CYMATIC REVELATIONS

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By

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ABSTRACT

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Thesis supervised by Lynn Emberg Purse, M.M.

_Cymatic Revelations_ is a multi-media composition that aims to artistically reveal the power of vibration through the synchronous use of cymatic pattern imaging, real-time video projection, and live music. When musical vibrations are channeled through a malleable medium such as a liquid, the vibrations cause the medium to arrange itself into visible geometries known as cymatic patterns. Being that these patterns are created by the sounds themselves, the projected visual elements are used to visually connect the audience to what they hear. While incorporating archetypal elements of light, reflection, and symmetry, _Cymatic Revelations_ utilizes cutting-edge music technologies to expose this common thread of vibration in the world around us. The piece combines the real-time generation of cymatic events, videos, and slideshows, with a live ensemble that features both electronic and acoustic instruments.
DEDICATION

This project is dedicated to my family. To my wife, Dina, who, while pregnant with twins, has supported my efforts, loved me, believed in me, and has tolerated my many late nights in preparing this thesis. Our daughter, Mia, who has been a continuous source of inspiration, and, with her smile and enthusiasm for life, has consistently reminded me to have fun and to find liberty in my exploration.
ACKNOWLEDGEMENT

I would like to thank Prof. Lynn Emberg Purse for introducing me to the concept of cymatics, supporting and sharing my passion, and for being an exceptional mentor in music and beyond. I would also like to thank Prof. Bill Purse for sharing his unyielding knowledge of technology in music production and performance, Dr. Judy Bowman for imparting priceless pedagogical skill sets that have helped me tremendously in structuring this thesis, and Prof. Tom Kikta for sharing his intellect and insight in helping me investigate the many potential uses of cymatics in music as well as industry. Finally, I would like to thank the ensemble members that agreed to perform the premiere of Cymatic Revelations. There is no greater honor for a composer. Thank you, all.
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Merging Sight and Sound

At the core of *Cymatic Revelations* is a desire to visually connect the audience to what they hear. The intended goal is to artistically reveal the power of vibration in the form of a multimedia composition. The piece combines live cymatic projections with videos, slideshows, and a live ensemble that features both electronic and acoustic instruments. Incorporating archetypal elements of light, water, reflection, and symmetry, *Cymatic Revelations* aims to expose the common thread of vibration in the world around us. The piece is also intended to display the capabilities of modern electronic and computer-based instruments and demonstrate how the use of these technologies in music composition can lead to unique and inspirational sonic experiences.

The visual elements of this multimedia composition spiraled outward from the production of cymatic images. Cymatics, a term coined by Dr. Hans Jenny (b.1904-d.1972), a brilliant physicist and medical doctor, is described throughout his research as a study of vibration and its effect on the organization of matter (Jenny, 2001, p. 20). Dr. Jenny's studies in the 1960’s revealed that vibrations arrange matter into highly organized and often symmetrical or repeating patterns. His experiments included, but were not limited to, channeling vibration through dry mediums ranging from sand to fine powders, as well as a wide variety of liquids, gels, and magnetized fluids.

The term cymatics has its origins in the Greek word *kymat*, meaning waveform (Jenny, 2001, p. 259). The discovery and observation of waveforms has inspired
mathematicians, astronomers, scientists, and artists for millennia. Pythagorean ratios and Fibonacci numbers have governed and dictated everything from the elements of nature to the building blocks of sacred architecture (Doczi, 1981, p. 3-4).

Coming to Know the Cymatic Phenomenon

The concept of creating cymatics was first introduced to me by Professor Lynn Emberg Purse. During a composition lesson, she presented a short educational video produced by musician and educator John Telfer in which he generated cymatic patterns in a vessel of water by placing it on a vibrating speaker (Telfer, 2010). While observing related video productions of other scientists and performers, conveniently suggested by YouTube and Vimeo, I noticed more artistic uses of cymatic patterns. The work of two artists in particular, John Nigel Stanford and Sven Meyer, became a source of great inspiration (Meyer, 2013; Stanford 2014). Meyer included more of an organic connection with the patterns and even used them to visually supplement a kind of group meditation known as a sound bath (Meyer, 2014). In observing the productions of Stanford and Meyer, along with the experiments described throughout Dr. Jenny's Cymatics, I developed a fascination with the concepts and principles at the heart of the visualizations. It was this fascination that quickly inspired the framework for a multimedia composition.

Exploring the Science of Cymatics

I felt personally compelled to use cymatics as a visual instrument, as an element that was neither static, nor simply reactive, but interactive. To accomplish this I would
have to build my own visual instrument, a device Jenny refers to in *Cymatics* as the tonoscope (Jenny, 2001, p. 63). Simply, I needed a way to create and observe these vibrational effects. In all that I had systematically observed and researched there seemed to be three basic steps to this process of manifesting cymatic patterns (Fig. 1).

1) There had to be a device or mechanism for producing the vibration itself, most often a powered speaker or vibrating plate with amplification controls.

2) Vibrations needed to be channeled through a malleable medium such as a liquid or powder. Liquid mediums, given their fluid nature, are typically contained in vessels. Each vessel has a symbiotic relationship with specific resonant frequencies that affect the organization of the patterns. Changes in the size or shape of the vessel were reflected directly in the arrangement of patterns.

3) There had to be a method of lighting and capturing the events occurring within the medium. Altering lighting techniques and intensities greatly influenced the overall visibility and appearance of the cymatic images.

I began to assemble my own tonoscope starting with an amplified speaker laying level on its back (Fig. 2). I placed a metal plate of equal diameter on the woofer cone (8") and upon it a vessel containing the liquid medium. Then using a combination of a ring light with a dimmer pack, and an HD camera I was able to evenly distribute light...
upon the meniscus of the liquid and capture the resulting images on video. I could now directly observe the reactions occurring within the vessel when sound was produced by the speaker. To efficiently project these cymatic events I decided to make use of the HD camera in my iPhone 6, which is capable of wirelessly transmitting the image via Bluetooth to my computer screen. This made it possible for the cymatic events to be projected and observed in real time. After some basic experimentation I was able to see, first hand, how the patterns were being created. Figure 3 illustrates the physics behind creating cymatic patterns.

![Figure 2 - Photograph of tonoscope hardware.](image1)

![Figure 3 - Emission and refraction: the basic physics of cymatics.](image2)

The vibrations being generated by the speaker causes waves to be emitted from the center of the vessel outward, evenly in all directions. When the waves hit the walls of the vessel the energy is refracted inward, in the opposite direction, back toward the center. This collision of directionally charged energies causes ripples and distortions in the surface of the liquid that is then revealed by the ring light and video lens.
Conducting Experiments

To compose music for an interactive cymatic experience I would have to know the answer to two questions:

1) Are the patterns consistent?

2) Can they be replicated live in a performance?

Even though I did not yet know if there were any consistencies, I was able to hypothesize that certain frequencies would be more resonant with the vessel and its contents than others. An idea emerged to create a map charting the interaction of various frequencies to display this resonance. Figure 4 displays my initial sketch of the concept. The project goal was to acquire a library of images that coincided with specific frequencies at various amplitudes within a constant medium. The hope was to uncover some pattern-generating frequencies that correlated to the piano keyboard’s equal – tempered scale and were "in tune" with other instruments. Using my established tonoscope setup, I created an audio session within ProTools software (Fig. 5) and used a sine-wave tone generator plug-in to gradually shift frequencies and amplitudes to locate pitches according to a chart that converted notes to frequency (Suits, 1998).
The results of these experiments were more than satisfactory. In the process of cataloging more than 500 images I answered the questions of consistency and replication. By keeping the volume and viscosity of the liquid as well as the dimensions of the vessel identical, I could generate predictable and consistent results in the cymatic patterns. I was able to proceed with the construction of a map that I could then visually reference and use to reliably incorporate the cymatic images into the composition process.

At this point all of the dimensions of manifesting these patterns could be controlled and or manipulated. In my observations, I concluded that the frequency generated by the speaker, when resonant with the dimensions and shape of the vessel and medium, would create visually stable patterns. The amplitude of the waveforms being created by the speaker determined the level of complexity in the patterns themselves, due to the fact that increased amplitudes result in higher levels of emission, refraction, and collision. Figure 6 illustrates these results.
Figure 6 - Excerpt from the completed cymatic tone map displaying frequencies at various amplitudes while indicating resonance.
Incorporating Cymatic Patterns Into Live Performance

In order to transfer the same research methods and techniques of creating the patterns into a live performance setting, I had to have the tones organized in a kind of matrix where they could be easily accessed. I needed a software program that could not only organize files (sounds), but also play them back at the touch of a button. In working with digital audio programs for nearly two decades, I have come to know the strengths and limitations of most mainstream audio programs. Many are built upon a common interface that allows you to record and view waveforms, make edits, as well as perform a final mix-down on a virtual console that mimics the analog predecessors. However, Ableton Live, a music performance and recording software, has a rare set of additional advantages that lend itself to a project such as this.

Ableton is arranged in two layers that can operate independently or synchronously with one another. One layer contains the standard views and functionality mentioned above (mixing controls, faders, waveforms, editing capabilities etc.) and can be used to record/playback audio and MIDI information. In addition, channels for electronic and virtual instruments, as well as microphone channels for vocals can be added to function as in a live mix situation. This functionality, which is standard in most programs, allows for pre-recorded sequences and audio to be played while simultaneously performing live instrumentation and or vocals.

The second layer is unique in that it functions as a playlist for each channel in the session. A channel’s playlist is made up of empty cells that can be filled with audio or MIDI information. So, if I have 8 channels within my Ableton session, I then have 8 individual playlists with cells that can interact with those in other channels (Fig. 7).
Cells can store anything from a sound effect or someone speaking, to a 12-bar blues pattern, or even an entire MIDI sequence. These cells can then be coded to play once through and stop, or loop at designated points. For this phase of development I needed to store and recall specific frequencies in the cells. I went back to my ProTools session and, using the sine-wave generator, I created audio files of each frequency in the first 2 octaves of the chromatic scale. These frequencies were then consecutively imported into an Ableton channel as a playlist. Once imported, a file can be moved freely from one cell to another, color coded, or renamed to suit its use in the session. Once the files were arranged in a playlist I duplicated the channel so that I could begin to experiment with intervals and observe the cymatic reactions between two pitches (Fig.7).
Another benefit to using Ableton Live as the performance platform is the integration of a control surface. Ableton can communicate easily with a variety of MIDI-based controllers, but the software functions at its fullest when used with a designated hardware controller such as the APC-40 in figure 7. The control surface is designed to allow the user to trigger the start and stop commands for each cell in a playlist while simultaneously accessing other parameters, such as effect values or volumes, through the use of knobs and faders. On a performance level I could now access any 2 pitches (within a range of 2 octaves) and manipulate the volume of each note with a fader creating aural effects that had corresponding visual changes.

**Constructing a Library of Cymatic Techniques**

A dramatic visual effect can be achieved when one wave is out of phase with, or disrupted by another. I was able to merge waveforms of different frequencies using the continuous control of the APC-40's faders. I began to catalog the interactions between multiple waveforms and note the visual representation of pulsating waves and beat frequencies. Figure 8, below, is an excerpt of the score from the opening of *Cymatic Revelations* in which a pattern-generating frequency is disrupted by higher pitches.

![Omnisphere](image)

*Figure 8* - The lower voice of this line contains the frequency primarily responsible for generating the cymatic visual while the upper notes disrupt the output creating visual disruptions as well.

Intervals, when played simultaneously, can add or take away from a pattern’s stability. In my experiments, I could generate cymatic patterns with intervals by combining two cells (one from each channel), or by playing a virtual instrument against a
cell, or singing against a cell, or any combination thereof. Intervals such as the octave and perfect fifth were consonant in that they added to the resonance of the stable pattern (Fig. 9). However, as the intervals got closer together the visualizations became less stable and, especially in the lower frequency range (25-100Hz), would either pulsate or become distorted. The resonance of intervals depreciated concordantly in succession of the overtone series developed by Pythagoras (octave, 5th, 4th, 3rd, and so on). Combining waves gives motion to the cymatic patterns and makes for exciting visual changes. Utilizing intervals, consonant and dissonant, makes the patterns come to life and take on a variety of forms as well as behaviors. It is within that motion and reflection that cymatics becomes its own instrument, emitting visible waveforms that are synchronous with the projected sound.

**Layers That Do Not Generate Cymatic Patterns**

Equally, just as it was desirable to create cymatic patterns in the liquid, it was desirable to have sonic layers that had little or no visible effect on the contents of the vessel. Consider any number of orchestral pieces of the common practice period that have multiple layers of sound occurring simultaneously. Each instrument has its place in the frequency spectrum in that some create high and mid-range pitches while others rumble away in the lower register. In the case of generating cymatic patterns within the vessel, some frequencies make patterns while others do not. In developing the cymatic
map I noticed that lower frequencies formed visible patterns at softer amplitudes than higher frequencies. Lower frequencies move larger quantities of matter than do higher ones because of the wavelength being physically larger. In short, there was a cut off point, a perceptive frequency range to the visibility of the cymatic patterns. There was a point where the tone being played was of a high enough frequency that it did not carry enough energy in its shorter wavelength to continue to generate visible disturbances in the medium.

Compositionally, this translates as the ability to play pedal tones, drones, and intervals (mostly 5ths and octaves) to sustain patterns and visual effects while higher frequencies (C6 roughly 1khz and up) and even mid range tones (C4-5 roughly 260-520hz) can occur simultaneously without altering the visualization. To only use tones that generate cymatic patterns would be sonically restrictive, much like an ensemble of tubas that are only allowed to play one or two pitches. Compositionally, it is beneficial that the cymatic elements are contained in this way because it allows for additional sound and music to occur simultaneously without affecting the patterns. The cymatic dimension can have its own soundtrack and accompanying ensemble that operate independently of the visualizations while maintaining the ability to support them.

**Revealing the Common Thread**

In observing the cymatic events I began to see other images within the patterns. Like watching clouds take on animal forms, or gazing into the shape-shifting dance of a fire, these patterns effortlessly suggested a near infinite variety of lines, curves, shapes, and images. The images I saw within the patterns ranged from flowers and lotuses, to
chapel ceilings and stained-glass rosettes (Fig. 10). I wanted to create a movie that would play as part of the larger work in order to effectively share this insight and inspire my audience to make similar connections. I began to take notes on the images I saw in my cymatic gazing and compile them into a list so that I could efficiently photograph the actual subjects that were being suggested in the patterns. My goal was to gather enough material to be able to cross-fade short videos and slides with the cymatic images that I had already catalogued.

Figure 10 - Comparison of cymatic images with those in nature and architecture.

I had set aside days for filming and photographing throughout the city of Pittsburgh. I captured roughly 50 GB of video and still images over the course of a few weeks. This process of gathering imagery that resembled cymatic patterns inspired me in ways that brought much of the composition to life. The similarities I witnessed (Fig. 10) built up a charge that left my mind dancing. Being a composer, this inspired energy naturally took on the form of music in my mind. Eventually, I found myself singing a theme that would become the backbone of the piece. Figure 11 displays the transformation from my initial sketch of that theme to its final realization.
In analyzing this theme I noticed the rise and fall of the line itself created a kind of reflection. Given the importance of reflection as a theme in this project I began to think of other ways in which I could translate the concept into music notation. There was also a strong thread of sacred inspiration that came from not only observing the patterns themselves, but in photographing the rosettes and architectural elements of churches and cathedrals. These sacred threads led me to make strong use of modes throughout the piece, in particular Dorian. Figure 12 is an excerpt from *Cymatic Revelations* that clearly demonstrates these elements coming together.

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**Figure 11** - Displaying the translation of music from the mind, to paper, and finally to print.

**Figure 12** - Dorian phrase utilizing mirror inversion.
In addition, the weaving together of all this content and material inspired me to compose lines the converged toward a focal pitch. To accomplish this effect I chose to make use of the cello due to its range and flexibility. I wanted converging lines to bend with a fluidity that reflected the malleable nature of the liquid in the cymatic vessel. The cellos in figure 13 contain a variation of the main theme previously displayed in figure 11 as well as the aforementioned convergence.

Another important concept I wanted to translate compositionally was that of emergence. In my experiments I often adjusted the volume output of the speaker in the tonoscope setup, raising and lowering amplitudes to find the points in which patterns first formed, stabilized, and inevitably distorted. The desired effect inspired the use of a synthesizer with volume pedal control to create the effect of a sound emerging from the depths of the unknown (Fig. 14). It was in finding ways to implement these kinds of effects and techniques that prescribed the specific instrumentation of the ensemble itself.

Figure 13 - Cellos reinforcing thematic material and demonstrating flexibility with converging pitch bends.

Figure 14 - A volume pedal allows for sound to smoothly emerge from silence.
Visuals That Inspire Sounds

The strongest examples of emergence and fluid-like pitch bends occur within the *Scrubbing Module* of the piece at letter E (Fig. 15). Take special notice of the following:

- There is only one measure for each instrument. That measure is separated from the rest of the score.
- The measure contains no meter of any kind, but rather a suggested length of time (5-6 seconds).
- Most of the instruments are instructed to perform a specific kind of pitch bend.
- Half of those instruments bend pitch in opposing directions reinforcing the idea of fluidity and reflection.

The most unique element is that this one measure is cued to start and stop visually.
On the projected visual I am tracing the rim of the cymatic vessel and gently touching the meniscus of the liquid causing the pattern to physically spin (Fig. 16). In observing this effect and considering what to call it, I was reminded of experiences in analog tape editing in which the reels of the tape machine would be turned by hand, or "scrubbed" to find a sufficient edit point. The action was reminiscent of how DJs spin vinyl in a similar fashion, as well as the historically popular playing of wine glasses or a glass harp. It was the look of the effect itself and the images it conjured that inspired me to create a sound effect that could be triggered in Ableton to play while I “scrubbed” the vessel. I used the sonic properties of tape, vinyl, and glass to build an aural effect that had elements of sound going backwards at high speeds, and had a bending glass-like resonance. To me it sounded like rewinding or spinning time, so I appropriately titled the cell in Ableton as "Prehistoric". The cell to be triggered is indicated in the score (Fig. 15). It was the functionality of Ableton cells and how they are triggered that sparked the idea of simultaneously triggering the live players with the “scrubbing” visualization.

Assembling the module led to the realization of a technique in which an image or pattern within the cymatic vessel can have additional layers of corresponding sounds triggered simultaneously. I considered this technique in thinking about how to begin the piece. In my experiments, I regularly had to add or take away a few drops of liquid from the contents of the vessel to attain optimal surface tension on the meniscus. I utilized an
eyedropper to facilitate this precise action. In adding single drops to the lit surface, which illuminated a simple ripple effect, the creation of the opening measures was stimulated. The idea came crashing in like the crest of an ocean wave. All at once I could imagine adding two drops with an accompanying bell sound, and on the third playing a note that would initialize the first emergence of a cymatic pattern (Fig. 17).

**Figure 17 -** Opening measures of *Cymatic Revelations* in which bells are played in sync with the addition of 2 drops. On the third drop, a low C is played generating the first pattern.

Figure 18 displays the division of patch layers used to play these opening measures without changing patches on the keyboard. The first four layers contain the sounds

**Figure 18 -** Screenshot of patch layers used in the opening Omnisphere passage.
responsible for generating the cymatic pattern that is initialized in measure 5 (Fig. 17). The fifth layer plays only in the higher register allowing me to transition between two sets of sounds seamlessly. Figure 19 captures the exact moment in which the third drop is added and the low C is played initializing the cymatic pattern. The most difficult performance element is in timing the notes with the moment each drop hits the surface of the liquid. The effect creates a unique shift in perception suggesting that the liquid itself is responsible for creating the sound and the drops within the eyedropper contain the source of the vibration. I found it to be a natural fit for the opening of the piece being that it played on the elements of reflection, both literally, in the drops creating the first reflected ripples, as well as the metaphorical reflection of those drops being the source of sound.

Figure 19 - The moment of contact: Initializing the first cymatic pattern.
Conclusion

Composing *Cymatic Revelations* called for a combination of science, patience, insight, artistry, reverence, and creativity. What began as a fascination led me to discover ways in which sight and sound could genuinely be merged. In the process, I cultivated a new appreciation for the power of sound and established an organic connection to sacred geometric principles and the many who have come before me and have demonstrated this understanding of vibration in mathematics, architecture, and music.

For me personally, cymatics has become a bonding agent capable of demonstrating the connective fiber of sight and sound in a way that organically connects the audience to the experience. This project has provided me with an evolving set of tools that will allow me to continue to develop new performance techniques and compositional methods that utilize cymatics to reveal the common thread of vibration in the world around us. In the future I can see myself using these tools to perform lectures, demonstrations, and performances that help bring an empowering and therapeutic awareness of sound to both musicians and audience members alike.
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APPENDIX

Musical Score of *Cymatic Revelations*

Composed by Thomas B. Carraher

© 2016
Bb Tpt.

Bb Cl.

Hn.

Vx Soloist

Omni

SyCh

Sy 1

Sy 2

C 1,2

C 3,4

E.B.

Perc.

2 bars - Conducted as large 4

*consider as 3, 4 pickup

*consider as 3+4+ pickup

*consider as 3, 4 pickup

Sus. Cymbal

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Spin 3x while triggering

\[ \text{w} \]

\[ \text{w} \]

\[ \text{w} \]

\[ \text{*slow pitch bends 2-3 semitones} \]

\[ \text{œ œ# œ} \]

\[ \text{œ} \]

\[ \text{Grand Piano} \]

\[ \text{pp} \]

\[ \text{*slow pitch bends} \text{ 2-3 semitones} \]

\[ \text{pp} \]

\[ \text{*partial row from F to C improvised in random order} \]

\[ \text{pace} \]

\[ \text{p} \]

\[ \text{*slow pitch bends - octave range} \]

\[ \text{Cymatic Solo & Movie} \]

\[ \text{Tacet Ensemble} \]

\[ \text{Scrubbing Module (played 3x) 5-6 seconds each} \]

\[ \text{Start cued by pattern spin} \text{  : Stop cued by finger lift} \]

\[ \text{niente} \]

\[ \text{p} \]

\[ \text{niente} \]

\[ \text{niente} \]

\[ \text{pp} \]

\[ \text{*slowly melt using a grinding bow pressure} \]

\[ \text{mf} \]

\[ \text{*slowly melt using a grinding bow pressure} \]

\[ \text{mf} \]

\[ \text{*essence of a sinking ship} \]

\[ \text{mp} \]

\[ \text{Bowed Crotales} \text{ *freely select from notes} \]

\[ \text{Perc} \]

\[ \text{cast off each} \]
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