that the vertebrae yield so as to be pushed together horizontally, as shown in the smallest cut.

In an interesting paper by Virchow, we find the statement that, when Marinelli stands erect, there is no kyphosis of the back, but that when he bends very far forward, a slight kyphosis is noticeable. At a later examination, Virchow found a slight convexity toward the back. Even after considerable observation, I would not like to say, without having examined Marinelli's back with a measure and plumb, that his back is as hollow as the above mentioned statement would lead one to suppose.—*Illustrirte Zeitung*.

SOME OF THE CONDITIONS AFFECTING THE DISTRIBUTION OF MICRO-ORGANISMS IN THE ATMOSPHERE.*

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THAT the air we breathe is more or less laden with living organisms is a fact which is far from acceptable to most persons, and yet it would require but little persuasion to convince the majority of mankind that air without organisms would be undesirable indeed; for without one micro-organism at least, which is very widely distributed in the air, we should have to forego those numerous, complex, and much appreciated pleasures which are derived from the consumption of alcohol in its various forms. How many would vote the earth flat and stale but for the products which are alone elaborated by yeast, which was the first micro-organism to receive attention, and which, in spite of the many powerfully organized endeavors to undermine its position, is likely also to be the last to absorb the interest of man.

But there are other micro-organisms in the air besides yeast, and it is the firm conviction that many zymotic diseases are propagated by means of air-carried microbes, that renders the investigation of the subject of aerial micro-organisms peculiarly interesting and attractive.

Passing over a number of isolated observations by Leeuwenhoek, Ehrenberg, and Gaultier de Claubry, the systematic examination of the aerial micro-organisms commences with those marvelous discoveries with which the name of Pasteur is so inseparably connected, and with which the latter half of the nineteenth century will forever be associated.

These now classical researches of Pasteur's on the presence of micro-organisms in the atmosphere were undertaken in connection with the fierce controversy which raged, some thirty years ago, on the "Spontaneous Generation of Life."

As most of you are doubtless aware, it was contended by the teachers of this doctrine that the presence of the smallest particle of air was sufficient to determine the generation of low forms of life in certain highly putrescible substances, such as milk, blood, infusions of meat, and the like. The opponents of this doctrine, marshaled by M. Pasteur, contended, on the other hand, that it was not the air, but certain living germs suspended in the air, which, gaining access to these putrescible materials, gave rise to those growths which make their appearance in them.

"Were this the case," replied his antagonists, the preachers of spontaneous generation, "these aerial germs would give rise to a fog as opaque and impenetrable as steel." But Pasteur's convictions were not to be shaken by dogmatic and baseless assertions of this kind, and he therefore undertook to prove his case by experiments so clinching and unanswerable that they could leave no shadow of doubt in any unbiased mind.

PASTEUR'S EXPERIMENTS.

The methods by which Pasteur not only revealed the presence of micro-organisms in the atmosphere, but, at the same time, roughly mapped out their distribution, are so striking in their beautiful simplicity, that I must, at the risk of being charged with telling an old tale, refer to them in more detail than might appear warrantable.

Pasteur's Apparatus.—The apparatus employed by Pasteur for this purpose consisted of a number of small flasks, such as you see here. Into these flasks, which were about one-quarter liter capacity, was introduced a small quantity of what is known as a *cultivating medium*, i. e., a material in which these lower forms of life are capable of flourishing and multiplying abundantly. The cultivating medium employed in this case was clear broth, which forms an excellent nourishing material for the greater number of known micro-organisms. The necks of these flasks were then drawn out to a fine aperture, and the contents heated to boiling for some time, with the double object of *sterilizing*, or destroying, any living matter in the culture-medium on the one hand, and, on the other, of expelling the air from the flask. The open extremity of the flask was then sealed with the blowpipe, while steam was still issuing from the mouth. Pasteur found that the cultivating material in flasks thus prepared remained sterile for an indefinite period of time, and by this and numerous other experiments, into which I cannot enter here, conclusively disproved the theory of the spontaneous generation of these lower forms of life.

With a collection of flasks of this kind, Pasteur then explored the atmosphere of a number of different places. For, by breaking off the drawn-out extremities of the flasks in any given place, the vacuum inside the flask is immediately filled with a sample of the air in question, with all that it holds in suspension. The broken point is then immediately resealed before the blowpipe, and on preserving the flask at a suitable temperature for a few weeks, the presence of any living organism which has gained access along with the air will become revealed by its growth in the broth, rendering the latter turbid.

Now Pasteur exposed—

20 flasks in the open country of Arbois.

20 more on the lower heights of the Jura Mountains.

20 more at the Montanvert, close to the Mer de Glace, at a height of upward of 6,000 feet.

These three series of samples were deposited by Pasteur in the bureau of the Academy of Sciences, in the

month of November, 1860. The result, which was awaited with the utmost interest by the numerous savants who had taken part in the previous discussions, was as follows:

Of the 20 flasks opened in Arbois, 8 developed living organisms.

Of the 20 flasks opened on the Jura, 5 became affected.

While of the 20 flasks opened on the Montanvert, only 1 broke down.

These results speak for themselves, and require no comment.

TYNDALL'S EXPERIMENTS.

These investigations were not, however, confined to France, for in this country the subject was, as is well known, pursued by Professor Burdon Sanderson, Sir Joseph Lister, Dr. Tyndall, and Professor Lankester, to all of whom we are indebted for so much of our knowledge concerning the conditions of life of these lower organisms. It is, however, with Dr. Tyndall's researches on aerial micro-organisms that we are more particularly concerned this evening. Tyndall's experiments were more especially directed toward tracing the connection between some of the optical properties of air and the presence of living organisms in it.

As is well known, when a powerful beam of light is passed through the air of an ordinary room, the path of the beam is rendered visible by the illumination of a vast multitude of floating particles. Now, Tyndall found that if the air in an inclosed chamber be allowed to remain at rest for some time, and a beam of light is then passed through the chamber, its path is no longer visible, the air within the chamber being free from suspended particles capable of reflecting and dispersing the light of the beam. He further showed that this "moteless air," as he called it, was incapable of causing alteration in boiled broth and other cultivating media, or, in short, that the moteless air was sterile or free from micro-organisms.

The great importance of these experiments lies in the conclusive demonstration which they yield of the comparatively short time which is required for suspended micro-organisms to subside in calm air, to which point we shall have occasion to refer again subsequently.

MIQUEL AND FREUDENREICH'S EXPERIMENTS.

We must now pass on to those endeavors which have been made to demonstrate the actual number of living micro-organisms present in a given volume of air—attempts, in fact, to raise the examination of air for micro-organisms from a *qualitative* to a *quantitative* one.

As we have noticed, in Pasteur's experiments already a certain indication was obtained of the relative abundance of micro-organisms in the air of different places, but these experiments made no pretensions to indicating the actual number of organisms present in a given volume of air. Pasteur's results simply show that there were less organisms in a given volume of air collected on the Montanvert than in the same volume of air collected at a lower altitude, but they make no claim to determining the actual number of organisms in a cubic foot or any other given volume of the air of any of the places referred to.

The experiments of Miquel and Freudenreich, however, lay claim to revealing, with more or less accuracy, the actual number of organisms present in a given volume of air, and we must now examine the basis upon which the claim of these investigators rests.

The principal method which these experimenters have devised for examining the air for micro-organisms consists in aspirating a certain volume of air through a small plug of glass wool, in passing through which the suspended matter, including any micro-organisms, is arrested. The plug of glass wool is then thoroughly mixed with a certain volume of sterilized water. The mixture thus obtained is then subdivided into such a number of equal parts that each part shall contain not more than one organism. Each of these subdivisions is then introduced into a tube or flask containing sterile broth. These tubes or flasks are then preserved at a suitable temperature, and any that have received a living organism will, in course of time, exhibit the fact by suffering visible alteration. Thus, supposing the plug through which 100 liters of air was drawn was mixed with 50 cubic centimeters of water, and a series of 50 tubes of broth were then each inoculated with 1 cubic centimeter of this mixture, and if then on keeping these 50 tubes at a suitable temperature it was found that only 40 of them suffered alteration, it would be concluded by Miquel and Freudenreich that only 40 organisms were present in the 50 cubic centimeters of water distributed among the 50 tubes, or, in other words, that the 100 liters of air contained 40 living organisms.

This method, which is extremely ingenious, and which is, perhaps, as perfect as a method in which a liquid cultivating medium is employed can be, still labors under defects which at the present time are altogether inadmissible.

The grave defect of this process consists in the difficulty of mixing and equally distributing the micro-organisms collected on the plug of glass wool. Thus, in the first place, if the mixture is not sufficiently subdivided, or, in other words, if the whole of the tubes into which the subdivided mixture is inoculated become affected, there is obviously no possibility of estimating the number of organisms present, for there is no evidence as to whether each tube succumbed to the presence of a single organism or to the presence of several. In this case the experiment is entirely lost, and all the care and trouble expended in its execution wasted.

But, even if the experiment is successful, and only a part of the inoculated tubes become affected, it is obvious that the deductions made from the result are not necessarily true, for it is only an assumption that each of the tubes affected has become so from the introduction of a single organism. As is well known to all who have practical experience in these matters, it is frequently quite impossible to secure an even distribution of organisms in a liquid containing suspended matter, such as the glass wool in the present instance. There is, in fact, no guarantee that the affected tubes have not succumbed in each case to more than one organism, and that, consequently, the subsequent calculation as to the number of microbes in the air operated on is not involved in serious error.

By means of this process, however, Miquel and

Freudenreich have carried out a very large number of experiments on the presence of micro-organisms in the atmosphere, and the results are doubtless fairly comparable *inter se*.

SOLID CULTIVATING MEDIA.

The enormous progress which has, during the last ten years, been made in the study of micro-organisms is undoubtedly due to the far greater facilities which are now afforded by the beautiful methods of cultivation which have been so prominently brought before the scientific world by the masterly researches of Robert Koch. As might be anticipated, these methods of investigation, which enable all studies in connection with micro-organisms to be carried on with an exactitude and rapidity which was quite beyond the reach of the older observers, have also entirely altered the problem of approaching the micro-organisms present in the atmosphere.

The fundamental principles underlying the modern methods of bacteriological study are the substitution of solid for liquid cultivating media and the isolation of micro-organisms by plate cultivation.

The first adaptation of these new methods to the investigation of the micro-organisms of the air was made by Koch, who exposed dishes containing sterile solid cultivating material to the air, the organisms falling upon which subsequently gave rise, by their growth and multiplication, to visible colonies often possessing characteristic appearances. If the dishes are exposed to the air for a suitable length of time, the colonies resulting from the deposited organisms are sufficiently distant from each other to prevent their mutual interference. The number of these colonies can be readily counted, and the organisms belonging to each colony separately studied.

The number of colonies on dishes thus exposed gives no clew as to the number of micro-organisms present in a given volume of air, but only as to the number of organisms falling on a given surface in a given length of time. There exists, however, no better method than this for simply collecting organisms from the air, as in this manner pure cultivations of the various aerial microbes are obtained with the greatest facility. The exposure of such surfaces of solid culture materials at once added a very important point to our knowledge concerning the occurrence of micro-organisms in the air, for it was found that the colonies developing on surfaces are almost invariably pure cultivations—i. e., the individual organisms constituting each particular colony are all of the same kind—thus clearly showing that the different varieties of organisms present in the air are separated from each other, and do not occur adhering together.

HESSE'S METHOD.

The solid cultivating media were first adapted by Hesse to determining the number of micro-organisms in a given volume of air. Hesse made the very remarkable discovery that, if air is slowly drawn through tubes of wide diameter, practically the whole of the micro-organisms suspended in the air are deposited within a very short distance, thus confirming and extending the observations which had been previously made by Tyndall in the case of his closed chambers.

In order to turn this remarkable gravitating property of aerial micro-organisms to account, Hesse constructed tubes, of about 3 ft. in length and 1½ in. in diameter. These tubes were internally coated with a solid layer of sterile gelatine-peptone. Protected by means of an India-rubber cap at one end, and a cork with a glass tube plugged with cotton wool at the other, the internal coating of gelatine remains unaltered for an indefinite period of time; but when the tube is to be used, the India-rubber cap is removed, and an aspirator attached to the glass tube at the other extremity, by means of which a slow current of air—about one liter in two to three minutes—is drawn through the tube.

The number of liters aspirated depends upon the comparative richness or poverty in microbes which experience leads one to anticipate that the air under examination will possess. For if there are only few organisms in the air, it is desirable to aspirate a considerable volume, perhaps twenty liters or more, while if the air is highly charged with microbes, a smaller volume must be taken, otherwise the resulting colonies in the tube will be so densely packed that they may interfere with each other.

After a definite volume of air has been drawn through the tube, the cap is replaced, and the tube kept at a suitable temperature for several days. On then inspecting the tube, it will be found to present a highly interesting appearance. The inside of the tube contains a number of colonies, each resulting from an organism which was deposited on the surface of the gelatine during the aspiration of the air.

Two highly characteristic points with regard to the distribution of these colonies at once strike the observer.

In the first place, the colonies are not found dispersed all over the tube, but are wholly confined to the bottom of the tube, the upper part being generally entirely free from colonies.

In the second place, it will be seen that the colonies are not by any means uniformly distributed over the bottom of the tube, but that they are more or less crowded together toward the front end of the tube, while the latter half is generally almost entirely free from colonies altogether.

As regards the nature of the colonies, they are, as in the case of those on the gelatine dishes already referred to, pure cultivations often possessed of characteristic appearances, sufficiently characteristic, at any rate, to enable the observer at once to discriminate between mould colonies and colonies of other micro-organisms.

A little closer attention to the contents of the tube generally shows a very remarkable arrangement of the mould colonies as distinguished from the bacterial colonies; for the mould colonies will be found, on the whole, further from the front end of the tube than the bacterial colonies, the extreme colony being almost invariably a mould, often very considerably further down the tube than the last bacterial colony.

Thus the examination of air by Hesse's method brings to light certain very important facts concerning the aerial micro-organisms; first, their rapid gravitation in comparatively still air, and, secondly, the more rapid gravitation of the bacterial organisms than of the mould organisms.

* A lecture recently delivered before the Society of Arts, London. From the Journal of the Society.

As a means of determining the number of micro-organisms in air, Hesse's apparatus is far more convenient than the method of Miquel and Freudenreich, which I have already described; it is, moreover, free from the objections which I have pointed out in connection with Miquel's process. On this account I availed myself of Hesse's method in making experiments on the distribution of micro-organisms in air.

To some of the results of these experiments I would now draw your attention. In studying the distribution of micro-organisms in air, I selected, as both a suitable and convenient spot for my central observatory, the roof of the Science Schools at South Kensington. This position is well fitted for observations of this kind, being sixty to seventy feet above the ground, and thus removed from local and accidental influences. A number of experiments were made here with the view of ascertaining the influence of season and atmospheric conditions generally on the abundance of aerial micro-organisms. These experiments, which were extended over the whole of the past year, are summarized in the following table and in the diagram on this page:

Roof of Science Schools (South Kensington).

1886.	Average number of colonies obtained from 10 liters of air (Hesse's method).
January.....	4
March.....	26
May.....	31
June.....	54
July.....	63
August.....	105
September.....	43
October.....	35
November.....	13
December.....	20

EXPERIMENTS ON THE DISTRIBUTION OF MICRO-ORGANISMS AT DIFFERENT ALTITUDES.

I have also made experiments with the view of ascertaining the relative abundance of micro-organisms at different altitudes in towns. These comparisons were effected by collecting samples of air at different elevations, on the spire of Norwich Cathedral, on the dome of St. Paul's, in London, and on Primrose Hill. The results of these experiments are exhibited in the accompanying diagram:

Place of experiment.	No. of organisms found in 10 liters of air.
Primrose Hill, May 19, 1886.	
Top.....	9
Bottom.....	24
Norwich Cathedral Spire, April 26, 1886.	
Top (300 ft.).....	7
Tower (180 ft.).....	9
Bottom (ground).....	18
St. Paul's Cathedral, May 26, 1886.	
Golden gallery.....	11
Stone.....	34
Churchyard.....	70

EXPERIMENTS ON THE DISTRIBUTION OF MICRO-ORGANISMS IN COUNTRY PLACES.

In a number of experiments made in the country, principally at Reigate and in Norwich, a very appreciably smaller number of micro-organisms was observed than in the case of the air in London. Moreover, the more remote the place is from human habitations, and from the frequented thoroughfares of traffic, the dust of which is always rich in refuse organic matters, the freer does the air become from suspended microbes. Thus I found the air of an extensive heath near Norwich, and that of the Chalk Downs, in Surrey, exceedingly free from micro-organisms, while the air of gardens contained considerably more. Thus:

Place of experiment.	No. of organisms found in 10 liters of air.
Reigate Hill, Feb. 7, 1886.....	2
" May 23, 1886.....	13
Heath, near Norwich, April 23, 1886....	7
" April 27, 1886....	5
Garden at Reigate, May 23, 1886.....	25
Garden near Norwich, April 23, 1886....	31

EXPERIMENTS ON THE DISTRIBUTION OF MICRO-ORGANISMS IN OPEN PLACES IN LONDON.

It is particularly interesting to compare the number of micro-organisms found in country air with that found in the air of parks within London. For this purpose I have made some experiments in Hyde Park, in Kensington Gardens, and on Primrose Hill. These experiments show that, although the park air generally contains fewer micro-organisms than the air even on the roof of the Science Schools, and consequently much less than in the streets below, yet the number exceeds that in the country air. The experiments in the parks were made on large surfaces of grass, from which practically no dust could be blown about, so that the microbes found are doubtless those which have been carried by the wind from the surrounding thoroughfares.

Place of experiment.	No. of organisms found in 10 liters of air.
Kensington Gardens, April 1, 1886.....	13
Hyde Park, May 18, 1886.....	43
" June 7, 1886.....	18
Roof of Science Schools, June 7, 1886....	62
Exhibition road, June 7, 1886.....	94
" June 8, 1886.....	554
" " ".....	309
" June 10, 1886.....	18

MICRO-ORGANISMS IN SEA AIR.

In striking contrast to the number of micro-organisms found in the various places referred to above, is the number found in air at sea. I have not myself had an opportunity of making any experiments at sea, but recently some examinations of sea air have been made by Dr. Fischer, a surgeon in the German navy, and as he has used substantially the same methods as those which I have described, his results may be fairly regarded as comparative. Dr. Fischer's experiments may be thus summarized:

I.—14 experiments with an average of 113 liters of air contained no organisms.

II.—5 experiments with an average of 80 liters of air contained one organism.

III.—2 experiments with an average of 110 liters of air contained 2 organisms.

IV.—3 experiments with an average of 146 liters of air contained 3 organisms.

V.—6 experiments with an average of 62 liters of air contained 4-13 organisms.

They may be more instructively classified, however, by taking into consideration the distance from the nearest land at the time of the observations, thus:

Maximum distance from land in sea miles, 90; 1 organism to 26 liters.

Minimum distance from land in sea miles, 120; 1 organism to 93 liters.

Moreover, out of 12 experiments, made at a minimum distance of 120 sea miles from land, in 11 the air was absolutely germ free, and in the remaining 1 only a single organism was found; while out of 12 experiments made at a maximum distance of 90 sea miles from land, in 7 cases organisms were demonstrable, and in only 5 cases not demonstrable. In 3 of these latter 5 cases, however, although the land actually nearest the ship was less than 90 miles, the nearest land in the direction from which the wind was coming was in two cases upward of 500 miles, and in one case 200 miles. In the other two the land was, in one case, 60 miles, and in one case only 8 miles distant, but in this case the land in question was only a small, slightly cultivated, and thinly populated island.

This clearly demonstrates, what we should have been led from *a priori* considerations to anticipate, that the principal factor is the distance from land in the direction from which the wind is proceeding. It would further appear that the maximum distance to which, under ordinary circumstances, micro-organisms

CURVE SHOWING THE AVERAGE NUMBER OF MICRO-ORGANISMS IN TEN LITERS OF AIR.

can be transported across the sea lies between 70 and 120 sea miles, and that beyond this distance they are almost invariably absent.

Of particular interest in these experiments is the very distinct manner in which they show that the micro-organisms which are abundantly present in sea water are not communicated to the air, excepting in the closest proximity to the surface, even when the ocean is much disturbed.

MICRO-ORGANISMS IN THE AIR OF BUILDINGS.

It is obviously of interest also to ascertain whether the air which we breathe in our houses, and in inclosed spaces generally, is more or less charged with organic life than that which we meet with in the open. As the greater part of our life, in this country at any rate, is spent within doors—in dwelling houses, in assembly rooms, in offices, in laboratories, in railway carriages, and the like—it is only natural that we should be particularly inquisitive as to where and under what conditions in these various confined places we are likely to encounter the most living matter in the atmosphere.

In the following table I have collected the results of some of the experiments which I have made in this direction:

Place of experiment.	No. of organisms found in 10 liters of air.
Chemical Laboratory:	
Jan. 13, 1886.....	13
Oct. 15, ".....	30
" 16, ".....	14
" 27, ".....	32
Nov. 12, ".....	8
Kensington Museum:	
Friday, May 14, 1886.....	18
Saturday " 15, ".....	73
Natural History Museum:	
May 21, 1886 (a.m.).....	50
" (p.m.).....	70
June 14, 1886 (Whit Monday).....	280
".....	267

Place of experiment.	No. of organisms found in 10 liters of air.
Burlington House (Royal Society):	
June 9, 1886 (19° 5' C.).....	326
" (22° 0' C.).....	432
" 10, 1886 (17° 0' C.).....	130
Consumption Hospital, Brompton:	
May 21, 1886.....	43
".....	130
".....	42
June 1, 1886.....	19
".....	34

ORGANISMS FALLING ON A GIVEN HORIZONTAL SURFACE IN UNIT OF TIME.

In order to obtain an idea of the number of microbes which may, under favorable circumstances, become suspended in the air, I have made some experiments in places where I considered it probable that there would be a microbial population even denser than that in any of the previous cases to which I have referred. Owing, however, to my not having the necessary apparatus available at the time, I was only able to make rough tests as to the number of micro-organisms falling upon a given horizontal surface in a given time. As, however, I have made similar tests in the case of nearly all the experiments previously alluded to, I am able to make use of them by way of comparison.

Thus the number of micro-organisms falling on a horizontal square foot of surface in one minute was as follows in the case of some of the experiments which we have already discussed:

Place.	Number of micro-organisms falling on 1 sq. ft. in 1 minute.
Chemical Laboratory (4 experiments).....	15
Kensington Museum (2 experiments).....	54
Natural History Museum (2 experiments).....	196
Natural History Museum, Whit Monday (2 experiments).....	1,662
Burlington House (3 experiments).....	222
Brompton Hospital (5 experiments).....	54

We will now compare with the above the two cases to which I wish to draw your attention.

The first is that of a railway carriage (third class) on a journey from Norwich to London. Soon after leaving Norwich I tested the air; there were at the time four persons in the carriage, one window was closed, the other open, and the experiment was made near the open window. I found that under these conditions 395 organisms were falling on the square foot in one minute. On reaching Cambridge, the carriage was taken possession of by a number of men returning from Newmarket races. The carriage remained quite full (ten persons) to London. About half way between Cambridge and London I made a second experiment, one window being shut, and the other was only open four inches at the top. The air was tested near the closed window, with the result that no less than 3,120 organisms were found to be falling on the square foot in one minute.

On another occasion I made an experiment in a barn in which flail thrashing was going on. The atmosphere was visibly laden with dust, and on testing it with a gelatine dish, I found that upward of 8,000 organisms were falling on the square foot in one minute.

It would probably be difficult to find a place in which the number of suspended microbes was greater than this, the great abundance of bacterial life in the material under treatment, the dryness of the latter, and the violent commotion occasioned by the thrashing being all highly conducive to the distribution of an enormous multitude of micro-organisms throughout the air.

LATER IMPROVEMENTS IN APPARATUS AND METHODS.

A lengthened experience with Hesse's method of determining the number of micro-organisms in air convinced me that, although the method possesses many good qualities, it is by no means perfect, and that it has, in fact, many very serious defects, more especially when it is used in outdoor experiments. The fundamental defect in the process is that when the apparatus is used in a disturbed atmosphere, the results are liable to become seriously affected by aerial currents. Thus, if Hesse's tubes be exposed *without drawing any air through them*, a number of organisms gain access to the tube notwithstanding, and the number of these accessory organisms is dependent upon the strength and direction of the air currents during the experiment.

In all my experiments with Hesse's apparatus, I have endeavored to place the tube at an angle of 135° from the direction of the wind, so as to avoid a current of air entering the open end of the tube, but in several cases I have had to reject experiments in consequence of a sudden alteration in the direction of the wind, and in the open air there are almost invariably minor fluctuations.

In consequence of this and several other defects, to which I need not here enter, I have devised a method in which I have endeavored to overcome these objections. In this method, a definite volume of air is drawn, by means of an air pump, through a short piece of glass tubing containing two small porous plugs placed one in front of the other. Of these two plugs, the first is constructed of glass wool only, while the second is formed of glass wool and glass or sugar powder. The object of this arrangement is that the second plug, through which the aspirated air has to pass, shall offer more resistance than the first, and, consequently, if the second plug is found to be free from microbes, it may safely be assumed that the first plug has been sufficiently obstructive to the micro-organisms in the air passing through, and that they have all been retained by it.

Each plug is then transferred, with special precautions, to a small flask containing a small quantity of sterile melted nutrient gelatine; with the latter the plug is now agitated, so as to cause the rapid disintegration of the plug, and the liquid gelatine, throughout which the *débris* of the plug and its contained microbes are distributed, is then evenly spread over the interior of the flask, and there congealed by rotating

the flask in a stream of cold water. The flask is then maintained at a suitable temperature, and in due time the colonies, each resulting from one of the original micro-organisms deposited on the plug, make their appearance, and can be counted or further examined. That this process is, in contrast to Hesse's, practically independent of aerial currents, is seen from the fact that, if plugged tubes are simultaneously exposed without drawing air through them, the plugs are almost invariably free from organisms.

When air is simultaneously examined by Hesse's method and the "flask method" which I have just described, we find that indoors, and in an undisturbed atmosphere generally, the results are in very close accord, but that in a wind, more especially when the direction of the latter is variable, the results obtained by Hesse's method are considerably higher than those obtained with the flask method, the difference being obviously due to the defect which I have already pointed out in Hesse's method.

The practical identity of the results obtained under favorable circumstances by these two methods throws light upon the state of aggregation in which micro-organisms exist in the atmosphere. Thus, the colonies in Hesse's tubes are not necessarily each derived from a single microbe, but each colony might just as well be the result of a mass of organisms, which might be numbered by tens, hundreds, or even thousands. Each such aggregate, falling upon the surface of the gelatine in a Hesse's tube, would give rise to perfectly similar colonies. The colonies in the flasks, however, are obtained in a very different manner. Here any masses of organisms would have become more or less broken up in the process of agitation to which the plugs are exposed in mixing with the gelatine. Consequently, if such masses existed, the number of colonies to which they would give rise in the flasks would exceed, and possibly to an enormous extent, those obtained in the Hesse's tubes; but, as we have seen, this is not the case, the number of colonies in the flasks being practically identical with those in the tube. It is thus evident that the aerial micro-organisms do not float about in aggregates, or masses, but as isolated individuals.

Experiments made with the flask method on the dome of St. Paul's tell the same story as those previously made with Hesse's method, and to which I have already referred. These experiments also illustrate the degree of accuracy which is attainable with the flask method.

St. Paul's Cathedral, November 19, 1886.

Organisms found in 10 liters of air, in each case by flask method.

Golden Gallery..	I.....	10
	II.....	11
	III.....	11
Stone Gallery..	I.....	25
	II.....	40
Churchyard.....		47

NATURE OF THE AERIAL MICRO-ORGANISMS.

The organisms present in the atmosphere are of many different kinds—moulds, bacilli, micrococci, and various forms of yeast or saccharomyces. Of these several kinds of organisms, the moulds have received most attention at the hands of botanists, and, indeed, even the general public is only too familiar with the commoner forms, such as the *Penicillium glaucum*, which is so much at home in pots of preserved fruit, and which is a highly unwelcome guest in the larder. Indeed, some of these moulds appear to be the most widely distributed of all organisms, and are the most difficult to banish from the air. Thus as a general rule, in those places where fewest organisms are found, e.g., at high altitudes and in the open country, the relative proportion of moulds is much higher than in the air of towns and inclosed spaces. It is not difficult to account for this wide distribution of moulds in the atmosphere, when we call to mind their behavior in Hesse's tubes; there, you will remember, the mould colonies were generally found penetrating further into the tubes than any of the bacterial colonies, clearly showing that their buoyancy in air is greater than that of the other organisms, and on this account also they are floated by aerial currents to altitudes and distances which are not reached by the other forms of organisms.

The different kinds of bacilli and micrococci occurring in the air are less generally known, and it is only now that their identification and characterization are beginning to attract much attention. A few forms giving rise to very striking appearances when growing on natural nutritive media, generally articles of food, have been long known, and have at times excited much curiosity. Perhaps the most notable of these forms is the so-called *M. prodigiosus*—really a bacillus, and not a micrococcus—which gives rise to a superb blood-red color, which you see here. This organism flourishes in milk, to which it imparts the same intense color, which was formerly supposed to be due to disease in the cow. It also thrives well on bread, and has occasionally been known to make its appearance on the sacred wafer, where it has not unnaturally given rise to superstitious fear and consternation.

There are several other bacilli or micrococci frequently present in the air, which also produce striking pigments when cultivated on suitable materials. Examples of these I have here:

- M. candidans* (very common).
- Sarcina lutea*.
- " *aurantiaca*.
- M. rosaceus*.
- M. carnicolor*.
- B. aureus*.
- B. fluorescens*.
- B. aureus siccus*.
- B. chlorinus* (very common).

Another pigment forming micro-organism which is frequently present in the air is *Saccharomyces roseus*. Of the other bacilli, the hay bacillus, or *B. subtilis*, may be mentioned as of very frequent occurrence in the air.

As regards the functions of these various micro-organisms found in the atmosphere, very little indeed is at present known. That the various processes of spontaneous fermentation, decay, and putrefaction,

which take place in suitable substances when these are exposed to the air, are due to micro-organisms gaining access from the air, is well established, but only in very few cases has it been shown that particular changes of this kind have been traced to the action of particular and well characterized organisms. Indeed, recent researches have shown that many of the most familiar changes of this kind, such as the conversion of urea into carbonate of ammonia, of ammonia into nitric and nitrous acids, of sugar into lactic and other acids, are capable of taking place through the agency of totally different forms.

Of pathogenic forms, it may be stated that practically none has been demonstrated in the air, but this need not excite surprise, when it is remembered that in all cases in which pathogenic organisms may be expected to pass into the air, as in the drying up of diseased products of various kinds, these pathogenic forms will be accompanied by an enormous preponderance of non-pathogenic or "saprophytic" forms, so that the actual discovery of the comparatively few pathogenic among the overwhelming number of saprophytic organisms becomes an almost hopeless matter. Among the aerial organisms, however, a few have been discovered which are pathogenic to some of the lower animals; thus, quite recently an aerial organism, of comparatively frequent occurrence, has been shown to be identical with a bacillus which was previously supposed by Emmerich to be the inducing cause of Asiatic cholera, and which was discovered by him in the tissues of cholera patients, during the Naples epidemic of two years ago.

Indeed, many of the organisms which have been found in air may be pathogenic to man, although they are not connected with any of the commoner zymotic diseases. In this case, however, it is impossible to make actual experiments in this direction. But it is with the object of excluding such possibly pathogenic forms in the air, that the stringent precautions in the antiseptic treatment of wounds are taken.

But although the organisms connected with the common zymotic diseases have not been discovered in air, yet there can be no doubt that, in the immediate vicinity of the foci of disease, such organisms are present, and that their distribution and conveyance in the air will take place in just the same manner as in the case of those organisms the distribution and conveyance of which, through the atmosphere we have been considering this evening. The investigations on the distribution of micro-organisms, by showing us what circumstances are favorable and which unfavorable to their dissemination, teach us how we may avoid distributive influences coming into play in the case of the organisms of infectious diseases. The scanty microbial population of country, of mountain, and more especially of sea air, which these investigations reveal, points to the security from zymotic disease which these surroundings are well known to confer. On the other hand, we learn that in the air of towns, and still more conspicuously in the air of crowded apartments, we are invested with an atmosphere laden with living organisms, among which, therefore, the chance of inimical forms being present is greatly enhanced. We have seen, however, that in rooms and even in hospital wards the number of organisms is very small provided the air is undisturbed, and this points to the importance of preventing any aerial commotion during the exposure of wounds in surgical operations, and in places generally where pathogenic organisms may be expected. We learn, moreover, the great importance of removing all dust and refuse matter generally in a moist condition, and with the least possible delay, for the micro-organisms present in a moist substance can only be transferred to air in two ways, viz., first, through its desiccation and conversion into dust, and, secondly, through the formation of spray, especially through the generation of gas in the liquid medium—e.g., in the putrefaction of sewage.

In conclusion, I should like to express my opinion that it is the chemical side of bacteriology which at the present moment imperatively demands attention, and which should no longer be suffered to remain in neglect.

In the most prominently attractive department of bacteriology—the pathological—a vast amount of material has already been collected, and, owing to the high degree of perfection to which the methods of studying micro-organisms have been brought by the investigators in this department, much of the difficulty which previously stood in the way of the investigation of the chemical phenomena of bacterial life is now removed.

THE CONSTANT OF ABERRATION.

THE question that we are to consider is that of the aberration of light. The so-called fixed stars, as well known, really have motions, although these seem to be very slight on account of the great distance of each of the stars from us. There is nothing stationary in this world, either among organized or unorganized objects, from the atom to the star.

In addition to real motions, there are apparent ones. Thus, among others, each star seems to have an annual motion, and this results from the motion of the earth around the sun. Yet this motion is not the only one, but is involved with another that is due to the fact that the light from a star takes some time to reach us. Just as the sound of a bell or a gun does not reach us until after a certain interval of time that depends upon the distance of the bell or gun from us, so light does not reach us until the end of a period depending upon the distance that we chance to be from the luminous body. Light, as well known, travels at the rate of 192,000 miles per second. Now, the earth moves at the rate of 19 miles per second in the curve that it describes around the sun. The velocity of light, then, is ten thousand times greater than that of the earth; but, however great it be, absolutely or relatively, it is comparable with that of the earth.

What results from this double motion? A comparison will make this understood. Suppose that the rain is falling vertically, in calm weather; then, if you remain immovable, umbrella in hand, the rain will fall all around you, and the umbrella will protect you. But if you walk along, holding the umbrella erect, it will no longer be the same, for you will get wet in front; first, your shoes will get wet, then the bottom of your trousers, and finally your upper garments, in measure as you walk faster and faster. Imagine, in

fact, a drop falling from the edge of the umbrella, from a height, say, of five feet. It will take a certain length of time for it to reach the earth, and during this period you will meet it as you proceed. The quicker you move forward, the sooner you will meet it, that is to say, higher and higher up on your person will it fall, and you can avoid it only by slanting your umbrella forward at an angle depending upon the rapidity of your gait.

Let us now return to our observer, who has his eye at the telescope, and who is receiving, not water, but light. It will be necessary for him to incline his instrument in such a way that the light shall traverse the length of it while he himself is advancing, as a result of the motion of the earth. The observer may then think that the telescope is giving him the true direction of the star; but such is not the case. It is just as if, in the preceding comparison, we thought that the rain was coming toward us in the direction of the inclined umbrella. So we do not see the stars in their true place, and herein consists the aberration of light. The angle formed by the two directions—the apparent and the real—is the angle of aberration. The effect of aberration was first ascertained by the illustrious English astronomer Bradley, about the year 1725. It was while trying to account for the periodical variations observed in the zenithal distance of a star of Draco that he was led to this discovery, as well as to that of notation. The cognition of the aberration of light has confirmed that of its velocity, and has permitted of indirectly determining the solar parallax, and consequently of verifying the figures obtained by other methods. It is therefore a discovery of the first rank, and the exact determination of the constant is a matter of great importance.

There are several methods of determining and correcting aberration, but they are unfortunately very complex, and require long and patient observation. What renders such research especially delicate is the multiplicity of the errors that may be committed, and that may vitiate the accuracy of the result—accidental errors in observation, errors in instrumental constants, errors in clocks and personal equation, uncertainties

APPARATUS FOR CORRECTING THE ABERRATION OF LIGHT.

due to too inaccurate a determination of the precession of notation, and an insufficient knowledge of the proper motion of the stars and their parallax.

Any method that would permit of avoiding these numerous dangers, and of surmounting every difficulty, should be regarded as a remarkable discovery, and, better still, as a genuine benefit. We owe such a method to Mr. Loewy, of the Institute.

Instead of comparing the absolute positions of the stars, this gentleman takes differential observations as a basis. A double mirror formed in the same block of glass is placed in front of the telescope objective, and sends into the field of the instrument the images of two stars belonging to different celestial regions; and then the slight angular distance of these two neighboring images is measured. These two stars are observed at various determinate epochs, and then the results obtained are compared in couples. The difference in the measurements furnishes a multiple value of the aberration independent of errors due to the instrument. The measurement of the arc comprised between the two stars is independent of the precession and notation. If the angle of the two mirrors is 45°, we shall obtain, for two zodiacal stars, a variation in the distance equal to twice the constant at the end of three months, and to thrice the constant at the end of six months.

As the angle of the mirror is liable to be modified through variations in temperature, Mr. Loewy gives a process that permits of determining the expansion of the mirror and of taking it into consideration. To this effect, an observation is made of one of the pairs of stars in which the effect of aberration upon the distance remains nil for the entire year. The difference between the measurements effected at different epochs will make the variation in the angle known, if any such exists.

The following is the principle of the method, which is absolutely accurate: We determine the sidereal instant in which the direction of the earth's motion happens to be in the plane of the horizon. Starting from the longitude corresponding to such direction, we determine the co-ordinates of two pairs of stars, so that the four stars shall be daily at the same height above the horizon, and that the effect of aberration shall be notable upon the two distances, and of contrary sign. Then, at the same physical instant, we compare the two arcs included between the two pairs of stars.