Music Is Life

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Abstract

Some thoughts about life, organization, organicism and coherence in science and in music.

»Music is life, and like it inextinguishable.«[1]

CARL NIELSEN

1 Introduction

CARL NIELSEN's *Symphony No. 5 CNW 29 Op. 50* (composed: 1920-22) is a good example for organicism and coherence in music. ALLAN PETTERSSON's *Symphony No. 6* (composed: 1963-66) describes life. The music inspires me, to think about organization and life in nature, science and in music. The philosophical perspectives behind are Reductionism and Organicism.

2 Empty space - Silence

No organization needed, because no matter is available. In music, silence is representing this state. An example of a piece with complete silence is JOHN CAGE's opus 4'33".

Figure 1: Empty Space

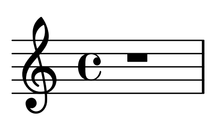

Figure 2: Silence

[*]Initial release of this manuscript: February 25, 2013.

[1] Claus Røllum, *Preface to Carl Nielsen Symphony No. 4*, Edition Wilhelm Hansen, Copenhagen: The Royal Library: 2000, xiv.

Part I
Monophony

3 Basic Organization

3.1 Atom - Tone

Definition. The name atom comes from the Greek ἄτομος (atomos, »indivisible«) which means uncuttable, or indivisible, something that cannot be divided further.[2] The basic unit of matter.

Figure 3: Atom

Figure 4: Tone C

Remark. It's representation in music is a tone.

3.2 Binary Number - Rhythm

Definition. Fundamental unit of information. In mathematics and computer science, the binary numeral system, or base-2 numeral system, represents numeric values using two symbols: 0 and 1. A bit can have only two values: either 1 or 0.[3]

0101

Figure 5: Binary numbers

Figure 6: Rest / Tone C

Remark. Corresponds to a rhythm.

[2] Wikipedia
[3] *Ibid.*

3.3 Water Molecule - Tremolo

Fact. *Two chemical elements (O, H).*

Definition. A chemical element is a pure chemical substance consisting of one type of atom distinguished by its atomic number, the number of protons in its nucleus.

The next step in organization is the formation of a small molecule.

Definition. A molecule is an electrically neutral group of atoms held together by covalent chemical bonds.[4]

An example is the inorganic compound water. Individual water molecules are held together by weaker hydrogen bonds.

Definition. Water is a chemical compound with the chemical formula H_2O. A water molecule contains one oxygen and two hydrogen atoms connected by covalent bonds. The water molecule forms an angle. Water covers 71% of the Earth's surface, and is vital for all known forms of life.[5]

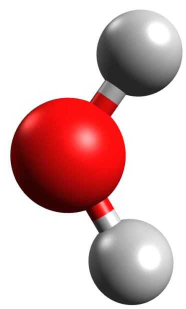

Figure 7: Water Molecule

Opening of NIELSEN's *5th Symphony:*[6]

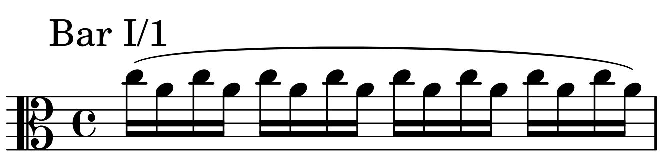

Figure 8: Opening Viola tremolo

Remark. Finalis C, G-Hypomixolydian (1♭).[7]

[4] Wikipedia.
[5] *Ibid.*
[6] All snippets from Score Carl Nielsen *Symphony No. 5, Op. 50* Copenhagen: Skandinavisk Musikforlag, 1950. Plate SM 4552. Public Domain.
[7] Mode established in the evil motive.

4 Philosophical Perspectives

4.1 Urea Synthesis

Urea is a small organic compound. It can be synthesized by two inorganic compounds. The first synthesis of urea was done by Friedrich Wöhler in 1828.

$$NH_4{}^+ + O^- {-} C{\equiv}N \xrightarrow{\Delta} H_2N{-}CO{-}NH_2$$

Figure 9: Urea Synthesis

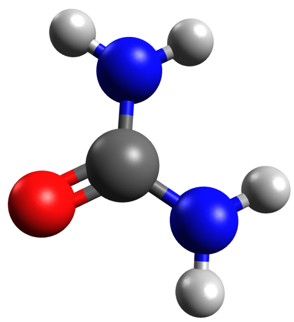

Figure 10: Urea Structure

Symmetry of the urea molecule in Figure 10[8] is $\mathcal{A} - \mathcal{B} - \mathcal{A}$.

Proof. It showed for the first time that a molecule found in living organisms could be synthesized in the lab without biological starting materials.[9] □

[8] Structures made with Avogadro: an open-source molecular builder and visualization tool. Version 1.1.0, http://avogadro.openmolecules.net/.

[9] Wikipedia.

4.2 Vitalism

Definition. Living organisms are fundamentally different from non-living entities because they contain some non-physical element or are governed by different principles than are inanimate things.[10] (»*vis vitalis*«)

Fact. *The urea synthesis is contradicting the theory of vitalism.*

Remark. At the time of composition of Nielsen's *5th Symphony* (1922) the theory of vitalism was clearly disproved.

4.3 Reductionism

Definition. Reductionism is a philosophical position that holds that a complex system is nothing but the sum of its parts.[11]

4.4 Organicism

Remark. American biologist William Emerson Ritter first used the term organicism in a biological sense in 1919.

Definition. The larger organization of an organic system has features that must be taken into account to explain its behavior. Whole organism biology is not fully explainable by atomic mechanism. Organicism rejects mechanism/reductionism and vitalism.[12]

Remark. Nielsen's composed *Symphony No. 5 CNW 29 Op. 50* 1920-22 under the influence of this philosophical perspective.

In a letter to Ture Rangström written in February 1920 [1, p.19]:

> For what matters now and in the future is certainly to work towards uniting the utmost freedom in terms of individual content and the utmost strictness with regard to organicism: that is to say, coherence.
>
> Carl Nielsen

[10] Wikipedia.
[11] *Ibid.*
[12] *Ibid.*

5 Organic Molecule and Theme

The molecule in Figure 11[13] mimics the enzyme superoxide dismutase.[14]

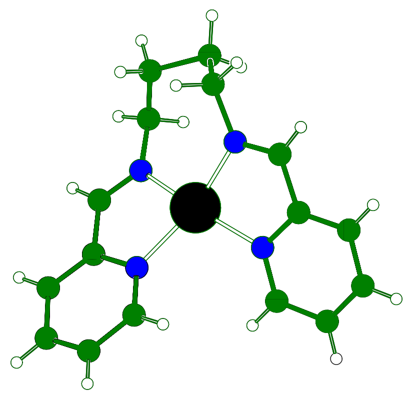

Figure 11: Organic Molecule

The structural symmetry of this monomer molecule is $\mathcal{A} - \mathcal{B} - \mathcal{A}$. The organic molecule consists of four different chemical elements (copper, nitrogen, carbon, hydrogen).

This structural unit can be represented in music by motives or themes.

Figure 12: NIELSEN Opening *Symphony No. 5* (single voice)

The structure of this theme is asymmetric $\mathcal{A} - \mathcal{A} - \mathcal{B}$. Mode is D-Dorian (0♭). Five different tones.

[13] Structures taken from my thesis.
[14] Biological task of the enzyme superoxide dismutase (molecular weight 32,500) is the antioxidant defense in cells exposed to the aggressive oxygen derivative superoxide.

6 Advanced Organization

6.1 Dimer - Voice Pair

The simplest way to archive organization of the molecule is a dimerization. The helical dimer of the molecule in Figure 11 is shown in Figure 13. It is an example for duality and self-organization[15]. Monomer (Cu^{2+}) and dimer (Cu^{+}) operate as a redox switch.

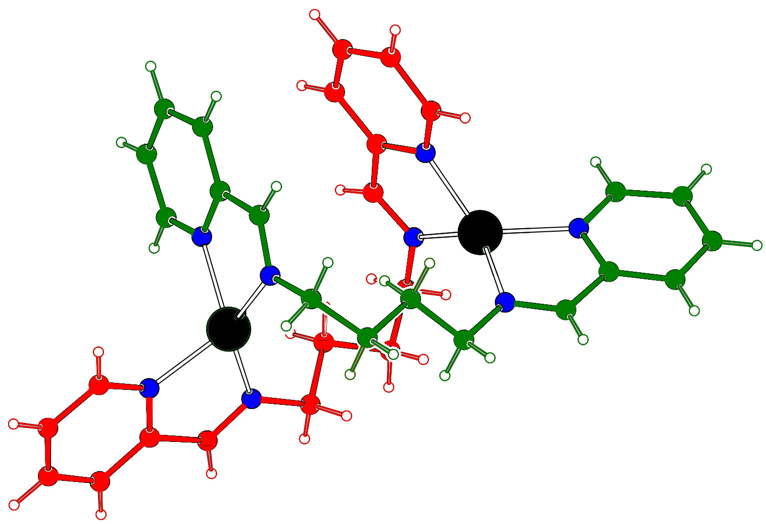

Figure 13: Molecule Dimer

NIELSEN uses a pair of bassoons for the initial theme.

Figure 14: NIELSEN Opening *Symphony No. 5*

The two movement structure underlines the importance of duality and dualism in NIELSEN's *5th Symphony*. Also the moral dualism manifested by the conflict between good and evil. The »male« and »female« phrases in the opening of MOZART's *»Jupiter« Symphony* are another example for dualism. Form of the asymmetric Classical theme: $\mathcal{A} - \mathcal{A} - \mathcal{B}$.

[15] Self-organization is a process where some form of global order or coordination arises out of the local interactions between the components of an initially disordered system. (Wikipedia)

6.2 Amino Acid: Asymmetry

Example. Asymmetry in nature: amino acid alanine.

$$H_3C-CH(NH_2)-COOH$$

Figure 15: Alanine

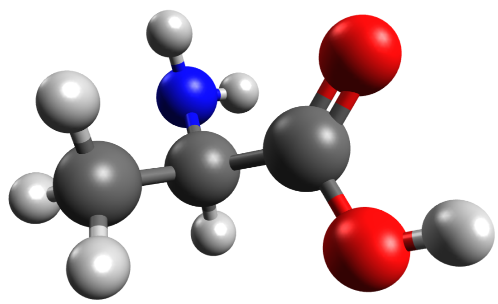

Figure 16: L-Alanine Structure

Example. Asymmetric amino acids, essential for life and the origin of life, exist in »right handed« and »left handed« versions.

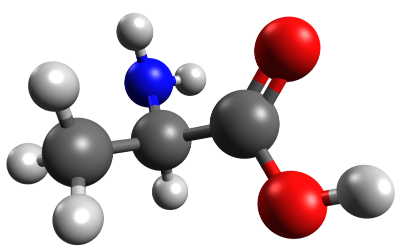

Figure 17: L-Alanine Structure

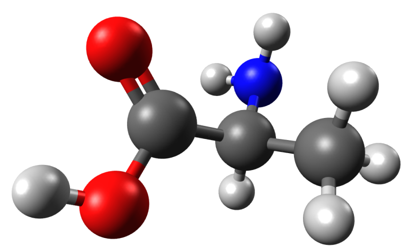

Figure 18: R-Alanine Structure

Proposition. *Asymmetry and duality are essential for the existence of life.*

6.3 Base Pair - Mode Pair

Definition. Amino acid base pairs are the building blocks of the DNA double helix, and contribute to the folded structure of both DNA and RNA. The complementary nature of this based-paired structure provides a backup copy of all genetic information encoded within double-stranded DNA.[16]

- Adenine (A) . . . Thymine (T)
- Guanine (G) . . . Cytosine (C)
- Cytosine (C) . . . Guanine (G)
- Thymine (T) . . . Adenine (A)

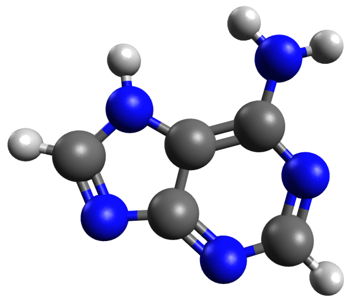

Figure 19: Adenine Structure

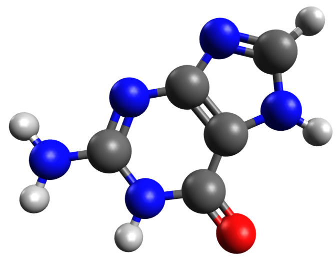

Figure 20: Guanine Structure

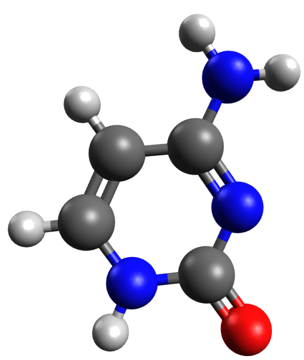

Figure 21: Cytosine Structure

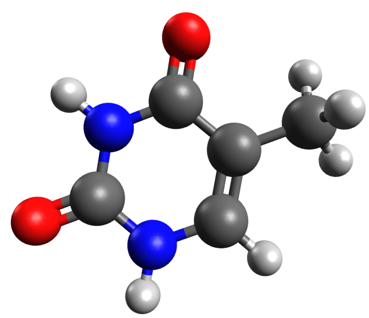

Figure 22: Thymine Structure

[16] Wikipedia.

Remark. The complementary two bases are attracted by hydrogen bonds. (see also hydrogen bonds in water Section 3.3)

In music, church modes (Section 8.2.1) build pairs of same semitone position, but different finalis.[2] The complementary, but coherent, pair Dorian ... Hypomixolydian can be found at the opening of NIELSEN's *5th Symphony*.

- C-Ionian (C)[17] ... C-Hypolydian (F)
- D-Dorian (D) ... D-Hypomixolydian (G) (high symmetry)[18]
- E-Phrygian (E) ... E-Hypoaeolian (A)
- F-Lydian (F) ... F-Hypolocrian (B)
- G-Mixolydian (G) ... G-Hypoionian (C)
- A-Aeolian (A) ... A-Hypodorian (D)
- B-Locrian (B) ... B-Hypophrygian (E)

Example. Dorian ... Hypomixolydian.

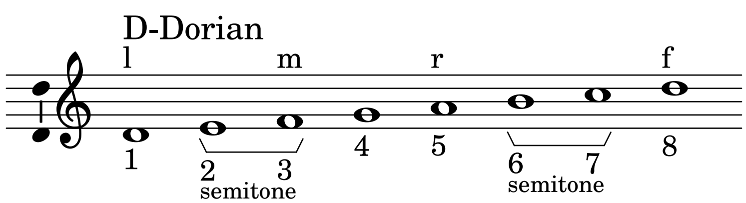

Figure 23: D-Dorian Scale

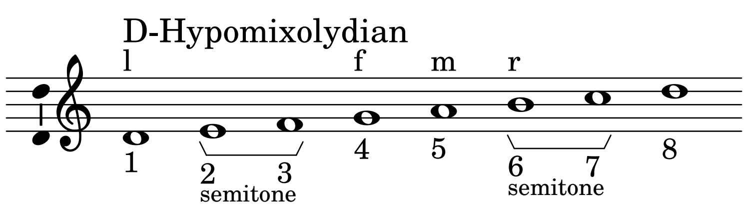

Figure 24: D-Hypomixolydian Scale

[17] Finalis C (0♭).
[18] Retrograde scale has also identical semitone position.

6.4 DNA

The double helix of DNA (structure: Watson, Crick 1953, [8]) is an important example for duality and asymmetry in nature. (asymmetric base pair: Section 6.3)

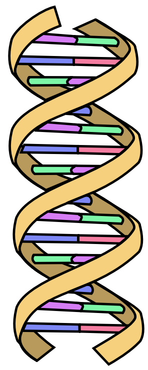

Figure 25: Nucleic Acid Double Helix (Public Domain)

7 Wave–Particle Duality

Remark. Applies only to very small objects on atomic scale, like electrons.

Figure 26: Particle

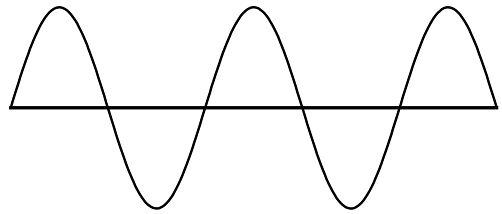

Figure 27: Wave

Definition. Wave–particle duality postulates that all particles exhibit both wave and particle properties. A central concept of quantum mechanics, this duality addresses the inability of classical concepts like »particle« and »wave« to fully describe the behavior of quantum-scale objects.[19]

[19] Wikipedia.

8 Waves

8.1 Pure Tone

Definition. A pure tone is a tone with a sinusoidal waveform. A sine wave is characterized by its frequency, the number of cycles per second.[20]

$$C_5 = 523.251 \text{ Hz}$$

8.2 Melody Building

8.2.1 Church Modes

Example. A melody by an unknown composer in the plagal mode Hypomixolydian is shown in Figure 28.

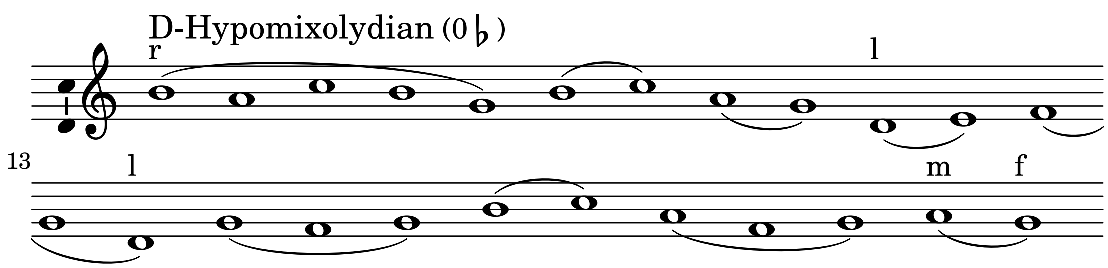

Figure 28: D-Hypomixolydian Plagal Mode Melody

- r = reciting tone, tenor (B) - third over finalis in plagal modes
- l = lowest tone in scale (D) - fourth under finalis (plagal)
- m = mediant (A)
- f = finalis (G) - last tone

Remark. The diatonic melody surrounds the finalis G in a wave-like manner. Finalis G is played seven times.[21]

[20] Wikipedia.
[21] It is the maximum of the probability distribution (0,3,4,4,7,3,1,2).

Problem. What is the basic physical principle behind this melody building?

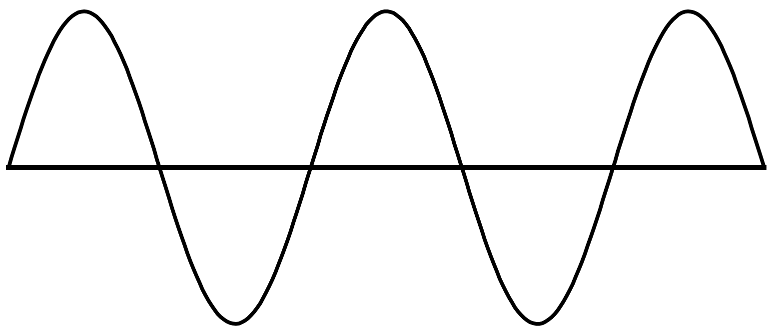

Figure 29: Sine Wave

We have a central pitch, called finalis. Finalis is the most important and last tone of a modal piece and usually played more often. This is represented by the basic zero line of the model wave, a symmetrical sine wave $\sin(x)$[22] (Figure 29). There is an important difference to the twelve-tone technique.

Definition. In twelve-tone technique all 12 notes are given more or less equal importance.[23]

Plagal modes are asymmetric, the octave ambitus is divided by the finalis. Below finalis is a fourth, above the finalis a fifth.

Example. Plagal Mode.

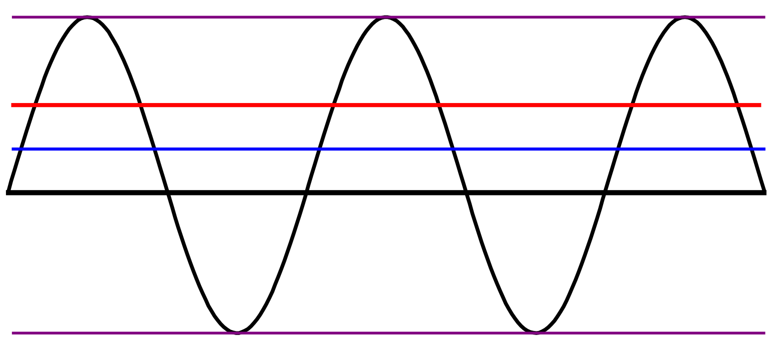

Figure 30: Schematic Frequency Quantization. Plagal Mode.

[22] Smooth repetitive oscillation.
[23] Wikipedia.

Beside finalis, there are other discrete pitches of greater importance, for example the reciting tone. In physics this would correspond to quantum mechanics. Also the »jump like« mutation in biology reminds a physicist of quantum theory.[5][24]

Definition. The name quantum mechanics derives from the observation that some physical quantities can change only in discrete amounts (Latin quanta), and not in a continuous (cf. analog) way.[25] The quantized physical quantity is for example energy. The electrons in atoms are located with a higher probability in discrete orbitals.

In music, some pitches are more important then others and were played more often. The peak-to-peak amplitude of the wave (ambitus), or frequency is quantized.

Example. Authentic Mode.

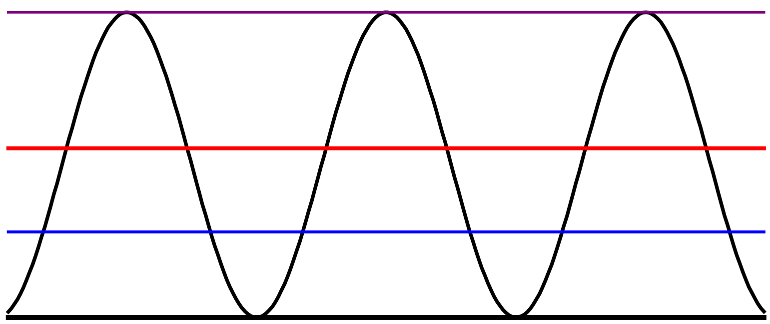

Figure 31: Schematic Frequency Quantization. Authentic Mode.

Claim. The energy-quantized electron orbitals in atoms correspond to the frequency quantization in church mode melody building.

[24] Erwin Schrödinger (12. August 1887 – 4. January 1961), was an Austrian physicist who developed a number of fundamental results in the field of quantum theory, which formed the basis of wave mechanics: he formulated the wave equation (stationary and time-dependent Schrödinger equation). (Wikipedia)

[25] Wikipedia.

The plagal melody in Figure 28 in short form:

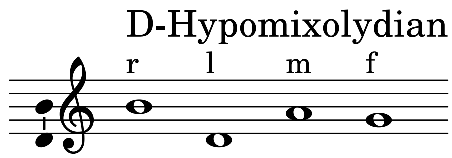

Figure 32: D-Hypomixolydian

and the Hypomixolydian scale:

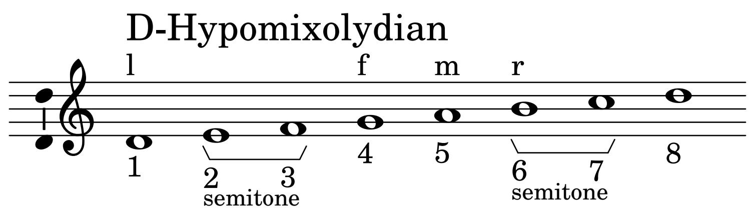

Figure 33: D-Hypomixolydian Scale

8.2.2 Plagal Mode Chain

The 1st movement's main theme in NIELSEN's *5th Symphony* is constructed on basis of a plagal mode chain.

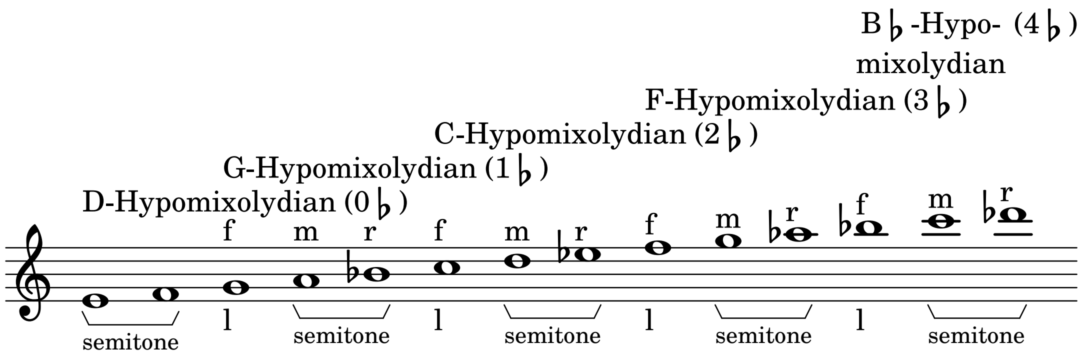

Figure 34: Pitch Structure of the Melody (Bar 44-67)

Fact. *Flatward shift for higher pitches.*

We have four finalis. Most important is the lowest finalis G. The schematic quantization of the wave is shown in Figure 35.

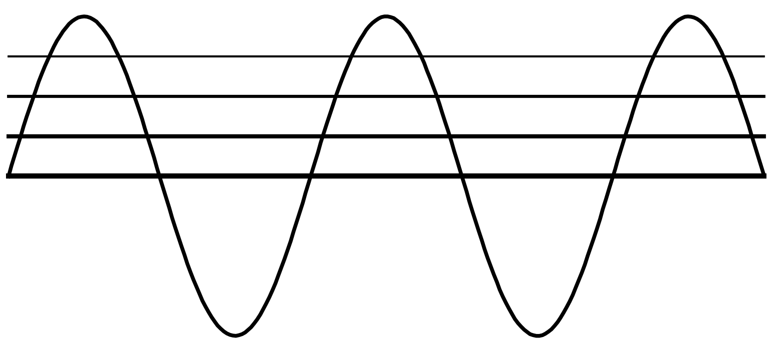

Figure 35: Schematic Wave with four Quantization

Remark. The four finalis are separated by the interval of a fourth.

8.2.3 Bohr Model

In atomic physics, the Bohr model, introduced by Niels Bohr[26] in 1913, depicts the atom as small, with a positively charged nucleus surrounded by electrons that travel in circular orbits around the nucleus.[27]

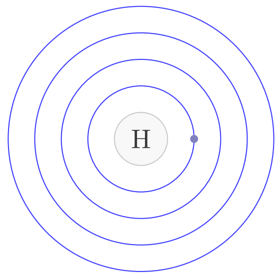

Figure 36: Bohr Model

Electrons can only gain and lose energy by jumping from one allowed orbit to another, absorbing or emitting electromagnetic radiation with a frequency ν determined by the energy difference ΔE of the levels according to the Planck relation:[28]

$$\Delta E = h\nu \tag{1}$$

$h = 6.62606957 \times 10^{-34} Js$

Remark. h is a very small constant.

Fact. *The orbits (more precise: orbitals) are characterized by the principal quantum number n.*

Example. Hydrogen H (see Figure 36), one proton, one electron ($1s^1$).

The emission spectrum of atomic hydrogen is divided into a number of spectral series. These observed spectral lines are due to electrons moving between energy levels in the atom.[29]

[26] Niels Henrik David Bohr (7 October 1885 – 18 November 1962) was a Danish physicist, philosopher and footballer, who made foundational contributions to understanding atomic structure and quantum mechanics, for which he received the Nobel Prize in Physics in 1922. (Wikipedia)
[27] Wikipedia.
[28] *Ibid.*
[29] *Ibid.*

Conjecture. *Bohr Model and Plagal Mode Chain.*

Table 1: Bohr Model versus Plagal Mode Chain

Bohr	Nielsen
nucleus	finalis F (Bass)
$n = 1$	finalis G
$n = 2$	finalis C
$n = 3$	finalis F
$n = 4$	finalis B♭

Claim. The main theme of Nielsen's *5th Symphony* mimics the Bohr model.

9 Vegetatio

Proposition. *The natural and musical transition from cold inorganic matter to life.*

Nielsen development of the material is organic with the principle of non-repeatability and permanent change. He uses the terms »Vegetatio«. What are the principles for that organic growth in nature and in music?

9.1 Organic Growth in Nature

- Self-similarity, Fractal

Definition. In mathematics, a self-similar object is exactly or approximately similar to a part of itself.[30]

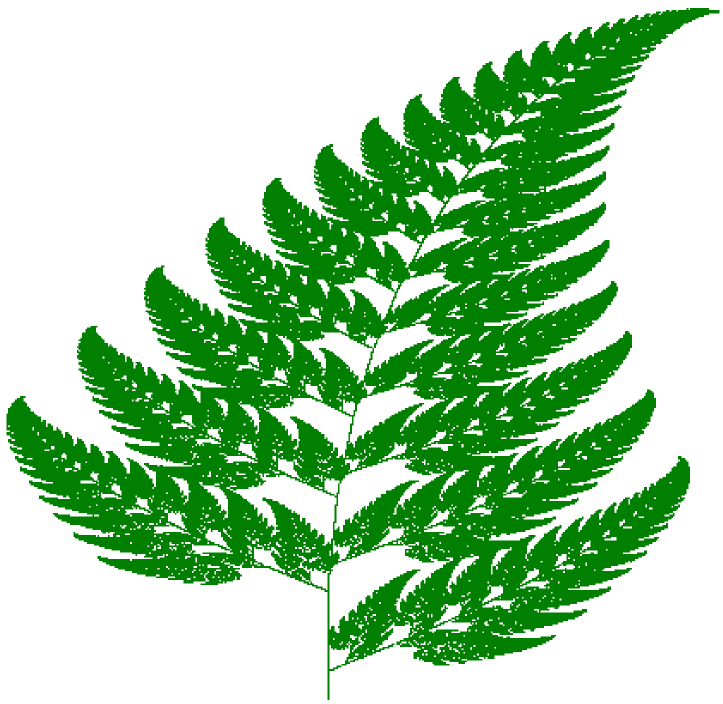

Figure 37: Barnsley fern plotted with VisSim

Figure 37.[31,32,33]

[30] Wikipedia.
[31] DSP-user using model written by Mike Borrello, Creative Commons Attribution-Share Alike 3.0 Unported.
[32] The fern is one of the basic examples of self-similar sets, i.e. it is a mathematically generated pattern that can be reproducible at any magnification or reduction. Like the Sierpinski triangle, the Barnsley fern shows how graphically beautiful structures can be built from repetitive uses of mathematical formulas with computers. (Wikipedia)
[33] Michael Barnsley *Fractals Everywhere*, Boston, MA: Academic Press, 1993, ISBN 0-12-079062-9.

Figure 38: Real *Asplenium* ferns

Figure 38.[34]

[34] Sanjay ach, Creative Commons Attribution-Share Alike 3.0 Unported.

Example. Sierpinski Triangle (1915), named after POLISH mathematician WACŁAW SIERPIŃSKI (Figure 39)[35].

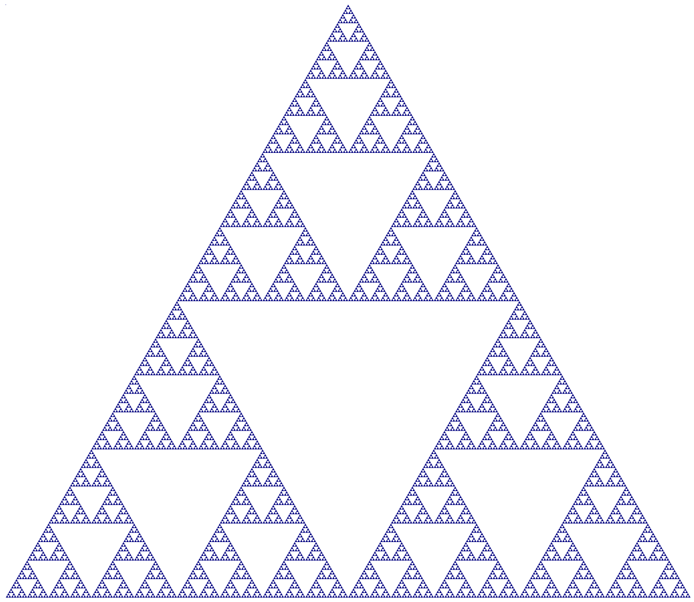

Figure 39: Mechanical Self Similar Fractal (Sierpinski Triangle)

Algorithm 1 Sierpinski Triangle, Chaos Game Method

1: Take 3 points in a plane to form a triangle, you need not draw it.

2: Randomly select any point inside the triangle and consider that your current position.

3: Randomly select any one of the 3 vertex points.

4: Move half the distance from your current position to the selected vertex.

5: Plot the current position.

6: Repeat from step 3.

[36]

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[35] Public Domain.
[36] Wikipedia.

9.2 Organic Growth in Music

Figure 40: Main Theme in 1st Movement (Bar 44-67) of NIELSEN's *5th Symphony*

Problem. Is this melody-line self-similar?

Definition. Self-similar melodies are melodies constructed entirely by repeated applications of a single procedure.

Conjecture. *A single procedure could be:*

Algorithm 2 Main Theme Nielsen's *5th Symphony*

1: lowest tone.

2: finalis ($\longrightarrow$ lowest tone).

3: reciting tone.

4: finalis ($\longrightarrow$ finalis).

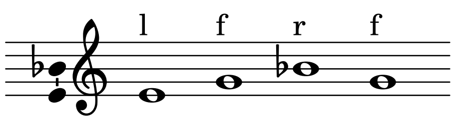

Figure 41: D/G-Hypomixolydian

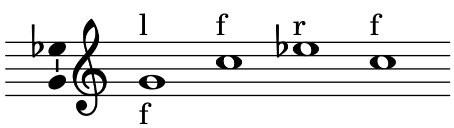

Figure 42: G/C-Hypomixolydian

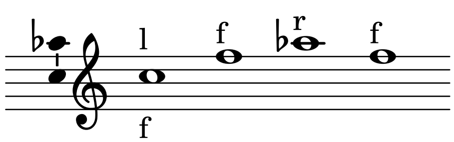

Figure 43: C/F-Hypomixolydian

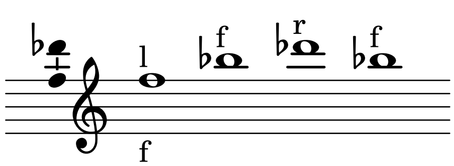

Figure 44: F/B♭-Hypomixolydian

Conjecture. *Schematic Structure of the Waves.*

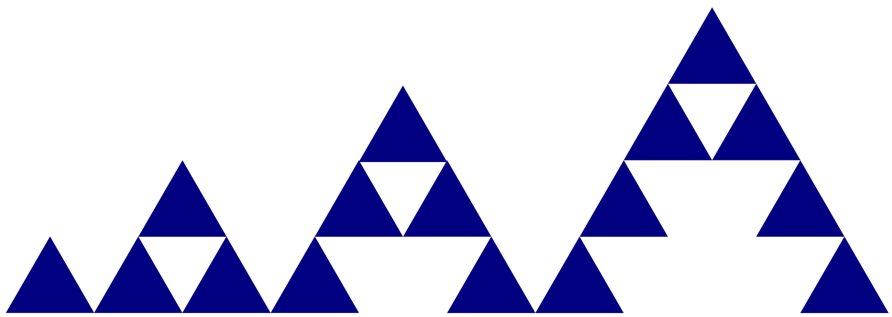

Figure 45: Proposed Schematic Structure of the Waves

Part II
Energy

10 Energy in Physics

10.1 Kinetic Energy

Definition. In physics, the kinetic energy of an object is the energy which it possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass m from rest to its stated velocity v.[37]

$$E_{kin} = \frac{1}{2}mv^2 \tag{2}$$

10.2 Potential Energy

Definition. In physics, potential energy is the energy of an object or a system due to the position of the body or the arrangement of the particles of the system.[38] (m mass, g gravity, h altitude)

$$E_{pot} = mgh \tag{3}$$

10.3 Conservation of Energy

Definition. The law of conservation of energy, first formulated in the nineteenth century, is a law of physics. It states that the total amount of energy in an isolated system remains constant over time.[39]

$$E = E_{kin} + E_{pot} \tag{4}$$

[37] Wikipedia.
[38] *Ibid.*
[39] *Ibid.*

11 Energy in Music

Theorem. *Maximum of Kinetic Energy*

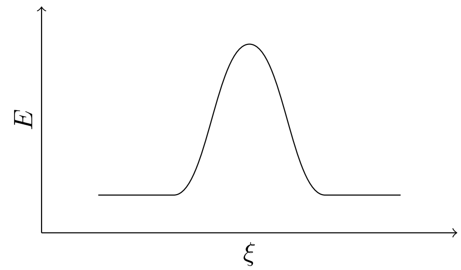

Figure 46: Maximum of Kinetic Energy

Theorem. *Decrease of Potential Energy*

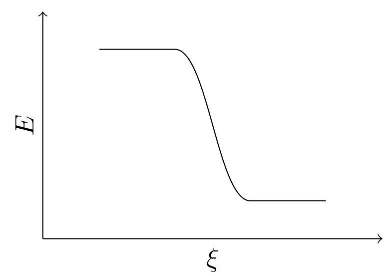

Figure 47: Decrease of Potential Energy

Based on considerations made by Ernst Kurth.[3]

Remark. These plots are similar to the reaction path or mechanism in chemical reactions (activation energy diagrams).

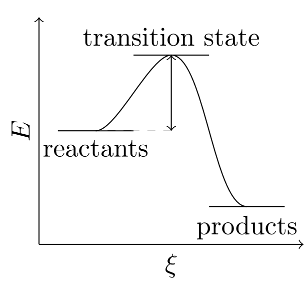

Figure 48: Reaction path of an exothermic chemical reaction

11.1 Kinetic Energy in Music

Fight between opposite forces (dualism).

Example. Nielsen *5th Symphony* 1st Movement. Fight between good and evil (Section 6.1). Renegade snare drummer (Section 13.1.2).

Example. Pettersson *6th Symphony*. First half. Fight of individual against the elements.

Example. Pettersson *9th Symphony*.[40] White water.

The constituting principal structural elements for motion expressing high kinetic energy are:

11.1.1 Runs

Figure 49: *9th Symphony* Runs in White Water

11.1.2 Amplitude

Broadened ambitus, expanded to extreme registers.

11.1.3 Rhythm

Pronounced rhythm.

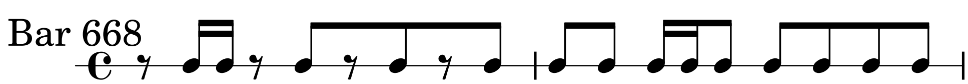

Figure 50: *9th Symphony* Drum Rhythm in White Water

[40] Snippets of *9th Symphony* from Score *NMS 10649* Copyright © 1989 by AB Nordiska Musikförlaget, Stockholm and © Internationale Musikverlage Hans Sikorski.

11.2 Potential Energy in Music

The definition in Section 10.2 suggests, that potential energy in music has something to do with the arrangement of notes, there relative position.

11.2.1 Tonality

In tonal music two chords can have different potential energy. (»Die Akkordspannung«.)[3, p.68]

Example. Authentic Cadence. SMETANA *The Moldau*.[41]

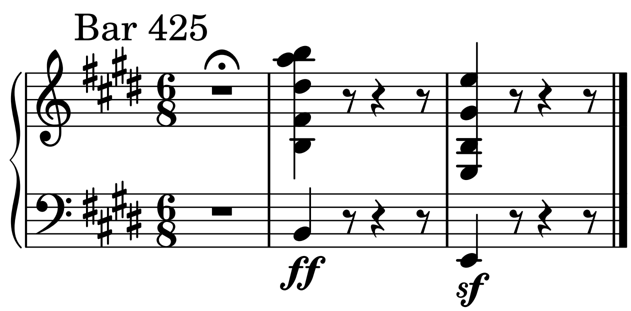

Figure 51: Perfect Authentic Cadence *The Moldau*

Remark. The final tonic chord has lowest potential energy.

11.2.2 Melody Building

reciting tone $\longrightarrow$ lowest tone $\longrightarrow$ mediant $\longrightarrow$ finalis

Remark. The finalis has lowest potential energy.

Example. See melody in Hypomixolydian mode in Figure 28 and Figure 32.

11.2.3 Opus

Opening: Fragment (Motive) + Fragment (Motive) $\xrightarrow{\text{synthesis}}$ Finale: Melody

Remark. The reduction of potential energy is caused by synergy[42] effects.

Example. PETTERSSON *6th Symphony*.

[41] Snippet of SMETANA *The Moldau* from Score Ernst Eulenberg, London-Zürich *No. 472*. Public Domain.
[42] Synergy is the interaction of multiple elements in a system to produce an effect different from or greater than the sum of their individual effects. (Wikipedia)

Part III
Polyphony

12 Stationary Systems

12.1 Crystal

A crystal is a solid where the atoms or molecules form a periodic arrangement. In Figure 52 the crystal structure of the dimer in Figure 13 is shown (cross-section). The stationary structure is three-dimensional.

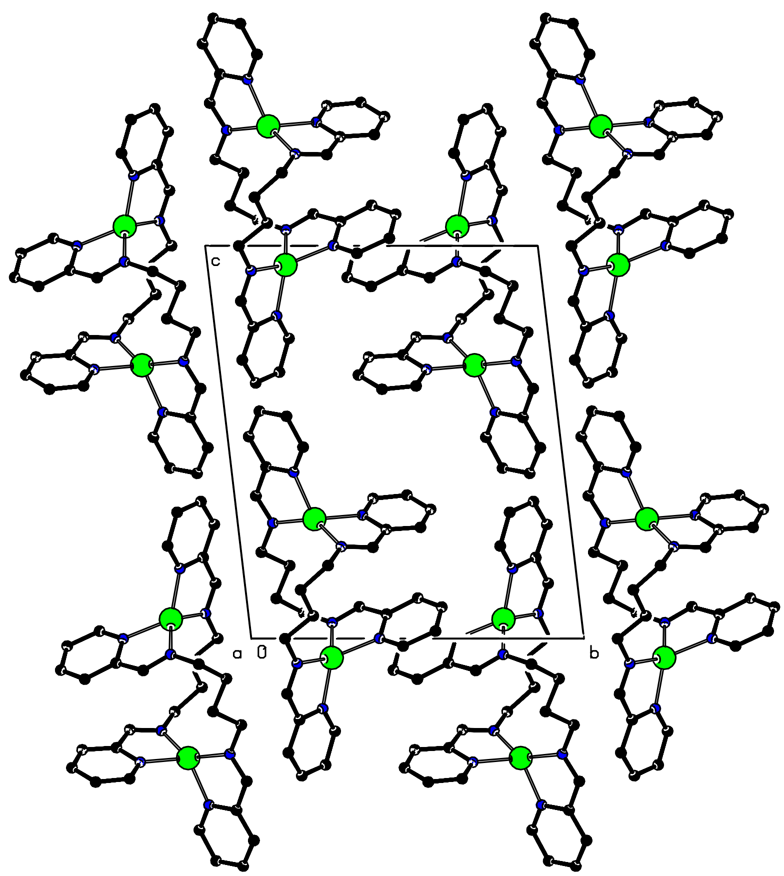

Figure 52: Crystal Structure of the Dimer Molecule

12.2 Periodic Structures in Music

In music, this periodic arrangement in Figure 52 corresponds to the one-dimensional to multi-dimensional repetition of a motive or theme, for example a polyphonic fugue. This stationary periodic repetition is typically for music of the Baroque and Classical era.

12.2.1 Repetition

Example. Repetition is a central concept in music. Multiple notations exist for repetitions.

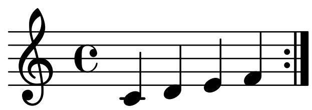

Figure 53: Volta

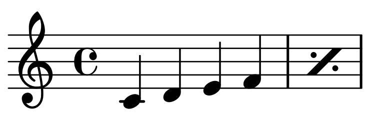

Figure 54: Percent

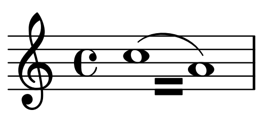

Figure 55: Tremolo

Tremolo: See also Nielsen *Symphony No. 5* Opening Viola (Section 3.3).

Example. Periodic arrangement in music. MOZART's *»Jupiter« Symphony*, composed 1788, Classical era. 4 Movements.

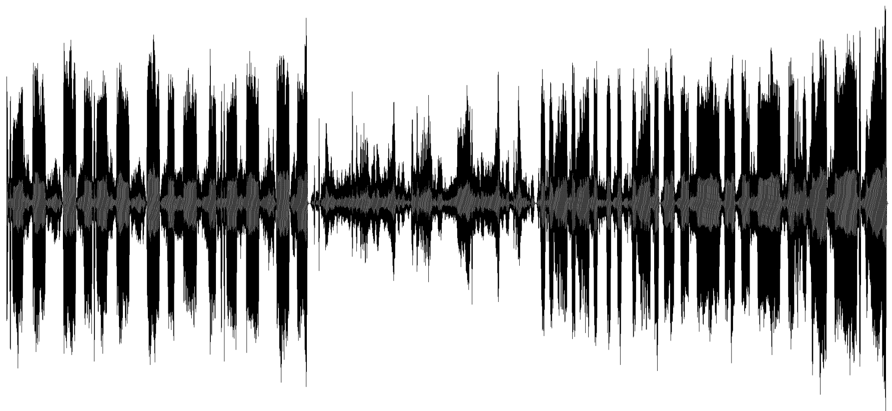

Abbildung 56: Waveform MOZART *»Jupiter« Symphony*

Same construction can be found in the second movement of NIELSEN's *5th Symphony*. The second movement in four sections[43] consists of an »exposition«, a fast fugue, a slow fugue and a brief coda.[44]

[43] »Tetramer«, linear structure: $\mathcal{A} - \mathcal{B} - \mathcal{C} - D$.
[44] Wikipedia.

12.2.2 Ostinato

Definition. In music, an ostinato is a motif or phrase, that persistently repeats in the same musical voice, usually at the same pitch.[45]

Example. PETTERSSON *Symphony No. 8* Part II, Opening.

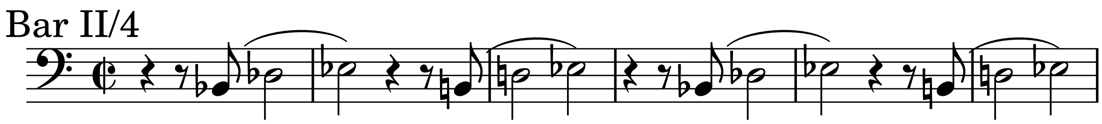

Figure 57: Ostinato

12.2.3 Fugue

Example. JOHANN SEBASTIAN BACH *Fugue in C major BWV952* Opening.[46]

Figure 58: Fugue

[45] Wikipedia.
[46] Taken from: http://www.mutopiaproject.org/, Public Domain.

12.3 Metal

12.3.1 Metallic bonding

Iron, Copper, Silver, Gold are metals. Metals have extraordinary physical properties, for example ductility. The cause is a special kind of bonding: the metallic bonding.

Definition. Metallic bonding constitutes the electrostatic attractive forces between the delocalized electrons, called conduction electrons, gathered in an electron cloud, and the positively charged metal ions.[47]

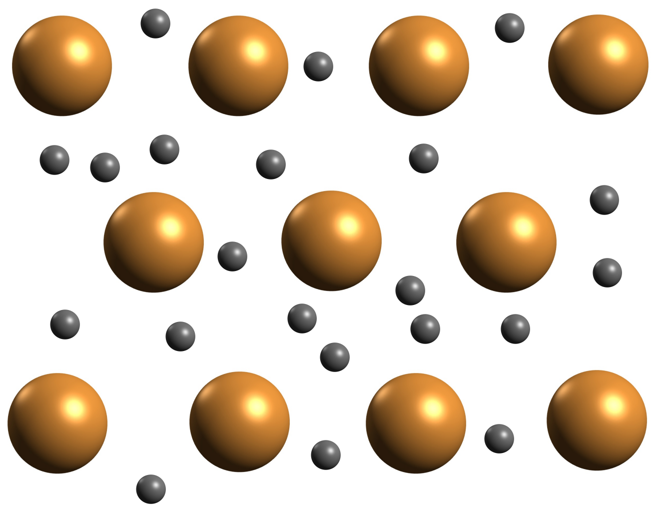

Figure 59: Metallic Bonding

The metal ions are stationary and form a lattice, the small electrons are floating free and are building a electron cloud or a free electron gas.

[47] Wikipedia.

12.3.2 Heterophony

Definition. In music, heterophony is a type of texture characterized by the simultaneous variation of a single melodic line. Such a texture can be regarded as a kind of complex monophony in which there is only one basic melody, but realized at the same time in multiple voices, each of which plays the melody differently, either in a different rhythm or tempo, or with various embellishments and elaborations.[48]

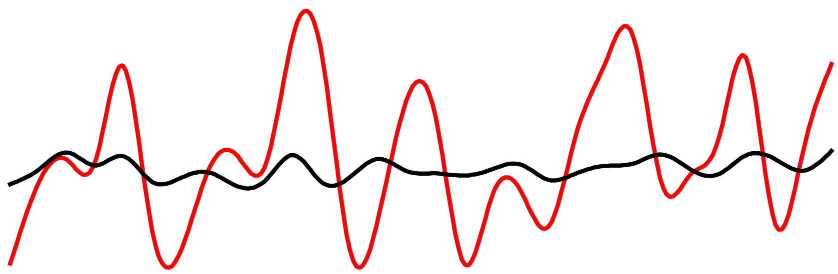

Figure 60: Heterophony

Example. Allan Pettersson *Symphony No. 8* Part I, second theme.

[48] Wikipedia.

13 Dynamic Systems

13.1 Laminar Flow

13.1.1 Fluid

Remark. Laminar flow applies to fluids like water H_2O (see Section 3.3).

Definition. Laminar flow, sometimes known as streamline flow, occurs when a fluid flows in parallel layers, with no disruption between the layers. At low velocities the fluid tends to flow without lateral mixing, and adjacent layers slide past one another like playing cards.[49]

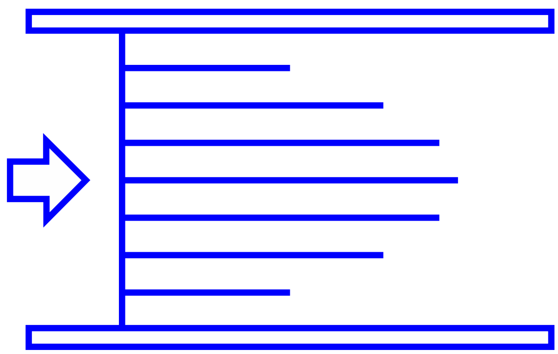

Figure 61: Laminar Flow

Remark. The walls of the stream or pipe are stationary. Flow velocity of the fluid is in that area low. In the middle of the stream or pipe the flow velocity is highest. The different velocities are a result of friction between the layers.

[49] Wikipedia.

13.1.2 Music

Example. Carl Nielsen *Symphony No. 5* Movement I, Finale. Renegade snare drummer.

Bar 351-376: The orchestra plays *Tempo giusto* ♩ = 100. The side drummer plays his own tempo, as through determined at all costs to obstruct the music. He keeps to his own beat by following a metronome placed in front of him, set to ♩ = 116.[50] (Figure 62 and Figure 63)[51]

Voice A

Corni.

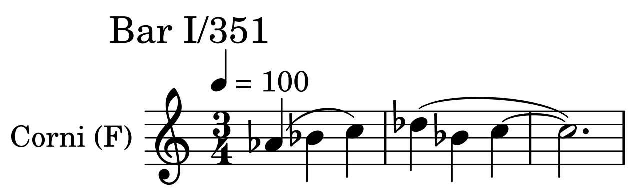

Figure 62: Nielsen *Symphony No. 5* Movement I, Finale.

Voice B

Tamburo piccolo.

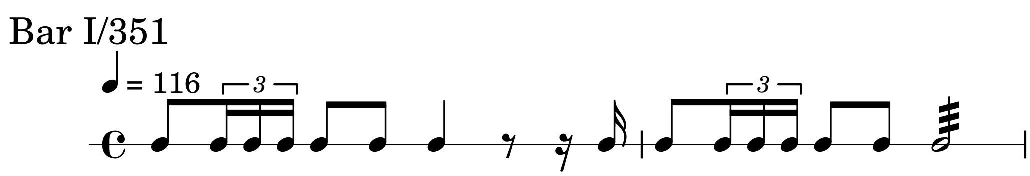

Figure 63: Nielsen *Symphony No. 5* Movement I, Finale.

Remark. This is an example for a destructive and obstructive use.

[50] From Score: *Carl Nielsen – Vaerker, Series II, No. 5*, Michael Fjeldsøe, Copenhagen: Carl Nielsen Udgaven, Det Kongelige Bibliotek, Copyright © 1998. CC BY-NC-ND 3.0.
[51] All snippets from Score Carl Nielsen *Symphony No. 5, Op. 50* Copenhagen: Skandinavisk Musikforlag, 1950. Plate SM 4552. Public Domain.

Example. Allan Pettersson *Symphony No. 8* Part II, Opening.[52]

Remark. Basic material is a simple leap figuration.

Voice A

Duration: $2\frac{1}{2}$, Period: 4 bars. Clarinet Basso.

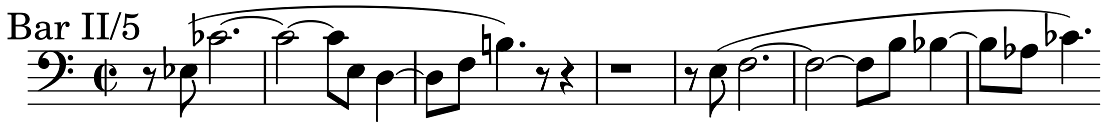

Figure 64: Voice A - Opening Part II *8th Symphony*

Voice B

Duration: 1, Period: $1\frac{1}{2}$ bars. Bassoon.

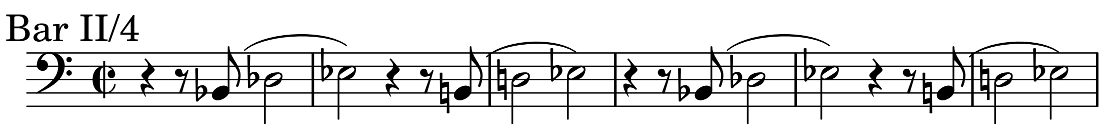

Figure 65: Voice B - Opening Part II *8th Symphony*

Voice C

Duration: $1\frac{1}{2}$ bars, Period: $1\frac{1}{2}$ bars. Contra Bassoon.

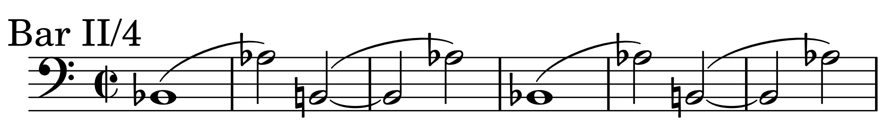

Figure 66: Voice C - Opening Part II *8th Symphony*

[52] All snippets of Allan Pettersson *8th Symphony* from Score *NMS 10642* Copyright © 1984 by AB Nordiska Musikförlaget / Edition Wilhelm Hanson, Stockholm.

Voice D

Duration: 1 bar, Period: $1\frac{1}{2}$ bars. Cello.

Figure 67: Voice D - Opening Part II *8th Symphony*

Voice E

Duration: $\frac{1}{2}$ bar, Period: 3 bars. Tamburo rullante.

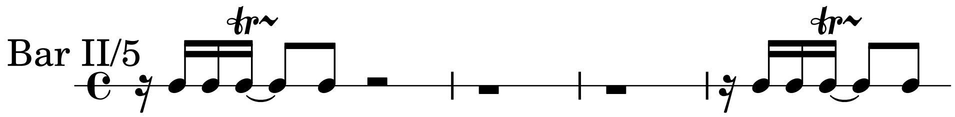

Figure 68: Voice E - Opening Part II *8th Symphony*

Remark. Voice A represents the highest flow velocity, Voice D (E) the lowest. This polyphonic structure can be compared to the lower half of the scientific fluid model in Figure 61. Thus a compilation of different dimensions of time.[6, p.24]

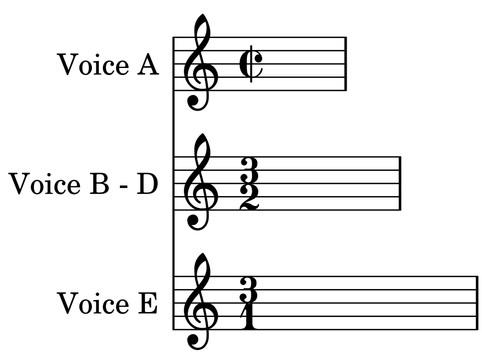

Figure 69: Hidden Metrics

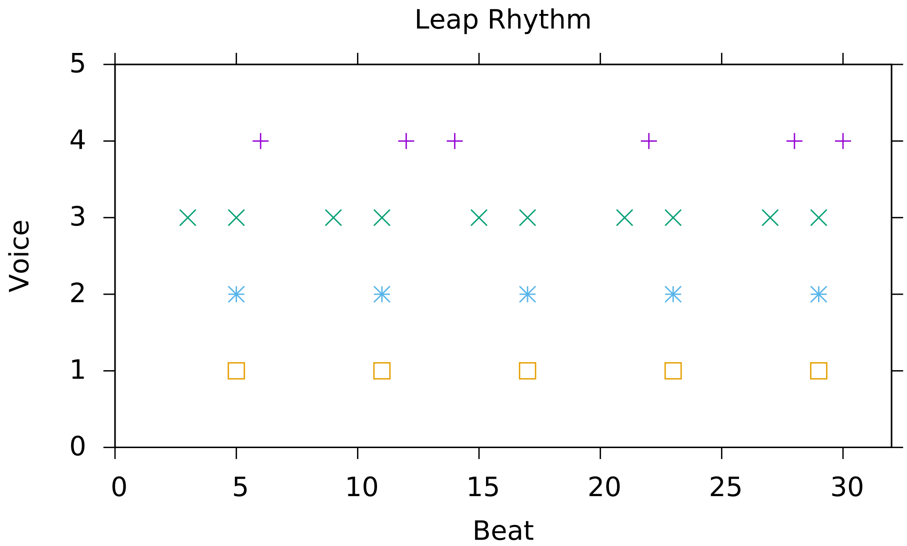

Figure 70: Leap Rhythm, Opening Part II *8th Symphony*

13.2 Turbulent Flow

13.2.1 Science

Definition. In fluid dynamics, turbulence or turbulent flow is a flow regime characterized by chaotic and stochastic property changes. This includes low momentum diffusion, high momentum convection, and rapid variation of pressure and velocity in space and time.[53]

13.2.2 Music

Example. SMETANA *The Moldau* (Vltava) *St John's Rapids* (Svatojánské proudy).

Example. PETTERSSON *Symphony No. 9* White Water (Section 11.1).

[53] Wikipedia.

13.3 Aperiodic Crystals

13.3.1 Science

> ... building up a more and more extended aggregate without the dull device of repetition. That is the case of the more and more complicated organic moleculein which every atom, and every group of atoms, plays an individual role, not entirely equivalent to that of many others (as is the case in a periodic structure). We might quite properly call that an aperiodic crystal or solid (the material carrier of life).
>
> Erwin Schrödinger (1944, [5])

Example. Structure of enzyme copper, zinc superoxide dismutase in Figure 71.[7]

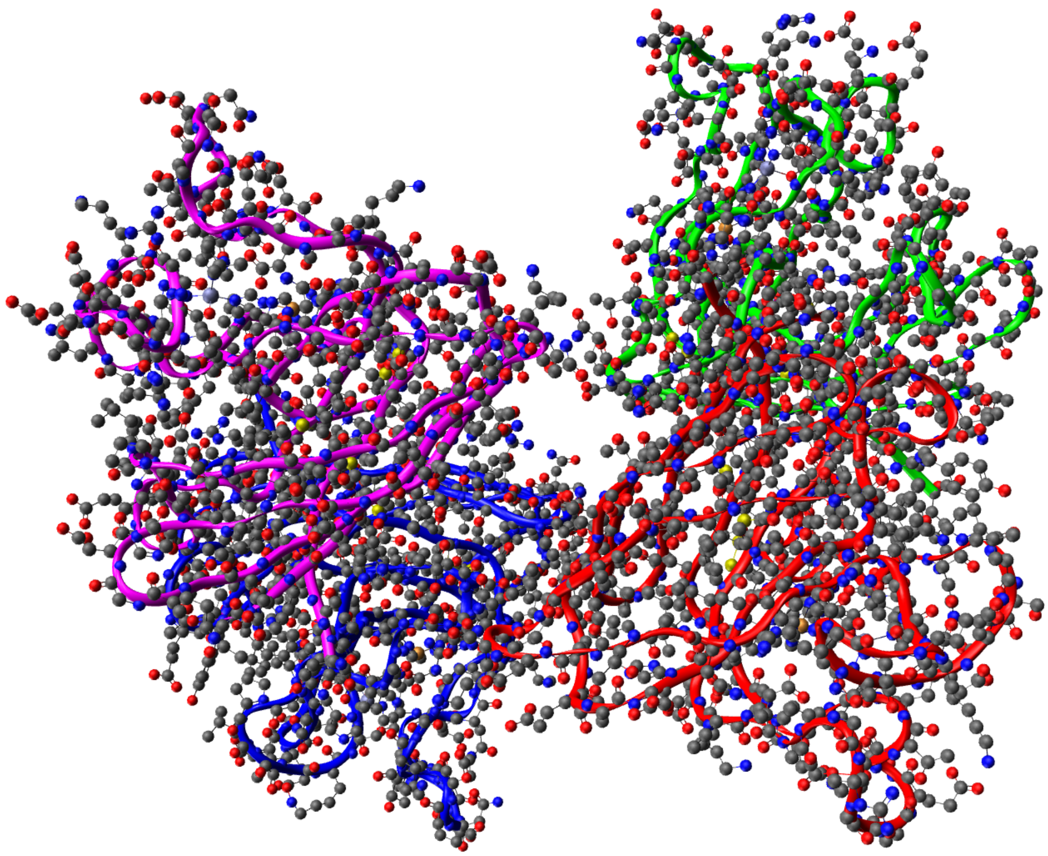

Figure 71: Superoxide Dismutase Structure

The shown enzyme copper, zinc superoxide dismutase builds a tetramer[54,55] (four subunits). The enzyme is highly efficient. It traps and dismutates superoxide, before it can damage DNA. The active site is funnel shaped. Positively charged amino acids guide the negatively charged superoxide to the copper and zinc center on the base of the funnel. (model compound: Section 5)

13.3.2 Music

Analogous aperiodic structures can be observed in Allan Pettersson's symphonic works. His polyphonic structures grow exuberantly (»organic unfolding«)[56].[6, p.28] Example is his *6th Symphony*, that presumedly interprets life from birth to death. Nielsen's philosophy of nature and »universal laws for all life« in music demands an »organic counterpoint« in contrast to a »mechanical counterpoint«.[4, p.71]

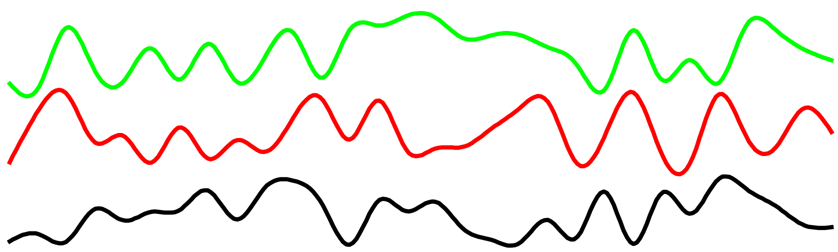

Figure 72: Polyphony

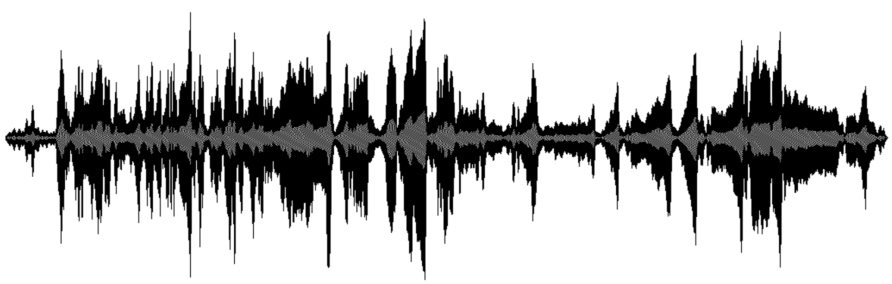

Figure 73: Waveform Pettersson *6th Symphony*

[54] Oxygen transport protein hemoglobin builds also a tetramer.
[55] Tetramer structures: 1D - linear, 2D - square-planar, 3D - tetrahedral.
[56] German: Organische Entfaltung.

Index

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