AN ESSAY ON CONTAGION: ITS NATURE AND MODE OF ACTION.

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[This paper was written in April 1878, as an article for Dr. Quain's forthcoming *Dictionary of Medicine*, and, from the intention with which it was written, has the form and references of a dictionary article. By way of postscript, two notes bearing present date, have been added.—November, 1879, J. S.]

THE word "contagion" is applied in pathology to the property and process by which, in certain sorts of disease, the affected body or part causes a disease like its own to arise in other bodies or other parts; and the Latin word *contagium* (pl. *contagia*) is conveniently used to denote in each such case the specific material, shown or presumed, in which the infective power ultimately resides.

The property of contagiousness belongs to a very large number of the diseases which affect the human body. And in more than this direct way the property is of great interest to mankind. Contagiousness of disease is a fact not only for man, but apparently for all living nature; and the influence of contagion in spreading destructive diseases among domestic animals, and among those parts of the vegetable kingdom which contribute to the nourishment of man, is such as to make it of immense social importance that the laws of contagion should be well studied and understood. Further, just as contagion in the case of living bodies and their parts spreads disease from one to another, so, to an immense extent, in the case of certain matters which, though of organic origin, are not living, it spreads various processes of decay. The so-called fermentations which yield alcohol and vinegar, as well as that in which putrefaction consists, are contagious affections of the respective matters in which they occur: every cheesemonger knows that moulds of different kinds spread by inoculation, each in its own kind, from cheese to cheese; and if the Greek proverb "grape mellow to grape" be true of the living fruit, the apple-loft gives analogous experiences of contagion among the fruit which is garnered.

The rationale of the word "contagion", as now used, is that the property is understood to attach itself essentially to a material contact; not necessarily that, when infection is spread from individual to individual, the contact of the individuals must have been immediate; but that in all cases there must have been such passage of material from the one to the other as was in itself at least a mediate contact between them. And similarly, in those very instructive illustrations of the process of contagion which are furnished within the limits of a single diseased body by the propagations of disease from part to part of it, we can in general easily see that infection advances from part to part, either in proportion as part touches part, or in proportion as the one receives from the other the outflow of lymph or blood or secretion.

The various specific matters which effect contagion in the living body, the respective "contagia" of the given diseases, seem all to have in common this one characteristic: that in appropriate media (among which must evidently be counted any living bodily texture or fluid which they can infect) they show themselves capable of self-multiplication; and it is in virtue of this property that, although at the moment of their entering the body they in general do not attract notice, either as objects of sense or as causes of bodily change, they gradually get to be recognisable in both of these respects. Now, the faculty of self-multiplication is eminently one of the characters which we call vital; and when it is said that all contagia are self-multiplying things, this is at least very strongly to suggest that perhaps all contagia are things endowed with life.

In order to any general consideration of the question thus suggested, contagia may conveniently (even if but provisionally) be distinguished as of two main classes, differing, or at present seeming to differ, from each other in their mode of action on the organisms which they infect: one class, namely, that of Parasites; and the other class, that of the true or Metabolic Contagia. Of this separation, so far as present knowledge seems to justify it, the assumed grounds are: that each true contagium, in proportion as it multiplies in the body, transforms, in a way which is specific to itself and is different from the ways of other contagia, the bodily material with which it has contact; while, on the contrary, the parasite, however much it may grow or multiply in the body, produces no qualitative effects specific to itself, but only such effects as are of common kind to it and all other parasites—indications, namely, of its mechanical intrusiveness in the parts which it occupies,

and sometimes of the drain which it makes on its host's general nutritive resources.

A.—Of Parasites, in relation to processes of contagion, little needs be said in the present article. When an organism or part of it is, in greater or less amount, inhabited by other organisms, animal or vegetable, which subsist on it, or its food or refuse, it of course may be a centre of infection to other (if susceptible) bodies or parts, to which it can transmit live parasites or their germs or seeds; for, when this transmission takes place, growth and self-multiplication, as in a colony, are the natural results which have to be expected; and in proportion as these occur, the newly-infected body or part gradually gets to suffer, like the old, from these particular derangements which make the type of parasitic disease. Some parasitic diseases, especially some of those of the skin, spread actively by direct contagion in ordinary intercourse; as, for instance, scabies by the migration of its acari, and porrigo (among children) by the spores of its microphyte; and the spreading of such diseases where they exist may, of course, be to any extent facilitated by aggregation of persons and uncleanness of personal habits. There are cases in which parasitic disease spreads from animal to animal only in proportion as the one feeds on the other, and eats it with parasites still living in it; or in proportion as live parasite eggs or larvæ, discharged from the body of one animal, get conveyed with food (especially on raw herbage and in water) into the bowels of another. Considerable epidemics of trichinosis in the human subject have been traced, chiefly in Germany, to infection from the pig, in cases where pork, abounding with trichinæ, has been eaten, as sausage-meat or otherwise, in a raw or imperfectly cooked state; and in Iceland the very great sufferings of the human subject and the cattle from echinococcus have been traced to the influence of the dogs in spreading contagion from the slaughter-house, where they eat hydatidised offal, to the kitchen-gardens and water-sources and pastures, where they discharge tapeworm eggs from their bowels. (See articles on Porrigo, Scabies, Trichina, Hydatid, etc.)

The diseased states which consist in being colonised by parasites are diseases of indefinite duration, tending in some cases to indefinite increase. In cases where the disease consists in the presence of swarms of blood-sucking or otherwise exhausting animal parasites, symptoms of the blood-drain will of course gradually arise; but otherwise the parasite, whether animal or vegetable, operates only as a mechanical presence. Skin and mucous membrane will be irritated in their superficial layers, and in some cases more deeply, by the animal or vegetable parasites which breed on or in them; just as they might be by dead mechanical irritants: solid organs having cystic entozoa in them will in like manner show evidence of irritation by encapsulating the colonists; and the surrounding tissue will of course suffer compression and displacement in proportion as the colonisation (e.g., in case of echinococcus) is compact and massive. In the case of trichinosis—but, in our ordinary experience, in no other—the multiplication of the parasites, the burrowing of their young, and the general diffusion of these in the body, are processes of such extreme activity that, if the quantity of contagium taken into the stomach have been large, the innumerable local irritations suffice to make a very acute fever; but, even in this extreme case, the merely irritative type, though exaggerated, is essentially preserved.

As different sorts of animals are notoriously liable to different sorts of parasites, so, even among animals of one sort, as, for instance, in the human kind, the liability of different bodies to receive particular parasite-infections does not seem to be quite equal for all. Especially, the vegetable parasites seem to have their affinities determined or modified by the general state of health of the recipient; and there are cases in which it looks as if there ran in particular family-lines (perhaps with some slight chemical idiosyncrasy) a special liability to particular intestinal worms. There, however, is no reason to believe that in regard of the more important animal parasites, as particularly of trichina and the teniæ, the susceptibility of individuals to attacks is other than universal and practically equal.

B.—The true or Metabolic Contagia (to which the rest of the present article will exclusively refer)—the contagia which, in their respective and specific ways, operate transformingly on the live bodily material which they affect, are, perhaps, the most important of all the incidental physical influences which concern mankind. Whether they may all, at some time hereafter, admit of being named, like the parasitic contagia, in terms of biological classification, is a question which needs not in the first instance be raised; for meanwhile the identity of each separate true contagium is settled in experimental and clinical observation by the uniformity of the operation of each on any given animal body which it affects. Each of the diseases propagates itself in its own form in as exact identity as if it were a species in zoology or botany; and in each such repetition of the disease there is a multiplication—always a large, and sometimes an inconceivably immense multiplication—of material which has the same infective property. Evidences innumerable to that

effect are under daily clinical observation in this climate in instances of small-pox, measles, scarlatina, whooping-cough, enteric fever, mumps, typhus, syphilis, cow-pox, diphtheria, erysipelas, hospital gangrene, purulent ophthalmia and gonorrhœa, venereal soft chancre and phagedæna, etc.: for, barring fallacies, no man ever sees any one of those diseases produced by the contagium of any other of them; and any man who has before him a case of any of them can see that, however minute may have been the quantity of contagium by which the disease was started, the patient's diseased body (part or whole) yields for the time an indefinitely large supply of the specific agent. It is more or less habitual to some of the diseases that the infectedness of the patient is first made known to the observer by such general pyrexia as tells of change already far advanced in the circulating mass of blood; and it is only after this has shown itself that other symptoms, adding themselves to the fever, complete the more or less complex type which establishes the identity of the disease. But in many of the diseases it may be the case (either naturally or as result of experimental infection) that the first, and in some diseases the main or even the only, effects of the contagion are local changes, passing where we can from the first observe them; and the broad facts of metabolic infection, as regards waste of bodily material with concurrent increase of contagium, are, in many such cases, among our most familiar experiences. Most instructive, too, are the facts of contagion which are to be learnt in the study of tubercle: the contagium, introducible either by tubercular and certain septic inoculations through the skin, or internally by the infective action of the milk or diseased organs of tubercular animals if taken as food; and the contagium, when introduced, gradually spreading as it multiplies, and as lymph and blood carry it from the first infection-spot to other organs which now will repeat the process. And similarly in cancer (though the primary disease is at present of unknown origin and cannot be created by experiment) the repetition of the primary disease in secondary and tertiary propagations in the body of the sufferer is one of the most striking of all evidences of contagion; because of the great number of structural types which pass under the name of cancer, and the fidelity with which each of them is reproduced in the organ to which the contagion extends. A further fact of contagion, deserving notice in the present context, is the local spread of certain of these processes by continuity of tissue; as, for instance, in the continuous extension of phagedæna or hospital-gangrene from any centre of first inoculation, or of tubercular softening or cancer at the place where it begins: a mode of extension which indicates successive infective actions of matter on matter in spheres of ever-widening circumference;* and the like of which, but in rudimentary degree, may be traced in the areola of any acute inflammation.

In the physiology of the metabolic contagia, no facts are more characteristic or more important than those which show the relativeness of particular contagia to particular receptivities of body. First, and in intimate connection, as would seem, with a chemical electiveness of action which will presently be imputed to contagia, there is the preference which some particular contagia (however introduced into the system) show for particular organs of the body; so that, by the exercise of this preference, there is given to each of the diseases its own set of clinical and anatomical characters. Compare, as instances in this point of view, the respective local affinities of small-pox, enteric fever, mumps, syphilis, hydrophobia, etc.—Secondly, it may be noted that, in regard to some of the contagia, different persons, and particularly persons of different family-stocks, show original differences of susceptibility; original, namely, as distinguished from others, hereafter to be mentioned, which are acquired; so that, for instance, the severity with which scarlatina or diphtheria will strike in particular families contrasts with a comparative mildness of the same disease in other families or perhaps even with cases of apparently complete personal immunity under exposure to the particular danger: and recent researches have seemed to suggest as possible that, in the very wide differences of degree with which tubercular disease prevails in different families, an essential condition may be, that the families have widely different degrees of original predisposition towards some of the septic contagia.—Thirdly, there is the extremely suggestive fact with regard to many of our best-known febrilising contagia, that they run a course of definite duration, and that in this course, provided the patient do not die, all present, perhaps all future, susceptibility to the particular contagium is utterly exhausted from the patient; so that reintroduction of the same contagium will no more renew that patient's disease than yeast will excite a new alcoholic fermentation in any previously well-fermented bread or wine. The inference from this fact seems unavoidable, that each such contagium operates with a chemical distinctiveness of elective affinity on some

special ingredient or ingredients of the body; and that exhausting this particular material in febrile process, which necessarily ends when the exhaustion is complete, is the bodily change which the contagium "specifically" performs.—Of not all metabolic contagia, however, can it be said that their operation runs so definite and self-completing a course. For, first, there are particular acute infections which, as a rule, kill; either (as appears to be the case in splenic fever when affecting man) because of the extreme magnitude of the transforming process which the contagium sets up, or else (as appears to be the case in hydrophobia) because the elective incidence of the contagium is on an organ indispensable to life; so that in such cases there is in fact hardly such an event as passing alive through the whole process of the disease.* And, secondly, there are the contagious dyscrasias, which are clearly characterised by their tendency to indefinite duration: syphilis, which oftener than not relapses in successive outbreaks, and often as years pass invades the body more and more deeply, and may after all never during life be ended; and tubercle and cancer, which, with almost invariable persistence, will in general steadily advance month by month to infect more and more of the body till the process eventuates in death.

The transmission of various contagious diseases in communities is of course greatly influenced, both in detail and in aggregate, by such differences of individual receptivity as were mentioned in the last section. Notably, as regards communities through which particular acute infections have had full run, fresh sparks of the contagium may find little or no fuel on which to act; and much new diffusion of the disease may not again be possible, till immigration, or births, or lapse of time operating in other ways, shall have reconstituted a susceptible population. And, given the susceptible population, circumstances of time and place are infinitely various (especially as regards quantity and quickness of personal or quasi-personal intercourse) in determining how far this population shall have particular contagia thrown in its way.

Also there are conditions, not primarily of a personal kind, which operate on a very large scale in determining the spread of some of the metabolic infections: giving to them respectively at certain times, in ways not hitherto understood, a special increment of spreading power, and in some instances also special malignity: and thus enabling them respectively from time to time to come into comparative prominence in national life, and perhaps at once or successively in many different countries, in the form of so-called Epidemics. Thus, it is matter of familiar knowledge that the fevers which are most habitual to this country, scarlatina, measles, small-pox, enteric fever, are of nothing like uniform prevalence,—that scarlatina, for instance, will be three times as fatal in one year as in another, and that small-pox is liable to even greater exacerbations: and it is known that temporary differences of this kind are not exclusively local,—that, for instance (to quote a late official report) "the epidemic of small-pox which began in England towards the close of 1870, and terminated in the second quarter of 1873, was part of a general epidemic outbreak of that disease, of world-wide diffusion, marked wherever it occurred by an intensity and malignity unequalled by any previous epidemic of the disease within living memory". The wider the survey which we take of epidemiology, the more certain it becomes to us that, outside the conditions which are independently personal or local, there are cosmical conditions which have to be considered. Doubtless, there are great epidemiological facts—such, for instance, as the first spreading of small-pox to America, or in our own times the increasing frequency of Asiatic cholera in Europe, which may be ascribed to novel conditions of international intercourse: but there are others, equally great, to which apparently no such explanation can be applied. For what reason it is that cholera every few years has its definite fit of extension in India,—or why diphtheria, which scarcely had a place in history till it overran Europe in the sixteenth century, and which since then had been rarely spoken of, began again some twenty-odd years ago to be comparatively important in England,—or why the plague of the Levant has for the last two centuries been so unfamiliar to us,—or why the yellow fever of the Mississippi has in particular years raged furiously in parts of Europe,—or why our black-death of the fourteenth century, though apparently still surviving in India, has never but that once been in Europe,—or whether has gone our sweating-sickness of three centuries ago—whence have come the modern epidemics of cerebro-spinal meningitis:—these, and many like questions, which cannot at present be answered, seem to be evidence enough that, in the making of epidemics, contagion and personal susceptibility may be factors in a partly conditional sense. Influences which are called "atmospheric"—the various direct and indirect influences which attach to the normal succession and occasional abnor-

* Compare Tennyson's

"Little pitted speck in garnered fruit,
Which, rotting inward, slowly moulders all."

* Since the above was written there has been published by Dr. Ad. Offenberg of Wickrath in Rhenish Prussia, an apparently not incredible case of recovery under use of curare. See his pamphlet, *Geheilte Hundswuth beim Menschen*, Bonn, 1879.—November, 1879.—J. S.

mality of seasons, in respect of the insolation of our planet, and of the temperature and humidity of air and earth, are in general far too vaguely regarded as elements of interest in the present question, but are possible factors which no epidemiologist should omit from scientific consideration. For any definite knowledge which exists on the relation of particular conditions of season to the prevalence of particular epidemics, the reader is referred to the article "Epidemics", and to articles on the respective diseases.

In the passage of the metabolic contagia from person to person, various agencies may be instrumental,—bedding or clothing or towels which have been used by the sick, dirty hands, dirty instruments or other utensils, the washerwoman's basket, foul water-supply, stinking house-drains, contaminated milk or other food, the common atmosphere, etc.; but differences of that sort are only differences as to the means by which such communication is established with a diseased body as brings its products into relation with healthy persons; and the disengagement of infectious products from the bodies of the sick is pathologically the one influential fact. As regards the products which ought to be deemed infectious, the specially-diseased surfaces and organs of the patient, and the discharges and exhalations which they respectively yield, must always be regarded with chief suspicion; but suspicion, however much it may insist on them, must never disregard other sources of danger. Of some of the metabolic contagia we practically know, and of many of the others we may by analogy feel sure, that, when a given body is possessed by one of them, no product of that body can be warranted as safe not to convey the infection. Presumption against every part and product of the diseased body is by everyone readily admitted where there are vehement general symptoms of disease; but it is important to know that not only in such febrile states, but even in states of chronic dyscrasy, and even at times when the dyscrasy may be giving no outward sign, the infected body may be variously infective. Thus, in regard to constitutional syphilis, it is certain that the mere utero-catarrhal discharge of the syphilitic woman, or the sperm of the syphilitic man, or the vaccine lymph of the syphilitic infant, may possibly contain the syphilitic contagium in full vigour, even at moments when the patient, who thus shows himself infective, has not on his own person any outward activity of syphilis. Similarly, in regard to tubercular disease, experiment has proved beyond question that the milk of animals suffering from tubercle will, if taken as food by other animals, infect them through the intestinal mucous membrane; and there are independent reasons for believing that the tubercular contagium (like the syphilitic) will at times during the dyscrasy be contained in the seminal fluid, and that men, tubercular perhaps only in some degree which is not immediately important to themselves, may by that secretion convey fatal infection to women with whom they have conjugal relations.* Regarding many of the metabolic contagia, conclusive evidence exists that, when they are in operation in pregnant women, the foetus will in general be infected by them; and this though the diseases (*e.g.*, small-pox, cholera, syphilis) be of the most different pathological types; but, with regard to pregnant animals affected with splenic fever, it is noticeable that Brauell, in his extensive researches, found the blood of the foetus not to be infective.

In general, each contagium has its own favourite way or ways of entering the body; and these preferences are not only of speculative interest, as attaching to varieties of nature and natural habits among the contagia, but are of obvious practical importance as measures of the widely different degrees in which the different contagia are qualified to spread in communities. Thus, inoculation at broken surfaces of skin or mucous membrane has long been known as the ordinary mode by which the infections of syphilis, hydrophobia, splenic fever, cow-pox, and farcy or glanders, get admission to the body; and our best knowledge of some other infectious diseases (notably of tubercle) has been derived from inoculations intentionally made with their contagia for purposes of study. While probably all infections which tend to be of general action on the body can be brought into action in that way, and while some infections are not known to pass by any other mode of transmission, there are many infections which spread freely from subject to subject by atmospheric and dietetic communication; and the meaning of these preferences is hitherto not fully known. It seems that some contagia are so acted upon by air and water that they seldom or never reach the body in an effective state by those common means of communication,—some hardly, if at all, by water, and some not by air except with very close intercourse; and further, that, of contagia which reach the body in an effective state, some require, while others do not require, that an abnormal breach of surface shall give them special opportunity for taking hold. In some of the cases where a disease can be propagated in both ways—*i.e.*, certainly in small-pox, and apparently

also in bovine pleuropneumonia, the artificially inoculated disease tends to be much milder than the disease otherwise contracted; but pathologically it is difficult to conceive any essential difference between those different modes of contagion. It may be presumed that, in the modes which are not by true inoculation, acts which are comparable to inoculation take place on internal surfaces; that, for instance, when particles of scarlatina-contagium are caught in the tonsils, and inhaled into the bronchi, and swallowed into the stomach, they begin by penetrating the texture of the mucous membrane, and by thus effecting as real an inoculation, with regard to the blood, as that which art or accident provides in other cases through the punctured skin. That previous abnormal breach of surface by artificial puncture or otherwise is not necessary to allow the infection of mucous surfaces is illustrated in ophthalmia and gonorrhoea; where apparently no other condition has to be fulfilled than that a particle of the blennorrhagic contagium shall be deposited on the natural surface of the mucous membrane. It deserves notice that, while a considerable number of the worst diseases of the domestic animals admit of being communicated to man by artificial inoculation, atmospheric communication seems to be very inapt, if not absolutely unable, to infect man with any one of them; and in this connection it may be of interest to remember that syphilis, one of the most familiar of human infections, but hitherto not traced to any brute ancestry, differs from our other current infections in requiring inoculation to transmit it.

When any metabolic contagium enters the animal body, it requires an interval of time, and in most cases a considerable interval, before its morbid effects can become manifest even to skilled observation. The period of latency or so-called incubation varies greatly in different cases. In hydrophobia, it is very rarely less than of one month, is certainly often of several months, and is said to be sometimes of years. In syphilis, the inoculated spot remains generally for at least a fortnight, and may remain even as much as five weeks, without any ostensible change; and the roseola of the general infection will not be seen till some weeks later, when generally at least three months will have elapsed since the first inoculation. In the acute eruptive fevers, when their contagium is transmitted by air, the first changes which ensue on infection are not external, and we cannot be sure what early internal changes may take place; but in small-pox, the fever (which is the first overt sign) does not attract notice till about the twelfth day after infection, nor the eruption till two days later; and in measles the incubation time, though perhaps less uniform, seems to be little (if any) shorter than that of small-pox. The septic contagia and the contagium of splenic fever seem to be of particularly quick operation; but even the most virulent septic contagium, when without admixtures which tend to complicate its action, will not begin sensibly to derange the infected animal till at least several hours after it has been inoculated. As regards the contagia last referred to, it is conceivable that the self-multiplication of the contagium in the form in which it proves fatal to life is a process which goes on continuously and uniformly from the moment of inoculation to the moment of death, and that the moment when signs of general derangement become manifest is the moment when this uniformly advancing process has accumulated in the system a certain quantity of result; but it does not seem easy to apply this explanation to the diseases of long incubatory period; and we can hardly conjecture what may be the latent processes—for instance, of small-pox, during the first ten or more days after contagium has been received.

[To be continued.]

POPULATION STATISTICS IN RUSSIA.—The official Board of Statistics at St. Petersburg has published some population figures, from which it appears that, in European Russia, there are annually born 1,619,108 males and 1,544,297 females, or an average total of 3,163,405 children of both sexes. On the other hand, the average annual deaths are 1,214,467 males and 1,167,929 females, or a total of 2,382,396 persons of both sexes. The population, therefore, shows an average increase of 781,000 a year—a percentage which, supposing the inhabitants always to multiply at the same rate, would double the population in fifty-eight years; whereas in Sweden, according to a similar method of calculation, this result would only be attained in sixty-two years; in Germany in sixty-eight; in Belgium in seventy-nine; in Austria in ninety-five; in Switzerland in ninety-nine; and in France in one hundred and sixty-five years. The high percentage of mortality in Russia is chiefly caused by the numerous deaths among children, more than the fourth part of whom perish before they are a year old; whereas in Prussia, of 1,000 infants only 165, and in England 140, die before that age. Measles, scarlatina, and diphtheria (says the *Novoye Vremya*) are making great ravages among the juvenile population of the capital; and, in certain districts of the Empire, the danger is so great that several colleges and infant schools have been closed.

* See Dr. Weber, in *Clinical Society's Transactions*, 1874.