

# Sound and Music Computing Meets Philosophy

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## ABSTRACT

Philosophy was born in Greece: it raised fundamental questions, some of which were revived since 1957, when it became possible to compute sound and music. All material substances are made of atoms: modularity is at work in chemistry, linguistics, but also in music. Sounds can be synthesized from other sounds, but one cannot exhibit genuine atoms of sound. The question of simple versus multiple is crucial: as Chowning demonstrated, a mix of sound components can be heard as a single sonic entity or as a multiplicity of sounds. Sounds have objective reality, but auditory illusions demonstrate the idiosyncrasies of perception and remind us of Protagoras' claim that "of all things the measure is man". Chaos was present in the views of Anaxagoras. Pythagoras – echoed by Leibniz - insisted that numbers rule the world, including musical harmony, whereas Aristoxenus argued that the justification of music is in the ear of the listener rather in a mathematical rationale. Sound and music computation follows Pythagoras, but the importance of aural perception supports the motto of Aristoxenus. Myths like the *New Atlantis* and the Nietzschean distinction between apollinian and dionysiac are still with us. Sound and music computing is still an Odyssey.

## 1. INTRODUCTION

It is a great pleasure for me to address the ICM-SMC 2014 Conference in Athens at the invitation of Anastasia Georgaki. Greece is the country of many beginnings. As democracy and mathematics, philosophy was born here. Music has been termed a metaphysical craft, and the theme of *philosophy and music* is most appropriate.

Of course, music existed earlier in other places : but, whether apollinian or dionysiac, music is a gift of the muses. Important topics of computer music are reflected in the archetypes of three muses : Melete for research, Mneme of memory, and Aidos, for voice and music. Scholars such as Henri Marrou or Anne Belis remind us that in antique Greece music was quite important and elaborated. Plato even wrote that changing the musical scales would change the fundamental state laws. At the 2007 SMC Conference in Lefkada, I started my presentation by playing a reconstitution of ancient Greek music accompanying a play from Aristophanes.

Greek mythology has illustrated strong archetypes, which remain vivid and influential. I shall play an example from the music of André Jolivet, who

encouraged me to compose. In his 1943 *Suite delphique*, Jolivet evoked *the dogs of Erebus*, the gloomy space of darkness between Earth and the dark underworld of Hades: Jolivet resorted to the *Ondes Martenot*, an early electronic instrument still alive and well.

The philosophers of antique Greece raised fundamental questions about the nature of the universe, the problems of truth, ethics and society, the meaning of life. Nietzsche wrote that later philosophy did not add anything essential. Some of these early questions were revived since the 1950s, when it became possible to compute sound and music. In 1957, Max Mathews implemented the computation of sound with a real genius of design, which was very important for the development of computer music. In the early days of the exploration of digital sound synthesis, James Tenney, John Chowning and I benefitted from his deeply thought-of programs exploiting modularity – a concept I discuss below. Today, I would like to relate several questions raised by the early Greek philosophers to issues encountered in the practice of computer music.

## 2. ATOMS, MODULARITY, GRANULARITY

What exists? The "atomist" philosophers, Leucippus of Milet and Democritus of Abdera, answered that only the atoms and the vacuum exist. The different arrangements of atoms create the diversity and variety of the world. This conception implies that a multiplicity of forms originates from a simple structure connecting minimal elements. This "atomic hypothesis" has been validated by the progress of chemistry in the XIXth century: all possible types of material can be synthesized from a few dozens of substances, namely the chemical elements formed of a single type of atoms. Contemporary physics has qualified the atomic hypothesis: atoms can be broken into elementary particles, although this does not happen in usual conditions on earth. Also the standard model theory states that the quantum vacuum is not really empty: it is a necessary ingredient to provide mass to the particles, and its fluctuations lend energy to virtual particles.

Atomism implied a less demanding concept: *modularity*. By selecting among a collection of modules and connecting them in various ways, one can implement a large number of possibilities, as in construction sets such as Meccano or Lego. The modular approach is at work in human languages: a small number of basic elements – the phonemes – are articulated into words and phrases, allowing an immense variety of utterances from

a limited elementary repertoire. In fact, the idea of a system articulated from a small number of distinct, discontinuous elements – “discrete” in the mathematical sense – had been clearly expressed in the early XIXth century by the linguist Wilhelm von Humbolt. Biology also gives rise to an incredible diversity of animals and plants: common living “bricks” of life have only been identified some fifty years ago.

Thanks to programming, one can synthesize sounds in many different ways. But when Max Mathews began to write programs for sound synthesis, he soon realized that he would have to spend his life writing different programs to implement different musical ideas. So he undertook to write a really flexible program, as universal as possible. The main key to flexibility was the modular approach. Starting with Music3 (1959), the *Musicn* programs – written by Max and by others - would be compilers, that is, programs that could generate a multiplicity of different programs. The user has to decide about the kind of sound synthesis he or she wants to implement: he must then make the appropriate choice among a repertoire of available modules, each of which corresponds to an elementary function of sound production or transformation (oscillator, adder, multiplier, random number generator, filter...). The user must then assemble the chosen modules at will, as if he or she were patching a modular synthesizer. Any connection of modules corresponds to a particular synthesis model: it is called *instrument* by analogy. An instrument can play different *notes* corresponding to instantiations of that instrument. To use a synthesis program like Music5 or Csound, one must define the instruments and provide a list of notes that activate these instruments. One should not take the terms of instruments and notes too literally, since they could lead to believe that the program is tailored to a “music of notes”: this is not so. A single note, in the sense of the program, can last a hundredth of a second or ten minutes, it can span a complex evolution comprising thousands of notes in the usual sense; it can also fuse with other notes to give rise to a unique sound entity.

Contrary to a common belief, Max Mathews’s modular conception did not copy that of synthesizers: on the contrary, it inspired the analog devices built by Moog, Buchla and Ketoff using voltage control - these appeared after 1964, while Music3 was written in 1959. This modular concept has influenced most synthesis programs –Max’s Music4 and Music5, but also Music10, Music360, Music 11, CMusic, Csound. It also inspired most analog or digital synthesizers – such as Arp, DX7, 4X, SYTER, compilers for physical modeling - such as Genesis, Mimesis, Modalys, real-time programs like MaxMSP and Pure Data - and more widely flow-based and object-oriented programming, used in languages for electronic circuits simulation or signal processing such as MATLAB. The *Musicn* programs are *software toolboxes*.

The modules are *virtual*; they correspond to portions of program code. Connections are stipulated by a declarative text that must follow conventions specific to the program. It is meaningful to represent the connections in terms of a diagram: the *Musicn* programs are *block-diagram compilers*. Fig. 1 below shows two Music4 instruments, hand-written by Mathews for a 1965 *Gravesaner Blätter* article commissioned by Hermann Scherchen. In certain later implementations, the connections can be defined graphically, as in a MaxMSP patch.

From 1964, I myself used Music4 and Music5 to build sounds by additive synthesis, for example, imitations of trumpets or bells, in which each partial is defined by a separate note, and also sound textures with various morphologies in which the notion of note vanishes. This affords wide and precise possibilities to define and transform sound - to compose the sound itself. From 1964 also, John Chowning adapted Music4 to the PDP10 computer of the Artificial Intelligence Laboratories in Stanford – Music10 - to implement his experiments on illusory movements and frequency modulation.

At this point of my ICMC-SMC 2014 keynote speech, I present *Several examples exemplifying the synthesis of sounds from elementary sounds : sine waves for quasi-periodic tones (Fourier, violin, trp), Gabor grains and wavelets; textures with various morphologies.*

All periodic tones of frequency  $f$  can be produced through Fourier synthesis by adding sine waves of frequency  $f$ ,  $2f$ ,  $3$ , etc, with the proper amplitudes and phases. Quasi-periodic tones can be obtained by adding sine waves of frequency  $f$ ,  $2f$ ,  $3$ , etc, with the proper amplitudes – but it may be necessary to introduce a noisy component (cf. Serra & Smith). Synthesis can use other elementary components, such as Gabor grains or wavelets, which permit to resynthesize all “regular” sounds, as shown by Morlet, Grossmann, Arfib, Kronland-Martinet and Boyer. I insist here on the fact that sound synthesis is *modular* but not *atomic*: while chemical components require the presence of specific elements, a given sound can be synthesized from different elementary components such as sine waves, Walsh-Hadamard periodic square waves, Gabor grains (a process similar to certain windowed Fourier analysis-synthesis), wavelets, decaying sinusoids. Even if two syntheses using different elements produce the same end result, the various methods differ by their convenience and also by the aural acceptability of approximations: an approximate synthesis using the Walsh-Hadamard decomposition does not deteriorate gracefully as one using a decomposition in terms of sine waves. Granular synthesis has been initially introduced by Curtis Roads as a new synthesis method, used notably by Barry Truax and Horacio Vaggione.

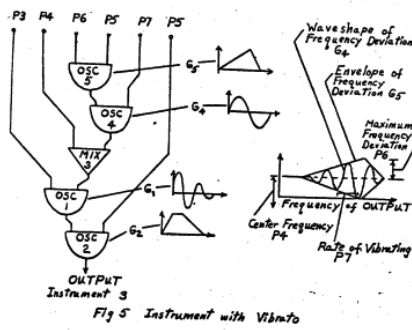


Fig 5 Instrument with Vibrato

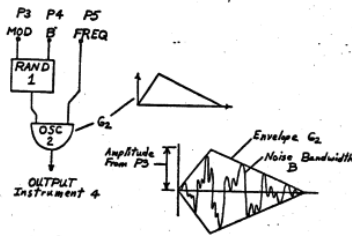


Fig 6 Noise Instrument

Fig. 1. Diagram of two Music4 instruments.

### 3. UNITY, MULTIPLICITY

The concept of unity versus multiplicity – monism versus dualism or plurality - had a lively history in antique Greek philosophy. In a few words, Heraclites insisted that the universe changes constantly. Parmenides of Elea reacted against this disturbing idea of an eternal flux by proposing the opposite notion of universal stasis: according to him, things are stable, permanent, of the same nature; change and diversity are illusory. Zeno negated motion through paradoxes such as Achilles and the tortoise – an aporia solved later by the infinitesimal calculus of Newton and Leibniz. Parmenides thus proposed a monist conception of what exists – the being - which cannot be what our senses tell us. Empedocles found this proposal untenable: plurality cannot emerge from the singular. Hence he rejected monism and proposed that instead of one single substance, there are four primitive substances: earth, water, air, fire. Modern physics indeed distinguish four states of matter: solids, liquids, gases, and plasmas (ions present in fires and at high temperatures). Other related notions were added by Anaxagoras – mixing, unmixing – and by the atomists Leucippus and Democritus.

Again, modern physics showed that these ideas were visionary. How do they relate to sound and music computing?

Stretching Parmenides' conception of permanence, one might relate it to the notion of timbral constancy or invariance. It is a common observation that a sound source can be reliably identified over a wide variety of circumstances. A trumpet or a singing voice are readily identified as such, regardless of pitch or dynamics, and they remain recognizable even when heard over a distortion-ridden pocket-sized transistor radio. Thus, the question arises as to the physical correlates of this constancy. Is there a physical invariant or a characteristic feature mediating a given timbre? The issue is important to understand how to evoke a given timbre

by synthesis: one must be able to describe it in terms of the physical structure of sound. Here the strategy of *analysis by synthesis* gives us a foolproof test. I thus showed that a relation between loudness and spectrum can evoke a brassy sound. **Example on synthesis of trumpet.** Max Mathews showed that a relation between pitch and spectrum was the cue to the very specific vibrato of bowed strings. **Example of electronic violon** We could illustrate this by applying the relation typical of the brass to the spectra of Max Mathews' electronic violon, using Bob Moog's voltage-controlled bandpass filters: played with a bow, the violin then sounds brassy! **Examples of brassy electronic violon.** Thus timbral identity may depend upon spectral flux and interdependence of parameters.

The question of simple versus multiple is crucial in sound synthesis: When several tones are heard together, will the ear interpret them as a single sonic entity or as several distinguishable sounds? This relates to our capacity for *auditory scene analysis*, as Al Bregman calls it. The answer is complex. The sense of hearing is well equipped to distinguish several simultaneous sounds, but certain configurations of simultaneous sounds favor their fusion: harmonicity – sounds will tend to fuse if their frequency ratios are harmonic, proportional to 1, 2, 3, ...; small spacing; last but not least, common fate. These features are *ecologically justified*: they help the listener unravel many sonic components to distinguish between several sources. Through analysis by synthesis, John Chowning has shown that simultaneous sound components can be heard as a unique sonic entity – by imposing them a common fate - or as a multiplicity of sounds - by controlling minute differences between their behaviour. He has thus given a brilliant explanation of our capacity to distinguish two tones in unison. This understanding allowed him to make distinct voices emerge from a sonic magma in his work *Phone*.

#### **Examples of fusion/segregation: Chowning /soprano-baritone/ Bell-Fluid**

I have been inspired by the four elements of Empedocles: my work *Elementa*, realized at GRM in 1998 (50<sup>th</sup> anniversary of musique concrète) resorts to different sound morphologies to evoke *Aqua, Focus, Aer, Terra*.

#### **Examples from Aqua, Focus, Aer, Terra**

### 4. THE OBJECTIVE WORLD, PERCEPTION, ILLUSIONS

Early philosophers of the so-called Milesian school such as Thales were concerned mostly about the nature of the physical world – the *physis*. Their philosophy was scientific and materialistic: it replaced mythological religious beliefs about the origin of the world by rational explanations. Later, philosophers became concerned about the human realm in addition to cosmological matters.

The teachings of Pythagoras claimed that numbers rule the world – the rules of musical harmony as well as the motion of stars. Pythagoras founded a religious group distinguishing between spirit and matter,

harmony and discord – an early dualism, and he developed a genuine mystic of numbers, which was influential in encouraging the use of mathematics in Western science, according to Jean-Marie Souriau, a contemporary physicist specialist of general relativity and cosmology. Indeed, Galileo stated that the laws of nature use the language of mathematics. Leibniz was confident in physical predictability through calculation, long before Laplace's determinism. Leibniz wrote that music is the pleasure the human mind experiences from counting without being aware that it is counting. There is a continuing tradition of trust in the esthetic value of mathematical foundations, illustrated in different ways by Bela Bartok, Joseph Schillinger, George Gershwin, Henry Cowell, Milton Babbitt, Alain Danielou, Olivier Messiaen, Guerino Mazzola, Iannis Xenakis.

In contradistinction, Aristoxenus of Tarentum, a disciple of Aristotle, argued that the justification of music is in the ear of the listener rather in a mathematical rationale. "Aristoxenus the musician" knew the mathematical prescriptions used in the elaborate musical theories of his time, but his experience led him to argue with Pythagoras and to agree with the relativism of Protagoras: he preached for the autonomy of the science of music. Sound computation echoes Pythagoras, but the exploration of sound synthesis stressed the importance of aural perception, thus supporting the view of Protagoras and Aristoxenus.

Protagoras claimed that *of all things the measure is man*. This motto expresses a radical relativism, implying that truth, morality and beauty are relative to the human specificities: there are no external truths, eternal standards or absolute canons. This opens the door to individualism. It also stresses the specificity and the importance of human perception. Plato – followed later by Descartes - despised the errors of the sense: yet, in spite of his intellectualist point of view, our senses are our only windows to the world. As Purkinje wrote, sensory illusions are errors of the senses but truths of perception.

***Some examples of auditory illusions: illusory motions by Chowning and Doppler effect; my pitch and rhythm illusions: a sound that goes down in pitch when its frequencies are doubled; a beat that slows down when one doubles the sampling rate; a sound that goes up in pitch and speeds up but which ends lower and slower.***

Music is anchored in us. The musical phenomenon only takes place within certain ranges: our hearing limits its frequency span, but also its rhythmic span. Music no longer sounds as musical when one increases or decreases frequencies or speeds by a factor of 4. Echoing this relativism, Max Mathews reminded that man's ear should remain the measure of all sounds: technology can produce an unlimited variety of sounds, but many of them are ugly, dangerous or inaudible.

## 5. CHAOS, FLUX

Otto Rössler considers that the 'inventor' of chaos is the pre-socratic philosopher Anaxagoras. Around 1970, Rössler, a chemist self-proclaimed "specialist of non-specialization", exhibited impressive examples of chaotic

dynamics, in particular a remarkable *strange attractor* with a fractal structure. Anaxagoras had imagined primordial chaos as a homogenous mixture, a confused soup or milk containing all things. All things existed from the beginning, but they were undifferentiated and indistinguishable, as tiny pieces that had to be segregated. "Mind" or "spirit" (noös) could unmix the mixture, "separate the like from the unlike", thus making the simple emerge out of the complex. Nutrition is an example of the process of mixing/unmixing. Anaxagoras also appears to have been aware of self-similarity - fractality - and eternal recurrence.

Similar views exist in some cosmologies. At the end of the XIXth century, Poincaré justified the idea of eternal recurrence, evoked independently by Nietzsche. In the XXth century, self-organizing systems were evoked by Pierre Teilhard de Chardin and Ilya Prigogine: such systems produce "order from chaos". The idea of unmixing seems to be confirmed by recent theories of the big bang.

Stravinsky viewed music as a construction instituting an order in things, specially between man and time. In the 1950s, information theory suggested that significant intelligible messages should have an information rate intermediary between order and disorder, periodicity and noise, predictability and unpredictability. Lejaren Hiller proposed to use computer programs to extract order from a "chaotic multitude of available possibilities". Xenakis composed "stochastic music": he sought a minimal structuration for music, initially for the macrostructure (composition), then, in Gendy3, for both macrostructure and microstructure – for syntax and vocabulary.

Unmixing could be related to subtractive synthesis. This method consists of submitting a spectrally rich wave to a specific type of filtering, thus arriving at the desired tone by eliminating unwanted elements rather than by assembling wanted ones. Subtractive synthesis is better adapted to certain types of sounds, specially voice-like sounds using predictive coding, and violin-like sounds using filters mimicking the resonances of the violin box, as demonstrated by Mathews and Kohut (1973).

Anaxagoras' concept of unmixing is put to work in the powerful process of blind deconvolution, developed by Paris Smagardis and others: this process permits to separate two "voices" mixed together in a stereo recording (for example to get rid of the piano accompaniment in a stereo recording of a soprano lied recital).

Chaotic phenomena have taken considerable importance in contemporary science: it imposes severe limits to predictability. Even simple dynamic systems may have chaotic behavior. Dynamic systems are characterized by their *attractors*, a kind of out-of-time multidimensional representation: chaotic systems have *strange attractors* with a fractal structure. The dialectic between order and chaos reminds of the debate between Parmenides and Heraclites. Creativity seems possible only at the frontier of order and chaos.

The figures of chaos have often inspired music: Nicolas Darbon has written a treatise on the music of chaos. I have myself referred to chaos more or less literally or metaphorically in several works: *Phases* and *Strange Attractors* in 1988. Here is a brief passage en route to chaos at the end of my work *Pentacle* for harpsichord and computer (Elizabeth Chojnacka, harpsichord)

***En route to chaos (Pentacle)***

As I mentioned earlier, Heraclitus of Ephesus insisted that the universe changes constantly. “It is impossible to step twice in the same river”. The Japanese Ukiyo-e school of painting shows images of an impermanent floating world. Modern views agree that evolution is the dominant law for stars, for civilizations, and for living beings - Darwin’s theory of evolution is no longer disputed. Hearing does not measure the physical parameters of the sound, but it is finely tuned to the physical laws, since natural selection has favored the evolution of senses so as to help survival in a mechanical world buzzing, rustling and humming with acoustic sounds. This explains the interest of physical modelling for sound synthesis. Here is an early example of physical modelling, which makes kinematic sense.

***\*\*Bouncing ball\*\*Cadoz***

This strongly evokes a bouncing ball. It was produced around 1980 by Claude Cadoz at ACROE, Grenoble, by solving the Newton equation for motion. ACROE has developed modular software – Cordis-Anima-Genesis – which allows to connect massive points: a particle model.

**6. PLATO, ARISTOTLE, NEW ATLANTIS**

Plato, an essential philosopher, argued that there exists a realm of transcendental forms, a world of *Ideas*. His “allegory of the cave” suggests that people unaware of this theory of forms only see shadows and mistake appearance for reality. Following Socrates, Plato wanted to lay foundations for ethics based on absolute knowledge, hence fighting the stands of Protagoras.

Plato was concerned about music : he apparently did not trust art for ethics and social organization. According to him, poets are bad teachers forging fables, and painters merely copy the *phenomena*, the appearances, which are only degraded copies of reality. Thus Plato recommended to cover poets with flowers and to ban them from the *Republic*.

Aristotle was intent on increasing scientific knowledge. Less of an idealist, he was favorable to experimentation – and to art. He considered that the process of artistic creation mimics the processes of nature – a fight of form against matter, but he distinguished between imitation – mimesis – and creation – poesis – (creation of boats or of tragedies as well). Aristotle was intent on developing science; his view was that the universe was governed by purpose. In that sense, as Heraclites, he was a precursor of Darwin, even though natural selection is not really *teleological* – but it works as though it were.

Plato evoked a mythical continent, *New Atlantis* – perhaps a reminiscence of the destruction of the

Minoan civilization, more than ten centuries B.C., by huge volcanic eruptions which caused considerable damage between the island of Santorin and Crete. This evocation inspired Sir Francis Bacon, Lord Chancellor of England, who described in his book *The New Atlantis* (1624) the utopia of a continent where scientific progress would strongly influence the daily life of the community. Here is a striking passage describing experiments on sound:

*We have also sound-houses, where we demonstrate and practice all sounds, and their generation. We have harmonies which you have not, of quarter-sounds, and lesser slides of sound. Divers instruments of music likewise to you unknown, some sweeter than any you have: together with bells and rings that are dainty and sweet. We represent small sounds as great and deep: likewise great sounds extenuate and sharp: we make diverse tremblings and warblings of sounds, which in their original are entire. We represent and imitate all articulate sounds and letters, and the voices and notes of beasts and birds. We have certain helps which set to the ear do further the hearing greatly. We have also divers strange and artificial echoes, reflecting the voice many times, and as it were tossing it: and some that give back the voice louder than it came: some shriller, some deeper ; yea, some rendering the voice differing in the letters or articulate sound from what they receive. We have also means to convey sounds in trunks and pipes, in strange lines and distances.*

I was impressed by this text, which seems an amazing prophecy of the recent possibilities of digital sound synthesis and processing. The visionary imagination of Bacon had been set in motion by the suggestion of the devices invented in his time, specially the development of the automated organ and other music machines. Similarly Edgar Varèse called for new musical materials from electricity after he heard from Ferruccio Busoni about Thaddeus Cahill’s *Dynamophone*. I had an occasion to design an evening of music around Bacon’s *New Atlantis*. From the book, I excerpted a script guiding the listener throughout a kind of journey to the new continent imagined by Bacon. The actual purpose was to explore the new sonic continent of digital music - indeed a different realm: digital sounds can be pure constructions, they are not necessarily the trace of visible objects, they can be virtual, unreal, even paradoxical. Programming the synthesis of sounds permits to play with perception, to probe our innermost hearing mechanisms so as to give the appearance of presence and identity to illusory and immaterial sound objects escaping mechanical constraints. Sound processing also helps us to metamorphose natural sounds into hybrids that retain certain features of a given sound and other features of another one – sonic chimeras. The idea of the evening was to show that the computer does not have to make our sound world duller or smaller: on the contrary, digital sound should be used to expand the sonic world, as Varèse longued to do, to take advantage of our perceptual features, to explore new territories, and to invoke powers of the inner self. The strange sounds evoked by Bacon were demonstrated, and the music presented was chosen with the hope that it would convince the listener that the

computer can also foster imagination, dream and fantasy. The prophetic text of Bacon, read by actors, was illustrated by significant milestones of the continuing exploration of the digital domain, notably by John Chowning and myself (simulations and metamorphosis of acoustic instruments or the human voice, paradoxical sounds which go up and down, which speed up and slow down at the same time, illusions of sound movements in space). Besides my own pieces *Sud*, for computer-synthesized sounds, and *Dérives*, for chorus and computer-synthesized sounds, one could hear John Chowning's *Phoné* and Michel Redolfi's *Immersion* (Redolfi pioneered underwater concerts)/*New Atlantis* was presented in 1988 in the Giacometti Yard of the Fondation Maeght in Saint-Paul-de-Vence, with the essential contribution of Bruno Meyssat, a refined and musical sculptor of light.

## 7. CONCLUSIONS

I feel uneasy to have ventured on philosophical grounds. I refer to the a monumental treatise about concepts at work in western music, « Mathesis and subjectivity », written by the outstanding French composer and philosopher Hugues Dufourt. John Chowning and I can testify that since 1974 Dufourt has commented important issues of musical informatics with a deep and encouraging understanding. Dufourt suggests that contemporary music highlights what was rejected in the Greek world : it rather captures the evanescent, the ephemeral, the ambivalent, the Erebus, it favors the endless metamorphosis of qualities and forms ; as Nietzsche proclaimed, western music tends toward the liberation of the dionisiac dimension and the acceptance of the unacceptable part of myths.

I wish to mention a philosophical question implicit in the preoccupations of the antique Greek philosophers, a question was asked by the Gestalt psychologist Kurt Koffka in 1935. « Does the world appear the way it does because the world is the way it is, or because we are the way we are ? » To this question, Roger Shepard gave in 1981 the following answer: « The world appears the way it does because we are the way we are » (we do not see infra-red or ultra-violet, we do not hear infra-sound or infra-sound, we do not have the sharp sense of smell of dogs) « but we are the way we are because we have evolved in a world that is the way it is. ». Shepard commented that evolution has caused living beings to internalize certain physical laws since it favored survival. Such a statement is fully supported by the understanding of hearing gained by the exploration of digital sound synthesis and processing. This understanding can be helpful to explore new sonic territories : but sensory validity is not a sufficient criterium of esthetic success – faithfulness to external models, to mathematics or formalism is not either.

The speculative visions of antique Greek philosophers about chaos, atoms, elements, flux, have found amazing confirmations in modern science, as though their brains were tuned to the physical world. Recently the mathematician Alain Connes and the neurologist Jean-Pierre Changeux argued: were

mathematics discovered or invented ? Connes believes that mathematical objects exist independently of man, while Changeux believes they are constructions of the human brain. To some extent the human brain is the way it is because it has evolved in a world that is the way it is. This suggests that one should not seek refuge in either formalism or empiricism, mathematical or perceptual justifications : raone should rather endeavour to reconcile them in unpredictable ways. Creation must assume the uncertainty of wandering in unmapped territories : computing sound and music is still an Odyssey.

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