

MUSICAL INSTRUMENTS: THEIR CONSTRUCTION AND CAPABILITIES.—III.*

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HAVING described in the previous papers those musical instruments (whether string, pipe, or reed) which belong to such combinations as the orchestra and military band, we will now consider those furnished with keyboards, by which they are manipulated; and, as this contrivance originates a fresh order of

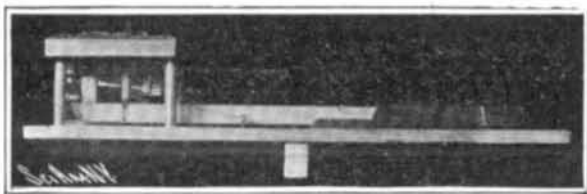


GLOCKENSPIEL, WITH A COMPASS OF TWO OCTAVES.

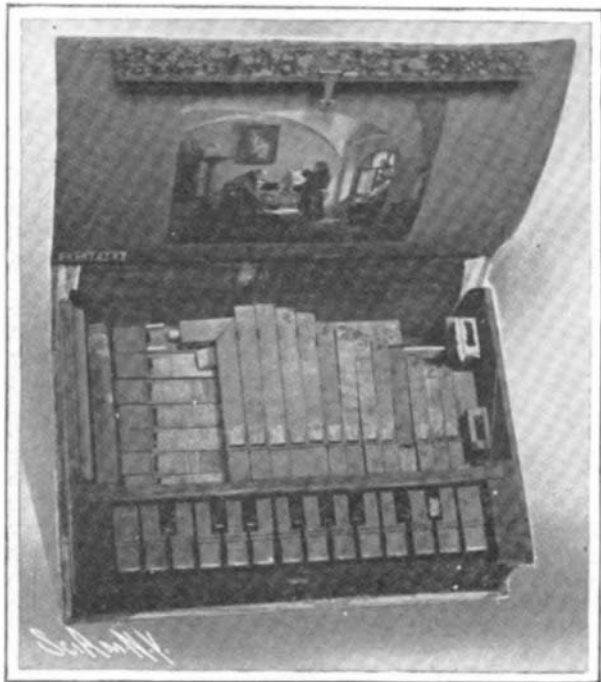
A small case containing twenty-five hemispherical gongs which, on pressing the keys, are struck by little hammers.

treatment, I have decided to group keyboard instruments as a separate class. Without the keyboard, music, in its modern European development, would hardly have been known, the orchestra might not have progressed beyond the Hungarian gypsy band, and there would have been no organ to aid religious service, or support choral masses in harmony; and the facilities for the composer the pianoforte offers would have been wanting. Indeed, there can be no doubt that the keyboard, by the privilege it gives for the trial of several voices or parts, has helped to build up counterpoint, and, ultimately, harmony.

Before proceeding to the various instruments that

MODEL OF ACTION, NUREMBERG PIANO.
Primitive Viennese method without escapement.

are accessible, by the keyboard, to full harmony in any combination of notes, it will be well to consider the keyboard alone, and to try to make out its history. Like all inventions that have required time for their recognition, and an ever-widening use to bring out their importance, the record is imperfect, and the materials fragmentary, that can throw light upon its development. Its origin was either in the organ, when an aggregate of pitch pipes only, or in connection with the monochord, the normal mediæval pitch measure. It is accepted that organs, hydraulic or otherwise, ex-



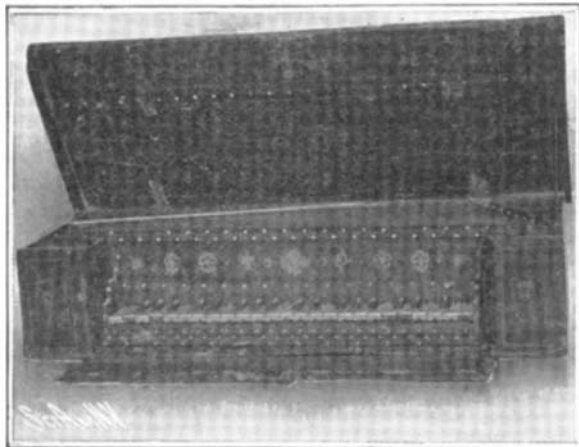
AN OLD GERMAN BOOK ORGAN IN THE FORM OF A PARCHMENT-COVERED BOOK.

The keyboard and blowing apparatus consists of a small bellows and a reservoir. Beneath the keyboard and the bellows are the stopped wooden pipes.

isted in the time of the Roman domination, and may have been of Greek invention. In the eighth and ninth centuries organs were heard of in England,

* The illustrations of these articles depict instruments in the admirable collection of Mrs. Crosby Brown in the Metropolitan Museum of Art, New York city.

France, and Germany; but up to the eleventh century, there appears to have been no use made of balanced levers or keys to produce the notes. Sliding rods, like modern drawstops, seem, from the imperfect notices existing, to have been the only means for obtaining and controlling sound from the pipes. As single notes only were practicable, there could have been no harmony whatever, unless two persons, drawing out slides

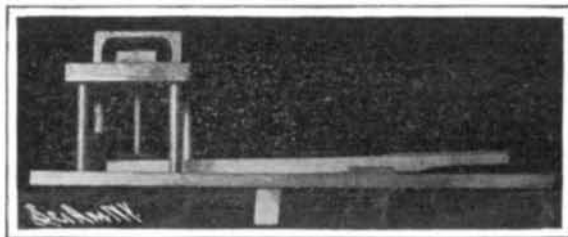


SPINET OR VIRGINAL.

Inscribed "Franciscus Bonafinis 1585," also "after a lapse of 132 years, repaired by me N. N. the year 1717."

simultaneously, could have set two notes going. There are three ways open to us to trace historically the construction and improvement of musical instruments, or whatever appertains to them.

The sure one is the examination and comparison of existing instruments; the next is found in graphic representations, to be valued according to the realistic or conventional treatment the draftsman may employ. The last and least satisfactory is that of written description, the difficulties of which are made more perplexing by the confusion attending names used by writers in different places and at different times. With

MODEL OF SPINET ACTION SHOWING THE
QUILLED JACK ON KEY.

the early keyboard we are only left with such indications as we can get from pictorial or written evidence, as no known keyboard is older than the end of the fifteenth century. At this point of our inquiry we ought not to overlook the keys of the hurdy-gurdy or vielle, the viol sounded by a wheel instead of a bow. The fact of this instrument having strings tuned as drones puts back its origin to when the drone was the only addition to melody.

The bagpipe was the wind instrument similarly burdened, and there is every reason to believe that the drone early became characteristic of the organ. It is a principle of great antiquity, perhaps prehistoric, still existing in the East, and particularly in India. The

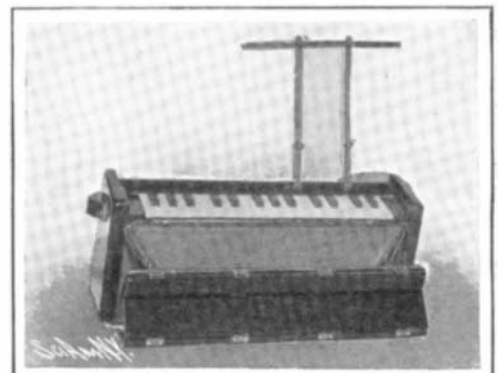
SPINET OR VIRGINAL MADE IN FLANDERS, 1600,
BY CRISTOFEL RUCKERS.

Only two specimens of Ruckers spinets are known.

keys of the hurdy-gurdy are simply slides pushed back by the player, with projections to stop the strings and produce notes according to the vibrating length required; and as the instrument is held with the keys downward, these slides when released fall back by their own weight. It is possible that the hurdy-gurdy keys suggested the contrivance of balanced levers for stop-

ping the monochord, and thus the clavichord, a complex of monochords, for at first the strings of it were of equal length, came about; but it is equally possible that the invention of balanced lever keys was earliest applied to the organ. We have to step with great care in this inquiry.

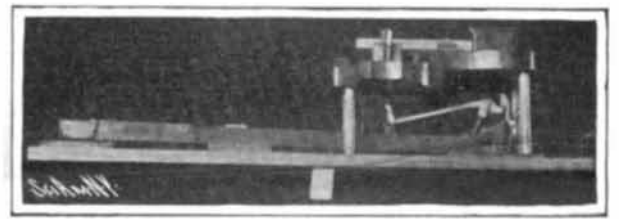
Of what happened, if anything, in the eleventh and twelfth centuries concerning keyboards, we know nothing. The first glimmering of light is in the thirteenth century. At that epoch a small portable organ for processional use, a shrill pitch giver and little



PORTABLE MELODEON.

At the back a single bellows; in the front an air-reservoir. A double set of free reeds in unison. The instrument is contained in a small red mahogany case with a leather carrying strap.

more, had been invented. One of the valuable results of the music division of the inventions exhibition of 1885 was the publication of important books concerning music and musical instruments, two of which were undertaken by Mr. Quaritch. The one I now particularly refer to is entitled "Notes on Early Spanish Music," with illustrations of thirteenth and fourteenth century instruments. The author is Don Juan Riaño, who was the special commissioner appointed for Spain, in connection with the music loan collection attached to that exhibition.



MODEL OF ACTION.

Piano by Vatter; Viennese method; hammer in pin and on key. Perfect escapement.

In Don Riaño's book there is a drawing, copied from an authenticated manuscript of the thirteenth century, in which a portable organ, or *portatif*, appears. It has nine pipes, but it has been sufficient to the artist to figure three keys, which are hardly keys, in the sense of levers, but evidently represent those gimlet-looking finger stops of which I shall give other instances. When depressed by the fingers they lowered, by some internal contrivance, the valves or pallets necessary to admit wind to the pipes they served. There is no clew to the actual notes. The set of drawings this example is contained in belongs to the *codex*

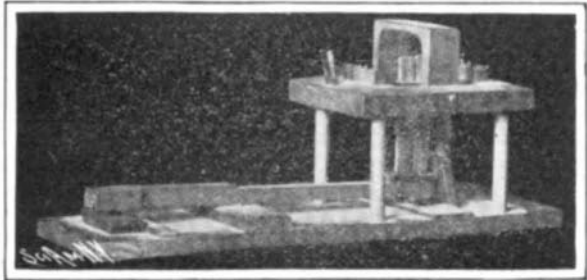


SERAPHINE MADE IN UNITED STATES IN 1840.

The seraphine was invented in 1833 and was the precursor of the harmonium.

of the "Cantigas de Santa Maria," of which there are three manuscripts: one in the National Library, Madrid, and two in the library of the Escorial. The Spanish Royal Academy have published this work; but these interesting and important musical miniatures had already appeared in "Instrumentaria Española," by Don Francisco Aznar, Madrid, 1880.

I will defer the next illustration from Don Riano's book, in order to continue with these finger stops, which evidently remained in use in portable organs after balanced keys had been employed. An instance of them may be seen in the National Gallery, in an altar piece by Orcagna, the date of which is given in the catalogue as A. D. 1357. The order of these stops is not clear, but seems to be chromatic, and the sharps



MODEL OF HARPSICHORD ACTION. KEY WITH QUILLED JACK.

are of the same color as the naturals, not contrasted as afterward became the custom. Another instance of such an instrument is found in a beautiful female figure, representing Music, depicted in a fresco, attributed to Taddeo Gaddi, and preserved in the Spanish chapel of Santa Maria Novella, Florence. She is represented as singing, while touching with her third finger one of these stops. There are two rows of stops, as in Orcagna's altar piece; and that the back and upper one is chromatic, I entertain no doubt. It is true that the back row appears to have as many stops as the front one, as may be seen in Mr. Timothy Cole's woodcut of



CLAVICHORD MADE IN ITALY IN 1537 BY TRASONTINUS.

the figure in the Century Magazine, March, 1889. This artist has favored me with a photograph of the painting, to prove the accuracy of his engraving, so it may be assumed either that Taddeo Gaddi has not cared to be exact or that some of the finger stops were dummies.

Fifteenth century illustrations of similar stops may be seen in *portatifs*, depicted by Memling in paintings preserved in the hospital of St. John at Bruges. The accuracy of these delineations is unquestionable, as is also the complete chromatic order of the stops. One of these representations of a *portatif* is in a painting in the famous shrine of St. Ursula; the other and



OCTAVE SPINET HAVING COMPASS OF TWO OCTAVES AND A FOURTH.

Quill plectra. Made in Italy in the 17th century. These small spinets were tuned an octave above the ordinary pitch and were sometimes included in a larger instrument.

larger in the "Marriage of St. Catherine." The latter is dated 1479, but the instruments represented may have been already old when the painter selected them for delineation. I now return to Don Riano's next illustration of a *portatif*, which is different. It is copied from a fresco, an altar piece in the Cistercian Monastery of Nuestra Senora de Piedra, Aragon, and is dated 1390. Here is shown a *portatif* with three rows of pipes

and balanced white natural keys, with one square chromatic key let in. Assuming that the treble of the instrument terminates at A, which occurs in fifteenth century positive organs, and recognizing the necessity in the plain song of a B flat for transposition, we cannot be wrong in regarding this square key as that note. If there is another B flat an octave lower, which according to Guido's scale was likely to be the case, the



MODEL OF CLAVICYTHERIUM ACTION.

Quilled jack on key, showing mechanism for upright form of harpsichord.

hand of the player covers it. Viridung, in 1511, figures a diatonic keyboard with two B flats, but this drawing is not altogether to be relied upon as an exact representation. There were such keyboards no doubt, only of an older fashion. Fra Angelico, who was painting in the first half of the fifteenth century, represents *portatifs* with diatonic keyboards, and, in one important instance, a dubious indication of incidental upper keys. I think, however, it is proved that full chromatic keyboards were in contemporary use with diatonic ones, including B flat, which was reckoned a diatonic note in the fourteenth and fifteenth centuries.

With regard to the keyboards of large church organs I cannot do better than briefly summarize the information on them, supplied by Praetorius in the second volume, "De Organographia," of his great work entitled "Syntagma Musicum," and published at Wolfenbuttel, A. D. 1618; it was completed by the Theatrum Instrumentorum seu Sciagraphia, that is to say, the illustrative plates, A. D. 1620.

I will pass by what he says about the earliest organs in churches, because he is not speaking from personal knowledge, to start with the famous Halberstadt organ, with which he was familiar. This organ was built, according to inscriptions upon it, in A. D. 1361, and renovated in A. D. 1495. Whatever happened in this renovation we shall find that the manual keyboards and compass of keys were undisturbed, and that prob-



A MELODEON MADE IN EARLY PART OF NINETEENTH CENTURY.

Compass three octaves and two notes. One pedal works a bellows, the other a small swell shutter.

ably the pedal keyboard was original, but as to this doubt may be allowed. The compass of the two highest keyboards was the same, and exactly that of the ancient Greek scale of fourteen natural notes, extending from B natural in the bass clef, "hypate hypaton," to A in the treble clef, "nete hyperbolæon." Thus proving that the church organ keyboard was a scholastic conception in the first instance, and we shall find it, although afterward only partially, for some time

adhered to, and with Pythagorean, which was a non-harmonic tuning. The fifteenth natural key in that conception was the B flat near middle C, which belonged to the conjunct tetrachord, "trite synnemenon." But the necessities of the transposition of the plain song to accommodate voices, for which we have the authority of Arnold Schlick, who published his book in the same year as Viridung, A. D. 1511, had



GLASSICHORD.

The hammers strike small plates of glass arranged in two rows.

brought about the intercalation of the chromatic keys or "ficti" as they were then called—feigned notes—and consequently the restricted compass of the Halberstadt organ was, I have no doubt about it, originally chromatic. The lowest manual was a bass keyboard from an approximately 32-foot B natural to 16-foot C.



BIBLE REGAL.

An oak case in book form placed at the back of the keyboard contains two bellows, which are lifted alternately, supplying wind to the instrument. Immediately behind the keyboard is a set of pipes, furnished with beating reeds placed on their sides. The keyboard folds in the middle, and with the pipes can be placed within the book-shaped case. Hence the name book or bible organ.

The highest was for the mixture, various pipes of different but related pitches sounding together when a key was put down, without any attempt to sort them into various registers. In fact, the first essay in this direction is here seen, in the speaking pipes in the



A SEVENTEENTH CENTURY GERMAN CABINET ORGAN.

Ebony keys with white sharps. The organ is blown by a carved lever which projects from the right-hand side of the cabinet. The air reservoir (now missing) was originally placed on top of the cabinet.

front of the organ, the "principal," as it was called, being on the second or intermediate keyboard apart from the mixture, and on the third or bass manual connected with the large, deep bass pipes in the side towers. This principal was a four-foot stop, the measure of an English principal of the present day, and it is curious that this old German tradition has really been maintained in England while it has not in Ger-

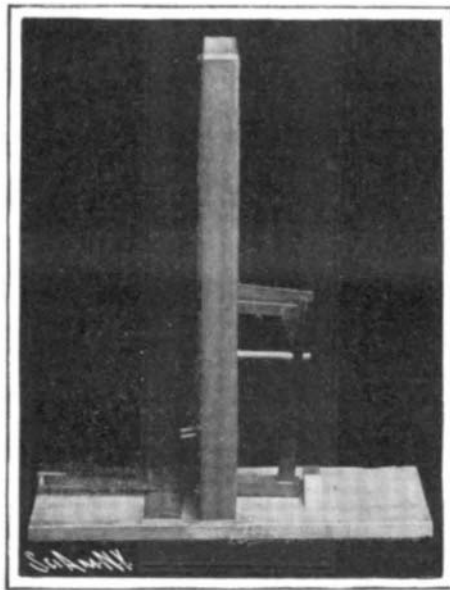
many, where the eight-foot foundation register is now the principal. We call the eight-foot foundation stops diapasons—that is to say octaves below our principal, diapason being the Greek equivalent for octave. I can hardly accept the explanation which derives this name from an organ builder's rule, inasmuch as though called diapason his rule would serve to measure any pipe in any register. I believe the deep third keyboard pipes were originally used for drones, and to keep such notes continuously sounding was how pedals first came into use. We call a drone now a pedal point, and composers use it, especially for the tonic or dominant, with great effect. The Halberstadt pedals were for bass notes to the mixture, and were mixture notes themselves, although without the highest rows of pipes. We may consider the pipes in the side towers were also upon the pedals, but as to this the text is not clear. If the usually received statement that pedals were invented by Bernhard, organist to the Doge of Venice, in 1470, be true, then the Halberstadt pedals were no older than the renovation; but I think we may safely follow the suggestion of Prætorius that pedals had been long in use in Germany, and were only introduced by Bernhard at that date into Italy. They were not generally adopted in other parts of Italy, or in England either, until the present century. The compass of the Halberstadt pedals was only an octave: B natural, C, C sharp, D, D sharp, E, F, F sharp, G, G sharp, A, and B flat. We learn from Schlick that B flat had been the highest pedal key, and some inconvenience had been caused to organists by changing this note to B natural.

Now, the Halberstadt keys were very wide, on the two upper keyboards four inches from center to center of each key, with chromatic keys two inches wide, placed two and a half inches above the diatonic. The keys of the two discant manuals were rounded, but in the bass keyboard they were square. I am indebted to Dr. Hopkins for these measurements, which are given in his valuable article upon the organ in Sir George Grove's dictionary, and I presume, are founded upon Prætorius' text and drawings. There could be, with this keyboard, no question of stretching an octave with the extended hands, or even more than a major third, and what we call fingering was entirely out of the question. The organist used the side of his clenched hand to depress the keys.

I will now briefly show, from Prætorius, the gradual upward extension of compass; but, for a long while, the B natural in the bass clef remained the starting note, according, as I have said, to the old Greek scale. It would appear that the pitch of the renovated Halberstadt organ was about a tone above our medium pitch of C, 528 double variations a second; but the pre-Reformation B natural was a fourth higher than this Halberstadt pitch, as was the case in the old Magdeburg organ, which was still remaining in Prætorius' time. We have seen that the Halberstadt organ had no higher key than the old Greek A in the treble clef. Prætorius describes the keyboard of the church organ of St. Egidius, at Brunswick, the date of which was A. D. 1456, as permitting the stretch of a fifth, instead of a major third, as at Halberstadt. He gives a drawing but, unfortunately, not the compass of the Brunswick keyboard; but he does of another organ of the same period, that of St. Salvator, at Vienna. In this the manual compass extended to C in the treble clef; the pedals as at Halberstadt. An undated organ at Minden, with keys 2½ inches wide, according to Prætorius's own measurement, had the same compass, pedal and manual as this Venetian organ. The next quoted by him was the organ of St. Sebald, at Nuremberg. Here the pedals went down to the lower A of the bass clef, the "Greek proslambanomenos," with B flat also added, but the manual kept to the normal B natural, ascending however to treble clef D. Another by the same builder, Heinrich Traxdorff, was in the Church of Our Lady of Nuremberg, without pedals, and only ascending in the manual to the Halberstadt A, but he introduced the octave register in the St. Sebald organ, and presumably in this, in addition to the already separated principal; the mixture remaining as the Hintersatz or Back organ. A further extension was made by Krebs and Mulner in the organ at Mildenberg, where the manual was advanced to the higher F of the treble clef; the lowest bass key still remaining B natural but the pedal starting from A, and from thence to the A above, a chromatic octave. We are now nearing the period of a great change in the organ keyboard, when Conrad Rotenburger built about A. D. 1475 the great organ at Bamberg, with similar compass, but to change it eighteen years later, that is in A. D. 1493, to the "long measure" in the bass, for the pedals, F, G, A, B flat, and then from B natural, chromatically, to the B flat above the bass clef, altogether an octave and a fourth; and for the manuals from the same F below the bass clef to A above the treble, three octaves and a third. The width of the keys was gradually being lessened until, when Cranz, in A. D. 1499, built the great organ of St. Blaise, at Brunswick, the octave was only the width of nine keys of Prætorius's time, when the octave had come to be comfortably grasped, as it has remained ever since, by an average hand. I ought here to state the compass of a modern German organ, and will take that of the great organ of Ulm, built by Walcker of Ludwigsburg, and accounted one of the finest German instruments. The manual keyboards, three in number, go from C below the bass clef to F above the treble, fifty-four notes, and the pedals from the octave lower C to D in the bass clef, twenty-seven notes. Large organs built in this country exceed this compass. Messrs. Hill's Sydney organ has five octaves, from C to C, on all five manuals

sixty-one notes, and pedals from C to F, thirty notes.

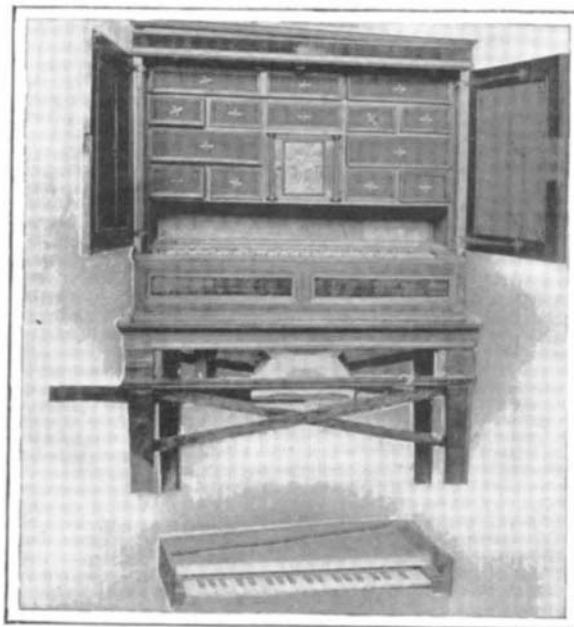
From the end of the fifteenth century the drone bass notes, as tonics or dominants to an octave system, appear to have got the better of the scholastic tetrachordal idea of the scale. Where the long measure, as it may be called, to the low F was not carried out on the keyboard, it was, in fact, as far as possible by substitution of pipes. The B natural key served no longer for that note, but for the G below it; the C sharp key doing duty for A; and the D sharp, when not retained



MODEL OF CLAVICYTHERIUM ACTION SHOWING QUILLED JACK.

for E flat, for B natural; but as this was hardly a drone note, E flat was often preferred. This was the short measure—for 300 years the well-known "short octave." In Italy the short octave has remained quite up to the present time, but generally with E for the apparently lowest key, which really sounds C, as F sharp sounds D and G sharp E; neither of these chromatics being good drone notes. Long drone pipes may be observed in pictures in which are represented the old portatifs, or processional organs, as in the Orcagna altar piece and the Spanish fourteenth century miniature I have mentioned. I can give many examples. And, in the Cecilia panel by the Van Eycks, painted for the Church of St. Bavon, Ghent, but now at Berlin, a positive or small chapel organ is painted in the most realistic manner, and the lowest note, D, has a special key situated below the keyboard at the left-hand side, while above this key there is a latch, the only possible use for which could have been to fix a drone. Perhaps the deep drones came later into large church organs on account of the greater cost of the deep bass pipes.

It will now be interesting to trace the general history of the organ up to that epoch when it may be regarded as a complete instrument. We learn from Prætorius that the back organ, or huge mixture, as I have said,



CABINET ORGAN WITH REMOVABLE SPINET.

Compass, three octaves and eight notes—C to A. On opening the folding doors a cabinet is disclosed, having 14 drawers and a central cupboard with bronze door-mounts, and a decorative bronze panel representing the Entombment of Christ. Below is the keyboard of the organ. The organ is blown by a handle attached to the side of the stand of the case, and working a small bellows beneath the cabinet, from which the wind is transmitted to a wind reservoir placed on the top. Immediately above the keyboard of the organ is placed in a recess an octave spinet. This instrument may be played either within the cabinet or may be withdrawn for separate use. Germany, 1598. Maker, Laurentius Hauslals. On the jack-rail of the Spinnet is the following inscription: "D. G. Quid possibile apud Laurentium Hauslals X Toribergensur," i. e., "By the favor of God, see what Lawrence Hauslals of Nuremberg can do."

of many pipes to a key, was about the time of Luther's Reformation and translation of the Bible, dissected by the contrivance of separating rows of pipes of different degrees of pitch, as 16-foot, 8-foot, 6-foot, 4-foot, and so on, into registers by means of slides acted upon by drawstops. About this time, also, pipes, which had all

previously been open from the mouth piece to the upper end, were supplemented by certain registers of covered or stopped pipes closed at the upper end, thereby introducing the contrast of a quieter and less penetrating tone quality. These stopped pipes were an octave lower in pitch than open pipes of the same length, from an acoustical reason that a node is formed at the closed end of the pipe, and thus the wave length becomes equivalent to twice the wave length of an open pipe corresponding in length. An important structural change, such as the formation of independent registers, was soon taken advantage of for introducing contrasts of various tone qualities. Improved methods of wind supply, and, as has been explained, an extended manual compass with narrower keys admitting of an octave being grasped, an extended pedal compass and lastly the invention of reed stops, which Prætorius places about A. D. 1530, made the sixteenth century organ complete in all essentials; but to be improved upon, added to, and transformed until, in the present day, it has become a triumph of tone, color, and effective combination, and of mechanical skill, assisted by pneumatics and electricity.

The sketch of a complete organ is as follows: A wind supply, pumped by hand labor, hydraulic power, or gas, the air being compressed, as well as collected, from the bellows, is conveyed to the wind chests, where it remains until liberated for use by the player. The top of the wind chest, upon which the pipes stand, is called a sound board, but has nothing to do with resonance; and the pallets, or valves of the channels of air which lead to the pipes, are closed until acted upon by the key mechanism, which is under the control of the player. The action of a key with the old tracker movement is very simple. When the player puts one down, the other end of the balanced lever raises a sticker, which acts upon mechanism governing what is technically and expressively called a "pull down" attached to the pallet.

Formerly, the weight of a touch, and consequent amount of force required from the player, was in direct proportion to the increase of weight from the accumulation of tracker movements; but by contrivances to equalize wind pressure, and particularly by the pneumatic lever, the invention of the late Mr. Barker, who also invented an electric action, the touch of the organ may be as light, with any number of stops drawn, as that of a piano or harmonium. The pneumatic lever is a small power bellows attached to each key, and supplied with high-pressure wind by the key being put down. The service of this invaluable lever is auxiliary to the finger in raising the action. The pipes are of metal or wood, those of metal being a mixture of tin and lead, and are either flue pipes with mouth pieces or reed pipes in which is inclosed a vibrating tongue of metal. Flue pipes may be, as already mentioned, open or stopped at the upper end. Their length and size varies with the pitch of the note; and their scale and form of air column varies according to the quality of tone required. The air, entering a metal flue pipe from a wind chest, is arrested by a flat piece of metal, called the "languid," and, being diverted by it in its direction, is forced through the mouth between an under and an upper lip, the latter being a fine beveled and indented edge, against which the wind thus directed breaks into a state wherein, according to Mr. Hermann Smith's theory, suction alternates with compression, and that portion which goes into the pipes sets up isochronous vibrations, that, agreeing with the period of vibration of the pipe, make the note, and last as long as the pallet remains open. In a wooden pipe the air is divided by a wooden block, performing the same office as the metal "languid." This is the same in principle as the flute player's *embouchure*. His breath passes from the throat, through the mouth and lips, against a sharp edge, giving access to the air contained in the flute. The effective length of an open pipe is measured from the languid to the upper end of the pipe, and in a stopped pipe from the block to the stopper and back again. In the reed pipe the foot is a metal case called a boot. In the boot is a round piece of metal also called a block, pierced in two places, the larger of which contains the reed, and the smaller the tuning wire which regulates the length of the tongue or reed so as to give the true note. The complete reed is a brass tube, in which there is a narrow opening, covered by a tongue of the same metal, the lower end of which is free to vibrate. Air when admitted to the tube forces the tongue away from the orifice, to which it returns by its own elasticity, and the puffs of air thus ejected establish the note, their rapidity determining its pitch. The length and shape of the tube affect the tone quality. As the tongue when at rest covers the opening, unlike that of the harmonium, which is free of such contact, it is known as a beating or striking reed. By the operation of slides which exclude or admit air to whole rows of pipes are formed the registers or varieties of pitch, power, and tone quality, governed by the draw stops. Each of these is really a separate instrument, but bands of them, so to speak, which have certain affinities, are grouped into departments, under control of separate keyboards, called the great, choir, swell, solo, and pedal organs. Not all necessarily in one instrument, especially the solo. Mechanical couplers and composition pedals, the latter the invention of the late Mr. Bishop, assist the player in his combinations. In adapting the pneumatic principle to these mechanical arrangements Mr. Henry Willis has done very much to facilitate performance upon large organs. The great organ has the typical pipes of the organ, the diapasons, and in England, before pedal organs were introduced, which was not, as already

said, effectively done until the beginning of the present century, were upon a light wind and of a fine mellow quality. The different balance of power in the modern organ has unfortunately, yet unavoidably, done away with this musical excellence. As well as these foundation stops there are gathered upon the great organ all those stops, flue and reed, that are most brilliant, as well as the mixtures; and also the reed trumpets and clarion, of 16, 8, and 4-foot stops, which have great richness and power.

The choir organ contains stops of lighter character, and carries with it the idea of accompaniment, as the name implies. The swell organ has grown into very great importance on account of the expression gained by its being in a box with Venetian shutters, which when closed materially reduce the tone, and as they open, produce an effective crescendo. The swell organ is entirely of English origin, and the expedient of louvres or Venetian shutters, in use for the last hundred years, is an adaptation of the harpsichord Venetian swell, invented in 1769 by Burkhard Tschudi, the founder of the house of Broadwood. It is now well known in France, and is there called *Récit*. It is less known in Germany.

The chief advocate for the extended introduction of the swell box in this country is Mr. G. A. Audsley, who has not only urged it on logical grounds in his treatise on "Concert, Church, and Chamber Organs," published in the columns of the *English Mechanic* (1886-8), and his recent lectures on the "Swell in the Organ," but has practically proved the great advantages to be secured by the multiplication of expressive departments in the organ. About twenty-five years ago he schemed and constructed his own chamber organ, which was, when finished, and still remains, for its size, the most flexible and expressive pipe organ existing. This can easily be understood when it is known that out of its nineteen speaking stops fifteen are rendered expressive by being inclosed in swell boxes. The two expressive divisions of the great organ, on the lower clavier, are inclosed in two independent swell boxes; the only stop here uninclosed being the *principale grande* (open diapason 8-foot). The upper or choir manual being entirely expressive. The range of expressive effects and *nuances* secured by these means is remarkable, while the tone qualities of the stop remain unaffected. Mr. Audsley now advocates inclosing a portion of the pedal organ to make the bass also expressive. Among organ builders of the present time, Mr. Roosevelt, of New York, makes the greatest use of the swell box. For instance, in his organ recently erected in the auditorium at Chicago, he has, out of its eighty-six manual speaking stops, rendered seventy-nine expressive by inclosing them in five separate swell boxes.

The solo organ is quite modern. Its introduction is attributed to the late Cavaille-Coll, in France, and Mr. Hill, in this country. The intention of the solo organ is to supply certain effective reed stops on exceptionally heavy wind. The pedal organ is the general bass to the whole instrument. In the largest instruments the 16-foot diapason and other stops are doubled by 32-foot open metal and reed stops, and Messrs. Hill & Son, in their great Sydney organ, have actually introduced a 64-foot reed, the harmonics of which blend in the general effect. To complete the pedal organ, softer stops are now required, of which Mr. Casson is the earnest and able advocate. The charm of a soft bass, in these days of mechanical progress and corresponding stress of life, seems to be everywhere disregarded. I cannot but think that the mechanical progress so wonderfully shown in the modern organ has now gone beyond the intrinsic musical value of the instrument, and attention should be given rather to the improvement of voicing and combining allied registers in suitable families, with the general advancement and proportioning of tone quality, so as to secure a real economy of the various departments. With regard to the extraordinary inventions which have attached pneumatic and electric aid to the organ, something I think may still be said for the old tracker action, which does allow a player gifted with a fine sense of touch some personal control, through the pallet, over the tone denied to him when these natural forces intervene. I should say mechanical ingenuity is not exhausted for ameliorating any difficulties presented by the old movement. I admit that the influence of personal touch on the organ is a debatable question; but I am not alone in upholding its possibility, and the occasional revelation of such a power in the player. The incompleteness of this sketch of the organ would, I am afraid, appear impertinent if I could not refer those who desire more information to the admirable articles by Dr. Hopkins, in Sir George Grove's "Dictionary of Music and Musicians," by R. H. M. Bosanquet, in the "Encyclopædia Britannica," and one in Sir John Stainer's and Dr. Barrett's "Dictionary of Musical Terms."

In the seventeenth century, and perhaps the sixteenth, an interesting offshoot of the organ was the regal, a complete reed stop taken from it and used as a separate instrument for accompaniment in convents and elsewhere. These beating reed instruments are now very scarce. I believe I possess the only large regal in this country; it is an almost portable vox humana. The regal might have been regarded as the prototype of the harmonium, had there not been an unbridged gap between the discontinuance of the regal, which became entirely forgotten, and the invention of the harmonium and its congeners, which did not happen until the present century had come in. The principle of the harmonium is the free reed, the opposite to the beating reed of the organ, the regal, or clarionet. The tongue does not touch the frame surrounding it,

and the action of the air in the harmonium is to force it away, and in a now favorite variety of that instrument, the American organ, by suction from the opening, to which it returns by its own elasticity, thus setting up, by puffs of air, isochronous vibrations. The inventor of the principle of the harmonium was a Frenchman, Grenié, who, early in the century, contrived a free reed keyboard instrument, and called it *orgue expressif*. The invention was completed in 1840, by the late M. Debain, who introduced air channels, to control tone quality, and gave his instrument the name of harmonium. It had an air reservoir, to insure a uniform wind pressure. M. Alexandre, also of Paris, gave the player the discretion of doing without this reservoir, by letting the wind supply act, by means of an expression stop, directly under the reeds, thereby giving the harmonium a power of expression it had not before. The harmoniums of Mustel, of Paris, are the most expensive and the most admired. The American organ, which acts by wind exhaustion, is said to have emanated from Alexandre's, but was first made popular in America. The tone is softer, and of less characteristic tone quality than that of the harmonium, and the expression stop is wanting.

Mr. Casson informs me that, by a pressure-regulating screw of his invention, he can give the harmonium and American organ an almost indefinite gradation of power, from *pianissimo* to *fortissimo*; and that the valve is so sensitive that a slight trembling of the finger on a key will produce a vibrato. If this is carried out, the harmonium will be much increased in importance as an artistic instrument. In another direction, that of purity of intonation, an harmonium has been invented by a Japanese amateur, Mr. Shohe Tanaka, called by him, from a suggestion of Dr. Hans von Bülow, "Enharmonium," which, by dividing the octave into twenty keys, increased by a single mechanical contrivance giving enharmonic changes, governed by a knee lever to twenty-six notes, obtains with certain scarcely perceptible limitations absolute purity of intervals and chords; and by a transposing movement, effective throughout the range of the whole chromatic octave, all keys with their modulations are played in the C major or A minor position. The value of this instrument, the fingering of which, owing to the transposition, is not difficult, for choral accompaniment is evident. The instrument has really thirty-six distinct vibrations in each octave, of which only twenty-six are utilized in any one position of the transposed keyboard.

Before proceeding to the last instrument of which I have to treat, the pianoforte, it will be interesting to go back to its precursors, the clavichord, spinet, or virginal, and harpsichord. The use that has been made of all these instruments, and their common possession of strings, resonance boards, and keyboards, makes the clavier instruments a group apart, but of the highest importance to the historical development of music. The original member of this group was probably the clavichord, but it is an inference only, from the simplicity of its construction and the certainty that it was based upon the mediæval monochord. The invention is nowhere recorded. The earliest reference that has been met with to a clavier instrument has recently been discovered by Mr. Edmond Vander Straeten, a well-known Belgian musical archæologist. It is to be found in the seventh volume of his great work, "La Musique aux Pays-Bas." It appears that, in A. D. 1387, King John, of Aragon, requested his brother-in-law, Philip the Hardy, to procure for him an instrument which he calls "exaquir"; and in repeating this request the following year, he describes it as "resembling an organ, but mounted with strings." He also asks for a player able to touch both organ and "exaquir." There has been a musical instrument mentioned in the fifteenth century French poetry long waiting for identification—the "echiquier." There can be but little doubt, according to Spanish and French phonology, of the identity of these names. Curiously enough there is a German form, "schachtbret," in some old rules of the Minnesingers, bearing date A. D. 1404. Whether this organ with strings was a virginal or clavichord we cannot say, but the name "echiquier"—"chequers"—may have come from an alternated color of the keys, or perhaps from a pattern upon the case of the instrument, as seen on some old portatifs. Both clavichord and spinet or virginal were known in the fifteenth century, and the latter had certainly, and the clavichord presumably, attained a useful degree of completeness. There is no clavichord so old known to exist, but an Italian trapeze spinet-shaped one was shown in the Paris exhibition of 1889, dated A. D. 1547. This is the earliest I know of. The clavichord came from the monochord by adjusting a keyboard to a set of monochord strings, that is to say, strings of the same length and pitch, like an Æolian harp is made, and stopping them by little brass up-rights, a little widened at the top where they came in contact with the strings, these stoppers—which not only excited the sound but acted as bridges—being called tangents. There was only one wooden bridge, that on the narrow soundboard; a strip of cloth interwoven among the strings prevented any jarring on the further side of the tangents, and also damped the strings all along, when the tangents by the return of the keys quitted them. The strings were early attached in pairs, similar to the lute and other stringed instruments. By making the keys twisted, two, three, or even four tangents were made to act on one pair of strings. At the beginning of the eighteenth century the clavichord got its full number of strings, each pair having its own tangent, and this was the clavichord of Bach, a gentle instrument, which best renders the

tender sentiment with which much of his keyboard music is charged.

The spinet was the application of the key-board to the mediæval psaltery, a form of dulcimer, but with plectra, not hammers. The oldest known spinet is dated A. D. 1490, and was shown in 1888 at the Bologna exhibition. Existing records show how much this instrument came into favor about that epoch. When, in 1509, the Chevalier Bayard, the famous knight without fear or reproach, was severely wounded at the siege of Brescia, he was carried to the house of a nobleman whose wife and daughter nursed him and entertained him during his convalescence by playing to him upon the lute and *espinette*, as the French call the spinet. The upright spinet was called "clavicytherium." I am of opinion that the beautiful upright spinet Mr. Donaldson owns, obtained from the Correr collection, and shown in the Loan Collection of 1885, although undated, may be as old as the 1490 spinet of Count Manzoni. There is an exact drawing of it by William Gibb, in my "Musical Instruments, Historic, Rare and Unique" (A. & C. Black, 1888). The spinet had one string only to each note, and the sound was excited by a little point of quill projecting at a right angle from a wooden upright placed upon the end of the key and called a jack. This also bore a cloth damper. According to Scaliger, the quilled plectra were introduced in his boyhood. He was born A. D. 1484. Buff leather was introduced in later years, but never superseded the use of crow quills. Perhaps brass wire preceded the quill points, as Mr. Donaldson's upright spinet certainly had such plectra. After the sixteenth century the musical value of the spinet hardly increased, but it gained somewhat in power, and was a brilliant instrument compared with the clavichord. Extended lengthways into the grand piano shape, and with two, three, and sometimes four strings to a note, generally with one string an octave higher in pitch, more rarely one an octave lower or bourdon, the spinet thus multiplied early became the more powerful and important harpsichord. Double keyboards and stops for registers showed its affinity, at least in idea, to the organ. The harpsichord certainly existed in the sixteenth century; there is one in South Kensington Museum, dated A. D. 1521; it died out with the spinet and clavichord in the last quarter of the eighteenth, unable to maintain the struggle for existence against the piano. Perhaps the last harpsichord was one bearing Clementi's name, dated 1802, which was also shown at the Bologna exhibition. Beethoven's "Moonlight" sonata was published in 1802 for harpsichord or piano-forte, and there is a record that Himmel played upon a harpsichord in public, at Berlin, as late as 1805. All the keyboard stringed instruments, whatever the size and however the sound may be produced, have certain structural peculiarities in common, and especially the apparatus for resonance, the barred soundboard, of cypress in the old Italian spinets, of spruce in the modern piano; all come under the same acoustic generalization of resonance, as Strad fiddles, Bologna lutes, or Andalusian guitars.

The piano-forte was invented by Cristofori, of Padua, in the first years of the eighteenth century, to satisfy the desire for a stringed clavier that should combine the expressiveness of the clavichord with the effectiveness of the harpsichord; it was, at first, a sufficiently facile instrument, and contained those principles of resonance—resistance to strain and suppleness of key action—that still characterize it. Cristofori solved three important problems, the first of which was to counteract the strain of the thicker strings necessary to withstand the impact of hammers. The second, allied to the first, was to compensate for the weakness caused by the opening between the turning-pin block—technically, "wrest-plank"—and the sound-board, imperative for the hammers to rise to the strings. The third was the mechanical control of the rebound of the hammer from the strings—technically, "escapement"—so that the hammer should not block against the strings and prevent vibration. All this he did, and more, for he invented the check, or movable rest for the hammer-tail, the simplest expedient to preserve the position of the hammer for a repeated blow—technically, "repetition." I am glad to be able to show models of Cristofori's actions, one made from the diagram in Scipione Maffei's account, published in the *Giornale dei Letterati*, A. D. 1709; the other, a remarkable piece of mechanism showing the check as well as the ingenious escapement, from grand pianos actually existing, dated 1720 and 1726. The much-talked-of pianos by Silbermann, acquired by Frederick the Great, and still at Potsdam, have Cristofori's action. Now if we raise the lid and look inside a modern grand piano, we shall see first the strings, three in number for each note, of cast steel wire—perhaps the strongest tensile material in the world—with the length and diameter increasing from the treble to the bass, and single bass strings for the lowest notes, overspun with fine copper or white metal wire to add to their weight, to make up for the strings in that part of the scale being theoretically too short. It may surprise some here to know that each of these three string notes, when up to the pitch of a London orchestra, has, in Broadwood's concert grand pianos, an average drawing power or tension of approximately 500 pounds, so that the notes have a strain, and that always when at that pitch, of nearly twenty tons. This large aggregate is exceeded by some foreign makers. To withstand this enormous strain, the strings are held at one end by coils round the tuning pins, which are driven into a strong structure of beech and wainscot, called the wrest-plank; and at

the other end are hitched upon smaller pins fixed into an iron or steel plate which is carried around the bent side to the end of the case. Their bearing points are upon the bridge attached to the sound-board, and the brass agraffes which collectively form the wrest-plank bridge. Bars of metal cross from the wrest-plank to the string-plate, and are so adjusted and fixed that the instrument proper is in an immovable iron frame. American and German makers have a single casting. Beneath the strings from where the hammers rise, to the bent side, back, and end of the case, is the sound-board of spruce fir, barred beneath with batons, usually of the same wood, technically "belly-bars," which strengthen the belly, and by increasing its elasticity, extend its power to form nodes or centers of vibration, and thus respond more promptly and effectively to the vibrations which are passed to it from the strings, when set in movement, through the hardwood belly bridge. A good sound-board reproduces all figures of vibration, however complex, exactly, and as freely as they are brought to the ear through atmospheric air, and re-enforces them so that the almost inaudible sound of the wires becomes the satisfactory fullness of tone we hear when a good piano is played. All pianos, upon whatever system they are made, have the features I have just described in common, also a wooden substructure of heavy beams, which keeps the case intact and rigid; but there are differences of application which are the choice of the makers, and are sometimes of their invention. In Broadwood's concert grand, one diagonal bar bears the greater part of the strain, its angle to the string plate being disposed with that object, while Steinway's and nearly all foreign grand pianos, have more bars, and the bass strings crossing the long steel strings, with the wider scale and expanse of sound-board permitted by that disposition. For me, the tone of an overstrung bass is unduly powerful, and is open to the same objection I have touched upon in large organs, that soft, pure basses are not attainable. We have reached an aggregate of power in the grand piano which almost silences the stringed quartet, and even competes with the full orchestra. What we want is a pianoforte tone that gives us all the power and all the charm of varying nuance we can desire, with a tone-quality as specialized in character as the harpsichord tone was, that shall have the brightness and energy of vibration of the trumpet, without the blare.

I must pass by the advisability of iron frames in a single casting, for which the great convenience and popularity place my own want of faith at some disadvantage, to make some reference to the not less important question of the mechanism or action. The hammers attack the strings with an almost incredible variety of velocities, according to the player's scale of force. It is wider and more various in the English action, and is, therefore, more open to the characteristic individual feeling for tone; while Erard's action, which, in principle, is generally adopted abroad, is considered far more facile for the pianist's technique.

The domestic upright piano is now restricted to the various modifications invented with the instrument about 1800, by Isaac Hawkins, and improved some sixty years since by Robert Wornum, the general merits of which have caused it to be, in these latter days, employed in every piano-making country.

The structure of smaller pianos is, in principle, the same as the concert grand. I have, in this paper, preferred to deal with the general principles of piano construction, rather than to touch upon the debatable points, which would take long to discuss, and could hardly be settled, inasmuch as piano making, like all other musical instrument making, is an art, and cannot be brought down to the level of mere mechanical manufacture. I think those who play the piano should have some acquaintance with those general principles, including that of sympathetic vibration, which the player controls with the pedals, a natural Æolian charm and prerogative of the instrument, divined by Beethoven, but the true use of which we owe to Chopin. I believe, if consideration were given to those principles more than it is, the unreasonable demands some players make upon this singularly responsive instrument might be reduced, and to the advantage of the cultivation of a feeling for tone which is incumbent on wind and other stringed instrument players, but is too frequently disregarded by those who play the piano.

I ought to refer the inquirer for further information about the construction of the piano to my paper upon it, read before the Society of Arts, March 7, 1883.*

OSCILLATIONS OF SHORE LINES.

DR. NANSEN, the Swedish explorer, during his recent visit to London, described the results of his investigations and theories regarding the phenomena of "Oscillations of Shore Lines," before the Research Department of the British Royal Geographical Society. The variations in the comparative level of land and sea is a question to which the eminent explorer has devoted a great deal of attention, and his results are of great interest to geographers. As Dr. Nansen pointed out, this question is a widely controversial one, opinions being very divergent regarding the nature and causes of variations in the shore line of the continents during geological ages. One popular contention is that the continental coasts have even recently been subject to great oscillations of level—that at some places the coasts have been much elevated, while at others they have been depressed, and that they still remain at these different levels. This opinion, however, he main-

tains to be fallacious, and he states that a thorough and systematic investigation of the problem would show this view to be incorrect; for there were many and strong evidences that, though there had been great oscillations of level, the mean level of the continental shore lines had for long geological periods past been very nearly the same as to-day over vast regions of the earth.

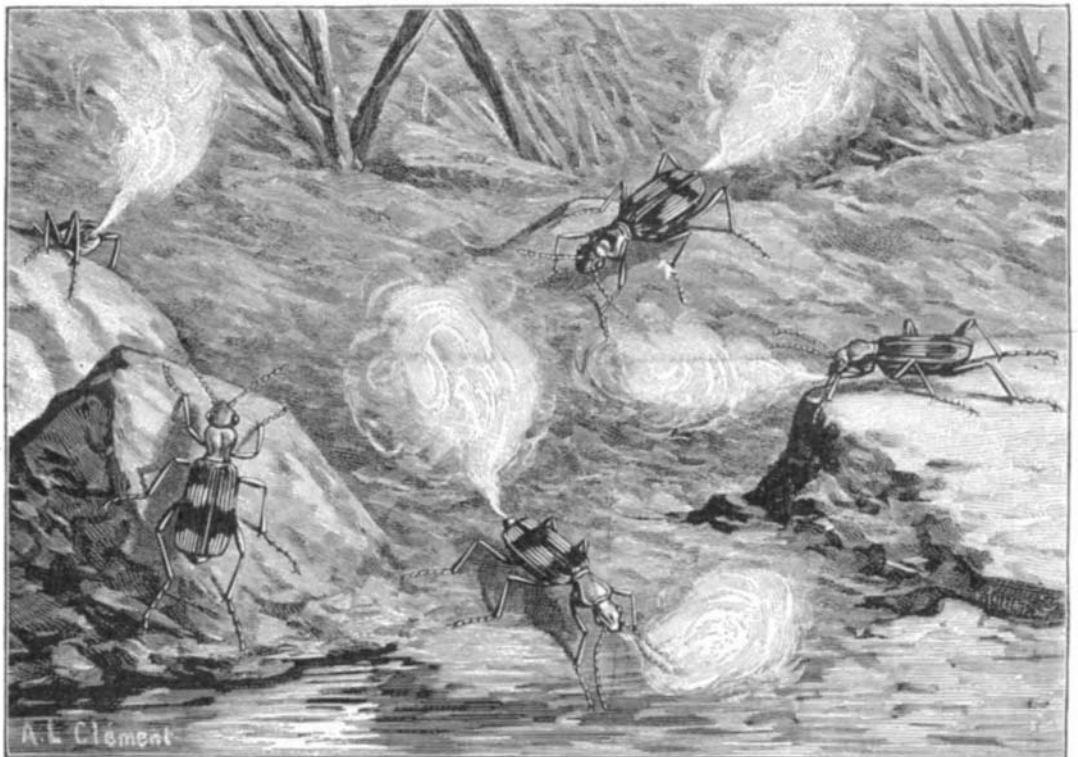
According to Dr. Nansen the coastal platforms and terraces formed by the so-called marine denudation—marine and atmospheric erosion combined—afford the best means of studying the problem. In this connection he discussed the characteristics of the coast platform and continental shelf lying off the Norwegian coast. The former extending from Christiania to Finmarken, and comprising the almost continuous belt of low islands and skerries that fringe the mainland, are situated between 100 feet below the present sea-level, and 100 feet above it. Probably the platform was formed in glacial and interglacial times. The continental shelf varies greatly in depth and width. At some places it is high and narrow, lying at a mean depth of from 200 feet to 300 feet, while at other points it is very broad and deep, lying from 700 feet to 900 feet below sea-level. To a very great extent this continental shelf must be composed of rock and must actually have been cut by erosion, though the coastal deposition of continental waste also played an important part in the building up of continental shelves. Being largely cut in the solid rock, the Norwegian shelf could not have been developed at present sea-level, but must have been formed during periods of vertical oscillations of the shore line. As in the case of the coast platform the shelf would be cut to its lowest levels where the coastal rocks were comparatively soft, or where the marine denudation was most active. This investigation combined with the consideration of the conditions prevailing in other parts of

as fishermen. The census supervisors reported that fish forms the principal article of flesh diet for about nine-tenths of the Filipinos. The annual consumption approximates half a million tons, or 800 pounds per average family. It is estimated that 119,000 persons are engaged to some extent in this calling, employing 28,000 boats. An industry followed by the Moros of the Sulu archipelago is fishing for pearls, mother-of-pearl shells, and sharks.

CURIOUS INSECTS OF THE AMAZON.

THERE exists in the region of the Amazon a variety of insects which are provided with a truly remarkable means of defense. These are coleoptera of the genus *Cicindela*, with thorax and legs of a light brownish yellow, black elytra marked with yellow, and of a total length of from 0.6 to 0.7 of an inch. Although these insects are sometimes seen in the daytime, it is at night that they can most easily do their hunting. "In the paths of my garden," says M. Le Cointe, in *La Nature*, "by directing the light of a dark lantern toward the ground, I have seen them running in all directions seeking a refuge in the clefts between the stones of the borders, or concealing themselves under tufts of grass. Every time that I have tried to seize one of them, a slight noise has been heard like that of steam under pressure escaping from a valve raised by jerks, while a jet of smoke has made its exit with force, in most cases from the extremity of the abdomen, and sometimes even from the mouth, and disseminating a strong odor of nitrous gas."

"At such times I have experienced quite a strong feeling of heat in the hand, and the body of some of the insects that I succeeded in catching appeared to me to be hot. My fingers and the parts of my hands that had been touched by the hot smoke were stained an indelible brown. It would seem as if this were



A DRAGON IN MINIATURE—PHEROPTOPUS ÆQUINOXIALIS.

the world, furnished strong evidence that during recent geological periods the level of the shore line along most continental coasts had oscillated much below as well as above the present level. A very important and striking fact, notwithstanding these great oscillations, is that the shore along nearly all coasts is at the present moment, very much at the same level as it was during by far the greater part of recent geological periods. Forty-two per cent of the continental surface of the earth stands between 600 feet above and 600 feet below the present sea-level. In Norway the coast platform is situated very nearly at its present level, though in post-glacial times it had been depressed in places 700 feet below its present level, while in other places the depression had been very much less—only 30 feet to 60 feet. Consequently, in spite of this great difference in its depression, the coast had afterward been elevated almost exactly to the level at which it stood before depression. This appeared to prove that the land, or crust, had a remarkable tendency after disturbances of its level, to return to a certain mean position of equilibrium. In his opinion, in Norway during the last glacial epoch the land had been pressed down by the weight of the ice-cap, and when this weight was removed the crust gradually resumed its former level. While, however, oscillations in the shore level were thus due to movements of the earth's crust, a survey of the available evidence shows that the level of the ocean has, on the whole, risen to an appreciable degree during late geological times.

FISHING IN THE PHILIPPINES.

As fish forms one of the principal articles of food, one of the most important occupations in the Philippine Islands is fishing, but the extent of the industry cannot be estimated readily, as a large proportion of the people assist in the maintenance of their families by this calling, but few devote themselves to it exclusively. Only 3.8 per cent of the producing class were reported

a very caustic substance which the insect projects with violence in an impalpable dust against the enemies that threaten it, and that it holds in reserve for important occasions.

"This process is not absolutely abnormal, since a number of other animals also have recourse to projections of liquids or odors against their enemies for their defense. But this denotes in our insect both a special chemical talent and a special resistance of the intestines that may be qualified as most remarkable."

"Upon the whole, this little coleopter is nothing less than a dragon that projects fire and flame from both of its extremities and that differs in principle from the famous monster of antiquity only in its dimensions. It may very well have been that our ancestors also knew some gigantic cicindele, the remains of an antediluvian fauna, and that they have not prevaricated as much as might seem to be the case in relating to us the misdeeds of the marvelous and terrible animal committed in the days of yore in guarding caverns in which was hidden every sort of treasure worthy of the name."

N-RAYS.—O. Rosenbach writes a "critique of the N-ray problem," in which he takes the view that the N-ray phenomena are not actually seen by the normal observer (though this has been denied), but are due to an unconscious visualization of muscular processes. He describes an experiment in this connection which, he maintains, everyone can perform with ease. In a perfectly dark room the hand is held before the eyes. The fingers will then be seen black on a background filled with vague luminous impressions such as are always present. On moving the fingers, their motions are seen. The vision is, of course, not real, but due to an association of ideas which has by habit become irresistible.—O. Rosenbach, *Physikalische Zeitschrift*, March 16, 1905.

* Published in SCIENTIFIC AMERICAN SUPPLEMENT No. 385.