over a limited area. They are entirely wanting when the excavation has taken place in the lower lobe, as the thickness of the muscular covering in that region offers great resistance to their transmission. Cough, especially when followed by expectoration, weakens them very much, or abolishes them for a time. (See chapter on Râles.)

7. Fluctuation in the Thorax.

In cases of pleurisy in which the effusion is very considerable in quantity, almost completely filling one side of the chest, a feeling of fluctuation may sometimes be elicited by placing the palmar surface of one hand on the side or back of the thorax and tapping on the front with the finger of the other hand.

One might *a priori* expect to find fluctuation in such a case; occasionally, however, the rigidity of the thorax is such that the force imparted by the finger does not reach the fluid, or the chest-wall does not yield to the wave even when the fluid is set in motion. The presence of a thick covering of exudation on the pleuræ may also prevent the production of fluctuation,—a further consideration which also explains the comparative rarity of the phenomenon.

PERCUSSION OF THE THORAX.

Historical Note.

The discovery of thoracic percussion we owe to Auenbrugger, who was born at Gratz in 1722 and died at Vienna in 1809. When engaged in the study of empyema and the indications for the practice of thoracentesis he learned in 1753 to distinguish the healthy from the diseased side by the different sounds which they yielded to percussion. After having worked at this subject about seven years he published, in 1761, his "Inventum novum ex percussione thoracis humani ut signo abstrusos interni pectoris morbos detegendi." Auenbrugger himself recognised the value of his new method of exploration in the diagnosis of diseases of the chest,—though he had no conception of the wide application it was to receive in our day,—and insisted on its importance in his "Monitorium" addressed to his fellow-physicians. It was, nevertheless, much neglected by them: to some it remained quite unknown, by many it was confounded with the Hippocratic *succussion* observed in pyopneumothorax and accordingly ridiculed as the "Inventum novum antiquum," while by others (van Swieten and de Haen) it was set aside as unworthy of serious consideration. It was only by a very few, the principal of whom was Stoll, that it was employed in practice; and when the latter died in 1787 the great discovery passed into utter oblivion. Not until 1808, shortly before Auenbrugger's death, did the "Inventum novum" become generally known to German physicians, through Corvisart's French translation. Corvisart extended the application of percussion to the diagnosis of cardiac diseases and aneurism of the aorta. But it is to Piorry and Skoda that the most important advances in the study and practice of percussion are due. The former invented the Pleximeter (in 1826), and was also the first to avail himself of percussion in the examination of the abdominal organs; the latter clearly traced the special qualities of the percussion-sounds to their general physical causes, he originated the doctrine on which all our notions regarding percussion in normal and pathological conditions are based, and added to our knowledge of the sounds that may be produced by striking on the thorax by his exhaustive researches on the subject of tympanicity (1839).

For many details concerning the interpretation of the various qualities of the percussion sounds we are indebted to Wintrich (tympanicity), Traube (the pitch of the sound), Biermer, Geigel, Wintrich, Gerhardt (variations in the pitch of tympanitic and amphoric sounds), and many others.

Wintrich invented the percussion-hammer in 1841.

Methods of Percussion.

There are two methods, *immediate* and *mediate*.

1. *Immediate* percussion, the method employed by Auenbrugger and also for some time by those who came after him, is performed by striking the thorax directly with the points of the fingers. In this way the more obvious of the differences in the intensity of the percussion sound are easily enough recognised. We thus obtain in the upper part of the chest a sound which we at once perceive to be distinctly clearer than that of the hepatic region; and we may also, by this means, define the various organs from each other with considerable exactness, and succeed in determining the presence and extent of many pathological conditions, such as pleuritic exudation, pneumonic hepatization, &c. The sound elicited by immediate percussion is loudest over the osseous portions of the thorax, more especially over the broad smooth surface presented by the sternum. Much less clear is the tone yielded by the direct percussion of the softer parts,—the intercostal spaces, the supra-clavicular and supra-spinous regions, and the abdomen. This method has now, however, been generally abandoned, as it does not enable us to distinguish with sufficient precision between the finer shades of difference in the pitch or quality of percussion sounds.

2. *Mediate* percussion. It may be practised in three different ways,—with the finger of one hand interposed between the body and the percussing finger, with the finger and pleximeter, or with the hammer and pleximeter.

a. The method which consists in applying the second or index finger of the left hand to the skin and striking it with the middle finger of the right is best suited for the examination of the irregular or uneven parts of the thorax, to which the pleximeter cannot be made to adapt itself accurately; it is thus applicable in cases of depressed sternum, of undue prominence of the ribs, (particularly in emaciated persons), when the intercostal spaces are narrow, and we wish to define sharply the boundary line between solid organs and those permeable to air.

b. As the interposed finger is apt to become the seat of considerable pain and swelling if frequently percussed upon a pleximeter is usually substituted for it.

This instrument is commonly made of ivory, though sometimes vulcanite or other hard substance is used in its construction. The most useful form of pleximeter is an oblong, slightly oval plate of simple ivory, about 2½ cmtr. in breadth, and fitted at each end with small vertical ears roughened on their outer aspect. The accurate delimitation of organs is much better accomplished by narrow than by broad pleximeters. Instruments made with movable metallic handles should not be used, as the handles become loose and make a clattering metallic sound when the plate is struck. In using the pleximeter it is above all necessary to see that it is closely applied to the surface of the body, especially when examining uneven parts, as otherwise a small quantity of air may lodge between the instrument and the skin, the disturbance of which by percussion may give rise to accessory vibrations.

In percussing parts whose surface is very unequal the double pleximeter proposed by Seitz, made of caoutchouc and shaped somewhat like the bent tongue spatula, will be found very convenient. In such cases also we may percuss on the end of the finger, which forms a pleximeter having the advantages of being easily adaptable to all parts and of being small enough to serve for minute examination. The same object is accomplished by placing the pleximeter not on its flat side but erect, endways, and percussing on one of the fixed ear-like handles should these be large enough to answer the purpose; in such circumstances, however, percussion with the fingers alone is easier and gives the most trustworthy results.

In percussing, both on the finger and on the pleximeter, the finger with which the stroke is delivered should always be half-bent, while the movement of the hand should be entirely from the wrist. The proper execution of this manœuvre demands a degree of skill which is acquired by many only by long practice; those, however, who are accustomed to play on musical instruments, especially the piano, already possess the necessary command over the wrist.

c. Percussion performed on a pleximeter with Wintrich's hammer. This method is the easiest to learn, it is, as the finger is not used, the least disagreeable to practice, and by it louder and more definite sounds may be educed than when the finger is used as the striking agent. Very marked differences in resonance, such as that between the lung and liver sounds, are most clearly demonstrated in this way. Nevertheless, with this powerful percussion-sound is associated the great disadvantage that in it the finer degrees of difference in tone are completely lost. It may be laid down as a rule that the stronger the percussion the larger the area over which the vibrations are distributed. It is on account of possessing more of this penetrative power that hammer-percussion is apt to lead to erroneous

conclusions, that a clear sound may be produced even though the medium immediately behind the part struck be void of air, the neighbouring air-containing structures being thrown into vibration; this source of error has to be specially guarded against in examining the cardiac and splenic regions. Another objection to the practice of hammer-percussion is that it involves the loss, to a great extent, of the sense of resistance which is experienced in finger-percussion. Both disadvantages may be partially overcome by percussing with a light stroke, and by grasping the hammer, not at the end, but at the middle of the handle, and at the same time keeping the index finger closely applied to the hammer-head; the finger is thus brought nearer to the percussed structure, and the sense of resistance communicated by the latter more readily detected. When the utmost precision is demanded in mapping out the size of organs and in tracing the boundaries which separate parts containing air from those which do not, when, for instance, we propose to define with rigorous exactness lung from liver, heart, spleen, &c., it is better to use the finger rather than the hammer, as by this *tactile* system of percussion the slight resistance of parts permeable to air and the greater resistance of those which are impermeable, are most distinctly appreciable.

Whatever be the method of percussion adopted, if the examiner have acquired sufficient skill in its performance an absolutely accurate result may always be obtained.—Although hammer-percussion, being the most easily mastered, is most generally employed, it will be found advantageous to percuss always with the finger and pleximeter so long as we can thereby elicit a distinctly defined sound. *He who is skilled in digital percussion will be able to percuss equally well with the hammer,—an axiom the inverse of which does not hold good.* It is also obvious that besides being proficient in the technical part of the proceeding it is necessary to possess a sensitive ear, educated to distinguish between the finer gradations of sound.

Rules regarding the employment of *forcible* or *gentle* percussion can be set forth only in a general way.—The stroke should be somewhat *forcible* in examining those parts of the chest which are covered by a thick layer of fat or muscle,—the mammary and supraspinous regions,—in order that the vibrations may be carried through them to the lung beneath; gentle percussion in these parts would not give the true pulmonary resonance but only the dull sound of the superficial soft parts. Similarly, a *strong* percussion-stroke is necessary to determine the condition (as regards the *presence of air*) of *deeply-seated structures*, lying below other internal organs or tissues which may or may not contain air. (See p. 79).

On the other hand percussion must be *gentle* where *solid* and *air-containing organs* (lung and liver, lung and heart) *border on each other* superficially, and in all cases in which it is desired to ascertain the density of parts situated immediately below the surface. The line of demarcation between lung and liver may thus be most sharply defined by percussing downwards with so little force that on reaching the liver only the sound caused by striking the pleximeter is heard; just at this point, however, at the end of a full inspiration the lower border of the lung encroaches slightly on the liver, and we then again obtain the clear pulmonary sound. In this way we find that the ear appreciates more promptly the difference between *absolute dulness* and *slight resonance* than that between the *greater* or *less clearness* of the tone produced by more forcible percussion.—The percussion-stroke must also be less energetic in children than in adults, because in them the thorax is more yielding and the internal organs are smaller, so that the vibrations generated by percussion at any part are more widely conducted through the tissues, and in that way the more delicate alterations in the nature and quality of the sound are hidden; thus it often happens that in percussing the chest in children a powerful stroke is answered by a sound of a tympanitic character proceeding from the simultaneous vibration of air in the intestines.—It is advisable also to percuss less vigorously in the vicinity of inflamed and painful parts, over pulsating aneurisms (to avoid the danger of bursting them) and cavities in the lungs; rough treatment of patients in whose lungs destructive processes are going on gives rise not only to pain but frequently also to attacks of coughing. Those who have shortly before suffered from hæmoptysis, or are still bringing up blood in the expectoration, should not be subjected to examination by percussion; cases—usually phthisical—are not wanting in which hæmoptysis has followed repeated percussion of the chest performed for the purpose of practical clinical teaching.

One of the most important rules is always to percuss the thorax *symmetrically* on the two sides. Although the more marked deviations from the normal resonance are usually at once appreciated by the ear, it is only by careful comparison with the sounds given by the corresponding part on the healthy side that the slighter variations can be satisfactorily made out. Thus in examining the lungs in front they should be percussed symmetrically from the supraclavicular regions downwards to the fourth rib, at which point the heart is encountered on the left side; laterally and posteriorly the same comparative method of examination may be continued downwards quite to the lower borders of the lungs. The muscles on both sides should as nearly as possible be in the same state of tension; if they be more tense or prominent on one side than on the other the resonance will be somewhat diminished on that side. In percussing the back of the chest the arms should be crossed in front in order to increase the space between the shoulder-blades and to ensure that the muscles of the back shall be in an exactly similar state of contraction on both sides. In like manner in percussing the supraclavicular fossæ the patient must hold his head

erect, with the face looking directly forwards; should he incline it to one side, as he is apt to do for the convenience of the examiner, the sound becomes less clear from the increased tension of the soft parts of the neck. So far as the percussion of the lungs is concerned it is immaterial whether the patient assumes the sitting, standing, or recumbent posture.

The Thoracic Percussion-Sound.

This sound is of a complex nature. *It is produced essentially by the vibration of air contained in the pulmonary air-vesicles, in part also by the vibration of the thoracic parietes,* and is to a certain extent influenced by the degree of tension of the parenchyma of the lungs. That the normal clear percussion-note depends principally on the vibration of air in the lung is proved by the facts that it becomes decidedly duller as the capacity of the lung diminishes, and that when a lung which has become quite impermeable to air (*e.g.*, consolidated by pneumonic hepatization) is extracted from the thoracic cavity and percussed it gives a perfectly dull, almost inaudible, sound. That the vibration of the chest-wall also is concerned in the production of the sound under discussion is indicated by the circumstance that the lung, when removed from the chest and inflated, is less resonant than when still within the thorax. And lastly, that the percussion-sound is to a certain extent modified by the varying state of the lung as regards the tension of its tissue, is shown by some pathological observations, to be mentioned further on.

Many authors deny that the chest-wall participates in any degree in the causation of the percussion-note, by others the part it plays is much over-estimated, while by some it is considered the only part concerned in the production of the sound. Williams explains the normal thoracic resonance *exclusively* in this way; he believes that the vibrations of the thoracic parietes, which are readily propagated through a lung filled with air, are disturbed in their transmission or completely arrested by an impermeable lung, or by the presence of fluid or solid exudation in the pleural sac,—just as the tone emitted by a violin-string becomes feeble when the mute is placed on the bridge of the instrument. Such a theory is fitted to explain only the diminution in the intensity of the sound in condensation of the lung, though it is not to be forgotten also that a hepatised lung, when taken from the chest, is just as non-resonant as before its removal; it does not, however, satisfactorily account for the production of tones having a tympanitic and metallic timbre. Williams' theory requires no detailed refutation. It is evident, on the other hand, from the following considerations, that the chest-wall *does contribute* in some degree to the formation of the percussion-sound: Mazonn has shown that when the free vibration of any part is prevented by the pressure of the hand or of weights laid on the surface the note obtained in the region concerned loses in resonance, even after extraction of the thoracic organs; increase in the tension of the ribs or skin raises the pitch of the sound, decrease in the tension of the ribs (as after removal of the sternum) lowers it; the elevation in pitch which accompanies deep inspiration depends chiefly on the greater tension of the ribs caused by the expansion of the chest and on the contracted state of the muscles; this raising of the pitch also occurs at various parts behind which no portion of the lung is situated,—a fact which negatives the idea that the inspiratory expansion of the lungs has anything to do with it; it is moreover well known that increase in the volume of the lungs in inspiration has the opposite effect,—it lowers rather than raises the pitch (Rosenbach; see p. 88).

The Properties of the Percussion-Sound.

The classification of the properties of the percussion-sound is based on that of the qualities of a musical tone, though strictly speaking these two species of sounds cannot be regarded as absolutely identical with each other in all respects. A musical tone is described as possessing Pitch, Timbre, and Intensity.

The *pitch* of a musical tone varies with the number of vibrations (as of a string or a column of air) which take place in a given unit of time.—Its *timbre* depends on the construction of the musical instrument, all those made of like materials (stringed instruments, for example) giving tones of an exactly similar character; timbre is also slightly different according to the particular variety of instrument used, so that a cultivated musical ear is able at once to tell whether a given note has been sounded on a violin or violoncello.—The *intensity* of a musical tone depends on the amount of force expended in producing the sonorous vibrations, and consequently on the amplitude of the latter.

The three qualities which distinguish musical tones are not found in the *normal* thoracic percussion-sound,—it possesses pitch and intensity, but not timbre; it is not, in fact, a musical tone in the sense in which that expression is used in physics, but is better described simply as a *sound*. As this normal sound, however, does acquire timbre, the tone ("klang") which renders it of musical quality, in certain pathological conditions, a third property must be ascribed to it,—that of *absence of timbre* (want of distinct musical character, non-tympanicity). Of these three

qualities,—intensity, pitch, and absence or presence of the peculiarity called timbre,—the most important is the first.

The Intensity of the Percussion-Sound.

(Clearness and dulness.)

The opposite extremes in the intensity of a sound are strong and weak, loud and soft; but in the terminology of percussion which prevails in Germany, the extremes are designated *loud* and *dull*, the intermediate varieties of resonance *muffled* or *obscured*.

However convenient this nomenclature may be, if we wish to indicate the qualities of the percussion-sound as far as possible in terms similar to those employed in describing musical tones the above expressions must be considered badly chosen, as *dull* is not the opposite of *loud* but of *clear*. On the other hand *clearness* and *dulness* are not the opposite extremes of *intensity* of a tone, because a clear tone may be very weak (soft) and a dull one very loud; nevertheless *loud* and *dull* may be used to designate contrary qualities of a tone with respect to timbre and pitch.—It would thus be more appropriate to speak of the normal pulmonary sound as being both *loud* (strong) and *clear*, the opposite of which would be *soft* (weak) and *dull;* in this way we should indicate both the intensity and timbre of the sound. The term soft ("*leise*"), however, is one that has never been definitely adopted into the terminology in question.—*Muffled* is a very fitting term by which to express the transition from loudness (clearness) to dulness, as a muffled sound is not only less loud but also less clear.

Apart from the mere force exerted in percussion, the intensity of the sound depends, 1st, on *the structure and thickness of the chest-wall;* and, 2ndly, on *the quantity of air contained in the lungs*.

1st. The shock produced by the percussion-stroke is much diminished in force in its passage through the thoracic parietes to the lungs, this enfeeblement during transmission being the more marked the thicker the tissues through which the impulse has to be conveyed; frequently, therefore, the amount of vibration set up in the lung is but very slight. Thus the sound that is given by the lung, even when the latter is in a normal condition as regards air-contents, is always somewhat duller at those parts at which the subcutaneous fat is abundantly developed; in the mammary region in females, when the breasts are large, it is

almost absolutely dull, especially on percussing gently; it is also less clear over those parts occupied by large masses of muscle, as over the whole posterior surface of the thorax, especially in the supraspinous regions; it further diminishes in intensity when the covering of the thorax is thickened by œdematous swelling. Similarly, the percussion-sound becomes duller, sometimes even to a considerable degree, when the ribs are strongly curved and the chest-wall thereby increased in thickness; this is especially noticeable on the posterior surface of the thorax in those suffering from kyphosis.

2. The sound is *muffled* when the quantity of air in the chest suffers diminution, and is rendered positively *dull* when the substance of the lung becomes completely *impermeable to air*. The sound obtained on percussing a lung which is entirely void of air is quite indistinguishable from that yielded by any other solid organ, such as the liver or the *thigh;* the typically dull sound is therefore sometimes called the *femoral* sound.

The decrease in the volume of air in the lung, however, must be considerable, and must implicate the organ somewhat extensively before it can produce any very sensible effect on the percussion-sound; a very slight diminution does not alter it in any degree. In percussing a lung removed from the body and powerfully inflated we obtain a clear sound; after allowing a small quantity of the air to escape we find that the sound remains quite as clear as before. In like manner it is frequently observed that in the beginning of acute, or in the course of chronic, diseases of the lungs the percussion note remains unaffected, notwithstanding the marked falling-off in the volume of air which the lung is capable of accommodating, a diminution which is the inevitable consequence of the nature of the morbid process going on, and the existence of which is proved also by certain auscultatory signs to be subsequently considered.

It is necessary, in order to the production of any marked decrease in the intensity of the percussion-sound, that the portion of lung rendered less permeable to air should have an area of at least 4 square cmtr., and that it should lie near the surface. *Very circumscribed* portions, even when situated superficially and perfectly consolidated, do not modify the sound, and still less is this effect produced by more deeply-seated lesions, even when they are of considerable extent. In the first case the

sound continues unchanged because it is impossible to confine the vibration caused by the percussion-stroke to an area so limited, in the second case because the condensed parenchyma is at all points covered by lung tissue which contains air and which gives a clear sound.

It has already been stated (p. 74) that in order to detect deep-seated consolidation it is necessary to percuss with a fair amount of force, when it is found that the tone rendered by the part in which such consolidation occurs is less loud than usual; positive evidence of its existence, however, is attainable only when it is comparatively near the surface and involves a somewhat large portion of the lung. The generally-accepted view, that this muffling of the resonance over those parts of the lung in which consolidated tissue is sheltered behind tissue that is freely permeable is due to the diminished depth of the stratum of air thrown into vibration, is supported by the fact that the percussion-sound of large portions of lung removed from the body and fully distended is clear, that of smaller pieces being somewhat duller. This is in accord with Weil's statement that the dulness is not owing to any quality communicated to the sound by the solid part, —a theory that is founded on the following simple experiment; Weil found that two portions of lung of equal size, removed from the body, gave an equally clear sound to percussion, and that the relation was not disturbed even when one of the pieces was placed on a solid substance, such as the liver.

When the ear is accustomed to the normal pulmonary percussion-sound very marked dulness is at once recognised without any comparative examination of the healthy side, though it is only by the latter method that the slighter deviations from the normal resonance are detected. Should the sound be of nearly equal intensity at two symmetrical points,—above or below the clavicles for instance,—percussion of the surrounding parts must be trusted to show whether or not it is normal.—Obviously the stroke must be equal in force on the two sides.

The diseases of the respiratory organs associated with *decrease in the intensity* of the percussion-sound may be arranged in two groups, those in which the air vesicles are *infiltrated* with plastic exudation, and those in which they are *subjected to pressure*, and thus temporarily or permanently closed (by the presence of fluid or tumours in the pleuræ).

1. *Dulness* due to *infiltration of the lungs*.

In pneumonia in the stage of hepatization the percussion-

sound becomes dull, the alveoli of the lung being completely filled with a fibrinous exudation which displaces the air they normally contain. The more nearly this hepatization, which usually involves one entire lobe,—most commonly the lower,—approaches the surface of the lung the more marked is the dulness, so that frequently the latter closely resembles the perfectly dull liver-sound. The absence of resonance, on the other hand, is less appreciable when the consolidated parts are separated by healthy lung tissue, and the sound suffers no sensible diminution if the induration be in very small isolated patches (see p. 79), even when these are superficial; and similarly when the affection, though comparatively extensive, occupies the central parts of the lung, as in central pneumonia, the percussion-note remains quite unaltered.

In the first stage of pneumonia, when, though the pulmonary capillaries are engorged with blood, the alveoli are still free of exudation, the thoracic resonance is normal; it is only towards the end of this stage, when a certain amount of exudation has been poured into the air-cells, but not enough to completely dislodge the air, that the intensity of the percussion-sound diminishes; it becomes slightly muffled, and acquires a tone of a somewhat tympanitic character (see p. 99), from the relaxation of the pulmonary parenchyma; in the third stage the exudation disappears, the air again gains entrance into the alveoli, and we have the same physical conditions as at the end of the first stage—the presence of both air and fluid in the air-cells producing a dull percussion-sound, which gradually becomes clearer, and at the same time assumes a tympanitic quality as the absorption of the infiltration goes on. This tympanitic character is lost when the process of absorption is ended and the lung has returned to its normal state. In those cases in which the infiltration, instead of being absorbed, passes into cheesy degeneration, or a state of chronic induration, the capacity of the alveoli is permanently lessened, and the thoracic resonance is more or less diminished.—It is not unusual to find all three stages represented simultaneously in the chest of one patient, one part of the lung being hepatized, another part having reached the stage of resolution, and a third portion of the same or another lobe just taking on inflammatory action; it is in that way that we are able to explain the sudden transition from an absolutely dull to a