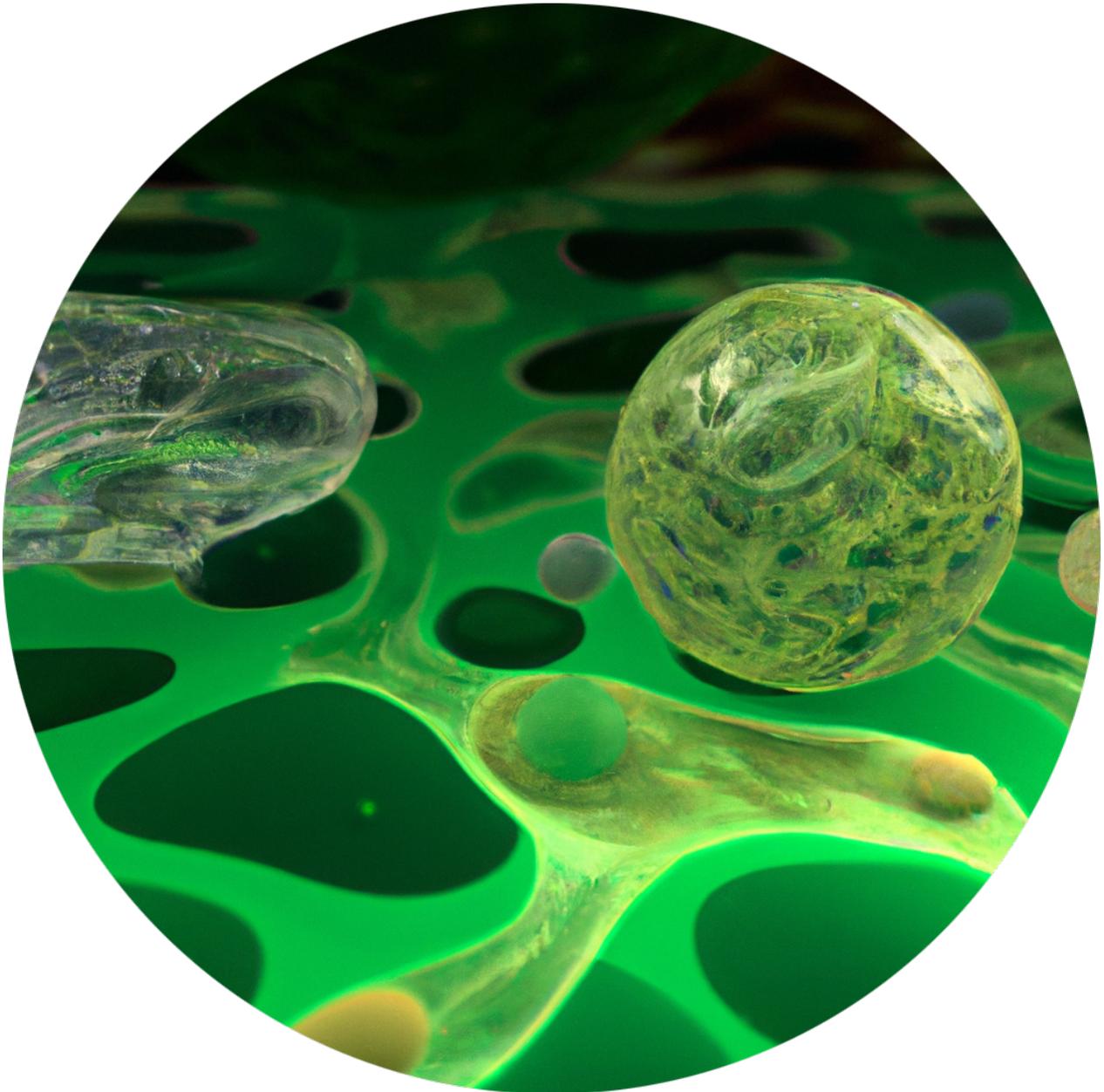


# Stochastic Genesis: Phenomenologies of complex sound in modular synth environments



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## Research Abstract

*“Solely the balance between evidence and lyricism can allow us to achieve simultaneous emotion and lucidity”*

*Albert Camus (1942)*

As sound synthesis technology advances and proliferates, the tools we use to create music hold increasing immaterial influence over our creative capacities and understanding. This research investigates the degree to which human interfacing with sound synthesis technology for sound creation affects us on core sensory and psychological levels, and how technology manifests as a mode of comprehension. Electronic music literature increasingly intersects with other fields, so this research embraces an interdisciplinary approach.

*Stochastic Genesis* adopts a practice-based research approach, where studio experimentation and analysis formulate enquiry, and the application of technology for creative purposes acts as means of revealing. The research draws from sound and synthesis theory, philosophy, complex systems theory, and contextualises the studio practice in a narrative based on the natural sciences, particularly fundamental physics, biochemistry and theories surrounding the emergence of life on earth.

The project’s validity was inspired by increasing democratisation around electronic music technology, (most people have access to a computer which can run music production software, some of which is available for free) and growing emphasis around sonic art and sound design in academia, evident in our own institution (with expanding courses, electives and research surrounding sound theory, sonic art, digital/electronic music and ambisonics).

The project embraces principles of meta-narrative: certain themes interlink the various relevant contexts, studio methodologies and academic fields, namely, emergence, embodiment, interconnectivity, generativity, stochasticity, wonderment and transformation.

The project is parsed into two volumes. *Volume I: Thesis* describes applied philosophies, sound and synthesis theory, methodological approaches for the applied studio practice (in moderate detail), and explores the insights and findings from the synthesis of theory and the studio practice outcomes. *Volume II: Portfolio* articulates the methodological approaches and studio practices in detail and includes the forty-two sonic artefacts and eight composite soundworks created for the research project, examining their design, motivations, and findings in finer detail.

## Acknowledgements

I would firstly like to thank Lynn-Sayers McHattie, Marianne McAra and Michael Williams, for providing such an exciting, welcoming, and inspiring entry into the world of research at GSA. Their advice, patience, active encouragement and steering were invaluable to these outcomes and have shaped my trajectory beyond measure.

Secondly, my supervisors, Jessica Argo, Michael Pierre-Johnson & Paul Chapman, whose expertise across their fields informed every facet of the project, and whose consistent guidance helped me realise my ambitions and future aspirations as a writer, artist, researcher and teacher. Their encyclopaedic knowledge, disciplinary passion and approach to pedagogy continue to inspire me.

Thirdly, Linda Vickers & Marjory Bond, for their enduring kindness, understanding and consideration, and for always keeping me right with Ivor.

I'd particularly like to thank all of those above for providing unwavering warmth and support across what has undoubtedly been the most personally challenging period of my life. The support from all of those at GSA extends beyond my academic activities and has brought me endless purpose, comfort and joy.

For; Alex, for being a nerd with me forever, Francesco, for modulating with me from the beginning, and Toby, for giving me the confidence to learn and to write, and for my whole family and for Mum, for giving me music and everything else.

## Note to the Examiner

The intent of this research is to provide a detailed breakdown of creative methods developed and explored and express their findings. *Volume I: Thesis* (comprising of the 10,000-word thesis portion of the submission) is subject to marking independently of *Volume II: Portfolio*, which functions as a more expansive studio journal along with the sonic outputs. It is assumed that anyone reading Volume II is using it as companion to the thesis or has read the thesis in full. Reading alongside a library of the audio files is recommended, alternatively referring to them online (links provided in Secs 5.1 & 8.1). Examiners are not expected to read/listen to the portfolio in full, instead, Volume II serves as evidence for the scope of the overall practice-based research undertaking, and it is the hope of the author that examiners peruse Volume II at their leisure, sampling some of the creative processes, generated sound artefacts and completed compositions to build a more robust understanding of the studio process. Many of the processes described in the thesis are expanded on in the portfolio. A glossary of general terms is included in the appendices.

## Declaration

I, Ruari (Rory) Green, declare that the work across this thesis and portfolio is wholly my own, and that it meets the regulations for submission set out in the course handbook.

This work has not been submitted for any other academic award.

Ruari Green

Glasgow School of Art, December 2024

# Table of Contents

## Volume I: Thesis

<b>1</b>	<b><i>Introduction</i></b> .....	<b>2</b>
1.1	Structure Overview .....	2
1.2	Aims/Objectives .....	3
1.3	Research Questions .....	6
1.4	Scope Overview.....	7
<b>2</b>	<b><i>Literature Review Part 1: Phenomenology, Neural Synthesis &amp; Sensory Data</i></b> .....	<b>8</b>
2.1	Technology and Perception .....	8
2.2	Aural Phenomenology: Sound, Music & Momentary Perception.....	13
2.3	Harmony in Complexity: Exploring the Dynamics of Complex Systems .....	15
2.4	Wonderment as Phenomenological Utility .....	17
<b>3</b>	<b><i>Literature Review Part 2: Stochasticity and Sound Synthesis Systems</i></b> .....	<b>20</b>
3.1	Geneses of Generative Practice .....	20
3.2	Modular Synthesizers: Modularity as Method.....	22
3.3	Microsound & Granular Synthesis: Morphologies.....	25
3.4	Hyperrealities: Musical, Spatial & Temporal .....	29
<b>4</b>	<b><i>Methodology Part 1: Foundations of Emergent Practice</i></b> .....	<b>31</b>
4.1	Practice Based Research .....	31
4.2	Metanarratives.....	33
4.3	Data Sonification: Analogic vs. Symbolic Depictions.....	34
4.4	Philosophical Foundations .....	35
<b>5</b>	<b><i>Methodology Part 2: Studio Practice</i></b> .....	<b>36</b>
5.1	Narrative Outline & Composition.....	36
5.2	Embodied Systems .....	37
5.3	Synth Formats, Artefacts & Meta-modules .....	38
5.4	Composition: Beyond Modularity .....	40
5.5	System Design, Implementation and Composition.....	42
5.6	Meta-modules: Applied Examples .....	42

5.7	Patch Instability .....	50
5.8	Complex Irreducibility .....	50
5.9	Synesthetic Paradigms .....	52
5.10	Non-linearity & Cellular Automata .....	54
5.11	Mesostructural Fluctuations & Disintegration .....	55
5.12	Further Process Paradigms: Space Colonisation, Fractals.....	55
<b>6</b>	<b><i>Discussion</i></b> .....	<b>56</b>
6.1	Emergent Patterns & Creative Methods .....	56
6.2	Synesthetics: Phenomenologies of Auditory Spatial and Textural Phenomena	57
6.3	Generative Components: Applied Stochasticity .....	59
6.4	Modularity Anywhere: MaxMSP vs. Modular Synths .....	59
<b>7</b>	<b><i>Evaluation &amp; Reflection</i></b> .....	<b>62</b>
7.1	Phenomenological Analysis .....	62
7.2	Ecological Implications: Instability and Collapse .....	63
7.3	Research Questions: Conclusion .....	64
7.4	Scope & Methodological Critique .....	65
7.5	Future Applications .....	65
7.6	Closing Statement .....	67

## Volume II: Portfolio

<b>8</b>	<b><i>Portfolio Introduction</i></b> .....	<b>70</b>
8.1	How to Read the Portfolio.....	70
<b>9</b>	<b><i>Scientific Overview</i></b> .....	<b>71</b>
9.1	Positioning the Author .....	71
9.2	Depth of Scope .....	71
<b>10</b>	<b><i>Studio practice: Beyond modularity</i></b> .....	<b>73</b>
10.1	Introducing Workflow & Balancing Modularity .....	73
10.2	DAW Implementation .....	74
10.3	Compositional toolkit/skills.....	75
10.3.1	Modular System .....	76
10.3.2	Other Synthesis Hardware Used .....	78
10.3.3	Software Instruments .....	79
<b>11</b>	<b><i>Soundwork Overview</i></b> .....	<b>80</b>

<b>11.1</b>	<b>Origin State .....</b>	<b>80</b>
11.1.1	Composition_01: Origin State.....	80
11.1.2	Artefact_01 Ionise.....	82
11.1.3	Artefact_02_Shimmer Compounds .....	83
11.1.4	Artefact_03: Settle/Flow.....	86
11.1.5	Artefact_04: Aeriform .....	89
11.1.6	Artefact_05: Polymerize.....	93
11.1.7	Artefact_06: Cryogenian .....	94
<b>11.2</b>	<b>Origin State: Summary.....</b>	<b>96</b>
<b>11.3</b>	<b>Reactor .....</b>	<b>98</b>
11.3.1	Composition 02: Reactor.....	98
11.3.2	Artefact_07: Fundamental Mechanism .....	99
11.3.3	Artefact_08: KREEP .....	100
11.3.4	Artefact_09: Amino .....	101
11.3.5	Artefact_10: Periodic Network .....	102
<b>11.4</b>	<b>Reactor Summary.....</b>	<b>102</b>
<b>11.5</b>	<b>Abiotic Forms .....</b>	<b>103</b>
11.5.1	Composition_03: Abiotic Forms .....	103
11.5.2	Artefact_11: Aleatoric Interplay.....	104
11.5.3	Artefact_12: Broken Lines .....	105
11.5.4	Artefact_13: Ghost Mechanism .....	106
11.5.5	Artefact_14: LUCA Forms.....	109
11.5.6	Abiotic Forms: Summary .....	111
<b>11.6</b>	<b>Replicator .....</b>	<b>112</b>
11.6.1	Composition_04: Replicator .....	112
11.6.2	Artefact_15: Metal Spaces .....	113
11.6.3	Artefact_16: Tactile Surface .....	113
<b>11.7</b>	<b>Momentary Split .....</b>	<b>114</b>
11.7.1	Composition_05: Momentary Split.....	114
11.7.2	Artefact_17: Cellular Smatter.....	115
11.7.3	Artefact 18: Chemodynamism.....	115
11.7.4	Artefact_19: Modulated Systems.....	116
<b>11.8</b>	<b>Mitochondria/Photosynthesis.....</b>	<b>117</b>
11.8.1	Composition_06: Mitochondria/Photosynthesis.....	117
11.8.2	Artefact_20: Gene Sequence Data .....	117
11.8.3	Artefact_21: Germination, Bifurcation.....	118
11.8.4	Artefact 22: Photons .....	118
11.8.5	Artefact 23: Mesosstructural Forms.....	119
<b>11.9</b>	<b>Radiolaria .....</b>	<b>120</b>
11.9.1	Composition_07 Radiolaria.....	120
11.9.2	Artefact_24: Axopoda.....	121
11.9.3	Artefact_25: Amorphous Zone .....	121
11.9.4	Artefact_26: Fractal Emergence.....	121
11.9.5	Artefact_27 Particle Physics .....	122
<b>11.10</b>	<b>Instability/Collapse .....</b>	<b>123</b>
11.10.1	Composition_08: Instability/Collapse .....	123

11.10.2	Artefact_28: Sunken Monolith.....	124
11.10.3	Artefact_29: Instability.....	124
11.10.4	Artefact_30: Disquieting.....	125
11.11	Unknown Artefacts.....	125
12	<i>Closing Remarks</i> .....	<b>131</b>
13	<i>AI Image Gallery</i> .....	<b>133</b>
14	<i>Appendices</i> .....	<b>147</b>
14.1	Glossary.....	147
14.2	User Survey.....	151
14.3	User Survey Questions.....	152
14.4	Patch Diagrams.....	157
15	<i>References</i> .....	<b>166</b>

# Table of Figures

<u>Figure 1.1 Scope Overview (Author's own) .....</u>	<u>7</u>
<u>Figure 3.1 Wendy Carlos at the Moog modular synthesizer, photograph, ca 1967 (Linda Hall Library, 2024) .....</u>	<u>22</u>
<u>Figure 3.2 Modular Synthesiser Creative Processes (Author's own).....</u>	<u>24</u>
<u>Figure 4.1 Overview of the generative process (McCormack et al, 2009).....</u>	<u>33</u>
<u>Figure 5.1 Modular System used for Stochastic Genesis (Author's own).....</u>	<u>38</u>
<u>Figure 5.2 Meta-module: Water (Author's own) .....</u>	<u>39</u>
<u>Figure 5.3 Patch Symbol Clusters: Function Examples (Author's own).....</u>	<u>40</u>
<u>Figure 5.4 Patch Symbol Clusters: Module Examples (Author's own) .....</u>	<u>40</u>
<u>Figure 5.5 Workflow Methodology Diagram (Author's own).....</u>	<u>41</u>
<u>Figure 5.6 Meta-module: Prerequisite (1) (Author's own).....</u>	<u>44</u>
<u>Figure 5.7 Meta-module: Prerequisite (2) (Author's own).....</u>	<u>45</u>
<u>Figure 5.8 Meta-module: Water (Author's own) .....</u>	<u>46</u>
<u>Figure 5.9 Meta-module: Cyclical Function Generator (Author's own) .....</u>	<u>47</u>
<u>Figure 5.10 Meta-module: Evaporation/Melting (Author's own).....</u>	<u>48</u>
<u>Figure 5.11 Meta-module: Water Cycles (Author's own).....</u>	<u>49</u>
<u>Figure 5.12 Modular Patch: DNA Formation (Author's own).....</u>	<u>52</u>
<u>Figure 5.13 Selected Dall-E Outputs (Author's own).....</u>	<u>53</u>
<u>Figure 10.1 Workflow Methodology Diagram (Author's own).....</u>	<u>74</u>
<u>Figure 10.2 Modular System used for Stochastic Genesis (Author's own).....</u>	<u>76</u>
<u>Figure 10.3 Make Noise 0-Coast, Semi-modular Synthesiser (Make Noise, 2017)...</u>	<u>77</u>
<u>Figure 10.4 Mutable Instruments Plaits, Eurorack Module (Music Store, n.d.).....</u>	<u>78</u>
<u>Figure 11.1 Periodic Table of Elements (ReAgent, 2023).....</u>	<u>81</u>
<u>Figure 11.2 Meta-module: Prerequisite (1) (Author's own).....</u>	<u>83</u>
<u>Figure 11.3 What is Granite and How is it Formed?: Granite minerals composition (GeologyIn, n.d.) .....</u>	<u>85</u>
<u>Figure 11.4 Meta-module: Prerequisite (2) (Author's own).....</u>	<u>86</u>
<u>Figure 11.5 Habitable Trinity Model (Dohm &amp; Muruyama, 2015).....</u>	<u>87</u>
<u>Figure 11.6 Meta-module: Cyclical Function Generator (Author's own) .....</u>	<u>88</u>
<u>Figure 11.7 Meta-module: Water (Author's own) .....</u>	<u>89</u>
<u>Figure 11.8 Meta-module: Evaporation/Melting (Author's own).....</u>	<u>90</u>
<u>Figure 11.9 Modular Patch: Aeriform (Author's own) .....</u>	<u>91</u>
<u>Figure 11.10 Modular Patch: Prerequisite (4) (Author's own) .....</u>	<u>92</u>
<u>Figure 11.11 Modular Patch: Prerequisite (5) (Author's own) .....</u>	<u>94</u>
<u>Figure 11.12 Modular Patch: Prerequisite (7) (Author's own) .....</u>	<u>95</u>
<u>Figure 11.13 Nuclear Geyser Model, taken from the film "The Whole History of the Earth and Life" produced by the Hadean Bioscience Project (Muruyama et al, 2019) .....</u>	<u>98</u>

<u>Figure 11.14 Patch for Creating Artefact 07: Fundamental Mechanism (Author's own) .....</u>	<u>100</u>
<u>Figure 11.15 Abiotic Forms, Timeline Overview (Author's own) .....</u>	<u>105</u>
<u>Figure 11.16 DNA Helixes (Dickerson, 1983) .....</u>	<u>107</u>
<u>Figure 11.17 Meta-module: Helix Function Generator (Author's own).....</u>	<u>108</u>
<u>Figure 11.18 Modular Patch: DNA Gene Sequencer (Author's own) .....</u>	<u>109</u>
<u>Figure 11.19 LUCA Evolution, (Weiss et al, 2016) .....</u>	<u>110</u>
<u>Figure 11.20 1: Radiolarian Shell (Bhate et al, 2019) 2: Hexancistra quadricus (Göransson, 2021).....</u>	<u>120</u>
<u>Figure 11.21 OP-1 Tombola, particle sequencer (Teenage Engineering, n.d.).....</u>	<u>122</u>

Volume I: Thesis

# 1 Introduction

*Stochastic Genesis* inhabits an intersection between abstract music, sonic art and complex systems theory, employing generative electronic methods to emulate processes of abiogenesis – the primordial emergence of life from non-living matter. The portfolio embraces principles of emergent complexity, where chaotic, aleatoric sound processes evolve into unified musical compositions.

Informed by Barret and Bolt's (2007) performative research paradigms, the portfolio involved the creation of forty-two sonic artefacts which were used to compose eight composite soundworks that move through the narrative of abiogenesis. Employing modular synthesis workflows, digital soundscape environments and musical improvisation, the research adopts Heideggerian phenomenology in its analysis of temporality, technology and synesthetic sound relationships.

The compositional methodology is iterative, intertwined with research, blending improvisation and programming with generative principles, demonstrating the coexistence of theoretical and practical experimentation in both electronic sound and music composition. The resulting research resonates both with generated sound, and the scientific and philosophical principles that underpin and inspire sound creation.

## 1.1 Structure Overview

The literature review sets out philosophical foundations before going on to discuss relevant sound theory, and linking with complex systems theory. The methodology sections initially set out practice-based research philosophies before moving on to list process examples from the studio practice. The discussion and evaluation

sections describe how the applied practices provide insights surrounding creative sound design practices, with modularity at their core, and further scientific, societal and ecological implications, as well as relaying the degree to which the research questions (Sec 1.3) were answered.

## 1.2 Aims/Objectives

The primary aim of this research project is to explore, demonstrate, develop and articulate the importance of modularity (Hetrick, 2017) in sound synthesis - which refers to sound synthesis methods that encompass systems of interacting modular components. The project situates techniques in a narrative framework (scientific theory surrounding emergent life) creating an auditory experience that reflects on organic processes, drawing parallels between organic natural systems and modular processes, and applies philosophy as analytical framework. The research posits new directions stemming from existent practical techniques by integrating phenomenology into the design and conceptualization of sound and music.

The research is motivated in part by the authors own interest in system design and modularity in sound synthesis. Modular synthesis methodologies embrace a plethora of exploratory, experimental compositional modes (outlined further in Sec 3.2) with near-infinite patch/parameter possibilities per given modular system. This is inherently inspiring to synthesists and can often lead practitioners down previously unintended/unexplored creative pathways. This led to assumptions surrounding the validity of using modularity in sound synthesis for modelling emergent scientific phenomena to create emergent music or art reflecting on said phenomena. Various eurorack module designs draw from scientific models (cartesian sequencers, co-ordinate grids etc.) or models for biological phenomena, (fractals, cellular automata, space colonisation etc.), so a gap in the literature was

identified surrounding the creative application of these modules for practitioners, along with the use of scientific models themselves as experimental musical score sources. Furthermore, ecological motivations behind the creation of art and music are omnipresent in the current stage of the climate crisis. It is the belief of the author that in the coming years, the climate crisis will worsen exponentially, calling for fundamental societal restructuring. This may in turn require complete reimagining of modernity: a new ecological enlightenment of sorts. Just as during the historic Enlightenment, art occupies a vital role. The relationship between humans, technology, and climate breakdown is obvious, and this project aims to articulate forms of symbiosis between nature and technology, alluding to new modes of ecological thought.

A common phrasing of music and sound entails sensory perceptions; with descriptions such as “warm,” or “tinny”. While these make informal sense in common parlance, formally defining such terms is meaningless without a framework with which to study the sensory interpretation of sound. What does it mean for music to *sound* “warm”? Evidently, it arises from the blending of cross-modal sensory perception and mental interpretation to relate, at a core psychological level, certain experiences to others. This is driven by the interrelation between the sensory experience (as an *external* presence) and psychological *qualia* experience (as an *internal* presence). This is precisely the study of phenomenology.

Both sound creation and intended reception of said sounds are entwined with principles of phenomenology. Whilst a layman may understand something to sound “warm,” specialists understand such descriptors are based in emphasised elements in the lower-midrange frequency spectrum. This understanding, however, isn’t based on pure mathematical or frequential abstraction or optimisation: it is governed by some kind of sensory universality. Whilst this is far from rigid, i.e. some

listeners may have subjective feelings about sounds or experience sounds differently, there is sufficient commonality for us to describe such sounds as “warm”. Spectral properties and frequency domain characteristics are meaningless without the lived experience of the listener. The science *stands for* the phenomenological universality.

The project’s objectives are multifaceted; the portfolio exhibits experimentation with modularity within sound synthesis that *embody* certain aspects of emergent abiotic processes, particularly the emergence of what we can tangibly call “life”. It also employs stochastic compositional techniques to create dynamic sound matter for use in broader compositions, exploiting randomness and generative principles and investigating the degree to which such principles can coalesce into compositionally viable sound materials. A further objective is to observe how synesthetic/cross-modal sensory relationships can link visual, tactile and auditory textures for exploration of narrative in sound, and how ingesting said relationships into narratives can yield meaningful results.

### 1.3 Research Questions

1. How useful are modularity and modular synth interfaces in sonic exploration & depiction of natural/scientific phenomena?
2. How useful is phenomenology as a tool for informing *and* analysing sonic outputs and their derived psychoacoustic qualia?

The projects' practical objectives are as follows;

1. Design and implement practices using modularity in sound synthesis for exploring complex phenomena
2. Demonstrate overarching philosophies of embodying subject matter in system/instrument design, expressing the validity of such practices
3. Emphasize modularity as a crucial concept in sound synthesis – why should a practitioner learn modular?

## 1.4 Scope Overview

The following schematic breaks down the overall undertaking of the project:



*Figure 1.1 Scope Overview (Author's own)*

## 2 Literature Review Part 1: Phenomenology, Neural Synthesis & Sensory Data

*“Phenomenology is the universal doctrine of the essences, in which the essence of the science of knowledge finds its place. It describes a science, a link between different scientific disciplines, but at the same time it refers to a method and an intellectual attitude.”*

*Edmund Husserl (1913)*

Literature Review Part 1 describes the phenomenological principles applied in the creation of the studio practice, which are also used as analytical framework for assessing their validity in Secs 6 & 7. It links phenomenology with complex systems theory and axioms surrounding wonderment in science/art, which define the practice-based research methodology.

### 2.1 Technology and Perception

The practice-based research methodologies across *Stochastic Genesis* require an epistemological, auto-ethnographic approach that balances perceptual and material, abstract and tangible, and subjective and systemic modes of knowledge. Phenomenology emphasises intentionality, lived experience, and common structures of perception, (with particular reference to sensory perceptions), providing a compelling framework to explore the aforementioned epistemological intersections in the context of consciousness, technology, art and sound.

Furthermore, foundational texts regarding technological interfacing are applicable to the technologies used across the project, and phenomenological fundamentals allow for critical examination of engagement with scientific phenomena *and* artistic

process. *Stochastic Genesis* concerns experiential and emergent realities *beyond* the objective study of musical systems. Application of the phenomenological paradigm allows for exploration of the effects of complex generative processes on human consciousness, the influence of technology on artistic process, and the search for meaning in dynamic, non-deterministic sonic realities.

Phenomenological enquiry studies structures and commonalities of conscious experience with reference to the situatedness of a human subject within given perceptual frameworks, (historical, societal, situational or physical) (Armstrong, 2005 pp.562; Husserl, 1913). It implicates a subjective nature of perception, a "*consciousness-of-consciousness*" (Sartre, 1956, pp.121) that hypostasizes the function of one's experience through different forms of perception (Merleau-Ponty, 1945), making it ideal bedrock upon which to explore links between external artistic sensory stimuli and internal discernment of meaning in sound, art, music and technology. Here we acknowledge that this research subscribes to the phenomenological doctrine of being, (existence preceding essence), and intends to exploit it in forming artistic methodologies and practicing creative exploration.

Heidegger was chosen as a foundational scholar for *Stochastic Genesis*, where his notions surrounding technology formulate bases for contextualising the project primarily due to their being technological in nature - relevant to the creative tools employed across the project and how the existential implications surrounding non-deterministic artistic processes prompt reflection on how technology mediates creativity and creative agency in general. Furthermore, Heidegger was selected to further the ecological implications introduced in Sec 1.2 (see table 1). Whilst Heidegger's texts provide fundamental ontological perspectives for the purposes of *Stochastic Genesis* as a thesis, it is worth noting alternative, more contemporary insights, such as Ihde's *Postphenomenology* (1995) with reference to his emphasis

on *embodiment relations* (referring to tools becoming extensions of the phenomenological self) which align closely with the performative and improvisational aspects of the *Stochastic Genesis* portfolio. Also, Merleau-Ponty's positions surrounding embodied perception constitute understanding of the act of listening itself (Zelenka, 2021), and how listening constitutes a form of knowing. Heidegger's fundamentals make up the cornerstone for these perspectives, but only as part of a broader interpretive tradition.

Following in the footsteps of phenomenology's constitutional scholar (Husserl), Heidegger develops Husserl's fundamental ontological principles of "eidetic analysis", namely, acute investigations into the nature of "objects" and their essential properties independent of empirical observations (Crowell, 2001, pp.323), and how subjective experience is built through this system of intentionality (Husserl, 1964). Heidegger (1977) posited that technology imposes a technological mode of thinking resulting in a potentially subconscious reframing of our essence of being. His central claims can be broken down threefold;

Table 1: Heideggerian Claims on Technology

---

1. Technology is more than a mere instrument/tool, and ultimately materialises as a means of comprehension.

---

2. This is not necessarily a conscious human activity; technology has empirical effects *beyond* our comprehension.

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3. Technology poses an existential degree of threat to humanity, and our collective consciousness must build adequate metaphysical comprehension of it, or we risk viewing existence through a purely technological lens leading to dire - potentially apocalyptic - emanations.

---

Whilst awareness of technological threat is crucial, it's worth stating explicitly that both his position and this research aspire to an exploration in conscientious synergy with technology for creative, ontological and epistemological purposes. Heidegger posits that technology's metaphysical essence can manifest as means of revealing; it is "*the realm of truth*" (1977), a position that *Stochastic Genesis* wholly embraces. This metaphysical essence does not contradict the intended utility, the essence is separate from the intended use but in no way contradictory.

Heidegger's (1962) concepts of *vorhandenheit* and *zuhandenheit* are central to the creative capacities of *Stochastic Genesis*. It's a truth self-evident amongst musicians that throughout the performative capacity of composing or playing music the instrument (technology) seems to disappear, as Heidegger would claim - becomes a subconscious extension of the musician's body. For Heidegger, tools and objects are not only encountered as detached things (*vorhanden*), instead, we perceive them as having integral integration into networks of meaning or purpose – defined as *a totality of equipment* (1962). Once absorbed in practical or creative activity, such as making programmed music or system patching, the tools themselves become almost invisible to us, functioning instead as extensions of the user's body and phenomenological self. This second mode of engagement, ready-at-hand, is

labelled *zuhandenheit*, where the object is phenomenologically inhabited through use, rather than merely observed by the beholder.

This embodiment of a given object or tool is disrupted when the tool no longer functions as expected – through a fault (i.e. a circuit being patched incorrectly and causing feedback/glitching, or code not working as intended), or when a generative sound algorithm provides unexpected sonic results – at which point the object or tool becomes present-at-hand, or *vorhandenheit*: the object or tool is thrust back into the user’s thematic awareness. The user no longer “inhabits” the tool as a mode of expression and is pulled out of the flow of practical activity, the equipment becoming external to their phenomenological experience, to be amended, mended or analysed. In electronic creative practice, this binary between presence and readiness is complicated. System design as creative flow-state involves a deliberate oscillation – or even a kind of phenomenological superposition – between these two modes, whereby *zuhandenheit* subsumes *vorhandenheit*, and the user becomes simultaneously aware of the system as equipmental (ready-to-hand) and as objectal (present-at-hand) attending to its properties of internal logic, computational limitations and generative potential.

In this sense, programmed (or more specifically to *Stochastic Genesis*, patched) music creation can be seen to induce continual tension between embodied immersion and analytical detachment. Csikszentmihalyi’s (1990) premises surrounding flow states resonate with *zuhandenheit*, whereby creative action unfolds from the user through the given tool or interface *without* conscious deliberation. Computational (in this case modular synthesis) environments however, demand periodic returning to *vorhandenheit*, particularly across generative systems, where specific sonic intent is ignored in favour of experimental and exploratory sound design approaches. *Stochastic Genesis* embraces awareness of this dynamic

movement between the two modes and assumes the dynamism *itself* offers fertile ground for creative insight and exploratory implementation of generative sound creation, mirroring Heidegger's claim that truth, (*aletheia*) emerges through processes of "unconcealment". Instead of resisting interruptions and emergent anomalies, *Stochastic Genesis* revels in the unforeseen disruptions and fluctuations of generative systems, employing deliberate complexity so that perturbations are not only likely, but inevitable. These moments in time exploit technology's place within user comprehension, making its essence differently available for creative exploits.

The overlap between some of Csikszentmihalyi's (1990) nine dimensions of mental flow and Heidegger's premise of *zuhandenheit* are intentionally present in and exploited by the practical approaches across the portfolio, namely; the merging of action and awareness, the loss of self-consciousness, deep concentration on the task, intrinsic enjoyment in the task (rather than just the outcome), immediate and unambiguous feedback, and the seeming transformation of time. The other dimensions, namely; challenge-skill balance and clear goals, are present but less directly relevant to the project's Heideggerian methodological principles.

## 2.2 Aural Phenomenology: Sound, Music & Momentary Perception

In *Being and Time* (1962) Heidegger describes "temporal ecstasy," a state of momentary being mentally synthesised by the manifestation of awareness of both past and future, and crucially the internal actualisation of these two temporal realities that constitute our perception of the present. Applying this to experiencing sonic art and music emphasizes the act of listening not as a passive act of hearing, but rather an engagement with the shifting and evolving of musical and textural

components. "Shifting" and "evolving" specifically are *temporal* terms. Thus the "music" materialises in waves of momentary perceptual fluctuations that are defined by what we have just heard, and what we expect to hear, which is further defined by our past experiences of art or music and our presupposed notions of the future. An individual's uniquely informed perspectives and interpretations affect how they engage with a musical work's meaning and significance.

Therefore, music unfolds in time. Dissimilar to for example, a painting, which presents its wholeness at once, music exists as durational experience perceived by the listener. Each note, melody, chord, rhythm, or sonic object/event exists in relation to its surrounding sound phenomena: what comes before or next, and therefore exists within a constantly unfolding artistic sonic context. Temporal unfolding such as this is paramount to how we as listeners or practitioners construct musical meaning, intuit our own expectations (to be resolved or challenged), recognise deviation, and identify patterns, tension and resolution. Within this listening temporality, phenomenology becomes useful, and why approaches such as Celibidache's hold relevance even in the world of abstract electronica. His emphasis on lived, moment-to-moment perception colour the ontology of musical experience.

Celibidache's phenomenology of music serves as a basis for understanding music as perceived phenomena and helps link phenomenological enquiry around temporality, complex systems and technology to music. Building on the teachings of both Husserl and Eastern philosophy, Celibidache believed there were two components in understanding music using phenomenology: *"the study of sound as part of a musical piece, and the relationship between a sound and human listener"* (Marín, 2015, pp.12).

Celibidache posits that music has no definition per se (Celibidache, 1993; Marín, 2015) meaning the phenomena of music emerges from sound components within the beholder's perception: music emerges from a phenomenological point of view. Aligning with aspects of complexity theory that *Stochastic Genesis* incorporates, essentialising multiplicities of sound phenomena is key: unifying the given cacophony into a transcendent comprehension, from which we draw meaning. The meaning here attributed is dependent on the perceiver of the phenomena, be it conscious or unconscious. This can stem from anything; beauty, wonderment, consciously prescribed attainment of knowledge, new perspectives, etc.

### 2.3 Harmony in Complexity: Exploring the Dynamics of Complex Systems

Complex systems theory presents a lens through which we can perceive and explore the fundamental nature of dynamical natural (and artificial) systems. The theory's constitutional claim is that systems comprised of entangled and interacting sub-elements produce emergent patterns, i.e. behaviours and emergent phenomena that the systems' underlying parts could not produce independently: the sum of their interactions is irreducible to their parts (Gleick, 1987). Examples of complex systems include "*ecosystems, societies... opinion formation, epidemic spreading, or the internet and social media*" (Turner et. al, 2018), significant properties therein including "*efficiency, robustness, resilience, and proneness to collapse.*" The theory examines the given systems' outputs, and the nonlinearity, interconnectedness, and fluctuations that created them.

Post-Enlightenment approaches in natural science have been thoroughly reductive: in order to understand phenomena, we isolate and reduce them to their atomic components. Complex systems are dissimilar: we cannot either reduce them down to mere isolated components nor broadly consider properties of generic ensembles.

For example, an atom can be understood by decomposing the electronic and nucleic structure, from which a high degree of accuracy can be considered independently. On the other end, a gas consisting of many (millions) of particles can be studied by approximating it as a continuum and determining mean particle velocities etc. Complex systems inhabit an entropic middle-ground where neither approach is viable. A single cell has substantial internal structure which has (genetic) “purpose” within the cell, but it is insufficient to solely consider fundamental properties such as temperature or particle velocity.

A lone oscillator could be considered structurally, comprising of fundamental properties (such as signal generation) which are parametrically controlled in predictable, malleable manners, resulting in predictable sonic results. A composite modular synth patch, however, can create behaviours and outputs aurally and parametrically irreducible to their constituent components, therein constructing dynamic phenomenological experiences irreducible to interacting circuits. Contemporary generative art and music generally (particularly within the scope of *Stochastic Genesis*) incorporate randomness and unpredictability to create malleable dynamism within given creative interfaces and outputs, arguably making many generative procedures complex systems in and of themselves. Here we find a useful symbiosis: complex systems theory allows for a framework for analysis of the construction of generative art, and generative art provides creative methods which can depict, express and explore emergent complex systems in nature, technology and physics.

This topic *a priori* seems disparate from the phenomenological principles previously discussed, but phenomenology is vital to understand complex generative techniques. There is of course phenomenology in play when listening to traditional instruments, (Celibidache, 1993) and this emphasis is heightened in complex

acousmatic sound. Acousmatic sound design processes inform the mind in nontrivial and abstract ways, similarly to abstractions an individual might make about complex systems. *Stochastic Genesis* intentionally exploits and expresses this abstraction as sonic art and music.

Consider the example from Sec 1.2 of something sounding “warm”: the composite electronic components are abstracted from the listener’s synesthetic perception of “warmth” (as are the complex, molecular components of what might feel physically warm), yet the sonic/synesthetic universality remains, emergent from the systems within. How can these universalities be encompassed into sound design for music composition? Why might they be affective?

## 2.4 Wonderment as Phenomenological Utility

Aristotle implies that wonderment is at the core of all epistemological enquiry:

*“(I)t was because of wonder that men both now and originally began to philosophize... (T)hose puzzles that were to hand, such as about the affections of the moon and events connected with the sun and the stars and about the origins of the universe... the man who is puzzled and amazed is thought to be ignorant... (a)nd so, if men indeed began to philosophize to escape ignorance, it is clear that they pursued science for the sake of knowledge and not for any utility.” (Aristotle, 2004, 982b)*

Aristotle defined wonder linearly: the philosopher is puzzled and so seeks an answer through enquiry until a conclusion is reached and the puzzlement and wonder are replaced by knowledge, a seemingly limiting view when compared to Platonic wonder: wonder can arise through the acquisition of knowledge and remain thereafter, basking in the concluded enquiry and the proceeding emergent

enquiries. Platonic wonder, argues Sophia Vasalou (2015), is twofold. Firstly, Socratic dictum defines wisdom as understanding the extent of one's own ignorance, and uncertainty should not be resisted. Secondly, *"wonder is linked, not to puzzlement or perplexity, but rather to a sense of awe"*. Wonder relates to the beholder's capacity to see *"true, eternal, transcendent world-forms"* (Vasalou, 2015, pp.63).

The evocation of Platonic awe also provides an aesthetic framework for the natural sciences, illustrated in a renowned conversation between Richard Feynman and an artist. Feynman quotes his friend as claiming that science detracts from the beauty of nature by deconstructing it, mathematicising it, stripping it of its immediate phenomenological beauty. Feynman counters with the example of a rose, immediately and objectively beautiful without further scientific enquiry, but science opens doors to the beauty of the dynamical processes within; the fractal construction of petals, the spatial and temporal scales inaccessible without scientific enquiry: *"science... only adds to the excitement and mystery and the awe"* (Feynman, 1999, pp.2). Again, we contradict Aristotle. Wonder and awe permeate enquiry before and after the conclusion is reached, and we see highlighted the succinct beauty within the complex natural systems at play, which scientific knowledge, technology, and enquiry, make *more* phenomenologically attainable. A further utility of wonder concerns ethics. We touch on this briefly here, signalling ahead to ecological implications across the portfolio. Wonderment towards others, or any sentient being, can induce other-acknowledging compassion, understanding and empathy (Hepburn, 1984, pp.145; Vasalou, 2015, pp.205). This research posits that wonderment-inducing art surrounding science and nature raises questions about the fragility of life and condemns how human technology and industry are damaging the world. The question ultimately points to notions of an (already underway) human-induced mass extinction event and highlights the miraculous and

unlikely characteristics of the natural processes and systems we would suffocate, again drawing paradigms from Heidegger's (1977) hypotheses on technology.

### 3 Literature Review Part 2: Stochasticity and Sound Synthesis Systems

Literature Review Part 2 lays out history and theory surrounding generative music, modular synthesis, granular synthesis, and other relevant practical premises that informed the overall research undertaking, drawing paradigms with phenomenological/synesthetic principles and complex systems. Such paradigms are what the studio practice intends to exploit in creating sound/music.

#### 3.1 Geneses of Generative Practice

Aleatoric composition has existed in music since at least as far back as the renaissance, with stochastic mathematical abstraction permeating musical experimentation across the works of Guido d'Arezzo, Raimundus Lullus and Athanasius Kircher, (Nierhaus, 2009; Alexander & Collins, 2017; Crane, 1956). These composers are included here to insinuate commonalities surrounding exploratory composition: a common yearning for the interweaving of stochasticity into creative intent, and to highlight lineage between historical compositional objectives and the proliferation of generative musical tools today.

The 20<sup>th</sup> century saw advancements in computers coincide with the advent of algorithms and autonomous systems within music. Mid-20<sup>th</sup> century composers like Stockhausen and Xenakis pioneered algorithmic compositional techniques that laid foundations for generative music as we know it today, and the 1960s and 1970s saw progressions in digital technology facilitating the works of Cage, Isaacson and Hiller (Husarik, 1983). Hiller's *Iliac Suite for String Quartet*, generally agreed to be the first score for traditional instruments composed by an electronic computer, was a significant milestone in the world of generative sound and music. In the 1980s,

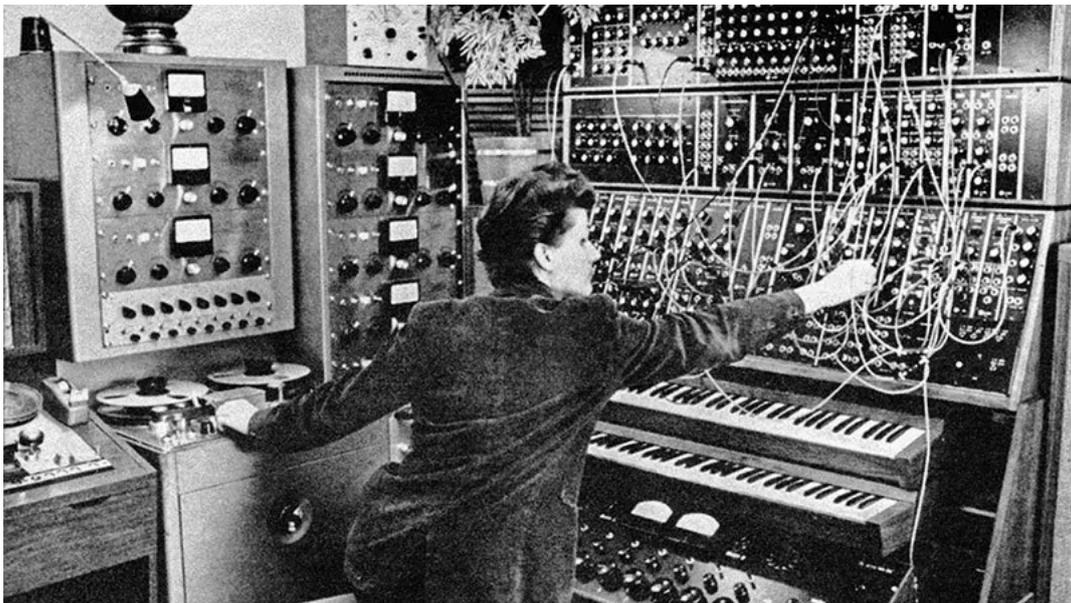
generative systems began to influence popular culture, most notably with Brian Eno's use of tape loops and delay systems to create evolving soundscapes that went on to become *Music for Airports* and other popular works (Eno, 1978). Aleatoric methods can exist within a compositional framework to differing extents, either making up a part or system of parts within an overall musical construct (usually incorporating stochasticity as a means of explorative composition on the way to a predefined sonic, aesthetic or musical goal), or can exist as the fundamental philosophical premise for a piece of work (using aleatoric principles for reasons experimental, academic, practical, or other) (Roads, 2015, pp.346-352). These fields are by no means mutually exclusive. Practitioners like John Cage lean towards a kind of "generative purism," where the aleatoric essence of his work make up the very substrate of the work's purpose (Husarik, 1983), but aleatoric methods can be used to whatever extent the composer desires.

We can observe an explosion of generative aleatoric methods in the contemporary creative sound and music landscape, (Heffler, 2023; White, 2019; Dadman et al., 2022) not to mention the surfacing and proliferation of fully automated AI music generation (Civit et al., 2022; Hight, 2024; Hilsdorf, 2023).

After the development of the eurorack modular synth format - a miniaturized version of classic modular synthesizers developed by Dieter Doepfer in the 1990s/2000s (Intellijel, n.d.; Nagle, 2017) – modular synths became more commonplace across consumer markets, eventually seeing a sharp rise in popularity across the mid-late 2010s (Brody, 2018). Alongside this, virtual modular synth emulation environments also surged in popularity, alongside node-based graphical coding interfaces such as Puredata (freeware) and MaxMSP. The modern proliferation of modularity in sound synthesis and general electronic music and sound composition is here evident,

positioning resultant research as significant enquiry in an expanding, relevant industry.

### 3.2 Modular Synthesizers: Modularity as Method



*Figure 3.1 Wendy Carlos at the Moog modular synthesizer, photograph, ca 1967 (Linda Hall Library, 2024)*

Modular synthesisers defined the history of electronic sound and music and maintain profound influence on contemporary experimental sound and music creation (Teboul et. al, 2024). Generally accepted to have been invented by Harald Bode in 1961 (Manning, 2013), modular synths are essentially collections of synthesiser modules *without* a fixed signal flow architecture. The signal flow is defined at the user's leisure by connecting patch points on the modules with patch cables, meaning each synth can be patched in all manner of ways for all manner of purposes. Their applications come close to rivalling those of computers, arguably surpassing computers in areas like aesthetics, ergonomics, physical interfacing and philosophical creative areas like limitations and inspiring sonic exploration. Five characteristics relevant to *Stochastic Genesis* are here listed;

Table 2: Relevant Characteristics of Modular Synthesisers

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Diversity of constituent components (modules): each module has unique design and distinct functionality from the next, with varying degrees of complexity therein. From basic oscillators, filters, envelope generators, sequencers or modulation sources to complex synth voices, digital resonators, drum machines or experimental modules.

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Non-fixed architecture: modular synthesisers are designed by their user from a constantly expanding market of eclectic and heterogenous modules, making each system unique to their owner, designed in line with the owner's unique creative aspirations.

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Complexity and sound exploration: modular synths provide substantial canvas for complex sound exploration. Modulation sources can themselves be modulated, parametric interplay is possible to a superior degree than in many DAWs, sound sources can be modulated, filtered, sampled, resampled, processed and altered in any way the given system could allow for. This means layers of complexity can amass quickly, often surpassing the user's expectations and even their ability to follow exactly what is happening within the patch, resulting in purely explorative creative experiences.

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Momentary creative workflows: parametric recall, (i.e. save states) is taken for granted in music software. A modular patch however is much harder to recall. Precise re-patching and re-programming of all parameters is necessary, and even then, phase differences and changes in temporal events may be impossible to recall, giving each patch a sense of transitory being in temporary world-space.

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Melding of schools of synthesis: a patch could involve subtractive, additive, FM, wavetable, physical modelling and granular synthesis methods, amongst others, within systems constructing a single voice or any number of distinct or interweaving voices.

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These characteristics allow for three distinct creative processes *before* any sound is even necessarily played; design of synth modules as artistic instrument-artworks in and of themselves; the selection, design and combination of said modules into a broader modular synth instrument; and a near limitless depth of patch combinations across said broader instrument, allowing for a lifetime of sonic exploration and immersion in sound design.

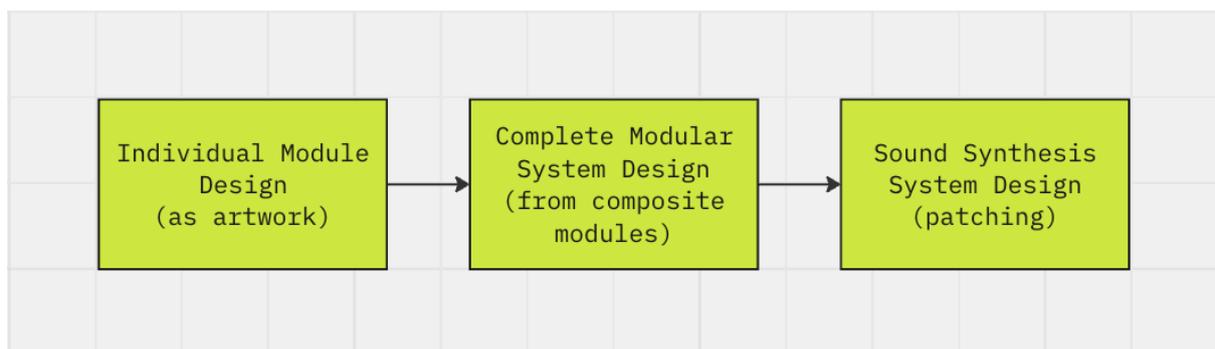


Figure 3.2 Modular Synthesiser Creative Processes (Author's own)

In conceptual or creative terms, “modular synthesis” or “modularity” (Hetrick, 2017) can exist outside dedicated modular synthesisers. Semi-modular synthesisers (machines having varying degrees of fixed architecture that also incorporate patch bays which can extend or breakout their signal flow) are now commonplace, and all manner of modular programming environments exist digitally, (MaxMSP, Puredata, Softtube Modular, VCV Rack etc.). Even modern fixed-architecture hardware synths with prerequisite signal flows sometimes contain deep modulation matrixes that in a sense make their workflow somewhat “modular”, for example the ASM Hydrasynth, where digital “modules” are arranged on the UI and can be virtually “patched” with modulation routings, allowing for a pseudo-modular workflow (ASM, 2019). Modularity as *method* incorporates the features listed above, departing from fixed architecture signal flow synthesiser design and giving sound designers maximum manipulation of signal flow as means of creative control. Modularity as methodology was incorporated everywhere possible into the hardware synthesisers and software applications used across the portfolio.

### 3.3 Microsound & Granular Synthesis: Morphologies

One primary source for the de/reconstructive sound design philosophies across *Stochastic Genesis* is Curtis Roads’ *Microsound* (2004). Whilst dated in terms of DSP and granular synthesis, Roads lays foundations upon which granular synthesis theory and practice have evolved and proliferated. *Microsound* examines sound at a miniscule level, focussing on the following relevant central theses;

*Table 3: Microsound, Relevant Theses*

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Granular synthesis as method: a technique involving the shattering of digital sound samples into “grains” (smaller splices of sound) and rearranging them to create new textures and tones.

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Sound models: how particle models of sound synthesis emerged, and relevant taxonomies therein.

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Temporalities & Timescales: examining the nature of sound across nine timescales ranging from micro (milliseconds) to macro (whole soundworks and compositions).

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Microsonic Structures: the importance of sonic microstructure, examining sound particles as the building blocks for complex audio (particularly relevant in the digital domain), and related particle models of sound.

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Compositional applications of microsound and particle techniques, and the emergent aesthetics therein.

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Microsound methods and granular synthesis play key roles in productional and creative techniques across *Stochastic Genesis*. Granular synthesis facilitates both the desired phenomenological and aesthetic premonitions of the portfolio, as well as providing thematic consistencies within the abiogenesis narrative.

Pierre Schaeffer identified the need for taxonomizing sound objects (this research will refer to sound/sonic objects in line with Schaeffer's tradition) but later recognised the infinite scope for sound morphologies (Schaeffer 1966, 1976, 1977; Chion 2009), which informed Denis Smalley's theory of *spectromorphology* which "is concerned with perceiving and thinking in terms of spectral energies and (sound) shapes in space, their behaviour, their motion and growth processes" (1997 pp.125). Spectromorphology defines shapes and structural functions of mesostructure or "the perceived sonic footprint of a sound spectrum as it manifests in time" (Smalley, 1986 pp.84-105; 1997 pp.107-126). Some common examples of mesostructure in music include repetitions, melodies, variations and polyphonies but can expand to any structure or superstructure that makes up part of the overall musical system.

In *Composing Electronic Music: A New Aesthetic* (2015) Roads analyses Smalley's theory of spectromorphology in terms of mesostructure and expands traditional concepts of polyphony to include multitrack mixing of independent lines of mesostructural phrases within electronic compositions. Roads highlights terms like *fission* (sound splitting) and *fusion* (sound merging) within the scope of electronic polyphony. Some morphologies relevant to granular taxonomies and the compositional methods used in *Stochastic Genesis* are listed;

*Table 4: Granular Synthesis, Fluid Morphologies*

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## **Fluid Morphologies**

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*Masses*: more-or-less fused textures form a monolith of sound, superimposition of multiple sources. Evolves relatively slowly. (Roads, 2015, pp.308)

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*Streams*: continuous emission of microsonic particles, flowing like fluid (Roads, 2015, pp.308)

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*Clouds*: Statistically scattered microsonic particles (Xenakis, 1960)

- Note: cloud evolutions can exist within domains of amplitude, tempo, grain density, harmonicity and frequency spectrum
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*Table 5: Granular Synthesis, Fluid Morphology Audio Processes*

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## **Fluid Morphology Audio Processes** (Roads, 2015, pp.312)

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*Coalescence*: moving from silence to increasing particle density, or amplitude until a tone forms

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*Evaporation*: regularly decreasing density or diminution of amplitude

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*Intermittencies*: irregular interruptions of particle density or amplitude

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*Transmutations/morphogenesis*: continuous change of identity within a stream or cloud

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These theoretic foundations and taxonomies informed the design of some of the most successful eurorack modules on the market, (Mutable Instruments' *Clouds* and the Make Noise *Morphagene* are apparent in their names), thusly informing the design of sound using these tools, and implicitly the works in *Stochastic Genesis*.

### 3.4 Hyperrealities: Musical, Spatial & Temporal

Post-structuralist definitions of hyperreality punctuate electronic music and sound design production. Inspired by classical phenomenology, Jean Baudrillard's (1994) theory surrounding the blurring boundaries between simulations and reality are applicable within the context of sound synthesis and sampling, in that sonic depictions of auditory phenomena are themselves synthetic – divorced from the real-world phenomena that inspire them but maintaining characteristics of said phenomena, (spatial, motional, temporal, textural etc). Acousmatic sound landscapes that induce auditory qualia in listeners are ever-present in contemporary

popular and electronic music, and the distinction between real and hyperreal sound environments is increasingly irrelevant to the audience.

A person's understanding of their location within a given spatial field derives from the senses, as delineated by Schultz & Kersten (2008) in their defining of the optic field (spatial field defined by sight) and the haptic field (spatial field defined by touch). This research refutes Schultz & Kersten's stating that spatial understanding of the acoustic field is *overtly* defined by haptic and optic fields, in that notions of aural locomotion "*are based upon preconstituted spatial experiences which (are) not purely auditive ones*" and that "*the ear is not able to build up the dimension of space*" (pp.35-36).

Contemporary sound theory recognises that both sound and music should be regarded as spatial experience (Knakkegaard, 2013; Salter 2019), with music in particular holding navigational information like direction and locomotion within a perceived space. The sole act of listening delineates a person's perception within said space, where motional phenomena is relative to "*sonic environments, which listeners inhabit as phenomenological subjects*" (Voegelin, 2014, pp.3). Music in particular imposes a "*dominant aural reality*" (Salter, 2019, pp.18) where "*the constant orienting of the organism to its environment is inevitable.*" (Clarke, 2005, pp.31).

The dissolution of boundaries between the real and hyperreal within soundscapes informs the creation of both auditory spatial settings and the autonomous sonic entities that inhabit them, defining the listener's perception of space, their navigation of sonic worlds and their interactions with phenomenological subjects therein, allowing listeners to experience synthetic sound artefacts and locomotion as a more tangible auditory reality.

## 4 Methodology Part 1: Foundations of Emergent Practice

Methodology Part 1 interlinks creative theoretic parameters with principles of meta-narrative, which informed the symbiosis between melded theories and studio practice across the project, as well as describing how the generated artefacts and composite soundworks function as performative research outcomes.

### 4.1 Practice Based Research

The Stochastic Genesis portfolio provides an opportunity to apply Celibidache's phenomenology of music in the realm of generative electronica designed in modular synth environments. Also, the soundworks themselves are inherently emergent and complex; acousmatic sound artefacts overlay, combine and interweave into something that can more reasonably be referred to as "music". This cacophony-to-multiplicity-to-unification-to-music sequence of perceivable sound phenomena is at the core of the portfolio's developmental philosophy, based on Celibidache's musical phenomenology outlined in Sec 2.2.

The portfolios' development provided opportunities for exploring these concepts as practice led research, aligned with the Performative Research Paradigm (Barrett & Bolt, 2007, pp.151). Accepting Carole Gray's definition of practice led research (pp.147), the portfolio draws extensively from Haseman's presentation of a third category of research data: performative research, "*expressed in non-numeric data, but in forms of symbolic data other than words and discursive text. These include material forms of practice... music and sound... live action and digital code.*" (Barrett & Bolt, 2007, pp.151). This sets the groundwork for the studio practice, wherein phenomenologically informed/observed creative processes formulate enquiry.

Application of phenomenological analysis across the practice-based components of the portfolio meant placing the focus on the lived, embodied experience of creating and engaging with modular synthesis systems. The approach implemented first-person, sensory-informed, auto-ethnographic reflection via journaling, studio recordings, iterative listening and improvisational sessions with the designed systems. Encounters with technological systems unfold in real time, and observations were made about technological agency and perceptual response. The methodology involved attuning listener-performer to emergent behaviours, in order to react reflexively, rather than to impose structure on the given system's internal dynamism. Perceptual touchpoints – moments of collapse, stasis, proliferation, chaos or climax – are analysed phenomenologically for both their aesthetic qualities *and* the affective qualities they generate in real time for both listener-performer and audiences. In this way, phenomenological analysis offers means of identifying, interpreting and deepening of the understanding of sound and cross-modal phenomena as they emerge from complex sound synthesis processes.

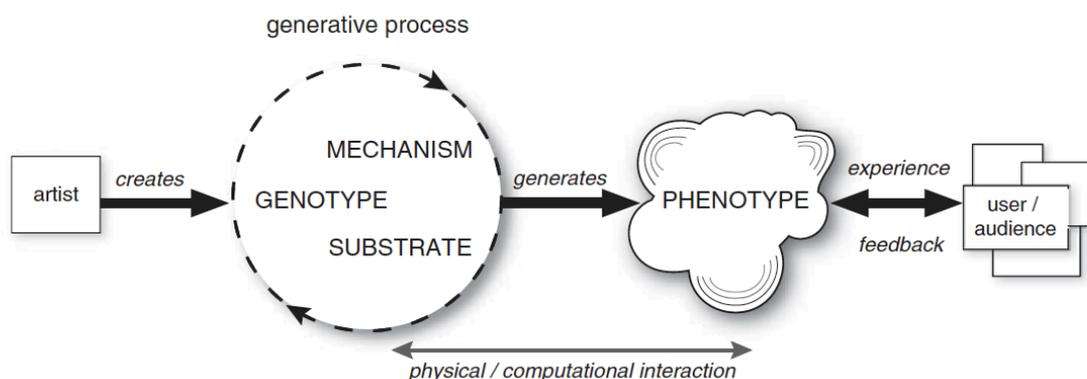
As practitioner-researcher, the author's role is distinct from that of a practitioner in how attention across creative processes is directed and held. Artistic practitioners may prioritise aesthetics, expression, and cohesion of outcomes, whereas practitioner-researcher attends to what the act of making can reveal, regarding (in this case) perceptual responses, system behaviour, cross-modal sensory phenomena and emergent properties of sound. This approach adopts heightened reflexivity across iterative processes of creating, interpreting, analysing, and reconstructing in a way that is methodologically distinct from conventional music making. The aim is to understand how sound can behave with reference to the embodied, cognitive and affective responses evoked in the listener.

This practice-led methodology pertains to meaningful engagement with technology not as fixed instrument but as dynamic, responsive environment, where immersion is a key component. Phenomenology permits tacit, embodied understanding of this immersion, in ways more difficult to traditional theoretical or observational models.

## 4.2 Metanarratives

In *The Postmodern Condition* (1984) Jean-François Lyotard critiques universal narratives that claim to legitimise knowledge, culture or history, arguing that grand narratives like Marxism or Enlightenment rationality have lost credibility in postmodern society. He suggests that knowledge is fragmented and localised, and notions of single unifying truths should be challenged and dismantled. A diversity of perspectives should be embraced, recognising interwoven complexities of sub-narratives that permeate composite human experience.

McCormack et al's (2009, pp.357) diagram for the generative process draws succinctly from biotic processes and is an optimal visualisation for the creation of *Stochastic Genesis*, both in terms of artistic practice, and theory formation.



**Figure 18.1 Overview of the generative process.**

*Figure 4.1 Overview of the generative process (McCormack et al, 2009)*

Here lies a foundational example of meta-narrative inherent across the project. Certain themes permeate the substructure of all undertakings involved and inform the derived experiential qualities of both thesis and portfolio. *Stochastic Genesis* adopts overarching thematic metanarratives of emergence, genesis and proliferation across research, theoretical construction, practical sound synthesis and composition processes. Instances of emergence from the abiogenesis narrative inform the emergence of sound artefacts and also the research itself, which in turn inform one another alongside the synthesis of theory. The artistic and methodological research processes are interdependent and are meant to form a kind of symbiotic complex system in and of themselves. This too informed the core creative principle of embodied systems, described in Sec 5.2.

#### 4.3 Data Sonification: Analogic vs. Symbolic Depictions

*Stochastic Genesis* does not adhere to strict principles of data sonification, which itself is a perpetually evolving and conflicting term. Described by Bly (1994) as audio representations of multivariate data, Scaletti (1994) expands this, including mapping of numerical data to acoustic forms that understand or communicate the data's fundamental relationships. Barrass (1997) expands further, describing the mapping of information and system *behaviour* rather than pure data depictions. The 1999 Sonification Report (Kramer, et al.) makes distinctions regarding analogic (relational and connotative) and symbolic (denotative and categorical) representations, dependent on the practitioner's desired application.

The portfolio can be considered as *analogic* artistic soundwork. The behaviour of instruments, systems and processes across the portfolio comprise of and are *inspired by* mathematical and biological systems such as cell division, fractals,

germination and proliferation - from which creative tools like fractal sequencing and cellular automata originate (Secs 5.10, 11.7.2) - but do not map specific datasets precisely. This, similarly to the departure from Cage's generative purism (Husarik, 1983), was to ensure that said systems work fundamentally as artistic tools, yielding desirable and refined auditory and musical outputs.

#### 4.4 Philosophical Foundations

Heideggerian concepts of *zuhandeit* and *vorhandeit* were embraced alongside complex systems theory, where the use of complex tools (such as modular synthesisers) oscillate between immediate creative intuition and objects of contemplation. This dual relationship enhanced the creative process in that it helped induce flow state where intuition and considered system design unify into mesmeric artistic expression. This allowed for sound to emerge as a dynamic response system with user improvisation providing a further pseudo-stochastic (and authentically "living") component, whilst pertaining to Csikszentmihalyi's (1990) flow state dimension of immediate and unambiguous feedback. The aforementioned (Sec 2.1) synthesis of Heideggerian premises and the attempt of the author-practitioner to realise them within a state of flow are employed wherever possible across the system design, improvisational sound creation portions of the studio practice. Chion's (1994) modes of listening informed sound design specifics, reflected on in Sec 6.2.

## 5 Methodology Part 2: Studio Practice

Methodology Part 2 refers directly to studio outcomes, the methods that were used to create them, and the application of previously described theories in their creation and arrangement. It describes the studio practice as research methodology (further expanded on in Volume II) and links theoretic principles (phenomenology, sound theory, synesthetics, complex systems) back to the research questions and aims using pragmatic examples of studio practice.

### 5.1 Narrative Outline & Composition

This methodology section will refer directly to completed soundworks from the digital portfolio, which can be accessed here:

<https://rorygreenarts.bandcamp.com/album/stochastic-genesis-compositions>

Individual sonic artefacts can be accessed here:

<https://rorygreenarts.bandcamp.com/album/stochastic-genesis-sound-artefacts>

*Stochastic Genesis* uses principles outlined in the literature review to create musical works that tell the story of emergent life on earth, specifically focussing on emergent abiotic phenomena chosen partly for their scientific credibility as theories, but also their capacity to influence and inspire emotionally affective artworks, and to induce wonderment in practitioners, audiences, scientists, listeners and fundamentally the author.

The narrative moves through the prerequisite conditions necessary for abiogenesis to occur (Dohm & Muruyama, 2015), a model for inducing abiotic emergence that centres around naturally occurring underground nuclear geysers, (Ebisuzaki & Muruyama, 2016), abiotic formation of nucleic acids (including DNA and RNA, proteins, lipids and glycans), single celled prokaryotic creatures and LUCA (last universal common ancestor) (Weiss et al, 2016), with implied reference to missing links and gaps in the science, mitochondria, photosynthesis, cell division, and complex single celled organisms such as Radiolaria and diatoms.

The following section will discuss subject matter within the soundworks across the narrative and describe some of the applied methodological approaches for each compositional technique therein. The examples chosen delineate the applied creative methodology and patching philosophy. Methods are not limited to any single soundwork and were applied to differing degrees across the portfolio. They have merely been presented thusly to aid in general pedagogy of the compositional process. Additional processes and expansions are set out in Volume II.

## 5.2 Embodied Systems

*Stochastic Genesis* introduces the premise of “embodied systems”, referring to the creation and implementation of sound synthesis systems that embody the science from the given narrative. Effectively, sound generation systems based on principles of modularity that embody or encompass characteristics of an observed system that the given artist intends to create sonic art or music about. This is at the crux of the creative methodology of the portfolio – the goal is to create sound synthesis systems that embody the principles of the natural systems from the narrative, in that they mimic them or behave similarly in some way. This principle was applied at every possible creative stage.

### 5.3 Synth Formats, Artefacts & Meta-modules

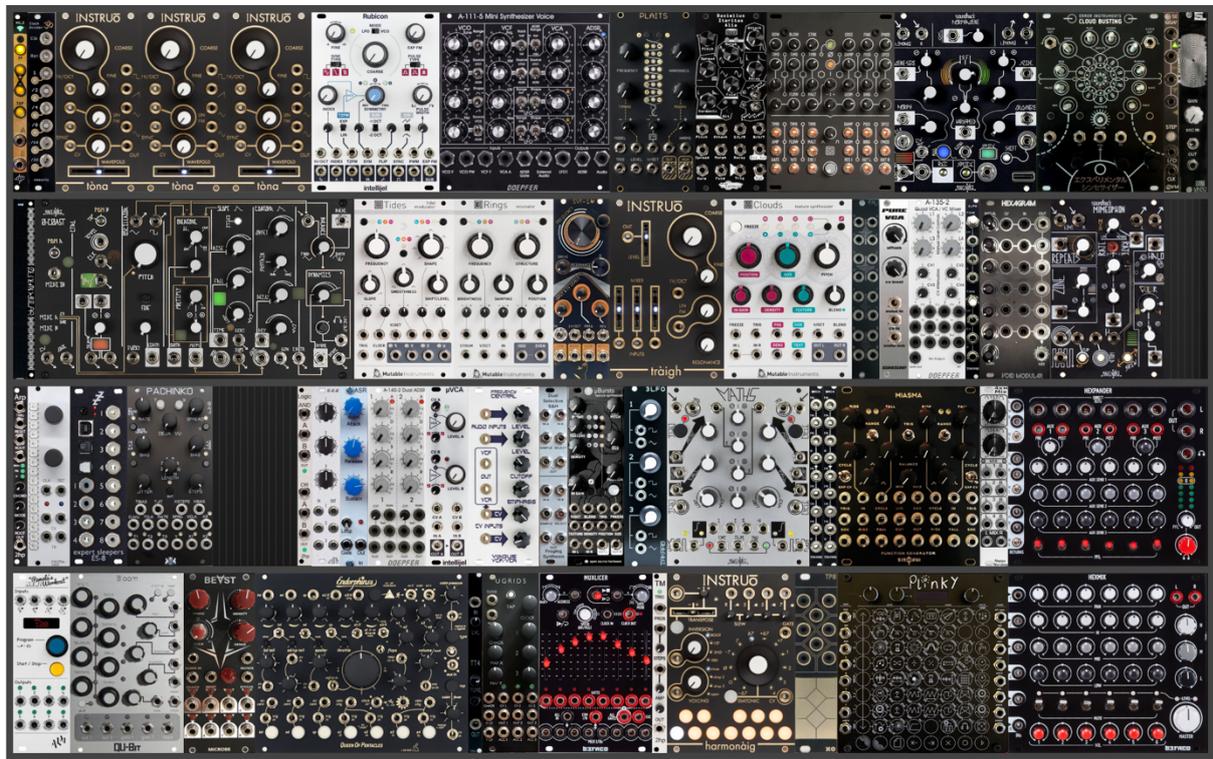


Figure 5.1 Modular System used for Stochastic Genesis (Author's own)

Stochastic Genesis uses a broadly capable modular synthesizer (pictured above, accessible: <https://modulargrid.net/e/racks/view/1566504>), as well as digital tools within Ableton Live and other hardware synths and samplers. An Expert Sleepers ES-8 module interfaces the modular and Ableton for using digital CV tools and transferring audio. The project draws heavily from Hetrick's *Taxonomy and Toolkit for Designing Modularity in Audio Software Hardware* (2017), particularly concerning "meta-modules," - sets of modules that frequently function together to perform specific tasks.

Stochastic Genesis extends the notion of meta-modules (which would originally comprise of examples such as patching oscillator-filter-amp-envelope comprising of a single subtractive synth voice) to creating module-based analogic depictions of

phenomena in the abiogenesis narrative. Instead of using precise patch diagrams of the specific modular system across the portfolio, system diagrams allow for the translation of functional behaviour, meaning that research premises can be translated to and adopted by all manner of sound synthesis systems with varying degrees of modularity.

The full list of patch symbols from *Patch and Tweak* (Bjørn et al., 2018) can be found in the appendices (Sec 14.3) and is accessible: <http://patchandtweak.com/symbols/>

Meta-module diagrams exist in two forms across the project, *systems* and *clusters*, depicting either a system of functions from various modules that have been patched (with the connecting lines depicting cables and the direction of signal flow) like the following meta-module for depicting water:

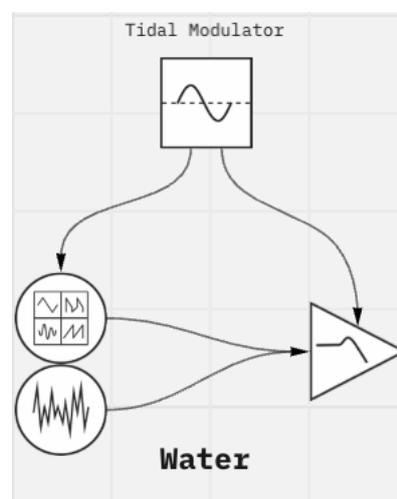


Figure 5.2 Meta-module: Water (Author's own)

*Clusters* of patch symbols depict either a certain function or a specific module type, (eg. synth voice, granular sampler or complex modulation source):

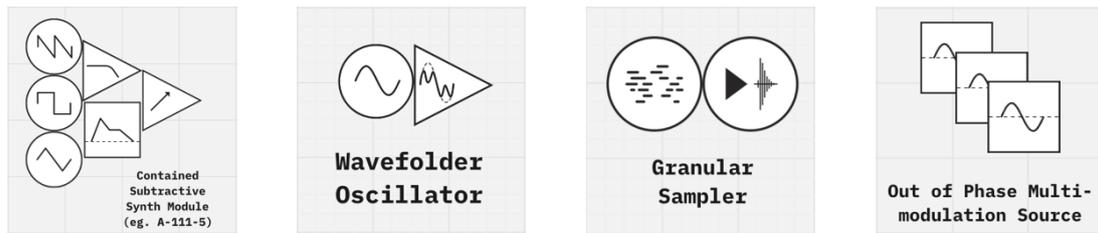


Figure 5.3 Patch Symbol Clusters: Function Examples (Author's own)

Or specific modules, (clusters for specific modules comprise of patch symbols for their constituent functions and are labelled with the name of the module):

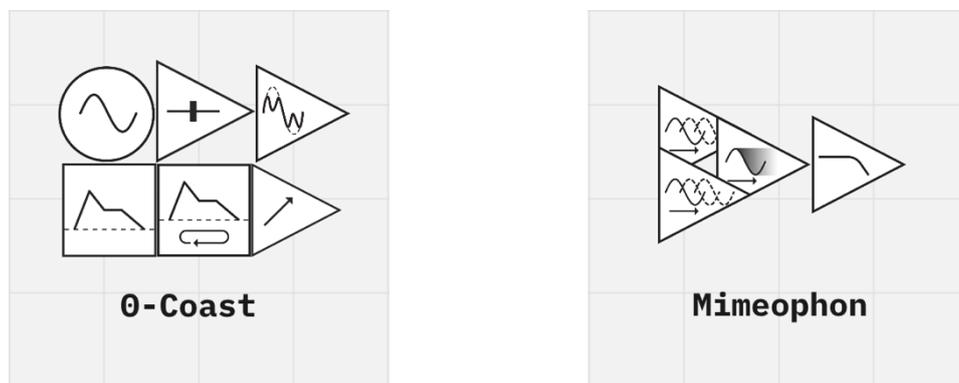


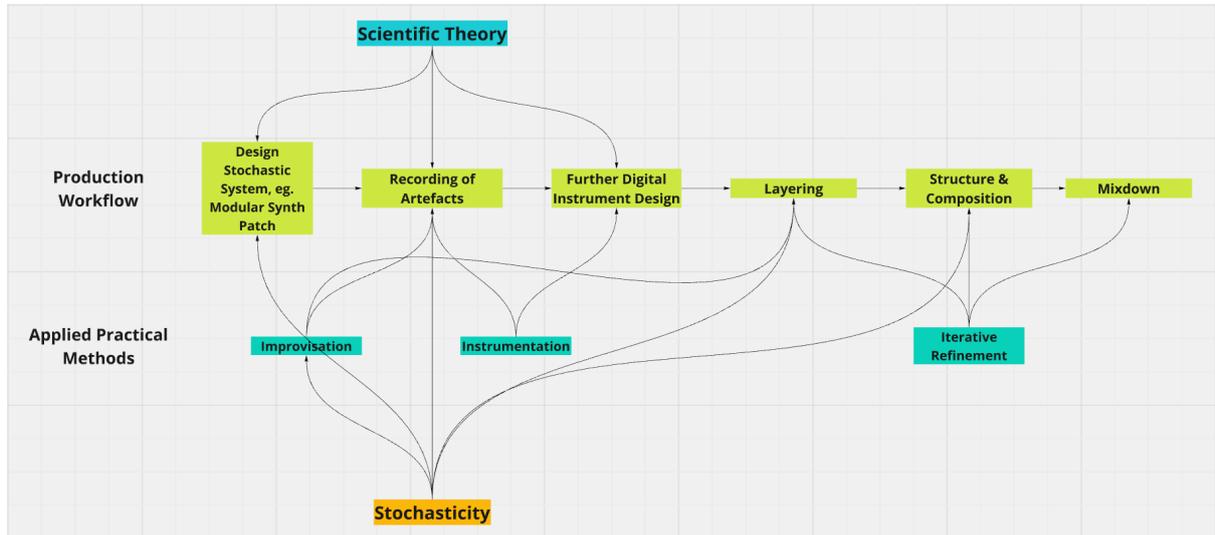
Figure 5.4 Patch Symbol Clusters: Module Examples (Author's own)

Sonic artefacts were recorded via composer interaction with meta-modules and patches, (as well as other embodied systems within DAWs and hardware synthesisers) effectively improvising short performances on them, providing a living stochastic component to the sound outputs. These artefacts were included in the pieces, sampled, resampled, manipulated, or used as compositional material in any number of ways.

#### 5.4 Composition: Beyond Modularity

The diagram below shows the production workflow methodology throughout the portfolio, the applied practical methods involved, which stages are informed by the

scientific theory of abiogenesis, and which stages encapsulated stochasticity in their execution.



*Figure 5.5 Workflow Methodology Diagram (Author's own)*

Ableton facilitates a balance of generative and non-generative composition principles throughout the portfolio, acting as the “compositional canvas” upon which the compositions are assembled and structured. Pseudo-generative processes such as polyphonic layering of mesostructures (Roads, 2015), layering of loops of differing lengths (Eno, 1978), expanded modulation mappings, stochastically functioning plugins, overtly generative instruments (such as *Tree Tone*) and others are employed to imbue stochasticity as both technique and narrative tools wherever useful.

## 5.5 System Design, Implementation and Composition

The following sections (5.6 through 5.13) refer directly to the eight composite soundworks from the portfolio, the titles of which are here listed;

*Table 6: Composite Soundworks, List of Titles*

1. <i>Origin State</i>
2. <i>Reactor</i>
3. <i>Abiotic Forms</i>
4. <i>Replicator</i>
5. <i>Momentary Split</i>
6. <i>Mitochondria/Photosynthesis</i>
7. <i>Radiolaria</i>
8. <i>Instability/Collapse</i>

Relevant applied processes are described to illustrate how the implementation of embodied systems informed compositional processes, and how the studio practice served as an exploration of melded theories (phenomenological, complex systems, morphologies/spectromorphologies etc.) and themes across the musical components of the portfolio.

## 5.6 Meta-modules: Applied Examples

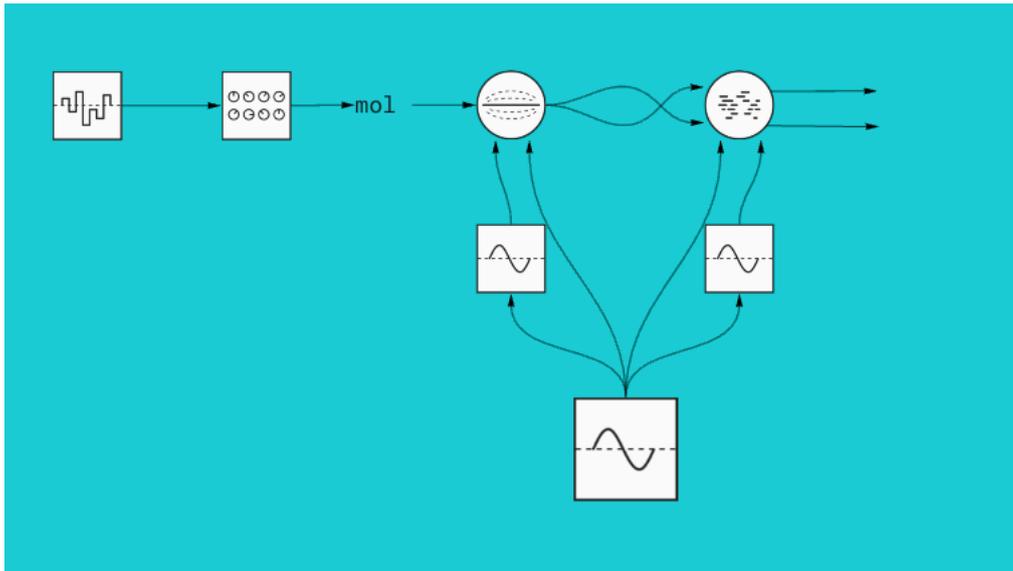
*Origin State* comprises of sound synthesis processes inspired by the prerequisite conditions necessary for abiogenesis to transpire around a naturally occurring nuclear geyser (Muruyama et al, 2019). The nine prerequisite conditions and emergent theory outlined by Dohm & Muruyama in *Habitable Trinity* (2015) inform

the compositional structure of the work;

*Table 7: Nine Prerequisite Conditions*

(1) an energy source (ionizing radiation and thermal energy)
(2) a supply of nutrients (P, K, REE, etc.)
(3) a supply of life constituting major elements; CHON (carbon, hydrogen, oxygen and nitrogen)
(4) a high concentration of reduced gases such as CH <sub>4</sub> , HCN and NH <sub>3</sub> in caverns
(5) dry-wet cycles to create membranes and polymerize RNA
(6) a non-toxic aqueous environment
(7) Na-poor water (less salt, fewer heavy metals, and neutral pH)
(8) highly diversified environments
(9) further cyclic conditions (such as day-to-night, hot-to-cold etc.)

Embodied systems were designed around these prerequisites, recorded as artefacts and used as mesostructural components in the final composition. The following diagram shows the first meta-module created, which depicts prerequisite (1) an energy source, and the effects of thermal ionisation on subatomic particles and electromagnetic waves. Thermal energy is produced when rises in temperature cause atoms and molecules to move faster and collide with each other.



*Figure 5.6 Meta-module: Prerequisite (1) (Author's own)*

The above patch comprises of a random voltage modulating a sequencer, inducing stochastic note variation (with constrained harmonic scaling, keeping the output in key), driving a particle-excited physical modelling corpus, which is sent to a granular processor. Out-of-phase LFOs modulate parameters across sound generators and are in turn modulated by a further LFO creating unpredictable behaviour and shifting sonic characteristics. Modulation is attenuated in accordance with the desired sonic output of the patch. Behaviours shift, but the degree of shifting is fine-tuned towards a desired result, an example of departure from Cage's "generative purism" (Husarik, 1983) and towards using chaotic behaviour for inducing subtle movement within deliberate narrative sonic processes.

The random voltage controlling the notes represents the chaotic movements of the subatomic particles, which are depicted by the particle excited physical modelling corpus, and the resulting ionized radiation and thermal energy are depicted by the output of the granular processor. This is a relatively simple example of the practical approach of the portfolio, exemplifying how modular synthesizers can emulate

scientific phenomena (synthesizer components themselves function with basic physics) due to their open format, versatility and non-fixed signal flow architecture.

A slightly more complex example is the patch designed for prerequisite (2) a supply of nutrients:

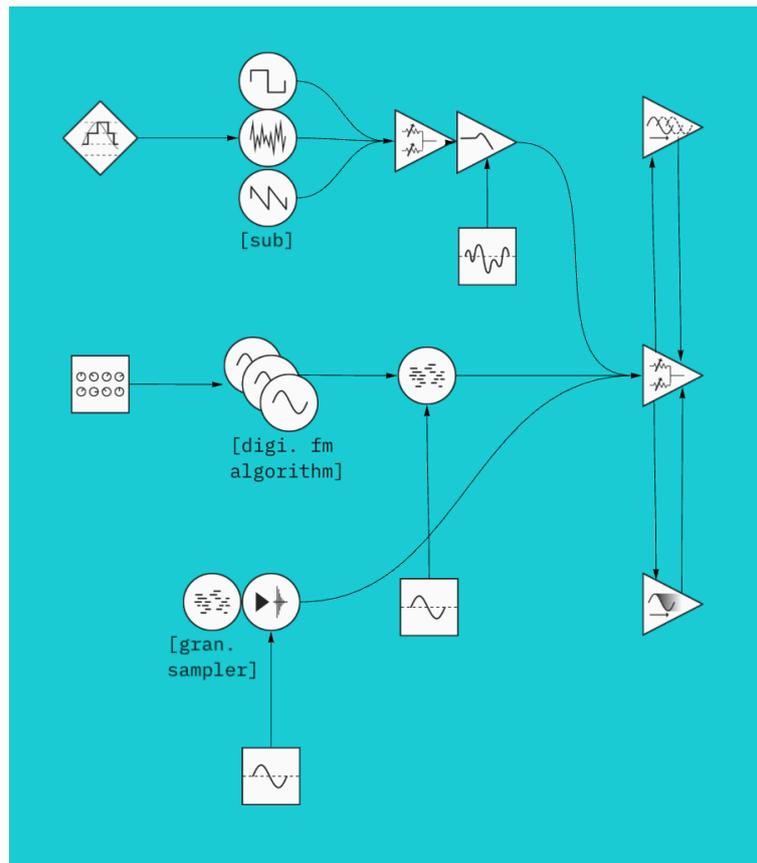


Figure 5.7 Meta-module: Prerequisite (2) (Author's own)

Due to the relative complexity of the set of elemental compounds in prerequisite (2), which include a supply of phosphorus and potassium as well as a subset of earth metals and minerals, a more vivid, analogical approach was useful.

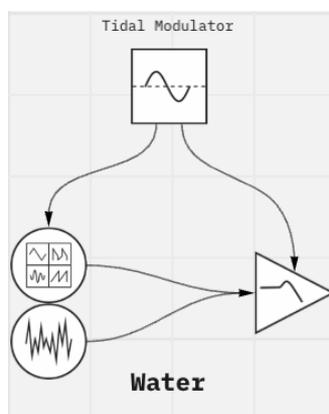
Phenomenological sense perceptions and sonic depictions of sense-based phenomena come into play here. Igneous rocks *feel* coarse to the touch, requiring distorted elements that *sound* rough. They are visually complex, so a diversity of

sonic textures is required. Minerals containing nutrients are visually bright, glittering, crystalline, so jittering FM synthesis and sparse granular clouds were recorded. Rocks grind when in motion, so geological audio samples were loaded into a granular sampler and spliced, depicting geological shifting or breaking.

The diagram above depicts three distinct meta-modules being mixed, where the mixer is bussed to delay and reverb circuits that depict perceived world-space. The upper subsystem represents igneous rock make-up, creating sub-frequential drones, where a pitch-quantized oscillator set is mixed and filtered (a smoothed random LFO modulated the filter frequency, creating the aforementioned grinding/shifting). A less analogic, more literal subsystem of meta-modules can be found for prerequisite (5) dry-wet cycles to create membranes and polymerize RNA. The patch consists of three interacting meta-modules:

### 1. Water

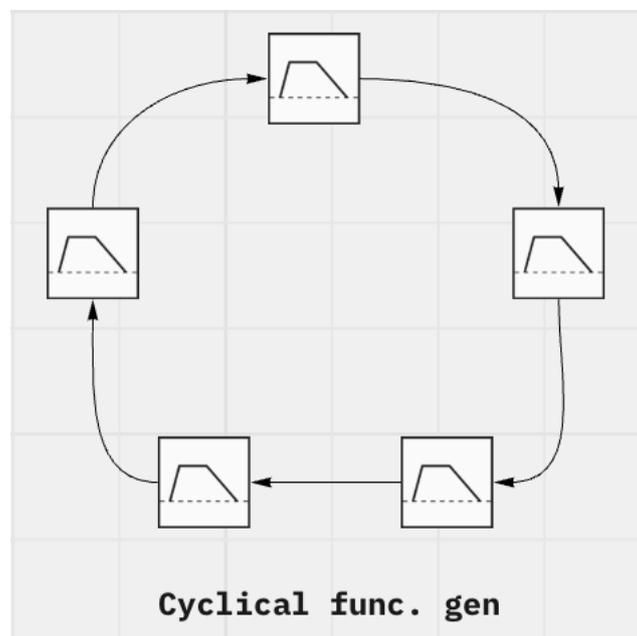
A wavetable oscillator (wavetable oscillators sweep through wavetables similarly to how water moves in nature), is combined with a white noise source, (water produces white noise in nature) and a filter modulated with a tidal modulator (for further sweeping auditory motion akin to actual water).



*Figure 5.8 Meta-module: Water (Author's own)*

## 2. Cyclical Function Generator

A set of five function generators (usually simple rise/fall circuits like on Make Noise's *Maths*) triggering each other in series, before looping back, creating a cycle. This meta-module was used throughout the portfolio for cycles present in the narrative and was expanded with phase-locked modulation for helixes.

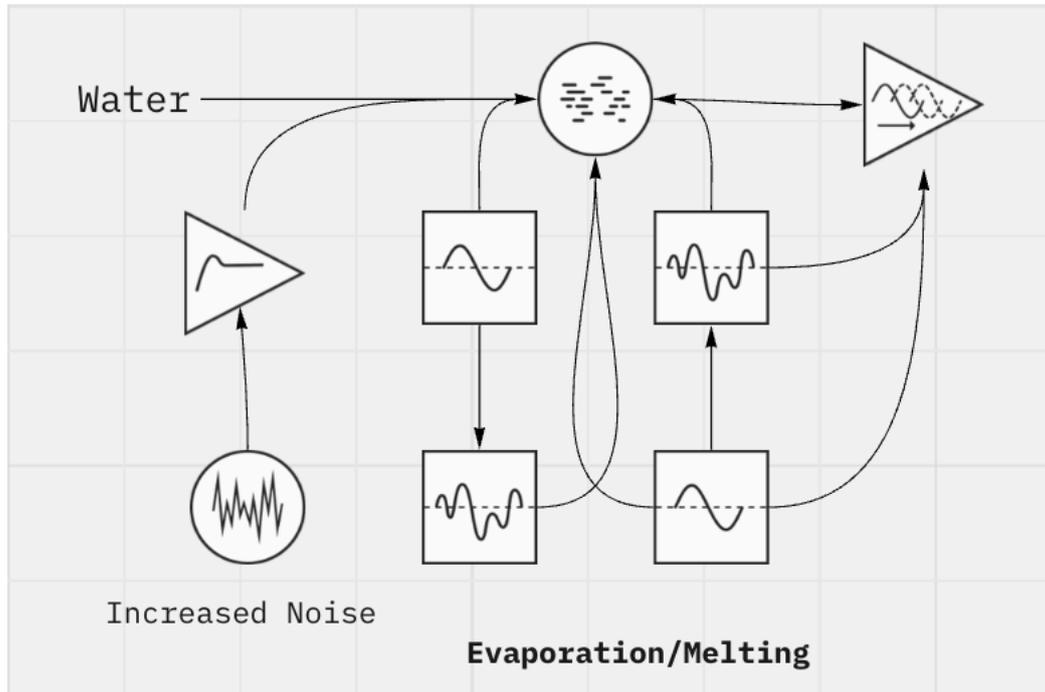


*Figure 5.9 Meta-module: Cyclical Function Generator (Author's own)*

## 3. Evaporation/Melting

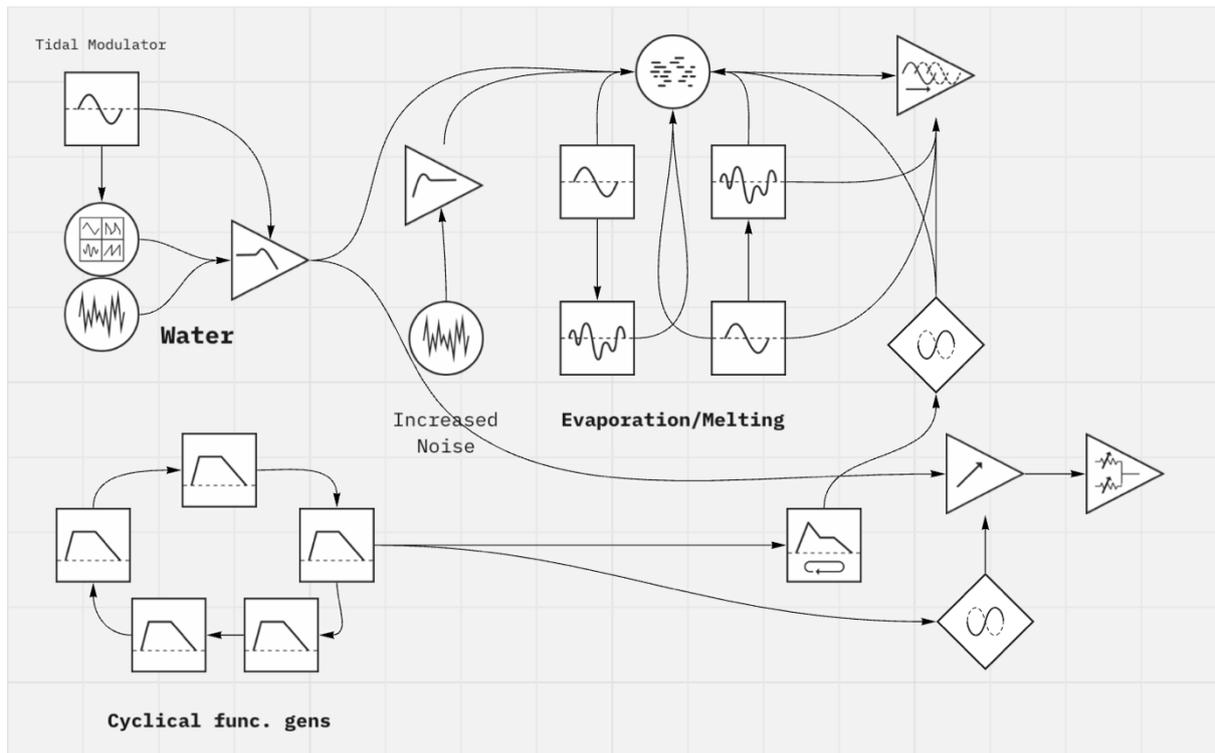
Running the water meta-module into a granular processor that is modulated to move between different states of grain distribution. Roads' (2015) taxonomy for fluid morphologies comes into play here. Grains behave as streams, clouds or masses depending on the given stage of the water cycle; coalescing, evaporating and transmutating to achieve desired behavioural

results.



*Figure 5.10 Meta-module: Evaporation/Melting (Author's own)*

The aim of the resulting system of meta-modules was to exploit Roads' (2015, pp.312) morphological principles with modularity, linking them back to the prerequisite conditions using phenomenological sensory characteristics. The following diagram shows the full patch functionality.



*Figure 5.11 Meta-module: Water Cycles (Author's own)*

This diagram shows the nature of interacting meta-modules within narrative structure and alludes to how combinations of - and interactions between - meta-modules embody emulations of complex systems, behaving similarly to the natural systems that inspired them. Here, previously articulated theses of complex systems embody a meta-module-based instrument: the sum of their interactions is not reducible to their parts (Gleick, 1987).

Whenever “water cycles” were depicted across the portfolio this patch was implemented. Parameters, modulation speeds and phasing are variable across uses, but the circuitry behaves characteristically similarly, allowing for fine tuning of desired sonic results from the thematically embodied relevancy of water cycles. The approach of meta-modules for complex physical system depiction was used throughout each piece where necessary and won’t be covered in as much depth as for *Origin State*. Instead, following sections will describe other compositional methods and points of interest across the portfolio.

## 5.7 Patch Instability

*Reactor* reflects on the nuclear geyser model (Muruyama et al, 2019) and explores the theory of a naturally occurring uranium reactor in synthesizing the building blocks of life (Ebisuzaki et al, 2016), the spatiality surrounding the reactor, and some of the motional components of the prerequisite conditions.

Many existing meta-modules from *Origin State* were reused for *Reactor*. Aural objects depicting the reactor itself were processed by running them into various resonators, delays and reverbs, informed by what might sound phenomenologically “nuclear” to our ears (expanded upon in Volume II, Sec 11.3, 11.4), in order to place narrative occurrences in phenomenological sonic world-space.

Chemical instability turned out to be one of the more effectively embodied premises across the narrative. A rhythmically unstable patch must ingest a degree of instability in the way circuitry is patched, (allegorising unstable aspects of the narrative), and aural results happen upon their desired intention without much parametric tailoring. Instability in rhythm (or any other mesostructural musical constant) is almost always bound to *sound* or *feel* unstable to our ears, raising questions about whether symmetry in rhythm or harmony is learned or inherent in the nature of rhythm/wave-form interactions in the harmonic series and physics. Most people can discern that ingested parametric instability will yield unstable *sounding* results.

## 5.8 Complex Irreducibility

*Abiotic Forms* explores the emergence of amino acids, peptides, proteins, RNA and DNA, and expresses movement towards what can tangibly be considered “life.”

The piece employs a shift away from abstract, broken and chaotic sonic artefacts and an arranging into grid-based rhythmic structures and mathematically spaced formations, depicting the “organising” of molecules into cells. The tone of *Abiotic Forms* intends to explore wonderment inherent in missing links and gaps in science; the “so-called “chicken and egg relationship” in the present life systems” regarding proteins and DNA: “DNA carrying genetic information cannot be replicated without proteins, whereas proteins cannot be reproduced without genes.” (Ikehara, 2005, pp.178).

As the abiotic processes in the narrative multiply and convolute, so too does the compositional process. *Abiotic Forms* exploits mesoscopic layering to cacophonise multiple lines of stochastic sound generation into a kind of chaotic textural concourse. The process involved synthesised individual percussive sounds sampled from the modular and sequenced in Ableton creating the aforementioned chaotically structured rhythms. Methodologies outlined in the next section (5.9) explore textural philosophies of sounds used within these sequences. Temporal interactions between randomly generated sound objects scattered around structured rhythms imply stochastic interactions of molecules around a driven direction towards complex cell formation, forming an embodied rhythmic system. In *Phenomenology and Complexity*, Zhok (2022, pp.1057) states that complexity “cannot represent a new unitary paradigm, because it includes plural forms of phenomenal irreducibility, which by essence resist unification.”

The use of layering intends to exploit this irreducibility – articulated in Husserlian eidetic phenomenology, where complexity is perceived as a “formal essence” of the material “life-world” (Husserl, 1954) – in creating a perceivable musical/artistic qualia-based ontology, and eliciting emotional response in the composer/listener. This irreducibility ties paradigms with gaps in science: *Abiotic Forms* reflects

simultaneously upon mechanisms within our understanding of abiotic processes (doing so mechanically with modularity and parametric tailoring) and also wonderment inherent in remaining mysteries, such as those surrounding the first dividing cell (doing so tonally, compositionally and structurally).

A patch was created embodying various concepts present within DNA formation. The goal again was to ingest marginal order into generative patches, implying the ordering of DNA helixes from RNA (Forterre et al, 2013). Phase-locked modulation was applied to a cyclical function generator to create a “modulation helix” which modulated the sequencer effecting the notes driving a subtractive synth module.

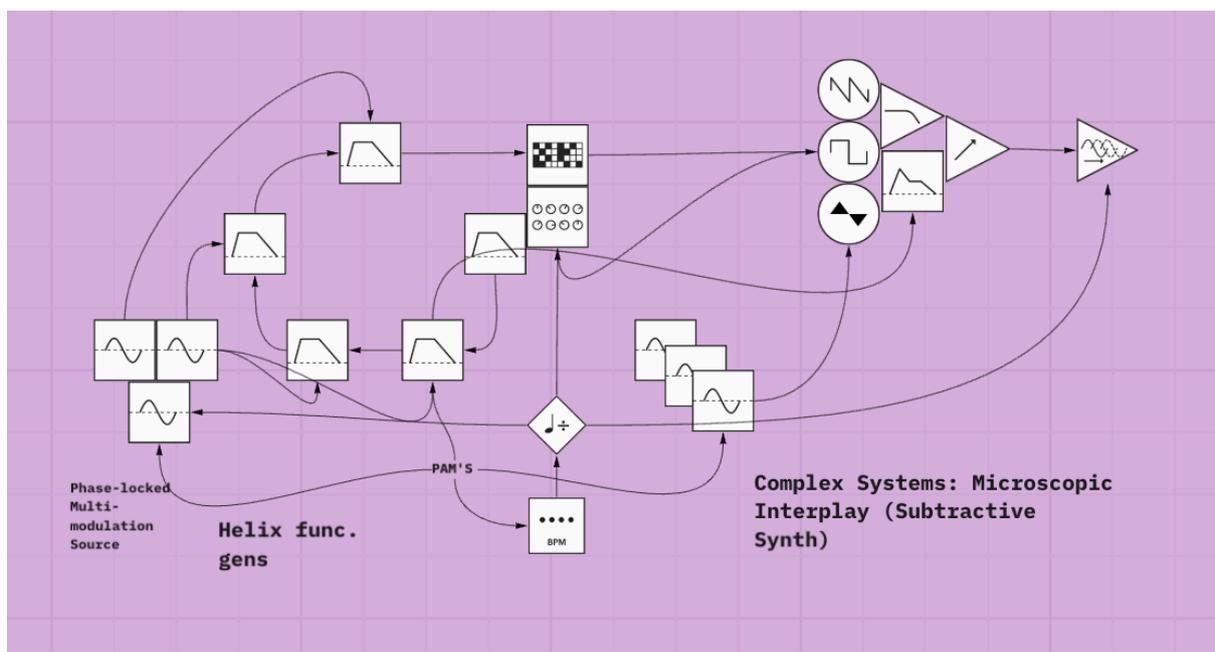
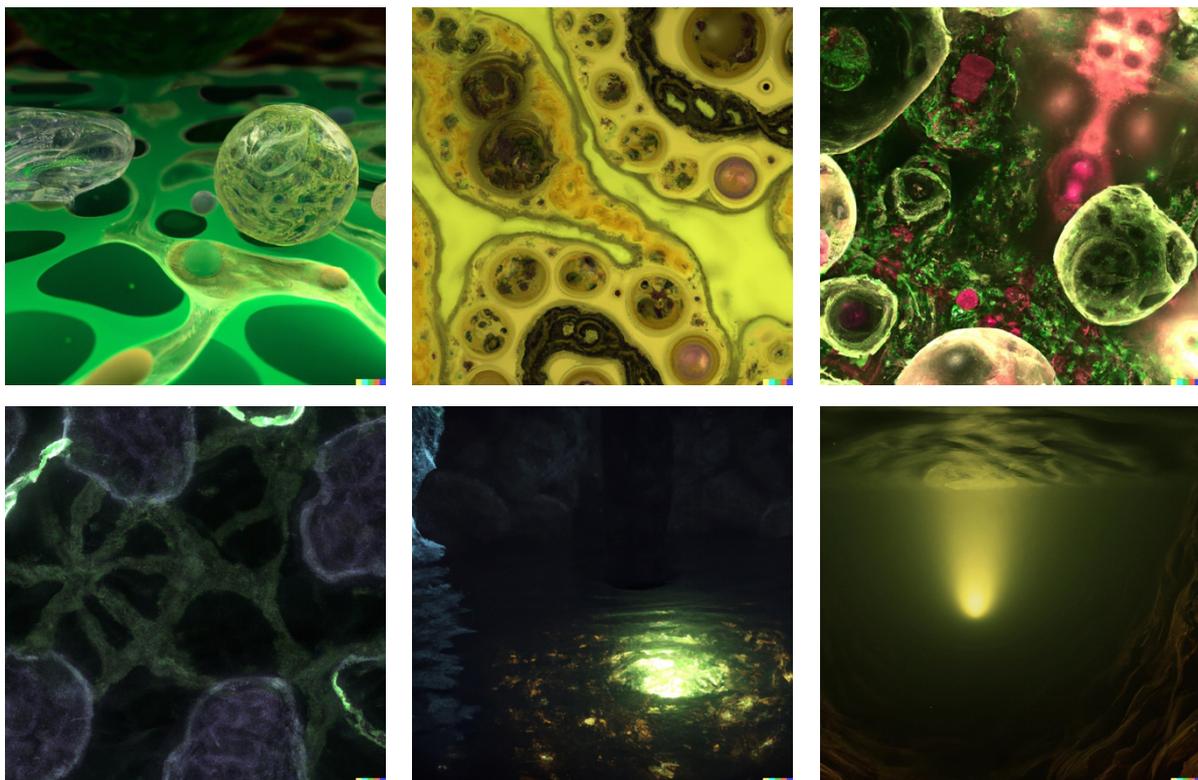


Figure 5.12 Modular Patch: DNA Formation (Author's own)

## 5.9 Synesthetic Paradigms

*Replicator* explores textural and spatial phenomena with reference to synesthetic paradigms that interconnect our senses, exploring the relationship between sonic, visual and tactile phenomena.

An AI image generator (DALL-E 2, accessible: <https://openai.com/index/dall-e-2/>) was fed with creative writing passages inspired by papers on the prerequisite conditions, (Muruyama et al, 2019) cell division (Cooper, 2000), LUCA (Glansdorff et al, 2008, Weiss et al, 2016), early primordial organic compounds (Weiss et al, 2016) and DNA and RNA (Clancy, 2008) and selected outputs were chosen with regards to aesthetic appeal and visual tone.



*Figure 5.13 Selected Dall-E Outputs (Author's own)*

An exemplified prompt is as follows;

*“shifting cells split in the primordial ooze, glistening proteins dance and form new life, underground uranium shimmers giving off light in a cave full of boiling water, granitic rock degrades filling the water with nutrients”*

The prompt adopts dramatic, unrealistic language, inducing the desired tone of the eventual soundwork, pushing resultant image generations in definable aesthetic directions. The image generator functioned as means of generative visual texture creation where images act as phenomenological artefacts from which corresponding auditory textures were articulated. Textures present within the images (fluidity, plasticity, synthetic smoothness, humectation, etc.) were explored via sound design.

### 5.10 Non-linearity & Cellular Automata

Bilotta et al (2002, pp.152) explore extensive applications of cellular automata "*in interpreting complexity (or music in general) as well as in producing musical compositions as narrative pieces*". *Momentary Split* adopts cellular automata as means of MIDI sequencing, which involves algorithmic processes that generate note patterns based on rule-based systems that simulate cellular "*attributes of auto-organization and emergence, which might also model spontaneous formation and the growth in complexity of natural languages and of music*" (Bilotta et al, 2002, pp.153). Cellular mimicry allows for emergent rule-based behaviours characteristic of Bertalanffy's (1968) structures and ordering of life. An IOS app, *Xynthesizr* (accessible: <https://phonolyth.com/products/xynthesizr>), was used to send cellular MIDI around Ableton and modular synth, but cellular automata is easily achievable in a software like MaxMSP (Bielharz et al, 2006) and free MaxMSP patches exist (accessible: <https://cycling74.com/tutorials/algorithms-less-concepts-max-for-live-device-cellular-automata>) which can quickly populate Ableton sessions with cellular automata sequencing. Cellular automata is also present in some eurorack modules, such as the Beast Tek Microbe (<https://www.beast-tek.com/microbe.html>) which was utilised for cellular automata within eurorack patches across this piece and those following.

## 5.11 Mesostructural Fluctuations & Disintegration

The melodic and mesostructural symbolism in the final piece represent extinction via its modes of transition from interacting and densely textured soundscape design, towards a more minimal movement as the sound objects decay. “Collapse” is marked by reductions in sonic objects and their interactions, marking a shift from earlier pieces’ systems of sonic and rhythmic complexity. The piece intends to employ a kind of sweeping emptiness, a phenomenological disquieting, leading the listener into sound-space that implies desolation, wherein once-thriving structures of sonic ecosystems deteriorate. Principles of degradation were based on William Basinski’s *Disintegration Loops* and are expanded on in Volume II (Sec 11.10.3).

## 5.12 Further Process Paradigms: Space Colonisation, Fractals

Qubit’s *Bloom*, a fractal eurorack sequencer, and Ableton’s *Tree Tone* instrument each integrate principles surrounding germination, growth, mutation and branching, facilitating relevant embodied systems practice into the compositional methodology. *Bloom*’s mutative capabilities (Qubit, 2019) were useful in several areas, such as representing endosymbiosis and mitochondrial evolution (Gray et. al, 1999) and also a sprawling and expanding tree-of-life.

*Tree Tone*’s space colonisation algorithm (Bastan, 2021; Runions et al, 2005) mirrors similar branching structures. Both tools embody interplay between generative processes and thematic relevance, and centre around emergent patterns and the portfolio’s philosophical underpinnings. Implementation of such procedures is expanded on in Volume II (Sec 11.8.2, 11.8.3)

## 6 Discussion

*The process of composition is essentially creative decision-making: up or down, long or short, sparse or dense, loud or soft, same or different, etc. Out of a universe of possibilities, we choose specific elements and order them in time to construct a musical morphology.*

- Curtis Roads (2015)

Sec 6 reviews the validity of the practical processes implemented and reflects on some of the decision making surrounding the nature of abstract sound design. It also discusses general implications arising for modularity as creative doctrine.

### 6.1 Emergent Patterns & Creative Methods

The creation and use of meta-modules across the project aligned with the selected theoretical principles and functioned well in enabling emergent and adaptive generative sound structures, effectively mirroring and depicting the self-organisational behaviours inherent in complex systems outlined by Bertalanffy (1968). By integrating meta-modules that embody facets of the chosen scientific narrative, rule-based mechanisms that include aspects of stochasticity were easy to exploit in audio creation, as well as recalling and re-implementing consistent scientific structures across different parts of the portfolio.

Layering stochastic soundscapes was viable in depicting emergent systems, mirroring interactions within said systems. Variability and unpredictability inherent in the designed systems reflect the fundamental nature of the natural systems that inspired them with reasonable analogic accuracy. Emergence, cellular growth and

ecological proliferation all hold thematic relevance and consistency within these methods, allowing the system's user to feel deeper connections with the natural systems they aim to emulate.

Granular synthesis proved useful in modelling depictions of complex natural phenomena, particularly in embodying concepts like emergence, coalescence and collapse, where Roads' (2015) theories surrounding sound fission and fusion are exploited to create textural outputs, sonically and characteristically similar to the chosen narrative.

## 6.2 Synesthetics: Phenomenologies of Auditory Spatial and Textural Phenomena

Sound design and parametric tailoring was informed by Michel Chion's (1994) taxonomy for modes of listening; causal, semantic and reduced. *Causal listening* refers to listener interpretation based on a sound's source or significance, which is useful for distinguishing and identifying environmental and metaphorical elements in sonic contexts. *Semantic listening* focuses on decoding symbolism, such as language-based content (a mode less emphasised in ambient or acousmatic sound). Crucially, *reduced listening* – an expanded concept from Pierre Schaeffer (1966) – considers engagement with sounds as objects in and of themselves – closely analysing sonic textural and timbral qualities, (i.e. "scraping", "grinding", "gargling", and onomatopoeic phrases like "tapping" or "booming") and is useful for deeper understanding of sound, linked with the aforementioned phenomenological universalities of sound descriptors (such as "warm") and synesthetic cross-modalities.

The exploration of synesthetic paradigms through the use of AI-generated visual artefacts allowed for the articulation of relationships between qualia arising from written prompts, visual stimuli, tactile textures and aural phenomena. Sound objects gain new meaning from multisensory stimuli, suggesting that cross-modal methodologies can be utilised in music creation, especially in dealing with phenomenological, qualia-based understanding of complexity in nature and physics.

Hyperrealities and abstract sound components were generally embraced in the production of the portfolio. Why then, in a largely generative portfolio, does *Stochastic Genesis* impulsively steer away from chance or random control over spatialization? In part, the music is referring to observable scientific phenomena which took place in definable non-abstract world-space, so depictions of existent emergent phenomena within surrealist spatiality felt inappropriate. Dennis Smalley's "transmodal perceptual contingencies" (2007, pp.40) informed the use of shifting parametric control and how manipulating amplitude, tonality, and implied surface phenomena introduce perceived stillness, propulsion or locomotion within a defined sonic world-space. These methods helped define the behaviour of acousmatic sound objects within the acoustic field, without warping, expanding or contracting the surrounding spatial field in ways that sound intrusively surreal, or transcend naturalistic acoustics. Constrained focus on centrally generative sound artefacts creates predefined naturalistic spatial audio environments, where spatial effects such as reverbs, delays, resonators, and stereo imaging are carefully parametrically programmed, rather than left to the whim of stochastic modulation sources.

### 6.3 Generative Components: Applied Stochasticity

Drawing from Xenakis (1992), the portfolio integrates stochasticity for the purpose of balancing emotional evocation and thematic relevance, positing that art should aim to elicit some kind of exaltation in its audience. For this project, purely aleatoric principles were rejected in place of predefined aesthetic, thematic and tonal sonic/musical practices where necessary, using considered application of stochastic components within. As Roads (2015, pp.348) asserts *“if formal consistency is all that matters, then one result should be as good as any other”*. This project embraces that artistic intent is paramount in shaping meaningful outputs. Whilst stochasticity is a useful tool - the very driving force behind the portfolio - the uncertainty derived from purely aleatoric creative philosophies can yield results less universally phenomenologically evocative. As Roads states (2015, pp.295) *“the quest for rigor through the use of formal processes is not a guarantee of artistic success.”*

### 6.4 Modularity Anywhere: MaxMSP vs. Modular Synths

Hardware modular synthesisers and graphical coding languages (particularly MaxMSP) offer unique advantages and limitations. Modular synths offer tactile immediacy, organic and emergent modes of music creation, and spontaneous, performative models of usage. Their physicality is what sets them apart. By no means is this to say that MaxMSP is inferior in generating system complexity, general “synthesis power”, precision, and pleasing sonic results. MaxMSP surpasses modular synths in many areas – data flows, parametric control of signal pathways, process visualisation, saving patches, near-unlimited patching without logistical limitations of any given synth, the list goes on. But crucially, the intangibility of digital instruments/interfaces and limited playability offered by graphical coding languages is significant. We here refer back to Heidegger’s premises of

*vorhandenheit* and *zuhandenheit*, where flow state emerges around conscious application of system design. The author found, (as is often generally assumed by hardware synthesiser users, rather than software-based interfaces) that *zuhandenheit* materialises more organically with a physical modular synth, allowing for faster immersion in creative flow. Feedback is more immediate and less ambiguous, a greater sense of control is perceived, time seems to transform, self-consciousness is lost and, perhaps most importantly, the intrinsic reward of using a physical interface above dedicated synthesiser circuitry (more so than software modelling) outweighs that of interfacing with a computer. These dimensions of Csikszentmihalyi's flow were found to be punctuate using physical synthesisers, in ways that software dilutes. Modular synths provide uniquely inspiring, productive canvases in part *due* to their physicality. Inherently, it seems to come down to the user and what their creative priorities are – and for many the clunky workflows, hefty price-tag, transitory nature of patches and general unpredictability of hardware are not only well worth the resulting workflows, but the limitations themselves seemingly make the emergent processes creatively stimulating and beautiful.

That being said, the creation of the portfolio became reliant on computational methods around logistical constraints like arrangement and creating outputs to deadlines. swathes of the musical composition relied entirely upon computers. It is worth stating that, whilst modular synths inspired the process for the project and the creative principles therein, the project *could not* have been realised without the use of computers and *could* have been realised without a modular synth. Modularity can comfortably exist in the domain of computers, and accessibility of computers is now near universal. For practitioners without access to a hardware modular synthesiser, all of these concepts can be realised affordably with computers. The creative principles across the project do not require a physical modular synth, just the creative doctrine of modularity. As the portfolio progressed, opportunities to ingest

modularity within DAWs arose, and it became clear that principles of pseudo-modularity are comfortably attainable within Ableton. It is my hope that this research emphasises modularity as creative philosophy over the importance of physical hardware.

## 7 Evaluation & Reflection

Evaluation & Reflection will articulate the findings of the overall research undertaking, their implications across art and music creation, as well alluding to technoscientific attitudes across modernity and the human condition. It concludes the research questions and signals forwards toward future applications of the designed practical processes and new research avenues.

### 7.1 Phenomenological Analysis

Phenomenology sets aside both the application of sciences such as physics and psychology, as well as “common sense beliefs” by means of Husserlian bracketing (closing oneself off from any unconscious biases or presuppositions). Science does not *prove* things for phenomenologists per se, as phenomenology explores a given phenomenological object’s system of metaphysics, rather than pragmatically describing it. Phenomenology calls for a reinterpretation of science that includes the emergent qualia. This is useful in that a given science’s phenomenologies can lead to new insights and appreciations for the science, with those appreciations being what we as artists can exploit creatively.

Heidegger’s reflections on technology suggest that technology’s role is deeper than mere utility; warning that our understanding of technology, or lack thereof, contours and colours our very approach to existence. In *The Question Concerning Technology* (1977), he introduces “enframing” (*Gestell*), positing that technology’s influence over human conscious and subconscious can position reality as a resource to be controlled, disconnecting humanity from authentic engagements with the world in place of reciprocal, utilitarian and extractive outlooks. Technological thinking restricts our understanding of being, and collective awareness surrounding

technology is crucial in remedying one-dimensional thinking and a technology-driven shaping of our collective future. The concept of “enframing” aligns with this thesis’ aim in exploring and interrogating the impact of complex technologies on the creative process, identifying how technological frameworks make up a fundamental component of human perception, and can constrain or embellish our lived experiences. The outcome of this application of thought is a clear advocacy for a shift towards more open-ended, complex systems-based approaches in music creation, which by extension advocates for a similar collective awareness of complex systems and complexity in other aspects of our lives.

This work seeks to dissolve purely utilitarian views of technology and embody emergent, symbiotic perspectives and practices that embrace unpredictability and multiplicities in sound design, broader creative practice, and even philosophical perspectives when considering our collective future across the unfolding of the twenty-first century. Collective understanding of both technology and complex systems theory, and their interconnection, could counterbalance enframing by cultivating understanding of technology as emergent phenomena and a means of comprehension, not a tool for domination or extraction of the natural world and its own emergent complex systems.

## 7.2 Ecological Implications: Instability and Collapse

We here refer to Feynman’s rose and what he expresses about perceiving natural systems. Our lived experience of the world is reducible to our subjective internal synthesis of sensory data from a myriad of chaotic and indeterminable phenomena, resulting in incorporeal sets of perceived qualia. Abstracted temporal scales like those surrounding emergence and evolution can be irreducible and intangible to our technologically shaped perspectives, but engaging with technology and art with

an awareness of inherent complexities can push us to consider our position in time; societally, evolutionarily, and with regards to the climate crisis.

Such awareness could steer humanity towards an urgent responsible reengagement with technology, acknowledging its potential for both positive and adverse influences on our future. Better understanding of complex systems could reshape our orientation from one focused on extraction and control and towards one of symbiosis, adaptability and the integration of insights from fields such as ecology, network theory and cybernetics, pointing towards sustainable development, ethical responsibility and authentic, mindful experiences of the world.

### 7.3 Research Questions: Conclusion

The overall practice-based research undertaking answers the research questions (Sec 1.3) thusly;

1. Modularity across modular synth interfaces is highly useful in sonic exploration and depiction of natural/scientific phenomena, in particular complex systems, which the developed practice of embodied systems displays by means of performative research data (Barrett & Bolt, 2007, pp.151) across Volumes I & II of this research project.
2. Phenomenology is adept in both informing *and* analysing cross-modality in sound creation outputs, as well as the derived psychoacoustic qualia for both practitioner and audience.

These findings are articulated across Secs 5 & 6, with the situated studio practice serving as evidence for the research outcomes, further evidence for which can be

found in Volume II. The projects' aims (Sec 1.3) were also realised to a relatively full extent. Implemented practices were designed for sonic exploration and depiction of complex scientific phenomena with adequate analogic accuracy, relevant philosophies applied to system/instrument design were demonstrated to a decent extent, and it is the hope of the author that modularity was emphasised as a crucial concept in sound synthesis and design – particularly in the realms of acousmatic sound and abstract music creation.

Shortcomings of the research is articulated in the next section, as well as Secs 9.1 and 12 of Volume II.

#### 7.4 Scope & Methodological Critique

Fundamentally, the melding of disparate fields - spanning phenomenology, sound synthesis theory, complex systems theory, and synesthetic perception, alongside theories of emergent life – extends far beyond the scope of this research project. Such interdisciplinary convergence risks diluting focus and hinders exhaustive, scientifically robust conclusion within the specific domains. The projects' aims however were not to provide definitive findings in any of said fields, rather to provide insights surrounding their cross-sections through the medium of sound. Emphasizing connections rather than mastery, the project proposes frameworks for artistic endeavour where the very intersections *themselves* yield meaningful and enriching contributions to our lives as artists and audiences, and suggest further application of the designed processes within the sciences.

#### 7.5 Future Applications

In terms of implications for practice, three key thematics can be drawn from the research for use by practitioners. Firstly, the project emphasises the potential for

embracing uncertainty and emergence within generative compositional and artistic processes. By designing systems that leave deterministic control up to chance, practitioners can build and explore aesthetic territories that exist *beyond* the realm of their creative intent or imagination. Secondly, *Stochastic Genesis* embraces and reinforces the importance of perceiving sound or music as fundamentally temporal phenomenological experiences, underscoring the shift of focus away from considering sound objects as static, and towards morphological and dynamic perceptual engagement. Finally, the research explores a novel approach to applications of complexity theory in creative sound practice, demonstrating that the application of complex systems can push practitioners beyond aesthetic strategy to further ethical and ecological themes. The mirroring of interconnectedness and fragility of complex systems helped to cultivate deeper sensitivity to relational dynamics, be those environmental, technological or social. These thematics strengthen notions surrounding expanded practitioner worldviews of creative outputs that embrace emergence, ecological consciousness and phenomenologically informed practice.

It is my hope that this research poses new insights surrounding sonic art and synthesis, opening avenues of enquiry beyond the scope of the portfolio and thesis. Universalities and commonalities across the expanded corpus of electronic artists and experimentalists could be investigated to ascertain concrete findings around the aggregate nature of modularity as creative principle. Embodied systems practice could be applied to all manner of physical or naturalistic systems as subject matter, and more contemporary academic perspectives, (namely Ihde's postphenomenology, and his positions surrounding embodiment and transhumanism) applied within the given context. The blurring of lines between user and system pose interesting avenues for sonic exploration, and I hope to pursue these avenues across a PhD.

## 7.6 Closing Statement

*Stochastic Genesis* explores the intersection of modularity in sound synthesis, generative music and interdisciplinary narratives, highlighting sound design's capacity for embodying complex systems and expressing philosophical concepts therein. Integrating scientific frameworks and creative methodologies, the work demonstrates how modularity and generative principles are prolific tools for artistic expression *and* conceptual realisation. Whilst limited in areas, the insights affirm the value of cross-disciplinary approaches in advancing creative practices. The portfolio at once reflects a study of sound, and also a broader enquiry into interconnectedness surrounding technology, complexity, systems, and creativity.

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# Volume II: Portfolio

## 8 Portfolio Introduction

Volume II exists as a journalistic account of the processes applied across the creation of the portfolio. It details many of the applied generative procedures, and particularly the influence of scientific principles from the abiogenesis narrative, going into more detail than the thesis allowed for, and displays a more in-depth creative process breakdown.

### 8.1 How to Read the Portfolio

The portfolio is broken into sections delineated by full compositions and their composite sonic artefacts where they are relevant. It is recommended that the reader samples completed compositions and sonic artefacts whilst reading – feel free to listen along as you go.

Full Compositions: <https://rorygreenarts.bandcamp.com/album/stochastic-genesis-compositions>

Sonic Artefacts: <https://rorygreenarts.bandcamp.com/album/stochastic-genesis-sound-artefacts>

## 9 Scientific Overview

### 9.1 Positioning the Author

One purpose of the included portfolio and its structure is to display the degree to which science informed the creation of the portfolio, and its emergent findings. It is worth noting that *Stochastic Genesis*' author is solely an electronic musician, sonic artist and synthesist, *not* a biologist, or any form of scientist out with the domain of sound. The purpose of the research is to explore potential creative avenues for sound design from the perspective of the sound designer. The overall research project alludes to potential methodologies intended for collaboration with scientists, but the research itself errs further from scientific rigour and closer towards artistic reflection *inspired* by science. The portfolio premise posits that artistic modes and methods can be particularly useful for exploring and communicating abstract or convoluted concepts in science, (in this example complex systems and abiogenesis). The approach is based upon the premises outlined in Sec 2.4 *Wonderment as Phenomenological Utility*, positing that collaborative methods between the arts and scientists can translate elusive, abstract concepts and their derived allure to the layman, and even help scientists to express what motivates them in their discipline.

### 9.2 Depth of Scope

The scope of the overall undertaking limits the feasible amount of scientific research and implementation and instead focusses on methods surrounding sound design and in particular modularity and generative music as creative practice. The project prioritises an exploration of compositional techniques and practical applications, enabling focus on the phenomenological aspects of sound creation, nuanced

parametric interplay and the philosophical creative findings therein. A larger project, or one that involves collaboration with scientists would allow for deeper scientific enquiry and accuracy.

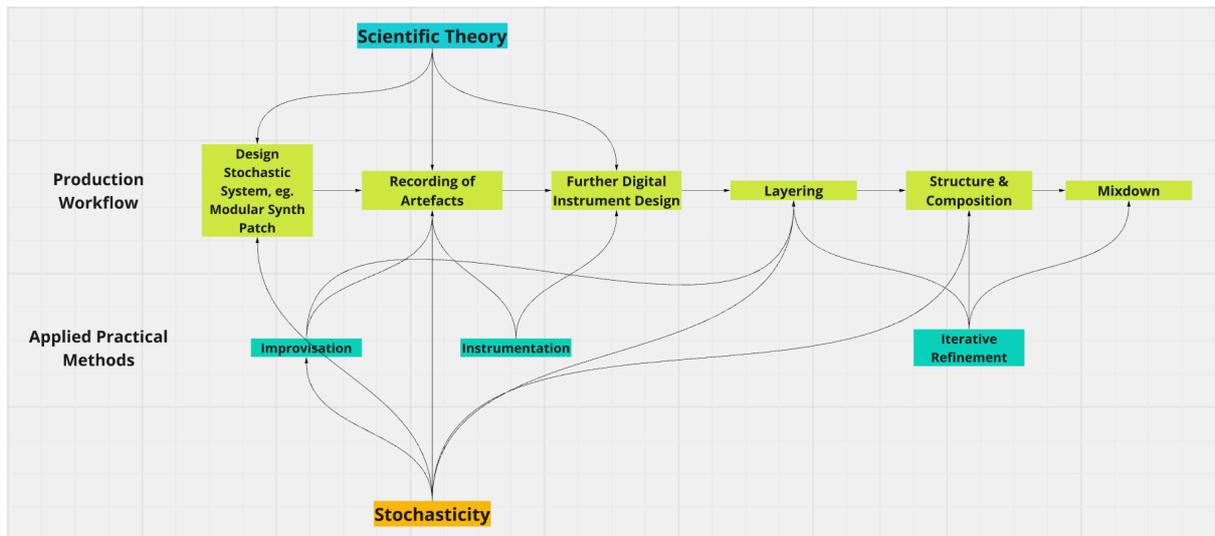
## 10 Studio practice: Beyond modularity

### 10.1 Introducing Workflow & Balancing Modularity

The composition across the portfolio is generally experimental as the portfolio employs stochastic processes based on the abiogenesis narrative. “Happy accidents” are inevitable, and wholly embraced, (where they contribute to desired sonic aesthetic), which should be taken into account whilst analysing the applied processes.

Sonic artefacts were created using the embodied scientific principles and then used as compositional tools or materials during the arrangement process. The arrangement process was also, where possible, inspired by the scientific narrative and principles of modularity were ingested everywhere possible to augment the goals of the portfolio (using modularity as creative foundation).

We again refer to the iterative and intersecting creative macrostructure diagram in Sec 5.4.



*Figure 10.1 Workflow Methodology Diagram (Author's own)*

The diagram is useful in that it depicts clearly which stages of the overarching compositional process are informed by either/both scientific theory, and practical compositional methods. This is worth remembering moving forward: the process is *inherently* iterative, and different modes of production were applied at different stages of the overall composition, reiterated, revisited, embellished, edited and deleted, depending on the desired sonic outputs with reference to aesthetic goals, narrative foundations and phenomenological premises.

## 10.2 DAW Implementation

Ableton Live provides the structural backbone of the completed soundworks, as well as providing recording capture for the individual artefacts. It was utilised in assembling the sound materials generated from the meta-modules and other sound sources across the project. Ableton thrives as a tool for combining generative, semi-generative and non-generative compositional techniques, blending modularity with conventional synthesis/sequencing methods. Many of its MaxforLive modulation devices are now mappable to practically every parameter, giving way for pseudo-modular workflows that incorporate modularity as creative process.

It is worth here noting the existence of BitWig (accessible: <https://www.bitwig.com/>), an arguably far more “modular” DAW. Regrettably, the author didn’t have access to BitWig across the project but would like to state that when ingesting maximum modularity into all possible workflows, BitWig is arguably a much more powerful tool than Ableton Live, and interfaces with hardware modular synths more fluidly.

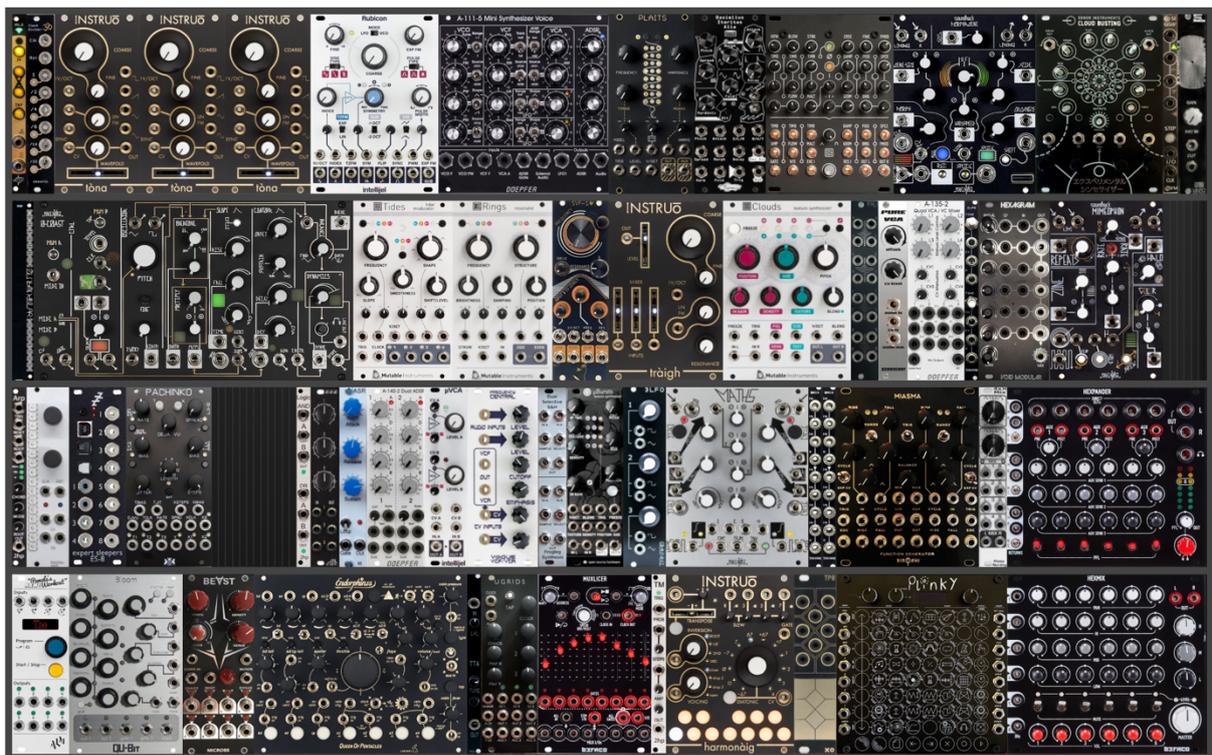
To clarify, many of the melodies, granular textures and sampling processes were composed within Ableton Live and not modular synth, in order to help tie together and structure the compositions created from the artefacts. The artefacts – predominantly created with embodied systems - were used in all manner of different ways as will become clear across the portfolio; sample sources, drones, whole parts of musical mesostructures, sources for granular engines, and many more. They were treated like versatile sound materials, available for inclusion as complete components or to be drawn from in any and all ways possible.

### 10.3 Compositional toolkit/skills

Other electronic hardware was used across the creation of the portfolio, once again, embracing modularity where applicable. Various analogue and digital synthesizers and a “ 12 track drum computer and synthesiser” (the Elektron Syntakt, for the purposes of this project effectively a drum machine) were used in tandem with the eurorack system and Ableton to create artefacts, (which leaned much more heavily on the modular system) and complete compositions (utilising standalone synths, samples and software instruments to create instrumentation/texture design to tie the composite pieces together).

### 10.3.1 Modular System

The modular system used across the portfolio went through several changes as the pieces progressed, but at time of completion it is set up as follows:



*Figure 10.2 Modular System used for Stochastic Genesis (Author's own)*

Accessible: <https://modulargrid.net/e/racks/view/1566504>

Full list of modules & their functions:

[https://modulargrid.net/e/modules\\_racks/data\\_sheet/1566504](https://modulargrid.net/e/modules_racks/data_sheet/1566504)

It's worth noting here that there is conflicting literature and wildly varying nomenclature around many terms existent within the world of electronic musical instruments. Rather than a lack of definitions, we can observe manufacturers creating unique and unusual instruments that bend classic definitions. For example, on parameter controls on instruments designed by Make Noise we see classic

envelope stage definitions (attack, decay, sustain, release) give way to *rise, fall, onset, slope, exp.*, (for their differently staged function generator designs, named *slope* and *contour*).



Figure 10.3 Make Noise 0-Coast, Semi-modular Synthesiser (Make Noise, 2017)

Manufacturers will name their control interfacing however they please, and generally the more experimental the synth or module, the more unusual the parameter definitions. Some panel controls may work as “macro-controls,” (i.e. on macro-oscillators such as the Mutable Instruments’ Plaits) and have rudimentary parameter labels (such as timbre, morph, and harmonics) that control vastly varied parameters dependent on the state of the module.



*Figure 10.4 Mutable Instruments Plaits, Eurorack Module (Music Store, n.d.)*

This is something to be cognisant of moving forward and can often support and excite the creative principles of complexity as method in *Stochastic Genesis*. The project focuses more on universally recognised functionalities than parameter controls specific to certain devices.

### 10.3.2 Other Synthesis Hardware Used

ASM Hydrasynth (desktop): <https://www.ashunsoundmachines.com/hydrasynth-desk>

UDO Audio Super 6: <https://www.udo-audio.com/super-6>

Elektron Syntakt: <https://elektron.se/explore/syntakt>

Behringer Deepmind: <https://www.behringer.com/product.html?modelCode=0722-AAA>

Waldorf Blofeld: <https://waldorfmusic.com/blofeld-keyboard-en/>

### 10.3.3 Software Instruments

All Ableton stock instruments: <https://www.ableton.com/en/packs/>

Samplr (ios): <https://samplr.net/>

Xynthesizr (ios): <https://apps.apple.com/gb/app/xynthesizr/id720810459>

Spitfire LABS: <https://labs.spitfireaudio.com/>

## 11 Soundwork Overview

What follows is a breakdown of the soundworks that make up the portfolio, including all completed compositions and their constituent sonic artefacts. The breakdown is not fully comprehensive (i.e. it is not a list of every single incremental production process and method applied across the creation of the portfolio, which would be beyond the scope of this overview), but instead focusses on the applied processes relevant to the principles at the core of the practice based research undertaking, and reflects on generative themes, embodied systems, complex systems theory, modularity and phenomenological sound. Modular patches may have been expanded on with further modulation or audio processing once recorded to achieve desired, predefined and musically pleasing results. They can be accessed in the digital portfolio, or via the links provided in Secs 5.1 and 8.1.

### 11.1 Origin State

#### 11.1.1 Composition 01: Origin State



The first completed soundwork is the most comprehensive in terms of studio documentation, relevant practice-based research processes, and serves as an overarching example for the succeeding embodied systems and compositional processes. It became apparent after the creation of *Origin State*, that the scope of the project would not allow for such in depth scientific reflection, so a less extensive approach was taken. However, it serves as the most thorough example of the appliance of embodied systems.

*Origin State* – telling the story of the accumulation of prerequisite conditions necessary for the emergence of early biomatter – comprised of a set of techniques and meta-modules that embody some of the natural systems that make up *Nine requirements for the origin of Earth's life: Not at the hydrothermal vent, but in a nuclear geyser system* (Muruyama et. al, 2019) and their functions in *Habitable Trinity* (Muruyama et. al, 2015). A periodic table may be useful moving forward.

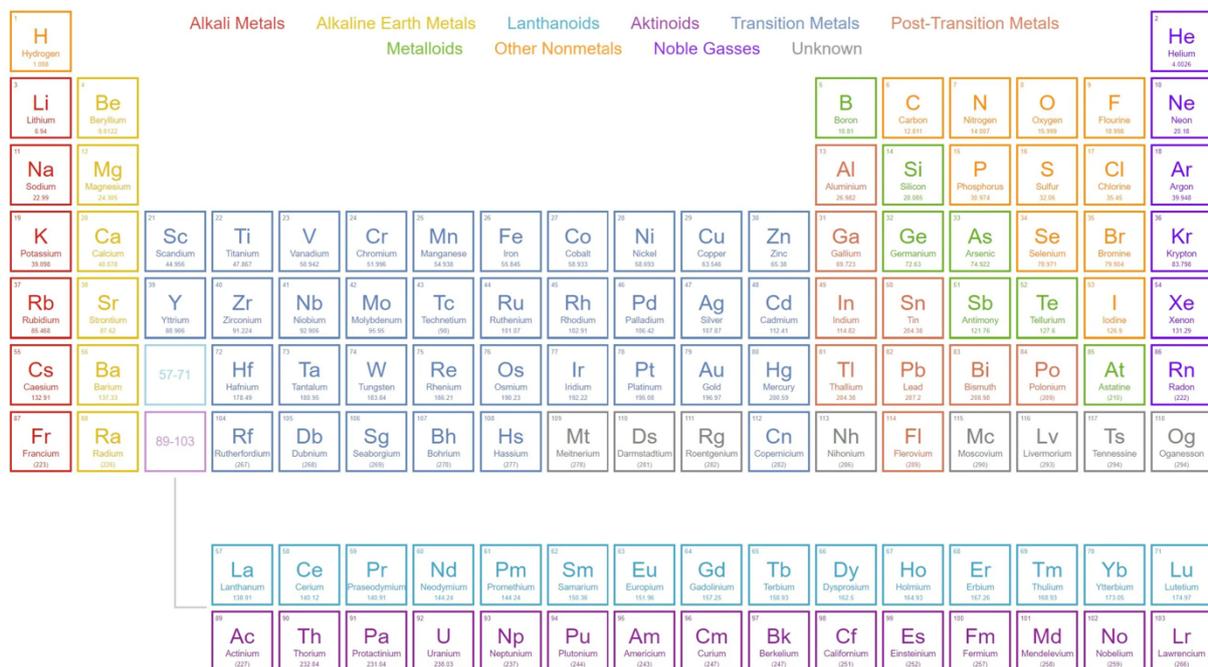


Figure 11.1 Periodic Table of Elements (ReAgent, 2023)

The nine requirements are;

- (1) an energy source (ionizing radiation and thermal energy)
- (2) a supply of nutrients (P, K, REE, etc.)
- (3) a supply of life constituting major elements; CHON (carbon, hydrogen, oxygen and nitrogen)
- (4) a high concentration of reduced gases such as CH<sub>4</sub>, HCN and NH<sub>3</sub> in caverns
- (5) dry-wet cycles to create membranes and polymerize RNA
- (6) a non-toxic aqueous environment

- (7) Na-poor water (less salt, fewer heavy metals, and neutral pH)
- (8) highly diversified environments
- (9) Further cyclic conditions (such as day-to-night, hot-to-cold etc.)

*Origin State* comprises of embodied systems for, or - in the cases of prerequisites (6) and (7) - thematic reflection upon each of these prerequisite conditions. The contained sonic artefacts, and meta-module patch designs are as follows;

### 11.1.2 Artefact 01 Ionise



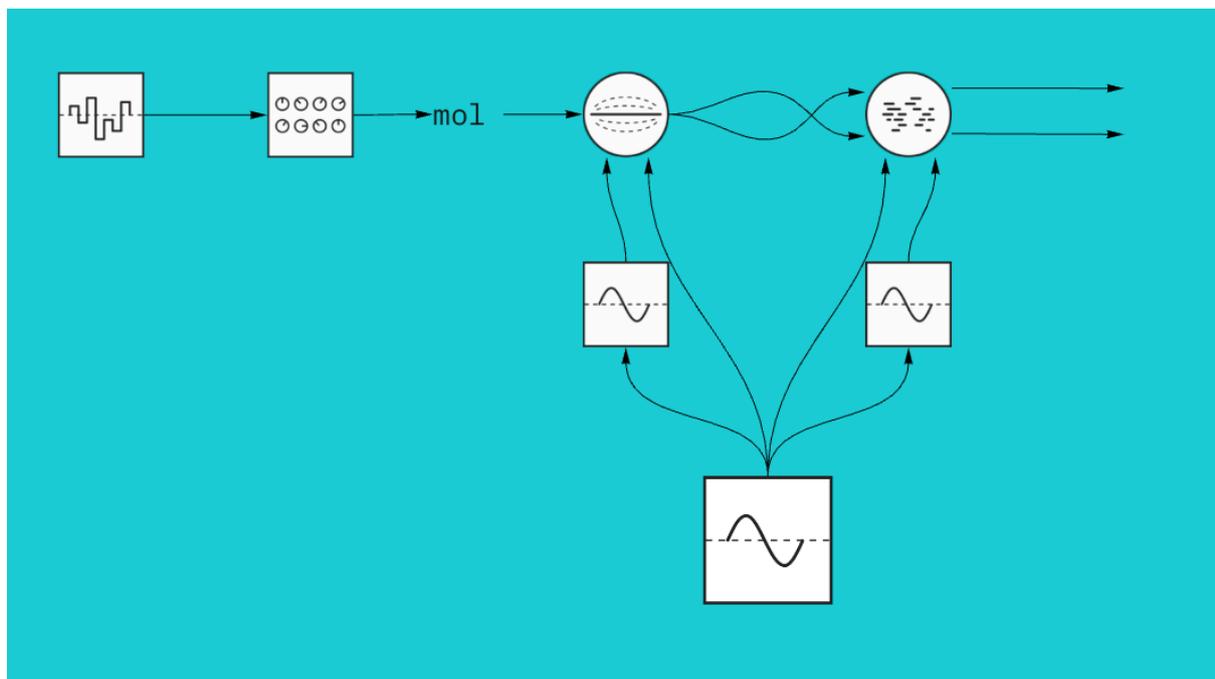
#### **(1) an energy source (ionizing radiation and thermal energy)**

Thermal energy (also called heat energy) is produced when a rise in temperature causes atoms and molecules to move faster and collide with each other. The energy that comes from the temperature of the heated substance is called thermal energy.

Patch breakdown:

- Random voltage generator representing the chaotic movements of subatomic particles
- Particle-excited physical modelling corpus (in this case, Mutable Instruments' *Elements*) representing the particles themselves in phenomenological subatomic world-space
- Granular processing of the resonator representing the emergent ionized radiation

Note: across the portfolio, modulation and parametric control are applied and fine-tuned wherever it may be sonically pleasing. The final goal here is emotionally affective symbolic soundwork rather than strict analogic data representation (Kramer, et. al, 1999) as explained in Sec 4.3.



*Figure 11.2 Meta-module: Prerequisite (1) (Author's own)*

(2) a supply of nutrients (P, K, REE, etc.)

### 11.1.3 Artefact 02 Shimmer Compounds



The nutrients listed are as follows;

- Phosphorus
- Potassium
- Rare Earth Elements (metals/minerals, for example lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium etc.)

C, H, O, and N make up 95% of living organisms, and the remaining 5% is made up by nutrients such as potassium (K), phosphorus (P), iron (Fe), calcium (Ca) and magnesium (Mg).

Translating these scientific principles into sonic artefacts for use in the finished composition involved investigating their behaviours and creating embodied systems that reflected on them, with varying accuracy. How do these compounds effect DNA/RNA?

- P: protein synthesis, regulation of gene expression (Raven, 2013)
- K: stabilisation of main functional ligands such as messenger RNA and transfer RNAs, as well as ribosomal RNAs and ribosomal proteins, via the interaction with nitrogen and oxygen atoms of side chain residues, nucleotide bases, polypeptide or sugar-phosphate backbones (Rozov et al, 2019)
- REE - essential nutrients for life are derived from granitic continents enriched in K, P, rare earth elements (REEs), and other elements (Muruyama et. al, 2019)

Basically, these come from granitic rocks.

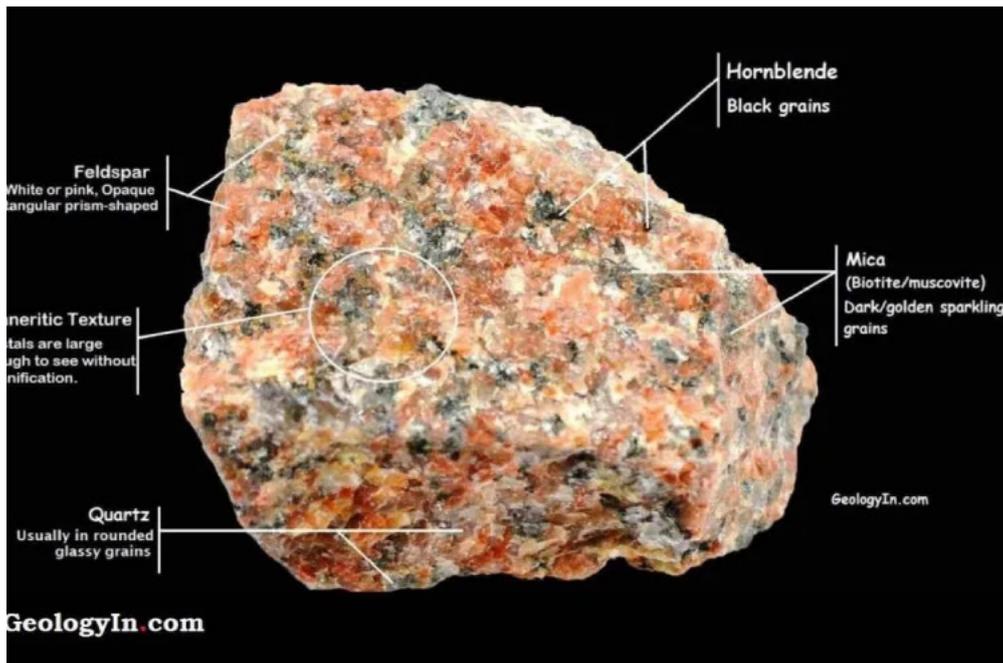


Figure 11.3 What is Granite and How is it Formed?: Granite minerals composition (GeologyIn, n.d.)

Due to the relative complexity of the diverse elemental compounds present at this stage, and the componential size of this single prerequisite condition, a more vivid, analogic approach was found to be useful, considering granitic, mineral rich igneous rocks and the expression of textural, phenomenologically synesthetic sentiments with modular. The rocks are coarse so “rough-sounding” analogue distortion was applied. They are visually complex so different sonic textures were blended. They glitter, so jittering FM synthesis was employed, processed with sparse granular bursts rich in high frequency content, implying shimmering or glistening. Geological recordings were loaded into a granular sampler to express breaking, shifting and grinding, as per Roads’ (2015) principles of sound fission.

Patch Breakdown:

- Oscillator and noise bank, filtered: representing igneous make-up
- FM algorithm through granularization: representing nutrients within
- Granular sampler playing back geological samples: representing shifting, breaking, splitting

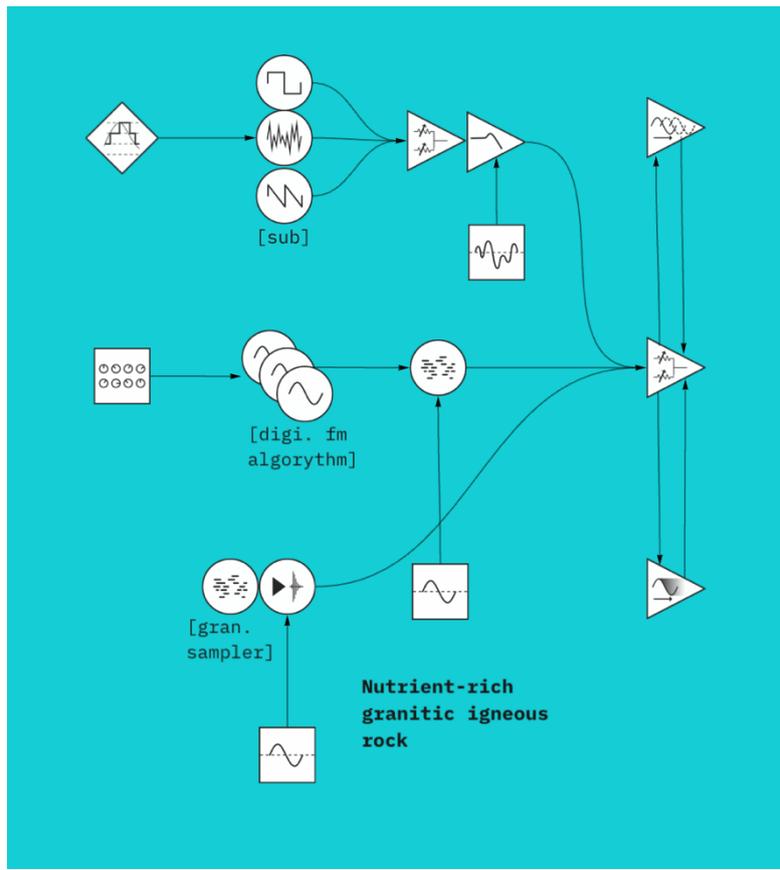


Figure 11.4 Meta-module: Prerequisite (2) (Author's own)

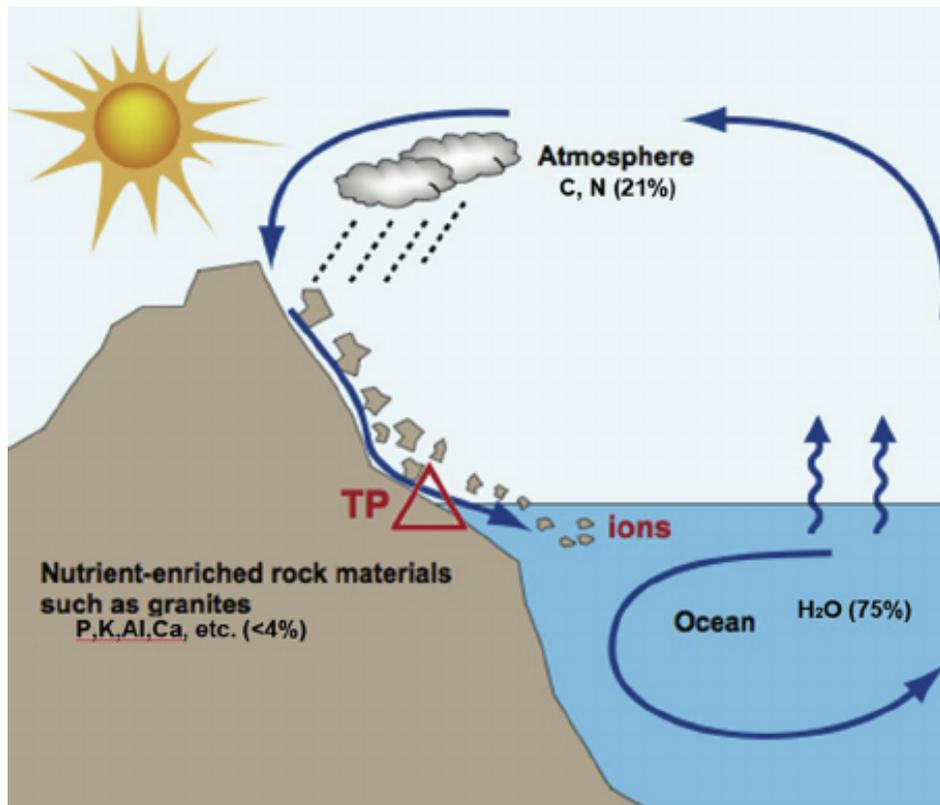
A review of this patch can be found in Sec 5.6 so won't be repeated here.

#### 11.1.4 Artefact\_03: Settle/Flow



(3) a supply of life-constituting major elements; CHON/Habitable Trinity

Artefact\_03 reflects on the following diagram and subsection from *Habitable Trinity* (Dohm & Muruyama, 2015).



*Figure 11.5 Habitable Trinity Model (Dohm & Muruyama, 2015)*

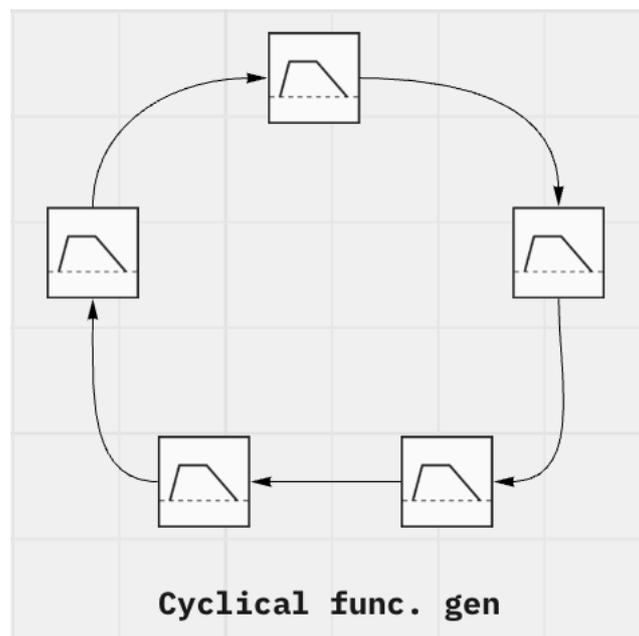
The habitable trinity model is comprised of;

- (1) water (elements derived from ocean)
- (2) C and N (from atmosphere), and
- (3) nutrients (from landmass).

According to Dohm & Muruyama, interactions between the atmosphere, oceans and landmasses encompassed vital systems for life's origin and evolution. Chemical weathering and erosion transported necessary nutrient rich material to oceans, providing essential prerequisites for abiogenesis to occur. Energy and material circulation, driven by the sun, supported life's emergence and proliferation.

The identification of the cruciality of cycles became paramount in the design of embodied systems across the portfolio's synth patch methodology. Balanced cycles

with gentle disruptions or mutations are a key concept in the emergence of life on earth, as well as introducing instability to “stable” patches embodying stable complex systems, so a meta-model was designed called “cyclical function generator”, wherein a system of multiple function generators (essentially simple attack/decay circuits) are chained and then cycle back so that modulation patterns can cycle around in tandem.



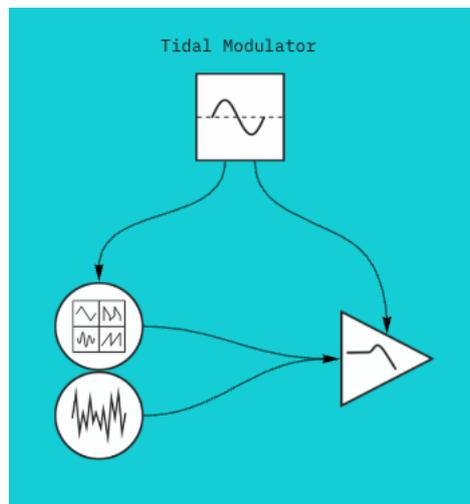
*Figure 11.6 Meta-module: Cyclical Function Generator (Author's own)*

Each function generator can be programmed in accordance with the given nature of the meteorological phenomena depicted. The rise/fall circuits themselves will control amplitude/trigging of the depictions of said phenomena (particularly useful in employing Roads' (2015) fluid morphologies, Sec. 3.3), creating a cyclical path, with dependent motion and overlap where appropriate for the narrative subject matter.

### 11.1.5 Artefact 04: Aeriform



Aeriform reflects on water cycles, where a cyclical function generator guides audio from the meta-module for water (below) through Roads' (2015) fluid morphologies for granular synthesis, depicting the water evaporating, coalescing, moving as particles or streams, and then back around.



*Figure 11.7 Meta-module: Water (Author's own)*

The wavetable oscillator in the water meta-model is modulated to mimic the behaviour of water, dependent on the behaviour of the water in the given context in the narrative, for example; ocean waves, splashing water within caves, running over rocks, etc.

The meta-module for evaporation/melting is as follows:

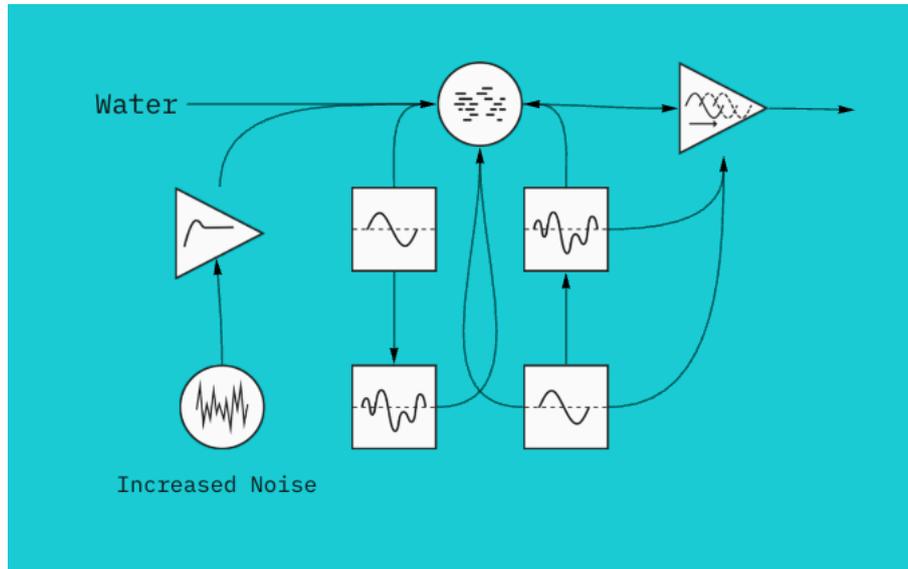
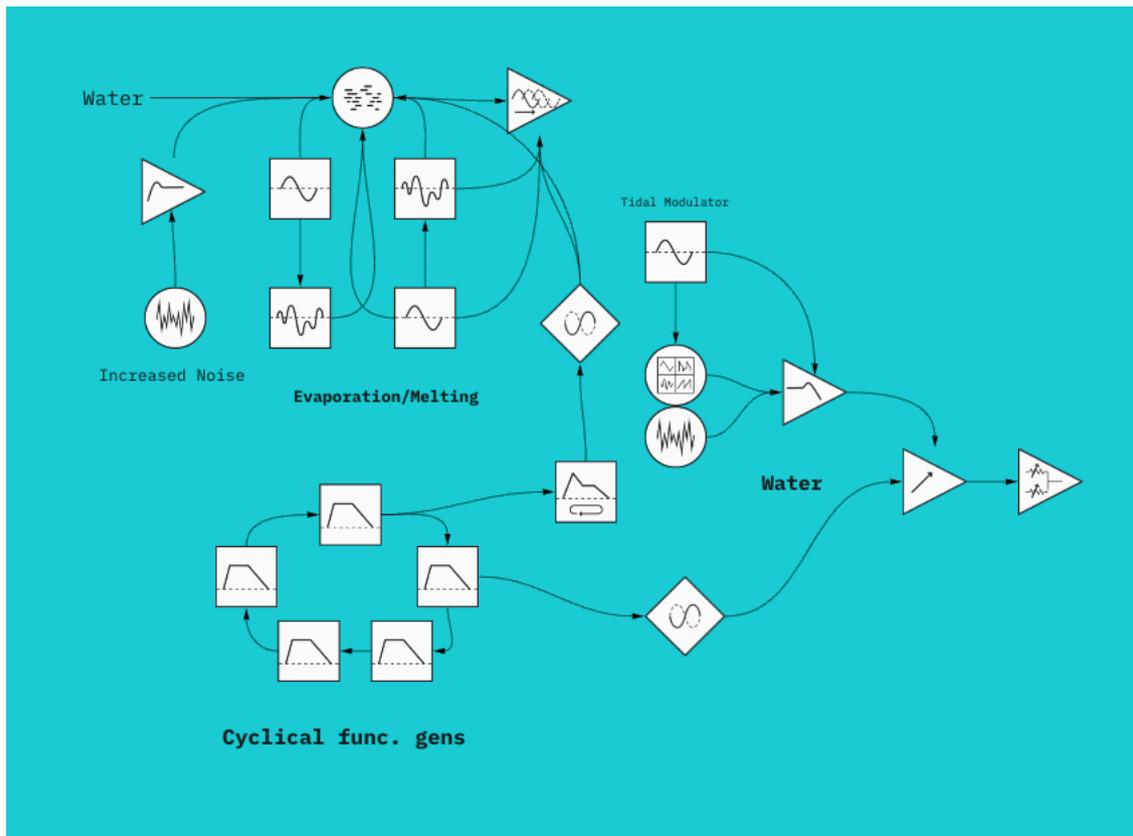


Figure 11.8 Meta-module: Evaporation/Melting (Author's own)

Again, deriving from fluid morphologies, granularization is employed for allegorical depiction of shifting states of water.

The combination of meta-modules for the patch that was recorded for the creation of *Aeriform* functions roughly as follows (roughly as modulation sources were added to fine-tune or embellish certain sonic characteristics of audio output to the taste of the author's creative intentions):



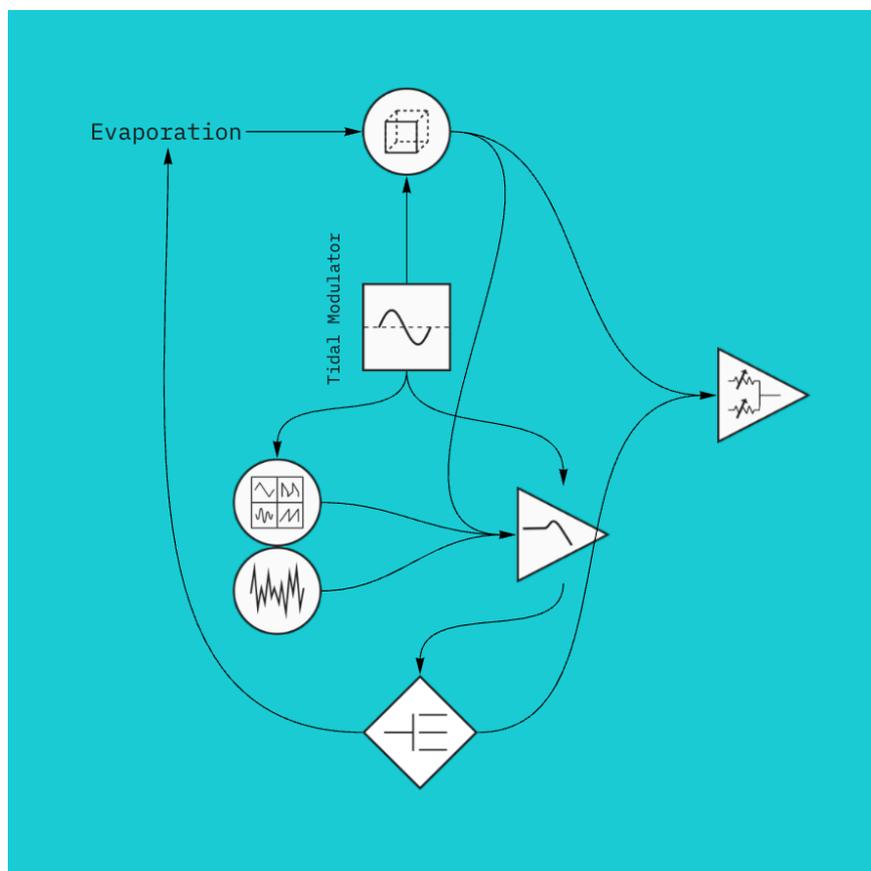
*Figure 11.9 Modular Patch: Aeriform (Author's own)*

Cyclical function generators (inverted) push granular output and delay to dry, settling granular/delay tap cloud structures. At the same time, water's amplitude increases, and another function generator moves the speed of the tidal modulator from a state of excited streams to a slower state, depicting near-stationary waves. Flow settles and the system returns to original state, ready for the cycle to begin again. Further white noise and quietening of said noise was included to imply settling, where noise phenomenologically depicts vapour, such as steam, (as steam can make white noise in the real world). Roads' (2015) taxonomy was followed, (as it was self-evidently inspired by shifting states of water) and functioned well in embodying water cycles.

(4) a high concentration of reduced gases such as CH<sub>4</sub>, HCN and NH<sub>3</sub>; caverns

Difficulties arose in the design of embodied system mechanisms to emulate gasses. Reduced gasses are diffused into open atmosphere or ocean, after they are produced through serpentinization, which is the case at mid-oceanic ridges or surface environment. To overcome this problem, an underground cave setting is ideal, because the reducing gas produced could be accumulated over time on the ceiling (Maruyama et al., 2019).

It seemed appropriate to create some kind of embodied cavernous resonator using Mutable Instruments' Elements, and then run the evaporation patch through it. Coalescent monolithic gaseous structure depictions can function similarly as in the previous patch, but running them as an exciter into the cave-corpus will produce drastically different sonic results.



*Figure 11.10 Modular Patch: Prerequisite (4) (Author's own)*

### 11.1.6 Artefact 05: Polymerize



#### **(5) dry-wet cycles to create membranes and polymerize RNA;**

The prebiotic reactions necessary for the emergence of the building blocks for life include the polymerization of amino acids to peptides and then the synthesis of RNA from nucleotides from repeated dehydration-hydration cycles in tidal flats, which has been consistently emphasized in the field (Deamer, 1997; Damer & Deamer, 2015). The tidal impact of the moon was considerably stronger during the Hadean eon than our own, (likely completing five tidal cycles daily instead of our humble two) (Benz et al., 1989).

*Pamela's New Workout* - a kind of clocking brain eurorack module - with dense capabilities around clocking, waveform generation, Euclidian step sequencing and pitch quantization (amongst many others) depicts the moon, holding temporal control over the tidal modulator, moderating the rate of the cyclical behaviour of Tides.

Seeing as water (as a physical construct) had already been explored, wetness on surfaces felt more interesting and appropriate, focussing on aural phenomenologies of wetness and dryness as a state upon perceived textural surfaces (embodying the aforementioned tidal flats).

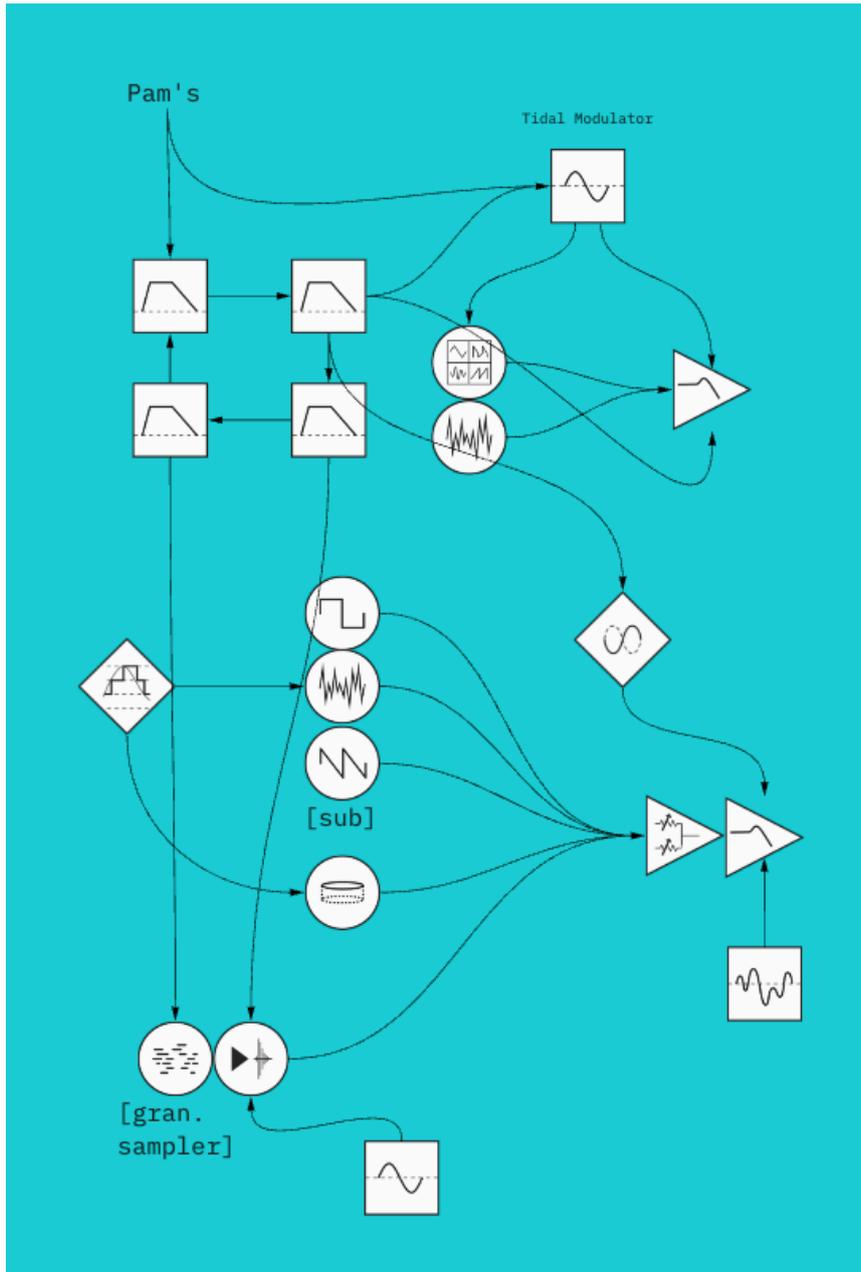


Figure 11.11 Modular Patch: Prerequisite (5) (Author's own)

### 11.1.7 Artefact 06: Cryogenician



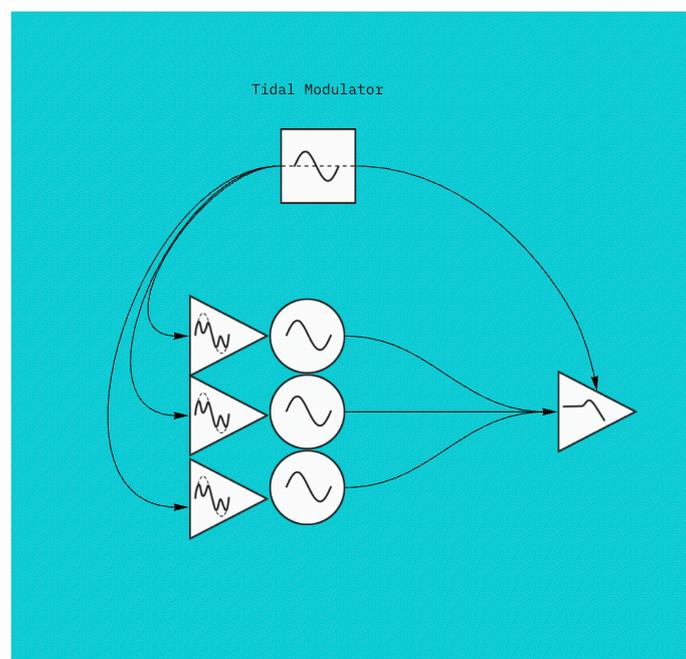
(6) a non-toxic aqueous environment; &

(7) Na-poor water;

The composition of *Origin State* served as an informative undertaking in how much complex audio generation is viable for a three-or-so-minute composition, without resulting in a work that sounded excessively overloaded with sonic objects.

Thankfully, prerequisites (6) and (7) are characterised more by their lack of toxicity and heavy metals in the subaqueous environments the abiotic processes inhabit.

Hadean water was enriched with Na and nearly devoid of K, so the sonic embodiment for prerequisites (6) and (7) was designed around a lack of harmonic content, focussing on gently folding sinewaves, which are in turn filtered, acting as a harmonic bed to lay under the overall composition. A tidal modulator shifts wavefolders, affecting behaviour “beneath” the embodied water, where the filter depicts the “surface” of the water – delineating a phenomenological depiction of a cleaner, non-toxic environment.



*Figure 11.12 Modular Patch: Prerequisite (7) (Author's own)*

## **(8) highly diversified environments**

Prerequisite (8) is at once more abstract than the prior seven (containing no explicit chemical processes) and contains the previous prerequisites themselves. For this, it felt thematically appropriate to convey prerequisite (8) by utilising the existing recorded artefacts, along with other samples and compositional processes within Ableton Live. Processes such as layering, sidechaining between elements, granular sampling and processing of existing recordings, timestretching and digital audio processing (with effects) were employed to imply diversity through dense textural interplay and stochastic interactions, mostly within Ableton's arrangement view. The resulting cacophony of sound object interaction embodies the diversified environments.

## **(9) cyclic conditions, such as day-to-night, hot-to-cold etc.**

The final prerequisite was depicted with the arrangement of the aforementioned artefacts created with cyclical function generators, in line with the principles outlined surrounding prerequisite (8). Sonic artefacts and their composite parts cycle in and out of the composition's final structure. This is interwoven with the pre-recorded cyclical components of the narrative, and further helped to build up the work as something of a partially cyclical complex system in and of itself, all of which was realised quite naturally during the piece's iterative composition phase. This became common practice across the remaining compositions.

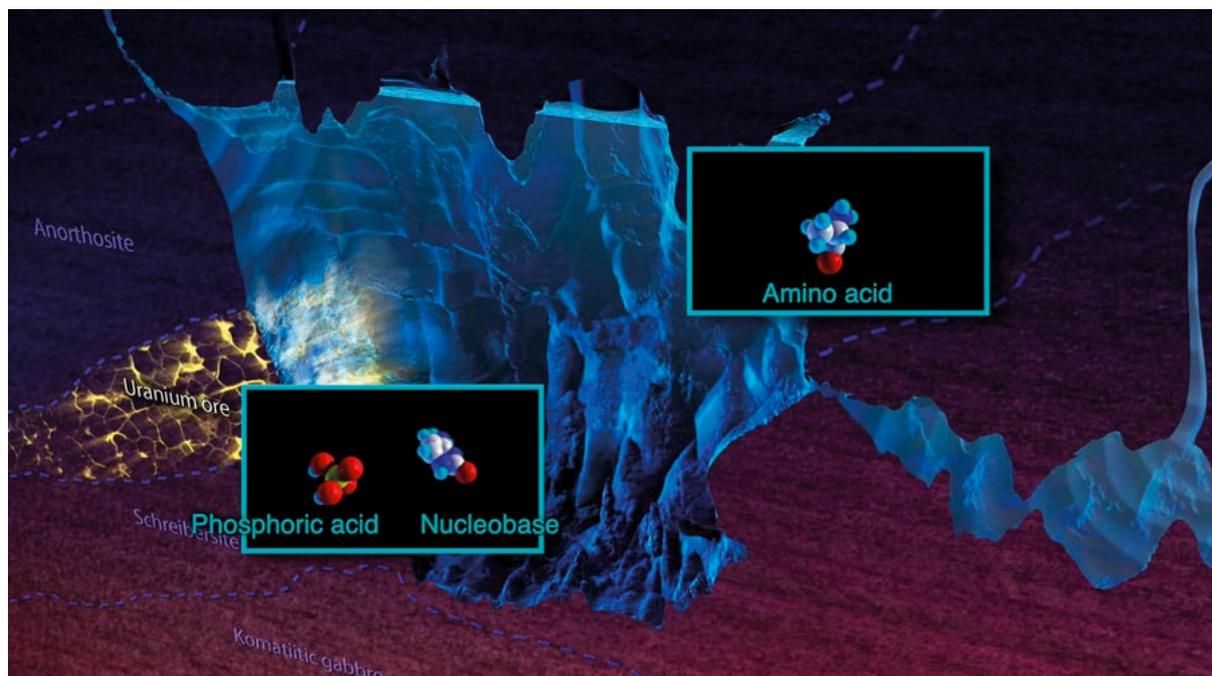
## **11.2 Origin State: Summary**

The creation of *Origin State* defined the implementation of meta-modules across the portfolio, as well as the scope. Upon creating the final patches and artefacts, it

was clear how much studio practice was necessary for realising concept, system design and testing for each composite soundwork. From here on, the portfolio prioritised implementing explorative methods and system design on a smaller scale: the purpose being to ingest examples of these implementations as practice-based research, not to exhaustively repeat them as fundamental artistic process. As the portfolio expanded, iterations of the work involved leaning more heavily on digital production methods, editing sonic artefacts in Ableton along with principles like layering and techniques for stochastic interplay of mesostructural sub-elements, and arranging the layered artefacts with further instrumentation and texture design into finished compositions.

## 11.3 Reactor

### 11.3.1 Composition 02: Reactor



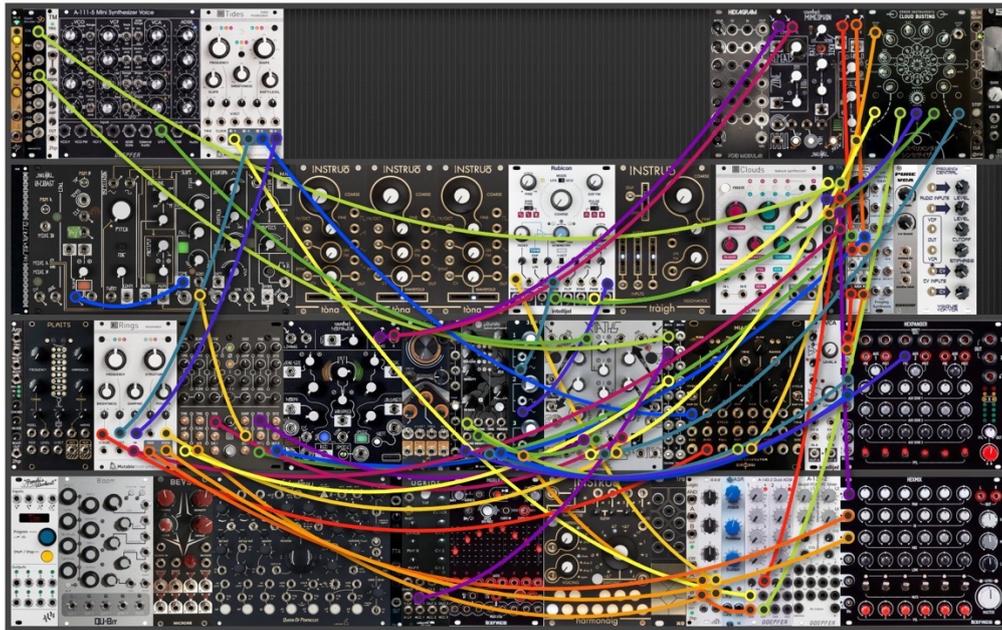
*Figure 11.13 Nuclear Geyser Model, taken from the film "The Whole History of the Earth and Life" produced by the Hadean Bioscience Project (Muruyama et al., 2019)*

*Reactor* reflects on the nuclear geyser model of abiogenesis (Ebisuzaki, 2016; Muruyama et al., 2017; Muruyama et al., 2019), where uranium ore provides radiation, causing nearby molecules in the surrounding water to irradiate and drive further chains of chemical reactions. *Reactor* ingests artistic notions of perceived qualia surrounding what might sound “nuclear” to our ears, as well as exploring the spatiality of the underground or subaqueous environments where such reaction chains may have taken place.

### 11.3.2 Artefact\_07: Fundamental Mechanism



The following image depicts a relatively simple patch used to create *Artefact\_7*. It is included to display inherent complexity in patch design and also to reiterate that common function-based patch diagrams are the optimum route for relaying patch methodologies, rather than precise patch diagrams unique to this particular modular system. The quantity of eurorack modules available, and the specifically tailored systems that vary from user to user mean that globally applicable patch philosophies should be based on commonly found functions rather than specific patch diagrams. It is also included to emphasise the resulting complex nature of each of the patches themselves.



MODULARGrid.net

*Figure 11.14 Patch for Creating Artefact 07: Fundamental Mechanism (Author's own)*

Reactor not only contains resampled audio from Composition 1, but also adopts meta-modules and practices that were developed therein. Here we see the creation of *Origin State's* applied processes informing the basis of the creation of the following artefacts and compositions. This reflects in the overarching meta-narrative, where prerequisite conditions depicted in *Origin State* actually drive the processes depicted in later soundworks.

### 11.3.3 Artefact 08: KREEP



Chemical instability is depicted in *Reactor* by means of unstable, random, inharmonic and arrhythmic modulation which is applied everywhere; the frequency of the frontmost impacts, the shape of the exciter of the impacts, the geometry,

dampening and spacing parameters on the resonator (Mutable Instruments *Elements*), the position at which the exciter “strikes” the resonator. Whilst some of this modulation is quite light, it ingests chaotic, shifting morphologies across the acousmatic hierarchy, resulting in mesoscopic interplay across every level of the sound generation process.

The drone in the background is modulated similarly, except modulation is applied harmonically, (or in-harmonically) and the unstable modulation applied works to much the same effect – destabilising aspects that we expect to sound harmonic (in line with Celibidache’s phenomenology of music) in order to imply instability.

The lead melody uses a single MIDI channel running into four software instruments in Ableton that are layered, and each is modulated extensively and asynchronously from one another, with cross modulation happening between and across layers and sources, employing complex modularity within Ableton Live. This layering of instruments draws from Roads’ (2015) mesoscopic layering as well as Eno’s (1978) approach of asynchronous looping (here using looping modulation patterns in Ableton’s modulation window rather than audio loops) and was used on multiple software instruments across the portfolio.

#### 11.3.4 Artefact\_09: Amino



Artefact\_08 utilises inharmonic sound design and large, dark spatialization to aurally emulate what might sound phenomenologically “*nuclear*” to our ears (explored further in Sec 11.4). Connotations of Geiger counters, metallic resonances and dark, empty world-spaces were taken into account whilst designing the artefacts, referring

to perceived sonic signifiers of man-made nuclear reactors as a narrative device within sound.

### 11.3.5 Artefact 10: Periodic Network



The final artefact for *Reactor* was designed as a kind of tonal bed for the rest of the composition to lay over top of. Minimal harmonic tonality was employed in order to leave space for exploratory melodic direction, allowing any intuition-based improvisation to be followed to its logical musical conclusion. Chords from analogue oscillators within the modular were sampled into a granular sampler, which was modulated lightly and run through a relatively extreme analogue distortion. Though driven, the artefact is layered softly in the mix, providing textural depth and emphasising spatialization with additional convolution reverb.

### 11.4 Reactor Summary

The process of creating the finished piece was another exercise in process design that went on to influence succeeding compositions. The scientific narrative was imbued into skeletal sound design and meta-modules were implemented to develop rudimentary artefacts before improvising and iterating repeatedly until the desired mesostructures emerged. We here observe further embodiment of themes within the abiogenesis narrative; emergence, proliferation and stochasticity.

Whilst most of the pieces tell stories using fluctuating acousmatic sound objects situated in defined world-spaces, there are instances where the listener “travels”

through various world-spaces, observing different spaces and sound artefacts within them. In *Origin State* and *Reactor* the principles surrounding propulsion and locomotion rely on different acoustic fields, as per Dennis Smalley's "transmodal perceptual contingencies" (2007, pp.40) explored in Sec 6.2. For example, *Origin State* depicts water vapour condensation in air, flowing into oceans and then into underwater caves. The designed artefact moves from depicting gaseous subjects in air, submerged locomotion, and chemical reactions in cavernous spaces. Each of the spatial acoustic fields for these particular environments were designed with reference to realism, rather than randomly propagated, again adhering to predefined spatial principles. Such dense considering in narrative is arguably not explicit to listeners, but served to position the author phenomenologically in situated narrative stages as a further kind of embodied process.

The use of inharmony across the piece draws reference from narrative-based film music, in particular Hildur Guðnadóttir's *Chernobyl* (2019). Guðnadóttir not only embraces inharmony across her scoring of the work, but also sampled the Chernobyl reactor itself, which inspired the *Reactor's* phenomenological portraiture of how nuclearism can be connoted aurally.

## 11.5 Abiotic Forms

### 11.5.1 Composition 03: Abiotic Forms



Zhok (2022) describes the outputs of what we can tangibly call complex as having outputs inherently irreducible to their deductive components, and that phenomenological perspectives differ from reality, as any explanatory level must

comprehensively surmise the fullness of the complex system in question. Irreducibility from the perspective of both composer and listener is exploited in both the sonic outputs of the portfolio (using complex patch and system design to create acousmatic sound objects which are irreducible without comprehensive knowledge of the sound synthesis used to create them), and in its exploratory creative methodology, as explained in Sec 5.8.

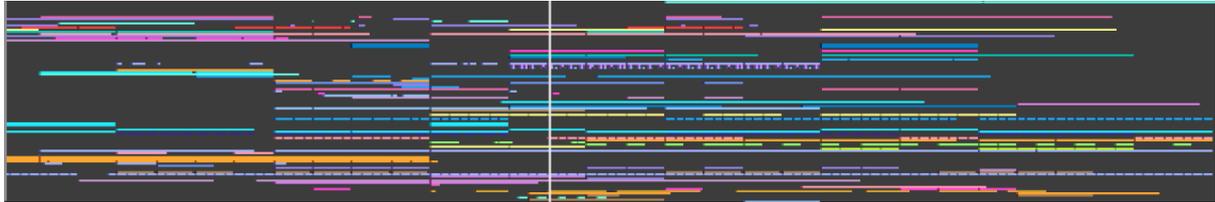
Embracing and expanding Csikszentmihalyi's (1990) principles surrounding flow state, the expansion of meta-module-based systems (and other compositional processes across the portfolio) involves a kind of flow-based mode of synth interaction. Once the narrative-based system is set up and functioning (based on Csikszentmihalyi's Flow principle of having clear goals), any further patching, parametric tailoring, and added stochastic function were generally left up to intuition (based on the Flow principle of immediate and unambiguous feedback). This process was often carried out quite quickly, and before long inherent complexity built up within patches, irreducible to the author, creating a mode of irreducibility in the patch make up itself.

#### 11.5.2 Artefact 11: Aleatoric Interplay



Generative and semi-generative methods were utilised heavily across *Abiotic Forms'* composition. Ableton's note probability functionality ingested stochastic melody generation across several instrument channels. These channels were layered, and the interplay between the resulting sound objects generated by each is intended to create a kind of aleatoric cacophony containing generative melodies. Extensive

layering of audio channels and MIDI based instrumentation was employed to explore complexity in textural, melodic and rhythmic fullness (*Abiotic Forms* comprises of ninety-six audio channels).



*Figure 11.15 Abiotic Forms, Timeline Overview (Author's own)*

Again, stochastic note selection and use of random voltage sources as well as sample and hold style LFOs within Ableton all cacophonise into an irreducible whole, where sounds appear to interact, diffuse, shatter apart, and converge.

### 11.5.3 Artefact 12: Broken Lines



One of the priorities across the creation of *Abiotic Forms* was to reflect on what scientists can tangibly call "alive." This is reflected in places its rhythm design. The skittering and sprawling artefacts intend to convey phenomenological properties of sensory interactions with organisms; microscopic cellular interplay, rudimentary biomatter etc. What are the perceived sensory components of these phenomena and how can they be expressed through sound?

A rhythmic patch on modular synth was created, sequenced by means of grid-based step sequencing, cellular automata, and various asynchronous follower functions (to

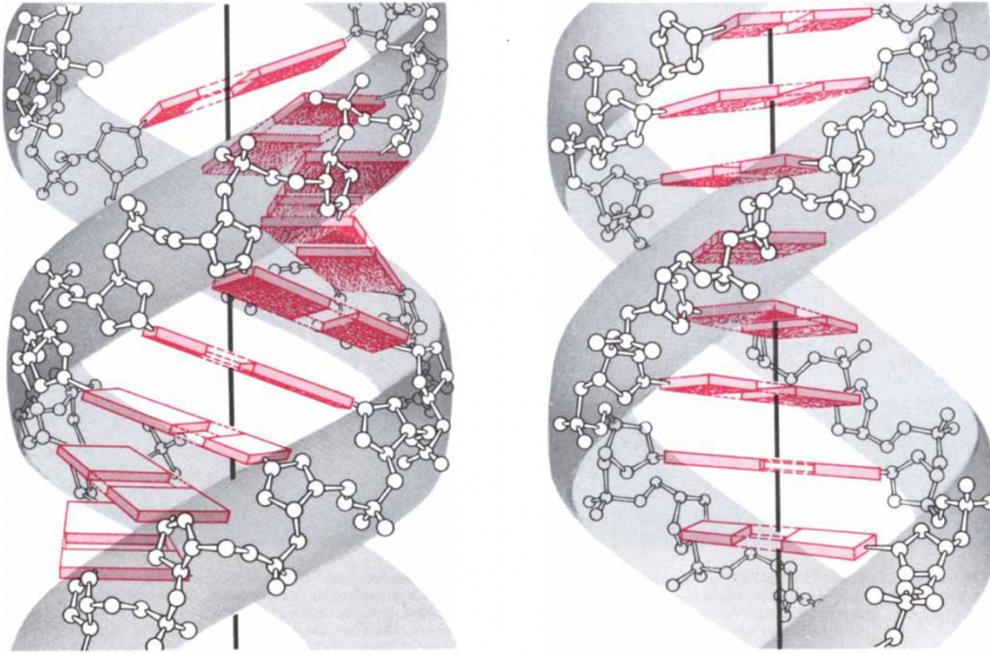
break away from overtly gridlocked rhythmic structures, with the intention of rhythms sounding more organic). The resulting rhythmic output was run through a modulated physical modelling resonator corpus.

The semi-gridless approach to rhythmic structuring was inspired in part by the rhythm design on Burial's 2009 record, *Untrue*, a ground-breaking work of imagined electronic dystopia. Burial used the free audio recording software Audacity to create *Untrue*, which has no grid features whatsoever. Arranging his rhythmic structures visually (by looking at the transients and waveforms) and according to ear, Burial created his iconic "galloping" effect, which breaks away from the more "robotic" sounding rhythmic form of grid or step-based percussion sequencing. This approach was emulated by shifting certain rhythmic artefacts off kilter from Ableton's arrangement view grid, and by playing in elements by hand, as well as DJ-esque "beat-matching" of certain quantised elements from the modular, and simply letting sequences drift asynchronously from the confined grid.

Many of the percussive sounds in *Abiotic Forms* were created with generative modular synth patches and then sequenced in Ableton. Sprawling sound design sessions and recordings of generative patches - including some of the Unknown Artefacts (see Sec 11.11) - were chopped up and re-assimilated into something resembling a traditional beat, before being layered into the composition.

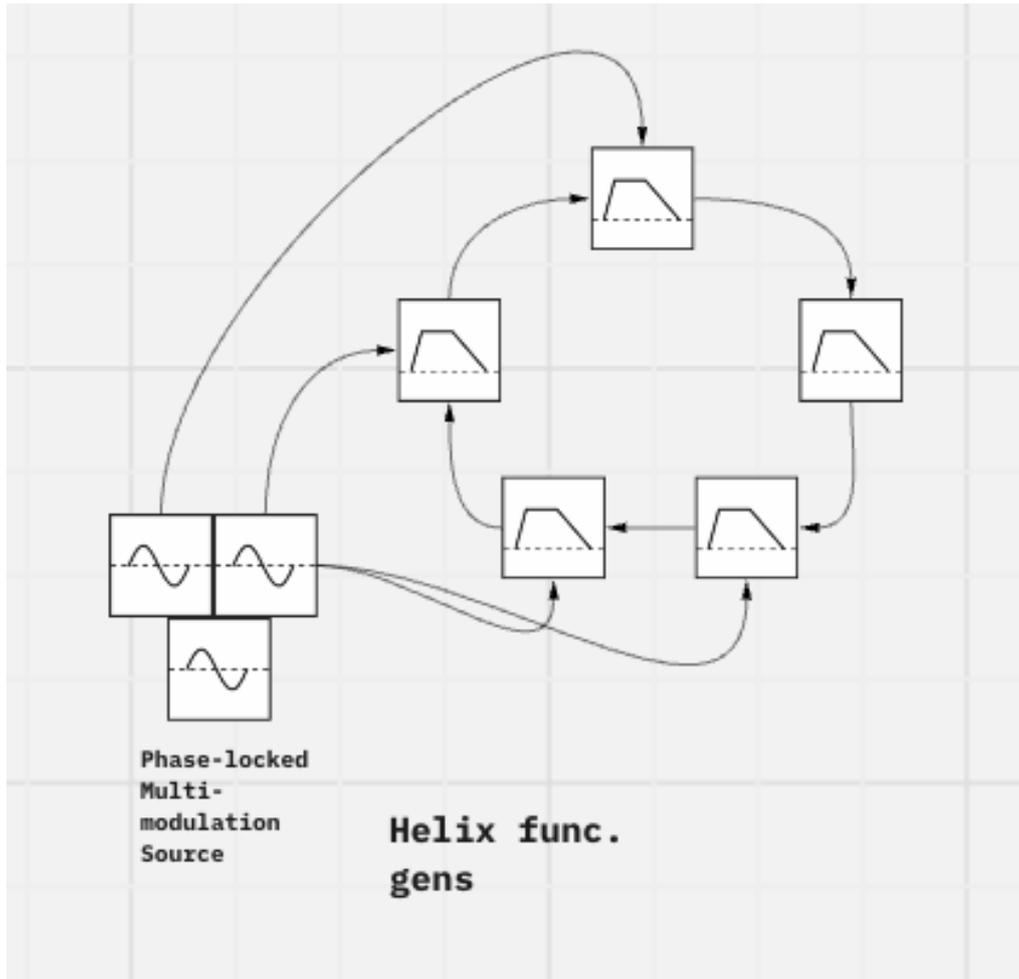
#### 11.5.4 Artefact 13: Ghost Mechanism





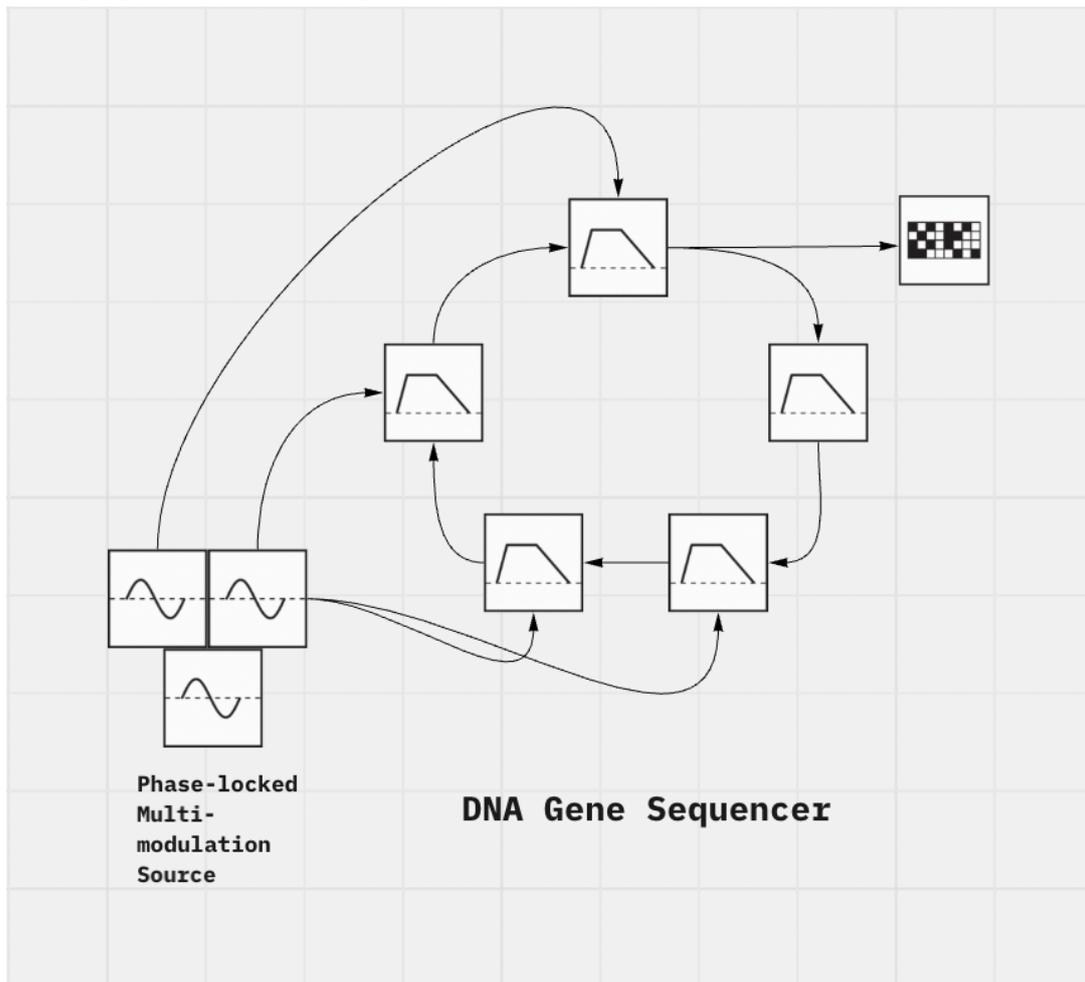
*Figure 11.16 DNA Helixes (Dickerson, 1983)*

*Ghost Mechanism* used stochastically generated transient sonic objects sequenced using a meta-module that depicts helices. Helixes are present in DNA/RNA, proteins and nucleic acid, all of which are reflected upon across the portfolio, so a meta-module for helices in general seemed apt. DNA gene data can be read as a sequence, (Dickerson, 1983) so the DNA patch uses a sequencer modulated by the helix meta-module.



*Figure 11.17 Meta-module: Helix Function Generator (Author's own)*

Which in this example led on to modulating a sequencer thusly:

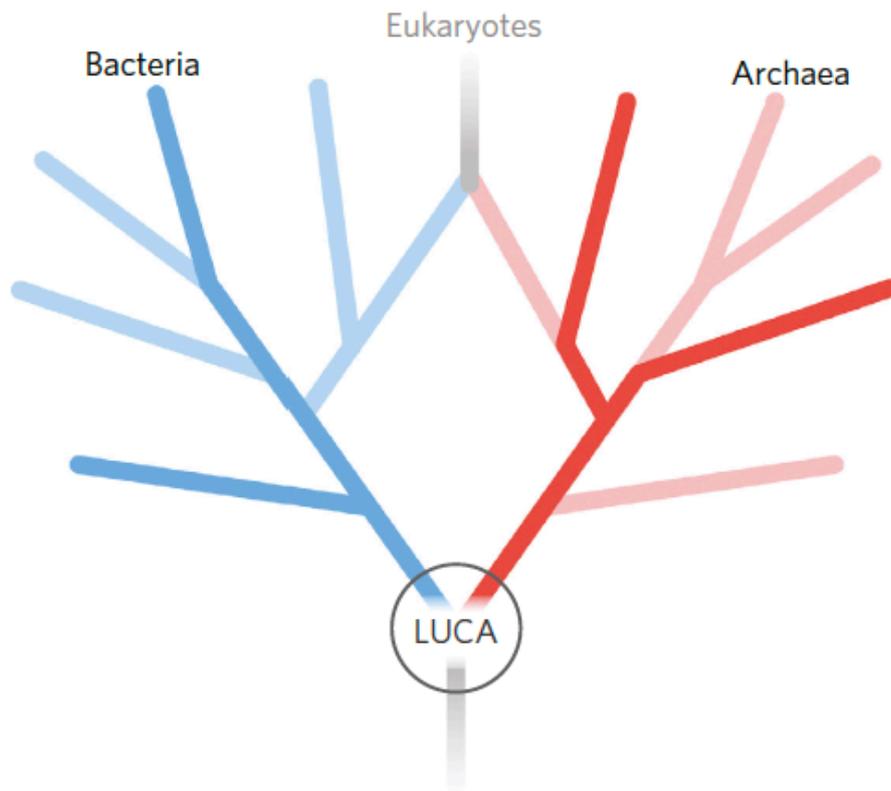


*Figure 11.18 Modular Patch: DNA Gene Sequencer (Author's own)*

In general, modulating sequencers within eurorack and Max for Live became an integral part of ingesting stochasticity across the portfolio.

#### 11.5.5 Artefact 14: LUCA Forms





*Figure 11.19 LUCA Evolution, (Weiss et al, 2016)*

The concept of a LUCA, or Last Universal Common Ancestor, is the suggestion in science that all life stems from one common ancestor (Weiss et. al, 2016) which went on to form bacteria, eukaryotes and archaea. This inspired considerable awe in the author during both research and creative phases. LUCA is described as proto-eukaryotic and nucleus-having, so employed patches imitated aspects of the make-up and function of a cell nucleus according to Dunder & Misteli (2001) using the principles of embodied systems. The branching structure from the figure above was explored in this and later pieces using various eurorack and software instruments, explained in Secs 5.12 & 11.8.2.

### 11.5.6 Abiotic Forms: Summary

*Abiotic Forms'* composition raises questions about the limit of how complex a sound piece can tangibly be before becoming overwhelming, or how complex it needs to be. Obviously, like anything dependent on an individual's sonic palette, this is likely subjective. Because complexity was one of the inherent concepts being explored, any notions rejecting maximalism were disregarded at the sound generation stage, veering away from the goal of affective musical results and more towards pure exploration of certain techniques. Here we see a clear example of the jostle between explorative procedure as method and the disruption of the desired product, similar to questions surrounding analogic and symbolic data representations in sonic art and music, and the rejection of Cage's generative purism (Husarik, 1983). Many of the applied processes and experiments were later destructively edited to make space for others in order to create more cohesive, finished music.

This research posits that a useful approach is for creators to explore every possible avenue and then simply iterate, refine and edit their composition until a desirable, useable sonic result is attained.

## 11.6 Replicator

### 11.6.1 Composition 04: Replicator



The creation of *Replicator* relies heavily on synesthetic connections between visual, tactile and sonic textures, and will refer to AI generated visual artefacts, a gallery of which can be found in Sec 13 in the appendices. Phenomenology again serves as a useful tool in investigating synaesthesia, where people experience cross-modal sensory associations (hearing sounds as colours, experiencing sounds as tactile phenomena, seeing sound etc.) (Cytowic, 1995) and *Stochastic Genesis* intends to exploit these associations as a creative premise where possible. AI image generation was chosen for the following reasons;

Visually surreal and interesting textural outputs: Dall-E 2 generates images with distinct surrealistic visual texture, which was useful in translating visual artefacts into sensory cross-modality, and then into acousmatic sound.

Generative principles & emergent properties: LLM-based AI image generators are inherently generative, their outputs emergent from their neural networks, so are stochastic in their functionality.

Encapsulation of tone: Text-to-image AI systems work on written prompts and respond accordingly to the linguistic tone of the input. By engineering prompts with certain creative writing methods,

appropriate visual aesthetics can be drawn out from the LLM. This contributes to contextual relevance and tonal consistency for the overall portfolio.

Synesthetic connections are drawn between the generated visual textures, which inform tactile associations, and then translated into sound design.

Phenomenological principles informed these cross-modal translations, drawing primarily from Schaeffer & Chion (1977; 2009) and the principles outlined in Sec 6.2. Tactile experience can inform the nature and role of emotions and even contribute strongly to psychiatric illness (Ratcliffe, 2008), a premise again exploitable in creating visceral and moving sound and music.

#### 11.6.2 Artefact 15: Metal Spaces



#### 11.6.3 Artefact 16: Tactile Surface



Both of the above sonic artefacts are combined in the finished composition melding the previously explored principles of layering, spatialization and musical harmony to embed principles of synesthetic cross-modality in a musical composition. Their sound design is phenomenologically motivated.

## 11.7 Momentary Split

Single celled organisms existed for billions of years before initially dividing. The first cell, or instance of what we can tangibly call “life” emerged at least 3.8 billion years ago (Cooper, 2008), whereas cell division did not occur until some 2.1 billion years later. There also exists a question here as to why cell division even initially occurred (Buchanan, 2017). Without this minute instance of cellular splitting, life as we know it would not have evolved. This moment holds profound significance.

The moment raises questions about the very mechanisms of our existence, and therein intense feelings of wonderment and intrigue. The timeframes here are also of interest, encompassing several billions of years of primordial single celled beings, (lasting longer than our multicellular reality has even existed for) leading up to this one crucial evolutionary turning point. All of this induces certain perceptual qualia surrounding philosophical enquiry, and contains inherent irreducibility surrounding timescales (billions of years are difficult for use to adequately comprehend). Qualia stemming from irreducibility is further reflected on in *Momentary Split*, suggesting that abstracted feelings surrounding perceiving this science are worth expressing and exploring with music.

### 11.7.1 Composition 05: Momentary Split



Cell make up and division characterise the inspiration behind many of the compositional methods involved across *Momentary Split's* sound generation and musical arrangement.

### 11.7.2 Artefact 17: Cellular Smatter



Cellular automata are computational models of grid-based cells whose state change according to a rule set based on real world interactions of living cells (Bilotta et al, 2002). The outputs of said models create complex and evolving patterns that can be used for sequencing synthesizers both rhythmically and melodically, (typically with x-axis rows collating to sequencer steps and y-axis columns relating to pitch information) which can, in modular domains, also translate to parametric modulation information. As the patterns evolve, they produce variations based on interactions with neighbouring “cells,” yielding dynamic, non-linear, algorithmic sequences, a premise that has been heavily exploited in ambient music.

### 11.7.3 Artefact 18: Chemodynamism



With CV Tools (accessible: <https://www.ableton.com/en/packs/cv-tools/>), modulation can be received from a modular system into Ableton. *Momentary Split* contains examples of translating modularity from the modular synth back into the software.

The piece reflects on cell make up, cell division and Bertalanffy's (1968) General System Theory, where he discusses limitations inherent in the "living machine" model and defines life as a complex system. The key difference in living and non-living systems, says Bertalanffy, lies in certain structures and orders that allow living systems' persistence, development, growth and reproduction. Analogies likening life to mechanical systems fall short – complex organisms are chemodynamic, directly converting energy from their environment to an output, continuously building up and breaking down materials.

#### 11.7.4 Artefact 19: Modulated Systems



Due to nonlinearity and adaptive properties, modularity in synthesis interfacing can parallel the chemodynamic nature of living systems. Importing modulation into Ableton *from* the modular synthesiser allowed for the application of open-system dynamics onto software parameters within fixed architecture plugins in DAWs, reinforcing a holistic, systems-based approach to auditory complex system depictions and furthering principles of embodied systems. CV Tools allows for the embodied systems from meta-modules to modulate parameters on nearly anything within Ableton, which was of great use in reinforcing themes and meta-narratives. Systems of meta-modules like the one depicted in the diagram in the Sec 11.5.4 were adapted and used to send complex modulation (across multiple channels) to stock Ableton plugins and other software instruments.

## 11.8 Mitochondria/Photosynthesis

### 11.8.1 Composition\_06: Mitochondria/Photosynthesis



Piece 6 adopts a similar approach as Piece 3 where dense layers of stochastically generated channels of audio create mesostructural polyphony, this time to imply the sprawling and convoluting of the beginnings of an evolutionary tree of life. Directional and motional information is conveyed by structuring rhythmic embellishments, creating the aforementioned “galloping” tone, drawing from off-grid rhythmic structuring inspired by Burial’s *Untrue* (Resident Advisor, 2017). This further embodies a melding of structured and unstructured biological formation.

### 11.8.2 Artefact\_20: Gene Sequence Data



Ableton’s *Tree Tone* instrument (Bastan, 2021) derives from an algorithm called *space colonisation* (Runions et al, 2005) which is “based on the principle of space competition for plant growth” and generates “skeletons” in accordance with said algorithm (Fu et al, 2023). The instrument is part of Live 11’s generative tools and holds obvious thematic relevance to several facets of branching structures within the abiogenesis narrative; germination, bifurcation, venation etc. (Webb, 2021). The instrument was used to create shifting drones that were modulated randomly as per

complex modulation principles previously articulated, and also comprises of a resonator which creates spatial and chorale depth to existing channels of audio in the piece.

### 11.8.3 Artefact 21: Germination, Bifurcation



A eurorack module, *Bloom* from Qubit (accessible: <https://www.qubitelectronix.com/shop/p/bloom>) was used for melody generation within the piece and across others. *Bloom* is a “fractal sequencer” which takes a melody (programmed at the user’s leisure) and creates a “tree of related subsequences that can be strung together to create large musical sequences that relate back to the originally programmed sequence” (Qubit, 2019). *Bloom* provides another (heavily modulatable) opportunity for immersing principles surrounding germination, growth, fractals and crucially mutation into the mechanistic operations of instrument systems. The mutation parameter on *Bloom* was ideal for expressing shifts in endosymbiosis and the changes in gene sequence data necessary for mitochondrial evolution (Gray et. al, 1999).

### 11.8.4 Artefact 22: Photons



The behaviour of photons was investigated via recent quantum research (Cohen-Tannoudji, et al, 2024) and embodied using particle synthesis (Roads, 2001), particle triggered sequences, (explored in Sec 11.9.4) and deep spatialisation. The emergent sound objects represent the behaviour and wave-particle duality inherent in photon movement and interaction, implying scattering and diffusion. The representation of quantum phenomena was an interesting avenue: multidimensional reality representation is outside of the scope of this research project but is something that the developed premises and practical methods could excel at, and it is the hope of the author to pursue this across PhD study. Questions concerning the nature of physicality arose, another example of an abstracted concept that acousmatic sound could potentially excel at depicting for audiences: in depicting abstracted knowledge, abstract art/music is viable.

#### 11.8.5 Artefact 23: Mesostructural Forms



*Mesostructural Forms* involved the creation of arguably the most extensive “patch” across the portfolio. In an attempt to utilise every piece of hardware available, along with Ableton, all of the hardware listed in Sec 10.3 was interfaced, where the ES-8 module provided a link to and from the modular, as well as the CV routing on Hydrasynth. The intention here was to attempt to get the whole studio working as a kind of generative, emergent ecosystem, relating back to emergent mitochondria from the narrative. None of it was clock-synced, and cross modulations were applied wherever possible, allowing for sound object interaction and cross-relationships. This process was an exciting process in and of itself, and a more pleasurable way to create music than the process for the broader portfolio. The

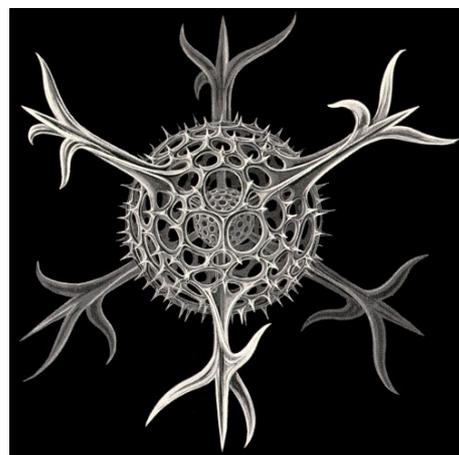
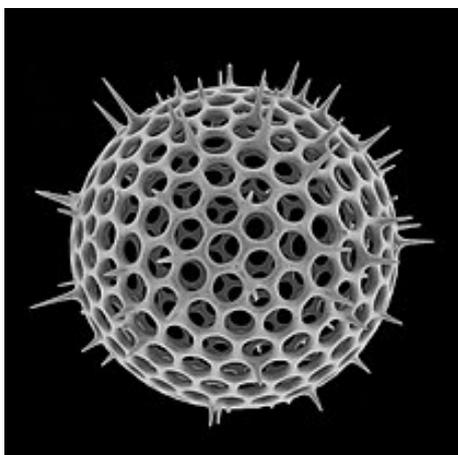
results include aleatoric functionality, and the processes without genuine stochastic functionality become pseudo-generative very quickly. The process represents one of the more fulfilling aspects of generative music creation – gentle sound tailoring and steering until pleasurable results are happened upon, with sonic object interplay emerging organically.

## 11.9 Radiolaria

### 11.9.1 Composition\_07 Radiolaria



Radiolaria, a kind of single celled holoplanktonic protozoa that form complex, siliceous skeletal lattices around their nuclei (Anderson, 1983) were chosen as inspiration for Piece 7, which intends to express wonderment around complex single celled organisms that emerged from previously explored unfolding genetic transformations.



*Figure 11.20 1: Radiolarian Shell (Bhate et al, 2019) 2: Hexancistra quadricus (Göransson, 2021)*

### 11.9.2 Artefact 24: Axopoda



Recordings using a hydrophone in various settings, (the sea, rivers, a watering can) were experimented with, running through various resonator corpora (such as *Tree Tone* and Ableton's *Corpus*, as well as Mutable Instruments' *Rings* and *Elements* in the eurorack) with the intention of having real-world physical interactions with the hydrophone working as means of stochastic resonator excitement. The recordings (fed via Ableton or transferred to and processed by a *Make Noise Morphogene*) depict the emergence of inner nuclei and ectoplasmic and cytoplasmic properties, while the resonators were parametrically tuned to represent phenomenological properties of the Radiolaria's lattice shell, axopoda and spinal properties. The differing shapes of Radiolaria are incredibly diverse, so shifting modulation was applied to these resonators to express this diversity of external cell architecture.

### 11.9.3 Artefact 25: Amorphous Zone

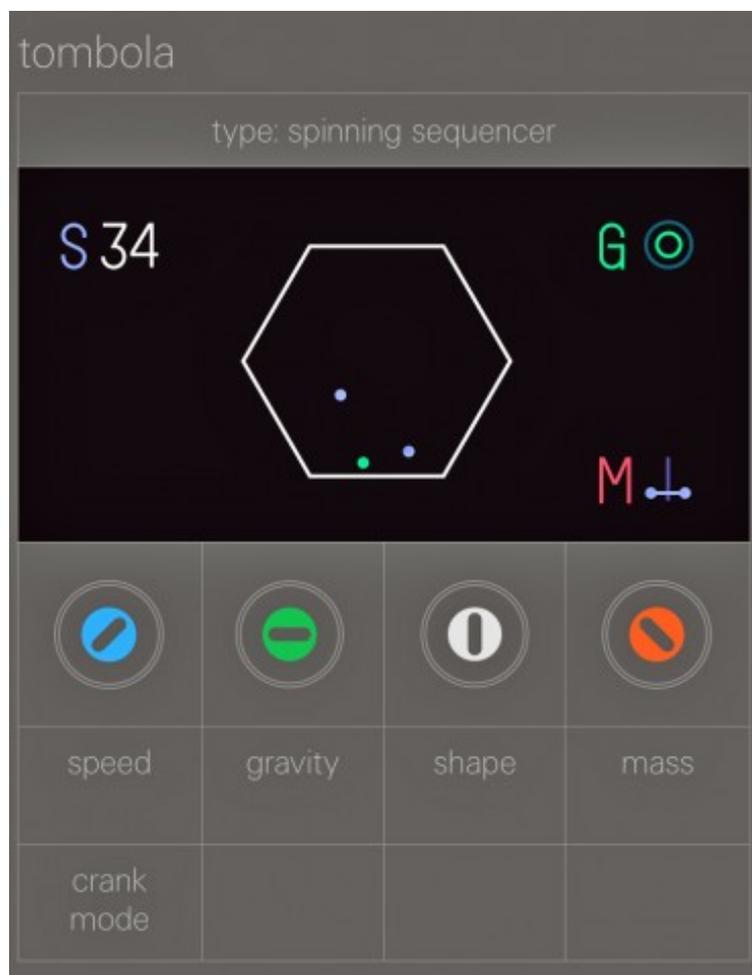


### 11.9.4 Artefact 26: Fractal Emergence



Piece 7 also uses a physics-based particle sequencer across artefacts 25 & 26 to create depictions of the pseudo-random movements of Radiolaria in water.

#### 11.9.5 Artefact 27 Particle Physics



*Figure 11.21 OP-1 Tombola, particle sequencer (Teenage Engineering, n.d.)*

For some instances of physics based particle sequencing, an OP-1's *TOMBOLA* sequencer was used, (pictured above), but other instances of particle interaction

sequencing across the portfolio include Live 11's *Bouncy Notes* (Bastan, 2021) and *TOMBOLA*'s recreation in Max for Live (available here: <https://maxforlive.com/library/device/8201/tombola-sequencer>).

The instrument triggered in the OP-1's *TOMBOLA* was designed with asynchronous granular principles from *Microsound* (Roads, 2004). The output from the OP-1 was sampled into a Mutable Instruments *Clouds*. Grain density, duration, start and end time and amplitude were all modulated to create amorphous clouds of grains, a sonic image depicting a diverse plethora of stochastic Radiolarian interaction in phenomenological world-space, an example of the parametric capabilities of densely modulatable granular synthesiser interfaces in creating diverse and evolving soundscapes.

## 11.10 Instability/Collapse

### 11.10.1 Composition\_08: Instability/Collapse



*Instability/Collapse* represents the culmination of conceptual and methodological ambitions from across the project. By this stage, the compositional methodologies had been mostly realised. The work comprises of a balance between structure, improvisation and stochastic emergent properties. The piece was inspired by Precambrian mass-extinction events, alluding forth to our modern-day mass extinction.

### 11.10.2 Artefact 28: Sunken Monolith



To explore the concept of complex system instability and collapse, various artefacts were created using balanced systems of modulation from cyclical function generator meta-modules. The function generators themselves can be modulated in a number of ways, so sample and hold style random modulation generators were utilised for introducing instability and breaking down the cycles of functions, destabilising the regularity of the function generator patterns, with the intention of mimicking inherent instability and eventual entropy of real-world complex systems such as oceanic ecosystems. Minor fluctuations in modulation can proliferate, leading to emergent non-linearity, disrupting the system's steady equilibrium. This methodology allows for the incorporation of theoretical models of collapse phenomena into modular synth instrument and patch design.

### 11.10.3 Artefact 29: Instability



Basinski's *The Disintegration Loops* (2001) provided a creative premise for emulating ecosystem instability in *Instability/Collapse*. The accidentally discovered method involved playing tape loops endlessly and utilising lossy tape degradation as creative method (Bogalheiro, 2018), and was employed in practice, (by resampling damaged recordings made to tape), and also digitally recreated. Various

digital techniques can induce similar kinds of saturation; tape emulator plugins themselves (that include parameters like drift/flutter amount & speed/head tilt & frequency), saturation and other distortions, frequency modulation with white noise, etc. Digital degradation is also possible with timestretching, and with Ableton's multiple warp modes, wherein diverse results are possible from any given audio source. Running audio signals through power starved or broken circuitry (in this case eurorack modules) was another plentiful source of signal degradation. Essentially, signal degradation is possible in many ways, and useful for phenomenological goals: similarly to instability in rhythm or harmony, degraded audio signals are almost bound to *sound* phenomenologically degraded to audiences, making them useful for thematic, narrative and tonal depictions.

#### 11.10.4 Artefact 30: Disquieting



#### 11.11 Unknown Artefacts

Throughout the creation of the portfolio, a collection of “unknown artefacts” were generated during various studio experiments, modular and digital sound design sessions, and exploratory sessions initially unintended for inclusion in the portfolio that happened upon thematic, tonal or textural relevance. They were used heavily in the compositional or iterative refinement stages of the portfolio and have been included in the portfolio and listed with a brief description below.

### Artefact 31: Chop Drone I



Granular polyphonic textural experiment with spatialisation and multiple modulation lines, discerning situatedness of listener in sonic world-space, and aural navigational information.

### Artefact 32: Chop Drone II



Re-pitching and down-sampling of Chop Drone I, exploring denser textural territory.

### Artefact 33: Generative Salts



Generative modular patch exploring various granular morphologies and superstructures. Phenomenological depiction of organisms with stochastic sonic object emergence. Used extensively across the portfolio as generated malleable sound matter.

### Artefact 34: Opal Bones



Composite modular synth patch exploring shifting filters when processing granular outputs from a melodic sample source. Additional stochastic lines of melody generation, and tailored analogue distortion, touching upon tangential distortion territory generate harmonic emphasis through saturation.

### Artefact 35: Life Sink Drone



Further modular drone experiments incorporating resonators and exploring tonal darkness. Gradual, random modulation was used to create stochastic interplay between modulated resonators/filters, (where filter resonances form sonic objects that excite resonator modules).

### Artefact 36: Dark Shapes



Inharmonic rhythmic experiment using asynchronous (or loosely synchronous) delays to create partially gridless, “galloping” rhythmic forms. Further use of resonators as spatial corpora.

Artefact 37: Awaken



Polyphonic experiment using Mutable Instruments *Plaits* chord mode and Make Noise *Mimeophon* for spatialisation. Investigation into audio repeaters as spatial processors and modulating chord voicings to create dynamism in repetitive sequences.

Artefact 38: Slip Register



Experimenting with the principle of “organismic synthesis” (Kriemer, 2016) and embodying phenomenological tactile properties of primordial living matter. Intended to sound “biological” using principles of apparent aural “wetness” and sonic depictions of biomatter in moisture.

### Artefact 39: Density Drone



Emotionally affectional experiment balancing texture and spatialization, along with harmonic substructure. Playing with notions surrounding perceived aural “warmth” and attempting to make the same spectral principles that apply feel “cold” instead, mainly using reverb.

### Artefact 40: Deep Collision



Further experiments surrounding resonators and modulating them to create “realistic” sounding acousmatic rhythmic forms. Resonators, once again, imbue spatial properties into the sonic objects they generate.

### Artefact 41: Unknown Artefact I



Flow state modular synth patching, following intuition.

## Artefact 42: Unknown Artefact II



Flow state sound generation with hardware synths (ASM *Hydrasynth*), following intuition. Chords triggered by hand, reacting to the parametric modulation interplay unfolding.

## 12 Closing Remarks

A poignant shortcoming of the research process was a direct focus on fundamental philosophical foundations (mainly Heidegger's constitutional texts) *rather* than focussing on how his premises have already been applied in the fields of electroacoustic music and modular synth theory. Application of Heideggerian theory to modular synth music in particular arose continuously across furthered research (O Connor, 2023), too late to include in primary sources, and the project would likely have been bolstered considerably in using said texts as foundation, rather than starting from the elementary philosophy and working forwards from there. This was however useful in providing a rudimentary understanding of 21<sup>st</sup> century philosophy.

Obvious questions arising from the creation of the portfolio surround complexity in music. How much is necessary? How much is too much? Immersing oneself in complicated subject matter proved useful for inducing the kinds of wonderment explored in the thesis, but is this really a viably translatable mechanism for emotionally affective music? The delicate irony is that, with the wisdom of retrospect I actually *prefer listening* to the individual artefacts themselves. They are less busy, allowing for acousmatic sound objects to exist clearly in sonic world-space, letting their spatial and textural components shine through without the dense cacophonisation of the composite soundworks. The music I have made in my free time during the realisation of *Stochastic Genesis* has veered towards an embrace of minimalism, and I strongly feel that (given the nature of complex systems as a core theme) the project fails somewhat in terms of finesse, and should have taken more care in embracing better considered, less-is-more, calculated approaches.

Were the practically applied and research processes worth it? For the author: probably. From my own perspective, theory is extremely motivating and artistically stimulating, but I wouldn't suggest this approach is at all necessary, let alone crucial for others. For some producers and songwriters, a free DAW, a sample pack and a half hour are all that's needed to create something beautiful, and there is as much validity there than anywhere here. What counts is how enriching the process is and how viable the outcomes are. In narrative-based projects such as this, if your story is being told efficiently, and audiences find some exaltation therein, the processes and practices pale in comparison to the perceived experience of you, the artist, and the audience.

## 13 AI Image Gallery

The following gallery contains images generated for the project by Dall-E 2 (accessible: <https://openai.com/index/dall-e-2/>), selected due their usefulness as sources from which to draw synesthetic textural phenomena, and their appropriate/appealing aesthetics. Whilst already dated by today's AI standards, Dall-E 2 was selected over more realistic LLM-based image generators such as MidJourney because of its more unusual textural outputs, which were useful in inspiring cross-modal sonic texture creation. The prompts were created and iterated upon largely through creative intuition, and reflection upon, as well as interspersed terms like "photorealistic" and "8k" to increase realism.

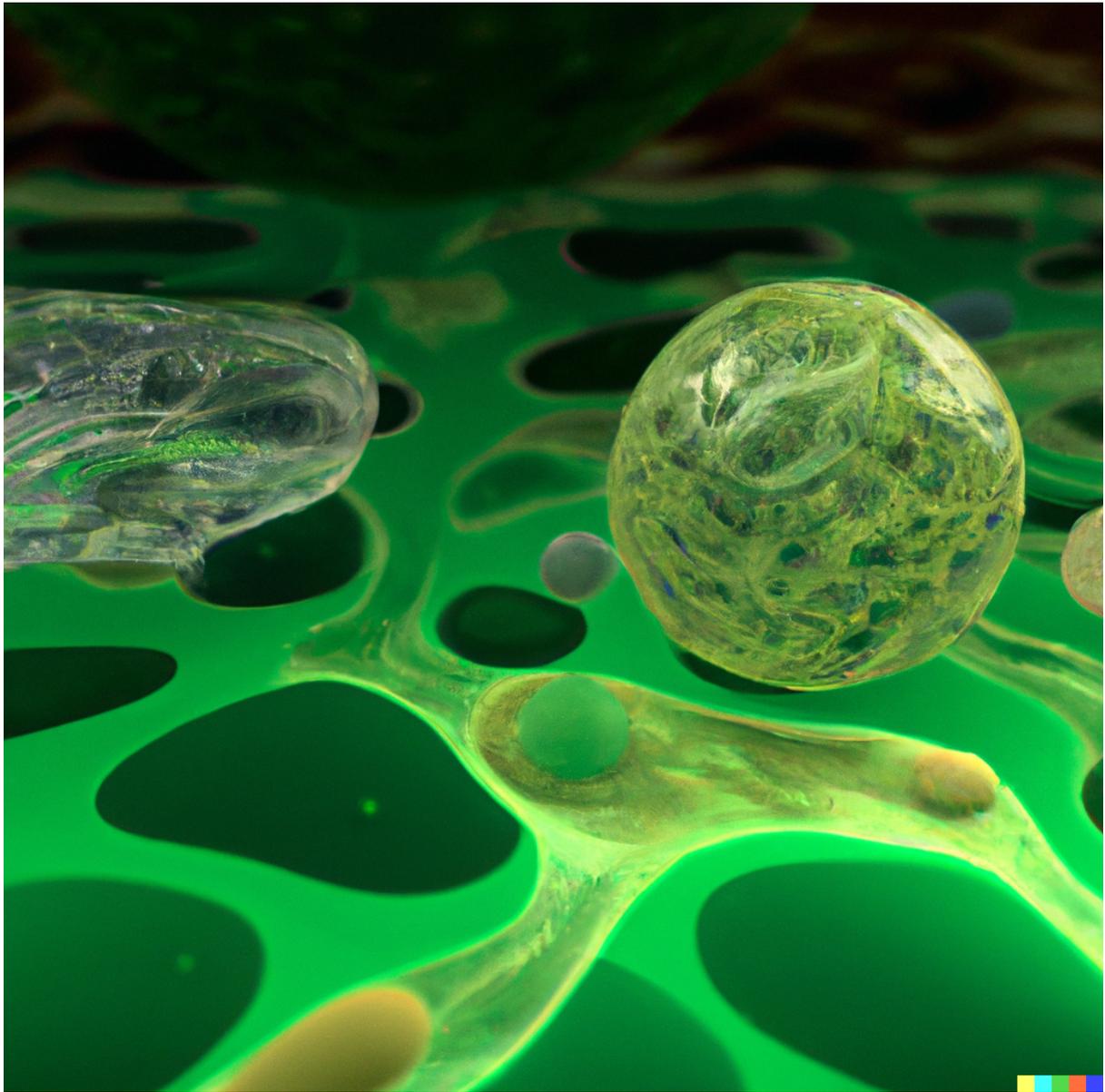
Prompts used;

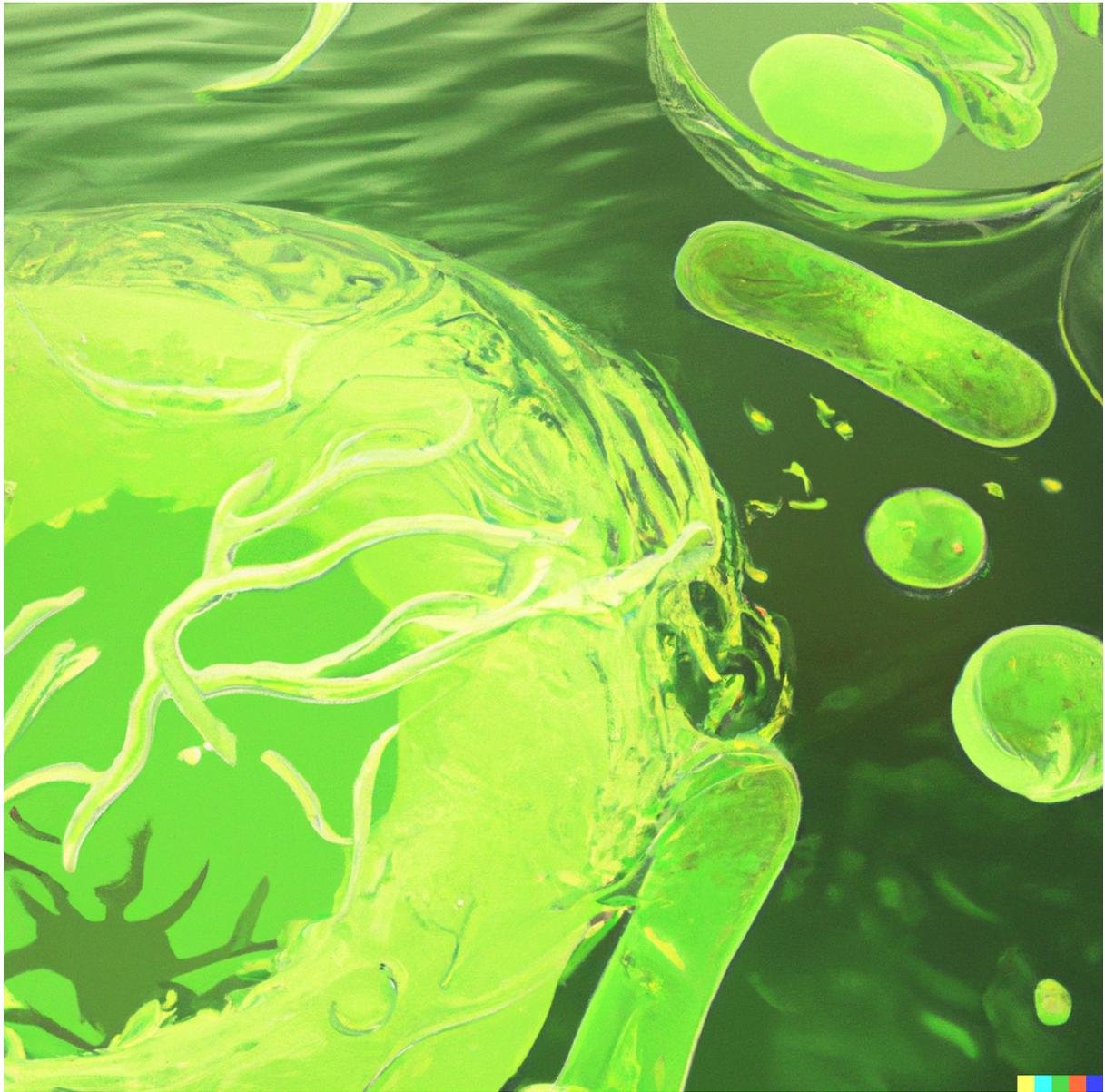
*"shifting cells split in the primordial ooze, glistening proteins dance and form new life, underground uranium shimmers giving off light in a cave full of boiling water, granitic rock degrades filling the water with nutrients"*

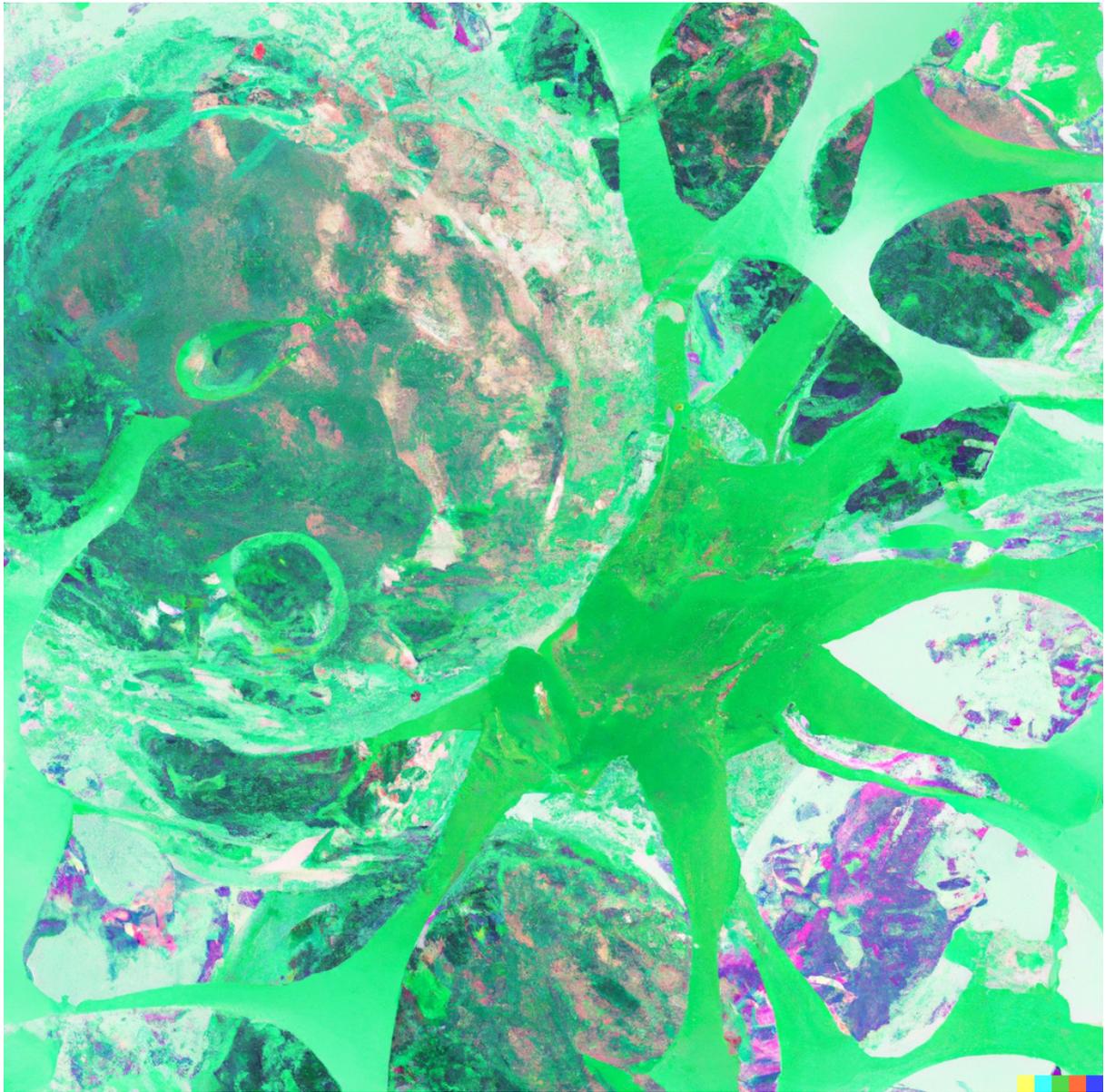
*"nuclear geysers burst into lifelight in an underwater cavern, proteins dance in the simmering ooze, light beats down from the Precambrian sun"*

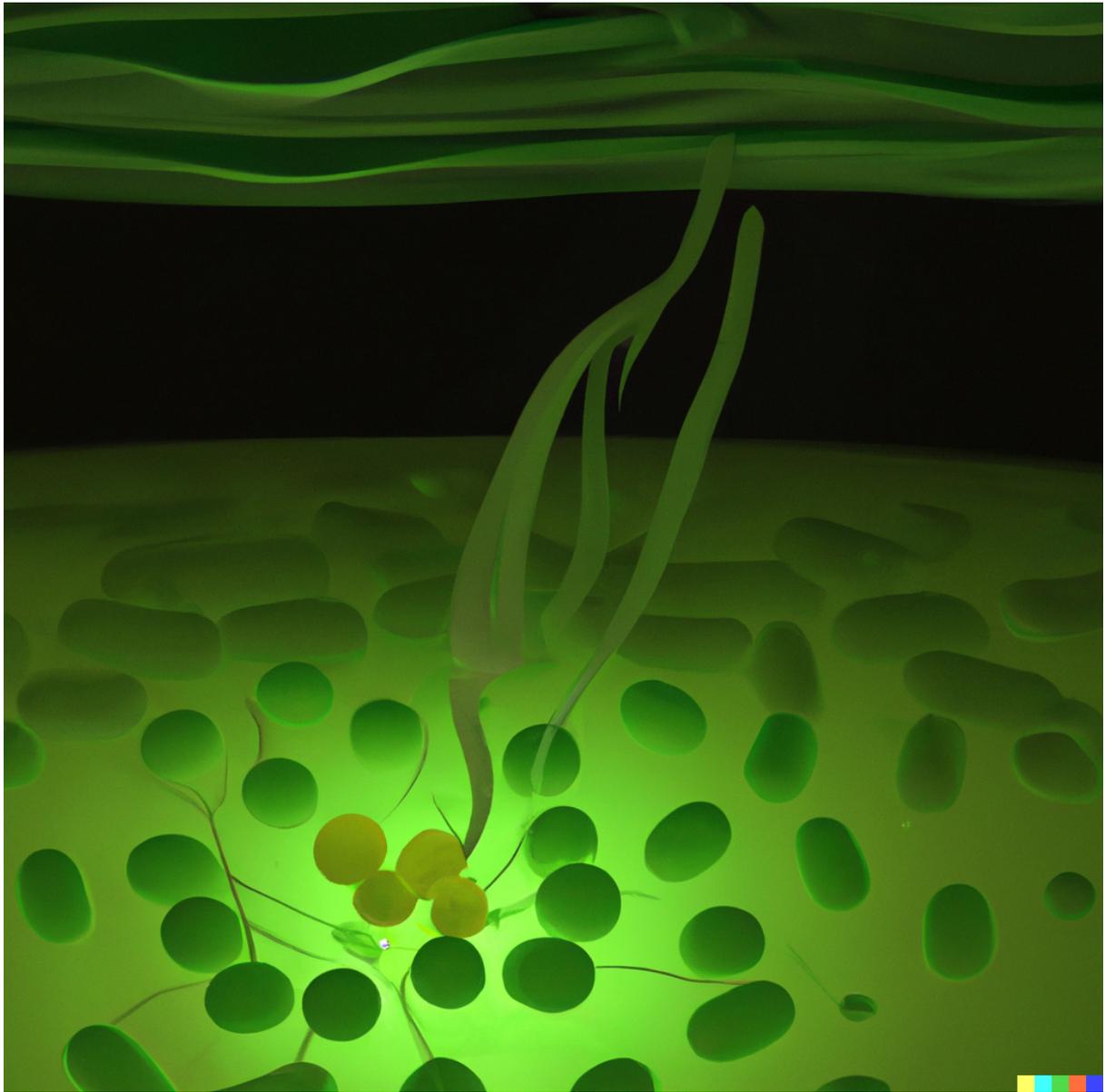
*"shards of minerals flicker around in shifting water, touching and combining, amino acids form chains of 32 components, they fold and twist into protein"*

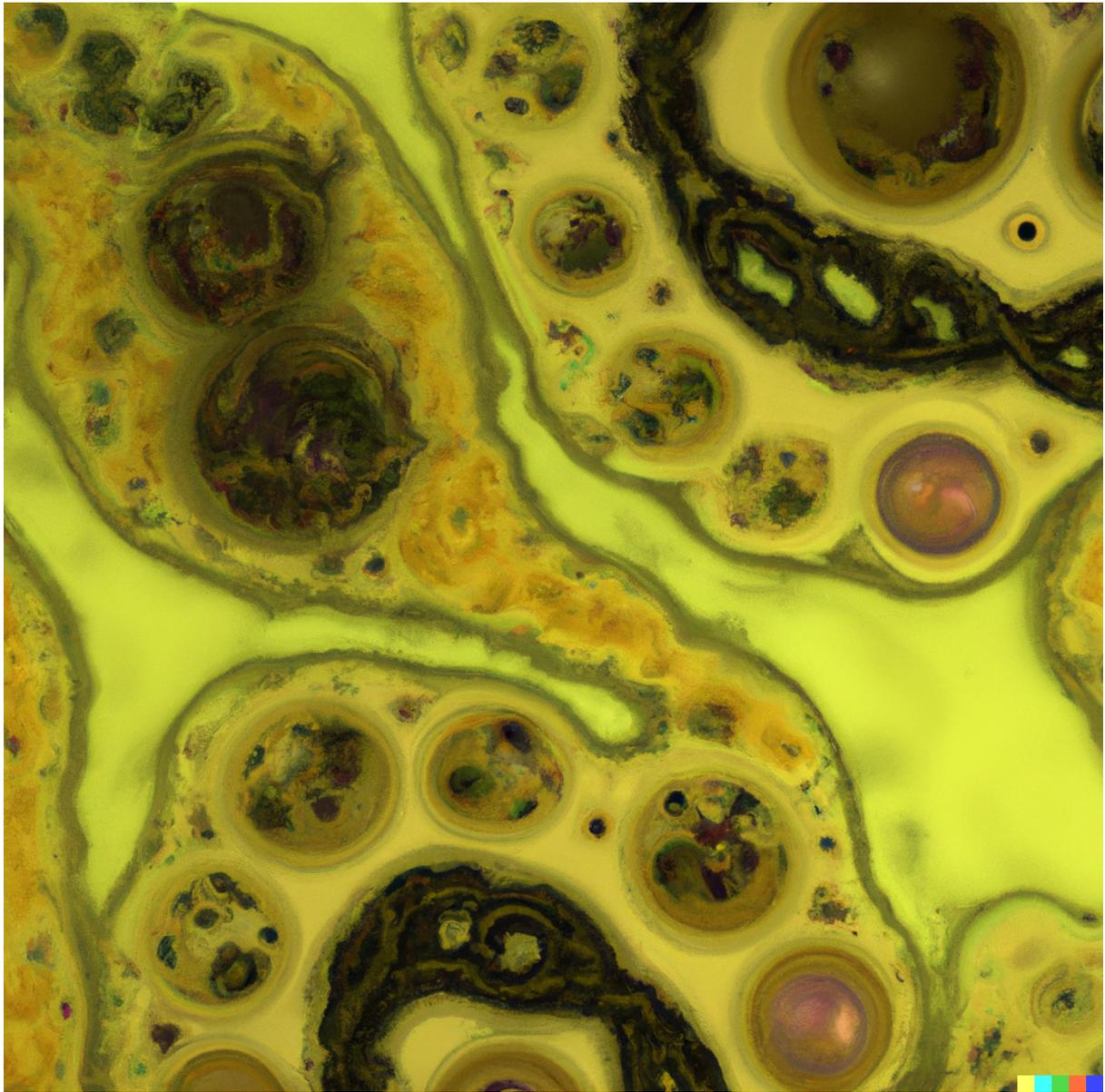
*"cells form beside underground uranium, shimmers giving off light in a cave full of boiling water, organic matter, granitic rock degrades filling the water"*

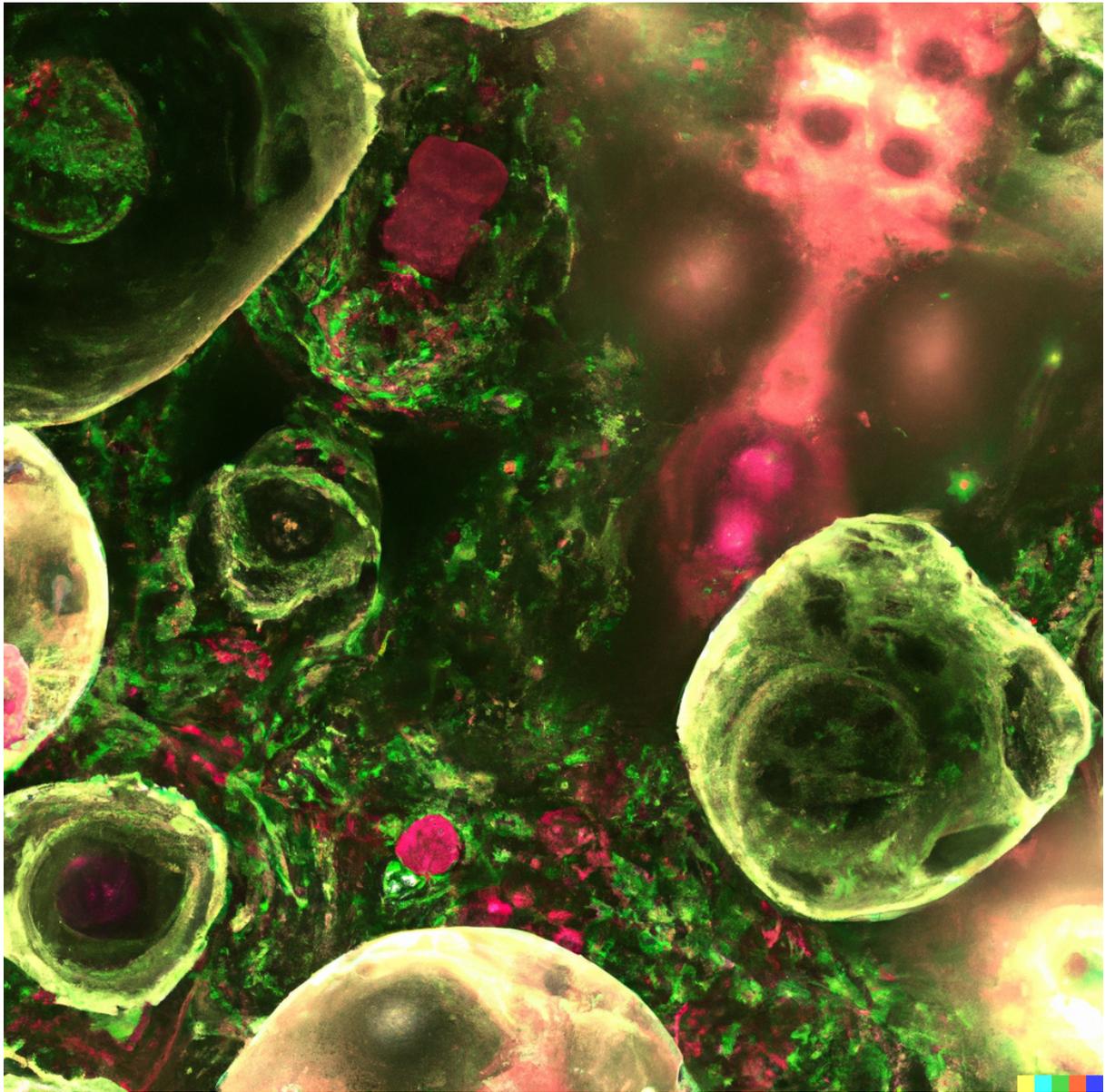


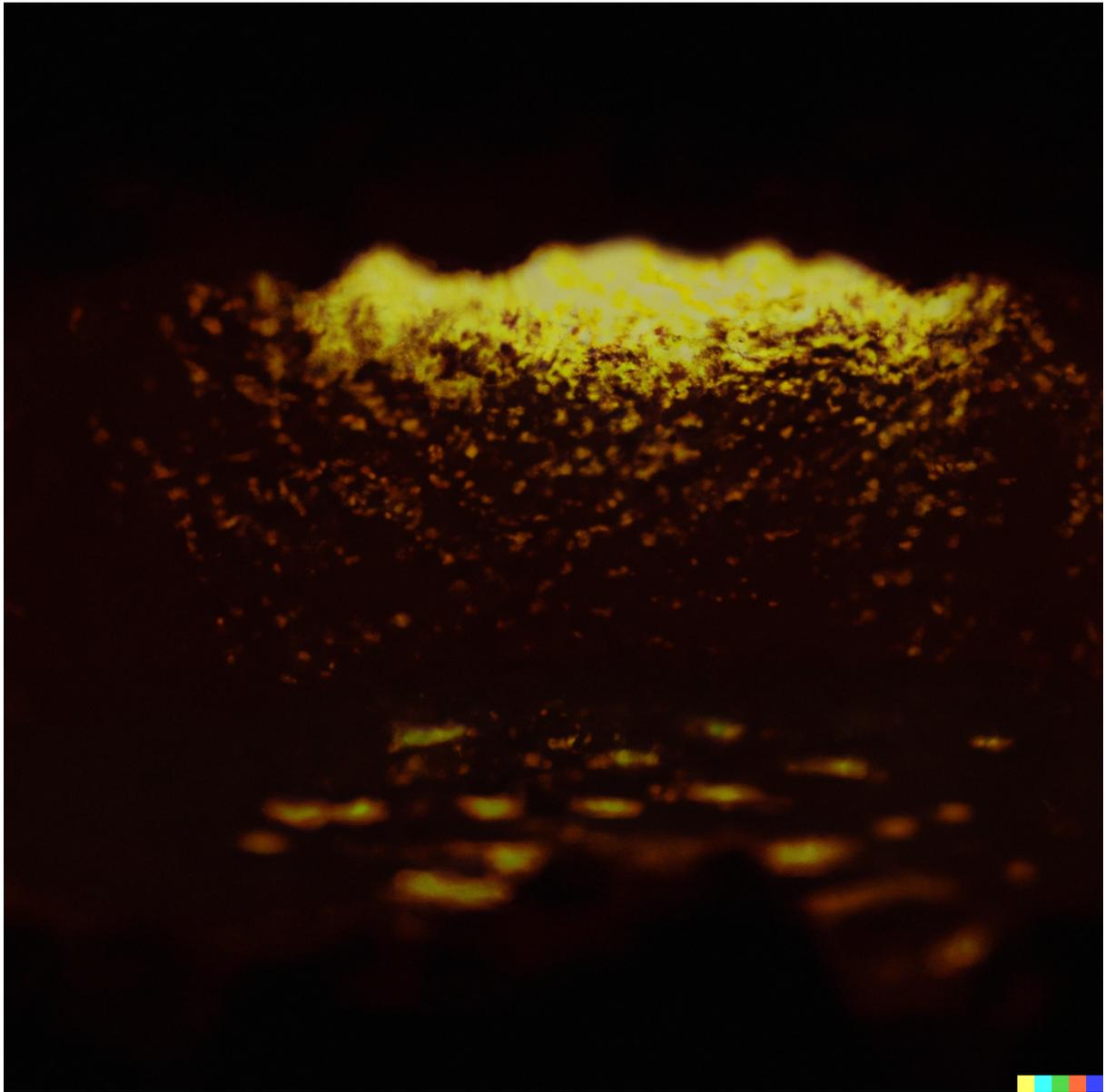






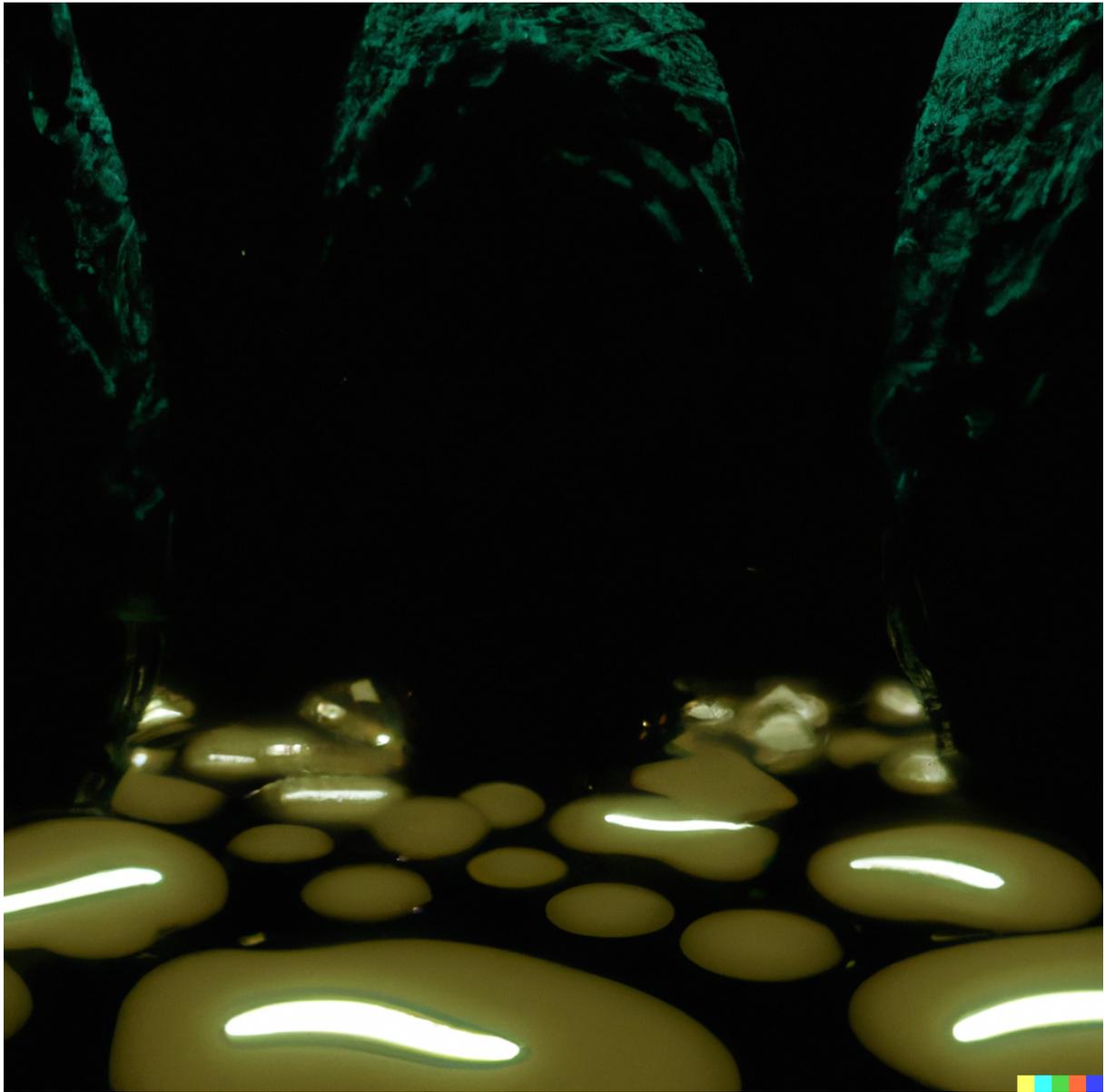


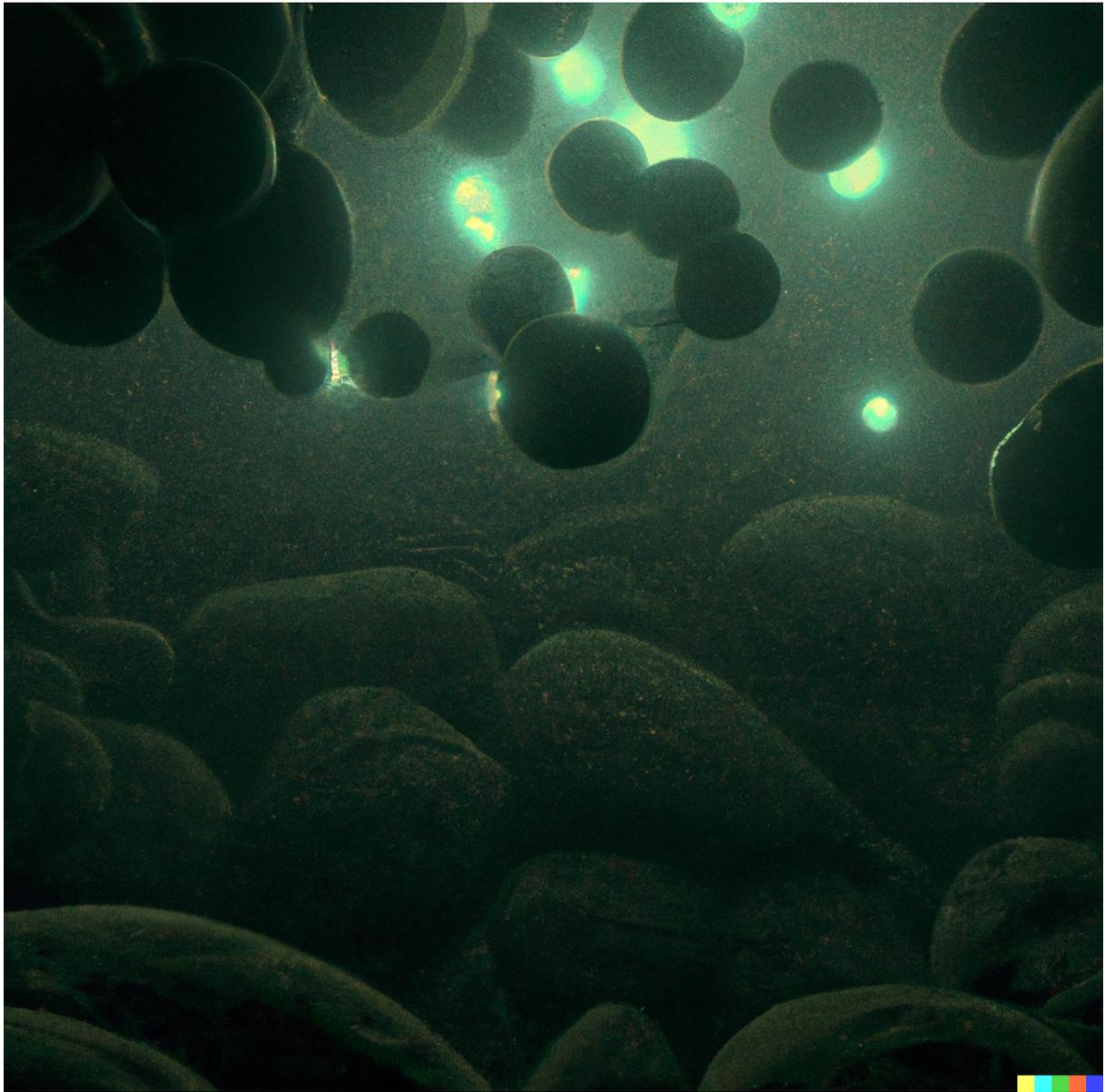


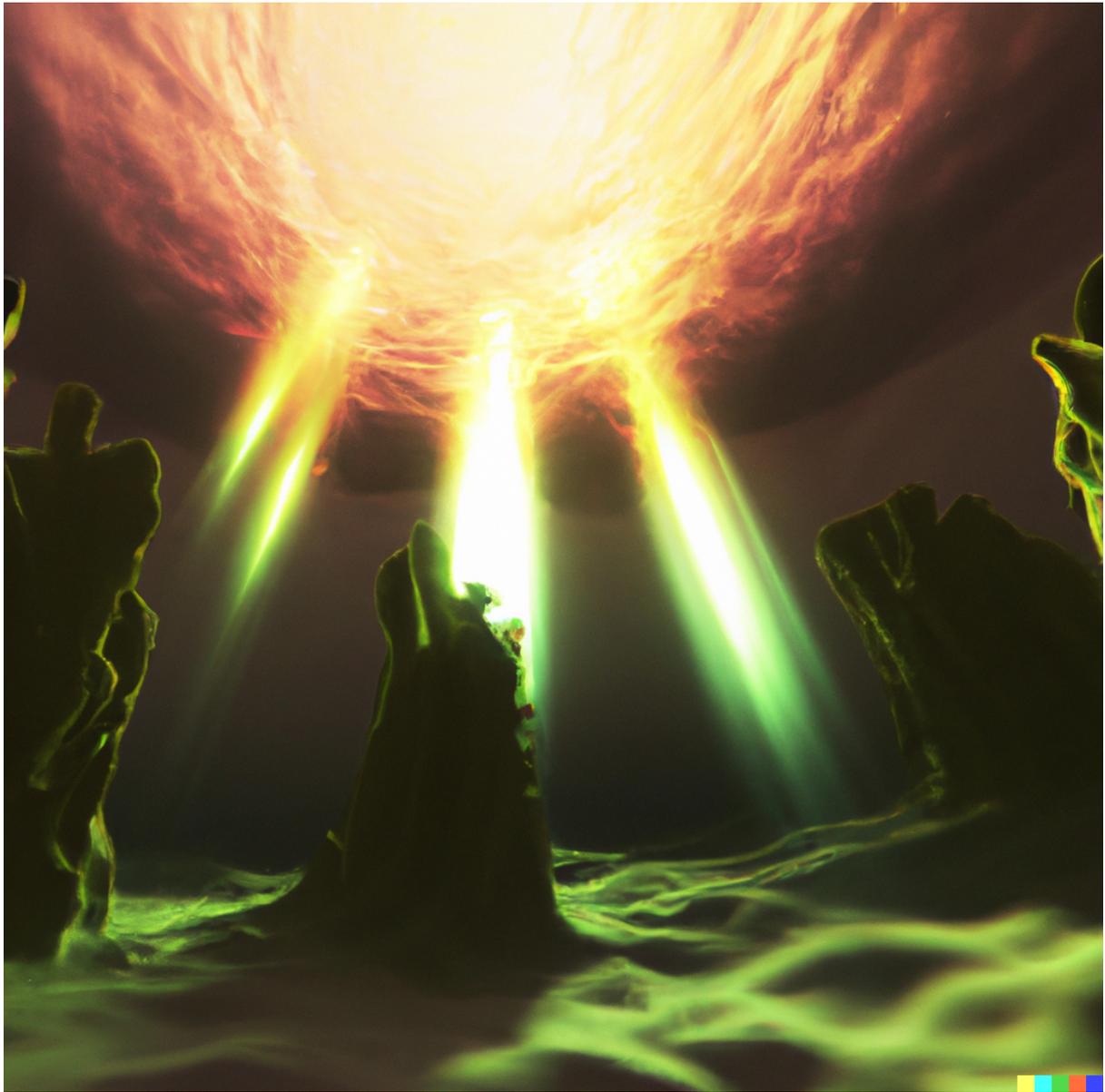


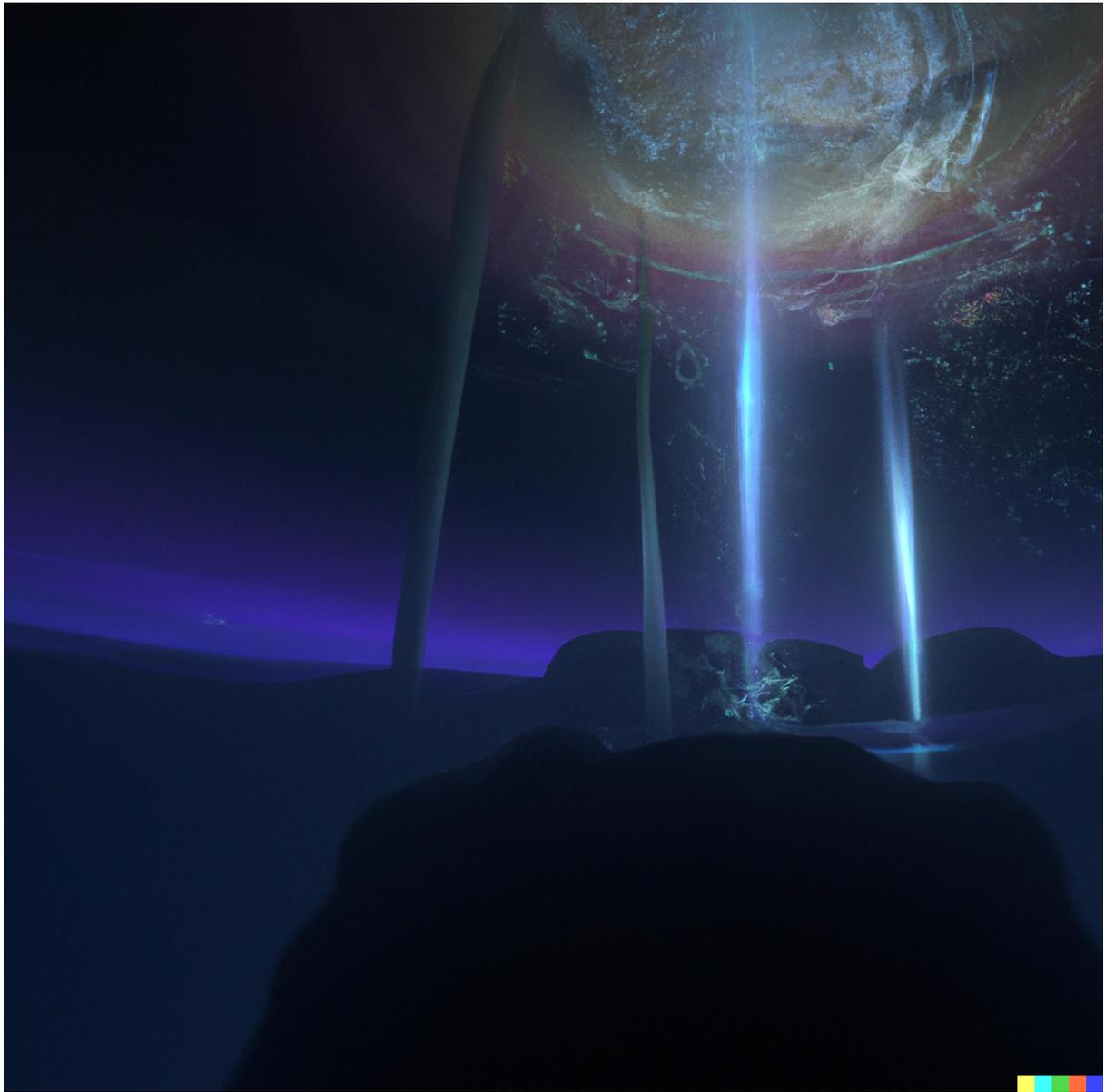












## 14 Appendices

### 14.1 Glossary

Note: A comprehensive glossary of synthesis, philosophical and scientific terms seemed unnecessary for the purposes of the research project, so a non-exhaustive collection of general and commonly used terms used has been included here, containing terms from all relevant disciplines/fields. Definitions have been selected from various sources in order to aid in clarity within the context of the research project.

*Abiogenesis*: the original evolution of life or living organisms from inorganic or inanimate substances (Oxford Languages)

*Ableton/Ableton Live*: Prominent DAW (see *DAW*)

*Acousmatic*: Sound that is heard without an originating cause being seen: the source of the sound is unknown to the perceiver (Schaeffer, 1966)

*Aleatoric*: relating to or denoting music or other forms of art involving elements of random choice (sometimes using statistical or computer techniques) during their composition, production, or performance (Oxford Languages)

*Cross-modal*: refers to perception involving interactions between two or more different senses (Lacey & Sathian, 2015)

*Chemodynamic*: the study of dynamical chemical behaviour in an environment (Oxford Languages)

*DAW*: Digital Audio Workstation, versatile software for sound design or music composition (Avid, 2024)

*Embodied Systems*: Sound synthesis systems that use modularity to embody behavioural aspects of a separate observed system (Author's own)

*Eurorack*: popular modular synthesiser format, common across consumer markets (Author's own)

*Eidetic*: related to or denoting mental images having unusual vividness and detail, as if actually visible (Oxford Languages)

*Granular Synthesis*: sound processing technique that breaks down sound into small pieces, or “grains”, and then plays them back in different ways to create new sounds (Output, 2022)

*Generative*: [contextual]

1. Relating to or capable of production or reproduction (Oxford Languages)
2. Music that is ever different and changing, and that is created by a system (Eno, 2020)

[see also *semi-generative*]

*Hyperreality/hyperreal*: [contextual]

1. In a mediated context, an artificially created copy that is perceived as somehow more real than the real thing, or too real: modelled on reality but with an exaggerated intensity, such as computer-generated films with unnaturally bright and vibrant colours. In visual art, often a synonym for photorealism
2. For Baudrillard, that which has gone beyond the real, supplanting or erasing it (Oxford Reference)

*Irreducible/irreducibility*: not able to be reduced or simplified (Oxford Languages)

*MaxMSP/Max for Live*: Graphical coding interface (commonly used for audio-visual art) that works within Ableton Live (Ableton, n.d.)

*Mesostructure*: a structure or superstructure of intermediate size or complexity (Oxford languages), here applied to musical multiscale organisation (Roads, 2015)

*Meta-module(s)*: systems of modular synthesis components that work together to perform specific tasks (i.e. a subtractive synthesiser voice) (Hetrick, 2017)

*Metanarrative*: overarching narrative about smaller narratives, encompassing and explaining other “little stories” within totalising a schema (New World Encyclopaedia)

*Metaphysics/metaphysical*: branch of philosophy that deals with the first principles of things, including abstract concepts such as being, knowing, identity, time, and space. (Oxford Languages)

*Modular synthesiser/modular synth*: electronic musical instrument made up of individual modules that are connected together to create electronic sounds (Thomann, 2019)

*Modulation*: [in sound synthesis] process of making parameters move/change automatically over time with other signals (FaderPro, 2023)

*Modularity*: the quality of consisting of separate parts that, when combined, form a complete whole (Cambridge Dictionary) in particular sound synthesis systems (Hetrick, 2017)

*Morphology*: [in sound/electroacoustic theory & synthesis] property of dynamic sound objects changing/morphing over time (Schaeffer, 1977), see also *Spectromorphology*

*Phenomenology/phenomenological*: the science of phenomena as distinct from that of the nature of being (Oxford Languages)

*Polyphony*: [contextual]

1. [music theory] the style of simultaneously combining a number of parts, each forming an individual melody and harmonizing with each other (Oxford Languages)
2. [sound design theory] multiple mesostructural components forming horizontal macrostructures (Roads, 2015)

*Psychoacoustic(s)*: the scientific study of how people perceive sound (Mariam Webster)

*Resonator*: [in sound synthesis] type of frequency synthesizer comprising of filter(s) i.e. comb, or equalization module(s) (digital or hardware) that generates or selects specific frequencies to create tones, commonly derived from modal, Karplus-strong, other physical modelling or other synthesis methods (Meyer, 2016; Author's own)

*Qualia*: a quality or property perceived or experienced by a person (Oxford Languages)

*Semi-generative*: [sound synthesis] system encompassing some degree of generative capacity, which is not fully generative (see *generative*) (synthesiser parlance)

*Sonic objects/sound objects*: perceptual, intentional auditory object that can be observed and recognised by the listener (Schaeffer, 1966; 1976)

*Soundscape*: work of art or performance that combines sounds in order to create a particular effect (Cambridge Dictionary)

*Spatialisation*: [sound synthesis/audio] process of causing a sound or set of sounds to assume spatial properties

*Spectromorphology*: defines shapes and structures of sound spectrums as they manifest in time (see morphology) (Smalley, 1986; 1997)

*Stochastic(ity)*: having a random probability or distribution pattern that may be analysed statistically but may not be predicted precisely (Oxford Languages)

*Synesthetic*: relating to the experience of synaesthesia (see *cross-modal*) (Oxford Languages)

## 14.2 User Survey

To gather qualitative data surrounding using modular synths for creating abstract or generative music, brief user surveying was conducted across various synthesiser communities online and around Glasgow. The survey gathered perspectives on tools used by practitioners and weighed these up against their inherent modularity and the degree to which modularity was valued in processes with predefined aesthetic outcomes. Questions such as *“Which do you value more (only choose one) ... Precision/Experimentalism?”* (full survey questions can be found in Sec 14.2) were asked to ascertain users’ intentions. Their responses were logged in line with which kinds of instruments/processes they used.

Findings confirmed presuppositions surrounding exploration of sound with modular and using modularity as means of catharsis or escapism, disconnecting from the world and connecting with oneself, particularly within ambient/experimental genres.

The survey was limited – the communities it circulated in were generally pro-modular synth, so by their very nature responses might not be objective. This does however mean that we observe responses from people who have significant time/financial investments into the medium and can work to ascertain why so many people feel it was worthwhile. The survey seemingly affirmed preconceived notions about the use intentional use of modular within certain creative frameworks and as means of catharsis or escapism, but did little to challenge them/bring new information to light. For these reasons the user survey was not included in the thesis. The survey is here included to point toward a future, participant facing avenue of research, identifying data driven identification of commonalities amongst practitioners.

## 14.3 User Survey Questions

### Stochastic Genesis - User Survey

Hello,

Thanks for completing this survey - please include as much detail as you can be bothered with, and write as much or little as you like, (the more the better!)

For the purposes of this survey "modular" means any modular interface; modular synths of any format, semi-modulars, virtual modular synths such as VCV rack, modular coding interfaces, even programmable digital synths with modular workflows or deep modulation matrixes, etc.

If you don't "patch" your music (physically or digitally) per se, please just answer as if patch means program or play. If the survey states "modular synth" or similar and you don't use any kind of modular interface, just assume it means DAW, synthesizer, groovebox, sampler etc.

Also, the tone of the questions is a bit formal/academic but don't feel like you have to be: just be as honest as you can, write in any way you like.

Please email completed surveys to [rory.f.green@hotmail.co.uk](mailto:rory.f.green@hotmail.co.uk) or back to me on social media.

Finally, I'm extremely grateful for you taking the time out to do this, and always more than happy to chat about synths. If anyone would like to talk about how to shoehorn modular synths/electronic music into your studies (or anything else for that matter) please reach out to me. All of the "sonic

artefacts" generated for this research project will be available to participants as a sample pack.

Thank you!

### Questions

Please feel free to share your name and links to any music you might have out. This isn't compulsory:

(I won't mention your name/music within any of the thesis/portfolio - it just serves qualitative data to see what you mean in a musical context).

What are your predominant tools for creating electronic music? Would you *personally* classify any of them as modular in nature? (Just write "yes" after the chosen tool).

Which genre(s) do you create/produce?

In your own words, *why* do you make electronic music?

On a scale of 1 - 10 how confident are you with synthesis, sound design and complex modulation routing?

What appeals to you about modular synth interfaces & environments?

Do you consider yourself as more of a (choose one cluster or both equally/interchangeably) ...

Producer/technician/engineer

Artist/songwriter/creative ?

Do you consider narratives/themes when you make electronic music, or is your patching purely exploratory and centres around things just "sounding good", or do you do both? Which narratives/themes have you considered in the past if any?

Which matters more to you (you can only choose one cluster) ...

Abstract sound design/texture

Melody, harmony & rhythm ?

Whilst *writing* music with your chosen (modular) interface, are you presently and mindfully calculating each chosen patch/parameter change, or are you on mindless autopilot, entering a kind of "flow state"? Do you jump between the two

constantly or at different stages of production? Feel free to add any comments or describe habits you might have noticed.

Which do you value more (only choose one)

Precision

Experimentalism        ?

What would you say the purpose(s) of electronic music is/are for you personally? (Anything from dancing, partying, creating, listening, immersion, meditating, whatever). Feel free to make a list.

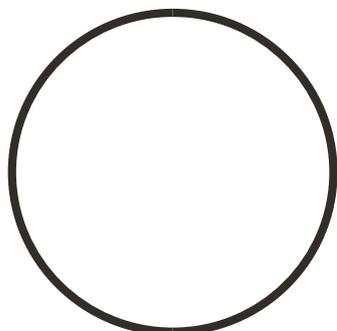
Do you let any of your other interests influence your productions? If so, what are they, and how do they influence your processes?

Do you identify with touch-textural descriptions of audio? (i.e. a filter resonance sounding "wet" or a distortion sounding "dry" or FM synths sounding "cold" vs. analog "warmth") feel free to expand on this as much as you can.

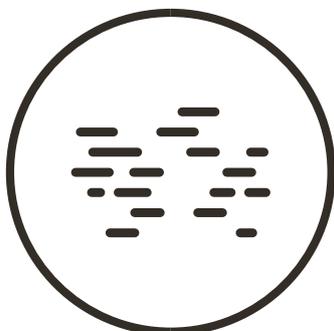
What would you define as "generative music"? How often do you create it?

That's it! Thank you so much once again.

# Patch Symbols: Audio Sources



audio-src



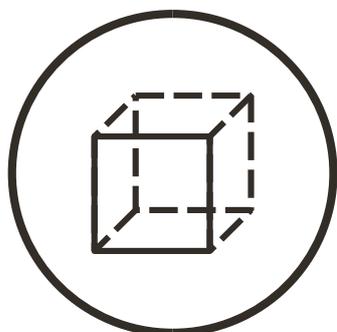
granular-synth



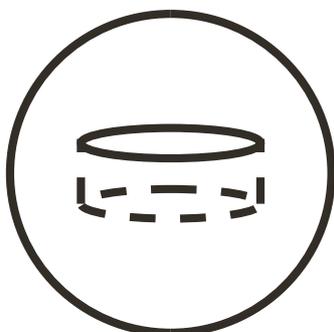
microphone-input



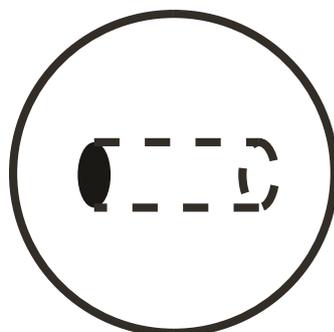
noise



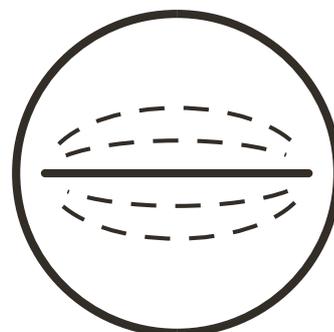
physical-mod-generic



physical-mod-membrane



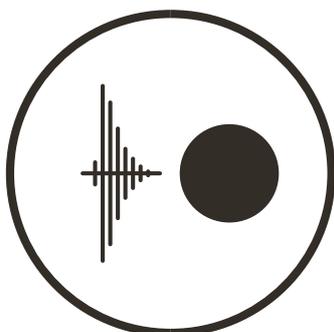
physical-mod-pipe



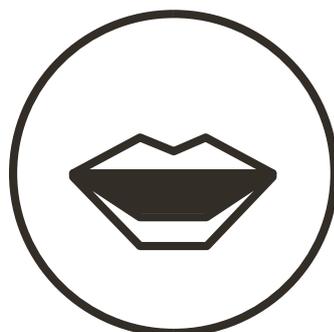
physical-mod-string



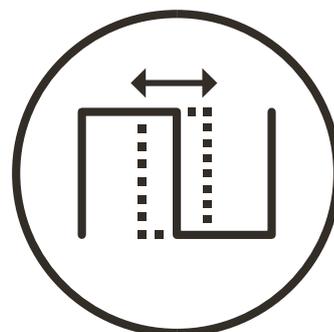
sample-player



sample-rec



speech-synthesis



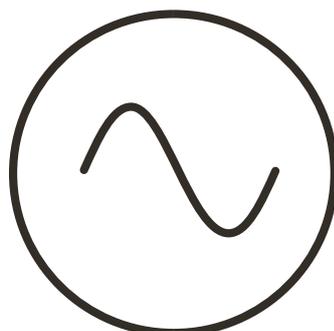
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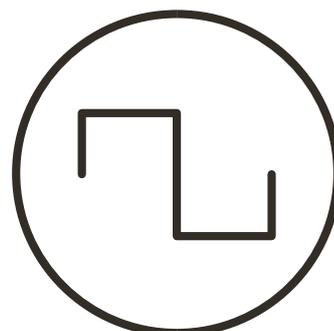
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vco-saw

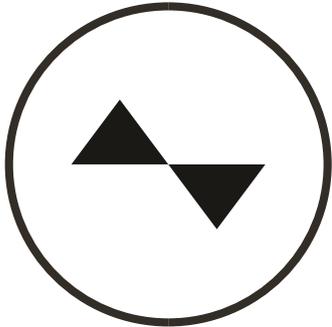


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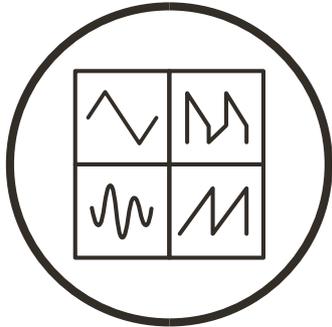


vco-square

# Patch Symbols: Audio Sources

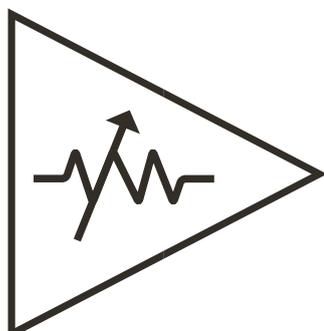


vco-triangle

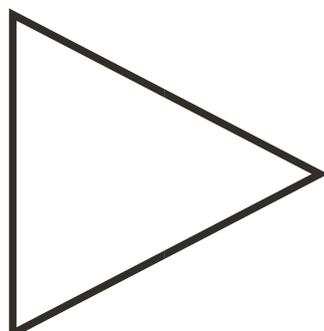


vco-wavetable

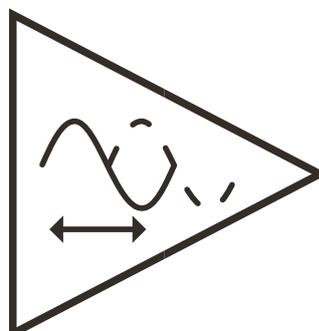
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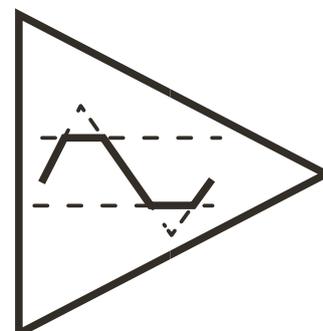
attenuator



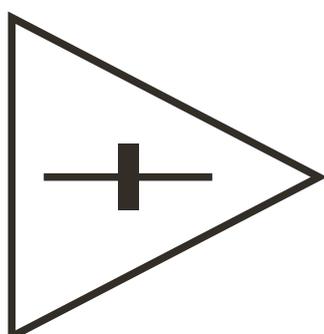
audio-processor-generic



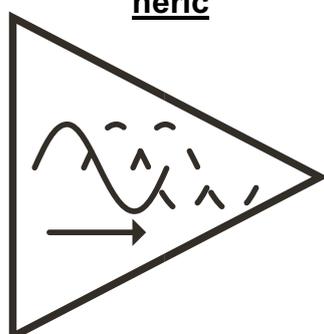
chorus



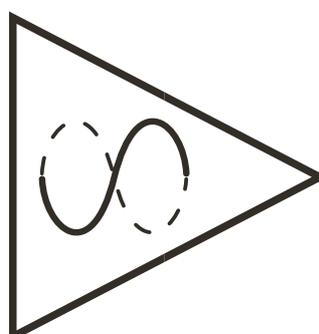
clipper



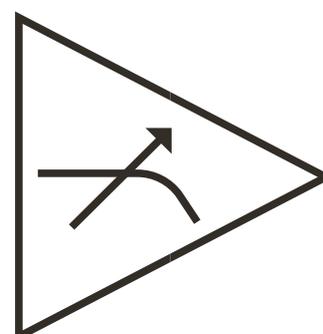
crossfader



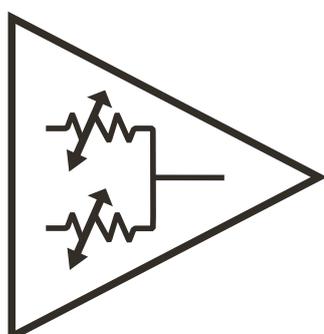
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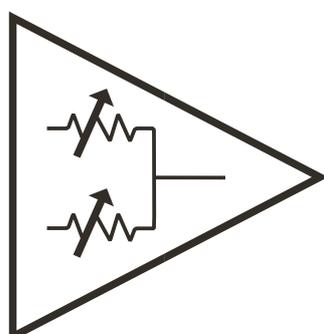
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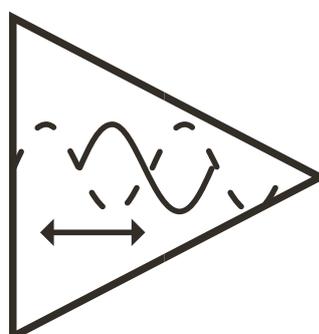
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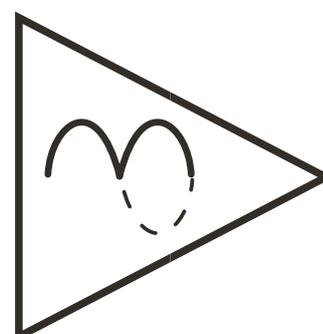
mixer-inverting



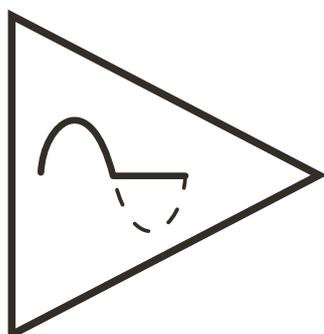
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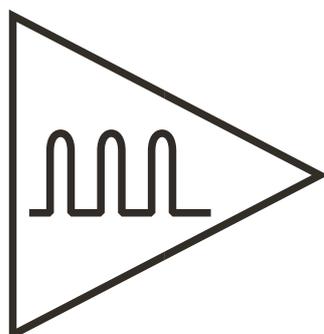
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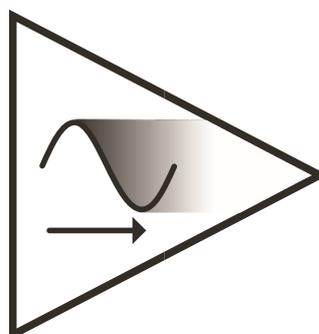
rectifier-full



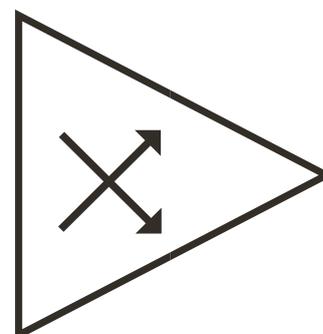
rectifier-half



resonator

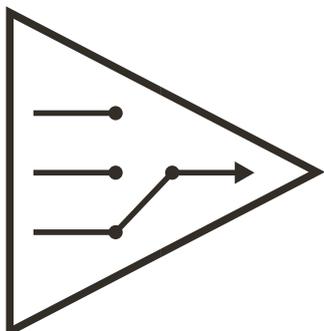


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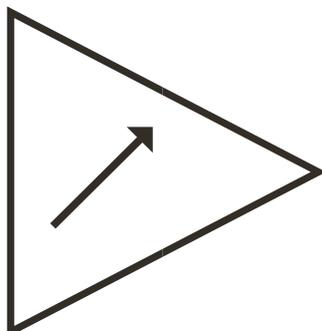


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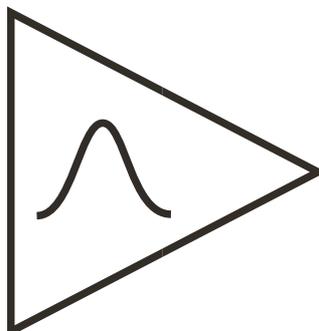
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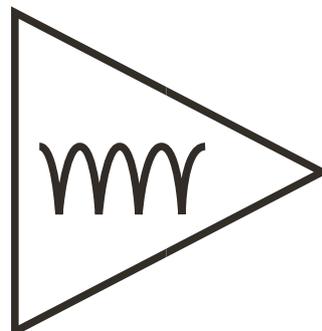
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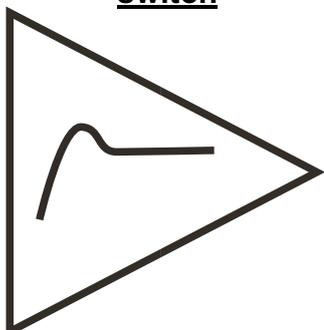
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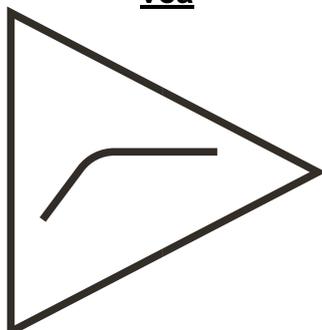
vcf-bandpass



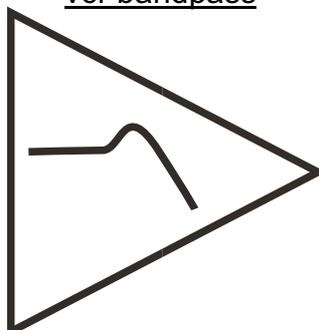
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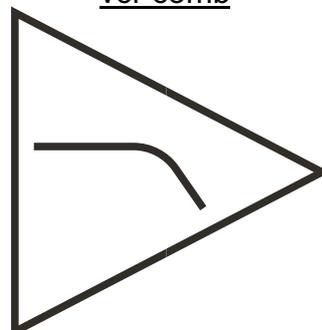
vcf-highpass-res



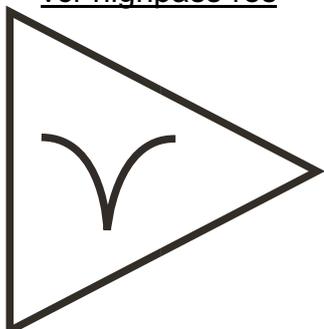
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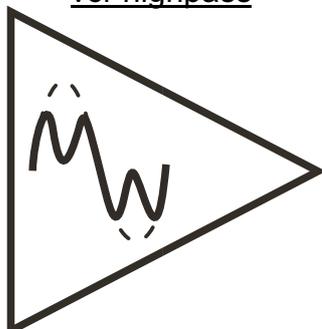
vcf-lowpass-res



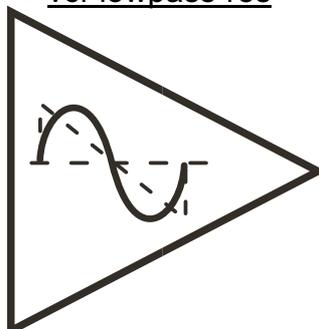
vcf-lowpass



vcf-notch

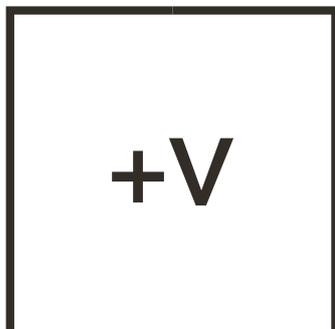


wavefolder

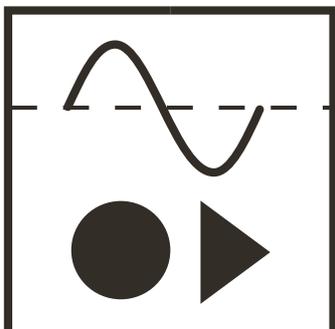


waveshaper

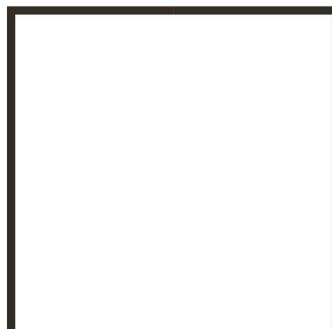
# Patch Symbols: CV Sources



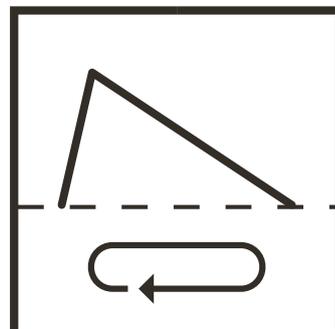
bias-voltage



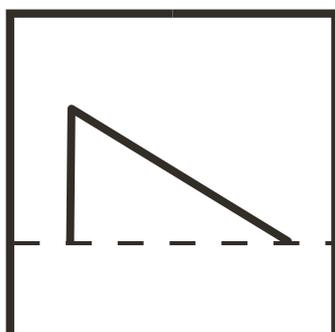
cv-recorder



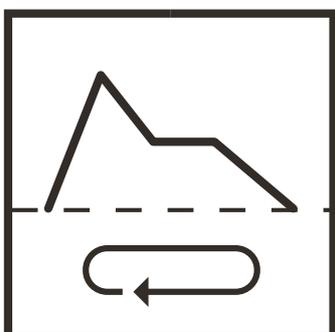
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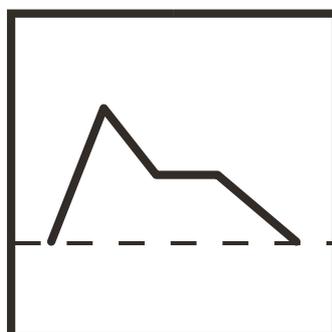
env-ad-loop



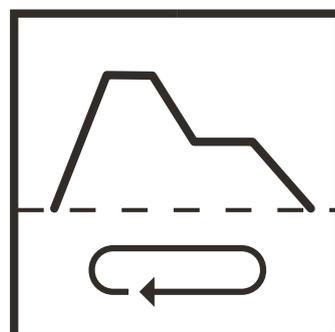
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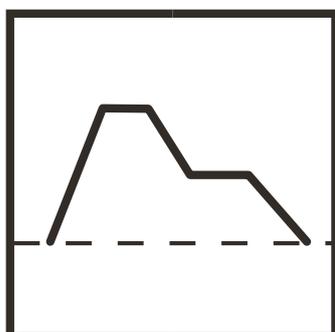
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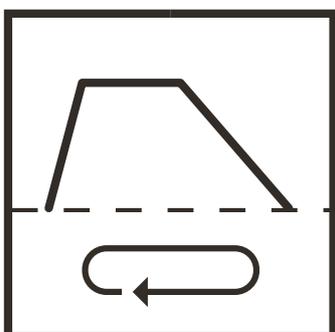
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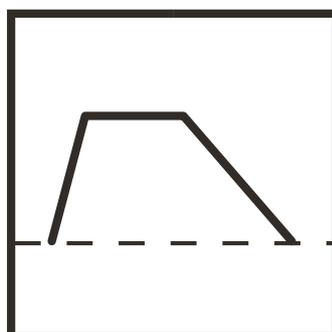
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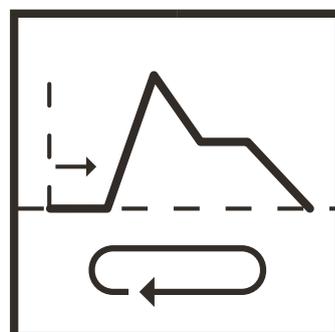
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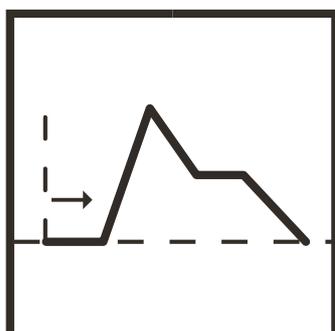
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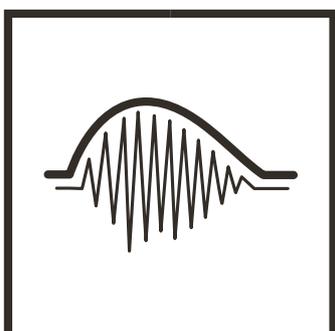
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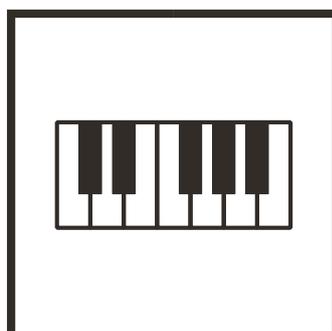
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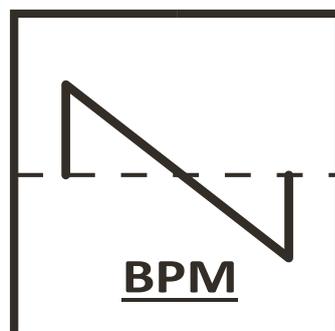
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envelope-follower

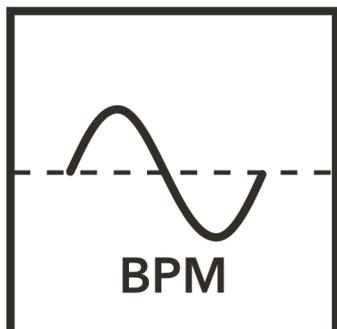


keyboard-ctrl

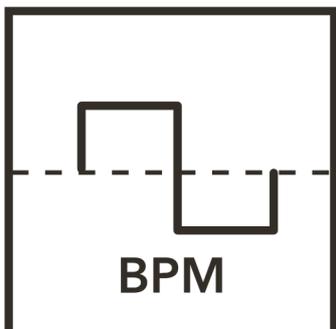


lfo-bpm-saw

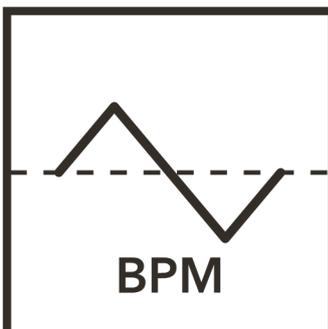
# Patch Symbols: CV Sources



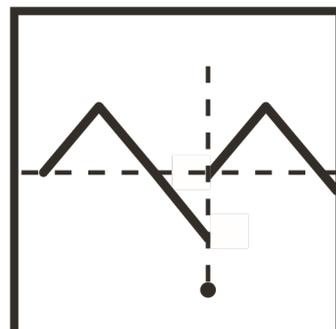
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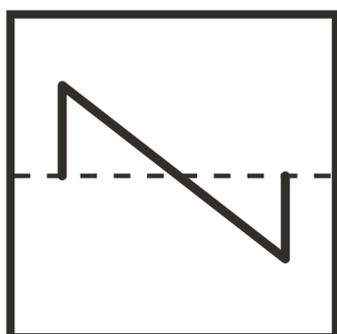
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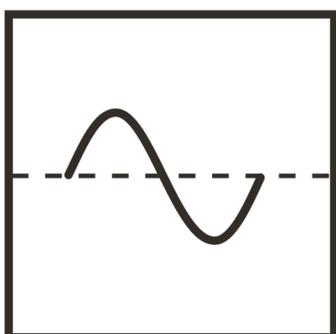
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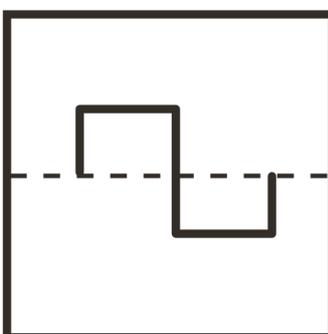
lfo-reset-sync



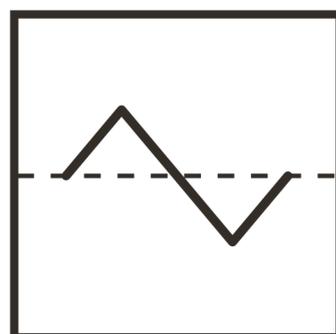
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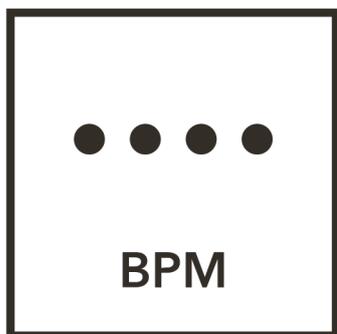
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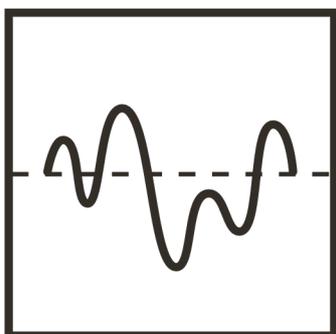
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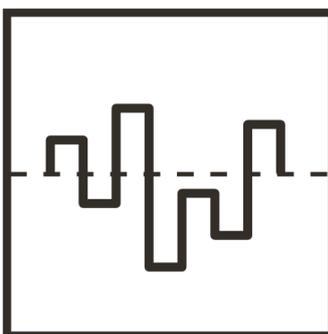
lfo-triangle



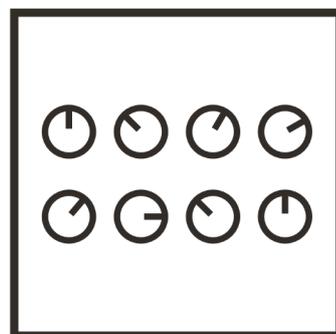
master-clock



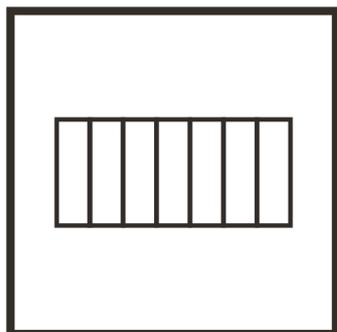
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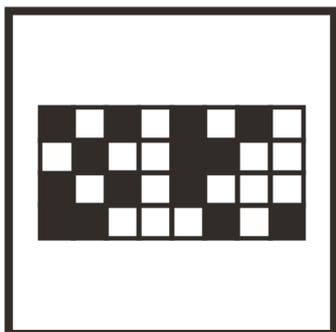
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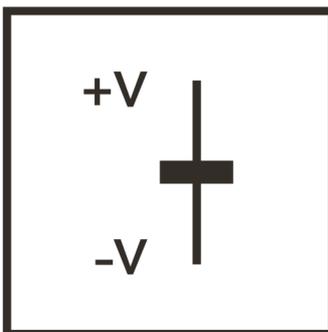
seq-cv-gate



touch-ctrl

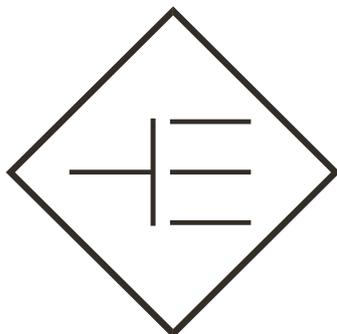


trigger-pattern-generator

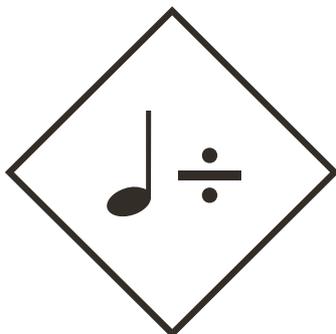


voltage-slider

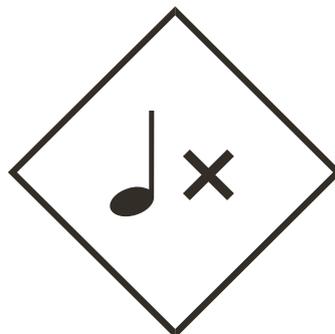
# Patch Symbols: CV Modifiers



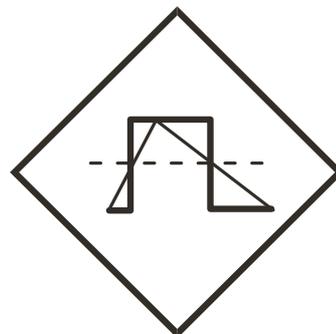
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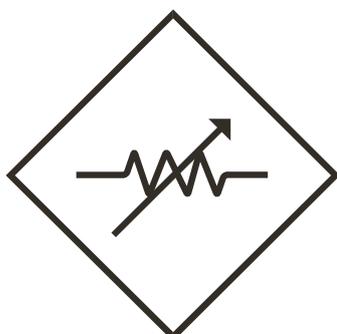
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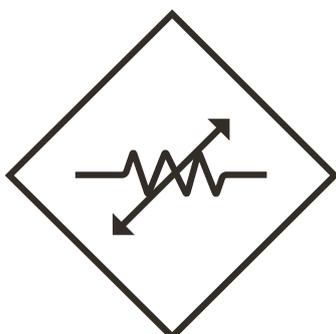
clock-multiplier



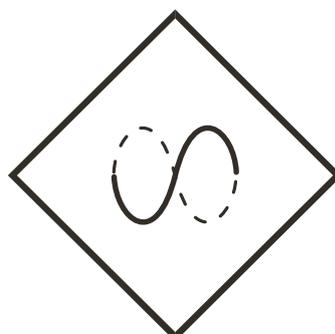
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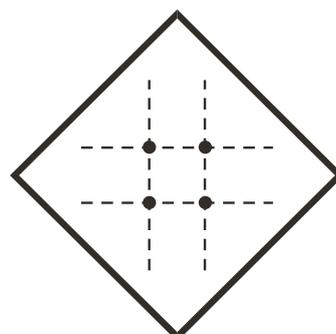
cv-attenuator



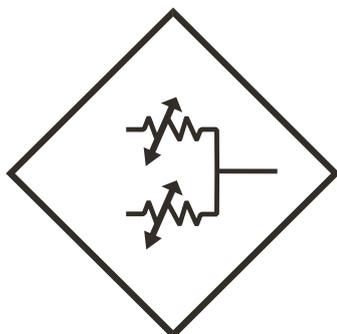
cv-attenuverter



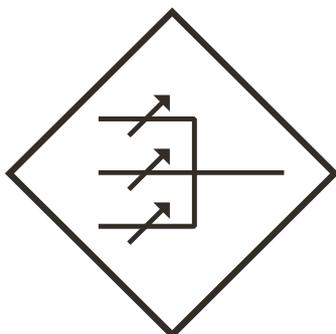
cv-inverter



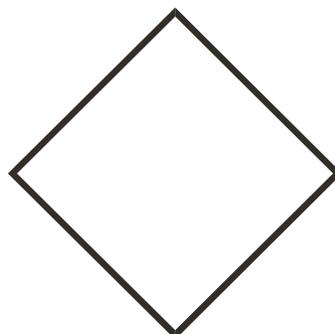
cv-matrix-mixer



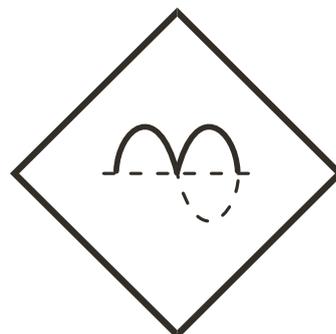
cv-mixer-attenuverting



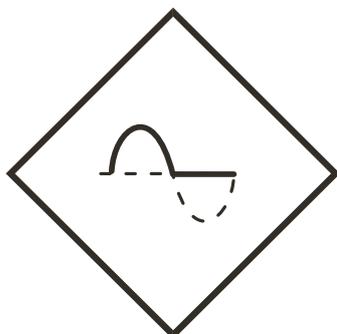
cv-mixer



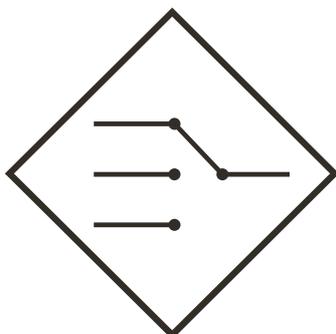
cv-mod-generic



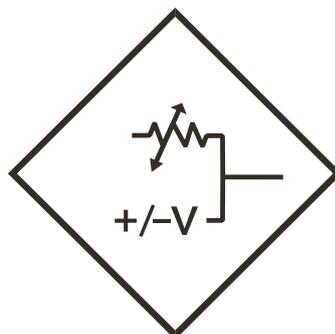
cv-rectifier-full



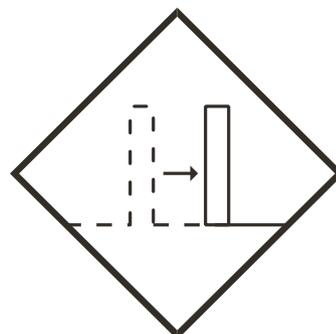
cv-rectifier-half



cv-switch

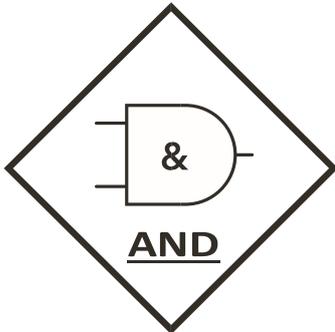


cv-utility-mixer

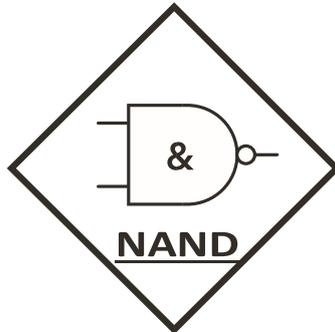


gate-delay

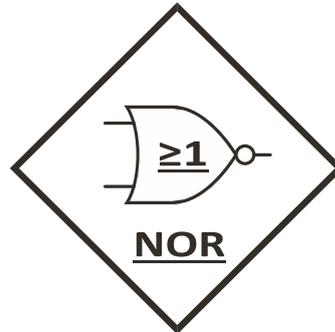
# Patch Symbols: CV Modifiers



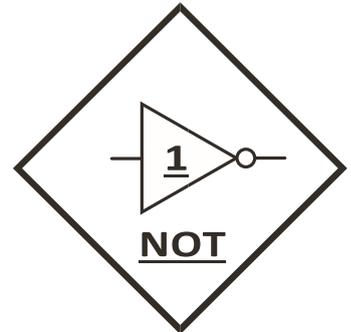
logic-and



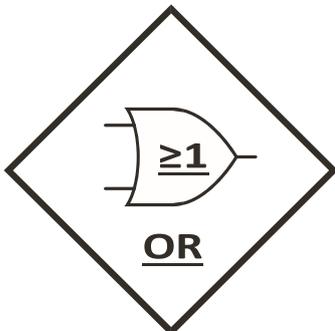
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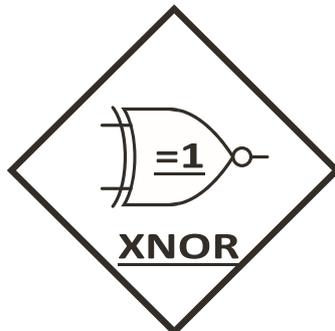
logic-nor



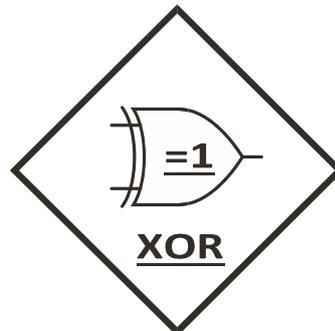
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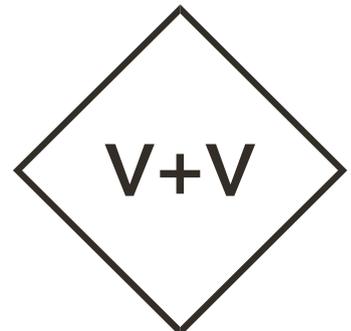
logic-or



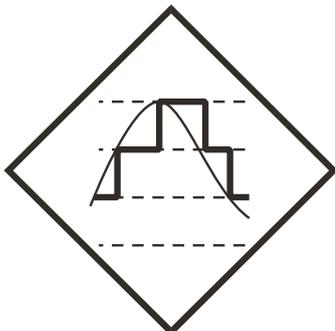
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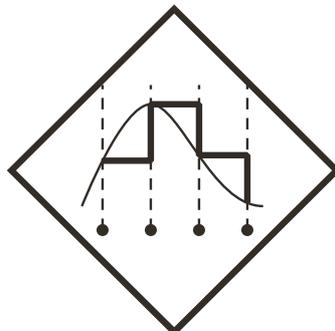
logic-xor



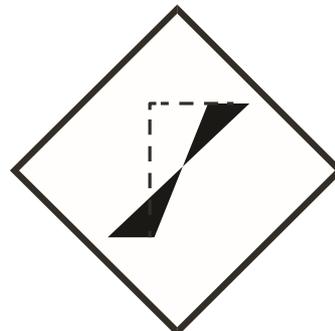
precision-adder



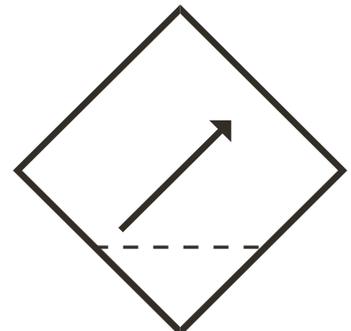
quantizer



sample-and-hold



slew-limiter



vca-dc

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