PHYSICS OF THE VIOLIN AND ITS DEFINING INFLUENCE UPON TECHNIC

THESIS

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by

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CHAPTER I

INTRODUCTION

Statement of Problem

The purpose of this work is to set forth the physical characteristics of the generator and resonator of the violin and to determine in what manner and degree they influence the technic of artistically manipulating the instrument.

Need for Study

The writing of this study was prompted by the realization that in order to obtain the quickest and soundest results from the learning process, it is necessary for the student to carry in his mind at all times, a clear understanding of the mechanical as well as the artistic basis of his field. D. C. Miller, an eminent scientist and educator in the field of physics of musical sound, expresses somewhat the same sentiments in his lectures at the Lowell Institute.

> The artistic world has rather disdainfully held aloof from systematic knowledge and quantitative and formulated information; this is true even of musicians whose art is largely intellectual in its appeal. The student of music is rarely given instruction in those scientific principles of music which are established. Years are spent in slavish practice in the effort to imitate a teacher, and

> and the mental faculties are driven to exaustion in learning dogmatic rules and facts....Experience indicates that a month devoted to a study of the science of scales and chords and of melody and harmony, will advance the student more than a year spent in the study of harmony as ordinarily presented.[1]

As a general rule, violin students as well as teachers have very limited knowledge of the physics of the instrument. Consequently, they advocate and use types of technic that run counter to the maximum possibilities of the instrument. Since there has never been any conclusive study made of the physics of the violin, it is impossible to prove without doubt that any one technic is more applicable than another. Until such a study is made, there will be no complete standardization of performance upon the violin. There have been a number of studies made, however, of isolated phases of the physics of the violin. If the findings of these studies are gathered together, a fairly complete picture of the entire physical aspect can be obtained. From such a grouping of facts,it should be possible to set up conditions of performance that will produce superior results over other less practical technic. Since it is entirely within the range of possibility that several mechanical processes will produce the same results, it must be stressed that any suggestions made as to methods of performance are the author's own preference and any process that is efficient

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[1] D. C. Miller, The Science of Musical Sounds, p. 264.

consistently from the standpoint of the entire technic, has just as great a claim for universal use as any other.

Scope of Study

The discussion of the physical aspects of the violin is intended to cover all the phases as completely and as compactly as is possible. Research on a number of the phases, such as the path of vibrations and its influence upon well balanced resonance is not yet definitely completed; therefore, it will be necessary to piece together as much data touching on the subject as can be accumulated. Only the basic technic of performance will be discussed. Because of the great number of slight variations upon the basic bow strokes, it is not practical to attempt to seek out and explain the qualitative differences of each from the fundamental strokes. If the demands of artistic performance are applied to the fundamental stroke as it is described, the problem is capable of being analyzed and solved by the individual.

Organization of Study

The various phases of the physics and technic are organized in the order of their importance. The generator is discussed first, being subdivided under the headings of the bow and the strings. Included under the discussion of the strings is a complete survey of compound sound, both as a single and a complex phenomenon. The resonator is the next to be analyzed, its features being divided into three divisions, the vibrational path, resonating areas and quality. The technic of performing upon the resonator and generator is divided under two headings, the action of the right and the left hands. Because of the importance of the right hand in tone production, it is discussed first. The legato stroke is analyzed as the fundamental movement upon which all styles of bowing are based. Variations of a fundamental nature upon the legato stroke are discussed. Any slight variations that would come under these headings are left to the analysis of the reader. This is done because of the wide variations of opinions between the schools of violin playing. The artistic demands upon bow passage from string to string and support of the instrument precede the discussion of the actual manipulation of the left hand. The technic of changing the pitches of the strings is organized into two sections, the evolution of the universal position and the various aspects of manipulation. The discussion of the universal position is an attempt to find the position that meets all the demands of performance and is also the same in all positions. Under the technic of the left hand, such subjects as touch, pulling strings, shifting, finger preparation and vibrato receive attention. The discussion of tuning, intonation and positions of performance represents a new approach to the solving of these problems. The analysis of the perception of accurate intonation upon the violin is especially objective.

Source of Data

Material for the first section of the work was gathered from the better known books on violin construction, magazines, and various acoustical references touching upon compound sound and instrument quality. Special help was obtained through personal correspondence with several of the present day authorities who are doing considerable work in this field. These contacts made it possible for the author to obtain published works that otherwise would not have been available. The results of the second section are authenticated by the use of references from the leading books upon violin playing. These references are used to verify the findings evolved from the facts gathered concerning the physics of the violin. Since little work has been done in objective analysis of the actual performance upon the instrument, few references can be located bearing out the procedure of evolution.

CHAPTER II

THE GENERATOR

The Bow

The bow is a very essential part of the generator mechanism, for it is the agent that most generally sets the string in motion. There are several different sizes and types of bows that all operate on the same principle. This discussion will not attempt to enumerate and classify the various divisions or schools of bow making, but rather, will take up those general principles that have a bearing upon the technic involved in performing upon the violin.

The bows that have found the greatest favor with violinists have a hair length of around 25½ inches and their center of gravity is about 7½ inches from the nut.[1] This balance point and the tempering of the wood in the stick are the two main factors that a violinist considers in choosing and using a bow. The "tempering" of the stick of the bow refers to the process of heating various points of the stick for certain lengths of time to achieve or realize the best springing quality from the wood. There is quite an art to this process and it sometimes means the difference between good and mediocre bows. This quality that is produced in

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[1] The Violin. How to Make It, pp. 120-121.

the bow by tempering is a temporary condition and the same process must be renewed at various intervals.[2]

The round long hairs from the tail of the horse are the direct agents used to set the strings of the violin in motion. The scales of the hair, coated with rosin, do the actual work of plucking the strings and setting up transversal vibrations in the strings. The scales of the hair of the tail of the horse fall into the imbricate division of the infrahominidal classification of mammals; that is, the scales of horse hair have flattened distal (outer) edges and these edges extend on the average straight across the outer portion of the hair. Each one of the scales does not extend completely around the circumference of the hair, but, like the scales of the fish, overlap and compliment one another.[3]

The part the rosin plays in setting the string in motion is not quite clear. It is known however, that rough or even grades of rosin, and the various degrees of application have a definite effect upon the evenness of tone production. Oftentimes unskillful, rough, scraping and variable performance is due directly to this factor.[4] It is the experience of all violinists that a bow that has never been coated with

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[2] "Flame Tempering Bows for Resiliency," Popular Mechanics, LXXI (May, 1939), 729.

[3] L. A. Hausman, "Recent Studies in Hair Structure Relationships," Scientific Monthly, XXX (March, 1930) 260-264.

[4] Hermann L. F. Helmholtz, Sensations of Tone, p. 67.

rosin provides little friction between the hair and string. It is my own personal conception that the rosin is caught and held by the scales of the bow and that the rosin does the actual plucking of the string while the hair in a greater or lesser degree is merely the agent for holding the rosin in place.

Here is a very good description of the action of the bow-hair upon the string by Arthur Tabor Jones.

> The rosined bow is drawn at right angles to the string during the production of vibrations. As the bow is drawn across the string, there is a growing friction between them. This increase goes on until a maximum static friction is reached. Then the string slips backward along the bow; the static friction is replaced by kinetic friction, and in spite of the forward motion of the bow, the string swings backward and then starts forward again. As soon as the string is moving forward at the same rate as the bow, the friction becomes static friction, and the string moves with the bow until the maximum static friction is again reached. The maintainance occurs because the forward pull on the string just before it begins to slip is greater than the forward pull just after it begins to slip.[5]

It is also pointed out that it is entirely possible, though not probable, that a condition might be reached in which kinetic friction would just balance the restoring force so that the bow might hold the string steady in a displaced position instead of causing it to vibrate.[6] The production of uninterrupted and pure musical quality of tone

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[5] Arthur Tabor Jones, Sound, p. 220.

[6] Ibid.

is the result of maintaining the vibrational forms of the string in a uniformly steady and unchanged condition. The scratching noises of a violin must therefore be regarded as irregular interruptions of the normal vibrations of the string. The noises are the result of the stopping and recommencing of vibration.[7]

The Strings

There are four conditions which govern the pitch of a stretched string. These considerations are, (1) its density, (2) its length, (3) its diameter, and (4) its tension. The vibration number varies inversely with the diameter. Halve the diameter and the vibration number will be doubled; that is, the resultant tone will be an octave higher. The vibration number varies as the square root of the tension. If the string is screwed four times as tight, the vibration number is doubled. The vibrational number varies inversely as the square root of the density. If a string four times the usual density is used, the vibration number of the note it gives will be half that of the usual note.[8] The diameter affects the relative strength of the partials produced by a string to a certain extent. Helmholtz asserts, in referring to partials of the compound tone, that, "using thin strings which

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[7] Helmholtz, op. cit., p. 85.

[8] Percy C. Buck, Acoustics for Musicians, p. 58.

have loud upper partials, I have thus been able to recognize the partials separately up to the 16th."[9] When the sections which lie between the nodes are too short and stiff to be capable of sonorous vibrations, they cease to be formed.[10] From these statements it could be concluded that thin strings, as a general rule, are stronger in the upper partials than thick strings. This fact, if applied to the rules governing quality of tone, would indicate that instrument quality is in some measure dependent upon the inherent quality of the strings as well as the reproducing powers of the resonator. Material referring to the influence of density, length and tension upon the harmonic structure have not been brought to the author's attention as yet. It is possible that research in this field would be of value to violinists, with emphasis on the proper balance between the various factors with a view to producing the most desirable tone.

String materials also have an effect upon the strength of the various partials. Frederick Saunders makes some comments on this factor in a personal letter of April 4, 1941.

> One can say in general that the strength of the upper partials decreases as we go up the scale on the average. This decrease is more rapid for materials (e.g. gut) with high viscosity, (and less rapid for steel). All metal strings often have a steel core, a soft wrapping, and an outer metal

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[9] Helmholtz, op. cit., p. 50.

[10] Ibid., p. 46.

> winding. The middle layer may furnish viscosity. Anyhow, these strings are not so "metallic" as a steel E string.[11]

Another view on this phase of string quality is provided by Paul Stoeving. According to this authority, "lightness of the material of the strings is also conducive to the production of very high partials, which gives brilliance of sound, while the low elasticity of the cat gut causes these high overtones to die away quickly, thus softening the final quality of the tone."[12]

The Strings and Compound Sound

The harmonic series.--The importance, in the field of music, of the acoustical phenomenon which has been called the harmonic series, has been very adequately stated by Arnold Schoenberg.

> To elucidate the relationship between tones, one must first recall that every tone is a compound sound, consisting of a fundamental tone (the strongest sounding one) and a series of overtones. We may now make this statement, and to a great extent test and prove it, that all musical phenomena can be referred to the overtone series, so that all things appear to be the application of more simple and more complex relationships of this series.[13]

There are a great number of different types of generators that produce compound sound; so, in this work, since it is

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[11] Personal letter from Dr. Frederick A. Saunders, Professor of Physics, Harvard University, April 4, 1941.

[12] Paul Stoeving, The String Quartet, pp. 12-13.

[13] Arnold Schoenberg, Schoenberg, pp. 269-270.

intended only to apply the harmonic series as it is present in the violin string, the discussion will be limited to the compound sound production of the wire or string.

A string may produce two types of vibrations; transverse and longitudinal. In all stringed instruments the transverse and not the longitudinal vibrations are utilized.[14] A simple illustration of what is meant by transverse vibrations can be shown by tieing one end of a rope to a post, and after drawing it taut, throwing waves down its length by using a whipping motion of the arm. By using a wire which has been drawn tight and is fixed at both ends, it will be seen what happens when such a wave is initiated and maintained along its length.

When the action of a bow or pick is applied at one end of the wire, the resulting movement of the wire appears to the eye to be blurred resembling Figure 1. This shape is the result of a transverse wave of displacement traveling along the wire, being reflected at the opposite fastened end, and returning back down the wire with the same velocity to that end where the wave was initiated.

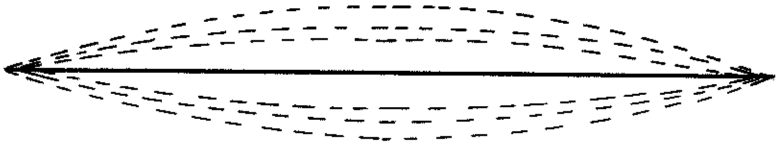

Fig. 1.--Appearance of wire in motion.

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[14] G. W. Stewart, <u>Introductory Acoustics</u>, p. 97.

As long as the bowing or picking continues, the wave will appear to be stationary. This semblance of fixed form, as it appears to the eye, occurs because the condition of stationary waves is fulfilled, and there are two waves of equal frequency and amplitude traveling in opposide directions. This is true only as long as the agitating force is applied. The largest and most obvious wave has as its nodes, the fixed points of the string (nodes indicate the divisions of a string). This wave has the greatest amplitude and the lowest frequency possible to that string. The wave with the lowest number of vibrations is called the fundamental of the compound tone. The vibrations of the next higher frequency of which the wire is capable, has one additional node. Successively higher frequencies that are possible have two, three, etc., additional nodes respectively, as shown in Figure 2.[15] This subdivision goes on to a limit fixed by the combined effects of thickness,[16] tension, density,[17] and place and nature of agitation of the string.[18]

The string may vibrate simultaneously with the frequencies indicated in Figure 2. The lowest of these frequencies

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[15] Ibid., p. 98.

[16] Helmholtz, op. cit., p. 50.

[17] Buck, op. cit., p. 58.

[18] Helmholtz, op. cit., p. 52.

are called overtones.[19] The various frequencies are called partials. Because of the fact that it was necessary to

Fig. 2--The first several divisions of the string.

classify them for use in orderly investigation, the partials were given order numbers according to the number of times the frequencies of the various partials exceeded that of the fundamental, or, using its new name, the first partial.[20] Therefore, the frequency of the second partial of a-440 could be reckoned by multiplying the frequency of the first partial by the order number of the second partial. The result would be 880. Similarly, the frequency of each of the higher partials could be found by multiplying the first partial's frequency by the order number of the partial being considered.

This grouping of frequencies occurring in a compound tone has been termed the harmonic series, possibly because our fundamental harmonies are directly drawn from it. If Figure 3 is observed, it is evident that the distance between the first and second partials is an octave; between the second and third partials, a fifth; between the third and fourth

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[19] Stewart, op. cit., p. 99.

[20] Buck, op. cit., p. 67.

partials, a fourth; between the fourth and fifth partials, a major third, and between the fifth and sixth partials,

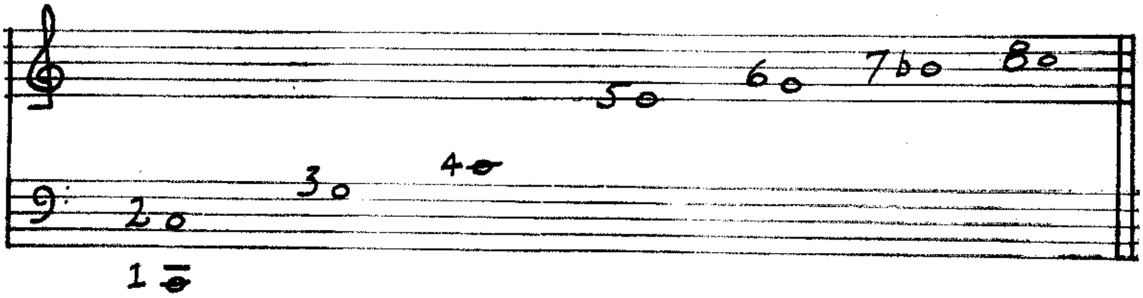

Fig. 3--A chart of the first eight partials and their order numbers as they occur above C below the bass cleff.[21]

a minor third. The intervals falling between the fundamental and the various partials are; between partials 1 and 2, an octave; 1 and 3, a twelfth; 1 and 4, two octaves; 1 and 5, two octaves and a major third; 1 and 6, two octaves and a fifth. A major chord is found between the 4th, 5th, and 6th partials. The major sixth lies between partials 3 and 5, the minor sixth occurs between partials 5 and 8.[22]

<u>Combination tones</u>.--When two tones are played together, not only are the fundamental tones represented to the ear, but also a number of other tones which are the result of the simultaneous performance of these two tones. These combination tones whose frequency number is equal to the combined pitch numbers of the two generating tones are known as combination tones of the second class.[23]

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[21] Buck, op. cit., p. 67.

[22] Ibid., p. 67.

[23] Helholtz, op. cit., p. 153.

__Difference tones__.--The first class of combination tones are called differential tones because their pitch number is the difference of the pitch numbers of the generation tones.[24] "Generating tones" refer not only to the two fundamental tones but also, different combinations of the two fundamental tones and the difference tones that they produce. The types of difference tones are distinguished from one another by a system of orders, the characteristics of which are determined by the combination of generating tones that is producing them.

First order differential tones are the differentials arising directly from the two fundamental generating tones themselves. Second order differential tones are the tones arising between either of the fundamental generators and the first order differential. Differentials of the third order are the tones arising between the second order difference tones and all of their predecessors.

Differentials are produced amongst themselves and the fundamentals and not between themselves and any overtones. The most easily heard of the difference tones are those of the first order, the others are present and can be produced in the laboratory. Overtones do produce difference tones of their own, but they can be ignored for all practical purposes.[25]

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[24] __Ibid__., p. 154.

[25] Buck, __op__. __cit__., pp. 134-135.

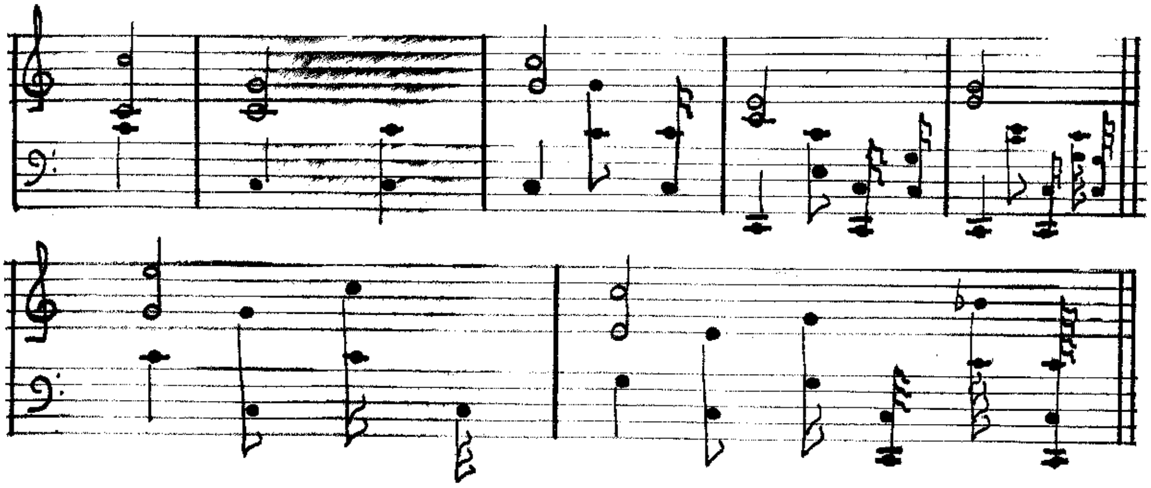

Fig. 4--A representation of the difference tones arising from the various perfect and consonant intervals.[26]

Octave, notes 4:8. Diff. 8-4 equals 4

Fifth, notes 4:6. Diff. 6-4 equals 2
2nd order, 4-2 equals 2, 6-2 equals 4

Fourth, notes 6:8. Diff. 8-6 equals 2
2nd order, 8-2 equals 6, 6-2 equals 4.
3rd order, 6-4 equals 2, 6-2 equals 4.

Major Third, notes 4:5. Diff. 5-4 equals 1.
2nd 4-1 equals 3, 5-1 equals 4.
3rd 4-3 equals 1, 5-3 equals 2.
4th 4-2 equals 2, 4-1 equals 3.

Minor Third, notes 5:6. Diff. 6-5 equals 1.
2nd 5-1 equals 4, 6-1 equals 5.
3rd 5-4 equals 1, 6-4 equals 2.
4th 4-1 equals 3, 6-2 equals 4.
5th, 6-4 equals , 6-3 equals 3.

Major Sixth, notes 6:10 Diff. 10-6 equals 4.
2nd 10-4 equals 6, 6-4equals 2.
3rd 10-2 equals 8, 6-2 equals 4.
4th 6-4 equals 2.

Major Sixth, notes 5:8. Diff. 8-5 equals 3.
2nd 5-3 equals 2, 8-3 equals 5.
3rd 5-2 equals 3, 8-2 equals 6.
4th 3-2 equals 1, 5-3 equals 2.
5th 5-1 equals 4, 8-1 equals 7.
6th.8-7 equals 5-4 equals 1, 4-2 equals 2, 8-4 equals 4.

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[26] Helmholtz, *op. cit.*, p. 155.

The notations of the figure on page 17, represent the differential tones of the different orders. The generators are one-half notes, the difference tones of the first order are quarter notes, the second order, eighth notes and etc. The same tones also occur with compound generators as combinational tones of their upper partials. The existence of these differential tones of the higher orders cannot be considered as completely established.

Summation tones.--The second class of difference tones were named summation tones by their discoverer, Hermann Helmholtz. The vibrational numbers of summation tones are equal to the sum of the vibration numbers of the two generators. The summation tones are very weak and can only be heard with very much ease on the harmonium and the polyphonic siren. Summation tones are always higher in pitch than either of the two generators. Summation tones arise from the overtones of the generators, but are so weak that it would be practically impossible to produce loud enough for the ear to

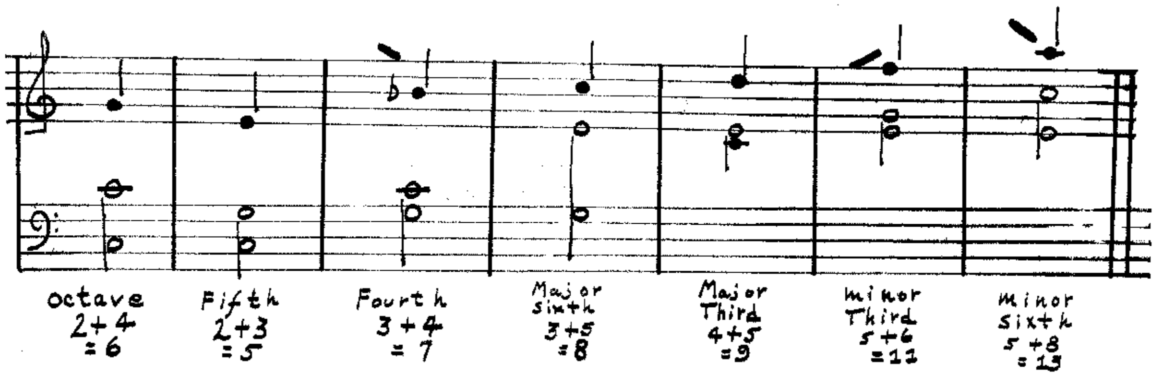

Fig. 5--A notation of the first order summation tones of the perfect and consonant intervals.

hear. Because of the fact, only those summation tones that will bear on the subject are charted.[27]

Beats.--Beats are very hard to represent objectively because of the fact that the frequency numbers of both difference tones and beats resulting from the same intervals are identical. The number of beats resulting from the simultaneous performance of two tones is found by subtracting the lower frequency from the greater frequency of the interval being investigated.[28] D. C. Miller calls the phenomenon "beat tones", and maintains that beats have a musical quality just as do the generating tones.[29] The majority of the other authorities in this field however, separate the two, and consider each of them as a separate force in acoustics. According to Percy Buck, beats are the double amplitude caused when the vibrations are present at the same instant. This causes a throb. Beats may arise between the primes, between one prime and the overtone of another, between the overtone of one and the overtone of another, and between combination tones.[30] Beats may also arise between combination tones and the primes and the overtones.[31]

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[27] Helmholtz, op. cit., pp. 255-256.

[28] Ibid., p. 64.

[29] Miller, op. cit., p. 183.

[30] Buck, op. cit., pp. 142-143.

[31] Ll. S. Lloyd, Music and Sound, p. 42.

The parts that beats play in intonation and chord voicing can possibly be emphasized best by quoting a statement from Helmholtz.

> When two musical sounds are sounded at the same time, their united sound is generally disturbed by the beats of the upper partials, so that a greater or less part of the whole mass of sound is broken into pulses of tone, and the joint effect is rough. This relation is called dissonance.
>
> But there are certain determinate ratios between pitch numbers, for which this rule suffers an exception, and either no beats at all are formed or at least only have so little intensity that they produce no unpleasant disturbances of the united sound. These exceptional cases are called consonances.[32]

From these statements it seems logical to draw the conclusion that the perception of beats is the key to good intonation, for beats are the factors that determine consonance and dissonance.

Harmonics.--Harmonics are produced by eliminating the fundamental and certain other series of partials of a bowed string. This is done usually by touching the string lightly with the tip of the finger upon one of the nodal points of the series that the performer desires to sound as a fundamental. All of the simpler divisions of the string are in this manner eliminated. Thus, if the production of the twelfth or third harmonic is desired, the strings must be touched at 1/3 or 2/3 of the string length and all the simpler divisions of the string with no such node will be silenced.

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[32] Lloyd, op. cit., p. 51, quoting Sensations of Tone, by Helmholtz.

If no such node is present at the point of contact of the finger and string, no sound will emanate.[33]

There are two types of harmonics, artificial and natural. Natural harmonics are divisions of the open string and are producible with certain amount of ease at any of their nodal points on the string. This is true up to the tenth division of the string. Natural harmonics have no pitch vibrato. Artificial harmonics are produced upon a stopped string and are limited to the third and fourth divisions of the string. A rather effective pitch vibrato can be produced on artificial harmonics.

The basic structure of harmonics is comparable to that produced by open or stopped tones on the same string. The number of partials produced by harmonics is slightly less than that of a stopped tone on the same string having the same frequency, the lowest natural harmonics involving twelve partials, and the highest producing ten. The relative intensity of the partials under optimum conditions for tonal comparison and this probably explains the slight difference in quality experienced by the auditor. It is wrong to describe natural harmonics as flute-like or pure because there is too little qualitative difference between harmonic and natural tones to justify any very different classification. Possibly the lack of pitch vibrato on natural harmonics provides a

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[33] Helmholtz, op. cit., p. 52.

basis for comparison between the flute tone and the natural harmonic tone. Measurements of the total intensity of artificial harmonics has indicated several decibels difference between them and stopped tones or natural harmonics.[34]

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[34] Arnold M. Small, "The Violin in the Laboratory", _Music Teachers National Association Proceeding of 1938_, pp. 95-96.

CHAPTER III

THE RESONATOR

The Vibrational Path

"The functions of the violin bridge are to cut off, absorb, amplify, and transmit tone vibrations."[1] How this is done is a rather delicate and arbitrary process, for, up to this time, there have been found no very different shapes or patterns for the bridge than that designed and exploited by the early Cremonese makers. Attempts have been made to alter and improve upon the standard pattern, but as yet, no fundamental changes have been set up. It is probable that as long as the rest of the instrument retains its general properties, the bridge will keep its present outline.

The height of the bridge is a point of individual interest for each instrument, for it is the height that determines what amount of the tension will be allowed to press the feet of the bridge against the top of the violin. This tension or pressure against the top of the plate has a very definite effect upon the passage of the vibrations into the body and the resulting motion of the resonator.[2]

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[1] Herbert Sanger, "The Violin Bridge," Etude, LVI (February, 1937), p. 124.

[2] F. A. Saunders, "Secret of Stradivarius," Reprint from Journal of the Franklin Institute, Vol. CCXXVI, (January, 1940), p. 16.

The bridge is carved of bird's-eye maple which has been aged for a number of years.[3] The grain of the bridge is such as to provide the fastest communication of vibrations. One set of fibers runs longitudinally and supports the strings while the other is perpendicular and transmits the vibrations from the strings to the top. The thickness of the bridge, especially at the top, has much to do with the resulting tonal effect. Too thin a bridge will tend toward a scratchy type of tone.[4]

The bridge vibrates longitudinally (along the string) producing high and very objectional sounds. The cut of the upper parts of the bridge is such as to filter out these vibrations without affecting the feet of the bridge. This is interpreted to mean that there is no direct line of vibration from the strings to the feet. In noting the grain structure of Figure 6, it will be seen that the waist of the bridge is divorced from any direct communication with the strings for the direct route is disrupted in the shoulders. In order for the vibrations to reach the feet of the bridge they must pass through the shoulders into the waist, where they are fused, and then on to the hips. From here they are communicated directly on to the feet.[5] The motion of the right foot of

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[3] K. S. Rieder, "Carving a Golden Voice," Etude, LVII (September 1939), p. 604.

[4] Sanger, *op. cit.*, p. 124.

[5] Saunders, *op. cit.*, p. 17.

the bridge is small while the left foot transmits the most useful vibrations to the body.[6]

If a violin is shrill in timbre (too great a volume in the very high partials of 50,000 cycles a second and above), this can be remedied by the process of filing down the shoulders of the bridge. This phenomenon coincides with the statement previously made in reference to objectional noises due to the longitudinal vibration.[7]

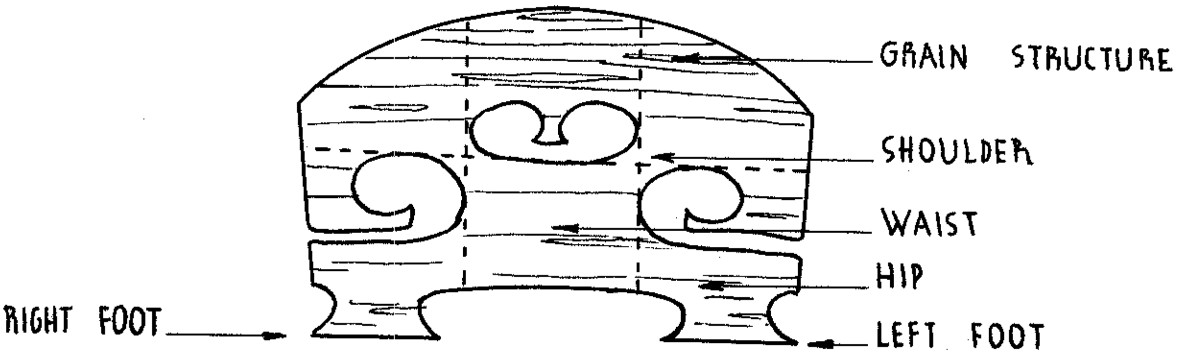

Fig. 6--The structure of the violin bridge.

The vibrations, as are indicated in Figure 6 are cut off from direct communication from the top ridge to the feet. The circuitous route they are forced to travel is obvious.

The paths of the vibrations after leaving the bridge are very complex and tempered by innumerable circumstances, some of these being; the position of the sound post; the pressure of the bridge on the top plate; the size and strength

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[6] <u>The Violin. How to Make It</u>, p. 47.

[7] Saunders, <u>op. cit.</u>, p. 17.

of the bass bar; the graduation of the plates; the influence of the ribs and blocks; the arch of the plates; the position and size of the f-holes and finally; the molecular structure of the wood itself. Every instrument is different and every frequency on one instrument possesses different qualities, so for this reason it is impossible to chart any final movements for the box's vibrations. General tendencies and conditioning factors have been observed however, and are mentioned in this discussion.

Savart's experiments have thrown some light upon the passage of string vibrations and the resulting position of the soundpost.

> The violin string tends to set up a vibration perpendicular to its axis in any object placed perpendicularly and transversally to it. The bridge does not, however, set perpendicular to the string in two planes because the fingerboard causes the string to meet the bridge at an angle of about eighty-five degrees, or five degrees less than a perfect right angle. Therefore, the vibration set up in the bridge tends to communicate itself to the violin top most strongly along a line to the rear of the bridge. For this reason the sound post is placed behind the right foot of the bridge.[8]

From this analysis it would seem that the center node of vibrations in the top plate would be in the region suggested by Savart.

The part played by the sound post is not that of transmitting the vibrations, but of propagating their movements

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[8] Lauren Harman, "Violin Making In America," <u>Etude</u>, LVIII (February 1940), p. 96.

in other parts of the instrument. A liberal generalization of the statements of Savart indicate that the deflections of the belly produce in the post a longitudinal movement, which, reacting upon the movements of the top table, determine therein a normal movement rather than an oblique one. The sound-post seems to hold the right foot of the bridge in a state of rigidity. The vibrations take form in other parts of the plates, but are not in evidence at the area around the right foot of the bridge. The degree of importance to be placed upon the transmission of vibrations from belly to back is minimized for it seems more evident that the sides and blocks do this to a greater degree than the sound-post, for they are in the area of greater vibration than the sound-post itself.[9] Other factors that enter into sound-post performance are those surrounding the grain of the wood itself. The number of rings contained by the sound-post should be around ten or twelve.[10] The position of this grain, in order to obtain the best type of results and also to prevent disasterous working of the wood fibers into one another, should be counter to one another in the sound-post and in the top and back table. The bass bar, which gathers up the vibrations from the left foot of the bridge, produces a similar movement over the entire surface of the top plate and prevents

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[9] The Violin. How to Make It, pp. 52-53.

[10] Margie Mathews, "How a Violin is Made in Mittenwald," Etude, LVI (March, 1938), p. 19.

it from dividing into ventra-segments by transversal nodal lines. All the parts of the instruments are thus entered into vibration.[11] Another function of the bass bar is to compensate for the amount of wood removed from the top table by forming the f-holes. The pitch of the top can be altered by adding or taking away from the bass bar. Of course the bass bar also adds to the strength of construction of the top table.[12] Since the time of Stradivari, the concert pitch has risen and also the amount of volume needed for the concert hall has expanded. Both of these needs have been taken care of by altering the size of the bass bar.[13]

The graining of the wood in the two plates has a certain effect upon the passage of vibrations and for this reason, certain rules have been formulated for the relation of the grain structure and the form of the instrument. The vibrations travel fastest in the direction of the length of the grain, slower across grain and slowest up and down grain. In accordance with this, the length of the grain is placed on the length of the body. The across grain position is from center to side of the instrument. The depth of the grain corresponds to the depth of the instrument.[14]

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[11] The Violin. How to Make It, p. 46.

[12] Ibid., p. 32.

[13] Saunders, op. cit., p. 2.

[14] Lauren Harman, op. cit., p. 96.

In testing various sections of the two plates, it has been found that the various sections give different tones. This is attributed to graduation. The various makers have individualities in this respect and the results are noticeable in variations of volume and quality. The Stradivarius violins have tops with the same thickness throughout, with backs thickest in the center. They are characterized as brilliant and mellow with fine carrying power. Joseph Guarnerius made the tops of his violins thickest at the edges and thinnest at the center. This results in great volume but little flexibility. Nicholas Amati made his tops thickest in the center and thinnest at the edges. These instruments are sweet but have little carrying power.[15] Frederick Saunders says that the smoothness of finish on the plates is important in that the production of low notes depends upon this factor. Lumps make for the production of high frequencies rather than low. Thick violins are shrill and weak in the low notes.[16] The effect of the degree of arch on the tables is such that purity is attained as the tables are flattened, but the sound will lose its brilliancy.[17]

The f-holes serve a double purpose. They act as an agent of pitch determination for the air chamber, and also

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[15] *Ibid*., p. 95.

[16] Personal letter from Dr. Frederick A. Saunders, Professor of Physics, Harvard University, April 4, 1941.

[17] *The Violin*. *How to Make It*. pp. 49-50.

act as an agent for more advantageously forming the shape of the top plate. The central area, running the full length of the top plate and corresponding to the grain position, is set in vibration by the combined action of the strings, bridge, sound-post, and bass bar. These natural vibrations are facilitated by cutting f-holes so that edges not under the strings, bridge, or tail-piece are free to vibrate. The more the f-holes slant or diverge from the general direction taken by the fibres, the greater should be the loudness of tone. This is a characteristic of the Guanerius model.[18] It is supposed that the short fibres pick out and vibrate the high tones and the long fibres do the same for the low tones.[19] In further reference to the vibrational patterns of this type, similar to those found in the top and back plate of the violin and usually studied in an apparatus known as a Chaldniplate, Saunders has this to say.

> Such patterns resemble those into which the top of the violin divides when a tone is produced which resonates with one of the natural vibrations of the plate. Thus a single plate may resonate to as many tones as the number of possible patterns into which it can break.
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> Its vibration will be affected by the sound-post just behind the right foot of the bridge, which connects the top plate with the back. Then the plates are bound all around their edges by being glued to the sides of the violin, the bass bar already mentioned introduces a complicating

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[18] Harman, <u>op. cit.</u>, p. 96.

[19] Katheryn Rieder, "Carving a Gold in Voice," <u>Etude</u>, LVIII (September, 1939).

> lack of symmetry, and finally there are the two f-holes cut in peculiar fashion which further aid in destroying the simplicity of the structure and therefore of its possible vibrations. All but one of the main peaks on the response curve may be explained as due to resonance in the body of the violin.[20]

These discussions illustrate the great difficulty of adequately tracing the vibrational paths in the violin. There are several of the finest physicists in this country and abroad at the present time working on this very problem. If they are able to discover and control the correct balance and disposition of these vibrations, there is no limit to the possibilities of improvements in the structure and reproductions of fine violins and other stringed instruments.

Resonance

The response curves of resonance indicate that the various peaks common to all violins and those of an individual nature are due to two factors. The first is that peak fixed by the internal volume of air and the position and size of the f-holes. The second is due to the natural vibrations of the body, especially the top or belly of the violin.[21] The total response of the violin at a given frequency is the sum of the responses of each vibrating part at that frequency.[22]

The volume of air has a very definite effect upon the

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[20] Saunders, op. cit., p. 9.

[21] Ibid., p. 10.

[22] Small, op. cit., p. 99.

total resonance of the instrument. The fundamental resonance corresponds to the pitch of the body of air enclosed between the two plates and ribs. This pitch, the same as is usually found in the violins of Stradivari, is near 512 double vibrations or 256 single vibrations. This frequency is better known as "do" flat or middle C of the Stradivari period.[23] This resonance associated with the internal body of air has the characteristic of dying away more slowly than any resonance provided by the body itself.[24]

Saunders has this to say on the resonance of the instrument.

> The similar peak common to all near the open D is obvious. Its position is fixed by the internal volume and the area of the two f-holes combined. It lies in a region in which the response of the violin would otherwise be weak, and its beneficial strengthening effect is felt over three semi-tones each way. The other peaks represent natural vibrations of the body. We know this because the addition of a load (mute) to the bridge lowers the pitch of these peaks in accordance with the general rule that heavy bodies vibrate slowly. Vibrations of the air inside the body are unaffected by loads on the bridge, so that these do not shift the peak near the open C. Each body peak corresponds to a different mode of subdivision of the vibrating plates. Probably the top plate is more important than the back, especially for the higher tones given by the violin.[25]

The two plates of the violin respond best at certain frequencies, the exact pitch of which varies slightly with various

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[23] The Violin, How to Make It, p. 42.

[24] R. B. Watson, W. J. Cunningham and F. A. Saunders, "Improved Techniques in the Study of Violins," Reprinted from The Journal of the Acoustical Society of America, Vol. XII, (January 1941).

[25] Saunders, op. cit., p. 10.

makers. Also, the pitch of the plates, when unassembled and when subjected to stress applied at the neck and ribs, differ slightly. This longitudinal stress at the neck joint has the tendency to produce clarity of tone in the plates which is not there when they are unassembled. Various parts of the plates give different frequencies, probably because of graduation.[26] This provides for resonation of the various pitches.

Savarts indicates that the general pitch of the two plates should differ from ½ to 1 tone in pitch. Violins with complete compliance are weak and if the plates differ enough, the beats are annoying. The pitch for the belly generally is around do-sharp$^{(3)}$ and re$^{(3)}$ and for the back, between re$^{(3)}$ and re-sharp$^{(3)}$.[27]

One method of approach in studying and imitating the old masters is by changing a trifle the proportions of experimental violins, taking off a bit of wood here or leaving a bit there. This allows the workman to imitate the response patterns of the old instruments successfully.[28] This method of building violins verifies the previous assertion that the graduation of the plates provides equal (in a degree) resonance of all the steps of the scale. Helmholtz found in his analysis of some of the better instruments, that this very equality of response all up and down the instrument was

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[26] Harman, *op. cit.*, p. 95.

[27] *The Violin. How to Make It*, p. 42.

[28] Secrets of the Master Violin Makers," *Popular Mechanics*, LXX (May 1938), p. 370.

one of the main factors in determining superiority of one instrument over another.[29] All of these things point to the fact that resonance is, within certain limits, a controllable factor, and as John Redfield says, "the problem of improving the structure of the violin is essentially one for the civil engineer, not for the musician."[30] As a last consideration, the problem of wolf tones is brought up. One of the most popular explanations and one that seems very likely is provided by C. V. Raman.

> The pitch of the wolf is that of a natural frequency of the instrument. If that note is played, the amplitude of vibration of the belly increases, and as it increases it takes energy from the string more and more rapidly. When the amplitude is small,the pressure of the bow is sufficient to maintain the usual vibrations of the string. With increase in amplitude,a point is reached at which the belly takes energy from the string faster than the bow can supply it without an increase in bow pressure. Consequently, the type of vibration of the string changes: The string jumps to the octave for maintainance of which the bowing pressure is sufficient. The natural frequencies of the belly are not harmonic, and the octave of the string is not a natural pitch of the belly so the vibration of the belly dies rapidly and the drain of energy from the string decreases. When the loss of energy has fallen to a point at which the bow can maintain the usual type of vibration, with the fundamental prominent, the string again takes up that type. Thus, the prominant pitch of the string is alternately the fundamental and the octave.[31]

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[29] Helmholtz, op. cit., p. 85.

[30] John Redfield, Music, a Science and an Art, pp.223-224.

[31] Jones, op. cit., p. 296.

It is this alternation of frequency, according to Raman, that gives the wolf tone its unpleasant effect.

Resonance, then, would seem to be dependent upon the degree which the body absorbs and enlarges upon the energy of the string, too much or too little being both undesirable. D. C. Miller puts the transfer of energy in this manner.

> The loudness and duration of sound from an instrument are dependent upon the damping or absorption of the vibration in the instrument and its surroundings. The energy of the waves which travel outward from a sounding body is derived from the vibration of the body; usually not all of the energy of vibration is transferred, some being absorbed and transferred into heat through friction and viscosity of the body.[32]

The complexity of the problem of determining and measuring all the factors involved in the mechanism of the resonator is staggering and will require a great deal of research and study by men of science, if they are ever to be truly controlled. It is difficult to adequately organize those facts that are known for a great many of them are incomplete and based on variable conditions. The field that has recieved the most concentrated attention up to this time seems to be that of the tonal quality of instruments. It is obvious that until a definite desirable quality is decided upon, little progress can be made in attempting to produce instruments to resonate this quality. There is much said and written of activity in this field of investigation at present.

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[32] Miller, op. cit., p. 179.

CHAPTER IV

QUALITY

The physicist, in determining the quality of an instrument, is interested in the balance of strength of the fundamental and overtones of all the tones possible on the violin from the lowest frequency, up four and one-half octaves.[1] The strengths of the tone as a whole are averaged into a curve known as the response curve and from this curve is drawn information regarding the note-to-note quality of a violin and where and why it is or is not good.[2]

Violins are generally characterized as possessing one of two types of quality. The violin with orchestral possibilities has its strength centered in the higher partials of the tone, giving a certain shrillness, and bright quality to the tone. The ear is very sensitive to these higher partials and for this reason, a violin possessing an excess of them will have superior carrying qualities.[3] The better quality of instrument which is a favorite in the concert hall, not only resonates a fair balance of high partials, but also brings

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[1] F. A. Saunders, Studies of the Instruments of the Curtis String Quartet, p. 2

[2] Ibid., p. 2.

[3] F. A. Saunders, "Secret of Stradivarius," Reprint from Journal of the Franklin Institute, Vol. CCXXVI (January, 1940)

out the low partials with a great deal of ease. These lower partials round out the tone, giving a mellowness combined with strength. This has been described by D. C. Miller as the "ideal tone".[4]

Miller characterizes the tones below middle C as weak in the fundamental and strong in their upper partials.[5] This is because the tones below the fundamental resonance of the instrument are too low for the body size to resonate properly while the upper partials are within the range of body size. This peculiar balance gives that special tone quality to the tones of the G string.[6] Above this fundamental resonance, the tones of the three lower strings are characterized by strong partials up to the fifth. The tones on the E string have a strong third partial. In general, according to Miller, "the tone of the violin is characterized by the prominence of the third, fourth, and fifth partials."[7]

Quickness of response of an instrument to trick bowing or fast light passages is a very desirable feature found only in the best instruments. This, along with the general tonal quality of good instruments, is thought to be a direct result of the degree of quickness, reckoned in 1/1000 of a

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[4] Small, _op. cit._, p. 92.

[5] Miller, _op. cit._, p. 197.

[6] Small, _op. cit._, p. 92.

[7] Miller, _op. cit._, pp. 197-198.

second that the vibrating parts of the body respond to the strings.[8] This quickness of response is thought by Saunders to possibly be the result of years of vibration breaking down some of the wood cells in the top plate or perhaps the evaporation of some of the constituents of the wood.[9]

Inferior instruments, both old and new, are also characterized by the degree of rapidity with which the tones fade away or "decay". An observation by Saunders on the results of some of his experiments is that, "the decay constants obtained so far indicate that tones produced by inferior violins new or old die away more rapidly than those of better quality instruments."[10]

The effect of varnish upon tone quality of the violin has been tested extensively by Meinel in Berlin. The only result that affected the response curve was that of leveling off some of the higher peaks and in general, evening it up. Meinel attributed to the idea of varnish increasing the viscosity, or inner friction of the wood so as to make it vibrate less freely in its natural modes. This change was however, very slight and carries little significance.[11]

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[8] F. A. Saunders, Science News Series, XXCVIII (November 1938), sup. 10.

[9] Ibid.

[10] Watson, Cunningham and Saunder, op. cit., p. 19.

[11] Saunders, "Secret of Stradivari", op. cit., p. 19.

CHAPTER V

THE LEGATO STROKE

The various schools of violin playing and instruction have evolved primarily through a hit and miss process that has set up for each group a definite collection of "musts" that distinguishes the technic of one from another. Since all groups perform upon the same instrument, they are all subject to the same limits set up by the physics of the instrument involved. The object of the first three chapters of this study was to collect and organize as many of the established facts concerning the physics of the violin as are available. The proposed object of the remaining chapters is to build a set of rules for performance upon the violin, not by collecting and selecting from the various empirical schools, but through evolution and logic from the facts at hand. The results can, for the most part, be verified through statements from the works of some of the leading authors in this field.

All of the various bow strokes must take into consideration the limitations of both of the elements making up the generator. These two elements, the physics of which have been discussed, are the bow and the string. These limitations have a defining influence upon the degree of success experienced by the performer in his attempts to accomplish them, and if they are not followed, the violinist will fail in his endeavor to secure adequate tone.

There is actually but one basic bow stroke that has been found practical upon the violin. Variations in treatment, with reference to pressure, speed, angle of approach, length, and amount of hair touching the string or strings of this movement, has led to a great variety of names being applied to the more common of these. The legato stroke will be analyzed as the basic stroke and the variations upon it will be discussed in Chapter VI under the headings of detache, marteie, staccato, bouncing bow and col legno.

The hairs of the bow are ringed by the projecting edges of the scales that form its cover. The combined effect of the scales is at a maximum when they are drawn at right angles across the string. If the hairs are not drawn at a ninety-degree angle with the string, the hairs will attempt to assume this angle due to the unbalanced load placed upon the various sections of the hair surface. There is also a certain amount of bow noise present when the bow is placed in motion across a string. This noise is at a minimum when the string is properly approached, but assumes a more prominent role when there is too great a number of scales sliding over, rather than catching the string. The further the angle of approach of the bow to the string varies from ninety degrees, the more noise and less tone is produced. In performance then, it would be most desirable to assume this relative position of hair and string. The most common way of describing this condition is through terming the bow and bridge as parallel.[1] This sets up an imaginary plane in which the bow stroke must always be described if this maximum of tone is the intent of the performer.

The second consideration is the plane in which each string is required to be bowed. This plane is determined by the position of the string in relation to the other strings and the bouts of the instrument. This plane is very exacting, for if the bow wanders out of it, the result will be the sounding of another string or the touching of the instrument proper.

In Chapter II it was indicated that the point of contact of the bow and string has much to do with the resulting tone quality which the string generates.[2] If the bow is applied at the center of the string, halfway between the bridge and the nut, the only partial that will be produced in the fundamental. The further the bow moves from the center toward the end of the string, the greater the number of partials that are produced.[3] There is a point very close to the bridge where the fundamental is no longer prominent and the resulting quality is termed ponti-cello.[4] The violinist

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[1] Carl Flesch, <u>The Art of Violin Playing</u>, Vol. I, p. 57.

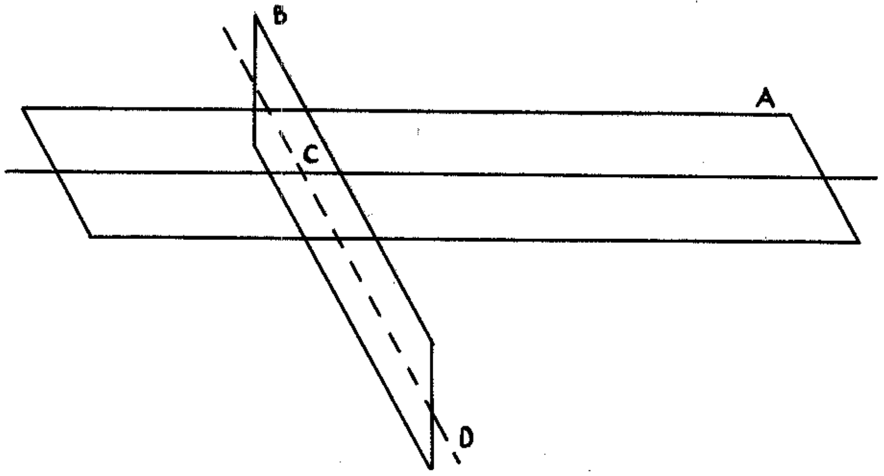
[2] Small, <u>op</u>. <u>cit</u>., p. 110.

[3] Helmholtz, <u>op</u>. <u>cit</u>., p. 52.

[4] <u>Ibid</u>., p. 85.

must determine in his mind what quality he desires to produce and then locate that spot on the string that will generate the balance of partials that most nearly meet the requirements.

There are then, two imaginary planes that the performer must observe. These two planes (Figure 7) will cross each other at whatever point of contact that the operator desires to utilize. Where the two planes cross, a line is created that indicates the path that the hairs of the bows must superimpose in order to comply with the requirements which created the planes. This imaginary line can be called the single-note bow-path for future reference.



A--plane of string
B--plane of bow
C--point of contact
D--bow stroke

Fig. 7--Two imaginary planes the violin performer must observe.

The problem of executing this single note bow path is the question that formed the basis for differences between the various schools of violinists. The obvious influence of individual differences in bodily structure, together with the styles of the schools has provided a great quantity of conflicting material on the subject. Such artistic and physical differences must be taken into consideration when evaluating any description of the actual performance of this stroke.

Control over all the various factors in bowing is for what every system has striven. The effect this control, or lack of it, has upon tone quality is summed up by D. C. Miller.

> The usual variations in bowing disturb the regularity of the vibrations, and produce a continually changing wave form....
>
> This particular shape depends upon the critical relation between pressure, grip, and the speed of the bow, and upon the place of bowing and the pitch of tone....
>
> The tone quality, as well as the wave form, remains constant so long as the bowing is constant in pressure, speed, and direction. The direction of bowing may be skillfully reversed without changing the tone quality.[5]

The logical approach to this problem is to find that manipulation which provides the least chance of producing variation in the wave form of the string and also allows the greatest degree of control over line of travel and pressure. This manipulation will require the greatest amount of efficiency from every part of the right arm and hand.[6]

In violin playing the most useful part of the right hand is the fingers[7] Not one part of them can be said to be more useful than another, for the primary action of gripping the

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[5] Miller, op. cit., pp. 195-196.

[6] E. E. Cramer, The Basis of Artistry in Violin Playing, p. 11.

[7] Flesch, op. cit., p. 51.

bow requires the full use of every part of the finger. The natural position of the fingers for grasping the bow can be observed if the hand is allowed to hang at the side in complete relaxation. The fingers will be observed to be slightly arched. They are, in this position, capable of exerting force, either by straightening or gripping. The knuckles are almost flat with the back of the hand. The wrist is not bent, but it is flat. All of the muscles are in "neutral", capable of exerting the maximum of power in any possible direction. This must be, then, the position of maximum efficiency for the entire arm and hand. It is logical that this is the position to be utilized in manipulating the bow, as far as it is possible to mold it to the physical features of the bow.

The position of the elbow during the bow stroke should be in the same plane as that of the string. This allows the bow to freely cross to either of the adjacent strings with equal facility.[8] The rest of the arm should remain the same as the natural position described in the previous paragraph with the exception of the thumb, which should be placed directly under the second and third fingers in order to better balance the influence of the index and little fingers. Also, the little finger will be raised slightly higher than the others in order to rest upon its tip.

The grip of the fingers upon the bow must necessarily be

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[8] Cramer, op. cit., p. 14.

such as to allow the addition and release of pressure, movement of the bow either in or against the direction of travel, and the adjustment of the number of hairs in contact with the string.

The addition and release of pressure is accomplished through adjustments in the position of the index and little fingers in relation to the rest of the hand. In the addition of pressure of the bow to the string, the index finger recieves and augments the weight of the entire forearm. This weight is applied through a semi-rotary motion of the forearm from the elbow. In the counterbalancing of this pressure, the little finger has only to press downward while the rest of the hand remains in the same position.[9] This process leaves fingers number two and three, and the thumb, which is directly below them, in a role of the fulcrum in a lever. The stick itself is in the position of a lever, the index finger exerting pressure upon one end and the little finger counterbalancing this weight at the other end.

The movement of the bow with or against the direction of travel of the forearm can be accomplished by straightening or increasing the curvature of the various fingers of the right hand. If the movement is to be downbow, the little finger and the two middle fingers straighten downward while the index finger increases its curvature. If the movement

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[9] Flesch, <u>op</u>. <u>cit</u>., p. 53.

is upbow, the index finger and the two center fingers straighten upward while the little finger increases its curvature. The chief thrust in either of the two cases is provided by the combined action of fingers number two and three and the thumb.

For adjustments in the amount of hair touching the strings, an increase hooking of the fingers as a whole decreases the number touching, while a flattened position of the hair upon the strings requires a slightly more "neutral" position of the fingers. The stick, in the former process, tends to move further away from the bridge than the hair.

In drawing the bow, the considerations that must be observed are the change of direction of travel and a minimum of excess motion anywhere in the right arm and hand. The reversal of direction of travel of the bow involves the situation of completely stopping, and then beginning anew in the opposite direction, the vibration forms of the string.

Miller gives a graphic illustration of this reversal in his book, The Science of Musical Sounds.[10] Figure 8 in

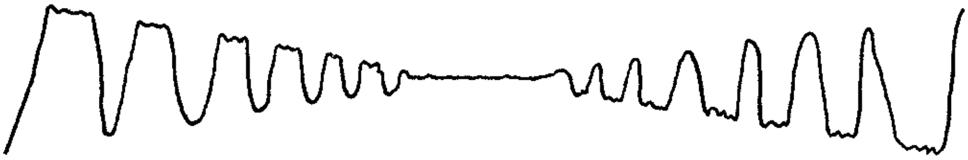

Fig. 8--The reversal of direction of travel of the bow.

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[10] Miller, *op. cit.*, p. 197.

this work shows a copy of his illustration. The quotation of his reproduced on page 43 of this work, makes clear the delicacy of this maneuver, the success of which depends upon an undisturbed wave form. In order to accomplish this, all unnecessary movements and pressure must be eliminated. A complete stop and immediate simple start in the opposite direction completes the reversal of direction easily and the continued resonance of the instrument covers up the short stoppage in the vibrations. If no percussive noise of any type is present, the change of bow from the auditory standpoint, can be made unobservable.

The simple process of changing the direction of the bow stroke and at the same time, using a minimum of arm movement, requires that the bow, from the middle to point, be pushed down by the process previously mentioned. The bow is simply stopped, a reversal of direction of travel affected by the arm, and the bow pulled back to the middle with no attack evident at the point of bow change. On the up-stroke, from middle to point, the same process is experienced. The bow is pushed to the frog, stopped, pulled down again and thus, an entire legato stroke can be described. From middle to frog, it is pushed up, stopped and pulled back again. From middle to tip, it is pushed down, stopped and pulled back.[11] In all this stroke, there is no exaggeration of movement of the wrist or the forearm. The upper arm and elbow move only

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[11] Franz Kneisel, Principles of Bowing and Phrasing, p. 13.

enough to satisfy the requirements of keeping the bow parallel to the bridge. This process remains the same for the legato stroke regardless of speed or pressure.

CHAPTER VI

VARIATIONS IN BOWING

All bow strokes are executed by the same fundamental process as evolved in Chapter V. Variation in treatment of pressure, speed, angle of approach, length, duration and amount of hair touching has led to the formation of six big divisions of bowing. There are numerous variations upon these large divisions themselves, each school of violinists advocating their favorite style. The basic foundation for the five remaining divisions will be discussed and no attempt will be made to enlarge upon variations according to schools.

Detache

The detache is the legato stroke confined to one bow length. When two or more notes in succession are played detache, each note is articulated at the change of bow. This does not infer that there is an accent at the reversal of direction, but does imply a slight pause. This pause must be there, regardless of how small or long it may be, for if it is not present, the stroke will be immediately classified as legato.[1]

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[1] Flesch, op. cit., p. 66.

The detache can be executed at any point upon the bow. It can be described upon the full length or upon as small a space as the hair of the bow will support. Those strokes smaller than the full length can be drawn in the general areas of the point, middle or frog. Differences of character of the detache stroke in the several areas is dependent upon weight distribution in the right arm and point of contact between the bow and string.

At the frog, the weight of the whole arm plays the most important part in forming the character of the stroke. The ability of the performer is here dependent upon the degree control he has over the finger action in the bow stroke. Due to the awkward position of the arm at this point, its whole weight being collected directly above and behind the bow, the frog stroke is generally termed rough and heavy.[2] Great power is the rule, and as a result, this is the favorite position for the performance of legato chord passages.[3]

The stroke at the middle is the most commonly used of the detache strokes,[4] for it carries enough weight from the arm and hand to possess power and lies in the most easily maneuvered portion of the bow.

The detache at the tip is also a very common stroke.

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[2] *Ibid.*, p. 66.

[3] *Ibid.* p. 64.

[4] *Ibid.*, p. 67.

Here, more pressure from the hand and index finger is required in order to provide any power.[5] The very fact that this stroke requires the indiscriminate use of strength has made it very popular with violinists who are not so clever with weight distribution.

Difference of color in the tone is produced by the point of contact of bow and string. These are the same as found in the legato stroke. A common way of causing the tendency of the tone to be weak when produced toward the middle of the string, is by edging the bow toward the center of the string when a phrase is being ended. This process is often described as the "cresent" stroke because of its appearance. The forearm and upper arm perform a crescent movement in the accomplishment of this effect. It provides a sure way of letting the tone die out evenly. This bowing is valuable to the performer who has little control over relief of pressure at the end of a natural detache.[6]

Martele

The martele bears all the characteristics of the detache with the exception of a very definite accent present at the beginning of each new martele stroke.[7] This accent, from the physiological standpoint, has the characteristic of raising

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[5] Paul Stoeving, The Art of Violin Bowing, p. 37.

[6] Cramer, op. cit., pp. 19-20.

[7] Stoeving, op. cit., p. 73.

the intensity of the tone from three to five decibels over the sub-speaking values. There is an immediate return to former values experienced.[8] After this accent, the bow is carried the desired length and the stroke is ended with an abrupt stop. Most generally, the martele is performed from the center to the tip area of the bow.[9]

The accent present at the beginning of each stroke is initiated by the addition and immediate release of pressure upon the stick with the index finger. If a great deal of power is needed here, the forearm and sometimes the entire arm is added to the weight. Stiffness of the wrist and a general state of tension can be observed over the entire arm when this is the case. The bow hair should be flat upon the string in order to utilize the entire force of the bow at the time of the attack. When the stroke is produced at the frog. the bow has its greatest power and is especially valuable for the production of two and three note unbroken chords. Speed and smoothness of manipulation is evidenced from the center to the tip area. This is the region that sees the most service.[10]

Staccato

There are two types of staccato used generally by violinists. One is termed controlled and the other uncontrolled.

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[8] Small, op. cit., p. 105.

[9] Stoeving, op. cit., p. 73.

[10] Cramer, op. cit., p. 23.

Literally, both are controlled but the former allows it in a greater degree than the latter.

Staccato is nothing more than a series of very short martele strokes performed in one direction of travel upon the bow.[11] Very often, a great speed is required in performing staccato passages. When this is true, the uncontrolled staccato is utilized. On slower passages either type can be used, either depending upon the command the performer has over it.

The controlled staccato is executed most easily on the up-stroke.[12] The same procedure as was described for the martele is used here with the exception that it is performed in one direction. The down-stroke controlled staccato follows the same procedure.

The uncontrolled staccato is also best done on the up-stroke. A great variety of methods have arisen for the performance of this stroke. All methods have in common, the explanation of the tremor produced by one muscle pulling against another. This tremor, which is generally very fast, can be made to supplant the slower more labored finger and hand action necessary for the controlled staccato. This tremor can be controlled by practicing it in doublets and triplets.[13] On the up-stroke, a high elbow should be

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[11] Stoeving, op. cit., p. 90.

[12] Ibid., p. 9.

[13] Flesch, op. cit., p. 72.

maintained. On the down stroke, a low elbow is used. The stick is turned toward the operator on the down-stroke and away from him on the up-stroke.[14] The up-bow staccato is done near the tip of the bow and the down-stroke slightly more in the center of the bow.[15]

Bouncing Bow

The bouncing bow can be divided into two divisions. The first, called spiccato, allows the stick to jump, the hair remaining upon the string. The remaining type of bouncing bow allows both hair and stick to jump away from the string.

The first of these is called the controlled spiccato, and is most easily done when the point of contact is close to the balance point of the bow. Here, it is presumed, the smoothest stroke will be accomplished because the stick will jump evenly.[16] In order to start the stick jumping, a very fast and short martele must be performed near the balance point. The bow is pressed down for the attack and then suddenly released. The recurrence of this process produces the phenomenon of the bouncing bow. The quicker the stroke is performed, the more the point of contact travels toward the tip.[17]

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[14] Cramer, _op. cit._, p. 22.

[15] Flesch, _op. cit._, p. 72.

[16] Cramer, _op. cit._, p. 21.

[17] _Ibid._, p. 21.

Finding the exact point of contact for each speed is a matter of experimentation, for each bow has a different point of balance and individual resiliency. The exact reason for the movement of the point of contact toward the tip, in relation to slower to faster speeds of spiccato, is not quite clear. It is suggested that the bow is much lighter in its upper portions and therefore responds more readily to the more rapid bouncing movement of the spiccato type.

Bouncing bow strokes, in which both the stick and the hair jump, can be either controlled or uncontrolled. The controlled type can be performed at any point on the bow, usually being done at the tip. The effect is percussive, for the bow is scarcely drawn; but it strikes the string sharply and disturbs the wave forms considerably. The rebound of the stick pulls both the stick and hair away from the string.[18] The uncontrolled or semi-controlled type of bouncing bow is merely a series of bounces along the bow, the first of which is begun by striking the string smartly with the bow and the continuing to apply pressure for as many bounces as is desired. This stroke requires exceptional coordination of the ear, and the left and right hands.

Col Legno

The wood of the stick is sometimes used to set the generator in motion. The stick itself is very smooth and offers

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[18] Flesch, op. cit., p. 73.

therefore, very little uneven surface to the string. The effect is obtained by merely striking the string with the stick.[19] The first disturbed wave form produces a noise, but then the string settles down into a brief period of normal vibration, giving tonality to the sound.

This stroke is not very practical because of the difficulty of playing stopped strings in the higher positions. The string being agitated, when pressed down by fingers in the higher positions, has a plane of performance which is very close to those of adjacent strings. When the stick of the bow strikes, the string gives way slightly to its force and its plane of performance crosses that of the other strings. The result is that several strings are sounded instead of just one.

Pizzicato

Although this method of tone production is not associated with the bow, it is generally produced with the index finger of the right hand, and for this reason it is included in this chapter.

The point of contact between the finger and the string is subject to the same laws as is the bow string.[20] Therefore, the most fruitful point of contact should be the same as is used by the bow. Due to the presence of rosin upon the strings and the chance of the transfer of oils from

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[19] Eugene Gruenberg, Violin Teaching and Violin Study, pp. 100-101.

[20] Small, op. cit., p. 101.

the fingers to the bow by way of the strings, this point of contact is impractical. The obvious area to pluck the string is then, that area directly over the end of the fingerboard. If the finger approaches too close to the bridge, instead of ponti-cello, a tone color resembling that associated with the banjo is produced. If the center of the string is approached, a dull quality is in evidence. For the pizzicato of single strings, the thumb should be placed on the corner of the fingerboard and the positions of the strings estimated by the first finger from this position. For broken chords this same position should be used. For simultaneously sounding notes, application of the first finger should occur more in the center of the string to avoid too great an articulation of sound. A brushing motion of the tip of the first finger will produce a sound without too much of the initial attack present.[21]

Left hand pizzicato is self defining, for the left hand both determines the frequency and initiates the vibration. The tone quality approximates that which is obtained from plucking the string very close to the bridge. Since the finger action used in left hand pizzicato is that of picking the fingers from the string rather than placing them upon it, the only practical movement of intervals is downward. Any upward pizzicato involves the double action of placing the finger, determining the frequency, and placing and removing the finger initiating the vibration.

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[21] Gruenberg, op. cit., p. 54.

CHAPTER VII

BOW PASSAGE TO ADJACENT OR REMOTE STRINGS

The manipulation of the bow in its passage from one string to either of the strings closest to it is tempered entirely by the intent of the phrase being performed. If the phrase demands an unbroken dynamic line, great care must be taken in the change of strings. If the phrase requires a definite articulation, either through the use of the martele or the detache, the change of string can be attempted with slightly more abandon. The first consideration is by far the most important of the two, for unobservable string crossings, with allowances for change in string quality, are at once, the sure mark of the proficient violinist and the stumbling block of the amateur. A long phrase line, possessing a range crossing several strings, demands that the beginning wave form of the string being approached be as well formed as the wave form of the string being abandoned. If any jerk is in evidence during the process, the wave form of the string being approached will be highly disturbed and an accent similar in character to that of the martele will be produced. This, of course, will disrupt the formation of the dynamic line of the phrase. As the majority of the influence of the bow upon the strings is directly traceable to motions of the right hand, wrist and arm, it is here that the violinist must look in order to analyze the problem.

The curve, in art, has long been the symbol of smoothness and tranquility. The angle represents the opposite of this and can be described as abrupt and dissonant. An accent, which is formed by a sudden attack upon the string, will be produced if the bow, in leaving the first string, approaches the second too suddenly. This abrupt transfer of the bow arm and hand from the plane of one string to the plane of the other, produces two angles in the figure described by the right hand. The first angle is formed upon leaving the first plane and the second angle is formed on joining the second plane. The obvious solution to this problem is the anticipation of the string crossing the performer and the execution of a curve of approach. When the second string is to be set into vibration, the bow is already practically touching the string. Thus, in making any simple string crossing, the figure described by the right hand will always be that of a curve or an arc.[1]

In crossing to remote strings, the problem is to cross the intervening string or strings without setting them in motion. The only solution to this, if the bow is to remain on the strings, is to make a complete stop while the bow touching the string that is not to sound, and then resume the

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[1] Flesch, op. cit., p. 62.

stroke when the desired string is reached. This is true whether the direction of travel is to be reversed or continued. It also applies to all divisions of bowing.

All figures or phrases, regardless of reversal of direction, string crossings, place or speed of bowing, describe some certain path in the air with the right hand. This path can be isolated and analyzed into a series of circles, curves, lines, or angles. There is one bow path that the right hand must assume in order to correctly execute any certain passage. When the violinist has determined for himself what path the right hand should follow in order to properly perform the string crossings and bow changes required by the passage, the right-hand problem is in a large measure solved. Slow, careful practice of the bow path insures adequate performance, from the bowing standpoint, of any difficult passage.[2]

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[2] Cramer, <u>op</u>. <u>cit</u>., pp. 15-16, 34-41.

CHAPTER VIII

THE SUPPORT OF THE VIOLIN

The force that has the greatest influence upon the position of the violin, other than the bodily structure itself, is the law of gravity. This law determines the relative position of the plane of the strings and the floor. (The plane of the strings as a whole is the plane that represents the average of all the string planes. Both the D and A strings lie entirely within this plane while the G and E lie beneath it.)

The bridge to nut dimension of the plane should be parallel to the floor. If the strings are not in this position, the bow will be pulled by gravity to that area of the string that is closest to the plane of the floor. If the scroll is pointed toward the floor, the bow will be pulled toward the finger board.[1] If the scroll is held too high, the bow will be pulled toward the bridge. This last consideration is advocated by many teachers because of the difficulty in teaching students to play close enough to the bridge. It seems most practical for the violinist to assume either of the last two positions, for the further the point of contact of the bow and strings wander from the area of the bridge,

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[1] Paul Stoeving, What Violinists Ought to Know., p. 7.

the less the qualitative possibilities of the resonator are exploited.

The dimension of the plane of the strings which parallels the length of the bow is the next consideration. At first thought, it would seem advisable to also allow this dimension to be parallel to the floor. However, this position is not practical. If there was but one string to be performed upon, then a parallel position between the plane of the string and the plane of the floor would utilize the full force of the pull of gravity. Since there are four strings, all of which cannot conform to this condition at the same time, this position is impossible. It is obvious that the bow arm is normally at the right of the violin proper. Generally speaking, the height of the right hand during performance never exceeds that of the instrument.[2] This is also true when the left arm manipulates the bow. If the bow arm did exceed the instrument in height, the entire weight of the arm would be above the bow and would have the effect of making the tip to frog passage heavier in character than that of the frog to tip movement. This complication then would involve the use of vastly different technical equipment when bowing upon the lower strings than is generally used upon the higher. Thus, it is suggested that the plane of the G string be allowed to assume a position parallel to the

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[2] Ibid., p. 10.

floor. The plane of the strings as a whole will be automatically determined. The bow, when applied to the E string under the conditions suggested, will be the least affected by gravity. However, gravity will still have a very definite pull upon the bow. Since this entire condition is more practical than that of a tipped G string plane, the performer generally chooses the lesser of two evils.

It is suggested then, that in order to find the relative position of the violin to the floor, the violinist should discover the plane of the G string and place it parallel to the floor. One way of determining the relative position of the violin to this plane is by placing the bow on a string without touching an adjacent string or the bout and in a plane parallel to the floor. The plane of the body of the violin proper will then vary about thirty degrees from the plane of the G string.[3]

There are several different sets of violin movements generally advocated by violinists, designed to aid the movement of the bow.[4] It must be taken into consideration when using these movements, that for every deviation from the established central position, a complete new set of planes of performance is set up and perfect adherance to the physical limitations of these planes is not always practical. Thus,

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[3] Ibid., p. 11.

[4] Cramer, op. cit., p. 24.

when one portion of the central position is altered for convenience of performance at that point, some other portion of the technic suffers an alteration to an equal degree. Since the central position was chosen for maximum efficiency at all points, any alteration upon this balance will result in a lower over all efficiency of performance. It is advocated then, that any mannerisms in the form of unnecessary violin movements be avoided.

The proximity of the ears to the resonator must be taken into consideration in regard to the position of the head, when holding the violin beneath the chin. If one ear is much closer to the resonator than the other, an exaggerated and distorted tone is likely to be received by the mind. It is desirable that the performer hear the tone under as much the same conditions as the audience. For this reason, the logical position of the head seems to be the one that will allow each ear an equal chance to hear the tone. This, if observed, will force the violinist to look straight down the finger board of the instrument. This position, if the head is held erect, under normal conditions, will allow the proper assumption of the plane of the strings. All this is subject to variation under abnormal conditions of structure of the factors involved.[5]

Provided that all of the conditions, as evolved to this point, remain constant, a cramped condition of the right arm will result if the violin is held in a frontal position. The

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[5] Auer, Leopold, Violin Playing As I Teach It., p. 32.

problem of support from beneath the violin must also be considered. The only possible source of support in this region is the left shoulder. Thus, the violin, in order to successfully adhere to both of these conditions, must be placed to the left of the normal frontal position. The exact position is dependent upon the length of the right arm and the ability of the performer to shrug the shoulder into position beneath the left side of the violin. Generally speaking, the head is forced to turn to the left at about a fifty-degree angle from the normal frontal position.

In order to support the violin, the shoulder is pushed upward and the chin downward in a type of pincer action. Provided the chin is supported by a chin rest, the only factor affecting the action of the resonator is the contact between the left shoulder and the back plate of the violin. Numerous shoulder pads have been designed to offset this influence and also reduce the strain upon the shoulder muscles, produced by the shrugging action.[6] From an artistic standpoint, the possibility of muting the tone at will with the left shoulder is very desirable. This fact has left a breach in the ranks of violinists as to which consideration is the most desirable for all-around performance. This, of course, is matter of choice and it is not deemed advisable to lay down any hard and fast rules concerning it at this point.

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[6] *Ibid.*, p. 32.

For consistent and efficient performance upon the instrument, a steady, firm grip by the shoulder and chin should be maintained. For reasons of facility in the left hand, it is suggested that the violin proper be held as motionless as possible and supported entirely by this point of contact.[7]

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[7] Stoeving, What Violinists Ought to Know, p. 10.

CHAPTER IX

THE POSITION OF THE LEFT HAND

There are a great many types of left hand technics. Every artist has his own arm and hand set that enables him to perform difficult violin literature equally as well as most other violinists. Every school of violinists maintains that its particular brand of technic has advantages not enjoyed by any other school. It is impossible to determine which one has the greater claim to this honor, for differences in style, basic literature and tradition make the job very complicated. All of these technics are limited by physical make-up of both the performer and the instrument. It is the purpose of this chapter to discuss only those factors touching upon this point and not to enter into the perpetual battle of the schools.

The number and character of the points of contact of the left hand with the neck of the violin determines the measure of success the performer will experience in attempting to develop smooth shifting, flexible vibrato and accurate intonation. Possible points of contact are; the ball of the hand, the crotch formed by the thumb and index finger, the base of thumb, the base of the index finger, the ball of the thumb, the second joint of the thumb, the knuckle joint of the index finger and the tips of the fingers. Of all these, the only points of contact necessary for performance are the tips of the fingers and the tip or second joint of the thumb. It is obvious that the more the hand is tied down by unnecessary contact with the neck and finger board, the less freedom can be experienced in vibrato and shifting. As for intonation, if the root joint of the index finger touches the neck, the index finger is forced to curl up as much as possible in order to stop the first half step possible on each of the strings. Since this is accomplished with varying degrees of success, the intonation is, as a general rule, sharp. In order to address the tone properly, the root joint of the index finger must be pulled away from the neck and assume a position in line with the rest of the knuckles. Thus, all of the knuckles will be as parallel as is possible with the finger board. This allows equal access to the strings for all the fingers.[1]

The thumb can touch the neck at several points. The position at the crotch of the hand is impractical for the reason that one side of the crotch is the root of the index finger, a point of contact already mentioned as undesirable. The second joint is the favorite point of contact.[2] The thumb is usually bent in the form of a saddle in which the neck should lie. This position of the thumb must be altered

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[1] Auer, op. cit., p. 35.

[2] Emil Kross, The Study of Paganini's Twenty-Four Caprices, p. 18.

when performing in positions higher than the fifth or sixth because of the size and placement of the lower right ribs of the instrument. The last possible placement of the thumb is upon the tip.[3] This enables the thumb to assume a relaxed position much as is evidenced in the right hand technic. Also, this placement of the thumb allows the hand to assume a lower and more distant position from the strings, permitting all the fingers to have equal access to the strings and also allowing for the interference of the lower right ribs. For over all convenience and ultimate relaxation, this position seems superior to the other two, however, since its full value is often obscured by the immediate extremeness of its shape, it is not popular among violinists. The position of the thumb in relation to the hand as a whole is generally directly below the second finger. This allows for position identification and an equal distribution of strength among the fingers.[4]

The position of the wrist and elbow is defined directly by the position of the instrument and the number of points of contact used in the left hand. If the position of the instrument and fingers is that which has been suggested, the elbow and wrist will be pulled under the instrument as much as is possible.[5] Any extreme angle in the wrist produces

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[3] <u>Ibid</u>., p. 18.

[4] Auer, <u>op</u>. <u>cit</u>., p. 34.

[5] <u>Ibid</u>., p. 35.

tension and hampers freedom of motion. The suggested position of the wrist is that of being slightly arched away from the neck. This completes a gently increasing arch from the elbow to the tips of the fingers.

The possibility of independent action by the fingers must always be present. If the position assumed by the performer is such as to allow one finger to lie permanently against another, the efficiency of action of both is impaired.[6] Adjustments of a chromatic nature must always be made by the finger itself and not by the wrist.[7] It must be remembered that changing the hand, set to favor the placement of one finger, at the same time changes the intonation of all the other fingers.

For stretches greater than is normally possible in the hand, the movement of the stretch should be backward.[8] The index finger is normally longer than the little finger. If the little finger, or foreward stretch is utilized, the little finger and possibly the third finger will be straightened, thus losing the inherentstrength of the arch in each. If the backward stretch is used, all the fingers can be maintained in a rounded position and the great length of the index finger utilized to its ultimate possibilities. This technic is fundamentally the same as is used in performance of the stretch

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[6] Ibid., p. 35.

[7] Cramer, op. cit., p. 43.

[8] Ibid., p. 50.

on the cello and double-bass. As a last consideration, the advantages of a consistent hand position for all areas of performance is endorsed.[9] The position which is necessary to adequately manipulate the fingers in seventh position, is also the same position that allows the backward stretch in the lower positions. The fingers are all round and separated, the thumb is in a relaxed shape, the wrist and elbow are well under the instrument and the knuckles are parallel to the finger board. It is possible to hold this same position in all areas of performance, allowing consistency of intonation, vibrato production and touch. For all purpose performance, this position seems to be the most practical and logical one to assume.

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[9] *Ibid*., p. 44.

CHAPTER X

TECHNIC OF THE LEFT HAND

Touch

Differences of pitch on the strings is the result of lengthening and of shortening the string by fretting the string on the finger board with the tips of the fingers of the left hand. Each finger can determine an unlimited number of pitches upon the four strings. The quality of the frequencies initiated by the fingers is dependent upon where on the string the note is produced and how definitely the wave forms of the string are terminated by the finger. The more the string is shortened by a finger, the less is the number of high overtones that will be produced.[1] As the bridge of the violin is approached with the left hand, the height of the strings from the finger board is increasingly greater. Thus, when the string is stopped close to the gut, it is pushed down more easily than when it is stopped close to the bridge. It follows than that when the string is stopped close to the nut, the best results are obtained with the least effort. As the bridge is approached, the results decrease while the effort increases.

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[1] Helmholtz, _op_. _cit_., p. 46.

In order for the nodes of the overtones along the length of the string, to be well defined, the nodes at either end of the string must be well stopped.[2] If a finger does not form a firm terminal point, the smaller overtones will be malformed and as a result, the tone will be dull and without brilliance.

This ultimate in quality then depends upon how well the string is stopped. For the maximum results, there must be a firm juncture between the finger and the finger board, the string being held firmly between the two. In the performance of fast passages, a slow pressure of the finger is not fast enough to provide immediate results from the vibrating string. Therefore, the first contact of the finger with the string and finger board must be decisive and immediately set up a form nodal point for the string.

The arch has long been the symbol of strength in architecture. All portions of an arch closely support all ather sections. When a break occurs in the curve of an arch, the strength immediately dissappears. This is also true of the arch that is formed in the fingers of the left hand.[3] When the fingers are round and the bones support one another, very little pressure is needed to keep the string well stopped. If the arch is broken, much of the strength is lost at the weakener joint and unless a great muscular tension is applied,

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[2] Auer, op. cit., p. 89.

[3] Stoeving, What Every Violinist Should Know, p. 10.

the string is poorly stopped. The initial attack must be firm and decisive. After the first firm attack has determined the length of the wave form, the initial pressure can be relaxed, for the wave form, once started, tends to continue in its original path. If the first terrific pressure is maintained, undue tension is produced and the left hand fatigued very quickly.

The Trill

The mechanical action of the trill is merely a re-occurring of the process just outlined under the heading of Touch. For a very fast type of trill, a flutter can be produced by the same type of tension that was evidenced in the uncontrolled staccato.[4] If this tension is to be produced for any length of time, relaxation can be accomplished by a continual movement of the wrist.[5] This changes the length and placement of the muscles involved and thus does not produce too great a measure of fatigue in any one place. The trill occurs at a rate of about seven per second. This is an over all average for speed in the performance of this embellishment. The trill is accompanied with a synchronous intensity change of about 5 decibels at the same rate of performance. The accessory note is usually about 25% shorter the duration than the main note.[6]

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[4] Flesch, op. cit., p. 45.

[5] Ibid., p. 46.

[6] Arnold Small, "An Objective Analysis of Artistic Violin Performance," The University of Iowa Studies in the Psychology of Music, Vol. IV, pp. 223-224.

A rocking type of trill, produced by a rolling motion of the hand, does not possess enough force in the attack to adequately stop the string at a very high rate of speed. For this reason, it is seldom used although it is very easily done and very fast.

Pulling of the Strings

A common fault among violinists is that the fingers often pull the string away from its natural position on the instrument.[7] This forms an unnatural relationship of the string with the other strings and by the varying of the size of the string itself, alters consistent intonation.

If the string is pulled away from its natural position, the distance from one string to another is altered enough to change the conditions of string crossings. Thus, if the A string is pulled to the right, the distance of the bow crossing from the D to the A would be much greater and from the A to the E much smaller than the distance would be under normal circumstances.

If a finger is placed on a string at a point that ordinarily produces one frequency, and the string is stretched out of line, the length of the string will be changed and as a result, the intonation altered. Therefore, if the violinist is not consistent in the production of either condition, he can never be sure of perfect intonation at any one point

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[7] Cramer, op. cit., p. 86.

upon the finger board. It is suggested that in order to maintain consistent conditions of string crossing and intonation, the finger be placed straight down upon the string, and any pulling of the string out of its natural position upon the finger board be avoided.

Intonation

Most authoritative investigations on violin intonation in the performance of single melodic lines indicate that the Pythagorean intervals are observed to be the ones most utilized.[8] In the performance of simple harmonies and double stops, the natural or just intonation is followed.[9] Pythagorean intonation includes expanded major sixths and thirds and contracted minor sixths and thirds. The perfect intervals of both Pythagorean and just intonation are the same.[10] The Pythagorean system is fairly easy to master, but just intonation referred to in the performance of double stops, is more abstract and difficult to accomplish.

One method of developing the use of correct just intonation was discovered by Tartini, and this method has been followed by violinists ever since his time.[11] This system involves the use of difference tones, the production of which

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[8] Paul C. Greene, "Violin Performance with Reference to Tempered, Natural, and Pythagorean Intonation," The University of Iowa Studies in the Psychology of Music, Vol. IV, p. 250.

[9] Lloyd, op. cit., p. 34.

[10] Ottokar Cadek, "Problems of String Intonation," Music Teachers National Association, Proceedings, 1938, p. 124.

[11] Paul Stoeving, The Violin, Its Famous Makers and Players, p. 42.

demands strict adherance to the ratios of the harmonic series, and depends upon correct tone production as well as careful listening. The problem of hearing can be overcome by directed attention or anticipation of the "Tartini tone", that results from the interval in question. A simple method of identifying this frequency is found in the order system used in locating the frequencies of the partials of the compound tone.

The major and minor sixths and thirds, perfect fourths, fifths and octaves, all occur at various places in the harmonic series. If Figure 3 is consulted, all of these intervals can be found. The octave occurs between 1 and 2, the fifth between 2 and 3, and the fourth between 3 and 4. The major third occurs between 4 and 5, and the minor third between 5 and 6. The major sixth occurs between 3 and 5, and the minor sixth between 5 and 8.

Tartini tones are the same as difference tones whose frequencies are equal to the difference of the frequencies of the intervals in question. (Difference tones of the first order are discussed on page 16 of this work.) Since the order numbers of the partials of the harmonic series indicate the number of times the frequency of the partial exceeds the fundamental, it is possible to find what the position of the difference tone will be by subtracting the lower order number from the higher one. (Figure 4 of this work contains a notation and chart of difference tones of the various orders as determined by this system.) As an example, let us take the minor sixth, which occurs between 5 and 8 (Figure 3). Subtract 5 from 8 and the result is 3, or in this case of the series in Figure 3, the combination of e and c produces g in the bass cleff. The perfect fifth falls between 2 and 3, therefore, the difference tone of this combination will have the order number 1, or in this case, the fundamental C. Thus, it is obvious that once the interval pattern of the harmonic series is memorized, it is relatively easy to locate the desired difference tone.

Difference tones of the second and third order are observable on the violin. However, they are very difficult to produce and demand the ultimate in tone production. When the student of the violin can produce several orders of difference tones at any point on the bow, his bowing is equal to any test of legato technic.

Tuning

The violin is tuned in perfect fifths. The fifth bears the order numbers of 2 and 3, therefore, when the fifth is in its correct ratio, the first order difference tone, one octave below the lowest frequency of the interval will be produced. If this difference tone is not produced, the fifth is not in tune. In tuning the A and E, A in the bass cleff should be heard. For the D and A, D in the bass cleff should be heard. For the G and D, G in the bass cleff should be heard.

The observance of beats, or the lack of them, form the second method of determining whether or not perfect intervals are in tune. (The physiology of beats is discussed on pp. 15 and 16 of this work.) Beats can be produced between the third partial of the lower frequency and the second partial of the higher frequency of a perfect fifth if the fifth is not quite in tune. When the beats are no longer evident, the fifth is in perfect tune. This phenomenon is easily identified and can be discerned even under conditions of mediocre tone production. The octave can be tuned by the observance of beats formed by inaccurate tuning of the lower frequency and the first order difference tone or the higher frequency and the first partial of the lower frequency.

Positions of Performance

The positions of performance upon the strings are numbered according to the size of the interval. The first finger will produce from the open string. When performing in the key of C, the first note, that the index finger will produce, indicates the first position, the second note, the second position. The rest of the positions are determined in the same manner. This same process is applicable in all keys. The certain identification of position can always be accomplished if the thumb maintains its position in the center of the hand. The first position, by reason of its obviousness, needs no method of location. The second position cannot be isolated because of its remoteness from any identifying structure. In third position, the thumb should touch the curve of the neck where it joins the body of the violin.[12] The first finger in the majority of keys will, when in this position, be one step behind the position of the thumb. In fourth position, the thumb will still touch the curve of the neck and the first finger will usually be directly above it. In fifth position, the first finger will generally be one step ahead of the thumb and so on up to the seventh position. These identifying measures are altered chromatically to allow for flat and sharp keys of three accidentals or over. This process makes it possible to pick out the higher positions and isolated notes with comparative ease. Unless these measures are followed, the performer can never be sure that the high position that is being sought will be located.

Shifting

When moving from one position to another upon the violin, at least one finger will remain upon the finger board. Generally speaking this finger is the index finger although there are many occasions for the second or third also to remain.[13] The reason that the first finger generally remains is that the positions are identified by the first finger.

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[12] Kross, _op. cit._, p. 21.

[13] Flesch, _op. cit._, p. 28.

The movement from one position to another, while the finger is still touching the string, produces what is known as glissando. This glissando should never be prominent in shifting, for a crescendo here would detract the attention from the note.[14] Flesch suggests that the pressure be relaxed during the slide. This throws the entire support of the instrument upon the shoulder and neck of the performer. However, if the slide is to be unimpaired by unnecessary grabbing of the thumb in order to support the instrument, this firm support by the shoulder must be maintained. Generally speaking, the most difficult shifts are downward because the hand pulls the instrument away from the neck.[15] Smooth slides are desirable, for any jerk will upset the bow and cause distracting noises. During the upward shift, the elbow should pull the hand around. The elbow should maintain this extreme position also during the downward shift.

Finger Preparation

The performance of quick broken chord passages demands that the fingers be placed in position before the bow ever touches the string. The accumulating of all the separate finger placements into one simple finger-set simplifies the most difficult passages and makes possible, that which otherwise would have been practically impossible.[16] Emil Kross

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[14] *Ibid.*, p. 28.

[15] *Ibid.*, p. 27.

[16] Cramer, *op. cit.*, p. 48.

suggests that the first finger always be used as a movable nut which forms a starting point for the fingerings above it.[17] This coincides with the theory of shifting and positions which places the burden of technic upon the first finger. Any finger by itself will experience difficulty in being consistent in intonation all over the finger board. If the first finger becomes the guide and all of the rest of the fingers reckon their distances from the first finger, greater consistency can be accomplished in intonation. In double-stops, since the first finger is the most accurate as to intonation, all of the higher finger placements should be adjusted to it. This continual holding down of the first finger also helps hold the strings down for the higher and the weaker fingers.[18]

Vibrato

Pitch vibrato has been determined as a movement of about .25 of a tone above and below the pitch being produced. The average rate of vibrato is about 6.5 cycles a second. The rate and extent of the pitch vibrato are independent of each other. This is true, both for the individual and for the ensemble.[19] There is also a type of vibrato known as intensity

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[17] Kross, op. cit., p. 42.

[18] Ibid., p. 41.

[19] Arnold Small, "An Objective Analysis of Artistic Violin Performance," The University of Iowa Studies in the Psychology of Music, Vol. IV, pp. 223-224.

vibrato.[20] This vibrato, however, does not enter the mechanical technic of performing upon the violin that can be adequately controlled and therefore is incidental to the discussion.

As a general rule, vibrato performed upon the lower frequencies is slower and wider than that applied to the higher frequencies.[21] Variations in vibrato speed and extent is purely a matter of taste upon the part of the performer and depends upon his emotional background and conception of the import of the phrase he is reproducing.

The alteration of pitch can be produced by an individual finger motion, a hand and finger motion, a wrist, hand and finger motion, or a pulsation of the entire arm. The last two of these are easily done but are impractical because of the smallness of movement and the slowness of speed. The most satisfactory motion is that of the hand and finger motion from the wrist.[22]

The hand moves back and forth from the wrist in a waving motion and the finger, while the tip rocks back and forth, takes up the greater movement of the hand proper by a type of shock absorber motion of the joints. This means, that as the hand moves foreward, the finger curls up and as the hand moves backward, the finger straightens out. During the

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[20] Ibid., p. 217.

[21] Cramer, op. cit., p. 85.

[22] Flesch, op. cit., p. 36.

entire operation, the finger still retains its basic arch, maintaining the pressure upon the string while varying its point of contact.[23] This isolation of the vibrato motion to the hand and fingers alone produces a quiet technic that can be controlled as to size and speed. Vibrato should not be considered as a constant member of the technic, but only as a measure to enable the tone of the slower strokes. Its presence in fast passages is disasterous to intonation and efficiency. Discretion in its use must be exercised at all times.

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[23] Personal interview with Louis Persinger, New York.

CHAPTER XI

RECOMMENDATIONS AND CONCLUSIONS

As a final thought, it is the author's opinion that educational effort in the field of music could take greater advantage of logical justification of technical processes than it is now generally doing. In the skills, patterns of performance have been arbitrarily set up and followed for generations by teachers and pupils, without any consideration on their part as to the scientific validity of such a process. It is the writer's belief that wider study and interest in the scientific basis of music will produce more practical performers and teachers, and consequently, less unanalytical and intolerant musicians.

There is room for further investigation in both of the fields discussed in this document. The complete physical properties of the violin will, no doubt, be set down in due time, for at present there are several serious attempts by competent scientists to do just that. The artistic phase of technic, being more abstract in nature than the more concrete properties of the instrument itself, provides a situation that, in order for technic to be adequately analyzed, the investigator must be at once a scientist and fine violinist. Until such a person undertakes the job, there can be no final answer to the question of which combination of rules forms a basis for the more adequate technic.

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