in the direction in which force is applied (Wintrich) to give rise to an amphoric sound, and even then it is heard only under certain conditions: the cavern must be quite superficial, bounded by walls of homogeneous structure, entire, not subdivided into smaller cavities by portions of lung-substance which may have escaped disintegration (bands of connective tissue, &c.), and must not contain too much fluid; it is further necessary that the thoracic parietes be not over-resistant, otherwise the sonorous vibrations are much weakened in transmission through them. In phthisical cavities in the upper lobes, if the other conditions necessary to the development of amphoric resonance be present, the thoracic resistance is usually also sufficiently diminished, as the chest is always considerably emaciated when the disease has reached this stage.—The sound is further increased in intensity by opening the mouth when the vomicæ communicate freely with one of the larger bronchi.—In cavities of bronchiectatic origin the metallic echo is wanting, partly because the disease is not one which causes general wasting, partly because the spaces are seldom of the necessary size, but chiefly as the affection is most common in the *lower* lobes, where the resistance of the posterior wall of the chest is undiminished.

The metallic percussion-sound is heard with great distinctness in *pneumothorax*, as soon as the air confined in the pleura reaches a certain (not over-exaggerated) degree of tension.* Sometimes the sound is metallic from the very outset, at other times it is tympanitic and attended by a metallic echo. It is not always so loud as to be audible at a distance from the chest; this is particularly the case if the thorax be much distended, when its walls are tense and rigid. In such cases it is proper to combine auscultation with percussion, by striking the affected side of the chest with the pleximeter, or percussing on the latter with the hammer, while with the ear to the surface we listen for the sound so produced; should the metallic sound still be inappreciable it will be necessary to percuss on the pleximeter with a *hard unelastic body*, such as the *handle* of the hammer or a

* If the tension of the air in the thorax be too great the metallic sound is absent; it returns, however, after death, as the cooling of the air reduces its tension. Similarly, on the dead body, a pre-existing amphoric sound may be caused to disappear by opening the abdomen and pushing the diaphragm upwards and so augmenting the pressure within the pleura (Traube),—provided that the gas has no avenue of escape, such as a persistent pulmonary fistula.

rod of metal. In this way the overtones are brought out with great clearness, and free from the tympanitic note which otherwise precedes the amphoric sound (Heubner).

As pneumothorax is always followed after a certain time by effusion of fluid into the pleural cavity the region in which amphoric resonance may be elicited gradually decreases in extent, and, even though a sufficient volume of air remain above the effusion, the sound frequently disappears entirely, giving place to a tone of purely tympanitic character.

On *changing the posture* of patients suffering from pyo-pneumothorax the percussion-sound undergoes modifications analogous to those described at p. 97; there is at the same time an alteration in the pitch of the amphoric sound (Biermer), it becomes higher on shortening, deeper on lengthening, the long diameter of pneumothoracic cavity.

According to Biermer the amphoric sound is more acute when the patient is in the recumbent posture, as the fluid sinks to the back of the chest, and the diaphragm, freed from pressure, rises, so that the long diameter of the resonant chamber is shortened; whilst in the upright position the diaphragm is forced downwards by the weight of the effusion, the air-space is lengthened, and the tone becomes graver. It may happen, nevertheless, as was observed by Björnström in three cases and by me in one, that the opposite effects may result from change of posture,—the space containing air may be shortened when the patient stands erect (from the extension upwards of the fluid) and lengthened when he lies prostrate; in the former case the pitch of the sound rises, in the latter it falls. Next to the quantity of the effusion the resistance offered by the diaphragm to the downward pressure of the fluid exercises the most important influence in determining the pitch of the sound, as it is to it that the greater or less degree of displacement of that structure in sitting and lying is due.—In *inspiration* also the descent of the diaphragm increases the length of the air-filled cavity, and renders the pitch of the amphoric sound *lower* than in expiration (Björnström); Biermer states, however, that inspiration may raise the pitch of the sound.

In a few instances, as in certain cases of pneumonia (Skoda), a ringing metallic sound, supposed to be caused by an unusually rapid, severe, and extensive relaxation of the lung-substance, has been detected, apparently unconnected with the presence of cavities in the lungs. This explanation can scarcely be said to be satisfactory, as it is exactly in these circumstances that the tympanitic percussion-sound is developed in pneumonia.

Topographical Percussion.

The formation of an opinion regarding pathological alterations

of the percussion-sound is impossible without a knowledge of the normal pulmonary sound, of the boundaries of the areas over which it is audible, and of the physiological differences in its intensity and pitch at various points on the surface of the thorax. In the practice of percussion, therefore, the study of the normal sound must precede that of its pathological modifications; but the didactic representation of the results of topographical percussion, on the contrary, can be properly understood only after the causes and diagnostic significance of the different qualities of percussion-sound and its pathological alterations have been discussed.—Besides the ordinary anatomical descriptive terms, such as supra- and infra-clavicular, supra- and infra-spinous regions, &c., the ribs and intercostal spaces, the sternum and vertebral column, are all made available in topographical nomenclature. The numbering of the ribs starts at the first,—when it cannot be distinctly felt, at the second, the sternal insertion of which stands out prominently. The number of any of the lower ribs is best determined by counting from below upwards, the twelfth being always easily made out.—As aids to more exact topographical description the anterior, lateral, and posterior surfaces of each side of the thorax are divided by vertical lines drawn at nearly equal distances from each other: the *median line* passes vertically through the middle of the sternum, the *sternal line* parallel with it at the edge of the bone, *the mammillary line* through the nipple, the *parasternal line* midway between the two last-mentioned lines, the *middle axillary line* through the middle of the axilla (in front of and behind this being the *anterior* and *posterior* axillary lines), the *scapular line* perpendicularly through the inferior angle of the shoulder-blade.

1. The Normal Limits of the Lung.

a. *The upper limit.* The lungs on both sides rise anteriorly 3 to 5 cmtr. above the clavicles, occupying there a triangular space the outer side of which is formed by the free edge of the trapezius muscle, the inner by the clavicular portion of the sternomastoid, the base by the clavicle. Posteriorly the apex of the lung occupies an area bounded externally by the trapezius muscle, inferiorly by the spine of the scapula, superiorly by the spinous process of the seventh cervical vertebra.

b. *The anterior (inner) limit* follows the line of the anterior

inner margins of the lungs. These, passing downwards from the apices, approach each other and meet behind the sternum at the level of the second rib, and remain in apposition, separated only by the anterior mediastinum, as far as the level of the fourth rib; beyond that point they diverge, the left, after turning abruptly outwards, inclines again slightly towards the sternum behind the cartilage of the fifth rib, and ends, opposite the sixth costal cartilage, in the left lower margin; the right runs nearly perpendicularly behind the sternum from the level of the fourth rib to the sixth costal cartilage, where it joins the inferior border at almost a right angle.

c. *The inferior limit* is formed by the lower borders of the lungs. When the diaphragm is in a moderate state of contraction, as during quiet respiration, the inferior margin of the *right* lung is found at the upper edge of the sixth rib in the parasternal and mammillary lines, at the upper edge of the eighth rib in the axillary line, at the ninth rib in the scapular line, and at the tenth rib close to the vertebral column. The lower margin of the *left* lung is situated at the lower border of the sixth rib in the mammillary line, at the upper border of the eighth rib or in the eighth intercostal space in the axillary line, at the ninth rib in the scapular line, and at the tenth rib close to the vertebral column.—In aged persons the pulmonary boundaries are about a rib's breadth deeper, in children about the same distance higher.

The lungs, when expanded in inspiration, pass over these limits, especially inferiorly and anteriorly, least of all in the upward direction. In ordinary circumstances, when respiration is slow and tranquil, any extension of the boundaries of the lung which may take place is but trifling, almost imperceptible, the displacement at the right lower border, in the mammillary line, amounting only to about 1 cmtr. When inspiration is forced, on the other hand, the lower edge of the right lung may sink to the extent of 3 cmtr. in the parasternal and mammillary lines, or even as much as 4 cmtr. in the axillary line; the ascent of the upper part of the lung varies from ½ cmtr. when breathing is quiet to 1½ cmtr. on making a full inspiration. Change of posture also gives rise to some displacement of the margin of the lung; on turning from the back to the side while in the recumbent position the lung which is uppermost descends

usually about 3 cmtr. in the axillary line, and about 2 cmtr. in the mammillary line.

For diagnostic purposes it is of the greatest importance to define accurately, by means of percussion, the lower border of the right lung, inasmuch as if it be shown that it does not go beyond its normal limits the possibility of the existence of one of the most common lung diseases, vesicular emphysema, is excluded. This, fortunately, is easily accomplished, as the lung, anteriorly and laterally, is separated from the liver merely by the thickness of the diaphragm, so that a marked difference between the clear pulmonary sound and the dull hepatic sound is at once perceived. The line of demarcation of the lower margin of the right lung is thus identical with that of the upper edge of the liver.

The delimitation of the right lung inferiorly affords an excellent opportunity of studying the gradual transition of the percussion-sound from perfect resonance to absolute dulness. In the first place, during quiet respiration or, still better, after forced expiration, the upper boundary of the *absolutely* dull hepatic area in the mammillary line should be defined and marked on the skin with black dermographic crayon (crayon lithographique), when it will usually be found to coincide with the lower edge of the sixth rib. In the same way the lowest point at which the pulmonary-sound is still perfectly clear, which is generally about the level of the fifth rib, is to be ascertained and shown on the surface. The region lying between these two points is about an inch in depth, and constitutes the zone of transition from resonance to dulness; in it the percussion-note is somewhat muffled or obscured. If this part be further examined by percussing with one finger on the other the definite boundary line between lung and liver is found, as a rule, at the upper edge of the sixth rib. The same method of procedure is adopted in delimiting the lung in the parasternal and axillary lines. The extreme accuracy and trustworthiness of the results so obtained have frequently been shown on the dead body, by inserting long needles into the tissues along the lines indicated by physical examination.

It is of importance from a diagnostic point of view also to ascertain the *mobility of the lower border of the lungs*. As in full inspiration the lung stretches downwards to a point 2 to 3 ctmr. lower than in expiration, the upper part of the area which in the latter condition gives a dull liver-sound, is in the former case perfectly clear and resonant: this change, when present, proves the complete mobility of the lung. When this rising and falling movement of the margin of the lungs is wanting, as in cases in which the visceral and costal pleuræ are extensively adherent, the percussion-sound of the region in question remains

unaltered in both phases of respiration. In severe cases of pulmonary emphysema, also, the edge of the lung is nearly or quite motionless in inspiration; here, therefore, percussion reveals to us the fact that the alveoli of the lower part of the lung are no longer elastic, but have lost their capability of expansion.

To determine the *upper* margin of the lung, the highest point at which the clear pulmonary percussion-sound is appreciable should be noted during expiration; if the apex of the lung be expansible the clear area extends upwards during inspiration, but if, as so frequently happens, it be the seat of cheesy degeneration, the clear percussion-area is lower in point of position even during expiration (Seitz) and rises but slightly or not at all during inspiration. The difference in the extent of the movement at the apices on the healthy and the affected sides, measured with Haenisch's stethograph, varies from $\frac{1}{4}$ to a little over $\frac{1}{2}$ ctmr. If the percussion-sound be absolutely dull, the apex being completely consolidated and void of air, inspiration does not make it clearer. When the apex of one lung is affected, however, the range of movement possible on the healthy side is also generally somewhat restricted.

The movements of the *anterior inner* borders of the lungs may be traced by the percussion-sound becoming louder (clearer) over the sternum and in the cardiac region during inspiration. In deep inspiration the edges of the lungs creep forward, so that the greater part of the heart is covered and the cardiac dulness almost entirely masked.

When the *anterior* border of the *left* lung is pathologically distended (by emphysema) the cardiac dulness is diminished in area or completely obliterated, and the sound over the heart is loud and clear; if, on the other hand, it be adherent to the costal pleura, incapable of expansion or forward movement, the area of cardiac dulness is unaltered either in inspiration or expiration. When this part of the left lung atrophies it retreats, the base of the heart comes to a large extent into contact with the chest-wall, the pulsation of the heart is seen and felt as far upwards as the third or fourth intercostal space, and the region of cardiac dulness is enlarged. The mobility of the anterior margin of the *right* lung is recognised by the greater clearness of the sternal percussion-sound in inspiration.

The movements of the *posterior upper and lower* borders of

the lungs, also, are well-marked and easily made out by the extension of the clear percussion-sound during inspiration.

Pathologically the *posterior upper* margins of the lungs recede in contraction of the apices, while the *posterior lower* borders extend downwards to the eleventh or twelfth rib in pulmonary emphysema.

The position of the lobes of the lungs, with relation to the thoracic wall, is as follows:—

Right lung (three lobes).—The *upper* lobe reaches downwards on the front of the chest to the fourth or fifth rib, laterally to the fourth rib, posteriorly to the spine of the scapula; the *lower* lobe lies between the spine of the scapula and the tenth rib posteriorly, and laterally between the sixth and the eighth ribs. Between the upper and lower lobes comes the *middle* lobe, which laterally occupies the space included between the fourth and sixth ribs, and anteriorly extends to the lower margin of the lung.

Left lung (two lobes). The *upper* lobe comes down on the front of the chest to the sixth rib in the mammillary line, (to the inside of which point lies the heart), and laterally to the fourth rib; below this, and reaching to the base in front and from the spine of the scapula to the base behind, is the *lower* lobe.

2. Regional Percussion.

On the *right* side of the chest in *front*, from the apex to the fifth intercostal space, the percussion-sound is loud (clear), deep, and non-tympanitic; resonance is greatest from the clavicle to the fourth rib,—the clavicle itself giving a note scarcely less clear than that of the supraclavicular region,—and least at the apex (on account of the smallness in volume of the subjacent portion of lung) and in the fifth intercostal space (owing to the thinning of the lung at this point and its proximity to the liver). From the sixth rib to the margin of the thorax the sound is absolutely dull; but about the lower edge of the liver, more particularly in children, the intestines give to the percussion-sound a more or less distinctly tympanitic quality.

In the neighbourhood of the sternal insertions of the two first ribs on both sides, most often on the right side, the percussion-note is usually less clear than (for example) in the infraclavicular region. This

is caused by the thinness of the lung towards the border, the volume of air thrown into vibration being small.

On the *sternum* the sound is clear, deep, and non-tympanitic. On the manubrium sterni it is somewhat less clear than on the body of the bone, but is nevertheless nearly as clear as that obtained at the apices. That the manubrium sterni should be resonant to percussion though there is no portion of the lung-tissue behind it, but only the trachea, the œsophagus, blood-vessels, &c., admits of explanation only on the supposition that its power of entering into vibration is such that the movements excited in it by the blow are at once transferred to the neighbouring lung-tissue. This is what occurs also at the lower part of the sternum,—though here and over the xiphoid cartilage the sound is less loud and clear, owing to the proximity of the right ventricle of the heart and of the left lobe of the liver.

The sternum may be rendered less vibratile if during the examination an assistant press firmly with both hands on the sides of the thorax near the sternum (Mazonn), when the sound over those parts of the bone behind which no part of the lung is situated, becomes decidedly duller.

The percussion-sound is clear on the *left* side in *front*, from the apex of the lung to the upper edge of the fourth rib, and dull from the fourth rib downwards through the cardiac region to the point at which the apex-beat of the heart is perceptible (the fifth intercostal space). On the sixth rib we have the first trace of the tympanitic stomach-sound, which, lower down, about the margin of the thorax, passes into that of the colon.—At the base of the left side of the chest, lying along the anterior lower border of the ribs, is a certain region in all parts of which the percussion-sound is tympanitic; it reaches posteriorly to the ninth or tenth rib, is about 8 or 9 cmtr. in breadth at its broadest part and somewhat crescentic in general conformation (Traube). This space is encroached upon by the lung at each inspiration, when its upper part yields the clear pulmonary sound; and, similarly, it becomes smaller in all pathological conditions (pulmonary emphysema, for example) involving downward displacement of the diaphragm and stomach, and is enlarged in those conditions (atrophy of the left lung, for instance) in which the diaphragm is drawn upwards. It is reduced in size also in cases of effusion into the left pleura,