Editorial

Als wir uns entschlossen, die letzte Ausgabe von KunstMusik ganz auf Englisch herauszugeben, konnten wir nicht wissen, wie groß die internationale Resonanz sein würde. Wegen des großen Interesses über den deutschsprachigen Raum hinaus wird auch diese Ausgabe wieder komplett auf Englisch erscheinen. Aufgrund der Fülle der Beiträge haben wir entschieden, das in zwei Hefte aufzuteilen. Hier also KunstMusik 17 (Vol. 2), im November 2014 erschien KunstMusik 16 (Vol. 1).

Gastgeber ist diesmal der in Berlin lebende kanadische Komponist ***Marc Sabat****. In seiner Arbeit spielt Intonation, also die Feinstimmung innerhalb eines musikalischen Prozesses, eine bedeutende Rolle. Vor diesem Hintergrund hat er Kolleginnen und Kollegen gefragt, was ihnen zu diesem Thema einfällt. Wir betreten hier einen Bereich, bei dem die klassische temperierte Stimmung, wie sie das ungeübte Ohr im alltäglichen Zusammenhang gewohnt ist, berührt und in Frage gestellt wird. Was sind die Alternativen? Was sind unsere Hörgewohnheiten, was können wir noch wahrnehmen, wie unterscheidet sich die temperierte Stimmung von der Stimmung innerhalb der Natur-(Oberton-)reihe? Was kann man mit alternativen Stimmungen machen, welche Traditionen gibt es, und am Ende auch: wen juckt es, wo liegt das politische Potenzial? Wir freuen uns, dass unter den Autorinnen und Autoren eine Reihe von sehr jungen Komponisten sind, aber gleichzeitig erweisen wir unsere Reverenz einem ganz großen „Intonatoren" der älteren Generation: Es ist Christian Wolff, der in diesem Jahr seinen 80. Geburtstag gefeiert hat. An ihn geht unser Dank und Glückwunsch.*

When we decided to publish the previous issue of KunstMusik entirely in English, we didn't realize how positive the international response would be. Given such great interest coming from many non-German-speaking countries, the current issue is once again released in English. Because of the extent of the contributions the texts are spread across two issues: continuing here as KunstMusik 17 (Vol. 2), following the publication of KunstMusik 16 (Vol. 1) in November 2014.

This time our host is Berlin based Canadian composer **Marc Sabat**. In his work intonation, the process of fine tuning, how it determines musical processes and their perception, plays a central role. He asked colleagues about their approaches to this subject. We enter an area which examines and calls into critical question the

general assumption of classical tempered tuning in European and American music, the system that an untrained ear is exposed to in an everyday listening context. What are the alternatives? What are habits of hearing, what are we able to perceive, what is the difference between a tempered tuning and the "natural" just intonation of a harmonic series? What can one do with alternative tunings, where are the traditions, and as well, in the end: who cares and where does the political potential lie? We are very pleased that the authors include some very young contributors, but at the same time we want to pay respects to one of the great "intonators" of the older generation: Christian Wolff, who celebrated his 80th birthday this year. To him our heartfelt thanks and congratulations.

KunstMusik *Intonation*

> *…Our notions of law and harmony are commonly confined to those instances which we detect; but the harmony which results from a far greater number of seemingly conflicting, but really concurring, laws, which we have not detected, is still more wonderful. The particular laws are as our points of view, as, to the traveller, a mountain outline varies with every step, and it has an infinite number of profiles, though absolutely but one form. Even when cleft or bored through it is not comprehended in its entireness…*
>
> Henry David Thoreau, *The Pond in Winter* from *Walden* (1845–54)

At Maria de Alvear's invitation, I began several years ago to curate a series of essays for KunstMusik around the theme intonation, which continues to inspire my own artistic work. For me, it represents a very particular kind of listening to sound, and a way of composing and experiencing music that emerges therefrom.

I have asked artists from several generations to consider intonation in relation to their work or to work close to them, suggesting the possibility of thinking about any kind of inflections of sounds in relation to sounds heard. In some way, I was seeking to underline how making experimental music, these days, is perhaps most about finding ways of listening. I was especially curious to extend the discourse around tuning and temperament into other perspectives without excluding traditional Pythagorean and Aristoxenean expositions of very specific pitch designs.

Taking often unexpected positions, the authors have drawn analogies between diverse images and practices of intonation, historical and contemporary, and pursued their extensions into diverse forms of music-making reflected in a social and political context. As is always the case in such an undertaking, the process of editing has revealed as many contexts left unexplored, authors and topics which could immediately fill several sequel volumes, omissions which I look forward to correcting in the future.

I would like to dedicate this collection, spread across two issues – KunstMusik 16 and 17 – as a kind of 80th birthday hommage to Christian Wolff. I see his compositions, with their gentle and radical exploration of social intonations mirrored in ensembles of players/listeners, as emblematic of fundamental changes manifesting in the music of our times.

Marc Sabat, Berlin, 7 June 2014

ill. 1: Fra Angelico: *Annunciation*, 1440, San Marco Florence

ill. 2: Fra Angelico: *Annunciation*, 1433/34, Cortona

The prelude is all. Sketches on the how and what of intonation

Intonation to the unheard-of

An intonation, often improvised, sets the tone, prepares modes and affects of chants to follow, by turns motivic and (voluntarily) actualizes a system of classification – in the sense, for instance, of its tuning structure. In the San Marco convent in Florence (ill. 1), in the northern corridor, the *how* of this musical practice is given stunning visual expression. It was painted around 1440. Mary sits on a wooden stool and is receiving intonation of something unheard-of. An angel reveals what is to come, what will enter her life. The scenery is modest and the application of colour restrained, with subcutaneous tension; the colonnade as partly open auditorium nearly fills the fresco; on the left, a *hortus conclusus* may be suggested, with woods behind it, seen once again through a small window. Nothing else distracts from the annunciation. The inflection of this promise is private in character. Fra Angelico shows the intimacy of a *way* of speaking, but at the same time suspends narration. There seems to be no "outside" for the *how* of what is being said, almost as in a dream that addresses the dreamer completely – we are not free to immediately reject what is being experienced, to form an opinion, to turn away; we believe in it completely; its *Werkmeister*[1] render a picture-perfect weaving, introducing heterogeneous things to one another. Here, a singular moment is performed alone; something unprecedented shown. Strikingly so, exactly because of this missing *anamnesis*. A communication that, if you will, exists pure, apart from any existing experience. *If you come before the figure of the untouched virgin, be sure in passing that you do not forget to speak the Ave*[2] is written at the lower edge of the picture.

1 "Foremen" of dream work, according to Freud: condensation and displacement.

2 VIRGINIS INTACTE CUM VENERIS ANTE FIGURAM PRETEREUNDO CAVE NE SILEATUR AVE.

Intonation as showing

The Annunciation in Cortona (ill. 2) was painted earlier. The *what* of intonation – intonation as a type of musical form or composition[3] , as an adjustment of an instrument's sound, fine-tuning it to the acoustics of a particular space – is introduced, apparently unbounded on several sides, and also upwardly. The expulsion from Paradise – beyond good and evil – in this case, shown, provides the anamnesis: a loss handed down, following from the consciousness of differences. A loss with intermediate stations. Isaiah – hewn in stone *in front of* the scene – prophesies the Annunciation. Mary has a book open on her lap. She is sitting on a golden throne, above her the Holy Dove. The angel appeals to an informed thee: the spoken is also shown (*deixis*). Mary seems poised, as if she were prepared; the message seems comprehensible in the sense that one thing meaningfully follows from another, or at least as a transparent polyphony of dense references and symbolism. The Mother of God as listener induces an amendment; she makes good the loss of Paradise. Here, the colours of paint – Florence is a fresco, Cortona is not – are clear, opulent, set off against one another. A *sequence* in baroque music, *playing* with the principle of recognition, where colours result from transposing a motive through different registers, each appearance made new by the changing intervals of an unequal temperament.

The scenes in Fra Angelico's visual renderings of the Annuntiatio Domini can be read as fields of action where intonation comes to bear. "Read" also in the sense of defining more precisely the full meaning of the word. In San Marco: something unheard-of – the biologically disconcerting moment of immaculate conception to come, an incarnation of God – out of the blue, a psychological provocation, a destabilisation. Poetic, intimate, tender. Mary and the angel – two sides in a listening *relation* – do not leer at a Before nor an After: their Now is all.[4] Nuances are the desiderata of this listening. In Cortona: a story of unfolding motivic variation, the preparation of a covenant in stages. The auditive space of Cortona is more familiar, handed down, that of a shared apperception.

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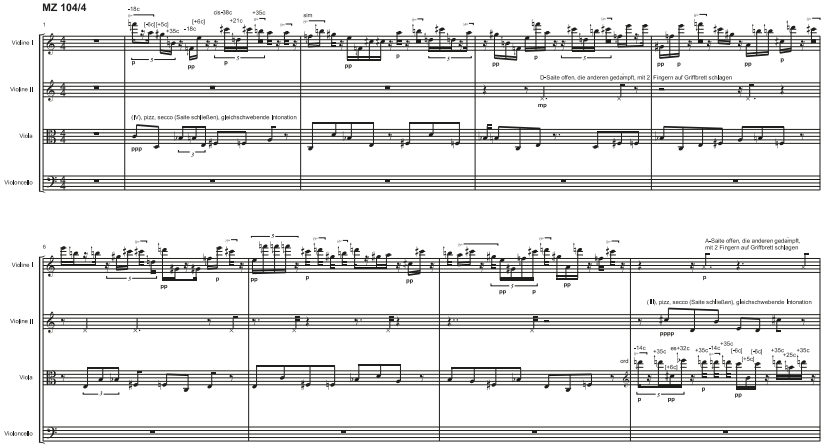
3 An entry in the Wernigerode Charter of 1330 indirectly (since the organ remains silent during Lent) confirms this practice for intoning organ and liturgical singing (of the priest). *Sunder in der vasten unde in allen vasteldagen, denne scal he rede syn unde scal ansigen swenne men myddeme orgen* [...] Particularly during Lent and on each day of fasting, he should speak and sing as if it were together with the organ [...]

4 Schoenberg: "I said to Webern: For my music one must have time. It is not for people who have something else to do." Citation in H. H. Stuckenschmidt: *Schönberg. Leben, Umwelt, Werk*. München/Mainz: Piper/Schott 1989, S. 145.

In pieces I explore both of these ways of parsing intonation into several aspects. Two examples: one addresses the tuning-up, fine adjustment and tonal regulation of instruments; a second operates with symbolic relationships, figures of similarity and, here and there, speculatively, with music-historical constants of tuning, setting things that are per se silent (book and image) within the sound.

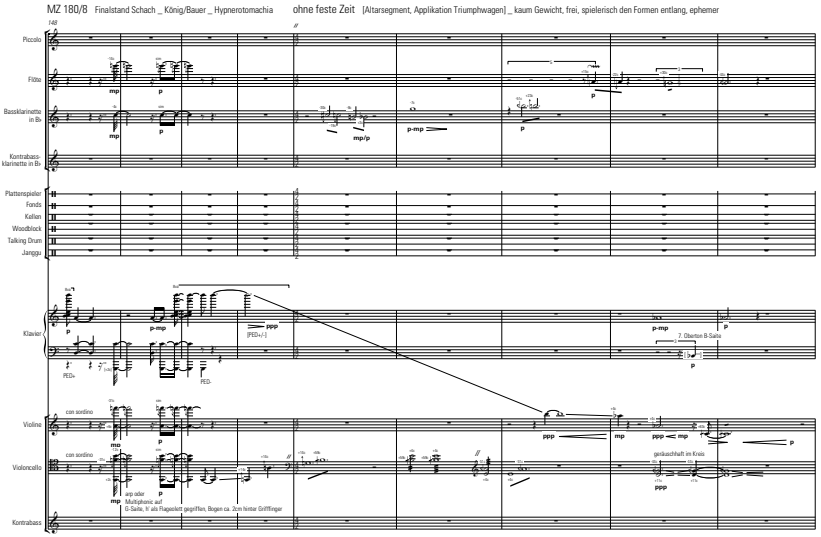


Ill. 3: From *Licht, Steg*

Licht, Steg (ill. 3) is an intonation-music for string quartet about the subtle *magic of beginnings*[5], which overextends the praxis of intonation, erasing its role as the preparation – *for what is to follow* – by drawing it over the entire dimensions of the piece. The intervals and figurations at the beginning are derived from a universal technique employed on stringed instruments. A finger divides the string in two: finger to bridge, and finger to nut. This affects not only the two resulting pitches A and A'; the sound on the other side of the stopping finger is fundamentally different; there is no direct connection to the sounding body of the instrument by means of the bridge. The bridge transmits the frequency-proportions, forges sound and its partials; the bridge marks and raises the strings. Moreover, the space occupied by the stopping finger measures out a remainder. A small cluster. This (Pythagorean) comma, this cultural difference describes a dilemma; a second player has to step

5 "Und jedem Anfang wohnt ein Zauber inne" is a line from the poem *Steps (Stufen)* by Hermann Hesse: "A magic dwells in each beginning".

in if the demands of this dual presence are to be exactly realised. Temperaments mostly operate using differences that they conceal (distribute) or heighten. In *Licht, Steg*, the comma of the not-identical is notated; the interpreters play passages *before* the comma of this "semantics", and in other places following *after* it. This doubling is made apparent by means of repetition. A returning figure is, initially,[6] manifested through contrapuntal techniques, proposing an ongoing opening (of the closed garden) and the question, how may *a relation* be brought about between two distinct sound-images.



Ill 4: From *Fonds, Schach, Basar*

Fonds, Schach, Basar (ill. 4) also plays upon plateaus of intonation. Quite differently, however. With an eye on colours (Giovanni Bellini, Basaiti, Caravaggio) and drawing in an casual way upon the contingencies of cultural history. For example, a chess match from 1972 between Bobby Fischer and Boris Spassky is sketched into the piece and its final position is interwoven with two passages from Francesco Colonna's *Hypnerotomachia Poliphili* from 1499. The defeated player's pawn is identified with an altar segment and the winner's king with the decoration of a triumphal

6 See score example, *Licht, Steg*.

chariot; they are figuratively similar. Spatial measurements are thus transcribed as intervallic relationships and are associated with four different models of intonation:
1) architectural measurements as described in Colonna's book;[7]
2) meantone temperament[8] with 19 pitches to the octave – an exposure with tonal light;
3) 12 semitones per octave (tuned according to the harmonic series up to the 19th partial tone above C and with respect to its untempered under- and over-fifths)[9];
4) finally, a quarter-tone series (also in steps of unequal size, selected from the overtones 33 to 63 above C), an accurate realisation of which turned out to be difficult, sometimes utopian, for the woodwinds. This piece for small ensemble and record player pursues – nowadays over the hill, and as a gesture from disparate references – a music historical trajectory back to meantone temperament, enquiring about characteristics qualities of carrying sound (Tonträger), and resuming, as soon as the match played is seen from one side as loss, the other as gain, with a tuning dreamed up with Colonna.[10]

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7 Altar segment and decoration of a triumphal chariot (in millimetres or cents):

2 1/2 piedi (feet) = 740.88
3 palmi (hands) = 222.264
1/2 palmo = 37.044
piede e 3 palmi = 518.616
2 1/2 palmi = 185.22
1/4 di piede = 74.088
1 1/2 piedi = 444.529 = cubito (cubit)

8 According to Marchetto da Padova (see *Lucidarium in arte musicae planae* from 1317/18), the whole tone "consists in the perfection of the number nine"; it expresses a "relation". Marchetto examines its parts, of which there are five. For example, the chromatic semitone (chromaticism as "colour of beauty") is made up of the diatonic semitone plus *diesis*, which corresponds to the meantone difference between # and b, as we can trace it via Vicentino, who equates the fifth part of a meantone (somewhat approximately) with the small enharmonic diesis, up to Mozart: a line of intonation conventions with subtle divergences. Mozart has his composition student Thomas Attwood begin his training in harmony, counterpoint, and free composition by writing up the major and minor scales, differentiating between *mezzi tuoni grandi and mezzi tuoni piccoli*.

9 Derived analogously to Schoenberg's chromatic scale (see *Problems of Harmony*), but instead of the 7th, 11th and 13th overtone there is a division of the octave into tempered semitone steps as follows:

G +2¢		19/G=Bb -0.5¢	27/G=E +8¢	81/G=B +10¢
C 0¢	17/C=Db +5¢	19/C=Eb -2.5¢	27/C=A +6¢	
F -2¢	17/F=Gb +3¢	19/F=Ab -4.5¢	27/F=D +4¢	

10 See score example, *Fonds, Schach, Basar.*

Glossary of terms with respect to intonation
by Clarence Barlow

basilar membrane
A thin tissue strip of variable thickness running along the length of the coiled cochlea in the inner ear. It forms the base (whence its name) for 3500 movement-sensitive hair cells that provide the sense of hearing and specifically of pitch perception.

bark scale
A psychoacoustical scale proposed by acoustician E. Zwicker in 1961, that measures off successive ↑***critical bands*** in *barks* (named after physicist H. Barkhausen) along the audible human pitch range; 1 bark = 1 critical band. The frequencies for 1–24 barks are given as 100, 200, 300, 400, 510, 630, 770, 920, 1080, 1270, 1480, 1720, 2000, 2320, 2700, 3150, 3700, 4400, 5300, 6400, 7700, 9500, 12000 and 15500 Hz. Determined by the structure of the ↑***basilar membrane***, which also gives rise to the ↑***mel scale*** of subjective pitch, the bark scale forms a useful alternative to the latter by also playing a significant role in the measurement of loudness, of ↑***consonance***, and of the just noticeable pitch difference between two alternating sine ↑***tones***.

complex tone
↑***tone***.

consonance
A term frequently also used for ↑***harmonicity***, but as "sensory consonance" clearly a distinct entity. It denotes the "smoothness"—or its converse "dissonance" the "roughness" – of musical ↑***intervals*** consisting of simultaneous ↑***tones***, e.g. the "consonant" octave and the "dissonant" tritone. Acousticians R. Plomp and W. Levelt (1965) empirically measured the dissonance of a wide range of ↑***sine-tone*** intervals and determined that for a widening interval starting at a fully consonant unison, the consonance decreases to a minimum of 0 (the dissonance to a maximum of 1) at 0.25 ↑***bark***, thereafter returning to full consonance at 1 bark. Consonance = 1 – dissonance. In the middle of the audible range, consonance and harmonicity largely

concur, but in low registers below 100 Hz the opposite is often the case. Examples of the consonance of sine-tone intervals according to Plomp and Levelt are given in parentheses for e.g. unison (1.0 in all registers), tempered (↑***temperament***) semitone (0.73 centered at 100 Hz, 0.01 centered at 440 Hz), tempered whole tone (0.37 at 100 Hz, 0.38 at 440 Hz), tempered fourth (0.02 at 100 Hz, 0.99 at 440 Hz) and tempered tritone (0.12 at 100 Hz, 1.0 at 440 Hz). A ↑***sine-tone*** tritone is more consonant than the fourth. The roughness of a complex-tone (↑***tone***) tritone is due to the dissonance between the ↑***partials***.

critical band
A frequency bandwidth within which two ↑***sine-tones*** (also ↑***tone***) interfere with each other's perceived loudness. The ↑***bark scale*** maps the way the critical bandwidth varies with register.

dissonance
↑***consonance***.

equal-tempered
A system of ↑***intonation*** in which an ↑***interval***, most frequently the octave, is logarithmically divided into a number of equal segments. A good example is the widely used equal-tempered twelve-tone chromatic scale, in which twelve equal semitones add up to form an octave. The frequency ratio of two ↑***tones*** separated by a semitone is $1:\sqrt[12]{2}$, because rising by a semitone is tantamount to multiplying the frequency by the factor $\sqrt[12]{2}$ (1.059463094). Another example of equal temperament is the Bohlen-Pierce scale, in which a perfect twelfth is divided into 13 equal steps.

formant
A peak in the ↑***frequency*** ↑***spectrum*** of a sound, mainly used in the science of phonetics to identify the acoustical characteristics of a ↑***phoneme***. For instance vowels: each can be coded by two main formants, F1 and F2—e.g. [u:], the vowel in "boot" (better: German *Fuß*), at F1 = 300 Hz, F2 = 800 Hz. A two-dimensional chart with F1 on the x-axis from 200–1000 Hz and F2 on the y-axis from 500–4000 Hz can display all humanly pronounceable vowels.

frequency
A measure of pitch in cycles per second, termed hertz (named after physicist H. Hertz), Hz for short. Based on the standard violin string A = 440 Hz, Middle C is set at 261.626 Hz. 1000 Hz can also be written "1 kHz" (kilohertz).

frequency ratio
A relationship measure for a musical ↑***interval*** in terms of its two frequencies, for instance for any and every perfect octave as 1:2 (with the higher frequency double that of the lower) independent of register, a perfect fifth as 2:3, a perfect fourth as 3:4, a major third as 4:5 (↑***prime limit*** 5) or 64:81 (↑***prime limit*** 3) etc. The ratio can also be written in reverse, e.g. 2:1, or as a quotient, e.g. 2/1 for a rising octave, 1/2 for a falling octave.

functional harmony
A term introduced by composer-theorist H. Riemann (late 19th century) for the traditional practice of progression in ↑***harmony*** in Western classical music from 1700–1900, based on ↑***scale*** degrees and manifest in ↑***melody*** and ↑***polyphony***.

functional harmonic grammar
A strict set of rules first codified by composer-theorist J.-P. Rameau (early 18th century) and others, prescribed for the implementation of ↑***functional harmony***.

fundamental
The lowest ↑***partial*** of a harmonic ↑***spectrum***; the partial frequencies are ↑***integer*** multiples of the fundamental's frequency.

gradus suavitatis
A formula developed in 1739 by mathematician L. Euler to capture the "degree of sweetness" or "softness" (↑***harmonicity*** or ↑***consonance*** in current terms) of a musical ↑***interval***. Expressible as GS = $1+\sum(p-1)$, one plus the sum of all the interval's frequency ratio component primes (p) minus one, it yields the following values in parentheses e.g. for the octave 1:2 (2), perfect fifth 2:3 (4), perfect fourth 3:4 (5) and augmented fourth 32:45 (14). The lower GS is, the "sweeter" the interval.

harmony
A study and/or conscious usage of the "agreement", expressed by the adjective "harmonic", between component ↑***tones*** in ↑***intervals*** in ↑***melody*** and ↑***polyphony***. For example, the octave is considered "more harmonic" than the major third, which in turn is considered "more harmonic" than the tritone.

harmonicity
A measure of the agreement (↑***harmony***) between component ↑***tones*** in ↑***intervals*** contained in ↑***melody*** and ↑***polyphony***. Also a formula devised in 1978 by the author for the quantification of the same, expressed as $H(P,Q) = \mathrm{sgn}(\xi(Q)-\xi(P))/(\xi(P)+\xi(Q))$, where sgn (signum) is the sign, plus or minus, of the following argument in parentheses, ξ is the ↑***indigestibility*** of the following argument, P and Q are the components of the ↑***interval*** ↑***frequency*** ratio P:Q, and Q is larger than P. Examples of harmonicity are given in parentheses for the octave 1:2 (+1.0), perfect fifth 2:3 (+0.273), perfect fourth 3:4 (-0.214) and augmented fourth 32:45 (+0.06). The higher the value, the more harmonic the interval.

indigestibility
A measure combining an ↑***integer's*** size and indivisibility, devised in 1978 by the author in the form of the formula $\xi(N) = 2\sum(n_r(p_r-1)^2/p_r)$, where N is an integer and p_r and n_r are the r^{th} prime factor and its respective power (i.e. $N = \prod p_r^{nr}$). For example, the indigestibility of the numbers 1 to 6 are 0.0, 1.0, 2.67, 2.0, 6.4 and 3.67. Primes are more indigestible than immediately adjacent integers.

integer
A natural or whole number.

interval
A pair of successive or simultaneous frequencies expressible in terms of ratio (e.g. 2:3), pitch distance (e.g. 7.02 semitones) or name (e.g. perfect fifth).

intonation
A variably precise prescriptive or descriptive determination of the ↑***frequency*** of a ↑***tone***, in theory or in practice, in composition or in performance, according to numerous considerations: ↑***pitch*** space, subjective pitch, ↑***harmony***, ↑***consonance***, ↑***sonority***, ↑***phonetics***, ↑***speech*** and ↑***melody***, and by extension tempo, ↑***rhythm*** and/or metre.

just intonation
A system of ↑***intonation*** exclusively using ↑***integer*** ratios.

lattice
A one- or more-dimensional chaining of ↑***intervals***, e.g. the circle of (perfect) fifths or the two-dimensional perfect fifth-major third lattice.

melody
A series of single ↑***tones*** of variable ↑***pitch*** and duration in time. Also applied by extension to a series of different ↑***timbres*** (called *Klangfarbenmelodie* in German = timbral melody).

mel scale
A psychoacoustical scale (named from ↑***melody***) ranging from 0 to about 4000 proposed by psychoacoustician S. S. Stevens and others in 1937, empirically mapping pitches subjectively perceived by invited listeners as equidistant. Hertz-mel correspondences differ from source to source; a popular approximation is given by the formula $m = 1000 \log(1 + f/1000)/\log(2)$ and its converse $f = 1000(2^{m/1000} - 1)$, where m is the mel and f the Hz value. According to this, the pitch series corresponding to equal differences of 125 mels is 91, 189, 297, 414, 542, 682, 834, 1000, 1181, 1378, 1594, 1828, 2084, 2364, 2668, 3000, 3362, 3757, 4187, 4657, 5169, 5727, 6336, 7000 Hz etc., somewhat similar to the frequencies of the more standardised alternative ↑***bark scale***.

noise
A sound which instead of containing partials manifests a frequency spread of variable loudness. Its ↑***spectrum*** consists of a continuous line or lines. In theory, white noise displays a flat spectrum as a straight loudness curve parallel to the x-axis; in

practice the spectrum fluctuates slightly in time. It is possible to regard a noise as a ↑***sine-tone*** ↑***stochastically*** fleeting from frequency to frequency, the loudness curve of the spectrum of any given moment of time showing the relative probability of the frequency at that moment.

partial
A ↑***sine-tone*** which together with others forms a ↑***spectrum***. If the partials are all ↑***integer*** multiples of one lower frequency, the ↑***fundamental***, the spectrum is harmonic, else inharmonic.

phoneme
A sound unit of language, which may be a vowel or a consonant. Phonemes are frequently written in the International Phonetic Alphabet, e.g. [æ] for the vowel in "cat" and [ʃ] for the consonant in "show".

phonetics
A detailed scientific study of the sounds of spoken language.

pitch
A perceptual phenomenon pertaining to the frequency of a sound within the audible range. It can be described, like frequency, as "high" or "low".

pitch continuum
A term referring to the continuity of the audible ↑***pitch*** range.

pitch-rhythm continuum
A term referring to the contiguity of the audible ↑***pitch*** range and time. Frequencies higher than around 20 Hz are heard as ↑***tones*** in the so-called "microtemporal" region, those below as ↑***rhythms*** in the so-called "macrotemporal" region. The revving up of a motor from purring to a continous tone takes place in this continuum.

pitch space
A term referring to the audible ↑***pitch*** range as a harmonically or timbrally neutral space for the positioning or locating of frequencies.

polyphony
A term used here in a very general sense for the simultaneous sounding of several ↑***tones***, including other textures such as counterpoint, homophony, a stream of chords etc.

prime limit
A number indicating the highest prime factor of a ratio, typically of a musical ↑***interval***. For instance, 1:4 is a 2-limit interval, 1:3 and 9:16 3-limit intervals, 4:5 and 32:45 5-limit intervals, 10:21 a 7-limit interval etc. An n-limit system of ↑***intonation*** contains intervals in which the prime limit is n and possibly also less than n.

quarter tone
An interval half the size of a ↑***semitone***. If twelve-tone ↑***equal-tempered***, its size is a 24^{th} of an octave; if rationalised, it could be e.g. 27:28, 35:36, 32:33, 125:128, 48:49, 26:27 or 44:45 etc., listed in decreasing order of ↑***harmonicity*** and ranging from 0.35-0.65 equal-tempered semitones.

rhythm
A succession in time of durations, possibly alternating sound with silence; it could also apply to visual images.

scale
A sequence of pitches used or to be used in a piece of music, commonly ordered by increasing frequency. A common example is the ↑***equal-tempered*** twelve-tone chromatic scale.

semitone
An interval which, if twelve-tone ↑***equal-tempered***, is a 12^{th} of an octave in size, the distance between two adjacent notes in the equal-tempered twelve-tone chromatic ↑***scale***. If rationalised, it could be e.g. a minor second (15:16), a chromatic semitone (24:25), a septimal diatonic semitone (14:15), a large limma (25:27), a Pythagorean limma (243:256), a septimal chromatic semitone (20:21) etc., listed in decreasing order of ↑***harmonicity*** and ranging from 0.71-1.34 equal-tempered semitones.

sine-tone
A pure tone with a waveform shaped as a ↑***sinusoid***, most commonly found in nature and musical instruments as partials of a complex ↑***tone***. It is made artificially by a sine tone generator.

sinusoid
A curve generated graphically by the sine function of an angle, oscillating smoothly and repetitively. It is applied in sound to the ↑***sine-tone***.

sonority
A term used here to describe properties of particular sonic interest due to the strategic placement of frequencies in ↑***pitch space***. It could apply to pitches sounding together to form a striking result, and/or the ↑***intonation*** of pitches at unusual (e.g. ↑***quarter tone***, or high prime limit) positions.

spectral centroid
A term used to describe the "centre of mass" of a sound's ↑***spectrum***, usually associated with the "brightness" of the sound. It is calculated as the average of the spectrum's frequencies, each multiplied by its own loudness. Examples of a musical instrument with a high centroid: harpsichord, with a low centroid: clarinet.

spectral flux
A term used to describe the speed of change of a ↑***spectrum***. Examples of a musical instrument with a high flux: guitar, with a low flux: bassoon.

spectrum
A representation, usually in two dimensions, of a sound in terms of ↑***frequency*** (usually the x-axis) and loudness (y-axis). In the case of sounds with high ↑***spectral flux***, a third dimension, time, is added (z-axis). ↑***Tone*** spectra show ↑***partials*** as parallel vertical lines, their length depicting their loudness; ↑***noise*** spectra show no partials but the loudness against frequency as a fluctuating curve. Sounds containing both tone and noise will have spectra combining both types.

stochastic
A term used to describe probabilistic statistical properties of a system. Introduced to music by composer-architect I. Xenakis, it can be used e.g. to compute and depict the probability of an event such as a pitch against time. The event can be generated using pseudo-random numbers.

temperament
A system of ↑***intonation***, frequently ↑***equal-tempered*** but also asymmetrical, e.g. meantone tuning, in which almost all fifths are narrowed by a fixed small ↑***interval***.

timbre
A term used for the "colour" of a sound. ↑***Phonemes*** and musical instruments differ from each other mainly by timbre. A ↑***spectrum*** visualises timbre and ↑***spectral centroid*** and ↑***spectral flux*** along with attack time are useful criteria for measuring, i.e. quantifying timbre.

tone
A sound, not ↑***noise***, which can be a ↑***sine-tone*** or a complex tone; the latter is an aggregate of ↑***partials*** forming a harmonic or inharmonic ↑***spectrum***.

totient function
A formula introduced in 1760 by mathematician L. Euler to count the "totatives" of a number, i.e. those positive integers less than or equal to the number that share no common factors with it. For instance, the prime number 5 has four totatives: 1, 2, 3 and 4. But 6 has only two totatives, 1 and 5. The formula is $\phi(n) = n\prod(1-{}^{1}/_{p})$, the number (n) multiplied by the reciprocal of all its component primes (p) subtracted from 1. For the ↑***integers*** 1-10, ϕ equals 1 1 2 2 4 2 6 4 6 4. This function—with its highly totient primes—resembles, but yields much less differentiated results than the author's own ↑***indigestibility*** function, used to calculate ↑***harmonicity***.

CATHERINE LAMB

(b. 1982, USA), is a composer exploring the interaction of elemental tonal material and the variations in presence between shades and beings in a room. In 2003 she turned away from the conservatory in an attempt to understand the structures and intonations within Hindustani Classical Music, later finding Mani Kaul in 2006 who was directly connected to Zia Mohiuddin Dagar and whose philosophical approach to sound became important to her. She studied (experimental) composition at the California Institute of the Arts (2004-2006) under James Tenney and Michael Pisaro. It was there also that she began her work into the area of Just Intonation, which became a clear way to investigate the interaction of tones and ever-fluctuating shades, where these interactions in and of them-selves became structural elements in her work. She received her MFA from the Milton Avery School of Fine Arts at Bard College in 2012 and is currently residing in Berlin, Germany.

ANDREW McINTOSH

Composer, violinist and violist Andrew McIntosh has a unique and diverse approach to music-making, prioritizing his work as a composer and focusing his performances primarily around the repertoire of compelling and experimental music from the last 800 years. He is known for being a specialist in microtonal tuning systems and also for being a member of the Formalist Quartet. He holds degrees in violin, composition, and early music performance from the University of Nevada, Reno, the California Institute of the Arts, and the University of Southern California. As a composer, McIntosh strives to write vibrant and engaging pieces while bringing a spirit of experimentalism to the music, often finding models for his work in the natural world. His music is regularly performed around the US and Europe.
A native of rural Northern Nevada, McIntosh is currently based in the Los Angeles.

ALEXANDER MOOSBRUGGER

born in Austria in 1972. Studies at the Vorarlberger Landeskonservatorium (organ and harpsichord), at the Universität Wien (philosophy) and at the Staatliche Hochschule für Musik und Darstellende Kunst Stuttgart. Moosbrugger's work encompasses a fine differentiation of the entire soft dynamic range. He primarily is writing in chamber ensemble settings, rarely doubled, preferring among other genres the string quartet. Moosbrugger establishes musical relations through translations extra-musical points of reference, analysis of symbolic functions. Playing techniques manifest

the “speaking” of musical images and are devised anew in each piece, or series of works. His compositions are internationally played, in festivals of contemporary music and in ensemble concert series. Moosbrugger’s concern with “Listening/ Hearing” as compositional arena motivated studies in philosophy at the Universität Wien. Since then, he researches and works with aspects of hearing as sounding reflections about the history of philosophy. Since 2007 Moosbrugger is the artistic director of Bludenzer Tage Neuer Musik. He lives and works in Berlin.

STEPHA SCHWEIGER

She started making music at a very early age, which was when she also discovered her passion for performance and audio recordings. While learning her main instrument – the piano – and when playing other instruments, she became captivated by the impact of different states of tuning and detuning. While a student of composition at the University of the Arts in Berlin, she began to learn more about microtonality and spectral music. She studied experimental electronic music, amongst others during her year-long course at the IRCAM in Paris and at the Institute of Sonology at the Royal Conservatoire in The Hague. Lectures and workshops at Institut für Neue Musik, Hochschule für Musik Hanns Eisler (Berlin), University of New Mexico (USA) and IRCAM (Paris). She has produced numerous specially commissioned works. Her music is published under her own label, “little salt”.

CHRISTIAN WOLFF

was born in 1934 in Nice, France, but has lived mostly in the U.S. since 1941. Though mostly self-taught as a composer, association with John Cage, Morton Feldman and others have been important for him. Wolff’s work has concerned itself principally with the introduction of various new modes notation and freedom of the musical event, both for the composer and performer as well as the listener. Wolff himself has also been active as a performer and as an improviser. He is a member of the Akademie der Künste in Berlin and has received an honorary Doctor of Arts degree from the California Institute of the Arts. Academically trained at Harvard as a classicist, Wolff has taught classics at Harvard and from 1971 to 1999 was professor of Classics and Music at Dartmouth College.