pages, with plates, an account of experiments made by him under the auspices of the Municipal Council of Paris, on the currents of the North Atlantic. The work deals more particularly with the Gulf Stream, and with the details of the experiments made on board the *Hirondelle* with the assistance of the Prince of Monaco, but also takes into consideration the results of investigators from the earliest times. The experiments refute the idea that the French coast is warmed by the Gulf Stream; M. Pouchet states that they show clearly that, at least in summer, no surface-current reaches France from the south-west, but that, on the contrary, there is a current from the west and north-west.

THE following details about the Tomsk University have been published. The buildings constitute the finest edifice in the town, and are situated in the middle of a magnificent park. When the staff is complete there will be twenty-five Chairs—thirteen ordinary, eleven extraordinary, and one for orthodox theology. There will also be librarians, teachers of music, and surgeons and assistant-surgeons. There are already seventy-two students, who pay about 12 or 13 roubles a month for lodging, books, and attendance, and it is expected that this number will be largely increased before the end of the year.

THE Pilot Chart of the North Atlantic Ocean for the month of September shows that the most important storm during the month of August was one first reported about San Domingo on the 19th, whence it moved north-westward over the Bahamas and afterwards recurved and followed the course of the Gulf Stream. During the first half of the month the pressure along the Atlantic States was persistently high, and the tracks of all storms from the continent lay well to the northward of this area of high barometer, moving mostly beyond the region of observation. No storm can be traced all the way from the American continent to the British Isles, although several originated in mid-ocean and moved in an east-north-east direction. A severe tornado was reported off Cienfuegos, Cuba, on August 4. Ice was reported in great quantities about the Straits of Belle Isle, but very little off the Grand Banks.

METEOROLOGICAL science will be much enriched by the recent contributions of the Danish observers in Greenland during 1882–83 ("Expédition Danoise," vol. ii., part 2, Copenhagen, 1889). The principal station was at Godthaab, on the west coast of Greenland, in latitude about 64°, where the observations were made under the direction of M. Adam Paulsen. A large series of observations of temperature was made and the results are given in tables, as well as represented by curves. The temperature was taken every hour during twelve months, and the mean temperatures at each hour for each month are given in the tables. As might be expected, the greatest variation occurs in August—namely, from + 3°·5 C. at 3 a.m. to + 7°·2 at 2 p.m. The minimum variation is in February, from − 15°·4 to − 15°·7. During the summer months the maximum occurs about 1 p.m., and in winter about 2 p.m. Similar results are recorded for the stations at Reykjavik, in lat. 64° and Stykkisholm, in lat. 65°. The maximum monthly mean temperature occurs in July, and the minimum in February. Observations were also made of the direction, force, and velocity of the wind, form and direction of clouds, temperature of the soil, &c., full details of which are given in the report. An appendix contains the results of various meteorological observations in the Kara Sea in 1882–83, and at Nanortalik and D'Angmagsalik. Observations of auroræ at the two latter stations and at Godthaab also form part of the appendix. It is greatly to be regretted that the spectroscope was not employed in the auroral observations.

THE additions to the Zoological Society's Gardens during the past week include a Mealy Amazon (*Chrysotis farinosa*) from South America, presented by the Hon. and Rev. F. G. Dutton; two Cape Crowned Cranes (*Balearica chrysopelargus*) from South Africa, presented by the Hon. Mrs. Barker; seven Common Slowworms (*Anguis fragilis*), British, presented by Miss Alice Leonora Selly; a Common Chameleon (*Chamæleon vulgaris*) from North Africa, presented by Mr. J. Watkins; a Long-nosed Crocodile (*Crocodilus cataphractus*) from West Africa, presented by Mr. John R. Holmes; a Royal Python (*Python regius*) from West Africa, deposited; four Common Rheas (*Rhea americana*) from Holland, purchased.

ASTRONOMICAL PHENOMENA FOR THE WEEK 1889 *OCTOBER* 13–19.

(FOR the reckoning of time the civil day, commencing at Greenwich mean midnight, counting the hours on to 24, is here employed.)

At Greenwich on October 13

Sun rises, 6h. 23m.; souths, 11h. 46m. 11·5s.; daily decrease of southing, 14·0s.; sets, 17h. 10m.: right asc. on meridian, 13h. 15·1m.; decl. 7° 57′ S. Sidereal Time at Sunset, 18h. 40m.

Moon (at Last Quarter October 17, 1h.) rises, 19h. 7m.*; souths, 2h. 57m.; sets, 11h. 0m.: right asc. on meridian, 4h. 24·4m.; decl. 19° 11′ N.

Planet.	Rises. h. m.		Souths. h. m.		Sets. h. m.		Right asc. and declination on meridian. h. m.		° ′
Mercury..	7 2	...	12 4	...	17 6	...	13 32·8	...	12 4 S.
Venus.....	3 25	...	9 56	...	16 27	...	11 24·3	...	5 19 N.
Mars......	2 45	...	9 29	...	16 13	...	10 57·6	...	8 5 N.
Jupiter....	12 47	...	16 39	...	20 31	...	18 9·0	...	23 30 S.
Saturn....	1 36	...	8 44	...	15 52	...	10 12·6	...	12 27 N.
Uranus...	6 32	...	11 54	...	17 16	...	13 23·1	...	8 8 S.
Neptune..	18 54*	...	2 43	..	10 32	..	4 10·3	...	19 21 N.

* Indicates that the rising is that of the preceding evening.

Oct.		h.		
16	...	0	...	Mercury in inferior conjunction with the Sun.
16	...	13	...	Venus at least distance from the Sun.

Variable Stars.

Star.	R.A. h. m.	Decl. ° ′		h. m.	
U Cephei	0 52·5 ...	81 17 N. ...	Oct. 15,	2 45	*m*
λ Tauri...	3 54·5 ...	12 11 N. ...	,, 16,	21 36	*m*
ζ Geminorum ...	6 57·5 ...	20 44 N. ...	,, 13,	23 0	*M*
			,, 19,	2 0	*m*
U Coronæ	15 13·7 ...	32 3 N. ...	,, 17,	23 5	*m*
β Lyræ...	18 46·0 ...	33 14 N. ...	,, 16,	22 30	*M*
U Aquilæ	19 23·4 ...	7 16 S. ...	,, 19,	19 0	*M*
η Aquilæ	19 46·8 ...	0 43 N. ...	,, 13,	22 0	*M*
T Vulpeculæ ...	20 46·8 ...	27 1 N. ...	,, 19,	19 0	*M*
δ Cephei	22 25·1 ...	57 51 N. ...	,, 16,	21 0	*m*
S Aquarii	22 51·2 ...	20 56 S. ...	,, 14,		*M*

M signifies maximum: *m* minimum.

Meteor-Showers.

	R.A.	Decl.	
Near γ Andromedæ ...	26° ...	43° N. ...	Slow; faint.
,, ξ Ceti	31 ...	9 N. ...	Slow; trained.
,, ν Arietis	41 ...	20 N. ...	Swift.
,, κ Cephei	307 ...	77 N. ...	Slow; faint.

THE LIFE-WORK OF A CHEMIST.[1]

IN asking myself what subject I could bring before you on the present occasion, I thought I could not do better than point out by one example what a chemist may do for mankind. And in choosing this theme for my discourse I found myself in no want of material, for amongst the various aspects of scientific activity there is surely none which, whether in its most recondite forms or in those most easily understood, have done more to benefit humanity than those which have their origin in my own special study of chemistry. I desired to show what one chemist may accomplish, a man devoted heart and soul to the investigation of Nature, a type of the ideal man of science—whose example

[1] An Address delivered to the members of the Birmingham and Midland Institute, in the Town Hall, Birmingham, on October 7, 1889, by Sir Henry E. Roscoe, M.P., D.C.L., LL.D., F.R.S., President.

may stimulate even the feeblest amongst us to walk in his footsteps if only for a short distance, whose life is a consistent endeavour to seek after truth if haply he may find it, whose watchwords are simplicity, faithfulness, and industry, and whose sole ambition is to succeed in widening the pathway of knowledge so that following generations of wayfarers may find their journeys lightened and their dangers lessened.

Such men are not uncommon amongst the ranks of distinguished chemists. I might have chosen as an example the life and labours of your sometime townsman, Joseph Priestley, had not this theme been already treated by Prof. Huxley, in a manner I cannot approach, on the occasion of the inauguration of the statue which stands hard by. To-day, however, I will select another name, that of a man still living, the great French chemist—Pasteur.

As a chemist Pasteur began life, as a chemist he is ending it. For although, as I shall hope to point out, his most important researches have entered upon fields hitherto tilled, with but scanty success, by the biologist, yet in his hands, by the application of chemical methods, they have yielded a most bountiful harvest of new facts of essential service to the well-being and progress of the human race.

And after all the first and obvious endeavour of every cultivator of science ought to be to render service of this kind. For although it is foolish and shortsighted to decry the pursuit of any form of scientific study because it may be as yet far removed from practical application to the wants of man, and although such studies may be of great value as an incentive to intellectual activity, yet the statement is so evident as to almost amount to a truism, that discoveries which give us the power of rescuing a population from starvation, or which tend to diminish the ills that flesh, whether of man or beast, is heir to, must deservedly attract more attention and create a more general interest than others having so far no direct bearing on the welfare of the race.

"There is no greater charm," says Pasteur himself, "for the investigator than to make new discoveries, but his pleasure is more than doubled when he sees that they find direct application in practical life." To make discoveries capable of such an application has been the good fortune—by which I mean the just reward—of Pasteur. How he made them is the lesson which I desire this evening to teach. I wish to show that these discoveries, culminating as the latest and perhaps the most remarkable of all, in that of a cure for the dreaded and most fearful of all fearful maladies, hydrophobia, have not been, in the words of Priestley, "lucky haphazardings," but the outcome of patient and long-continued investigation. This latest result is, as I shall prove to you, not an isolated case of a happy chance, but simply the last link in a long chain of discoveries, each one of which has followed the other in logical sequence, each one bound to the other by ties which exhibit the life-work of the discoverer as one consequent whole. In order, however, to understand the end we must begin at the beginning, and ask ourselves what was the nature of the training of hand, eye, and brain which enabled Pasteur to wrest from Nature secret processes of disease the discovery of which had hitherto baffled all the efforts of biologists. What was the power by virtue of which he succeeded when all others had failed, how was he able to trace the causes and point out remedies for the hitherto unaccountable changes and sicknesses which beer and wine undergo? What means did he adopt to cure the fatal silkworm disease, the existence of which in the south of France in one year cost that country more than one hundred millions of francs? Or how did he arrive at a method for exterminating a plague known as fowl cholera, or that of the deadly cattle disease, anthrax, or splenic fever, which has killed millions of cattle, and is the fatal woolsorters' disease in man? And last but not least how did he gain an insight into the working of that most mysterious of all poisons, the virus of hydrophobia?

To do more than point out the spirit which has guided Pasteur in all his work, and to give an idea of the nature of that work in a few examples, I cannot attempt in the time at my disposal. Of the magnitude and far-reaching character of that work we may form a notion, when we remember that it is to Pasteur that we owe the foundation of the science of bacteriology, a science treating of the ways and means of those minute organisms called microbes, upon whose behaviour the very life, not only of the animal, but perhaps also of the vegetable, world depends—a science which bids fair to revolutionize both the theory and practice of medicine, a science which has already, in the hands of Sir Joseph Lister, given rise to a new and beneficent application in the discovery of antiseptic surgery

The whole secret of Pasteur's success may be summed up in a few words. It consisted in the application of the exact methods of physical and chemical research to problems which had hitherto been attacked by other less precise and less systematic methods. His early researches were of a purely chemical nature. It is now nearly forty years ago since he published his first investigation. But this pointed out the character of the man, and indicated the lines upon which all his subsequent work was laid.

Of all the marvellous and far-reaching discoveries of modern chemistry, perhaps the most interesting and important is that of the existence of compounds which, whilst possessing an identical composition—that is, made up of the same elements in the same proportions—are absolutely different substances judged of by their properties. The first instance made known to us of such isomeric bodies, as they are termed by the chemist, was that pointed out by the great Swedish chemist Berzelius. He showed that the tartaric acid of wine-lees possesses precisely the same composition as a rare acid having quite different properties and occasionally found in the tartar deposited from wine grown in certain districts in the Vosges. Berzelius simply noted this singular fact, and did not attempt to explain it. Later on, Biot observed that not only do these two acids differ in their chemical behaviour, but likewise in their physical properties, inasmuch as the one (the common acid) possessed the power of deviating the plane of a polarized ray of light to the right, whereas the rare acid has no such rotatory power. It was reserved, however, for Pasteur to give the explanation of this singular and at that time unique phenomenon, for he proved that the optically inactive acid is made up of two compounds, each possessing the same composition, but differing in optical properties. The one turned out to be the ordinary dextro-rotatory tartaric acid; the other a new acid which rotates the plane of polarization to the left to an equal degree. As indicating the germ of his subsequent researches, it is interesting here to note that Pasteur proved that these two acids can be separated from one another by a process of fermentation, started by a mere trace of a special form of mould. The common acid is thus first decomposed, so that if the process be carried on for a certain time only the rarer lævo-rotatory acid remains.

Investigations on the connection between crystalline form, chemical composition, and optical properties, occupied Pasteur for the next seven years, and their results—which seem simple enough when viewed from the vantage-ground of accomplished fact—were attainable solely by dint of self-sacrificing labours such as only perhaps those who have themselves walked in these enticing and yet often bewildering paths can fully appreciate, and by attention to minute detail as well as to broad principles to an extent which none can surpass and few can equal. A knowledge of the action of the mould in the changes it effects on tartaric acid led Pasteur to investigate that *bête noire* of chemists, the process of fermentation. The researches thus inaugurated in 1857 not only threw a new and vivid light on these most complicated of chemical changes, and pointed the way to scientific improvements in brewing and wine-making of the greatest possible value, but were the stepping-stones to those higher generalizations which lie at the foundation of the science of bacteriology, carrying in their train the revolutions in modern medicine and surgery to which I have referred.

The history of the various theories from early times until our own day which have been proposed to account for the fact of the change of sugar into alcohol, or that of alcohol into vinegar, under certain conditions, a fact known to the oldest and even the most uncivilized of races, is one of the most interesting chapters in the whole range of chemical literature, but, however enticing, is one into which I cannot now enter. Suffice it here to say that it was Pasteur who brought light out of darkness by explaining conflicting facts and by overturning false hypotheses. And this was done by careful experiment, and by bringing to bear on the subject an intelligence trained in exact methods and in unerring observation, coupled with the employment of the microscope and the other aids of modern research.

What now did Pasteur accomplish? In the first place he proved that the changes occurring in each of the various processes of fermentation are due to the presence and growth of a minute organism called the ferment. Exclude all traces of these ferments, and no change occurs. Brewers' wort thus preserved remains for years unaltered. Milk and other complex liquids do not turn sour even on exposure to pure air, provided these infinitely small organisms are excluded. But introduce even the smallest trace of these microscopic beings, and the peculiar changes which they alone can bring about at once begin. A few cells of the yeast plant set up the vinous fermentation in a sugar solution. This is clearly stated by Pasteur as follows:—"My decided opinion," he says, "on the nature of alcoholic fermentation is the following. The chemical act of fermentation is essentially a correlative phenomenon of a vital act beginning and ending with it. I think that there is never any alcoholic fermentation without there being at the same time organization, development, multiplication of globules, or the continued consecutive life of globules already formed."

Add on a needle's point a trace of the peculiar growth which accompanies the acetous fermentation, and the sound beer or wine in a short time becomes vinegar. Place ever so small a quantity of the organism of the lactic fermentation in your sweet milk, which may have been preserved fresh for years in absence of such organisms, and your milk turns sour. But still more, the organism (yeast) which brings about the alcoholic fermentation will not give rise to the acetous, and *vice versâ*, so that each peculiar chemical change is brought about by the vital action of a peculiar organism. In its absence the change cannot occur; in its presence only that change can take place.

Here again we may ask, as Pasteur did, Why does beer or wine become sour when exposed to ordinary air? And the answer to this question was given by him in no uncertain tone in one of the most remarkable and most important of modern experimental researches. Milk and beer which have become sour on standing in the air contain living micro-organisms which did not exist in the original sound fluids. Where did these organisms originate? Are they or their germs contained in the air, or are these minute beings formed by a process of spontaneous generation from material not endowed with life?

A controversy as to the truth or falsity of the theory of spontaneous generation was waged with spirit on both sides, but in the end Pasteur came off victorious, for by a series of the most delicate and convincing of experiments he proved the existence of micro-organic forms and their spores—or seeds—in the air, and showed that whilst unpurified air was capable of setting up fermentative changes of various kinds, the same air freed from germs could not give rise to these changes. Keep away the special germ which is the incentive to the pathological change, and that change cannot occur. In the interior of the grape, in the healthy blood, no such organisms, no such germs exist; puncture the grape or wound the animal body, and the germs floating in the air settle on the grape-juice or on the wounded tissue, and the processes of change, whether fermentative or putrefactive, set in with all their attendant symptoms. But crush the grape or wound the animal under conditions which either preclude the presence or destroy the life of the floating germ, and again no such change occurs; the grape-juice remains sweet, the wound clean.

I have said that every peculiar fermentative change is accompanied by the presence of a special ferment. This most important conclusion has only been arrived at as the result of careful experimental inquiry. How was this effected? By the artificial cultivation of these organisms. Just as the botanist or gardener picks out from a multitude of wild plants the special one which he wishes to propagate, and planting it in ground favourable to its growth, obtains fresh crops of the special plant he has chosen, so the bacteriologist can by a careful process of selection obtain what is termed a pure cultivation of any desired organism. Having obtained such a pure cultivation, the next step is to ascertain what are the distinctive properties of that special organism; what characteristic changes does it bring about in material suitable for its growth. This having been determined, and a foundation for the science having thus been laid, it is not difficult to apply these principles to practice, and the first application made by Pasteur was to the study of the diseases of beer and wine.

In September 1871, Pasteur visited one of the large London breweries, in which the use of the microscope was then unknown. A single glance at the condition of the yeast instantly told its tale, and enabled him to explain to the brewers the cause of the serious state of things by which frequently as much as 20 per cent. of their product was returned on their hands as unsaleable—this being that this yeast contained foreign or unhealthy organisms. And just as pure yeast is the cause of the necessary conversion of wort into beer, so these strange forms which differ morphologically from yeast, and whose presence can therefore be distinctly ascertained, are the cause of acidity, ropiness, turbidity, and other diseases which render the beer undrinkable. It is no exaggeration to say that, whereas before Pasteur's researches the microscope was practically unknown in the brewhouse, it has now become as common as the thermometer or the saccharimeter, and by its help and by the interpretations we can place upon its revelations through Pasteur's teaching, yeast—of all brewers' materials the least open to rough and ready practical discernment—becomes easy of valuation as to its purity or impurity, its vigour or weakness, and, therefore, its behaviour during fermentation. Thus, while in former days the most costly materials were ever liable to be ruined by disease organisms unconsciously introduced into them with the yeast, at the present day the possibilities of any such vast pecuniary disasters become easily avertable.

Of all industries, brewing is perhaps the one which demands the most stringent care in regard to complete and absolute cleanliness. The brewers' materials, products, and by-products, are so putrescible, there is always so vast an abundance of disease-organisms in the brewery air, that the minutest amounts of these waste products lying about in vessels or pipes transform these places into perfect nests for the propagation of these micro-organisms, whence, transferred into the brewings, they inevitably ruin them, however carefully and scientifically prepared in other respects. Without the microscope, any breach of discipline in the way of the supreme cleanliness necessary is impossible of detection; with it we can track down the micro-organisms to their source, whether it be in uncleanly plant, in impurity of materials, or in carelessness of manipulation.

Among the more direct applications of Pasteur's researches, the so-called Pasteurization of beer claims a place. Pasteur showed that temperatures well below the boiling-point sufficed for destroying the disease organisms in alcoholic fluids, and, based on these results, enormous quantities of low-fermentation beers are annually submitted to these temperatures, and thus escape the changes otherwise incident to the micro-organisms which have succumbed to the treatment. This process is, however, for several intricate reasons, not suited for English beers, but if we cannot keep our beers by submitting them to high temperatures, we can foretell to a nicety how they will keep by artificially forcing on those changes which would occur more slowly during storage. The application of a suitable temperature, the exclusion of outside contamination, a microscopic examination of the "forced" beer, and the knowledge which we owe to Pasteur of what the microscopic aspect means, suffice to make each brewing foretell its own future history, and thus suffice to avert the otherwise inevitable risks incident to the storage and export of beer, the stability of which is unknown.

Brewing has thus become a series of precise and definite operations, capable of control at every point. Instead of depending—as it had to depend—on intuition and experience handed down in secrecy from father to son, it now depends upon care, forethought, and the soundness of the brewer's scientific training. This change in the nature of the brewer's operations, and in the persons who govern them, is primarily due to Pasteur. Other men have done much to carry on his work, but it is to his example of ceaseless patience, and to his example of freely publishing to the world all the results of his work, that the brewers of all countries are indebted for the connection of each phenomenon with a controllable cause, and for thus emancipating their industry from empiricism and quackery.

Much the same story has to be told about Pasteur's investigation of wine and its diseases. As with the brewer, so with the wine-grower Pasteur has pointed out the causes of his troubles, and, the causes having been ascertained, the remedies soon followed, and the practical value of these researches to the trade of France and other wine-producing countries has been enormous.

The next labour of our scientific Hercules was of a different kind, but of a no less interesting or important character. The south of France is a great silk-producing district. In 1853 the value of the raw silk was represented by a sum of some five millions sterling, and up to that date the revenue from this source had been greatly augmenting. Suddenly this tide of prosperity turned, a terrible plague broke out amongst the silkworms, and in 1865 so general had the disease become that the total production of French silk did not reach one million, and the consequent poverty and suffering endured in these provinces became appalling. Every conceivable means was tried to overcome the disease, but all in vain. The population and the Government of France—for the evil was a national one—were at their wits' end, and a complete collapse of one of the most important French industries seemed inevitable. Under these circumstances the great chemist Dumas, who was born at Alais, in the centre of one of the districts most seriously affected, urged his friend Pasteur to undertake an investigation of the subject. Pasteur, who at this time had never seen a silkworm, naturally felt diffident about attempting so difficult a task, but at last, at Dumas' renewed entreaty, he consented, and in June 1865 betook himself to the south for the purpose of studying the disease on the spot. His previous training here again stood him in good stead, and in September 1865 he was able to communicate to the Academy of Sciences results of observation and experiment which, striking at the root of the evil, pointed the way to the means of securing immunity from the dreaded plague. This paper was freely criticized. Here, it was said, was a chemist who, quitting his proper sphere, had the hardihood to lay down rules for the guidance of the physician and biologist in fields specially their own. Why should his proposals be more successful than all the other nostrums which had already so egregiously failed?

In order to appreciate the difficulties which met Pasteur in this inquiry, and to understand how wonderfully he overcame them, I must very shortly describe the nature of this disease, which is termed *pébrine*, from the black spots which cover the silkworm. It declares itself by the stunted and unequal growth of the worms, by their torpidity, and by their fastidiousness as to food, and by their premature death.

Before Pasteur went to Alais the presence of certain microscopic corpuscles had been noticed in the blood and in all the tissues of the diseased caterpillar, and even in the eggs from which such worms were hatched. These micro-organisms often fill the whole of the silk organs of the insect, which in a healthy condition contain the clear viscous liquid from which the silk is made. Such worms are of course valueless. Still this knowledge did not suffice, for eggs apparently healthy gave rise to stricken worms incapable of producing silk, whilst again other worms distinctly diseased yielded normal cocoons. These difficulties, which had proved too much for previous observers, were fully explained by Pasteur. "The germs of these organisms," said he, "which are so minute, may be present in the egg and even in the young worms, and yet baffle the most careful search. They develop with the growth of the worm, and in the chrysalis they are more easily seen. The moth derived from a diseased worm invariably contains these corpuscles, and is incapable of breeding healthy progeny."

This moth-test is the one adopted by Pasteur, and it is an infallible one. If the female moth is stricken, then her eggs—even though they show no visible sign of disease—will produce sick worms. If in the moth no micrococci are seen, then her immediate progeny at any rate will be sound and free from inherited taint, and will always produce the normal quantity of silk. But this is not all. Pasteur found that healthy worms can be readily infected by contact with diseased ones, or through germs contained in the dust of the rooms in which the worms are fed. Worms thus infected, but free from inherited taint, can, however, as stated, spin normal cocoons, but—and this is the important point—the moths which such chrysalides yield invariably produce diseased eggs. This explains the anomalies previously noticed. The silkworms which die without spinning are those in which the disease is hereditary, viz. those born from a diseased mother. Worms from sound eggs which contract the disease during their life-time always spin their silk, but they give rise to a stricken moth, the worms from which do not reach maturity and furnish no silk.

As I have said, these results were but coldly received. It was hard to make those engaged in rearing the worms believe in the efficacy of the proposed cure. Then, seeing this state of things, Pasteur determined to take upon himself the *rôle* of a prophet. Having in 1866 carefully examined a considerable number of the moths which had laid eggs intended for incubation, he wrote down a prediction of what would happen in the following year with respect to the worms hatched from these eggs. In due course, after the worms from a mixed batch of healthy and unhealthy eggs had spun, the sealed letter was opened and read, and the prediction compared with the actual result, when it was found that in twelve out of fourteen cases there was absolute conformity between the prediction and the observation, for twelve hatchings were predicted to turn out diseased, and this proved to be the case. Now all these "educations" were believed to be healthy by the cultivators, but Pasteur foretold that they would turn out to be diseased by the application of the moth-test in the previous year. The other parcels of eggs were pronounced by Pasteur to be sound, because they were laid by healthy moths containing none of the micrococci, and both these yielded a healthy crop. So successful a prophecy could not but gain the belief of the most obtuse of cultivators, and we are not surprised to learn that Pasteur's test was soon generally applied, and that the consequence has been a return of prosperity to districts in which thousands of homes had been desolated by a terrible scourge.

I must now ask you to accompany me to another and a new field of Pasteur's labours, which, perhaps more than his others, claims your sympathy and will enlist your admiration, because they have opened out to us the confident hope of at least obtaining an insight into some of the hidden causes and therefore to the possible prevention of disease.

In the first place, I must recall to your remembrance that most infectious diseases seldom if ever recur, and that even a slight attack renders the subject of it proof against a second one. Hence inoculation from a mild case of small-pox was for a time practiced, but this too often brought about a serious if not fatal attack of the malady, and the step taken by Jenner of vaccinating, that is of replacing for the serious disease a slight one which nevertheless is sufficient protection against small-pox infection, was one of the highest importance. But Jenner's great discovery has up to recent years remained an isolated one, for it led to no general method for the preventive treatment of other maladies, nor had any explanation been offered of its mode of action. It is to Pasteur that science is indebted for the generalization of Jenner's method, and for an explanation which bids fair to render possible the preventive treatment of many—if not of all—infectious diseases. It was his experience, based upon his researches on fermentation, that led to a knowledge of the nature of the poison of such diseases, and showed the possibility of so attenuating or weakening the virus as to furnish a general method of protective or preventive inoculation.

I have already pointed out how a pure cultivation of a microbe can be effected. Just as the production of pure alcohol depends on the presence of the pure yeast, so special diseases are dependent on the presence of certain definite organisms which can be artificially cultivated, and which give rise to the special malady. Can we now by any system of artificial cultivation so modify or weaken the virus of a given microbe as to render it possible to inoculate a modified virus which, whilst it is without danger to life, is still capable of acting as a preventive to further attack? This is the question which Pasteur set himself to solve, nor was the task by any means an apparently hopeless one. He had not only the case of Jennerian vaccination before him, but also the well-known modifications which cultivation can bring about in plants. The first instance in which Pasteur succeeded in effecting this weakening of the poison was in that of a fatal disease to which poultry in France are very liable, called chicken cholera. Like many other maladies, this is caused by the presence of a micro-organism found in the blood and tissues of the stricken fowl. One drop of this blood brought under the skin of a healthy chicken kills it, and the same microbe is found throughout its body. And if a pure culture of these microbes be made, that culture—even after a series of generations—is as deadly a poison as the original blood. Now comes the discovery. If these cultures be kept at a suitable temperature for some weeks exposed to pure air, and the poisonous properties tested from time to time, the poison is found gradually to become less powerful, so that after the lapse of two months a dose which had formerly proved fatal now does not disturb in the slightest the apparent health of the fowl. But now let us inoculate a chicken with this weakened virus. It suffers a slight illness, but soon recovers. Next let us give it a dose of the undiluted poison, and, as a control, let us try the action of the same on an unprotected bird. What is the result? Why, that the first chicken remains unaffected, whilst the second bird dies. The inoculation has rendered it exempt from the disease, and this has been proved by Pasteur to be true in thousands of cases, so that, whereas the death-rate in certain districts amongst fowls before the adoption of Pasteur's inoculation method was 10 per cent., after its general adoption it has diminished to less than 1 per cent.

We can scarcely value too highly this discovery, for it proves that the poisonous nature of the microbe is not unalterable, but that it can be artificially modified and reduced, and thus an explanation is given of the fact that in an epidemic the virus may either be preserved or become exhausted according to the conditions to which it is subjected. We have here to do with a case similar to that of Jenner's vaccine, except that here the relation between the weak and the strong poison has become known to us, whilst in Jenner's case it has lain concealed. This, then, is the first triumph of experimental inquiry into the cause and prevention of microbic disease, and this method of attenuation is of great importance, because, as we shall see, it is not confined to the case of chicken cholera, but is applicable to other diseases.

And next I will speak of one which is a fatal scourge to cattle, and is not unfrequently transmitted to man. It is called anthrax, splenic fever. or woolsorters' disease. This plague, which has proved fatal to millions of cattle, is also due to a microbe, which can be cultivated like the rest, and the virus of which can also be weakened or attenuated by a distinct treatment which I will not here further specify. Now, what is the effect of inoculating cattle or sheep with this weakened poison? Does it act as a preventive? That the answer is in the affirmative was proved by Pasteur by a convincing experiment. Five-and-twenty sheep, chosen promiscuously out of a flock of fifty, were thus inoculated with the weak virus, then after a time all the fifty were treated with the strong poison. The first half remained healthy, all the others died of anthrax. Since the discovery of this method, no fewer than 1,700,000 sheep and about 90,000 oxen have thus been inoculated, and last year 269,599 sheep and 34,464 oxen were treated. The mortality which, before the introduction of the preventive treatment, was in the case of sheep 10 per cent., was, after the adoption of the method, reduced to less than 1 per cent. So that now the farmers in the stricken districts have all adopted the process, and agricultural insurance societies make the preventive inoculation a *sine quâ non* for insuring cattle in those districts. This is, however, not the end of this part of my story, for Pasteur can not only thus render the anthrax poison harmless, but he has taught us how to bring the highly virulent poison back again from the harmless form. This may go to explain the varying strength of an attack of infectious disease, one case being severe and another but slight, due to the weakening or otherwise of the virus of the active microbe.

Last, but not least, I must refer to the most remarkable of all Pasteur's researches, that on rabies and hydrophobia. Previous to the year 1880, when Pasteur began his study of this disease, next to nothing was known about its nature. It was invested with the mysterious horror which often accompanies the working of secret poisons, and the horror was rendered greater owing to the fact that the development of the poison brought in by the bite or by the lick of a mad dog might be deferred for months, and that, if after that length of time the symptoms once make their appearance, a painful death was inevitable. We knew indeed that the virus was contained in the dog's saliva, but experiments made upon the inoculation of the saliva had led to no definite results, and we were entirely in the dark as to the action of the poison until Pasteur's investigation. To begin with, he came to the conclusion that the disease was one localized in the nerve-centres, and to the nerve-centres he therefore looked as the seat of the virus or of the microbe. And he proved by experiment that this is the case, for a portion of the matter of the spinal column of a rabid dog, when injected into a healthy one, causes rabies with a much greater degree of certainty and rapidity than does the injection of the saliva. Here, then, we have one step in advance. The disease is one of the nerve-centres, and, therefore, it only exhibits itself when the nerve-centres are attacked. And this goes to explain the varying times of incubation which the attack exhibits. The virus has to travel up the spinal cord before the symptoms can manifest themselves, and the length of time taken over that journey depends on many circumstances. If this be so, the period of incubation must be lessened if the virus is at once introduced into the nerve-centres. This was also proved to be the case, for dogs inoculated under the *dura mater* invariably became rabid within a period rarely exceeding eighteen days.

Next came the question, Can this virus be weakened, as has been proved possible with the former poisons? The difficulty in this case was greater, inasmuch as all attempts to isolate or to cultivate the special microbe of rabies outside the animal body had failed. But Pasteur's energy and foresight overcame this difficulty, and a method was discovered by which this terrible poison can so far be weakened as to lose its virulent character, but yet remain potent enough, like the cases already quoted, to act as a preventive; and dogs which had thus been inoculated were proved to be so perfectly protected, that they might be bitten with impunity by mad dogs, or inoculated harmlessly with the most powerful rabic virus.

But yet another step. Would the preventive action of the weakened virus hold good when it is inoculated even after the bite? If so, it might be thus possible to save the lives of persons bitten by mad dogs. Well, experiment has also proved this to be true, for a number of dogs were bitten by mad ones, or were inoculated under the sk with rabic virus; of these some were subjected to the preventive cure and others not thus treated. Of the first or protected series not one became mad, of the other, or unprotected dogs, a large number died with all the characteristic symptoms of the disease. But it was one thing to thus experiment upon dogs, and quite another thing, as you may well imagine, to subject human beings to so novel and perhaps dangerous a treatment. Nevertheless, Pasteur was bold enough to take this necessary step, and by so doing has earned the gratitude of the human race.

In front of the Pasteur Institute in Paris stands a statue worked with consummate skill in bronze. It represents a French shepherd boy engaged in a death struggle with a mad dog which had been worrying his sheep. With his bare hands, and with no weapon save his wooden *sabot*, the boy was successful in the combat. He killed the dog, but was horribly bitten in the fight. The group represents no mythical struggle; the actual event took place in October 1885; and this boy, Jupille, was the second person to undergo the anti-rabic treatment, which proved perfectly successful, for he remained perfectly healthy, and his heroic deed and its consequences have become historic. "*C'est le premier pas qui coute*," and as soon as the first man had been successfully treated, others similarly situated gladly availed themselves of Pasteur's generous offer to treat them gratuitously. And as soon as this cure became generally known, crowds of persons of all ages, stations, and countries, all bitten by rabid animals, visited every day Pasteur's laboratory in the Rue d'Ulm, which, from being one in which quiet scientific researches were carried on, came to resemble the out-patient department of a great hospital. There I saw the French peasant, the Russian *moujik* (suffering from the terrible bites of rabid wolves), the swarthy Arab, the English policeman, with women too and children of every age, in all perhaps a hundred patients. All were there undergoing the careful and kindly treatment, which was to insure them against a horrible death. Such a sight will not be easily forgotten. By degrees this wonderful cure for so deadly a disease attracted the attention of men of science throughout the civilized world. The French nation raised a monument to the discoverer better than any statue, in the shape of the "Pasteur Institute"—an institution devoted to carrying out in practice this anti-rabic treatment, with laboratories and every other convenience for extending by research our knowledge of the preventive treatment of infectious disease.

For, be it remembered, we are only at the beginning of these things, and what has been done is only an inkling of what is to come. Since 1885, twenty anti-rabic institutions have been established in various parts of the world, including Naples, Palermo, Odessa, St. Petersburg, Constantinople, Rio Janeiro, Buenos Ayres, and Havannah.

We in England have also taken our share, though a small one, in this work. In 1885 I moved in the House of Commons for a Committee to investigate and report on Pasteur's anti-rabic method of treatment. This Committee consisted of trusted and well-known English men of science and physicians—Sir James Paget, Sir Joseph Lister, Drs. Burdon Sanderson, Lauder Brunton, Quain, Fleming, and myself, with Prof. Victor Horsley as secretary. We examined the whole subject, investigated the details of a number of cases, repeated Pasteur's experiments on animals, discussed the published statistics, and arrived unanimously at the opinion that Pasteur was justified in his conclusions, and that his anti-rabic treatment had conferred a great and lasting benefit on mankind. Since then His Royal Highness the Prince of Wales, who always takes a vivid interest in questions affecting the well-being of the people, has visited the Pasteur Institute, and has expressed himself strongly in favour of a movement, started by the present Lord Mayor of London, for showing to Pasteur, by a substantial grant to his Institute, our gratitude for what he has done to relieve upwards of 250 of our countrymen who have undergone treatment at his hands, and likewise to enable poor persons who have been bitten, to undertake the journey to Paris, and the sojourn there necessary for their treatment. This lasts about a fortnight, it is nearly painless, and no single case of illness, much less of hydrophobia—due to the preventive treatment—has occurred amongst the 7000 persons who have so far undergone the cure.

Now let me put before you the answer to the question, Is this treatment a real cure? For this has been doubted by persons, some of whom will I fear still doubt or profess to doubt, and still abuse Pasteur whatever is said or done! From all that can be learnt about the matter, it appears pretty certain that about from fifteen to twenty persons out of every hundred bitten by mad dogs or cats, and not treated by Pasteur's method, develop the disease, for I need scarcely add that all other methods of treatment have proved fallacious; but bites on the face are much more dangerous, the proportion of fatal cases reaching 80 per cent. Now of 2164 persons treated in the Pasteur Institute, from November 1885 to January 1887, only thirty-two died, showing a mortality of 1·4 per cent. instead of fifteen to twenty, and amongst these upwards of 2000 persons, 214 had been bitten on the face, a class of wounds in which, as I have said, when untreated, the mortality is very high; so that the reduction in the death-rate seems more remarkable, especially when we learn that in all these cases the animal inflicting the wound had been proved to be rabid. The same thing occurs even in a more marked degree in 1887 and 1888. In 1887, 1778 cases were treated, with a mortality of 1·3 per cent., whilst last year 1626 cases were treated, with a mortality of 1·16 per cent.

Statistics of the anti-rabic treatment in other countries show similar results, proving beyond a doubt that the death-rate from hydrophobia is greatly reduced. Indeed, it may truly be said that in no case of dangerous disease, treated either by medicine or surgery, is a cure so probable. Moreover, in spite of assertions to the contrary, no proof can be given that in any single case did death arise from the treatment itself. And as showing the safety of the inoculation, I may add that all Pasteur's assistants and laboratory workers have undergone the treatment, and no case of hydrophobia has occurred amongst them.

You are no doubt aware that Pasteur's anti-rabic treatment has been strongly opposed by certain persons, some of whom have not scrupled to descend to personal abuse of a virulent character of those who in any way encouraged or supported Pasteur's views, and all of whom persistently deny that anything good has come or can come from investigations of the kind. Such persons we need neither fear nor hate. Their opposition is as powerless to arrest the march of science as was King Canute's order to stop the rising tide. Only let us rest upon the sure basis of exactly ascertained fact, and we may safely defy alike the vapourings of the sentimentalist and the wrath of the opponent of scientific progress. But opposition of a much fairer character has likewise to be met, and it has with propriety been asked—How comes it that Pasteur is not uniformly successful? Why, if what you tell us is true, do any deaths at all follow the anti-rabic treatment? The answer is not far to seek. In the first place, just as it is not every vaccination which protects against small pox, so Pasteur's vaccination against rabies occasionally fails. Then, again, Pasteur's treatment is really a race between a strong and an attenuated virus. In cases in which the bite occurs near a nerve-centre, the fatal malady may outstrip the treatment in this race between life and death. If the weakened virus can act in time, it means life. If the strong virus acts first, prevention comes too late—it means death. So that the treatment is not doubtful in all cases, but only doubtful in those which are under well-known unfavourable conditions. This, it seems to me, is a complete reply to those who ignorantly fancy that, because Pasteur's treatment has not cured every case, it must be unreliable and worthless.

One word more. I have said that Pasteur is still—as he has always been—a chemist. How does this fit in with the fact that his recent researches seem to be entirely of a biological character? This is true. They seem, but they really are not. Let me in a few sentences explain what I mean. You know that yeast produces a peculiar chemical substance—alcohol. How it does so we cannot yet explain, but the fact remains. Gradually, through Pasteur's researches, we are coming to understand that this is not an isolated case, but that the growth of every micro-organism is productive of some special chemical substance, and that the true pathogenic virus—or the poison causing the disease—is not the microbe itself, but the chemical compound which its growth creates. Here once more "to the solid ground of nature trusts the man that builds for aye," and it is only by experiment that these things can be learnt.

For further details, see Dr. Ruffer, *Brit. Med. Journ.*, Sept. 21, 1889.

Let me illustrate this by the most recent and perhaps the most striking example we know of. The disease of diphtheria is accompanied by a peculiar microbe, which, however, only grows outside, as it were, of the body, but death often takes place with frightful rapidity. This takes place not by any action of the microbe itself, but by simple poisoning due to the products of the growing organism, which penetrate into the system, although the microbe does not. This diphtheritic *Bacillus* can be cultivated, and the chemical poison which it produces can be completely separated by filtration from the microbe itself, just as alcohol can be separated from the yeast granules. If this be done, and one drop of this pellucid liquid given to an animal, that animal dies with all the well-known symptoms of the disease. This, and similar experiments made with the microbes of other diseases, lead to the conclusion that in infectious maladies the cause of death is poisoning by a distinct chemical compound, the microbe being not only the means of spreading the infection, but also the manufacturer of the poison. But more than this, it has lately been proved that a small dose of these soluble chemical poisons confers immunity. If the poison be administered in such a manner as to avoid speedy poisoning, but so as gradually to accustom the animal to its presence, the creature becomes not only refractory to toxic doses of the poison, but also even to the microbe itself. So that instead of introducing the micro-organism itself into the body, it may now only be necessary to vaccinate with a chemical substance which in large doses brings about the disease, but in small ones confers immunity from it, reminding one of Hahnemann's dictum of "Similia similibus curantur."

Here then we are once more on chemical ground. True, on ground which is full of unexplained wonders, which, however, depend on laws we are at least in part acquainted with, so that we may in good heart undertake their investigation, and look forward to the time when knowledge will take the place of wonder.

In conclusion, I feel that some sort of apology is needed in thus bringing a rather serious piece of business before you on this occasion. Still I hope for your forgiveness, as my motive has been to explain to you as clearly as I could the life-work of a chemist who has in my opinion conferred benefits as yet untold and perhaps unexampled on mankind, and I may be allowed to close my discourse with the noble words of our hero spoken at the opening of the Pasteur Institute in the presence of the President of the French Republic:—

"Two adverse laws seem to me now in contest. One law of blood and death, opening out each day new modes of destruction, forces nations to be always ready for the battlefield. The other a law of peace, of work, of safety, whose only study is to deliver man from the calamities which beset him.

"The one seeks only violent conquests. The other only the relief of humanity. The one places a single life above all victories. The other sacrifices the lives of hundreds of thousands to the ambition of a single individual. The law of which we are the instruments, strives even through the carnage to cure the bloody wounds caused by this law of war. Treatment by our antiseptic methods may preserve thousands of soldiers.

"Which of these two laws will prevail over the other? God only knows. But of this we may be sure, that science in obeying this law of humanity will always labour to enlarge the frontiers of life."

THE PHYSICAL PAPERS AT THE BRITISH ASSOCIATION.

PROF. A. W. RÜCKER, F.R.S., read a paper on cometic nebulæ. Prof. Lockyer has suggested that comet-like nebulæ may be caused by the passage of a very dense swarm through a stream of meteorites, the relative velocity of the two being very considerable. The author has, therefore, attempted to calculate the increase in the number of collisions which takes place in the rear of an attracting mass which passes through a swarm of meteorites so sparsely scattered through space that the main effects of the attraction are produced in a distance which is small compared with the length of the mean free path. Assuming, with Clausius, that the particles have equal velocities equally distributed in all directions, and which are small compared with the relative velocity of approach, the collisions will be most numerous within a cone the apex of which is the attracting body or nucleus, and which contains the lines which are parallel to the relative velocities of the individual meteorites