THE GERM THEORY OF DISEASE AND ITS RELATIONS TO HYGIENE[1]

A TEORIA DO GERME E SUAS RELAÇÕES COM A HIGIENE

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No more striking evidence can be adduced of the intellectual advancement characteristic of modern times, than the general recognition among men of the universal reign of law. It is true that this general recognition has not yet become quite universal. There are not wanting many, even in our enlightened age, to whom the advent of a comet still brings feelings of dismay, and in whose belief the wind literally bloweth where it listeth, every day. The belief in lucky and unlucky days has by no means disappeared, and among even the well educated there are yet some who would not willingly put to sea on the brightest Friday morning that ever shone. It is difficult to disabuse the mind of impressions which almost inevitably find a place there in the infancy of individuals and of peoples. Every event of which the causes are obscure, is naturally attributed by the ignorant or inexperienced, either to blind chance or to the purposed interference of some supernatural power; and such is the strength of the imagination that the feeling often survives long after reason has exploded the error.

There is no class of natural phenomena which the men of all times have been disposed to look upon as being more completely exempt from the dominion of law, than those which concern sickness and health. The illness of an individual appears always to have been esteemed an event entirely fortuitous, which no humnan prescience could anticipate, and no human precaution could avert; and the simultaneous sickening and death of multitudes has more frequently been regarded as an evidence of Divine displeasure, directly interfering with the usual order of nature, than as a grave and interesting phenomenon to be patiently investigated and rationally explained. The truth is, nevertheless, that the laws of health and of disease in living organisms are as fixed and invariable as, in abstract science, are those of mathematics. The difference lies in the greater difficulty of their discovery. This is well illustrated in the history of the subject which I have ventured, with a presumption which in this presence may seem like temerity, to select as the theme of my remarks this evening.

The germ theory of disease is not, as is commonly supposed, a theory which has originated in very recent years. More than two hundred years ago it was brought forward, at least as an hypothesis, by the celebrated Father Kircher, in his "*Scrutinium Physico-Medicum contagiosae luis que pestis dicitur*" to account for the infectious propagation of the plague. How-ever plausible this theory might at that time have seemed, it could then, nevertheless, claim no higher rank than that of a bare hypothesis; and it has only been in times comparatively recent that observation has brought to light a sufficient number of facts apparently favoring it to justify our advancing it in the arena of scientific discussion to the higher dignity of a theory.

General principles bearing on the subject

Before proceeding to consider the evidences bearing on the truth of this theory, for or against, a few observations of a general nature may properly here find place. No living organism enjoys an existence of unlimited duration. Every such organism, under favorable circumstances, passes through three distinct stages, which are those of growth, vigorous maturity, and decline. The organism commences as a germ, and ends in dissolution and disintegration. Since the laws of life, as well as those of physics, are fixed and definite, there is reason to believe that all organisms of the same species, if placed in conditions equally favorable to their development, would be equally long-lived; yet, in point of fact, those which pass through the regular stages constituting their normal life are comparatively few. In the large majority, the vital functions are, earlier or later, more or less disturbed, if not arrested, by an endless variety of causes tending to

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produce disease and premature death. In the human race life is often shortened by ignorant or willful disregard of the conditions necessary to the preservation of health.

Accident, also, often exposes individuals to deleterious influences. Thus, in many cases, diseases arise from exposure to extremes of temperature, or from excesses in eating and drinking, persisted in until the organs of digestion become debilitated and fail to fulfill their proper functions. But besides these causes of disease, which may be classed under the head of "injurious conditions," there are other influences directly morbific, which, whenever they come into play, cut short the duration of life. Poisons belong to this class, but the effects of these are felt only in occasional and accidental instances. Other noxious influences, of which the pernicious consequences are more widely spread, are those which produce the diseases called zymotic. Such are malaria, contagion, and infection, instrumentalities to which are owing the wide-spread ravages of epidemics.

It may be remarked tlhat there are many cases of disease in which the cause is not traceable directly to any of the sources above mentioned, but in which the disease has been transmitted by inheritance from a parent similarly affected. In such cases there is nevertheless every reason to believe that the disease in its first appearance was produced in a healthy organism by causes belonging to one or the other of the classes above named. The diseases which it is the objects of the present paper to consider are only those which belong to the epidemic or contagious class.

Theories of contagion

No subject has occupied more the careful attention of physicians, or has been a subject of more elaborate observation and experiment, or has led to more marked differences of opinion or more animated controversy, than that of thenatu re of the influences by which these diseases are transmitted from individual to individual. That many epidemics arise from peculiar conditions of the atmosphere, not in the least as yet understood, can hardly be doubted; and in this case the influence which excites disease simultaneously in many is not dissimilar to that by which contagious diseases are transmitted from individual to individual.

Confining ourselves, however, for the moment to this latter mode of transmission, it may be observed that two theories distinctly opposed to each other have long been held on the subject, each of them counting in its advocacy authorities of the very highest character. These may be distinguished as the chemical theory of infection and the germ theory. The chemical theory is founded on a presumed analogy between the propagation of disease in living organisms, and the process of fermentation in certain forms of organic matter without life. This theory assumes a ferment to be an organized substance in a certain state of decay, which possesses the property of exciting the same decay in other organic substances with which it is in contact.

Applying this theory to disease, it supposes that infection is communicated by the instrumentality of particles thrown from the person, or from substances proceeding, from the person diseased, and borne by the air to other persons in full health, in whom they excite, probably by contact with the membranous linings of the lungs, the same diseased condition wlhich exists in the patient. The opposing theory presumes that the diseased person is suffering, from an invasion of his system by microscopic algoid or fungoid vegetative forms having the property of rapid self-multiplication, and that the spores which proceed from these fungi or the cells of the algae are wafted in like manner by the air from person to person, penetrating the systems of the healthy, and establishing new colonies to generate disease in them[i].

Evidences favoring the germ theory

A *primâ facie* evidence, which, so far as it goes, is favorable to the germ theory, is found in the well-known fact that all the forms of cryptogamic vegetation are propagated by spores, which they shed freely abroad in all directions, and that these are borne in infinite numbers through the atmosphere, which they pervade near the surface of the earth in all places. The fact of their universal presence is made manifest by the promptness with which fungoid growths spring up in all circumstances in which the conditions favor their development. Such conditions embrace a congenial temperature, and the presence of some organic substance suitable to serve as a nidus, and furnish for them their proper food. There are peculiar forms of fungus which appear on particular forms of organism and nowhere else. Thus the hoofs of dead horses are overspread, when exposed at a moderate temperature to moisture, with a vigorous growth which is seen in no other situation, and some of the larger plants are infested by their own peculiar fungi.

This constant appearance of minute forms of vegetable life could not take place so invariably in all varying situations vere not the spores of the fungi continually present in the air throughout its whole extent. We know that the numbers of these spores which all fungi produce are incalculable. The larger fungi give us evidence of this. The spores of a single puff-ball have been estimated to be more numerous than the entire human population of the globe. It is true that to ordinary observation the presence of foreign matters in the atmosphere is not perceptible, except when such foreign matters take the gross form of clouds of smoke or dust; but particles of smoke or dust, and in general of all inorganic substances, are so heavy that they soon subside; yet when the air is thus left apparently free from all foreign admixture, it is demonstrably full of organic particles so extremely light as not to subside for many hours or even days of perfect rest. The chemist, it is true, is unable to detect them by his tests, delicate as they are; for being organic, and composed in general of but two or three elements - which elements are in great part those of the atmosphere itself they produce no distinctive reactions under the ordinary processes of analysis.

But there is a mode of analysis much more delicate than even that of the chemist. It is that which has been applied incidentally to this question by Professor Tyndall, in his interesting investigation into the chemical effects of light upon vapors. Professor Tyndall discovered that there are many substances of great volatility which, when in the state of vapor, are easily decomposed by light. He found that a perfectly transparent vapor, like steam, when traversed by a luminous beam, is absolutely invisible; while we all know that if we admit a beam of sunlight into a darkened room, through an aperture in the shutter, the path of the beam through the apartment is as distinctly marked as if it were a solid bar. That this visibility of a beam of light in the air is not owing to the power of the aerial particles themselves to reflect light, is demonstrated by him by proofs entirely conclusive.

A beam of light from an electric lamp was made in his experi-ments to pass through a large glass tube closed at both ends by plates of glass cemented on. No light was permitted to escape into the room; and, accordingly, when the tube was exhausted of air altogether, and no light from its interior was reflected to the eye, it was perfectly invisible. But if the air of the room were allowed to reenter it, it immediately became brilliantly luminous, as in the case of a sunbeam admitted through the window shutter.

If, however, the air before being admitted into the empty tube had been passed through a red-hot tube of platinum, the tube thus filled remained as completely invisible as when it was a perfect vacuum. This experiment, which is but one of many employed by Professor Tyndall to demonstrate the same proposition, shows not only that the air is full of foreign matters, but that these foreign matters are organic; for, were they not Iso, they could not be destroyed by fire. He proved also that these particles are so numerous that they cannot be entirely arrested by passing the air through the most energetic chemical reagents, as sulphuric acid, caustic potash, and the like; but that, though these substances arrested a large portion of the organisms, they allowed still not a few to escape. He showed, however, that a filter of rather closely compacted cotton will shut off entirely, or almost entirely, the organic matters which the air contains; and he showed, finally, that absolute rest for a long period of time will cause these particles completely to subside.

Thus a large flask which had been standing in the store-room was found to be, as he expressed it, "optically empty" that is to say, the rays of light passed through it without showing any more trace of their path than if it had been a vacuum. He also experimented to ascertain how long a time would be required to free the air by subsidence of its suspended particles in a space completely closed; and for this purpose he constructed such a closed space, cubical in form and several feet in linear dimensions, glazed so as to permit him to pass through it a beam of light, and to observe the path of the beam. This small apartment was made absolutely air-tight, and left to itself. On each succeeding day the brilliancy of the transmitted beam grew less and less, and at length, at the end of a week, it could no longer be perceived at all. The apartment was optically empty.

These experiments, and others no less interesting, by Professor Tyndall, thus prove in the most conclusive manner, that the ordinary air at the surface of the earth is always completely filled with particles of organic matter. It is not necessary to suppose that all these particles are living germs of vegetable or animal organisms; but when we see how constantly such organisms spring up wherever the conditions favor germination, it is impossible to doubt that a vast many of them have this character; and that these are the source of those growths of minute cryptogams which thus seem to spring up spontaneously. There is no other mode of accounting

for such growths, except to suppose that they are actually spontaneous; and accordingly the view has been taken by some physiologists -perhaps I should say many -that the true mode of accounting for the appearance of microscopic forms of life, is to suppose that they originate without organic antecedents, or as these philosophers express it, *de novo*.

Theories of the origin of life

No question at the present day is more sharply debated than that which relates to the origin of life. There is no -subject which has been pursued experimentally with more zeal, more earnest solicitude to reach the truth, or more singularly discordant results than this. The notion of spontaneous generation is not, by any means, of modern origin. It has been entertained by naturalists in every age since the dawn of scientific history. But the earlier naturalists, Aristotle and Lucretius, for instance, conceived that organisms of a high order of complexity, such as insects, or fishes, or reptiles might be directly produced out of the moist earth softened by showers, or out of the slime and mud of rivers; whereas those of our time have long since abandoned any such extravagant notions, and confine themselves to the assertion that life in its spontaneous origin is manifested only under the simplest forms.

The latest example of an hypothesis resembling the ancient is found in the argument presented in a work entitled "Vestiges of Creation," which appeared about thirty years ago, in which the experiments of Mr. Andrew Crosse upon electric currents of low intensity directed for a long time through a solution of inorganic salt, were supposed to have produced an insect of the Acarus family; such an insect having actually made its appearance during the course of the experiment. But this result has long since been recognized to have been merely accidental, and probably owing to the presence of ova of the insect introduced in some unexplained way into the apparatus. The modern advocates of the theory of spontaneous generation

hold, however, or at least most of them hold, only to the certainty of the spontaneous appearance of organisms of a very low type, called bacteria, vibriones, and monads, organisms familiar to the microscopist, and which are sure to make their appearance in every putrefying organic infusion.

Less than three centuries ago the belief here spoken of, that living things may originate without eggs, or germs, or living parents from which to proceed, may be said to have been universal in Europe. Of the truth of this belief there was supposed to be visible evidence in the invariable occurrence of maggots in putrefying flesh. Curiously enough, scriptural authority was cited in proof of this view, and the Old Testament story of the bees found by Samson in the, carcass of the dead lion, was presumed to confirm it. The doctrine was therefore held as matter of faith, and those who first assailed it were naturally accused of impiety and irreverence. Prominent and perhaps first among these was Francis Redi, an Italian philosopher, scholar, and poet, born in 1626. He presented a conclusive disproof of the spontaneous generation of maggots in putrefying flesh, by simply inclosing, in open-mouthed jars covered with gauze, pieces of flesh still sound, and leaving them in the sun to putrefy.

Putrefaction occurred as before, but no maggots made their appearance. The maggots, nevertheless, did appear on the gauze, and a little observation made their origin manifest. The flies, of which they are the progeny in the larvae state, being attracted by the odor of the flesh, but unable to reach it, laid their eggs upon the covering of the jar, and out of these the larve were presently developed. Having demonstrated the falsity of the popular belief on this subject in a case so conspicuous, Redi naturally generalized his conclusion, and took the ground that no living thing comes into existence without deriving its life from something previously living. He did not say, as it has been said later, "*Omne vivum ex ovo*", but "*Omne vivum ex vivo*". He still believed that out of a living plant may arise a living animnal, as the insect within the gall of the oak, or the worm within the fruit which presents no external puncture.

His doctrine was, therefore, that which Huxley has named Biogenesis, in contradistinction to spontaneous generation, called by him Abiogenesis, and by Bastian Archegeonesis. But archegenesis had been put aside only to return again under a new form. Among the earliest revelations of the microscope was the remarkable fact that whenever a dead organic substance is infused in water, myriads of minute creatures presently make their appearance in the infusion, all possessing most extraordinary and many of them very varied powers of reproduction. They multiply by means of ova, by means of buds, or gemmation, and by means of self-division, or fissuration. All this was strongly favorable to the doctrine of biogenesis. Where so many means of reproduction

existed, every one of them so effectual and sufficient, to provide that the same forms of life should be produced without any organic antecedents, seemed "wasteful and ridiculous excess".

This view, however, met here and there with a dissentient. About a century and a quarter ago, John Turberville Needham, an English naturalist, resorted to an experiment which, with various modifications, has been, since, many hundreds and possibly many thousands of times repeated, with the view thoroughly to test the question whether, in its application to infusorial life, the doctrine of biogenesis is universally true. He prepared an infusion, thoroughly boiled it in a flask, corked it tight, sealed the cork with mastic, and covered the whole with hot ashes, designing to destroy by heat any germs which might be in the infusion, in the substance infused, or in the air above the liquid in the flask. After some days or weeks, he found that, notwithstanding all these precautions, living organisms did make their appearance in the flask, precisely such as in freely exposed infusions habitually appeared earlier. This experiment was immediately repeated by Spallanzani, an Italian ecclesiastic and naturalist; but Spallanzani, instead of corking his flask, and cementing his corks, sealed the vessels by fusing the glass, and having thus completely cut off communication with the outward air, kept them at the boiling temperature for three quarters of an hour. No life appeared in the infusions of Spallanzani, and the doctrine of biogenesis was again apparently triumphant.

The question was, however, not yet universally admitted to be settled. Dissentients made themselves heard from time to time, among them Gleichen, Otho Muller, and Treviranus; the latter of whom pointed out the significant fact that, while the species of infusorial animals found in infusions of the same kind were constantly the same, those which appeared in different infusions were not so. Early in the present century the celebrated naturalist, Lamarck, ranged himself on the side of spontaneous generation. Oken took the same view, and subsequently Bory St. Vincent, J. Muller, Dujardin, Burdach, and Pineau; while on the opposite side appeared, among others, Schwann, Sclhultze, and Ehrenberg.

The experiments of Schultze and Schwann, undertaken for the purpose of testing the accuracy of those of Spallanzani, were remarkable. Subsequently to the date of Spallanzani's experiments, the importance of air, or of oxygen, one of its constituents, to the maintenance of animal life had been discovered, and doubts had arisen whether, in those experiments, the air had not been rendered unfit for the support of life by the operations to which it had been subjected. In repeating the experiments, Schultze admitted to the flasks, after boiling the infusions, only such air as had been passed through concentrated sulphuric acid; and Schwann only such as had been conducted through red-hot tubes. No animalcules made their appearance; and these results, reached as long ago as I836 and I837, were regarded by the great body of naturalists as finally settling the question.

Renewal of the controversy

The controversy, however, after resting for twenty years, was revived and prosecuted with even more animation than before, by Mr. Pouchet, in the first instance, on the side of spontaneous generation, and Mr. Pasteur, on that of biogenesis; but more recently by many naturalists of distinction, among Nvhom may be named Dr. Jeifries Wyman, of our own country, whose experimental researches tend rather to the support of the archegenetic theory, and Professor Huxley, of London, whose opinion, given on a survey of the whole history of the controversy, and expressed before the British Association in 1870, is very decidedly the other way.

While the controversy was between Mr. Pasteur and Mr. Pouchet, there can be no doubt that, in the judgment of the world, the former had by far the best of the argument. His experiments, which were substantially repetitions of those of Needham and Spallanzani, but which were variously modified, so as to render his demonstrations, in every possible way, cumulative, seemed to have disposed of the doctrine of spontaneous generation, effectually and forever. In multitudes of instances, infusions hermetically sealed while boiling, remained for indefinite periods of time free from all traces of organic life, while portions of the same infusions exposed side by side with these, but open to the air, were speedily swarming with animalcules.

He found that even an unsealed flask, of which the neck had been stopped during the boiling only with a plug of cotton closely pressed together, continued to be equally free from these organisms so long as the stopper remained in its place. This last experiment presented a rather curious resemblance to that of Redi, with his gauze-covered jar; for the cotton forming the plug was found, on a microscopic examination, to contain the germs which its presence had

prevented from entering the flask. Mr. Pasteur finally discovered -and this result was long supposed to have furnished an unanswerable reply to all the arguments of the advocates of archegenesis - that flasks containing infusions treated by boiling as before, required neither sealing nor stopping with cotton to prevent invasion of the contained liquids by these low forms of life; provided that only the necks of such flasks had been originally bent over, so as to direct their mouths downward. This result he had predicted as probable, holding, as he did, that the germs by which such infusions are repeopled when the living embryos they may contain have been destroyed by heat,. must necessarily subside into them from the air above.

The experiments of Wyman, Bastian, Cantoni, and others, more recent than those of Pasteur, have led to results singularly, and at present, we must say, unaccountably at variance with his. Professor Wyman found that bacteria will make their appearance in infusions which have not only been boiled before being sealed up, but which, after being sealed, have been kept at a boiling heat for many hours. He found, moreover, that these same organisms, after their appearance, perish when exposed to a heat not over l340 Fahrenheit. Bastian, in a very extended series of experiments, has pushed the heat in the tubes containing his infusions as high as 300^{o} Fahrenheit, maintaining this high temperature, in some instances, not less than four hours; and has yet found that living forms do not fail subsequently to appear in them. Such forms appear, also, according to him, in solutions containing nothing of organic origin, whatever, but composed entirely of certain salts of soda and ammonia; and he even affirms that in such solutions he has occasionally seen very remarkable fungi to present themselves with their full fructification, drawings of which he has given in his work, recently published, entitled "The Beginnings of Life".

It seems to me that no one can rise from the perusal of the extraordinary book just mentioned without feeling that, if it does not embrace and contain the conclusion of the whole matter, it is at least for the present unanswerable. It leaves us, nevertheless, still perplexed, perhaps more deeply perplexed than before; for it is impossible to understand how the results reached by so many naturalists, all in the first rank of scientific investigators, all conscientiously laboring to elicit the truth of this great question, should be, after all, so singularly discordant.

And another weighty consideration adds to this perplexity. It is the existence of a practical refutation of the conclusions of the class of experimenters to which Dr. Bastian belongs, which is presented under our eyes every day on the grandest scale, in the operations of one of the most important departments of modern industry. I cannot state this consideration better than in the words of Huxley: "There must", remarks this distinguished physiologist, be some error about these experiments, because they are performed on an enormous scale every day with quite contrary results. Meats, fruits, vegetables, the very materials of the most fermentable and putrescible infusions are preserved, to the extent I suppose I may say, of thousands of tons every year, by a method which is a mere application of Spallanzani's experiment.

The matters to be preserved are well boiled in a tin case provided with a small hole, and this hole is soldered up when all the air in the case has been replaced by steam. By this method they may be kept for years without putrefying, fermenting, or getting mouldy." He argues - and the argument has a weight that must be felt -that there is no mode of explaining this universal and invariable result but the exclusion of germs from these cans. And, in view of the marvelous discrepancy between the results on the small and the grand scale placed side by side, one can hardly repress the suspicion that if there be any such thing as spontaneous generation, it is a thing which occurs only under rare and extraordinary conditions, which conditions Dr. Bastian has unintentionally succeeded in establishing, while as a matter of practical importance or daily interest it is as if it were not.

Bearing of the question on the future of the intelligence

There is a view of this question, however, which, though it may seem out of place here, I cannot forbear to mention. To the philosopher, the demonstration of the theory of spontaneous generation, should it ever be demonstrated beyond all possibility of doubt or cavil, cannot but be a matter of the deepest interest. But to the man who finds himself compelled to receive it, this interest, it seems to me, must be no less painful than it is deep. Nor is this the only theory which the investigators of our time are urging upon our attention, of which I feel compelled to make the same remark. There are at least two besides which impress me with a similar feeling, and the three together constitute a group which, though to a certain extent independent of each other, are likely in the end to stand or fall together. These are the doctrine of spontaneous generation, the doctrine of organic evolution, and

the doctrine of the correlation of mental and physical forces. If these doctrines are true, the existence of an intelligence separate from organized matter is impossible, and the death of the human body is the death of the human soul. If these doctrines are true, the world becomes an enigma, no less to the theist than it has always been to the atheist.

We are told, indeed, that the acceptance of these views need not shake our faith in the existence of an Almighty Creator. It is beautifully explained to us how they ought to give us more elevated and more worthy conceptions of the modes by which He works His will in the visible creation. We learn that our complex organisms are none the less the work of His hands because they have been evolved by an infinite series of changes from microscopic gemmules, and that these gemmules themselves have taken on their forms under the influence of the physical forces of light and heat and attraction actin, on brute mineral matter. Rather it should seem we are a good deal more so. This kind of teaching is heard in our day even from the theologians. Those sentinels on the watch-towers of the faith, whose wont it has been for so many centuries to stand sturdily up in opposition to the science which was not, in any proper sense, at war with them, now, by a sudden and almost miraculous conversion, accept with cheerful countenances, and become in their turn the expounders and champions of the science which is. But while they find the mystery of the original creation thus satisfactorily cleared up in their minds, they seem to have taken very little thought as to what is going to come of the rest of their theology. It is indeed a grand conception which regards the Deity as conducting the work of His creation by means of those all-pervading influences which we call the forces of nature; but it leaves us profoundly at a loss to explain the wisdom or the benevolence which brings every day into life such myriads of sentient and intelligent beings, only that they may perish on the morrow of their birth.

But this is not all. If these doctrines are true, all talk of creation or methods of creation becomes absurdity; for just as certainly as they are true, God himself is impossible. If intelligence presupposes a material organism, of which it is a mode of action, then God must be a material organism, or there is no God. But it is the law of all living organisms that they grow, mature, and perish; and since God cannot perish, he cannot be ani organism.

But we are told it is unphilosophical, in the pursuit of truth, to concern ourselves about consequences. We should accept the truth with gladness, whatever it may be, and let consequences take care of themselves. To this canon I am willing to subscribe up to a certain point. But if, in my study of nature, I find the belief forced upon me that my own conscious spirit, as well as my animal life, is but a mere vapor, which appeareth for a little time and then vanisheth away forever, that is a truth which I cannot receive with gladness, and for which I shall never thank the science which has taught it me. Much as I love truth in the abstract, I love my hope of immortality still more; and if the final outcome of all the boasted discoveries of modern science is to disclose to men that they are more evanescent than the shadow of the swallow's wing upon the lake, it seems to me no better than a heartless mockery to talk of the countless treasures which, along with this withering revelation, she has poured out at their feet. No, if this, after all, is the best that science can give me, give me then, I pray, no more science. Let me live oni, in my simple ignorance, as my fathers lived before me, and when I shall at length be summoned to my final repose, let me still be able to fold the drapery of my couch about me, and lie down to pleasant, even though they be deceitful dreams.

Facts as to parasitic invasions of living organisms

To return from this long digression:- In order that we may be able to judge of the probability that an infectious disease of which the cause is unknown is a result of the invasion of the blood or the viscera of the patient by a parasitic vegetation, it is important to consider first what has been already ascertained of the effects of such parasitic growths infesting the animal organism. A simple form of fungus, called the *Sarcina ventriculi*, is often found in matters thrown up by persons laboring under disorder of the stomach. It has also been met with in other parts of the body when diseased. But it is likewise found, and not unfrequently, in the stomachs of persons in perfect health; and, as Dr. Carpenter says, it may accumulate there in considerable quantities without causing inconvenience. This parasite, therefore, cannot be regarded as an inciting cause of disease.

The stomachs of many worms and insects are found, moreover, to be frequently infested with fungi, which grow there in great luxuriance. Many of these have been examined and described by Dr. Leidy, of Philadelphia. It does not appear that they occasion inconvenience to the

animals within whose bodies they thus establish themselves. On the other hand, some of the dipterous and hymenopterous insects, and some caterpillars, are liable to invasion by fungoid growths, which speedily spread through their entire bodies and destroy their lives.

In the West Indies, according to Dr. Carpenter, it is not at all uncommon to see individuals of a species of Polistes (corresponding to our wasp) flying about with plants of their own length projecting from some part of their surface, the germs of which have been introduced through the breathing-pores at their sides. This fungous growth, however, soon kills the insect, and a similar effect follows a similar cause in the case of certain caterpillars in New Zealand, Australia, and China, of which the bodies become so thoroughly interpenetrated and, as it may be said, replaced by the fungoid vegetation, that when dried they have almost the density of wood, so that, in the language of Dr. Carpenter, "these caterpillars come to present the appearance of twigs, with long slender stalks formed by the projections of the fungus itself". Our common house-fly is a not unfrequent victim of a similar parasitic visitation.

A fungus called the *Empusa muscae*, originating from the germination of a single spore brought in contact almost anywhere with the body of the insect, pervades after a time its whole interior, and, while leaving the surface uninjured, emphatically eats out its substance. When the animal's life is nearly exhausted he comes to rest, and fungoid shoots put forth from his body on all sides, clothing him apparently with a kind of fur, consisting of filaments each bearing a fructification of innumerable spores. The harvest of spores becomes very conspicuous when the unfortunate animal makes his last stand upon the window pane, forming a thin film over the glass to a considerable distance around him; and if by any chance a healthy individual of the same species comes within the limit of this infected area, the disease which has destroyed his fellow will be sure to attack him also.

There are some forms of parasitic disease affecting insects which have had consequences of serious importance to certain great industrial interests to which these humble forms of animal life are tributary. A fungus called the *Botrytis bassiana* is the occasion of the disease in silk-worms known by the name of *Muscardirne*. The spores of this fungus, entering the breathing pores of the worms, soon germinate, and death is the invariable consequence. It is only or at least rarely however, the case that the cause of the fatality is manifest until after death has occurred; but then the fungus shoots forth luxuriantly, especially at the junction of the rings of the body. A still more destructive epidemic among silk-worms is that which has received the name of *Pébrine*, which is caused by the multiplication of a parasitical organism called *Panhistophyton*, fungoid in its nature. This disease is the more difficult to deal with, in that it is transmissible by inheritance, the *Psorospermiae* entering into the eggs of the diseased worm.

It was thoroughly investigated by Mr. Pasteur, who pointed out the means by which it might be extirpated; means which have since been successfully applied. But there are diseases produced by invasions of parasitic fungi in animals of much higher grade than worms or insects. The epidemic among cattle, called in England "the blood" is shown by the researches of Davaine to be occasioned by the presence in the blood of the diseased animals of innumerable living organisms resembling *vibrios*. This disease is communicable to man, producing what is called "malignant pustule," and this is attended with the development of the same organisms in the pustules thus produced. Professor Lister, an eminent surgeon of Edinburgh, long ago observed that when a chronic abscess is discharged by means of a *canula* and *trochar*, the subsequent accumulations of fluid are frequently attended with putrefaction, though none had existed before. The putrid mass is also found to be swarming with *vibrios*, though non had been present in the first discharges. No explanation of this singular phenomenon, according to him, can be given, except that the germs of these organisms were introduced in the original operation with the *canula* and *trochar*.

Another remarkable fact noticed by Professor Lister seems strongly to corroborate the theory of inflammation and putrefaction above given. A wound in the chest producing effusion of blood in the pleural cavity is attended with great danger, in consequence of the liability of the extravasated blood to putrefy. Yet when the lung is wounded by a broken rib, without any external opening, the blood, though escaping into the cavity in quantity, undergoes no decomposition and excites in the surgeon no concern, even though air at the same time enters in such volume as to inflate the cellular tissue of the entire body. "These facts", says Professor Lister, "involved to me a complete mystery until heard of the germ theory of putrefaction, when it at once occurred to me that it was only natural that the air should be filtered of germ s by the air passages "of the lungs. Now, what Professor Lister conjectured a priori, Professor Tyndall,

interested by this remark, subsequently proved experimentally. Through the path of the beam of light made visible by his lantern in the dark room described above, he caused the air from his own lungs to pass, by breathing through a tube.

The current at first but slightly affected the brightness of the beam; but as the air from the larger passages passed away, and that from the deeper network of the lungs succeeded, the light progressively faded, and at length gave place to absolute blackness. The experiment fully confirmed the anticipation of Professor Lister, that the air which passed through the lungs would no longer contain the germs of living things, or any other suspended foreign matter. But what an idea does this give us of our liability, through our lungs, to absorb into our systems anything noxious - which the air may contain, no matter how minute in quantity, or how finely divided? If the quantity in given volume is minute, it is to be remembered that the volume we inhale in a limited time is enormous, amounting to two or three thousand cubic feet a day; and the accumulation which must result, from even the partial exhaustion of this great mass of its impurities, must become very considerable.

Having spoken now of the cases in which disease, local or general, in animals, is manifestly occasioned by the presence of parasitic vegetation, it is proper to mention, briefly, similar examples in plants. The smut in wheat, the rust in cotton, the *Oidium* in grapes, and the *Botrytis* potatoes, are examples of fungi, constantly concomitant with disease, and presumably, almost certainly, in the last two instances, its cause. Neither in plants nor animals, however, is it to be supposed that the noxious effects observed are occasioned merely by the presence of these parasites mechanically interfering with and obstructing the vital functions, or by acting directly as poisons in the ordinary sense: but rather by their own vital activity decomposing the substance of the organisms they infest, and making them their food. The consequences of their extensive prevalence to the material interests of communities and peoples, and to their means of subsistence, have been occasionally of the gravest character. The *Oidium* may be said to have exterminated the vine from the Island of Madeira; the *Panhistophyton* cut down the product of silk in France from 130,000,000 of francs per annum, to 30,000,000; and the *Botrytis* threatened to depopulate Ireland, by destroying the vegetable which constituted, for the common people, the staple article of their food.

The germ theory at least partially true

Putting together these, the known facts regarding this subject, before proceeding to more doubtful cases, we may say that the germ theory has an amount of *primâ facie* evidence in its favor which entitles it to careful consideration. In certain instances, and in a certain sense, the evidence is complete that the germ theory is true. But when we come to apply it to infectious diseases in general, we find the analogies which they present with the limited class of examples above enumerated, to be unexpectedly feeble, while the points of dissimilarity are numerous and marked. It is not even enough to discover that in such diseases there are actually present in the blood, or in the tissues, or in the secretions, or in the dejections, of the suffering individuals, living forms of, microscopic cryptogams, since the evidence is rarely conclusive either that these minute bodies are injurious to the patient, or that they were present antecedently to the attack. And if, as to the first of these points, the evidence in some cases is satisfactory, as to the second it can hardly be pronounced to be so in any.

As to the frequent presence of vegetable organisms in the blood of men or animals suffering under infectious diseases, it is impossible to entertain a doubt. The testimony of all the observers who have occupied themselves with this subject is concurrent to this effect. Coze and Feltz, Klebs, Burdon-Sanderson, Klein, and many others, have found bacteria invariably in the blood of patients suffering under typhoid fever, small-pox, scarlet fever, puerperal fever, *pyaemia*, and *septicaemia*. Dr. J. H. Salisbury, of Cleveland, Ohio, affirms, as the result of his own observations, that in healthy as well as in diseased blood there are always present two species of cryptogams, the one algoid and the other fungoid. In the pustules of small-pox Dr. Salisbury has observed a cryptogam described by him as having, both a fungoid and an algoid development, and the spores of this he has also found in the blood.

In cow-pox, or in the disease produced in the cow by inoculation from a small-pox subject, only the algoid form appears. This the discoverer has named *los vacciola*, while the entire plant in its double form he calls *los variolosa vacciola*. In typhoid fever the same writer has detected peculiar algoid vegetation developing itself upon the external surface of the entire body, and upon the mucous membrane of the interior cavities. This he regards as the efficient cause of the disease, and the

means by which it is propagated. Dr. Ernst Hallier, of Jena, who has published largely on this subject, and has made himself prominent as an advocate of the germ theory, has described a large variety of vegetable forms found by him in diseased men and animals, many of which he has subjected to systematic cultivation, in order to study their modes of development.

A new and peculiar fungus, found in the rice-water discharges of cholera patients, and within the intestinal canal of such persons, has been cultivated by him with special attention. This plant is described as being as marvelous for the rapidity of its development as for its strange forms of growth, and its terribly fatal destruction of the epithelial tissue of the intestine. It is called by Professors Thomé and Klobe the *cylindrotaenium*, but is regarded by Dr. Simon and Dr. Harris as being an exotic member of the family to which belong the *urocystic* and *oidium* blights of cereals and fruits.

Among the interesting facts observed in the cultivation, it may be mentioned that the presence of an abundance of nitrogenous matter, and the absence of acids in the fluid or substance employed, were proved to be essential conditions of the propagation and growth. Also, that wlhen the fungus cells, in the course of their development upon a piece of intestinal membrane, reached a certain stage, they rapidly increased, and the epithelium as rapidly wasted away. After reading this, it is rather disappointing to find in the last and recently published edition of Dr. Parkes' Manual of Practical Hygiene," the following succinct statement: "As regards cholera, the careful observations of Drs. Lewis and Cunningham, in Calcutta, seem to have disproved the possibility of either fungi or bacteria being the cause of cholera".

The disease which appeared in 1868 among the beef cattle brought to this city from the West, and which is known as the Texas cattle disease, was investigated at the time by Drs. Harris and Stiles, of the New York Health Department, who found the spores of a peculiar species of fungus both in the blood and in the bile of the diseased animals. Specimens of these cryptogams were sent by these gentlemen to Professor Hallier, by whom they were successfully cultivated, and who succeeded in deriving from them three distinct forms of the fungus. The epizootic, which attacked all the horses of the country twelve months ago, was also marked by the presence of fungi in the blood and the urine of the animals affected, which were described by Dr. Endemann, and by Dr. Charles Amende, of Hoboken.

These examples will probably be thought sufficiently numerous to justify the generalization that in infectious diseases the presence of microscopic algoid or fungoid cryptogams is a fact of invariable occurrence. What is the significance of this fact? In all these cases, we find that the fluid in which the cryptogams occur is itself diseased. Is not the disease of the blood the very condition that is necessary to the development of the plant? When mould makes its appearance on the surface of paste, is it the presence of the mould which causes the paste to putrefy, or is it the putrefaction of the paste which provides a congenial nidus for the mould?

About forty years ago, the yeast plant was discovered by Cagniard de la Tour, and almost simultaneously by Schwann. Till that discovery, the chemical theory of disease had a strong support in the imagined analogy of fermentation. To the suggestion, after the discovery, that fermentation is probably a consequence of the rapid growth of the plant, there was at first a very general and natural dissent; but when, in I843, Helmholtz made a direct experimental test of the question, by placing a fermenting liquid side by side with one of the same kind not fermenting, both being contained in the same vessel but separated by a membrane which permitted the mingling of the liquids, but prevented the passage of the plant, that analogy lost its force, for the fermenting liquid continued to ferment, while the quiescent liquid remained quiescent.

The case of fermentation assumed now significance quite the contrary of that which it had before seemed to possess, and it began to be claimed to be quite as conclusive in favor of the germ theory as it had been before in favor of the chemical. This theory, however, though among its advocates have been, and continue to be, counted many of the most distinguished physicians and physiologists of the past and the present generation, has never met with universal acceptance. Serious difficulties present themselves which it fails to explain, among which are the objections strongly put by Dr. Bastian, that the theory demands a belief in the existence of about twenty different kinds of organisms never known in their mature state, and whose existence is not demonstrated, but simply postulated; and that these germs, if they exist, are not the germs of any known organisms, because such germs have been experimentally shown to be incapable of producing the particular diseases these are assumed to cause. Moreover, feeding on putrid flesh, as is habitual among the Kalmucks, is followed by no

injurious consequences, though such flesh swarms with bacteria; and as the author just referred to affirms, the organisms of ordinary putrefactions may be introduced even into the blood of men and animals without producing any of these specific diseases. The same writer asserts that in sheep-pox the blood and the secretions are not infective, though this disease is allied to, and even more virulently contagious, than human small-pox.

Diseased conditions the pabulum for fungi

What accounts shall we give, therefore, of the multiplication of fungi and alge in diseased blood, if these organisms are not the cause of the disease? Simply, that the diseased condition furnishes to the organisms the pabulum, which is not present in the healthy state. For the cause of the disease we must, on this supposition, look elsewhere, and we shall be compelled, perhaps, to fall back upon the chemical doctrine of sympathetic decomposition. Many causes, in fact, produce profound changes in the blood with which parasites have nothing to do. This is true of the venom of serpents, and of prussic acid, both of which produce fatal effects with singular rapidity. Of " the black death," which raged in the fifteenth century, Bastian quotes Hecker as saying that "many were struck as if by lightning, and died on the spot," and he cites the testimony of Dr. Aitken to the fact that, when the cholera reached Muscat, instances occurred in which only ten minutes elapsed from the first apparent seizure till life was extinct. These are cases for which the germ theory affords no solution.

On the other hand, we have the numerous observations and experiments of Coze and Feltz, of Burdon-Sanderson and Klein, of Klebs, of Davaine, of Zahn and Tiegel, and others, in which rabbits and guinea-pigs were inoculated with bacterious blood drawn from persons laboring under a great variety of infectious diseases, including *pyaemia*, *septicaemia*, small-pox, measles, scarlet fever, typhoid fever, etc., observations and experiments which seem to leave little room for doubt that these organisms are, in fact, in these cases, the vehicles of the infection, and the causes of these several diseases.

It was observed, for instance, that successive inoculations increase the intensity of the virus, and that along with the increase of toxic power, the number of the organisms in the fluids manifesting it was correspondingly increased. It is true that the diseased fluid is itself necessarily introduced into the animal inoculated, along with the contained bacteria, so as to leave the question still somewhat in doubt to which to ascribe the induced disease. Some light is thrown upon this question by certain experiments of Drs. Zahn and Tiegel, who in cases of *septicaemia*, filtered the parasites from the liquid; and having done this, found that the clear liquid caused heavy but transient fever without suppuration, while the same fluid with the parasites produced suppuration extraordinarily wide-spread.

In view of the conflicting character of the evidence surrounding the vexed problem under consideration, the conclusion to which the present speaker has been led, if it may be permitted to one so moderately versed in physiological science to have a conclusion at all, is that neither the germ theory of contagious disease, nor the chemical theory, is exclusively true; but that each of these morbific influences has a range of action of its own, and that in some cases it is eminently probable that the disease in its inception is attributable to one of these causes, and that is the chemical; but owes its subsequent virulence mainly to the other, that is, to the presence of rapidly multiplying vegetable organisms. It appears to me that by the proper application of this key we shall be able to solve most of the perplexing anomalies which particular examples have seemed to present, and shall afford a common ground on which the champions of opposing views may meet and harmonize their differences. I make the suggestion with much diffidence, conscious how far I am stepping beyond my own proper province in doing so; but also on that very account to a certain extent reassured by the consideration that, whatever acceptance it may meet with in this learned body, I have no professional reputation to be prejudiced or advanced in making it.

Bearing of the question upon public hygiene

As to the bearing of this question upon public hygiene, and the principles which should govern sanitary legislation, it is to be observed that, if we accept the chemical theory of contagion as exclusively the true one, we can hardly avoid admitting the possibility that contagious disease may originate in a healthy individual without communication with a person already diseased. The causes, whatever they may be, will be found in surrounding conditions. If I have understood what has been said during the present session of this association, the cholera in the West

during the season that is past did not originate from without. Somewhere conditions must have existed which favored its origination de novo in our own country. In this view of the subject, the business of sanitary science is to discover the nature of the deleterious conditions tending to induce disease, and to prevent their occurrence.

If, on the other hand, infectious disease is propagated by living germs alone, what we have to aim at is to devise measures for promptly extirpating those germs the moment the disease appears. But as the necessary measures of precaution or of extirpation will be substantially the same, whatever may be the theoretic views entertained as to the nature and the origin of the evil to be met, our legislation in any case is likely to be practically the same, however in its motive it maybe logically different.

Pure air, pure water, wholesome food, thorough drainage, rigidly enforced cleanliness, the severe exclusion from towns and cities of industries which contaminate the air with noxious gases or offensive effluvia, especially such as arise from decaying organic matter, the prevention of overcrowding in dwellings, the prompt and complete disinfection of every spot where pestilence may lift its head, and of every article and substance, including the dejecta of the sick, which may serve as a vehicle of disease, and finally, a well-organized sanitary police, and untiring vigilance on the part of its members - these are the objects which the guardians of the public health must labor to secure, to whatever school of ethology they may happen to belong. It is, indeed, a fortunate circumstance, a fact observable in no other department of practical human effort that I happen to remember, that here the champions of conflicting theories, however freely they may splinter lances in the arena of controversy, are always found, in the field of actual warfare and in the face of the common enemy, marching harmoniously side by side.

The study of the laws of hygiene is assuming in our time, in the estimation of the public and of the profession themselves, an importance which places it above even the proper business of the profession, - that of the science of Therapeutics. Drugs, whether remedial or prophylactic, are falling more and more into disrepute; and it is felt that prophylactic action is infinitely better than prophylactic draughts.

Such has been the success of modern measures for closing up all the insidious approaches by which disease has hitherto effected its entrance into the family, the community, or the individual organism, as to encourage a hope, even so seemingly wild and visionary, as that a time is coming in which disease itself shall be utterly extirpated, and men shall begin to live out the days which Heaven intended for them. When that time arrives, if it ever shall, your honorable and learned profession may find, like Othello, its occupation gone; but it will be itself which will have destroyed it, and which will have established, in doing so, a nobler title to the gratitude of mankind than all its untiring labors for the relief of suffering humanity, through centuries of self-sacrificing devotion hitherto, have already won.

[i] The germ theory, as it is here stated, and as it is commonly understood, presumes that the minute organisms which cause disease are parasites. Dr. Lionel S. Beale, of London, has put forth a germ theory materially different from this. Holding first that the life of all organisms resides only in that semifluid matter which occupies the interior of living cells, or is seen without an integument in the white globules of the blood, while the cell-walls and the structures built up of them are "formed matter" without life; and giving the name Bioplast to each minute separate mass of this living matter, he shows by the evidence of the microscope, that the bioplasts of the blood multiply by a kind of gemmation, of which the result is to produce other bioplasts resembling the first. In a morbid condition of the blood, however, the process of gemmation is accelerated, and the resulting bioplasts of each generation are more and more minute in size, their numbers becoming incalculably great. These minute bioplasts escaping from the diseased organism, and becoming invested with a protecting coat of " formed matter," may be wafted to great distances and may preserve their vitality for long periods; so that when, by any chance, they are introduced into the circulation of other organisms, where they find material to be assimilated, they multiply once more in this new habitat with the same abnormal rapidity as before; and thus engender disease similar to that in which they originated. This theory is developed by Dr. Beale with gr-eat ability in his work entitled, Disease Germs, their Aahzizre and Origin, published in IS72. According to this theory, disease germs are not parasitical, but "originate in man's organism, and have descended from the normal bioplasm of his body." The theory avoids many of the difficulties which attend the chemical theory on the one hand, and the theory according to which disease is the effect of a parasitic invasion on the other; but as yet the evidence in its favor cannot be regarded as conclusive.