SPUTUM:

ITS

MICROSCOPY AND DIAGNOSTIC AND PROGNOSTIC SIGNIFICATIONS.

Illustrated with numerous Photo-Micrographic Plates and Chromo-Lithographs.

BY

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"Est quôdam prodire tenus, si non datur ultra."—HORATII EPIST. I., LIB. I.

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PREFACE.

SINCE the discovery of the tubercle bacterium much more interest has been manifested in the microscopical examination of the pulmonary secretions, a department which had up to that time been neglected by most medical men, and treated as a step-child and Cinderella of their science. This book, imperfect and defective in many ways (for instance, the chemistry of sputa has been almost entirely pretermitted, as being of little practical value), has been written in the hope that it would prove a useful guide to those desirous of applying this branch of study to their every-day work, and help to disseminate knowledge which has proved of service in my own practice.

To secure absolute conformity to truth and reality I have photographed, what in these days of micro-organisms must be called the coarser microscopic constituents of sputum, and have had the negatives employed to illustrate this work reproduced by a process named "Photogravure," which, while equal in clearness and crispness to silver-printing, has the great advantage of being perfectly permanent; its only drawback is its expensiveness, which is so serious as to have caused the omission of many illustrations I had intended to introduce. This task of photogravuring has been successfully accomplished by Messrs Annan & Swan, of London and Glasgow, to whom it was entrusted. My thanks are also due to Mr W. Forgan, President of the Photographic Society, and to Mr Michael Scott, photographic artist: to the former for lessons and excellent advice in photo-micrographic work and construction of apparatus; to the latter for instruction in developing.

Not having succeeded in a sufficiently perfect way in photographing the bacteria of sputum, Dr F. M. Caird gave me his valuable assistance, and made and coloured the original camera-drawings which bear his name, and Mr W. Cathie did the others. Those drawings have been skilfully and faithfully chromolithographed by Messrs W. & A. K. Johnston.

All the chromos and photographs have been prepared from specimens selected as typical, and the Hospital for Incurables has furnished me with inexhaustible materials for investigation, and for sifting the truth or error of preconceptions and opinions, sometimes adopted too hastily and on too inadequate grounds.

FRANCIS TROUP.

1 Minto Street, Edinburgh,
Nov. 1886.

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Diagnostic and Prognostic Signification of Sputum.

CHAPTER I.

Introductory—Microscope—Photo-micrography.

The examination of sputum, by which is meant all the stuff which coughing and hawking mechanically eject from the respiratory passages, is of importance, because through it pathological products, which have been formed in organs hidden from sight, are brought to view, and indicate by their character and quality the existence of processes whose exact nature cannot perhaps be estimated, at least for the time, by any other means.

It happens not unfrequently that elastic tissue, at a time when auscultation and percussion give negative or uncertain indications, can be demonstrated in sputum, and if Koch's bacillus is also present, then a diagnosis, which otherwise would remain long in suspense, is accurately and immediately made. Or reversing the case, a patient has symptoms very like those of phthisis, if no curly fibre or bacilli can be shown the diagnosis is settled against tubercle. Or again, a disease beginning as a pneumonia becomes bacillary, or an emphysematous condition of lung hides percussory and auscultatory physical signs of a phthisis, and the bacillus in the sputum settles the point. These are cases where valuable aid is given, but, unfortunately, expectoration does not always afford so pathognomonic indications.

If there were sputa of certain characters for trachea, bronchial tubes, and lung proper, and if one could put any dependence on the subjective feelings of a patient as to the locality from which his expectoration had been cast off, then the semeiotic worth of those secretions would be considerably augmented; but notwithstanding many drawbacks, in certain cases the contents of a spit-box give information which cannot be too highly estimated, and which cannot be obtained in any other way. The bronchial secretions of persons in good health very seldom leave any residuum to be expectorated. When disease attacks the tubes it is very different; the morbid products then formed must be eliminated, and when frequently recurring catarrhal affections have caused a chronically congested condition of the bronchial lining, there is present always a redundancy of matter exciting cough, and only to be got rid of by expectoration. The basis of the stuff spat up is constituted by mucus, albumen, and watery fluids. Mucus, being the secretion special to the mucous membrane, must be present in every sputum, and gives tenacity and transparency to it; albumen is most abundant in severe inflammatory affections of the air-passages, and when there is plastic exudation into the parenchyma of the lung, as in croupous pneumonia; water is more or less a constant constituent, and is furnished by the buccal cavity, and then contains the epithelial scales of the lining of the mouth, or it is derived from the tubes into which a sudden copious flux of watery fluid has been poured, as in humid asthma, or it may originate in the alveoli, as in œdema pulmonum, in which the abundant frothy expectoration has the consistence and appearance of white of egg and water.

Roughly speaking, the secretion from an irritated bronchial mucous membrane may be divided into the following classes, according to the constituent which seems to predominate most:—

(1.) **Mucous.**—This usually marks the earlier stages of a bronchitic attack; it is clear, viscid, glassy, tenacious, and can be drawn into long threads. As a general rule, the more severe the inflammation the greater the viscosity, and when irritation diminishes the sputum becomes less adhesive and more opaque, a recrudescence of the malady being marked by a return of the expectoration to its original form. But this clear mucous variety may also be the mere forerunner of an opaque kind, which may or may not be accompanied by feverish general symptoms. Here the secretion is of a dull gray or dirty white colour, with streaks of white or yellow or minute yellow dots interspersed through its substance, and its surface is bossed with air bubbles of medium size. If spat up without much watery admixture such a sputum coalesces into a homogeneous, gluey mass. If there is more serous ingredient, then globular, woolly-looking lumps will be seen floating in or sunk at the bottom of a yellowish-green serosity, containing tags and frayed striæ of albuminous matter.

(2.) **Muco-puriform.**—This mixture is the commonest of all, and is present in almost every acute bronchitis in its second stage, and is sometimes most abundantly secreted.

(3.) **Purulent.**—Pure pus, as if from an ordinary abscess, is an unusual spectacle, save when derived from vomicæ or empyemata which have perforated and discharged through the bronchi. Microscopically it consists of pus cells.

(4.) **Serous.**—This expectoration may be seen in bronchitis and phthisis alongside of the other and more distinctive sputa of the respective diseases, and it often precedes the mucous sputum of a bronchial catarrh; but is most characteristic, as previously mentioned, where sudden fluxes have taken place into the tubes or into the pulmonary alveoli.

Every sputum may be assigned to one or other of those classes, or it may be a medley of two or more. In certain diseases, however, other constituents are added, such as blood in pneumonia, dust particles in the pneumo-konioses, and the sputum may be designated as sanguineous or pigmented, and so on; but an accurate valuation of the diagnostic and prognostic signification of any expectoration can only be obtained by careful microscopy and discovery of certain histological elements, to be presently discoursed of at length.

For many centuries, therefore, sputa have been solicitously examined by physicians, and our ancestors had, possibly, more practical skill than their successors of to-day in deducing from their look what were the variations, what the temper or disposition, and what was to be the probable issue of the disease which furnished them. Their naked eye appearances, with which they had to be satisfied, were minutely noted and described; their colour, weight, form, consistence, smell, and taste, all were pressed into the service, and gave material to them to form opinions more or less correct, generally more, as to the kinds which were of good or evil omen, or which were useful or useless and unprofitable for the resolution of the disease which was their parent. What things tended to suppress or promote expectoration, what were the effects of suppression, what was the model sputum of any pulmonary complaint at any stage, and what was portended by any, even a trivial, departure from the customary standard, were all known with a fulness of knowledge which is worthy of imitation to-day.

The Microscope.—For the investigation of what may be called the grosser morphological elements of sputum, such as elastic tissue, spirals, crystals, etc., an expensive microscope is by no means a necessity. Since 1851, I have had in constant use for such purposes an Oberhäuser of the pattern suggested for medical men, and recommended and figured by Dr Hughes Bennett in his *Introduction to Clinical Medicine*. With Nos. 3 and 7 objectives, and Nos. 3 and 4 eye-pieces, a magnification is obtained, varying from 25 to 420 diameters, amply sufficient for the coarser work of days gone by, but totally unsatisfactory and insufficient for the bacterial researches which have risen into such prominence in those latter years. Instead of dry lenses, those called immersion are essential, and the ordinary mirror must be supplemented by some form of condenser, such as Abbé's. I do not for one moment say that good work may not be done with dry glasses, but the very great superiority in brilliancy and definition of a wet lens is very perceptible to any one who has been in the habit of using the dry systems, and water immersion is as much preferable to the dry glass as the oil immersion is to the water. I generally work with the K. water immersion of Zeiss for cleanliness and handiness' sake, and in doubtful and difficult cases use his $\frac{1}{12}$ oil immersion, which has a wonderful power of laying bare tubercle bacilli, for instance, hidden away in nooks and corners of a cover glass not too evenly or thinly spread, and I would not like to give a negative diagnosis in a perplexing case without the assistance of either the water or oil immersion. A great deal, of course, depends on habit, and one accustomed searching for the parasite, even where it is not very abundant, can spot it easily with a Zeiss DD and ocular No. 1 and the Abbé condenser; but where many fields may have to be traversed and searched in vain, I would feel no confidence or security that no bacillus had been missed, unless the investigation had been made by means of either the water or oil system. As Zeiss' stands and glasses are now in very common use, I give, on the next page, a copy of his table of the magnifying powers of his objectives with the various Huyghenian oculars.

For microscopic drawing, the best and easiest apparatus to use which I have yet seen is the camera lucida of Abbé. It is specially adjusted for Zeiss' No. 2 ocular, and is firmly retained in position on it by means of a pinching screw: its cost in etui is 30 shillings.

Magnifications of the Objectives of Zeiss with the Huyghenian Eye-pieces, and with a Length of Tube of 155 *Millimetres.*

	Ocular:	1	2	3	4	5	
	a_1	7	11	15	22		a_1
	a_2	12	17	24	34		a_2
	a_3	20	27	38	52		a_3
	a*		4–12	7–17	10–24		a*
	aa	22	30	41	56	75	aa
	A, AA	38	52	71	97	130	A, AA
	B, BB	70	95	130	175	235	B, BB
	C, CC	120	145	195	270	360	C, CC
	D, DD	175	230	320	435	580	D, DD
	E	270	355	490	670	890	E
	F	405	540	745	1010	1350	F
Water Immersion.	G	260	340	470	640	855	G
	H	320	430	590	805	1075	H
	J	430	570	785	1070	1430	J
	K	570	760	1045	1425	1900	K
	L	770	1030	1415	1930	2570	L
Homogeneous Immersion.	$\frac{1}{8}$	260	340	470	640	855	$\frac{1}{8}$
	$\frac{1}{12}$	380	505	695	950	1265	$\frac{1}{12}$
	$\frac{1}{18}$	605	810	1110	1515	2020	$\frac{1}{18}$
		1	2	3	4	5	

Photo-micrographic Apparatus.—The apparatus by which all the negatives of the plates illustrating this book were taken was planned and made by Mr W. Forgan, President of the Photographic Society here. It consists essentially of a stout tripod stand, the square legs of which converge, and are mortised and screwed into a circular block of wood, two inches thick and nine in diameter. Half way between bottom and summit there is also a strong triangular board, to the squared-off corners of which the legs are also fastened by screws, so that the whole affair is stoutly compacted together. In the centre of these two binding boards a bar of wood, two and a half inches square, plays up and down according to the level wished, and is provided with a series of holes two inches apart, through which a pin can be thrust, and thus support the bar on the crown of the stand; a pinching-screw at the side is an additional precaution against any alteration of level. To the summit of this pillar the long flat board which is to carry the lamp and microscope and camera is fixed securely, not directly, but through the medium of two boards, the upper of which is much broader and longer than the under one; in fact, between them they exactly represent the capital of a pillar: greater freedom from vibration is thus attained.

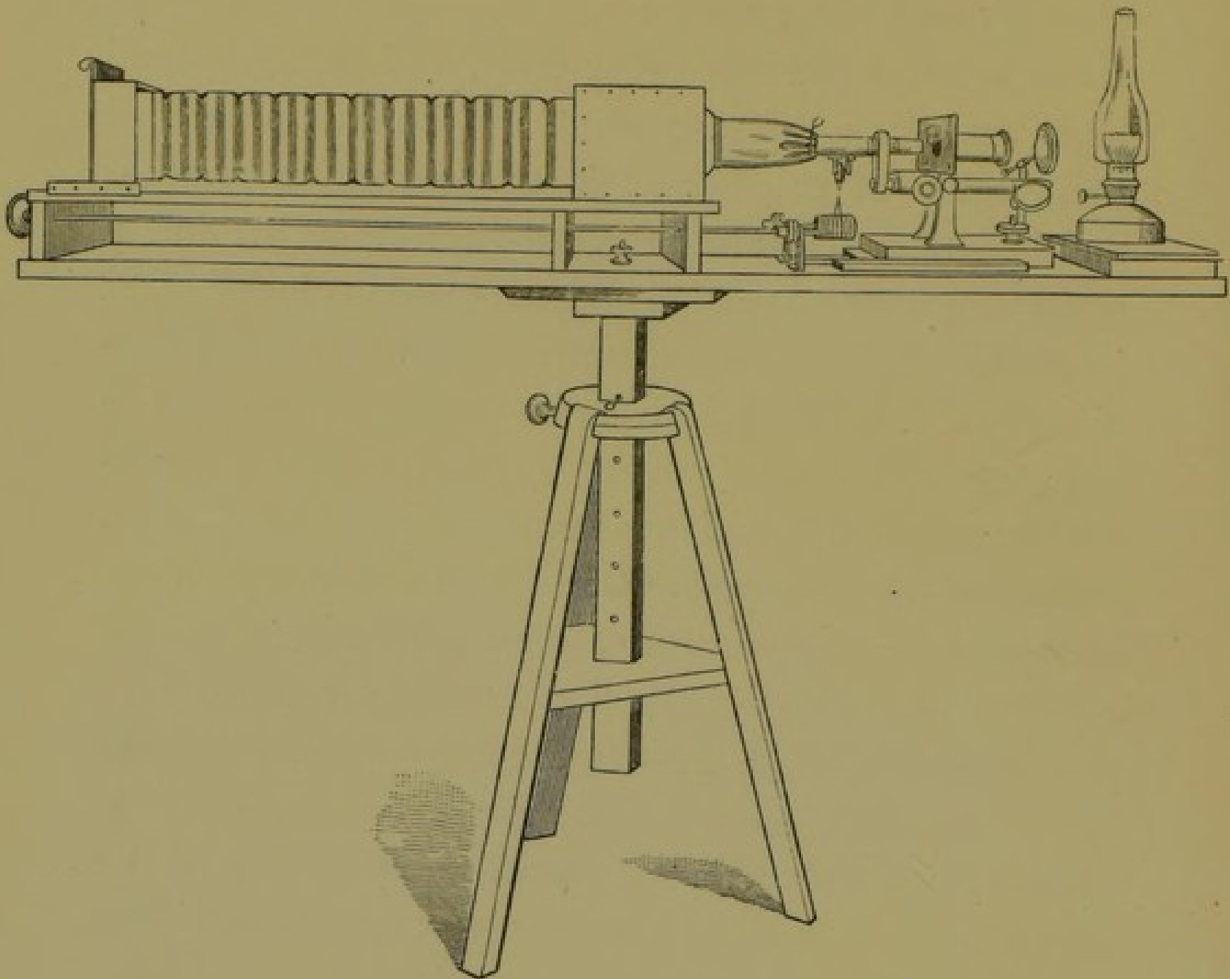
At one end there is a slightly raised rest for a broad-wick paraffin lamp, with a row of little nails which mark out the position for the lamp-stand, and keep it in the optical axis of the microscope. The microscope on its flat pedestal is fixed to the board by means of a pinching-screw, and is also kept in proper position by two pieces of wood, against which its rest travels when moved backwards or forwards as desired; the slot in the board in which the pinching-screw works being, of course, as nearly as possible in the mathematical centre of the long axis of the board.

At the other end the box-camera and bellows, raised on three rests of such a height as to keep everything in the optical centre, are fixed on a lightly made board of their own, leaving a space between the basis board and themselves, which makes a very handy shelf for laying things, such as focussing glass or measuring rule, out of one's hand when at work. The bellows have a guide of metal attached on each side of the box in which the plates are exposed, and have a pinching-screw working in a central slot running the whole length of the board, so that a to and fro movement can be made always centrally, and arrested and fixed when wished by a turn of the screw.

The end of the camera directed towards the microscope has a long sleeve of black calico nailed on it; the free end of this sleeve has a cord run through it, and when adjusted over the tube of the microscope the string is closely drawn and tied, and light is thus most effectually excluded.

The microscope has affixed to the under surface of the stage a well in which a condenser, consisting of two plano-convex lenses, with a pin hole cap, slides easily, and thus the rays of light from the bull's eye are again parallelized and made more or less vivid according to the distance of the pin hole from the under surface of the exposed slide. The fine adjustment is controlled in a very ingenious and most comfortable way. On the right hand, and running through the rests on which camera and bellows stand, a brass rod three feet long, and with a milled head, ends in a wooden wheel; by means of a cord the motion of this wheel is transferred to another and larger one, whose iron axle carries at its end a much smaller grooved wooden cylinder placed right below the fine adjustment, the milled head of which is grooved. Motion is again conveyed from the cylinder to the adjustment by means of an india-rubber cord, which can be easily slipped off and on when the microscope is wanted in a vertical position, to search for the portion of slide which contains the object to be photographed. The apparatus is simplicity itself when seen, and the drawing may help to make the text more intelligible. No assistant is needed, and one can sit comfortably and use the focussing glass, and at the same time move the fine adjustment in any way that is considered necessary.

A rough focal adjustment is first made on a ground glass slide, and for the fine one a plate of glass in a frame is used. I have tried for this focussing screen a sensitive plate exposed to a flash of light and then developed; I have covered the glass plate with the thinnest possible film of smoke, with oiled tissue paper, but nothing equals Mr Forgan's recommendation, namely, daubing (the merest touch suffices) the surface of the plate glass with damp putty, and then rubbing gently with a soft cloth. This affords the finest surface I have yet seen, and one freest of grittiness.



This matter of focussing minute markings is a very great difficulty, and hard of accomplishment, owing to the comparative coarseness of the surface which receives the image, the minuteness of the image itself, and want of light. A focussing glass, to be obtained in any shop where photographic apparatus is kept, overcomes one of these perplexities, but the other two are not so easily disposed of; a faultless screen is yet a desideratum, and light can only be increased within limits, for too much of it, although making a clearer picture, renders structure paler and more indefinite and indistinct.

The plate carriers to be substituted for the focussing screen when the image is to be taken should work very smoothly, for, especially with high powers and long bellows, the slightest shake or vibration disturbs a focus which has cost a deal of trouble to perfect, and they should always carry two plates, so that several can be exposed at one sitting, and thus time and developing solutions are saved. Even walking across the room while a plate is in the camera should be avoided, in case of causing any vibration of the instrument.

It is well to have an exact idea of the magnification in each case, and this is easily done. After removing, or before putting the sensitized plate into the camera, a stage micrometer such as Zeiss's, one millim. divided into 100 parts, is substituted for the object, focussed on the ground glass plate, and measured with a rule. If one of the divisions corresponding to the one-hundredth of a millimetre on the micrometer measures two millimetres on the ground glass, the magnification equals two hundred diameters. Note the length of bellows by which this has been brought about, and it is a simple question of the rule of three what magnification is obtained with same objective and any length of bellows. I had all my objectives measured in this way, and the absolute amount of their magnifying power was thus established correctly.

Success is not to be easily obtained: the photos in the work represent three or four times as many failures, and no one who has not tried can have any idea of the time and labour expended, first, in finding out the bit of slide you wish to photograph; second, in focussing; third, in discovering the correct time of exposure, for slight differences in thickness of film necessitate longer or less exposure; and, lastly, in developing it is heart-breaking to see frequently that all is a failure and has to be begun *de novo*. I made a note of every subject exposed, time of exposure, objective used, and the result, and slowly accumulated materials which enabled me to guess pretty nearly the time needed for my subject. I soon found out that the ferrous oxalate developing process, although producing denser negatives, was not so good for me as the pyro and ammonia one, for with the latter an over or under exposed plate could be helped to a certain extent, but not so with the oxalate.

I have made numerous attempts to photograph pathogenic bacteria, and hitherto have only produced negatives, which I do not consider good enough for printing, the details wanting sharpness and crispness. This is regrettable, because a photograph, securing as it does a perfect objectivity, is perhaps of more value than the original preparation, inasmuch as it is accessible to, and can be examined simultaneously by many individuals. In consequence of this want of success, and in the meantime, I have had to be satisfied with drawings which show, as well as can be shown in that way, the appearance of the micro-organisms spoken of in the text, but I have not yet abandoned the attempt to reproduce them photographically as a hopeless one.

CHAPTER II.

Constituents of Expectoration.

I. Formed Elements.

Among the formed elements of sputum to be met with on microscopical investigation, some of them physiological and others pathological, are :—

1. *Epithelium.*

1. Normal squamous epithelium is a constant constituent, and is derived either from the respiratory or commencement of the digestive tract, cavity of mouth, salivary glands, tongue, etc. Its exact place of origin can only be guessed, neither is it of any clinical importance to determine; when old and shrivelled, and denucleated and arranged in certain ways, I have known it mistaken for elastic tissue, as will be noticed farther on, *cfr.* Plate XXXIII. Epithelium from the lung alveoli frequently, *cfr.* Plates XXVII., XXVIII., and cylindrical cells with or without ciliæ seldomer, *cfr.* Plate XX., but more commonly than is generally supposed, and a chief characteristic of the spiraliferous sputa,

to be afterwards spoken of, are also elementary parts. The *choanae narium*, in people who shut the mouth and inspire strongly through the nostrils before expectorating, furnish a proportion of those ciliated cells, but not nearly so large a one as has hitherto been believed, as I have had occasion to verify in my own case and in others who took pains to *expectorate* without this preliminary nasal inspiration.

These normal cells may be pathologically altered by fatty changes and pigmentation, or both. The alveolar epithelium of adults is almost always more or less replete with black pigment, and in brown induration of the lung consecutive to cardiac valvular mischief, the same cells are saturated with a golden brown or yellow colour from imbibition of altered hæmoglobin. Endosmotic incidents also modify the form and size of cells, and have to be taken into account in forming a judgment; in fact, the alveolar epithelium, as it appears in sputa, owes its spherical shape to such influences.

2. *Mucus and Pus Corpuscles, cfr. Plate XXIV.*

The latter have a more granular appearance than the mucus corpuscles, and have also more nuclei. Both of them undergo fatty metamorphosis, and diffusion also exercises its influences over them, and causes them to lose their granulated appearance, to swell and burst; at other times the cell protoplasm assumes a homogeneous, highly refractive character, and hyaline balls may be seen swimming about without trace of nucleus, or this colloid matter may push aside the contents, and the whole cell wall surrounds the oily-looking sphere as if it were a ring, and sometimes the nucleus projects like the seal of a signet ring at one point of the circle. Free granules and molecules and nuclei may also be seen as the residual elements of cells which have completely disintegrated. When such molecular detritus is abundant, a putrid process must be in operation, such as lung gangrene, or the sputa themselves have become decayed from stagnation in caverns or bronchiectasies.

3. *Blood Corpuscles.*

Blood corpuscles, *cfr.* Plates XXI., XXII., XXIII., as a rule, remain unaltered for a relatively long time, retaining their colour and bi-concave discoid form, or they are drawn out into flattened pear or balloon shapes, or become crenated and mulberry-like from shrinkage or exosmosis, or swollen into colourless spheres by imbibition, and in this condition may be mistaken for fungus spores. In cases where they are abundantly present, they preserve their ordinary histological behaviour, and gather into heaps, or stick together by their flat surfaces in coin-like piles, or adhere only by a portion of their circumference, and then the rouleaux are open on one side, in a V shape or bellows form, and unite into forked and ramified patterns like leafless twigs.

4. *Fibrinous Coagula.*

It has been known for a very long time that moulds of the bronchi appeared in sputa, but the incident was misinterpreted. In tom. iv. of van Swieten's *Commentaries on Boerhaave's Aphorisms*, published at Lugdunum Batavorum (Leyden) 1764, at pages 30 and 31, Galen is quoted, lib. 1, "De Locis Affectis, cap. 1, page 379," who says, "that he has seen not a small portion of a vessel cast out by coughing, and which sufficiently demonstrated by its magnitude that it must have come from the lung, as the trachea had no vessels of such a size." Tulpius, lib. 2, *Observationes Medicæ*, cap. 12, 13, 14, 1641, has observed similar bodies, and believed that a whole pulmonary vein might be ejected by coughing, and he gives two excellent figures of the casts, which he designates "Surculi venæ arteriosæ expectorati." In 1683, in *Acta Eruditorum*, pages 218, 219, an anonymous observer has given a drawing of one, and remarks very candidly, "that this was a venous vessel, or twig of the pulmonary vein, equalling the palm of the hand in length, the texture of its substance compelled one to conjecture, but, on the other hand, the fission of it where it probably had separated from the larger trunk, and its fleshy substance, *not unlike a polypus*, made it allowable to look upon polypus as the prime actor in the tragedy." Tulpius wondered and thought it miraculous that such large branching vessels could be separated without any sign of pus or shred of adherent lung substance, just as if "otiosus anatomicus removisset circumpositi visceris impedimentum." Ruyschius had more observant eyes (*oculatior*), and when speaking of a polypus or thrombus of the longitudinal sinus, takes occasion to say, "that many have deceived themselves in affections of the chest when such polypi have been coughed up, believing that they were exhibiting expectorated veins." To come to more recent times and nearer home, Dr John Cheyne, in the *Edinburgh Medical and Surgical Journal*, vol. iv., page 441, 1808, relates a case of bronchial polypi, and rightly connects their appearance with an inflammatory croupous condition, and he phlebotomized the patient very frequently, as was then the custom, with the result that the casts disappeared. In his copiously illustrated work on the pathology of the membrane of the larynx and bronchia, 1809, the same case is repeated; he distinguishes two sorts of polypi, one from hæmoptoë, when the polypus is merely a blood coagulum moulded into shape by the bronchial tube, into which the blood had been poured; the second species is of a "purer white, generally ramified, lamellated, sometimes solid, sometimes tubular; in consistence much more dense." "These concretions are preceded by catarrhal complaints, and attended with cough, wheezing, and dyspnœa. The fit of coughing which displaces them is sometimes alarmingly violent. After their expectoration the lungs feel lightened, as if something which had impeded their play were removed." This description is true to nature, and shows that

> "Vixêre fortes ante Agamemnona
> Multi."

Which the Agamemnons of the present day are sometimes slow to recognise. Remak, in *Diagnostische und pathogenetische Untersuchungen*, Berlin, 1845, drew the attention of the profession in Germany to those coagula, and rightly interpreted what they were. They are common in croupous pneumonia, either idiopathic or complicating a croupous bronchitis, appear from the third to the seventh day of the malady; cases are exceptional where they are seen earlier or remain later; they announce the commencement of hepatization, and thus indicate the stadium of the disease. In the book referred to above, at page 77, Remak gives a perfect description of their form. He says "the bronchial coagula form ramifying cylinders with rectilinear borders and dichotomous division, so that the twigs, in general, gradually diminish in length and thickness. Yet the chief trunk is commonly thinner than the nearest twigs, and at its free end runs out in a filiform manner. At the branching-off places (Verästelungstellen) there is often noticeable a slight dilatation, which is probably dependent on a similar condition of the bronchial twigs. Sometimes the cylindrical coagulum is somewhat flattened, sometimes swollen into knots in certain places, and this arises from enclosed air, which contributes to cause it to float in water." Six representations of those bronchial stolons are given at the end of his collection of papers. As to colour, they are reddish or yellowish-white, and pure white after washing and unrolling in water.

To this category also belong the so-called Curschmann spirals which I brought under the notice of the Edinburgh Medico-Chirurgical Society by means of photo-micrographs at the meeting, November 4, 1885 (*Edinburgh Medical Journal*, December 1885, page 573); some of them look very much like as if the bronchial epithelial lining had desquamated in its entirety. Those very curiously compounded formations will be treated of in a separate chapter.

5. *Crystals.*

Fatty crystals, such as cholesterine and the margarine combination of palmitine and stearine, are encountered in sputum, the latter much more frequently and numerously than the former. The rhombic plates of cholesterine are thin and colourless, and have a mother-of-pearl lustre. The angles of the laminæ, and even the step-like notches which their sides often display, are 79° 30′ and 100° 30′.

If the scales are aggregated, the longer sides lie parallel, and as their margins do not exactly overlap, various strange forms are assumed. They are soluble in hot alcohol and ether; insoluble in water, acids, and alkalies. Concentrated sulphuric acid liquefies the plates, and renders them greasy and unctuous. The same acid and iodine produce a blue colour in the first stage of decomposition. Some incline to doubt their presence in sputa, others say that they only appear in such as have come from caverns, or pulmonary abscess, or empyemata which have broken through into a bronchus. According to my own observations, they are to be met in sputa, and the best specimens I ever saw were in a bronchiolitic spiral-bearing expectoration. I can also testify that they are a rare sight in the spit of phthisis.

The palmitine-stearine crystals are not rare, and are most numerous where putrefactive processes are going on in confined spaces, as in circumscribed lung gangrene, and in bronchiectatic cavities. They generally assume a slender needle or dart shape, and pack into close bundles, the individual crystals of which radiate from a common centre, *cfr.* Plate XXX. When the needles are long and bent and twisted, as they sometimes are, they simulate "curly fibre," but chloroform or ether at once shows their fatty nature. Although generally indicating putridity, they are to be seen where there is no question of such changes; for example, the mucus of a healthy

Schneiderian membrane and the catarrhal sputa of many non-putrefactive lung affections contain them, not abundantly it is true, but still they are there.

Crystals first noticed by Charcot in the spleen, the blood, and marrow of the bones in cases of leukæmia, and generally associated with his and Leyden's names, are also constant concomitants of spiral-bearing expectoration, and will be noticed separately, *cfr.* Plates XVIII. and XIX.

Pigmented crystals are a rare sight in spit, and Plate XXII. is on that account all the more valuable. I have several times seen another form of the hæmin or hæmatoidin in expectoration stained with blood, and where the mixture with the other cellular elements was an intimate one, viz., rhombic lozenges of a ruby-red colour and considerable thickness, very like a usual form of uric acid in everything but the tint. A common object is triple phosphate with its transparent, coffin-lid, knife-rest, faceted, bevelled, and truncated prismatic forms, or the same comminuted into heaps of irregular, angular frustules, or very rarely in stellar form, with plumose, runcinate, and dendritic rays. Brownish-yellow spherules, varying in size from ·005 to ·001 of an inch, are also met with, particularly in putrefying sputa. I take them to be phosphate of lime, and they are evidently a result of purely chemical influences. The triple phosphate is found in absolutely fresh sputa, but more abundantly when putrefaction has set free in quantity the nitrogen necessary to form ammonia.

6. *Fungous Growths.*

Mycelial fungi of various kinds — Leptothrix, Oidium, Penicillium, Aspergillus—have been long recognised in sputa, and Sarcinæ have also been seen in a few cases, but such an event must belong to the rarities, as it has never been my lot to fall in with them in the long years I have been conversant with such examinations. Many of those cryptogams are bred in the mouth and pharynx, and possibly owe their existence to decomposition of mucus and of remains of food; and during coughing and hawking they get dislodged, and add themselves to the expectorated matters in their passage through the mouth. They also come directly from the lungs; at least one of them, figured on Plate VII., certainly does so. One can easily believe that they may be carried down the respiratory tract by the current of inspired air, and frequently find in cavities and bronchial dilatations a suitable soil and food. Leptothrix buccalis, *cfr.* Plates VI. and XXXII., abounds in the tartar of the teeth and fur of the tongue, in the normal condition growing from a granular matrix which covers the epithelial processes of the filiform papillæ. Undoubtedly the largest and best developed specimens of the plants in question are those of Oidium albicans and lactis and Penicillium; and the first of these three, in the course of one day, has appeared with mycelia and spores innumerable in all stadia of germination in one spit-glass, while numbers of others exposed on the same table for weeks before have shown no trace of any fungus, and are apparently quite passed over. The expectoration which afforded such desirable pabulum came from a case of acute phthisis, and will be spoken of at another part of this book, *cfr.* Plates VIII. and IX. In this connexion (although it has nothing to do with spit, yet I think it not altogether destitute of scientific interest) it may be mentioned that sarcinous vomit exposed beside the expectoration glasses, in a few days showed thirty centres of fungous vegetation, conditioned by four or five different fungi ; so that it was no want of germs which kept the missed vessels sterile.

7. *Entozoa.*

Hydatids are sometimes discharged by expectoration, usually in consequence of a hepatic cyst opening a way through the diaphragm into the base of the lung, but the cysts may also develop in the lungs themselves. Perfect cysts, or only membranous shreds of the echinococcus bag may be coughed up. These shreds seem structureless, but actually consist of a great many layers, which in cross-section have been likened to the leaves of a book. "The echinococcus is an ovoid, clear, vesicular body, and has two unequal segments separated by a slight constriction. The smaller anterior part bears the rostellum and suckers; the posterior is attached to the common brood-sac. The rostellum is an oval projection which can be retracted within the body of the parasite, and carries a double circle of hooklets, as well as in its hinder segment four suctorial eminences. The hooklets are arranged in two rows, one of which consists of somewhat longer ones than the other, being from 1-550th to 1-1000th of an inch in length. They are curved like the claw of a cat, have a broad oblique base with a bifid extremity" (*New Sydenham Society's Lexicon*—Echinococcus). In a preparation in my possession containing two specimens, the longest diameter of the circlets, which are flattened out in a fan-shaped manner, is 1-70th, and the shortest 1-120th of an inch. The claws, which are beautifully seen, measure—the longest 1-175th, the shortest 1-270th of an inch. They are not easily counted, but number about twenty-six in each specimen. The shreds of the sac which contains the parasite exhibit a tendency to curl up like very fine shavings, but the hooklets with their bifid extremity are the surest as well as the most permanent vestige of the echinococcus, and, if discovered, leave no room for doubt as to the nature of the disease. The sac can become the seat of calcareous deposits, and as such concretions are from time to time coughed up in cases of phthisis, it is worth while to remember this. I have no personal experience of this disease, but cases of its presence in the lungs are detailed by Todd, *Medical Times and*

Gazette, vol. i., 1852; Bowman, *Lancet*, 1876; Bird, *Lancet*, 1871; "Of Echinococci in Sputa," Peacock, *Medical Times and Gazette*, 1852; and in *Edinburgh Medical Journal* for February 1870, there is an article by Dr Hjaltelin on the "Echinococci Endemic in Iceland."

8. *Debris of Lung Tissue.*

Elastic fibres will be spoken of in a separate chapter, and their diagnostic signification fully considered. Connective tissue is occasionally seen in sputa of tuberculosis and lung gangrene. In the former case it is not unlikely to be newly formed tissue which has lined the walls of a cavity, and one has also to think whether it may not be derived from fragments of food. If it comes from the lungs, it will, unless a recent pathological production, be studded with black pigment granules. It appears in the guise of opaque, dark gray tags and shreds, easily separated from the rest of the sputum by dilution with water. When treated with acetic acid, it clears up and the pigment grains are better shown. Of course it may come from any part of the lung where such tissue is found, from neighbourhood of alveoli, from bronchi or interlobular septa; if from the latter, it will be thoroughly pigmented. I have seen it in cases of gangrene of the lung, never in phthisis. Unstriped muscular fibres and fragments of cartilage from ulcerated bronchi are conceivable constituents of expectoration. The former might be confounded with the spindle cells of the intima of arteries, and would probably come from the muscular coat of the bronchi or the media of an artery. Cartilage I have never encountered in sputum, but have known vegetable ducts to be mistaken for cartilaginous rings of the bronchi.

9. *Micro-organisms.*

The Bacillus tuberculosis and other micro-parasites will be specially treated of. The discovery of the tubercle bacillus seems now to have solved the problem which has troubled physicians from the days of Hippocrates, viz., how to diagnose phthisis from the contents of the sputum. At one time it was the presence of pus, till that was found out to be a catarrhal production as well; at another it was certain chemical constituents which were characteristic of tubercular pus, and no other; at another it was tubercle corpuscles; at another it was the yellow-white, friable masses which are seen in phthisical sputum, and which deceived even Laennec (*Forbes's Translation*, 1829, page 356), till he found out that such fragments came from the mucous follicles of the tonsils: but now the tubercle parasite is generally considered to be pathognomonic, and by its morphological and chemical characters to fix and determine, when found in a sputum, that such discharge comes from a tubercular focus.

10. *Extraneous Ingredients.*

Even in hospitals where trained nurses who know what is wanted are at command, it is no easy matter to get expectoration free of foreign admixtures. The spit-cup is a favourite receptacle for all odds and ends which helpless patients cannot otherwise dispose of, or lazy or untidy ones will not trouble themselves to do. People smoke and chew and snuff tabacco, and the yellow-brown parenchyma and porous vessels of this plant, and the crystals of salts used in its preparation for consumption, are met in the contaminated bronchial secretions of such persons. The remains of esculent vegetables, fruit, etc., stick about the mouth and teeth, and get mixed with the spit. This is unavoidable, and it is therefore of some importance to be able to distinguish such accidental constituents, and so avoid errors into which even Gruby fell, for his *sphæræ lenticulares* of phthisical sputum turned out to be nothing more than grains of starch from bread crumbs. A pretty extensive knowledge of animal and vegetable tissues is therefore necessary to fulfil a thorough examination of sputum. Many vegetable cells are dodecahedral, but when flattened out by the cover glass, they have the aspect of hexagonal meshwork, the sap vessels forming the threads thereof. Grains of chlorophyll are often present in their interior, or raphides of calcic phosphates and oxalates, isolated oxalate octohedres in the onion, or agglomerated in stellate masses, as in rhubarb. Spiral vessels and spiral fibres may also be seen, *cfr.* Plate X. The starches, enclosed in cells, or free as from bread crumbs, are known as colourless, oval or rounded bodies with a concentric lamination, which is best brought out by polarized light, which causes each grain to exhibit a dark cross, the intersection of the arms being at the hilum. Tincture of iodine at once settles doubt by the formation of the well-known blue colour.

Fibrillæ of muscle, *cfr.* Plate XXXIII., elastic fibres, and connective tissue, etc., from debris of animal food, oil globules from milk or medicaments, such as emulsions, etc., may also be the source of error; and I have seen the acarus of cheese turning up in an expectoration give rise to much speculation; and a word of warning is necessary as to the eggs of insects, such as the house fly, and the tracheal systems of it and others, and the microscopic inhabitants of the water used to wash the spit-glasses.

Foreign bodies find their way into the lungs or air-passages, and after causing much disturbance are sometimes ejected in expectoration, with relief to all the preceding distressing symptoms. I have personal knowledge of three cases — in one a thread, in another a piece of the shell of a hazel nut, were, after years of pulmonary symptoms supposed to be phthisical, expectorated, and health was immediately regained. The third is a very remarkable case. Boys toss peas to each other, to be caught in the open mouth. While engaged in this pastime, it came to pass that one unlucky lad inhaled a pea into his chest. For eleven weeks he had cough and difficult breathing and frequent suffocative attacks. At the end of that time a great discharge of blood and matter was coughed up, and in it the offending pea, which had germinated and sent out a shoot at least half-an-inch in length. Stokes (*New Sydenham Society*, 1882, page 238, *et seq.*) gives a tabulated list of twenty-two cases with symptoms, nature of foreign body, and result. In seventeen cases the intruder was expectorated, and recovery ensued in fourteen.

There are "dust diseases," where particles of metallic or siliceous or vegetable matter (I have seen carbonized fragments of pinewood in sputa of people living in rooms heated by wood fires) find their way into the chest, and are expectorated, *e.g.*, the "black spit" of colliers, *cfr.* Plate XXIX., which is not now so common as it used to be, owing to better ventilation of mines. Special diseases have special morphological elements, which will be noticed under appropriate headings.

II. Amorphous Elements of Sputum.

What may be called *macro*-chemistry, with its quantitative and qualitative analyses, has not helped diagnosis much till recently. This reproach has now been wiped away by the aniline dyes and better modes of microscopical illumination, and micro-chemistry aids the clinician in a most emphatic manner. The basis of the sputum is constituted of formless principles, the chief of which is water. According to Biermer, the average sputum, subject to variations from the character of the disease producing it and outward influences such as evaporation, contains 882 to 979 parts of water per 1000. In the initial stadium of a catarrh, the secretions are more liquid than at a later period ; and in emphysema and hooping-cough, and particularly in œdema pulmonum, the matter expectorated is very aqueous. The more water the thinner the expectoration, and the more of the pavement epithelium of the mouth will it contain, unless indeed the liquid has come, as above mentioned, from the pulmonary alveoli or some sudden deluge of the bronchial tubes.

The albuminous principles and derivatives which may be contained, and have been found by various investigators, in sputum are numerous,—serum albumin, egg albumin, paralbumin, myosin, paraglobin, and mucin, which is the secretion proper of the mucous lining of the air-passages, is present in every specimen, and gives it its different grades of viscosity and transparency. Albumen is more abundant in the sputa of plastic bronchitis and pneumonia than in other chest affections, and we owe the demonstration to Beale that, in the latter disease,

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while the urinary chlorides are diminishing those of the sputa are increasing.

The mineral substances found in sputa are chlorides of lime, soda, and magnesia; phosphates and carbonates of magnesia; phosphates, carbonates, and sulphates of lime and soda; traces of lactates, silicates, and salts of iron oxyde.

Colouring matters have been alluded to when speaking of pigmented crystals, and will be still further commented on under the head of "Pigmented Sputa" as appearing in pulmonary cells and tissues.

Sugar has been found in the sputa of diabetics. I have never succeeded in demonstrating it, although it was always present in the saliva of the same patients. This is curious enough. One would have thought that in its passage through the mouth the expectoration would have carried out with itself some portion of the saccharine saliva. There is a very advanced case of diabetes at present (1886) in hospital, the patient having also a chronic bronchitis and a very great deal of expectoration. When this man washes his mouth very carefully (he is now almost edentulous), and then by sucking causes a flow of saliva, which he transfers to the test-tube, I never fail to find obvious indications of sugar with the potassio-cupric-tartrate test; in the spit never. The method adopted to test for the sugar is the following:—The sputa are diluted and digested with distilled water and filtered; the filtrate inspissated and treated with alcohol, albumen and mucus separating;

again filtered and evaporated, and extracted with alcohol diluted with water, and tested in Trommer's way with cupric sulphate and potass, or with Fehling's solution. I have never found a drop of this extract, allowed to dry on a slide, show the warty, granular conglomerate, with hardly any crystalline faces, or if any, of a rhombic habit, which characterize the deposit from concentrated solutions of glucose.

That fat is present in sputa is known microscopically, and has already been spoken of, and its chemical demonstration is usually conducted in the following way:—The sputa are evaporated to a syrupy consistence and extracted with hot alcohol or ether. The extract is again evaporated, washed with water, and again extracted with ether or alcohol. The extract, if set on fire, burns with a smoky flame. The average chemical composition of expectoration is,—

Water, . . .	94			
Organic Solids, . .	5	Mucin, . . .	2	5
		Albumen and Fat, .	1	
		Extractives, . .	2	
Inorganic Solids, . .	1			
	100			

CHAPTER III.

Elastic Tissue.

In the year 1846, Schrœder van der Kolk (Nederlandsch., *Lancet*, and in 1850, Sur la présence des fibres élastiques dans les crachats des phthisiques. Bruxelles 1850) and Remak (*Deutsche Klinik*, No. 27, also in 1850), called attention to the presence of fragments of the areolar and elastic tissue of the lung in the sputum before the signs of lung ulceration were well characterized. The late Dr J. H. Bennett of Edinburgh, in 1852, published *An Introduction to Clinical Medicine*, in which this discovery was confirmed; but at the same time the statement was made that the physical signs were well characterized where he had found tissue, and at page 89 he says, "the diagnosis of pulmonary diseases is capable of being so accurately determined by percussion and auscultation that the microscope is, in this respect, of secondary importance." The verdict of to-day is very different. No one can speak with much certainty as to the specific or non-specific nature of some lung diseases, unless his diagnosis is supplemented and corroborated by microscopical examination, and by lenses and tinctorial methods which were not dreamed of in Bennett's days.

Diagnostically and prognostically the presence of pulmonary elastic tissue is of very great importance, and Dr Bennett, in his large work, *The Principles and Practice of Medicine*, 1858, fully values and again confirms van der Kolk's observations. It becomes, then, a matter of some moment to recognise this so-called "curly fibre" when seen even in fractional pieces under the microscope. Seen in mass, this recognition is a matter of little or no difficulty to any one acquainted with its microscopic appearances; but when in fragmentary morsels, which it so often is, its correct differentiation from other fibres, mayhap of extraneous origin, is very hard to be done, until a certain amount of proficiency has been acquired by patient scrutiny of undoubted specimens of the article. Perhaps the best way to attain this preliminary and necessary skill is to take a scraping of lung, put it on a slide with a drop of water or solution of potash, press the cover-glass well down, and attentively examine the tangled skein brought into view, say by a power of 170 diameters, which is quite high enough for the purpose. The inimitably graceful sweeps and curls and segments of circles, the skeleton outlines of the fibrous framework of the pulmonary alveoli, are to be noticed, and it will be strange if some very small isolated pieces, mere adumbrations and sketches as it were, broken off from the surrounding coils and loops, are not visible in some of the fields of view. Careful attention to the following remarks should suffice to identify tissue anywhere.

Elastic tissue elements are composed of solid, cylindrical or fasciculated, refractile fibres, branching dichotomously, with dark contours. The diameter of the coarser specimens with which we have to do here varies from ·006 to ·011 mm. Their ends are always squarely broken over as if cut, never fluffy or teased out or conical; their outline also is never notched or rough or ragged or varicose, but smooth and clean, and, as indicated above, nothing can excel the exquisite symmetry and elegance of their intricate convolutions and tracery when seen in quantity, and as *ex pede Herculem*, so flowing outlines betray the source of even very minute fragments. In cases of laryngeal phthisis, or where laryngeal ulceration complicates lung phthisis, the fibres coming from the larynx may be distinguished from those coming from the lung by the more rectilinear course they run; they are much finer, and their sinuosities have more of an undulated character, and less of the segmented roundness of the pulmonary ones, *cfr.* Plates I. and II. Strong acetic acid causes elastic tissue to swell in the cold, and prolonged boiling dissolves it. Caustic potass and soda do the same, and therefore when treating sputum by Fenwick's method the boiling must not be too lengthy. The author's mode of examining sputum is extremely simple: a particle of the suspect is placed on the slide with or without a drop of a 30 per cent. solution of caustic potass or soda, the cover-glass pressed down, and the examination proceeded with. Of course if only a small amount of tissue is present the aggregate expectoration of twenty-four hours should be treated in Fenwick's way, viz., boiling with an equal quantity of a 20 grain to the ounce solution of caustic soda till the sputa become fluid, dilution with four times the bulk of water, which *need not be distilled*, allowing subsidence to take place, and tissue, if present, will be readily found in the black precipitate; but, as stated above, over-boiling will either dissolve it entirely or render it so beaded, diaphanous, and spectral, that it may be altogether missed if the light from the mirror of the microscope is too bright. In trying to preserve characteristic specimens in potass it is noticeable that if the cover-glass (which never firms) is left undisturbed they long retain their form, but if the cover is moved in the smallest degree they crumble into a mass of granular debris. Where the air-cells abut on each other, the trabeculæ of fibres are much broader and riband-like, *cfr.* Plate III.

Ninety per cent. of the cases in which curly fibre is present are cases of tubercular disease of the lung; it is also found in masons' and colliers' phthisis, and in other professional pulmonary complaints, such as those of knife and needle grinders; the remainder of the ten per cent. is made up of cases of pulmonary abscess, bronchiectasis (in which, however, I have hitherto failed to find it), and pulmonary gangrene. In this latter disease Guttmann says that few or no elastic fibres are present, because the putrefactive material seems to destroy them. To show that this statement is not always true, it is worthy of mention that I have seen them abundantly in three months old expectoration from a case of gangrene of the lung. The fibres also resist ordinary putrefaction for a very long time, as I have found them apparently unchanged in sputa fourteen months old. The fact is, that in putrid sputa the tissue gets sanded up, as it were, with molecular debris, and so gets easily overlooked or mistaken for some fungiform growth.

It appears to me that the diagnostic value of curly fibre is apt to be much under-estimated in the present day when the tubercle bacillus, like Aaron's rod, swallows up everything else. In many cases whose symptoms and progress called up initial phthisis into the mind, I have demonstrated elastic tissue where no tubercle bacilli were to be found; and in one remarkable case in the Longmore Hospital for Incurables, I had the opportunity of watching and seeing the advent of the bacillus months after elastic tissue was first noticed in that patient's expectoration. And long ago, thirty and more years, I sent a patient to town here to be examined by the late Sir Robert Christison. The sputum of that man, who was sixty years of age, and was a mason, contained very large quantities of elastic tissue. The patient himself was feverish, had a very quick pulse, perspired at night, and was emaciating very rapidly, and yet Dr Christison failed to hear any characteristic auscultatory or percussory sounds, and remarked that "in six weeks I would know better:" in six weeks the patient was buried. So that, to one who knows how to examine, very correct and painful information may be gathered as to the serious nature of a disease before patients or their friends have formed the slightest suspicion that there is much amiss. Since the author became acquainted with Koch's discoveries and manipulations, he has carefully examined many hundreds of sputa, and has arrived at the conclusion that curly fibre is actually a prodrome or precursor of the bacillus, and the supposition seems a reasonable one; for before the bacillus can appear in the expectoration, ulcerative changes must have taken place, and the debris resulting therefrom would be the first apparition in point of time. In ancient, long-spun-out cases of phthisis, tissue is also to be found pretty constantly, though sparingly and in minute morsels, while the bacillus may be missed entirely or for long intervals. A remarkable instance of this kind will be noticed when speaking of the tubercle bacillus.

Plates I.–V. give faithful representations of both laryngeal and pulmonary tissue as they appear in sputum, and Plates VI.–XI. equally true delineations of various fungi and fibres which carelessness might mistake for real tissue. In its passage from the lungs to the spit-box, sputum acquires many puzzling addenda from throat and mouth: casts or moulds of tonsillar crypts, which have a certain amount of resemblance to the areolæ of the tissue of the pulmonary alveoli, *cfr.* Plate XXX.; cornified epithelial moulds of the filiform or other papillæ of the tongue, *cfr.* Plate XXXII.; luxuriant specimens of leptothrix buccalis, *cfr.* Plate VI.; fragments of food, such as muscular fibrils, *cfr.* Plate XXXIII.; squamous epithelium, which in tangled heaps, in nest form, or lying edgeways, has a wonderful likeness to elastic tissue; fungi of various kinds which become visible so soon that one is almost tempted to believe that they have their habitation in the air-passages, *cfr.* Plates VIII., IX.; one, greenish-yellow in colour, is so frequent that the author has no doubt it flourishes saprophytically in the lung—it is aspergillus fumigatus (?) and has an exceedingly complicated mycelial meshwork which closely resembles tissue, *cfr.* Plate VII.; but also in the *crachoir* expectoration receives additions of many kinds from deposition of particles floating in the atmosphere; hairs of various animals, portions of feathers, fibres of flax, cotton or silk, woody fibre from floor sweepings, and spiral vessels of varied origin, *e.g.* tea-leaf. Ludicrous errors are sometimes committed by the uninstructed. Expectorated bits of "sloughing bronchi," when examined by better informed eyes, have been resolved into annular ducts derived from the immigration into the spit-box of microscopic atoms of bran or sawdust with which the patient was stuffing pin-cushions.

Fibres of silk are tapering or evenly cylindrical, have clean contours, and do not branch dichotomously; fibres of cotton are flat, and being composed of very elongated cells and hairs, the membranes of which contract and twist in drying, have curious central markings and are often coloured, as may also be the others mentioned and to be mentioned. Fibres of flax, jointed, of uniform diameter and with ragged uneven ends, lying like broken sticks in the field of view, are easy of recognition ; but ends and edges frequently fray or get teased out into brush-like conglomerations of fibrils which, when detached from the parent stem, simulate tissue very closely. A correct decision can always be made by regarding the general fluffy and tattered look of the fibrils when straight, and when they happen to have an alveolar arrangement by noticing the lack of that elegance and symmetry of curve which peculiarize the elastic tissue of the pulmonary alveoli. Plates X. and XI. show many of the extraneous substances liable to be met with in sputum. Another specious counterfeit of tissue may be mentioned here ; it is that afforded by fibrillation of the mucin of certain viscid sputa ; the molecular striations, and fibrillar networks, and curved bands, and streaks formed by it are abundantly remarkable, and Plate XXVI., from a case of bronchitis, reproduces them excellently well, and gives a far better idea of their points of similarity and contrast to genuine elastic fibres than any description, however elaborate.

As practical appendix to and summary of the foregoing remarks, the author, after nearly forty years of experience of the subject so far as tissue is concerned, considers it not far from the truth to say :—

1. That where the elastic tissue of the pulmonary alveoli is seen in sputum the correct diagnosis in nine cases out of ten will be that of tubercular phthisis; the tenth, whether it be bronchiectatic, pulmonary gangrene or abscess, or a pneumokoniosis, can be made out and differentiated from the others by cautious consideration and weighing of history, signs, and symptoms.

2. Careful microscopy of the expectorated matters can frequently detect its presence in a very early stage of phthisis, even when percussion and auscultation practised by skilled observers give only doubtful or negative results.

3. When great leashes of tissue, filling a whole field of view, as may be seen in Plate V., are observed, it is *absolutely certain* that the process of destruction is going on actively in the lung, and therefore the prognosis is bad; and conversely, when the portions are small and fragmentary, one can as safely conclude that the melting down of lung is going on less rapidly, and therefore the prognosis is better.

4. Seeing that tissue is found in tubercular cases even where the specific, recently discovered, micro-organism of tubercle is temporarily or persistently absent, its discovery in a sputum becomes of as great diagnostic value and help as the bacillus itself.

5. It cannot be too emphatically or too often asserted that quantity of lung-tissue in a sputum is a far more faithful prognostic guide than number or size of bacillary parasites. In hospital practice, where serial observations can be conveniently made, I have seen repeated examples of continuously high pyrexial symptoms with a minimum of bacilli, several microscopical fields having to be scrutinized before falling in with two or three of them. In such cases, which as a rule go to ground rapidly, there was always a plethora of shreds of tissue. Not that cases are unknown where there is high fever and a sputum crammed with bacilli, but what I contend for is, that here also elastic tissue will be plentiful, and will be a truer measure of the disintegration which is going on in the lungs than the numbers of the parasites.

PLATE I.

Scraping from surface of a laryngeal tubercular ulcer complicating lung-phthisis. The straighter course and less alveolar arrangement of the fibres (compare Plate V.), as well as their smaller diameter than those of pulmonary tissue, are to be noticed. Nothing was done to the scraping save spreading it out on the slide, and clearing with a drop of a thirty per cent. solution of potash before pressing down the cover-glass. Compare with Plate II.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Note.—*All* the Plates should be examined with the aid of a lens of low magnifying power. The magnifications are very correctly given, having been accurately measured with a stage micrometer.

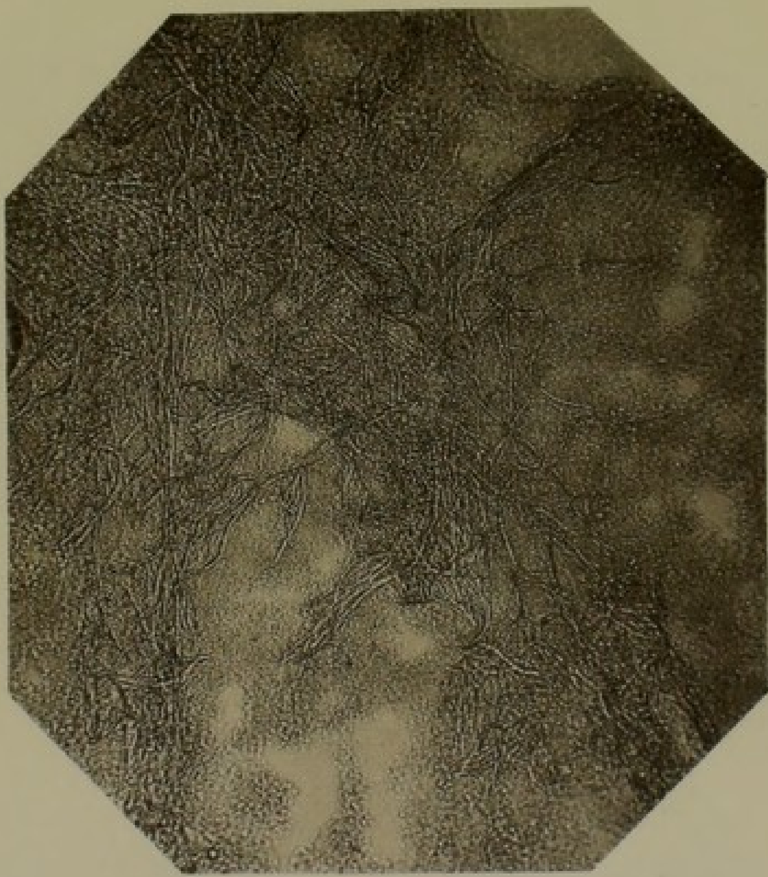
Pl

PLATE II.

Laryngeal elastic tissue from sputum of a case of non-tubercular ulceration of the inter-arytenoid region and mucous lining of the arytenoid cartilages. No pulmonary complication. Compare with Plate I.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Pl. L



H

PLATE III.

Pulmonary elastic tissue from sputum of phthisis. A very characteristic specimen; the cellular elements are those of pus.

Objective, Zeiss, C C.
Magnification, $\frac{125}{1}$

The negative from which this plate has been photogravured was taken by Mr W. Forgan from a preparation mounted by the author.

Pl. III.

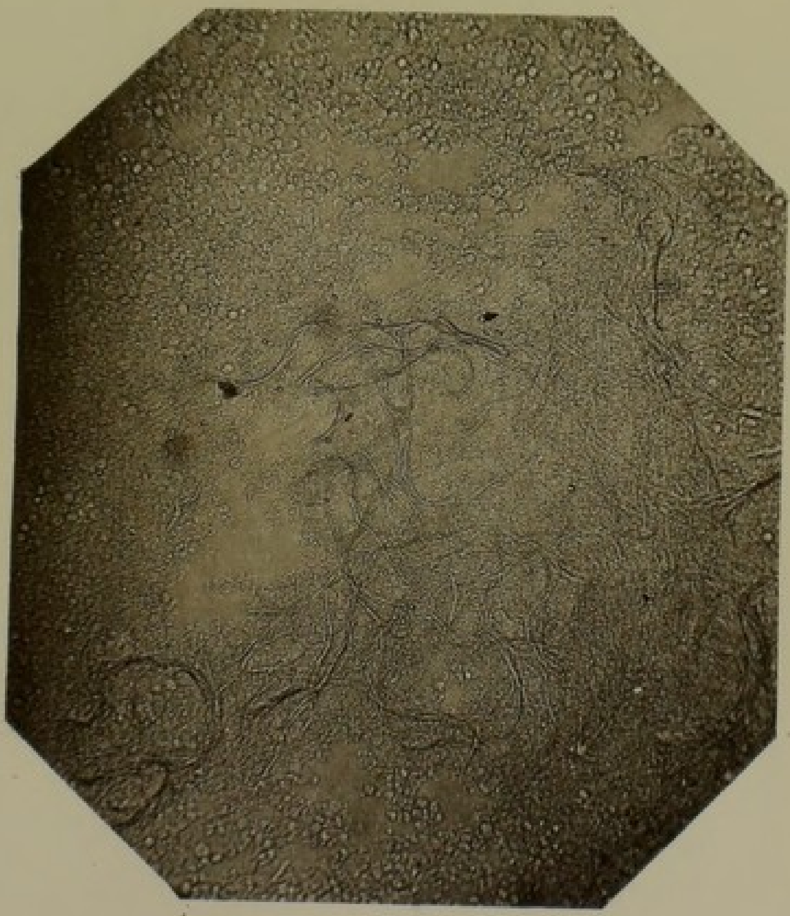


PLATE IV.

Another specimen of pulmonary elastic tissue, with pus cells.

Objective, Zeiss, C C.
Magnification, $\frac{125}{1}$

Mr W. Forgan's negative from preparation mounted by the author.

Pl. IV.

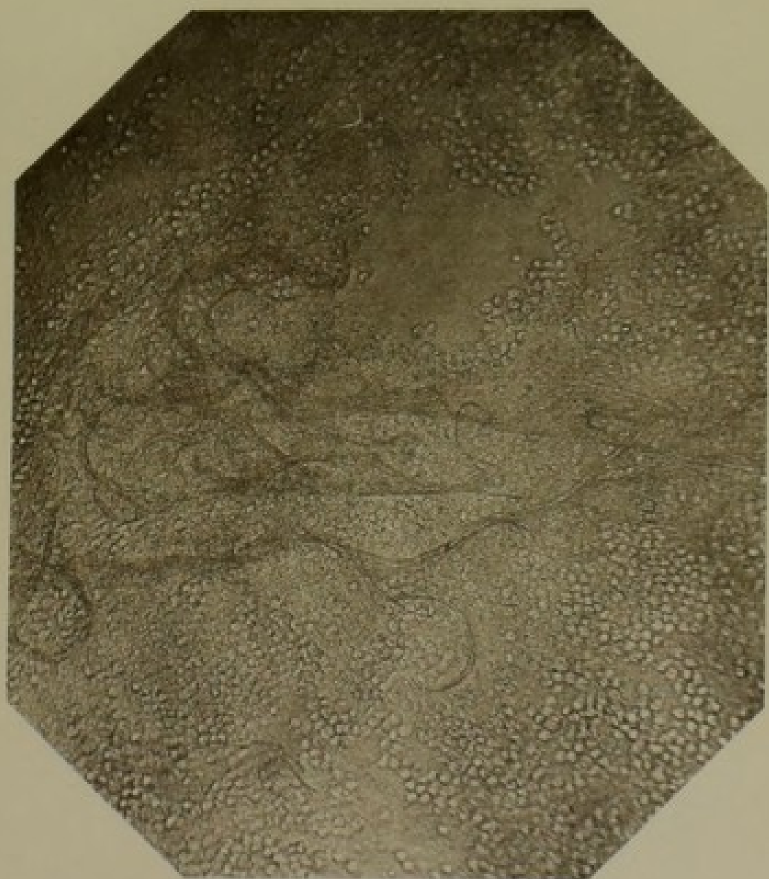


PLATE V.

A very large leash of pulmonary elastic tissue from the sputum of phthisis. The patient was taking a daily short walk at the time such masses were, not infrequently, expectorated. The alveolar arrangement of the trabeculæ and bands of the tissue is well seen.

Objective, Zeiss, D D.
Magnification, $\frac{150}{1}$

Mr W. Forgan's negative from preparation mounted by the author.

Pl. V.

PLATE VI.

Luxuriant specimen of *Leptothrix buccalis,* from sputum boiled in twenty per cent. solution of caustic soda. One not much acquainted with the subject might easily mistake this for elastic tissue; when compared with the preceding Plates the contrast, however, is sufficiently sharp and distinctive.

Objective, Zeiss, D D.
Magnification, $\frac{270}{1}$

Pl. VI.

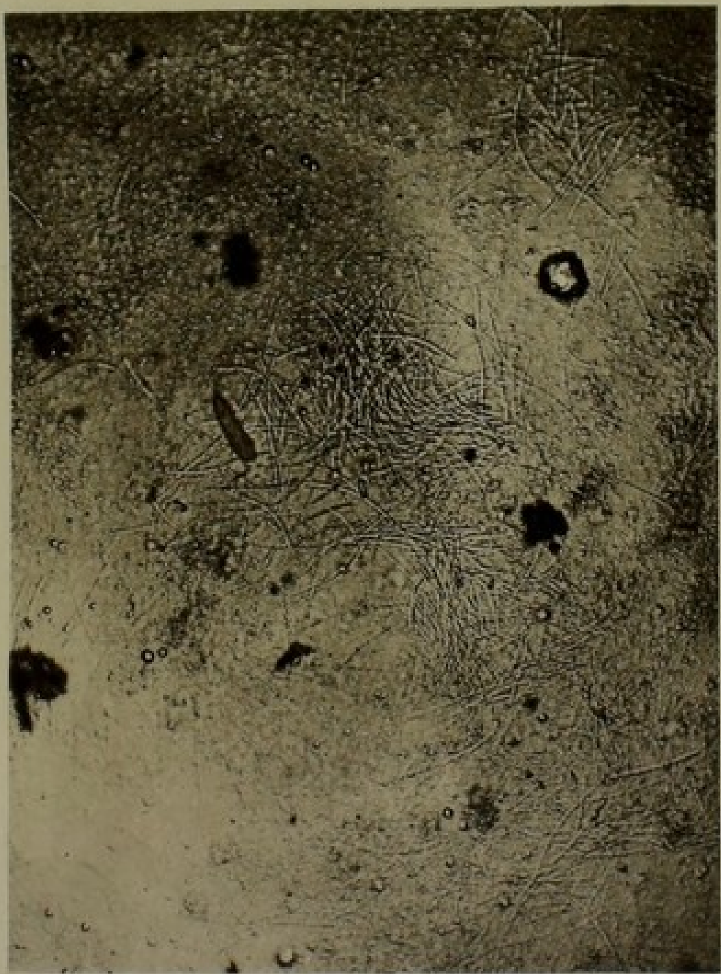


PLATE VII.

Mycelium of *Aspergillus fumigatus* or *flavus* (?) It simulates elastic tissue very closely; has the same network arrangement of fibres, and if the photo is examined with a magnifying glass this is rendered more evident. Cells of mucus or pus are scattered about, and in the upper right-hand corner are two or three ciliated and columnar cells.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

Pl. VII.

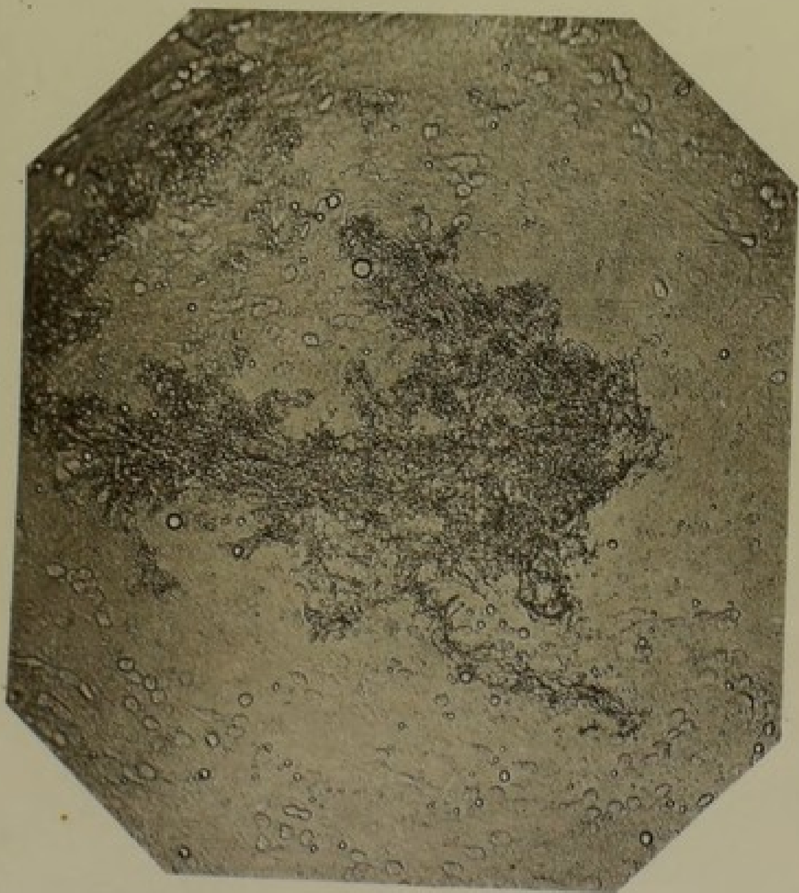


PLATE VIII.

Mycelial septate threads of a hyphomycete, *Penicillium glaucum*, a not uncommon spectacle in sputum, and having a slight resemblance to tissue.

Objective, Zeiss, D D.
Magnification, $\frac{270}{1}$

Pl. VIII

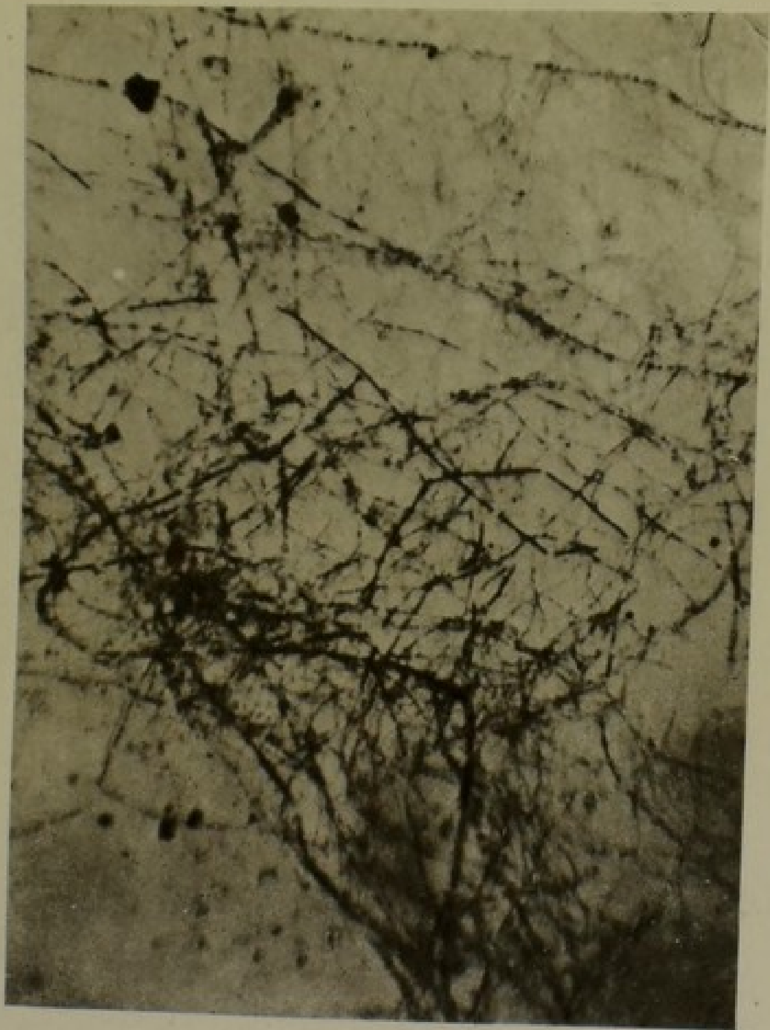


PLATE IX.

Mycelial septate hyphae and scattered spores of another fungus, probably *Oidium albicans*, often present in sputa, and apt to be wrongly interpreted.

Objective, Carey's $\frac{1}{4}$ inch.
Magnification, $\frac{80}{1}$

Pl. IX.

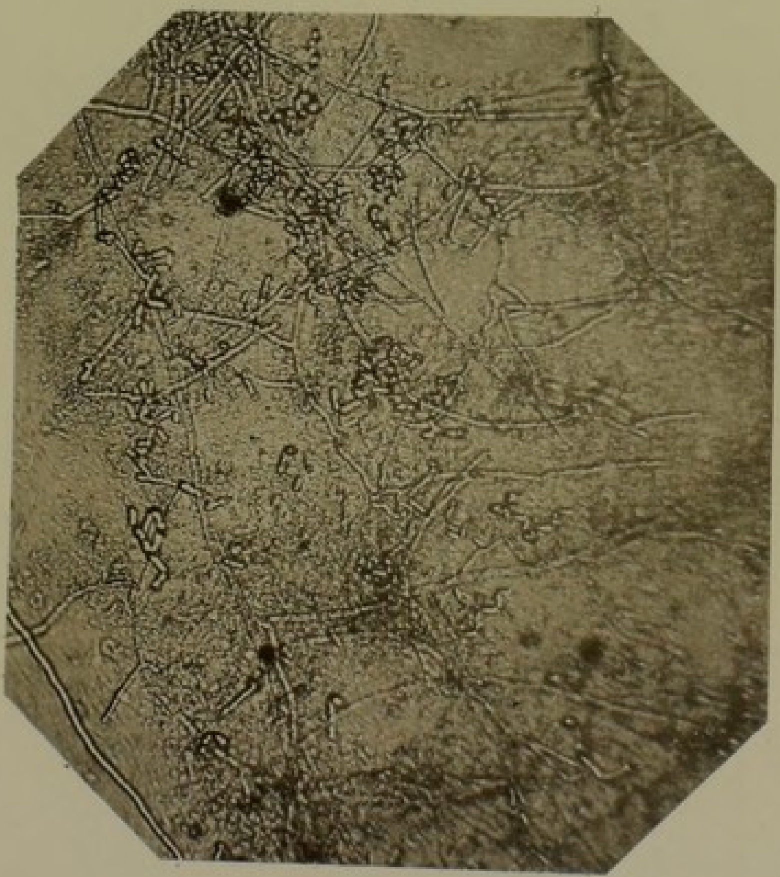


PLATE X.

Represents many of the extraneous substances occasionally found in expectorated matters. The upper half of the shaft of a dark hair, seen on the left side, lies over a large piece of vegetable epidermic tissue, which fills nearly half of the field of view. Its roundly-angular cells and ramifying bundles of spiral vessels are beautifully seen with the aid of a small pocket lens. There are also fibres of cotton, silk, and linen, and below to the right of the centre, and running perpendicularly, there is a conical bit of feather down, crossed near its upper end by a teased-out spiral vessel and a fibre of cotton. The vegetable tissue is probably tea-leaf.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Pl. X.

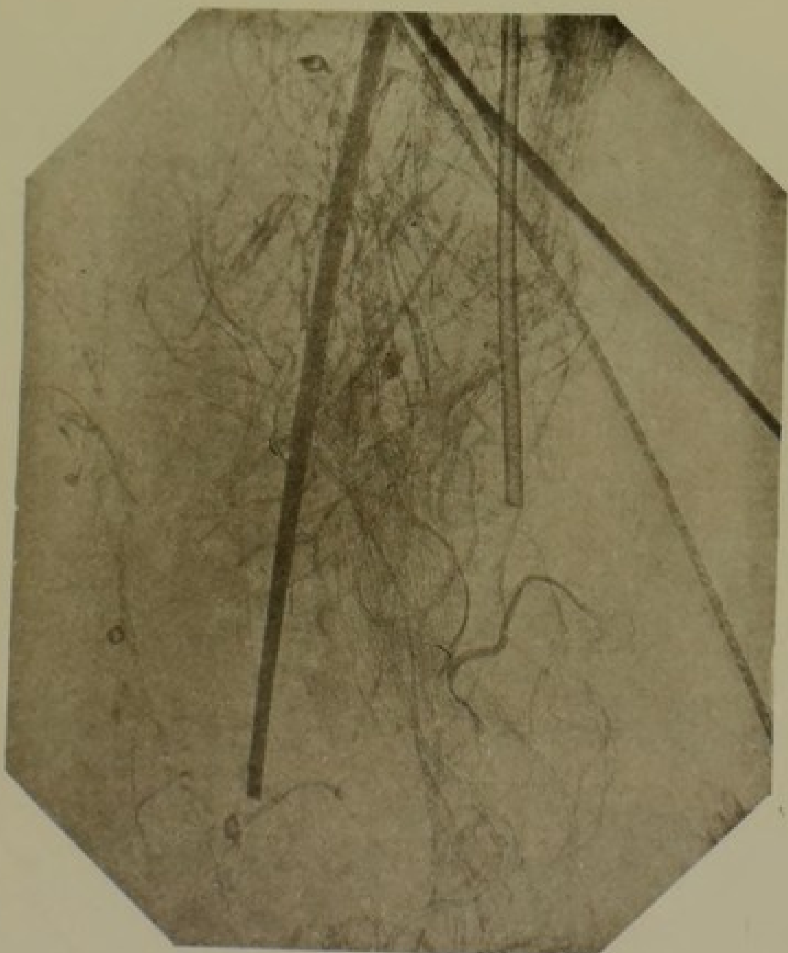
K

PLATE XI.

Reproduces, on a smaller scale than 10, hairs of animals from blankets or clothing, and fibres of varied kinds, some of which have a general resemblance in form or arrangement to the elastic tissue of lung or larynx, and which, when observed side by side with real tissue, cause no difficulty of identification, but when seen alone might occasion perplexity or error.

Objective, Oberhäuser, No. 3.
Magnification, $\frac{25}{1}$

Pl. XI.



CHAPTER IV.

Curschmann Spirals and Charcot-Leyden Crystals.

I. Curschmann Spirals.

Those strangely compounded spiral formations now to be noticed differ *toto cœlo* from the ramified bronchial coagula which Remak, *Diagnostiche und pathogenet. Untersuch.*, Berlin, 1845, rediscovered and found so characteristic, in diverse quantity in diverse stadia, of the croupous form of pneumonia. The bronchial moulds dichotomise, are not spirally wound, and although in most cases enclosed or merely covered over with granular cells resembling pus corpuscles, yet this sheathing is destitute of the elaborate plaitings and woven texture formed by the cylinder and spindle cells—the latter not unlike the formative cells of elastic fibres or connective tissue—which clothe the central core or alone make up a Curschmann spiral.

Potash or soda lye dissolves the spirals, as also happens with the bronchial casts; and it seems to me that the *core* of the spiral and the totality of the bronchial moulds consist of very much the same material. It is difficult to believe that the fibrine of the blood can pass unaltered through the walls of unruptured vessels and through the epithelial layers of the bronchioles; therefore an exudation of lymph, or, as will be suggested further on, a cementing together of desquamated cylindrical and ciliated epithelium by this lymphatic extravasation may be the stuff from which both central threads and casts are moulded.

It seems wonderful that those spirals, so conspicuous and strange in shape, should have been overlooked and left undescribed so long. Now when attention has been drawn to the matter, it is experiencing the two phases through which almost every new discovery passes: 1*st*, "There is nothing in it." When it cannot be hidden that there is something in it, phase 2*nd* comes on, viz., "Everybody knew it before." It is so easy to make an egg stand on end when one has been shown the way. It is perfectly true that spirals are not characteristic of any one lung disease, but it is no less real that wherever they are seen an inflammatory condition of the bronchioles, croupous, catarrhal, or both combined, may be diagnosed.

Leyden (*Virch. Archiv*, Band 54, S. 349) mentions and clearly describes those spirals without, however, entering closely upon their meaning or importance. Zenker also, in 1881, in the *Journal of the Erlangen Pathological-Anatomical Institute*, speaks of the sputum of a bronchial asthmatic which contained Charcot-Leyden crystals and peculiar exquisitely spirally twisted bundles of fibres, made up of fibrillæ also arranged in a spiral manner, and sometimes straggling over several fields of view when seen in their long axis, and having the appearance of concentric rings when seen end on. Curschmann of Hamburg, however, first in 1880 at a meeting of the Hamburg Medical Society, and more at length in 1883 in *Deutsch. Archiv für Klin. Medecin*, Band 32, made the subject his own, and handled it in so complete a manner that, by common consent, the spirals are known in Continental medical literature as the "Curschmann Spirals." In November 1885 the author had the pleasure of showing, at a meeting of the Medico-Chirurgical Society of Edinburgh, many photo-micrographs of the spirals in question, and then learned that very little was known about them in the Edinburgh Schools of Medicine.

Curschmann gives the provisional name of "Bronchiolitis exsudativa" to the well characterized form of disease in which they are so commonly found, and accounts for many cases of secondary nervous asthma by the pre-existence of this inflammatory condition of the bronchioles. Its type is seldom pure and uncomplicated; rather it is overshadowed and rendered difficult of recognition by manifold pathological phenomena, such as chronic catarrhs and emphysematous conditions of lung, either dry or with much muco-purulent expectoration. Phthisis is closely simulated where there have never been any asthmatic seizures, and where there have, it sometimes is the closing scene of the drama. Very recently I had the opportunity of seeing one patient, about forty-five years of age, who had his first attack of asthma under my care when fourteen years old, and now pulmonary elastic tissue and bacilli of tubercle are to be found in his, otherwise bronchiolitic, expectoration. What chiefly differentiates this bronchiolitis from other pulmonary diseases is the sputum. In different cases, or even in the same case at different times, the amount expectorated varies greatly,—from a daily teaspoonful or two to ten or twelve ounces. The consistence and colour of the sputa are also remarkable and almost distinctive. They are grayish-white or greenish-yellow or sea-green, and transparent and exceedingly tenacious, so that when a particle is pressed between slide and cover-glass it almost creaks; and when the pressure is relaxed its elasticity is such that it immediately shrinks back almost into its original size, and decidedly declines being spread out into a very thin film. This tenacity is the cause of its being very difficult to expectorate, and consequently a deal of frothy mucus accompanies it; and thus another peculiar quality is given to this sputum, for the froth will remain on the surface unaltered for days: it is the "*sputum valde spumosum*" of our forefathers. It is ropy and sticky, and so cohesive that the whole contents of the spit-box may be poured out in a long, stringy, unbroken mass, and one finds it necessary to use scissors to cut the stream across, and so secure a suitably-sized morsel for examination. If this is put on the slide and laid on a dark background, one can by the naked eye, or more certainly with a lens of low power, recognise balls and lumps of transparent mucus for all the world like grains of boiled sago, and sheaves of more or less transparent whitish or yellow threads twisted into corkscrew shape or other less spiral form. The length of these threads is very variable; I possess a photograph of one, 4 inches in length, expectorated by an elderly patient after one of his sudden asthmatic attacks which come upon him from outside causes, the nature of which it is not easy to settle. His dyspnœa is very painful to witness: the body and extremities become cold and cyanosed and bathed in perspiration; the rattling sounds in the chest are very loud and continuous, as if the bronchi were flooded with viscid secretion through which air passed with difficulty; and yet the number of respirations per minute is not increased, but rather the reverse, and the respiratory distress is much more of an expiratory than inspiratory character.

When examined microscopically certain curious formations are constantly to be found in such sputa, and Plates XII., XIII., XIV., XV., XVI., and XVII. may be looked upon as thoroughly representative of the class. The threads are seldom straight, but rather coiled and serpentine, meandering with many exquisite tortuosities through two or more fields of view, *cfr.* Plate XVII., in which the thread lies white and naked among granular debris and shadowy mucus and pus cells. Plate XIII., in which it is bare on the left and in the remainder of its course on the right, lies imbedded in a sheath of tenacious mucus, composed of round and spindle cells; and Plate XII., where the central core is seen winding with many kinks and bends through the whole length of its environing covering. Wherever this central thread is seen, it is composed of an apparently homogeneous, glittering, highly refracting, almost phosphorescent substance, which becomes dark when the focus is altered. The *locus nascendi* of this central thread must be in the very terminal bronchioles or partly in the alveolar passages, for occasional specimens are seen with clubbed infundibular moulds at one end.

Much looking at spirals has convinced me that a considerable part of the core is composed of columnar and ciliated epithelium, cemented by some fibrinous or albuminous material. A few of these cells get entangled by their curled or hooked extremities, *cfr.* Plate XX.; the nucleus thus formed, growing by accretion of new matter, becomes spun and twisted and kinked into a thread, which, as it is swept out of the finer lumen of the bronchioles under the united influence of the ciliated cells, unequal contractions of the bronchial muscles and, perhaps, also the diaphragm, doubles and twists in the line of least resistance, very much as a stiff elastic straw rope does in the process of its manufacture. Gradually forced forward and out of its parent tubule towards those of larger calibre, it acquires an outer casing of spirally arranged round and spindle cells, and this covering is, I believe, sometimes *an actual cast of the tubule;* for in this bronchiolitis the irritation must be very great, as the desquamation of the ciliated epithelium and deeper layers of the bronchial mucous membrane is enormous. Such epithelium is not very common in expectoration, even a large amount of catarrhal swelling being inadequate to cause its separation in any quantity, such as is found in every specimen of the sputum under consideration. Vierordt, Jaksch, and Pell say they have observed similar fibres in pneumonic sputum, spiral fibres with and without central threads, and also isolated central threads embedded in mucus and pus. With special reference to this question I have examined numerous pneumonic sputa, but have failed to find anything like the specimens represented in the plates. Possibly the cases which furnished those observers with their specimens were not pure and uncomplicated; the pneumonia may have been an epiphenomenon in a chronic bronchiolitic affection.

Frequently the chief spiral—the "Haupt-Spiral" of Curschmann—has no central thread, *cfr.* Plate XV., where the various strands and plaits of fibrils, composed chiefly of fusiform cells, are seen twisted into a very characteristic rope-like mass almost as transparent as the background on which it lies, and exceedingly difficult to photograph. Occasionally similar strands lie so deeply embedded in a thick detritus of finely granular matter, and round and spindle cells densely strewn with fine or large Charcot-Leyden crystals (to be presently spoken of), that they are hid from view and easily overlooked, unless the cover-glass gets an extra squeeze down; and not rarely the bigger spirals are blown out into ampullary dilatations containing air, and if these are numerous and alternate with portions free of air, a sort of beaded appearance is given to the whole spiral. At other times, *cfr.* Plates XIV. and XVI., the graceful sinuosities of the spirals gradually or suddenly cease. The fibrils composing them run a much straighter course; open out and show that the central thread is not a mere optical illusion; become so fine as to be almost invisible; re-unite, and again run with many windings and undulations, and perhaps end in a fan-shaped bundle or sheaf, the striæ composing which, of the greatest possible tenuity, may be moderately straight or very much zig-zagged, with short and sharp turns and angles. Plates XIV. and particularly XVI. show some of the phases mentioned above; and although particular examples differ much from each other, yet in their fashion and build and general outlines and root-idea, as it were, they all have very much in common.

Isolated threads may vary in length from ·001 to ·07 of an inch, and the "Haupt-Spirals," depicted on Plates XII. and XVI., measure respectively ·08 and ·16 of an inch. I have seen specimens which reached a length of ·5 of an inch. With a magnification of three or four hundred diameters, the smallest zig-zag examples seem homogeneous, but an immersion lens sometimes reveals that they are made up of twisted columnar or ciliated cells, and it seems not unreasonable to suppose that larger ones may be similarly agglomerated. It is, at least, curious that the ciliated and columnar cells have the same dazzling, glancing appearance, changing to dark contour when focussed at different depths, as the central core of the spirals. As previously remarked, the desquamation of such cellular elements in so-called bronchiolitis exsudativa is excessive, and Plate XX. gives a perfect representation of a cluster of them and of their fantastic and bizzare appearance as they show under the microscope; some of them tad-pole like, others cup, chalice, and goblet-shaped, as first described by Schulze, *Archiv f. Mikroscop. Anatomie*, Band 3, S. 192 *et seq.* All of them have highly refractive granular contents within their thecæ.

On standing for a few days in the expectoration dish or other containing vessel, the sputa of which I have been speaking, if not originally green in colour, always becomes so, and those green from the first become much more markedly so, and the supernatant fluid which has separated from the subsided denser constituents becomes a very dark green. What is the exact chemical nature of this pigment I do not know; it is not hæmoglobin modified by exposure to the continued influence of oxygen, for the occurrence is observed where no blood has been primarily in the sputum. Nitric acid shows that it is not biliary; neither is it due to the development of fungi, the coloration taking place in the coldest weather, and the microscope revealing no saccharo- or hyphomycetes.

When the fluid is treated with alcohol, a dirty white flaky precipitate falls down, and the pigment must be dissolved in the spirit as the filtrate has acquired the green tint. When this alcoholic solution is concentrated and a drop allowed to dry on a slide, various crystalline forms make their appearance.

1. Green crystals agglomerated into rounded drusy masses, which exhibit a tendency to split from centre to circumference into wedge-shaped pieces, the point of the wedge pointing to the centre. The individual elements of these wedges are also cuneiform—the broad end turned to the rounded periphery, the pointed end to the centre of the mass. Moving the cover-glass to-and-fro over the slide comminutes the concreted crystals, and cleaves them into their component rays. They show gorgeous hues by polarized light.

2. Perfectly circular, well-defined, greenish-brown or yellow bodies whose periphery is not smooth, but bristles with very delicate acicular crystals, of which the dimly transparent mass seems chiefly to be

composed. This form shows colours, but not so brilliantly as No. 1, by polarized light.

3. Large circular flat discs or rings with a cushion-like rim and of a pale oily lustre; in their interior a number of beads or drops arranged peripherally. No colours by polarized light.

4. The same rings, only having instead of oily drops in their interior one *central* tuft of closely-packed, radiating, needle-shaped crystals. Colours are shown by the central clump when the polariscope is used.

5. Spherules, colourless or yellowish, attached to each other sometimes in pairs in a cup-and-ball way, or having flattened sides from this connexion having been ruptured. They are often divided into three or more apparent sections by irregular cracks or lines radiating from centre to circumference. They do not polarize.

6. Plates of cholesterine diminutive in size and small in quantity.

7. Crystals, colourless, dendritic, ramified and rigid like leafless twigs, or foliaceous and star-shaped; neither sort polarizes.

8. Rounded, brownish, granular, non-transparent aggregations of pigment.

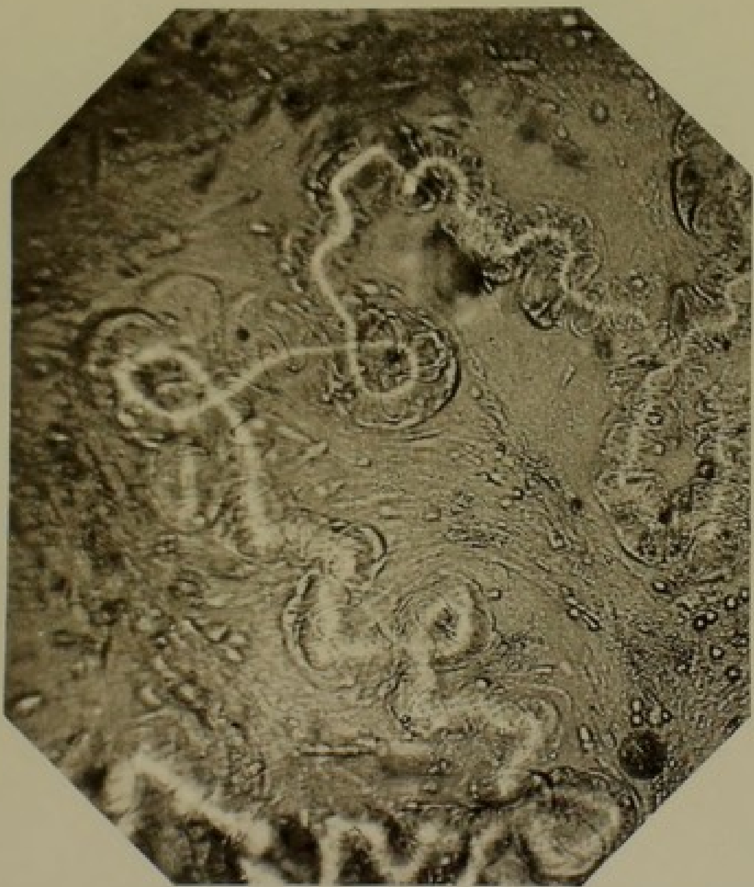
The *microparasites* of this spiral-bearing sputum are mainly of the coccal forms, and dispose themselves in a binary manner as diplococci, or form tetrads by the juxtaposition of two diplococci. Two sizes are apparent: 1. The largest with two oval-round elements are about 2·5 micromillimetres in the major axis, and half that measurement transversely. They lie arranged linearly in single or many files, but never so closely apposed as to form chains; or they are tumbled about irregularly or grouped into zoogloeic masses. The line of fission between the two component cells is very evident in some, and then both cells are round or oval; where the dividing line is not so distinct the two cocci are joined together in a cup-and-ball way, or both are somewhat flattened in their line of apposition. 2. The smaller diplococci are miniatures of the larger ones, gather into heaps alone, or commingled with the other kind, and have the faculty of coupling themselves into longer or shorter chains (streptococci), some of which are very graceful. They also assume a bacillary shape; not more than two diplococci unite and give the idea of a short, dumpy rod, which, in some of the samples of expectoration I have examined, is so abundant as to seem the only organism in the field; and where this is the case, enormous numbers of what I may call single diplococci, and out of which the short rods are fashioned, are also a striking characteristic of the microscopic view. Chromos 3, 4, and 5 give an idea of what is meant.

PLATE XII.

Quite a gigantic specimen of the chief spiral—the "Haupt-Spiral" of Curschmann. The many kinks and turns and windings of the tube, and the much-crossed and interlaced fibrils and spindle cells of which its walls are composed, come out pretty well. In this example the central thread is certainly nothing more than the lumen of the spiral, whose walls are too tough and elastic to admit of their collapse, either empty space or filled with air. The circular dark spot at right hand lower corner has been caused by a microscopic fault in the gelatino-bromide dry plate.

Objective, Carey's $\frac{1}{8}$
Magnification, $\frac{150}{1}$

Pl. XII.



M

PLATE XIII.

Another spiral. Running from right to left is a sheath of spindle and round cells, which, however, are not well individualized, the central thread, this time of solid matter, at first almost a straight line, but with a just perceptible waviness, then undulating more decidedly, turns sharply downwards, leaves its case, and is naked for the rest of its course. Pus and mucus cells are scattered about, and the dark rectangular bar in right lower half is the edge of an intrusive air-bubble.

Objective, Carey's $\frac{1}{8}$
Magnification, $\frac{150}{1}$

Pl. XIII.

PLATE XIV.

A spiral with central thread running partly naked and partly encased in a "Haupt-Spiral." At either extremity the core unravels itself into a leash of very delicate, twisted fibrils, and crossing transversely near the centre there is a long wavy riband of fibres which is the ending of the central thread of another spiral; on the left lower corner, where the riband begins, indications of its plaiting are clearly visible, and on the right it fines off into fibres so delicate as to be almost invisible. Many of the pus cells seen show their granulations very well.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

Pl. XIV.

PLATE XV.

A spiral without central thread and without lumen, its sides having collapsed. On the slide it showed very delicate and transparent, and its image is consequently not all that one would wish; however, the tangled crossings and recrossings and oblique interlacings of its constituent parts are very visible, and it is a sufficient model of one of the many aspects under which the spiral presents itself.

Objective, Carey's $\frac{1}{4}$
Magnification, $\frac{90}{1}$

Pl. XV.

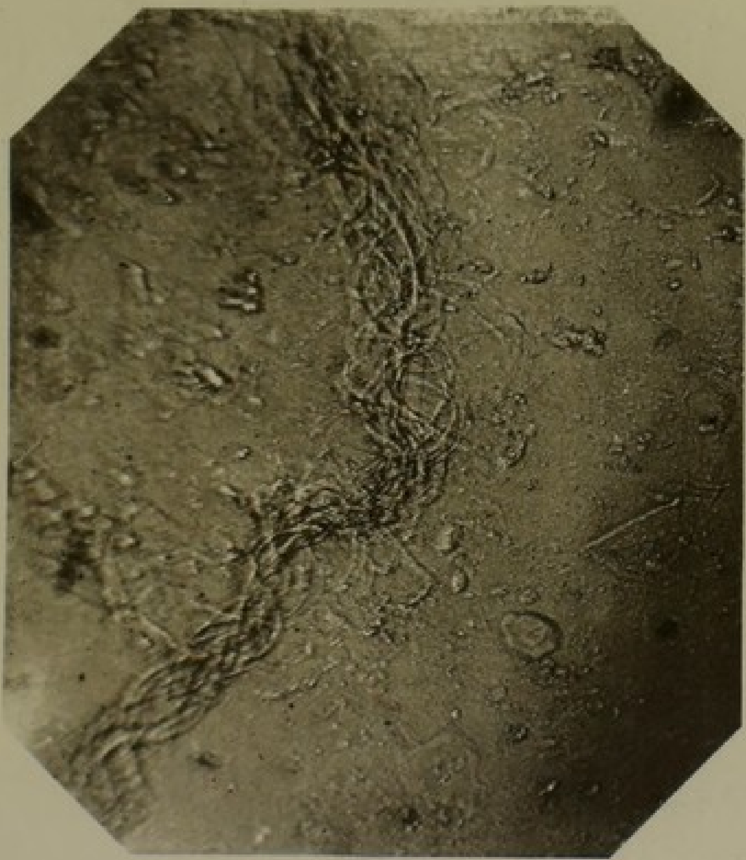


PLATE XVI.

Is an epitome of most that can be said about, or seen in Curschmann spirals. The specimen has the central thread and the sheathing, the latter in the upper part of its course embedded in a broad stratum of mucus. Following its course downwards the central thread gradually untwists and resolves into many separate fibres, which intertwine inextricably and inexplicably, and tail off into almost invisible tenuity, gather together again, increase in apparent numbers, form strands which coil around each other in many plies, and, after running a longer or shorter curvilinear course, again melt away and vanish from view among the surrounding cellular elements.

Objective, Carey's $\frac{1}{4}$
Magnification, $\frac{90}{1}$

Pl. XVI.

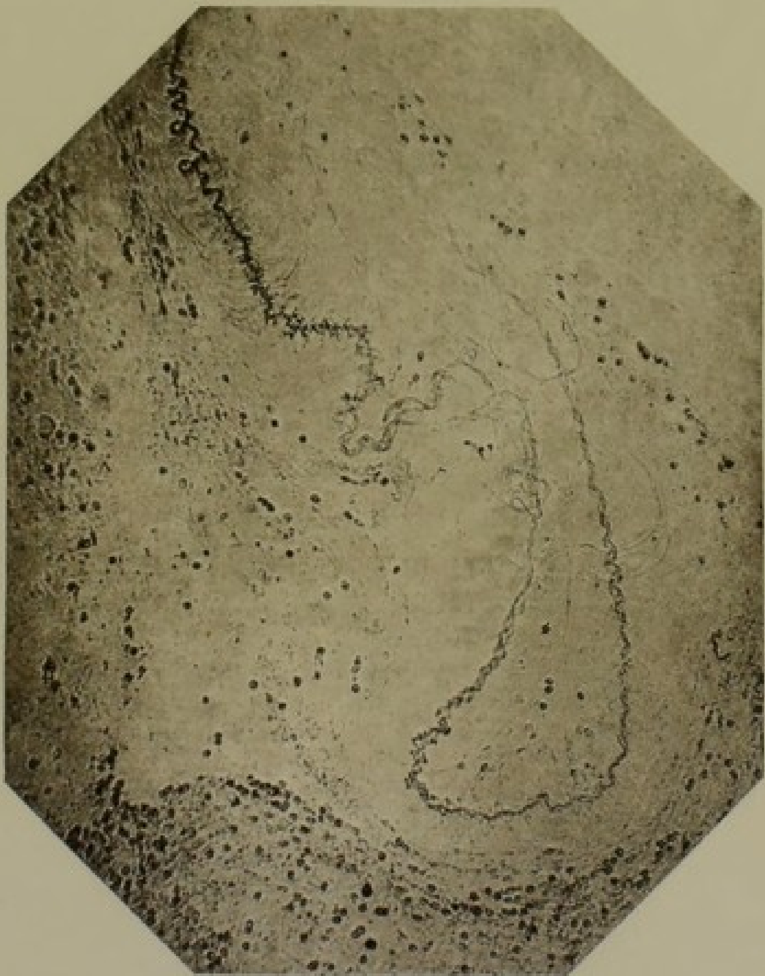
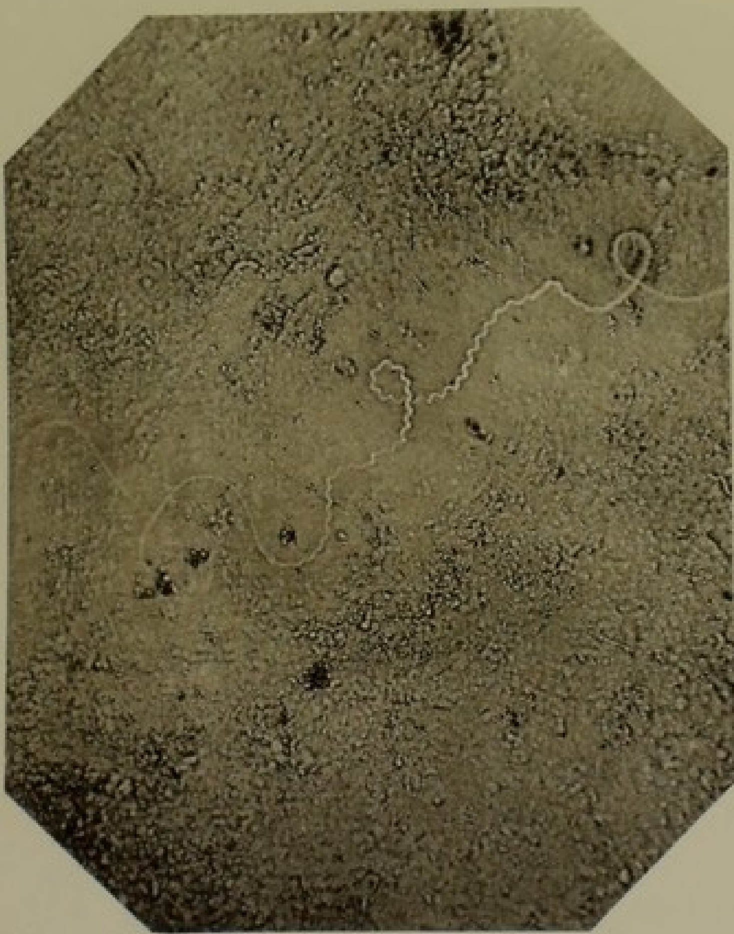


PLATE XVII.

A very slender, naked, central thread; the photograph shows scarcely the half of its original length; it was destitute of sheath through all its course. A low power lens will reveal many minute, shadowy, out-of-focus Charcot crystals lying among the cellular debris.

Objective, Zeiss, E.
Magnification, $\frac{250}{1}$

Pl. XVII.



II. Charcot-Leyden Crystals.

Another strange peculiarity of the expectoration under review is the presence in it of numerous (occasionally countless in the green-yellow variety) microscopic Charcot-Leyden crystals, in the form of very long and pointed octohedres, or of sharp or truncated fusiform bodies, varying greatly in size, a magnification of $\frac{220}{1}$, showing them as mere specks or as large as is represented in Plates XVIII. and XIX. They resist putrefaction for a long time, being sometimes as plentiful in sputum some months old as when it was fresh; they do not dissolve in chloroform or alcohol, nor do they show colours by polarized light. Their exact chemical composition is still a doubtful matter; Curschmann supposes that they are "Alters-produkte" of the regressive metamorphosis of the round and spindle cells among which they lie, and probably this is true of the most and of the smaller of them; but there is another source for the larger ones, and that is the columnar epithelium and spindle cells from which I believe them to be *directly* formed, the cell head undergoing a process of lengthening out, and the tail a sort of absorption or amputation, the result being the fusiform bodies so frequently truncated at one end as seen in the plates. As corroboration of this belief, it may be mentioned that the crystals are very highly refractile, or dark according to the depth of foccussing, just like the cells from which I believe they originate; photographs also in my possession show very evident transition stages between the two, and it is matter for regret that the expense of photogravuring the negatives is so great as to preclude their reproduction along with the other plates.

At the meeting of the Edinburgh Medico-Chirurgical Society formerly alluded to, I was assured by many present that, equally with the spirals, such crystals as occurring in sputum were quite new to many Edinburgh observers. They are to be found also in emphysematous and chronic bronchitic cases, but it is a mistake to say that they are most copiously present in the sputum of bronchial asthma, as I have seen myriads of them, and of all sizes, in a case erroneously supposed to be phthisical, and in which there never had been any dyspnœal seizures. This fact destroys at a stroke Leyden's theory that the sharp crystals, by irritating the peripheral ramifications of the vagus, might directly cause the dyspnœal attacks of bronchial asthma. Rather one might say that spirals and crystals together seem to bring about a mechanical blocking of the lumen of the finer bronchioles, and then spasm of the bronchial muscle comes on—perhaps in a supreme effort to get rid of the infarctions. The sudden transition from a feeling of well-being to the most urgent dyspnœa can only be explained in some such way, as also the sometimes equally sudden return to quiet breathing, without much expectoration, after chloral and hypodermic use of morphia. Cases where spirals are present in quantity without resultant asthmatic attacks may be interpreted by assuming limited extent of the diseased bronchial territory, and small irritability of the affected individual. While writing these sentences an exquisite example of asthmatic dyspnœa, which furnishes ample corroboration of the foregoing statements, has come under my observation. The sputum of the patient was of the boiled sago variety, and was scantily expectorated towards the end of the attack in the form of balls or ragged lumps which, when floated in water, reeled off, as if from a clew of yarn, thick beaded threads which contained many spirals without central cores; but not a single crystal was to be found, either in the expectoration immediately succeeding the attack or in that obtained some days afterwards. Another remarkable and constant feature of this patient's sputum, and well deserving mention here, was the presence of (*1st*), numerous, isolated, caudate, highly refractile spore-like globules, having a diameter of ·04 of an inch, sometimes having creeping amœboid movements; and (*2nd*), bunch-of-grape-like clusters of rings and discs, all with an oily lustre; or (*3rd*), asymmetrical plaques of discs and annular refractive masses, the component rings of which, adhering or fusing together in parts only of their circumference, gave the whole plate the appearance of chain mail; or (*4th*), there might be droplets of indeterminate figure very like the myelin drops of nervous tissue; all of which appearances were presumably owing to a myeloid or colloid change in the cellular elements of the expectorated phlegm. I have in my possession a silver print, from a negative taken in October 1885, of the first-mentioned curious sporoid bodies.

To summarize: The following propositions seem legitimate deductions from the preceding statements:—

1. A sputum containing spirals alone or crystals alone, or a combination of the two, is not pathognomonic of any one specific lung disease.

2. Charcot crystals may be present in very great abundance without causing, or, more correctly, being accompanied by any asthmatic attack. Conversely, very severe seizures may happen, and not a single crystal be demonstrable in the expectorated matters.

3. Spirals are never-failing constituents of asthmatic sputa, and help to bring on the paroxysms in a simple mechanical way.

4. In very many, one may say all of the cases furnishing crystaliferous and spiraliferous sputum there is also associated a great desquamation of the ciliated and columnar epithelium of the bronchioles. As the attachment of such epithelium to the mucous membrane is of a very intimate character, a great amount of inflammatory irritation must be present to bring about so excessive a separation.

5. Where a sputum contains spirals and crystals the presumption is strong that it does not come

from a tubercular disease of the lung, however closely simulated such an affection may be. That this is not absolutely true the case formerly alluded to demonstrates, but in it phthisis was not primary, but supervened after long years of bronchiolitis.

6. This phthisical issue may not happen even after the lapse of twenty-five years. I have recently examined, with a negative result, a sputum for tubercle bacilli and elastic tissue in a case which was known to me as long ago as 1861. The sputum is spiral and crystal-bearing, and no doubt has been so from the time the patient was first seen by me.

PLATE XVIII.

Represents Charcot-Leyden crystals lying embedded among pus cells. A low power lens should be used to scrutinize the plate, and bring into better view the shadowy indications of crystals—very minute some of them—which are not in correct focal plane; examples truncated, sharp at both ends and fusiform, are scattered about. The patient from whose spit the photograph was taken never had any asthmatic seizure.

Objective, Zeiss, E.
Magnification, $\frac{220}{1}$

Pl. XVIII.

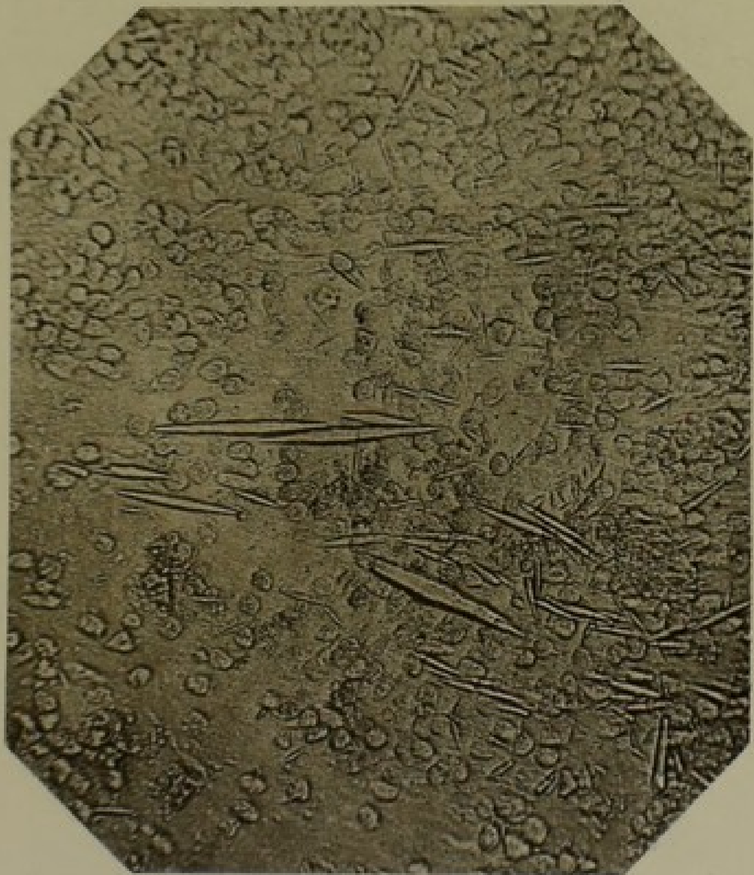


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PLATE XIX.

Another and even better and richer, so far as numbers are concerned, specimen of the Charcot crystals. The lens will show a few truncated samples which look very like transformed ciliated cells. The patient from whose richly crystalophorous sputa the photograph was obtained, like the one previously mentioned, has not as yet had any dyspnœal attacks.

Objective, Zeiss, E.
Magnification, $\frac{220}{1}$

Pl. XIX.

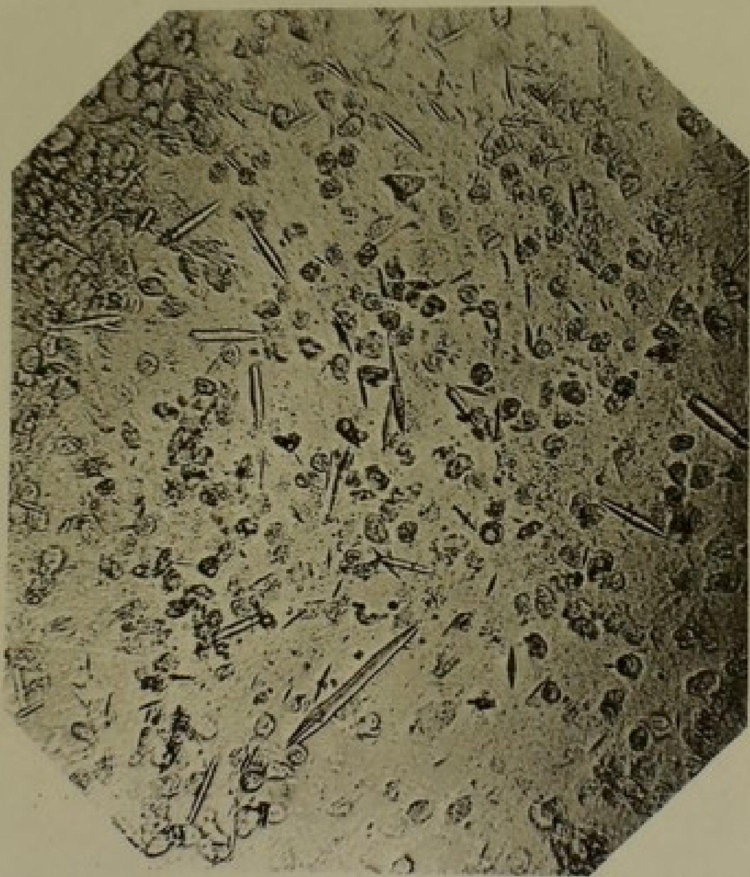


PLATE XX.

A characteristic group of ciliated columnar epithelium from bronchiolitic sputum. The cylinders show their ciliæ gathered into a point, or agglutinated into one or more horn-like processes; the caudal extremity is generally prolonged into a slender filament bent on itself, sharply or comparatively straight. The elongated rounded nucleus, and also the granular refractile contents, are seen in them all. It is a singular fact that, although the mucous membrane of the air-passages, with the exception of the vocal ligaments which have squamous epithelium, is lined from the base of the epiglottis to the finest bronchioles with those ciliated cylinders, there should normally be so little desquamation of them; and that even in disease of the respiratory passages *extensive* detachment of them should be so rare a phenomenon, the cells remaining uninjured and adherent beneath puriform or even croupous exudations. When unstained the cells are very difficult to photograph, owing to their refractive index differing so slightly from the background and to their very delicate structure; and when stained—at least this is true of yellow—the dry plate does not give good results as to detail. There is much shedding of those cylinders in obstinate apical catarrhs, the morning sputa of which always contain examples; and initial phthisis has also comparatively large numbers of them in its starchy, transparent, viscous morning expectoration, and their presence should make one suspicious of more serious disease than appears on the surface.

Objective, Zeiss, E.
Magnification, $\frac{250}{1}$

Pl. XX.

CHAPTER V.

Bacillus of Tubercle.

HENLE's doctrine of "contagium vivum" awakened scientists to the idea that infectious diseases were possibly the result of the introduction of living organisms of animal or vegetable origin into the diseased body. This has now passed from the region of conjecture to that of actual knowledge. Improved microscopical appliances, new methods of staining, and pure cultivations of bacteria, have, in the hands of many observers, cleared the subject of much that was doubtful and controversial, and rendered bacteriology much more satisfactory as a study.

Hitherto the most important outcome, from the physician's point of view, of bacterial research has been the demonstration, made independently and almost simultaneously by Koch and Baumgarten, that the pathogenic agent of tuberculosis is a specific bacillus differing from almost all other bacteria in size and form, and in its chemical behaviour with staining agents. Koch, by his famous inoculation experiments and ingeniously contrived and consummated pure cultivations, proved beyond the possibility of doubt that the tubercle bacilli alone, without aid or co-operation of any other constituent of the tuberculous substance, was able to engender genuine tuberculosis; and Baumgarten (*Centralbl. f. d. Med. Wissensch.*, 1883, No. 42), by his anatomical-histological observations of the march of events in tuberculous infections, has in an equally convincing way confirmed the proposition that it is exclusively the bacilli contained in the tubercular materials which have power to call a tuberculous process into being; in fact, his affirmation is, "Without tubercle-bacteria no tuberculosis; without tuberculosis no tubercle-bacteria."

In the series of mutually related and dependent facts, with which Koch's researches have made us acquainted, there was left a hiatus, which, though not prejudicing the correctness of his conclusions, did yet interrupt the sequence of his scrupulously exact arguments and reasonings. His demonstrations of specific micro-organisms in the diseased tissues and his pure cultivations were beyond cavil, and infected the creatures on whom they were inoculated, but he had not analyzed and dissected the component stages of the infective process, and it was not firmly established *how* the bacilli, which had in one way or other smuggled themselves into the tissues, displayed their poisonous influence on the cells, and the share these latter had in the formation of tubercle. Baumgarten (*Ueber Tuberkel und Tuberculose*, 1 Theil, Berlin, 1885) has taken up this part of the subject, and so handled the histogenesis of the tuberculous process, the fringe of which had scarcely been touched by other investigators, as to settle many important points in a clear and convincing manner.

He inoculated rabbits in batches of eight or ten simultaneously and with the same bacilliferous material, in the anterior chamber of the eye, the classical terrain for such experiments, and then the globes, in determinate intervals, were successively removed from the living animal and examined. Baumgarten incidentally remarks that, as his rabbits were of the most various bodily constitution, big and little, strong and weak, fat and lean, old and young, *individual disposition has not the very slightest influence on the development of the tubercular process in so far as this is called into existence by bacilli endowed with great virulence, and suddenly invading the tissues in great numbers.* In this manner the stages, as it were, of the road taken by the bacilli as carriers of disease were solidly established, and the comparison of a series of preparations in their proper order showed in successional course, and step by step, what a *post-mortem* discloses only in a slump sort of way. The bacilli increase in numbers first in the inoculated spot, swarm out from this primary breeding-place, invade the granulation tissue of the recent cicatrix, and, even as early as the sixth day, multitudes of them encroach upon the otherwise undamaged tissues of the cornea and iris, where they lie partly *free* in the intercellular substance, partly enclosed in the *fixed tissue-cells, never in leucocytes.* The advancing parasites then form rounded tufts or nests, the beginning of tubercular nodules which are microscopically visible about the tenth day; new swarms migrate again from them, forming new nodules; the lymphatics of the ear and lower jaw are attacked, and the more distant infections, such as the kidney, are brought about by the circulation. Immigration of bacilli is everywhere and always the first event, tubercular alterations of the tissues follow after a very distinct interval. These experiments, which are really of the nature of pure cultivations in the living body, decisively prove, if more proof were needed, that the bacilli themselves contain the virus which stimulates the tissues to the formation of tubercle. In what way all this falls out, what tissue-cells first react, and *how* they react against the pathogenic irritation of the parasite, may be read in the text and seen in the beautiful illustrative plates of Baumgarten's recent work.

Koch has formulated three criteria which must be satisfied before the doctrine can be accepted, that a specific organism is the cause of a specific infectious disease. They are:

1. There must be microscopical demonstration of a morphologically well-characterized micro-organism in the morbid tissues.

2. A pure cultivation of the organism found must be made.

3. This cultivation must be inoculated on a susceptible animal, man or brute, and reproduce the original malady and the same organism.

This tripod of postulates has been rigidly satisfied in certain cases, but in some, one or other of those cardinal points has remained unsolved. Among parasitic microbes representing the highest degree of parasitic adaptation (de Bary's strictly obligatory parasitism "*Streng obligater Parasitismus*"), it may be possible to demonstrate the organism, while pure cultivation or inoculability of it may totally fail, or the latter may only succeed on a limited number of animals; or again, a bacterium may possibly be pathogenetic, pure cultivations of it may be successfully made, but inoculation cannot be carried out because susceptible animals are not to be found. Happily bacillus tuberculosis responds to all those fundamental tests: it is present in a specific disease, it can be cultivated, and when inoculated unfailingly generates an authentic disease in no wise differing in its anatomical and clinical traits from tuberculosis acquired spontaneously, and is further legitimated, as Baumgarten (*Zeitsch. f. Klin. Med.*, Band vi. H. 1. S. 1–2) first pointed out and emphasized, by the occurrence of caseous degeneration of its tubercular products in the last stadium of their existence.

Sceptical onlookers may and do say, some other pathogenetic substance perhaps adhered to the inoculated material, and the actual infective virus might reside in it and not in the bacilli, which they look upon as mere attendants, but admittedly constant ones, of this infective process. This extra-bacillary hypothetical infection-stuff seems so bound to the bacilli that only with and through them can it arrive at efficiency, in fact it and the bacilli are identical. The same objection could be made to artificial cultures of the bacilli because, just the same as in the animal body, this suppositive infectious matter might cling to, and multiply with the bacilli *ad infinitum* in the nutrient media employed.

To take a very common manifestation of tubercular disease, lung phthisis, which alone is responsible for one-seventh part of the mortality of the human race, some deny altogether that it is primarily a mycotic process; they say that first of all there are in the lung tissue chronic inflammatory infiltrations, of themselves innocuous and non-specific, which afford to the ubiquitous parasite, incapable of development in the normal lungs of normal individuals, the possibility of settlement and propagation, and thus benign lung affections are converted into the virulently fatal processes of strictly tubercular phthisis. This sceptical spirit is dying out, and Koch's bacillus is now believed by many who once doubted to be the *causa causans* of phthisis, and its manifold lesions; the search for its presence in the sputa, looked upon as a craze not so long ago, is already taking a prominent and proper place alongside of auscultation and percussion as a supplemental and trustworthy help to diagnosis, and should be carried out by all who are not intrepid enough to offer an exact opinion before exhausting every means of investigation, however novel or apparently troublesome these may be. But really not much time or trouble is needed for the process, and what is unavoidable can be much minimised by an orderly way of going to work: the prepared cover-glasses can be swum on the staining fluid and left—they want no watching, and take no harm from prolonged soaking—till leisure is found to complete the other necessary manipulations.

The tubercle bacilli are tiny, motionless rods, $1\frac{1}{2}$–$3\frac{1}{2}$ or even 8 micromillimetres long (when the length is so much two are probably joined together), or in a general way one may say from a half to a quarter of the diameter of a red blood-corpuscle in length: their diameter or breadth, which never seems to vary, is exceedingly small, so that their build is very slim and graceful when lying isolated, but when cohering in twos or threes their conformation seems somewhat coarser. They have rounded ends and are straight or slightly curved, or quite sharply bent, and occasionally in the more lengthy examplars, so warped as to give indications of a screw form: most of them are beaded, and thus have a contour which is crimped and ridgy-looking. The separate dots or beads or cell elements of which they are composed may number roughly 3 to 6 or 8. Spore formation takes place in the animal body, and causes the appearance of bright vacuoles in the rods, and as their individual joints retain their cohesion, spore-containing bacilli, when stained, are visible as dark threads barred by clear egg-shaped spaces. When bacilli are very abundant in sputa they form A or V or Y-shaped clusters, or every conceivable combination of straight lines not unlike Chinese alphabetical characters; or they lie about in strata like spills at the end of a game of spillikins; or they assume shapes resembling the marks which masons notch on their hewing tools for purposes of identification; or they may be so densely packed as to make up a jungle of sheaves and faggots and circular colonies of all dimensions, round the free edges only of which the bacillus-form is recognisable, *cfr.* Chromo I., Figs. 1 and 2.

Koch and his disciples regard the sputa of consumptives, delivered in the aggregate in such enormous quantities, as the head source of the continuous transmission of their malady. Rich in bacilli and spores, and expectorated everywhere, they have ample opportunity of drying up and pulverizing, and of thus getting wafted ubiquitously through the air, and so reaching the lungs, whether healthy or diseased, of mankind. Seeing that this is the case, it is a little strange that the percentage of those who sicken and die of tubercular maladies is not larger than it is; perhaps healthy lungs with sound epithelium deny power of ingress of the bacilli to their tissues, or if they do penetrate, perhaps they become encysted, or the healthy cells or blood or tissue-juices are chemically so constituted as to destroy or starve the intruders. There still reigns much that is enigmatical in this struggle of cells and bacilli for existence, and no one has yet given an unexceptionable explanation of the preponderating occurrence of cerebral and intestinal tuberculosis in children and of pulmonary in adult life.

It is fortunate that the bacilli do not propagate at all, *or only very slowly*, outside of the animal body, at least in our latitudes and under natural conditions; they belong to the category of de Bary's "strictly obligatory parasites," that is, the completion of their entire evolutional career can only take place naturally in a parasitic manner and in a living body.

The bacillus has strong resistant powers against external noxious influences. It bears without being killed a temperature very near the boiling point. Koch has successfully inoculated bacilliferous sputa 186 days old, and it thus withstands putrefaction for a very long time. In a sputum fourteen months old, which must have been putrescent over and over again, I have easily demonstrated its presence intact in form and in capacity for imbibing staining fluids; not only that, but Dr A. Edington, in Professor Chiene's University laboratory, has made a successful cultivation for me of this same sputum. Incidentally this shows what nonsense it is to spray Bacterium termo into phthisical lungs, and the foolishness of speaking of cures or ameliorations as the result of such treatment. I have said the bacillus is ubiquitous; it almost seems that it is also sempiternal. Through the kindness of Dr Joseph Bell, I have seen Dr Vincent D. Harris's pamphlet *On the Presence of Tubercle Bacilli in Old Specimens of Diseased Lungs.* He has demonstrated their presence in sections of preparations which he was remounting for the museum of St Bartholomew's Hospital—the youngest specimen dated from 1846, the oldest back to 1812. All examined were at least 40, several probably 70 years old, and the search was almost in every case, ten or twelve in number, successful.

Koch has established that the bacillus can grow in a pretty wide thermometric range — 82°·4 to 107°·6 F., but its temperature optimum lies between 98°·6 and 100°·4 F. I have come to believe that it also multiplies in spit-bottles at ordinary chamber-temperatures. Outside the living animal body, it thrives best on the solidified blood serum of such animals as sheep and cattle. It is also curious that the serum of dogs may be utilized for purposes of cultivation, although the canine race is rather refractory to the induction of tuberculosis.

In examining sputum for diagnostic purposes, the cover-glasses, if they have been in use before, should be purified thoroughly by prolonged immersion in sulphuric or nitric acid, and subsequent washing in absolute alcohol or methylated spirit. By this means all adventitious fat, which might cause the film of sputum to scale off while tarrying in the staining fluid, and all accidental bacteria whose presence might complicate or falsify diagnosis, are effectually removed. It is evident, also, that the needle or scalpel, or whatever instrument is employed in spreading the expectoration, should be heated red-hot before it touches the discharges of every new case; in fact, I always heat the needle immediately before using it, and this is perhaps the safest way to go to work. To obtain an average specimen of the sputum to be scrutinized, it is well to pick a portion here and another there, to mix them thoroughly, and from this blend to select the particle to be spread by needle if preferred; or by placing it between two cover-glasses, pressing them together, removing by blotting paper the superfluous stuff which exudes round the edges, drawing, *not lifting*, them asunder, when the opposed surface will be left smeared with a desirably thin film of the suspect. Obtained in this way or that, the film should be allowed to dry thoroughly, protected from dust in the air of the room, or, if desiccation is to be hastened a little, the glass may be held high above the flame of gas or spirit-lamp, the armed side, of course, uppermost. If heat is too rapidly applied, the albuminoids, not being yet dehydrated, will infallibly coagulate, and, instead of being homogeneous and transparent, as they should be, will become opaque, and precipitates will form when the staining solutions are added. To fix the albumen securely, and to bake the sputum to the cover-glass, so that its dropping off will be rendered impossible, the glass, after perfect drying and with its free surface undermost, should be slowly drawn three times through the Bunsen or spirit-lamp flame. By so doing, Koch has shown that the bacterial forms are not in any way altered, that the albumen becomes insoluble, and that no precipitates, on addition of the stains, will obscure either the preparation or the proper interpretation of it. A good deal of what I have said may seem to some to be trivial and repetitive, but attention to the minutest details will save disappointments and the miscarriage of not a few preparations.

The preparation thus air-dried and passed thrice through the flame is now ready for staining, and most workers agree in saying that methyl violet and fuchsin are, for intensity and permanence of results, best adapted for the coloration of the tubercle bacillus. It is matter for regret that the colours do fade after a time, which is longer delayed if the mounts are kept in a dark cabinet, but I find that unmounted cover-glasses, exposed to diffuse daylight and what sun might be going, week by week lose some of their original vividness, till in six weeks to six months scarcely a bacillus may be visible. Of the two colours named, I am inclined to give the palm to methyl violet, which fades last and least both in light and in darkness. I have just carefully inspected two specimens of richly bacilliferous sputum of the same patient mounted on the same day, now a year ago. The methyl violet mount is quite unfaded and fresh, the Gibbes' magenta one much less so, and, strange to say, a third one stained by Gibbes' double stain is perhaps the least faded of the three; a fourth one stained with fuchsin, after Koch's plan, and now eighteen months old, is still permanent, but exhibits symptoms of beginning decolorization.

This want of permanence of the stain is brought about by several factors. 1. A reducing action on the aniline bases is exercised by the media used for clearing up and mounting. Clove oil, turpentine, and balsams dissolved in chloroform and turpentine, are dangerous to the durability of the colouring. Cedar oil to clear up, and the benzol-xylol series of hydro-carbons to dissolve the resin used for mounting, are preferable. 2. The acid nature of the balsam, which forms new and colourless combinations with the aniline dye. 3. The residuum of the acids used to decolorize the preparation, and so to differentiate the tubercle bacillus from other microbes. 4. The alcohol used to dehydrate must also be credited with not a slight influence in effecting the gradual fading of the specimens. Should this bleaching have attained such a degree as to render the preparation worthless, and if it is one which it is thought desirable to conserve, it can be re-stained by liquefying the balsam in which it is embedded by gentle heat, lifting the cover-glass, and allowing it to soak for twenty-four hours in oil of turpentine; then it is transferred for other twenty-four hours to absolute alcohol, taken out, and put through all the staining processes it underwent at first. The result will be equal to its first estate.

When the staining solution is not heated for the mere sake of speed, and when the glass is left to soak for many hours, twelve or more, a much more stable and enduring tint is obtained, and in all cases of doubt or difficulty, and where bacilli are not numerous, this plan of prolonged steeping in a cold solution is to be recommended; or the aniline water may be warmed to boiling, poured into a watch-glass, and the proper quantity of the saturated alcoholic solution of the dye to be used added drop by drop. Not only has one in this way all the benefit to be obtained from heat, but the warm aniline takes up a more considerable quantity of the stain, and the protracted soaking counselled above will be sure to tinge any bacillus in the film.

I usually employ solutions of fuchsin or methyl violet as described by Koch (*Mittheil. a. d. Gesundheitsamte*, Band ii.) The formula is as follows:—

Saturated alcoholic solution Fuchsin or Methyl Violet,	11
Aniline Water,	100
Absolute Alcohol,	10

The aniline water is made by agitating thoroughly and frequently together 5 c. cm. of pure aniline and 100 c. cm. of distilled water. At a temperature of 60° F. about 3 or 4 parts of the oil will be dissolved, the remainder sinks to the bottom of the vessel in largish drops. After an hour or so the solution is to be filtered, the filter paper being moistened first with distilled water. The filtrate must contain no suspended drops of the aniline; if it does the operation must be repeated till absolute clearness is procured. Aniline water is a very unstable solution, and when wanted should be freshly made, or about 5 per cent. of alcohol may be added, and thus its durability secured. It is a mistake to prepare too much of the solutions at a time: they are constantly prone to decomposition, even in the dark, need filtration before using, and one is tortured with the apprehension that their staining powers may have been lost, especially if the result of an examination is negative. For the statical comfort and security of my own mind I have now for a long time made the aniline water freshly, every few days, and to 10 or 11 drops of it in the watch-glass I add 4 or 5 of the saturated alcoholic methyl violet or fuchsin solution (which keeps indefinitely long if the stoppered bottle has a crystal of thymol in it), quite a sufficient quantity for one cover-glass. In perplexing cases and with negative results of staining, I am in the habit of making a control experiment by using the undoubted bacilliferous sputa, which I always have at hand, and swimming a cover-glass prepared from *them* on the fluid which has failed to demonstrate the bacillus in the case under examination, so that absolute certainty is thus attained that the staining power of the solution is unimpaired.

The solution being thus prepared, the cover-glass, with its armed side undermost, is held lightly between the thumb and index or middle-finger, and dropped flat and level on the surface of the fluid so that it may swim: very simple and easy to do till one has tried. Either air-bubbles are left below, which would of course prevent the coloration of the film where they were, or the glass slowly disappears beneath the surface. Air-bubbles may be removed by floating the glass to the side and gently raising its edge till the air is liberated, and then letting it down as gently again on the surface. To prevent evaporation the watch-glass should be covered either with another, or with one of the handy glass dishes or capsules used for washing and section-staining.

When the preparation is believed to be sufficiently stained, the differential diagnosis must be made between the Koch bacillus and the other bacteria among which it lies. This is managed by using chemical reagents which extract the colour from the cells and nuclei and accompanying schizomycetes, but which the tubercle bacillus withstands. Such chemicals are:—1. Other aniline colours (vesuvin by Koch); 2. Acids (nitric by Ehrlich, muriatic by Orth, sulphuric by Neelsen, glacial acetic by Petri, who says, and therein is corroborated by B. Fränkel, that a stained preparation may lie a whole night in this acid and yet coloured bacilli be left in it); 3. Acidulated alcohol; 4. Solutions of certain salts as used by Gram, de Giacomi, and Gottstein. The mode I use and find so trustworthy that I never change, save for comparative purposes, is the Ehrlich-Koch one by nitric acid. A solution of one part acid in three of distilled water answers well: a little of this is put into a watch-glass, which stands on the left of other two glasses, the middle one three-quarters filled with distilled water, the right hand one with alcohol. I never vary this arrangement of locality, and always am sure of what is in the glass. The cover-glass is caught lightly by the forceps, and freed of superfluous colouring matter by being held edgeways under a tap, or distilled water may be sprayed over it, or nothing prefatory may be done, but it may be at once plunged into the nitric acid glass; it must not be kept too long there else many or all of the bacilli may be decolorized. The following changes will be noticed during this operation,—the red fuchsin becomes a yellow red, the blue methyl violet becomes a green blue, and the process must not be continued till *all* colour disappears. Koch says now to rinse in 60 per cent. alcohol, but I always pass the cover-glass through the distilled water, in the middle-glass, to wash off adhering acid, and then transfer it to the alcohol, in which it is merely dipped, and then set aside to dry, which it does rapidly. When taken from the acid solution and passed through the water the colour, red or blue respectively, comes back again (if too dark it may again be put in the acid, but caution is needed, as the after-treatment by alcohol also decolorizes as well as dehydrates). The reason of this play of colour is that the monacid combination of fuchsin or methyl violet is changed in the nitric mixture into a triacid one, and the fuchsin becomes yellow, and the methyl violet green-blue; in water the triacid union decomposes again into the simple one, and acid is set free. The preparation is now ready for examination, or if preferred it may be coloured with a contrast stain, blue for the red bacillus (methylene blue), or yellow or brown for the blue (vesuvin or chrysoidin). The cover-glass may again be floated on a watery solution of these, or what is better, a drop or two may be placed on its prepared side; it is then laid in a flat watch-glass held between thumb and forefinger, the wrist half-way between pronation and supination, and by a see-saw, mill-hopper sort of movement of the wrist and hand combined, the drop is kept circulating over the preparation and evenly dyes its surface; it is now just rinsed in alcohol, set up to dry, and can be preserved in balsam or laid aside on a slip of paper dated, and with name of patient, in a pill-box. This is a capital mode of keeping anything good, one box with its paper partitions holding easily twelve or more tiers of cover-glasses.

The lepra bacillus, some yeast-fungi, and some occasional spores react in the same way as the tubercle bacilli do towards mineral acids, and so do hairs and the horny layer of the epidermis and pathologically cornified tissues. The morphologically similar lepra bacillus is, according to Baumgarten, much more easily stained than the tubercle one. Six or seven minutes' exposure to a solution of five or six drops of fuchsin in concentrated alcoholic solution in a watch-glass of distilled water sufficing to stain, then rinsing in acidulated alcohol (1 part nitric acid, 10 parts alcohol) for 15 seconds, then contrast-staining with methylene blue, the bacilli appear as red rods on blue ground in a time so short that the tubercle bacilli would not have imbibed any colour at all.

The whole process for tubercle bacilli staining, according to Koch (*Mittheilungen*, Band ii. S. 10), with adoption of the aniline water introduced by Ehrlich, may be synoptically rendered as follows:—

1. Cover-glass specimens, after drying, to be three times passed through the flame.

2. Colouring with the Weigert-Koch solution of methyl violet or fuchsin for twelve hours (for sputum half-an-hour to one hour suffices).

3. Treatment with diluted nitric acid (1 to 3 or 4) for a few seconds.

4. Rinsing in 60 per cent. alcohol; a to-and-fro movement a few times is all that is necessary (or simple distilled water may be used).

5. After-staining for a few minutes in vesuvin or methylene blue (or chrysoidin).

6. Washing again in alcohol to dehydrate, and examination in water.

Contrast-staining is seldom necessary for mere diagnostic purposes in the case of sputum. The specimen may usually be examined after treatment with nitric acid and alcohol. Of course there is this to be said in favour of the after-stain, that it very much facilitates focussing, and, if this or the other casual bacillus has not been decolorized by the acid, it will certainly be concealed by the second colour. Longer acquaintance with the tubercle bacillus, and with its modes of behaviour in presence of staining agents, have shown the erroneousness of the belief, at first generally entertained, that there is any qualitative difference between it and other bacteria; rather it is a quantitative one. The bacillus is more difficult to colour, and, when stained, it keeps a firmer grip of the dye it has selected than the other elements do. In varied ways and by various observers it has been demonstrated over and over again that alkalies or weakly alkaline aniline are not absolutely essential additions to the staining stuffs, they seem only to facilitate the ingestion of them, and other aromatic bodies operate in a similar manner.

For behoof of those who wish to know and prove some of the numerous methods of staining other than the Koch-Weigert-Ehrlich one, a few are appended.

1. *Gibbes' Double Stain.*—For rapid clinical work is very good. It is simple and very clean, but is not so trustworthy as it is neat. The bacilli, under

the simultaneous influence of two aniline dyes, colour themselves with the one to the exclusion of the other, while if the same dyes are applied in another way, they colour equally well with either. The formula is as follows:—Rosaniline hydrochlorate 2 grammes, methylene blue 1 gramme; rub together in glass mortar; dissolve 3 c. cm. aniline oil in 15 c. cm. rectified spirit; add slowly to the stains till all is dissolved; then slowly add 15 c. cm. of distilled water. Keep in stoppered bottle. The stain is heated till steam rises; the cover-glass is dropped and swum upon it for five minutes, and is then washed in methylated spirit till no more colour comes away. If used cold, the preparation must be kept in contact with the fluid for at least half an hour. The bacilli show red on a blue ground.

2. *Gibbes' Magenta.*—The formula is,—magenta 2 grammes, commercial aniline oil 3 c. cm., alcohol of sp. gr. ·830, 20 c. cm., distilled water 20 c. cm. Same time of staining and same after-treatment as the Koch-Ehrlich.

3. *Orth.*—Stain in Koch-Ehrlich way; decolorize with acidulated alcohol, 1 part hydrochloric acid to 100 parts of a 70 per cent. alcohol.

4. *Baumgarten.*—The prepared cover-glass is immersed in a watch-glass of distilled water, to which a few drops of a 33 per cent. solution of caustic potash have been added. On pressing the cover-glass down on the slide and examining with a power of 500, the bacilli of tubercle will be seen in an un-

stained condition. As control experiment, the glass may be lifted and stained, after drying, with an aqueous solution of any nucleus-tinting preparation of aniline. The bacilli remain unstained among the red or violet putrefactive bacteria.

I have often tried this method, and where the tubercle bacilli were abundant, have easily identified them by their graceful, slender, and beaded appearance, and their characteristic collocation; but where their numbers are few, and where, of course, difficulty of diagnosis is greatest, I would most certainly not *trust* to this process.

5. *Neelsen.*—Fuchsin 1 part, 100 parts of a 5 per cent. watery solution of carbolic acid, 10 parts of alcohol. When used, it should be warmed in a watch-glass till the steam rises, the cover-glass swum on it for a few minutes, then rinsed in a 5 to 25 per cent. watery solution of sulphuric acid, then in distilled water, and after-stained with, if desired, methylene blue.

This solution keeps for months without perceptible diminution of its staining powers. It is also a very rapid stain. I have frequently spread the cover-glass, dried it over the flame, heated the solution, stained and found the bacilli in five minutes from the time of commencing operations.

6. *Ziehl.*—Stain in Ehrlich's method; use no nitric acid; after-stain with methylene blue, which will displace the colour from all save the tubercle bacilli.

7. *B. Fränkel.*—Solution as in Koch. The aniline water is heated to boiling, poured into the watch-glass, and the Koch solution dropped into it till a strongly opalescent colour is obtained. Two minutes suffice to stain, but five or ten make this absolutely certain. Contrast-staining and decolorization are done at the same operation in the following manner:—For fuchsin preparations—As much methylene blue as will dissolve in 50 parts of alcohol, 30 of distilled water, and 20 of nitric acid; filter and rinse the specimen in the mixture; in one minute the double colouring is done. For methyl violet preparations—As much vesuvin as will dissolve in 70 parts of alcohol and 30 of nitric acid; filter and rinse the specimen as before; in one and a half or two minutes the second colour has been taken on, but, of course, as to time, much will depend on the original intensity of the coloration and the thickness of the film. I can speak well of both methods. The preparation is then washed in distilled water or in a 50 per cent. alcohol acidulated with 1 per cent. acetic acid, and well dried before it is put aside.

8. *Kaazer.*—Cover-glass is kept for twenty-four hours in a cold saturated alcoholic solution of gentian violet, or if warmed up to 196° F. for only three minutes. It is decolorized in a mixture of 100 c.cm. of 90 per cent. alcohol, water 20 c. cm., and 20 drops of strong hydrochloric acid. It is then rinsed in 90 per cent. alcohol, and after double-staining with

concentrated watery solution of vesuvin, it is washed in distilled water, and dried.

9. *In Baumgarten's Jahresbericht*, 1885.—The following proceeding, employed in the military medical department in Bonn, is given:—1. The sputum is spread and dried in the air. 2. Aniline water is prepared by half-filling a test-tube with water, pouring as much aniline oil in as just fills the rounded end of the tube, shaking thoroughly, and filtering into a watch-glass in which 8 to 10 drops of concentrated alcoholic solution of fuchsin, methyl violet, or gentian violet are already placed. 3. The air-dried preparation is drawn thrice through the flame, floated on the prepared solution, and heated till steam rises—about half a minute. 4. Washed in water, after-stained with malachite-green or Bismarck-brown or vesuvin according to the dye used for two minutes, washed again and dried with blotting paper, and mounted in glycerine or Canada balsam for examination. A magnification of four or five hundred is sufficient to show the bacilli, and immersion lens or Abbe apparatus is unnecessary. But if perfect certainty as to the presence or no-presence of tubercle bacilli is desired, then immersion lens and Abbe are absolutely essential. The omission of the decolorization by acids in the above method seems also, in examinations made for purely diagnostic purposes, rather hazardous.

10. *Voltolini* (*Breslauer ärztl. Zeitschr.*, 1885, No. 15) makes the following communication:—If

a tubercle bacilliferous cover-glass preparation is laid for a very short time (a few seconds) in fuming nitric acid of sp. gr. 1450 to 1500 before the staining, which is then to be carried out in Ehrlich's way, the tubercle bacilli appear constantly granulated in a moniliform way ("perlschnurartig gekörnt"). This beaded appearance in stained tubercle bacilli is frequently observed without the preliminary immersion in strong nitric acid. Voltolini, however, regards this behaviour as an absolutely trustworthy criterion of this bacillus; he has found it in no other species of bacterium, not even in lepra bacilli. Voltolini is of opinion that those beads or grains in the substance of the tubercle bacillus have been taken for spores, and that this experiment of his shows that they must be regarded as particles of coagulated albumen. But competent bacterioscopists have never expressed this view. Spores were considered to be, *not the stained*, but the portions of the bacillus which remained *unstained*. I have tried Voltolini's procedure, and can confirm what is said above. The beading is exquisitely brought out, but not a whit better than in preparations which are long exposed to the action of the stain, say twelve to twenty-four hours, without the prefatory treatment with fuming nitric acid.

Celli and Guarnieri have found in sputum acicular crystals of fat which behave exactly as tubercle bacilli do in regard to dyes; but their diversity of size and utterly dissimilar collocation and form, as well as their solubility in ether or chloroform, should prevent all possibility of mistake. Fatty crystals are not infrequent constituents of expectoration, and will find mention further on, *cfr.* Plate XXX. In my view, broken threads of leptothrix bacterial forms may more easily be regarded as bacillary ; sometimes their colour has not been properly discharged, but the size and characteristic arrangement of the individual cell-elements, and the neighbourhood of longer undoubted leptothrix filaments, should betray their real nature. But there is a bacillus-form which is so like the tubercle one that I have known a practised eye misunderstand what it looked at. I have only seen this bacillus in one sputum, that of a young woman who had cough and apical dulness, and was fast emaciating. The first preparation was stained by Gram's method and after-stained with eosin ; a most lovely specimen was the result, and swarms of this bacillus, which I do not pretend to name, although I suspect it to be a pneumonic one, were conspicuous, and, through the great kindness of Dr F. M. Caird, a camera drawing of them was made and coloured for me, *cfr.* Chromo II., Figs. 1 and 2.

They are curved slightly, are a little longer and plumper than the tubercle bacilli, and have knobbed or clavate ends (so have tubercle bacilli sometimes) in which the staining stuff seems to accumulate and render the extremities darker than the body of the rod. Long parallel rows of diplococci of about double or treble the diameter of the bacillus-form, or colonies of the same are intermingled with the rods, which a very high power resolves apparently into a series of two, three, or four very minute dumb-bell cocci strung together. What differentiates this bacillus, so superficially like the Koch one, is the fact that nitric acid discharges its colour; and this is the reason why Gram's method has not been recommended here as one of the alternative modes of tinging sputum. The cardinal point in such examinations must be absolute security and certainty of differential diagnosis, and Gram, for the tubercle bacilli, does not give this, as the case related above shows.

Tubercle bacilli have been found by some (*New York Medical Record*, 28th March 1885) in the secretions of the skin of consumptives. All the endeavours I have made to verify those observations have resulted negatively, and I have had no better success with the breath of those suffering from phthisis, and even when their sputum was little else than a pure cultivation of bacilli. I had an apparatus constructed with tubes into which the patient breathed only in expiration, the inspiratory air being derived from the room in which the experiment was made; the receiver was set among ice, and its interior contained a sterile solution of albumen; hours were spent in this way, and the condensed aqueous vapour of the breath was afterwards thoroughly agitated with the albumen, and the mixture examined as I would a sputum, but with no positive result.

Among other non-putrefactive bacteria which lead a more or less saprophytic mode of life in the respiratory passages, one is frequently enough seen in phthisical sputum, and has been taken notice of by Koch (*Mittheilungen,* Band ii.) It assumes the form of a tetrad or group of four cocci arranged *sarcina-like*, and has been baptized "*micrococcus tetragonus*" by Eidam. The conjecture that it may take an active share in the destructive processes initiated by the tubercle bacillus has been hazarded by Koch, and the theme has been prosecuted by Gaffky (*Langenbeck's Archiv,* Band xxviii., Heft 1), who finds that the inoculation of a pure cultivation of this merismopedia kills off mice and guinea pigs in a few days. Koch believes that there may be a "*Mischinfektion,*" a mixed infection here, a combined invasion of bacilli and cocci. However this may be, it is quite certain that this micrococcus has not always pathogenic properties for a tetrad, indistinguishable microscopically from *micrococcus tetragonus*, and is a very usual inhabitant of the phlegm expectorated of a morning by people in perfect health, *cfr.* Chromo VI., Fig. 1.

I am glad to be fortified in this opinion by H. Fischer, "Ueber das Vorkommen von Sarcine in Mund und Lungen (*Deutsches Archiv f. Klin. Med.*, Band xxxvi., 1885, page 344), who has made the lung sarcina-forms the object of exhaustive research.

He found, as is now well known to myself, that they appear in the most diverse pulmonary diseases—bronchitis, phthisis with and without cavern symptoms, lung infarction, pneumonia, etc., as well as in the mucus of the mouth. An abundant bronchial secretion seems to favour their development. In the secretions of the mouth of perfectly sound persons they were also present in one-fourth of the cases examined. Accordingly, Fischer considers that those sarcina-forms are of no pathological signification whatever.

Another ellipsoidal dumb-bell or diplococcus, about 1 to 2 micro-millimetres in length, and which takes on the secondary stain, occasionally accompanies the bacillus of tubercle. It is relatively, however, much more abundant in certain other pulmonary diseases than phthisis; for instance, I have seen enormous swarms of it in cases where the Curschmann spiral was a common phenomenon. I have also observed it in the sputa of pneumonia crouposa in floods so complete as to give no room for other organisms to appear in the field of view, and much more sparingly it is to be noticed in acute and chronic bronchial catarrh, capillary bronchitis, and hooping-cough, either primary or as a sequela of measles. The dumb-bells very frequently cohere in pairs, and form a species of short rod, and sometimes scores of them cleave together, and make up long and gracefully winding threads, or they collect themselves into zooglœic botryoidal masses. Considering the kind of diseases in which it is present in greatest numbers in the sputa, the assumption seems not an unwarrantable one that this organism is indicative of inflammatory or other irritation of the finest bronchioles. I do not yet believe in its specificity, nor, simply because it is comparatively scanty where Koch's bacillus abounds, and is overwhelmingly preponderant where Koch's bacillus is entirely absent, can I suppose that the two are mutually antagonistic, a surmise I have heard made in all seriousness, *cfr.* Chromo IV., Fig. 1, and Chromo V., Fig. 1.

An exquisite example of the contemporaneous existence of tubercle-bacilli and the quasi-bacillus in question has just come under my notice. A patient, admitted into the Incurable Hospital with rheumatism and supposed abdominal aneurism in 1880, became the subject of enlargement and suppuration of some deep-seated cervical glands on the left side in 1885. Matter was evacuated and sinuses slowly healed. On my return from a short holiday in May 1886 I was told that this person suddenly one day coughed up ten or twelve ounces of blood. She now had a high evening temperature, dulness of left apex, and moist sounds, cough, and expectoration, which I found to contain elastic fibres and the bacillus of tubercle, but accompanied by great multitudes of this ellipsoidal diplococcus arranged pair-wise into short rods; this continued till death in August, and at the post-mortem both lungs were found diseased, the left much more so than the right.

It was excavated into a large cavern in the apex, was hepatized and friable, and infiltrated to the very base with cheesy purulent masses.

This patient had lain almost bed-ridden for five years: for four of them the occupant of the next bed was a sufferer from chronic phthisis, and the question is as interesting as it is obscure, whether the bacillary invasion which carried off the first-mentioned was derived from her consumptive neighbour or from her own suppurating glands. I must say that the condensed breath of this tubercular comrade, when examined by me for bacilli, never gave any but negative results, and in favour of the belief that the infection was autochthonous is the fact that the diseased process was very much farther advanced in the left than in the right lung, and consequently on the same side as the glandular mischief had been.

Cover-glass preparations of the juices taken directly from the lungs showed, in addition to Koch's bacillus, the same micro-organisms so strikingly abundant in the sputa, and which were as follow:—

1. Crowds of the elliptical diplococcus varying in length (as measured by Zeiss' micrometer, eye-piece No. 2) from 1 to 2·5 μ, and having a more constant diameter of barely ·5 μ. When 2 to 2·5 μ long the rod appearance was very accurate; the two ellipsoidal cell elements composing the parent diplococcus had elongated into what seemed to be two thin cylinders

with rounded ends, placed in very close proximity to each other, but still separated by a perceptible dividing line. Close examination, with oil immersion and high oculars, showed the seeming cylinders to be in reality diplococci, which were evidently constricted in their middle line, but not completely segmented, so that the whole organism was actually a combination of twin diplococci applied end to end. Occasionally specimens of the rods were seen with a connecting neck narrower than the diameter of their component terminal cocci, and then the formation had a drumstick appearance with two elliptical rounded heads.

The rod formations were often seen lying grouped in close, parallel, palisaded rows of two or three or four, seldom more, like marks of interjection, or huddled into multiform clusters which in their general configuration differed markedly from the aspects assumed by the tubercle-bacilli which lay among them, *cfr.* Chromo V., Fig. 2.

2. Round diplococci of double the size of No. 1, lying singly or forming tetrads, or having the semblance of large round micrococci from foreshortening caused by their very oblique or end-on position as regards the eye of the observer. Those did not form themselves into rods, and some had a colourless space or "Hof" around them, others not. Relatively they were much fewer in number than No. 1.

3. Still another diplococcal form, rounder and

fatter than No. 1, and smaller than No. 2, which, by junction of six to twelve members, formed short, gently undulating, torula forms (streptococcus).

This case is full of interest from its micro-parasitic side. A long series of almost daily observations had been made of the sputa which, superlatively rich in tubercle-bacilli, and used to test the worth of every staining method and after-treatment mentioned in this book, were always overrun with the bacillus-form described as No. 1, and represented in Chromo V., Fig. 2. The post-mortem was looked forward to with strong desire as likely to give satisfactory information as to the nature of the lesion which it accompanied. Dr Affleck was kindly present, and agreed with me that the destructive tubercular changes were associated with bronchitic and pneumonic processes, croupous as well as catarrhal.

My belief is strong that the three organisms above-mentioned are specifically identical. Bacteriologists are coming round more and more to the view that differences of form of bacteria are not to be recognised as proofs of real generic and specific distinctions, but are rather to be conceived as various growth or vegetative forms, through several of which transitional stages a bacterium may pass in its cycle of development. A big ball or coccus is just as much a ball as a smaller one, and so also a big or a little ellipse, or a short or a long bacillus are not, by form merely, specifically separated. The age of an individual cell influences its shape, and very young bacilli are as like cocci as anything else. One can easily imagine a gradual passage from perfectly circular cocci, through longer or shorter ellipses, to short or disc-shaped cylindrical rods. The incidents of fission seem also to teach that there is no rigid, inflexible pattern; the mother-ball elongates into an ellipse, divides, and two smaller balls are the result. An ellipse, as in organism No. 1, may be so drawn out that it is difficult to say it is not a short rod with rounded ends; it also cleaves across, and it is a puzzle whether the product is an ellipse or ball. Or it may well happen that organism No. 2 when dividing, instead of falling asunder into four balls (two diplococci), may remain united and present the torulose, rosary appearance asserted of No. 3 (*cfr.* Hooping-cough paragraph and Chromo V., Figs. 1 and 2). But a trustworthy solution of this problem can be obtained only by cultivation experiments.

As I have found those organisms in sputum several months old, I conclude that they resist putrefaction as steadfastly as the tubercle-bacilli: like them also they sink to the bottom of the containing vessel with the more solid constituents, but I do not think that they increase and multiply there as I have reason to believe that tubercle-bacilli do. It may be incidentally noticed here that the precipitate, which forms in the spit-glass after the lapse of weeks or months, presents an epitome of all the less destructible components of any sputum, and gathers into small compass, and therefore less likely to be missed, such elements as elastic fibres which may be present only in trifling quantity.

It is easy to understand from the foregoing statements that the semeiotic worth and meaning of the bacillary parasite, *when found* in sputum, are very considerable: it is the infallible, unchallengeable exponent and witness, the sign-manual as it were, that tubercular disease is actively at work in the respiratory organs, or, to be accurate without theorizing, that a "Bacillary Phthisis" (Germain Sée) is in full swing. Diagnosis has therefore made a great gain and acquired a certainty unattainable in any other way. In the very beginnings of tubercle, while the case is still very doubtful, or where a differential diagnosis between it and other ailments has to be made, the demonstration of its presence is of the utmost value, "*obsta principiis*" in treatment, if necessary anywhere is so here; but even in pronounced cases, where physical examination and the course of the disease and its general appearance leave no room for doubt, it is not a threshing of mere straw to have still further confirmation of this rigorous kind. Naturally the cases where the bacillus is demonstrable must be limited to those where disintegrating processes have opened a way for it outwards; it is precisely here that the search for elastic tissue should be carried on simultaneously, and, as mentioned when treating of that subject, it will be found before the bacillus has entered an appearance. So far as I know, no one has in the very initial stages of acute miliary lung tuberculosis, or of cheesy pneumonia, shown the bacillus in the lung excreta; but from many examinations made long before Koch's discovery was heard of, I know that tissue is to be found from a very early period; and from observations made for comparative purposes since that time my belief remains firm that, presupposing of course necessary patience and skill, curly fibre precedes the advent of the bacillus by a measureable but indefinite time, and will not escape notice if looked for with sufficient perseverance.

I always search for tissue first, and in one Longmore case (a woman of 40 who had suffered for eight or nine years from occasional hæmoptysis, and had cough, and was emaciating slowly, and had also profuse sweatings and abundant muco-purulent expectoration; in addition there was dropsy and highly albuminous urine; her left apex was flattened, immobile, dull, and breathing was amphoric; many who examined her believed the cavity was tubercular) I am within the mark when I say, that during the year of her hospital residence I made at least forty cover-glass preparations of her spit and never saw one bacillus, but I *never failed* to find elastic tissue, although the coils were never extensive. Unfortunately a sectio was not allowed, and the lessons of such a crucial case were interred with her.

The bacilli generally have a lung origin, but may also be derived from abscesses of a tubercular nature having their site in larynx or pharynx or tongue.

There are undoubted cases of laryngeal phthisis where no trace of tubercle can be found in the lungs, and, if ulceration has set in, secretions containing both bacilli and tissue can be taken directly from the larynx by the aid of the laryngeal mirror and a properly curved brush. It is somewhat astonishing that in the many cases of lung-phthisis without laryngeal complication in which I have examined secreta removed directly from the aditus laryngis, no bacilli were demonstrable. Ziehl has supposed that bacilli may be inhaled and appear in the expectoration, and yet that there may be no bacillary disease of lung: this supposition seems a far-fetched one, and I am not aware of its having passed beyond the region of mere hypothesis.

Supposing the bacillus hunt to fall out negatively, what opinion is to be formed? If morning sputum coughed up from the chest, not mere nasal or pharyngeal secretion, has been examined by one practically acquainted with the methods, and if no bacilli have been demonstrable, the presumption is strong that none are present; but to be surer, two or three preparations should be made at intervals of several days. If their examination shows the same result, one may safely say that there is no bacillary destructive process going on. But it must never be forgotten that bacilliferous sputa of consumptives may day after day, it may be very many (Gaffky, *Mittheil.* Band ii., page 130, tells of a case where none were to be seen from January 2nd to March

9th), be free of the organism. This may be brought about by retention of secretions, and then can only continue for a very few days; or a cavity may be cleaned out and cicatrize; or a temporary or permanent blocking up of its bronchial adit may have taken place; in those or similar ways one can imagine an intermittent discharge of bacilli, and here again I say that in all likelihood elastic tissue will be found. Gaffky (*l. c.*) in 982 preparations of consumptive sputa found the bacillus 938 times, consequently in 96 per cent., and "*si parva licet componere magnis*," my own observations numbering nearly a third of his are substantially the same. I may also say that I have *only once* missed elastic tissue where bacilli were present, and then the search was only made on one sample of the expectoration. As set off to this there is the case already related where tissue was for long the *avant-coureur* of the bacillus, and not a few others where I have found it, and where the bacillus has not yet appeared, but will by-and-by, unless, indeed, the impending phthisis is of a non-bacillary, fibroid kind, or the "*nimia diligentia medici*" bring about a cure.

Prognosis has not been so much helped as diagnosis by the discovery of Koch, and physicians are not in a position to prognosticate any better with than they were without it, for the scantiness or plentifulness of the bacillus has no constant relative proportion to the gravity of any given case. Balmer and Fränzel, however, supposed that number and form had everything to do with this; that small, starved-looking, non-sporangiferous bacilli betokened a case where disease was slow of progress or had gone to sleep; that large spore-bearing ones indicated rapid, *galloping*, phthisis *florida*. But if a preparation in which bacilli are numerous is examined, all forms and sizes will be recognised, and in some in my possession of acutely running cases the individual bacilli are certainly not larger, but rather the reverse, than those in others where the disease was protracted. Balmer and Fränzel, in order to obtain an average number, make a series of examinations of sputa obtained on different days, and reckon up the bacilli by one of the arbitrary scales to be afterwards given. Gaffky (*l. c.*) with great exactitude had twelve cases of phthisis serially examined for five months and registered, and his table is given below.

Patient	No. of Examinations.	Average.	Remarks.
A	39	4 3	Died.
B	20	3·6	
F	93	2·6	
L	73	2·6	
C	131	2·7	Still in Hospital.
E	129	5·5	
D	22	3 2	Dismissed Improved.
G	103	4·2	
I	106	3·3	
K	106	4·5	
M	98	5·3	
N	62	2·6	

The four first patients died shortly after or during the progress of the examinations, and yet the average number of bacilli is small. Of C and E, still in hospital, at the end of the researches C has also a small average, but did not improve, while E, with a much larger average, got better. The other patients, during or after the observations, were dismissed improved, K and M having sputa relatively rich in bacilli. Confirmation of the Balmer-Fränzel theory is not found in the above table, but rather the reverse. This average means the average number of bacilli seen in one field of view according to the scale devised by Gaffky, and which is perhaps a rather intricate muster-book, and one which leaves a good deal of latitude to the subjective appraisement of each observer, it is the following :—

1. In the whole preparation, only 1-4 bacilli.
2. On the average of several fields of view, 1 bacillus.
3. On the average in each field of view, about 1 bacillus.
4. On the average in each field of view, about 2-3 bacilli.
5. On the average in each field of view, about 4-6 bacilli.
6. On the average in each field of view, about 7-12 bacilli.
7. On the average in each field of view, a good many bacilli.

8. On the average in each field of view, numerous bacilli.
9. On the average in each field of view, very numerous bacilli.
10. On the average in each field of view, enormous quantities of bacilli.

Fränkel's scale is much simpler: he calls No. 1 where several fields of view have to be searched before a bacillus comes into view; No. 2, where about 20 are in each field; and No. 3, where the bacilli are very numerous. Hunter Mackenzie (*Edinburgh Medical Journal*, Feb. 1884, page 683) has adopted a scale from 1-9 inclusive. 1-3 represent few, 4-6 abundant, 7-9 very abundant bacilli. Whichever rubric is chosen, and every observer will, I daresay, have his own method of notation, and the less complicated the better it will be, it must be kept always in mind that no cover-glass can be mathematically spread with equal thickness of film over every field of view, that therefore any plan of summation will give only a guess-work and random total. As bacilli may freely flourish and find abundant food in cavern-contents, they may be very numerous without at all influencing the progress of a case or causing the development of tubercle in other organs; neither can any inference be drawn from their numbers how many foci of tubercle, ulcerating and to ulcerate, are in existence in any one case—in fact, quite other factors than sputum and its contained bacilli determine the prognosis; fever may be high where they are few. There is at present (1886) in the Longmore a female patient who has had for months a persistently high temperature, sometimes reaching 104° F., never below 99° F.; her expectoration contains much elastic tissue, and only a moderate amount of bacilli, but she is steadily losing ground. Then again no one can foretell hæmoptysis or pleurisies, or perforations and pneumothorax from the numbers of bacilli in the sputum, and Niemeyer's dictum that "*the greatest danger to most phthisical patients is the development of tubercles*" (Niemeyer, *Lectures on Consumption*, New Sydenham Society, 1870, page 11), which, translated into the pathological shibboleths of the present day, means an irruption of bacilli into the circulation and a consequential multiplication of tubercular foci, indicates a danger which no sputum can ever prognosticate. Their steady diminution or total disappearance for a prolonged period is a sign that a healing process has set in.

A few words may be said about the macroscopic appearances of phthisical sputum, the varieties of which are very numerous. In acute miliary lung tuberculosis, and in caseous pneumonia before softening and disintegration of lung has set in, the sputa may be innocent enough in their looks, and differ little, if at all, from those of an ordinary catarrh. They are clear, with perhaps white or yellow flecks, ropy, viscid, and, according to the difficulty or not of expectoration, mixed or not with frothy, spumous bubbles of air and mucus, or, particularly in the morning, pellets of glutinous, starchy stuff are ejected with force. When cavity formation has taken place, the expectoration becomes very, but not exclusively, characteristic. It is copious, heavy, muco-purulent, spat up usually with ease, particularly in the morning. If discharged into a vessel containing water, it assumes a globular shape, and has a ragged, woolly contour. It usually sinks to the bottom, but may remain suspended half-way or float, according to the quantity of air-containing mucus investing or mixed up with the pus. The ancients believed such sputa, which "*ad fundum tendunt*," to be of bad omen, and Hippocrates recommended salt water as the menstruum into which the patient should spit, because from its greater specific gravity the "*presagium*" would be all the more certain. If the expectoration dish is free of water, then the spit spreads out into a flat orbicular mass, called "nummular" from its resemblance to a coin, or into egg-shaped lumps of the form and often of the colour of the sage leaf. Generally as to colour, such sputa may be dirty-white or grey, yellow, yellow-green, blue-green, perhaps streaked on the surface with blood, or mixed up more intimately with it, and then the tinge varies from a just perceptible brick-red to deep chocolate. As to odour, there is little or none, unless the secretion has been long retained in a cavity or got mixed with other fluid necrosed debris,.or unless it contains many of the rounded, cheesy particles which owe their origin to the follicles of the throat or pharynx, and which have a most unholy smell, or also except necrotic fragments of lung-tissue or cavern walls are largely intermingled with it.

Calculous concretions, which consist chiefly of calcic and magnesian salts and traces of silica and oxyde of iron cemented together by mucus, albumen, and detritus of cells and lung-tissue, are occasionally expectorated, and give the name "*phthisis calculosa*" to the variety of consumption in which they are seen. I have not often met those chalky nodules in spit. They are sometimes hard as bone, at other times soft and like dirty mortar or putty. The mode of formation of such bodies seems to be that the moisture of retrograding tubercle evaporates or becomes absorbed, and the dried residue irritates and is coughed up; or an excavation may be extending and lay bare the encysted chalky remains of old atrophied tubercle which now get extruded with the sputa.

What, in comparison with the bacterial forms now considered, may be called the grosser microscopic elements of phthisical sputa are the following:— Pus corpuscles; free nuclei; free fat; casts of lingual papillæ; molecular amorphous detritus from cavern walls, etc.; fattily metamorphosed cells of all kinds, as, for instance, alveolar epithelium, which is usually very darkly pigmented also; mucus corpuscles and squamous epithelium in the mucous portions of them;

elastic and connective tissue, which have already been spoken of.

With no thought of being dogmatic, I would be inclined to express my views as to the practical diagnostic and prognostic value of Koch's discovery in the following propositions :—

1. If expectoration is bacilliferous, it is absolutely certain that tubercular disease exists somewhere in the lungs or respiratory tract.

2. In the very initial stadia of a genuine miliary tuberculosis or a cheesy pneumonia, the expectoration does not contain the specific bacillus, but elastic lung-tissue, which seems to be an earlier and more constant constituent of the diseased sputum than the bacillus itself, will in all probability be found on careful search.

3. In a very small percentage of cases behaving clinically like phthisis, in the common acceptation of the term, the bacillus may not be demonstrable at all. Such cases are either not tubercular, or if so, the bacilli have become encapsuled, or for the time there are no melting bacillary foci discharging their contents outwards. Here again pulmonary elastic fibres will be discovered if assiduously sought after.

4. Nevertheless a negative result in the hands of a competent observer is of high value, and wonderfully helps to the formation of a correct decision on a case.

5. In cases attended by high fever, perspirations, and emaciation, the bacilli may not be excessively

numerous, and, *e contra*, in cases with low temperatures and torpid circulation they may be plentiful, therefore a prognosis laid on such a basis as numbers would be deceptive: abundant or sparing quantity of elastic tissue is a safer guide.

6. If bacilli steadily diminish in numbers a healing process has probably set in; but the correct *relative* enumeration of such micro-organisms is not very feasible, and therefore the long-known signs and general symptoms which herald and accompany a favourable change are more trustworthy and more easily appreciated.

The question arises, How is mankind to be protected from the perilous immigration of this virulent microbe? When once it has gained admission and lodged itself in the lungs, no drugs seem able to poison it without at the same time killing off its host; nor has any method as yet been discovered of starving it by prohibiting certain foods in the dietary of its landlord; nor does there seem much chance of inoculation of an attenuated virus ever succeeding in conferring immunity from its ravages; but there is one source of possible infection which might be dried up almost completely—the sputa could be disinfected or destroyed. Every patient with developed phthisis may be regarded as a laboratory in which pure cultivations of the tubercle-bacillus are steadfastly and successfully made and expectorated daily, it may be for many years. Schill and Fischer (*Mittheilungen*, Band ii., pages 143–146) made on this point an extensive series of experiments with various chemicals, and came to the conclusion that, for sputa, the cheapest and best disinfectant was carbolic acid in a five per cent. solution, added to an equal part of the expectoration. They found apparently that in six months the sputa lost their virulence, but an experiment I have already related proves that at fourteen months the bacilli or spores are still viable (page 117).

Since writing those pages, I have had a second opportunity, after the lapse of eleven months, of examining the chest and sputum of the young person mentioned in page 134 as having a remarkable bacillus in her expectoration. She still complains of cough, and hawks up a tough, starchy, pellet kind of mucus, which will hardly squeeze out on the slide: she has sweatings and loses strength and flesh; the hair of the head is also falling out slowly; her pulse is quick. The apical dulness formerly noticed cannot now be substantiated, but breathing is wavy and expiration prolonged; the voice-sounds are natural, but the subclavian whiff is audible on left, and an occasional dry click which coughing does not dislodge is to be heard; expansion of chest is natural. The sputa are sometimes blood-stained, but contain no curly fibre, and still swarm with the organisms represented in Chromo II.; but the rod-like bodies are not so markedly curved, and commingled with them, as before, are rows and zooglœa masses of the larger diplococcus, many of which seem surrounded with a "Hof," or capsule or colourless space, and with good light and good eyes each member of the pair exhibits a tendency to transverse division, and when aggregated into colonies or nests all gradations in size are recognisable, giving one the idea that the smaller are younger, and the larger are older specimens of one coccal form, which to me seems to affiliate itself to the coccus of pneumonia, *cfr.* Chromo IV., Fig 1.

It may be profitable to compare Fig. 2 of the same plate, which is a specimen of the bacterial contents of the sputum of a blacksmith of 60, lately admitted (1886) into the Incurable Hospital. Six months ago he had the half of his tongue and his tonsil, and half of the lower jaw on the right side, ablated for an epitheliomatous disease: while under treatment for this in the Royal Infirmary, he acquired a pneumonia, probably aspiratory, of the right upper lobe which never resolved itself. On admission into the Longmore he had a quick pulse, perspirations, and high evening temperature (it may be noticed here that occasionally in phthisis the temperature maximum is found at mid-day or thereabout, a gradual remission during afternoon and evening to a midnight minimum taking place, again to attain its maximum at mid-day); percussion was dull, breathing amphoric, and sometimes gurgling, and expansion much curtailed over right upper front; the copious, blue-green, sage-leaf sputa contained lots of curly fibre, and whole fields of view were made up of deeply pigmented alveolar epithelium, his avocation (he had wrought in a shop where forty fires were going) doubtless supplying the pigment, and causing the slatiness in the green of the expectorated matters. In the drawing a few very slender rods are here and there visible, they react chemically like Koch's tubercle-bacillus, and are so in reality, and their presence, in what was presumed to be and doubtless was at first pneumonic infiltration merely, seems to lend countenance to Biedert and Sigel's contention ("Chronische Lungenentzündung, Phthise und Miliartuberculose," *Virchow's Archiv*, Band xcviii., Heft 1), that lung-phthisis is not always primarily mycotic, but may be a graft and epiphenomenon of other processes of a simple and non-specific nature.

But returning from this not altogether irrelevant excursus, it is easily seen that the rod-forms of both figures are very similar, only they are plumper in Fig. 2, but comprise the same cell-elements lying in juxtaposition as those in Fig. 1. It will also be noticed that the curved bacilli of Fig. 1, Chromo II., after the lapse of nearly a year, have given place to shorter and straighter rods made up of the ellipsoidal dumb-bells to which attention has been drawn in page 137. In the Chromo illustrating pneumonia crouposa similar rod-shaped images are abundantly seen, and I have little doubt that all are related to each other as well patho- as morpho-logically; that they are varied growth-forms of the same organism as it passes through certain cycles of development, now assuming a coccus form or elongating into rods and threads of various length, *cfr.* hooping-cough Chromo. One thing, however, has to be noted, that the organisms here spoken of do not resist putrefactive changes for such a length of time as the bacillus of tubercle. Although the diseases are diverse in which I have seen those bacterial forms, varying so much quantitatively in different cases, yet they find a common platform and have a fundamental, pathological sameness in the inflammatory changes which are associated more or less intensely with them all.

When a sputum richly laden with tubercle-bacilli has been kept in a tightly closed bottle for a very long time,—(the specimen of which I now speak is at least eighteen months old, and has been utilized just now to test the staining powers of Neelsen's method, which I find to be of prime worth. The watery solution of sulphuric acid used for decolorization, which in Baumgarten's *Jahresbericht* for 1885 is recommended to be a 5 per cent. one, seems to me to be too weak, and one of 15 or 20 per cent. would be more effectual. However, with a dilute preparation there is less chance of the colour being all extracted from the bacilli by an inexperienced operator),—and a drop of the greenish-yellow, somewhat turbid, supernatant fluid examined for the micro-organism in question none or very few will be discovered; they have settled at the bottom with the denser constituents. If a cover-glass preparation of this precipitate is made the bacilli will be found grouped into irregularly rounded colonies of very varied magnitudes, and into short sinuous lines and arabesques, perhaps with tapering ends and thicker middle, the closely-packed individual bacilli of which lie with their long axis parallel to or at a very acute angle with the long axis of the curve, and, where laxly confederated, somewhat resembling the stitch called *double feather*. In fact it is difficult to resist the belief that a pure cultivation is being looked at, and that an actual process of growth and multiplication has happened.

Cases of seeming inoculation of genuine tuberculosis in man from accidental or intended traumatism occasionally appear in the journals. Tscherning (*Fortschritte der Medicin*, 1885, No. 3,) publishes details of a servant, not scrofulous or tainted hereditarily, having wounded the palmar surface of the first phalanx of the middle finger with fragments of a glass vessel soiled with bacilliferous sputa. A whitlow which did not suppurate formed in fourteen days, and in other eight a tubercle, the size of a pea and composed of granulation-tissue, lay between the skin and tendinous sheath; this was scraped away. After some months a tubercular tendinitis, with tuberculosis of cubital and axillary lymphatic glands of the same side developed. The finger and glands were removed, and sections showed giant cells and tubercle-bacilli.

Elsenberg (in No. 35, 1886, *Berlin Klin. Wochen-*

schrift) details a case of inoculation from a premeditated wound. It seems that among Jews of the lower classes, the beastly habit of sucking the penis after the performance of the rite of circumcision is invariably practised by the operator or some one of the guests invited to witness the religious ceremony, in order to staunch the bleeding and obviate swelling of the wounded parts. A child was brought into the Warsaw Jewish Hospital, five months after operation, with the parts unhealed and abscesses in groins and over left mastoid process and squamous portion of the parietal bone. There was nothing abnormal in lungs or bowels or mucous membranes, and there was no skin-rash. Tubercle-bacilli were abundantly found in stained sections of ulcerated foreskin and lymphatic glands. The operator was sought out and found to have bacilliferous sputa, some of which Elsenberg believes to have inoculated the wounded prepuce. This is perhaps a more convincing case than the former one, but of both many will be inclined to say that a latent predisposition was called into action by the injury, just as is constantly seen in local tubercular manifestations which follow hard upon traumatism of joints.

Some remarkable cases of triple contagion of tuberculosis—from man to man, from man to fowls, and from fowls to man—are related (page 600, *British Medical Journal*, September 25, 1886).

X

CHROMO I.

Fig. 1.

Bacillus Tuberculosis.

From a preparation of sputum of a patient who had laryngeal and intestinal complications, and whose expectoration was almost a pure cultivation of the bacilli ; nevertheless repeated trials to discover them in the condensed breath resulted negatively. Dr Caird has very successfully and naturally reproduced their figurate arrangement.

Objective, Zeiss, K. Water Immersion. Oc. 2.
Magnification, about = $\frac{760}{1}$

Fig. 2.

Bacillus Tuberculosis.

From the same slide as Fig. 1. Staining of both by methyl-aniline-violet and vesuvin.

Objective, Zeiss, $\frac{1}{12}$. Oil Immersion. Oc. 5.
Magnification, about = $\frac{1265}{1}$

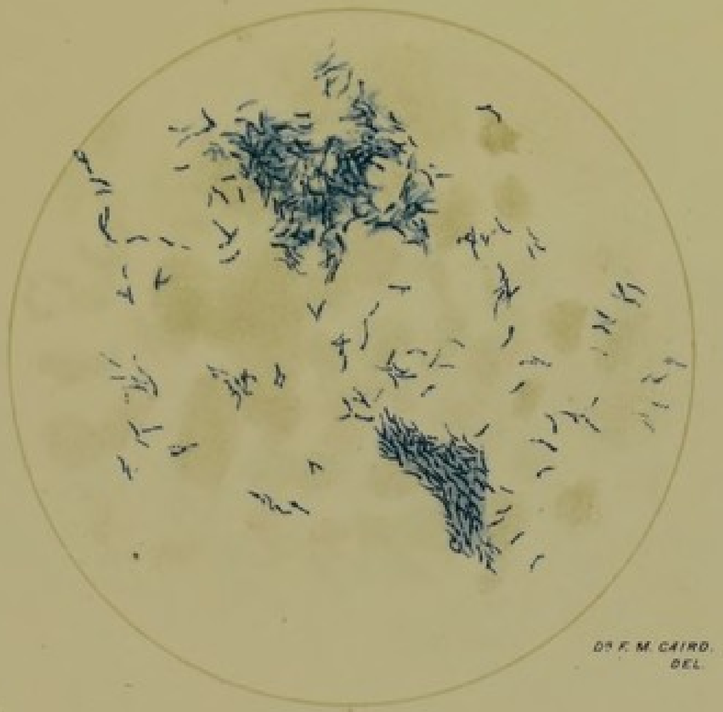


FIG. 1.

BACILLUS TUBERCULOSIS.
Aniline Methyl-Violet & Vesuvin.
Zeiss K. Water immersion – Oc. 2.

FIG. 2.

BACILLUS TUBERCULOSIS.
From same slide as Fig 1.
Zeiss 1/12 Oil immersion – Oc. 5.

Chromo-Lithog. by W. & A. K. Johnston, Edinburgh.

CHROMO II.

Fig. 1.

The rod-shaped, curved formations which are mentioned on page 134, and which so closely simulate the tubercle bacillus. Their present appearance may be contrasted by looking at Chromo IV., Fig. 1, but note that No. 3 ocular has been used instead of No. 2, as here. The patient is so much out of reach that frequent examination of the sputum is out of the question. The slide figured here was made eleven months ago, that on Chromo IV. the other day. Whether the curved form alternates with the straighter one I cannot tell, but this is certain, that both are compacted of minute cocci arranged pair-wise or singly into shorter or longer filaments, which seem quite identical with the bacilliform organisms of pneumonia represented in Chromo III., and of hooping-cough in Chromo V., and of unresolved aspiratory (?) pneumonia, ending in tubercular phthisis depicted in Fig. 2, Chromo IV.

Objective, Zeiss, K. Water Immersion. Oc. 2.
Magnification, about $= \frac{760}{1}$

Fig. 2.

From the same slide. The rows of large diplococci, one sample of tetrad arrangement of smaller diplococci, and chains and bacilli represented in Fig. 1. Both, of course, are stained in the same way,—Gram's method and eosin.

Objective, Zeiss, $\frac{1}{12}$. Oil Immersion. Oc. 5.
Magnification, about $= \frac{1265}{1}$

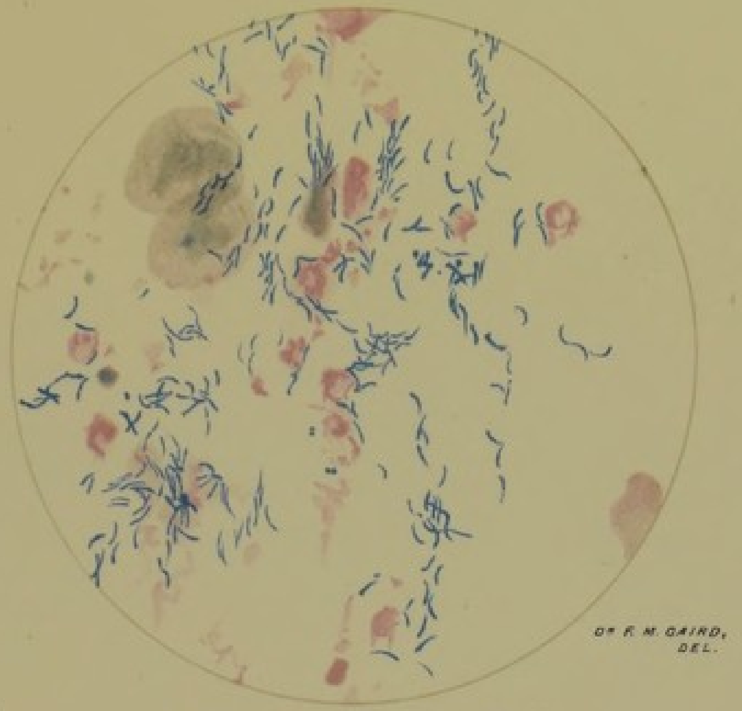


FIG. 1.

PSEUDO-BACILLUS.
Gram and Eosin.
Zeiss K. Water immersion.-Oc. 2.

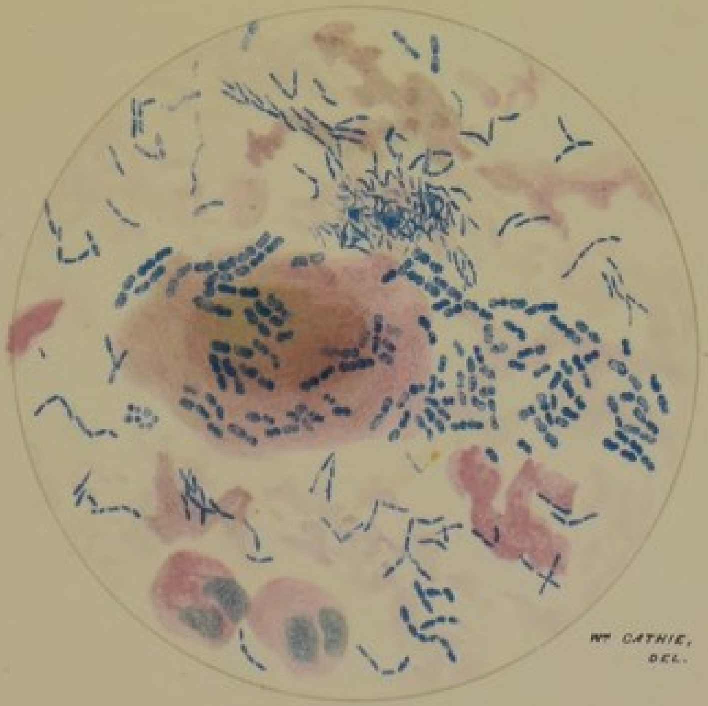


FIG. 2.

From same slide.
Zeiss $\frac{1}{12}$ Oil immersion.-Oc. 5

Chromo-Lithog. by W. & A. K. Johnston, Edinburgh

CHAPTER VI.

Pneumonic Sputa.

In the first stage of a croupous pneumonia, which perhaps has been ushered in by rigors and high fever, the sputum is scanty and catarrhal, somewhat frothy, transparent, sticky and tough, so that it will draw out like the melted glass which it resembles. If tinged with blood at this period the blood may be smeared or flecked on its surface; this is the way a pneumonia occasionally announces itself, but more usually the spit is intimately mixed up with the blood and is, at this stage, of a very faint brick-red or yellow colour. At this time there may be no local symptoms, or the malady may have begun in the central parts of the lung, and thus the sputum becomes of great help in diagnosis.

As alveolar exudation goes on the expectoration increases in tenacity, its frothiness diminishes somewhat, it can hardly be spat out of the mouth, and has to be wiped away, or if projected into the spit-dish it clings to its sides or coalesces on the bottom into a quivering, homogeneous jelly-like mass which will not drop out although the vessel be inverted and rudely shaken. According to the quantity of blood with which it is now interpenetrated and intimately amalgamated, its colour is yellow or tawny or rusty or even darker red. The mass of it still remains remarkably transparent, but whitish-yellow flakes or threads from portions of the tubes affected by concomitant catarrh can be detected here and there through it. This the classical "*sputum flavum sincerum cum panco sanguine mistum*" of a normal acute pneumonia is not an absolutely constant feature of the malady; the more or less pronounced participation of the bronchi will contribute more or less of catarrhal elements to it, and if the inflammation begin in and limit itself very much to the alveoli, only a trifling amount of secretion will be eliminated for a time or possibly during the whole course of the disease; if the stage of engorgement is very intense a moderate hæmorrhage may overshadow and conceal, for the time, the other elements and clinical appearances of the sputa. *In the pneumonia of children expectoration generally fails entirely.*

Excluding bacteria, the formed elements of pneumonic expectoration at the very first consist principally of abundant mucus and scanty blood-corpuscles and squamous epithelium, but when the disease is in full swing there will be found:

1. Strands of fibrine entangling red and white blood-corpuscles, *cfr.* Plate XXI.

2. Fatty, deeply black pigmented alveolar epithelium; occasionally the cells are of a golden-yellow

or brown tinge from imbibition of hæmoglobin, *cfr.* Plate XXIII.

3. Ciliated and columnar epithelium, *cfr.* Plate XX.

4. Very rarely pigmented crystals, such as the rhombic plates of hæmatin of which an exceptionally good example is given in Plate XXII.

5. Still more rarely the irregularly pyramidal bodies which can scarcely be called crystalline, figured in Plate XXXI. They seem to me to consist of epithelium which has undergone oily or colloid changes and then coalesced; they refract light very strongly.

6. Dendritic fibrinous moulds of the bronchial tubes, soluble in potash or soda, and already referred to, *cfr.* page 29. These casts are physically and chemically similar to the exudations of primary croup of children, and consist of aggregations of parallel-running, exceedingly fine molecular threads which are straight or wavy, and entangle pus-cells betwixt their strands or lie covered over with similar granulated corpuscles. These casts are only seen from the beginning to the acme of hepatization, therefore from the third to the seventh day of the affection. Unless a new focus of disease is lighted up they disappear after that period owing to melting down of the exudation. As in the case of the central thread of the Curschmann spirals, I believe that those bronchial casts are partly built up of the cylinder and ciliated epithelium (which

desquamates in much greater quantity than is commonly believed in this and other inflammatory conditions of the mucous lining of the air tubes) cemented and compacted by albuminous exudations.

7. Shorter or longer plugs of highly refracting exudation, straight or zig-zagged at acute angles, or straight with a cork-screw ending, or straight with a clubbed end, owing to being moulded in infundibula, are also met in pneumonia as well as in other inflammatory states, but spirals, such as Curschmann describes, and such as are figured in Plates XII. to XVII., I have not yet encountered, although other observers (Vierordt, Jacksch, Pell) have been more successful.

When resolution commences in the diseased focus, and *no new one forms*, the character of the expectoration at once alters. It becomes less and less sanguineous, less tenacious, and thus more easily coughed up. It assumes a more or less globular shape, and is now more opaque and whitish from admixture with pus cells and fatty debris of various kinds. It is now "*sputum coctum, album, blandum, rotundum.*" It increases, perhaps, in quantity for a short time, then gets less and less copious, and finally ceases entirely when resolution is complete.

Microscopic investigation of the sputa at this stage shows all degrees of cellular regressive changes, molecular detritus, free nuclei, fatty cells, and free fat; and the large alveolar epithelium, in many instances, has changed its protoplasm to globules of fatty matter, which fill the cells or exude through their torn walls.

Should the inflammatory process end in the formation of a circumscribed abscess or vomica, which bursts through the air-passages, there will be a sudden discharge of purulent matter similar to that from an abscess in any other quarter, and which may or may not smell badly at first, but will do so eventually. Should gangrene, diffuse or circumscribed, be the issue (such events are rare terminations of pneumonia, but I have seen both a number of times), the pungent, rotten, fruity odour of the sputa is something indescribably offensive, and taints the air for long distances from the sick-room. They are thin, brown like liquorice water, or reddish-black, with dirty gray or white necrosed shreds and strings floating about in the mess.

The microscope shows plates of cholesterine, acicular fatty crystals, hæmatoidin, *elastic tissue*, blood corpuscles, plugs of disintegrating exudation, pigmented shreds of connective tissue, and pus, and free fat and molecular detritus. The differentiation of a stinking vomica and a gangrene cannot be made, therefore, from the presence of elastic fibres in the one and their absence in the other. Elastic tissue may be present in both, and a case of gangrene has already been mentioned where this was noticed, *cfr.* page 48.

Should neither abscess nor gangrene be the cause of a fatal issue, it may result, as I have seen in drunkards, from the occurrence of pulmonary œdema, in which event the sputa become watery-serous, profuse, exceedingly foamy and frothy, and their red tinge is of a darker hue than the normal expectoration, and gets the name of prune-juice sputum.

When acute passes into chronic pneumonia, the sputum becomes continuously catarrhal, and in catarrhal pneumonia from the outset the elements of the expectoration are cellular more than fibrinous. As secondary to bronchitis in hooping-cough and measles, the catarrhal process creeps downwards from the bronchi to the alveolar parenchyma, and causes the expectoration of a mucous or muco-purulent air-mingled sputum which contains no fibrinous coagula, or only thin thread-like specimens destitute of branches, or, perhaps, there may be a few scanty stunted plugs of coagulated exudation present. Blood may also speckle the surface of this sputum, and now and then, *but never for long*, it may contain isolated samples of the tenacious, pellucid, yellow, or tawny secretions characteristic of the croupous form of pneumonia.

Some anomalies of pneumonic expectoration have already been hinted rather than described. Ancient physicians considered that if there was no expectoration it was of bad omen. Now it is a likely thing that if the inflammation beginning in the alveoli fail to implicate the bronchi the sputa will be deficient, and yet the prognosis may be good enough; but if the deficient expectoration is owing to a want of power in the patient to expectorate, or a failure of his nervous system to appreciate the necessity for expectoration, then *no* sputum is indeed an evil sign.

As already noticed, the sputum may be *flecked* with blood at the very outset of the disease, and precede the more intimately mixed "*crachats rouillés.*" This may arise from the inflammation being more catarrhal than croupous at first. Sputa may also never be bloody at all, and they may be green or yellow, or shades of both, and yet show no reaction of biliary colouring matter.

From a prognostic point of view, it has been imagined that the depth of tint of the sputa would afford a trustworthy clue to the issue of a case. This is no certain exponent, but in a general way it may be said truly, and this is as old as Hippocrates, that the darker and blacker they are the more unfavourable the opinion that should be held of them ; but even this is not always true, for sputa by long retention in the air-passages may have a black enough colour when expectorated, and yet tell nothing as to the condition of the lung.

Like phthisis, acute genuine pneumonia has now got a micro-organism of its own. C. Friedländer (*Fortschritte der Medicin*, 1883, Band i., and *Virchow's Archiv*, Band lxxxvii.) found in the alveolar exudation and in the lymph channels of the affected portion of lung, in the pleural and pericardial effusions and in the juices aspirated, in the living subject as well as in the dead, from pneumonics a characteristic species of micrococcus. It is nearly always of the same size and form, and is often mixed with spindle and rod-shaped formations. The cocci are ellipsoids of about 1 micro-millimetre in length and one-third less in breadth. Spherical forms are also to be seen, but that arises sometimes at least from looking at the ellipse end on, in its long axis. The cocci cling together in pairs—diplococci—but also form chains of various lengths, which are easily recognised as aggregations lengthways of diplococci. In the fibrinous coagula of the bronchi and in the alveolar and pleural exudations the cocci lie strewn about independently, usually not forming zooglœic masses, which they sometimes do in the interior of the lymphatics. In the alveolar infiltrates they lie between the round cells and blood corpuscles in astonishing numbers, 100–1000 in each alveolus, and they have been seen embedded in the protoplasm of the round cells, 6–10 in each, of the red hepatization of a newly-born child, but were not visible in the free exudations of the same subject.

Günther found that those cocci had often a capsule of mucin or some allied substance around them, and the best way to show this envelope is to stain the cover-glass with an aniline water solution of gentian violet or fuchsin, then it is washed in alcohol, which quickly abstracts the colour from the ground substance, and much more slowly from the cocci and capsules. A stain recommended by Ribbert (*Deutsche Med. Wochenschrift*, 1885, S. 136), I have found to do better; it consists of a mixture of 100 water, 50 alcohol, 12½ glacial acetic acid, which are warmed and saturated with dahlia violet. The cover-glass preparation is brought in contact with this solution and only for a short time—one or two minutes—and washed in water. The cocci are found to be deep blue and the capsules a lighter blue, but too long operation of the dye will stain both so darkly that the sheath will not be easily recognised. If the stained cover-glass is treated with alcohol, the stain is removed from the capsule, and the coccus is seen surrounded by a colourless space, *cfr.* Chromo IV., Fig. 2, and Chromo III., Fig. 1, in which latter the rod-shaped structures which associate themselves with the cocci, in this case so abundantly, are stained with eosin.

Inoculation experiments have been made on rabbits, guinea-pigs, mice, and dogs. The rabbits seem altogether refractory to the organism, but the mice certainly die in 18–24 hours, and pneumococci are found in the inflamed lungs and pleural exudations, and the blood shows capsule bearing micrococci, so that there seems to be a general invasion of the system. Guinea-pigs and dogs are not so susceptible. A few inhalation experiments, spraying a cultivation of the coccus rubbed up with distilled water, were made, and mice were killed with certainty, and the usual post-mortem changes were found in lungs, etc., and the coccus with its capsule found in the exudation. Klein (*Micro-organisms and Disease*, 1886, pages 73, 74) seems to doubt entirely that the mice died of a pneumonia; he rather ascribes their disease to a septicæmia caused by a capsulated micrococcus, which is probably identical with one occasionally present in the mouth fluids of even healthy persons. He doubts also the accuracy of the statements of other observers who have, by artificial cultures of the micrococci of human pneumonia, produced pleuro-pneumonia in cattle; but he makes no mention of what his own observations were, and meanwhile the carefully detailed experiments and cultures of Friedländer and Frobenius are surely as worthy of belief. Nevertheless the conjecture that the pneumococcus is the *causa causans* of pneumonia has by no means obtained the same general acceptance as is the case with regard to Koch's bacillus and tubercle. Friedländer himself admits that it is not always demonstrable in the malady, and explains that the oneness of the pneumonic process is not satisfactorily proved, and that there may be several micro-organisms capable of engendering a pneumonia just as there are several endowed with pyogenic qualities. Except in old cases micrococci are to be found abundantly nearly always, but when separated and cultivated the results are negative, or if successful the crop behaves differently, both as regards *mode* of growth and effects on animals, from the pneumococcus.

Cover-glass preparations of pneumonic sputum or exudations may also be stained in Gram's way and after-treated with eosin, which is the method adopted in Chromo III., Figs. 1 and 2; or they may be floated for twenty-four hours on *weak* solutions of the aniline dyes; or Ribbert's plan, which has already been explained, may be given a trial, and the result may be seen in Chromo IV., Figs. 1 and 2; or osmic acid, by which the contour of the capsule is said to be well brought out without blackening. I have no practical experience of this last mode.

I have just read in *Berlin Klin. Wochenschrift*, June 28 and July 5, 1886, a remarkable confirmation of Friedländer's supposition that there may be several exciters of pneumonia. A boy, admitted to the Moabit Infirmary with typhoid and a noma complicating it, died, and among other things revealed at the autopsy there was a lobar pneumonia of right lung. In the cover-glass preparations made with the juices of the diseased lung and stained with aniline-gentian-violet great numbers of cocci, oval and round, and lying mostly in pairs, were found; they occasionally formed chains (streptococcus) of from 3 to 6 cocci, and heaps of 20 to 30 or more, in which groups of diplococci or rows of them remained distinguishable. Cultivations and inoculations convinced Dr H. Neumann that he had to do with an organism differing little from the coccus of pus from phlegmonous erysipelas. The source of infection was supposed to be the gangrenous mouth. The paper concludes with mention of a case of purulent bronchitis and broncho-pneumonia after measles in which staphylococcus albus and aureus were found in the lung-juices.

Pages 10 to 17 of Baumgarten's *Jahresbericht* for 1886 also reveal how much of uncertainty and divergence of views still obtain among investigators as to what is the real mycotic cause of croupous pneumonia. *Platonow*, in cultures made from pneumonic lungs and pneumonic blood, found that both cocci and bacilli developed, and he looks upon both as genetically allied. Further, in bronchiectatic sputum, and in mucus from the nose and saliva of which cultivations were made, he saw the nail-shaped mode of growth considered characteristic of the pneumococcus, and infers from all this, that neither microscopical examination of sputum nor successful pure cultivations suffice to give results so clinically useful as to enable one to say that this and not another micro-organism is the cause of lobar pneumonia.

Dreschfeld, on the other hand, finds capsule-bearing micrococci in the exudations, in the alveolar vessels, in one case in the kidneys, and has no doubt that they are pathognomonic of pneumonia.

Sternberg considers the microbe of saliva, discovered by Pasteur in 1881, and falsely believed to be the cause of rabies, to be identical with the pneumococcus of Friedländer. He can excite in rabbits quite the same maladies by pneumonic sputum, pneumonic exudations, and Pasteur's saliva-microbe.

Fränkel finds this saliva-microbe in the rusty spit of pneumonia and in hepatized lung, and believes that it can operate as an exciter of genuine croupous pneumonia.

Rühle, in one case, found the pneumococcus two days before the pneumonia was betrayed by its usual physical signs.

Schou, who set himself to isolate the diverse sorts of bacteria found in the blood and in the alveolar and pleural exudations in so-called vagus-pneumonia, met with three micro-organisms in the vagotomized rabbits; one of medium size and elliptic form was isolated, cultivated, and when inhaled or injected into the trachea or directly into the lung-parenchyma, an affection anatomically and pathologically identical with vagus-pneumonia was induced. The other two organisms did not seem to be pathogenic, although present in abundance in the blood in which, strange to say, the pathogenetic microbion could not be demonstrated.

PLATE XXI.

The rusty sputum of acute (croupous) pneumonia, showing the delicate fibrillation of the coagulated fibrine of the expectorated blood, in which many blood corpuscles, chiefly red, are entangled. In some places they are united into rouleaux. No ciliated or columnar cells are visible, but in many other parts of the preparation from which the photograph was taken they were so, and stamped the somewhat free bleeding in this case as a pulmonary one.

Objective, Zeiss, E.
Magnification, $= \frac{250}{1}$

Pl. XXI.

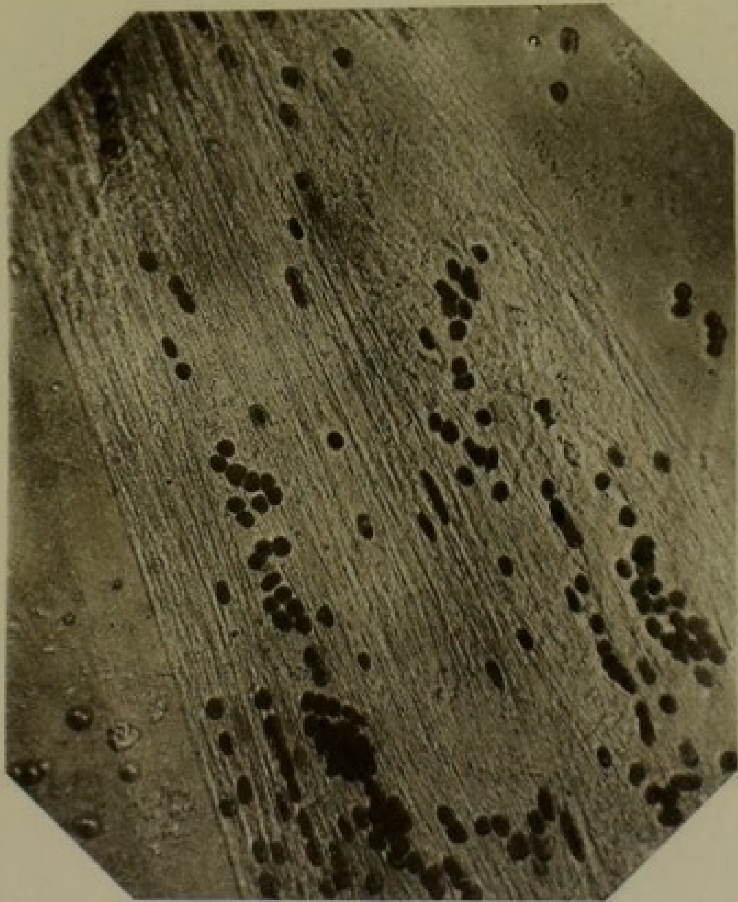


PLATE XXII.

Rhombic plates of hæmin or hæmatoidin from the same sputum as Plate XXI. Red corpuscles are also scattered about and collected in great quantity in right lower corner. The crystals are a yellowish-red when seen by transmitted light. Many of them are notched on their short sides like cholesterine; others have the appearance of rectangular parallelopipedons or square rods, because their side of least superficial area is turned to the eye of the observer. This pigment-crystal is a very rare find in sputum, at least in the great numbers of this specimen. I have also seen it on several occasions in the form of rhomboidal, thick, almost square lozenges of a beautiful ruby colour, which in everything but tint called uric acid crystals to mind.

Objective, Zeiss, E.
Magnification, $= \frac{250}{1}$

Pl. XXII

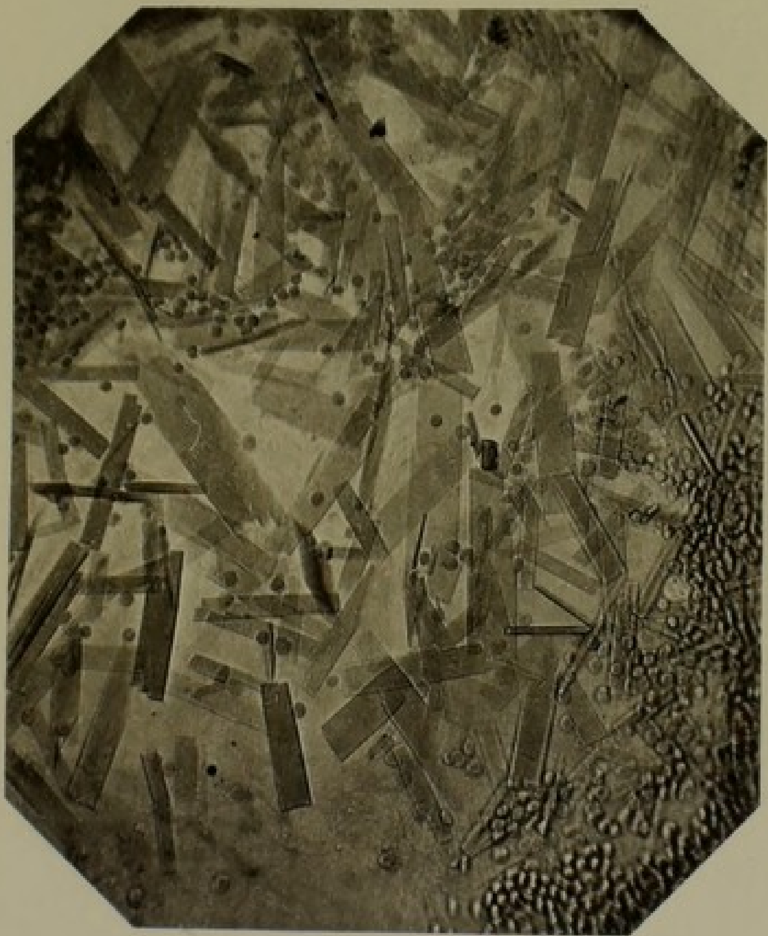
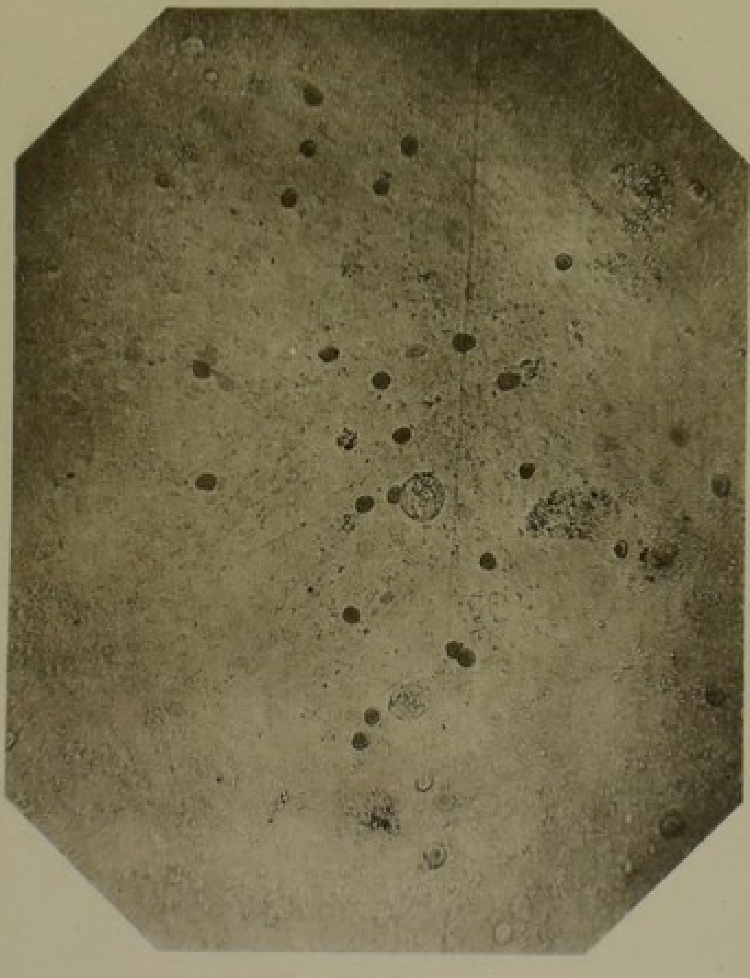


PLATE XXIII.

From another case of pneumonia, in which the expectoration was merely an orange colour, not at all rusty, the extravasated blood being small in amount. Red corpuscles are, however, present, and a good many pigmented forms of alveolar epithelium, some of them liquefying owing to fatty degeneration, but still retaining form and consistence; others so far dissolved as to be mere formless chaotic heaps of granules.

Objective, Zeiss, E.
Magnification, $= \frac{250}{1}$

Pl. XXIII.



CHROMO III.

Fig. 1

Represents the organisms found in the expectoration of a pneumonia ending in recovery on the fifth day. The preparation was made on the third day of the disease, when the sputum was at its rustiest. Enormous quantities of rod-shaped formations are seen made up of diplococci arranged in twos and threes. Circular or oval and larger diplococci are also scattered about. The stain is Gram and eosin.

Objective, Zeiss, K. Water Immersion. Oc. 3.
Magnification, about = $\frac{1000}{1}$

Fig. 2.

Preparation from pneumonic sputum made on the fifth day of disease, which ended fatally on the ninth. The same rod-shaped organisms are plentiful, and are similarly constituted of juxtaposed minute diplococci as in Fig. 1. The larger isolated diplococci have a very evident colourless space or capsule around them. They are also, like the bacilli, heaped into large and crowded colonies in some parts of the field. Both figures should be compared with the two in Chromo IV.

Objective, Zeiss, K. Water Immersion. Oc. 3.
Magnification, about = $\frac{1000}{1}$

Note.—I have never been able to demonstrate in the pneumonic sputa which I have examined the large capsulated cocci and rods which are so evident in a dry preparation brought from Germany, and shown to me through the courtesy of Dr A. W. Hare of the University Pathological Department. Is it possible that a German croupous pneumonia is specifically different from the one we see, or can we not stain properly?

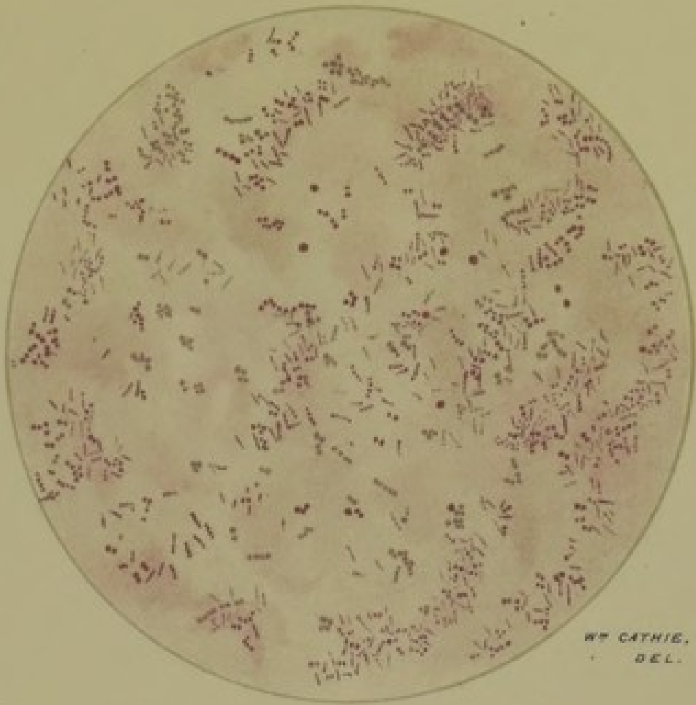


FIG. 1.

BACTERIA OF PNEUMONIA CROUPOSA.
Gram and Eosin
Zeiss K. Water immersion-Oc. 3.

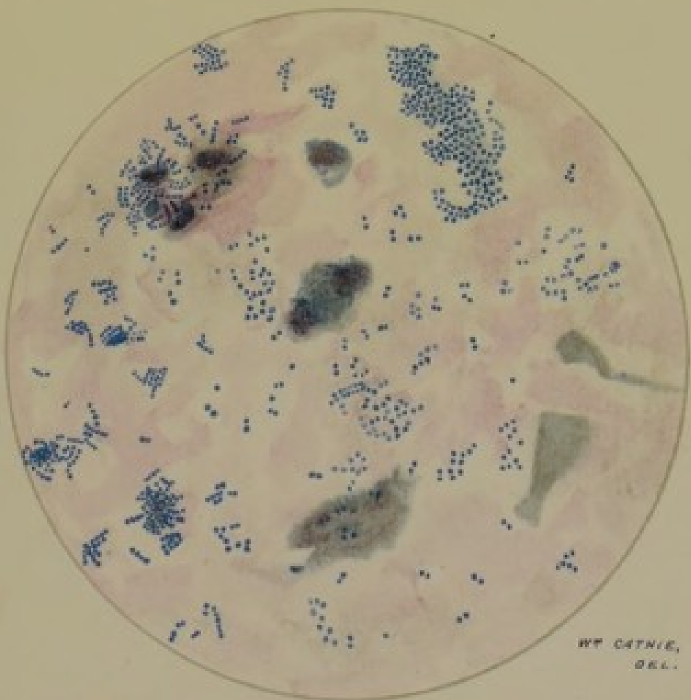


FIG. 2.

FROM A DIFFERENT PREPARATION OF PNEUMONIC SPUTUM.
Gram and Eosin.
Zeiss K. Water immersion- Oc. 3.

Chromo-Lithog. by W. & A. K. Johnston Edinburgh.

CHROMO IV.

FIG. 1.

From the sputum, after the lapse of eleven months, of the same patient who furnished the organisms represented in Chromo II. The rod-forms are now straighter, but are compacted of the same cell elements as before, namely, small diplococci arranged in twos or threes or longer chains, and larger diplococci isolated or disposed in tetrad forms; also colonies of rods and diplococci intermingled. Ribbert's dahlia stain.

Zeiss, K. Water Immersion. Oc. 3.
Magnification, $\frac{1000}{1}$

FIG. 2.

From sputum of an unresolved pneumonia, alluded to on page 156 of text. It now contains abundance of elastic fibres, and is also moderately rich in tubercle bacilli, exactly twelve of which are present in the field, and are easily recognisable by their slenderness and slightly curved outline. It scarcely needs to be said that such were found to be Koch's bacillus in the usual way of decolorization by nitric acid. Ribbert's stain has also shown them well enough. Many of the large cocci have a clear space around them, and so also have some of the rods, and the whole of the organisms, exclusive of the tubercle bacilli, greatly resemble those of croupous pneumonia on Chromo III., with which comparison should be made.

Zeiss, K. Water Immersion. Oc. 3.
Magnification, $\frac{1000}{1}$

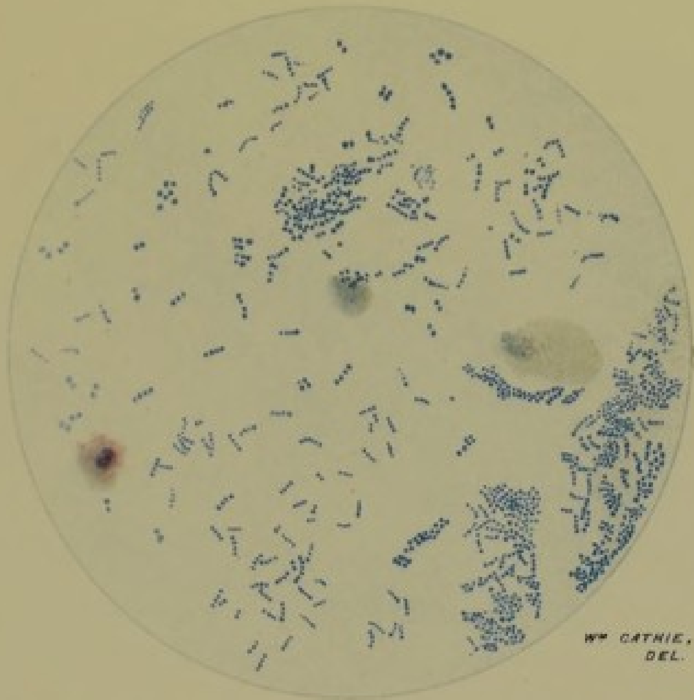


FIG. 1.

PSEUDO-BACILLUS AS IT APPEARS IN SPUTUM OF SAME PERSON.
AFTER LAPSE OF ELEVEN MONTHS - CFR: CHROMO. 2
Ribbert's Dahlia stain.
Zeiss K. Water immersion _ Oc.3.

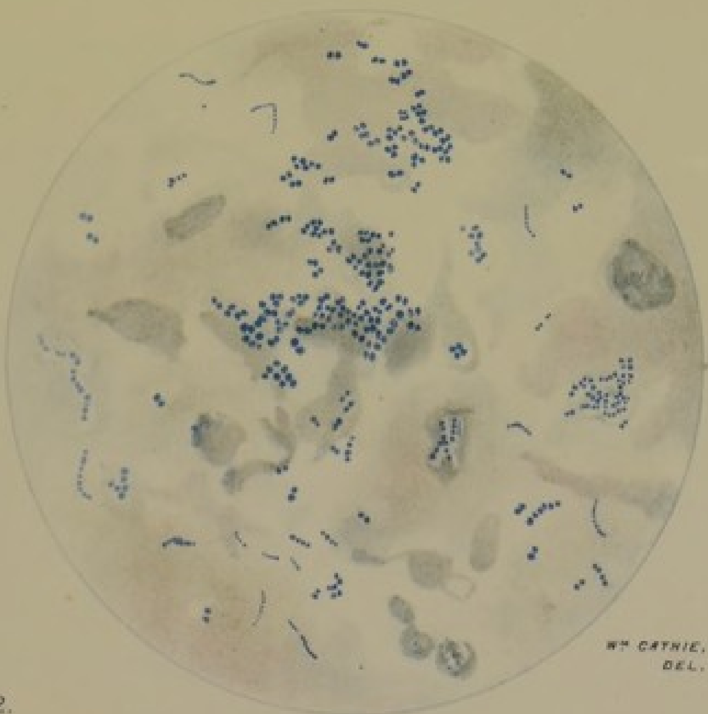


FIG. 2.

SPUTUM OF UNRESOLVED PNEUMONIA.
Ribbert's Dahlia stain.
Zeiss K. Water immersion _ Oc.3

Chromo-Lithog. by W. & A. K. Johnston, Edinburgh

CHAPTER VII.

I. Bronchitic Sputum.

THE air-tubes when in a normal condition do not secrete much material to be expectorated, but when irritated by causes from without or from within, great qualitative and quantitative changes of their secretions are effected, and, owing to participation of the bronchi in almost every pulmonary disease, form a large portion of every sputum.

A catarrhal inflammation of the bronchi is a frequent occurrence, and in its very first stage the sputa are serous, glassy, very viscid, somewhat like white of egg diluted with water, and as their expectoration is difficult, they are also mixed with frothy saliva; the transparent ropy mucus has threads or specks of white or yellow streaked through it. As the disease goes on, the viscosity of the sputa increases; they become more opaque, and are now greenish-white or greenish-yellow in colour and are intimately incorporated with air, bubbles formed by which boss their surface; they are also often dotted with stains of blood, or with hair-like radiating filaments of the same. When they become "sputa cocta" more of pus is blended with the mucus, and they now become less glairy and adhesive, still more opaque and yellow, and flatten out into a nummular aspect when spat into a dry vessel. In less favourable cases the sputa may dry up, as happens in suffocative catarrh, or they may remain of a watery mucous nature as in "pituitous catarrh."

Seeing that many different stages of the catarrhal process are represented in one and the same sputum, the cell elements will naturally be very various, but all of them are mere variations, as to age and rapidity of formation, of mucus, pus, and epithelial corpuscles. The more rapid the exudation the more the cell forms will be those of mucus and pus; the slower the exudation these same elements will have time to grow into large cells of an epithelial character.

When an acute catarrh of the bronchi becomes a chronic one, the expectoration possesses an extraordinary diversity of appearance. It is more opaque and purulent, and has sometimes the globular aspect of a phthisical sputum; it may be dirty gray or green in colour, and is occasionally admixed with blood so intimately as to give it a homogeneous reddish clayey tinge, or the centre only of an expectorated mass will have this uniform dirty red hue, while its periphery has a halo of a more pronounced shade. Now what I have here attempted to describe, if the spit is flat and blotchy as well, will cause even an experienced man to wonder whether he has to do with a simple bronchial catarrh or with more serious disease implicating the lung parenchyma. This vital question will be accurately decided by settling whether the bronchial secretion contains or does not contain elastic pulmonary tissue or bacilli of tubercle.

The tenacity of this chronic secretion is also very great, if the containing vessel is tilted over, the mess will flow out in a sticky, ropy, homogeneous flood, which as it moves will show panoramically the great variety of coloration present in the same dish,—a gray yellow-white, yellow-green colluvies, speckled with air-bubbles and topped with white frothy serum and saliva. After standing for many days it separates into three layers; the undermost and heaviest consists of the sputa proper, and contains a relatively large amount of unaltered pus-cells; the middle is a turbid, glutinous, yellow-green liquid with ragged flocci of mucus suspended in it; the uppermost is a large-bubbled persistent covering of saliva, or a foul sloppy serosity in which molecular debris, fatty disintegrated and disintegrating cells and epithelium are abundant.

The figurate elements in such a mess are as varied as its macroscopic appearances; plaques of old and young squamous epithelium; cornified casts of filiform lingual papillæ, *cfr.* Plate XXXII.; patches of the fungus figured on Plate VII., and which simulates elastic tissue; infundibular moulds clavate at one end; short bronchial casts; aborted Curschmann spirals; mucus and pus cells, *cfr.* Plate XXIV.; molecular debris and oily globules; crystals are represented by cholesterine, but not very frequently; triple phosphate very commonly; solitary Charcot-Leyden bodies; needles of fat isolated or tufted, wavy and twisted, or straight; or straight and hooked at one end like a shepherd's crook; or wedge-shaped and clustered as in Plate XXX. Among those which are less usual are octohedral forms of oxalate of lime; in this latter case one cannot help suspecting that they are of extraneous origin. In one sputum of a diabetic I found those crystals, and taxed the man with rhubarb or onions. He denied having had either; but another chronic bronchitic patient in the same ward who had partaken of rhubarb had used the diabetic's spit-dish, as was afterwards discovered. Still I have found the oxalate on several occasions where close inquiry could not elicit any outside origin for it. Spindle and round and columnar and ciliated cells are frequently present, and deeply pigmented and fatty alveolar epithelium is also a constant constituent, and is sometimes so abundant as to lend its colour to the sputum and to fill whole fields of the microscope; but more will be said about this cell-form hereafter, *cfr.* Plate XXVIII.

The bacterial forms present are usually of the coccal kinds:—

1. Circular and cylindro-elliptical diplococci of various sizes—1·5 μ to 3·5 μ in length, and 1·5 μ to barely ·5 μ in diameter.

2. Heaps of the same, large and small, and

numbering from twelve to thirty or more in one cluster, and giving one the idea that the smaller are daughter cocci of the larger.

3. Chains composed of small diplococci laid end to end, each pair being distinctly separated from those before and those behind it. When the chain is composed of two to four elements, it has an evident capsule ; when of twelve or more separate pairs, the sheath is not so apparent. Occasionally the chain is wound up into the semblance of a clew of yarn, or has many twistings and knots on it.

4. Tetrads large and small ; sometimes each coccus of the pair of the tetrad is *seen* to be cleaving transversely. The result will be that two groups of four, with individually smaller cocci, will lie beside each other. Sometimes the tetrad, instead of being composed of four single round cocci, is formed of two diplococci of equal size, lying parallel to and almost touching each other, and each element of the diplococcus may be frequently seen to have a constriction exactly in its equator; and this I take to be the beginning of its transverse fission.

The catarrhal inflammation of the bronchi may attain a higher grade, and become croupous in an acute or more commonly in a chronic form. Of course it is possible that an acute bronchial croup might continue uncomplicated, but generally it extends to the alveoli and then becomes a pneumonia, which disease is always attended by croupous inflammation of the bronchioles and bronchi. The essential microscopic sign in the sputum is the finding of fibrinous coagula. As already mentioned, those casts, when spread out or floated in water, display dichotomous subdivisions like the tubes in which they are moulded ; sometimes, however, their ramifications are not well marked, or are not to be seen at all, owing to the fragmentary size of the main branch. In this case their appearance is that of microscopic filaments of a singularly beautiful, dazzling whiteness, *cfr.* Plate XXV. In this sputum also there may be seen rope-like masses of large calibre at one end, which curl in wide loops across a microscopic field and terminate in a fan-shaped expansion or brush of exceedingly slender fibrillæ, many of which are straight ; others are zig-zagged obtusely or acutely, and all are of the glistening white just spoken of.

When the cover-glass is pressed down on a particle of this tough expectoration, its mucin puts on the appearance presented by Plate XXVI. ; this happens more certainly if it has been treated with a drop of acetic acid. Fibrillation takes place very much in the same way as the blood fibrine does in pneumonic sputum, only much more intricately convoluted streaks and bands are formed ; and they counterfeit elastic tissue so successfully that a warning has already been given against such a mistake.

Generally the course of an uncomplicated bronchial croup will be very chronic, and in addition to the dichotomized casts of the tubes the spirals of Curschmann will be present in the expectoration. Should there be complication, with an extensive catarrhal condition of parts of the respiratory passages, *its* cell formations will add their quota to the sputum, and there will be, in all probability, an irritable, feverish condition of the general system.

II. Bronchiectatic Sputum.

Dilatation is an organic lesion of the bronchial tubes which occasionally follows upon their chronic catarrhal conditions, and this has been explained by supposing that the voluminous sputa first of all dilate temporarily, and by-and-by permanently, the passages over which they travel, especially if the resilience of their walls is impaired; or the bronchial walls may dilate from the violence of coughing driving a rush of air into certain portions of the lungs.

The fusiform or sacculated dilatations become lined with a membrane which partakes more of a serous than mucous nature, and its secretions are not easily got rid of even by severe coughing. A consequent accumulation takes place, and high temperature of the body and communication with the air bring about their putrescence.

The sputum of this bronchiectatic condition has the general characters of a chronic bronchial catarrh. It is mucous or muco-puriform, or sometimes quite purulent; or it may be of a dirty yellow-white or yellow-green colour. It is extremely copious in quantity, especially in the mornings, and is often brought up in mouthfuls, instead of being expectorated in the ordinary way; indeed, it comes off occasionally with a rush as if a vomica had suddenly ruptured. It is rarely odourless; more generally it is very fœtid because of its stagnation and consequent putrescence in the sacculations and anfractuosities of the implicated bronchi. This fœtor has been likened by some to the odour of a soap-manufactory; by others, to that of rotten eggs or garlic. Its perfume is therefore variable, and is worst when it is recently ejected, and may be very slight in the intervals between the clearing out of the dilatations and their subsequent replenishment and evacuation. A pint or more may be expectorated daily.

But, as hinted above, bronchiectatic sputa do not always stink; in the intevals, as said, and in favourable atmospheric conditions, warm climates, or summer in our latitudes, nothing but an ordinary mucous catarrhal expectoration may be eliminated.

After standing undisturbed in the *crachoir* for hours or days, the sputum separates, as described when talking of chronic bronchitis, into three layers of very much the appearance then described, only the upper stratum has none of the spumous, frothy saliva, but is a semi-transparent or dirty brown or red fluid turbidity. Chemical examination has shown that such sputa contain ammonia, hydrogen sulphide, volatile fatty acids, and fat crystals.

Microscopically the morphological elements already enumerated in the chronic bronchitic sputa—at least many of them—are to be found, and also, it is said by good observers like Dr C. T. Williams (*Brit. Med. Journal*, 28th May 1881), lung-tissue in considerable amount. If this is a common phenomenon in bronchiectasy, the differential diagnosis between it and chronic phthisis would only be possible by demonstrating the absence of the tubercle bacillus, and history and careful local examination might suffice to exclude a chronic pneumonic process. I have never met with any such fibres in this disease, but could well conceive that the putrid contents of the dilated tubes might cause some corrosive action on the cavity walls or putrescent inflammation of the lung substance, and thus furnish elastic tissue to the secretions. If such fibres come from the bronchi they will not have the alveolar arrangement which obtains in those from the air-cells.

It may be said here that fatty crystals in needles or sheaves are by no means confined to the sputa of gangrene, putrid bronchitis, or bronchial dilatation. They, as well as cholesterine plates, are occasional constituents of non-putredinous expectorations; and Plate XXX. shows tufts of margarine inside the cast of some mucous, tonsillar (?) crypt, and which were found in a sputum which did not come from lungs undergoing any destructive process. When the needles of fat are long and curved, and have a hamular process at one end, they have a slight resemblance to pulmonary tissue, but chloroform or ether will speedily dissolve the fat, and have no effect on curly fibre.

III. Hooping-cough Sputum.

A few observations may here be made about the expectoration of hooping-cough. The sputa of this undoubtedly specific disease are catarrhal; clear, vitreous-transparent, ropy, tenacious mucus (or later on mixed with yellow purulent matter) is brought up in quantities so great as to fill the mouth and fauces. If examined attentively on a slide laid on a black ground, wavy or cork-screw threads of dull white or yellow may be seen coursing through the jelly-like mass. These streaks frequently contain formations similar to the Curschmann spirals, but are mostly made up of round, oval, and spindle cells, and columnar and ciliated epithelium, the last in small quantity. The viscid mucus fibrillates, *cfr.* Plate XXVI., and entangles cells of all kinds, which assume the linear arrangement of the fibrillæ; tiny Charcot-Leyden crystals may also sparsely dot the mucous threads. Great plaques of darkly pigmented catarrhal cells, of the form and size of alveolar epithelium, and very finely granular or molecular moulds of bronchioles, measuring $\frac{1}{250}$ of an inch in length and $\frac{1}{1700}$ in breadth, with clear indications of dichotomizing, are also present; as are also glittering plugs of fibrinous material, lumpy and clubbed at one end, the other drawn out into fine long lines which are zig-zagged or cork-screw shaped, seldom straight; others of these coagulates are long, broadly undulating lines, with fusiform dilatations here and there in their course; others look like wrinkled, gauzy, homogeneous membranous shreds of such extreme delicacy as almost to elude the eye of a practised observer, although the sinuous, disconnected lines and foldings which map them out may straggle over the greater part of a field. In the stage of decline the "sputum crudum" becomes "sputum coctum;" it gets less adhesive and more opaque, yellow and puriform, and exhibits chiefly the cell elements of Plate XXIV.

The micro-parasites I have found in this sputum are—

1. Isolated diplococci, or the same joined together into short staff-forms, or forming very long winding chains with knots and bows on them, or much shorter straight or curved threads.

2. Nests or colonies of the same diplococci varying much as to number and *size* of the individual elements.

3. Larger cocci arranged pair-wise, or as tetrads.

4. Chaotic heaps of all those four varieties intermingled.

5. Very slender staff-forms (three of them are seen on the left of Chromo V., Fig. 1, near the middle) made up of diplococci laid end to end.

6. Felted clumps of No. 5 intermixed with the before-mentioned micro-forms, *cfr.* Chromo V., Fig. 1.

All of those types seem to me to be very much allied to each other, and to appear in *every* expectoration where an inflammatory condition, whether croupous or catarrhal, prevails. Like the daughters of Doris—

> "Facies non omnibus una,
> Nec diversa tamen: qualem decet esse sororum."

Spores and mycelium of fungous growths have been found in the sputa of hooping-cough, and have been believed to be the specific cause of the disease. The devotees of this creed say that the more rapidly the fungus grows, the more it irritates the mucous membranes, and the more violent the "tussis ferina" it induces; as soon as an abundant secretion of mucus takes place, the parasites are floated away and expelled with the expectoration, and a mitigation of the paroxysmal cough at once happens. Fungi taken from a hooping-cough sputum and introduced into the trachea of a rabbit caused catarrh and explosive cough. It is, I believe, well established that *Aspergillus fumigatus* causes fatal epidemic lung-disease in geese and pigeons, but that pertussis is a pneumo-mycosis of a similar kind is extremely doubtful. Plates VIII. and IX. show that various mycetes may flourish in the *crachoir*, and I have a cover-glass preparation of a sputum, sent to me for examination by Dr Jack of H.M.S. Lord Warden, which is richly dotted with groups of spores without any mycelial threads, and which have been stained a beautiful blue by the formula of Gram—the disease in this case was a catarrhal pneumonia.

CHROMO V.

FIG. 1.

This drawing must not be supposed to display any organism specific to hooping-cough. It has been introduced more for the purpose of comparison with the other chromos, which show the microbes present in inflammatory conditions of the pulmonary organs. The long, gracefully winding chain is nothing more than a string of diplococci, laid end to end, and growing longitudinally, and its individual elements do not differ from those seen lying in heaps or strung into short rods. A few very fine bacilli are seen, similar to those so abundant in Fig. 1. of Chromo III., which represents the micro-organisms of a pneumonia.

Zeiss, K. Water Immersion. Oc. 2. Magnification, $\frac{760}{1}$

FIG. 2.

From the sputum of the case of acute phthisis mentioned at length at page 138, in the chapter on Bacillus of Tubercle, as furnishing an exquisite example of the co-existence of tubercle bacilli and other quasi-bacilli indicative, as I believe, of inflammatory conditions, croupous as well as catarrhal. The upper half of the drawing gives a good idea of the rod-like shape and parallel manner of the arrangement of the organisms, so different from that of the tubercle bacilli which are coloured red and lie around in numbers. The preparation is stained with fuchsin-aniline first, and then, without the intervention of nitric acid, with saturated aqueous solution of methylene blue (Ziehl's method), which displaces the red colour from all the bacteria save the tubercle bacillus. The lower half is from the same slide, only a higher ocular has been used, and thus the diplococcal elements of the quasi-rod are better seen.

Zeiss, $\frac{1}{12}$. Oil Immersion. Oc. 3. Magnification, $\frac{695}{1}$
Zeiss, $\frac{1}{12}$. Oil Immersion. Oc. 5. Magnification, $\frac{1265}{1}$

Fig. 1.

BACTERIA OF HOOPING-COUGH.
Zeiss K. Water immersion _ Oc. 2.

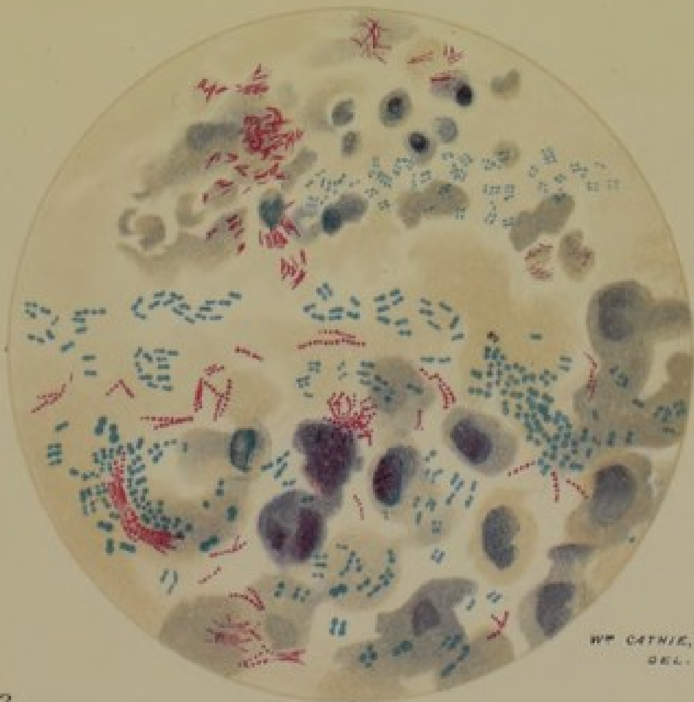


Fig. 2.

PSEUDO-BACILLUS SEEN IN ACUTE PHTHISIS ACCOMPANYING BACILLUS TUBERCULOSIS.
Upper half Zeiss 1/12 Oil immersion _ Oc. 2.
Lower half „ „ „ „ „ 5.

Chromo-Lithog. by W. & A. K. Johnston Edinburgh

2 C

PLATE XXIV.

Pus cells from a case of bronchitis when the sputa have become *concocted* or muco-purulent, consequently in the stadium of return to health. Towards the centre a number of the corpuscles seem to be surrounded by another fine homogeneous membrane, or endosmotic changes have taken place in them and caused the appearance.

Objective, Zeiss, E.
Magnification, $\frac{220}{1}$

Pl. XXIV.

PLATE XXV.

Plugs and casts of highly refracting fibrine from a case of croupous bronchitis. This plate does not represent the exceedingly fine lines and twistings of the fibrinous threads so well as the silver print from the same negative.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

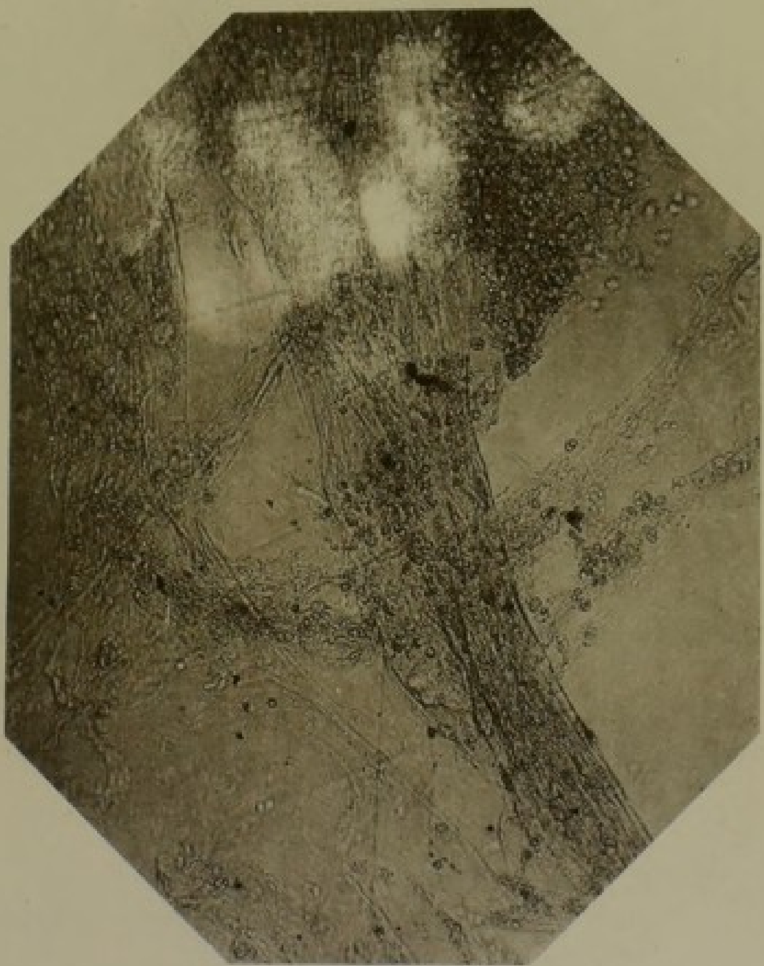
Pl. XXV.

PLATE XXVI.

Fibrillation of bronchitic sputum entangling in the meshes formed many corpuscular elements. The general resemblance to the strands and interlacings of elastic fibres is striking enough. Many faintly outlined fibrinous coagula are to be seen in the left lower corner of plate. The white marks above are finger-marks evidently, and no doubt made when developing the negative, or the gelatino-bromide plate may have been faulty originally.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

Pl. XXVI.



IV. Alveolar Epithelium.

It was believed at one time that adult pulmonary alveoli had no epithelial lining, and from a physiological point of view the presence of such a stratum would seem more an impediment than a help to proper aeration of the blood; and perhaps this thought tended to bias the minds of histologists and make them more readily persuaded that because a certain thing seemed a superfluity or worse, therefore it would not be present. By-and-by it was shown conclusively that the alveolar epithelial layer of homogeneous, continuous, polygonal, or irregularly spheroidal, flattened cells of the mature fœtus, with membrane, granular contents, and clear spherical nucleus, was continued into adult life. It was also demonstrated that the cells then became pigmented with the black grains which, more or less abundant in the alveolar walls, interstitial connective tissue, and other parts of the pulmonary substance, give to the lungs their dark spotted appearance.

After the existence of such cells was demonstrated, their presence was recognised also in sputum, and it was seen that the fauces were not the only or even principal *locus nascendi* of such cell-shapes which had lost their flattened form and become spherical from imbibition of fluids, pigmented more or less deeply, and engaged in fatty or myelin degenerative changes. Such cells are round or somewhat oval, and there are very great differences in their size from age, endosmosis, etc., *cfr.* Plates XXVII. and XXVIII. They contain a granular protoplasm and nuclei and nucleoli, both of which, however, are often obscured by the pigmentary and other changes just mentioned.

In "sputa margaritacea," the tough, starchy, airless, pearly-gray, semi-transparent pellets, dyed through or merely speckled with points of black pulmonary matter expectorated by many who have a morning cough, this epithelium is abundant, and its appearance, in stained or unstained condition, can be conveniently studied. The fineness of their granulation is very diverse, some being so coarse as to have a crenated or serrated contour; others seem to have no investing membrane, but to be mere granular lumps of protoplasm; others are pale and indistinct, with, perhaps, a portion of their contents tumbled out and lying in a heap beside the half-empty cell-wall; some have large fatty or myelin drops oozing from their surface, the boundaries of which are very faint; others form a chaotic, but still obscurely rounded, heap of highly refracting granules and drops. When many lie in proximity so close as to touch each other, they become polyhedral in shape with rounded-off angles, *cfr.* Plate XXVIII. Round, spindle, ciliated, cylindrical, cup and goblet cells from all the strata of the bronchial mucous layer often lie intermingled with them or on the edges of the patches in which they are grouped.

In the chapter on Charcot-Leyden Crystals (page 101) I alluded to a certain sputum, and noticed the presence of caudate, spore-like, refractile bodies among its constituents ; and I now draw attention to the fact, that in young persons expectorating alveolar epithelium a great proportion of those cells are undergoing this myeloid change. Their characteristic outline has faded, their contained protoplasm has become impregnated with, or replaced by, a highly refracting substance; at first in droplets, which coalescing increase in size and push aside the uninvaded portion of the cell, which then seems to become a mere appendage of the large refracting drop ; or the cell-wall is riven by the multitude of oily-looking enclosed globules which escape and blend together into very irregular, rounded, elongated and sinuous, or shorter balloon shapes, in which all trace of cell is lost. When the globules are free to float, the spore-like body is a frequently assumed form, and sometimes its tail is so prolonged that the whole formation resembles a spermatozoon ; gliding, amœboid movements of the larger globules, very strange to look at, may frequently be seen going on until the particle of sputum has dried on the slide.

What is the significance of this alveolar epithelium when it is found in an expectoration ? At one period whenever I saw it I suspected phthisis, and searched most carefully and patiently for curly fibre, but a more extended experience has greatly modified my views with regard to this subject, and the gravity of its meaning is now considerably less in my mind than formerly. It is true that such cells are abundant in all forms of phthisis, but then they are also common enough in many other respiratory affections, whether primary or complications of cardiac troubles. They are to be found in special abundance in obstinate catarrhs of the apex, when also they will be associated with columnar and ciliated cells. Now such a catarrh may or may not develop into a consumption (I have known such a state of matters continue unchanged for a score of years), but one cannot help fearing that such a fate will be the ultimate issue of many cases of this nature. Here, then, the physician should be put on his guard, as the microscope will warn of the possible danger long before any physical sign can be discovered by the most skilful ear; the younger the person, if free of cardiac mischief and consequent pulmonary complications, the more likely that such forebodings will be realized. I have for three years examined the sputa of every patient admitted into the Incurable Hospital here, young and old, with every sort of disease, pulmonary or not, and can say in a general way that alveolar epithelium is almost never missed; this makes me doubt the correctness of the statement, that under thirty, and in healthy people, it does not appear even when they may be the subject of bronchial catarrh. In a boy of 12, admitted with carious spine and psoas abscess, and an enormous bed-sore over the left hip and trochanter, with a slight cough and no elastic fibres or tubercle-bacilli in his sputum, there was abundance of this epithelium. One of course might argue that this was a case of apical catarrh, and that phthisis would have came on by-and-by, had he not succumbed to discharge and amyloid changes in bowels and elsewhere before a grave structural lesion of the lungs had got time to develop.

PLATE XXVII.

Alveolar epithelium and mucous corpuscles and molecular debris from the *sputa margaritacea*, expectorated in the morning by a healthy man who has had a morning cough for many years. None of the ciliated or columnar cells which usually accompany it are visible, the magnification is too small; the fibrillation of the mucin is well seen in some places. A small magnifying-glass will show well the granulations of the cells.

Objective, Oberhäuser, No. 7
Magnification, $= \frac{170}{1}$

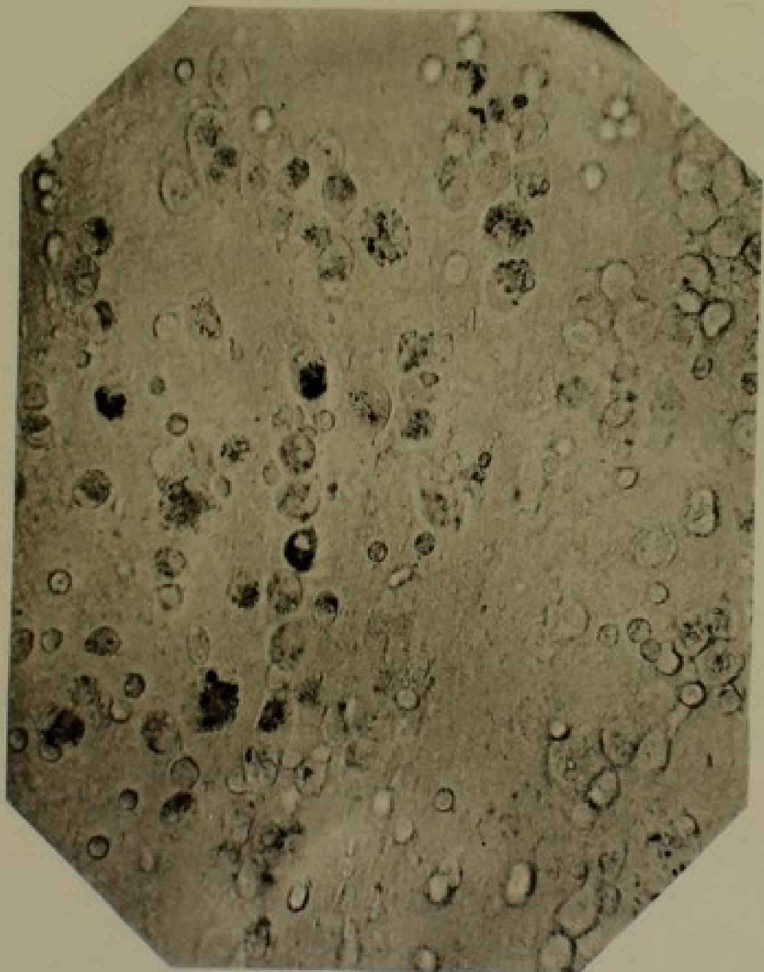
Pl. XXVII.

PLATE XXVIII.

Alveolar epithelium from a case of phthisis. Some of the cells are shadowy and indistinct, because out of the focal plane ; some, indeed many, give an excellent idea of their dark granulation and pigmentation as seen on a slide. In some the oil drops oozing from the surface are seen, and in others the appearance of an acorn in its cup is given by a heaping-up of the granular pigment at one of the poles of the cell, leaving the protoplasm of the other free.

Objective, Zeiss, E.
Magnification, $= \frac{250}{1}$

Pl. XXVIII.



CHROMO VI.

FIG. 1.

Microbes of the morning expectoration of a man who coughs a little every morning, otherwise in perfect health. Many of the tetrads which Koch believes assist the tubercle bacillus in disintegrating the lung in phthisis are seen. This matter has been alluded to on page 136 of the text.

Zeiss, K. Water Immersion. Oc. 2.
Magnification, about $\frac{760}{1}$

FIG. 2.

The normal microbes of the mouth of a healthy subject. There are numerous specimens of Leptothrix buccalis, and in the centre is a felted mass of the same. Long threads, formed of cocci, are abundant, and many of them have broken up into spiral and spirochaete forms.

Zeiss, K. Water Immersion. Oc. 2.
Magnification, $\frac{760}{1}$

CHROMO VI.

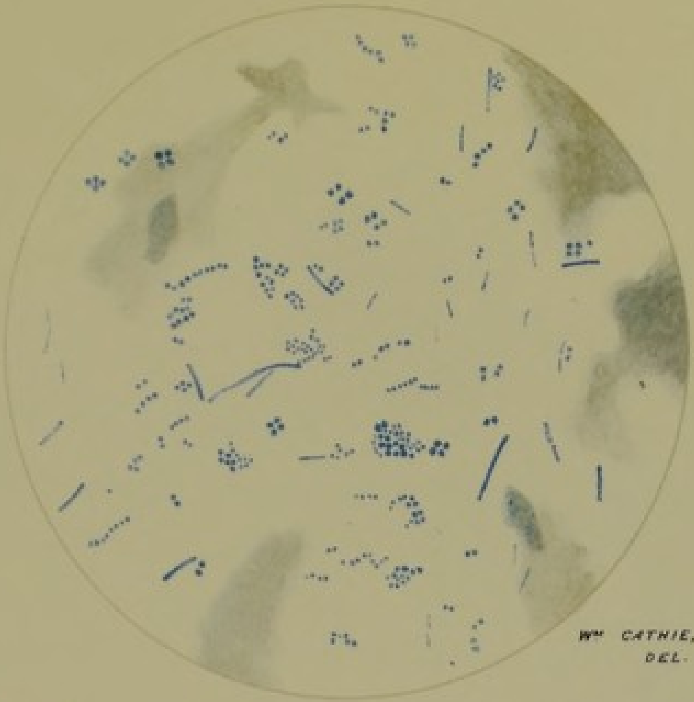


Fig. 1.

BACTERIA OF MORNING SPUTUM.
Methyl-Violet-Aniline.
Zeiss K. Water immersion — Oc. 2.

Fig. 2.

BACTERIA OF MOUTH.
Methyl-Violet-Aniline-Eosin.
Zeiss K. Water immersion — Oc. 2.

Chromo-Lithog. by W. & A. K. Johnston, Edinburgh.

CHAPTER VIII.

Pigmented Sputa.

Pigmentation of very varied degree and duration occurs in the sputa of persons engaged in the exercise of certain avocations, and is the result of the inhalation and deposition in some part of the respiratory tract or lung parenchyma of fine particles, which may be of animal, vegetable, or mineral origin, and which have been suspended in the respired air.

In former times, when coal-gas was unknown in the villages of Fife, and when hand-loom weaving was the staple industry of the villagers, the weaving shops were lighted during the winter season by means of smoky oil-lamps, and black spit was common enough during the short days, and disappeared after artificial lighting had been discontinued. In operatives engaged in the scutching and heckling flats of tow and flax factories, where the air is loaded with fine dust, I have seen disease caused and expectoration tinged with microscopic particles of those textile fabrics; similarly, in sawyers working among very hard wood, such as the teak which at one time was largely used in ship-building, I have witnessed cough, night sweats, and wasting as in ordinary phthisis, and have recognised woody tissue in the sputum. Where wood fires are mainly used, expectoration often contains carbonized splinters with thorny processes, or showing medullary plates of some size, and recognisable sometimes as being of coniferous derivation by their punctated tissue with double circle or disc; the colour of such fragments, when viewed by transmitted light, is not black, but a very dark ruby red. I have attended professionally the workmen of a brick and tile factory, who noticed that during the days on which they were employed in emptying the kilns of their burnt and dried contents they spat up bloody-looking sputa. Mason's phthisis also came not unfrequently under my notice among young men who had migrated, and after working in the sheds of large towns, returned ill to their native places. But the most exquisite example of expectoration coloured *ab extra* is the "black spit" of colliers, which better ventilation of pits and shorter hours of labour are doing much to diminish. The micro-photograph, Plate XXIX., was taken from a specimen of such a sputum sent to me for examination by Dr Dow of Dunfermline.

It is amazing how long the black stuff is expectorated even after pit-work has been completely given up. I once attended a man whom I knew only as a master baker; he had cough, sweats, and dropsy; his sputa were black as ink, and contained elastic fibres. On my asking him if he had ever been a coal miner, he said he had, but had not been down a pit for twenty years, and that he only spat the black material when he had a bronchitic attack; his bronchitis was disintegration and liquefaction of his lungs, which set free the imprisoned carbonaceous materials inhaled and deposited during his underground life.

Not only is the sputum drenched with this black pigmentary matter, the pulmonary structures themselves are extensively infiltrated by it, and most people now believe with the late Prof. W. Thomson, who had ample opportunity of studying the disease in the Old Glasgow Infirmary, that it is the carbon, derived from coal dust, smoke of gunpowder used in blasting, and of oil-lamps, by which the atmosphere in which the miners labour is so highly impregnated, which causes the pigmentary changes in the lung. Wherever there is ciliary motion the inspired carbonaceous particles are extruded and appear in the sputa, but when they have penetrated as deeply as the alveolar parenchyma, where there are no ciliæ to expel them, owing to the intrinsic hardness and angularity of even their finest atoms they penetrate the tissues and find their way to the pleural, subpleural, and other connective structures, or are carried to distant parts by corpuscular elements such as leucocytes, which possess the quality of incorporating particles with their protoplasm, or reach the mediastinal lymphatic glands in the lymph stream.

But there is an autochthonous, *ab intra* pigmentation of which notice must be taken. Looking into the spit-dish of a man of 29, first a hewer in the mason trade, then a soldier in Egypt, admitted this summer (1886) into the Incurable Hospital with aortic stenosis and regurgitation, the colour of the mucous sputa struck me as peculiar; it was of a snuffy, yellow-brown tinge, and at first sight seemed as if minute flakes of softened loaf-crust had been peppered over it, or, as Dr Affleck remarked, as if drops of beef-tea had been spilt over its surface. The quantity of expectorated matter was scanty, its separate pellets were small and viscid, and mucous, and did not readily coalesce in the dish. When examined microscopically the abundant alveolar epithelium was found to be dyed with various shades of yellow or golden-brown, and nevertheless much of it remained so transparent as to show cell nuclei and nucleoli easily. The contrast between this yellow pigmentary matter and the black carbonaceous stuff which usually fills such cells to repletion was very impressive; the question arose, Is this siliceous impregnation from his quondam trade, or Egyptian sand, or hæmoglobin? The microscope revealed no *free* angular particles however minute, nor on the other hand were any blood corpuscles visible, or if present they were in such a state of dilapidation and disintegration as to be indistinguishable among the other figurate elements of the sputum: agitation of a small portion of it with distilled water in a test-tube, the addition of a few drops of Tinct. Guaiaci and renewed agitation, and finally pouring a stratum of ozonized ether atop of the whole, was used as a blood test. In a very few seconds a green-blue or blue coloration became very distinct at the junction of the supernatant ethereal layer with the denser substratum, thus showing that the pigmentation in question was due to altered hæmoglobin.

The sequence of events here seems to be the following :—Obstinate congestion of the pulmonary tissues consecutive to the heart mischief, rupture of minute arterioles or capillaries, or transudation of blood-stained serum or a diapedesis of red corpuscles through the uninjured walls of vessels, separation of the alveolar epithelium, and soakage and adoption of the blood-pigment into its protoplasm. The anatomical condition of lung must be either hæmorrhagic infarct or more likely a state of brown induration.

The micro-bacteria which I have found on staining the sputum of this case are very much the same as those of a chronic bronchial affection : they are chiefly of the twin-coccal sorts, which possess either perfectly circular or bluntly elliptical cell elements ; they lie in heaps, or in parallel rows, or rayed out in a fan-like manner with their long diameter in the long axis of the rays, and large and small are intermixed : the largest are $3 \cdot 5\ \mu$ in length, with a breadth of $1 \cdot 5\ \mu$: often they have a capsule formation around them which assumes the shape of the enclosed diplococcus, having a well-marked equatorial constriction if it is of a figure of 8 shape. The elements of the medium-sized varieties are almost cylindrical, but those of the very smallest, which are barely 1 μ long and ·4 μ broad even when joined into diplo-form, are perfectly round, and are the only ones which I find united into short torulose combinations similar to what is seen in Chromo V., Fig. 1.

Bile pigment is an occasional constituent of the pulmonary secretions, and gives the expectorated matters a bright yellow, buff, or green tinge. In the catarrhal sputa of a patient intensely jaundiced from malignant liver disease, I never can obtain with nitric acid any reaction indicative of biliary colouring matter; but several times in pneumoniæ, of which icterus was a concomitant or complication, the saffron-yellow expectoration has, in my hands, given distinct indications of the presence of bile pigment when treated in this way. The last occasion on which I witnessed this was in a case of right-sided pneumonia with typhoid symptoms, and the recovery of the man, long very doubtful, was a very slow but ultimately a perfect one. This has not often been my experience, for when icterus and pneumonia met, especially if the urine was at the same time albuminous, the result was generally fatal. Dr Watson (*Principles and Practice of Physic*, 3rd edition, 1848, page 541) makes mention of a very strange sputum in a pneumonic patient who became also jaundiced; tenacious mucus of a deep grass-green colour was expectorated, with here and there patches of yellow: "collected in a basin, large pyramidal bullæ projected among it of green colour and crumpled irregular surface, looking like bells of moulded green glass. And when the summits of those bullæ were broken through, the bubbles did not collapse, but their brittle walls remained firm, as they might have done if really vitreous." Dr Watson does not state that tests were applied, simply saying that "the secreted mucus of the air-passages had received its very unusual hue from the bile that circulated with the blood." The microscopic examination of this sputum would have been an interesting one.

I have somewhere read the remark that nitric acid dropped on a colourless mucous sputum will cause a play of colours, or at least a greenish tinge, and so simulate the presence of cholepyrrhin. With regard to this I can say that I have so tested the spit of all the residents in the Incurable Hospital, and find that the sole change occasioned by the nitric acid is that it becomes of a dull leaden-white or very pale yellow colour, in concentric rings or streaks and bands, from coagulation of albumen in the neighbourhood of the drop.

The green pigmentation of spiraliferous sputa, and which increases with age up to a certain point, has been spoken of at length in the chapter on Curschmann Spirals.

Traube has observed in the warm summer months a *yellow* sputum, the so-called *egg-yolk* sputum, in which the coloration is occasioned by masses of spores and filaments of Leptothrix buccalis. He found that in the mouth and among the teeth of patients who expectorated secretions of this nature, large quantities of leptothrix were accumulated, and as this fungus is naturally of a yellow tinge, the colour would be much intensified if its growth in the expectoration-dish were luxurious. I have never seen this "egg-yolk" sputum, which can have no diagnostic or prognostic signification, considering the extrinsic cause of its appearance.

2 F

PLATE XXIX.

The sputum of a collier who had wrought in mines for a generation. Only the fragments of carbon, which are very abundant, and some of them very large and angular, are shown. The catarrhal cells are not in focal plane, but they were very deeply pigmented—in fact, perfectly black. The edges of the solid particles, when looked at by transmitted light, seem not so much black as a blackish-brown colour. At the first examination of this sputum a year ago, I found no tubercle bacilli or elastic tissue. To-day, having kept the specimen in a narrow glass tube all this time, I re-examined the thick inky deposit which has settled at the bottom, and find elastic tissue sparingly, plenty of coffin-lid triple phosphates, coal and wood-charcoal debris, and very long fusiform fatty crystals.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Pl. XXIX.

CHAPTER IX.

Bloody Sputa.

THE most intimate and uniform diffusion of blood through the bronchial secretions takes place in the alveoli and finest bronchioles, and according as one or other constituent preponderates, all shades of yellow, brown, or red will be presented. The *crachats rouillés* of pneumonia, the characteristics of which have been already detailed, afford the most perfect example of this homogeneous mixture.

The sputa of hæmorrhagic infarction have also a certain resemblance to those of pneumonia; in them also blood and pathological secretions are very closely mingled, and if there has been no large or moderate initial hæmoptysis, and if the quantity of amalgamated blood is slight, the similarity becomes very deceptive. To make a correct diagnosis it has to be remembered,—1. That lung infarctions mostly depend on valvular heart-mischief, or, as I have repeatedly witnessed, on the presence of putrid ill-conditioned sores in some part of the body, such as the pressure-sores of paraplegics from fractured spine; 2. That generally there is first of all a moderately large hæmoptysis; and 3. That often the sanguinolent tinge of the expectoration rapidly disappears, or comes and goes or lasts a much longer time, and so behaves quite differently from that of pneumonia.

Brown induration, the sputa of a case of which have been described above, Chapter VIII., depending also on heart-lesions, may cause difficulty and be confounded with infarct, but the blood-staining goes on from day to day and week to week without any notorious outbreak of bleeding; and, from the congested condition of the lungs, the expectorated matters are of a watery mucous nature, not destitute, however, of toughness and resiliency under the cover-glass.

Whenever sputa are sanguinolent, a careful inspection of gums and mouth and fauces should always be made. Some people have an unconscious habit of sucking the gums, and thus causing slight bleeding, and if they have a cough the expectoration will be tinged with red. Microscopically, I have been able to tell the source of such a hæmorrhage from the great quantity of squamous epithelium present in the spit.

Should bleeding of moderate amount take place in the last stages of a phthisis, the pus of the cavernous secretions will incorporate intimately with the extravasated blood, and either tolerably fresh-looking masses of a bright red will be expectorated, or, if stagnation in cavities has been of some duration, they will be of a dirty-brick or clay colour. If examined microscopically the blood elements will of course be met with in addition to the shreds of elastic tissue, and amorphous detritus from cavern walls, free nuclei, pigmented cells, and pigment grains, and the multitudinous pus-cells, which latter form the basis, while all of them are characteristic of such sputa.

But a hæmoptysis may be so large as to be mortal in a few minutes. Excluding aneurisms, this happens chiefly in cases of phthisis where tolerably large excavations exist, with vessels of some size traversing their walls or stretching across their interior, and which become eroded by ulceration or ruptured in fits of coughing. It is amazing that extensive bleeding does not occur more frequently. I made a sectio lately, and found that the right lung constituted one spacious cavern with ragged, honey-combed walls, dripping with pus and filth, and having many cords of obliterated arteries extending from side to side, and yet that patient had never a trace of blood in his very copious sputa.

A very large hæmorrhage may also announce the fact that phthisis, as yet unrecognisable by physical signs, has begun its career. A case of this nature has been related at length in the chapter on the Tubercle Bacillus at page 138. Bleedings, larger or smaller, may also attend the progress of a consumption throughout its whole course; and an approaching hæmorrhage is sometimes preceded by an extreme rise of the nocturnal temperature. Of course I do not speak now of cases where the amount of blood lost amounts only to a few daily or weekly specks. Such patients have an evening temperature little over the normal, and the morning nadir is often a good deal below it, and their disease runs a very chronic course. And when speaking of temperatures it is well to say that occasionally in phthisical patients the temperature maximum may be found at mid-day, and the lowest depth of remission at mid-night.

If a bleeding is large and sudden the question always arises, Is it a hæmoptysis or a hæmatemesis? It is often said that lung-blood is either fluid or, if coagulated, is firmly so, and is of a bright red arterial colour and frothy; that, on the other hand, gastric blood is blacker, and has a softer, more friable clot, which may contain fragments of food or other stomach contents. It is a very difficult matter to tell offhand, from mere inspection of the clots, whether they have come from lungs or stomach, or it may be both. When blood from the lung is coagulated, air-bubbles are sometimes included in the coagulum which, when cut across, shows a porous, spongy section. This I have had frequent occasion to verify, and it may help to settle a doubtful diagnosis. But "*latet dolus in generalibus*," extravasation may take place into the lung and clot among cavern contents, and be decidedly dark; and a pulmonary origin may be wrongly assigned to blood which has leaked from nose or mouth or fauces, trickled into the trachea and bronchi, acquired a certain amount of floridness of colour, excited cough, and been spat up. Frequently the puzzle may be solved microscopically by finding the cell-forms peculiar to the air-passages intermingled with the expectorated matters.

Supposing it decided that the hæmorrhage is of pulmonary origin, the next point is, from what portion of the respiratory organs has it flowed? and whether is it from rupture of vessels or merely exhaled from the mucous surfaces? The patient's feelings can sometimes settle the first, but the general rule is that laryngeal or tracheal bleedings are rare, and that their most frequent site is in the bronchi and lung-parenchyma.

Whatever causes remora or stasis and hyperæmia of the pulmonary circulation, such as cardiac or tubercular diseases, will cause extravasation of blood; and just as in epistaxis, so in hæmoptysis, hæmorrhages profuse enough to endanger life can occur without any mechanical lesion of vessels. The blood is exhaled from the mucous surfaces of the air-passages *per anastomosin* or *per diapedesin*, as this mode of morbid bleeding was variously designated by the old physicians. This capillary transudation, not unknown in persons with all the outward signs of flourishing health, is a frequent concomitant of purpura hæmorrhagica, and sometimes lays the foundations of the phthisis to which numbers of such patients fall victims.

When I began practice, spitting of blood, if not "vicarious" (as the phrase was) of some suppressed catamenial or hæmorrhoidal discharge, was looked upon as the certain index of one of two things—cardiac disease or tubercle; but by-and-by I saw repeated large pulmonary hæmorrhages take place, and the subjects of them recover without apparent damage to their lungs; and I have personal knowledge of two very aged gentlemen who had in youth extensive recurring hæmoptysis, who underwent the then regulation treatment of phlebotomy, blistering, and depressants of all kinds, and yet who have led active and useful lives, and have outlived fourscore years.

Blood effused in this way may, however, if it penetrates to and remains in the alveoli, become the starting-point of pneumonic processes which may not resolve but end in cheesy infiltrations, leading to phthisis. Niemeyer, in his clinical lectures (1870), adopted this view, which is now pretty generally accepted as correct, and as likely to happen, at least if the bleeders are of feeble constitution or placed in unfavourable hygienic circumstances. It was thought at one time that cardiac affections and phthisis were antagonistic, or rather that the subjects of heart disease enjoyed immunity from phthisis. This is too dogmatic a statement. There is at present (1886) a patient in the Incurable Hospital here with cavity in left apex, bacilliferous sputa, and serious aortic and mitral lesions.

When blood is extravasated subcutaneously, a metamorphosis of its colouring matter takes place. It presents first a violet, then a green, and, finally, a yellow tinge as time wears on. Analogous changes happen when the extravasation is discharged into the bronchi and alveoli, and stays long enough there to permit of the higher oxydation of its hæmoglobin. The spit of a croupous pneumonia, as the disease passes through its various phases and ends in resolution, affords an excellent model of those colour mutations: first red, then a tawny red-brown, then yellow-red; lastly, shades of yellow, ranging from saffron to lemon. As formerly noticed, yellow-green or grass-green of sundry shades in pneumonic sputum, in my experience, sometimes depends not on blood colouring-matter, but on the presence of biliary pigment.

To recapitulate—

1. Putting aside injuries to the thoracic walls and aneurisms, the cause of lung bleeding may be shortly stated as local hyperæmia in the respiratory organs.

2. Cardiac disease and tubercle are frequent causes of such congestion leading on to transudations of blood, and in the latter ailment blood may be expectorated before physical examination reveals anything amiss in the lung.

3. Therefore, where heart lesions can be excluded, frequently recurring hæmoptysis is of gloomy import.

4. And yet cases happen where no damage seems to accrue any more than from the epistaxis of *young* people, but such are the exceptions which "*firmant regulam.*"

5. Blood is extravasated in bronchitis, in pneumonia, in hæmorrhagic infarct, and in brown induration.

6. Large bleedings may take place without demonstrable mechanical lesion of vessels, but they also happen from ulcerative processes, such as in chronic pneumonia, phthisis, bronchiectasy, gangrene, and metastatic abscesses. In every case age, sex, subjective and objective signs and symptoms, and anamnestic phenomena must be taken into consideration and duly pondered.

PLATE XXX.

Crystals of fatty acids found in the expectoration where no putrid or gangrenous process was going on in the lung. Most of them are embedded in an irregularly oval, dimly transparent, molecular mass of detritus. It is the cast of a mucous crypt, probably tonsillar.

Objective, Zeiss, E.
Magnification, $\frac{250}{1}$

Pl. XXX

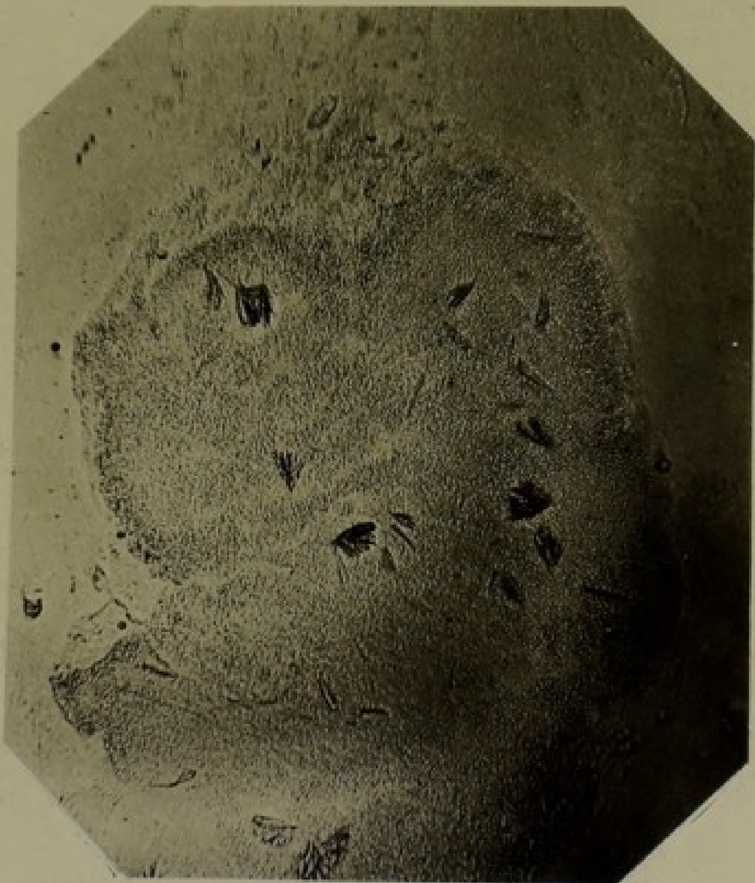


PLATE XXXI.

Bodies found in pneumonic sputa. They refracted light very strongly, and had an oily lustre. They seem to be either cells rendered hyaline and expanded by endosmosis, or an agglomeration of cells which have undergone some fatty metamorphosis, or become infiltrated with amyloid matter—the so-called "corpora amylacea,"—rarely to be found in sputum. I have only once seen those formations, and do not pretend to say precisely what they are.

Objective, Oberhäuser, No 7.
Magnification, $\frac{150}{1}$

Pl. XXXI.

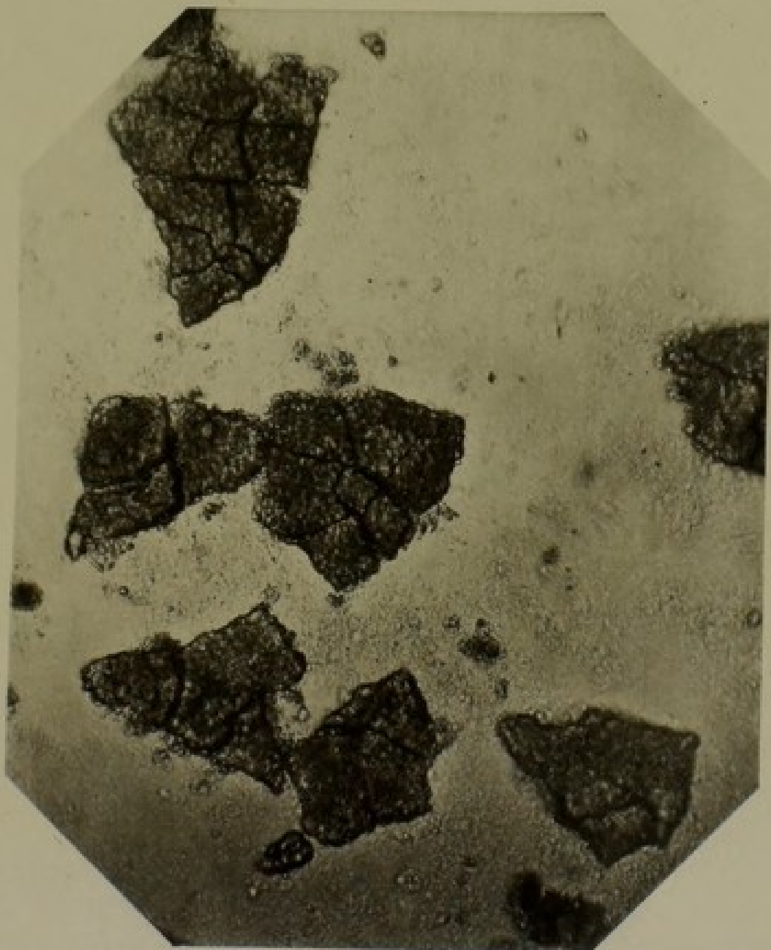


PLATE XXXII.

Cornified epithelial cast of filiform papilla of tongue. A frequent sight in expectoration, and apt, when the component scales are not packed densely together, to be mistaken for elastic fibres. Generally such bodies are brownish in colour, have a dark arborescent axis, and a finely granular cortex, which serves as a matrix for luxuriant growths of Leptothrix buccalis, which, with a power of 300 or 400 diameters, may sometimes be seen throwing out forests of capillary filaments dishevelled like the hair of a Medusa.

Objective, Carey's $\frac{1}{4}$
Magnification, $\frac{80}{1}$

Pl. XXXII.

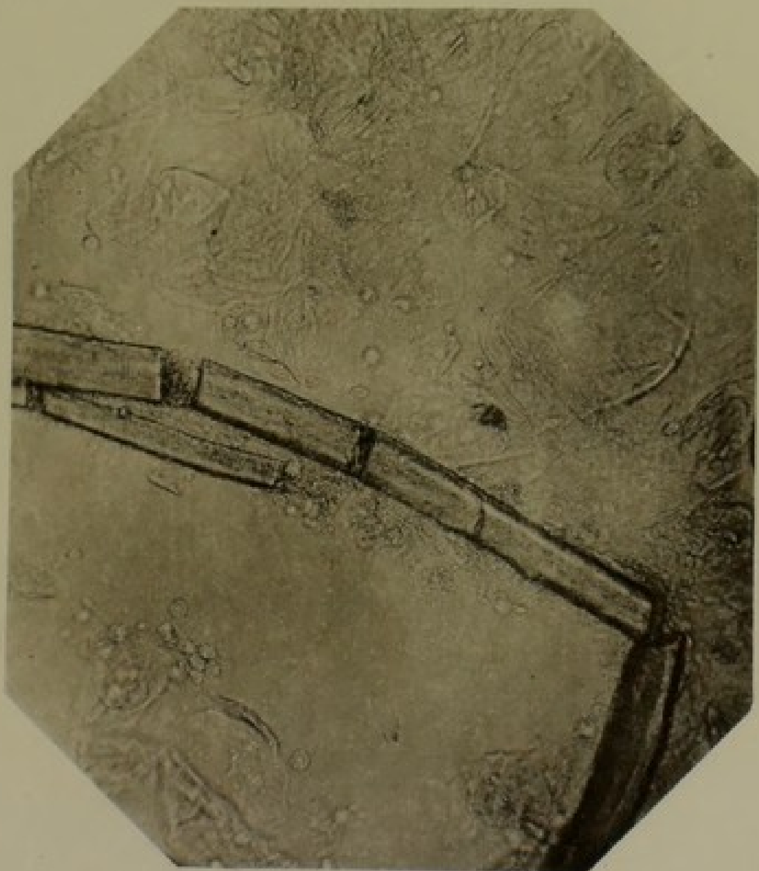
2 H

PLATE XXXIII.

Epithelial scales and fragments of muscular fibre contributed to the sputa in their passage through the mouth. The rounded polygonal form and transverse striation of the muscular fascicle has come out well. Numbers of pus cells are scattered about.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Pl. XXXIII



CHAPTER X.

Sputum in Diseases of the Larynx and Neighbourhood.

As the mucous lining of the larynx and trachea, save over the vocal ligaments, is quite identical histologically with that of the bronchial tree, the pathological events which occur in the two territories are also similar, so that qualitative differences of the secretions eliminated are not of great magnitude, and one would be rash who would say positively, from their general appearance merely, that one specimen had come from the windpipe, or another from a lower source. Even when a person has the subjective sensation that he has hawked up secretion from a definite spot in his larynx, it may nevertheless have been transported thither by ciliary action from deeper parts.

It is confidently said that laryngeal sputa are rounded, lumpy coagula of small size, and it has also been asserted that the starchy "*sputa margaritacea*" of the morning have no profounder origin than the *ventriculi laryngis*. But all this must be taken *cum grano*, as I have observed the discharges from an ulcerated larynx, when spat into a dry vessel, expand into flat, blood-stained nummular masses; and it has been no rare experience of mine to find, in the starchy, gluey morning expectoration of early phthisis the bits of alveolar parenchyma, which showed too plainly the depths from which the secretion had travelled. Where bundles of tissue of the sort figured in Plates I. and II. are demonstrated in a sputum, their source is evident enough, but the laryngoscope is a much safer diagnostic guide than any sputum in most of the diseases to which those parts are liable.

It is worthy of remembrance that an elongated uvula may cause laryngeal irritation of so violent a nature as to give rise to suspicions of serious organic disease. The cure of this particular state is generally of easy accomplishment, by truncating the lengthened uvula, for which operation an ordinary bistoury, or scissors and forceps, are all that are necessary. There is no need for the special instruments depicted on plate vii. of Horace Green's work on *Bronchitis*, published in New York in 1849, and from which book I first learned this practice of staphylotomy.

Inflammatory affections of the larynx and trachea, just as in the bronchi, are simply catarrhal or of a croupous nature, and may also be acute or chronic in their course. When catarrhal, the sputa differ in nothing from ordinary catarrhal secretions of the deeper parts, and consist of the cellular and amorphous elements which have already been noticed. The primary croup of children, which has in general a precedent but short-lived catarrhal stage, is an excellent example of a croupous condition. Whenever the mucous lining of the windpipe is covered with the exudation, expectoration ceases, or in more favourable cases the false membrane may be coughed up. Laryngeal complications are also not uncommon in diphtheria, scarlet fever, and other exanthemata (I have seen a fatal croup in roseola æstiva); and other specific diseases travel from the throat downwards, and cause abscess and necrosis of the cartilages. Or the inflammatory changes may reach the bronchi and pulmonary parenchyma, and then the branched, cylindrical casts and rusty colour of a pneumonic sputum will show themselves.

In ulcerative processes affecting the larynx, as has been already pointed out, expectorated fragments of tissue, when seen under the microscope, support in a very substantial manner what may have been learned by local examination and the laryngoscope. The staining for tubercle bacilli will also enable one to speak with precision as to the simple inflammatory or tubercular nature of an ulcer when seen laryngoscopically.

Doubt no longer reigns as to whether phthisis laryngea is ever a primary disease or always consecutive to a lung tuberculosis,—the seeming exceptions being explicable on the supposition that the antecedent pulmonary mischief had been either latent or misinterpreted. The secondary involvment of the larynx, mayhap from its serving as outfall and *cloaca magna* for all the bacilli-laden sputa, is certainly the one most frequently met with; but it has been settled on the post-mortem table that the lungs may be quite free of tubercle or phthisis when the upper part of the windpipe is the seat of bacillary ulceration or abscess. Ziehl has related (*Deutsche Med. Wochenschrift*, 1883, page 64) a very pertinent example in which a woman was tracheotomized for laryngeal stenosis. The lung secretions, which could thus be perfectly divorced from those of the larynx, were free of bacilli, while those taken directly from the laryngeal ulceration contained them. The possibility of obtaining the two secretions unmixed has been alternately denied and doubted, but it can be done even where there is no tracheotomy, and no special dexterity in handling brush and laryngoscope is needed to do it successfully.

A young lady once consulted me for a hoarseness and aphonia of some months' duration; her chordæ vocales were the seat of a tumefaction which had the appearance of sessile warts; her chest furnished no proof of a lung lesion. After the lapse of a year or more I saw her again, and found her dying, with plain enough evidence that the laryngeal troubles had gone on to ulceration, and that both apices were excavated. This was in all likelihood a case of primitive laryngeal injury and secondary lung-mischief. Some beautiful cover-glass preparations of bacilli, present in scrapings from laryngeal tubercular ulcers, are in my possession.

The voice of such patients is at first hoarse, and by-and-by whispering. The cough is hard, grating, explosive—a *tussis ferina* without expectoration at all, or with discharge of transparent, watery, perhaps bloody, mucus. When ulceration is established the sputum is gray-yellow or quite purulent, and under the microscope is seen to contain pus cells and fibres, such as are depicted in Plates I. and II. The comparative slenderness and more rectilineal course of such laryngeal elastic tissue differentiate it from the pulmonary "curly fibre," which is much more flexuous and contorted, and, when moderately abundant, has many alveolar loculi marked off by the dissepiments and plaitings of its component threads, *cfr.* Plates I. to V., and note the different magnifications.

Cases are now and again admitted to the Incurable Hospital with malignant affections of tongue, tonsils, fauces, and larynx, which work their way down through the cervical glands to the mediastina and lungs. The matters expectorated by such persons often contain morsels of exfoliated tissues in which the cell-formations distinctive of their disease can frequently be detected. Sometimes also, from aspiration of purulent discharges and necrosed debris, and from invasion of the lung by the neoplasms, pneumonic processes are set up, which end in gangrene (diffuse or circumscribed by a limitary wall) of large or smaller patches of pulmonary substance. This gangrene is not necessarily the result of the *absolute* violence of the inflammatory attack, but rather of its relative severity as acting on tissues devitalized by a malignant constitutional malady, or whose nutrition is impaired by pressure of the new growth on nutrient arteries or trophic nerves, just as in persons reduced by fevers sphacelating sores are apt to form from the very slightest of causes.

However brought about, this mortification rapidly extinguishes life, with almost uncountable, thready pulse, cold extremities, and hippocratic face, the patient perhaps having a feeling of well-being, and wondering why any fuss is made about him. The sputa brought up are fœtid and bloody, look like thin black-currant jelly, and contain large shreds of elastic fibres, membranous tags of connective tissue, bits of cartilage sometimes, crystals of triple phosphate and fatty acids, amorphous detritus, and blood corpuscles, globular, biconcave, or so much crenated as to have an asterisk form, or so ragged, deformed, and decolorized as to be almost unrecognisable.

Sometimes the true nature of intra-laryngeal growths is disclosed, and the correctness or error of a diagnosis arrived at in other ways is established, by microscopy of disrupted pieces of them which have been eliminated with the sputum, which generally in such cases has a muco-purulent quality.

Plates XXXIV., XXXV., and XXXVI. were furnished by a case in point: a nodule, said to have been expectorated, was sent to me for examination. A tiny morsel teased out and squeezed below the cover-glass gave me the photo-micrograph of which Plate XXXIV. is a reproduction; and Dr A. Edington kindly made and mounted the sections from which Plates XXXV. and XXXVI. were obtained.

To summarize—

1. Secretions, unmixed with lung products, can be withdrawn directly from the larynx.

2. The bacillary or other nature of existing laryngeal ulceration can be thus determined, and the patient shielded from useless or harmful treatment.

3. Laryngo-phthisis, without phthisis pulmonum as accomplice, is an actual entity, and can be demonstrated *ante mortem*.

4. In bacillary lung-phthisis with sound larynx it is a very rare thing to find bacilli in the secretions directly removed from that organ: if found, they have a lung origin.

5. The correct diagnosis of the essential nature of neoplasmata occurring in those parts is sometimes greatly helped by the examination of fragments ejected with the sputa.

6. Pneumonic processes ending in lung-gangrene not rarely wind-up cases of malignant disease of the upper portions of the air and digestive tubes.

PLATE XXXIV.

A papillomatous growth from larynx. The specimen has undergone no treatment ; it was found in sputum, and a scraping was teased out and pressed down on the slide and examined with a drop of water. The papillæ are mostly branched.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{150}{1}$

Pl. XXXIV.

PLATE XXXV.

From a section of the same papilloma, made and mounted by Dr Alex. Edington. In the upper left-hand part of the Plate the stratum corneum is seen ; beneath are rounded-polygonal, flattened, nucleated, epithelial squames ; and in the right-hand lower corner there is the axis of the papilla, with a layer of somewhat columnar epithelium (not very well seen, however) surrounding it.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

Pl. XXXV.

PLATE XXXVI.

Another section of the same, also prepared and mounted by Dr A. Edington. It seems to have been made chiefly through the connective tissue basis of the papilla, as the cells are mostly spindle ones. On the right, a little above the middle, a transverse section of a branch has been made, and shows the rounded, columnar, or germinal layer of cells; there is also another, but scarcely so well defined, transversely cut branch on the left.

Objective, Oberhäuser, No. 7.
Magnification, $\frac{170}{1}$

Pl. XXXVI.

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