Sound: Advanced Topics II

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Project Mapping: Dante's Inferno within Cellular Division

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About

This paper is not intended as a traditional academic analysis aimed at advancing a formal argument through critical engagement with alternative perspectives. Rather, it functions as a reflective account of the process I undertook in developing this project, tracing the conceptual, technical, and creative decisions that shaped its evolution. It outlines the questions that continue to guide my inquiry and offers insight into the directions I intend to pursue as the work progresses. That said, some calculations presented may not be entirely accurate; however, their inclusion is purposeful, serving as a provisional framework that I hope to refine through forthcoming discussions with relevant faculty. In this way, the paper acts as a sketch, mapping out potential directions rather than presenting a fixed conclusion.

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Introduction: The Journey

For my final project, I chose to develop a segment of a larger conceptual work titled *The Mitosis of Love*. My initial intention was to construct a spatial representation of Dante's *Inferno*, specifically *Canto V*, situated within a biological cell undergoing telophase. However, upon engaging with Galileo's calculations of the infernal geometry, it became evident that embedding *Canto V* within the microscopic confines of a telophase-stage cell posed significant spatial limitations. The proportions proved incompatible, not only on a physical level, but also metaphorically, as the resulting asymmetry disrupted the symbolic coherence of the broader narrative I am working to develop.

In the early stages of my research, I was deeply inspired by the field of sonocytology—the study of sound production by living cells at the nanoscale. This discipline emerged from a 2002 breakthrough by Professor James Gimzewski and Andrew Pelling at the UCLA Department of Chemistry, who discovered that yeast cells exhibit oscillatory behavior at the nanoscale. By amplifying these cellular oscillations, they were able to render sounds perceptible to the human ear. Departing from the traditional approach of scanning a surface with an AFM (Atomic Force Microscope), Gimzewski and Pelling instead held the probe stationary on the yeast cell's surface, allowing the natural vibrations of the cell wall to be recorded directly. This technique, which Gimzewski termed *sonocytology*, became a foundational inspiration for my project.

To explore the possibility of using AFM technology in my work, I reached out to Professor Philippe Chow at Columbia Engineering, who advised that access to an AFM would require funding. This led me to Professor Martin Chalfie at the Department of Biological Sciences, who directed me to Edmund B. Wilson's *The Cell in Development and Heredity*, a comprehensive study of mitosis. The principal takeaway from our conversation was the realization that mitosis can proceed asymmetrically, with the smaller daughter cell often undergoing programmed cell death, which opened up new conceptual directions on potential metaphorical visualizations regarding the separation of one lover from another.

When I shared my intention to sonically render the process of cellular division, namely the cell physically splitting, Professor Chalfie referred me to Professor Erin L. Barnhart for guidance on geometric dimensions of mitotic cells, and to Professor Ozgur Sahin for support with AFM-based creative experimentation. Both, based in the Department of Biological Sciences, have kindly agreed to further discussions in the coming week to explore the viability of this project.

This prompts discussion as to the questions I am grappling with as the project evolves. First: how can I approach the scaling of the cell to ensure maximum spatial and conceptual accuracy? Is it potentially reductive, or even myopic, to scale it at a ratio of 1 μm to 1 unit or centimeter? How might such a decision affect the mechanics and coherence of the imaginary world I am constructing? Furthermore, if different cells emit distinct sonic and structural characteristics during mitosis, should I commit to following the behavior of a single cell throughout, or selectively combine different phases from various cells to better align with my visual and sonic objectives? And if I choose the latter, does this compromise biological fidelity? Would it amount to a disservice to the underlying science, or is artistic interpretation permissible within this hybrid framework? These questions foreground a central tension in my work: determining my priorities as I balance empirical accuracy with creative freedom.

Taking all of this into account, I have outlined the following steps moving forward:

1) Acquire precise geometric data and determine placements of sounds within their space
2) Collect additional environmental soundscape samples that align with my poetic descriptions;
3) Compose a foundational structure for the piece that does not rely on the imported samples;
4) Experiment with all available materials and produce the final track *ad libitum*, embracing improvisation as an integral method of sonic exploration.

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Incompatibility: *Canto V* in Telophase

According to Galileo's interpretation, Dante's *Canto V* is located ~1,000 km beneath the Earth's surface, situated within an inverted, conical structure that is ~ 4000 km wide at its opening and gradually narrows toward the Earth's center. Each successive circle of Hell is represented as an annular frustum—a geometric form created by slicing the top off a cone (or pyramid) with a plane parallel to its base, resulting in two parallel circular (or polygonal) bases. Thus, the second circle of Hell lies along the sloped interior of this conical structure, and to determine its surface area, one must calculate the area of a conical frustum using the formula:

$$A = \pi\,(r^1 + r^2)\,\times\,l$$

Where:

- r1 is the radius of the upper base (3,500 km or 3.5×10^6 m),
- r2 is the radius of the lower base (3,200 km or 3.2×10^6 m),
- l is the slant height between r1 and r2,
- A is the lateral surface area.

Given that the vertical depth between these two radii is approximately 300 km (or 3.0×1 10^5 m), the calculated surface area of this frustum would be approximately 8.92×10^12 m^2.

The volume would be:

$$V = \frac{\pi h}{3}\,(R^2 + Rr + r^2)$$

$$V \approx 1.058\,\times\,10^{19}\,m^3$$

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If the radius of the upper base is 3500km, the speed of sound is 343 m/s, and $T = \frac{D}{v}$

then 3,500,000 m / 343 m/s would be ~ 10,204 (s) / 2.8 hours. Sound wouldn't

reach the other end for 3 hours or so.

$$V = \frac{\sqrt{K}}{P}$$

(The square root goes over both the K and P.)

Where:

- K is the Bulk Modulus (~ 1,000 pa to 10 Kpa, *So* K = 5000 pa)
- P is the density (1,050 kg/m^3)

$$V = \frac{\sqrt{5{,}000}}{1{,}050}$$

$$= \sqrt{4.76} \approx 2.18\, m/s$$

The time for sound to travel between two nuclei in telophase? = $2 - 20\mu s$

$$d \approx 20\mu m = 20 \times 10^{-6}\, m$$

$$V = 1 - 10\, m/s$$

Lower Bound Cytoplasm

$$= \frac{2 \times 10^6}{1m/s} = 20\mu s$$

Upper bound Cytoplasm

$$= \frac{2 \times 10^6}{10m/s} = 2\mu s$$

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Reoriented Vision: *Canto V* adapting to Telophase

This incompatibility prompted a re-evaluation of the project's conceptual framework. Rather than attempting to embed the entirety of *Canto V* within a cellular scale, I shifted the approach toward interpreting the *canto* through the structure and dynamics of the cell itself. The cell would thus serve as the primary architectural and symbolic space, to be sonically rendered using SPAT Revolution.

The Geometrical shape of telophase is a prolate spheroid undergoing cleavage (starting to split into two daughter cells).

$$Minor\ Axis = 30\ \mu m\ \ 2C = 15\ \mu m$$

$$Major\ Axix\ b = C = 20\ \mu m$$

$$V = \frac{4}{3}\pi a^2 C$$

Where:

- $a\ is\ 10\mu m$
- $C\ is\ 15\ \mu m$

Surface Area

$$A \approx 2\pi a^2 + \frac{2\pi a C}{e}\sin^{-1}(e)$$

Where:

- a is the semi-axis
- C is the semi-major axis
- e is eccentricity

Eccentricity measures how much an ellipse deviates from being a perfect circle. When **e = 0**, the shape is a perfect circle or sphere. As **e** approaches **1**, the shape becomes increasingly elongated, resembling a stretched oval.

For a prolate spheroid

$$e = \sqrt{1} - \frac{a^2}{c^2}$$

$$e = 0 \leq e < 1$$

Where:

- a is the semi-minor axis, where $a = 10\mu m$
- c is the semi-major axis, where $c = 15\mu m$

$$\text{so, } e \approx 0.745$$

So, if,

$$A \approx 2\pi a^2 + \frac{2\pi aC}{e} \sin^{-1}(e)$$

Then,

$$A \approx 1426\ \mu m$$

i) Interpreting the ellipsoid

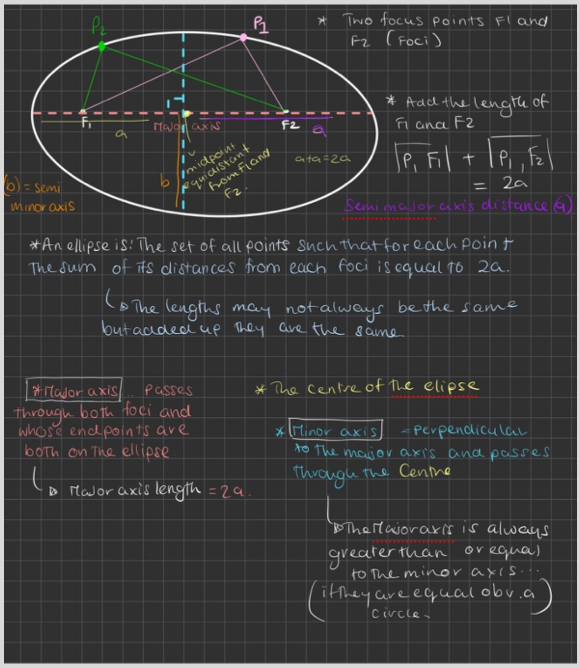

Figure 1Sketches from planning process

General equation of a 3D ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{C^2} = 1 \text{ , with } c > a$$

Prolate ellipse condition

$$a = b < C$$

Where:

a is

- Semi-axis along the x-axis
- Represents half the width of the ellipsoid (side-to-side)
- Equals b (circular symmetry in the horizontal plane)

b is

- Semi-axis along the y-axis
- half the width (front-to-back)
- Equal to a → horizontal cross-section is a circle

c is

- Semi-axis along the z-axis
- Longer than a and b
- Represents half the height of the ellipsoid (top-to-bottom)
- Determines the vertical stretch

During the project's planning phase, I made preliminary estimations of spatial dimensions using the given equation; however, I did not end up implementing them. I encountered limitations when attempting to modify the default sphere shape in SPAT to form an ellipsoid.

For a cell in telophase:

$$Minor\ Axis = 20\ \mu m$$

$$Major\ Axis = 30\ \mu m$$

2*a* = 30 units, so *a* = 15 units

2*b* = 20 units, so *b*=*c*=10 units

$$\frac{x^2}{225} + \frac{y^2}{100} + \frac{z^2}{100} = 1$$

$(\pm c, 0)$

$C^2 = a^2 - b^2$

$c^2 = \sqrt{225} - 100$

c =11.18, *(the distance between foci one and foci two)*

The distance *c* is particularly intriguing because, in a whispering chamber, when a sound wave originates at one focus point, it reflects off the elliptical dome and arrives at the other focus point. So, if Francesca and Paolo were standing 11.18 units apart within one of the nuclear membranes, the metaphorical illusion could be emphasized: the deceitful lover being heard within that exact distance. This is especially compelling to me because, at this point in the project, I am speaking about my lover being wrapped in Dante's Inferno, in the arms of another. So, if I were to visually interpret them speaking at this point, whatever they said would be heard by me, or at least echo back, reinforcing the irony of the lovers' affair being not-so-secret at 11.18 units ha-ha. What's even more fascinating is that Francesca da Rimini is not recorded in historical accounts prior to *The Divine Comedy*, which doubles the irony: the power of the woman my lover is caught up with in Dante's Inferno is not only caught in the 11.18 act, but perhaps never existed at all, only relevant at Dante's mention, and thus by citation, at mine too.

ii) May 7th Final presentation

During office hours, Professor Seth Cluett suggested a temporary workaround, placing the sounds closer to the center of the sphere to simulate the perceptual effect of an ellipsoid. He also introduced the concept of the "cone of confusion," a phenomenon in spatial localization in which sounds originating from points along a conical surface generate identical interaural time and level differences, making it challenging for listeners to discern directional changes between the right and left. Given these constraints, I focused on sound quality rather than strict spatial geometry.

I utilized processed samples from a kettle, a pond, and a ventilator to simulate the sound of wind. Specifically, I automated the volume of the boiling kettle sample in a triangular waveform at regular intervals to mimic gusts of wind.

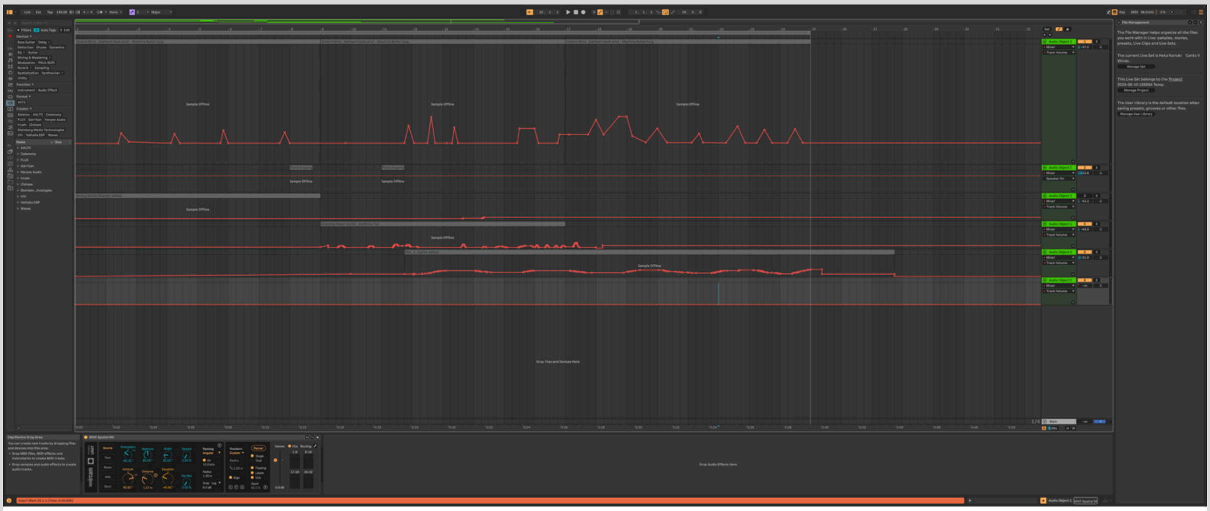

Figure 2 Triangular Volume Automation

Additionally, I modulated speaker elevation in a crisscross pattern to enhance the sensation of wind encircling the listener at the center.

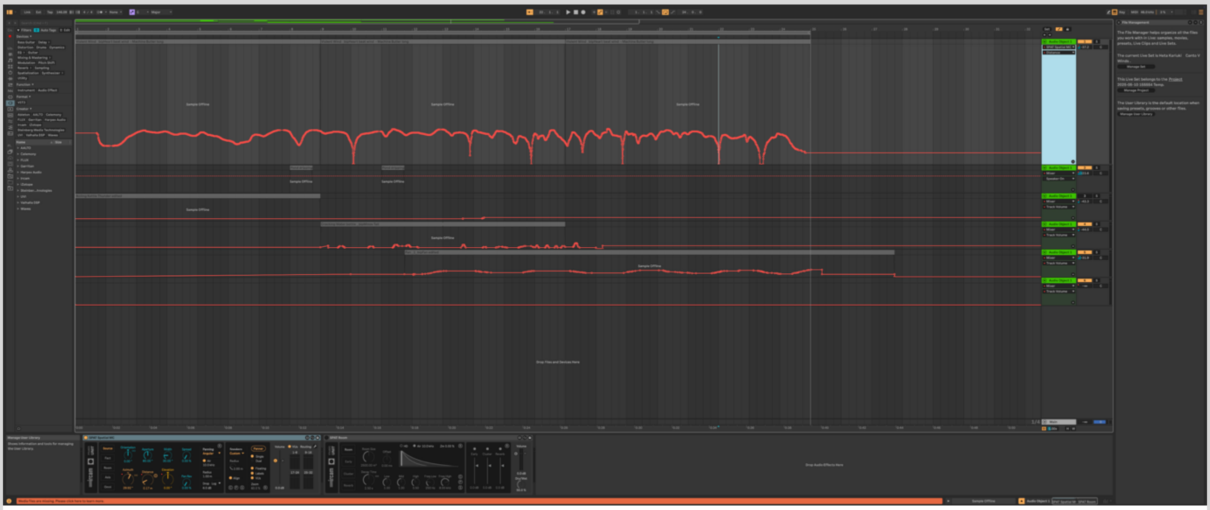

Figure 3 Spat MC Elevation

The ventilator sample formed a low-frequency base, contributing an eerie undertone reflective of the hellish atmosphere of *Canto V*. This persistent buzzing was designed to aurally evoke the sensation of traversal through the *canto's* chaotic environment.

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Conclusion

With further academic support and collaboration, I believe this project holds strong potential both as a research inquiry and an artistic exploration. I look forward to maintaining contact with the Computer Music Center (CMC) and hope to complete the project over the summer.