

# Journey to the Heart of Music

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## *Chapter 15 – Wider Horizons*

### FROM PARTICLES TO PLANETS

I begin this closing chapter of *Journey to the Heart of Music* with some trepidation and in a spirit of exploration, knowing full well that I am venturing far beyond the reasonable competence of a piano tuner and student of music. Indeed, I must confess to being in two minds over whether to include the chapter at all. However, if in these documents any progress at all has been made, in at least enlarging my own understand of music (if no one else's), the principal method by which it has been achieved, is through the comparative study of organisation and structure in tonal music and natural systems, side by side. To put it bluntly, without the guidance afforded by the detailed and objective information available about atomic structure – the electronic configuration of atoms in the Periodic Table of Elements – wrestling with the far less objective and tractable structural imperatives of tonal music would have been very much more difficult. Basically, by studying the two systems in tandem (with occasional help from other well documented physical systems), when the path became difficult and uncertain in music, with luck, the structures and processes evident in the Periodic Table offered help or inspiration. It is for this reason, so as to tell the full story of the *Journey to the Heart of Music*, that I venture upon such dangerous territory for the amateur. It is absolutely not my intention or purpose to offer explanations or solutions to difficult and arcane problems in twenty-first century physics – which lie far beyond my understanding – but rather to ask questions and point to interesting features arising out of the musical perspective taken in this narrative; which, perhaps others more knowledgeable in these fields, might consider worthy of further investigation.

## 15.2 - FROM PARTICLES TO PLANETS

In the early part of the last century, the influential Danish physicist Niels Bohr constructed a new atomic model, which led him to confront a difficult problem: according to James Maxwell's theory of electromagnetism – a crowning achievement of late nineteenth century science – oscillating electrons should radiate energy and quickly collapse into the nucleus of atoms. This clearly doesn't happen. Borrowing an idea pioneered by Max Planck, Bohr made a quantized model of the atom that used ratios of the harmonic series to confine electrons to discrete energy levels: a structural device providing for the atomic stability which is observed in nature. Together with Planck, Bohr was laying the foundations of quantum mechanics, a difficult to comprehend but very successful description of the physical world at the fine scale of atoms.



Picture courtesy Wikipedia

**Niels Henrik David Bohr (1885–1962)**, was born into a cultivated and well to do family living in Copenhagen, Denmark. His father was a professor of physiology and his mother, of Jewish extraction, came from a family of bankers. A keen sportsman (as was his brother Harald an eminent mathematician), Bohr studied at Cambridge and later took his doctorate at Copenhagen University. At Cambridge he studied under Ernest Rutherford and used his teacher's discoveries and theories, along with Max Planck's recent insight, to construct a quantized model of the electronic structure of the atom. Bohr postulated that electrons could jump between different fixed energy levels and thereby absorb or radiate discrete amounts of electromagnetic energy – photons. The young Einstein also made contributions in this area, for which he was, officially, awarded the Nobel prize. Bohr's theory assigned energy levels to the hydrogen atom in the ratios of the harmonic series as: principal quantum numbers ' $n$ ' = 1, 2, 3, 4, etc. Still in his early thirties, in 1916, Niels Bohr was appointed professor at Copenhagen and then director of the Institute of Theoretical Physics in 1920. Under his direction the Institute became a leading center for advanced atomic research. During the second world war Denmark was occupied by German troops and in 1943 Bohr, being half Jewish, fled to Sweden and later the USA where he worked on the atomic bomb. Like many scientists, he was deeply uneasy and ambivalent about the Manhattan Project, and the legacy they were creating for humanity. Bohr was married and had six children, one of which, Aage Niels became a physicist too and, like his father, won a Noble Prize.

As the 20th century progressed toward its end, a similar problem remains unresolved, at the larger 'classical' scale of human perception, and beyond. Knowledge of the wider cosmos reveals that it too possesses a varied and stable structure, which according to the logic of thermodynamics, should collapse to a state of equilibrium – but doesn't, or at least, hasn't yet. One of the many (speculative) proposals being put forward to explain this puzzling, yet most welcome situation, is the idea that some type of *discrete computational process* lies embedded within our familiar physical world of space and time – a mechanism to account for the order, structure, variety and stability we see about us: A dynamical self-organizing universe, built on quantum foundations of tiny integer units.

### 15.3 - FROM PARTICLES TO PLANETS

Musicians also inhabit a quantized world. A universe described primarily by discrete units of rhythm and pitch (and volume – though the quantized units of energy which Max Planck postulated in 1900 are far too small to be aurally perceived). Glissando and free rhythm excepted, for the most part our music proceeds by quanta, little steps and jumps of pitch and duration from note to note and chord to chord. This amazing graininess appears to present no obstacle to our perception of a musical flow, which we recover at units of larger scale – motives, phrases, melodies etc. Many experimental attempts have been made to create music out of a continuum of pitch and duration: like the machine which now resides in the Percy Granger Museum in Melbourne and the many electro-acoustic devices that have followed in its path; however, to date, they have shown little sign of replacing the traditional methods of ‘quantum music’.

Over many years, indeed centuries, musicians have learnt some interesting tricks about how to work such a system of discrete units: how to create structure, to integrate detail, and make the many components hang together as a coherent whole. Our rich musical heritage is the result. But it is a reward that had to be worked for, over a considerable time, with contributions from across Europe: the creation of composers, musicians and not least their patrons, the audience – by exercising choice and selection. In particular, the system of keys (tonal centers) was not invented over night but rather grew up slowly, as each generation of composers explored the boundaries; until, moving forward through ever more keys, eventually brought the system back to where it had started from! This remarkable structural device, the cycle of key centers which ‘returns to itself’, and the mechanism of modulation which allows music to step from one tonal center to another, was a collective artistic achievement, an evolutionary development over an extended period of time.

The evolutionary trajectory taken by western music was I suspect, beyond the overall control of individuals and groups. Once musicians strode forth in harmonic steps of whole number relationships, they became unknowing players in an evolutionary game destined to find an organisational solution for music which follow fundamental principles that apply to all oscillatory systems. Essentially, it could be argued, rather than creating some arbitrary scheme of musical organisation, over the centuries, western musicians evolved or developed a rough facsimile of nature’s own organisational solution. A solution which perhaps almost inevitably emerges from the combination of simple (oscillatory) whole number relationships, and thus forms a class of phenomenon in the material world with probably quite extensive coverage. For indeed, everything with a temperature above absolute zero is involved at some level, in forms of periodic behaviour – vibration, rotation, revolution: oscillation.

The idea, the thread running through *Journey to the Heart of Music*, is that by closely examining the structures of our musical system and the organisational principles of tonal music which evolved during the period of its great flowering (roughly 1500 to 1900 AD) – principles and techniques for the manipulation of quantized sound, regulated by the whole number relationships of modulation – some interesting and useful insights and general perspectives might be gleaned; and perhaps, subsequently, applied to illuminate the nature of other oscillatory systems.

One of the great ironies of music history is, I feel, that just at the point where musicians were beginning to discover this powerful principle of organisation, their position within the medieval triumvirate of mathematics, astronomy and music – the disciplines concerned with *ratio* – was being lost. As the new Renaissance learning blossomed into the scientific revolution in the seventeenth century, music became increasingly sidelined, viewed more as art than science; and the organisational scheme that musicians were

to come to understand viscerally, and implicitly explain in their music theory, was to go relatively unregarded. Certainly, from quite an early date, the organisational principles which underpin tonal music were available for mathematical and scientific enquiry and analysis. Quite how they came to be so neglected is, I think, a great mystery. Perhaps, with the developments in the techniques of calculus, configuration spaces, etc.; and the *principle of the continuum* which they imply, the mind-set of mathematicians and scientists became skewed away from the older ideas of ratio and proportion, in favour of an idealised system of smooth curves and transitions containing an infinity of points. Only now, at the beginning of the twenty-first century, with the digital computer a commonplace artifact and String Theory plus other similar approaches, serious and productive branches of enquiry in physics, is attention being drawn back to the study of systems, which evolve by discrete units.

The connections between music's implicit organisational model and recent developments in theoretical physics are interesting, even tantalising. In particular the unifying conception of symmetry employed in mathematical group theory, which runs through so much of contemporary physics and cosmology, also, as touched on in previous chapters, extends its sway to music – as viewed from the perspective of the MOS model (as well as many other theories and models constructed by music theorists in recent years). Perhaps, I wonder, might future generations of music theorists again have cause to discuss with their colleagues in mathematics and the sciences, matters of serious concern and relevance to all parties? As was the situation at the start of the scientific revolution with Vincenzo Galileo, the music theorist, and his famous son; or later during the Enlightenment, Rameau addressing the French Royal Academy of Sciences in 1749 and collaborating with Rousseau, Diderot and d'Alembert. Indeed, this chapter is to some extent an exploration of what today's connections could, or might, be – a pathfinding reconnaissance – and, as far as I know, the ideas in the form presented in *Journey to the Heart of Music* have not appeared elsewhere. Though, of course, it must be acknowledged that the works of a vast range of individuals inevitably become combined in the mind over time; and in particular, I should record again the indelible mark left by R. F. Goldman's portrayal of the dominant-seventh acting dynamically, forcefully driving toward the tonic, encountered so many years ago, in his wonderful book *Harmony in Western Music*. An acknowledgement which could also be read as a proclamation of the fundamentally musical perspective which has guided this narrative throughout.

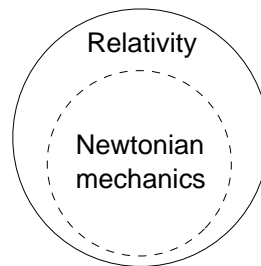
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Looking back over the broad development of science since music's departure from the fold of the disciples of ratio; the basic concept of a wholly relational world system was perhaps first put forward by Gottfried Leibniz during 'the great debate' between his and Issac Newton's followers. Though a truly relational approach proved too difficult to develop at that time, and had to wait for twentieth century relativity and gauge (symmetry) principles. Newton, however, found that by setting matter, and tracing motion, against an absolute fixed background of (infinitely divisible) space and time, spectacular progress could be made. His dynamical system swept all before it and dominated thinking for more than two hundred years, until an unknown patent clerk from Berne wrote a challenging paper in 1905, examining the implications of combining the fixed speed of electromagnetic waves (including light) found by Maxwell, with the effects of relative motion – Special Relativity. In the long run, the approach of Leibniz, won through: he had seen that the explanation of physical reality had, ultimately, to be relational. Einstein praised Newton for his courage in making an essential 'staging-post' on the mountain – but read the relational

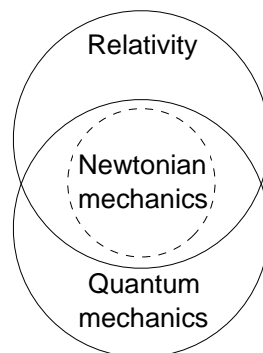
## 15.5 - FROM PARTICLES TO PLANETS

authors, Leibniz and Ernst Mach for inspiration and guidance on a route ahead.

Each of these steps, though, has been more an *extension* of the area of application, than an overturning of previous work; so that Newton's mechanics *fits within* the broader scope of later work, as a perfectly good approximation (in normal everyday conditions) to relativity's more subtle interpretation. Also over time the various branches of scientific knowledge have tended to join up and overlap, bring about a deepening integration and coherence to scientific knowledge. As for example, has happened with the application of thermodynamics to fields far removed from the original study of steam engine efficiency. A trend which has allowed the disparate patterns of reality to be viewed from an ever more unified standpoint.

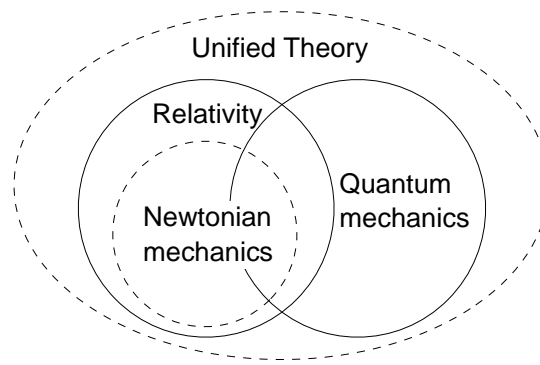


The great problem which emerged during the early twentieth century, however, is that science developed two fundamental theories, which don't fit wholly together: Relativity and Quantum Mechanics. Explanations of the workings of the large scale and the small: the classical domain of human perception (extending outward to the cosmological scale) and the domain of atomic phenomenon.



Considerable time and effort has been, and continues to be expended, in the hunt for something capable of drawing both together, a unifying principle or perspective capable of accommodating what is known of nature, on both the large and small scales. At the heart of the problem lies the question of whether the fundamental units of the material world are interpreted as being point (zero size) particles with intrinsic qualities or spatially extended waves with the quality of relatedness. After much effort and many earlier failures, String theory and other similar related approaches, hold out the promise of progress, based on the simple unifying principle: *that all matter and forces arise out of the relationships between the different resonances (notes) of one fundamental entity*. This is equally a musical conception as a scientific postulate, and one befitting Rameau's epithet: *nature's gift*.

## 15.6 - FROM PARTICLES TO PLANETS



String theory to a degree, marks a return to the situation of ancient learning and philosophy, where without the tools and techniques of measurement and observation developed during the seventeenth through twentieth centuries – which allowed experimental science to *lead* theory – scientific advance is again more dependent on the exercise of logic, mathematics and philosophy to probe regions far beyond the direct reach of today’s technology. String theorists, like music theorists, are searching for a logically consistent fundamental theory, based on a few simple assumptions, which can be naturally and convincingly extrapolated to encompass, perhaps even explain, all the phenomena of their respective worlds, whether musical or material. This is of course an ambitious undertaking, both in science and music; but ultimately, there is nowhere else to go, no other destination so worthy of our striving. Though it remains an open question as to precisely which course offers the best prospects of success, the ‘string’ approach both in music and physics, overall, is now probably the most promising general direction to follow. Essentially, the *standard model* of particle interactions developed in the second half of the twentieth century, provides a hugely successful predictive description of the atomic world, but explains very little. String theory attempts to rectify this shortcoming through an analytic, rather than synthetic, approach. Similarly in tonal music, the traditional ‘Roman numeral’ approach (see Chapter 16) provides a comprehensive description of harmonic progression, without enlightening us much as to why chords are arrayed in the particular ways that we find them. The numeral approach provides a very useful synthetic description but not an analytic understanding of tonal music. The route taken in *Journey to the Heart of Music* has been not unlike that of laying out a ‘string theory’ for tonal music: An attempt to probe tonal music’s most fundamental nature and attributes, and, construct a coherent model capable of linking these foundations to the superstructure of observed musical practice. And, on a less serious level, might it not be that a piano tuner is rather well placed to take on the task of concocting such a ‘string’ theory for music?

As discussed in Chapter 9, if you remove a note, any note, from a piece of music, what do you get? A frequency, an amplitude and a duration – a few bare facts from which little meaning can be extracted. It is the relative relationships within a composition which carry the significant information, not the absolute qualities of notes in isolation. Which is to say the nature of music is fundamentally relational. What a note is – its *identity* in a piece of music – is the sum of its relationships with the other notes in the piece; and that fundamentally, a musical composition is a sequence of changes to these note relationships – a scheme of musical *events*. Significantly, all of these relationships, and changes in relationships, can in principle be expressed in *whole numbers*; and, as documented in earlier chapters, created via the workings of the modulation algorithm of symmetrical exchange.

## 15.7 - FROM PARTICLES TO PLANETS

Richard Feynman wrote in his book: *The Character of Physical Law*:

“... I have often made the hypothesis that ultimately physics will not require a mathematical statement, that in the end the machinery will be revealed, and the laws will turn out to be simple, like a chequer board with all its apparent complexities.”

Overall, each step along the road of scientific discovery and understanding has also been, paradoxically, a stepping back or away from the (apparent) complexities of reality, as we experience and see them; so that as wider horizons are encompassed, the categories and principles needed to describe them actually become simpler and more universally applicable. For example, as scientist probe back towards the origins of the material universe they find that both the conditions, and the laws which governed those conditions, become simpler, more uniform, increasingly symmetrical. Logically, this process is tending toward just one category and just one principle: a description of *identity*, ‘what things are’, and an account of how things change – *events*. A view first clearly expressed by Gottfried Leibniz: that ultimately, the description of the physical world would, necessarily, have to be made in such wholly relational terms. That *identity* finds its source in relationships and that *events* are changes in these connections<sup>1</sup>.



Picture courtesy Wikipedia

**Gottfried Wilhelm Leibniz (1646–1716)** was born in Leipzig, the son of Friedrich Leibniz a professor of philosophy at Leipzig University who died when Gottfried was only six years old. Leibniz, like his father, had the gift of great intellect; and from his mother, Catherina, he inherited a deep religious conviction. Perhaps significantly, his early education had some degree of autodidacticism based on the extensive library of texts left by his father. Gottfried Leibniz entered Leipzig University at fourteen to studied law and philosophy, graduating in 1666. Failing to find a teaching position at Leipzig, Leibniz switched to the University at Altdorf; and then, when offered a position there, decided instead to work in the service of Johann Christian von Boineburg at the Court of the Elector of Mainz. His duties included diplomatic negotiations and overseeing legal reforms. Leibniz was appointed to the Appeal Court of the Electorate of Mainz and travelled to Paris and London in his diplomatic role, which allowed him to meet many of the leading mathematicians and scientists of the age. At the Royal Society in London, Leibniz demonstrated a calculating machine of his own invention. Much of Leibniz’s work was to foreshadow later developments: as with this calculator and Babbage’s mechanical computers, in his ideas concerning a universal ‘algebra of thought’ and Boole’s work on binary logic (Leibniz invented the binary number system), and in his concept of fundamental entities – monads – and contemporary string theory. A significant amount of Leibniz’s vast output, across a wide range of fields was to lie undiscovered in letters and private papers. Also his contributions were underestimated because his conclusions clashed with those of Newton, and, it was not until twentieth century science ‘court up’ with his relational view of the world that his reputation as a natural philosopher was to be rehabilitated. In 1674 the Elector of Mainz died and Leibniz had to find another

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patron, luckily he had been in contact with the Duke of Brunswick for some time; and, in 1676, he took up a position in the duke's service. Leibniz was to remain with the family for the rest of his life as counsellor, historian and archivist. Leibniz cultivated and corresponded with a wide range of friends and admirers, which went some way to soften the isolation he felt in being mostly kept away from the great cosmopolitan centers of learning and fashion. Perhaps the greatest mathematical achievement of Gottfried Leibniz was his independent discovery of calculus in the 1670s (Issac Newton developed a similar system of fluxions). Indeed, Leibniz introduced a superior method of notation for calculus, which remains in use down to the present day. In 1711 an argument erupted as to whether he or Newton was the inventor of calculus, the implication being that Leibniz had stolen Newton's then unpublished ideas, while in London. Historians generally discount this version of events, and although the accusation darkened his last years and dimmed his reputation after his death, yet today, the light of this thought shines forth clearer than ever. Leibniz did not marry, and many distrusted the mixture of charm and guile he had acquired as a career diplomat. Perhaps his greatest admirer was the Electress Sophia of Hanover, whose support he repaid with sincere friendship and advice to her, and many of her female relatives. Gottfried Leibniz died at Hanover in 1716, out of favor with his patron and unregarded by the world. His insights, in so many fields were profound, but often had to wait decades or centuries to be appreciated; so to with music:

“Music is the pleasure the human mind experiences from counting without being aware that it is counting.”

The modern scientific tradition grew up on foundations laid in the renaissance – the re-discovery and re-evaluation of ancient learning. In the middle of the sixteenth century the Franciscan scholar and composer (later to be maestro da cappella at St Mark's, Venice) Gioseffo Zarlino, 1517-1590, was busily engaged in this enterprise of unearthing the old knowledge; and importantly, interpreting and extending what he found. *Le Istitutioni Harmoniche* of 1558, by Zarlino stands at the beginnings of modern music theory. In this work Zarlino attempts to combine a synthesis of the ancient learning with new ideas, so as to incorporate the contemporary musical practice of using intervals of a third and sixth, within an all embracing scheme that also incorporated the older schema of the Pythagorian scale. Zarlino (and others) were not content simply with re-learning the old knowledge, they wanted to use it as a foundation and stepping stone to a new and fuller understanding of present musical practice. Like Rameau, Zarlino was a practical musician: theorist, composer and teacher. Significantly perhaps, amongst his pupils was Vincenzo Galilei, whose son, Galileo, was destined to become the ‘father’ of modern science. Indeed as a young man Galileo, an able musician himself, assisted his father in his acoustic experiments to determine the nature and benefits of different scale temperaments: Providing Galileo with an early experience of empiricism and mathematical explanation, the hallmark of modern scientific method. This makes Gioseffo Zarlino, and his pupil Vincenzo Galilei, in some degree, ‘grandfathers’ of modern science. Music theory was a participant in the beginnings of the scientific revolution, and though subsequently left trailing in the wake of the scientific juggernaut, a connection has been maintained: through Rameau's interest in Newtonian theory in the eighteenth century to the thoroughly scientific approach of Helmholtz and Oettingen in the nineteenth. At the start of twentieth century, the development of the quantum principle by Planck and Bohr, began to draw science and music theory closer again; and, at the beginning of the twenty-first century, string theory is continuing the trend. Modern music theory and modern physical theory began together, children of the Renaissance hand-in-hand, and perhaps some day in their maturity, they will link arms again.

There are many excellent books describing the development of science in general and String theory in particular, this chapter is not intended to be another in that honourable but crowded line. *Journey to the Heart of Music* takes a radically different approach to the material, turning the tables about and viewing

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mathematical and scientific concepts and hypotheses from the perspective of *Music Theory*! By looking through the lens of music and essentially asking the questions: Does the study of music have anything to offer science? Could the organisational principle discovered or evolved by musicians through their music making, actually contain hints of an approach capable of unlock the workings of other (natural) systems? Ridiculous, maybe. But it is perhaps salutary to remember that Max Planck, the father of the quantum, was himself a talented pianist who only narrowly chose science over music, as a career. One wonders: were his musical instincts, as much as his scientific intuition, involved in his great discovery? This is certainly an *adventurous proposition* to put forward – to suggest that music might have something to contribute to twenty-first century mathematics and science – but I believe it is a proposition worth considering, though of course, it is most definitely a long shot, and probably, a shot in the dark.



Picture courtesy Wikipedia

**Max Karl Ernst Ludwig Planck (1858–1947)**, was born into a scholarly and conservative family of lawyers and theologians from the university town of Göttingen. His father was Professor of Law at Kiel and after 1867 at Munich. At school Planck excelled in academic subjects and music, he played many instruments and perhaps significantly, dabbled in composition. Against the advice of his physics teacher, he chose science over music as a career, because he felt he was more likely to be able to make a contribution in that field. In 1877 Planck went to Berlin to study under Helmholtz, who was to become a firm friend (they played music together) and by 1880 he had completed his academic and teaching qualifications. His chosen branch of physics was to be heat theory and general thermodynamics. In 1885 Planck became an associate professor at Kiel and in 1889 was working back in Berlin, becoming a professor there in 1892, where he stayed until retirement in 1926. Planck was offered but turned down Boltzmann's position in Vienna in 1907. Married twice, first to Marie Merck (the sister of an old friend) who died in 1909 and later in 1911 to Marga von Hoesslin; Planck was sadly fated to see all four children of his first marriage die, the two girls in childbirth and the two boys in wars. Before these tragedies, the Planck family lived happily in Berlin, their home a center for musical and social gatherings. Einstein and Helmholtz both enthusiastic amateur musicians, on occasions swelling the family band. Planck was right in his choice of vocation for he truly did make a contribution, arguably one of the greatest of the twentieth century, that of founding quantum theory. In his Radiation Law published in 1901 he was able to answer a long standing problem concerning the emission of radiation, by assuming that it could only be released or absorbed in discrete units. Like the music he played, he postulated that the radiation of electromagnetic energy proceeded by steps and jumps and was not smoothly continuous. Planck, at least at first, viewed his quantum theory more as a mathematical construct than as a description of reality at the smallest scale. Einstein took the theory more literally and used the idea of discrete particles in his papers on electromagnetism. Planck supported his precocious younger colleague despite doubts, which enabled the concepts of relativity to become established much sooner than would otherwise have been the case. Max Planck returned to his family's home town of Göttingen, where he died in 1947.

## ELEMENTS OF MUSIC?

The information presented below is certainly of a speculative nature, the question mark in the title is more than decoration, the intention here is exploratory; to ask questions, follow intuitions, rather than providing accepted scientific exposition or explanation. Indeed, in applying musical principles to the electronic configuration of the atom, my aim is to draw attention to the remarkable congruence between the two systems, rather than actually provide a scientifically rigorous description. The story of atomic structure, given in terms of the underlying principles of tonal music, is told as a means of highlighting the parallels displayed between the outward appearances of the two systems. Whether this congruence points to some degree of common ground, an inner unity of organisational principle, is certainly an open question and one I leave to others better qualified to judge. Though perhaps at times challenging, I hope the reader will find a musical journey through the *Periodic Table of Elements* interesting, informative and perhaps enjoyable.

To recap: The argument is that rather than creating some arbitrary scheme of musical organisation, over the centuries western musicians evolved or developed in tonal music and practice, a rough facsimile of nature's own oscillatory organisational solution. A schema perhaps to be found in a broad range physical systems. And that modulation, the algorithm of symmetrical exchange, is the mechanism by which these physical systems achieve that organisation – compute structure or its equivalent, process information. Despite appearances to the contrary, the ultimate subject matter being presented is not music or physics but mathematics: computation by mutable numbers. The ideas put forward below, which are obviously extremely speculative and unsubstantiated, are developed only as far as to cover the opening section of the Periodic Table of Elements, yet sufficient to demonstrate the principles involved.

In his book *Nature's Building Blocks* (2001) John Emsley records a number of attempts to draw parallels between schemes of organisation founded on music and the regularities evident amongst the elements – the basic constituents of our familiar material world. As early as 1829 J. W. Dobereiner proposed a *Law of Triads* linking elements in groups of three with the middle element the mean of the outer two atomic weights, eg. Lithium, Sodium and Potassium. And Leopold Gmelin extended the idea further to encompass ten triads, three tetrads and a pentad. Later J.A.R. Newlands (1837-1898) presented a paper to the London Chemical Society in 1864 entitled *The Law of Octaves* which noted the recurring pattern of eight in the properties of the then known elements – coming very near to preempting Dimitri Mendeleev's (and J.L. Meyer's) discovery of the Periodic Table. Newlands' ideas were ridiculed at the time by his peers as unscientific. What Newlands missed for the most part, but Mendeleev realised, was that spaces for elements as yet undiscovered needed to be left in the table. It was the rapid discovery of many of these predicted, but then unknown elements, that confirmed Mendeleev's discovery of the Periodic Law – the full working out of Newlands' law of octaves. It is this octave feature, a pattern which repeats itself after eight steps, that provides the basis for making a link between tonal music, the algorithm of symmetrical exchange and the structure of the Periodic Table.

So what follows is another (brief) attempt in a long, if not hallowed, tradition. However, being clear that this is not an attempt to make the patterns in the Periodic Table follow the rules of music, though often for convenience and clarity musical terms and analogies are used. But rather, an application of what might, perhaps, be a general principle of self-organisation associated with modulating oscillatory systems, acting under the influence of the second law of thermodynamics, which informs both systems.

## Periodic Table I

In this section a brief description of the Periodic table and outline of the application of the MOS model to it is given. More detail is provided in Figure 15.5 and in the section *Periodic Table II*, Figures 15.12-21.

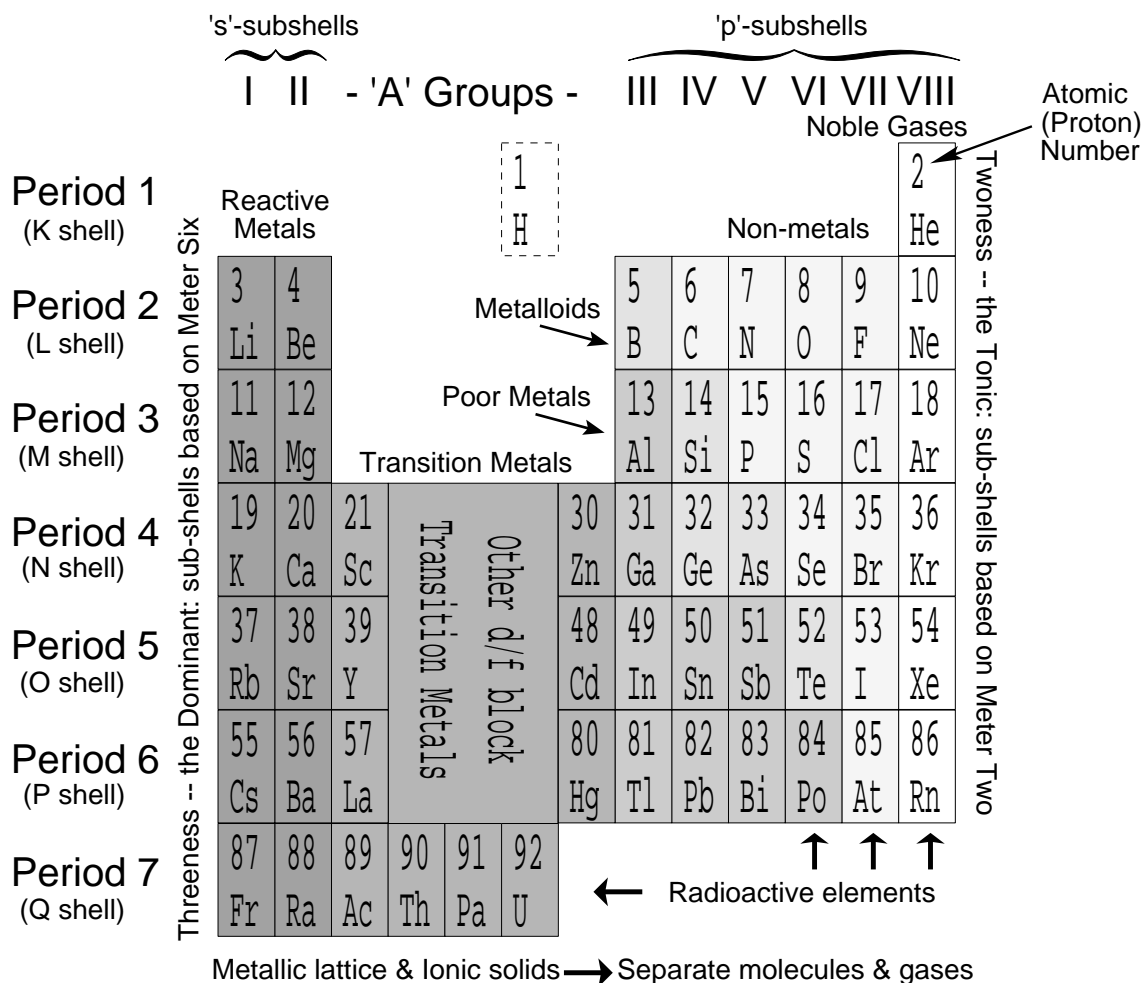
If all the elements, the basic ingredients of matter – Carbon, Oxygen, etc., are formed into a chart, running from the lightest and simplest, Hydrogen, up to the heavy complex atoms like Uranium; it was noted by Mendeleev that a series of repeating patterns of properties emerge. And with a particular arrangement of seven rows or periods, a repeating pattern of eight vertical families can be discerned, which in the older format of the table used here are marked by Roman numerals I to VIII.

Atoms consist of a small dense electrically positive nucleus surrounded by a cloud of negatively charged electrons. It is the arrangement of the electrons, particularly those in the outer layer of electronic structure, which principally determines the chemical properties of an element; and so, to which family it belongs. As the number of electrons (plus balancing protons and neutrons in the nucleus) increases through the table, the pattern of the outer layer of electrons repeats, and so produce *family likenesses* – the similarity of properties displayed by the vertically arrayed families. With this tabulation, the Roman numerals above each column, indicates how many electrons are in the outer layer and the family to which each element belongs (eg. the Carbon family IV has four outer layer electrons or Fluorine, Chlorine, etc., the halogen family VII, seven outer electrons).

Broadly, elements toward the left hand side of the table have metallic qualities and toward the right hand side are non-metals. The elements in the right-most column, family VIII, are special – the noble gases – they are almost totally unreactive, rarely forming associations with other atoms. When atoms other than noble gases do form molecular associations – molecules – the principal attraction of the association is that in combination their total compliment of outer layer electrons, is equal to that of the outer layer of a noble gas. In effect the atoms cluster together as molecules so as to emulate the outer layer electronic structure of the members of family VIII. The noble gas configuration marks a point of structural repose in the evolution of atoms – a sheltered, dipping, valley on an otherwise relentless climb up the mountain range.

After hydrogen and helium in Period 1, the next two periods consist of eight elements (shown in full in Figure 13.4), followed by two periods of eighteen elements, one period of thirty-two elements and a last incomplete period of nearly thirty-two elements (not shown in full). The complete table is given in Figure 15.21, however, the discussion here will be limited to covering only Periods 1 and 2, which will suffice for demonstrating the application of the overall concept of modulating oscillatory systems and mutable numbers to the structures in Periodic Table of the Elements. The elements of the first two periods, followed by their chemical symbols, are: hydrogen H, helium He, lithium Li, beryllium Be, boron B, carbon C, nitrogen N, oxygen O, fluorine F and neon Ne.

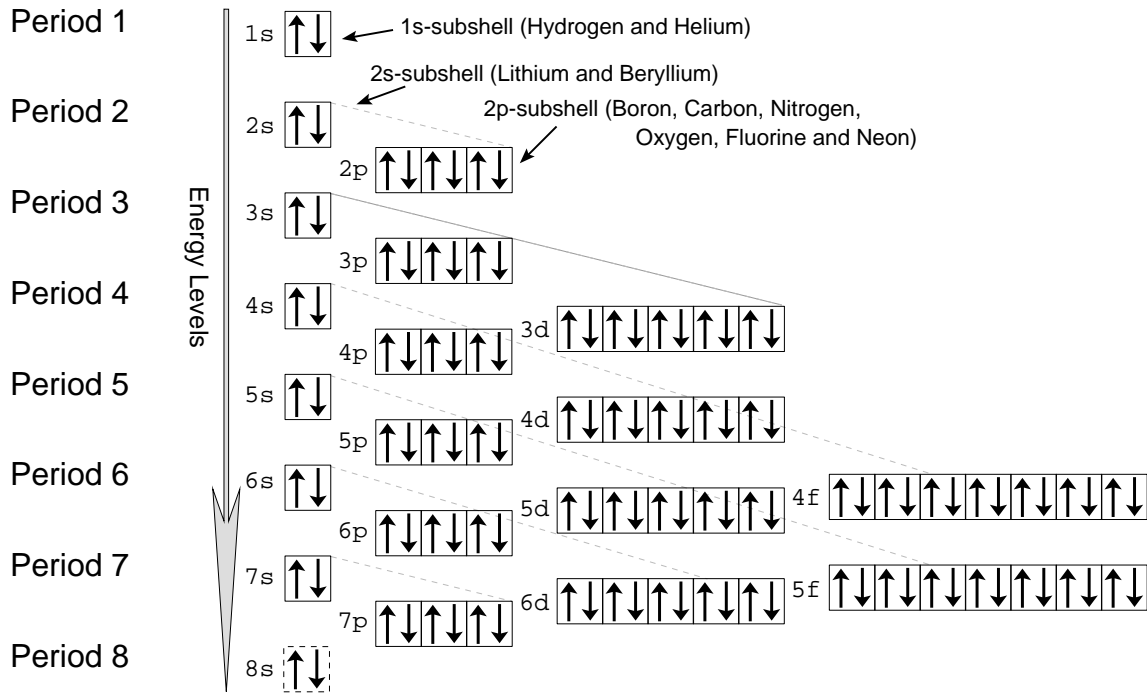
One remarkable coincidence that emerges from the crossover between music and physical theory is the similarity of symbolic nomenclature adopted by chemists in the periodic table, physicists for the fundamental particles of nature and musicians in their Roman numeral analysis of harmony. For example, what interpretation should be placed on the symbol  $I^-$ , is it the tonic chord in a major key with a lowered third or an Iodine ion with an extra electron? Does IVb refer to a family of elements in the transition metals or a subdominant in first inversion? Does  $B^0$  indicate a B-zero meson, a boron atom with its rightful complement of five electrons or a B-major chord without its root note present?



**Figure 15.4** Shading in the (truncated) Periodic Table illustrates how ‘threeness’, that is the metallic characteristics associated with subshells built on Meter Six foundations (the dominant relationship in music) progressively spread across the periods, until eventually overturning the whole system at the close of Period 6.

The structures formed by the electrons as they cluster around the nucleus, are regular (Figure 15.5); with two electrons combining to create an *orbital* and various numbers of orbitals combining to create *subshells*. The horizontal rows in the periodic table, the Periods 1, 2, 3, etc., form complete structural *shells* created from various combinations of subshells. Each period contains a number of subshells; they are named ‘s’ for sharp (two electrons), ‘p’ principal (six electrons), ‘d’ diffuse (ten electrons) and ‘f’ fundamental (fourteen electrons). These descriptive names originate from the appearance of the characteristic spectral emission lines – discrete frequencies of electromagnetic radiation – released by each element and related to that elements particular arrangement of electrons. Every period begins with a ‘s’ subshell. The Period 1 atoms, hydrogen and helium, have a single shell consisting of only the 1s-subshell. Period 2 has a 2s-subshell and 2p-subshell: the period begins with the reactive metals lithium and beryllium, their electrons forming the 2s-subshell structure, and then the period goes on to build the 2p-subshell with the electrons contributed by boron a metal-like element, followed by the non-metals carbon, nitrogen, oxygen, fluorine and the unreactive noble gas, neon.

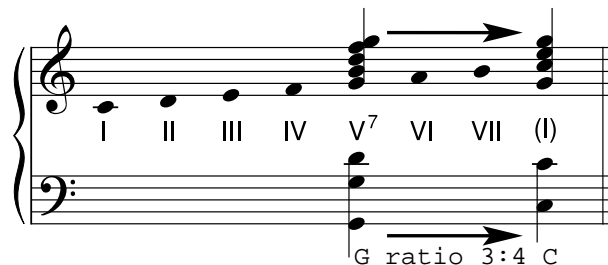
15.13 - FROM PARTICLES TO PLANETS



**Figure 15.5** The overlapping energy levels of the electrons in their shells (periods), subshells and orbitals. Individual electrons are illustrated as arrows and orbitals as boxes. Electrons have a quality termed 'spin' which can have the discrete value of plus or minus one-half, also denoted *spin-up* and *spin-down* – as indicated by the arrows.

### The Full Cadence and Period Two

As introduced above in terms of Newlands' law of octaves, overall, a likeness is drawn between the oscillatory patterns formed by the eight electrons added to the table in period two and the building up of a dominant-seventh chord consisting of eight notes. Both are in effect viewed as *systems of eight ratios* of the harmonic series. The likeness is continued through to the *cadence* at the end of the period where the system of eight ratios/electrons finds stability in the configuration of a family VIIIA noble gas: through the process of resolving (by means of a secondary sesquitertia 3:4 modulation) to a lower energy *system of six ratios* – the filled p-subshell of a noble gas. Essentially the progress through each period forms a gradual approach to a closing dominant-seventh to tonic *perfect or full cadence* ( $V^7 - I$ ), executed by the atom's outer grouping of eight electrons.



**Figure 15.6** Dominant-seventh chord on fifth degree of the C-major scale resolving to the common major chord on the first degree (tonic), a perfect or full cadence mediated by the modulation algorithm of symmetrical exchange.

In this chord progression, eight ratios of the harmonic series built on the note G are exchanged for six ratios built the note C. The accumulation of eight ratios – musically the dominant-seventh chord: G-G-D-G-B-D-F-G – represents a relatively highly ordered, low entropy state which is given an opportunity to release energy and order (once it reaches maturity) by a conjunction in the Table of Harmonic Series (Sieve of Eratosthenes) at row 1:24. The system, through the secondary sesquitertia 3:4 modulation, is able to exchange eight ratios of the harmonic series based on G, notionally *frequency 3*, for six ratios built on the note C, *frequency 4*. Thus finding increased stability by rearranging its internal relationships into a lower energy pattern. This new configuration of the electrons is that of a stable, unreactive noble gas, for example neon. (Of the leftover ratios/electrons, one is added to the fundamental series and the other forms a link upon which the next period is built.

### Twoness – the Tonic

Period 1, discounting hydrogen's 'unique' character, exhibits solely 'twoness' – in the form of the stable and almost totally unreactive noble gas helium. Hydrogen with one electron really stands separate from the table – like a system of Meter of One, it has in a sense, no Meter – a single uniform pulse, metrically undivided. The characteristics with which twoness, or the tonic, imbue an atom (in the outer layer of electron structure), are derived from the system's metrical self-sufficiency; systems based on h1-2 and its doublings are self-sustaining, finished units. Thus the family VIII elements – nested systems of electrons built on the powers of two – form gases: The atoms have no incentive to band together as liquids or solids. Helium only becomes a liquid at minus 269 degrees centigrade and a solid, under considerable pressure, at a fraction above absolute zero (-273C). Like ships "out of the swing of the sea", the noble elements ride serenely at anchor.

Period 2 contains much 'twoness' also. Particularly from nitrogen onward where we shall see, below, the first three electrons of the 2p-subshell slip (modulate) temporarily from h3's grasp, to h8. And similarly Period 3 from phosphorus onward. Other features derived from metrical self-sufficiency are both high and low melting points, and toughness and brittleness! This apparent contradiction flows from the strong and exclusive molecular bonds which twoness engenders. Where the twoness is achieved via molecular association – two or more atoms joining together to make up the number of electrons in their combined outer layers to form a family VIII noble gas configuration – sometimes this will take the form of giant interlocking structures like diamond, while in others, discrete molecules will be the outcome. Substances formed of giant interlocking bonds will generally be tough and have high melting points as a result of their interwoven type of structure. While substances formed of discrete molecules (again with strong covalent bonds) will generally be brittle (if solid) and have low melting points – as each individual molecule's twoness bonds it together strongly, but only weakly binds it to its molecular neighbours (if at all, as in a gas). The nitrogen or oxygen molecules, or Carbon dioxide, being good examples.

### Threeness – the Dominant

Threeness first enters the table in Period 2 where the 2s-subshell founded to start with on h2, when complete, modulates to h3 of the fundamental nesting series, and indeed, each succeeding period follows this pattern to produce s-subshells on h6, h12, etc. The characteristics with which threeness or the dominant (in the outer layer of electrons) imbue an atom are derived from an inherent instability. In a system founded on the ratios

h1 and h2, metrically, h3 and its multiples produce disruptive ‘unfulfilled’ structures – unfinished business. Thus structures of threeness are destined to breakdown, relaxing back to twoness – the tonic; or where they find a permanent existence, to eventually, by accumulation, break the structure and in so doing, bring the whole system back to twoness at a new frequency level. This eventually occurs in Period 6/7, where the accumulating ‘threeness’ in the d and f-subshells, overwhelms even the ‘twoness’ the noble gas Radon; perhaps marking the point where the electron-cloud as a whole is transformed by modulation, with extremely disruptive effects on the nucleus.

Between Period 2 and 7 the forward march of threeness is marked by the progressive extension of metallic qualities, such as malleability, ductility and conductivity, gaining ground across the table with each successive period. For example, in Period 2, family VA starts with the tonic-twoness of the gas nitrogen, but by Period 6, toward the bottom of the table, the family exhibits the threeness of a heavy metallic solid, lead.

Hydrogen	h1	MBN	1	value = one
Helium	h1+2	MBN	1×2	value = two
Helium	h1+2	MBN	2×1	(dupla 1:2 modulation)
Lithium	h1+2+4	MBN	2×2	value = four
Beryllium	h1+2+4+6	MBN	2×3	value = six
Beryllium	h1+2+3+6	MBN	3×2	(sequialtera 2:3 modulation)
Boron	h1+2+3+6+12	MBN	3×2×2	value = twelve
Carbon	h1+2+3+6+12+18	MBN	3×2×3	value = eighteen
Nitrogen	h1+2+3+6+12+18+24	MBN	3×2×4	value = twenty-four
Nitrogen	h1+2+3+6 (4)+8+16+24	MBN	3×2 & (4)×6	value = twenty-four
Oxygen	h1+2+3+6+12 (4)+8+16+24	MBN	3×2×2 & (4)×6	value = twenty-four
Fluorine	h1+2+3+6+12+18 (4)+8+16+24	MBN	3×2×3 & (4)×6	value = twenty-four
Neon	h1+2+3+6+9+12+15+18+21+24	MBN	3×8	value = twenty-four
Neon	h1+2+3+4+8+12+16+20+24	MBN	4×6	(sesquitertia 3:4 modulation)
Molecules-----				
Nitrogen	h1+2+3+6	MBN	3×2	
(N <sub>2</sub> )	4+8+12+16+20+24	&	4×6	value = twenty-four
Nitrogen	h1+2+3+6	&	3×2	
Oxygen	h1+2+3+6+12	MBN	3×2×2	
(O <sub>2</sub> )	4+8+12+16+20+24	&	4×6	value = twenty-four
Oxygen	h1+2+3+6+12	&	3×2×2	
Fluorine	h1+2+3+6+12+18	MBN	3×2×3	
(F <sub>2</sub> )	4+8+12+16+20+24	&	4×6	value = twenty-four
Fluorine	h1+2+3+6+12+18	&	3×2×3	

**Figure 15.7** A table of mutable base numbers in factor format representing the structure(s) of the elements in Period 1 and 2. Some elements have more than one structural form (eg. beryllium). Bottom of table: nitrogen, oxygen and fluorine form molecules in isolation.

### Fecund Mutable Numbers

In Chapter 1 it was noted that there was a set of particularly fertile mutable numbers, the numbers constructed from small prime factors (eg. 3×2×2 MBN twelve). The set of numbers begins:

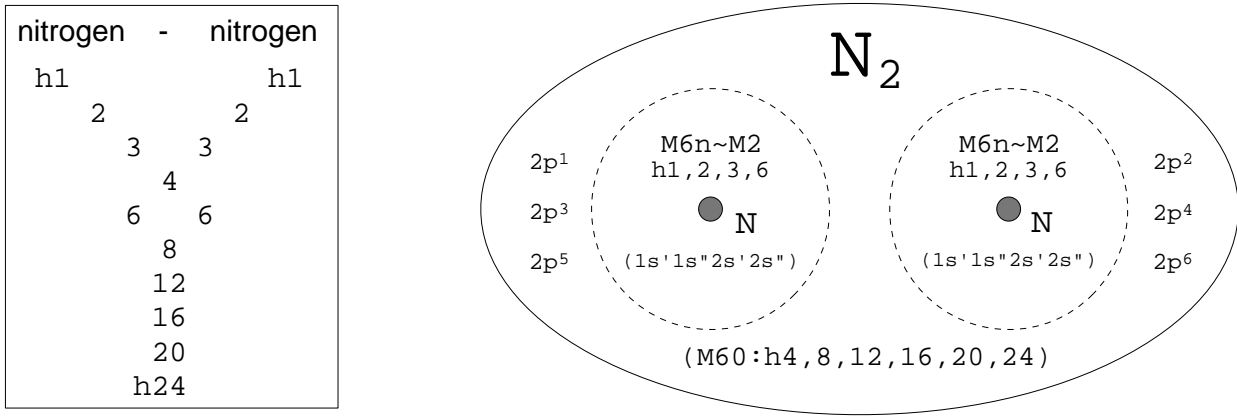
1, 2, 4, 6, 8, 12, 24, 36, 48, 72, 96, 120, 144, 192...

These are the numbers with the largest range of alternative digit sequences relative to their value. A little later in Chapter 1, the value twenty-four was noted as having twenty alternative mutable digit sequences and there were two of these twenty digit sequences ( $3 \times 8$  and  $4 \times 6$ ) that lay behind the full ( $V^7-I$ ) cadence. Looking at Figure 15.7, it can be seen that the structures created by the electron cloud, when represented as mutable numbers, are actually outlining more or less this set of fertile numbers. And once the evolution of the electronic configuration of the elements reaches the mutable number twenty-four at nitrogen in period two, it sticks there on twenty-four; with the gases of Period 2 (nitrogen to neon) all taking up various different digit sequences. These four gaseous elements in families V to VIII form a distinct subset and share many characteristics, underlining their common mutable value. As the periods continue, this common Meter Four heritage (i.e. twoness,  $2 \times 2$ ) in the outer electron layer, comes under increasing pressure from the underlying Meter Six at the core of all elements – except in the noble gases. The trend can be seen clearly in the ‘halogens’, the column of family VII, where chlorine retains a gaseous character, but bromine is a liquid and iodine a solid at room temperature. Subsets of elements in a period, with broadly similar characteristics linked to a fecund mutable number, become increasingly influential as the table unfolds. This could be viewed as a reflection of the exponential growth in digit sequences exhibited by mutable numbers and the fecund set of numbers in particular. The foremost examples of this phenomenon being the transition metals and the rare earths of the diffuse and fundamental subshells (shown in detail in Figure 15.21) – two large sets of elements with broadly similar characteristics.

## The Chemical Bond

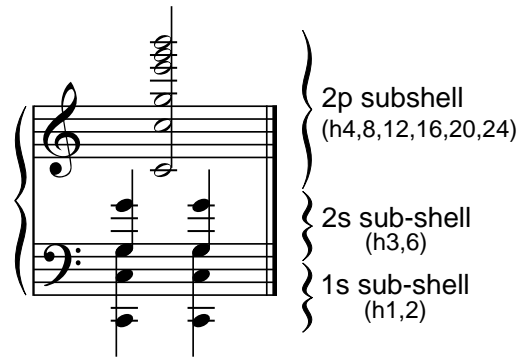
An extension of the metrical approach to the electronic structure of atoms leads naturally on to a similar metrical view of the chemical bond, a little of which can be glimpsed at the bottom of Figure 15.7. The electronic arrangements of the atom exhibit the features of a structure delicately balanced and interwoven, likely to readjust its internal configuration in response to any new event. Even small changes at the extremities may percolate down through many levels of nested structure, in a domino effect, as each level re-computes its relationships and thus creates a new situation for the next lower level. Occasionally, one tiny change at the exterior might cause the entire system to flip to a new configuration (e.g. at the close of a period or when atoms bond to form a molecule), and at others, only a small local responses occur.

The configuration of the nitrogen atom/molecule,  $N_2$ , contains much *twoness*, in that nitrogen’s three 2p-subshell electrons slip away from the *threeness* of the 2s-subshell ( $h3, 6$ ) to form a not entirely stable nested series built on  $(h4)+h8+h16+h24$  – as illustrated in Figure 15.7. This half-step towards the tonic – the family VIII configuration of neon – is reflected in nitrogen’s natural, none associative, discrete molecular state as a gas (as also oxygen and fluorine). With each nitrogen atom having three outer layer electrons ( $2p^1$ ,  $2p^2$  and  $2p^3$ ) this means that two nitrogen atoms can form a metrical alliance by sharing these outer layer electrons so that together they have the numbers to make up the full 2p-subshell – the noble gas configuration of neon. Or in musical terms enough ratios/notes (plus one spare) to form a dominant-seventh structure. The resolution of this combined system of eight electrons/ratios to a configuration of six, yields an electronic structure close to that of neon – except that buried inside the outer metrical grouping of Meter Sixty, lie two atomic nuclei, each of which harbour a Meter of Six (threeness – the dominant), at their core.



**Figure 15.8** Two schematic views of the oscillatory patterns of the electron cloud in a nitrogen molecule.

It is also possible to represent the MOS model and mutable number approach to the vibrational configuration of the nitrogen molecule as chords.



**Figure 15.9** The MOS view of the oscillatory patterns of the electronic configuration of a nitrogen molecule ( $N_2$ ), expressed in musical notation.

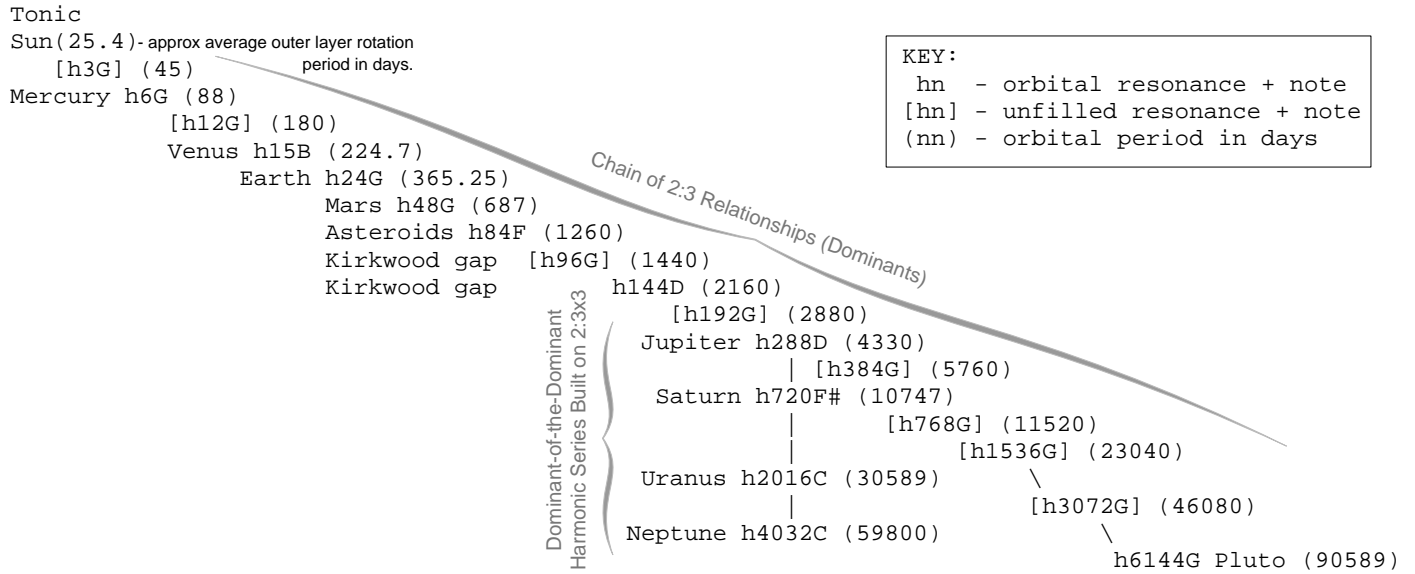
### Other Self-organising Physical Systems

Though the periodic table of elements is by far the most detailed and useful *reference structure* against which the rather murky and less certain structures of tonal music could be analysed and assessed. (And not forgetting the very helpful information available on isotopes and allotropes as well.) Two other physical systems have also provided some inspiration at times. They are, on the macroscopic level, the *solar system* and at the other end of the scale, the table of *fundamental particles*.

Viewed in terms of orbital periods or resonances (and using the harmonic series rather than arithmetic ratios for consistency), the planets of the solar system, when plotted against each other, appear to echo the telltale pattern of a modulating oscillatory system, through which flows a chain of 2:3 relationships leading to a nested harmonic series built on the 2:3×3 relationship – the dominant of the dominant ( $V^7$  of  $V^7$  in music theory). In tonal music this structure would be described in terms of an underlying tonic key or tonal center (nominally C major), the dominant chord (G dominant-seventh) and the dominant-of-the-dominant chord (D dominant-seventh) – the latter two features are present in the diagram, Figure 15.10. Indeed, the structure is somewhat reminiscent of the electronic arrangement of the atoms toward the end of the 5d-subshell described in the articles *Elements of Music?* (<http://www.archivemag.co.uk/>). However, any

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similarities or parallels, would be due to the application of the underlying principle of the modulation algorithm of symmetrical exchange lending a ‘family resemblance’ to any dynamic system of simple whole number relationships, upon which it operates. The actual mechanics of the modulatory process bring about the resonant alignments of the planets shown below, and recorded in Bode’s Law, presumably being accomplished by the gravitational effects of scattering, absorption and deflection of large amounts of planetesimal debris during the early formative period of the solar system<sup>2</sup>. Ultimately in this MOS and mutable base number approach, planetary systems are reduced to physical position-value counting schemes, though most often of a rather awkward and incomplete form, which grind to a halt when the process of modulation runs out of material to fuel further computation.



**Figure 15.10** The orbital periods of the planets of the solar system (illustrated as harmonic rather than arithmetic ratios for consistency). The inner planets together with the Asteroid Belt, Jupiter and Pluto form a G dominant-seventh harmony, while the gas giants (including Jupiter) outline an incomplete D dominant-seventh harmony.

These relationships, expressed in terms of planetary distance from the Sun rather than orbital period, were noticed by Johann Titus (1729-96) and published by J.E. Bode in 1772 (Titus-Bode Law). The base sequence: 0, 3, 6, 12, 24, 48, 96 and 192 (i.e. the dominant relationship in music and also fecund numbers) is manipulated by adding four to each term to produce a set of relationships which matches well for all the planetary distances, except for Neptune. The confirmation provided by the discovery of Uranus by William Herschel at roughly the right distance (term 192) prompted a search for a ‘missing planet’ corresponding to the base term 24. The search led to the discovery of Ceres and also in time many other asteroids. Gauss was able to calculate the orbit of Ceres, this feat established his reputation throughout Europe. In the twentieth century the tilted orbit of Pluto, probably a late captured ‘planet like object’, was found to match the term 384 quite closely.

While of course the exact orbital periods are not perfectly aligned with the harmonies of dominant and dominant by one remove ( $V^7$  of  $V^7$ ), they are near enough to motivate curiosity, or at least justify raising the question of why are thus and not otherwise: Perhaps a different configuration of gravitational resonances

yielding whole-tone harmonies? Or merely some random arrangement? For example, the ratio of the Earth’s orbital period to that of Jupiter’s is 1:12 (with an comma of minus 1.22%). However, it should be mentioned here that there does not appear to be clear evidence for a fundamental ‘tonic’ period associated with the Sun. The Sun’s outer layer rotates in a rather fluid manner (average 25.4 days), not as a single solid unit, with the equatorial region moving somewhat more quickly than the poles. Near pole rotation is in the range 33 to 36 days. The rotation of the core is generally thought to be between three and five times that of the outer layer, rotating as a rigid body. The Sun’s polar axis of rotation is 7.5 degrees off perpendicular to the planetary disc.

To round up this extremely adventurous and exploratory view of the orbital relationships of the solar system, it should be possible to attempt an interpretation the structure as a mutable number. Taking only the planets and other object lying in the plane of the disc, thus excluding Pluto, that number is MBN 28<sub>6</sub> 0<sub>8</sub> 0<sub>3</sub> 0<sub>1</sub> or in decimal notation 4032. Which, expressed as nested ratios with the planet’s positions marked by upper case letters is:

h1, 2, 3 nesting 6, 9, 12, 15, 18, 21, 24 nesting 48, 72, 96, 120, 144 nesting 288, 432, 576, 720,... 2016,... 4032  
 Sun.....M.....V.....E.....M.....Asteroids.....J.....S.....U.....N

Neptune is the one planet Bode’s Law fails to predict, with a distance from the Sun roughly halfway between term 192 and Pluto at term 384 of the series. In contrast the MOS model of mutable numbers is able to accommodate all the planets including Neptune. Interestingly, recent observations have found evidence for a similarity of distribution in other planetary systems<sup>3</sup> (e.g. pulsar PSR B1257+12) which has apparently bolstered the search for an underlying organisational principle in celestial mechanics.

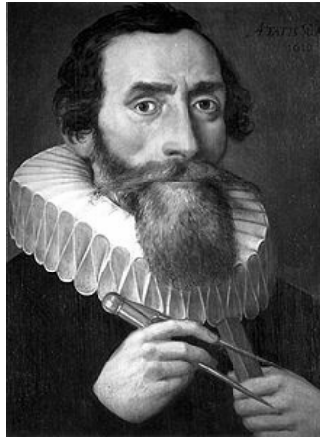
An interesting feature of this interpretation is the possibility of viewing the asteroid belt as an arena of modulation. An area where the algorithm of symmetrical exchange is at work bringing about a realignment of what was perhaps a planet broken up by gravitational stresses or original planetesimals long corralled. From such a perspective, the arrangement (or changes in the arrangement) of the outer group of planets from Jupiter to Neptune could be seen as percolating down into the next layer of nesting, stirring and reconfiguring these relationships. The process proceeding at the pace of a glacial minuet.

Finally, the number twelve, the point where the spiral/cycle of tonal centers ‘returns to itself’, as well as featuring in the examples from the periodic table and the solar system, not to mention the scales and keys of tonal music, also crops up in the table of fundamental particles: In all the experiments, observations and analyses available today, using the highest energies and finest measurements, there have been found to be just *twelve* basic matter particles. The twelve particles (or twenty-four if their anti-matter partners are considered separately) form family groupings in threes, with a similarity of character running horizontally across the table.

Particle Family One -----	Particle Family Two -----	Particle Family Three -----
Electron	Muon	Tau
Electron-neutrino	Muon-neutrino	Tau-neutrino
Up-quark	Charm Quark	Top Quark
Down-quark	Strange Quark	Bottom Quark

**Figure 15.11** The table of fundamental particles.

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**Johannes Kepler (1571–1630)** the son of a soldier was born at Weil der Statt near Stuttgart. Though Kepler's grandfather had been wealthy, and Mayor of Weil, his father Heinrich Kepler had not prospered and died early in Johannes life, leaving his mother Katharina (nee Guldenmann) an inn-keeper's daughter and healer to see to his upbringing. Johannes Kepler was not favored with a strong physical constitution, but from an early age showed remarkable natural mathematical prowess. His interest in astronomy grew out of childhood events where he was much struck by seeing comets and an eclipse, an interest perhaps also encouraged by his mother's involvement with the supernatural. In later life Katharina Kepler was to be tried for witchcraft, and luckily, after three tense years, acquitted. Johannes Kepler's education in local protestant schools led on to studies in philosophy, mathematics and astronomy at the University of Tubingen, where he received a Master's degree in 1591. Although Kepler had originally intended to become a Lutheran minister, and began theological studies, in 1594 the offer of a post teaching mathematics at the protestant seminary in Graz tempted him away. Kepler had long accepted the Copernican cosmological system which placed the Sun at the center of the solar system, and while teaching astronomy at Graz he found a way of inscribing the platonic solids in a particular order – octahedron, icosahedron, dodecahedron, tetrahedron, cube – within spheres carrying the then believed circular orbits of the known planets. The results of his speculations were published in the treatise *Mysterium Cosmographicum*, 1596; and this book established his reputation and paved the way for his later career as Imperial astronomer/astrologer. In this work, and throughout the rest of his life, Kepler united a deeply religious streak of mysticism (perhaps stemming from his mother's influence) with a rigorous mathematical mind and attention to detail. The latter trait was over the years to cause Kepler much disquiet, and eventually, also to be the source of his greatest achievement; in that the accuracy of his observations (he invented an improved astronomical telescope) forced him to abandon the metaphysical perfection of circular planetary orbits and substitute ellipses. The three planetary laws of motion buried within his writings were a significant step toward an empirical astronomy; and, the foundation for Issac Newton's discovery of the inverse square law of gravitational attraction. Johannes Kepler married Barbara Muller, a well-to-do widow of 23 years in 1597, they had five children together, the first two dying in infancy. The times were turbulent, and as the divisions between Catholics and Protestants became increasingly bitter, Kepler's ambitions to develop the geometric ideas presented in *Mysterium* where frustrated. However, by 1601 his contacts with Tycho Brahe, the Imperial mathematician and astronomer based in Prague, brought the offer of a post working as his assistant; and, on Tycho Brahe's unexpected death in the same year, Kepler was appointed as the new Imperial mathematician with the commission to complete the Rudolphine astronomical tables. In the years following 1601, Kepler used and improved upon Tycho's large body of observations and also produced new works: on optics, *Astronomiae Pars Optica*, and a number of astronomical treatise furthering his ideas and speculations. In one of these, *Harmonices Mundi (Harmony of the Worlds)* published in 1619, Kepler attempted to extend his geometric interpretation of divine order amongst the planets to a broader system of proportion, modelled in part on musical theory and practice, but also involving astrology. Again using the best data, coupled with a prodigious mathematical talent, Kepler eventually found that by determining the maximum and minimum orbital velocities of the planets he could interpret their motion, as seen from the Sun, in terms of musical scales. In this scheme the Earth moves through the interval of a semitone and Mercury a minor-tenth. He believed he had uncovered the real basis of the "music of spheres", postulated by ancient philosophers. Essentially, in *Harmonices Mundi* Kepler provided the raw material which, in combination with Christian Huygens' developments in dynamics, would underpin Newton's physically based empirical mechanics. In later life, owing to war and religious turmoil Kepler moved from Prague to Linz and other temporary havens; married again, happily, to Susanna (nee Reuttinger) and continued writing treatises, the most influential being the *Epitome of Copernican Astronomy*. He died in Regensberg Barvaria, of a fever, aged 58 years.

## Periodic Table II

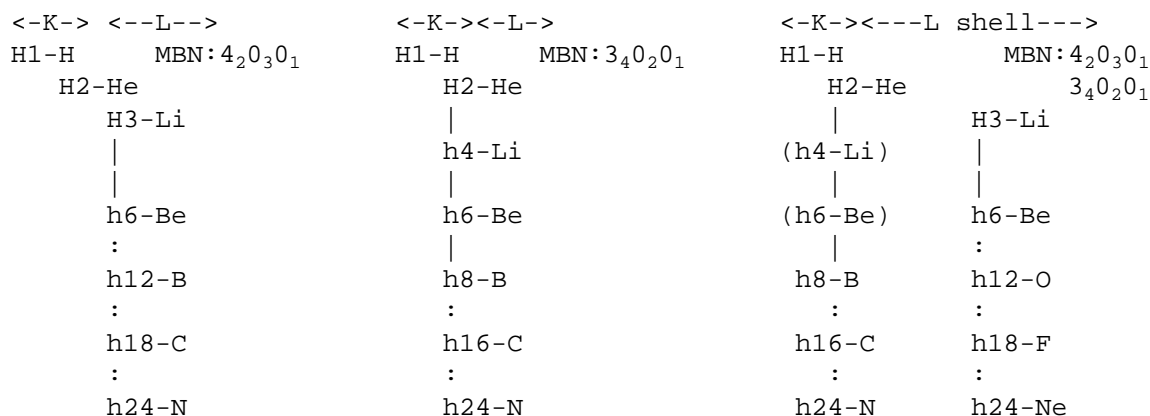
A version of the complete periodic table of the elements is given below – Figure 15.21. Before the table, a sequence of diagrams illustrates in more detail how the algorithm of symmetrical exchange and the processes of modulating oscillatory systems might usefully be applied to the electronic structure of the atom (Figures 15.12-20). In the diagrams each electron/ratio is labelled with the chemical symbol of the element which introduces it; this is simply a useful way of increasing the readability of a scheme composed of anonymous interchangeable units – ‘particles of frequency’. A list of the chemical symbols and full names of the elements can be found in the glossary. After Figures 15.12-21, there are a few closing remarks.



**Figure 15.12** The dupla 1:2 exchange, left to right diagrams: 1x2 --> 2x1. This subtle exchange in period one creates the foundations upon which the whole structure rests. Subsequent periods/shells are each built upon a similar ‘dupla link’, formed at the close of the previous period with the ejection of one electron/ratio by the family VIII configuration.

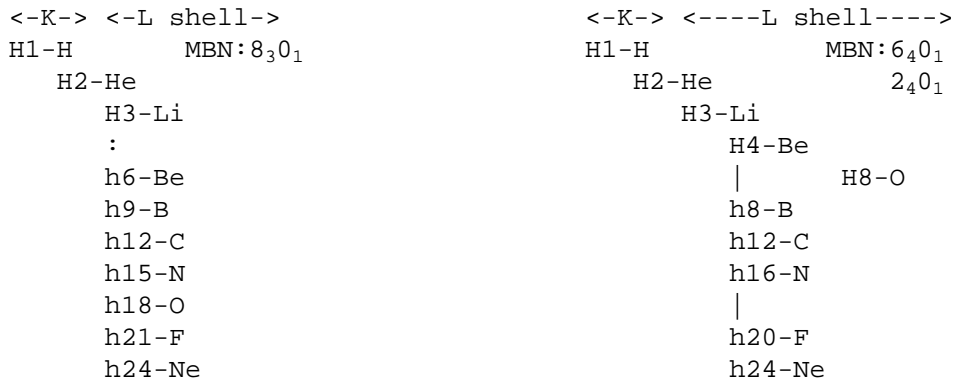


**Figure 15.13** On the foundations of the K shell (Period 1), the addition of two more ratios allow a primary sesquialtera 2:3 exchange to form a new shell, the L shell (Period 2). Up to this point the development is the same as that of the dotted line in the Table of Harmonic Series – Figure 9.2.

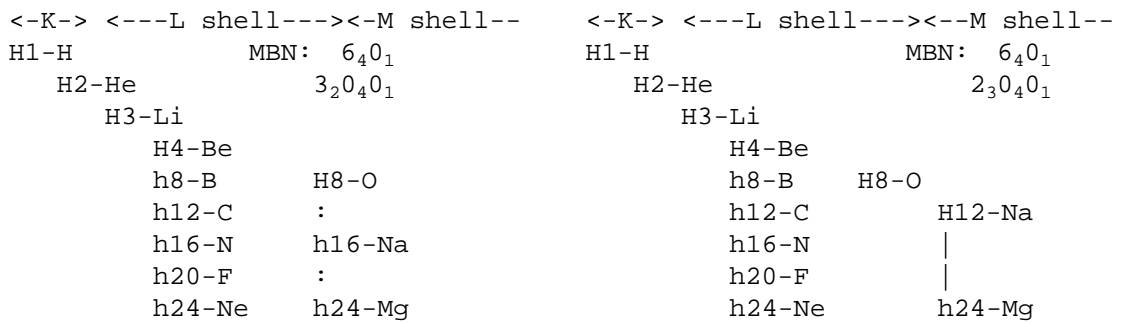


**Figure 15.14** The further development of the L shell diverges from the path of primary modulation exchanges (dotted line in THS), and instead, goes on to form secondary exchanges. The upshot of which is that a ‘seed ratio’ is left over from these secondary modulations to making a ‘dupla exchange link’ into each succeeding shell. The first two diagrams above (reading left to right), show the developments up to nitrogen and the third diagram up to neon. In the third diagram lithium and beryllium possibly ‘resonate’ between two configurations, simultaneously supporting ‘spin-up’ and ‘spin-down’ groupings in the 2p-subshell.

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**Figure 15.15** Once the full complement of 2p-subshell electrons/ratios is assembled, a secondary sesquitertia 3:4 exchange closes the shell. The ejection of one ratio by the modulation, allows a dupla 1:2 exchange to occur (on the outer edge of the system) between the fundamental series and the stray electron/ratio, forming a link upon which the M shell can form. Thus in this MOS view of the structure, the 'original dupla link' created by the *whole* K shell (Period 1), is similarly reproduced by the subsequent sesquitertia exchanges which close each succeeding shell: L, M, N, etc.



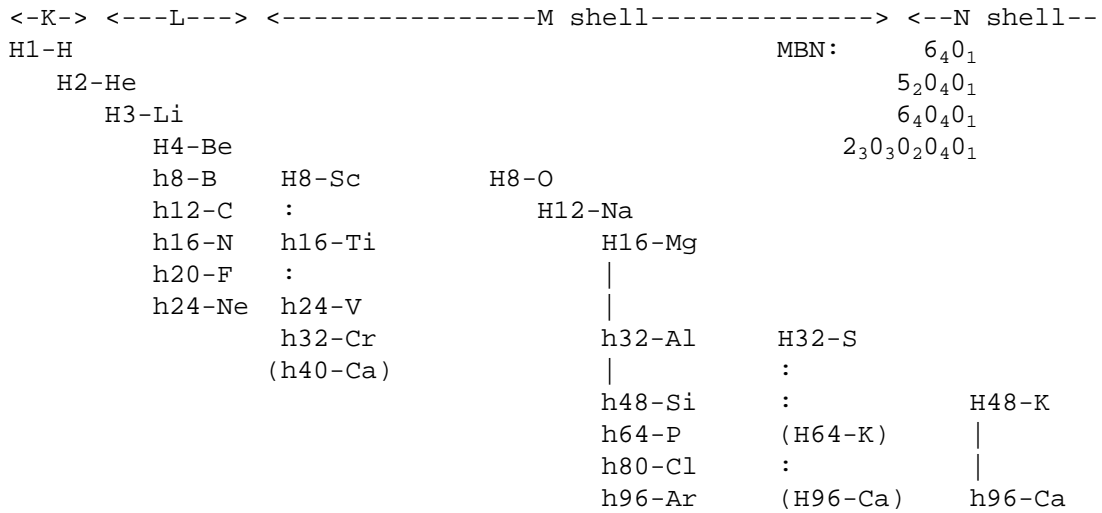
**Figure 15.16** This diagram essentially repeats Figure 15.13, the foundations of a new shell are formed (the 3s-subshell of the M shell) by a primary sesquialtera 2:3 exchange.

As the patterns of the 3p-subshell largely repeat those of the former shell the diagrams move on to the 3d-subshell – the transition metals – where empty spaces (relationships) within the structure are occupied by a process of 'back filling'. Thus at the close of Period 3 the structure is left with a yawning gap between the 2p-subshell built on H4 through h24 (neon), and the 3p-subshell built on H16 through h96 (argon). There is no p-type sub-structure built on H8 – a structural tonic position – the back filling of this hole is undertaken by the 3d-subshell.

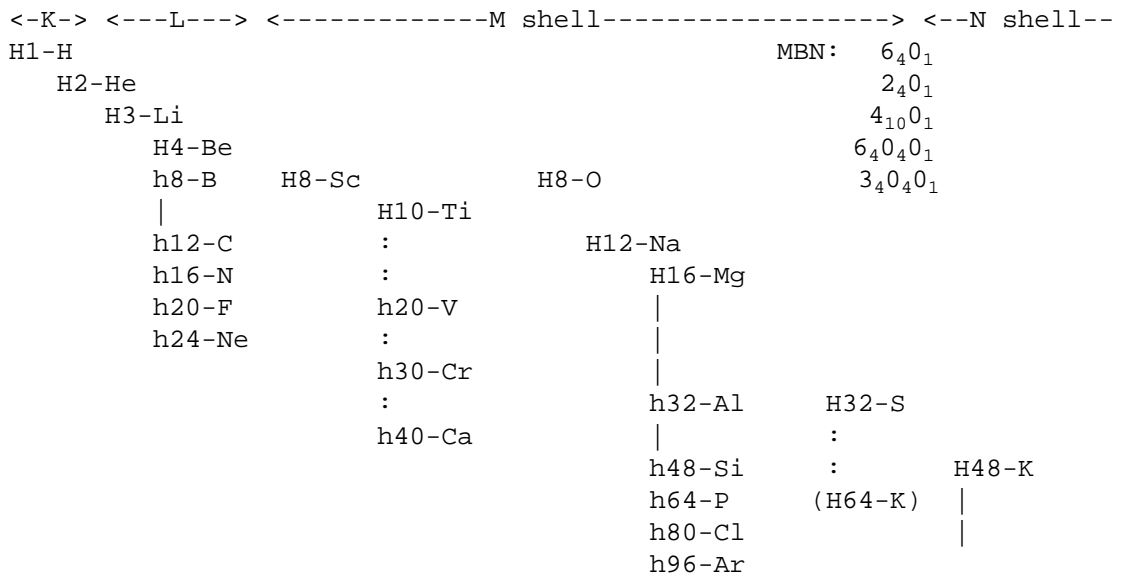
Hopefully by this point it can be readily seen that the structure being built up, through the gradual accretion of electrons/ratios, is broadly that of the Table of Nested Harmonic Series. By adding the electrons one at a time, placing them at the position/ratio next available within the structure, and, at all points applying the algorithm of symmetrical exchange as soon as any modulation to a lower energy configuration becomes possible, a path of 'least action' conducts the system, via this logical process, to a natural termination at the element iron. (Iron is the last of the sequence of elements manufactured by the normal fusion process within stars.)

One subtlety not catered for by upper and lower case lettering (H and h) is that each shell creates a new level of nesting. For example, H4, H8, H12 and H16 straddling the L and M shells, would be more correctly notated as a second spur H4, h8, h12 and h16 off the absolute fundamental series (to the 2p-subshell's first spur H4, h8, h12, h16, h20 and h24). However, in each shell after the K shell, an upper case H is used to denote what is really a nested fundamental series, this H is then conjoined with a ratio from the absolute fundamental series.

15.23 - FROM PARTICLES TO PLANETS



**Figure 15.17** Here the 3p-subshell (H16 to h96) has resolved and released one ratio (H32), upon which the 4s-subshell has grown (H48 and h96). Next come the ratios of the 3d-subshell which slip down into the hole or energy well within the M shell. Scandium, the first ratio, creates a new spur by forming a dupla 1:2 exchange with H4 – the outer edge of the lowest nested grouping ratio. On this new link the next ratios build a nested series – titanium, vanadium and chromium.



**Figure 15.18** The next ratio in the 3d transition metals' series above chromium, that is h40, allows a primary sesquiquarta 4:5 exchange to occur. To achieve this reduction in energy and complexity, the system draws in one ratio from the 4s-subshell. In relational terms at least, this configuration built on H10 nests within H1 and represents a (temporary) link directly to the K shell.

\* **Note to Figure 15.19** Beyond iron the atomic structures require an input of energy for their construction (via a supernova event), rather than releasing energy through fusion, and so at this point the self-sustaining process of growth through modulation exchange ends. All the later elements in the period table would in this scheme be produced as a result of a 'pressure cooker' mechanism, applied to this core arrangement, and ordered similarly.

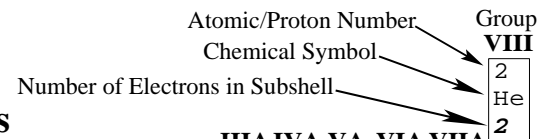
15.24 - FROM PARTICLES TO PLANETS

<-K->	<---L--->	<-----M shell----->	<--N shell-->
H1-H			MBN: 6 <sub>4</sub> 0 <sub>1</sub>
H2-He			10 <sub>2</sub> 0 <sub>4</sub> 0 <sub>1</sub>
H3-Li			6 <sub>4</sub> 0 <sub>4</sub> 0 <sub>1</sub>
H4-Be			3 <sub>4</sub> 0 <sub>4</sub> 0 <sub>1</sub>
h8-B	H8-Sc	H8-O	
h12-C	:	H12-Na	
h16-N	h16-Ti	H16-Mg	
h20-F	:		
h24-Ne	h24-V		
	h32-Cr	h32-Al	H32-S
	h40-Mn		
	h48-Fe	h48-Si	H48-K
	h56-Co		
	h64-Ni	h64-P	
	h72-Cu		
	(h80-Ca)	h80-Cl	
		h96-Ar	h96-Ca

**Figure 15.19** With more ratios added to the system (manganese to copper), the borrowed 4s ratio (h96) is replaced and the series built on H8 re-establishes itself. At h48 (iron) the 3d series forms the equivalent of a 'p-subshell'; this configuration represents the most tightly bound structure with three effective p-subshells built on H4, H8, H16 and the peripheral 4s-subshell echoing their sums, h48 and h96. (See note \*, above.)

<-K->	<--- L --->	<----- M shell ----->	<--- N shell --->
<u>H1-H</u>			MBN: 6 <sub>4</sub> 0 <sub>1</sub>
<u>H2-He</u>			2 <sub>2</sub> 0 <sub>4</sub> 0 <sub>1</sub>
<u>H3-Li</u>			8 <sub>10</sub> 0 <sub>1</sub>
<u>H4-Be</u>			6 <sub>3</sub> 0 <sub>2</sub> 0 <sub>4</sub> 0 <sub>1</sub>
h8-B	H8-Sc	<u>H8-O</u>	2 <sub>3</sub> 0 <sub>4</sub> 0 <sub>4</sub> 0 <sub>1</sub>
	:	h10-Ti	
h12-C	:		<u>H12-Na</u>
h16-N	H16-Ni		<u>H16-Mg</u>
h20-F		h20-V	
h24-Ne			
		h30-Cr	
			h32-Al
		h40-Mn	
			H32-S
		h50-Fe	
		h60-Co	
			h48-Si
		h64-P	
			H48-K
		h70-Cu	
		h80-Ca	
		h96-Ar	
			(h96-Zn)
			[H64]

**Figure 15.20** The back filling of the transition metals in the M shell finishes when copper (h70) plus again a 4s-subshell ratio complete the series H8 to h80, allowing a secondary sesquiquarta 4:5 exchange to take place. The ratio ejected by the modulation connects with H8, now left free by the exchange. The transition metals' series built on h10 is rather unstable, as it is not well connected to the fundamental series, and the structure of the series is easily disrupted giving the transition metals scope to take on many slightly different internal configurations: which is reflected in the wealth of ions these metals can produce. (Ions are atoms or molecules that carry extra or fewer electrons than their normal complement.) The basic structural backbone of interlocking nested Meter Twelve (h1,2,3,4) units have been highlighted with underlining.



## PERIODIC TABLE with the Electronic Configuration of Atoms

	IA	IIA																	IIIA	IVA	VA	VIA	VIIA	VIII																
1s	1 H 1	2 He 2	<i>(Dupla 1:2 Exchange, 2-&gt;1 ratios)</i>																						2 He 2															
	<b>K shell</b>																		<b>2p-subshell --&gt;</b>																					
2s	3 Li 2 1	4 Be 2 2	<i>(Primary Sesquialtera 2:3 Exchange: 3-&gt;2 ratios)</i>																<i>(Secondary Sesquitertia 3:4 Exchange: 8-&gt;6 ratios)</i>						5 B 2 3	6 C 2 4	7 N 2 5	8 O 2 6	9 F 2 7	10 Ne 2 8										
	<b>L shell - Period 2</b>																		<b>3p-subshell --&gt;</b>																					
3s	11 Na 2 8 1	12 Mg 2 8 2	<i>(Primary Sesquialtera 2:3 Exchange: 3-&gt;2 ratios)</i>																<i>(Secondary Sesquitertia 3:4 Exchange: 8-&gt;6 ratios)</i>						13 Al 2 8 3	14 Si 2 8 4	15 P 2 8 5	16 S 2 8 6	17 Cl 2 8 7	18 Ar 2 8 8										
	<b>M shell - Period 3</b>																		<b>4p-subshell --&gt;</b>																					
4s	19 K 2 8 8 1	20 Ca 2 8 8 2	<i>(Secondary Sesquiquarta 4:5 Exchange: 10-&gt;8 ratios)</i>																<i>(Primary Sesquialtera 2:3 Exchange: 3-&gt;2 ratios)</i>						21 Sc 2 8 9 2	22 Ti 2 8 10 2	23 V 2 8 11 2	24 Cr 2 8 13 1	25 Mn 2 8 13 2	26 Fe 2 8 14 2	27 Co 2 8 15 2	28 Ni 2 8 16 2	29 Cu 2 8 18 1	30 Zn 2 8 18 2	31 Ga 2 8 18 3	32 Ge 2 8 18 4	33 As 2 8 18 5	34 Se 2 8 18 6	35 Br 2 8 18 7	36 Kr 2 8 18 8
	<b>N shell - Period 4</b>																		<b>5p-subshell --&gt;</b>																					
5s	37 Rb 2 8 18 8 1	38 Sr 2 8 18 8 2	<i>(Primary Sesquialtera 2:3 Exchange: 3-&gt;2 ratios)</i>																<i>(Secondary Sesquiquarta 4:5 Exchange: 10-&gt;8 ratios)</i>						39 Y 2 8 18 9 2	40 Zr 2 8 18 10 2	41 Nb 2 8 12 1	42 Mo 2 8 13 1	43 Tc 2 8 13 2	44 Ru 2 8 15 1	45 Rh 2 8 16 1	46 Pd 2 8 18 0	47 Ag 2 8 18 1	48 Cd 2 8 18 2	49 In 2 8 18 3	50 Sn 2 8 18 4	51 Sb 2 8 18 5	52 Te 2 8 18 6	53 I 2 8 18 7	54 Xe 2 8 18 8
	<b>O shell - Period 5</b>																		<b>6p-subshell --&gt;</b>																					
6s	55 Cs 2 8 18 18 8 1	56 Ba 2 8 18 18 8 2	57 La 2 8 18 18 9 2	58 Ce 2 8 18 18 9 2	59 Pr 2 8 18 18 8 2	60 Nd 2 8 18 18 8 2	61 Pm 2 8 18 18 8 2	62 Sm 2 8 18 18 8 2	63 Eu 2 8 18 18 8 2	64 Gd 2 8 18 18 9 2	65 Tb 2 8 18 18 8 2	66 Dy 2 8 18 18 8 2	67 Ho 2 8 18 18 8 2	68 Er 2 8 18 18 8 2	69 Tm 2 8 18 18 8 2	70 Yb 2 8 18 18 8 2	71 Lu 2 8 18 18 9 2	72 Hf 2 8 18 18 10 2	73 Ta 2 8 18 18 11 2	74 W 2 8 18 18 12 2	75 Re 2 8 18 18 13 2	76 Os 2 8 18 18 14 2	77 Ir 2 8 18 18 15 2	78 Pt 2 8 18 18 17 1	79 Au 2 8 18 18 18 1	80 Hg 2 8 18 18 18 2	81 Tl 2 8 18 18 18 3	82 Pb 2 8 18 18 18 4	83 Bi 2 8 18 18 18 5	84 Po 2 8 18 18 18 6	85 At 2 8 18 18 18 7	86 Rn 2 8 18 18 18 8								
	<b>P shell - Period 6</b>																		<b>7p-subshell --&gt;</b>																					
7s	87 Fr 2 8 18 32 18 8 1	88 Ra 2 8 18 32 18 8 2	89 Ac 2 8 18 32 18 9 2	90 Th 2 8 18 32 18 9 2	91 Pa 2 8 18 32 18 8 2	92 U 2 8 18 32 18 8 2	93 Np 2 8 18 32 18 8 2	94 Pu 2 8 18 32 18 8 2	95 Am 2 8 18 32 18 8 2	96 Cm 2 8 18 32 18 8 2	97 Bk 2 8 18 32 18 8 2	98 Cf 2 8 18 32 18 8 2	99 Es 2 8 18 32 18 8 2	100 Fm 2 8 18 32 18 8 2	101 Md 2 8 18 32 18 8 2	102 No 2 8 18 32 18 8 2	103 Lr 2 8 18 32 18 9 2	104 Rf 2 8 18 32 18 10 2	105 Db 2 8 18 32 18 11 2	106 Sg 2 8 18 32 18 12 2	107 Bh 2 8 18 32 18 13 2	108 Hs 2 8 18 32 18 14 2	109 Mt 2 8 18 32 18 15 2	110 Uun 2 8 18 32 18 16 2	111 Uuu 2 8 18 32 18 18 1	112 Uub 2 8 18 32 18 18 2	113 Uut 2 8 18 32 18 18 3	114 Uuq 2 8 18 32 18 18 4	115 Uup 2 8 18 32 18 18 5	116 Uuh 2 8 18 32 18 18 6	117 Uus 2 8 18 32 18 18 7	118 Uuo 2 8 18 32 18 18 8								
	<b>7s-subshell</b>		<b>5f-subshell</b>						<b>6d-subshell</b>						<b>7p-subshell</b>																									

**Figure 15.21** (Above) The full Periodic Table of the Elements showing the atomic numbers (Z), chemical symbols and electron configurations (shells and subshells as cumulative totals) of the atoms.

## CONCLUSION

The question mark against the title *Elements of Music* is more than decoration. Whether the exploratory ideas hinted at above, in regard to underlying processes and structures in the material world, have any chance of seriously linking up with rigorous scientific method, lie far beyond my expertise. Though the general trend in thinking, in the speculative fields attempting to uncover or construct a unified fundamental theory of the physical world, is tipping towards the principles and methodologies of systems formed of discrete units (e.g. quantum mechanics, string theory, quantum gravity). And a certain logic to schemes founded on simple whole number ratios gives some encouragement, that, as well as (hopefully) offering a compelling analysis of tonally organised music, to some degree, mutable numbers and modulating oscillatory systems just might have something constructive to offer other disciplines. So being ever the naive and foolish optimist, I have record them here. Yet of course, it must be emphasised that the MOS concept and model is in no way an established method or accepted approach in music theory or any other theory for that matter; it remains entirely possible, probable even, that the whole idea is simply mistaken; fatally and irredeemably wrong.

Overall, this chapter takes a set of ideas appropriate for understanding the core harmonic structure of western tonal music, and transfers them across to other systems in the material world, in the hope of acquiring a deeper understanding of the systems themselves, music, and the wider world they both inhabit. An understanding of how, at the most basic level, the *simplest of relationships* could interact through the *modulation algorithm of symmetrical exchange* to develop structure, process information and create variety – the modulating oscillatory systems model. My instinct, from first glimpsing the patterns within the table of (nested) harmonic series, the THS (mathematicians might prefer TSE: The Sieve of Eratosthenes), has been that there might be something here of interest, indeed, something beautiful: To find that Bach and Beethoven, created musical structures which appear to obey essentially the same disciplines that scientists study, seek to understand and attempt to codify, would be yet another wonderful confirmation of the underlying oneness of the ‘Great World’ in which we live.

I have tried to give some sense of the possibly broad scope and application of *tonalism*. For which there are tantalising hints, both at scales above and below the level of individual atoms found in the Periodic Table of the Elements; that is, in the harmonic ‘flavor’ of the planetary Bode-Titus Law and the pattern of the *twelve* fundamental matter particles. (And yet quite frankly, I must admit that this chapter, and probably the whole book, resembles something like the wreckage from a head-on collision between an enthusiasm for music and some rather shaky high school mathematics and science. From which, I fear, the reader perhaps emerges in a dazed and confused state!) However, notwithstanding the many shortcomings, by putting the case, by making the argument, the ideas at least gain an airing; and, while I intend to continue investigating the musical aspects of *tonal computation*, it is my hope that others more knowledgeable in mathematics and the sciences, might find tonalism an interesting enough approach to consider investigating further.

When those first pedestrians set foot on the Millennium Bridge across the Thames, and found to their surprise that the structure began to sway as their random steps were guided into a common metrical pattern; they would perhaps not have realised that this somewhat worrying turn of events was an entirely natural

phenomenon. The elasticity of the span provided a means of communication and interrelationship binding the throng together into a whole, a system, a 'little world'; and, acting as such a unit, the bridge's 'elastic field' induced the pedestrians to convert the disorganised complexity of their individual gaits into an ordered structure. The millennium bridge by providing a means of communication between the pedestrians, drew their randomly distributed steps, gradually, into a commensurable meter. Effectively the bridge was converting the high level of entropy implicit in the individual pedestrian's varied and uncoordinated paces, into an explicit form of order – a Meter. Meters are mutable numbers; and, where meters are sufficiently complex (i.e. meters nested within themselves), mutable number processing via the modulation algorithm is possible; or, its equivalent description – structural change in material systems. Likewise in western music, once the ancient Pythagorean inheritance of scale steps consisting of whole-numbered proportions, was bound within a system of multiple melodic threads, the resultant communication across the 'tonal field' engendered by polyphony, ineluctably drew musicians towards the discovery of mutable numbers – the metrics of tonality. Similarly perhaps, across the vastly broader arena of the 'great world'; electromagnetism, gravity and the other forces of nature conspire, at very different scales, to draw together and order the systems of particles and planets? And perhaps aeons later, mathematicians (and musicians) observed and co-opted a little of this material order, to furnish the self-evident foundations of their own endeavours?

Of course, outward concordance or near concordance doesn't necessarily lead to a true understanding of inner mechanisms. The Ptolemaic astronomical model of the second century AD, which held sway for so long and so well accounted for the apparent wandering motion of the planets, relative to their starry background (with a scheme of epicycles), was misguided. Copernicus' simple revolutionary idea that the Sun rather than the Earth might lie at the center of the solar system eventually ousted it – after Copernicus' circular orbits were replaced by Kepler's ellipses. The Sun appears to circle the rotating Earth (viewed from the Earth's inhabited regions) but sometimes appearances are deceptive. Equally, the *appearance* of musical patterns and processes in other systems doesn't necessarily have to mean or lead on to anything more than blind coincidence, or mistaken observation. And here I should be absolutely clear that I do not have evidence beyond the rather vague ideas outlined above for the proposition that relational processes found in tonal compositions – computation with mutable numbers – might also turn up in other corners of the physical world. However, the existence of these patterns does at least raise suspicions and justify asking questions. Why this particular number of fundamental matter particles? Why this particular structure of planets in the solar system? Why this particular pattern of atomic shells and sub-shells in the periodic table?

It has taken a considerable effort (and much luck) to identify and extract the mutable base number system from the flux of complicated patterns typically comprising tonal compositions of the western tradition. Hints of a numerical underpinning to tonal music abound, almost every area of music reeks of numbers – rhythm, time signatures, harmony, scales, figured bass, etc.; yet to precisely decipher the underlying mechanisms of mutable numbers was neither easy nor straightforward. How much more true might this be of the vastly greater complexity to be found in the processes of the physical world? Our understanding of the material world has progressed in leaps and bounds, particularly from the beginnings of the scientific revolution in the seventeenth century. And it is clearly apparent, to quote Galileo, that nature's open book "is written in the language of mathematics". Indeed almost all of science's successes in unravelling nature's mysteries, are likewise redolent of mathematics. It is upon this basis that the proposition

outlined in the Introduction rests: *that western tonal music is one member, of a perhaps broad set of oscillatory systems found in the material world, which are all, at bottom, examples of physical position-value counting structures.* It is no more than the simple guess that like music, the material world might also be understood, fundamentally, in terms of dynamically evolving whole number relationships; that ultimately these relationships will delineate a form of number system; and that changes in such a number system will amount to number processing – computation.

In essence the idea is far from new, going back at least to the Pythagorean view of the underlying role played by number in the world. And in a later epoch Johannes Kepler similarly constructed around the orbs of planetary motion, a beautiful mathematical scheme of inscribed and circumscribed three-dimensional platonic solids, which he took to be evidence of the divine ordering of the world. Yet, despite his mystic and metaphysical inclinations, as the years passed and his observations became more accurate, he was forced to yield this static prescriptive model for a more dynamical approach involving harmony and proportion; which, rather than being decreed by perfect, abstract, immaterial forms, emerged naturally from the actual motions of the planetary bodies themselves. Likewise, in contrast to the orthodox Platonistic approach, which situates ‘abstract’ mathematics in some way beyond material existence – external to physical reality – the mutable base numbers of the MOS model are postulated to arise from processes, and consist of relationships, worked out wholly within the systems they inhabit – whether that be the ‘little world’ of western tonal music or the ‘great world’ of the material universe.

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Whilst all the mistakes in this book are wholly mine, many of the ideas presented are drawn from a wide range of writers, thinkers and scholars (upon whose footnotes I am not qualified to tread): And I have been acutely aware throughout, of how far beyond any sensible limits of competence the piano tuner has strayed in telling this story. If by some miracle of endurance you have managed to make it to the end of the book, I would like to thank you, the forbearing reader, for your company on the journey.

On that quiet Sunday morning in 2003, when the idea for a new music data format first dawned, in a sense, and totally by accident or mischance, an unnoticed door opened on to the garden of music, revealing a vista strange, yet not wholly alien. The familiar plants and flowers of tonal music could be discerned amongst the serried ranks of the Table of Harmonic Series, but their usual undisciplined blowsy lushness and natural freedom to grow, entangled by the arbitrary fancies of composers and musicians, was absent. In place of human creativity and invention, the stark parterres I saw appeared to be governed by some strict, unbending, mathematical law. That vista glimpsed through the first small crack was entrancing, coldly beautiful in its logic and economy, though not immediately intelligible overall. Intrigued, I pushed again and stepped through the low doorway, to begin a long, at times arduous and occasionally exhilarating, *Journey to the Heart of Music*.  
[28/07/09]

### **Notes**

1. Smolin, L., *The Life of the Cosmos*, (Oxford University Press, 1997). Many of the ideas expressed in this section are based on material to be found in Lee Smolin's books and other writings.
2. Hahn, J., & Tsiganis K., Gomes R., Morbidelli A., Levison H.F., *When Giants Roamed*, (Nature Vol.435 26/05/2005).
3. Gribbin, J., *Companion to the Cosmos*, (Weidenfeld & Nicolson, London, 1996) Bode's Law, page 66.