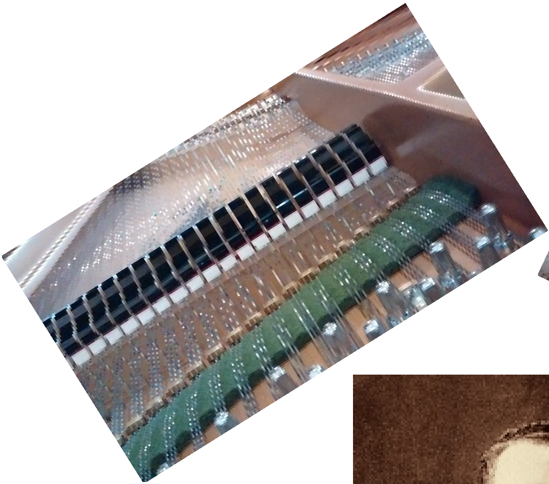
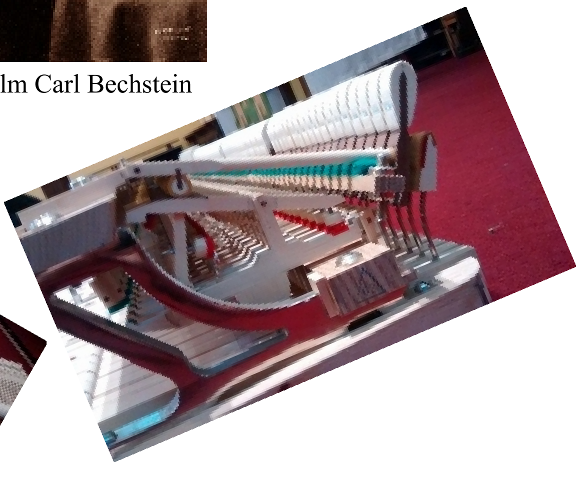
The Piano

By Les Sherlock



Friedrich Wilhelm Carl Bechstein



The Piano

A pre-concert talk by Les Sherlock at Lytchett Minster Parish Church, on 29.10.2016, to introduce their new Bechstein A208 Grand Piano. (See cover)

The talk took 35 minutes because much of the detail was on the Power Point slides and not read out, some of what is written here was forgotten (!), and some was deliberately omitted in a failed attempt to fit it into the half-hour I was allocated.

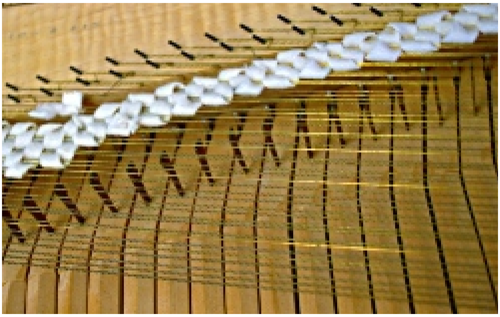
I am delighted you now have such a wonderful instrument here, which is five feet wide, six feet ten inches long, 836 lbs in weight, has 88 keys, 230 strings, and the total tension on them is 17.15 tons – so when I tuned it two days ago I shifted over 17 tons in under an hour with one hand, so don't mess with me, alright? ☺

History

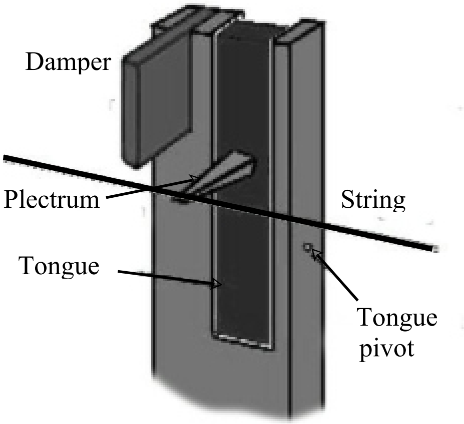
How did the piano evolve into what this sophisticated piece of kit is today, and how does it work?

There are three ways in which to make strings vibrate from a keyboard: push on them, pluck them and strike them. The first two methods appeared about 600 years ago. The first documented reference to the clavichord dates from 1404, and the mechanism in this instrument is very simple. A metal tangent fixed to the back of the key rises up when the key is played and presses onto the strings: there are two strings on each note. On one side of the tangents there is felt (or baize) woven between the strings to prevent that part of the strings from vibrating and keep them all silent when not being played. So the tangent acts as a bridge for the rest of the wire and determines the speaking length and therefore the pitch of the note.

There are two problems with this instrument. Because the tangent can only hit the string at the speed the key travels, it has not enough power to produce much volume; so, along with the thin, short strings, this means it is very quiet and not suitable for concerts, for example. Also, the harder you press down on the key, the higher the tangent rises, thus stretching the strings and sharpening the note. So it requires a very even touch to keep the notes in tune.



The second method, of plucking strings, appeared about the same time, the first documented reference to the harpsichord being 1397. This is more complex than the clavichord, with a jack resting on the back of the key: it is a rectangular piece of wood (or plastic in modern versions) in which is fitted a tongue with a tiny plectrum. At the



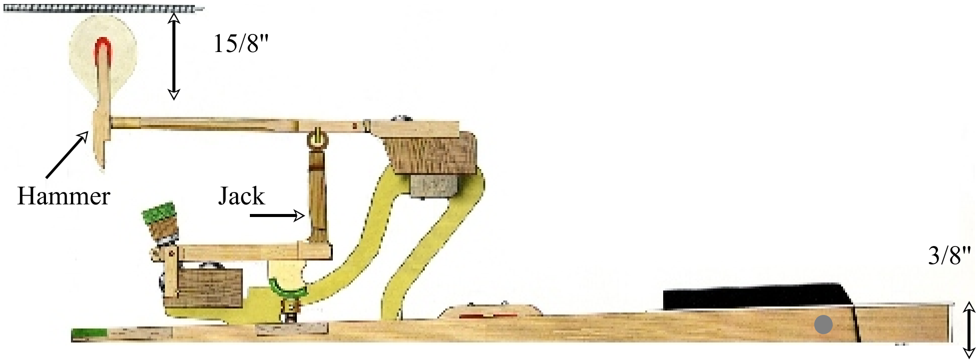
top of the jack is a small piece of felt (the damper) that rests on the string and prevents it from vibrating. When the key is pressed down, the plectrum plucks the string on the way up and of course the damper also lifts off the string to allow it to vibrate. When the key is released, as soon as the underside of the plectrum makes contact with the string, the tongue pivots backwards inside the jack to allow it to slip past and not pluck the string a second time.

The problem with this is that because the plectrum is always at the same position under the string, it doesn't matter how hard or gently the key is pressed down, the note is always at the same volume. (A guitarist will hold the plectrum more firmly to play a loud note, which means it releases the string when the plectrum is further under it. When he plays a quiet note he holds the plectrum gently, which means it plucks the string from higher up and therefore gives it less energy.)

So to produce variety of tones, in the same way a pipe organ will have several ranks of pipes, a harpsichord can have several ranks of strings (16', 8' and 4': three different octaves) and manuals (or keyboards). It will either have pedals or levers to bring these ranks into play, and may have an additional set of jacks that pluck the strings from a different position, or there may be a rail to push a tiny piece of felt against the end of the strings, all to bring variety to the tone. The change is always global though, and very rapid changes of tone or playing a melody line in the right hand louder than the accompaniment in the left, for example, is impossible on a single manual. In the photo, this Robert Goble harpsichord I have tuned many times, has one 16', one 4' and two 8' ranks of strings, two manuals and seven pedals.

One of the oldest string instruments is the dulcimer (going back 1,000's of years), which is played with beaters rather like a glockenspiel or xylophone. In order to have a keyboard string instrument that can strike the strings with beaters in a similar way, there are two obstacles to overcome in designing a mechanism to do this. With the benefit of hindsight we know how to do it now, but at the time, when no-one had done it before, it was a problem.

1. The beater, or hammer as it is called in a piano, needs to travel faster than the key in order to produce sufficient volume. The solution is for the hammer to be acted on by a jack (which pushes the hammer) close to



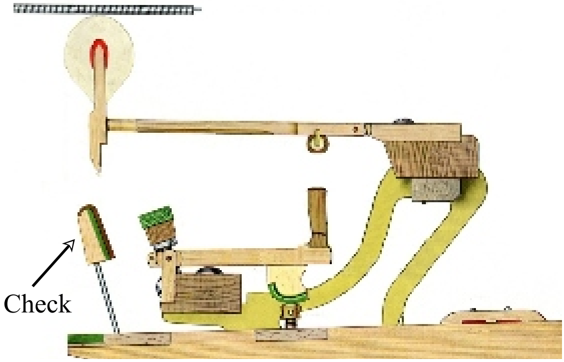
the point at which it pivots, with the hammer head some distance away from it. This means the hammer head travels further than the jack and, along with other action parts acting on each other similarly, is therefore faster than the key. When I was an apprentice it was 'dinned into me' that the front of the key travels 3/8", while the hammer head travels 15/8", which is a ratio of 1:5. Today's pianos may vary from these measurements, but only slightly.

If the hammer travels five times further, it will also be five times heavier on the key; so if it weighs 10 grams, the key will require 50 grams of pressure to raise it to the strings. It isn't 10 grams, though, because all the heads are a different size: large strings need large hammer heads; small strings need small ones. There is also the weight of the rest of the action and friction to take into account; but I mention 50 grams because this is the kind of touch weight most designers aim for. In fact this Bechstein is designed for the top note to be 49 grams and the bottom note, 52 grams. [1]

In order to achieve this, lead weights are inserted in the front or back of the keys; but this perfectly illustrates why this piano costs so much more than cheaper ones of a similar size. Piano designers calculate exactly where the leads need to go to achieve the touch weight they require and they are fitted when the keys are made. (At the same time there must be a minimum amount of weight on each side of the key, as increasing it creates more inertia, which makes it more sluggish.)

But this is not accurate enough for a concert instrument. So Bechsteins will completely build the action, regulate it and have it absolutely finished, before then carefully weighing each key individually and marking where the leads need to go. Then it is dismantled again, the leads fitted, and everything is reassembled all over again. This obviously takes more time than the previous method, and time costs money. So this kind of attention to detail at every point of construction, taking more time than other methods, along with top quality materials, explains the final price of the instrument; but the combination of a lot of tiny improvements makes the difference between an excellent-quality instrument and a concert-quality one.

2. When the hammer hits the string, it must be able to drop back away from it, otherwise it will prevent the string from vibrating. So when the jack pushes the hammer all the way to the string, the note will not play properly (as shown in the diagram above). If the key stops its travel just before the hammer contacts the string to allow the hammer to fall away, then it



because the key has to be pressed down so hard in order for the hammer to reach the string at all.

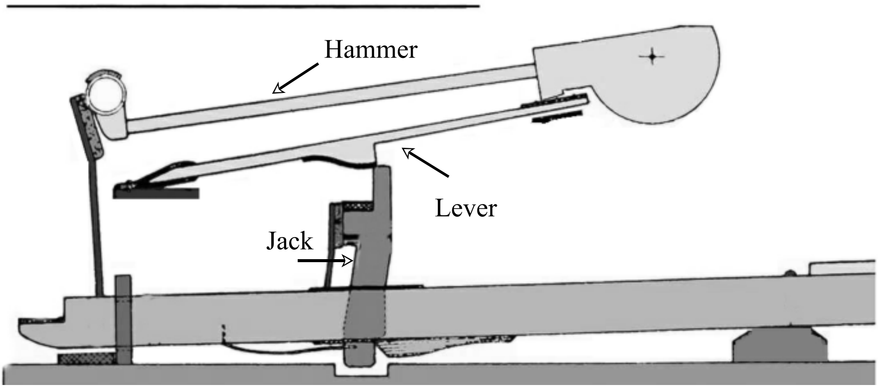
These two problems remained unsolved for around 300 years, until Bartolomeo Cristofori (1655-1758) came along. After he had worked on other instruments, the 1700 inventory of the Medici describes his latest idea, "*Un Arpicembalo di Bartolomeo Cristofori di nuova inventione, che fa' il* ***piano, e il forte****, a due registri principali unisoni, con fondo di cipresso senza rosa.*" (Translation: An "Arpicembalo" [literally harp-harpsichord] by Bartolomeo Cristofori, of new invention that produces soft and loud, with two sets of strings at unison pitch, with soundboard of cypress without rose..) [2]

will bounce off the string back onto the top of the jack, bounce off that back up to the string and continue to oscillate between the two while it has energy.

On the other hand, if an additional part, the check, is added to the back of the key to catch the hammer and stop it bouncing back up to the string, then the check has to be quite low and away from the hammer head, otherwise it will catch it on the way up and prevent it from striking the string. This means the jack has to be very short in order to allow the hammer to land on the check (as shown above), and therefore much of the travel of the key will not be pushing the hammer upwards. So while it would certainly achieve the objective, it removes the ability to play with variation of tone

The words in bold show where the instrument got its name. It is possible his first prototype was worked on in 1694, but his first instrument was probably built 1698-1700.

His solution to the problems, shown below, was to attach the jack to the key, which pressed on a lever half-way between the lever's centre (the pivot point) at one end and where it lifted the hammer at the other.



In turn, the lever lifted the hammer very close to its centre, with the head on a long shank; so plenty of hammer head speed was generated by this arrangement. The real secret, though, was the 'escapement', which meant that just before the hammer struck the string, the jack slipped off the 'notch' on the lever, allowing it to drop back down, which in turn allowed the hammer to fall back to be caught by the check.

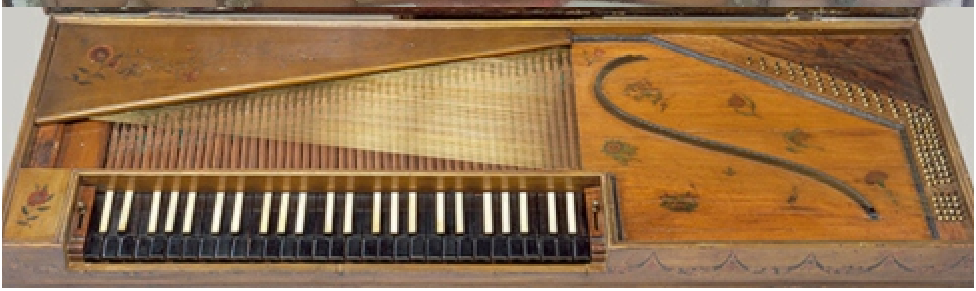
It may be that his invention did not receive immediate acclaim, but one of the early piano makers to take his idea on board and develop it, was the Englishman John Broadwood (1732-1812). I mention him because the Broadwood Company still exists today; and while the factory closed down some years ago, they are still able to make pianos to order and thus can justifiably claim to be the oldest piano manufacturing company in the world.

During the second half of the 18th century, John Broadwood probably made more square pianos than any other piano maker in the world. The influence of the clavichord can be seen quite clearly in this instrument (photos below: the upper one is a square piano, built early 19th century, I have tuned for many years). It has two strings per note and in appearance is very much like a clavichord (shown below) with a piano action underneath the strings, which in the square piano are rather longer and thicker.

Other key developments (if you'll forgive the pun) are:

- The double-escapement action (see later) by Erard in 1821

- The overstrung layout of strings by Jean Henri Papp in the 1820s, which has the lowest strings crossing over those in the middle section, thus enabling longer strings to be used. As a rule of thumb the longer the string and the larger the soundboard, the better the tone (up to a point: there is little



to be gained by having a piano larger than the present concert grands of 9' - 9' 6").

- The iron frame in 1843 by Chickering and Mackay, because it became apparent that longer, thicker and therefore tighter strings needed to be used to produce more power, and a wooden-framed piano could not take the pressure. All pianos are now built with iron frames, and any you meet without one will almost certainly date to pre-20th century.

Piano Design

On the topic of string design, there are three ways to alter the pitch of a note: change the length, thickness and/or tension of the string. However, there are fine limits regarding the utilisation of these methods. If one was to try to determine the pitch of all the piano's strings by length alone, then if top 'C' string was two inches long, bottom 'C' would be about 25 feet long because lowering the pitch by one octave needs the length to be doubled: clearly impractical.

Increasing the thickness of a string increases its stiffness: a short, thick string is much stiffer than a long, thin one. It also increases its inharmonicity (explanation later), which is detrimental to the tone.

There is a narrow balancing act regarding tension. If the string is too tight, there is a risk it will break; but the looser the string, the greater the inharmonicity, which, as just stated, adversely affects the tone. This is an important reason why a piano needs tuning regularly and keeping up to the correct pitch, because if it is allowed to go flat, as it will do if left untuned, the tone will deteriorate.

Obviously the piano designer needs to ensure that adjacent notes are as close in tone as possible to each other. This means the strings need to have a similar ratio of thickness to length in order to have a similar stiffness (and it is essential that where there are two or three strings on the same note they are identical, otherwise they are impossible to tune because of the difference in inharmonicity); and the tension needs to be a similar distance from breaking point when tuned to the correct pitch to have a similar inharmonicity.

There are about twenty different thicknesses of plain steel wire, increasing in 0.001" increments, available for use in the middle and treble sections of the piano. In the bass section the steel wire is wound with copper wire (two layers at the very bottom) in order to increase the mass of the wire without unduly increasing the stiffness, both the core wire and the covering gradually increasing in thickness the lower the note.

There is one final factor, which is that the hammers must strike the strings at a point exactly one seventh away from the end of the speaking length, which will be explained later. (But see note: [3])

Putting these four factors together (length, thickness, tension and striking point), explains why the layout of the iron frame and strings is the way it is: this is really the only way to meet all the requirements for the best quality and consistency of sound. Two formulae used to calculate string tension and frequency are as follows:[4]

$$f_0 = \frac{1}{2L}\sqrt{\frac{T}{M}} \qquad T = \frac{f_0^2 L^2 d_c^2 F}{k}$$

f_0 = frequency; L=length; T = tension; M = mass per unit length; d_c = diameter (of core wire for wrapped string); F = 1 for plain wire, more for wrapped; k = constant used for any material in any system of units.

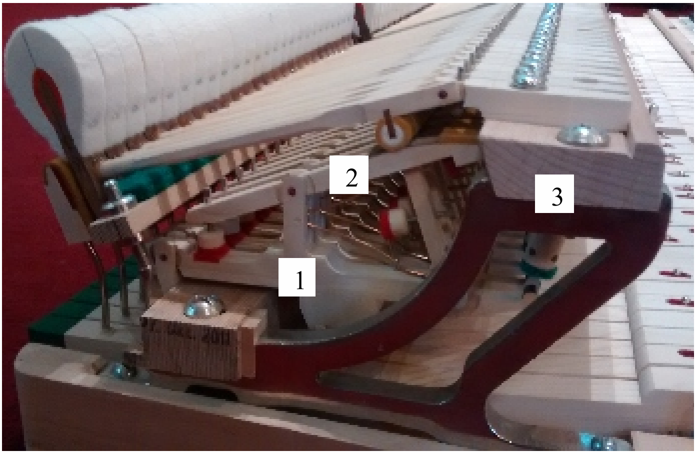
Since we are considering the Bechstein piano, here are some brief facts. Friedrich Wilhelm Carl Bechstein (June 1, 1826 – March 6, 1900) founded his factory in Berlin, Germany in 1853, and very quickly gained a reputation for quality. His first concert grand was built in 1856 and was widely used in concert halls by 1870, and he supplied Queen Victoria for the first time in 1881. The two World Wars hit Bechsteins badly, the factory suffering bomb damage, and the Berlin wall was also a major problem. In 1992 their factory in Seifhennersdorf, Saxony, S. E. Germany was opened, where their top quality instruments are made.

The outer rim is formed by layers of Birch and Mahogany glued together and cramped into the curved shape that becomes the side of the piano. After the glue is set it is removed from the cramps and stored in controlled conditions for six months to stabilise before being used to build a piano.

Above is the action taken out of your piano and put on the carpet here, and the end view below shows how it works.

Materials used in the Bechstein grand piano are: [1]

Rim: Birch and Mahogany
Soundboard: European Spruce
Soundboard Rim: Mahogany, Pine and Red Birch
Wrest Plank; Copper Beech
Cast Iron Frame: high quality grey iron
Bass strings: Steel core wrapped in high quality copper
Action parts: usually Maple or Beech
Keys: usually Spruce or Basswood
Key coverings: usually acrylic plastic



The lever (1) rests on a metal capstan (hidden by the action standard) on the key. At the end of the lever is the jack, the top of which passes through the repetition lever (2) and presses on the roller underneath the hammer shank. As the key is pressed down at the front, the capstan at the back pushes the lever upwards, which in turn pushes the 'L' shaped jack up, which pushes hammer up to the string. Just before the hammer reaches the string, the lower end of the jack makes contact with the set-off (or escapement) button (3). This makes the top of the jack flip away from the roller, allowing the hammer to bounce back after striking the string and be held by the check.

The repetition lever also presses against the hammer's roller, and fractionally before the jack sets off, it makes contact with the drop screw next to the hammer centre. This is the second (or double) escapement because there is a strong spring under the repetition lever that takes the weight of the hammer and could push the hammer onto the string when playing very quietly if it were not for the drop screw.

When the key is released, the repetition lever fractionally lifts the hammer off the check, allowing the jack to return underneath the roller very quickly and making possible very fast repeated notes. There is a single spring on the lever, which has two arms. One arm pushes underneath the repetition lever and the other fits into the bottom of the jack, thus pulling them both back into their rest position after the note is played. The tension on this spring is critical, and must be adjusted to ensure the repetition lever lifts the hammer just enough for the jack to return under the roller, but not so much that it pushes the hammer back up to the string after it is released from the check.

In fact every aspect of all the action parts is very carefully designed, angled and positioned for maximum efficiency. So, for example, the jack is 'L' shaped, which means the top moves away from under the roller very rapidly when the short section makes contact with the set-off button; but it does not travel any further away from it than necessary, otherwise it would take longer to return for a repeated note. It must be in exactly the correct position under the roller when at rest: too far under and it would take too long to slide out at set-off and this would create extra friction; not far enough and it would slip out without pushing the hammer up to the string.

You may see a pencil mark on the side of the hammer head. This is made when the action is assembled, in order to show the exact position of the striking point. As mentioned previously, it is essential for the hammer to strike the string one seventh along (but see note: [3]); so the end hammer in each section of the action is glued on first, making sure its striking point is as accurate as possible. When the glue is set all the other hammer heads are glued between the patterns in a straight line ensuring they are all in the correct position.

What do the three pedals do?

In the past I have been asked if using the loud and soft pedals at the same time will damage the piano. I think perhaps the person is thinking of pressing the accelerator and the brake at the same time in a car. However, the answer is "No" because for one thing the right-hand pedal is actually the 'sustaining' pedal. It works by lifting all the dampers off the strings, allowing them all to vibrate

freely. When any note is played with the sustaining pedal depressed, it will continue to play as long as the string has energy.

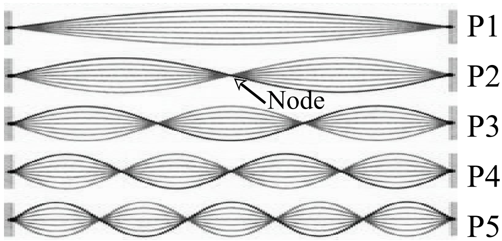
However, it does make the piano sound louder, and the reason can be demonstrated easily. Press down the middle 'C' key (C4) gently so the hammer does not strike the strings but the damper is lifted off them, then play a firm note on 'C' the octave below (C3) and release it straight away. You will now hear the middle 'C' strings playing quietly, and to prove it is coming from those strings the sound will stop as soon as you release the key.

However, the vibration of a piano string is very complex. To demonstrate this do the reverse: gently press down C3 key without the note sounding, then play a firm note on C4, again releasing it straight away. You will now hear the C4 note playing on the C3 strings. Now go up a fifth to G above C4 (G4) and do the same again. You will hear that note playing on the C3 strings.

These different notes on the string are called 'partials'. The fundamental note, in this case C3, is the first partial; C4 is the second; G4 is the third. These particular notes are in the 'harmonic series', which, based on C3 is:

C3	C4	G4	C5	E5	G5	A#5	C6	D6	E6	F#6	G6	A6	A#6	B6	C7
P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16

The reason the upper partials sound is that at the same time the entire string is vibrating as a whole unit to produce the fundamental note, it divides in half at the node and the two resulting sections also vibrate, producing the second partial. At the same time, the string also divides into three, creating the third partial. And so on…

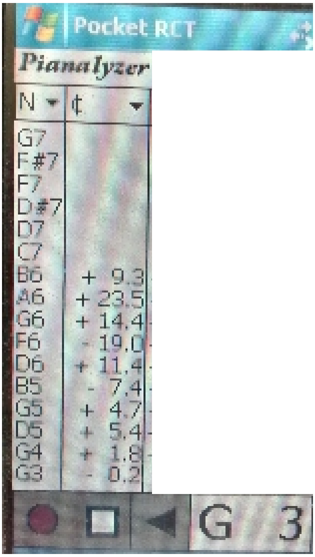


However, things become even more complicated, because the way in which the string divides means that (for example) the two sections playing the second partial are slightly shorter than half of the whole string playing the first. This means the second partial is very slightly sharper than the true octave to the first. In general, the higher the partial the greater the amount of sharpness to the first partial. This effect is called 'inharmonicity', which refers to the amount the partials of a string are out of tune with each other. The stiffer the string, the greater the inharmonicity.

This explains why there are 12 semitones in an octave and not 10 or 14: it is the natural way a vibrating string (or column of air in a wind instrument) divides. The characteristic is such that when the sustaining pedal is used, all the partials in all the strings of the piano in the same harmonic series as the one(s) being played will begin to vibrate, which is why the pedal makes the piano sound louder and fuller.

This is one reason why a big piano with long strings has a better tone than a smaller one with short, thicker strings: the strings are less stiff. Careful string design can help to minimise this for smaller pianos, by ensuring the ratio between length and thickness is kept to the optimum.

The electronic tuning device I use is capable of measuring the pitch of the partials, and below is the result on G3 of this Bechstein piano. The left-hand column shows the partial numbers and the right-hand one shows the amount of deviation in cents, there being 100 cents in a semi-tone.

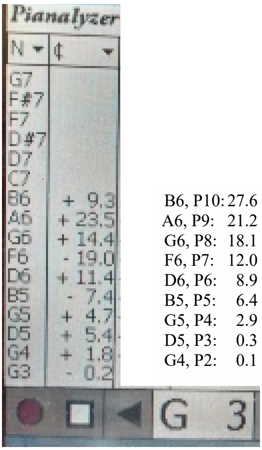


You will see that the first partial is 0.002 cent flat. This is because I did not tune it accurately! However, two thousandths of a semi-tone is beyond the range of human hearing, so I don't think many people will complain!

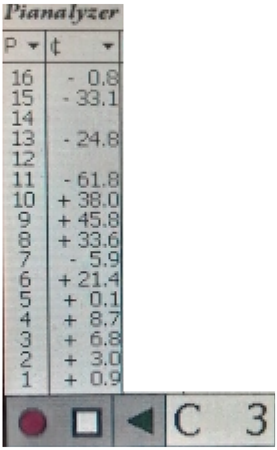
The result of inharmonicity is that when the piano is tuned, the upper note (e.g. C4) of an octave must be tuned as a perfect unison with the second partial of the lower note (e.g. C3): if it is tuned perfectly to the first partial it will sound flat. This means that the higher up the piano you play, the sharper the notes become; and in this piano the top note is slightly more than one third of a semi-tone sharp to what it would have been had there been no inharmonicity.

This also means all pianos are tuned differently, since they all have different amounts of inharmonicity. Even two identical models will have very slight variation, since when working with a natural material like wood there is always going to be tiny differences in grain density and direction; and no matter how accurate the processes, the positioning of the bridges, bridge pins and variation in the iron frame casting, although minute, will have an effect.

If a piano is allowed to go flat — usually through not being tuned regularly — the inharmonicity will increase. To demonstrate this, on a different piano I measured one string on G3. I then lowered the pitch of this string by one fifth, making it produce the note C3, and then measured it again. You can see the result below: the first columns show the note names in the left photo and the partials in the right one. The amount of sharpness in the upper partials is significantly greater in the flattened string. Because in both cases I did not achieve 'perfection' in tuning the first partial, I have put a table in the middle with figures



B6, P10:	27.6
A6, P9:	21.2
G6, P8:	18.1
F6, P7:	12.0
D6, P6:	8.9
B5, P5:	6.4
G5, P4:	2.9
D5, P3:	0.3
G4, P2:	0.1



showing the true difference. Obviously it would be very rare to find a piano this flat, but it does demonstrate the importance of having a piano at the pitch for which it was designed. The lower pitch has made the tenth partial more than a quarter of a semitone sharper, and shows why a very flat piano will always sound out of tune.

You will notice the 5th and 7th partials are mostly flat rather than sharp. This is because, while on average the figures are showing the true picture, they are all distorted because the partials of a piano are not in equal temperament. A piano's temperament is not how quickly it loses its temper, but the way in which the octave is divided into 12 semitones.

Equal temperament is almost universally used today, which means all the semitones are treated equally. When A4 is tuned to the pitch mostly considered standard in the UK, it will vibrate 440 times per second, usually called 440 Hertz (440 Hz). A#4 will be about 466 Hz; A5, an octave higher, will be about 880 Hz (depending on the strings' inharmonicity!); and A#5, 932 Hz. So the size of the semitone doubles for each octave (in this case from 26 Hz to 52 Hz) and in equal temperament they increase in size evenly. The way to calculate this mathematically is to multiply by the twelfth root of two: 1.0594630943592952646.

A	A#	B	C	C#	D	D#
440	466.1638	493.8833	523.2511	554.3653	587.3295	622.254
E	F	F#	G	G#	A	
659.2551	698.4565	739.9888	783.9909	830.6094	880	

The way to do it practically is to tune all the fifths slightly narrower than a pure fifth and the fourths slightly wider than a pure fourth. The deviation on the fourth is slightly greater than on the fifth, such that (for example) with the notes C3, F3, C4, the fourth C3-F3 will be wider by the same amount as the fifth F3-C4 is narrow; and since everything increases in size the higher it is, the deviation on the fifth is about half-an octave worth of deviation less than on the fourth. So now you know how to tune a piano!

In the past there have been very different ways of tuning the semitones, though, going back c. 2,500 years to Pythagorus; and his temperament perfectly demonstrates the problem. It gives 11 pure and one wild fifth.

If you were to tune the fifth C-G absolutely pure, then from that G the fifth G-D, then from that D the fifth D-A, and continued through the twelve notes, always with pure fifths, the last note would be F. However, if you checked from that F the fifth up to C where you began, you would find it is out of tune by about one quarter of a semitone. This is because an octave does not perfectly fit into twelve pure fifths and the discrepancy is called the comma, or the wolf — because it howls!

Equal temperament shares this discrepancy equally between all the intervals, which means all keys can be played and be equally acceptable. There have been a number of different ways in the past to deal with the problem, and all of them mean that different keys will sound different. Some keys will sound fine, while some intervals in other keys will be discordant: in some cases unacceptably so, making it impossible to play in these keys. Some of these alternative temperaments are as follows:

Just intonation: Marpurg's gives pure major thirds, three wild fifths.

Regular temperaments: Aaron's meantone: Salinas; Silbermann.

Irregular temperaments: Kirnberger; Vallotti; Werckmeister.

You will have seen that when I measured the partials for G3, on both pianos the seventh partial was 19 cents flat. This shows that with the natural way the string divides, most of the 'wolf' ends up on that partial, and is the reason piano makers have the hammers striking one-seventh along the string, which is the node (the point of least movement) for that partial. Doing this means the amount the seventh partial vibrates is minimised and therefore helps to dampen the most discordant sound (but see note: [3]).

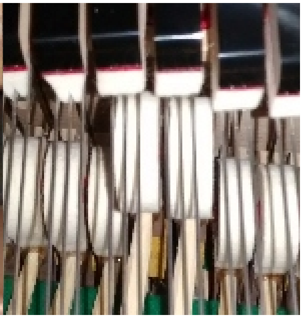
Finally on this topic, I currently play a top-of-the-range electric piano at the church I attend. In spite of sampled sound and some wonderful effects, it is unable to duplicate the performance from a real string that I have been describing. This is one of the reasons at the present time an electric piano cannot be a satisfactory substitute for a real piano when it is needed for quality concert use — particularly in classical music. If I brought that piano alongside this Bechstein, you would immediately hear the difference between the two, and a concert pianist would also say it does not have the same 'feel' on the keyboard.

All of that came from the sustaining pedal! What about the other two? The left-hand pedal is the soft pedal, and there are three ways to make a piano note quieter.

1. Push all the hammers closer to the strings while still at rest. This is called the 'half-blow' and means they have less impetus when they strike the strings, and help the pianist to play quietly. It is mostly used on upright pianos, although a few grand pianos function in this way.

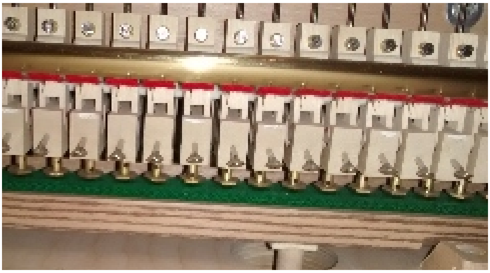
2. Place a piece of soft felt between the hammers and the strings (shown below). This was used in a lot of upright pianos for the soft pedal during the 19th and 20th centuries, but went out of favour because of the huge effect on the tone of the notes. Today quite a few new uprights have this as a middle pedal and call it the practice pedal, so you can practice your scales without upsetting the neighbours!

3. Move the action, and therefore the hammers, to one side so the hammer heads only strike two strings in a tri-chord (which is a note with three strings). You will see in the photos on the next page (taken from your piano) that on the left the centre string of the tri-chord is in the middle of the



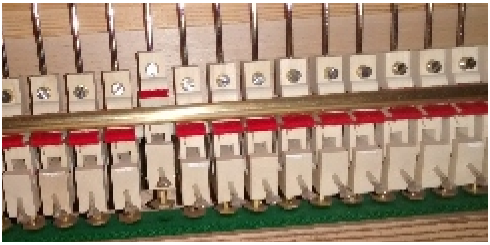
hammer, while on the right the right-hand string of the tri-chord is in the middle. So although the left-hand string is able to vibrate it does not have the power of the other two which are struck. *'Una corda'* dates from when Cristofori invented the device, since with only two strings per note, using it meant only one string was struck.

(There is another way to quieten the sound: my own idea I suggested some years ago is to have a second set of dampers moved by the pedal, which would wedge between the trichords and bi-chords and prevent one or two strings from vibrating on each note and a felt pad at the end of the single strings like the harpsichord pedal as described previously. This removes the problems of altering the touch with 'half-blow' or sliding the whole action to one side causing friction and uneven hammer wear; but no-one was interested — presumably because it would be too expensive or awkward to do! So the 'Sherlock' soft pedal is consigned to the dustbin of history!)



The middle pedal on this Bechstein is called the sostenuto pedal, which of course is the Italian word for 'sustaining', because it is a second sustaining pedal. In English the right-hand pedal is always called 'sustaining' and the middle pedal 'sostenuto' in order to distinguish between them.

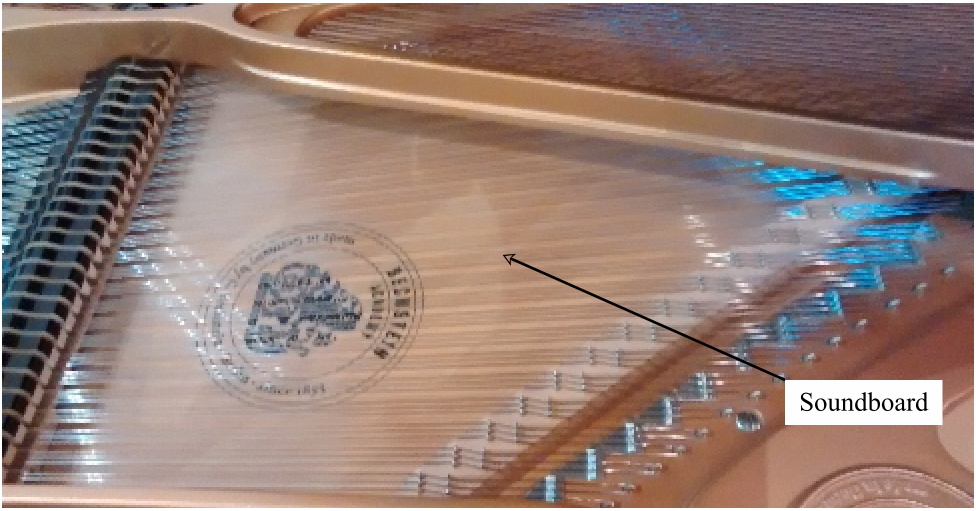
This pedal only sustains notes of keys that are being held down when it is used.
It means a single note or chord can be sustained at the same time as other chords, scales, arpeggios, etc. are played without the latter being sustained. If it was all sustained (as with the sustaining pedal) the sound would become muddied.



It works with a metal rail in front of the damper action parts that has a flap pointing toward them when the pedal is activated, but angled downwards at other times. The damper action parts all have a felt-covered flap in front of them. When a note is played, the damper action part lifts up and if the sostenuto pedal is pressed down, the metal rail catches the damper flap and holds it up. When other notes are played, the flaps on those damper parts come up beneath the metal rail but cannot get past it; so they drop back down when their key is released.

What makes a Piano go out of tune?

Moving it? In fact, if the piano is in good condition, this will have very little effect,



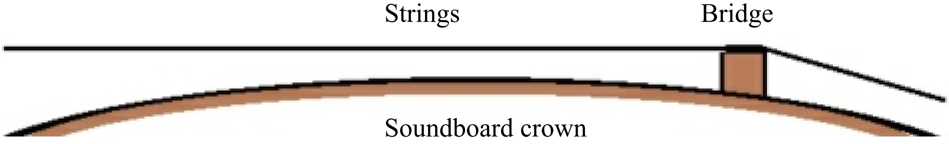
unless it is dropped, banged against the wall, or otherwise suffers a severe jolt. If it does go out of tune when moved, the reason will be one of the following factors.

Playing it? This too usually has far less effect than people may think. Occasionally when I arrive at a house to tune the piano, I am met with, “The piano has had a lot of use: a couple of hours a day!” Yet there is not a huge amount to do to tune it. Other times it would be, “The last time that piano was played was when you tuned it!” In this case there can be a great deal to do to bring it back into tune. A concert piano perhaps has more energetic playing during a recital (in a piano concerto, for example) than any other piano; but the tuner would be very disappointed if the tuning had moved significantly by the end of the concert. Once again, it will be the following factors to blame for tuning variation.

Temperature change. Obviously metal expands with heat, so a piano in hot conditions (under stage lighting, for example) is likely to drop in pitch, while in cold temperatures it will rise. However, this change is comparatively small and in most cases the effect will be swamped by the most important factor, which is:

Humidity change. In domestic situations, central heating will dry the air significantly, while in the summer time, with windows and doors open, the more moist outside air will raise the humidity level — particularly during a rainy spell.

The reason for this is the piano’s soundboard, which of course is wood. This Bechstein has a crown (a shallow dome shape: see edgeways diagram below) across the soundboard, on which is glued the bridge that supports all the strings and



transmits the vibration into it. (Sound is the vibration of air, and a string on its own is unable to move much air; so a soundboard is required in order to move a larger body of air to make it audible.)

When the moisture content of the air rises, the soundboard absorbs it and therefore swells. It cannot swell sideways because it is held by the rim and iron frame, so the only way it can go is upwards. This causes the bridges to rise, press on the strings, and tighten them. Thus the pitch rises.

Central heating, by warming the air, causes it to become dry and the opposite happens: the moisture evaporates out of the soundboard, which then sinks back, allowing the bridges to drop and the strings to become looser. The amount and speed of change will depend on how much varnish is on the soundboard, amongst other things like thickness, size and shape.

For many years I have measured the temperature and humidity everywhere I have tuned and noted the figures as they relate to the pitch of the piano. I have found humidity levels going down into the low 20%'s in extreme central heating, and up to the low 80%'s during rainy periods in the summer in England. In some schools, where there is often the greatest difference and I am tuning three times per year, I can find a pitch difference of up to a quarter of a semi-tone between tunings.

In order to keep your Bechstein as stable as possible and protect it from either extreme, we have installed a humidity control system underneath the soundboard. The main components are two heating bars: at the tail end of the piano and toward the front. There is a water tank with a tiny heater above it and two pads hanging over the heater and in the water. The most important part is the control unit, which is as close to the soundboard as possible without touching.

On the right of the photo is the secondary heater at the tail of the piano; in the middle is the water tank; and top left is the control unit.

Looking toward the front of the piano, the main heater behind the pedal-work and front legs runs along the bottom of the photo, with the water tank top right and the control unit top middle. The water filler pipe coils around just beneath the soundboard.

The air immediately under the soundboard is therefore constantly monitored and when it becomes too dry, the heater above the water tank is switched on, forcing some water to evaporate and warm moist air starts to rise. There is a 'baffle' above it to prevent the moisture from going directly into the soundboard above the tank, but distribute it more evenly across the piano.

When the air becomes too moist, the water tank heater is switched off and the other two heaters switched on. Now warm dry air rises up and circulates under the soundboard.

The system is designed to switch between the two regularly, and how long one is 'on' compared to the other is dependant on the humidity level of the room. There are warning lights on the side of the piano to show when the power is switched on, when the water level is becoming too low, and when the pads are losing their effectiveness. There is a tube clipped under the piano for filling the water tank, and a special 'watering can' that fits the tube and contains the correct amount of water to fill the tank when the light is on without it overflowing.

In the three or four months the piano has been in the church the pitch has remained very consistent, so it certainly seems to be doing its job!

Finally

Bechsteins estimate that there are around 70,000 100+ year-old Bechstein pianos around the world still being played, and during my 54-year career in the piano industry, I have regularly worked on pianos of this age. So you have a top-quality piano here, that is not only a huge benefit for today's community, but if it is looked after will be enjoyed for generations to come.

Notes

[1] Much of the information about the Bechstein piano is courtesy of Intermusic, Poole (who supplied the piano) and C. Bechstein, Germany. Return to text page 5; page 9

[2] https://en.wikipedia.org/wiki/ Bartolomeo_Cristofori. Return to text.

[3] Strictly speaking this is not necessarily 100% accurate, as, depending on the designer, the strike point may vary from this; but for simplicity (and because it is pushing the limits of my expertise), as this talk was not intended to be a detailed technical lecture but a 'layman's introduction' to the piano, I have used the one-seventh to illustrate the importance of accuracy here because the tiniest deviation from the intended strike point will adversely affect the tone. For the record, the famous piano designer Samuel Wolfenden, on page 51 of his (at the time of writing) exactly 100 year-old 1916 book *'A Treatise on the Art of Pianoforte Construction'*, in order to avoid notes in upper partials being discordant against those from the lower ones (e.g. D against C), recommends:

A1-C40, one-eighth
up to C52, one-ninth
up to C64, one-tenth
up to C76, one-twelfth
up to C88, one-fourteenth

Return to text page 8; page 10; page 14

[4] https://www.speech.kth.se/music/ 5_lectures/conklin/strings.html
Return to text.

Source of pictures:

All by Les Sherlock apart from:

Clavichord (page 3) adapted from http://www.blackswampadventures.com/?tag=clavichord

Harpsichord jack (page 3) adapted from https://en.wikipedia.org/wiki/Plectrum

Piano action (page 5 & 6) adapted from http://thetunersblog.blogspot.co.uk/2014/10/grand-action-diagrams.html

Cristofori action (page 6) adapted from https://www.youtube.com/watch?v=uZjcV3_0PqQ

Clavichord (page 7) adapted from http://andrewsalamanca.com/2016/05/piano-forte/

String partials (page 11) adapted from http://www.slideshare.net/arbinddhaliwal/standing-waves-final-ppt

'Adapted from' means the original picture has been modified and/or cropped by Les Sherlock