

the physical condition of the pulmonary substance in pleurisy with exudation, is the same as that of bronchophony, of which, indeed, it is simply a modification. It is not unusual to find ægophony and ordinary bronchophony in the same patient, and at points not far distant from each other.

According to Skoda ægophony occurs not only in cases in which there is fluid in the pleura, but also in the absence of such fluid, in some cases of pneumonia, in caseous pneumonic infiltration of the lung substance, with or without excavation, and sometimes even between the shoulder-blades of children in perfect health; no satisfactory explanation has yet been offered of its causation in such circumstances.

EXAMINATION OF THE SPUTA.

ALMOST all diseases of the organs of respiration are accompanied by more or less considerable catarrh of the bronchial mucous membrane, the secretions resulting from which are expelled by *coughing*. This coughing is characteristic of the expectoration of fluids secreted by the lining membrane of the respiratory apparatus proper, those from the pharynx or nares being got rid of by a quick, hawking expiration. Expectoration may also be entirely wanting at various stages, or during the whole course, of the pulmonary affection; its absence therefore does not *exclude*, nor does its presence *prove*, the existence of disease of the respiratory organs. Still another source of error has to be guarded against: the secretions may pass downwards from the fauces or nose into the larynx, and are then naturally discharged by coughing.

The sputum in the different diseases of the lungs consists of very diverse morphological and amorphous elements, by which its appearance and general characters are so modified that a rough estimate of its composition may usually be made even on examination with the naked eye, though its exact constitution can be determined only by means of the microscope.

MORPHOLOGICAL ELEMENTS OF THE SPUTA.

1. *Epithelium*. The expectoration usually contains pavement epithelium, more seldom columnar epithelium, most rarely of all ciliated epithelium.

The *pavement epithelium* may be derived from the upper portion of the air-passages; it usually comes from the buccal mucous membrane, however, and is mechanically mixed with the sputum in the passage of the latter through the mouth.

It is easily recognised by the polygonal outline of the individual cells, by their size, and their large nucleus.

Epithelium of this kind is most abundant in the sputa of those suffering from catarrh of the pharynx and mouth. The epithelial cells of the deeper layers of the buccal mucous membrane are more

flattened, have a very indistinct nucleus or none at all, resemble more the cells of the epidermis, and are in no way distinguishable from the pavement epithelium of the upper part of the air-passages.

Columnar epithelium is somewhat rare as a constituent of the sputum, though the air-passages are lined with it from the larynx down to the finest bronchioles. Its attachment to the mucous surface is of the most intimate nature, severe catarrhal swelling of the membrane, or even destructive morbid processes, being insufficient to separate it in any quantity. The *epithelium of the pulmonary alveoli* occasionally, though rarely, appears in the sputum.

Ciliated columnar epithelium is very seldom present in the expectoration in diseases of the air-passages; it is found oftener in catarrhal secretions coming from the mucous membrane of the nose and the sinuses connected with it.

2. *Pus corpuscles* (colourless blood-corpuscles).—These are simply the white blood-corpuscles, which pass through the walls of the capillaries in inflammation (Cohnheim); they occur in variable proportion, according to the intensity of the catarrh or inflammatory process, and are sometimes so abundant as to form the sole representatives of the morphological element in the expectorated matters. The sputum acquires certain macroscopic characters, which vary with the amount of pus present; it is thus rendered more or less opaque, and yellow or yellowish-green in colour.

Besides pus corpuscles there may usually be recognised in the sputa *mucus* corpuscles, shrunken or fatty cells, cell-nuclei, and granular masses.

3. *Red blood-corpuscles*.—Blood is expectorated sometimes merely in traces, at other times in more perceptible quantity, and occasionally so abundantly that it seems free of any intermixture with other matters, and itself to constitute the whole of the sputum. The presence of even the smallest trace of blood is generally indicated by its colour; but if the tinge be so slight as to leave any doubt, the question may be easily settled by microscopic examination.

Blood-corpuscles in the sputum exhibit their normal histological form and colour, as they are placed in precisely similar con-

ditions as while still in circulation, that is, they are in a fluid of alkaline reaction and containing alkaline salts. No distension or discoloration of the corpuscles takes place, therefore, from absorption of water; it is only when the quantity of blood present is very small, and the proportion of water consequently large, that the phenomena of diffusion are observed.

4. *Débris of lung-tissue*.—*Elastic fibres*. These are met with in the sputum only in those diseases which involve destruction of the tissue of the lungs and bronchi,—caseous pneumonia, bronchiectasis with ulceration of the bronchi, and pulmonary abscess. The portions of sputum in which they are suspended may often be distinguished, by their dull grey opaque colour, from the clearer mass of the expectoration. On being allowed to stand for a short time in a vessel they sink to the bottom with the heavier constituents, which are generally free of air-bubbles. The elastic fibres appear either as isolated, detached filaments, or collected into bundles, and these may be either straight or coiled and twisted; occasionally, also, they are interlaced after the fashion of trellis-work, or are so perfectly meshed as to closely resemble a net, and in the latter case present exactly the appearance of the fibrous framework of the alveoli. They are brought markedly into prominence by their dark colour when under a powerful light, particularly on the addition of acetic acid, which renders the rest of the tissues more transparent but has no effect on the elastic fibres.

The presence of elastic fibres may generally be regarded as diagnostic of phthisical disorganisation of the lungs, phthisis being the most common of the pulmonary diseases leading to destruction of tissue. Lung-tissue, however, occurs also in the sputum in cases of pulmonary abscess, of ulceration of the bronchi, and of bronchiectasis, but *not*, or only for a short time and in small quantity, in cases of gangrene of the lungs. In the last-named affection the elastic fibres are destroyed by the action of some imperfectly known substance, which is apparently of the nature of a ferment (see p. 203).

The discovery of these fibres in the expectorated matters in phthisis gives no indication as to the exact seat of the morbid process; they may come either from the walls of the alveoli or from those of the finer bronchi. The distinction which was formerly made, according to which the long, straight or slightly coiled fibres were supposed to

belong to the bronchi, and the reticulated fibres to the alveoli, is now generally admitted to be erroneous.

Schröder van der Kolk and Remak, who seem to have studied and written upon this subject simultaneously, were the first to direct attention to the presence of elastic fibres in the sputa.

Large fragments of lung-tissue are very rarely found in the phthisical sputum, and then only when the cavities formed are of very considerable dimensions. Smaller pieces, usually laden with a most offensive odour, are very frequently seen; being heavy they sink to the bottom of the receiving-glass on standing for a short time. They contain amorphous, diphtheritic detritus, derived from the walls of the excavations.

Unstripped muscular fibre, fragments of cartilage (from the bronchi, in cases of bronchial ulceration), and connective tissue, are also occasionally observed in the sputum. The last-mentioned constituent appears as small particles or membranous shreds, opaque, and dark grey in colour, easily separated from the rest of the sputum by diluting with water; microscopically, on the addition of acetic acid, these shreds have the appearance of an amorphous tissue, thickly beset with black pigmentary granules.

5. *Fibrinous coagula*.—These are firm coagula of somewhat variable size, enveloped in the mucus of the sputum, of a whitish yellow colour modified with a slight tinge of red, and generally recognised by their property of adhering to the sides of the expectoration-glass when it is tilted over or turned round; they are often observable only after washing with water, which unrolls them and causes them to assume a nearly pure white colour.

They consist of masses of coagulated fibrin, dichotomously branched, forming almost perfect casts of the finer bronchi. Rarely they exhibit ramifications of some considerable extent; more often they are broken short off, and are composed of rudimentary and exceedingly delicate filaments, the finest of which are visible only through a magnifying glass. In certain very rare instances these coagula occupy all the bronchi of one of the lobes of a lung, reaching as far upwards as the principal bronchus; this has been noticed by Lebert in a series of cases of epidemic influenza (*Grippe*). They are always the result of a fibrinous bronchitis, and occur very frequently in the croupous pneumonia of adults, which is generally accompanied by a fibrinous inflammation of the finest air-tubes. They appear in the sputum from the beginning to the acme of the stage of hepatization, that is, usually from the third to about the seventh day of the disease,

but are absent in the first stage, as exudation has not yet taken place, and in the third stage, the plastic exudation having then become fluid and in great part absorbed. In these later days of the affection, however, small fragments of fibrin may still be seen in the exudation discharged by expectoration, but they consist merely of minute flakes, showing no trace of dichotomous subdivision. Not uncommonly, (in about 10—20 per cent. of the cases), fibrinous coagula are entirely wanting in pneumonia, when the sputum is scanty and the patient weak and exhausted and unable to cough with any degree of force; in such cases, also, much less fibrinous matter is exuded than in more robust persons.—In the catarrhal pneumonia of children and the aged, and in chronic interstitial pneumonia, the bronchi are free of fibrinous exudation; in these conditions, therefore, fibrinous masses are never met with in the sputa.

Fibrinous casts of the bronchi are most numerous and most perfectly formed in cases of croupous bronchitis, acute as well as chronic.

The characters of the casts vary with the intensity of the morbid process and the calibre of the passages attacked by the croupous affection; in well-marked cases they are of considerable size, the primary stem being thick and rough, the dichotomous system of subdivision being followed out even to its smallest branches, till the ultimate twigs become of capillary fineness and display a beautiful whitish coloration. They are usually rounded, though some are also slightly compressed or ribbon-shaped, and are either solid, or contain, especially in the larger trunks, a small central canal. Occasionally they attain a length of 5—8 cmtr.; the thicker branches are also firm in consistence, the finer twigs softer. Such coagula may continue to be expectorated for weeks, months, or even years, though variable intervals occur in which simply catarrhal, not fibrinous, sputa are discharged, or in which the patient may even enjoy perfect health. Relapses are frequent; in two out of three cases which came under my own notice the fibrinous bronchitis recurred after intervals of some years' duration.—The objective symptoms of croupous bronchitis are simply those of dry catarrh; it is therefore not usually regarded as a serious disease. In some cases, nevertheless, the size of the casts, and their distribution over a wide area, have led to death by asphyxia.

These fibrinous coagula were not unknown to the physicians of the seventeenth century, who wrote of them as *Polypi*. In 1845 Remak rediscovered them in the expectoration of pneumonic patients, and first made out their true nature.

6. *Crystals*.—Those which occur most frequently in the sputum are the *crystals of the fatty acids*, which, though formerly thought to be simply margaric acid, are now known to consist of a combination of palmitic and stearic acids. Under the microscope, with a magnifying power of 300 diameters, they have the appearance of long, slender, colourless needles, lanceolate in shape, usually straight, sometimes curved, and occasionally also somewhat varicose. They are sometimes observed singly, detached from each other, at other times grouped in tufts or sheaves. In the sputum they are always found adhering to shreds or masses of matter of a dull greyish colour, and of exceedingly offensive odour. These shreds are met with in the expectoration which comes from gangrenous or bronchiectatic cavities, and in that of putrid bronchitis. The presence of crystals in the sputum is thus indicative of some morbid process involving destruction of tissue; they are observed, similarly, in gangrenous discharges from other parts of the body. They were first demonstrated by Virchow.—Their microscopic appearance is so characteristic that they can scarcely be mistaken for anything else; when the needles happen to be curved, however, they resemble somewhat closely the elastic fibres formerly referred to. In the latter case their chemical reaction serves to distinguish them at once; on the addition of chloroform or ether, the needles are quickly and completely dissolved, while the elastic fibres undergo no alteration.

Another kind of microscopic *crystals*, having the form of elongated, very pointed octohedra, of rhombic plates, or of fine, sharp, spindle-shaped bodies, has been found in the sputum in various diseases. They are colourless, the largest 0·01—0·02 mm. long, the smallest visible only under a magnifying power of 500 diameters. Their chemical nature is still obscure, though they are supposed to be of organic origin. They are insoluble in alcohol, and may therefore be preserved in spirit; but concentrated acids and alkalies dissolve them rapidly. They resist also for a long period the disintegrating action of putrefaction. These crystals, which were first noticed by Charcot, and with which his name is now usually associated, occur very frequently in leukæmia,—in the spleen, the blood, and the marrow of the bones. They may also be seen, and apparently not unfrequently, in the sputum in various affections of the bronchi, in chronic

bronchial catarrh, in pulmonary emphysema, in the expectorated casts in bronchial croup, but relatively most often in bronchial asthma, (as in six out of seven cases investigated by Leyden) particularly during, and immediately after the attacks, not usually in the free intervals.

Leyden thinks it not improbable that these crystals are the direct causes of the dyspnoæal seizure in bronchial asthma, his hypothesis being that they irritate the terminations of the vagus in the mucous membrane of the air-passages, and in that way, by reflex action, give rise to spasm of the finer bronchi; the remissions would thus follow the expectoration of the crystals, and the patient would have ease till the renewed formation of crystals produced another attack. But in a great many cases, in which there is no preceding dyspnoæal seizure, such crystals are found in the sputum, as Zenker observed in his own case, and in two instances of bronchial croup, in which the crystalline masses were incorporated in the fibrinous casts, embedded chiefly in their periphery.

Other crystalline formations also are occasionally seen in the sputum: *hamatoidin*, for instance, occurring as rhombic rods or as slender needles arranged in tufts, in cases of bronchiectasis, of empyema and peritoneal or hepatic abscesses which have opened into the bronchi; crystals of *cholesterin*, in cases of pulmonary abscess or empyema penetrating the lung, and sometimes in the phthisical sputum; *tyrosin*, also, is met with in the expectoration in putrid bronchitis.

7. *Fungous growths*.—The parasitic fungi which occur in the sputum are the thalli and spores of the *Leptothrix buccalis* and the thrush-parasite (*Oidium albicans*), and in rare cases *Sarcinæ*.

When the buccal cavity is lined with fungous growths, such as the more common and widely-distributed *oidium albicans* or the *leptothrix buccalis*, these parasitic vegetations frequently appear in the sputum, being detached from the mucous membrane and mixed with the expectoration in its passage through the mouth; in these cases their quantity is not great.—But such minute vegetations, found in the sputum, may come also from the lungs: they are sometimes transplanted from the mouth to the lungs, being carried downwards by the inspiratory current of air; there they grow rapidly, finding in the stagnant secretions of dilated bronchi and pulmonary cavities a soil which favours their development.—*Leptothrix* and *oidium albicans* are observed in the sputum in putrid bronchitis and gangrene of the lungs. It is not improbable that the offensive decomposition of the

bronchial and cavernous secretions which is so characteristic of these affections is due to the presence of fungi or of the bacteria which gain entrance with them. It appears also that even in healthy respiratory organs, under certain conditions, the introduction of microscopic fungi is sufficient to excite a kind of putrefactive action leading to putrid bronchitis (Rosenstein).

Large numbers of fungous growths, both thalli and spores, have been detected in the sputum in whooping-cough (Letzerich).

On treating such a sputum with iodine and concentrated sulphuric acid the filaments assume a beautiful blue colour, while the spores become brown.

Letzerich regards these bodies as the cause of whooping-cough (?); the frequency of the spasmodic seizures, according to him, depends on the greater or less rapidity of the development of the vegetations and on the irritability of the affected part of the mucous membrane, while the disease becomes less severe as soon as an abundant secretion of mucus takes place, along with which the parasites are expectorated. These fungi, taken from the sputum of a patient suffering from whooping-cough and introduced (through a fistula) into the trachea of a rabbit, produced in the latter catarrhal symptoms and a paroxysmal cough, and the sputum discharged contained growths exactly similar to those found in the original disease in the human subject.

Multitudes of *vibriones* are also frequently observed in the secretion of bronchiectatic and gangrenous cavities, and in that associated with various other disorders. When discovered in large quantity in sputum recently coughed up they probably come from the respiratory passages; they are found, however, in every sputum which has been exposed some time to the air. Occasionally, also, they are mechanically mixed with the expectoration in the mouth, being abundantly developed in the tartar which loads the teeth of those who do not regularly cleanse the mouth.

In a few cases of phthisis (recorded by Virchow, Cohnheim, and Heimer in Ziemssen's clinic) *Sarcina* have been seen in the sputum and in the lungs in considerable numbers, while at the same time no trace of their presence in the stomach was discernible; they were found in none of the other organs and were of very small size.

Echinococcus-vesicles, whole or in fragments, occur equally rarely in the sputum. When present they may proceed either from the liver, when a hepatic hydatid cyst, making its way through the diaphragm into the lung, perforates a bronchus, or from the lung itself, when the parasite is primarily developed in that organ.—There are more than 40 well-authenticated cases in which hydatid vesicles were expecto-

rated; in only one out of fourteen cases of hydatids that have come under my own observation was this symptom present.

Particles of food, muscular fibres, grains of starch, vegetable fibres, &c., which may all be *accidentally* mixed with the constituents of the sputum, are so readily distinguished by microscopic examination that a particular description of them is unnecessary.

AMORPHOUS ELEMENTS OF THE SPUTUM.

These constitute the basis of the sputum, and consist chiefly of mucus, albumen, and the watery fluids by which the mouth is kept moist.

Mucus (Mucin) is the proper secretion of the bronchial mucous membrane, and is present in every sputum. It is of varying consistence, being sometimes fluid, and at other times more viscous and capable of being drawn into threads; to the naked eye it is transparent. The chemical test by which it is most commonly distinguished is the formation of a cloud or precipitate on the addition of acetic acid.—The presence of mucus in the sputum has absolutely no diagnostic significance; persons in perfect health expectorate more or less of it every day, and in all forms of lung disease, from the mildest catarrh to the most severe affections, it is a constant constituent of the secretion.

Water, also, forms a considerable part of all sputa. The more abundant it is the more fluid is the expectoration. The water is commonly supplied by the mucous lining of the mouth, and in that case contains also some pavement epithelium; in certain other cases it comes from the air-passages, (when the bronchi are flooded with a profuse secretion of serous fluid), or from the pulmonary aveoli, (as in oedema of the lungs). The sputum in bronchial catarrh is at first thin and aqueous, but subsequently becomes more tenacious and deficient in water.

Albumen occasionally enters into the composition of the sputum, and it is always more abundant the severer the inflammation of the air-passages or pulmonary substance. It is present in greatest quantity in cases in which there is plastic exudation into the parenchyma of the lung and into the finer bronchi,—that is, in pneumonia.—Albumen is detected by acidulating the alkaline sputum with acetic acid, filtering, and boiling, or by adding nitric acid: in both cases the albumen is coagulated.

GENERAL CLASSIFICATION OF SPUTA.

Biermer arranges the sputa into the following groups, according to the nature of their principal constituent and the predominance of one or other microscopic element, conditions which are usually more or less easily distinguished even with the naked eye.

1. *The mucous sputum.* This consists almost exclusively of mucus, and is frequently brought up by perfectly healthy individuals, and in the earlier stages of bronchial catarrh.

2. *The muco-purulent sputum,* containing mucus and pus-cells. The latter constitute the sediment which falls to the bottom of the crachoir when the sputum is allowed to stand a short time, whilst the mucus and the air-bubbles usually scattered through it occupy the upper part of the vessel, floating on the top of the water. The miscibility of these sputa with each other depends on their consistence; they either run together, forming a thin, uniform fluid, or fail to coalesce, being divided into numerous viscid, globular masses. They occur both in simple bronchial catarrh and in every other affection of the bronchi and of the substance of the lungs, and are consequently the most common variety of sputum.

3. *The purulent sputum* is homogeneous in character, has exactly the colour of pus obtained from an abscess, is thick, though not capable of being drawn into threads, and sinks to the bottom of the expectoration-glass. Microscopically it is seen to consist almost entirely of pus-cells.—It is derived from suppurating pulmonary vomicae, or from a pleural cavity filled with pus, which perforates and discharges through a bronchus (empyema).—A purely purulent sputum is somewhat rare.

All sputa, may, with more or less justice, be included in these three groups, as all contain mucus or pus. But when, in certain circumstances, other constituents come into decidedly greater prominence, in respect either of their quantity or their morbid significance, the term by which the sputum is designated is determined by these; a good example of this is found in the *sanguineous sputum.*

This classification of the sputa into mucous, muco-purulent, purulent, and sanguineous, has this practical advantage, that the element most characteristic of the secretion in the individual case is at once

and plainly expressed. It is obvious, however, that it is only approximately, and in a small proportion of the cases, that the origin of the particular sputum and the nature of the disease which gives rise to it are indicated by these terms. A strictly accurate estimate of the nature and diagnostic importance of the sputa is possible only on taking into consideration a number of other signs, which are now about to be discussed: these are the form, consistence, weight, colour, odour of the sputum, and very specially the presence of the formerly-mentioned histological elements (fragments of lung-tissue and pathological products).

PHYSICAL CHARACTERS OF THE SPUTA.

Consistence of the sputum. This varies within very wide limits, all intermediate conditions being met with, from a consistence almost watery to that presenting the utmost degree of viscosity. The tougher the sputum the firmer is its consistence; the mucous and muco-purulent secretions, therefore, attendant on acute bronchial catarrh and the parenchymatous diseases of the lungs, (the cavernous sputa, for example), possess this character in a high degree.—If the sputum be deficient in mucus, the substance which binds together the various histological elements, it becomes less coherent; the simply purulent sputum is thus much less tenacious than the muco-purulent form.—Persistent expectoration of very viscid sputum points to a state of intense irritation of the bronchial mucous membrane.

The form of the sputum depends on its consistence. Very fluid sputa, such as the serous expectoration of pulmonary oedema or the purulent discharge from a pulmonary abscess or an empyema which has perforated one of the larger bronchi, do not remain separate but become intimately blended with each other in the crachoir, forming a homogeneous mass; very tough sputa, on the other hand, are irregularly globular in form, while less tenacious secretions become somewhat flattened or nummular. Mucous and muco-purulent sputa sometimes coalesce, and at other times assume various shapes determined by the greater or less consistence of the mucus. The spherical or nummular form prevails in the muco-purulent sputa proceeding from phthisical cavities, the configuration of each sputum being the more distinctly preserved the less the quantity of fluid bronchial secretion subsequently mixed with it. If the latter be very abundant, the circular, coin-shaped sputa, at first quite distinct