Bacteria Two square waves at 1000 Hz and 790 Hz were selecetd because the interference patterns generated were so significantly different from one another.

c) Experimental waveforms for Plants Two frequencies, 200 Hz and 8500 Hz were selecetd for experimentation on seed germination and growth. 200 Hz represents the base booming heard in cars and 8500 Hz represents the frequencies for bird chirps. These frequencies were also selected because with the test apparatus, they produced distinctly different interference patterns in sand which was one of the test criteria.

III. Bacteria Procedure Petri dishes were inoculated with *E. coli* on nutrient medium. Three petri dishes were placed on top of the rubber sheet and then exposed to either 790 Hz or 1000 Hz for 1.5 hrs. Following treatment, the plates were placed into a home made incubator at a temperature of 30^0 C. The plates were removed at intervals of 7 hrs, 23.5 hrs and 33.5 hrs and photographed to record colony size for measurement.

IV. Seed and Plant Procedure

a) General Twenty Alfalfa seeds for each of the 12 experimental sound treatments for both the 'wet exposed' and 'dry exposed' conditions (24 groups in total) were placed between folded strips of paper towel, approximately 3cm wide, into 2 - 23 X 28cm plastic lids (one for dry and one for wet exposures). They were moistened with water, covered with plastic wrap to prevent dehydration, and then put into a cardboard box incubator with a heat lamp to germinate and grow.

b) Sound Exposure Alfalfa seeds were exposed to 200 Hz or 8500 Hz sine, square, and sawtooth waves by placing the seeds in the folded paper towel into a petri dish that was placed directly on the rubber sheet on the coffee can. The Alfalfa seeds were either exposed to the two frequencies and 3 waveforms for 1/2 hr 'dry', or 'wet' with water. Exposures were done in one room of my house and the plants not being exposed were in another part of the house.

Results

I Bacteria

a) Interference Patterns in Sand The effects of sound is shown in Figure 4 for two square waves. Figure 4 (1) - for 790Hz -shows an interference pattern characterized by a central peak with some marginal accumulation as well. Figure 4 (2) - for 1,000Hz - shows an interference pattern characterized by a ring of sand with the center clear. There is some marginal accumulation and patterning as well.

b) Effects on the Size of Bacterial Colonies The different wavelengths affect the size of the bacterial colonies differently, as shwon in Figure 5. At all time intervals examined, bacteria exposed to 1000Hz exhibited significantly larger colonies ($p < 0.05$) than the control. By contrast, bacteria exposed to 790 Hz had significantly smaller colonies ($p < 0.05$) at 23.5 hrs after exposure, but, that reversed by 33.5 hrs where colony size was significantly greater than control ($p < 0.05$). See Table 1 for statistical details [1].

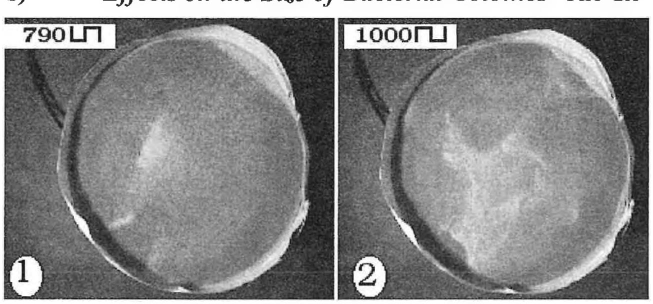


Figure 4. Interference Patterns in Sand.
1 - 790 Hz square wave; 2 - 1000 Hz sqaure wave.

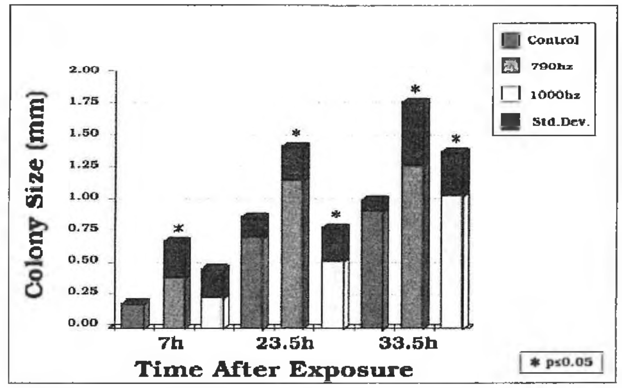


Figure 5. Size of E-Coli Colonies after expsoure to square waves for 1.5 hours.

Control vs 790 Hz			
p value	0.0393	0.0001	0.0001
Control vs 1000 Hz			
p value	0.5101	0.0001	0.0001
790 Hz vs 1000 Hz			
p value	0.0025	0.0001	0.0001

Table 1. Statistical details for Figure 5 [1].

II Sand The different wave forms (sine, square, saw-

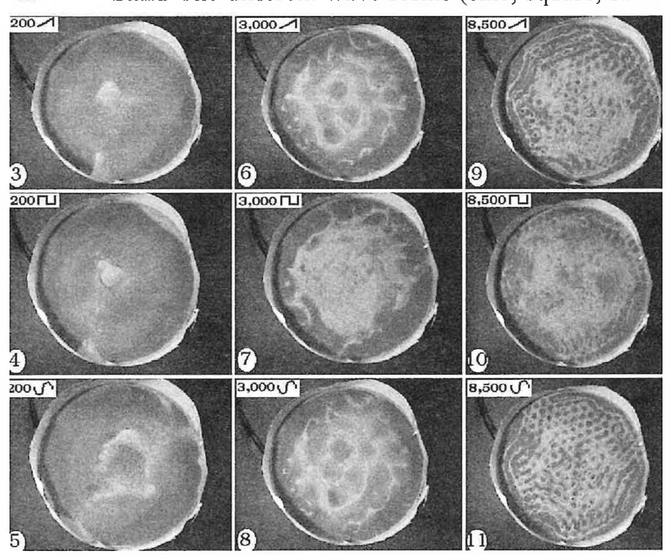


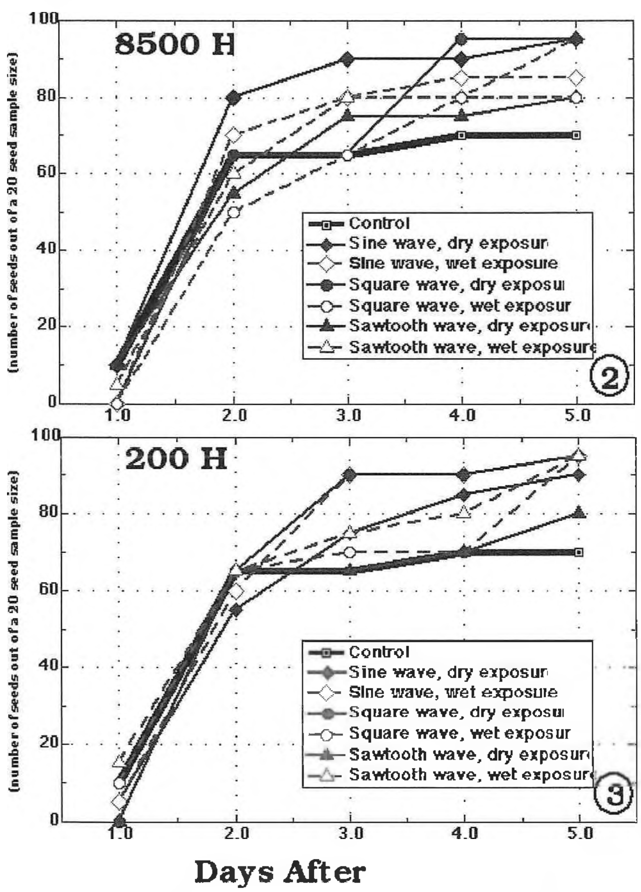
Figure 6. Interference Patterns in Sand.
a) 200 Hz Plates 3- sawttooth; 4 -square and 5 - Sine;
b) 3000 Hz Plates 6- sawttooth; 7 -square and 8 - Sine;
c) 8500 Hz Plates 9- sawttooth; 10 -square and 11 - Sine;

tooth) yielded different interference sand patterns as did the frequencies (200 Hz, 3000 Hz, 8500 Hz); moreover, as the frequencies increased, the interference patterns increased in complexity, as shown in Figure 6. The frequency of 200 Hz yielded the simplest sand pattern with the sawtooth (Plate 3) and square wave (Plate 4) forms resulting in a central dome while the sine wave (Plate 5) resulted in the negative of a dome, a central open circle. At the higher frequencies, the square wave resulted in a poorly defined interference pattern compared to the sawtooth and sine waves. Note the intricate patterning in the sand exposed to 8500 Hz compared to that of 3000 Hz (Plates 9-11 & 6-8) and 200 Hz (Plates 3-5).

III Alfalfa Seed Germination and Growth

<u>i) Germination</u> The effects of sine, square and sawtooth waveforms at 200 Hz and 8500 Hz on Alfalfa seed germination are shown in Figures 7 and 8. Three consistent observations are 1) that the exposure to the frequencies caused more seeds to germinate, and, 2) there does not seem to be any difference in the number of seeds germinated if the seeds are dry or wet, and 3) there was no special effect of the frequencies or waveforms tested on seed germination.

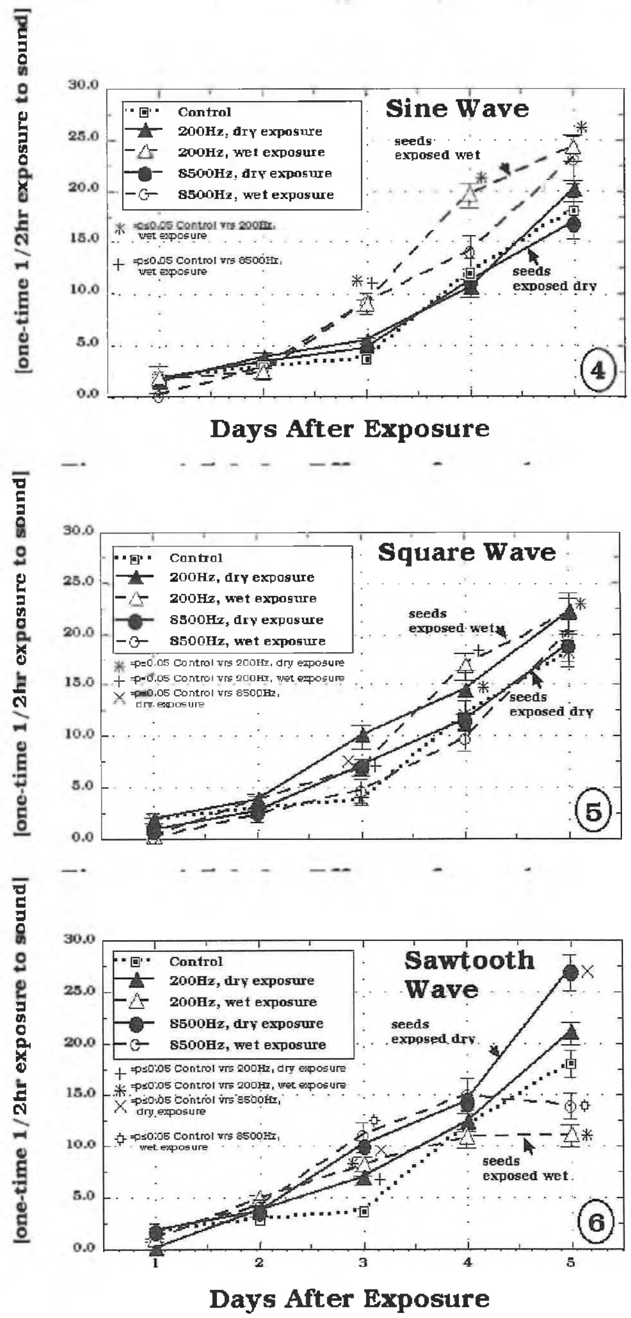
<u>ii) Growth</u> There was no consistent effect of frequency on Alfalfa seeds exposed dry or wet (Figures 9,10 and 11) over a 5 day assessment period, but, seeds exposed wet to sine waves at both 200 Hz and 8500 Hz grew significantly more than controls and seeds exposed dry (Figure 9); and seeds exposed wet or dry to sawtooth wave at both 200 Hz and 8500 Hz had reduced growth at 5 days compared to controls and seeds exposed dry.



Figures 7 and 8. Effect on Alfalfa Seed Germination.

Discussion

This research presents concrete evidence that links sound directly to an alteration in the structural organization of abiotic matter and subsequent effects in living tissue. The



Figures 9, 10 and11. Effect on Alfalfa Seed Shoot and Growth.

bacteria study showed an enhancement in the colony size that was different for the different frequencies and interference patterns. The sand pattern study showed a direct correlation between frequency and complexity of interference patterns. The Alfalfa seed germination and growth study showed that sound can enhance seed germination and that some waveforms at specific frequencies can have significantly different effects on plant growth. The plant literature study [3] reported showed how living organisms will either grow towards a set of vibrations and flourish, or away from vibrations and actually die. The animal literature studies [3] showed behavioral and neurological pathologies that resulted from short exposures to specific sounds that were irreversible!

One of the questions that I asked in this study was whether there was a direct link between an interference pattern and an effect on biotic matter. My results on bacteria seem to indicate this is the case because the sand interference patterns at 790 Hz and 1000 Hz were different, and, the sizes of the *E. coli* colonies were also different. The mechanism for this could be several things. It is possible that there was a stimulation of nutrient uptake by an alteration of the media itself, or by activation of enzymes responsible for growth in the bacteria. Also, changes in the bacteria genome are possible as vibrations can directly affect the expression of DNA as Drs. Bird and Schrekenberg have shown [3]. Clearly, more research is needed to understand how the colony sizes of the bacteria *E. coli* increased so much.

Because of the role of plant hormones in seed germination and growth, it is tempting to speculate that the sounds somehow affected hormone production, gibberellin and auxin. However, it is also possible that nutrient uptake from the seed, or water uptake into the seed and the root system was affected and this could alter germination and growth rates.

Conclusion

1) There is a direct correlation between increasing frequency and increasing complexity of interference patterns in sand , independent of waveform.
2) Frequencies and waveforms that produce different interference patterns in sand cause different rates of growth in *E. coli* bacteria and in Alfalfa seed germination and growth.

References

1) GraphPad software, scientific graphing, curvefitting (non-linear regression) and statistics (2001) http://www.graphpad.com/calculators/ttest1.cfm
2) http://www.aap.org/policy/01219.html
3) http://kuruvinda.com/health/music-6.html
4) Interference of sinusoidal waves http://www.journey.sunysb.edu/ProjectJava/WaveInt/home.html
5) Physics of Sound http://library.thinkquest.org/27153/mechanics/physics.html? tqskip1=1&tqtime=0301
6) Sound Research http://tuberose.com/sound%20research.pdf.

Acknowledgment

I thank my family for supporting me through this study because they had to listen to the nauseating sounds too. I also thank Dr. Girard for donating the rubber sheet, Mr. Kerfoot, University of Victoria, for loaning me the frequency generator, and Mrs. Nobel at Royal Roads University for preparing the E. coli bacteria plates.