

from the catarrhal secretion, unite with and are ultimately uniformly diffused through the homogeneous layer of mucus after standing some time in the vessel.

Weight of the sputa. The denser the sputum, and the fewer the air-bubbles it contains, the greater its weight. Sputa, therefore, of firm consistence and free of air sink to the bottom of the glass, while those of more fluid consistence and full of air-bubbles float about at the top. Sputa which sink in water preserve their form (cavernous sputa); the other less dense varieties soon break up into several layers, the lighter elements, air and mucus, swimming on the surface of the water, the heavier constituents, such as pus-cells, subsiding and forming a sediment at the bottom. The weight of the sputum thus indicates only its consistence, and usually also the elements which enter into its composition, but gives no clue as to its origin; the expectoration observed in bronchial catarrh in the stage of resolution may be just as heavy as that secreted by a pulmonary cavern.

The *quantity of the sputum* is exceedingly variable, in the acute as well as in the chronic diseases of the respiratory apparatus. Occasionally in the course of acute affections there is absolutely no sputum, and in chronic disorders also it may be wanting for a considerable period. In the severest types of disease the quantity of matter expectorated may be very small, while in much less grave affections it may be extremely great. General rules, therefore, with regard to the prognostic value of increase or decrease in the amount of the sputum in the different diseases of the respiratory organs cannot be laid down. Nevertheless, the following may be accepted as a generalisation, so far as this is possible, of what is known on the subject: in acute bronchitis, hooping-cough, and pneumonia the expectoration becomes more abundant,—and is then often a critical indication of the approaching termination of the disease,—simultaneously with the disappearance of the difficulty with which it is brought up, and when it begins to assume more definite shape and consistence; each exacerbation of the affection, on the other hand, materially diminishes the amount of the previously profuse secretion, while the difficulty and pain of expectoration increase, and the sputum acquires greater density. When, in acute diseases (bronchitis and pneumonia, for instance), the expectoration becomes scantier or fails altogether, while at the same

time the morbid process is obviously extending and increasing in severity, and while auscultation shows that the bronchi are loaded with an accumulation of fluid, we have direct evidence of a lowering of the irritability of the sensory terminations of the vagus in the lungs, or of the profound exhaustion of the patient; this sign is therefore one of grave import. The stertorous respiration of the dying, accompanied by rattling sounds produced in the chest and audible at some distance, furnishes the most familiar example of this condition.

It is in *Bronchiectasis*, of all diseases of the respiratory apparatus, that the largest quantity of expectoration is discharged at one time. This fact, in the absence of such other signs as would establish the diagnosis between this and like conditions, becomes a criterion of the first importance. The expulsion of several tablespoonfuls, and often more, of a muco-purulent, fetid secretion, as the result of one effort of coughing, is far from uncommon in this affection.—In like manner the *bursting of a pulmonary abscess*, or of a purulent *pleural exudation*, into one of the larger bronchi, is marked by the sudden evacuation of a large quantity of purulent, homogeneous sputum.

Odour of the sputum. This is quite wanting in very many cases, or is at most faint and of a somewhat mawkish or mouldy character. The sputa in pulmonary abscess, bronchiectasis, and putrid bronchitis, have a decidedly fetid odour, that of the discharge in gangrene of the lungs being extremely offensive. In the latter case the expired air is already considerably tainted even before any trace of a disagreeable smell is perceptible in the sputa. The fœtor is caused by the gangrenous putrefaction and disorganization of the tissues.

Putrefying fragments of food, such as those which adhere to the teeth, may communicate this offensive odour to the sputum in its passage through the mouth. Caries of the teeth, and especially certain affections of the mouth, are apt to produce the same result; it is from this source that, in the last stages of phthisis, in which various disorders of the cavity of the mouth, associated with the development of fungous growths, are so common, the sputa derive their odour of putrescence. This is lost when the expectoration has stood some time in the vessel.

COLOUR OF THE SPUTA.

A slight coloration, varying from white to yellow or yellowish-green, is given to the sputum by the presence of a large number

of pus-cells. A deeper tint is usually due to the admixture of the colouring-matter of various tissues; these are, enumerated in the order indicated by the frequency of their occurrence, the red colouring-matter of the blood and its different modifications, the biliary colouring-matter, and a black pigment.

RED, SANGUINEOUS SPUTA.

These consist either of blood alone, or of blood and other elements intermixed.

1. A sputum composed *solely* of blood, and expectorated in any considerable quantity, is invariably the result of rupture of some of the vessels of the lungs. The amount of blood thus lost at one time is very variable; it may be only a teaspoonful, or as much as several tablespoonfuls, or even more.

Hæmoptysis frequently occurs at the outset of pulmonary phthisis, at a time when the physical signs of the affection are still undeveloped; or it may take place, either once or repeatedly, in the course of the disease. *Hæmoptysis* may also be caused by affections of the cardiac valves, when these lead to overloading of the pulmonary circulation; an example of this is seen in *hæmorrhagic infarction* of the lungs following lesions of the mitral valve.

Blood effused into the lungs is for the most part *coughed up* immediately after the hæmorrhage.*

This fact affords one of the readiest means of distinguishing pulmonary hæmorrhage from hæmatemesis (in cases of round ulcer of the stomach, carcinoma, &c.), the blood in the latter case being rejected by *vomiting*. The *bright red* colour, the *fluid condition*, and *frothy* appearance of blood proceeding from the lungs, are further points which aid in establishing the diagnosis, blood coming from the stomach being usually dark reddish brown or chocolate-brown in colour, having

* Whether the blood remaining in the alveoli and ultimate bronchi after pulmonary hæmorrhage, when not entirely absorbed, excites inflammation and becomes the starting-point of caseous infiltration (F. Niemeyer), is still a disputed question. It has been clinically proved (Traube) that after the lapse of a certain time no trace of bleeding is discoverable in the lungs. Experiments on animals give different results according as the blood injected penetrates only to the finest bronchi or reaches the alveoli. Should the blood not go beyond the air-tubes its absorption is completed within twelve hours, and no inflammation follows (Perl and Lipmann); if it be forced into the alveoli, however, catarrhal pneumonia is set up, which, in healthy animals, ends in resolution (Sommerbrodt), but in men placed under unfavourable conditions (men of feeble constitution, &c.), results in caseous infiltration and phthisis. That hæmorrhagic infarctions in cases of cardiac disease never give rise to catarrhal pneumonia is probably in some way connected with the immunity from phthisis which the subjects of diseases of the heart seem to enjoy.

a close resemblance to *coffee-grounds*, and sometimes, when it has remained some little time in the stomach, forming clots in which are embedded fragments of food.—The mere external appearance of the blood, however, does not always furnish sufficient data on which to found an opinion regarding its origin. On the one hand, blood poured into the lungs may be retained there for some time, lodging particularly in dilated bronchi or in pulmonary cavities, when it becomes much darker in colour and is slightly coagulated, being thus not unlike that discharged in hæmatemesis; blood effused into the stomach, on the other hand, may be vomited immediately after escaping from the ruptured gastric vessels, when it has no longer the appearance above described, but resembles rather blood coming from the lungs. And finally, blood flowing from the nose, mouth, or pharynx, may, during sleep, pass through the larynx and into the bronchi, when it takes on a brighter red colour and receives a certain admixture of air, and as it is eventually brought up by coughing it may possess all the characters of blood originally extravasated in the lungs. In such cases the source of the hæmorrhage can be determined only on consideration of the patient's previous history and of the results of careful physical examination.

2. Blood may be *mingled* with the sputum in various proportions, intimately, or in streaks, or simply dotted through the mass. In these cases the presence of the blood need not necessarily be assumed to be due to rupture of any of the pulmonary vessels; it may be caused by the passage of red blood-corpuscles through the uninjured walls of the vessels (bleeding *per diapedesin*; Cohnheim).

The depth of the coloration of the sputa is in proportion to the quantity of blood present; whatever be the amount the fundamental colour is always red.

The lighter shades of red are produced by the greater or less predominance of the other constituents of the sputum; they depend also, to a certain extent, on the physical characters of the expectoration, varying according as the latter is of fluid or firm consistency, mucous or purulent, or has become tainted by putrefaction, &c.

The blood is the more *intimately* mingled with the other elements of the secretion the longer it has been in contact with them; the more tenacious the bronchial mucus the longer the time necessary for the effecting of such a thorough blending of blood and sputum as is observed when the expectoration is very thin (serous, for instance). The diffusion of the blood through the sputum is most complete in cases of fibrinous pneumonia. It

is only in very confined spaces, such as are presented by the alveoli and finest air-tubes, that a uniform and intimate mingling of pathological secretions and blood can take place.

Blood disposed in *streaks* through the sputum does not usually proceed from the pulmonary parenchyma but from the upper parts of the air-passages, and gives no indication, therefore, of the nature of the morbid process going on.—*Specks* of blood frequently appear in the sputum, both in the earlier and later stages of caseous pneumonic infiltration.

The expectoration may also show by its red colour that it certainly contains blood, though at the same time no red blood-corpuscles can be detected under the microscope; in such circumstances it is probable that the corpuscles have undergone considerable modification, are possibly shrivelled up, and indistinguishable from the other figurate elements of the sputum, or that their disintegration has been complete and their colouring-matter in that way set free.

METAMORPHOSIS OF THE COLOURING MATTER OF THE SANGUINEOUS SPUTUM.

The longer the sanguinolent sputum is retained in the bronchi the more marked and extensive is the change in colour which it undergoes. It first becomes gradually reddish-brown, then yellowish-red, and finally loses all trace of red coloration; it subsequently takes on a yellowish hue, which deepens into saffron-yellow, yellowish-green, or even grass-green. All these tints are given to it by the *substances which are produced by the higher oxidation of the colouring-matter of the blood* (hæmoglobin); they represent the successive stages of that process,—a metamorphosis which is often observed in parts in which blood has been effused under the skin. Green is the last of the series of colours displayed by the hæmoglobin and its products when exposed to the continued influence of oxygen.—So long as the colouring-matter remains unchanged, and the expectoration continues distinctly and unmistakably red, the blood-corpuscles are easily recognised, as they still possess their normal aspect and outline; but immediately the process of oxidation begins they are more or less altered in appearance, or may even be completely disintegrated, leaving behind them no visible trace of their previous existence in

the sputum.—The first of the above-mentioned shades, reddish-brown or rust-colour, is characteristic of the sputa in the stage of hepatization in pneumonia, while the yellowish-red, or citron-yellow, or saffron-yellow tints mark the stage of resolution.

Greenish, or even *grass-green*, sputa (coloured thus, not by biliary pigment, but by altered hæmoglobin) occur sometimes in croupous pneumonia when it ends gradually (by lysis, not critically) in perfect resolution; in pneumonia also, which is followed by pulmonary abscess, and at the beginning of subacute caseous pneumonia (Traube). In all these affections the secretions are retained some time in the lungs,—usually for a period long enough to permit their colouring-matter to pass through all the grades of oxidation and become distinctly green; but in pneumonia of the ordinary type the sanguinolent sputum is coughed up and expelled before its hæmoglobin is so far changed as to become green, so that it is merely of a yellowish tint.

Microscopic examination of green sputa reveals the presence of yellow pigment, yellow pigmented molecules, and here and there yellow pigmented epithelial scales.

Sometimes in the warm summer months there is observed a peculiar variety of *yellow* sputum, the *egg-yolk* sputum (Traube, Löwer), in which the coloration seems to be due, not to the presence of modified hæmoglobin, but probably to the development of fungous growths. The first trace of it is usually noticed after the sputum has stood a short time in the vessel, and in the frothy layer at the surface; it may appear in any sputum of a frothy, tenacious character, and disappears when the weather becomes cooler or when the expectoration undergoes further change.

Under the microscope this sputum is seen to contain numerous masses of spores, resembling closely the leptothrix buccalis, and here and there also undoubted filaments of leptothrix. It is from the larger groups of spores that the yellow colour is derived. These fungi are probably introduced mechanically into the sputum as it passes through the mouth, and develop in the expectoration-dish under the favouring influence of heat. As the leptothrix is naturally of a somewhat yellow tinge, the colour is of course intensified by the multiplication of filaments. Microscopic examination has shown, also, that in the mouth and between the teeth of those patients whose sputum was of this nature were lodged large numbers of leptothrix thalli. Diagnostically and prognostically this "egg-yolk" sputum has not the slightest signification.—Another variety of sputum, identical with the foregoing in microscopic and other characters, differing from it only in colour,—which was grass-green, was observed by Rosenbach in a case of bronchial asthma; the coloration was developed only about 24 hours after the sputum had been expelled.

BILIARY PIGMENT IN THE SPUTUM.

The presence of biliary pigment communicates to the sputum various shades of colour, from yellow to green or even to deep grass-green. In appearance, therefore, they are absolutely indistinguishable from the above-described yellow or green sputa which, as already stated, derive their colour from the products of the higher oxidation of their hæmoglobin. A yellow or green coloration of the sputum is known to be due to biliary pigment only when the skin and mucous membranes have the same jaundiced hue, usually the result of a duodenal catarrh. The ordinary test for the presence of the colouring-matter of the bile, the occurrence of the well-known play of colours on the addition of nitric acid, is not satisfactory, as this same reagent produces a slight greenish tinge in the usually colourless mucous sputum.

This complication, the association of icterus (duodenalis) with a disease of the respiratory apparatus, is met with in the bilious form of pneumonia, though not in every case of bilious pneumonia is the sputum also necessarily yellow or green. On the other hand, it may happen that any other affection of the respiratory organs, simple bronchial catarrh, for instance, may be complicated by the occurrence of duodenal catarrh with icterus, when the sputum at once turns yellow or green; I have seen one well-marked case of this nature.

BLACK PIGMENTED SPUTA.

The sputum may be blackened throughout almost its entire extent (a somewhat rare event), or only in certain parts. This staining is commonly caused by *particles of carbon* which have been carried into the air-passages and mixed there with the fluid secretions; the greater the number of these particles the more intimate is their combination with the sputum and the deeper the shade of the black pigmentation.

Quantities of carbonaceous matter are often seen in the sputum of those who are exposed to the habitual inhalation of the sooty smoke of a badly-burning lamp; in such circumstances it is not unusual to find that the secretions coughed up in the morning are black. Small quantities of snuff also sometimes slip down from the nose into the air-tubes and are recognised in the

catarrhal secretion as minute black particles. This black pigmented sputum probably occurs most frequently among those who work in coal-pits. In all these cases microscopic examination shows that the amorphous granules of carbon lie loose and free in the sputum; but they may also penetrate even into the substance of the lung itself, and are then incorporated with the epithelium of the air-vesicles and with the pulmonary texture.

Accurate investigations, carried on by Traube and Cohnheim, into the nature and surroundings of this carbon-dust have proved most clearly that it comes from without, and that it insinuates itself into the epithelium of the alveoli and into the interstitial tissue (in one case it had reached even to the bronchial glands); this is evident from the fact that the particles of which it is composed differ in no respect from those which float *freely* about in the atmosphere. In one of the two cases observed by Traube the specks of carbon found in the sputum resembled exactly those which the patient had habitually inhaled in the timber-yard in which he worked, their structural identity with the cellules of the *pinus sylvestris* being completely established. Böttcher has recorded an exactly similar case.

Absolute proof, however, that fine powdery matters, conveyed into the trachea, may be carried downwards into the air-cells and may work their way even into the tissue of the lung, is furnished by the experiments of Slavjansky. He introduced a certain quantity of cinnabar into the trachea of several animals, and afterwards found the particles of that substance in the epithelium of the alveoli, some of them scattered irregularly through the cells, others showing a definite and orderly arrangement; he discovered them also in the interalveolar septa, in the bronchial glands, and even in the blood, to which they had probably gained entrance through the lymphatic glands and vessels.

There is, further, sometimes seen in the sputum, a *black pulmonary pigment (Melanin)*, in the form of *black, uniformly pigmented cells*. There is little doubt that this *Melanin*, which differs from all other organic pigments in being insoluble in alkaline lye and in resisting the bleaching action of chlorine, is *simply inhaled carbon-dust*, by which the pulmonary epithelium is stained of a uniform black colour. *Phthisis melanotica* is thus merely a chronic form of pneumonia, excited by the inhalation of carbonaceous particles.

Besides carbonaceous matters other variously-coloured particles, such as the dust of cinnabar or iron, are found in the sputum; these not only communicate their colour to the secretions but also give rise to more or less serious affections of the air-passages and pulmonary parenchyma (catarrh, or chronic pneumonic infiltration), which Zenker classifies as "diseases from the inhalation of dust." To the cases of siderosis pulmonum recorded by Zenker may be added one of great interest reported by Merkel, in which the lung was of a brick-red colour from a deposit of oxide of iron; the patient had been employed

in a tile-work. Another patient, who had worked in an ultramarine factory and had suffered from chronic bronchial catarrh, brought up an exquisitely *blue-coloured sputum*.

THE SPUTA IN DISEASES OF THE AIR-PASSAGES.

Catarrh and inflammations of the respiratory passages, whether seated in the larynx or the larger or smaller bronchi, are always attended by the same species of sputum, as all parts of the mucous membrane have exactly the same structure.

At the beginning of an attack of catarrhal inflammation the sputum is simply mucous, consisting chiefly of a tough, vitreous, transparent mucus, with only a few figurate elements,—the mucus-corpuscles; in the expectoration-vessel it runs together and contains air-bubbles, and is therefore frothy and clear in colour. This is the *sputum crudum* of the ancients.—At a later stage of catarrhal affections it becomes richer in cells, contains, besides mucus and mucus-corpuscles, a few pus-corpuscles, and is thus of somewhat firmer consistence; as the inflammation abates the cell-elements are present in still greater numbers, the sputa take the form of irregularly globular masses (the *sputa cocta* of the older authors) and assume a dull yellowish colour. Both these stages, marked by a mucous and a muco-purulent sputum, are observed in every catarrhal or inflammatory bronchial affection; when the inflammation is of a croupous character, however, it is not *sputum*, in the ordinary acceptation of the term, that is expectorated, but chiefly the fibrinous bronchial casts already described on p. 180.—In putrid bronchitis and in bronchiectasis, also, the sputum has special characters, given in detail on p. 202.

THE SPUTA IN AFFECTIONS OF THE LUNG-SUBSTANCE.

The Sputum in Croupous Pneumonia.

The three stages of this disease are usually characterised by three distinct varieties of sputum.

1. In the *stage of engorgement* of the lungs the sputa, if present, are very scanty and tough, are composed mostly of mucus, include numerous bubbles of air, and are therefore transparent; they contain comparatively few morphological elements, are occasionally marked by streaks or spots of blood, and are of no definite

shape when expectorated. They coalesce in the receiving-glass, in which, on account of the large quantity of air enclosed in them, they float, forming a spumous layer on the surface of the water. The blood, which is present only in minute traces, is generally seen only on the surface of the sputum, and is not intimately mixed with it.—The expectoration of such a sputum, beset with specks of blood, is a point of great diagnostic importance, as by it pneumonia may be recognised some time before the physical signs of the disease are developed; lobular, central pneumonia is often first noticed, and distinguished from other acute affections of the respiratory organs by this symptom alone.

2. In the *stage of hepatization* increase of the plastic exudation in the alveoli and in the terminal bronchi is associated with a sputum more copious in quantity, exceedingly tenacious, less aerated, and more deeply tinged with blood; the latter is more intimately mixed with the mucus, and gives to it the *rust-colour* described as pathognomonic of the affection. The depth of the *coloration* varies with the relative amount of the blood and the length of time it lodges in the alveoli and bronchi. Reddish brown or rusty sputa are thus obviously of less recent date than those which are bright red. In the former are found, on microscopic examination, numerous altered blood-corpuscles, some distended, others shrivelled up and disintegrated, their colouring-matter being dissolved out and the round of oxidation-changes to which it is subject being already begun. The number of corpuscles seen under the microscope, therefore, is by no means proportionate to the intensity of the colour of the sputa when looked at with the naked eye. In bright red sputa, on the other hand, the histological structure and the colour of the corpuscles are preserved intact.—The *tenacity* of the sanguineous pneumonic sputum is such that the patient has often the greatest difficulty in getting it out of his mouth; it adheres to the sides of the crachoir and does not flow out when the latter is inverted. This toughness, and the transparency of the sputum, depend on the presence of mucus; increase of the number of the morphological constituents (blood-corpuscles and pus-cells) renders the sputum less transparent. The quantity of air, also, which is mixed in the sputum varies with the intimacy of the contact into which the respired air and the secretions are brought in the bronchi. Gradually, keeping pace with the advancing consolidation of the