Fundamentals of Piano Practice

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All the efficient piano practice methods I could find have been assembled in this one book, starting with the teachings of Mlle. Yvonne Combe. Included are the material from over fifty of the most popular books on learning piano, and hundreds of articles and internet sites, that are relevant to practice methods.

Combe's grandmother was a famous soprano in France and Combe's mother was a voice teacher and they gave Yvonne a good start in piano. Yvonne won the first prize for piano at the Paris Conservatory in 1910 and graduated at age 13. Franz Liszt had attracted high level pianists to Paris and the "French School of Piano/Music" developed some of the most advanced teaching methods. Combe's mentors were Long, Cortot, Debussy, and Saint Saëns. She helped Debussy transcribe his new compositions for publication as he played them out on the piano. Debussy even added some of Combe's suggestions into his compositions. She was one of the most promising pianists of her time, concertizing and performing under famous conductors such as Saint Saëns, until she injured her hand in a bicycle accident (she was quite an athlete, a good skier), ending her performing career at age 15. She subsequently dedicated her entire life to teaching, organizing schools with up to 30 teachers in England, Switzerland, and Plainfield, NJ, USA, where she briefly coached Van Cliburn because her teaching methods were similar to his mother's.

Piano pedagogy had incorrectly attributed success in piano to "talent" for over a hundred years, thus relieving teachers of the responsibility for the failure of their students. This mistake stagnated teaching until about year 2000, when information became readily available over the internet. Today, talent is being replaced by knowledge, empowering students to quickly learn piano skills that were previously considered the exclusive "talents" of "geniuses" that, we now know, can be easily taught. Piano pedagogy can finally catch up to established fields of study that have proper textbooks that provide teachers with all necessary material that should be taught, enabling every student to learn at rates that were impossible during the age of exercises (Hanon) and "lesson pieces" (Czerny) devoid of music. Piano lessons are all about learning the "genius skills", project management, empowerment through education and, above all, making music.

> **Warning:** This is a work in progress, some sections have not been copied over, there are probably a few formatting errors/inconsistencies, and generally nuttiness. Please ignore or contribute patches on GitHub.

CHAPTER

ONE

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1.1 About

1.1.1 The Author

Born in Taiwan, 1938; lived in Japan, 1945-1958; started piano lessons in 1949, then received a BS degree from RPI, Troy, NY (1962), and Ph. D. in Physics from Cornell Univ., Ithaca, NY (1967), USA. Worked as analytical research scientist, 1967-1998, mostly with the Bell Telephone companies in NJ. This book originated from my observations on the methods of Mlle. Yvonne Combe, who taught our two daughters. While writing it, I discovered that piano pedagogy had never been researched, documented, and analyzed properly; therefore, this book is my attempt at correcting that deficiency. Although this book is the best teaching aid available now, this book demonstrates that it is not a finished product: it is just a beginning.

1.1.2 The Project

This is Sphinx adaptation of Chaun C. Chang's excellent book, Fundamentals of Piano Practice. Why bother? Well this makes the book more accessible and readbale on different devices, allowing in particular to take advantage of any feature offered by the browser. By virtue of being a Sphinx project, this book is also available in HTML, PDF, and LaTeX. As a GitHub project, anyone can contribute to this project by adding in content from the book and fixing any discrepancies in formatting.

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1.2 Preface

This is the best book ever written on how to practice at the piano! The revelation of this book is that there are highly efficient practice methods that can accelerate your learning rate, by up to 1,000 times if you have not yet learned the most efficient practice methods (see IV.5). What is surprising is that, although these methods were known since the earliest days of piano, they were seldom taught because only a few teachers knew about them and these knowledgeable teachers never bothered to disseminate this knowledge.

I realized in the 1960s that there was no good book on how to practice at the piano. The best I could find was Whiteside's book, which was an utter disappointment; see my review of this book in References. As a graduate student at Cornell University, studying until 2 AM just to keep up with some of the brightest students from all over the world, I had little time to practice piano. I needed to know what the best practice methods were, especially because whatever I was using wasn't working although I had taken piano lessons diligently for 7 years in my youth. How concert pianists could play the way they did was an absolute mystery to me. Was it just a matter of sufficient effort, time, and talent, as most people seem to think? If the answer were "Yes", it would have been devastating for me because it meant that my musical talent level was so low that I was a hopeless case because I had put in sufficient effort and time, at least in my youth, practicing up to 8 hours a day on weekends.

The answers came to me gradually in the 1970's when I noticed that our two daughters' piano teacher was teaching some surprisingly efficient methods of practice that were different from methods taught by the majority of piano teachers. Over a period of more than 10 years, I kept track of these efficient practice methods and came to the realization that the most important factor for learning to play the piano is the *practice methods.* Effort, time, and talent were merely secondary factors! In fact, "talent" is difficult to define and impossible to measure; it had become a meaningless word we use to hide our ignorance of the true definition of effective talent. In fact, *proper practice methods can make practically anybody into a "talented" musician!* I saw this happen all the time at the hundreds of student recitals and piano competitions that I had witnessed.

There is now a growing realization that "talent", "prodigy", or "genius" is more created than born (see Olson) – Mozart is possibly the most prominent example of the "Mozart Effect". Some have renamed this "The Beethoven Effect" which might be more appropriate because Mozart had some personality weaknesses, etc., that sometimes marred his otherwise glorious music, whereas psychologically, Beethoven composed the most enlightening music. Listening to music is only one component of the complex Mozart Effect. For pianists, making music has a larger effect on mental development. Thus good practice methods will not only accelerate the learning rate but also help to develop the musical brain, as well as raise the intelligence level, especially for the young. The learning rate is accelerated, compared to the slower methods (it's like the difference between an accelerating vehicle and one going at a constant speed). Therefore, in a matter of a few years, students without proper practice methods will fall hopelessly behind. This makes those students with good practice methods appear far more talented than they really are because they can learn in minutes or days what it takes the others months or years. The most important aspect of learning piano is brain development and higher intelligence. Memory is a component of intelligence and we know how to improve memory (see III.6). This book also teaches how to play music in our minds – this is called Mental Play (II.12), which naturally leads to absolute pitch and the ability to compose music. These are the skills that distinguished the greatest musicians and led us to label them as geniuses; yet we show here that they are not difficult to learn. Until now, the musician's world was restricted to the few "gifted" artists; we now know that it is a universe in which we can all participate.

Practice methods can make the difference between a lifetime of futility, and a concert pianist in less than 10 years for young, dedicated students. Using the right practice methods, it takes only a few years for a diligent student at any age to start playing meaningful pieces from famous composers. The saddest truth of the past two centuries has been that, although most of these practice methods were discovered and rediscovered thousands of times, they were never documented and students either had to rediscover them by themselves or, if lucky, learn them from teachers who knew some of them. The best example of this lack of documentation is the "teachings" of Franz Liszt. There are a dozen Franz Liszt societies and they have produced hundreds of publications. Numerous books have been written about Liszt (see Eigeldinger, etc., in References), and thousands of teachers have claimed to teach the "Franz Liszt method", complete with documented teaching lineages. Yet there is not one publication that describes what that method is! There are endless accounts of Liszt's accomplishments and technical prowess, yet there is not one reference on the details of how he got that way. Evidence in the literature indicates that even Liszt could not describe how he acquired technique; he could only demonstrate how he played. Since piano pedagogy has succeeded in losing track of how the greatest pianist acquired his technique, it is little wonder that we did not have a textbook on learning piano. Can you imagine learning math, economics, physics, history, biology, or anything else without a textbook, and (if you are lucky) only your teacher's memory as a guide? Without textbooks and documentation, our civilization would not have advanced beyond that of jungle tribes whose knowledge base had been passed on by word of mouth. That's basically where piano pedagogy has been for 200 years!

There are many books on learning piano (see References), but none of them qualify as textbooks for practice methods, which is what students need. These books tell you what skills you need (scales, arpeggios, trills, etc.) and the more advanced books describe the fingerings, hand positions, movements, etc., to play them, but none of them provide a reasonably complete, systematic set of instructions on how to practice. Most beginner music books provide a few such instructions, but many of those instructions are wrong – a good example is the amateurish advertisement on how to become "The Virtuoso Pianist in 60 Exercises" in the title of the Hanon exercises (see III.7.h). In piano pedagogy, the most essential tool for the teacher and the student – a reasonably complete set of instructions on how to practice, had been missing until this book was written.

I did not realize how revolutionary the methods of this book were until after I finished my first draft of this book in 1994. These methods were better than what I had been using previously and, for years, I had been applying them with good, but not remarkable, results. I experienced my first awakening after finishing that book, when I really read my own book and followed the methods systematically – and experienced their incredible efficiency. So, what was the difference between knowing parts of the method and reading a book? In writing the book, I had to take the various parts and arrange them into an organized structure that served a specific purpose and that had no missing essential components. As a scientist, I knew that organizing the material into a logical structure was the only way to write a useful manual. It is well known in science that most discoveries are made while writing the research reports, not when conducting the research. It was as if I had most the parts of a terrific car, but without a mechanic to assemble the car, find any missing parts, and tune it up, those parts weren't much good for transportation. I became convinced of this book's potential to revolutionize piano teaching and, in 1999, decided to provide it free to the world on the internet. In this way, it could be updated as my research progressed and whatever was written would be immediately available to the public. In retrospect, this book is the culmination of over 50 years of research that I had conducted on piano practice methods since my first piano lessons.

Why are these practice methods so revolutionary? For detailed answers, you will have to read this book. Here, I briefly present a few overviews of how these miraculous results are achieved and to explain why they work. I did not originate most of the basic ideas in this book. They were invented and re-invented umpteen times in the last 200 years by every successful pianist; otherwise, they would not have had such success. The basic framework for this book was constructed using the teachings of Mlle. Yvonne Combe, the teacher of our two daughters who became accomplished pianists (they have won many first prizes in piano competitions and averaged over 10 recitals a year each for many years; both have absolute pitch, and now enjoy composing music). Other parts of this book were assembled from the literature and my research using the internet. My contributions are in gathering these ideas, organizing them into a structure, and providing some understanding of why they work. This understanding is critical for the success of the method. Piano has often been taught like religion: Faith, Hope, and Charity. Faith that, if you followed procedures suggested by a "master" teacher, you will succeed; Hope that, "practice, practice, practice" will lead you to the rainbow, and Charity that your sacrifices and paying your dues will perform miracles. This book is different – a method is not acceptable unless the students understand why it works so that they can adapt it to their specific needs. Finding the correct understanding is not easy because you can't just pluck an explanation out of thin air (it will be wrong) – you must have enough expertise in that field of knowledge in order to arrive at the correct explanation. Providing a correct explanation automatically filters out the wrong methods. This may explain why even experienced piano teachers, whose educations were narrowly concentrated in music, can have difficulty in providing the proper understanding and will frequently give wrong explanations for even correct procedures. In this regard, my career/educational background in industrial problem solving, materials science (metals, semiconductors, insulators), optics, acoustics, physics, electronics, chemistry, scientific reporting (I have published over 100 peer-reviewed articles in major scientific journals and have been granted 6 patents), etc., have been invaluable for producing this book. These diverse requirements might explain why nobody else was able to write this type of book. As a scientist, I have agonized over how to concisely define "science" and argued endlessly over this definition with other scientists and non-scientists. Because the scientific approach is so basic to this book, I have included a section on IV.2. Science is not just the theoretical world of the brightest geniuses; it is the most effective way to simplify our lives. We need geniuses to advance science; however, once developed, it is the masses that benefit from these advances.

What are some of these magical ideas that are supposed to revolutionize piano teaching? Let's start with the fact that, when you watch famous pianists perform, they may be playing incredibly difficult things, but they make them look easy. How do they do that? Fact is, they are easy for them! Therefore, many of the learning tricks discussed here are methods for making difficult things easy: not only easy, but often trivially simple. This is accomplished by practicing the two hands separately and by picking short sections to practice, sometimes down to only one or two notes. You can't make things any simpler than that! Accomplished pianists can also play incredibly fast – how do we practice to be able to play fast? Simple! By using the "chord attack" (II.9). Thus one key to the success of the methods discussed here is the use of ingenious learning tricks that are needed to solve specific problems.

Even with the methods described here, it may be necessary to practice difficult passages hundreds of times and, once in a while, up to 10,000 times before you can play the most difficult passages with ease. Now if you were to practice a Beethoven Sonata at, say, half speed (you are just learning it), it would take about an hour to play through. Therefore, repeating it 10,000 times would take 30 years, or almost half a lifetime, if you had, say, one hour per day to practice and practiced only this sonata 7 days a week. Clearly, this is not the way to learn the sonata, although many students use practice methods not too different from it. This book describes methods for identifying just the few notes that you need to practice and then playing them in a fraction of a second, so that you can repeat them 10,000 times in a few weeks (or even days for easier material), practicing them for only about 10 minutes per day, 5 days per week – we have reduced the practice time from half a lifetime to a few weeks.

This book discusses many more efficiency principles, such as practicing and memorizing at the same time. During practice, each passage must be repeated many times and repetition is the best way to memorize; therefore, it doesn't make sense not to memorize while practicing, especially because this turns out to be the fastest way to learn. Have you ever wondered how every concert pianist can memorize hours of repertoire? The answer is quite simple. Studies with super memorizers (such a those who can memorize pages of phone numbers) have revealed that they are able to memorize because they have developed memory algorithms onto which they can quickly map the material to be memorized. For pianists, music is such an algorithm! You can prove this by asking a pianist to memorize just one page of random notes, and to remember them for years. This is impossible (without an algorithm) although this pianist may have no trouble memorizing several 20 page Beethoven *Sonatas*, and still play them 10 years later. Thus what we thought was a special talent of concert pianists turns out to be something anyone can do. Students who use the methods of this book memorize and perform everything they learn, except when practicing sight reading. This is why this book does not recommend exercises such as Hanon and Czerny, that are not meant to be performed; by the same token, the Chopin Etudes are recommended. Practicing something that wasn't meant to be performed is not only a waste of time but also destroys any sense of music you originally had. We discuss all the major methods of memory, which empower the pianist to perform feats that most people would expect only from "gifted musicians", such as playing the composition in your head, away from the piano, or even writing the entire composition from memory. If you can play every note in the composition from memory, there is no reason why you can't write them all down! Such abilities are not for show or bragging rights, but are essential for performing without flubs or memory lapses and come almost as automatic byproducts of these methods, even for us ordinary folks with ordinary memory. Many students can play complete compositions but can't write them down or play them in their minds – such students have only partially memorized the compositions in a manner that is insufficient for performances. Inadequate memory and lack of confidence are the main causes of nervousness. They wonder why they suffer stage fright and why performing flawlessly is such a daunting task while Mozart could just sit down and play.

Another example of helpful knowledge is relaxation and the use of gravity. The weight of the arm is important not only as a reference force for uniform and even playing (gravity is always constant), but also for testing the level of relaxation. The piano was designed with gravity as the reference force because the human body evolved to match gravity exactly, which means that the force needed to play the piano is about equal to the weight of the arm. When performing difficult tasks, such as playing a challenging piano passage, the natural tendency is to tense up so that the entire body becomes one contracted mass of muscle. Trying to move the fingers independently and rapidly under such conditions is like trying to run a sprint with rubber bands wrapped around both legs. If you can relax all unnecessary muscles, and use only the required muscles for just those instants at which they are needed, you can play extremely fast, effortlessly, for long periods of time without fatigue, and with more reserve strength than needed to produce the loudest sounds.

We will see that many "established teaching methods" are myths that can cause untold misery to the student. Such myths survive because of a lack of rigorous scientific scrutiny. These methods include: the curled finger position, thumb under method of playing scales, most finger exercises, sitting high on the chair, "no pain, no gain", slowly ramping up your speed, and liberal use of the metronome. We not only explain why they are harmful but also provide the correct alternatives, which are, respectively: flat finger positions, thumb over method, parallel sets (II.11, III.7.b), sitting lower on the chair, relaxation, acquiring speed by understanding "speed walls" (III.7.i) and identification of specific beneficial uses of the metronome. Speed walls are encountered when you try to play a passage faster, but reach a maximum speed beyond which the speed will not increase no matter how hard you practice. What causes speed walls, how many are there, and how do you avoid or eliminate them? Answers: speed walls are the results of attempts to do the impossible (you erect speed walls yourself by using incorrect practice methods), there are effectively an infinite number of them, and you avoid them by using the correct practice methods. One way of avoiding speed walls is not to build them in the first place, by knowing their causes (stress, incorrect fingering or rhythm, lack of technique, practicing too fast, practicing hands together [II.25] before you are ready, etc.). Another way is to come down in speed from "infinite speed" by using the parallel sets (II.11), instead of increasing the speed gradually. If you can start at speeds above the speed wall, there is no speed wall when you come down in speed.

This book frequently deals with one important point – that the best piano practice methods are surprisingly counter-intuitive. This point is paramount in piano pedagogy because it is the main reason why the wrong practice methods tend to be used by students and teachers. If they weren't so counter-intuitive, this book may not have been necessary. Consequently, we deal not only with what you should do but also with what you should not do. These negative sections are not for criticizing those who use the wrong methods but are necessary components of the learning process. The reason why intuition fails is that the piano tasks are so complex, and there are so many ways to accomplish them, that the probability of hitting the right method is nearly zero if you picked the simplest, obvious ones. Here are four examples of counter-intuitive practice methods:

1. Separating the hands for practice (II.7) is counter-intuitive because you need to practice each hand, then both together, so that it looks like you have to practice three times instead of just once hands together. Why practice hands separately, which you will never use in the end? Approximately 80% of this book deals with why you need to practice hands separately. Hands separate practice is the only way to rapidly increase speed and control without getting into trouble. It allows you to work hard 100% of the time at any speed without fatigue, stress, or injury because the method is based on switching hands as soon as the working hand begins to tire. Hands separate practice is the only way in which you can experiment to find the correct hand motions for speed and expression and it is the fastest way to learn how to relax. Trying to acquire technique hands together is the main cause of speed walls, bad habits, injury, and stress.

2. Practicing slowly hands together and gradually ramping up the speed is what we tend to do intuitively, but it turns out to be one of the worst ways to practice because it wastes so much time and you are training the hands to execute slow motions that are different from what you need at the final speed. Some students compound the problem by using the metronome as a constant guide to ramp up the speed or to keep the rhythm. This is one of the worst abuses of the metronome. Metronomes should be used only briefly to check the timing (speed and rhythm). If over used, it can lead to loss of your internal rhythm, loss of musicality, and bio-physical difficulties from over- exposure to rigid repetition (the brain can actually start to counteract the metronome click and you may either not hear the click or hear it at the wrong time). Technique for speed is acquired by discovering new hand motions, not by speeding up a slow motion; i.e., the hand motions for playing slowly and fast are different. This is why trying to speed up a slow motion leads to speed walls – because you are trying to do the impossible. Speeding up a slow play is like asking a horse to speed up a walk to the speed of a gallop – it can't. A horse must change from walk to trot to canter and then to gallop. If you force a horse to walk at the speed of a canter, it will hit a speed wall and will most likely injure itself by kicking its own hoofs to shreds.

3. In order to memorize well, and be able to perform well, you must practice slowly, even after the piece can be played easily at speed. This is counter-intuitive because you always perform at speed, so why practice slowly and waste so much time? Playing fast can be detrimental to performance as well as to memory. Playing fast can cause "fast play degradation", and the best way to test your memory is to play slowly. Thus practicing the recital pieces at full speed on recital day will result in a poor performance. This is one of the most counter-intuitive rules and is therefore difficult to follow. How often have you heard the refrain, "I played awfully during my lesson although I played so well this morning."? Therefore, although much of this book is oriented towards learning to play at the correct speed, it is the proper use of slow play that is critical for accurate memorization and for performing without mistakes. However, practicing slowly is tricky because you should not practice slowly until you can play fast! Otherwise, you would have no idea if your slow play motion is right or wrong. This problem is solved by practicing hands separately and getting up to speed quickly. After you know the hand motions for fast play, you can practice slowly at any time.

4. Most people feel uncomfortable trying to memorize something they can't play, so they instinctively learn a piece first, and then try to memorize it. It turns out that you can save a lot of time by memorizing first and then practicing from memory (we are talking about technically challenging music that is too difficult to sight read). Moreover, for reasons explained in this book, those who memorize after learning the piece never succeed in memorizing well. They will be haunted forever by memory problems. Therefore, good memorizing methods

must be an integral part of any practice procedure; memorizing is a necessity, not a luxury.

These four examples should give the reader some idea of what I mean by counter-intuitive practice methods. What is surprising is that the majority of good practice methods is counter- intuitive to most people. Fortunately, the geniuses who came before us have found the better practice methods and you will see them here.

Why does the fact, that the correct methods are counter-intuitive, lead to disaster? Even students who learned the correct methods (but were never taught what not to do) can drift back into intuitive methods simply because their brains keep telling them that they should use the intuitive methods (that's the definition of intuitive methods). This of course happens to teachers as well. Parents fall for it every time! Thus mere parental involvement can sometimes be counterproductive, because the parents must also be informed. This is why this book makes every effort to identify, and to point out the follies of, the intuitive methods. Thus many teachers discourage parental involvement unless the parents can also attend the lessons. Left to their own devices, the majority of students, teachers, and parents will gravitate towards the intuitive (wrong) methods. This is the main reason why so many wrong methods are taught today, and why students need informed teachers and proper textbooks. All piano teachers should use a textbook that explains practice methods; this will free them from having to teach the mechanics of practicing and allow them to concentrate on music where the teachers are most needed. The parents should also read the textbook because parents are most susceptible to the pitfalls of intuitive methods.

Piano teachers generally fall into three categories:

A. Private teachers who can't teach

B. Private teachers that are very good

C. Teachers at universities and conservatories

The last group is usually fairly good because they are in an environment in which they must communicate with one another. They are able to quickly identify the worst teaching methods and eliminate them. Unfortunately, most students at conservatories are already quite advanced and so it is too late to teach them basic practice methods. The (A) group of teachers consists mainly of individuals that do not communicate well with other teachers and invariably use mostly intuitive methods; this explains why they can't teach. By choosing only teachers that have web sites, you can eliminate many of the poor teachers because these have at least learned to communicate. Groups (B) and (C) are fairly familiar with the correct practice methods, though few know all of them because there has not been a standardized textbook; on the other hand, most of them know a lot of useful details that aren't in this book. There are precious few group (B) type teachers and the group (C) teachers generally accept only advanced students. The problem with this situation is that most students start with the group (A) teachers and never progress beyond novice or intermediate level and therefore never qualify for the group (C) teachers. Thus the majority of beginner students give up in frustration although practically all of them have the potential to become accomplished musicians. Moreover, this lack of progress feeds the general misconception that learning piano is a lifetime of fruitless efforts, which discourages the majority of parents and youngsters from considering piano lessons.

There is an intimate relationship between music and mathematics. Music, in many respects, is a form of mathematics and the great composers explored and exploited this relationship. Most basic theories of music can be expressed using mathematical terms. Harmony is a series of ratios, and harmony gives rise to the chromatic scale, which is a logarithmic equation. Most music scales are subsets of the chromatic scale, and chord progressions are the simplest relationships among these subsets. I discuss some concrete examples of the use of mathematics in some of the most famous compositions (IV.4) and include all the topics for future music research (mathematical or otherwise) in Section IV. It does not make sense to ask whether music is art or math; they are both properties of music. Math is simply a way of measuring something quantitatively; therefore, anything in music that can be quantified (such as time signature, thematic structure, etc.) can be treated mathematically. Thus, although math is not necessary to an artist, music and mathematics are inseparably intertwined and a knowledge of these relationships can often be useful (as demonstrated by every great composer), and will become more useful as mathematical understanding of music progressively catches up to music and as artists learn to take advantage of mathematics. Art is a shortcut way of using the human brain to achieve results not achievable in any other way. Scientific approaches to music only deal with the simpler levels of music that can be analytically treated: science supports art. It is wrong to assume that science will eventually replace art or, on the other extreme, that art is all you need for music; art should be free to incorporate anything that the artist desires, and science can provide invaluable help.

Too many pianists are ignorant of how the piano works and what it means to tune in the temperaments, or what it means to voice the piano. This is especially surprising because piano maintenance directly affects the ability to make music and technical development. There are many concert pianists who do not know the difference between Equal and Well temperaments (*2. Chromatic Scale and Temperament*) while some of the compositions they are playing (e.g. Chopin, Bach) formally require the use of one or the other. When to use electronic pianos, when to change to a higher quality (grand) piano, and how to recognize quality in a piano are critical decisions in the career of any pianist. Therefore, this book contains a section on piano selection and a chapter on how to tune your own piano. Just as electronic pianos are already always in tune, acoustic pianos must soon become permanently in tune, for example, by using the thermal expansion coefficient of the strings to electronically tune the piano (see Gilmore, Self-Tuning Piano). Today, practically all home pianos are out of tune almost all the time because it starts to go out of tune the moment the tuner leaves your house or if the room temperature or humidity changes. That's an unacceptable situation. In future pianos, you will flick a switch and the piano will tune itself in seconds. When mass produced, the cost of self-tuning options will be small compared to the price of a quality piano. You might think that this would put piano tuners out of work but that will not be the case because the number of pianos will increase (because of this book), the self-tuning mechanism requires maintenance and, for pianos in such perfect tune, frequent hammer voicing and regulation (that are too often neglected today) will make a significant improvement in musical output. This higher level of maintenance will be demanded by the increasing number of advanced pianists. You might suddenly realize that it was the piano, not you, that limited technical development and musical output (worn hammers will do it every time!). Why do you think concert pianists are so fussy about their pianos?

In summary, this book represents an unique event in the history of piano pedagogy and is revolutionizing piano teaching. Surprisingly, there is little that is fundamentally new in this book. We owe most of the major concepts to Yvonne (Combe), Franz, Freddie, Ludwig, Wolfie, Johann, etc. Yvonne and Franz gave us hands separate practice, segmental practice and relaxation; Franz and Freddie gave us the "Thumb Over" method and freed us from Hanon and Czerny; Wolfie taught us memorization and mental play; Johann knew all about parallel sets, quiet hands (III.6.l), and the importance of musical practice, and they all showed us (especially Ludwig) the relationships between math and music. The enormous amounts of time and effort that were wasted in the past, re- inventing the wheel and futilely repeating finger exercises with every generation of pianist, staggers the imagination. By making the knowledge in this book available to the student from day one of piano lessons, we are ushering in a new era in learning to play the piano. This book is not the end of the road – it is just a beginning. Future research into practice methods will undoubtedly uncover improvements; that's the nature of the scientific approach. It guarantees that we will never again lose useful information, that we will always make forward progress, and that every teacher will have access to the best available information. We still do not understand the biological changes that accompany the acquisition of technique and how the human (especially the infant) brain develops. Understanding these will allow us to directly address them instead of having to repeat something 10,000 times. Since the time of Bach, piano pedagogy had been in a state of arrested development; we can now hope to transform piano playing from a dream that seemed mostly out of reach to an art that everyone can now enjoy.

This book is my gift to society. The translators have also contributed their precious time. Together, we are pioneering a web based approach for providing free education of the highest caliber, something that will hopefully become the wave of the future. There is no reason why education can't be free. Such a revolution might seem to put some teachers' jobs in jeopardy, but with improved learning methods, piano playing will become more popular, creating a greater demand for teachers who can teach, because students will always learn faster under a good teacher. The economic impact of this improved learning method can be significant. This book was first printed in 1994 and the web site was started in 1999. Since then, I estimate that over 10,000 students had learned this method by year 2002. Let's assume that 10,000 serious piano students save 5 hours/week using these methods, that they practice 40 weeks/year, and that their time is worth $5/hour; then the total yearly savings are:

$$\frac{\text{5 hours / week}}{\text{student}} \times \frac{\text{40 weeks}}{\text{year}} \times \frac{\$5}{\text{hour}} \times 10,000 \text{ students} = \frac{\$10,000,000}{\text{year}}$$

in 2002, which will increase every year, or

$$\frac{\$1,000}{\text{year}} \text{ per student}$$

$10M/yr is only the savings of the students; we have not included the effects on teachers and the piano and music industries. Whenever adoption of scientific methods produced such leaps in efficiency, the field has historically flourished, seemingly without limit, and benefited everyone. With a world population over 6.6B today (2007), we can expect the pianist population to eventually exceed 1% or over 66M, so that the potential economic impact of this book could exceed several $B/year. Such huge economic benefits in any sector have historically been an unstoppable force, and this engine will drive the coming piano revolution. This book is the beginning of that revolution. More importantly, music and any gain in the development of a young child's mind, are priceless.

1.3 Chapter One: Basic Practice Methods

1.3.1 1. Practice Routines, the Intuitive Method

Many students use the following practice routine:

1. First, practice scales or technical exercises until the fingers are limbered up. Continue this for 30 minutes or longer if you have time, to improve technique especially by using exercises such as the Hanon series.
2. Then take a new piece of music and slowly read it for a page or two, carefully playing both hands together, starting from the beginning. This slow play is repeated until it can be performed reasonably well and then it is gradually speeded up until the final speed is attained. A metronome might be used for this gradual speed-up.
3. At the end of a two hour practice, the fingers are flying, so the students can play as fast as they want and enjoy the experience before quitting. After all, they are tired of practicing so that they can relax, play their hearts out at full speed; this is the time to enjoy the music!
4. Once the piece can be played satisfactorily, memorize it and practice "until the music is in the hands".
5. On the day of the recital or lesson, practice the piece at correct speed (or faster!) as many times as possible in order to make sure that it is in top condition. This is the last chance; obviously, the more practice, the better.

Every step of this procedure creates problems, is based on false beliefs and will limit progress to about the intermediate level even if the students practice several hours daily. This method tells the students nothing about what to do when they hit an impossible passage except to keep repeating, sometimes for a lifetime, with no clear idea of when or how the needed technique will be acquired. A teacher who can't even play the piano can teach this method! It leaves the task of learning to play the piano completely to the student - the method teaches nothing. Moreover, the music will come out flat during the recital and unexpected flubs will be almost unavoidable, as explained in this book. All these problems are solved using **"efficient practice methods"**.

The above practice routine seems so intuitively logical. Although human intuition helps us solve simple problems, when it comes to highly developed fields such as learning piano, intuition can not compete with **learning tricks** that past geniuses have discovered. Without these learning tricks, students are stuck with what we shall call **"intuitive methods"**, that are not based on the most efficient practice methods. "Talented" students, it turns out, have teachers, such as Combe, who know some of the efficient practice methods, or have discovered them through a lifetime of dedication to piano, and can learn unbelievably quickly. Any student can progress equally quickly if there is a textbook containing all the known efficient practice methods. Though "intuition" generally denotes something good, I have chosen "intuitive methods" to denote the old, discredited teaching methods because **the best methods are usually counter-intuitive**, as we shall see.

There are numerous books on piano [*83. Book Reviews: General Comments*]; they all teach what you should play, such as scales, trills, a Mozart sonata, etc., but they seldom teach how to acquire technique so you can play them. This book is a compilation of practice methods for acquiring technique with explanations of why certain methods work while others don't. Without the explanations, there is no way to know if a method works or not. Just because a teacher used the method for 30 years is not a valid explanation because so many of them have turned out to be wrong. Textbooks will free teachers from having to teach the mechanics of practicing and allow them to concentrate on music where the teachers are needed.

Piano teachers know that students must practice musically in order to acquire technique. Both musicality and technique require accuracy and control. Practically any technical flaw can be detected in the music. Nonetheless, many students tend to practice neglecting the music, preferring to "work" when no one is around to listen. Their reasoning is, "I'll practice nonmusically (which is easier because you can shut off the brain) until I can play it well, then I'll add the music." This never works because learning piano is all about training the brain, not finger calisthenics. Such practice methods produce "closet pianists" who love to play but can't perform [CH1.42].

Using efficient practice methods, you can learn in less than five years, what you might achieve in fifty diligent years using the "practice, practice, practice" (intuitive) approach. This book is not claiming that it will transform you into Mozarts, Beethovens or Chopins, although that can't be ruled out. It only claims that you can learn to play their music with ease.

1.3.2 2. Bench Height and Distance from Piano, Posture

The **bench height** should be set so that the elbows are slightly below the level of the keys when the upper arms are hanging straight down with the hands on the keyboard in playing position. Sit on the front half of the bench, not in the center, and at a **distance from the piano** such that the body does not interfere with the elbows when they move towards each other in front of the chest. For beginners, benches with fixed height will not be problematic because they can adapt to a range of heights.

Low bench height has the advantage that it makes it easier to lift the fingers, especially the 4th, and it may allow a straighter wrist, thus reducing the chances of contracting carpal tunnel syndrome. The shoulders will be closer to the keys, providing a wider reach and the head will be closer to the keys, providing a more intimate feel of the keys. It also makes it easier to sit with a straight spine and to sit farther away from the piano, which provides more elbow space. Sitting lower is more compatible with many techniques such as CH1.21, using the Power Thumb [CH1.31] or the flat finger positions [*4. Curled and Flat Finger Positions, Curl Paralysis*], etc. It also allows the use of forearm rotation to rotate the wrist rapidly.

Posture is important: a high position can cause the players to hunch their backs, so that a conscious effort must be made to sit straight up. Massage therapists know that a crooked spine, head leaning forward, can cause long-term problems from stress.

The high position makes it easier to lean forward and exert downward pressure with the shoulders for loud passages. It may also make it easier to prevent "hand collapse" (HC), which is a controversial subject because the different types of HC have not been clearly defined, although HC is prominently discussed in several books.

Whatever advantages/disadvantages there are to different bench heights, they can be compensated by an adjustment in wrist position. In addition, each person has different ratios of the lengths of the spine, upper arm , etc., so that bench height alone does not determine the optimum position.

Bench height becomes important for advanced pianists; thus the best time to test for optimum height is at the advanced level. More factors favor the lower position, so that the optimum position is probably one with the elbow one to two inches below the keyboard. This will make most commercial non-adjustable benches too high by several inches. Adjustable benches are highly recommended.

A majority of teachers and books recommend sitting with the elbow at the level of the keys and a few, especially the older ones, recommend higher positions. Many concert pianists sit high, probably because they had teachers who preferred the high position, and became accustomed to it. The lower position is recommended here because it has more advantages.

1.3.3 3. Starting a Piece

Learn only music that you can perform. The days of "years of exercises and lesson pieces for technical development" are over. Start assembling a repertoire immediately; the list of great music containing technical lessons is effectively infinite, so you don't need anything else! It is never too early to practice performances; it is never too early to make music. One of the most harmful comments I have heard is that youngsters are too young for Chopin. Then there is kiddie music for the youngest: kiddie music exists only in the minds of adults. Children of any age can appreciate good music and perform them; there isn't a single reason why children should be held back.

Of course, beginners need *Beginner Books*, (Humphries, Beyer, Thompson, Faber & Faber, etc.) to learn the necessary conventions and basic music theory. There is no need to go through every page, just pick up those elements that are new to you. With the practice methods of this book, the student can start with performable music that may present challenges, but such challenges are just what is needed to learn how to use these methods. Exercise/lesson books such Hanon, Czerny, Cramer-Bulow, Dohnanyi Exercises, Cortot, etc., are obsolete. There are pianists who were raised on such exercises that still teach them and they are certainly not worthless, but there are better methods. There is plenty of easy starter music that are performable, such as Magdalena's *Easy Bach*. Most importantly, choose the music that you like. We shall choose Beethoven's Für Elise (*Music Sheet*) to illustrate the practice methods because it can be learned very quickly using these methods and contains all the elements needed to illustrate them.

Listen to recordings of pieces you decide to learn. This is the fastest way to learn musicality and improve technique. It is a great way to gather musical ideas, and explore new material. Listen to several recordings of the same piece. Your teacher should be able to play and demonstrate for you; it is better to have teachers who can play your pieces.

Next, analyze the structure of the piece and estimate how long it will take to learn it — these are necessary components of *59. Project Management*; advanced pianists become experts in project management. If you can not estimate the completion time, it means that you do not know all the practice methods needed to learn the piece. Of course, the estimate will be wrong, but the exercise of estimating teaches you what practice methods are needed. Without the estimate, there is a chance that you will never finish the piece; however, no music is ever finished, so how do you know you finished it? The performance! Once it is performed successfully, it is finished.

Start analysis by numbering all the bars. There are two versions of Für Elise sheet music differing in the way the repeats are indicated, which changes the bar numbers but does not change the music. I am using the long version with 124 full bars. The short version has (105) bars; the ( ) indicates the bars for the shorter version. The first 4 bars are repeated 15 times, so that by learning 4 bars, you can play 50% of the piece! Another 6 bars are repeated 4 times, so by learning 10 bars, you can play 70% of the piece. This 70% can be memorized in less than 30 minutes because these 10 bars are simple. There are two interruptions among these repetitions that are more difficult for a total of 50 distinct bars to learn. Each of the difficult sections can be memorized in one day, so you can memorize the entire piece in three days. Give yourself two more days to practice (additional instructions are given below), and you should be able to play the piece (with questionable quality) in a week. How long it will take you to polish this piece so that it is performable will depend on your skill level and knowledge of practice methods.

1.3.4 4. Curled and Flat Finger Positions, Curl Paralysis

The **curled position** has been defined in the literature as the "relaxed" natural position of the fingers when you hang the hands down your sides. This works for pianists who have been playing for years, but how a two-year-old, or a golfer, or swimmer, who had never played piano, would hang the hands can be any position. To properly define the curled position, place both hands on a tabletop, about a foot apart, palm side down. Form domes with the hand and fingers as if you are holding softballs, with finger tips touching the table. The right and left thumb nails should point towards the left and right shoulders, respectively. This is the starting position for the fingers and is called the curled position because the fingers are curled over the imaginary ball.

The advantages of the curled position are that it: provides firm control of each finger, facilitates playing between black keys, and aligns the fingers close to a straight line so that all keys are played at about the same distance from their pivots [balance rail, see *80. Grand Piano Action Diagram*]. Those with long fingers find it necessary to curl fingers 2-4 more in order to play the thumb. The disadvantages are:

1. you play with the fingertips that are easy to injure and do not provide sufficient padding for better control of touch or playing FFF and PPP; two types of finger tip injuries can occur with the curled position, see *60. Injury, Health*
2. the downstroke requires precise control of complex sets of muscles
3. it is easy to miss black keys because the finger tip area is smallest
4. it suffers from **curl paralysis**.

To demonstrate curl paralysis, stretch any finger (except the thumb) straight out and wiggle it up and down as if depressing a piano key. Then gradually curl the finger, keeping the same wiggle motion as before. Note that the maximum wiggle decreases with increasing curl: paralysis increases with curl.

One unusual position is the **"collapsed" position** in which the last phalange (nail phalange) is bent outwards, instead of the "normal" straight or slightly curled. There is no evidence that this position is harmful, and it has the advantage of playing more with the front pad of the finger. Furthermore, the muscle to this phalange can be relaxed because tendons naturally limit the outward motion, thus simplifying finger motions and increasing *Relaxation*. Although some teachers abhor this position because it looks unnatural, there is no known reason why it is bad and has advantages. Trying to "correct" this position can create terrible problems.

The curled position must be taught, especially to beginners, but there are many other positions that must be studied. Each pianist has his own natural position so that forcing every student to adopt a single "standard" curled position is a common mistake of older teaching methods that can significantly slow down a student's progress.

When both black and white keys are played, the black keys should be played with less curl because they are higher. We shall call the family of non-curl positions the **Flat Finger Positions (FFP)** - see *Prokop*, P.13-15 for FFP photos.

(1) The most extreme FFP is the straight flat position: all fingers are stretched straight out. It is the way V. Horowitz played and has the advantages that: the keys are played with the front pads of the fingers which reduces the probability of injuries from long practice sessions, and the keystroke motion is the simplest of all positions, requiring use of the smallest number of muscles. This facilitates relaxation. The finger contact areas with the keys are maximized, reducing the probability of missed notes, and you can feel the keys with the most sensitive front pads of the fingers. The sensitivity gives more tone control whereas, with the curled position, you are restricted to one tone which tends to be harsher. Because it is simpler, and does not suffer curl paralysis, you can play faster; however, the fastest position is one in which you play the black keys FFP and the white keys curled because this places every finger closest to its key. FFP increases the reach and reduces interference from the fingernails.

Proponents of the curled position argue that it is the strongest position because of the arch shape; this is false because athletes who do hand stands use the front pads, not the fingertips; thus the FFP is the stronger position.

Nomenclature: Phalange (also called phalanx; plural is always phalanges) is the name for the finger bones beyond the knuckle; they are numbered 1-3 (thumb has only 1 and 3), and the 3rd phalange is the "nail phalange" (see *Prokop*, P. 101).

With FFP, the tendons under the finger bones hold the fingers straight when playing. Unlike the curled position, no effort is needed to keep the fingers straight because tendons limit the amount of backwards bending. There are pianists whose nail phalange naturally bends backwards (collapsed position). There is nothing wrong with this and it does not interfere with FFPs. Learn to use these tendons to help with relaxation. The nail phalange should always be relaxed. The relaxed 3rd phalange also acts as a shock absorber. When playing fortissimo with curled fingers, both the extensor and flexor muscles must be controlled in order to hold the curled position. In FFP, the extensors are relaxed and only the flexors are needed, reducing stress and simplifying the motion. Thus the curled position is complex and requires a good fraction of a lifetime to learn properly, whereas the FFP is more natural. That is why self taught pianists tend to use more FFP.

The best way to practice FFP is to play the B major scale, in which fingers `2,3,4` play the black keys and `1,5` play the white for both hands. Since `1` & `5` should not generally play the black keys in runs (a fingering rule), this is exactly what you want for practicing FFP.

Play FFP with the palm of the hand almost touching the keys. This increases accuracy because you know exactly where the keys are. FFP legato is easier and different from legato using the curled position because the curled position produces a harsher tone. It is easier to play two notes with one finger FFP because the finger can be turned at an angle to the keys so that the large area under the finger can play two keys. Because Chopin was known for his legato, was good at playing several notes with one finger, and recommended practicing the B major scale, he probably used FFP. Combe taught FFP and noted that it was particularly useful for playing Chopin. One legato trick she taught was to start with FFP and then curl the finger so that the hand can move from white to black keys without lifting the finger off the key. Parts of the Bach Inventions are good for practicing FFPs, suggesting that he composed them with both FFP and curl in mind.

The freedom to play with any amount of curl is a necessary technique. One disadvantage of the curled position is that the extensor muscles are not sufficiently exercised, causing the flexor muscles to strengthen and even overpower the extensors. In FFP, the unused flexor muscles are relaxed; in fact, the associated tendons are stretched, which makes the fingers more flexible. There are numerous accounts of the extraordinary flexibility of Liszt's fingers. Liszt used FFP to improve tone (*Boissier, Fay, Bertrand*). Because of the tradition of teaching mostly the curled position, many older concert pianists under-use the FFPs and had to work unnecessarily hard to acquire technique.

(2) Another FFP is the pyramid position in which all the fingers are straight, but are bent down at the knuckles. This has the advantage that the downstroke action is simpler than for the curled position. Some pianists feel naturally relaxed with this position. If you are not naturally comfortable with this position, there is no need to learn it.

(3) The spider position is similar to the pyramid, except that the bend occurs mostly at the first joint after the knuckle. As with the pyramid position, the main reason for using this position is that it is a natural position for that pianist. Many pianists are unable to use this position, so don't be concerned if you can not. Of all the FFPs, the spider position may be the most versatile. The insect kingdom adopted this position after hundreds of millions of years of evolution.

Chopin's legato is documented to be particularly special, as was his staccato. Is his staccato related to the FFP? Note that all the FFPs take advantage of the spring effect of the relaxed third phalange, which might be useful in playing staccato.

It is easier to play FFP when the bench is lowered. There are numerous accounts of pianists discovering that they can play better with a lower bench height (Horowitz and Glenn Gould). They claim to get better control, especially for pianissimo and speed.

Don't worry if you can't use all these positions. Use those that are comfortable, natural positions for you. The purpose of these discussions is to caution teachers against forcing every student to use one idealized curled position because that can create problems. Each hand is different and each position has advantages and disadvantages that depend more on the person than on the position.

In summary, Horowitz had good reasons to play with flat fingers and the above discussions suggest that part of his higher technical level may have been achieved by using more FFPs than others, and sitting low. Although the curled position is necessary, the statement "you need the curled position to play technically difficult material" is misleading – what we need is flexible fingers. Playing with FFPs liberates us to use many useful and versatile finger positions. We now know how to play all those black keys, especially arpeggios, and not miss a single note. Thank you, Johann, Frederic, Franz, Vladimir, Yvonne (Combe)!

1.3.5 5. Reading, Fingering

Beginners who know nothing about reading, fingering, or how to start learning piano, should use the *Beginner Books*, where they can find the beginner information including fingerings (Beyer does not tell you that thumb is finger #1 and pinky is #5!). Here are the fingerings for scales and arpeggios: CH1.29; they should be practiced until they become automatic habits. Thumb is rarely asked to play the black keys because that places the other fingers too close to the fallboard.

Learning reading is always a struggle initially for beginners. Teachers should not help them by showing them the keys; let them struggle to find the keys because everybody must go through this stage. Start with easy material, making sure that the student has learned each material well before proceeding to the next. During the reading lesson, make sure that the student is actually reading and has not memorized the keys, by assigning new material; instruct the parents not to help them also while practicing at home.

The **time signature** at the beginning of each composition looks like a fraction, consisting of a numerator and a denominator. The numerator indicates the number of beats per measure (bar) and the denominator indicates the note per beat. For example, 3/4 means there are three beats per measure and each beat is a quarter note. Knowing the time signature is critical when accompanying or playing in a group because the moment that the accompanist starts is determined by the starting beat which the conductor indicates with the baton. This beat is indicated in the sheet music — it is frequently not the first beat of a measure! The **key signature** indicates the key in which the music is written and appears before the time signature. It indicates the locations of the sharps and flats.

Do not take extended reading lessons just to learn all the music notations because you won't remember them months later when you need them. Learn to read music notations as they are encountered in new compositions you learn, or when practicing scales and arpeggios. Teachers must balance the students' abilities to read and to memorize, which is treated in *14. Memorizing, Close Your Eyes and Play*.

The most important rule for fingering is that, for the same or similar passages, always use the same fingering. Changing the fingering after you have partially learned a section is a major decision because getting rid of old habits and establishing new ones takes a lot of work. During a performance, the old habits can suddenly pop up and result in a flub.

The standard fingerings are generally not indicated in the sheet music and they do not always work depending on what comes before and after, in which case you need non-standard fingerings; these are generally indicated in most sheet music. Although some indicated fingerings may seem awkward at first, you will find that they are needed when you get up to speed and play hands together.

For the **Für Elise**, look for editions that have the non-standard fingerings indicated. Bar 52 (31 short version) RH, can be played 2321231 where the 3212 is the turn, or 3432131.

1.3.6 6. Hands Separate (HS) Practice

Technique is acquired most quickly using hands separately (HS) practice for music that is difficult and require technical development. If it can be played hands together (HT) at final speed, skip HS work, and you are done. Beginning students should practice everything HS just to learn the methodology. Easy sections that don't require HS work will be completed very quickly, so little time is wasted. For difficult material, separating the hands speeds up the learning process by allowing the application of a myriad of learning tricks that are major topics throughout this book.

To practice HS, choose two sections to practice, one for each hand. Practice one hand and switch hands as soon as the working hand gets tired. In this way, you can work hard 100% of the time without fatigue because one hand is always resting. When a hand that had been working hard is rested, it is initially tired and sluggish. As it rests, it recovers and becomes reenergized and eager to play — this is the best time to switch hands because it can perform miracles. Rest it longer, and it will cool off and become sluggish again. Thus you must learn from experience, the best time to switch hands; the shortest times are about 10 seconds. Depending on the conditioning of the hands, the degree of difficulty, etc., this rest time can be longer. The best switching time is the shorter of the optimum rest time of the resting hand and the "tiring time" of the working hand.

HS practice is simpler than HT because most of the learning is confined to one hemisphere of the brain for each hand. HT practice involves both hemispheres which is more complex and takes longer to learn. HT is a separate skill [CH1.37] that must be practiced after all HS work is done. It is best to learn one skill at a time because, if two skills are practiced simultaneously, difficulties in one skill can prevent progress in the other.

A critically important HS skill is experimentation. This ability is what separates the mature musician from the perpetual student. It is impossibly difficult to experiment with new hand motions when practicing HT. Experimentation consists of two phases: diagnosing the problem and then solving it, as demonstrated throughout this book.

HS practice is used to increase your brain speed. Beginners can't play fast because every brain has its speed limit: it has never been asked to work faster. This limit is different from *12. Speed Wall* that are limited by lack of technique. Just because you have heard music at high speeds doesn't mean that your brain/fingers can execute them. Playing fast will actually alter the brain and its connections to the hand. When playing fast for the first time beyond the brain's old speed limit, you should feel a strange new sensation like the first time you learned how to ride a bicycle. At the highest speeds, this feeling can only be described as "exhilarating".

Technique can be pushed much further HS than HT, and is a lot of fun! It is superior to anything Hanon or any other exercise can provide. This is the time to figure out "incredible ways" to play that piece. The amount of time spent, working on pieces that have been completely mastered, is what separates concert pianists from amateurs, because this is when you really develop advanced techniques.

For beginners, HS is mainly for acquiring technique and getting up to speed for learning new music quickly. For advanced players it has a myriad uses limited only by human imagination. Some pianists not brought up with HS methods consider HS to be trivial and unimportant because it is so easy to learn. In practice, 80% of this book discusses what magic you can perform when the hands are separated. HS is trivial only for the uninformed.

Pianists who never practice HS will always have a technically weaker LH. The LH plays passages that require more strength (the lower hammers and strings are heavier), but it often lags in speed and technique because the melodic material in the RH tend to be technically more demanding (which is the clearest demonstration that technique is not finger strength). The HS method will balance the hands because you can give the weaker hand more work.

For passages that one hand can play better than the other, the better hand is often your best teacher. To let one hand teach the other, select a short segment and play it rapidly with the better hand, then repeat immediately with the weaker hand, one octave apart to prevent collisions. You will discover that the weaker hand can often "catch on" or "get the idea" of how the better hand is doing it. The fingering should be similar but does not need to be identical, because the LH is a mirror image of the RH and it is usually impossible to use the same fingering. An interesting alternative is to use mirror notes and identical fingering, but then the music from the two hands will not be the same. Once the weaker hand "gets the idea", gradually wean it off by playing the weaker hand twice and the stronger hand once, then three against one, etc., until the stronger hand is not needed anymore.

In the intuitive method, both hands are played together, hoping that the weaker hand will catch up to the stronger one. In reality, the opposite happens because at low speed, nothing happens to both hands and at high speed, the weaker hand is playing stressed, forming *12. Speed Wall* while the stronger hand keeps improving.

This ability of one hand to teach the other is more important than most people realize. It works with practically anything you practice HS. The reason for this broad applicability is that one hand always plays something better than the other

1.3.7 7. Difficult Sections First, Segmental Practice, Continuity Rule

Practice the **most difficult** sections first because you must spend the most time there. If the easy sections are practiced first, the difficult sections will never be learned sufficiently well because time will run out; that's not just human nature, but also a time management flaw. Technique acquisition also suffers because practicing the difficult sections is what advances technique. Practice the easy sections first only if that simplifies the learning of other sections, as we shall see for Chopin [*55. Chopin's Fantaisie Impromptu, Op. 66, Polyrhythms*].

Segmental practice

Choose two short segments to practice, one each for the right (RH) and left hand (LH). The segments can be any length, down to just one or two notes, but are generally about one bar. The shorter the segment, the easier it is to play, the more times you can practice it in a given time, and the faster you can play it without forming bad habits. Segmental practice, combined with HS practice, enables experimentation with new hand motions, etc., that results in a powerful method for acquiring technique.

Continuity Rule

When choosing a segment, include the beginning of the next segment. This overlap of segments, called a conjunction [*9. Parallel Sets (PSs), Conjunctions, Cycling*], facilitates the joining of segments later on. The continuity rule applies to segments of any length; for example, at the end of the first movement, include the beginning of the second movement. A related rule is the Contiguity Rule.

Contiguity Rule

Finish each project before moving on to the next, and finish related projects first. This means do not start on a second Beethoven Sonata until the first one is completely finished; otherwise, you may never complete either of them.

Our **Für Elise** example has two sections that are more difficult than the rest. They are bars 45 (24, short version) to 56 (35), and 82 (61) to 105 (84). The first section might be more difficult, so start with that: bar 53: practice the RH, including the first four notes of bar 54 (continuity rule); similarly, practice the LH, including the first chord of bar 54. The RH fingering is `251515151525,1254`. Repeat this procedure with bar 54. When satisfactory, connect the two (bars 53, 54), HS only.

HS and segmental practice are the most efficient practice methods for acquiring technique quickly.

1.3.8 8. Relaxation, Gravity

The human brain can be quite wasteful. In conducting any activity, the untrained brain activates many more muscles than is necessary, often activating opposing muscles that fight each other, or neglecting to relax the muscles after their work is done. This waste gets worse in difficult or complex situations. For simple activities, such waste does not matter. In piano, it can make the difference between success and failure because we are using the brain and hands at tasks beyond their evolutionary capabilities.

Relaxation in piano is not relaxing all muscles, but relaxing all unnecessary muscles so that the necessary ones can do their job; the necessary ones are frequently asked to work extremely hard. We also need to quickly relax the working muscles as soon as their work is done in order to reduce fatigue and to prevent interference with subsequent movements. This is called **rapid relaxation**; the relaxation speeds must match the keystroke speeds for the system to work. This requires conscious practice, because it is not normally required.

All pianists have experienced the phenomenon in which there is no progress for extended periods of practicing difficult material until suddenly, you can play it. What happened? There are various causes such as discovery of [CH1.36], but the most common cause is relaxation which produces a positive feedback loop: you have become good enough to relax; the more you relax, the better you can play, and the better you can play, the more you can relax, etc. Incorporating relaxation from the beginning immediately starts this positive feedback, greatly accelerating technique acquisition.

The realization that relaxation is important has spawned various schools of teaching, such as the arm weight method. Getting bogged down in such methods is not a good idea because they mostly emphasize what you shouldn't do over what you should do because the material is not sufficiently understood. Instead, understanding the basic principles is better. The arm weight is important in piano because humans evolved with muscle strengths that match gravity exactly. Accordingly, the piano was designed with all required forces as close to gravity as possible. Students not taught relaxation can press down on the piano constantly or tense their muscles most of the time, especially when practicing difficult material. Gravity provides a constant reference force of exactly the correct magnitude against which to measure the level of relaxation. This answers the question "how do I know if I am relaxed?" You are relaxed when you can feel gravity pulling on your body and hands.

This has led to the concept of the **gravity drop**. Raise your hand four to ten inches above the keyboard and drop it on one key with one finger, letting gravity pull the hand down, as if the hand is going to fall right through the keyboard. At the bottom of the keydrop, stiffen the finger so that the keyboard stops the hand and the finger is supporting the hand; then immediately relax the hand. If sufficiently relaxed, you will feel gravity pulling the hand down. If done correctly, you were relaxed during the fall and the finger accelerates through the keydrop, which is the process of "playing deeply into the keys" to produce a deep tone [CH1.42].

The gravity drop is not the way to play the piano, but is useful for illustrating relaxation, and everybody should practice it. A rising elbow is often an indication of stress; when this happens, relax by allowing gravity to pull the elbows (and shoulders) down.

1.3.9 9. Parallel Sets (PSs), Conjunctions, Cycling

Parallel Set (PS) practice, also called chord attack, provides the fastest way to increase finger speed. PSs are groups of notes that can be played simultaneously with one hand, such as 12345 or 1324 and every note appears only once. They are played in order from left to right.

Let's play a two-note PS, 23. Play middle C and D with RH fingers 2 and 3, one after the other. You can speed up this PS by playing them like grace notes. It can be played even faster by dropping the hand onto the keys, but letting 2 land slightly ahead of 3. You can increase the speed even more by letting 3 land closer and closer to 2. At the limit when they land together, you are playing at a mathematically infinite*[0] speed!

In practice, nobody can play infinitely fast because no one has such accuracy — the accuracy in playing intervals determines the fastest speed that the pianist can play, so it is necessary to practice playing accurate intervals in order to achieve hyper-speeds using PSs.

Let's apply PSs to speeding up the **Alberti** construct CGEG. The objective is to to play any number of CGEG in succession, at any desired speed, such as in the 3rd movement of Beethoven's Moonlight. LH: start with 5 on C3 and play 5131. Play it as fast as you can. Remember this speed and we will compare it to the final speed after applying the PS method. Since we need something for the RH so that we can switch hands, let's do the same with the RH: with 1 on C4, play CGEG,``1535``, as fast as you can play accurately, and again, remember this speed (measure it with a metronome).

LH: start with the simplest PS, two notes, 51. Practice in units of four PS repeats called a **quad**: 51,51,51,51. When this is satisfactory, practice four quads in succession: quad,quad,quad,quad, until the hand tires or stress starts to build up (perhaps 10 seconds), then switch hands and repeat a similar procedure for the RH. "Satisfactory" means final speed of about a quad per second (slower for beginners), *relaxed and easy*.

For increasing speed quickly, practice "chords" instead of PSs. Play both 51 notes simultaneously as an interval or chord, and practice rapid **chord quads**. Play each quad in one down movement of the hand, keeping all fingers close to the keys. Then raise the hand to play the next quad.

As you increase speed (chord quads), stress should start to build up. Then stop speeding up (or even slow down slightly) and relax the whole body (and hand) as you play, breathing comfortably. As you add relaxation, you should feel the stress draining out of the hand as you keep on playing. This is how relaxation is practiced! Switch hands as soon as it starts to feel tired and begins to slow down. The rested hand should be eager to play and it can now play faster than before.

To transition from quad chords to fast PSs, substitute the last chord of a chord quad with a fast PS: (chord,chord, chord,chord)   (chord,chord,chord,PS) keeping the repeat rate the same within each quad. Once this is satisfactory, substitute two PSs, etc., until the entire quad is PSs. This method enables you to transition immediately to fast PSs, because the chord and fast PS are similar.

Next let's try three-note PSs. LH: 513, RH: 153, and repeat the above procedure. Play all three notes in one down movement of the hand and practice the PSs in quads. Start with 513 chord quads if you have difficulties with the PSs. Complete this practice for both hands.

[0] In mathematics, infinity is defined as inf. = 1/n, n 0; "infinity is one divided by n, as n approaches zero". With PSs, you are conducting this mathematical operation on the piano using a two-note PS. Speed = 1/delta where delta is the time difference between the two fingers. As speed increases delta decreases, until it becomes zero when the two notes are played as an interval.

Conjunction

The final note in the CGEG is a repeat note and cannot be practiced as a PS (see definition of PSs at the beginning of this section). This G connects the PS, CGE, to the notes that follow, so it is called a conjunction. Conjunctions are what slow you down — you cannot play conjunctions infinitely fast. In order to practice fast conjunctions, we introduce the concept of Cycling.

Cycling

Cycling, also called looping, is a procedure in which the same short segment is cycled over and over continuously: `CGEG,CGEG,CGEG, . . . . . . .`. In this case, we can cycle without adding new notes. We say that `CGEG` is self-cycling because it has a built-in conjunction `G`. To enable rapid cycling, you may need to practice the PS `EG` and then `GEG`. Now cycle the `CGEG` twice: `CGEG,CGEG` with no pause in between. This step is facilitated by using the continuity rule [*7. Difficult Sections First, Segmental Practice, Continuity Rule*]: when practicing `CGEG`, include the first note of the next cycle and practice `CGEGC`. So practice `CGEGC` quads. Then practice cycling `CGEG` twice `CGEG,CGEGC`, then three times, etc. Play one `CGEGC` with one down motion of the hand. Finally practice cycling quads - now you are playing a quad of quads. Why always quads? In general, if you can do a quad comfortably, relaxed, you can play an indefinite number.

You are done! Now compare your new speed with what you did before applying the PS methods. A person who is experienced with these methods would start with `CGE` chord quads, then `CGE` PS quads, then `CGEGC` quads, then `CGEG` cycling, and finish the process in minutes. This is repeated several days in a row, until the final speed is faster than needed.

Cycling is pure repetition, but it is a device to minimize repetitive practicing. Use cycling to acquire technique so rapidly that it eliminates unnecessary repetitions. In order to avoid picking up bad habits, change speed and experiment with different CH1.36 for optimum play and always practice relaxation. Do not cycle the exact same thing too many times because that's how you pick up bad habits. Over 90% of cycling time should be at speeds that you can handle comfortably and accurately, for reasons to be explained in CH1.23. You are done when you can play at any speed for any length of time, completely relaxed, and with full control. Then cycle down to slow speeds because you might find that certain intermediate speeds give trouble. Practice those speeds because they may be needed when you start HT.

If a technique requires 10,000 repetitions (typical for really difficult material), cycling allows you to get them done in the shortest possible time. Representative cycle times are about 1 sec., so 10,000 cycles is less than 4 hours. If you cycle this segment for 10 min. per day, 5 days a week, 10,000 cycles will take almost a month. Clearly, very difficult material will take many weeks to learn even when using the best methods. This explains why students without proper guidance can practice for years without significant improvement.

Cycling is potentially the most injurious piano practice procedure. Don't over-do it the first day, and see what happens the next day. If nothing is sore, or you don't detect bad habits or non-musical tendencies the next day, you can increase the cycling practice time. The general rule for applying PSs is to break up each difficult passage into as large PSs as possible, e.g., `513` for practicing `5131`. If this is too difficult, then break it up into smaller PSs, e.g., `51`, `13`, and `31`.

PSs accomplish two objectives: (1) train the brain to handle high speeds (untrained brains are totally lost at new high speeds), and (2) increase speed as quickly as possible. For those brains that had never experienced such high speeds, you should briefly experience a strange sensation as the brain digests the implications of the higher speeds and adapts to the new capabilities, just like the feeling you get when you first learn to ride a bicycle, ski parallel, or swim on your own. Playing fast PSs necessarily positions the hands and fingers for high speed. The "Parallel" in PSs means that all the playing fingers move simultaneously (in parallel). The higher brain speed means that, when performing, you must be aware that the brain speed of the average audience is slower, and adjust your speed accordingly.

PSs are generally not how you play classical piano (they have been used in jazz, blues, etc.). They only bring you closer to the final technique quickly. The rest of this book provides the remaining steps for converting PSs to actual technique.

PS exercises are not mindless repetitions; they are still part of music and must be practiced musically, which means that anyone hearing you practicing PSs will admire that gorgeous piano sound. It means practicing softly, with attention to musicality. This is possible because you never spend too much time on any one PS exercise; it solves your problems quickly, so that you can move on.

For the Für Elise, you might cycle bars 1-6, then cycle 6-10 (9 short version). Then 17-20 (10-13) including the first note of 21 (14), then 21-22 (14-15), etc.; try to figure out the rest by yourself.

For bar 53 (32), practice the RH PSs 25 and 15, then 52 and 51, then 251, 152, and 151. Bar 54 (33) RH contains three PSs; don't forget the continuity rule. Similarly, bar 100 (79) has three PSs, 123, 135, and 432. To practice the chromatic scale of bar 103 (82), practice PSs 31, 13, 131, 313. The rest should be obvious, and you now have all the preliminary technique to play the whole piece.

1.3.10 10. Parallel Sets Catalogue

A unique property of **Parallel Sets (PSs)** is that they are both **diagnostic tests** for discovering weaknesses and **methods for correcting** them. A beginner should fail all the tests! Even for advanced players, PSs are used only when they fail the test. They are not exercises in the conventional sense to be practiced repeatedly, wasting time. They are used only when necessary to solve problems. Once solved, you have gained a technique for life — you never have to repeat that procedure again, unlike the Hanon type exercises that are repeated all your life with little assurance that they will solve your problems. Below are the major PSs listed in order of complexity with explanations of their properties and how to use them. They are listed using a representative member, such as `1111` (four repeats, a "**quad**", of the thumb), representing all repeats.

There is no need to practice all the PSs because you create just the PS you need depending on the problem, and there are too many of them. Study a few until you understand the concept.

PS #1: 1111, the repetition

This "PS" is somewhat of a misnomer because it contains no PS, but is a necessary member of the family of PS exercises.

It is the simplest, but is the most important. Because of its simplicity, it is too often ignored, and therefore not understood. It is used at the beginning of practically every PS session to separate out the motions of the large members (arms, hands, body, etc.) from the smaller motions of the fingers. Practice it as quads of quads: `1111,1111,1111,1111`, four quads in rapid succession (no rest between quads) followed by a brief pause. Difficult material requires a series of PS sessions such that each session prepares you for the next, and this is the starting PS.

- **Diagnostic test:** increase speed to more than one quad (`1111`) per second, playing comfortably, relaxed. Then two quads in a row without any pause between them: **1** 111, **1** 111, accenting the first of each quad, then three, etc., until you can do four quads. Next, do two 4- quads in a row with a pause between them, then three, and finally four (16 quads in all, or about 16 seconds). If you fail, practice it. The passing criteria depend on the individual and degree of difficulty. Thus beginners playing slower pieces may pass at one quad per two seconds; set the test speed according to the required final speed.

  Example: use PS #1 to start a two-note PS session with PS `23` of RH (fingers `2` and `3`). For actual applications, see CH1.35.

- **Test** using PS #1: play this: `2.3,2.3,2.3,2.3`; the `2.3` notation means that `2` and `3` are played simultaneously, as an interval, not a PS. Play one quad at faster than one per second. Then four quads in rapid succession in four seconds. Then, up to four 4-quads in 16 seconds. There is a tendency to play louder with increasing speed, but they must be played softly. If you fail any of these, practice them. One might think that once you practice PS #1 for, say, one finger, you have acquired the repetition skill so that you will never need PS #1 again. This turns out to be false. There is a large number of PSs, as we shall soon see, and the different fingers required for each PS necessitates that you start with PS #1 all over again, especially at the higher speeds. And, you will be increasing that maximum speed all your life! If you fail, how do you practice?

- **Solution:** Shorten PS #1 to just two units: `2.3,2.3`. If satisfied, do three, then a quad. Then two quads, etc., until you can play 4-quads, comfortably, softly, relaxed. To increase speed, keep the fingertips close to the keys and play each quad with one down motion of the hand, and a flexible wrist. As you increase speed, stress will build up and the quads will start to slow down; the slowing down is a sign of fatigue – it is time to switch hands. The motions must originate in the body, near the diaphragm, with small contributions from every connecting member up to the fingers. You fail unless you can play relaxed, see *Relaxation*. For advanced material, you may need weeks of work — you need to build stamina, etc. Without relaxation, this can create *12. Speed Wall*.

As the repetition speed increases, the fingers/hands/arms will automatically go into positions that are ideal; PSs will make sure of that; otherwise, you will not attain the required speeds. These positions will resemble those of concert pianists – after all, that is why they can play it. Bring your opera glass and watch the motions of advanced pianists after you have read this book. To the untrained observer, a concert pianist may seem to be doing nothing unusual, but if you know the hand motions as explained here, you will see them executed beautifully. If you pass the 4-quad test, you should be able to play the quads as long and as fast as you want, with control and without fatigue.

This exercise is important for practicing accurate intervals and chords, and this accuracy determines the fastest PS speed you can play. Since you can always increase the speed no matter what your skill level, PS #1 can be useful to everyone at all times.

PS #2: 123, linear sets

There are many of these, such as `234`, `543`, `135`, `1354`, `12345`. When practicing one PS, practice its reverse also. To practice `123`, practice `321`; otherwise, you tend to develop unbalanced technique; that is, the inability to play `123` well may be due to the fact that you cannot play `321` well. A right handed golfer should also practice lefty swings. Otherwise, the body will become unbalanced, the left hip bone will weaken while the right will be stronger than normal, which can result in osteoporosis of the left hip or bone fractures and other injuries. Massage therapists know that unbalanced bodies can cause numerous problems such as pain and injuries.

PS #3: 1324, alternating sets

These are practiced by breaking them down into smaller PSs; eg, `1324` is practiced as `13`, `32`, and `24`, or as `132`, then `324`.

PS #4: 1.3,2.4, compound sets

`1.3` is an interval. These are very difficult. To practice them, simplify them to `1.3,4`, then `1.3,2`, then `1,2.4` and `3,2.4`.

PS #5: HT PSs

PSs can be used to practice HT and to synchronize the two hands. See how this is used to practice the end of *57. Beethoven's Pathetique, Op. 13, First Movement*. In this application, the RH plays normally because it is easier, but the more difficult LH is simplified into PSs. Note the importance of PS #1 in this example. Thus PSs can be used as part of an outlining program [CH1.38].

PSs #1 to #5 are just samples of the most common ones. There is an indefinite number of them and, within each type, there are many subtypes. This shows how inadequate older exercises such as Hanon and Cortot are, in addition to the fact that they do not apply directly to the music you are practicing. By contrast, the relevant PSs are generated directly from the music you are learning.

1.3.11 11. Basic Key Stroke; Legato, Staccato

The **basic keystroke** consists of 3 main components, the downstroke, hold, and lift. This might sound like a trivially simple thing to learn, but it is not because each component has a method and a purpose, and the pianist must know how to use the keys to manipulate the jack, backcheck, and hammer shank flex (*Askenfelt, Anders, Ed.*). The fact is, few beginners do it correctly.

The **downstroke** is what creates the piano sound; in the correct motion, it must be a single *accelerating* motion, yet with control of the volume. The timing of this downstroke must be extremely accurate. The suggestion to "play deeply into the keys" means the downstroke must not slow down; it must accelerate all the way to the bottom so that control over the hammer is never lost. Practice this by starting the keystroke slowly rather than accelerating the end.

The Steinway "accelerated action" works because it adds acceleration to the hammer motion by use of a rounded pivot under the center key bushing [see item 5 in *80. Grand Piano Action Diagram*, where it is just a felt bushing instead of a rounded pivot]. This causes the pivot point to move forward with the keydrop thus shortening the front side of the key and lengthening the back side and causing the capstan to accelerate for a constant keydrop. This illustrates the importance piano designers place on accelerating the keydrop in order to produce good tone. The effectiveness of the "accelerated action" is controversial because there are excellent pianos without this feature - in which case the acceleration is entirely controlled by the pianist. Obviously, it is more important for the pianist to control this acceleration than to depend on the piano. Nonetheless, this factor might explain the overwhelming preference of concert pianists for Steinways. Adding accelerator features to digitals should be trivial, but may be meaningless because there is no hammer shank flex effect. Fast flexor muscles must be developed for the downstroke, as well as rapid relaxation after the downstroke.

The **hold** component holds the hammer still using the backcheck [item 26 in *80. Grand Piano Action Diagram*] to accurately control the note duration, which means that the pianist must maintain a downward force during the hold. Without the hold, the hammer can flop around and cause problems with repeated notes, trills, etc. Thus the hold is important in a trill. Beginners will have difficulty with making quick transitions from the downstroke to a relaxed hold. Do not push down on the key during the hold in an attempt to "push deeply into the piano", because this will result in stress, pain, and even injury. Although you may not press down firmly as a beginner, a student can end up pressing with incredible force after years of this bad habit. Gravity is sufficient to keep the key down and hold the hammer still with the backcheck. The length of the hold is what controls color and expression; therefore it is an important part of playing musically, and may be the most difficult component to control.

The **lift** causes the damper to fall onto the strings and terminates the sound. Together with the hold, it determines the note duration. The lift must be fast in order to control the note duration accurately. If the damper is not returned rapidly, it will make a buzzing sound with the vibrating string. Therefore, the pianist must develop fast extensor muscles. Especially when playing fast, many students forget about the lift entirely, resulting in sloppy play.

In **normal play**, the lift of the previous note coincides with the downstroke. If you had never practiced these components before, start practice with fingers `1-5`, `C` to `G`, `C` major scale, and apply the components to each finger. To exercise the extensor muscles, exaggerate the quick lift stroke; practice rapid lifts with immediate relaxation, not an isometric high lift and hold.

This basic keystroke practice is much more important than most students realize. It is obvious that you aren't going to play piano this way, so why practice it? With a minimum of practice, it quickly becomes an automatic part of how you play everything, because you will hear the difference in the music. The basic keystroke is another justification for the slow gradual approach to pianism used by many piano schools such as the arm weight, Alexander, and Feldenkrais schools.

Keep all the non-playing fingers on the keys, lightly. As you speed up the down and lift strokes, starting at about one note per second, stress may start to build up; practice until the stress can be eliminated. Then gradually speed up to some comfortable speed at which you can still practice each component. What is so magical is that if practiced diligently, the basic keystroke will be automatically incorporated into your play when playing at regular speed. There is no need to worry about losing these motions because the difference is clear: the music will deteriorate if they are not properly executed.

Now do the same with any slow music, such as the 1st movement of Beethoven's Moonlight, HS. If you had never done this before, HT will initially be awkward because so many components in both hands must be coordinated. However, with practice, the music will come out better, with more control over the expression and the music. The performances will be consistent from day to day, and technique will progress more rapidly. Without a good basic keystroke, different pianos, or pianos that are not in good regulation, can become impossible to play because the hammer will flop around uncontrollably.

In the old schools of teaching, students were taught to execute correctly by striving for good touch and tone, without worrying about jacks or backchecks. Today's better educated students must deal with the reality of what is happening in the piano because that provides more precise instructions on how to execute. For example, the implications of the basic keystroke change for digitals because they don't have jacks, backchecks, or hammers, which is one reason why advanced pianists prefer acoustic pianos. Still, the basic keystroke must be practiced with digitals because it is part of good technique and it is clearly audible.

Legato

Legato is smooth play. This is accomplished by connecting successive notes – do not lift the first note until the second one is played. *Fraser* recommends considerable overlap of the two notes. The first moments of a note contain a lot of "noise" so that overlapping notes are not that noticeable. Since legato is a habit that must be built into your playing, experiment with different amounts of overlap to see how much overlap gives the best legato for you. If you have already developed your own habit, it may be difficult to change; be prepared to work on this over a long time. Then practice until the optimized motion becomes a new habit. Chopin considered legato as the most important skill to develop for a beginner. Chopin's music requires special types of legato and staccato (Ballade Op. 23); you should listen to recordings and practice them using this Ballade.

Staccato

Astonishingly, most books on learning piano discuss staccato, but never define it! In staccato, the hammer is bounced off the strings and the damper is returned immediately onto the strings so as to produce a brief sound with no sustain. Therefore, the "hold" component of the basic keystroke is missing and the hand is held above the keys after playing the note, not resting on the keys. There are two notations for staccato, the **normal (dot)** and **hard (filled triangle)**. In both, the jack [#1 in *80. Grand Piano Action Diagram*] is not released. In normal staccato, the key drop is about half way down. In hard staccato, it is less than half way; in this way, the damper is returned to the strings faster, resulting in shorter note duration. The finger moves down and up rapidly. Because the backcheck is not engaged, the hammer can "bounce around", making staccato repetitions tricky at certain speeds. Thus if you have trouble with rapidly repeated staccatos, don't immediately blame yourself – it may be the wrong frequency at which the hammer bounces the wrong way. By changing the speed, amount of key drop, etc., you should be able to eliminate the problem.

In normal staccato, gravity quickly returns the damper onto the strings (grand pianos; in uprights, springs are used). In hard staccato, the damper is bounced off the damper top rail [*80. Grand Piano Action Diagram*, click on more detailed diagram link at the bottom], so that it returns even more quickly. At string contact, the hammer shank flex can be negative, which makes the effective mass of the hammer lighter; thus a considerable variety of tones can be produced with staccato. Therefore, the motions of the hammer, backcheck, jack, and damper are all changed in staccato. Clearly, in order to play staccato well, it helps to understand how the piano works.

Don't blame yourself when something unexpected happens because staccato is too complex to figure out; your only option is to try different things to see what works. Staccato is not just a very short note! Staccato can be divided into three types depending on how it is played: (i) finger staccato, (ii) wrist (or hand) staccato, and (iii) arm staccato which includes both up-down motion and arm rotation. As you progress from (i) to (iii), more mass is added behind the fingers; therefore, (i) gives the lightest, fastest staccato and is useful for fast, soft notes, and (iii) gives the heaviest feeling and is useful for loud passages and chords with many notes, but is also the slowest. (ii) is in between. In practice, most of us probably combine all three.

Since the wrist and arm are slower (heavier), their amplitudes must be correspondingly reduced in order to play faster staccato. Some teachers frown on the use of wrist staccato, preferring mostly finger staccato because of its speed or arm staccato for its power; however, it is better to have a choice (or combination) of all three. For example, you might be able to reduce fatigue by changing from one to the other, although the standard method of reducing fatigue is to change fingers. When practicing staccato, practice the three (finger, wrist, arm) staccatos separately before deciding on which one to use, or how to combine them.

1.3.12 12. Speed Wall

All pianists have experienced **"speed walls" (SWs)**. What are they, how do they form, how many are there, and how do you eliminate them? Any piano piece can be played if slowed down sufficiently. The first order of business when learning a new piece is to bring it up to speed. That is when you can encounter SWs, conditions in which you can't go above a certain speed, no matter how hard you practice. SWs form when you practice incorrectly and create bad habits or build up stress. Therefore, it is the pianist who erects SWs. There are as many SWs as bad habits, basically an indefinite number.

HS practice is an effective weapon against SWs because most SWs are HT SWs. The next weapon is **segmental practice** because the shorter a segment, the faster you can play it without problems. **Parallel sets are the most useful weapons** against SWs because you can start at speeds above the speed wall. **Relaxation** is essential at all times, but especially for avoiding SWs because stress is a major cause. **Outlining** is another effective weapon because it allows the large motions to be correctly played at final speed, thus avoiding the SWs in these motions [CH1.38]. **Quiet hands** is also helpful because you generally can not play quiet hands unless you have the technique [Quiet Hands & Fingers]. Any method for increasing the efficiency of motion helps; thus mixing flat finger and curled positions, keeping the fingers on the keys, and the various hand motions such as glissando, cartwheel, arm rotation, wrist motion, etc., that are discussed below, are all needed to prevent SWs. Musical play is not possible at SWs because you lack control; thus in principle, if you always practice musically, you will never encounter a SW.

A few SWs built up over years may be difficult to eliminate in a short time. Early detection of SWs is the key to removing them quickly. The solution of last resort for a really stubborn SW is not to play it, or only playing it slowly, for weeks or months and learning something new during that time. Learning new things is a good way to erase old habits.

SWs form when you try the impossible. Many teaching methods have evolved to avoid this problem by slowing down the learning process. This defeats the original intent of learning as quickly as possible. The best solution is to use the learning tricks of this book that achieve the objectives without doing anything impossible.

1.3.13 13. Metronome

The **metronome** is one of your most reliable teachers – once you start using it, you will be glad you did. Develop a habit of using the metronome and your playing will undoubtedly improve; all serious students must have a metronome. A student's idea of tempo is never constant; it can depend on what he is playing and how he feels at the moment. A metronome can show him exactly what these errors are. An advantage of HS practice is that you can count more accurately than HT. Use a metronome to check the speed and beat accuracy. I have been repeatedly surprised by the errors I discover, even after I "finish" a piece. For example, I tend to slow down at difficult sections and speed up at easy ones, although I think it is actually the opposite when playing without the metronome. Most teachers will check their students' tempi with it. As soon as the student gets the timing, *turn the metronome off*.

Metronomes must not be over used. Long practice sessions with the metronome accompanying you are the most common, and serious, abuses. Excessive use of the metronome leads to non-musical playing. When the metronome is used for more than about 10 minutes continually, the mind will rebel against the enforced repetition and start to play mental tricks so that **you lose the timing accuracy**. For example, if the metronome emits clicks, after some time, your brain will create anti-clicks in your head that can cancel the metronome click so that you will either not hear the metronome, or hear it at the wrong time. This is why most modern electronic metronomes have a light pulse mode. The visual cue is less prone to mental tricks and also interferes less with playing musically. Another abuse of the metronome is to use it to ramp up speed; this abuses the metronome, the student, the music, and the technique, as explained in the section on CH1.26. The metronome is for setting the tempo and for checking your accuracy; it can't teach you musicality. Once the tempo is set and checked, turn it off, so that *you* can practice playing at the correct tempo.

Electronic metronomes are better than mechanical ones although some people prefer the decorative value of the old models. Electronics are more accurate, can make different sounds or flash lights, have variable volume, are less expensive, are less bulky, have memory functions, etc. The mechanicals always seem to need rewinding at the worst possible times.

1.3.14 14. Memorizing, Close Your Eyes and Play

Memorizing Procedure

Memorize every piece of music you learn *before* practicing it. While learning any segment when starting a piece, memorize it. Since a segment is typically 10 to 20 notes, memorizing it is trivial and takes very little time. Then you will need to repeat those segments many times, before you can play the piece – that is many more repetitions than needed to memorize, and you have expended no extra time. Don't waste such a priceless, one-time opportunity! Always memorize first, then practice only from memory, because this way of memorizing requires no extra expenditure of time.

The memorizing process is nearly identical to the learning process — you can accomplish two things in one process! Moreover, by memorizing and practicing at the same time, you actually learn the piece faster than if you didn't memorize it because you save time by not having to look for the sheet music. It also eliminates the slow process of reading the sheet music and mentally translating it to what you are playing, which slows down technique acquisition. **Memorizing saves time!**

The old school of memorizing taught students to learn to play a piece first and then memorize it. If you separate the learning and memorizing processes, you will have to go through the same procedure twice (HS, segmental, etc.). Nobody has the patience or time to go through such an ordeal; this explains why those who memorize after they have learned the piece *never* memorize as well as those who memorize first.

Memorizing HS will be useful during a performance for recovering from blackouts, etc. There are many more uses of HS memory that we shall discuss later. Once a short piece or a movement is memorized, break it up into logical smaller sections of about 10 bars each and start playing these sections randomly. Practice the art of starting play from anywhere in the piece. Starting randomly should be easy because you learned and memorized in small segments. It is really exhilarating to be able to play a piece from anywhere you want and this skill always amazes the audience.

Once a section is memorized, never use the sheet music again except for specific purposes, such as double checking the memory accuracy or checking the expression markings. Do not repeat the same segment too many times because memory is not reinforced proportionately to the number of repeats. It is better to wait 2 to 5 minutes and to re-memorize again.

Everything you memorize is in the head indefinitely; this is why savants can have such miraculous memory. Forgetting is not loss of memory but the inability to retrieve information. The most common cause of memory loss is confusion; instead of retrieving the right information, the brain goes to the wrong place and gets stuck. Memorizing HS is effective because you are dealing with only one hemisphere of the brain. HT memory involves both hemispheres and there are more chances for confusion. **Slow practice is a good test for memory** because there is more time for the mind to wander around and get lost. It is also a good way to memorize because there is time for the material to go back and forth from brain to hand many times, to strengthen the memory.

Many students become either good readers but poor memorizers, or vice versa. In almost all cases, this happens not because the students are born that way, but because of the way they practiced. Once they become good at reading, they have less need for memorizing, and can ignore memory practice. Vice versa for good memorizers. Teachers must carefully balance the reading/memorizing abilities of students at the beginner stage.

For practically all students (including those who consider themselves to be poor memorizers) the most difficult passages are played mostly from memory. Non-memorizers may need the sheet music for psychological support and small cues here and there but, in fact, they are playing difficult passages mostly from memory (if they can play them). Students who do not memorize never learn anything well, and this limits their technical development.

Pianists often **close their eyes** when they want to concentrate on playing music with high emotional content – they need all the resources available to produce the high level of music. When the eyes are open, a tremendous amount of information comes into the brain because vision is a three-dimensional, multi-color, dynamic, source of high bandwidth video data that must be immediately interpreted in many complex ways. These data must be instantly processed because we must respond in real time to visual inputs. Thus a large portion of the brain is preoccupied with image processing at all times, not just when driving a car or playing tennis. Closing the eyes frees up this enormous amount of brain power for concentrating on music. Therefore, although most audiences admire that a pianist can play with eyes closed, it is actually easier. No concert pianist will intentionally make things more difficult for them during a difficult performance. They close their eyes because that makes it easier to play.

So, go ahead and play with your eyes closed and really impress the audience! Because it is simpler, it can be learned quickly. Besides, it is a skill any accomplished pianist should have. Learning to play with the eyes closed improves the ability to play with eyes open, because it requires skills such as feeling the keys [CH1.28] and listening to your own playing.

Types of Memory

The best way to learn how to memorize is to study the best memorizers. Some savants have super-human memories, but we do not understand how their brains work, so they provide little help except to provide proof that human brains can perform incredible feats of memory. However, there are plenty of ordinary people who are terrific memorizers that routinely compete in memory contests. These memorizers have written articles/books on how to memorize that you can easily find on the internet. These accomplished memorizers always use memory algorithms [(16) Human Memory Function]. For example, to memorize a set of numbers, they map those numbers into a story or scenery that is easy to remember. The best memorizers have all been found to have evolved their own algorithms. Savants probably use algorithms also; unfortunately, no savant has been able to tell us what algorithm they are using; apparently theirs is something not readily describable in human languages. It is instructive to study "intermediate" memory feats such as calendar calculations whereby a person can name the day of the week for every date, even thousands of years in the future or in the past. These are "modulo-A, B, . . . " problems and frequently have trivially simple solutions. For calendar calculations, A=leap year, B = month, and C = week. Simple calculations show that you need to memorize only a few numbers to be able to calculate the day of the week for every date in seconds. Let's examine a simple modulo case, our number system (modulo-9) in which we need to memorize only ten numbers, 0 to 9, in order to write down and make calculations with numbers of any size, an amazing feat. Thus these modulo systems can be extremely powerful. The analog of the calendar calculation in the number system is the problem of predicting the last digit of a very large number, such as 5621. The answer (1) is trivial in this case, because of the modulo system. Pianists use the modulo-12 system (the octave) every time they play. The audience watches in wonderment as the pianist runs the entire span of the keyboard at top speed, because they don't know that we only need to know how to play one octave to be able to play all 88 keys. There are numerous fascinating types of algorithms used by super memorizers, but that subject is outside the scope of this book. We don't need them for memorizing music because music itself is an algorithm! This is partly why all concert pianists can memorize such large repertoires - concert pianists are one type of super memorizer because piano practice provides them with several algorithms. Why music is such a good memory algorithm is not adequately understood; the answer certainly lies in the fact that music is a language [(68) Theory, Solfege].An old man can tell stories for hours, much as a concert pianist can play for hours from memory. Thus memorizing hours of repertoire is nothing unusual for the average human, if you know how the brain memorizes. Historically, music teachers have not taught memory methods, which explains why there is such a disparity between good and poor memorizers among pianists. The old school of music pedagogy had ascribed memory capabilities to talent because teachers did not know how to teach memory methods. The first step in studying memory for piano is listing the ways in which we memorize: the pianists' algorithms. There are many types of memory such as emotional, temporal (when it occurred), personal (people associated with the music), spatial (where), historical, etc.; that is, too many, because memory is associative [(16) Human Memory Function]. Here we discuss five types that are particularly useful for piano with their algorithms enclosed in ( ): 1. music memory (algorithm: the music itself), 2. hand memory (combination of the tactile feel of the playing, auditory inputs from the piano, muscle reflexes built up during practice, etc.), 3. keyboard memory (visual location of the specific keys played), 4. photographic memory (photograph of sheet music), and 5. theoretical memory (music structure, theory). (1) Music memory is based on melody, rhythm, harmony, expression, emotion, etc. The algorithm for music memory is mostly pre-wired in the brain; you don't need to be a music professor to enjoy music. Most of music memory is automatic, because it is associated with inborn and learned processes already in the brain. It works best for artistic and musical types of persons who have strong feelings associated with their music. Those with absolute pitch will also do well because they can find the notes on the piano from the memory of the music. Composers use music memory all the time. The music algorithm is a major component of memory and therefore musicality is important for memory. (2) Hand memory is a habituated reflex response to mental, auditory, tactile, etc., inputs acquired from repeated practice. A large component of any piano memory is hand memory, also called muscle memory — the hand goes on playing without having to consciously play each note. Before pianists understood the concept of associative memory [(16) Human Memory Function], hand memory was believed to be the only and best method of memory - "practice until the music is in your hands" we were told. We now know that this belief is wrong. Everybody must practice common constructs, such as scales, arpeggios, Alberti bass, etc., so that the hands can play them automatically, without having to think about every note. Hand memory is a necessary component of memory; fortunately, it is automatically acquired as a byproduct of repeated practicing. Hand memory is unreliable because it is prone to blackouts (whenever the normal stimuli change such as at a performance) and, if you get stuck in the middle of a piece, there is no way to restart because the stimuli have disappeared. Dependance on hand memory is the source of most piano memory problems because it relies on reflexes over which we have little control. Therefore, reliable memory can only be established by adding other memory methods, by adding more associations [see (16) Human Memory Function] such as the other memory methods discussed in this section. (3) Keyboard memory: In keyboard memory, you remember the sequence of keys and hand motions as you play. There is a piano in your mind, and you can play it, as explained in (15) Mental Play (MP). Keyboard memory has most of the advantages of photographic memory but the memorized notes are the piano keys that you play instead of tadpoles on a sheet of paper. This bypasses the process of translating from tadpoles to keys. Keyboard memory is the easiest to use, because it can be acquired while practicing the piece and the memory is reinforced every time you play it. Since music and hand memory are also automatically acquired, the combination with keyboard memory will provide a sound memory foundation with little extra effort. (4) Photographic memory needs to be cultivated if you aspire to become an advanced pianist, because it is necessary in advanced piano activities such as composing, sight reading, theoretical analyses and (15) Mental Play (MP), treated in the next section. At the very least, you should photographically memorize the first line or page of every piece you learn, especially the key and time signatures. If you do this with every piece you learn, you will automatically develop photographic capabilities so that, one day, you will suddenly discover yourself photographically memorizing a lot. The more you practice photographic memory, the easier it becomes and there is no limit to the number of pages that the human brain can store, because memory is associative [(16) Human Memory Function]. Start photographic memory by memorizing one hand at a time. Memorize bar by bar; do not add bars unless all the preceding material is well memorized. Take a accurate photograph of the page, complete with its defects and extraneous marks; remember, the more associations the better. If you have difficulty memorizing certain bars, draw something unusual there, such as a smiley face or your own markings that will jolt your memory. Then, to recall this section, think of the smiley face. Photographic memorization has many advantages; you can work on it without the piano, anytime, anywhere. You should read it in your mind, away from the piano, as often as possible until it is permanently memorized. If you get stuck in the middle of playing a piece, you can easily restart by reading that section of the music in your mind. It also allows you to read ahead while playing which helps you to think ahead. It will even improve your sight reading. The main disadvantage is that most people cannot retain photographic memory for long periods of time and maintenance requires more work than other methods because of the high bandwidth of visual images. Another disadvantage is that reading the printed music in the mind is a slow process that can interfere with the playing. However, if you follow the methods discussed here, you may find photographic memory to be easier than you thought. In principle, once you have memorized a piece, you know every note and therefore should be able to map it back to the sheet music. Once you have acquired most of the types of memories discussed here, adding photographic memory requires very little additional work (once you become good at it), and you reap considerable rewards. Thus every pianist should use a certain minimum of photographic memory and gradually expand it with time. For those who think that they do not have photographic memory, try the following. First memorize a short piece of music using keyboard memory. Once each section is memorized, map it back onto the score from which you learned the piece; that is, for each bar you play (from memory), try to picture the corresponding bar on the sheet music. Since you know every note, HS, mapping it back from the keyboard to the sheet music should be simple. Go back and forth, playing from photographic memory and mapping back from the keyboard to the sheet music until the entire (short) piece is memorized photographically. Then you can amaze your friends by writing down the score for the entire piece, starting from anywhere! Note that you will be able to write the whole music, forwards or backwards, or from anywhere in the middle, or even each hand separately. And they thought only Wolfgang could do it! (5) Theoretical memory: use the knowledge of music theory to memorize. What is the key signature and how does that affect the whole composition? Where are the chord progressions? Theoretical memory also includes structural analysis. What is the main theme and how is it developed? What are the relationships between the movements? How does the composer connect one bar or section to the next? How did the composer create a convincing ending? This is a difficult memory for beginners, but as you learn more music theory, its importance increases and becomes a major, indispensable element of memory for advanced pianists. Even with little knowledge of theory, anyone can conduct structural analysis, as we did by counting bars and repetitions in Für Elise in preceding sections. Which of the above five memories to use? The answer is all of them, and even more (such as emotional, historical, etc.); it is unrealistic to think of using only one method, because memory is associative; the more you memorize, the more you can memorize, and the better you can recall the memory. Beginners should learn keyboard memory first because it is the easiest and most rewarding. More generally, start with whatever memory method that is easiest for you. However, in the end, you will be (and already are, to some extent) using all of them; that is why it is beneficial to study as many memory methods as possible because that is how you improve the memory. Each person has a main memory method and supplements it with all the others, some of which are necessary, such as hand memory, and others are partly inborn, such as music memory. More theoretical details of how to improve your memory are discussed in (16) Human Memory Function. A useful memory device is the “forget 3 times” rule. If you can forget and re-memorize the same thing 3 times, you will usually remember it indefinitely. This rule works because it eliminates the frustration from forgetting and provides 3 chances to practice memory methods. Frustration with, and fear of, forgetting is the worst enemy of poor memorizers, and this method alleviates that frustration because instead of trying to memorize, you are trying to forget. Concert pianists always play from memory; why?? One obvious reason is the high level of technical skill and “talent” that is expected — you won’t have the time for reading the music, turning pages, etc. We discuss the many benefits of memorizing throughout this book, such as raising your IQ [(65) Creating Geniuses]; these benefits make memorizing a necessity, not a special talent or a luxury. That’s why concert pianists always play from memory — there is no better way. Memory maintenance: A memorized repertoire requires two investments of time: the first is the initial memorizing process, plus a second “maintenance” component for archiving the memory permanently and for repairing forgotten sections. During the lifetime of a pianist, the maintenance component is by far the larger one because the initial investment is zero or even negative as we have seen (you save time by memorizing). Maintenance is one reason why some give up memorizing: why memorize if I am going to forget it eventually? Maintenance can limit the size of a repertoire because after memorizing, say, five to ten hours of music, the maintenance requirements may preclude memorizing any more pieces. There are several ways to extend your repertoire beyond any maintenance limit. An obvious one is to abandon the memorized pieces and to re-memorize later as needed. Pieces that were well memorized can be re-polished quickly, even if they haven’t been played for years. If not well memorized the first time, you may have to go through the entire memorizing procedure all over again. So what does “well memorized” mean? If you memorized before practicing the pieces and practiced only from memory, the results generally qualify as well memorized. Memorize as many pieces as possible before the age of 20. Pieces learned in those early years are practically never forgotten and, even if forgotten, are easily re-memorized. This is why youngsters must memorize all their repertoire pieces. Material memorized after age 40 require more memorizing and maintenance efforts. Although many people have little trouble memorizing new material past age 70 using the above memory methods, they must know that the newly memorized material may need constant maintenance to preserve them. A most effective maintenance procedure is to use Mental Play (MP, playing it in the head, away from the piano, discussed in the next section). MP is also a good test of whether you memorized sufficiently well. Maintenance time is a good time to revisit the score and check your accuracy for the individual notes and the expression marks. Since you used the same score to learn the piece, there is a good chance that if you made a mistake reading the score the first time, you will make the same mistake again later on, and never catch that mistake. One way around this problem is to listen to recordings. Any major difference between your playing and the recording will stand out as a jarring experience and is easy to catch. Now memorize the Für Elise in its entirety (HS) as you practice each segment. For more step-by-step examples of how to do this, see (52) Practice Routines: Bach Inventions, Sinfonia.

1.3.15 Examples of Applications

Listed in order of difficulty; the three Beethovens are about equally difficult.

55. Chopin's Fantaisie Impromptu, Op. 66, Polyrhythms

TODO

57. Beethoven's Pathetique, Op. 13, First Movement

TODO

1.4 Chapter Two: TODO

1.4.1 1. Introduction

This chapter is for those who had never tuned a piano and who would like to see if they are up to the task. *Piano Servicing, Tuning, and Rebuilding*, by Arthur Reblitz, will be a helpful reference. The hardest part of learning to tune is getting started. For those fortunate enough to have someone teach them, that is obviously the best route. Unfortunately, piano tuning teachers aren't readily available. Try the suggestions in this chapter and see how far you can get. After you are familiar with what gives you trouble, you might negotiate with your tuner for 30 minute lessons for some agreed-upon fee, or ask him to explain what he is doing as he tunes. Be careful not to impose too much on your tuner; tuning and teaching can take more than four times longer than simply tuning it up. Each tuner has her/is own methods of solving problems; these solutions can't really be taught because what you do depends on how the piano "behaves". Also, be forewarned that piano tuners are not trained teachers and some may harbor unfounded fears that they might lose a customer. These fears are unfounded because the actual number of people who succeed in displacing professional tuners is negligibly small. What you will most likely end up doing is getting a better understanding of what it takes to tune a piano, develop a sensitivity to the tuning, and end up hiring tuners more often.

For pianists, familiarity with the art of tuning provides an education that is directly relevant to their ability to produce music and to maintain their instruments. It will also enable them to communicate intelligently with their tuners. For example, the majority of piano teachers to whom I posed the question did not even know the difference between Equal temperament and historical temperaments (*2. Chromatic Scale and Temperament*). The main reason why most people try to learn tuning is out of curiosity – for the majority, piano tuning is a baffling mystery. Once people are educated to the advantages of tuned (maintained) pianos, they are more likely to call their tuners regularly. Piano tuners can hear certain sounds coming from the piano that most people, even pianists, don't notice. Those who practice tuning will become sensitized to the sounds of out-of-tune pianos. It will probably take about one year to start feeling comfortable with tuning, assuming that you have the time to practice for several hours at least once every one or two months.

Let me digress here to discuss the importance of understanding the plight of tuners and proper communications with them, from the point of view of getting your money's worth from the tuner so that your piano can be properly maintained. These considerations directly impact your ability to acquire piano technique as well as your decisions on what or how to perform, given a particular piano to play. For example, one of the most common difficulties I have noted with students is their inability to play pianissimo. From my understanding of piano tuning, there is a very simple answer to this – most of these students' pianos are under-maintained. The hammers are too worn/compacted and the action so out of regulation that playing pianissimo is impossible. These students will never even be able to practice pianissimo! This applies also to musical expression and tone control. These under-maintained pianos are probably one of the causes of the view that piano practice is ear torture, but it should not be. An out-of-tune piano is one of the major causes of flubs and bad habits.

Another factor is that you generally have no choice of a piano when asked to perform. You might encounter anything from a wonderful concert grand, to spinets, to (horrors!) a cheap baby grand that was totally neglected since it was purchased 40 years ago. Your understanding of what you can/cannot do with each of these pianos should be the first input into deciding what and how to play.

Once you start practicing tuning, you will quickly understand why your spouse vacuuming the floor, kids running around, the TV or HiFi blaring away, or pots clanging in the kitchen is not conducive to accurate, quality tuning. Why a quick, $70 tuning is no bargain compared to a $150 tuning in which the tuner reshapes and needles the hammers. Yet when you query owners what the tuner did to their pianos, they generally have no idea. A complaint I frequently hear from owners is that, after a tuning, the piano sounds dead or terrible. This often happens when the owner does not have a fixed reference from which to judge the piano sound – the judgment is based on whether the owner likes the sound or not. Such perceptions are too often incorrectly influenced by the owner's past history. The owner can actually become accustomed to the sound of a detuned piano with compacted hammers so that when the tuner restores the sound, the owner doesn't like it because it is now too different from the sound or feel to which he had become accustomed. The tuner could certainly be at fault; however, the owner will need to know a minimum of tuning technicalities in order to make a correct judgment. The benefits of understanding tuning and properly maintaining the piano are under-appreciated by the general public. The most important objective of this chapter is to increase that awareness.

Piano tuning does not require good ears, such as absolute pitch, because all tuning is accomplished by comparison with a reference using beats, starting with the reference frequency of a tuning fork. In fact an absolute pitch ability may interfere with the tuning for some people. Therefore, the "only" hearing skill you will need is the ability to hear and differentiate between the various beats when two strings are struck. This ability develops with practice and is not related to knowledge of music theory or to musicality. Larger grands are easier to tune than uprights; however, most baby grands are harder to tune than good uprights. Therefore, although you should logically begin your practice with a lower quality piano (in case you damage it), it will be more difficult to tune.

1.4.2 2. Chromatic Scale and Temperament

Most of us have some familiarity with the chromatic scale and know that it must be tempered, but what are their precise definitions? Why is the chromatic scale so special and why is temperament needed? We first explore the mathematical basis for the chromatic scale and tempering because the mathematical approach is the most concise, clear, and precise treatment. We then discuss the historical/musical considerations for a better understanding of the relative merits of the different temperaments. A basic mathematical foundation for these concepts is essential for a good understanding of how pianos are tuned. For information on tuning, see White, Howell, Fischer, Jorgensen, or Reblitz in the *References* at the end of this book.

a. Mathematics of the Chromatic Scale and Intervals

Three octaves of the chromatic scale are shown in the table *Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale* using the `A, B, C, ...` notation. Black keys on the piano are shown as sharps, e.g. the `#` on the right of `C` represents `C#`, etc., and are shown only for the highest octave. Each successive frequency change in the chromatic scale is called a semitone and an octave has 12 semitones. The major intervals and the integers representing the frequency ratios for those intervals are shown above and below the chromatic scale, respectively. Except for multiples of these basic intervals, integers larger than about 10 produce intervals not readily recognizable to the ear. In reference to *Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale*, the most fundamental interval is the octave, in which the frequency of the higher note is twice that of the lower one. The interval between `C` and `G` is called a 5th, and the frequencies of `C` and `G` are in the ratio of 2 to 3. The major third has four semitones and the minor third has three. The number associated with each interval, e.g. four in the 4th, is the number of white keys, inclusive of the two end keys, for the `C major` scale and has no further mathematical significance.

Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale

Semitones	Note	Interval	Ratio
0	C	Unison	1:1
1	C#	Minor Second	16:15
2	D	Major Second	9:8
3	D#	Minor Third	6:5
4	E	Major Third	5:4
5	F	Perfect Fourth	4:3
6	F#	Tritone	25:18
7	G	Perfect Fifth	3:2
8	G#	Minor Sixth	8:5
9	A	Major Sixth	5:3
10	A#	Minor Seventh	9:5
11	B	Major Seventh	15:8
12	C	Octave	2:1

We can see from the above that a 4th and a 5th "add up" to an octave and a major 3rd and a minor 3rd "add up" to a 5th. Note that this is an addition in logarithmic space, as explained below. The missing integer 7 is also explained below. These are the "ideal" intervals with perfect harmony. The "equal tempered" (ET) chromatic scale consists of "equal" half-tone or semitone rises for each successive note. They are equal in the sense that the ratio of the frequencies of any two adjacent notes is always the same. This property ensures that every note is the same as any other note (except for pitch). This uniformity of the notes allows the composer or performer to use any key without hitting bad dissonances, as further explained below. There are 12 equal semitones in an octave of an ET scale and each octave is an exact factor of two in frequency. Therefore, the frequency change for each semitone is given by:

$$\begin{aligned} semitone^{12} &= 2 \\ semitone &= 2^{1/12} \approx 1.05946 \end{aligned} \tag{1.1}$$

Equation (1.1) defines the ET chromatic scale and allows the calculation of the frequency ratios of "intervals" in this scale. How do the "intervals" in ET compare with the frequency ratios of the ideal intervals? The comparisons are shown in *Table 2.2b: Ideal vs. Equal Tempered Intervals* and demonstrate that the intervals from the ET scale are extremely close to the ideal intervals.

The errors for the 3rds are the worst, over five times the errors in the other intervals, but are still only about 1%. Nonetheless, these errors are readily audible, and some piano aficionados have generously dubbed them "the rolling thirds" while in reality, they are unacceptable dissonances. It is a defect that we must learn to live with, if we are to adopt the ET scale. The errors in the 4ths and 5ths produce beats of about 1 Hz near `C4`, which is barely audible in most pieces of music; however, this beat frequency doubles for every higher octave.

The integer 7, if it were included in *Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale*, would have represented an interval with the ratio 7/6 and would correspond to a semitone squared. The error between 7/6 and a semitone squared is over 4% and is too large to make a musically acceptable interval.

Table 2.2b: Ideal vs. Equal Tempered Intervals

Interval	Frequency Ratio	Equal Tempered Scale	Difference
Minor Third	$6:5=1.2$	$semitone^3 \approx 1.1892$	$+0.0108$
Major Third	$5:4=1.25$	$semitone^4 \approx 1.2599$	-0.0099
Perfect Fourth	$4:3 \approx 1.3333$	$semitone^5 \approx 1.3348$	-0.0015
Perfect Fifth	$3:2=1.5$	$semitone^7 \approx 1.4983$	$+0.0017$
Octave	$2:1=2$	$semitone^{12}=2$	0.0000

It is a mathematical accident that the 12-note ET chromatic scale produces so many ratios close to the ideal intervals. Only the number 7, out of the smallest 8 integers (*Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale*), results in a totally unacceptable interval. The chromatic scale is based on a lucky mathematical accident in nature! It is constructed by using the smallest number of notes that gives the maximum number of intervals. No wonder early civilizations believed that there was something mystical about this scale. Increasing the number of keys in an octave does not result in much improvement of the intervals until the numbers become quite large, making that approach impractical for most musical instruments. Mathematically speaking, the unacceptable number 7 is a victim of the incompleteness (*a. Mathematics of the Chromatic Scale and Intervals*) of the chromatic scale and is therefore, not a mystery.

Note that the frequency ratios of the 4th and 5th do not add up to that of the octave ($1.5000 + 1.3333 = 2.8333$ vs. 2.0000). Instead, they add up in logarithmic space because $\frac{3}{2} \times \frac{4}{3} = 2$. In logarithmic space, multiplication becomes addition. Why might this be significant? The answer is because the geometry of the cochlea of the ear seems to have a logarithmic component. Detecting acoustic frequencies on a logarithmic scale accomplishes two things: you can hear a wider frequency range for a given size of cochlea, and analyzing ratios of frequencies becomes simple because instead of multiplying or dividing two frequencies, you only need to add or subtract their logarithms. For example, if `C3` is detected by the cochlea at one position and `C4` at another position 2mm away, then `C5` will be detected at a distance of 4 mm, exactly as in the slide rule calculator. To show you how useful this is, given `F5`, the brain knows that `F4` will be found 2mm back! Therefore, intervals (remember, intervals are frequency divisions) and harmonies are particularly simple to analyze in a logarithmically constructed cochlea. When we play intervals, we are performing mathematical operations in logarithmic space on a mechanical computer called the piano, as was done in the 1950's using the slide rule. Thus the logarithmic nature of the chromatic scale has many more consequences than just providing a wider frequency range than a linear scale. The logarithmic scale assures that the two notes of every interval are separated by the same distance no matter where you are on the piano. By adopting a logarithmic chromatic scale, the piano keyboard is mathematically matched to the human ear in a mechanical way! This is probably one reason for why harmonies are pleasant to the ear - harmonies are most easily deciphered and remembered by the human hearing mechanism.

Suppose that we did not know (1.1); can we generate the ET chromatic scale from the interval relationships? If the answer is yes, a piano tuner can tune a piano without having to make any calculations. These interval relationships, it turns out, completely determine the frequencies of all the notes of the 12 note chromatic scale. A temperament is a set of interval relationships that defines a specific chromatic scale; tempering generally involves detuning from perfect intervals. From a musical point of view, there is no single "chromatic scale" that is best above all else although ET has the unique property that it allows free transpositions. Needless to say, ET is not the only musically useful temperament, and we will discuss other temperaments below. Temperament is not an option but a necessity; we must choose a temperament in order to accommodate the mathematical difficulties discussed below and in following *b. Temperament, Music, and the Circle of Fifths* & *c. Pythagorean, Equal, Meantone, and "Well" Temperaments*. Most musical instruments based on the chromatic scale must be tempered. For example, the holes in wind instruments and the frets of the guitar must be spaced for a specific tempered scale. The violin is a devilishly clever instrument because it avoids all temperament problems by spacing the open strings in fifths. If you tune the `A-440` string correctly and tune all the others in 5ths, these others will be close, but not tempered. You can still avoid temperament problems by fingering all notes except one (the correctly tuned `A-440`). In addition, the vibrato is larger than the temperament corrections, making temperament differences inaudible.

The requirement of tempering arises because a chromatic scale tuned to one scale (e.g., `C-major` with perfect intervals) does not produce acceptable intervals in other scales. If you wrote a composition in `C-major` having many perfect intervals and then transposed it, terrible dissonances can result. There is an even more fundamental problem. Perfect intervals in one scale also produce dissonances in other scales needed in the same piece of music. Tempering schemes were therefore devised to minimize these dissonances by minimizing the de-tuning from perfect intervals in the most important intervals and shifting most of the dissonances into the less used intervals. The dissonance associated with the worst interval came to be known as “the wolf”.

The main problem is, of course, interval purity; the above discussion makes it clear that no matter what you do, there is going to be a dissonance somewhere. It might come as a shock to some that the piano is a fundamentally imperfect instrument! The piano gives us every note, but locks us into one temperament; on the other hand, we must finger every note on the violin, but it is free of temperament restrictions.

The name “chromatic scale” applies to any 12-note scale with any temperament. For the piano, the chromatic scale does not allow the use of frequencies between the notes (as you can with the violin), so that there is an infinite number of missing notes. In this sense, the chromatic scale is (mathematically) incomplete. Nonetheless, the 12-note scale is sufficiently complete for a majority of musical applications. The situation is analogous to digital photography. When the resolution is sufficient, you cannot see the difference between a digital photo and an analog one with much higher information density. Similarly, the 12-note scale has sufficient pitch resolution for a sufficiently large number of musical applications. This 12-note scale is a good compromise between having more notes per octave for greater completeness and having enough frequency range to span the range of the human ear, for a given instrument or musical notation system with a limited number of notes.

There is healthy debate about which temperament is best musically. ET was known from the earliest history of tuning. There are definite advantages to standardizing to one temperament, but that is probably not possible or even desirable in view of the diversity of opinions on music and the fact that much music now exist, that were written with specific temperaments in mind. Therefore we shall now explore the various temperaments.

b. Temperament, Music, and the Circle of Fifths

The above mathematical approach is not the way in which the chromatic scale was historically developed. Musicians first started with intervals and tried to find a music scale with the minimum number of notes that would produce those intervals. The requirement of a minimum number of notes is obviously desirable since it determines the number of keys, strings, holes, etc. needed to construct a musical instrument. Intervals are necessary because if you want to play more than one note at a time, those notes will create dissonances that are unpleasant to the ear unless they form harmonious intervals. The reason why dissonances are so unpleasant to the ear may have something to do with the difficulty of processing dissonant information through the brain. It is certainly easier, in terms of memory and comprehension, to deal with harmonious intervals than dissonances. Some dissonances are nearly impossible for most brains to figure out if two dissonant notes are played simultaneously. Therefore, if the brain is overloaded with the task of trying to figure out complex dissonances, it becomes impossible to relax and enjoy the music, or follow the musical idea. Clearly, any scale must produce good intervals if we are to compose advanced, complex music requiring more than one note at a time.

We saw in *Table 2.2a: Frequency Ratios of Intervals in the Chromatic Scale* and *Table 2.2b: Ideal vs. Equal Tempered Intervals* that the optimum number of notes in a scale turned out to be 12. Unfortunately, there isn’t any 12-note scale that can produce exact intervals everywhere. Music would sound better if a scale with perfect intervals everywhere could be found. Many such attempts have been made, mainly by increasing the number of notes per octave, especially using guitars and organs, but none of these scales have gained acceptance. It is relatively easy to increase the number of notes per octave with a guitar-like instrument because all you need to do is to add strings and frets. The latest schemes being devised today involve computer generated scales in which the computer adjusts the frequencies with every transposition; this scheme is called adaptive tuning (Sethares).

The most basic concept needed to understand temperaments is the concept of the circle of fifths. To describe a circle of fifths, take any octave. Start with the lowest note and go up in 5ths. After two 5ths, you will go outside of this octave. When this happens, go down one octave so that you can keep going up in 5ths and still stay within the original octave. Do this for twelve 5ths, and you will end up at the highest note of the octave! That is, if you start at `C4`, you will end up with `C5` and this is why it is called a circle. Not only that, but every note you hit when playing the 5ths is a different note. This means that the circle of fifths hits every note once and only once, a key property useful for tuning the scale and for studying it mathematically.

c. Pythagorean, Equal, Meantone, and “Well” Temperaments

Historical developments are central to discussions of temperament because mathematics was no help; practical tuning algorithms could only be invented by the tuners of the time. Pythagoras is credited with inventing the Pythagorean Temperament at around 550 BC, in which the chromatic scale is generated by tuning in perfect 5ths, using the circle of fifths. Unfortunately, the twelve perfect 5ths in the circle of fifths do not make an exact factor of two. Therefore, the final note you get is not exactly the octave note but is too high in frequency by what is called the “Pythagorean comma”, about 23 cents (a cent is one hundredths of a semitone). Since a 4th plus a 5th make up an octave, the Pythagorean temperament results in a scale with perfect 4ths and 5ths, but the octave is dissonant. It turns out that tuning in perfect 5ths leaves the 3rds in bad shape, another disadvantage of the Pythagorean temperament. Now if we were to tune by contracting each 5th by 23/12 cents, we would end up with exactly one octave and that is one way of tuning an Equal Temperament (ET) scale. In fact, we shall use this method in the section on tuning (*c. Equal Temperament (ET)*). The ET scale was already known within a hundred years or so after invention of the Pythagorean temperament. Thus ET is not a “modern temperament” (a frequent misconception).

Following the introduction of the Pythagorean temperament, all newer temperaments were efforts at improving on it. The first method was to halve the Pythagorean comma by distributing it among two final 5ths. One major development was Meantone Temperament, in which the 3rds were made just (exact) instead of the 5ths. Musically, 3rds play more prominent roles than 5ths, so that meantone made sense, because during its heyday music made greater use of 3rds. Unfortunately, meantone has a wolf worse than Pythagorean.

The next milestone is represented by Bach’s Well Tempered Clavier in which music was written with “key color” in mind, which was a property of Well Temperaments (WT). These were non-ET temperaments that struck a compromise between meantone and Pythagorean. This concept worked because Pythagorean tuning ended up sharp, while meantone is flat (ET and WT give perfect octaves). In addition, WT presented the possibility of not only good 3rds, but also good 5ths. The simplest WT (to tune) was devised by Kirnberger, a student of Bach. But it has a terrible wolf. “Better” WTs (all temperaments are compromises and they all have advantages and disadvantages) were devised by Werckmeister and by Young (which is almost the same as Vallotti). If we broadly classify tunings as Meantone, WT, or Pythagorean, then ET is a WT because ET is neither sharp nor flat.

The violin takes advantage of its unique design to circumvent these temperament problems. The open strings make intervals of a 5th with each other, so that the violin naturally tunes Pythagorean (anyone can tune it!). Since the 3rds can always be fingered just (meaning exact), it has all the advantages of the Pythagorean, meantone, and WT, with no wolf in sight! In addition, it has a complete set of frequencies (infinite) within its frequency range. Little wonder that the violin is held in such high esteem by musicians.

Since about 1850, ET had been almost universally accepted because of its musical freedom and the trend towards increasing dissonance by composers. All the other temperaments are generically classified as “historical temperaments”, which is clearly a misnomer. Most WTs are relatively easy to tune, and most harpsichord owners had to tune their own instruments, which is why they used WT. This historical use of WT gave rise to the concept of key color in which each key, depending on the temperament, endowed specific colors to the music, mainly through the small de-tunings that create “tension” and other effects. After listening to music played on pianos tuned to WT, ET tends to sound muddy and bland. Thus key color does matter. On the other hand, there is always some kind of a wolf in the WTs which can be very annoying.

For playing most of the music composed around the times of Bach, Mozart, and Beethoven, WT works best. As an example, Beethoven chose intervals for the dissonant ninths in the first movement of his Moonlight Sonata that are less dissonant in WT. These great composers were acutely aware of temperament. You will see a dramatic demonstration of WT if you listen to the last movement of Beethoven’s Waldstein played in ET and WT. This movement is heavily pedaled, making harmony a major issue.

From Bach’s time to about Chopin’s time, tuners and composers seldom documented their tunings and we have precious little information on those tunings. At one time, in the early 1900s, it was believed that Bach used ET because, how else would he be able to write music in all the keys unless you could freely transpose from one to the other? Some writers even made the preposterous statement that Bach invented ET! Such arguments, and the fact that there was no “standard WT” to choose from, led to the acceptance of ET as the universal tuning used by tuners, to this day. Standardization to ET also assured tuners of a good career because ET was too difficult for anyone but well trained tuners to accurately tune.

As pianists became better informed and investigated the WTs, they re-discovered key color. In 1975, Herbert Anton Kellner concluded that Bach had written his music with key color in mind, and that Bach used a WT, not ET. But which WT? Kellner guessed at a WT which most tuners justifiably rejected as too speculative. Subsequent search concentrated on well known WTs such as Kirnberger, Werckmeister, and Young. They all produced key color but still left open the question of what Bach used. In 2004, Bradley Lehman proposed that the strange spirals at the top of the cover page of Bach’s *Well Tempered Clavier* manuscript represented a tuning diagram (see Larips.com), and used the diagram to produce a WT that is fairly close to Vallotti. Bach’s tunings were mainly for harpsichord and organ, since pianos as we know them today didn’t exist at that time. One requirement of harpsichord tuning is that it be simple enough so that it can be done in about 10 minutes on a familiar instrument, and Lehman’s Bach tuning met that criterion. Thus we now have a pretty good idea of what temperament Bach used.

If we decide to adopt WT instead of ET, which WT should we standardize to? Firstly, the differences between the “good” WTs are not as large as the differences between ET and most WTs, so practically any WT you pick would be an improvement. We do not need to pick a specific WT - we can specify the best WT for each piece we play; this option is practical only for electronic and self-tuning pianos that can switch temperaments easily. In order to intelligently pick the “best” WT, we must know what we are seeking in a WT. We seek: pure harmonies and key color. Unfortunately, we can not have both because they tend to be mutually exclusive. Pure harmony is an improvement over ET, but is not as sophisticated as key color. We will encounter this type of phenomenon in “stretch” (see *j. What is Stretch?*) whereby the music sounds better if the intervals are tuned slightly sharp. Unlike stretch, however, key color is created by dissonances associated with the Pythagorean comma. With this caveat, therefore, we should pick a WT with the best key color and least dissonance, which is Young. If you want to hear what a clear harmony sounds like, try Kirnberger, which has the largest number of just intervals.

We now see that picking a WT is not only a matter of solving the Pythagorean comma, but also of gaining key color to enhance music – in a way, we are creating something good from something bad. The price we pay is that composers must learn key color, but they have naturally done so in the past. It is certainly a joy to listen to music played in WT, but it is even more fascinating to play music in WT. Chopin is somewhat of an enigma in this regard because he loved the black keys and used keys far from “home” (home means near `C major`, with few accidentals, as normally tuned). He probably considered the black keys easier to play (once you learn FFP, III.4.b), so that the fears many students feel when they see all those sharps and flats in Chopin’s music is not justified. Chopin used one tuner who later committed suicide, and there is no record of how he tuned. Who knows? Could it be that he tuned Chopin’s piano to favor the black keys? Because of the “far out” keys he tended to use, Chopin’s music benefits only slightly from WT, as normally tuned and frequently hits WT wolves. Conclusions: We should get away from ET because of the joy of playing on WT; if we must pick one WT, it should be Young; otherwise, it is best to have a choice of WTs (as in electronic pianos); if you want to hear pure harmonies, try Kirnberger. The WTs will teach us key color which not only enhances the music, but also sharpens our sense of musicality.

1.4.3 3. Tuning Tools

You will need one tuning lever (also called tuning hammer), several rubber wedges, a felt muting strip, and one or two tuning forks and ear plugs or ear muffs. Professional tuners nowadays also use electronic tuning aids, but we will not consider them here because they are not cost effective for the amateur. We shall learn aural tuning – tuning by ear. All professional tuners must be good aural tuners even if they use electronic tuning aids. Grands use the larger rubber muting wedges and uprights require the smaller ones with wire handles. Four wedges of each type will suffice. You can buy these by mail order or you can ask your tuner to buy them for you. The most popular muting strips are felt, about 4 ft long, 5/8 inch wide. They are used to mute the two side strings of the 3-string notes in the octave used to “set the bearings” (section 6). They also come as ganged rubber wedges but these don’t work as well. The strips also come in rubber, but rubber does not mute as well and is not as stable as felt (they can move or pop out while tuning). The disadvantage of the felt strip is that it will leave a layer of felt fiber on the soundboard after you are finished, which will need to be vacuumed out.

A high quality tuning lever consists of an extendable handle, a head that attaches to the tip of the handle, and an interchangeable socket that screws into the head. It is a good idea to have a piano tuning pin which you can insert into the socket using a vise grip so that you can screw the socket into the head firmly. Otherwise, if you grab on the socket with the vise grip, you can scratch it up. If the socket is not firmly in the head, it will come off during tuning. Most pianos require a #2 socket, unless your piano has been re-strung using larger tuning pins. The standard head is a 5 degree head. This "5 degree" is the angle between the socket axis and the handle. Both the heads and sockets come in various lengths, but "standard" or "medium" length will do.

Get two tuning forks, `A-440` and `C-523.3` of good quality. Develop a good habit of holding them at the narrow neck of the handle so that your fingers do not interfere with their vibrations. Tap the tip of the fork firmly against a muscular part of your knee and test the sustain. It should be audible for 10 to 20 seconds when placed close to your ear. The best way to hear the fork is to place the tip of the handle against the triangular cartilage (ear lobe) that sticks out towards the middle of the ear hole. You can adjust the loudness of the fork by pressing the ear lobe in or out using the end of the fork. Do not use whistles; they are too inaccurate. Ear muffs are necessary protection devices, since ear damage is a tuner's occupational hazard. It is necessary to hit the keys hard (pound the keys – to use a tuners' jargon) in order to tune properly as explained below, and the sound intensity from such pounding can damage the ear, resulting in hearing loss and tinnitus.

1.4.4 4. Preparation

Prepare for tuning by removing the music stand so that the tuning pins are accessible (grand piano). For the following section, you need no further preparation. For "setting the bearings", you need to mute all the side strings of the triplet strings within the "bearings octave" using the muting strip so that when you play any note within this octave, only the center string will vibrate. You will probably have to mute close to two octaves depending on the tuning algorithm. Try out the entire algorithm first to determine the highest and lowest notes you need to mute. Then mute all the notes in between. Use the rounded end of the wire handle of the upright mute to press the felt into the spaces between the outer strings of adjacent notes.

1.4.5 5. Getting Started

Without a teacher, you cannot dive right into tuning. You will quickly lose your bearing and have no idea how to get back. Therefore, you must first learn/practice certain tuning procedures so that you don't end up with an unplayable piano that you cannot restore. This section is an attempt to get you to the level at which you might try a real tuning, without running into those types of difficulties.

The first things to learn are what not to do, in order to avoid destroying the piano, which is not difficult. If you tighten a string too much, it will break. The initial instructions are designed to minimize string breakage from amateurish moves, so read them carefully. Plan ahead so that you know what to do in case you break a string. A broken string per se, even when left for long periods of time, is no disaster to a piano. However, it is probably wise to conduct your first practices just before you intend to call your tuner. Once you know how to tune, string breakage is a rare problem except for very old or abused pianos. The tuning pins are turned by such small amounts during tuning that the strings almost never break. One common mistake beginners make is to place the lever on the wrong tuning pin. Since turning the pin does not cause any audible change, they keep turning it until the string breaks. One way to avoid this is to always start by tuning flat, as recommended below, and to never turn the pin without listening to the sound.

The most important consideration for a starting tuner is to preserve the condition of the pinblock. The pressure of the pinblock on the pin is enormous. Now you will never have to do this, but if you were to hypothetically turn the pin 180º very rapidly, the heat generated at the interface between pin and pinblock would be sufficient to cook the wood and alter its molecular structure. Clearly, all rotations of the pin must be conducted in slow, small, increments. If you need to remove a pin by turning it, rotate only a quarter turn (counter clock-wise), wait a moment for the heat to dissipate away from the interface, then repeat the procedure, etc.; without such precautions, the wood surrounding the pin will turn to charcoal.

I will describe everything assuming a grand piano, but the corresponding motion for the upright should be obvious. There are two basic motions in tuning. The first is to turn the pin so as to either pull or release the string. The second is to rock the pin back towards you (to pull on the string) or rock it forwards, towards the string, to release it. The rocking motion, if done to extreme, will enlarge the hole and damage the pinblock. Note that the hole is somewhat elliptical at the top surface of the pinblock because the string is pulling the pin in the direction of the major axis of the ellipse. Thus a small amount of backwards rocking does not enlarge the ellipse because the pin is always pulled into the front end of the ellipse by the string. Also, the pin is not straight but bent elastically towards the string by the pull of the string. Therefore, the rocking motion can be quite effective in moving the string. Even a small amount of forward rocking, within the elasticity of the wood, is harmless. It is clear from these considerations that you must use the rotation whenever possible, and use the rocking motion only when absolutely necessary. Only very small rocking motions should be used. For the extreme high notes (top two octaves), the motion needed to tune the string is so small that you may not be able to control it adequately by rotating the pin. Rocking provides much finer control, and can be used for that final miniscule motion to bring it into perfect tune.

Now, what is the easiest way to start practicing? First, let's choose the easiest notes to tune. These lie in the `C3-C4` octave. Lower notes are harder to tune because of their high harmonic content, and the higher notes are difficult because the amount of pin rotation needed to tune becomes extremely small. Note that middle `C` is `C4`; the `B` just below it is `B3` and the `D` immediately above middle `C` is `D4`. That is, the octave number 1, 2, 3, . . . changes at `C`, not at `A`. Let's choose `G3` as our practice note and start numbering the strings. Each note in this region has 3 strings. Starting from the left, let's number the strings *123* (for `G3`), *456* (for `G3#`), *789* (for `A3`), etc. Place a wedge between strings *3* and *4* in order to mute string *3* so that when you play `G3`, only *1* and *2* can vibrate. Place the wedge about midway between the bridge and agraffe.

There are two basic types of tuning: unison and harmonic. In unison, the two strings are tuned identically. In harmonic tuning, one string is tuned to a harmonic of the other, such as thirds, fourths, fifths, and octaves. The three strings of each note are tuned in unison, which is easier than harmonic tuning, so let's try that first.

a. Engaging and Manipulating the Tuning Lever

If your tuning lever has adjustable length, pull it out about 3 inches and lock it in place. Hold the handle of the tuning lever in your RH and the socket in your LH and engage the socket over the pin. Orient the handle so that it is approximately perpendicular to the strings and pointing to your right. Lightly jiggle the handle around the pin with your RH and engage the socket with your LH so that the socket is securely engaged, as far down as it will go. From day one, develop a habit of jiggling the socket so that it is securely engaged. At this point, the handle is probably not perfectly perpendicular to the strings; choose the socket position so that the handle is as close to perpendicular as the socket position will allow. Now find a way to brace your RH so that you can apply firm pressure on the lever. For example, you can grab the tip of the handle with the thumb and one or two fingers, and brace the arm on the wooden piano frame or brace your pinky against the tuning pins directly under the handle. If the handle is closer to the plate (the metal frame) over the strings, you might brace your hand against the plate. You should not grab the handle like you hold a tennis racket and push-pull to turn the pin – this will not give enough control. You may be able to do that after years of practice, but in the beginning, grabbing the handle and pushing without bracing against something is too difficult to control accurately. So develop a habit of finding good places to brace your hand against, depending on where the handle is. Practice these positions making sure that you can exert controlled, constant, powerful pressure on the handle, but do not turn any pins yet.

The lever handle must point to the right so that when you turn it towards you (the string goes sharp), you counteract the force of the string and free the pin from the front side of the hole (towards the string). This allows the pin to turn more freely because of the reduction in friction. When you tune flat, both you and the string are trying to turn the pin in the same direction. Then the pin would turn too easily, except for the fact that both your push and the string's pull jam the pin against the front of the hole, increasing the pressure (friction) and preventing the pin from rotating too easily. If you had placed the handle to the left, you run into trouble for both the sharp and flat motions. For the sharp motion, both you and the string jam the pin against the front of the hole, making it doubly difficult to turn the pin, and damaging the hole. For the flat motion, the lever tends to lift the pin off from the front edge of the hole and reduces the friction. In addition, both the lever and string are turning the pin in the same direction. Now the pin now turns too easily. The lever handle must point to the left for uprights. Looking down on the tuning pin, the lever should point to 3 o'clock for grands and to 9 o'clock for uprights. In both cases, the lever is on the side of the last winding of the string.

Professional tuners do not use these lever positions. Most use 1-2 o'clock for grands and 10-11 o'clock for uprights and Reblitz recommends 6 o'clock for grands and 12 o'clock for uprights. In order to understand why, let's first consider positioning the lever at 12 o'clock on a grand (it is similar at 6 o'clock). Now the friction of the pin with the pinblock is the same for both the sharp and flat motions. However, in the sharp motion, you are going against the string tension and in the flat motion, the string is helping you. Therefore, the difference in force needed between sharp and flat motions is much larger than the difference when the lever is at 3 o'clock, which is a disadvantage. However, unlike the 3 o'clock position, the pin does not rock back and forth during tuning so that when you release the pressure on the tuning lever, the pin does not spring back – it is more stable – and you can get higher accuracy.

The 1-2 o'clock position is a good compromise that makes use of both of the advantages of the 3 o'clock and 12 o'clock positions. Beginners do not have the accuracy to take full advantage of the 1-2 o'clock position, so my suggestion is to start with the 3 o'clock position, which should be easier at first, and transition to the 1-2 o'clock position as your accuracy increases. When you become good, the higher accuracy of the 1-2 o'clock position can speed up your tuning so that you can tune each string in a few seconds. At the 3 o'clock position, you will need to guess how much the pin will spring back and over-tune by that amount, which takes more time. Clearly, exactly where you place the lever will become more important as you improve.

b. Setting the Pin

It is important to "set the pin" correctly in order for the tuning to hold. If you look down on the pin, the string comes around the right side of the pin (grands – it is on the left for uprights) and twirls around it. Therefore if you rotate the pin CW (clockwise), you will tune sharp and vice versa. The string tension is always trying to rotate the pin CCW (counter clock-wise, or flat). Normally, a piano de-tunes flat as you play it. However, because the grip of the pinblock on the pin is so strong, the pin is never straight but is always twisted.

If you rotate it CW and stop, the top of the pin will be twisted CW with respect to the bottom. In this position, the top of the pin wants to rotate CCW (the pin wants to untwist) but can't because it is held by the pinblock. Remember that the string is also trying to rotate it CCW. The two forces together can be sufficient to quickly de-tune the piano flat when you play something loud.

If the pin is turned CCW, the opposite happens – the pin will want to untwist CW, which opposes the string force. This reduces the net torque on the pin, making the tuning more stable. In fact, you can twist the pin so far CCW that the untwisting force is much larger than the string force and the piano can then de-tune itself sharp as you play. Clearly, you must properly "set the pin" in order produce a stable tuning. This requirement will be taken into account in the following tuning instructions.

c. Tuning Unisons

Now engage the tuning lever on the pin for string *1*. We will tune string *1* to string *2*. The motion you will practice is:

1. flat,
2. sharp,
3. flat,
4. sharp
5. flat (tune)

Except for #1, each motion must be smaller than the previous one. As you improve, you will add or eliminate steps as you see fit. We are assuming that the two strings are almost in tune. As you tune, you must follow two rules:

- Never turn the pin unless you are simultaneously listening to the sound.
- Never release the pressure on the tuning lever handle until that motion is complete.

For example, let's start with motion #1: keep playing the note every second or two with the LH so that there is a continuous sound, while pushing the end of the lever handle away from you with the thumb and 2nd finger. Play the note in such a way as to maintain a continuous sound. Don't lift the key for any length of time, as this will stop the sound. Keep the key down and play with a quick up-and-down motion so that there is no break in the sound. The pinky and the rest of your RH should be braced against the piano. The required motion of the lever is a few millimeters. First, you will feel an increasing resistance, and then the pin will start to rotate. Before the pin begins to rotate, you should hear a change in the sound. As you turn the pin, listen for string *1* going flat, creating a beat with the center string; the beat frequency increasing as you turn. Stop at a beat frequency of 2 to 3 per second. The tip of the tuning lever should move less than one cm. Remember, never rotate the pin when there is no sound because you will immediately lose track of where you are with respect to how the beats are changing. Always maintain constant pressure on the lever until that motion is completed for the same reason.

What is the rationale behind the above 5 motions? Assuming that the two strings are in reasonable tune, you first tune string *1* flat in step #1 to make sure that in step #2 you will pass the tuning point. This also protects against the possibility that you had placed the lever on the wrong tuning pin; as long as you are turning flat, you will never break a string.

After #1 you are flat for sure, so in step #2 you can listen to the tuning point as you pass through it. Go past it until you hear a beat frequency of about 2 to 3 per second on the sharp side, and stop. Now you know where the tuning point is, and what it sounds like. The reason for going so far past the tuning point is that you want to set the pin, as explained above.

Now go back flat again, step #3 but this time, stop just past the tuning point, as soon as you can hear any incipient beats. The reason why you don't want to go too far past the tuning point is that you don't want to undo the "setting of the pin" in step #2. Again, note exactly what the tuning point sounds like. It should sound perfectly clean and pure. This step assures that you did not set the pin too far.

Now conduct the final tuning by going sharp (step #4), by as little as you can beyond perfect tune, and then bringing it into tune by turning flat (step #5). Note that your final motion must always be flat in order to set the pin. Once you become good, you might be able to do the whole thing in two motions (sharp, flat), or three (flat, sharp, flat).

Ideally, from step #1 to final tune, you should maintain the sound with no stoppage, and you should always be exerting pressure on the handle; never letting go of the lever. Initially, you will probably have to do this motion by motion. When you become proficient, the whole operation will take only a few seconds. But at first, it will take a lot longer. Until you develop your "tuning muscles" you will tire quickly and may have to stop from time to time to recover. Not only the hand/arm muscles, but the mental and ear concentration required to focus on the beats can be quite a strain and can quickly cause fatigue. You will need to develop "tuning stamina" gradually. Most people do better by listening through one ear than through both, so turn your head to see which ear is better.

The most common mistake beginners make at this stage is to try to listen for beats by pausing the tuning motion. Beats are difficult to hear when nothing is changing. If the pin is not being turned, it is difficult to decide which of the many things you are hearing is the beat that you need to concentrate on. What tuners do is to keep moving the lever and then listening to the changes in the beats. When the beats are changing, it is easier to identify the particular beat that you are using for tuning that string. Therefore, slowing down the tuning motion doesn't make it easier. Thus the beginner is between a rock and a hard place. Turning the pin too quickly will result in all hell breaking loose and losing track of where you are. On the other hand, turning too slowly will make it difficult to identify the beats. Therefore work on determining the range of motion you need to get the beats and the right speed with which you can steadily turn the pin to make the beats come and go. In case you get hopelessly lost, mute strings *2* and *3* by placing a wedge between them, play the note and see if you can find another note on the piano that comes close. If that note is lower than `G3`, then you need to tune it sharp to bring it back, and vice versa.

Now that you have tuned string *1* to string *2*, reposition the wedge so that you mute *1*, leaving *2* and *3* free to vibrate. Tune *3* to *2*. When you are satisfied, remove the wedge and see if the `G` is now free of beats. You have tuned one note! If the `G` was in reasonable tune before you started, you haven't accomplished much, so find a note nearby that is out of tune and see if you can "clean it up". Notice that in this scheme, you are always tuning one single string to another single string. In principle, if you are really good, strings *1* and *2* are in perfect tune after you finish tuning *1*, so you don't need the wedge any more. You should be able to tune *3* to *1* and *2* vibrating together. In practice this doesn't work until you become really proficient. This is because of a phenomenon called sympathetic vibration.

d. Sympathetic Vibrations

The accuracy required to bring two strings into perfect tune is so high that it is a nearly impossible job. It turns out that, in practice, this is made easier because when the frequencies approach within a certain interval called the "sympathetic vibration range", the two strings change their frequencies towards each other so that they vibrate with the same frequency. This happens because the two strings are not independent, but are coupled to each other at the bridge. When coupled, the string vibrating at the higher frequency will drive the slower string to vibrate at a slightly higher frequency, and vice versa. The net effect is to drive both frequencies towards the average frequency of the two. Thus when you tune *1* and *2* unison, you have no idea whether they are in perfect tune or merely within the sympathetic vibration range (unless you are an experienced tuner). In the beginning, you will most likely not be in perfect tune.

Now if you were to try to tune a third string to the two strings in sympathetic vibration, the third string will bring the string closest to it in frequency into sympathetic vibration. But the other string may be too far off in frequency. It will break off the sympathetic vibration, and will sound dissonant. The result is that no matter where you are, you will always hear beats – the tuning point disappears! It might appear that if the third string were tuned to the average frequency of the two strings in sympathetic vibration, all three should go into sympathetic vibration. This does not appear to be the case unless all three frequencies are in perfect tune. If the first two strings are sufficiently off, a complex transfer of energy takes place among the three strings. Even when the first two are close, there will be higher harmonics that will prevent all beats from disappearing when a third string is introduced. In addition, there are frequent cases in which you cannot totally eliminate all beats because the two strings are not identical. Therefore, a beginner will become totally lost, if he were to try to tune a third string to a pair of strings. Until you become proficient at detecting the sympathetic vibration range, always tune one string to one; never one to two. In addition, just because you tuned *1* to *2* and *3* to *2*, it does not mean that the three strings will sound "clean" together. Always check; if it is not completely "clean", you will need to find the offending string and try again.

Note the use of the term "clean". With enough practice, you will soon get away from listening to beats, but instead, you will be looking for a pure sound that results somewhere within the sympathetic vibration range. This point will depend on what types of harmonics each string produces. In principle, when tuning unisons, you are trying to match the fundamentals. In practice, a slight error in the fundamentals is inaudible compared to the same error in a high harmonic. Unfortunately, these high harmonics are generally not exact harmonics but vary from string to string. Thus, when the fundamentals are matched, these high harmonics create high frequency beats that make the note "muddy" or "tinny". When the fundamentals are de- tuned ever so slightly so that the harmonics do not beat, the note "cleans up". Reality is even more complicated because some strings, especially for the lower quality pianos, will have extraneous resonances of their own, making it impossible to completely eliminate certain beats. These beats become very troublesome if you need to use this note to tune another one.

e. Making that Final Infinitesimal Motion

We now advance to the next level of difficulty. Find a note near `G5` that is slightly out of tune, and repeat the above procedure for `G3`. The tuning motions are now much smaller for these higher notes, making them more difficult. In fact you may not be able to achieve sufficient accuracy by rotating the pin. We need to learn a new skill. This skill requires you to pound on the notes, so put on your ear muffs or ear plugs.

Typically, you would get through motion #4 successfully, but for motion #5 the pin would either not move or jump past the tuning point. In order to make the string advance in smaller increments, press on the lever at a pressure slightly below the point at which the pin will jump. Now strike hard on the note while maintaining the same pressure on the lever. The added string tension from the hard hammer blow will advance the string by a small amount. Repeat this until it is in perfect tune. It is important to never release the pressure on the lever and to keep the pressure constant during these repeated small advances, or you will quickly lose track of where you are. When it is in perfect tune, and you release the lever, the pin might spring back, leaving the string slightly flat. You will have to learn from experience, how much it will spring back and compensate for it during the tuning process.

The need to pound on the string to advance it is one reason you often hear tuners pounding on the piano. It is a good idea to get into the habit of pounding on most of the notes because this stabilizes the tuning. The resulting sound can be so loud as to damage the ear, and one of the occupational hazards of tuners is ear damage from pounding. Use of ear plugs is the solution. When pounding, you will still easily hear the beats even with ear plugs. The most common initial symptom of ear damage is tinnitus (ringing in the ear). You can minimize the pounding force by increasing the pressure on the lever. Also, less pounding is required if the lever is parallel to the string instead of perpendicular to it, and even less if you point it to the left. This is another reason why many tuners use their levers more parallel to the strings than perpendicular. Note that there are two ways to point it parallel: towards the strings (12 o'clock) and away from the strings (6 o'clock). As you gain experience, experiment with different lever positions as this will give you many options for solving various problems. For example, with the most popular 5-degree head on your lever, you may not be able to point the lever handle to the right for the highest octave because it may hit the wooden piano frame.

f. Equalizing String Tension

Pounding is also helpful for distributing the string tension more evenly among all the non-speaking sections of the string, such as the duplex scale section, but especially in the section between the capo bar and the agraffe. There is controversy as to whether equalizing the tension will improve the sound. There is little question that the even tension will make the tuning more stable. However, whether it makes a material difference in stability may be debatable, especially if the pins were correctly set during tuning. In many pianos, the duplex sections are almost completely muted out using felts because they might cause undesirable oscillations. In fact, the over-strung section is muted out in almost every piano. Beginners need not worry about the tension in these "non-speaking" sections of the strings. Thus heavy pounding, though a useful skill to learn, is not necessary for a beginner.

My personal opinion is that the sound from the duplex scale strings does not add to the piano sound. In fact, this sound is inaudible and is muted out when they become audible in the bass. Thus the "art of tuning the duplex scale" is a myth although most piano tuners (including Reblitz!) have been taught to believe it by the manufacturers, because it makes for a good sales pitch. The only reason why you want to tune the duplex scale is that the bridge wants to be at a node of both the speaking and non-speaking lengths; otherwise, tuning becomes difficult, sustain may be shortened, and you lose uniformity. Using mechanical engineering terminology, we can say that tuning the duplex scale optimizes the vibrational impedance of the bridge. In other words, the myth does not detract from the tuners' ability to do their job. Nonetheless, a proper understanding is certainly preferable. The duplex scale is needed to allow the bridge to move more freely, not for producing sound. Obviously, the duplex scale will improve the quality of the sound (from the speaking lengths) because it optimizes the impedance of the bridge, but not because it produces any sound. The facts that the duplex scale is muted out in the bass and is totally inaudible in the treble prove that the sound from the duplex scale is not needed. Even in the inaudible treble, the duplex scale is "tuned" in the sense that the aliquot bar is placed at a location such that the length of the duplex part of the string is a harmonic length of the speaking section of the string in order to optimize the impedance ("aliquot" means fractional or harmonic). If the sound from the duplex scale were audible, the duplex scale would have to be tuned as carefully as the speaking length. However, for impedance matching, the tuning need only be approximate, which is what is done in practice. Some manufacturers have stretched this duplex scale myth to ridiculous lengths by claiming a second duplex scale on the pin side. Since the hammer can only transmit tensile strain to this length of string (because of the rigid Capo bar), this part of the string cannot vibrate to produce sound. Consequently, practically no manufacturer specifies that the non-speaking lengths on the pin side be tuned.

g. Rocking It in the Treble

The most difficult notes to tune are the highest ones. Here you need incredible accuracy in moving the strings and the beats are difficult to hear. Beginners can easily lose their bearing and have a hard time finding their way back. One advantage of the need for such small motions is that now, you can use the pin-rocking motion to tune. Since the motion is so small, rocking the pin does not damage the pinblock. To rock the pin, place the lever parallel to the strings and pointing towards the strings (away from you). To tune sharp, pull up on the lever, and to tune flat, press down. First, make sure that the tuning point is close to the center of the rocking motion. If it is not, rotate the pin so that it is. Since this rotation is much larger than that needed for the final tuning, it is not difficult, but remember to correctly set the pin. It is better if the tuning point is front of center (towards the string), but bringing it too far forward would risk damaging the pinblock when you try to tune flat. Note that tuning sharp is not as damaging to the pinblock as tuning flat because the pin is already jammed up against the front of the hole.

h. Rumblings in the Bass

The lowest bass strings are second in difficulty (to the highest notes) to tune. These strings produce sound composed mostly of higher harmonics. Near the tuning point, the beats are so slow and soft that they are difficult to hear. Sometimes, you can “hear” them better by pressing your knee against the piano to feel for the vibrations than by trying to hear them with your ears, especially in the single string section. You can practice unison tuning only down to the last double string section. See if you can recognize the high pitched, metallic, ringing beats that are prevalent in this region. Try eliminating these and see if you need to de-tune slightly in order to eliminate them. If you can hear these high, ringing, beats, it means that you are well on your way. Don’t worry if you can’t even recognize them at first– beginners are not expected to.

i. Harmonic Tuning

Once you are satisfied with your ability to tune unisons, start practicing tuning octaves. Take any octave near middle `C` and mute out the upper two side strings of each note by inserting a wedge between them. Tune the upper note to the one an octave below, and vice versa. As with unisons, start near middle `C`, then work up to the highest treble, and then practice in the bass. Repeat the same practice with 5ths, 4ths, and major 3rds.

After you can tune perfect harmonics, try de-tuning to see if you can hear the increasing beat frequency as you deviate very slightly from perfect tune. Try to identify various beat frequencies, especially 1bps (beat per second) and 10bps, using 5ths. These skills will come in handy later.

j. What is Stretch?

Harmonic tuning is always associated with a phenomenon called stretch. Harmonics in piano strings are never exact because real strings attached to real ends do not behave like ideal mathematical strings. This property of inexact harmonics is called inharmonicity. The difference between the actual and theoretical harmonic frequencies is called stretch. Experimentally, it is found that most harmonics are sharp compared to their ideal theoretical values, although there can be a few that are flat.

According to one research result (Young, 1952), stretch is caused by inharmonicity due to the stiffness of strings. Ideal mathematical strings have zero stiffness. Stiffness is what is called an extrinsic property – it depends on the dimensions of the wire. If this explanation is correct, then stretch must also be extrinsic. Given the same type of steel, the wire is stiffer if it is fatter or shorter. One consequence of this dependence on stiffness is an increase in the frequency with harmonic mode number; i.e., the wire appears stiffer to harmonics with shorter wavelengths. Stiffer wires vibrate faster because they have an extra restoring force, in addition to the string tension. This inharmonicity from stiffness has been calculated to within several percent accuracy so that the theory appears to be sound, and this single mechanism appears to account for most of the observed stretch.

These calculations show that stretch is about 1.2 cents for the second mode of vibration at `C4` and doubles about every 8 semitones at higher frequency (`C4` = middle `C`, the first mode is the lowest, or fundamental frequency, one cent is one hundredth of a semitone, and there are 12 semitones in an octave). The stretch becomes smaller for lower notes, especially below `C3`, because the wire wound strings are quite flexible. Stretch increases rapidly with mode number and decreases even more rapidly with string length. In principle, stretch is smaller for larger pianos and larger for lower tension pianos if the same diameter strings are used. Stretch presents problems in scale design since abrupt changes in string type, diameter, length, etc., will produce a discontinuous change in stretch. Very high mode harmonics, if they happen to be unusually loud, present problems in tuning because of their large stretch – tuning out their beats could throw the lower, more important, harmonics audibly out of tune.

Since larger pianos tend to have smaller stretch, but also tend to sound better, one might conclude that smaller stretch is better. However, the difference in stretch is generally small, and the tone quality of a piano is largely controlled by properties other than stretch.

In harmonic tuning you tune, for example, the fundamental or a harmonic of the upper note to a higher harmonic of the lower note. The resulting new note is not an exact multiple of the lower note, but is sharp by the amount of stretch. What is so interesting about stretch is that a scale with stretch produces "livelier" music than one without! This has caused some tuners to tune in double octaves instead of single octaves, which increases the stretch.

The amount of stretch is unique to each piano and, in fact, is unique to each note of each piano. Modern electronic tuning aids are sufficiently powerful to record the stretch for all the desired notes of individual pianos. Tuners with electronic tuning aids can also calculate an average stretch for each piano or stretch function and tune the piano accordingly. In fact, there are anecdotal accounts of pianists requesting stretch in excess of the natural stretch of the piano. In aural tuning, stretch is naturally, and accurately, taken into account. Therefore, although stretch is an important aspect of tuning, the tuner does not have to do anything special to include stretch, if all you want is the natural stretch of the piano.

k. Precision, Precision, Precision

The name of the game in tuning is precision. All tuning procedures are arranged in such a way that you tune the first note to the tuning fork, the second to the first, etc., in sequence. Therefore, any errors will quickly add up. In fact, an error at one point will often make some succeeding steps impossible. This happens because you are listening for the smallest hint of beats and if the beats were not totally eliminated in one note, you can't use it to tune another as those beats will be clearly heard. In fact, for beginners, this will happen frequently before you learn how precise you need to be. When this happens, you will hear beats that you can't eliminate. In that case, go back to your reference note and see if you hear the same beat; if you do, there is the source of your problem – fix it.

The best way to assure precision is by checking the tuning. Errors occur because every string is different and you are never sure that the beat you hear is the one you are looking for, especially for the beginner. Another factor is that you need to count beats per second (bps), and your idea of, say 2bps, will be different on different days or at different times of the same day until you have those "beat speeds" well memorized. Because of the critical importance of precision, it pays to check each tuned note. This is especially true when "setting the bearings" which is explained below. Unfortunately, it is just as difficult to check as it is to tune correctly; that is, a person who cannot tune sufficiently accurately is usually unable to perform a meaningful check. In addition, if the tuning is sufficiently off, the checking doesn't work. Therefore, I have provided methods of tuning below that use a minimum of checks. The resulting tuning will not be very good initially, for Equal temperament. The Kirnberger temperament (see below) is easier to tune accurately. On the other hand, beginners can't produce good tunings anyway, no matter what methods they use. At least, the procedures presented below will provide a tuning which should not be a disaster and which will improve as your skills improve. In fact, the procedure described here is probably the fastest way to learn. After you have improved sufficiently, you can then investigate the checking procedures, such as those given in Reblitz, or *Tuning* by Jorgensen.

1.4.6 6. Tuning Procedures and Temperament

Tuning consists of "setting the bearings" in an octave near middle `C`, and then "copying" this octave to all the other keys. You will need various harmonic tunings to set the bearings and only the middle string of each note in the "bearings octave" is initially tuned. The "copying" is performed by tuning in octaves. Once one string of each note is tuned in this way, the remaining string(s) of each note are tuned in unison.

In setting the bearings, we must choose which temperament to use. As explained in section 2 above, most pianos today are tuned to Equal temperament (ET), but the historical temperaments may be showing signs of gaining popularity, especially the Well temperaments (WT). Therefore, I have chosen ET and one WT, Kirnberger II (K-II), for this chapter. K-II is one of the easiest temperaments to tune; therefore, we will visit that first. Most people who are unfamiliar with the different temperaments may not notice any difference at first between ET and K-II; they will both sound terrific compared to a piano out of tune. Most pianists, on the other hand, should hear a distinct difference and be able to form an opinion or preference if certain pieces of music are played and the differences are pointed out to them. The easiest way to listen to the differences for the uninitiated is to use an electronic piano that has all these temperaments built into it, and to play the same piece, using each temperament. For an easy test piece, try Beethoven's *Moonlight Sonata*, 1st movement; for a more difficult piece, try the 3rd movement of his *Waldstein Sonata*. Also, try some of your favorite Chopin pieces. My suggestion is for a beginner to learn K-II first so that you can get started without too much difficulty, and then learn ET when you can tackle more difficult stuff. One drawback of this scheme is that you may like K-II so much over ET that you may never decide to learn ET. Once you get used to K-II, ET will sound a little lacking, or "muddy". However, you cannot really be considered a tuner unless you can tune ET. Also, there are many WTs that you may want to look into, that are superior to K-II in several respects (see *c. Pythagorean, Equal, Meantone, and "Well" Temperaments*).

You can start tuning ET anywhere, but most tuners use the `A-440` fork to start, because orchestras generally tune to `A-440`. The objective in K-II is to have `C major` and as many "nearby" scales as possible to be just (have perfect chords), so the tuning is started from middle `C` (`C4` = 261.6Hz, but most tuners will use a `C-523.3` tuning fork to tune `C4` partly because the higher harmonic gives twice the accuracy). Now, the `A` that results from K-II tuned from the correct `C` does not result in `A-440`. Therefore, you will need two tuning forks: `A` for ET and `C` for K-II. Alternatively, you can just start with only a `C` fork and start tuning ET from `C`. Having two tuning forks is an advantage because whether you start from `C` or from `A`, you can check your ET when you get to the other note.

a. Tuning the Piano to the Tuning Fork

One of the most difficult steps in the tuning process is tuning the piano to the tuning fork. This difficulty arises from two causes:

1. The tuning fork has a different (usually shorter) sustain than the piano so that the fork dies off before you can make an accurate comparison.
2. The fork puts out a pure sine wave, without the loud harmonics of the piano strings.

Therefore, you cannot use beats with higher harmonics to increase the accuracy of the tuning as you can with two piano strings. One advantage of electronic tuners is that they can be programmed to provide square wave reference tones that contain large numbers of high harmonics. These high harmonics (they create those sharp corners of square waves – you will need to know polynomial math or Fourier transforms to understand this) are useful for increasing the tuning accuracy. We must therefore solve these two problems in order to tune the piano accurately to the tuning fork.

Both difficulties can be solved if we can use the piano as the tuning fork and make this transfer from fork to piano using some high piano harmonic. To accomplish such a transfer, find any note within the muted notes that makes loud beats with the fork. If you can't find any, use the note a half tone down or up; for example, for tuning fork `A`, use `Ab` or `A#` on the piano. If these beat frequencies are a bit too high, try these same notes an octave lower. Now tune the `A` on the piano so it makes the same frequency beats with these reference notes (`Ab`, `A#`, or any other note you had picked). The best way to hear the tuning fork is to press it against your ear lobe, as described above, *3. Tuning Tools*, or to press it against any large, hard, flat surface.

b. Kirnberger II

1. Mute all side strings from `F3` to `F4`.
2. Tune `C4` (middle `C`) to the fork.
3. Then use `C4` to tune `G3` (4th), `E4` (3rd), `F3` (5th), and `F4` (4th), and `G3` to tune `D4` (5th) and `B3` (3rd).
4. Then use `B3` to tune `F#3` (4th),
5. `F#3` to tune `Db4` (5th),
6. `F3` to tune `Bb3` (4th),
7. `Bb3` to tune `Eb4` (4th) and
8. `Eb4` to tune `Ab3` (5th).
9. All tunings up to here are just. Now tune `A3` such that the `F3-A3` and `A3-D4` beat frequencies are the same.

You are done with setting the bearings!

Now tune up in just octaves to the highest notes, then tune down to the lowest notes, using the bearings octave as reference. In all these tunings, tune just one new octave string while muting the others, then tune the remaining one or two strings in unison to the newly tuned string.

This is one time you might break the "tune one string against one" rule. If your reference note is a (tuned) 3-string note, use it as it is. This will test the quality of your tuning. If you have a hard time using it to tune a new single string, then your unison tuning of the reference note may not have been sufficiently accurate and you should go back and clean it up. Of course, if after considerable effort, you cannot tune 3 against 1, you will have no choice but to mute two of the three in order to advance. When all the treble and bass notes are done, the only un-tuned strings left are the ones you muted for setting the bearings. Tune these in unison to their center strings, starting with the lowest note, by pulling the felt off one loop at a time.

c. Equal Temperament (ET)

I present here the simplest ET tuning scheme. More accurate algorithms can be found in the literature (Reblitz, Jorgensen). No self-respecting professional tuner would use this scheme; however, when you get good at it, you can produce a useable ET. For the beginner, the more complete and precise schemes will not necessarily give better results. With those complex methods, a beginner can quickly get confused without any idea of what he did wrong. With the method shown here, you can quickly develop the ability to find out what you did wrong.

Mute the side strings from `G3` to `C#5`. Tune `A4` to the `A-440` fork. Tune `A3` to `A4`. Then tune `A3-E4` in a contracted 5th; by tuning `E4` slightly flat until you hear a beat of about 1 Hz. The contracted 5th should beat a little under 1 Hz at the bottom of the muted range (`A3`) and about 1.5 Hz near the top. The beat frequencies of the 5ths should increase smoothly with increasing pitch. Keep tuning up in contracted 5ths until you cannot go up any more without leaving the muted range, then tune one octave down, and repeat this up-in-5ths and down-one-octave procedure until you get to `A4`. For example, you started with a contracted `A3-E4`. Then tune a contracted `E4-B4`. The next 5th will take you above the highest muted note, `C#4`, so tune one octave down, `B4-B3`. All octaves are, of course, just. To get the contracted 5th, start from just and tune flat in order to increase the beat frequency to the desired value and set the pin correctly at the same time. If you had done everything perfectly, the last `D4-A4` should be a contracted 5th with a beat frequency of slightly over 1 Hz without any tuning. Then, you are done. You have just done a "circle of fifths". The miracle of the circle of fifths is that it tunes every note once, without skipping any within the `A3-A4` octave!

If the final `D4-A4` is not correct, you made some errors somewhere. In that case, reverse the procedure, starting from `A4`, going down in contracted 5ths and up in octaves, until you reach `A3`, where the final `A3-E4` should be a contracted 5th with a beat frequency slightly under 1 Hz. For going down in 5ths, you create a contracted 5th by tuning the lower note sharp from just. However, this tuning action will not set the pin. In order to set the pin correctly, you must first go too sharp, and then decrease the beat frequency to the desired value. Therefore, going down in 5ths is more difficult than going up in 5ths.

An alternative method is to start with `A` and tune to `C` by going up in 5ths, and checking this `C` with a tuning fork. If your `C` is too sharp, your 5ths were not sufficiently contracted, and vice versa. Another variation is to tune up in 5ths from `A3` a little over half way, and then tune down from `A4` to the last note that you tuned coming up.

Once the bearings are set, continue as described in the Kirnberger section above.

1.4.7 7. Making Minor Repairs (Voicing and Polishing Capstans)

Once you start tuning, you cannot help but get involved in small repairs and conducting some maintenance.

a. Hammer Voicing

A common problem seen with many pianos is compacted hammers. The condition of the hammer is much more important to the proper development of piano technique and for cultivating performance skills, than many people realize. Numerous places in this book refer to the importance of practicing musically in order to acquire technique. But you can't play musically if the hammer can't do its job, a critical point that is overlooked even by many tuners (often because they are afraid that the extra cost will drive customers away). For a grand piano, a sure sign of compacted hammers is that you find the need to close the lid at least partially in order to play soft passages. Another sure sign is that you tend to use the soft pedal to help you play softly. Compacted hammers either give you a loud sound or none at all. Each note tends to start with an annoying percussive bang that is too strong, and the sound is overly bright. It is these percussive bangs that are so damaging to the tuners'/pianist's ear. A properly voiced piano enables control over the entire dynamic range and produces a more pleasing sound.

Let's first see how a compacted hammer can produce such extreme results. How do small, light hammers produce loud sounds by striking with relatively low force on strings under such high tension? If you were to try to push down on the string or try to pluck it, you will need quite a large force just to make a small sound. The answer lies in an incredible phenomenon that occurs when tightly stretched strings are struck at right angles to the string. It turns out that the force produced by the hammer at the instant of impact is theoretically infinite! This nearly infinite force is what enables the light hammer to overcome practically any achievable tension on the string and cause it to vibrate.

Here is the calculation for that force. Imagine that the hammer is at its highest point after striking the string (grand piano). The string at this point in time makes a triangle with its original horizontal position (this is just an idealized approximation, see below). The shortest leg of this triangle is the length between the agraffe and the impact point of the hammer. The second shortest leg is from the hammer to the bridge. The longest is the original horizontal configuration of the string, a straight line from bridge to agraffe. Now if we drop a vertical line from the hammer strike point down to the original string position, we get two right triangles back-to-back. These are two extremely skinny right triangles that have very small angles at the agraffe and at the bridge; we will call these small angles "theta"s (θ).

The only thing we know at this time is the force of the hammer, but this is not the force that moves the string, because the hammer must overcome the string tension before the string will yield. That is, the string cannot move up unless it can elongate. This can be understood by considering the two right triangles described above. The string had the length of the long legs of the right triangles before the hammer struck, but after the strike, the string is the hypotenuse, which is longer. That is, if the string were absolutely inelastic and the ends of the string were rigidly fixed, no amount of hammer force will cause the string to move.

A simple analysis shows that the extra tension force F (in addition to the original string tension) produced by the hammer strike is given by $f = F \times \sin\theta$, where f is the force of the hammer. It does not matter which right triangle we use for this calculation (the one on the bridge side or on the agraffe side). Therefore, the extra string tension $F = \frac{f}{\sin\theta}$. At the initial moment of the strike, $\theta = 0$, and therefore $F = \infty$! This happens because $\sin 0 = 0$. Of course, F can get to infinity only if the string cannot stretch and nothing else can move. What happens in reality is that as F increases towards infinity, something gives (the string stretches, the bridge moves, etc.) so that the hammer begins to move the string and θ increases from zero, making F finite (but still many orders of magnitude larger than your finger force).

This force multiplication explains why a small child can produce quite a loud sound on the piano in spite of the hundreds of pounds of tension on the strings. It also explains why an ordinary person can break a string just playing the piano, especially if the string is old and has lost its elasticity. The lack of elasticity causes the F to increase far more than if the string were more elastic, the string cannot stretch, and θ remains close to zero. This situation is greatly exacerbated if the hammer is also compacted so that there is a large, flat, hard groove that contacts the string. In that case, the hammer surface has no give and the instantaneous "f" in the above equation becomes very large. Since all this happens near $\theta = 0$ for a compacted hammer, the force multiplication factor is also increased. The result is a broken string.

The above calculation is a gross over-simplification and is correct only qualitatively. In reality, a hammer strike initially throws out a traveling wave towards the bridge, similarly to what happens when you grab one end of a rope and flick it. The way to calculate such waveforms is to solve certain differential equations that are well known. The computer has made the solution of such differential equations a simple matter and realistic calculations of these waveforms can now be made routinely. Therefore, although the above results are not accurate, they give a qualitative understanding of what is happening, and what the important mechanisms and controlling factors are.

For example, the above calculation shows that it is not the transverse vibration energy of the string, but the tensile force on the string, that is responsible for the piano sound. The energy imparted by the hammer is stored in the entire piano, not just the strings. This is quite analogous to the bow and arrow – when the string is pulled, all the energy is stored in the bow, not the string. And all of this energy is transferred via the tension in the string. In this example, the mechanical advantage and force multiplication calculated above (near $\theta = 0$) is easy to see. It is the same principle on which the harp is based.

The easiest way to understand why compacted hammers produce higher harmonics is to realize that the impact occurs in a shorter time. When things happen faster, the string generates higher frequency components in response to the faster event.

The above paragraphs make it clear that a compacted hammer will produce a large initial impact on the string whereas a properly voiced hammer will be much gentler on the string thus imparting more of its energy to the lower frequencies than the harmonics. Because the same amount of energy is dissipated in a shorter amount of time for the compacted hammer, the instantaneous sound level can be much higher than for a properly voiced hammer, especially at the higher frequencies. Such short sound spikes can damage the ear without causing any pain. Common symptoms of such damage are tinnitus (ringing in the ear) and hearing loss at high frequencies. Piano tuners, when they must tune a piano with such worn hammers, would be wise to wear ear plugs. It is clear that voicing the hammer is at least as important as tuning the piano, especially because we are talking about potential ear damage. An out-of-tune piano with good hammers does not damage the ear. Yet many piano owners will have their pianos tuned but neglect the voicing.

The two most important procedures in voicing are hammer re-shaping and needling. When the flattened strike point on the hammer exceeds about 1 cm, it is time to re-shape the hammer. Note that you have to distinguish between the string groove length and flattened area; even in hammers with good voicing, the grooves may be over 5 mm long. In the final analysis you will have to judge on the basis of the sound. Shaping is accomplished by shaving the "shoulders" of the hammer so that it regains its previous rounded shape at the strike point. It is usually performed using 1 inch wide strips of sandpaper attached to strips of wood or metal with glue or double sided tape. You might start with 80 grit garnet paper and finish it off with 150 grit garnet paper. The sanding motion must be in the plane of the hammer; never sand across the plane. There is almost never a need to sand off the strike point. Therefore, leave about 2 mm of the center of the strike point untouched.

Needling is not easy because the proper needling location and needling depth depend on the particular hammer (manufacturer) and how it was originally voiced. Especially in the treble, hammers are often voiced at the factory using hardeners such as lacquer, etc. Needling mistakes are generally irreversible. Deep needling is usually required on the shoulders just off the strike point. Very careful and shallow needling of the strike point area may be needed. The tone of the piano is extremely sensitive to shallow needling at the strike point, so that you must know exactly what you are doing. When properly needled, the hammer should allow you to control very soft sounds as well as produce loud sounds without harshness. You get the feeling of complete tonal control. You can now open your grand piano fully and play very softly without the soft pedal! You can also produce those loud, rich, authoritative tones.

b. Polishing the Capstans

Polishing the capstans can be a rewarding maintenance procedure. They may need polishing if they have not been cleaned in over 10 years, sometimes sooner. Press down on the keys slowly to see if you can feel a friction in the action. A frictionless action will feel like sliding an oily finger along a smooth glassware. When friction is present, it feels like the motion of a clean finger on squeaky clean glass. In order to be able to get to the capstans, you will need to lift the action off from the keys by unscrewing the screws that hold the action down for the grand. For uprights you generally need to unscrew the knobs that hold the action in place; make sure that the pedal rods, etc., are disengaged.

When the action is removed, the keys can be lifted out after removing the key stop rail. First make sure that all the keys are numbered so that you can replace them in the correct order. This is a good time to remove all the keys and clean any previously inaccessible areas as well as the sides of the keys. You can use a mild cleaning agent such as a cloth dampened with Windex for cleaning the sides of the keys.

See if the top, spherical contact areas of the capstans are tarnished. If they do not have a shiny polish, they are tarnished. Use any good brass/bronze/copper polish (such as Noxon) to polish and buff up the contact areas. Reassemble, and the action should now be much smoother.

1.4.8 59. Project Management

TODO

1.4.9 60. Injury, Health

TODO

1.5 Chapter Three: TODO

1.5.1 80. Grand Piano Action Diagram

TODO

1.5.2 83. Book Reviews: General Comments

TODO

1.6 Terms and Abbreviations

1.6.1 Abbreviations

- AP = Absolute Pitch (III.12)
- ET = Equal Temperament (*c. Pythagorean, Equal, Meantone, and "Well" Temperaments* & *c. Equal Temperament (ET)*)
- FFP = Flat Finger Position (III.4.b)
- FI = Fantaisie Impromptu by Chopin (II.25, III.2, III.5)
- FPD = Fast Play Degradation (II.25, near end)

- HS = Hands Separate (II.7)
- HT = Hands Together (II.25)
- K-II = Kirnberger II Temperament (*c. Pythagorean, Equal, Meantone, and “Well” Temperaments* & *b. Kirnberger II*)
- LH = Left Hand
- MP = Mental Play (*Fundamentals of Piano Practice*)
- NG = Nucleation Growth (III.15)
- PPI = Post Practice Improvement (II.15)
- PS = Parallel Sets (see below)
- RH = Right Hand
- SW = Speed Wall (III.7.i)
- TO = Thumb Over (III.5)
- TU = Thumb Under (III.5)
- WT = Well Temperament (*c. Pythagorean, Equal, Meantone, and “Well” Temperaments*)

1.6.2 Frequently Used Phrases

- Cartwheel Method (III.5.e)
- Chord Attack (II.9)
- Conjunction (II.8)
- Curl Paralysis (III.4.b)
- Intuitive Method (II.1)
- Mental Play (II.12, III.6.j)
- Parallel Sets (II.11, III.7.b, see *Fundamentals of Piano Practice*)
- Pyramid Position = “flat finger” position (III.4.b)
- Quiet Hand (III.6.l)
- Segmental Practice (II.6)
- Speed Wall (III.7.i)
- Spider position = “flat finger” position (III.4.b)

1.7 References

Note: Items in **bold** are reviewed below.

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1.7.1 Liszt's Teaching Bibliography:

Below is a list containing information on Liszt's teachings; the contents are disappointing. Liszt's father, Adam, did a terrific job of teaching Liszt but, after soaring to fame, Liszt only gave "master classes" to students who were already concert pianists, while complaining about the conservatories that could not teach. The few teachers who knew how to teach were the parents of Mozart, Beethoven, Chopin, Liszt, etc. That tells us something valuable. The anointed teachers: the great Masters and their students were led astray by the grandeur of "talent", dogma, endless practice, etc., (instead of research, knowledge, documentation, empowerment, etc.) and piano pedagogy ended up in a dead end with no way out.

1. Arthur Friedheim. *Life and Liszt*. Taplinger, NY, 1961.
2. *The Piano Master Classes of Franz Liszt: 1884-1886, Diary Notes of August Gollerich*, Indiana Univ. Press, 1996.
3. *Living with Liszt: From the Diary of Carl Lachmund, and American Pupil of Liszt 1882-1884*. Pendragon Press, Stuyvesant, NY, 1995.
4. William Mason. *Memories of a Musical Life*. Century Co., NY. 1901.
5. Bettina Walker. *My Musical Experiences*. R. Bently & Son, London. 1892.
6. There is a diary by Lina Schmalhausen, the other articles already cited (by Amy Fay and August Boissier), and the books by Ronald Taylor and Alan Walker.

1.7.2 Book / Video Reviews

Note: Need to import.

1.7.3 Web Sites, Books, Videos

Note: Need to import.

CHAPTER TWO

INDICES AND TABLES

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- modindex
- search