sound has no tympanitic quality. Large vomicæ render a tone which is the more clearly tympanitic the more superficial they are and the thinner the thoracic parietes; cavities, therefore, in the upper lobes of the lungs, in which region the chest-wall—which suffers also in the general emaciation connected with the original disease—is naturally thinnest, give a more decidedly tympanitic percussion-note than those occurring in the lower lobes, chiefly on account of the greater thickness of the layer of muscles covering the latter on the lower part of the dorsal aspect of the chest.

The tympanitic character of cavernous resonance is never so intense as that of the intestinal percussion-sound, as it originates in the vibration of a much smaller body of air. It may be either muffled or clear,—muffled when the quantity of fluid in the cavity is greater than the volume of air, clear when these conditions are reversed.

There is one very important sign which is, with very few exceptions (see pp. 96 and 99), associated only with the tympanicity dependent on *pulmonary cavern*,—provided always that the cavity communicates freely with one of the larger bronchi; that is that the *pitch* of the percussion-sound is *higher when the mouth is open, lower when the mouth is shut*, and lower still when the nostrils also are closed (Wintrich). The cause of this modification of the note lies obviously in the variation in the size of the external orifice of the cavity, as it has been already shown (p. 91) that the pitch of the sound given by an air-space which is not completely closed depends not merely on the length of the column of air in vibration, but also on the width of the opening by which it joins the outer air; thus, the tone rises in pitch when the outer orifice is enlarged, and falls when it is contracted, the length of the column of air remaining the same. A similar change can also be demonstrated by percussing on the side of the larynx or on the cheek, the sound becoming lower when the mouth is shut and higher when it is open. It has been observed further that the tympanitic cavernous sound is raised in pitch by full inspiration (Friedreich); this is not wholly attributable to dilatation of the glottis, as the inspiratory rise in pitch takes place even when the bronchus into which the cavity opens is blocked up by mucus,—a condition which is recognised by the disappearance of the sign described by Wint

rich, the modification of the percussion-sound by opening and closing the mouth; it proceeds rather from the increase in the tension of the chest-wall, which takes place when the lung expands (see p. 87). In expiration, on the other hand, the tympanitic sound becomes deeper; or it may almost entirely disappear, giving place to a muffled or less clear sound, especially during an attack of coughing. In the latter case the air in the cavities is compressed and for the most part driven into the bronchi by the great augmentation of the intrathoracic pressure, so that the only vibrations which are appreciable are those of the condensed lung tissue.

When the excavations are of very large size, so disposed that their *long diameter* corresponds with that of the lung and of the *body* as a whole, containing both air and fluid, it is sometimes observed that the *intensity* of the tympanitic sound is modified by changing the *position* of the patient; when he is standing or sitting the sound is of a dull tympanitic quality inferiorly, of clear tympanitic quality superiorly,—the fluid gravitating naturally to the lower part of the cavity, the air rising to the upper part; in the recumbent posture the tympanitic note becomes everywhere clear, owing to the uniform distribution of the fluid over the entire posterior surface of the cavity. Not only the intensity but also the pitch of the percussion-sound of large excavations is altered when the position of the body is changed; when the cavity is of such a form and so situated that its long diameter is directed from above downwards the tone becomes higher when the patient assumes the sitting posture, as in this way the vibrating column of air is considerably shortened; when the cavity is deepest antero-posteriorly the pitch of the percussion-note is lowered in the upright position (Gerhardt). The last-mentioned sign, when unmistakeably present, is absolutely pathognomonic of the existence of cavity, because under physiological conditions a deepening of the pitch of the percussion-sound is never produced by raising the body from the recumbent to the erect posture; the occurrence of the former phenomenon, however, the elevation of pitch in the sitting posture is less conclusive, as it may also be determined by the increased tension of the thoracic parietes (see p. 87).

Gerhardt also believes that the dimensions of pulmonary vomicæ may be definitely ascertained by means of Helmholtz's *resonators*. If

a suitable resonator be held before the patient's mouth, which should be open, the tympanitic cavernous percussion-note is greatly increased in intensity; and as the size of the cavern and that of the resonator which produces this effect stand in direct proportion to each other the diameter of the one may be taken to represent that of the other. The researches of Eichhorst and H. Jacobson do not confirm these statements; it was found on post-mortem examination that the actual size of the cavities differed very considerably from the estimate formed by means of the resonators, being sometimes three, five, or more times larger or smaller than had been expected. It was further shown that the same resonators which, when held before the open mouth, intensified the tympanitic cavernous sound, rendered more clear also the percussion-sound on the healthy side of the chest. This method of examination, therefore, cannot be depended on to give trustworthy results.

2. The Tympanitic Percussion-sound in Pneumothorax.

In pneumothorax the air with which the pleural cavity is filled is caused to vibrate by the percussion-stroke, while the waves of sound are regularly reflected by the chest-walls; the same conditions are thus provided for the production of the tympanitic sound as in percussing the larynx or the glass used in the experiment formerly described, (p. 91). The area rendered tympanitic varies in extent, being large or small according to the greater or less amount of compression of the lung which has taken place. Opening or shutting the mouth has no effect on the pitch of the sound, the cavity occupied by the air being a closed one; enlargement or diminution of the vibrating column of air therefore, in the sense in which these changes occur in pulmonary cavities which are in free communication with bronchi, is out of the question. It is only in very rare cases, in which the fistula through which the air has entered the pleural sac continues patent and is of sufficient size, that it is possible to drive a certain quantity of air from the cavity of the pleura with each percussion-stroke: in these cases the pitch of the sound may be varied by opening or closing the mouth.

Tympanicity in pneumothorax persists only so long as the tension of the imprisoned air continues moderate in degree. If the bronchial fistula or the rupture in the wall of the pulmonary cavern (the latter being the most common cause of pneumothorax) be not immediately closed by the products of adhesive inflammation, air rushes into the pleura at each inspiration, till the

lung is reduced to a state of complete collapse *; the tension of the air in the affected side of the chest thus becomes so great that the tympanitic quality is lost from the percussion-sound and is replaced by the metallic or amphoric sound to be subsequently discussed.

The irritation consequent on the admission of air into the pleura usually provokes an attack of inflammation in that structure, followed by more or less copious effusion; the fluid, as in most cases, may not rise above the lower and posterior part of the cavity, or it may encroach on it to a still greater extent, constituting the condition known as pyo-pneumothorax; it may even completely fill one side of the chest (pyothorax) and in that way bring about the cure of the pneumothorax. In the latter case the percussion-sound on the affected side is absolutely dull, in the former cases it continues tympanitic above the level of the exudation. In pyo-pneumothorax also *change in posture developes a change in the character of the sound*, as in each position in which the body may be placed the fluid invariably seeks the lower level, the air the higher. Thus the dull sound of the anterior and lower part of the chest in the standing or sitting position becomes at once tympanitic as the patient assumes the recumbent posture, that of the one side of the chest being similarly modified when decubitus is on the opposite side, that of the lower and posterior parts of the thorax when the patient lies prone on the abdomen. Should the pleuræ at any point have formed adhesions before the occurrence of the pyo-pneumothorax the air is excluded from certain parts of the cavity, and encysted pyo-pneumothorax is the result; in such cases change of attitude is attended by no modification of the physical signs.

3. Tympanitic Percussion-sound due to Diminished Tension of the Lung Substance.

Those conditions which favour the *retraction* of a greater or less portion of lung, (that is, its return to its dimensions in the relaxed state in which it is found when respiration has ceased, the pulmonary tissue being always more or less on the stretch during life), give rise very frequently to a tympanitic percussion-

* The air forced into the pleural sac during inspiration does not, or does to but a very slight amount, escape during expiration, as the pulmonary fistula is closed valve-fashion by the increasing pressure of the air in the cavity.

sound,—just as it occurs in the lung when removed from the thorax and so allowed to resume its *natural* volume.

Amongst these conditions are: *a*. Pleurisy, *b*. Pneumonia, *c*. Œdema of the lungs, *d*. Caseous pneumonic degeneration in the upper lobes.

a. In *exudative pleurisy* the lung shrinks to a degree proportionate to the amount of the exudation, and it consequently loses to the same extent in tension; when this retraction reaches a certain point, which is not the same in every case, the percussion-sound takes on the tympanitic quality. Even at the beginning of the exudative process, when the layer of effusion is not yet of sufficient thickness to give rise to percussion-dulness, the sound at the posterior and lower part of the thorax is often found to be of a dull tympanitic character; this speedily disappears with the augmentation of the exudation, and the parts become completely non-resonant.

In pleurisy with moderate effusion, the tympanitic sound is observed *above* the level of the fluid, in the anterior and lateral parts of the thorax. The tympanitic quality is more or less distinctly appreciable according to the degree to which the free portions of the lungs are reduced in volume; it is lost as the exudation increases, and reappears at the beginning of the stage of absorption when the lungs commence to expand again.

But not in every case of pleuritic effusion is the sound tympanitic above the region occupied by fluid; it is often merely *deepened in pitch*, and sometimes even shows no departure from the normal standard (see p. 89 *et seq.*). The causes of these differences in apparently identical physical conditions, so far as the exudation alone is concerned, should probably be sought in the unequal tension of the lung-tissue in different individuals. A greater degree of tension is necessary for the development of a tympanitic sound than for the production of one which is abnormally low in pitch but non-tympanitic. In some cases, in which the percussion-note above the effusion undergoes no change, a decrease in the elasticity of the lungs may be shown to exist, rendering any great degree of retraction impossible,—in chronic bronchial catarrh, for instance, especially when associated with vesicular emphysema; at other times there are other causes, such as a more rigid condition of the thoracic parietes, to account for this phenomenon.

It was Skoda who first drew particular attention to the occurrence of tympanicity in cases of pleuritic exudation, and satisfactorily made out the nature of the physical conditions on which it depends, though these seem to have been not quite unknown even to Auenbrugger. This sound is sometimes named the "bruit scodique" by French physicians.

b. A *tympanitic percussion-sound* is sometimes also heard in *pneumonia*, especially in the first stage and in that of resolution, though it is not unusual to find that in the stage of hepatization the permeable parts of the lung in the immediate neighbourhood of those which are completely consolidated give a sound of this character; it is further more common in the upper than in the lower lobes. Its cause may be of a twofold nature. Thus, when the *superior* lobe is hepatized a tone of tympanitic quality, arising from the vibration of the column of air contained within the principal bronchus of that lobe, may be elicited by forcible percussion; in these circumstances also the sound, like that of pulmonary cavern and of the larynx, is observed to vary in pitch on opening and closing the mouth. In hepatization of the *lower* lobes, on the other hand, where there are no large bronchi, the cause of the tympanicity is evidently loss of tension in the lung substance; the lung shrinks somewhat in the vicinity of hepatized parts, these latter being rendered abnormally large by the infiltration of the alveoli. In the first and third stages of pneumonia the relaxation of the pulmonary tissue is due to infiltration of the air-cells, caused by engorgement of the capillaries (first stage) or by the presence of fluid and air in their interior (third stage). The tympanicity of the first stage merges gradually or rapidly into absolute dulness as the process of hepatization begins; in the third stage it slowly passes off, giving place to the normal sound when the exudation has been removed from the alveoli by absorption.

c. The occurrence of the *tympanitic percussion-sound in œdema of the lungs*, in which the pulmonary vesicles are filled with transuded fluid and air, may be explained in the same way: the lung-substance loses in tension, the quantity of air contained in the alveoli being smaller.

This variety of tympanicity may be reproduced after death by forcing fluid through the trachea into the vesicles and at the same time *inflating* the lungs; (inflation is an absolutely

necessary part of the proceeding, as the non-distended lung gives *naturally* a tympanitic sound).

d. The percussion-sound is frequently observed to be *tympanitic* in the supra- and infra-clavicular regions when the summits of the lungs become the seat of *caseous pneumonic infiltration;* in such cases it is always somewhat muffled and does not change its pitch when the mouth is opened or shut,—features by which it may be distinguished from the tympanitic sound of pulmonary *cavity* in the apices. It is produced only when the infiltrated tissue has not yet been completely deprived of air, or when small scattered patches of permeable tissue are still found between the portions which have become consolidated. Here also the tympanicity depends on the relaxation of the lung-substance and diminution of its air-contents. Infiltration of the apices specially favours the development of the tympanitic tone, as the chest-wall over these parts is thin and becomes still thinner as emaciation goes on.

There is a special form of tympanicity which is observed in certain cases of condensation of the lung, most markedly in the first and second intercostal spaces and usually on the *left* side; this is

The Tracheal Resonance of Williams.

In percussing the trachea a tympanitic sound is obtained, which, like that given by pulmonary cavities, rises in pitch on opening the mouth and falls on shutting it, and which becomes still lower when the nostrils also are closed. This sound is lost at a point on the surface corresponding to the bifurcation of the trachea, being overpowered by that from the tissue which covers the principal bronchus. When, however, the upper lobe is completely consolidated this predominance of the ordinary pulmonary percussion-sound ceases, and the tympanitic sound from the column of air in the bronchus is appreciable on striking the front of the chest somewhat forcibly. The tone, like that furnished by excavations in direct communication with the trachea, becomes higher in pitch and louder on opening the mouth, and considerably deeper on closing it.

This tracheal resonance, therefore, is most usually observed when the upper lobe of the left lung is completely solidified by pneumonic *infiltration,* and occasionally also when this takes place from other causes,—when, for example, the lung remains in a state of collapse after the absorption of pleuritic exudation, and in those rare instances of *encysted* pleuritic exudation situated at the upper and anterior part of the left side of the chest; it is met with also in some cases of pleurisy in which the effusion is not confined by adhesions, when the quantity of fluid is not so great as to separate the lung too much from the front of the chest. The ribs, being somewhat flexible toward their sternal ends, yield to the force of the percussion-stroke, and in that way favour the production of the sound, whilst at the corresponding part of the posterior surface of the thorax this sign may be entirely wanting, owing to the greater thickness of the layer of muscles and to the rigidity of the chest-wall in that region. That this treacheal resonance is found almost exclusively on the left side is probably due to the greater length of the principal bronchus on that side.

Skoda regards the tracheal resonance of Williams as identical with the tympanitic sound of the retracted lung in pleurisy; this view, however, is opposed by the facts that it is audible in complete hepatization of the upper lobe, where no retraction exists, and that the pitch of the sound is subject to the usual variations on opening and closing the mouth, which is not the case with the true "bruit scodique."

To these three qualities of the percussion-sound Skoda added a fourth, *fulness* and *scantiness* of the sound. These terms are still frequently used by scientific writers and are generally considered as synonymous with loudness and dulness, though Skoda gave to them quite another signification. He intended them to bear reference to the size of the vibrating body, as is indicated by his citing, as an illustration of his meaning, the difference in the sounds given by bells of different sizes: he says, "the faintest sound from a large bell, or the loudest ringing of a small one, conveys to us at once the idea of the size of the bell in vibration,—the former sounds *full*, the latter *scanty*."

This fourth quality, which is still defended by Skoda, is now, on physical grounds, almost universally rejected. The following are the principal objections urged against it by various authors (Mazonn, Schweigger, Wintrich, &c.):—that which in music is designated as *fulness* coincides sometimes with the *intensity*, sometimes with the *pitch*, of a sound; the sound of a large bell is invariably deeper than that of a small one, and is louder also even when both are struck

with equal force. This difference does not depend on the volume of the resonant chamber, but on the material of which its walls are composed; a small violin may yield a fuller sound than a large one. Similarly in the human voice difference in sonorousness does not arise from difference in the size of the vocal cords. Even the examples quoted by Skoda in support of his theory regarding this quality of percussion-sound in the human chest and abdomen show that *fulness* is identical with loudness and depth, *scantiness* with dulness and elevation of pitch. Thus, if an entire lobe of the lung be hepatized, with the exception of a small spot situated near the surface, this isolated and permeable patch of tissue gives, according to Skoda, a sound which is indeed clear, but which is also scanty, inasmuch as only a very small body of air is caused to vibrate, whilst the rest of the pulmonary substance is incapable of entering into vibration; in the classification we adopt the percussion-sound in such a case is regarded as neither so loud nor so deep as that of the healthy lung, but as somewhat duller and higher in pitch. On the other hand, when the air has free access to all parts of the lung with the exception of a small superficial patch, the sound obtained over this hepatized spot is, according to Skoda, somewhat duller but still moderately full, as only a very small portion of lung is rendered unsusceptible of vibration; in our terminology, however, such a sound is described as less intense (muffled) but still moderately deep. In the same way the full sound rendered by the stomach is considered loud and deep, and the scantier intestinal sound is spoken of as being higher and less intense. The opposite of the full sound, the typically "scanty" sound, is absolutely indistinguishable from the perfectly dull sound. As the fulness and scantiness of the percussion-sound are traced to the longer or shorter duration of the vibrations of the resonant body, the scanty sound has also been named the *short or shorter sound*, —a term which seems inappropriate, as its opposite, the *longer sound*, has never been admitted into the nomenclature of percussion; *muffled* or *obscured* would be a more fitting term.

Two qualities of sound occasionally met with still demand consideration, the *cracked-pot sound* and the *amphoric* or *metallic resonance*.

The Cracked-pot Sound.*

(Bruit de pot fêlé).

This is a hissing or rattling noise, which may be imitated in two ways: by percussing with the hammer and pleximeter, applying the latter somewhat loosely to the chest-wall, so that beneath it is left an interspace containing air, though in this case the sound produced is wanting in the tympanitic or metallic quality;

* Lænnec was the first who employed this expression. Baas has more recently described it as the *percuto-auscultatory blowing-sound*.

and by laying the palms of the hands on each other crosswise, in such a way as to form a hollow chamber, and then striking the back of one of them against the knee. In the latter case the concussion produces a noise which is exactly like the chinking of money, a sound which well-marked bruit de pot félé simulates exceedingly closely. In both of the experiments above described the sound is caused by the *sudden escape* or discharge of *air subjected to pressure*. In health the cracked-pot sound may be elicited by percussing forcibly the chest of children when screaming, or that of adults when singing a long-sustained note, the air being thus suddenly compressed by the force of the percussion-stroke and made to rush out with a hissing sound.

When the chest is plentifully covered by hair this sound is not unfrequently heard, especially over the sternum; here it is caused by the presence of a small quantity of air which lodges in the meshes of the crisp wiry hair which grows in this region, and by its sudden escape when the percussion-stroke is delivered. It disappears on moistening the parts, the hair then lying flat and close to the surface of the chest.

The cracked-pot sound occurs in the following pathological conditions:

1. When there are *cavities of moderate size in the lung-substance*, communicating freely with a bronchus of medium calibre, situated superficially and at parts over which the chest-wall is sufficiently yielding and the covering of soft tissues has been rendered thin by emaciation. It is heard almost exclusively at the upper part of the *anterior* aspect of the thorax, from the first to the fourth rib, more especially in the infraclavicular region, being more distinctly audible when percussion is practised during expiration, and *most clearly when the patient keeps his mouth widely open*. After repeated examination, or accidental closure of the bronchus leading to the cavity, the bruit disappears, to return as soon as the cavity is refilled with air or the superabundant secretion of mucus has been expelled by coughing. To produce this sound a firm blow is necessary, so that it is better to use the hammer than the finger.—When connected with vomicæ in the lungs the percussion-note is further always of tympanitic or metallic quality, which, indeed, is the element from which it derives its "chinking" character; this tympanitic tone becomes inaudible at the instant in which the hissing sound is produced by the rush of air from the relatively wide

cavity into the relatively narrow bronchus, when the regular reflection of the sonorous waves, which is necessary to the formation of a tone, is interrupted. Should the cavern contain much fluid it also is agitated by the shock of percussion, and something resembling a râle is heard mingled with the cracked-pot sound.

2. In some cases of *pleurisy*, and at those parts of the lung, situated above the level of the fluid, to which the air still has access. The condition of the pulmonary vesicles, retracted and approximated to each other on account of the diminution of their air-contents, seems here to favour the escape of the air on percussion.—The bruit de pot fêlé sometimes observed in the vicinity of *pericardial exudation* (Leichtenstern) originates also in the retraction of the pulmonary substance compressed by the effusion.

3. Occasionally in cases of *pneumonia*, over those permeable and relaxed parts of the lung immediately adjoining those which are hepatized. The cause of the phenomenon is here the same as in pleurisy. Sometimes, however, it is heard also over the condensed portion; this, as in the case of a cavity containing air, can arise only from the sudden expulsion of air from one of the larger bronchi leading to the affected part.—At other times both causes, relaxation of the lung-tissue and concussion of the air in the bronchi, are in operation in pneumonia (Löb).—In pleurisy and pneumonia the cracked-pot sound does not become louder on opening the mouth.

4. In cases of *thoracic fistula*, such as those which sometimes occur after paracentesis thoracis. The air in the pleural sac escapes through the fistulous opening with a *hissing* noise on percussing in the immediate neighbourhood of the orifice; when the latter is closed the cracked-pot sound is not developed.—The same explanation is applicable in some instances of *pneumothorax* from stabbing or gunshot wounds.—In certain rare cases of pneumothorax from internal causes, in which the pleural cavity is in direct communication with a large bronchial fistula (Oppolzer, Rollet), the bruit de pot fêlé may be heard.

The cracked-pot sound is, as the foregoing facts indicate, always dependent on the same causes, though the particular conditions in which it is found may be very different anatomically; it is most frequently due to the presence of vomicæ in the upper lobes of the lungs, the cases of pleurisy, pneumonia, and pneumothorax in which it is observed constituting a very small

fraction of the total number met with. The occurrence of the sound, therefore, in the course of a pulmonary affection known to be phthisical, may be taken as absolute proof of the formation of *cavity*.

Amphoric Resonance.

(Metallic percussion-sound, metallic echo.)

This sound is identical with that obtained on striking on the side of an empty cask, a pitcher, or large india-rubber ball, &c.

On the whole, it most closely approaches in quality the tympanitic note, differing from it in being somewhat metallic in timbre, by being higher in pitch (its fundamental tone, which is variable, being also accompanied by overtones, or segmental tones), and by being of longer duration. The ordinary tympanitic sound ceases at once after the percussion-stroke; this amphoric resonance (the metallic "klang"), however, lasts some time longer, as the higher overtones die away much more slowly. This modification of the tympanitic sound by the addition of a metallic echo may easily be studied in one's own person: the cheeks, when relaxed, the mouth being closed, give a sound which is simply tympanitic, when powerfully distended a sound of amphoric character.

The examples cited above show that amphoric resonance is produced in *large air-filled caverns, surrounded by smooth walls* which regularly and uniformly reflect the waves of sound, completely enclosed on all sides or communicating with the external air by means of a narrow opening. Apart from the force of the percussion-stroke, the intensity of the sound depends chiefly on the size of the cavity; an audibly metallic note is obtainable only from a chamber whose transverse diameter is at least 3—4 cmtr., as has been proved by Merbach and Leichtenstern in a series of experiments with cylindrical vessels having tense elastic walls. The pitch of the metallic tone in vomicæ which are not spherical in shape varies with the length of the longest diameter; percussion in the direction of the shorter diameter gives a higher note, in the direction of the long diameter a lower note.

In the thorax amphoric resonance is heard over *large pulmonary cavities*, and in cases of *accumulation of gas in the pleural sac*.

Excavations in the lungs must have a length of at least 6 cmtr.