Twelve Scientists

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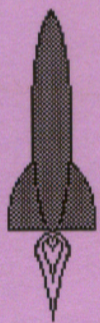

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Twelve Scientists

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Introduction

Twelve Scientists is a collection of twelve pieces, eleven of which were composed using twelve-tone (serial) composition techniques. The remaining work was composed using atonal practices, but not in a serial manner. The pieces which constitute the collection were inspired by the lives and works of scientists who made important contributions to their various fields of scientific study. (The composer has had a life-long fascination with science and, when younger, had considered entering some area of scientific work). The number of compositions was set at twelve to correspond with the number of pitches in an octave, and to reflect the composition technique used. These twelve do not represent the composer's idea of the twelve "most important" scientists; that could only be accomplished using a much larger number of representatives, (probably dozens), or by using extremely rigorous qualifications to reduce the number of candidates to a much smaller number, (probably three). Rather, these twelve represent those whose work has: (1) in some way inspired the composer; (2) in some way lent itself to the serial technique; or (3) in most cases, both. It must be admitted that in addition there are one or two that were included primarily because their work was so monumental it was felt no collection would be complete without them, (e.g. *Newton*). (This does not mean that these men are uninspiring, merely that they are famous).

All of the pieces were composed for an electronic medium, specifically synthesizer. However, an important consideration was the possibility of performance using traditional instruments at some time in the future; therefore the names on the staves use, whenever possible, the names of acoustic instruments. Traditional instrument ranges were also observed, but extreme ranges were used at times. This developed into something of a dilemma. A traditional range was desirable in light of a possible acoustic performance, but if this were strictly adhered to, it would eliminate one of the strengths of synthesis; i.e. the capability of extending acoustic sounds in a previously, (before synthesis), impossible manner. In the end, if a particular range were necessary for an effect, it was used, true acoustic range notwithstanding. (But this didn't happen very often). Using the same line of reasoning, the possibility of future acoustic performance was not allowed to prevent the composer from utilizing unusual sounds if they seemed necessary or desirable. Consequently, if some of the pieces were to be performed in an acoustic format, the ensemble would have to include a synthesizer to reproduce those sounds.

In addition, all of the pieces were composed *in* an electronic medium. All were realized on tape using a computer sequencer and several synthesizers; none have ever been performed "live" by human beings. Using a computer sequencer made possible a great deal of experimentation, and the composer could tell almost immediately whether or not a particular idea was appropriate. It also made possible a truly perfect performance; what is on the tape is *exactly* what was intended.

Some might be concerned with the degree to which the computer was involved in the actual composition of these pieces. The hardware and software played as much a part in the process of composition as Bach's quill pen did when he wrote *The Brandenberg Concertos*. Although there are computer programs available that can produce a rudimentary composition, this type of software is not used by the author, and played no part whatsoever in this project.

Nine synthesizers of various brands and descriptions were used in the production of Twelve Scientists, along with an IBM compatible computer and other MIDI-controlled mixers, digital delays, digital reverbs, and other necessary devices. The exact equipment used is listed separately, (see Appendix 3). Each individual work's commentary will include a list of sounds used and the synthesizers that produced them. Some sounds were "programmed" (i.e. created "from scratch") by the composer, and many were "tweaked" (i.e. adjusted for optimal effect), but the majority of sounds used are commercially available from professional programmers and/or the manufacturers of the equipment.

Each composition was written independently and is complete unto itself, as well as being a part of the entire work. Each composition uses a different ensemble of "instruments", (i.e., synthesizer programs), but many of the instruments are used in more than one piece. Hundreds of different programs were available for use; dozens of drums, basses, strings, etc. Generally, one or two of the best were chosen and used throughout the entire work in order to give it a more consistent timbre. Ninety-six different digital reverb programs were available; only three were used, (mostly only one), for the same reason. In contrast to these unifying factors, each composition is stylistically different. *Heisenberg*, for example, is an electric piano solo. *Galileo* is a fugue for pipe organ. *Doppler* could have been written for a (progressive) rock band; *Kepler* could have been written for a pops orchestra. The unity of the overall work and the differences of each constituent piece represent the large framework of science and the individuality of the scientists, each of whom was attempting to learn all he could about a small piece of the universe around us.

Heisenberg

Werner Karl Heisenberg (1901-1976) was a German theoretical physicist. He won the Nobel Prize in Physics in 1932 for his announcement of the uncertainty principal and work on the structure of protons and neutrons. During World War II, he was in charge of the German atomic bomb research program; (just how instrumental he was in furthering or hindering this research has recently been discussed in American newspapers and books.) Heisenberg's work led him to form the uncertainty principal, one of the foundations of modern quantum theory. Very simply stated, this principle says that by measuring a subatomic particle's velocity, it becomes impossible to ascertain the position of the particle; conversely, by determining its position, the particle's velocity can no longer be measured. Heisenberg's uncertainty principle was used to expand upon portions of Albert Einstein's theories of relativity, (much to Einstein's dismay). Einstein could not accept the idea that the physical universe is constructed upon probabilities, not certainties, and is credited with having responded to Heisenberg with the statement: "God does not play dice with the universe!" Einstein's opinion notwithstanding, today the work of both Heisenberg and Einstein form the basis of modern theoretical physics (Asimov, ii, 216-217).

Heisenberg was the first piece to be composed; in fact it was completed before the idea of doing a series occurred to the composer. It was written as a piano solo and was recorded on the accompanying tape with a Korg DW-8000 using an electric piano patch. The inspiration to begin this work was supplied by an assignment in Dr. Kenneth Keaton's Twentieth Century Music History course - i.e. write a composition using the following rules:

Table I - Rules for Atonal Composition

1. Avoid octaves, whether as melodic leaps or as intervals between simultaneous notes.
2. Avoid major and minor triads and dominant seventh chords, either broken or sounding together, without some other note.
3. When a melodic phrase exceeds one octave, avoid exposing equivalent octaves. Rarely use phrases of smaller range.
4. Rarely use more than three notes in succession belonging to any one major scale. After a series of notes belonging to one major scale, avoid returning to the same scale (Keaton, 13-14).

Since the composer had never written anything specifically atonal before, and was uncertain how the final effort might be received, a title pertaining to uncertainty was deemed appropriate, and *Heisenberg* it became. It is the only one of the Twelve Scientists pieces that is not serial in structure, and consequently is the only one which was composed without using a matrix.

The rhythmic organization of the piece was "done with mirrors". The treble clef of measures 5 and 6 contain the same rhythm as do measures 1 and 2, but in retrograde, (with one small modification in measure 5). The original rhythm is reused in measures 7 and 8, and appears again, in retrograde this time, in measures 11 and 12. The bass clef is looser in construction, but the same processes were used during its development. In addition, a mirror-like rhythmic pattern is apparent between the first six measures and the last six, and each six-measure section is one three-measure section mirrored.

The pitches in the first three measures were determined using the previously listed rules. The pitches in the second three measures were obtained by transposing the previous three bars down a half step, and making necessary adjustments so as to conform to the rules. The second half of the piece, (measures 7-12), is simply the first half over again, but the melodic directions are reversed; what formerly went up, now goes down.

The new mathematical science of chaos theory, (which, among many other things, suggests that it should be theoretically possible to "unstir" green paint into its constituent blue and yellow colors), would seem to support the idea that even in systems that are apparently chaotic, order can be found.

Heisenberg

KORG DW-8000 SYNTHESIZER ---- ELECTRIC PIANO

Euclid

The name Euclid of Alexandria (c. 300 BC) should be familiar to anyone who sat through a high school geometry class. He is credited with writing a very influential and virtually timeless book entitled Elements. In it, Euclid stated and defined the basic terms, postulates, and axioms of plane geometry.

A familiar aspect of any plane geometry class would be the use of *pi*, one of the first irrational numbers discovered. As is well known, *pi* is a non-repeating decimal of infinite length used to calculate the area of a circle. The value of *pi* has been worked out to several thousand decimal places without any sort of pattern emerging.

Like *Heisenberg*, *Euclid* was composed as the result of an assignment by Dr. Kenneth Keaton: write a twelve-tone serial composition following the rules laid down by Arnold Schoenberg. After some reflection, the author realized that a non-repeating number of infinite length seemed perfectly suited for use as a tone row, and so decided to base the composition upon *pi*.

Even after deciding to use *pi*, there was still the question of a title. There was at this time still no thought in the author's mind about composing an entire series, (that happened after *Euclid* was completed), but the name of a scientist was desired. Strictly speaking, any number of names could have been used; several people over many centuries have been associated with *pi*: Pythagoras, Eratosthenes, Archimedes, Gottfried Wilhelm von Leibniz, William Shanks, and, of course, Euclid. (Most of these names will probably be familiar to the reader except, possibly, William Shanks. In 1873, after working on the problem for fifteen years, Shanks published the value of *pi* to 707 places, which remained the record until 1949. In that year, the ENIAC computer calculated *pi* to 2035 places, and in doing so, discovered that Shanks had made an error in arithmetic, and the last hundred or so digits were wrong. In the opinion of the author, this effectively eliminated Shanks' name from consideration.) It was decided to call the composition *Euclid* because it was during high school classes in Euclidean geometry that the author received his first thorough indoctrination in the uses of *pi* (Asimov, i, 57-58).

Having decided to use *pi* as the basis for the composition, the author proceeded to consult literally dozens of almanacs, encyclopedias, math textbooks, and other sources of reference without being able to find a value that gave more than eight decimal places, (3.14159265). (Of course, as luck would have it, a week after completing the composition a value to forty-seven digits was found in an overlooked book in the author's own library.) As it turned out, this would not have a large effect upon the tone row.

In deciding how the digits in *pi* would determine the pitches of the tone row, a method similar to the one used in *Pythagoras* was utilized, based on intervallic relationships. However, where in *Pythagoras* each successive pitch was determined by its relation to the previous pitch, in *Euclid* each pitch would be determined based upon its distance in half-steps from the *first* pitch: A. For example, the first digit used was a zero. Since A is zero half-steps from A, it fit the pattern nicely. The second digit, 3, corresponded to a C, three half-steps up from A. The third (1) and fourth (4) digits yielded A# and C# respectively. The next digit of *pi*, a 1, was ignored because of the previous use of 1 in the series. The sixth (5), seventh (9), eighth (2), and ninth (6) digits led to D, F#, B, and D#. The next digit of *pi* is a five, which also had previously been used and was therefore ignored. Having run out of available digits, the last four pitches were determined by simply arranging the remaining unused four digits in numeric order: 7 8 10 11; yielding E, F, G, and G#. The complete row is thus:

0	3	1	4	5	9	2	6	7	8	10	11
A	C	A#	C#	D	F#	B	D#	E	F	G	G#

Euclid begins with all four instruments simultaneously. Synth 1 and synth 2 are each using P0; the piano and bass guitar are each using RI3. The bass guitar part goes through a particular sequence of rows: RI3 RI1 RI4 RI1 I5. (After measure 27, the bass alternates between RI1 and RI4.) The piano takes the sequence even further: RI3 P1 RI4 P1 RI5 P9 RI2 P6 RI5. Synth 1 begins by slowly moving through P0 until measure 7. At measure 8 it somewhat belatedly picks up a piece of *pi* (sic) and proceeds through R1 P4 P1 R5 and R9. The second synthesizer part alternates between P0 and R0 until measure 15, where the entire texture of the piece changes. The rows used at this point are: I3 (Synth 1), I1 (Synth 2), I4 (Piano), and I5 (Bass). Beginning at measure 26 and continuing through measure 30 is a somewhat convoluted section which uses I3, P3, RI3 RI0, RI1, R0, and RI4 in various voices. At this point, a return to some earlier portion of the piece was desired, as a summation. In order to achieve the desired effect, it was necessary that measures 32 through 36 be a repeat of measures 10 through 14. Unfortunately, that would begin the repeat in the middle of three different rows, (R1, R0, and RI4). To circumvent this difficulty, new material was introduced using the beginning elements of the necessary rows, and placed so as to precede the point of repetition, but written so as to function as a bridge between the center section and the repeat (end). As a result, a smooth transition is achieved. The composition is completed with a single measure in which all parts share row P0.

The time signature changes in *Euclid* follow the digits of *pi* as well. The piece begins with three measures of 3/4, followed by one measure of 1/4, four measures of 4/4, another bar of 1/4, and five measures of 5/4. At measure 15 nine measures of 9/8 begins, which coincides with the textural change mentioned earlier. Measure 24 begins two bars of 2/4, followed by six measures of 6/4. Measure 32 marks the beginning of the repeat section with five measures of 5/4. The last measure is in 3/4, which at the time was simply added to complete the song easily and logically, (the piece begins in 3/4); but as was later discovered, 3 is indeed the next digit in the sequence of *pi*. Thus, viewed as a whole (and adding a decimal point for clarity), the time signature changes are as follows: 3.141592653, giving the most accurate depiction of *pi* in the entire piece.

Euclid

Korg 01 R/W synthesizer ------	Piano (Piano Haven/T-series card)
Korg DW-8000 synthesizer -	Synthesizer 1 (voice-like)
Yamaha FB-01 synthesizer ----	Synthesizer 2 (Folk Guitar)
360 Systems Midi Bass --------	Bass guitar

Pythagoras

Pythagoras of Samos (BC 582-507 ?) was a Greek philosopher who dealt with mathematics. Legend has it that upon discovering the theorem that bears his name, he sacrificed a hundred oxen to the gods to show his gratitude for the gift. Fortunately for the oxen, this probably never took place, as he did not really discover the theorem. Pythagoras probably supplied the first proof; the theorem was already well-known to the Babylonians. The Pythagorean theorem states that for every right triangle in which c is the hypotenuse, (the longest side), and a and b are the shorter sides, then $a^2 + b^2 = c^2$. The simplest example of this relationship would be a right triangle with side lengths of 3, 4, and 5 (3x3=9, 4x4=16, 9+16=25, which equals 5x5=25). This series, 3 4 5, is the basis for *Pythagoras.* (Miller, 388-389).

This theorem has found applications in a wide group of disciplines other than pure mathematics; two of interest are: art (use of the "Golden Section" is an application of the Pythagorean theorem to situate the primary figures in a painting or photograph for the most "balanced" appearance); and music (the relationship of musical pitch to the length and mass per unit length of a plucked string can be described by the theorem) (Pierce, 22-23).

Pythagoras, and his group of followers, composed a secret society that considered itself to be engaged in discovering great truths of the universe within number relationships. They deduced "triangular numbers"; studied the known regular polygons and regular solids, (and searched for new ones); and generally studied number theory. The Pythagoreans thought their interest in such arcane subjects would cause ordinary people to condemn them as sorcerers, (or worse), so their discussions and meetings were held in secret. Their discovery of a regular dodecahedron, (a 12-sided solid), that used pentagons, (another important shape for the society), in its construction was considered very privileged information, and knowledge of the existence of the dodecahedron was kept from the general public (Pierce, 23) (Asimov, i, 56).

The matrix for *Pythagoras* was determined a bit differently from the other matrices in that the tone row itself was not derived from a significant number; the important consideration was the intervalic distance between the notes. The dodecahedron was of primary significance to Pythagoras, so it was decided the row would begin on a D. From there, the row traveled up a major 3rd to F#, then up a perfect 4th to B, then down an augmented 5th to a D#, (of course, this is really a minor sixth, but a sixth wouldn't fit the pattern, would it?), up again a perfect 4th to G#, down a major 3rd to E, up a perfect 4th to A, and down a major 3rd to F. Up to this point, the 3 4 5 pattern had remained relatively intact; after this, a little more imagination was called for. The next two elements, G followed by C#, were considered independently in order to continue the 3 4 5 series embarked upon earlier. The intervalic distance between G and C# was considered both an augmented 4th and a diminished 5th simultaneously; this along with the addition of the final unused pitch, (A#), completed an overall pattern of:

```
M3  P4 AUG5  P4   M3 P4 M3 - AUG4TH/DIM5TH  -   MIN7TH
D F#  B    D#  G#  E  A  F G              C# C      A#
```

(That the final interval had to be a min7th was unavoidable at that point, but it was deemed acceptable - seven was sometimes considered a "magic" number by early peoples.)

Pythagoras begins with pitched bells playing row P0. The length of each note follows the 3 4 5 pattern: the first note, D, is a dotted quarter note; 3 eighth notes. The second note's (F#) total duration in eighth notes is 4; G, the third note, lasts for a total of 5 eighth notes. The pattern continues: D# = 5 eighths, G# = 4 eighths, E = 3 eighths, A = 3 eighths, F = 4 eighths, G = 5 eighths, C# = 5 eighths, C = 4 eighths, and finally, A# = 3 eighth notes in duration. This method of using the 3 4 5 pattern is repeated beginning at measure 13 in the bass part. This time, however, the basic unit is a quarter note rather than an eighth.

The order of time signature changes also reflects the 3 4 5 sequence; the piece begins with 3 measures of 3/4, followed by 4 measures of 4/4, followed by 5 measures of 5/4. The order is then reversed, yielding 5 measures of 5/4, 4 measures of 4/4, and 3 measures of 3/4. These patterns are repeated throughout the piece, with the final bar being one of 5/4.

The 3 4 5 pattern is also reflected in the choice of rows, which was restricted to rows 0, 3, 4, or 5 throughout the composition. However, these could be used in prime, retrograde, inversion, or retrograde inversion forms.

The instrumentation was chosen with some thought to the instruments that might have been available to the Pythagoreans: drums, bells, plucked strings (bass guitar and "plucks", or pizzicato strings), reed instruments (oboe and bassoon), and human voice (loosely represented by the first synthesizer).

The author's first encounter with Pythagoras and his theorem took place some years ago, at an age when anything with the name Walt Disney on it was considered absolutely fascinating, (especially if it was a cartoon!) There was an animated segment entitled: "Toot, Whistle, Plunk, and Boom", which told the story of Pythagoras and his society of mathematical musicians in a delightfully whimsical fashion. This cartoon, it must be admitted, had a great deal to do with the author's choice to compose *Pythagoras*.

Pythagoras

Korg 01 R/W synthesizer ----- Bassoon

Korg DW-8000 synthesizer - Synthesizer 1 (strings/voice combo)

Yamaha FB-01 synthesizer --- Bells and Plucks

Yamaha TX81 Z synthesizer --- Oboe

Roland Juno 1 06 ---------------- Synthesizer 2 (similar to marimba)

360 Systems Midi Bass -------- Bass guitar

Sequential Drumtraks 400 - Drums and Cymbals

Einstein

Albert Einstein (1879-1955), the German-Swiss-American scientist who devised the Theory of Relativity, is without a doubt the most famous scientist in the world today. His very name has become synonymous with genius. It is somewhat amusing to realize that this most renowned of men is universally famous for performing work that is incomprehensible to all but the most gifted and educated people. Yet, even those people who haven't a clue as to the content or significance of Einstein's work remember his name; even his first name! It was both the author's personal admiration for this great man and the fact of the general public's familiarity with him that led to the writing of *Einstein*.

The young Einstein received the Nobel Prize in Physics in 1921, not for his relativity theories, as most people assume, but for a paper on the photoelectric effect. His Special Theory of Relativity was published in 1905, after his photoelectric paper, and that in turn was followed by the General Theory of Relativity, published in 1915 (Calder, 1).

These two theories, amazing in their insight, appalling in their mathematics, can nevertheless be discussed and pondered by people of ordinary intelligence. The Special Theory of Relativity deals chiefly with gravity; the General Theory deals with high-speed motion. The central idea of the latter can be stated by the famous equation:

Table II - Mass/Energy Equivalence

$$E = MC^2$$

$$\text{ENERGY} = \text{MASS} \times \mathit{186{,}282}\ \text{MI./SEC.}^2$$

This equation shows that matter and energy are really two forms of the same thing and that they can be transformed, one to the other. Mass is really "frozen" energy! (Calder, 1-13).

Einstein was born in Ulm, Germany, the son of working-class Jewish parents. His first years of school in Munich were made difficult by financial hardship and anti-Semitism. When he was sixteen he moved to Switzerland, and there completed his doctorate. By the age of twenty-three he had a job in the Swiss patent office, (which, incidently, gave him plenty of time to think). In 1905, he wrote the paper that would win the Nobel Prize years later (Sheldon, 1-14).

Einstein felt the coming winds of war when the Nazis rose to power in Germany, and in 1930 he emigrated to the United States, where he received a hero's welcome. He received a position at Princeton University, and worked and lived there for the rest of his life (Sheldon, 1-14) (Calder, 1).

Einstein's work and its ramifications are not for the author to discuss; there are many popular books on the subject that give a very clear understanding (see Bibliography). It will suffice to say that his theories were the first real modification of the ideas of physics since Isaac Newton. Many inventions and scientific techniques owe their development to the foundation laid down by Einstein, (e.g., lasers, atomic reactors, hydrogen bombs, etc.). In addition, many predictions are made by the two theories, only some of which have been observed. The deflection of light by a "gravity lens" is one phenomenon predicted by Einstein that has been observed; the existence of "black holes" is considered almost certain, but no object yet observed can be proven to be a black hole. There are some other interesting conclusions of the two theories; the math of General Relativity says that as an object approaches the speed of light, its mass increases exponentially, until, upon reaching that absolute speed limit of the universe, its mass becomes infinite, and it would be incapable of moving at all! At the same time, the amount of energy required to accelerate the object would also increase at an exponential rate, and would also reach infinity at the speed of light. In a seeming contradiction to these examples is another that says the length of an object approaching the speed of light will progressively shorten! More commonly known are the time-dilation effects of speed-of-light travel, popularized by many science fiction books, movies, and television programs. This observed and proven effect refers to the slowing down of the passage of time during high-speed travel (Russell, 20). (Interestingly, the very agencies that serves to popularize Einstein's theories are usually guilty of ignoring or circumventing portions of them. Many young viewers of television science fiction may be shocked to find out that humans can't really travel at "warp" speeds!)

The author shares the public's veneration of this great man, both for his work in physics, and for his gentle and unassuming demeanor. He was a pacifist, (although he did have his moments of non-pacifism; Hitler comes to mind), and was reported to have been dismayed by the huge build-up of nuclear weapons by the superpowers in the late forties and early fifties. He loved to smoke his pipe, sail in his small boat, and play the piano and the violin; (he was better on the violin). He sought no publicity for himself, and was content to be left to his work (Sheldon, 10-12).

Einstein worked until his death on a "unified field theory", which would combine all of the forces of nature into one. The problem then, as now, has been gravity. Perhaps in the future, as others pursue this same problem, the legacy of his work will expand humanities' horizons beyond imagining (Calder, 1).

The tone row for *Einstein* was derived from the speed of light - 299,792.5 kilometers per second, or 186,282.3976 miles per second (Hoffman, 202). The first number, in km/sec, had too many nines in it for easy use as a tone row, so the author chose to use the second number. The digits to the right of the decimal would have contained too many repeated digits, so they were ignored. It must be admitted that the method of obtaining a tone row from this number seems somewhat contrived, but it worked. First, the number was written twice, one after another:

1 8 6 2 8 2 1 8 6 2 8 2

Beginning at the second 2, a one is alternately either added or subtracted:

```
1 8 6 2 8 2 1 8 6 2 8 2
        X +1 -1 +1 -1 X -1 +1
```

(The digits marked with an X are temporarily ignored.)
yielding:

```
1 8 6 2 8 3 0 9 5 2 7 3
      X         X
```

Since the third 2 was ignored and didn't get a 1 added to it, the "neglected" 1 is also added to the last digit:

```
1 8 6 2 8 3 0 9 5 2 7 3
      X         X     +1
```

yielding:

```
1 8 6 2 8 3 0 9 5 2 7 4
      X         X
```

Finally, the two ignored digits are directly replaced by the two remaining unused digits of the row, yielding the final row:

```
1 8 6 2 10 3 0 9 5 11 7 4
```

The synthesizer keyboard was then assigned numbers to obtain the actual order of pitches:

```
G#  A#      C#  D#      F#
  A   B C   D   E F     G
_____________________________
0 1 2 3 4 5 6 7 8 9 10 11
```

(By starting the number sequence on G#, it was possible for the author to begin the prime row with **A E**, for Albert Einstein, of course.)

The actual composition of *Einstein* was guided much more by musical considerations than by strict guidelines, as was the case in *Euclid*, and later in *Kepler*. The major musical question was: "Does it sound good?" An effort was made to manipulate the tone rows currently being used in a rhythmic fashion in order to obtain as many tonal-type chords as possible; for example, in the beginning of the piece, (section A), the first notes heard are an A minor chord, formed from elements of P0 and P3. In the next measure, an F# Major chord is formed, next a C#[7](no 3rd), leading to a dotted half-note C minor in measure 5.

At this point, the String 2 part and the Bass Guitar part that doubles it begin a somewhat convoluted line in which the notes of P3 and P7 are alternated; every other note belongs to the same tone row.

Measure 9 (section B) features the entrance of the flute, heralding a sudden switch to a new texture. The flute is accompanied by tympani and pizzicato strings, and is joined briefly in measures 15-17 by an oboe for three bars of twelve-tone counterpoint. Throughout this entire section (measures 9-20), the flute is repeating a three-bar rhythmic motif with very little variation. This rhythmic motif is played a total of four times; the first two times using the pitches from row R0, and the last two times using R3.

In measures 21-43, (section C), the "pseudo-tonal" construction discussed earlier is implemented in a different way: three different tone rows are begun simultaneously in four voices - R2 (soprano), R5 (tenor), and R10 (alto and bass). The first notes of these rows form a Bb Major chord. The rows proceed in parallel fashion, locked together rhythmically as well, until at measure 24, an F Major is formed, (V in the key of Bb). The overall "harmonic progression" of measures 21 through 32 could be charted as:

```
    21   22         23   24   25         26   27          28   29      30      31   32
   |Bb  |   Fmi#5  |n/c |F   |Ebmi#5    |Eb  |Bbmi#5     A|n/c |E      |G#     C|D   |G  |
   |I   | v        |    |V   |iv        |IV  |i        * I|    |V/I    |III  IV|V   |I  |
Key:Bb                                        Bbmin      A      A/E          G      G
```

The key change from Bb to Bb minor (measure 27) is an abrupt modulation to the parallel minor key, previously hinted at in measures 22 and 25. The immediate change to the key of A is justified by use of a common tone (C#). In measure 29, the E functions as a pivot chord from the key of A to the key of E. In measure 30 the C which is common to both G# (Ab) and C chords functions as a common tone for modulation to the final key of G, which, with a IV-V-I cadence brings the 12 bar phrase to an end. This phrase is immediately repeated in bars 33 through 44.

This "harmonic progression" is not exactly a textbook example of a proper tonal progression, of course, and is only achieved by stretching the rules rather strenuously. For example, the alert reader will recognize the Fmi(#5) as an ordinary C# chord, but then it could not have been called the v chord of the key of Bb. As flimsy a structure as it is, it does lend a certain impression of tonality, or at least consonance, to this section of *Einstein*.

Section C also features the entrance of the brass at measure 29; the brass then becomes the focal point until the end of the section.

On the last beat of measure 44, section D begins with the String 2 part playing a low-pitched, powerful motif based on P3, accompanied by tympani and String 1 playing pizzicato. This section, in the opinion of the composer, somehow comes close to capturing the greatness and wonder of Einstein's scientific achievement. One cannot tell in advance precisely where the line is headed, but it nonetheless has a feeling of implacability.

The piece starts a repeat section at measure 51, (A^1), where the strings begin an exact repeat of the material at the start of the composition, but this time accompanied by a powerful rhythm section. At measure 59, a repeat of the D section, (D^1), begins and proceeds through measure 65. The piece ends with a two-bar "tag". The overall structure of *Einstein* is thus:

A B C D A^1 D^1

It was the composer's intent while writing *Einstein* to not concern himself with a lot of self-imposed restrictions and numerical relationships, but instead to adhere only to the very basic rules of serial composition. In this manner, it was hoped that, perhaps, a bit more emotion could be brought out in this, the composer's tribute to his favorite scientist.

Einstein

KORG 01 R/W SYNTHESIZER -----	BRASS
	STRING 1
	STRING 2
	PIZZICATO STRINGS
YAMAHA FB-01 SYNTHESIZER ---	FLUTE
YAMAHA TX81 Z SYNTHESIZER ---	OBOE
360 SYSTEMS MIDI BASS --------	BASS GUITAR
SEQUENTIAL DRUMTRAKS 400 -	DRUMS AND CYMBALS

Darwin

Charles Robert Darwin (1809-1882) was an English naturalist who is remembered primarily for his book, The Origin of Species, first published on November 24, 1859, and his theory of evolution contained therein. His observations of the flora and fauna of the Galapagos Islands (and other geographic areas) while serving as ship's naturalist on the H.M.S. Beagle, formed the foundation for the theory presented in the book, more fully titled: The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. The furor that erupted in both scientific and religious circles upon publication of this work continues to the present day, and has had the unfortunate effect of overshadowing some of his other work; e.g. his study of finches, and his still-definitive work with barnacles (Darwin, 1) (Petuch, 28).

In the opinion of the author and many others, Darwin has been widely misinterpreted, misquoted, and generally misunderstood. He has been called an atheist and accused of presenting an atheistic theory; he was in fact a devout Presbyterian and delayed publication of his work for some time, correctly fearing that his theory would be misunderstood and misinterpreted as an attack upon God and the Church.

Avoiding unnecessary and inappropriate detail, it will suffice to say that after extensive thought, the composer has reconciled the seemingly opposed ideas of science and religion, at least to his own satisfaction. Consequently, the composition *Darwin* reflects the evolutionary ideas of science as well as acknowledging the influence of God.

The tone row for *Darwin* was determined, appropriately, by random chance. Dice were rolled, and the following series of numbers was obtained: 7 12 3 11 8 9 4 6 5 10 2 (eleven numbers). If the roll of the dice produced a number previously used, it was ignored and the roll repeated. Since it is impossible to roll a 0 or a 1 with a pair of dice, the necessary 1 was merely added to the end of the row. In addition, the 12 was tossed out and the 0 substituted, yielding a final row of:

7 0 3 11 8 9 4 6 5 1 0 2 1

In altering the results of the die rolls, the composer could be said to have performed the same function as a "cosmic ray", causing the "mutation" in the tone row by making these changes. However, it should be remembered that if these changes had not been made, the result would not have been a true tone row, and would never have been utilized by the composer. Therefore, it can be stated that the tone row was arrived at randomly, but in the final analysis, only certain sequences of numbers fit the criteria for a tone row.

That particular idea seems to be a reflection of the anthropic principal, which attempts to resolve the question: "Why is the Universe as it is, rather than something else?", with the answer: "The Universe exists as we see it because if it were not in this particular configuration, we would not exist to see it in any other configuration" (Hawking, 124).

Of course, an alternative explanation could be that the Universe exists in its present form because of the intervention, in some way, of God. Perhaps this second alternative gains credibility when one remembers that, (in the case of *Darwin*, at least), there was a guiding intelligence who made certain, (even though random events seemed to govern the generation of the numbers), that the number sequence would eventually become a tone row.

Darwin is scored for solo flute, two violins, a single cello, a single double bass, and a synthesized choir singing a sustained "Ahhh". (Of course, on the included tape all parts were realized using synthesizers.) It is purposely a very mournful-sounding piece, reflecting the rejection of Darwin's ideas, the loneliness of his position, and, perhaps, the uncertainty of Man's importance in the Universe.

The work begins with the fade-in of synthesized voices; (the voices represent the touch of God throughout the piece.) Immediately, a solo double bass begins, which plays Row P0 through for the first time. At the end of this row, (measure 15), the choir returns and a new offshoot of the original row begins -

Row P5 - played by the second violin in parallel 4ths to the cello, which at this point begins a repeat (an octave higher) of the double bass line. These two rows proceed together, (*parallel organum*), until the reappearance, (in measures 27-30), of the voices and the creation of two new "species"; one a modification (mutation) of the original P0 row, the other a melody, (played by the 1st violin), which introduces new material based on row RI0 - which resembles the original P0 row only in that they are both played on stringed instruments. Soon after the entry of the voices in measures 29-30, other variations begin with the re-entry of the second violin and, in measure 33, the entry of a flute. Between measure 33 and measure 50, the voices return twice more and the various lines become more complex in their rhythmic interaction until the climax at measure 50, when the level of "specialization" becomes too top-heavy for "survival". With this last entrance of the voices, (measure 50), a mass extinction takes place, which leaves only the slowly-fading, primitive "life-form" represented by the double bass playing the original P0 tone row which began the piece.

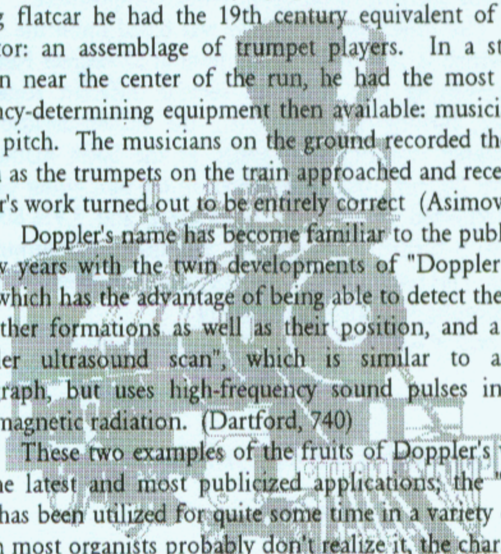
Strict serial rules were followed during composition, with the exception of the synthesized voices part. This part was composed without regard to time; that is, the entrance of notes may not follow the sequence exactly. The chords formed are all six-note chords, (except for measures 40-43), and the proper two chords taken together represent a complete tone row. The "timelessness" of this part seemed appropriate, considering the influences that the voices were meant to represent.

The meter of the piece is not constant, but it does display a twelve-bar pattern which starts at the third measure. (Measures 1 and 2 are the only 4/4 measures in the entire piece.) Beginning with measure 3, there are seven bars of 7/4, followed by three bars of 3/4, followed by two bars of 10/4. This pattern is repeated without variation five times, which, (along with the first two measures of 4/4), encompasses the entire piece.

Darwin

Korg O1 R/W synthesizer ----	Violin I
	Violin II
	Cello
	Double Bass
	Choir
Yamaha FB-O1 synthesizer --	Flute

Doppler



In 1842, Austrian scientist Christian Johann Doppler (1803-1853) decided to try an experiment to see if his equations describing the shifting of pitch of a moving sound source were correct. To that end, he obtained the use of a few miles of straight railroad track and a locomotive, and proceeded to propel a flatcar up and down the track at varying speeds for two days. On the moving flatcar he had the 19th century equivalent of a signal generator: an assemblage of trumpet players. In a stationary position near the center of the run, he had the most accurate frequency-determining equipment then available: musicians with perfect pitch. The musicians on the ground recorded the change in pitch as the trumpets on the train approached and receded, and Doppler's work turned out to be entirely correct (Asimov, iii, 98).

Doppler's name has become familiar to the public in the last few years with the twin developments of "Doppler weather radar", which has the advantage of being able to detect the velocity of weather formations as well as their position, and a medical "Doppler ultrasound scan", which is similar to an X-ray photograph, but uses high-frequency sound pulses instead of electromagnetic radiation. (Dartford, 740)

These two examples of the fruits of Doppler's work are only the latest and most publicized applications; the "Doppler effect" has been utilized for quite some time in a variety of fields. Though most organists probably don't realize it, the characteristic sound of a Leslie organ speaker is due to slight pitch shifts caused by rotating speaker elements. On a grander scale, astronomers have been using Doppler's equations in their work for many years. In the United States in the 1920s, Edwin P. Hubble (1889-1953) discovered that the further away a star or other heavenly body is, the further its light emissions will be shifted toward the red end of the electromagnetic spectrum. This "red shift", due to the Doppler effect, is easily converted into a velocity. These discoveries, and the subsequent observation that almost everything in the sky is racing away from us at an increasing percentage of the speed of light, directly support the "Big Bang" theory of the creation of the Universe. (Dartford, 740) (Asimov, i, 200).

After having recalled the above information, the author was practically compelled to write *Doppler*. The realization that musicians had played such an important part in the experimental justification of Doppler's equations - equations that would later be expanded upon to describe the nature and creation of the universe itself - suggested musical possibilities that were simply too good to pass up. Doppler's experiment itself supplied the beginning, the end, and the unifying factor of the entire composition.

The tone row for *Doppler* was based upon the speed of sound, which is 1088 ft/sec at sea level at 32 degrees Fahrenheit. After converting this figure to several different scales, (e.g., meters/sec, furlongs/fortnight, etc.), the author decided to use three different measurement scales as the basic mathematical criteria for *Doppler*: 1088 ft/sec, (used in the bass guitar part), 742 mi/hr, (reflected in the time signatures), and 3,916,800 ft/hr, (which, with further manipulation, was used in determining the tone row). This last number, 3,916,800, was "processed" to produce a non-repeating sequence from 0 to 11.
The last zero was dropped, yielding:

3 9 1 6 8 0

A 1 was then added to each digit, yielding:

4 10 2 7 9 11

This second sequence was appended to the first, yielding:

3 9 1 6 8 0 4 10 2 7 9 11

The second 9 was replaced by the single remaining unused digit, 5, for a final tone row of:

3 9 1 6 8 0 4 10 2 7 5 11

The synthesizer keyboard was then numbered from 0 to 11, starting with B as 0, and ascending to A# as 11. Since the tone row begins with a 3, putting B as 0 enabled the author to begin the composition on a D, for Doppler.

The piece begins with the sound of trumpets and trombones in unison, panned to one side, and quickly increasing in volume as it pans across the sound field. As the sound reaches its loudest volume and the center pan position, the pitch drops an augmented 4th, (to a G#), following an exponential curve. Immediately upon completing the pitch change, the volume decreases following the same linear curve, (inverted this time), that was used to fade in. This, of course, represents Doppler's original musicians during his experiment. (One cannot help but wonder what the trumpeters thought of this job and the apparently deranged man who hired them. Unfortunately, I have not yet discovered any records or personal memoirs that might shed some light on this question.) This pattern repeats six times, arriving at the end of tone row P0 at measure 22, and sustaining this A# until measure 25.

At measure 26, a section begins which is devoid of the sustained horn parts, and is instead dominated by Hammond organ. The score indicates a switch from Brass 1 to Trombone at measure 26. When using synthesizers, the differences between these two instruments are problematic; the new designation is used only to indicate a change of register. In measure 28, the trombones begin a new motif based on P0, which is repeated rhythmically in measures 31 and 32. The entire row is repeated beginning at measure 41, except this time, the first phrase has been transposed up an octave and the second phrase down an octave. This section lasts until measure 53, whereupon the 1st brass enter again with P0, playing sustained notes with a gliss down about halfway through. The final three measures of the piece feature the brass fading away into the distance.

The rhythm of *Doppler* is driving and full of energy, reminiscent of the locomotive that powered the investigation. The electric bass guitar and traps are very much dependant upon each other's part. This dependance is an important feature in most rock music; even though *Doppler* is not in straight 4/4 time, it has a something of a rock "feel" to it, which is reinforced by the choice of instrumentation.

The pattern of time signature changes is very regular: the piece begins with seven measures of 7/4, followed by four measures of 4/4, followed by two measures of 2/4. As mentioned earlier, this is based on the speed of sound in miles per hour at sea level - 742 mph. This pattern repeats five times for a total of 65 measures; measure 66 is in 7/4, measure 67 is in 4/4, and measure 68, (the last measure of the composition), is in 2/4. This 7 4 2 pattern is also utilized in the bass part, where it determines the tone rows used - P7 followed by P4 followed by P2.

The third number used in *Doppler* is found in the organ part. The speed of sound is 1088 feet per second, and the organ is restricted to using only those rows that feature these digits, and in the proper order. For example, the organ begins the piece with row P10, followed by two consecutive uses of row P8.

It must be admitted that while composing *Doppler*, very little consideration was given to limiting the level of difficulty human players might have in performing the piece. Consequently, certain aspects of the parts would demand a high level of skill. For example, while the 1st Brass part should be possible for a human, the long sustained brass notes would require excellent breath control. The glissandi would also be difficult to perform convincingly, considering the length of time it took the author to find the proper exponential curve for the pitch bends. Both the drum and organ parts are fast, complicated and don't repeat very often, but they certainly could be played by accomplished performers.

The glissandi in *Doppler* should be examined further. As stated above, a great deal of thought and time went into attaining the most realistic representation of an actual "Doppler Effect", in respect to the proper pitch bend curves used. The MIDI (Musical Instrument Digital Interface) specification allows synthesizers to send and receive information which will effect a "pitch bend", which can be similar to a glissando or the bending of a guitar string, depending on how it is used. The sequencing software used during the writing of Twelve Scientists, *Voyetra Sequencer Plus Gold*, allows for fine control of this parameter. Possible values range from -8192 to +8192; the negative values give a descending pitch, the positive values force the pitch up. The exact correspondence of these values to real pitches is complicated by the fact that the synthesizer that is "reading" these messages can be set to respond to pitch bends at any one of twelve different levels. This is in order to facilitate real-time use of a joystick to control pitch bend; if the pitch bend parameter has been set to a major 2nd, then pushing the joystick to the extreme right, (MIDI controller value +8192), would bend the pitch up a major second higher that the note held on the keyboard. By setting the pitch bend parameter to an octave, the same displacement of the joystick, (still MIDI controller value +8192), would cause the synthesizer to raise its pitch an entire octave. By using the octave setting, a total pitch bend range of two octaves was available for use. A few minutes with a calculator yielded the following table:

Table III - Pitch Bend Values

Minor 2nd---	682.5
Major 2nd---	1365.1
Minor 3rd---	2047.7
Major 3rd---	2730.3
Perfect 4th-	3412.9
Aug.4th-----	4095.5
Perfect 5th-	4778.0
Minor 6th---	5460.6
Major 6th---	6143.2
Minor 7th---	6825.8
Major 7th---	7508.4
Octave------	8191.0

Sequencer Plus Gold allows the user to "fill" a section of a track with data. The value of each insertion can be varied to increase or decrease in a predetermined manner, expressed in a percent of curvature. A curvature of 50%, for example, would result in a straight line from one pitch to the next - not a very realistic Doppler effect. This slope can be represented by graphing the equation -(x)=y using Cartesian co-ordinates:

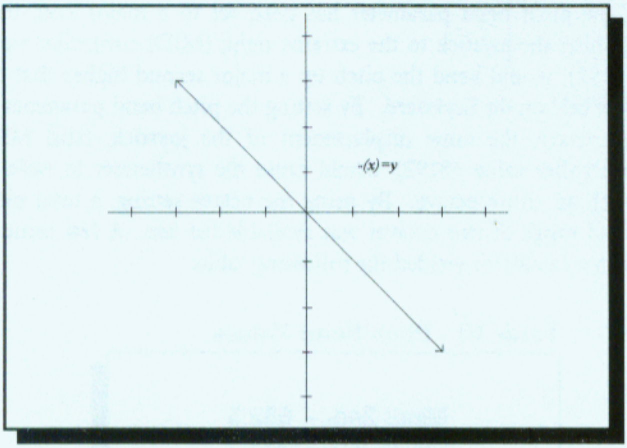


Figure 1 - Graph of the equation -(x)=y

The ideal solution was to perform the "fill" in two steps. The first data string was specified at a positive curvature of 70%, and was terminated in the center of what was to be the actual glissando. The second data string took up where the first left off with a specified curve of negative 70%. This complete process gives the effect of a glissando which begins to slowly descend in pitch, accelerating as it nears the halfway point, quickly descends past the center pitch, and progressively slows its rate of decent as time increases. A close approximation of this slope would be the graph of the equation $-(y^3)=x$:

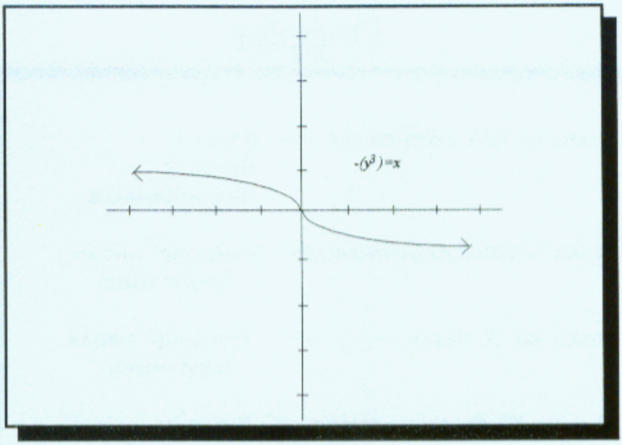


Figure 2 - Graph of the equation $-(y^3)=x$

In addition to, or perhaps in spite of, the above specifications, the glissandi were written with some artistic licence; the author suspects that some of the bends in *Doppler* would require a very fast train indeed, although no mathematic analysis was performed by the author to confirm this.

Doppler

Korg 01 R/W synthesizer ------	Brass 1 Brass 2 Crash Cymbals
Korg DW-8000 synthesizer -	"Hammond" organ (right hand)
Korg BX-3 organ ----------------	"Hammond" organ (left hand)
Yamaha FB-01 synthesizer ------	Bells
360 Systems Midi Bass ---------	Bass guitar
Sequential Drumtraks 400 ---	Drums and Cymbals

Kepler

Johannes Kepler (1571-1630) pondered the heavens while living on the ground in Germany. He was primarily a mathematician, working as a professor of that discipline, but was also very interested in theology and astronomy. Unfortunately, his work concerning the heavens was confined to working with other's observational data; when he was four years old, a childhood bout with smallpox left him with poor eyesight for the rest of his life. He did have the good fortune to be hired by the great naked-eye astronomer Tycho Brahe (1546-1601), who was known for his precise measurements of planetary movements. His accuracy was possible due to his use of the finest equipment of the age in the observatory built for him by King Frederick II of Denmark. (Tycho Brahe is also remembered for a few other reasons as well - he wore a metal nose after his own was cut off during a duel with swords; apparently he could be rather disagreeable - probably even more so after the loss of his nose. His demise was memorable in an equally bizarre fashion: he died after drinking too much - not from alcohol poisoning, but from a burst bladder) (Kuhn, 58-60).

Tycho had hired Kepler for his mathematical skills, and wanted him to attempt to verify Tycho's Earth-centered theory of the solar system. Kepler probably had different reasons for taking the job: he had his own ideas and theories that he wanted to test, but he couldn't see well enough to make his own observations. Tycho's measurements were the most accurateones made anywhere; taking a position as Tycho's assistant probably seemed like a good way to get his hands on the data.

After Tycho's death, Kepler continued to work with his data, searching for orbital shapes that could be used to predict the future position of the planets in a heliocentric model of the solar system that would match Tycho's observational data. After four years, he had worked out a system of circles and epicycles, (orbits around the earth that would account for retrograde motion of the planets), that would successfully predict the orbit of Mars to within 0.13 degrees. This was not good enough for Kepler; he knew that

Tycho's measurements were accurate to within about 0.1 degree, and so continued to look for an answer to the problem using perfect circles, as first suggested by Aristotle. After another nine years of work, he finally hit upon the answer that would eliminate that last 0.13 degree error - and the answer didn't use perfect circles at all, but ellipses! (Kuhn, 60-61).

This discovery was published in Kepler's book *The New Astronomy*. His work can be summarized into what are known today as the three laws of planetary motion, or just Kepler's Laws:

Table IV - Kepler's Three Laws of Planetary Motion

1. All planets follow an elliptical orbit around the Sun, with the Sun at one focus of the ellipse.

2. A planet travels in its orbit at a speed that varies in such a way that an imaginary line from the planet to the Sun will sweep out equal areas in equal periods of time.

3. The squares of the times that the planets require to make complete revolutions around the Sun are in proportion to the cubes of their distances from the Sun (Kuhn, 62) (Menzel, 16) .

Being a firm devotee of Pythagoras, Kepler also spent a lot of time studying the five symmetrical solids: the tetrahedron, cube, octahedron, dodecahedron, and icosahedron. He believed that they somehow held a place in the planetary scheme of things, and did finally come up with a consistent blueprint using these five solids to fix the distances of the six then-known planets, but he would have had no way to account for the planets discovered since his time (Kuhn, 64) (Menzel, 15).

As is so often the case for scientific researchers (and composers!), Kepler received little recognition for his work during his lifetime. He thought astrology was preposterous, but he was forced into casting horoscopes to feed his family. His mother was convicted of being a witch, and his wife and a child died of smallpox. At least, when he died, both his nose and his bladder were intact (Kuhn, 64).

Kepler was the first piece in the series composed under the supervision of Dr. Stuart Glazer at Florida Atlantic University. This work is on a larger scale than any of the preceding pieces, and is consequently more complex.

There are nine different parts for pitched instruments in *Kepler*, each instrument being chosen to represent a planet of the Solar System. In addition, comets, meteors, and asteroids are represented by non-pitched instruments.

Table V - Planet/Instrument Relationships

Mercury	Flute
Venus	Violin
Earth	Electric Piano
Mars	Trombone
Jupiter	Cello
Saturn	Clarinet
Uranus	Bells
Neptune	Bass Guitar
Pluto	Oboe
Comets	Tympani
Meteors & Asteroids	Percussion

Each planet/instrument relationship was determined by various things: history suggested that a brass instrument might be appropriate for the god of war, Mars; the agility of the flute seemed a perfect match for the Solar System's speed demon: Mercury. A romantic instrument such as violin was the only choice for Venus, the goddess of love, whereas the size and ponderousness of the king of the gods, Jupiter, called for cello and double bass, (which share the same part). At some time in the past the author has heard a piece of music (Stravinsky? Holst?), that used the clarinet to represent Saturn, the father of Jupiter, and the association was so strong no other instrument seemed appropriate. The distant coldness of Uranus, ancient father of Saturn and god of the heavens, suggested bells; the loneliness of Pluto, the brother of Jupiter and ruler of Hades, demanded an oboe. The Earth, the most familiar planet, is represented by a keyboard, (electric piano), the instrument that is most familiar to the composer. Quite frankly, Neptune, another brother of Jupiter, received the bass guitar as a representative instrument because that seemed one of the few remaining (traditional) sounds that would display enough of a difference in timbre; (the composer couldn't really think of an instrument that sounded as if it were underwater). The various tympani and percussion sounds that are featured in *Kepler* seemed perfect for those bodies that have wreaked such havoc upon all of the (visible) planetary surfaces for so long: comets, meteors, and asteroids (Hamilton, 13-74).

The MIDI specification allows pan settings to be transmitted from a sequencer to other devices. Each instrument in *Kepler* is panned to a different area in the sound field. Beginning from the left side, the order of panning is: clarinet (Saturn), cello (Jupiter), and flute (Mercury). Electric piano (Earth), bells (Neptune) and tympani (asteroids) are all in the center position. Continuing past the center to the right are: violin (Venus), trombone (Mars), and finally oboe (Pluto).

The times signature was settled upon quickly: 9/4. The nine represents the nine known planets; the four represents the four rocky planets of the inner solar system.

The matrix for *Kepler* took a bit longer to determine. After much thought and "doodling" with various numbers, it was decided to base the row upon the lengths of the semimajor axes of the planets in our Solar System. The semimajor axis of a planet's orbit is half of the greatest dimension of that orbit:

Table VI - Semimajor axes of the Planets

Planet	Semimajor Axis Kilometers	Row Number	Orbital Velocity Miles/Second
Mercury	5.790×10^7	5.8	29.75
Venus	1.082×10^8	1.0	21.76
Earth	1.496×10^8	n/a	18.51
Mars	2.280×10^8	2.3	14.99
Jupiter	7.780×10^9	7.9	8.12
Saturn	1.427×10^9	1.4	5.99
Uranus	2.870×10^9	[0]	4.23
Neptune	4.497×10^9	[11]	3.38
Pluto	5.900×10^9	6	2.95

As is illustrated in Table VI, the first two or three digits of the planet's semimajor axis were rounded off in various fashions to produce a two-digit approximation for use in the row. The figures for Uranus and Neptune would have been a repeat of previously used digits, and so were directly replaced by unused digits: Uranus' 2.9 became 0, and Neptune's 4.5 became 11, for a final row of:

5 8 1 0 2 3 7 9 1 4 0 1 1 6

Earth's semimajor axis was not included in the row.

In addition, each planet's orbital velocity was used to determine the rows that were to be used in the representative instrument's part. (In science, and indeed most other endeavors, it is usually desirable to have a standard unit of measurement to use in all numeric references. This was not done for *Kepler*, however; the use of different measurement units was necessary to generate usable numbers for the matrix and rows.)

Kepler begins with a planetary conjunction - all instruments entering simultaneously for the duration of a single half-note. All except the Earth fade away quickly, leaving the representative instrument of the first planet that humans were aware of playing solo for two measures, beginning a sequence of rows that outlines the orbital velocity of Earth: P0, P1, P8, P5, P1, and finally P0 again. This pattern of rows is repeated five times during the piece, and is always involved in the piano part except for a three-bar phrase beginning at measure 25 which uses only P1, and a use of P0 at the end of the work.

The electric piano's entrance is followed by the entrance of Venus' violin. It seemed reasonable to assume that, (being the brightest object in the sky except for the Sun and Moon), Venus would probably have been the first planet observed by primitive peoples. (This correspondence of order of instrumental entries to order of planetary discoveries was dropped in favor of musical considerations. The next "planet" that appears is Jupiter, but might just as well have been Mars.) The violin follows the rows specified by the orbital velocity, as do all of the pitched instruments, in this instance R0, R2, R1, R7, and R6. The reader will notice that only retrograde rows were used for Venus; perfectly reasonable due to the fact that Venus turns on its axis in retrograde motion, a direction opposite from that of most of the other planets. (Uranus and Pluto also display this oddity, therefore their instruments, bells and oboe, also use only retrograde rows.)

The cello, (Jupiter), makes its entrance at measure 5. The orbital velocity of Jupiter is 8.12 mi./sec., so the order of rows is P0, P8, P1, and P2. There is a single occurrence of P8 beginning at measure 28 that stands alone; at all other times, the above pattern is adhered to. Moving at a much slower pace that the Earth, Jupiter only manages to proceed through its pattern twice, unlike Earth's five times.

At measure 17, the electric piano begins a repeat of the material at the beginning of the composition, with slight modifications in the rhythm. The violin and cello drop out, and flute, clarinet, and trombone make their first appearance. The violin returns in measure 23, but is now playing pizzicato. Pluto's oboe enters at measure 26, the bells of Uranus at measure 28, and the bass guitar which represents Neptune at measure 29. From this point on, the instruments drop out and return in different places in the composition, displaying no real correspondence with any astronomical data available to the composer, but their "dance" of entries and exits may be taken to loosely represent the ever-changing combination of visible planets in the night sky.

The various percussion instruments, (cymbals, tympani, trap set, etc.), make their appearances when they are needed musically, since astronomically speaking, the appearance of (new) asteroids, comets, and meteors is still almost impossible to predict until these bodies are very close to the Earth, or are discovered by accident. These instruments are not following any row or underlying pattern, and are all non-pitched, except for the tympani, of course. The tympani is treated as if it were an non-pitched instrument; the notes it uses are either borrowed from an accompanying planet's rows, (some meteorites discovered on Earth are thought to be pieces of other planets "knocked off" by huge meteor collisions on those planets far in the past), or have no meaning at all, other than musically. Although the pitches used are not significant, there is an occurrence at measures 28-33 characterized by percussion and a change of rhythm that represents a meteoric bombardment, such as is thought to have happened to all planets many times in the past.

Another Grand Alignment of the planets takes place at measure 34, and another at measure 41. Together, these two occurrences of *tutti* and the musical material in between form a climax for the piece.

The work ends much as it begins, with yet another Grand Alignment of the Planets, all sounding a single, final note together.

Unlike most of the other pieces which comprise Twelve Scientists, the tempo of *Kepler* also carries significance; not in the actual tempo itself, but in the way the tempo varies. The piece begins at a moderately fast tempo, 130, and slowly accelerates, reaching its fastest speed (145) at measure 27, whereupon it begins to slowly decelerate back to the initial tempo. The change is subtle at first, but the closer the piece comes to measure 27, the fastest point, the faster the rate of acceleration increases. It takes 24 measures to speed up from 130 beats per minute to 140, but only requires an additional three measures to reach 145. Beginning at measure 24, there is a tempo increase every bar until measure 27 is reached, then a tempo reduction at every bar takes place until measure 30. This pattern of change is a direct reflection upon Kepler's third law, (see Table IV, page 40). At the time of composition, the composer was attending a course in astronomy at FAU, and the instructor, Dr. Stephen W. Bruenn, was kind enough to furnish the author with the equations necessary to precisely calculate the changes in speed. However, (as Dr. Bruenn had pointed out would probably be the case), the resulting speed changes, if applied to this composition, would have been so small as to have been completely unnoticed. Therefore, no actual planetary acceleration curve was followed in the tempo changes. Instead, a rate of change was adopted that still suggested planetary orbital speeds, but was altered enough to become detectable by the alert listener.

Kepler was without a doubt the most complicated piece of the series written up to that time. Previously, the individual compositions had featured fewer separate parts to contend with; *Kepler* has nine. Trying to keep all of the voices balanced and properly utilized as well as complying to the predetermined sequence of rows for each instrument, *and* ending up with a work that was musically meaningful was very complicated. The composer is indebted to the suggestions and constructive criticism offered by Dr. Glazer during the composition of *Kepler*.

Kepler

Korg 01 R/W synthesizer ------	Trombone Clarinet Violin Cello and C.B. Bells Tympani
Korg DW-8000 synthesizer -	Electric Piano
Yamaha FB-01 synthesizer ----	Flute
Yamaha TX81 Z synthesizer ----	Oboe
360 Systems Midi Bass ----	Bass Guitar Tympani
Sequential Drumtraks 400 -	Drums and Cymbals

Mendel

In the 1860s, an Augustinian monk named Gregor Johann Mendel (1822-1884) was living a quiet, contemplative life in Brunn, Austria. His interests, (besides religion), were botany and statistics. By way of satisfying these two urges, he had embarked upon a program of raising pea plants and keeping a statistical record of the results of his gardening efforts. After some time spent at this work, he began to notice some very interesting things about pea plants. First, he realized that if he crossbred two plants, one of which produced only yellow peas and the other only green peas, he didn't get a plant that produced yellow-green peas, or a plant that produced some yellow peas and some green peas; what these offspring produced were yellow peas exclusively. This, according to prevailing wisdom, should not have happened; it was expected that the peas of all plants would be yellow-green. Moreover, when these exclusively-yellow pea plants were allowed to reproduce, some of their offspring produced only yellow peas, (which was expected), but others produced only green peas (definitely not expected!)

By careful statistical record keeping and analysis, Mendel was able to form what are now known as the *Mendelian laws of inheritance*, which are recognized as being of central importance to all fields of biology, from breeding dogs or roses to modern genetic engineering. Mendel's laws have helped humans to understand some of the most perplexing problems ever contemplated by scientists, among them are: How does evolution work? What is the mechanism of genetic inheritance? Why do some diseases behave the way they do?

Mendel had no idea about the importance of his work. He was, after all merely an amateur biologist, had no sponsors, and was basically a nobody in the eyes of the scientific world. He did send his findings to a professor of botany at the University of Munich named Karl Wilhelm von Nageli. This emanate man was familiar with the idea of evolution, (put forth recently by Charles Darwin), and now was in possession of Mendel's work; work which could resolve many problems with evolutionary theory. In one of history's great blunders, von Nageli assumed that the work of an amateur was unworthy of consideration by one so highly placed as himself. Besides, Mendel's papers were covered with numbers, tables, and ratios; von Nageli, (like most other biologists of the time), cared little for mathematics and saw no need for its use in his field. He returned Mendel's work with a rude note pronouncing it unreasonable. Mendel eventually had the work published (1866) in a small, obscure scientific journal that was promptly forgotten. He was undoubtedly hurt deeply by von Nageli's rejection; he terminated his experiments and never returned to them. (He had also become very fat, and it was becoming difficult for him to bend over in the garden.) Mendel died in 1884 as a respected abbot, but without any scientific recognition (Asimov, i, 155-158).

Not until 1900, when three separate researchers independently worked out the same laws of inheritance, was Mendel's work re-discovered. These three men, (Hugo de Vries, Karl Correns, and Erich Tschermak), completely ignorant of each others' existence, performed the necessary experiments and were ready to publish their work and claim credit, when the idea occurred to them that perhaps they should search the available literature to see if anyone had ever done this sort of thing before. (Incidently, the accepted method in science is to research the literature *first*, then do the work. It usually saves a lot of time.) To their great credit, however, each man, upon finding Mendel's published work, immediately relinquished all claims and gave Mendel full credit. It is interesting to see such good examples of human boorishness, prejudice, and self-importance in the same story with three equally good examples of unselfishness and honor. Unfortunately, in repayment for their honorable actions, all three men were promptly forgotten (Asimov, i, 158-159).

Mendel is actually a work representing pea plants and their reproduction. It is simple in instrumentation, form, and rhythm. Mendel appears to have been a man with simple needs; content to tend his pea plants and write in his ledgers for many years without help or encouragement. *Mendel*, therefore, attempts to reflect an unencumbered pleasure at following one's own path, combined with a bit of disregard for the opinions of others. A certain delicacy is also strived for, recalling the fragile physical nature of a pea plant as well as the fragility of Mendel's emotional nature after his work was rejected.

It was decided that *Mendel* would have to be in 2/2 time, and chiefly in a two-voice form, even before the tone row was created. Since the piece describes reproduction, and there are two sexes, (as well as DNA being a double helix), two was held to be very appropriate as a numeric reference for the piece.

The original tone row was arrived at using a previously untried, (by the author), method of determination. A two-voice improvisation by the author at the synthesizer was recorded into the sequencer on a single track. Four other two-voice improvisations were also recorded on separate tracks, and, after carefully considering each improvisation, the author picked the one that seemed to convey the desired emotions best, and used it as the raw material for further development. The chosen improvisation was certainly based in tonality, although during the original recording, no attempt was made to either avoid or follow tonal practices.

The next step was to move each pitch of the upper voice of the improvisation to the nearest previously unused pitch, either up or down. The first note of the improvisation happened to be an E, so that became the first element of the tone row as well. The next three notes - A, G, and F, - were also acceptable and required no alteration. The next note of the original melody was an E, and therefore had to be changed. The closest available note was a D-sharp, and so that became the fifth element of the row. Next was a D, which remained unchanged, then another E, which was shifted to F#. Next was C, followed by B, neither requiring any action; then an A, which was replaced with an A#. Next, G was replaced by G#, and lastly, F was replaced by C#. Each new (serial) pitch was then listed in order, and a number, reflecting the number of half-steps between that note and the beginning note (E), was assigned to each pitch, yielding the row:

0 5 3 1 11 10 2 8 7 6 4 9

E A G F D# D F# C B A# G# C#

Using this basis, the matrix was constructed. The remaining upper voice pitches of the improvisation were modified to comply with the new tone row, P0 (pan flute I), and the bass voice was modified to comply with row R0 (pan flute II). The original rhythms of the improvisation were modified only slightly. In the second quarter of the piece, a new improvisation is used in the same way to produce a slightly different rhythm pattern, and the pitches shifted to comply with rows I0 (oboe) and RI0 (bassoon).

Mendel begins with pan flutes I & II playing a whimsical duet. Each voice represents one of the double strands of DNA in the pea plant's cells, each of which it had inherited from one of its parents; together they describe the new plant. As the plant grows to maturity, it remains unchanged at this, (the genetic), level, although the pan flutes are joined by pizzicato strings at measure 9, representing the flowering of the plant.

(Throughout the piece, the pizzicato strings are playing only notes that have been "borrowed" from either the pan flutes or, later in the piece, the oboe and bassoon. They never have a row of their own; they merely copy.)

At measure 9, while the pizzicato strings enter, the pan flutes begin an exact repeat of the previous eight measures, ending at measure sixteen.

At measure 17, with a wind chime announcing the event, the pan flutes and pizzicato strings drop out, and the piece is taken over by oboe and bassoon playing another - different - but equally whimsical duet. This is, of course, the second pea plant in the story, one that is somewhat different from the first, but still definitely a pea plant. It goes through the same eight-bar development, is joined by pizzicato strings in measure 25, (with a brief appearance of wind bells), while the oboe and bassoon begin an exact repeat, (just as the pan flutes had done earlier), and generally follows the same path as the first plant.

At the end of measure 32, however, there is a sudden gong, quickly followed by the sound of a choir, resulting in an unexpected, dramatic departure from the ordinary. This short section, (measures 33-37), is a musical representation of sex in pea plants, and characteristically, (at least in humans), is a bit confused.

However, beginning at measure 38, (the end of the "reproductive" section), a new duet emerges with pan flute I and the bassoon playing the parts. The parts played by each instrument are identical to the parts they had played earlier in the piece, but together now for the first time, they define a new pea plant; a hybrid constructed from two strands of melodic DNA, one from each parent.

At measure 54, a second hybrid is introduced by the second pan flute and the oboe, again constructed exclusively with material contributed from each parent. These two hybrids follow the same basic path of life their parents followed, (not really surprising for a pea plant), until, at measure 71, they are abruptly "harvested" by Mendel; whether to count in his studies or to enrich his diet is not elaborated upon.

Mendel

KORG 01 R/W SYNTHESIZER ------	PAN FLUTE I PAN FLUTE II OBOE (SWEET OBOE) BASSOON (SWEET OBOE, DOWN 8VA) PIZZICATO STRINGS CHOIR WIND CHIMES, WHISTLE, ETC.
KORG DW-8000 SYNTHESIZER -	SPECIAL EFFECT DURING "SEX"
SEQUENTIAL DRUMTRAKS 400 --	GONG

Cuvier

Baron Georges Leopold Chretien Frederic Dagobert Cuvier (1769-1832), was the Frenchman who is known as the father of vertebrate paleontology. He was not the first to study fossils, but his work with them led to the establishment of paleontology as a science separate from other sciences. His most important work in connection with the establishment of general principals of the history of life was published in 1825, bearing a title that, amazingly, was even longer than his own: "Discourse on the Revolutions of the Globe and on the Changes That They Have Produced in the Animal Kingdom" (Simpson, 7-9).

It was known to Cuvier that some fossils were similar to animals alive today, but others seemed to bear no resemblance at all to present forms. He formulated three hypotheses, any one of which could explain these facts:

Table VII - Cuvier's Hypotheses

1. The unknown animals found in the fossil record could still be alive in unexplored areas of the world.

2. The unfamiliar fossil animals could somehow have undergone a metamorphic change into familiar forms of the present day.

3. The unknown animals found in fossilized form were unknown simply because they had become extinct.

As would be revealed over time, all three of these hypotheses turned out to be correct. There have been several animals that were discovered in the fossil record first, and only later were living examples found. *Latimeria*, an example of the suborder Coelacanthina was thought to have been extinct since the

Devonian Period, some 400 million years, when a specimen was captured in the Indian Ocean in the 1950s. Darwin's theory of evolution shows that the second hypothesis is correct, and it has become evident over the years that the third hypothesis is correct as well. (The world has seen the last passenger pigeon, the last dodo, the last seaside dusky sparrow, and the last of many others species) (Simpson, 7-10).

Cuvier and others did finally come up with some guiding principals of the history of life:

Table VIII - Cuvier's Principles of the History of Life

1. The pattern of the history of life is not unilineal, but multiple.

2. When ancient rocks and the fossils found within them are arranged in chronological order, the fossil animals are found to have changed over time.

3. Many, or even most, of the animals found as fossils have become extinct (Simpson, 6).

In 1812, Cuvier published a massive work called Ossemens Fossiles, (Fossil Bones). In it, he included drawings of the first known skeleton of *Megatherium*, a giant ground sloth of the Miocene Epoch, (which lasted from 24 million to 5 million years ago) (Simpson, 9) (Stearn, 18, 285). The author has visited the George C. Page Museum in Los Angeles, and was greatly impressed by the huge skeleton of *Megatherium* which greets visitors at the door. Because of the importance of *Megatherium* in Cuvier's work, and this personal experience with the giant sloth himself, it was decided to base the tone row on this animal's name. (There are certainly plenty of numbers associated with the science of paleontology, but none of the important ones are precise enough to yield a 12-digit number suitable for use in a row.)

The name *Megatherium* was written down, and each letter given a number using the following method: the "a" in the name, being the first letter of the alphabet, was assigned a 1. The next closest letter (alphabetically) in the word is "e". The first "e" was given a 2; the second "e" a 3. Again, following the order of the alphabet, the next letter is "g", and it was assigned a 4. This method was continued until every letter had a number from 1 to 11 assigned to it:

M E G A T H E R I U M
0 7 2 4 1 10 5 3 9 6 11 8

The first number, 0, was simply tacked onto the beginning of the number sequence. Once again, the keyboard was numbered, this time beginning with C as 0:

	C#		D#			F#		G#		A#	
C		D		E	F		G		A		B
0	1	2	3	4	5	6	7	8	9	10	11

Finally, each number previously assigned to the name *Megatherium*, was matched with its corresponding pitch, yielding the final tone row:

0	7	2	4	1	10	5	3	9	6	11	8
C	G	D	E	C#	A#	F	D#	A	F#	B	G#

As might be expected, the beginning note of the piece is the first letter of the scientist's name: **C.**

The time signatures for *Cuvier* were chosen to represent one estimate of the age of the Earth: 4.5 billion years. Consequently, the piece begins in 4/4, (four measures and a lead-in bar), and then switches to 5/4. The times signatures continue to alternate throughout the piece: four measures of 4/4 followed by five measures of 5/4. (The last section of 4/4 at the end is three measures long; the "missing" bar is present at the beginning of the piece.)

Other numbers from the science of paleontology are

present in *Cuvier*, for example, the violins and cellos, (which are doubling the same part two octaves apart), follow the rows P0, P2, P4, and P5, which, (ignoring the leading 0), marks the beginning of the Triassic Period 245 million years ago. The choir part, in measures 22-34 uses rows P2, P0, and P8 - the beginning of the Jurassic Period 208 million years ago
(Stearn, 18).

Cuvier was written with a desire to create powerful-sounding music to reflect the large dinosaurs, reptiles, and mammals that once inhabited the Earth. Much more attention was paid to producing pleasing music than to strict rules; therefore examples can be found where strict serial technique was not employed. For example, the alto sax part is comprised of notes borrowed primarily from the brass part, and does not strictly follow a row of its own. However, the overwhelming majority of the work is strictly serial in nature.

Cuvier

Korg 01 R\W synthesizer -----	Alto Saxophone Brass Violin I & II Cello & Double Bass Choir Drums and Cymbals
360 Systems Midi Bass -------	Bass Guitar
Sequential Drumtraks 400 -	Drums and Cymbals Cabasa

Newton

Isaac Newton (1642-1727) was born on Christmas Day, a real Christmas present for the world of science. He was an Englishman who made amazing advances in almost every branch of science he was inclined to put his hand to. He is credited with inventing calculus, (in an amazingly short period of time). He invented the reflecting telescope, which used concave mirrors; he was the first to detect the compound nature of white light by studying a solar spectrum produced by a prism. Not content with that, he worked out a theory of universal gravitation, and three laws of physical motion. Newton's theories held up admirably for about two hundred years, until Einstein produced his theories of relativity, (which explained conditions in high-velocity travel that Newton's theories couldn't account for), in the first part of the Twentieth Century. Even today, for almost every purpose, Newton's Laws can still be used with complete accuracy (Asimov, i, 203).

Most people don't know that Newton was also something of a religious fanatic. The author remembers reading, (years ago in an unknown source), that Newton spent almost as much time on religious study as he did on science.

Newton is based on the scientist's work dealing with the nature of falling bodies. One could conceivably write a series of compositions based on Newton's work alone; the author contented himself with writing one.

In a vacuum, an object free-falling to Earth will gain speed at a rate determined by the mass of the Earth, the mass of the falling object, and the distance between the two. The actual relationship can be expressed in the following equation:
(Kuhn, 88)

Table IX - Gravitational Attractive Force

$$F = \frac{Gm_1 m_2}{d^2}$$

where:

F = Force

G = Constant (actual value depends upon units of measure)

m_1 = mass #1

m_2 = mass #2

d = distance between mass #1 and mass #2

This means that the free-falling weight mentioned earlier will, in the first second, fall 16.0833 feet, and continue on to obtain the following velocities:

Table X - Velocity of a Falling Body

Seconds of Fall	Velocity in feet/second
1	32.166
2	64.333
3	96.5
4	128.665

Rounding or truncating these numbers as needed, the following number sequence was arrived at:

32.1 64 97 <u>1 2</u>8.5

The first two digits of the last number were replaced with 0, and the two remaining unused digits, (10 & 11), were appended to the end, yielding the final number sequence:

3 2 1 6 4 9 7 0 8 5 11 10

The keyboard was numbered beginning with G as 0:

	G#		A#			C#		D#			F#
G		A		B	C		D		E	F	
0	1	2	3	4	5	6	7	8	9	10	11

Matching the pitches to the number sequence yields the final tone row:

3	2	1	6	4	9	7	0	8	5	11	10
A#	A	G#	C#	B	E	D	G	D#	C	F#	F

By arranging the pitches in this order, the note G appears in a diagonal across the matrix, stretching from upper left to lower right (see Appendix 1), standing, of course, for Gravity.

Newton begins a little differently than the other pieces constituting Twelve Scientists, starting with English Horn using row R0. The reason for this is simple: the horn part was written after the main beginning of the song, (which begins in a more conventional manner with row P0). When the English Horn was added, in order to have it end on the proper pitch, it was necessary to use row R0. (French horn was briefly considered for this part, but aside from being a more agile instrument, it was decided that English horn was more appropriate for an English scientist.)

All instruments enter using a "zero" row, (P0, Trumpet; R0, strings), at measure 2, except for the piano, which begins a sequence of rows which outlines the velocity of a falling body after a one-second fall: P3, P2, P1, and P6. This sequence ends at measure 10, where the piano drops out for four bars, and the focal point becomes the trumpet, which for these four measures plays using rows P1 and P6. At measure 14, the English horn becomes dominate in the next four-measure segment, utilizing rows I0, I2, I6, and I0. The last note of I0, an A, is not played by the English horn, but is played by clarinet and bassoon in measure 18. The section from measures 18 through 21 function as a transition leading to a piano "cadenza", which is only loosely serial in nature. The progression of the bass voice in the piano follows row RI10, but the right hand part makes no attempt at serialism. This is the only piece in Twelve Scientists that serialism is abandoned to such a degree, (except for *Heisenberg*, which was not conceived as a serial piece). The original intention was to improvise on the piano, and then adjust the pitches to conform to one row or another, but the composer liked the effect of a sudden, almost-tonal intrusion, and decided to leave it as is. (This decision was greeted by Dr. Glazer with his best poker face, but the composer did detect some low mumbling from him; something to the effect of "Too New Wave for me." He was very gracious, however, and stated that if that was what was intended, then it was acceptable to him. In his own defense, the composer wishes to point out that he does NOT listen to New Age music, and to be perfectly honest, is not even sure what the definition for New Age music would be. Perhaps the composer has re-invented the wheel; albeit a square one.) At measure 28, violins join the piano, and play through row I0, until the end of this section. A second "cadenza" appears later in the piece; it, too, is only serial in the bass voice.

The woodwinds in *Newton* deserve a comment; they are written in a sectional manner, something not done in any of the other pieces.

There are large sections of repeated parts in *Newton,* but they are usually accompanied by new material in a different instrument, or slightly modified in some way so as not to be a verbatim repeat of earlier material.

Newton ends with the flute, clarinet, English horn, bassoon, and pizzicato double bass, (in their order of entry), all fading out while playing a composite line from earlier in the piece. The technique used is a combination of *stretto* and augmentation. As each instrument enters, the individual notes used are a bit longer than the ones used in the preceding instrument; finally terminating with the double bass playing the last few lonely notes almost inaudibly.

Newton

Korg 01 R/W synthesizer ----- Flute
English Horn
Bassoon
Clarinet
Trumpet
Violins
Cellos
Double Bass
Piano
Percussion

Yamaha TX81 Z synthesizer --- Oboe

360 Systems Midi Bass -------- Tympani

Sequential Drumtraks 400 - Cymbals

Galileo

Galileo Galilei (1564-1642), was born on February 15, in Pisa, Italy. He was a contemporary of English poet John Milton, Shakespeare, and Johannes Kepler, with whom he corresponded. His father, Vincenzio Galilei, was an accomplished musician, and had also written books on music theory. (The fact that "some things never change" can be illustrated by the fact that later in life, Galileo found himself responsible for the unpaid bills of his brother, Michelangelo, who was, oddly enough, ...a musician.)

Galileo lost his sight in 1638, probably from years of peering at the Sun through his telescope while doing his study on sunspots. He was sentenced by the church to house arrest during the last year of his life; a result of his statements concerning the movement of the Earth around the Sun, which were considered heretical at the time. (The Catholic Church's official condemnation of Galileo and his work remained in effect until Pope John Paul II finally rescinded it just a short time ago.) He died on January 8, 1642. A century after his burial, his remains were disinterred and moved into his parish church, where a monument was erected to him and his work (Kuhn, 70-71).

Galileo didn't invent the telescope, but he was the first one to look at the sky through one. He discovered the first four moons of Jupiter, (the Galilean moons), studied and described features on Earth's moon, and, as previously mentioned, studied sunspots.

He was also active in the study of falling weights, pendulums, and other subjects, and is generally credited with forming the scientific method of experimentation.

Galileo lived the last forty-two years of his life in the Baroque Period. When this was realized by the author, the immediate thought was to write *Galileo* for pipe organ; an piece exclusively for that instrument had not yet been written for Twelve Scientists, and besides, the author has had a long-standing love for Baroque organ works. It was at the suggestion of Dr. Glazer that the author decided that the work would also be a fugue.

The tone row for *Galileo* is based on astronomical data having to do with the four moons of Jupiter that Galileo discovered in 1610. The orbital period of each moon was listed and examined: (Soderblom, 73)

Table XI - The Galilean moons of Jupiter

Galilean Moon	Orbital Period in Days	Rounded off to:
Io	1.77	1.8
Europa	3.55	3.5
Callisto	16.69	16.69
Ganymede	7.16	7.2

(The figure for Callisto was not rounded for reasons which shall become clear). These rounded-off orbital periods were written one after another, yielding:

1 .8 3.5 16.69 7.2

Any repeated digits were then dropped:

1 .8 3.5 6.9 7.2

The number of the Galilean moons, (four), was then inserted at the beginning of the number sequence, and after it a zero was placed to separate it from the orbital periods:

4 0 1 .8 3.5 6.9 7.2

The two unused numbers, 10 and 11, were then appended to the end of the sequence, and the decimal points were eliminated to yield the final number row:

4 0 1 8 3 5 6 9 7 2 10 11

As in previous Twelve Scientists compositions, the keyboard was then numbered, beginning with D# as 0:

```
D#      F#   G#   A#       C#
    E F    G    A    B C       D
0   1 2  3 4  5 6  7 8 9  10 11
```

By beginning the keyboard numbering with D# as 0, it was possible to begin the composition with the subject's initial: **G**

The piece is written in 4/4 to correspond with the number of Galilean moons. (Incidently, the latest information available to the author reveals that the most recent count of Jupiter's moons has reached sixteen!) The rhythmic placement of the notes was determined by the composer improvising at the keyboard until an appropriate rhythm was discovered.

Before proceeding further with this description, an explanation should be tendered about terminology. When speaking of fugues, there are many technical descriptive terms that unfortunately have been adopted, (with different meanings), by the present-day musical community, e.g., *sequence*, *voice*, etc. In the following description of *Galileo*, these terms will revert to their Baroque meanings.

The exposition of *Galileo* begins with row P0 presenting the subject of the fugue in the upper voice, (the piece is primarily in three voices). The countersubject appears in measure 5, with the answer accompanying it in the middle voice. The countersubject uses rows P1, P6, P1, and P0 in that order to reflect the year in which Galileo made his remarkable discovery of Jupiter's moons. (This date - 1610 - can be found in various other locations in the work as well.) At measure 9, there begins a sequence, using P9, P7, and P5. The sequence leads to the third introduction of the subject, this time in the bass (pedal) voice, which terminates with a cadence at measure 15. This cadence, of course, is not a tonal harmonic cadence, but as was pointed out to the author by Dr. Glazer, not all cadences need to be a V-I harmonic progression - a cadence is primarily a point of resolution, or a point of rest.

Needless to say, this made things much simpler, and no attempt was made by the composer to contrive tonal-type cadences in the piece.

After the cadence, (following standard fugal form), comes the development. Short sections of material from the exposition were used at varying pitch levels; e.g., the rhythmic motif formed by the first three notes of the composition, (dotted quarter, eighth, and a dotted quarter), is utilized in the upper voice in measures 16 and 18 in diminutive form, (dotted eighth, sixteenth, dotted eighth). At the same time, in measures 16-18, a rhythmic figure from the countersubject is offered; in the middle voice in bars 16 and 18, and in the upper voice in bar 17.

Measure 19 marks the beginning of a *stretto* section with the middle voice beginning a repeat of the subject, a perfect fourth higher than the original statement, followed in the upper voice in measure 20 with another repeat of the subject. At measure 23 the bass voice begins the subject once again, down an octave and a perfect 4th from the original. After completion in measure 26, the same voice begins an immediate repeat in measure 27, down a minor third from the original subject, but this time augmentation is used, extending the line through measure 33. The answer and countersubject are again heard together beginning at measure 35, at yet another pitch level.

Measures 39 and 40 comprise a transitional section, using material in the upper voice that is borrowed from the countersubject. However, this time the rows used are R0 and R1. By using retrograde (in the serial connotation of the word), rows, this section can also be described as retrograde in the fugal sense, as well. The two lower voices are using material that is essentially free, and playing together in parallel motion. Additionally, the rows used in this two-measure segment once again commemorate the year of discovery, 1610. These two measures form the end of the development.

The recapitulation starts at measure 42, with the subject in the upper voice and the countersubject in the middle. The subject enters for the last time in the bass at measure 46, and the fugue ends at measure 50 with a powerful D(no 5th) chord. (It would have been nice if the composition could have closed on some type of G chord, since the piece began on a G note, but a variety of considerations made this impossible.)

The author owes a debt of thanks to the clarity of Bruce Benward's text, Music In Theory And Practice, the guidance of Dr. Glazer, and to J. S. Bach, for his marvelous models of fugal perfection.

Galileo

Three synthesizers were combined to comprise the organ used. The voice names used by each are listed below.

KORG 01 R/W SYNTHESIZER --- FULL PIPES
POSITIVE (DEVELOPMENT)

YAMAHA FB-01 SYNTHESIZER - PIPE ORGAN 1
(DEVELOPMENT)

YAMAHA TX81 Z SYNTHESIZER - BIG CHURCH (MOST PEDAL PARTS)

Von Braun

Wernher von Braun (1912-1977) was a German rocket scientist who, during World War II, built V-2 rockets for Hitler. Near the end of the war, he surrendered to the Americans readily, and arranged for most of his staff and co-workers to go with him. He has maintained that he was completely caught up in the work at hand and had no thought as to how the actual labor was being performed; (imported slave labor from conquered countries), and that he had no influence over such matters, anyway. All of this is probably true; at least he was never charged with any war crimes (Dornberger, 282-293).

After coming to the United States, he and his colleagues were put to work developing the U.S.'s infant rocket program. Several A-4 rockets (V-2 was a military/political label; during research and development, the rocket was designated A-2, and later A-4) were brought to the U.S. and test fired under the direction of von Braun and his team.

Von Braun proceeded to play an instrumental part in the development of the Saturn 5 moon rocket, and thus helped realize one of Man's oldest dreams: traveling to the Moon. His former affiliations with Nazi Germany were not exactly hidden, but according to the memory of the author, they were rarely, if ever, referred to. The author considered von Braun a great hero, and was somewhat disillusioned and confused when, some years later, details of his past became known. (While attending grade school and high school, the author was an extremely avid follower of all things having to do with to space travel - and still is.)

Von Braun was to be the last work in Twelve Scientists. The author wanted to end the series with a "bang", as well as utilize some of the sound effect capabilities of the various synthesizers used in the series. Robert Goddard was considered as a subject; he was a far less controversial figure than von Braun. However, the very contradictions presented by von Braun tipped the scales, and so a former Nazi became the subject of the last composition.

The author found himself troubled by nagging questions about von Braun's moral fiber. Was he really completely innocent of wrongdoing during World War II? His invention, the V-2, killed hundreds of civilians, (its primitive guidance systems precluded use against smaller military targets). Does the fact that he helped mankind reach the Moon excuse any moral slips that may have taken place in his past? These questions have gone unanswered in the author's mind, but they have undoubtedly exerted some influence over the creative process that led to the creation of *Von Braun*.

The tone row for *Von Braun* is based on Earth's escape velocity: 11 kilometers per second. Of course, the number 11 doesn't really fill the bill as far as requirements for a tone row, so further calculations were called for. First the figure was converted to a scale that would give a number with more digits; 24,596.273 miles per hour. (This number is probably not precise; it was obtained by calculation from the 11 km/sec value, which was undoubtedly a rounded value to begin with. But it resulted in a useful number with only one repeated digit.) The second 2 in the number was directly replaced with a 0, and the four remaining unused numbers were placed ahead of and after the velocity number:

10 11 2 4 5 9 6 0 7 3 1 8

The now-familiar process of numbering the keyboard was the next step; this time starting with C# as 0:

C#		D#			F#		G#		A#		
	D		E	F		G		A		B	C
0	1	2	3	4	5	6	7	8	9	10	11

Again, the numbers were matched with pitches, yielding the final tone row:

10	11	2	4	5	9	6	0	7	3	1	8
B	C	D#	F	F#	A#	G	C#	G#	E	D	A

Determining the row for *Von Braun* was different in at least one respect: it was chosen with great care to make possible the inclusion of a phrase from another work; Richard Wagner's Tristan and Isolde. In casting about looking for ideas for *Von Braun*, the author happened upon a section of a book, Anthology for Musical Analysis, that contained a section on the Prelude and Liebestod from this work. On the very first page was a set of musical examples taken from Tristan; a set of six melodic leitmotifs, including three that had been traditionally assigned names descriptive of the psychological states of mind they were supposed to describe. Two of these motives seemed tailor-made for the purposes of the composer: the motive of Desire or Longing, and the motive of Death. The emotions of desire and longing were no strangers to von Braun; to his colleagues, at least, he made no secret of the fact that he desperately wanted to find a way for mankind to go to the Moon. (He was less talkative about this to his superiors in Germany; they would have considered him insane). The motive for death, considering the first use of his work, needs no explanation. In addition, these motives were appropriate because of their composer; Hitler considered the music of Wagner to be the perfect example of Germanic music, and held Wagner in high regard. This, unfortunately, has led to the virtual boycotting of Wagner's music in some circles, (certainly understandable when one finds out that Jewish musicians were forced to perform Wagner's music next to the lines of people walking into the gas chambers, in order to cover up the sounds of anguish and death).

Von Braun begins with the sound of a rocket being launched. Immediately a direct, unaltered quotation of the motive of Desire is heard on piano. (This is the only time in Twelve Scientists that another composer's work was used. The author wanted to make sure that it was recognizable as Wagner, and so made no modification whatsoever.) As the last notes of the piano are fading away, the sound of marching troops accompanied by a military snare drum approach from the left side of the sound field, gradually getting closer. As the troops pass in front of the listener, the sound of a large crowd of cheering people is heard. After a few seconds, the sound of the marching troops begin to recede into the distance on the right side of the sound field, while the rocket continues to get fainter as it "gains altitude". The beginning of the actual music contains the last two pieces of this sound collage; a drill whistle is sounded, and shortly thereafter, the sound of falling bombs is implied by a synthesizer sliding down in pitch from very high to very low. All of these sounds are produced through synthesis; the rocket launch and the "bombs" are synthesizer "patches" written by the composer, the sound of marching troops is constructed from two bass drum and two tom-tom sounds, all detuned below their normal pitch, and offset slightly from one another to give a more realistic "human" sound. The crowd sounds were a factory-supplied program on the Korg 01R/W synthesizer; it's actually a digital recording of a large crowd at a pop concert.

The music begins with a tom-tom pattern, (while the whistle is blowing), which introduces the first tone row. The first three notes of this row, P0, are the three notes that make up the Death motive. This single-voice motive is doubled in four octaves by violins, cellos, double basses, and electric bass guitar, resulting in a rather powerful sound. (Wagner's motive begins on beat four of a 6/8 measure; *Von Braun* is written in 4/4; in it, the motive begins on beat one.) By beat two of measure 20, Wagner is abandoned, and original material begins. At measure 25, however, Wagner's Death motive reappears briefly in the first three notes of the brass part as it begins row P0.

This first section of the piece is loosely representative of von Braun's period in Germany. The music is heavy and portentous, punctuated at times by the sounds of strange weapons falling from the sky. The rows used are mostly P0 and P1, P2 appearing once in the bass guitar part beginning at beat four of measure 21. From measures 27 to 29, the bass guitar is simply playing the lowest note that appears in the score above it; it is not following a row. At measure 30 a rhythmic change takes place, using rows R1, P1, and, at bar 35, P11. (The reader will recall that Earth's escape velocity is 11 km/sec). R1 is used by all of the strings, and bass guitar. At measure 35, these instruments begin a repeat of the previous four bars, while the solo trumpet moves on to new material, using rows P1, R1, P11, and R11. Measure 41 sees the first use of row RI9, which supplies the pitches for a very driving sixteenth-note pattern extending through measure 44.

The section from measure 45 through 49 is constructed in a completely different manner. Several hours of work were required to properly execute the intended design. The first three measures of the brass part is a restatement of the motive of Desire and Longing, but this time it is placed in an entirely serial setting. This was accomplished by carefully choosing the rows used and the notes within the rows. Row R0 was used to supply the first note, A, for the trumpets; element #8 of row RI9 supplied the second note, F. The third note was supplied by element #3 of row R0, element #2 having appeared in the harmony below the first note. The rest of the section was constructed in the same fashion, using rows R0, RI9, and R11. The composer also was concerned with making these five measures compatible with what had come before; a transition was desired, but not one so abrupt as to sound ridiculous. The resulting harmonic background of the motive is certainly different from the setting devised by Wagner, but it was never intended to be like his work.

The motive of Desire and Longing supplies a transition in another way, as well, by representing the end of World War II and the period in America afterwards, when the motive of Desire replaces the motive of Death. The sound heard immediately after is of a helicopter picking up a Mercury capsule from the ocean after re-entry. (Incidently, the computer sequencer was used to control the digital reverb used by the composer. By sending the proper MIDI commands, the reverb was turned off during the simulations of the troops, rocket launches and helicopter. After these parts concluded, the computer gradually increased the amount of reverberation to a preset level).

Measure 51 begins the era of American space exploration. The entire tone of the piece changes to a more American sound, featuring a walking bass part, a jazzy feel in the part for drums, and an alto saxophone playing an intricate solo over this foundation. The alto sax solo proceeds through rows P2, P4, P5, P9, P6, P2, P7, and P3, outlining the velocity of escape, 24,596.273 mi/hr. In the background, however, is a choir following row P0, and so, (since it is "built into" this row), the motive of Death has not been completely obliterated, (something of a philosophical comment by the author on the dual use of rockets for peace and war). The rhythm becomes increasingly more complex as the section starts a repeat at measure 59. Immediately after this repeat, there is a reprise of measures 39 through 49, which includes the serial arrangement of the motive of Desire. This section is symbolic of the preparations made for the launch of Apollo 11 (eleven again!), which is heard blasting off for the Moon, at this, the end of the composition. Finally, there is one more rendition of the motive of Desire and Longing, this time using a very heavy, but etherial sound, (ironically named "Death Star" by Korg, the manufacturer), symbolically saying that the end has not yet been reached, and that the Desire and Longing for the exploration of space continues to live on.

Von Braun

Korg 01 R/W synthesizer -- Grand Piano
Alto Saxophone
Trumpets
Violins
Cellos & Double basses
Military Snare Drum
Percussion
Drill Whistle
Choir
Cheering Crowd
Marching Troops
Death Star

Korg DW-8000 synthesizer ----- Surreal Dive
Bombers
Surreal Voices

Korg BX-3 Organ -------------------- "Hammond" organ

Yamaha FB-01 synthesizer -------- Helicopter

Roland Juno 106 synthesizer - Rocket Launches

360 Systems Midi Bass ------------ Bass Guitar

Sequential Drumtraks 400 ------ Drums and Cymbals

Appendix 1

Matrices

1. Heisenberg - no matrix

2. Euclid

based on pi - 3.141592653

	0	3	1	4	5	9	2	6	7	8	10	11
0	A	C	A#	C#	D	F#	B	D#	E	F	G	G#
9	F#	A	G	A#	B	D#	G#	C	C#	D	E	F
11	G#	B	A	C	C#	F	A#	D	D#	E	F#	G
8	F	G#	F#	A	A#	D	G	B	C	C#	D#	E
7	E	G	F	G#	A	C#	F#	A#	B	C	D	D#
3	C	D#	C#	E	F	A	D	F#	G	G#	A#	B
10	G	A#	G#	B	C	E	A	C#	D	D#	F	F#
6	D#	F#	E	G	G#	C	F	A	A#	B	C#	D
5	D	F	D#	F#	G	B	E	G#	A	A#	C	C#
4	C#	E	D	F	F#	A#	D#	G	G#	A	B	C
2	B	D	C	D#	E	G#	C#	F	F#	G	A	A#
1	A#	C#	B	D	D#	G	C	E	F	F#	G#	A

3. Pythagoras

based on the Pythagorean theorem - 3 4 5

	0	4	9	1	6	2	7	3	5	11	10	8
0	D	F#	B	D#	G#	E	A	F	G	C#	C	A#
8	A#	D	G	B	E	C	F	C#	D#	A	G#	F#
3	F	A	D	F#	B	G	C	G#	A#	E	D#	C#
11	C#	F	A#	D	G	D#	G#	E	F#	C	B	A
6	G#	C	F	A	D	A#	D#	B	C#	G	F#	E
10	C	E	A	C#	F#	D	G	D#	F	B	A#	G#
5	G	B	E	G#	C#	A	D	A#	C	F#	F	D#
9	B	D#	G#	C	F	C#	F#	D	E	A#	A	G
7	A	C#	F#	A#	D#	B	E	C	D	G#	G	F
1	D#	G	C	E	A	F	A#	F#	G#	D	C#	B
2	E	G#	C#	F	A#	F#	B	G	A	D#	D	C
4	F#	A#	D#	G	C	G#	C#	A	B	F	E	D

4. Einstein

based on the speed of light - 186,282 mi/sec

	1	8	6	2	10	3	0	9	5	11	7	4
11	G#	D#	C#	A	F	A#	G	E	C	F#	D	B
4	C#	G#	F#	D	A#	D#	C	A	F	B	G	E
6	D#	A#	G#	E	C	F	D	B	G	C#	A	F#
10	G	D	C	G#	E	A	F#	D#	B	F	C#	A#
2	B	F#	E	C	G#	C#	A#	G	D#	A	F	D
9	F#	C#	B	G	D#	G#	F	D	A#	E	C	A
0	A	E	D	A#	F#	B	G#	F	C#	G	D#	C
3	C	G	F	C#	A	D	B	G#	E	A#	F#	D#
7	E	B	A	F	C#	F#	D#	C	G#	D	A#	G
1	A#	F	D#	B	G	C	A	F#	D	G#	E	C#
5	D	A	G	D#	B	E	C#	A#	F#	C	G#	F
8	F	C	A#	F#	D	G	E	C#	A	D#	B	G#

5. Darwin

based on random chance

	7	0	3	11	8	9	4	6	5	10	2	1
4	Eb	Ab	B	G	E	F	C	D	Db	Gb	Bb	A
11	Bb	Eb	Gb	D	B	C	G	A	Ab	Db	F	E
8	G	C	Eb	B	Ab	A	E	Gb	F	Bb	D	Db
0	B	E	G	Eb	C	Db	Ab	Bb	A	D	Gb	F
3	D	G	Bb	Gb	Eb	E	B	Db	C	F	A	Ab
2	Db	Gb	A	F	D	Eb	Bb	C	B	E	Ab	G
7	Gb	B	D	Bb	G	Ab	Eb	F	E	A	Db	C
5	E	A	C	Ab	F	Gb	Db	Eb	D	G	B	Bb
6	F	Bb	Db	A	Gb	G	D	E	Eb	Ab	C	B
1	C	F	Ab	E	Db	D	A	B	Bb	Eb	G	Gb
9	Ab	Db	E	C	A	Bb	F	G	Gb	B	Eb	D
10	A	D	F	Db	Bb	B	Gb	Ab	G	C	E	Eb

6. Doppler

based on the speed of sound - 3,916,800 ft/hr

	3	9	1	6	8	0	4	10	2	7	5	11
9	B	F	A	D	E	G#	C	F#	A#	D#	C#	G
3	F	B	D#	G#	A#	D	F#	C	E	A	G	C#
11	C#	G	B	E	F#	A#	D	G#	C	F	D#	A
6	G#	D	F#	B	C#	F	A	D#	G	C	A#	E
4	F#	C	E	A	B	D#	G	C#	F	A#	G#	D
0	D	G#	C	F	G	B	D#	A	C#	F#	E	A#
8	A#	E	G#	C#	D#	G	B	F	A	D	C	F#
2	E	A#	D	G	A	C#	F	B	D#	G#	F#	C
10	C	F#	A#	D#	F	A	C#	G	B	E	D	G#
5	G	C#	F	A#	C	E	G#	D	F#	B	A	D#
7	A	D#	G	C	D	F#	A#	E	G#	C#	B	F
1	D#	A	C#	F#	G#	C	E	A#	D	G	F	B

7. Kepler

based on the semimajor axis of the planets

	5	8	10	2	3	7	9	1	4	0	11	6
7	A	C	D	F#	G	B	C#	F	G#	E	D#	A#
4	F#	A	B	D#	E	G#	A#	D	F	C#	C	G
2	E	G	A	C#	D	F#	G#	C	D#	B	A#	F
10	C	D#	F	A	A#	D	E	G#	B	G	F#	C#
9	B	D	E	G#	A	C#	D#	G	A#	F#	F	C
5	G	A#	C	E	F	A	B	D#	F#	D	C#	G#
3	F	G#	A#	D	D#	G	A	C#	E	C	B	F#
11	C#	E	F#	A#	B	D#	F	A	C	G#	G	D
8	A#	C#	D#	G	G#	C	D	F#	A	F	E	B
0	D	F	G	B	C	E	F#	A#	C#	A	G#	D#
1	D#	F#	G#	C	C#	F	G	B	D	A#	A	E
6	G#	B	C#	F	F#	A#	C	E	G	D#	D	A

8. Mendel

based on improvisation and the number 2

	0	5	3	1	11	10	2	8	7	6	4	9
0	E	A	G	F	D#	D	F#	C	B	A#	G#	C#
7	B	E	D	C	A#	A	C#	G	F#	F	D#	G#
9	C#	F#	E	D	C	B	D#	A	G#	G	F	A#
11	D#	G#	F#	E	D	C#	F	B	A#	A	G	C
1	F	A#	G#	F#	E	D#	G	C#	C	B	A	D
2	F#	B	A	G	F	E	G#	D	C#	C	A#	D#
10	D	G	F	D#	C#	C	E	A#	A	G#	F#	B
4	G#	C#	B	A	G	F#	A#	E	D#	D	C	F
5	A	D	C	A#	G#	G	B	F	E	D#	C#	F#
6	A#	D#	C#	B	A	G#	C	F#	F	E	D	G
8	C	F	D#	C#	B	A#	D	G#	G	F#	E	A
3	G	C	A#	G#	F#	F	A	D#	D	C#	B	E

9. Cuvier

based on the word Megatherium

	0	7	2	4	1	10	5	3	9	6	11	8
0	C	G	D	E	C#	A#	F	D#	A	F#	B	G#
5	F	C	G	A	F#	D#	A#	G#	D	B	E	C#
10	A#	F	C	D	B	G#	D#	C#	G	E	A	F#
8	G#	D#	A#	C	A	F#	C#	B	F	D	G	E
11	B	F#	C#	D#	C	A	E	D	G#	F	A#	G
2	D	A	E	F#	D#	C	G	F	B	G#	C#	A#
7	G	D	A	B	G#	F	C	A#	E	C#	F#	D#
9	A	E	B	C#	A#	G	D	C	F#	D#	G#	F
3	D#	A#	F	G	E	C#	G#	F#	C	A	D	B
6	F#	C#	G#	A#	G	E	B	A	D#	C	F	D
1	C#	G#	D#	F	D	B	F#	E	A#	G	C	A
4	E	B	F#	G#	F	D	A	G	C#	A#	D#	C

10. Newton

based on Gravitational Attractive Force

	3	2	1	6	4	9	7	0	8	5	11	10
9	G	F#	F	A#	G#	C#	B	E	C	A	D#	D
10	G#	G	F#	B	A	D	C	F	C#	A#	E	D#
11	A	G#	G	C	A#	D#	C#	F#	D	B	F	E
6	E	D#	D	G	F	A#	G#	C#	A	F#	C	B
8	F#	F	E	A	G	C	A#	D#	B	G#	D	C#
3	C#	C	B	E	D	G	F	A#	F#	D#	A	G#
5	D#	D	C#	F#	E	A	G	C	G#	F	B	A#
0	A#	A	G#	C#	B	E	D	G	D#	C	F#	F
4	D	C#	C	F	D#	G#	F#	B	G	E	A#	A
7	F	E	D#	G#	F#	B	A	D	A#	G	C#	C
1	B	A#	A	D	C	F	D#	G#	E	C#	G	F#
2	C	B	A#	D#	C#	F#	E	A	F	D	G#	G

11. Galileo

based on orbital periods of Jupiter's Galilean moons

	4	0	1	8	3	5	6	9	7	2	10	11
8	D#	B	C	G	D	E	F	G#	F#	C#	A	A#
0	G	D#	E	B	F#	G#	A	C	A#	F	C#	D
11	F#	D	D#	A#	F	G	G#	B	A	E	C	C#
4	B	G	G#	D#	A#	C	C#	E	D	A	F	F#
9	E	C	C#	G#	D#	F	F#	A	G	D	A#	B
7	D	A#	B	F#	C#	D#	E	G	F	C	G#	A
6	C#	A	A#	F	C	D	D#	F#	E	B	G	G#
3	A#	F#	G	D	A	B	C	D#	C#	G#	E	F
5	C	G#	A	E	B	C#	D	F	D#	A#	F#	G
10	F	C#	D	A	E	F#	G	A#	G#	D#	B	C
2	A	F	F#	C#	G#	A#	B	D	C	G	D#	E
1	G#	E	F	C	G	A	A#	C#	B	F#	D	D#

12. Von Braun

based on Earth's escape velocity – 24,596.273 mi/hr

	10	11	2	4	5	9	6	0	7	3	1	8
2	C#	D	F	G	G#	C	A	D#	A#	F#	E	B
1	C	C#	E	F#	G	B	G#	D	A	F	D#	A#
10	A	A#	C#	D#	E	G#	F	B	F#	D	C	G
8	G	G#	B	C#	D	F#	D#	A	E	C	A#	F
7	F#	G	A#	C	C#	F	D	G#	D#	B	A	E
3	D	D#	F#	G#	A	C#	A#	E	B	G	F	C
6	F	F#	A	B	C	E	C#	G	D	A#	G#	D#
0	B	C	D#	F	F#	A#	G	C#	G#	E	D	A
5	E	F	G#	A#	B	D#	C	F#	C#	A	G	D
9	G#	A	C	D	D#	G	E	A#	F	C#	B	F#
11	A#	B	D	E	F	A	F#	C	G	D#	C#	G#
4	D#	E	G	A	A#	D	B	F	C	G#	F#	C#

Appendix 2

Tables, Instrument Lists, & Figures

Instruments used for:

Tables

Figures

Appendix 3

Equipment used in the production of

Twelve Scientists

KEYBOARDS & SYNTHESIZERS

Roland Juno 106 polyphonic synthesizer
Korg DW-8000 polyphonic synthesizer
Korg BX-3 double keyboard organ w/MIDI retrofit
Korg 01R/W polyphonic synthesizer module w/M-series and T-series sound cards
Yamaha TX81Z polyphonic synthesizer module
Yamaha FB-01 polyphonic synthesizer module
(2) 360 Systems MidiBass sample playback modules

DRUM MACHINE

Sequential Drumtraks 400 digital drum machine

AUDIO MIXERS

Tascam MM-1 20x2 mixing board w/MIDI
Tascam M-216 16x4x2 mixing board

DIGITAL EFFECTS

Korg DRV 2000 MIDI programmable digital reverb
Effectron II digital delay

COMPUTERS & ACCESSORIES

PC Systems 486SX 33mhz (IBM clone) computer, 8mb RAM
Commodore C-128 computer
Commodore C-64 computer
Commodore 1571 disk drive
Commodore 1541 disk drive
Commodore 1902 color video monitor
Commodore 1702 color video monitor
Samsung SM3Ne Hi-Res VGA color video monitor
AVT monochrome video monitor (amber)
Sanyo monochrome video monitor (green)
Hercules monochrome graphics card
Paradise Super VGA color graphics card
Okimate 10 color printer
Epson RX-80 9-pin dot matrix printer

MIDI SWITCHERS

Casio TB-1 MIDI Thru box
Roland MPU-104 MIDI switching box
Roland MPU-105 MIDI switching box

MIDI INTERFACES

Voyetra V-22m dual-port MIDI interface (IBM)
Passport MIDI interface w/ tape sync (Commodore)

COMPUTER SOFTWARE

Sequencer Plus Gold sequencing software by Voyetra (IBM)
The Note Processor notation software by Thoughtprocessors (IBM)
Encore notation software by Passport (IBM)
Korg 8000 Voice Editor and librarian software (C64)
TX81Z Editor & Librarian software by Opspring (C64)
FB-01 Design editor and librarian software by Sonus (C64)
WordPerfect 5.1 word processor software (IBM)
WordPerfect 6.0a word processor software (IBM)
WordWriter 128 word processor software by Timeworks (C128)

EQUALIZATION

Alesis M-EQ-230 stereo 30-band graphic equalizer
DOD R-231 stereo 31-band graphic equalizer
Teac EQA-10 stereo 10-band graphic equalizer

POWER AMPLIFIERS

Phase-Linear 400
Peavey CS-400
Peavey CS-800
Pioneer VSX-5000 audio/video integrated amplifier

SPEAKERS

2 Electro-Voice Eliminator I speaker systems (15")
2 JBL 4312 control monitors (12")
2 Technics SB-L95 speaker systems (15")
2 Teac 5111 speaker systems (4")
2 Arkrat Model 8+ speaker systems (8")
Fostex T-20 Regular Phase stereo headphones

TAPE RECORDERS

Teac R-425 stereo cassette deck
Mitsubishi HS430UR HiFi stereo VHS VCR
Denon DAT digital mastering deck

MISCELLANEOUS

2 Hybrid keyboard stands
3 DeArmond volume pedals
hundreds of cables
Berol Mirado 174 #1 pencils
Pink Pearl erasers

Bibliography

Apel, Willi and Ralph T. Daniel. The Harvard Brief Dictionary Of Music. Cambridge, Massachusetts: Harvard University Press, 1975.

Asimov, Isaac. Adding A Dimension. New York: Avon Books, 1975.

Asimov, Isaac. Asimov On Physics. New York: Avon Books, 1976.

Asimov, Isaac. Isaac Asimov's Book Of Facts. New York: Grosset & Dunlap, 1979.

Beethoven, Ludwig van. Eighth and Ninth Symphonies in Full Orchestral Score. ed. Max Unger. New York: Dover Publications, Inc. 1976.

Benward, Bruce. Music In Theory And Practice, 2nd ed., 2 vols., Dubuque, Iowa, 1982, II, 51-76.

Brindle, Reginald Smith. Serial Composition. London: Oxford University Press, 1966.

Burkhart, Charles. Anthology For Musical Analysis, 4th ed. Fort Worth: Holt, Rinehart and Winston, Inc., 1986.

Calder, Nigel. Einstein's Universe. New York: Greenwich House, 1979.

Dartford, Mark, et al. "Doppler Effect," The New Illustrated Science and Invention Encyclopedia, 26 vols., ed. Elaine Landry, Mark Dartford, and Trevor Morris. Westport, Connecticut: H. S. Stuttman Inc., 1987, VI, 740.

Darwin, Charles R. The Origin Of Species, 2nd ed., New York: Thomas Y. Crowell Company, 1860.

Dornberger, Walter. V-2. New York: Bantam Books, Inc. 1979.

Gerretsen, J. and P. Verdenduin. "Polygons and Polyhedra, "Fundamentals Of Mathematics - Geometry, 3 vols., ed. H. Behnke. Cambridge, Massachusetts: The MIT Press, 1987, II, 238-292.

Glut, Donald F. The Dinosaur Dictionary. New York: Bonanza Books, 1984.

Hamilton, Edith. Mythology. New York: Mentor Books, 1964.

Hansen, Brad. The Essentials Of Instrumentation. Mountain View, California: Mayfield Publishing Company, 1991.

Hawking, Stephen W. A Brief History Of Time. New York: Bantam Books, 1988.

Hoffman, Mark S. ed. The World Almanac And Book Of Facts 1988 New York: Pharos Books, 1987.

Hofstadter, Douglas R. Godel, Escher, Bach: An Eternal Golden Braid. New York: Vintage Books, 1980.

Keaton, Kenneth. author's personal notes from lectures on Twentieth Century Music History. pp 13-14, Florida Atlantic University, October, 1991.

Kuhn, Karl F. In Quest Of The Universe. St.Paul, Minnesota: West Publishing Company, 1991.

Menzel, Donald H. Stars And Planets. New York: The University Society, Inc., 1931.

Miller, Charles D. and Vern E. Heeren. Mathematical Ideas, 5th. ed. Glenview, Illinois: Scott, Foresman and Company, 1986.

Morgan, Robert P. Twentieth-Century Music. New York: W. W. Norton & Company, 1991.

Petuch, Edward J. author's personal notes from lectures on Evolutionary Paleontology. pp 27-28, Florida Atlantic University, November 1, 1990.

Pierce, John R. The Science Of Musical Sound. New York: Scientific American Books, 1983.

Roemer, Clinton. The Art Of Music Copying. Sherman Oaks, California: Roerick Music Company, 1973.

Russell, Bertrand. The ABC Of Relativity. New York: Signet Books, 1962.

Sheldon, H. Horton. Space, Time, And Relativity. New York: The University Society, Inc.,1932.

Simpson, George Gaylord. Fossils And The History Of Life. New York: Scientific American Books, 1983.

Soderblom, Lawrence A. "The Galilean Moons of Jupiter," The Planets. New York: Scientific American and W. H. Freeman and Company, 1980.

Stearn, Colin and Robert Carroll. Paleontology - The Record Of Life. New York: John Wiley & Sons, Inc., 1989.