

# JOHN CRAWFORD AND HIS CONTRIBUTION TO THE DOCTRINE OF CONTAGIUM VIVUM<sup>1</sup>

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## JOHN CRAWFORD, 1746-1813

The last rearguard action directed against the powerful onslaught of the "new" anticontagionism that swept the United States at the beginning of the "wonderful century" was fought alone, by the subject of this essay. Relegated to the historic dust bin, smothered by the pontifical edicts of Rush and Webster, eclipsed by the spectacular accomplishments of the European sires of microbiology 70 years later, we now remove from the umbra of obscurity an American, dead these last 150 years. We do this not to magnify his achievements, nor to favorably distort his scientific position, but rather to sound the opening chords of the American recitative, too infrequently heard and too often dismissed. A more auspicious occasion could not be imagined than this first symposium on the history of microbiology sponsored by the American Society for Microbiology.

John Crawford, the second son of a Presbyterian clergyman, was born in the north of Ireland on 3 May 1746. Several events of his busy life are noted here, but more detailed accounts may be found in biographical sketches by Schultz (14), Cordell (3), and Wilson (17, 18).

Crawford was sent to Trinity College, Dublin, at age 17, and it was there that his medical studies began. Between 1772 and 1774 Crawford obtained valuable experience as ship's surgeon on the *Marquis of Rockingham*, which sailed to Bombay and Bengal in service of the East India Company. In 1779 he was appointed surgeon to the naval hospital on the island of Barbados. Ill-

ness forced his retirement to England in 1782, and, although he returned to the West Indies after recovering, he accepted a position as Surgeon-Major in the Dutch Colony of Demerara when offered to him in 1790.

In 1794 Crawford's health again failed, and he returned to England and thence to Holland and the University of Leyden. He received his M.D. degree from this institution, one of the leading medical centers of its time, in the same year. It may be noted, *en passant*, that Crawford's medical degree from St. Andrew's is dated 1791. Crawford detailed the problems of colonists (including himself) in adjusting to their new environmental conditions in an essay entitled, "A Letter Addressed to Lieutenant-General Mathew on the Means of Preventing, the Method of Treating, and the Origin of Diseases Most Prevalent and which Prove Most Destructive to the Natives of Cold Climates Visiting or Residing in Warm Countries" (unpublished manuscript in the library of the Medical and Chirurgical Faculty in Baltimore, Md.).

In 1796 Crawford emigrated to Baltimore, Md., a decision encouraged by his brother-in-law, John O'Donnell, a prosperous merchant of the city. In that year Baltimore had an estimated population of 20,000, of whom 27 were physicians. Crawford immediately plunged into the public affairs of Baltimore as well as into the attendant medical scene. He began a continuing correspondence with Benjamin Rush (8) of Philadelphia in 1797, and in 1800 John Ring (13) of London sent him samples of smallpox vaccine. Crawford and Benjamin Waterhouse of Cambridge, Mass., were therefore the first to employ this material in the United States. Crawford apparently was not successful in using this vaccine, and in any case there is no evidence that he preceded Waterhouse in

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FIG. 1. *John Crawford, 1746-1813. An original engraving commissioned as a memorial by the Cassia Lodge of the Masonic Order.*

this experiment. In the same year, Crawford seconded the Maryland Society for Promoting Useful Knowledge, and subsequently he was elected Grand Master of the Masonic Order of Maryland. A man of apparently inexhaustible

energy, he aided in the establishment of such Institutions as the Maryland Penitentiary, the Bible Society of Baltimore, the Baltimore Library, and the Baltimore General Dispensary, and, in addition, he was Chairman of the Medical

Faculty of Baltimore, Vice-President of the Medical Society of Baltimore, and consulting physician to the Board of Health and the City Hospital.

In 1804 Crawford began editing a small weekly magazine entitled *The Companion and Weekly Miscellany*, using the romantic pseudonym, "Edward Easy, Esq." In the latter part of 1806, his daughter, Eliza, assumed the editorship (thereby becoming the second woman editor in the United States) under the improbable name of Beatrice Ironside. The title of the magazine was changed to *The Observer and Repertory of Original and Selected Essays in Verse and Prose on Topics of Polite Literature*, but generally it was referred to as *The Observer*. This literary adventure, with Crawford as a constant contributor, concluded on 26 December 1807.

Crawford was lecturer in natural history at the College of Medicine of Maryland (later the University of Maryland) for a brief time in 1812. He died on 9 May 1813 in his 67th year, and was buried in the Presbyterian cemetery at Fayette and Greene Streets in Baltimore. Shortly thereafter, his medical library, which included works of Bonnet, Kircher, Linnaeus, Redi, Plenciz, Swammerdam, and others, and apparently one of the best in the United States at that time, was sold to the University of Maryland for \$500, a sum privately raised by the faculty.

Crawford's contributions to the theory of *contagium vivum* were first published in a series of "literary" articles (4, 5) in *The Observer* in 1807, and more formally in 1809 in Tobias Watkins' *The Baltimore Medical and Physical Recorder* (6). This was the first medical journal published in Maryland and the third in the United States. It was Watkins who delivered the eulogium on Crawford, his brother Mason, on 24 June 1813, and we may surmise that there were close professional and social ties between them.

Before considering the substance of Crawford's work in detail, a general, if necessarily brief, review of some theories of *contagium vivum* extant at this time would perhaps be helpful in appraising its merits.

#### THEORIES OF *Contagium Vivum*

Around 60 B.C. Lucius Junius Moderatus Columella, in his treatise *De Re Rustica*, warned against constructing dwellings near swampy places since there arise in these locations flying

animals possessing poisonous stings. In the same vein, Marcus Terentius Varro stated that if swamp land becomes dry, the dust therefrom may contain invisible agents which enter the mouth or nose and cause "obstinate diseases." These Roman writings are in the vanguard of a long line of theoretical speculations and conjectures concerning the possibility of a *contagium animatum* or *contagium vivum*. None of these theories was accompanied by a shred of experimental evidence, and the great bulk of these were based, at best, on empirical observation.

There were a number of theories expounded on in the 16th, 17th, and 18th centuries concerning the possibilities of animate contagious agents. In 1557 Geronimo Cardano (Jerome Cardan) suggested that the "seeds of disease" were living and that they reproduced in the manner of other minute living beings. Following him, Alessandro Benedicto (Alexander Benedict) in 1608 described minute "'lumbri' on the teeth, in the lungs and kidneys, and on the skin." Singer and Singer (16) wrote that "he appears to have been quite familiar with living creatures as a cause of disease and he certainly knew of the organisms of scabies." Nearly 50 years later (1650), August Hauptmann argued that fevers were caused by minute organisms of the nature of worms or their eggs. Christian Lange also believed that diseases were due to the entrance of minute living agents into the body. This view was documented at length in Lange's huge (698 pages), posthumously published, *Pathologia Animata* (1688). Contemporaneous with Lange was the mystical and metaphysical Jesuit, Athanasius Kircher. In considering the cause of plague, Kircher referred it to an effluvium consisting of imperceptibly minute living bodies. It is possible that this remarkable man was the first to use a microscope in studying disease, and, in any event, he reported that the blood of plague victims was invaded with numerous microscopic "worms." Garrison (10) wrote that Kircher "was undoubtedly the first to state in explicit terms the doctrine of a *contagium animatum* as the cause of infectious disease."

In 1717, Giovanni Maria Lancisi's important treatise in the history of insects as disease agents was published. In this work, *De Noxiis Paludum Effluviis Eorumque Remediis*, Lancisi considered the causes of marsh fevers. He wrote, "... if I, without experiments, venture to affirm that, in camp fevers of this sort, the worms penetrate and

ascend the blood vessels . . . it would be necessary that the blood of those suffering from marsh fevers should be let, which medical reason seldom admits, and to carefully examine the blood with a microscope for insects of this kind, if such there be. But, although worms might be seen in drawn human blood, it would still be doubtful that these insects should be considered the cause of the evil; or whether, which I consider more probably, it is the product of the breaking down of the fluids; whence all minute ovules, after they have been wrapped up in particles of the blood, are set free or are supplied from the external air. . . ."

In 1720 the doctrine that invisible insects or worms could be the causes of disease was advanced by Richard Bradley. He wrote a tract, published in London, entitled "The Plague of Marseilles Considered." According to Singer and Singer (16) it was the best attempt to solve the problem of infection before Pasteur. The little-known English physician, Benjamin Marten, presented a remarkably accurate analysis of the propagation of tuberculosis in 1720. He stated that the cause of this disease "may possibly be some certain species of animalcula or wonderfully minute living creatures that by their peculiar shape or disagreeable parts are inimicable to our nature but however capable of existing in our juices and vessels . . . or else generated there from their proper ova or eggs . . . which possibly being carried about by the air may be immediately conveyed to the lungs by that (air) we draw in. . . ." Although generally ignored by modern historians, Marten's book was sufficiently popular in its day to be printed in a second edition in 1722. The title of this unusual work was, "A New Theory of Consumptions; More Especially of a Phthisis or Consumption of the Lungs."

In America, apparently the only one prior to Crawford to consider the possibility of a *contagium animatum* was the Reverend Cotton Mather. In his *Angel of Bethesda, Visiting the Invalids of a Miserable World*, published in 1722, Mather assumed that minute "worms" were the causes of disease. He speculated that a safe and potent worm-killer would perhaps be an excellent cure for many diseases.

Finally, there is Marcus Antonius Plenciz' *Opera Medico-Physica*, published in 1762. In this work he envisioned airborne seeds of contagion which germinated to form animalcules as well as

leeches, flies, beetles, or gnats. Some of the animalcules were postulated to be invisible.

In a recent essay, Shryock (15) concluded that by the 1740's, "interest in the animalcular theory had now largely disappeared, for reasons which merit some attention in passing. This theory had been based on experience with large, pathogenic parasites and the revelation by microscopes of minute organisms which might play a similar role. Epidemiologic evidence suggested as much and lent the theory some plausibility, but laboratory verification was needed and could not be secured with the scopes [*sic*] and techniques then available. Even if techniques had been adequate, the identification of most infectious diseases was not yet specific enough to enable scientists to know what organisms they were looking for. A Pasteur would have found nothing had he searched for 'germs' causing such vague conditions as 'bilious fever' and 'inflammation of the chest'."

#### CRAWFORD'S THEORY

Crawford's theory appeared in *The Observer* in the form of two long essays. The first, "Remarks on quarantine suggested by Dr. Caldwell's oration," consisted of 71 pages distributed into short articles of 3 to 7 pages each, appearing in 14 separate issues. The second, "Dr. Crawford's theory and an application of it to the treatment of disease," followed, and it consisted of 48 pages appearing in 11 separate issues. *The Observer* was in existence from 29 November 1806 to 26 December 1807; thus, a Crawford contribution is found in approximately half the issues published.

It is Futcher's (9) opinion that, since Crawford's theory was regarded as ridiculous by his colleagues, he used a literary medium rather than risk rejection from a medical journal. Futcher also suggests that whenever Crawford's daughter, Eliza (Beatrice Ironside, the Editor), was short of copy, she approached her father for more on the "quarantine business." Crawford, however, wrote, "In the mode I have adopted for conveying my sentiments to the publick, I deviate very much from that which has been usually pursued. Medical information has been hitherto generally communicated in medical language, and has been only intended for the medical eye. In the present case, such a mode would be very unsuitable. It is of the highest importance that the community at large should be made acquainted with what is so materially the concern of every individual, and

it cannot fail to be highly advantageous, both to the physician and to the patient, to be united in their opinion as to the cause of disease" (*Observer* 2:183). Then he adds, wistfully, "I may fail to attract attention in the commencement of my labours; but I shall persevere, and shall adduce such arguments as I persuade myself, will at length overcome every obstacle. My great aim is to discover truth, and in the discovery, to promote the happiness of my fellow men. . . . It requires time and examination to be known; but when it is known its force is irresistible."

Crawford begins by stating that, "the all-wise and beneficent author of our existence has not exercised such wanton cruelty toward us as to render the cause of such dreadful calamities either visible or tangible; discoverable by any of our senses." He holds that, as we do not know the origin of such calamities, it is futile to attempt quarantine measures. In an analysis of the Baltimore yellow fever epidemics of 1797 and 1800, Crawford showed that there was a marked geographical limitation to the occurrence of this disease, and that fact, together with other observations concerning its incidence, "militated very strongly against the existence of any species of gas or modification of air, as a cause of epidemics . . . The yellow fever with us has always had a local residence."

There is a second reason for Crawford's belief in the futility of quarantine measures. He followed Malthus in considering epidemics and wars to be useful (albeit dreadful) controls in preventing overpopulation. This point is further fit into the structure of his theory in a most curious, one might almost say Darwinian, manner. A basic tenet in Crawford's view was that all living beings are subject to common natural laws regarding their generation, nutrition, and death. He says, "If we can be persuaded that we are necessarily amenable to the common law, then as organs are conspicuous in one animal, that are scarcely visible in another, so the manner in which the tribute of life is paid by one species, may be obvious, whilst in another species it is completely concealed." He points out that over-reproduction makes one species a source of food for another, thereby maintaining an equilibrium. Man is subject to the same laws, and, in common with all other living beings, he has open and concealed enemies. It is man's invisible enemies that at-

tack him and cause infectious disease, but he is unaware of the moment when this occurs.

According to Crawford, the other possibility concerning dissemination of epidemic disease, having ruled out air, aerial vapors, and gases, is that of direct contact between a diseased and healthy individual. Smallpox was considered as a striking example of such a disease. Crawford recalls the detailed investigation by James Sims of a smallpox epidemic in Tyrone County, Ireland. Sims observed that numerous cases of smallpox occurred simultaneously throughout the county among persons having no contact, and therefore other explanations of the incidence of this disease were required.

Crawford then focused attention on the fascinating machinations of the insect world. Here he reveals both depth and scope of learning, and he constructs a forceful, if unexpected, analogy between the silent, savage struggles among insects and the cause of human infectious disease. This exposition is logical, detailed, and closely knit, and there is nothing similar to it by even the most ardent contagionist preceding him. This is a persuasive reason why Crawford ought to be rescued from history's limbo. His thesis is that "by diligently comparing the relative properties of things that are exposed to view, he can, with a moral certainty, form conclusions that reach far beyond this limited evidence." The first example chosen is that of the plant aphids (pucerons). Crawford noted that some insects deposit their eggs on plant leaves colonized by aphids. When these eggs hatch, the young devour the aphids, and it appears that the latter are wholly ignorant of the existence of their enemies. An examination of the curious ways of the corn weevil, capricorn beetle, nut weevil, wood piercer, lady bird beetle, and lymexelon beetle shows that these insects are capable of introducing their eggs into or on the substance of other living plants in a variety of ingenious ways.

A classic case, in Crawford's view, is that illustrated by the ichneumon fly. These insects deposit their eggs in the bodies of other living insects, especially caterpillars. The ichneumon larvae are for the most part internal parasites, and they ultimately cause the death of their host. Equally forceful is the example of the gadfly, and its habit of depositing its eggs in the bodies of sheep, cattle, and horses. The larvae, known as "bots," produce painful tumors and even death in the

afflicted animals. Man himself does not escape the depredations of these insects.

After these detailed considerations, Crawford reiterates the conclusion that: "The assailed are so constructed as to be unconscious of the attack of the assailant. If this is inseparable from the oeconomy of nature, it necessarily follows that man must be subject to the depredations of oestri, ichneumons, . . . and perhaps, thousands of others, which the senses, aided by the directions of a correct understanding, may be able to trace in a way that will fall very little short of absolute demonstration. Insects of almost every description, have been found alive in different parts of the human system . . . but how they have obtained admission into it, has been hitherto unexplained." Further on he suggests, "If we can once be satisfied that the cause of death, obvious in any one creature, must resemble the cause producing death in every other, we shall be enabled to form conclusions respecting our own fate, that will generally give satisfaction. If this reasoning is just, it of necessity follows that as the plague of caterpillars, pucerons, and of all insect tribes, is the ichneumon . . . so the plague, yellow and every other fever, and every other disease we experience, must be occasioned by eggs insinuated, without our knowledge, into our bodies, externally or internally, or from eggs placed near our habitations which, when hatched, in either case prey upon us by parts. . . ." Finally, a Parthian shot at quarantine, "If diseases, without any exception, either as to object or nature, are occasioned by a living principle which attacks and preys upon its fellow mortal, how can a quarantine obviate the difficulty? If the origin of all diseases is a living principle, possessed of the power of removing from one place to another, and as our senses, it is alleged, are incapable of discerning it, how is it possible that one can devise any barrier against the invasion which is invisible?"

Crawford replied to Mead's disclaimer that, "the theory that existence of insect eggs, when hatched, causes disease is not grounded upon no manner of observation," by asking upon what observations the existence of an "active principle" generated from corruption was founded. He holds that eggs whose existence is certain, are easy to use for explaining disease causation, whereas "active substance" is not.

Crawford, following his experiences with yellow fever, and Sims' with smallpox, did not believe

that infectious disease may be spread directly from person to person. He argued, "If, as alleged, it is an host of flies which deposit their eggs either on our bodies, or near our bodies, so that their larvae can conveniently attack us, then all difficulty vanishes. Then they may either proceed from one body to another, or attack great numbers of bodies at the same time, and as other larvae herd together, we may readily see how it comes to pass that disease rages more in one part than in another, and at different parts in succession."

In "Dr. Crawford's Theory and an Application of It to the Treatment of Disease," a superficially different approach is made, but upon examination it is apparent that large portions are repetitious of the first essay. Emphasis is placed, not on the foibles of the insect world, but upon the writings of 17th and 18th century philosophers—natural and otherwise—whose work is cited as buttressing Crawford's theory. In addition, there are numerous passages in which Crawford inveighs against the narrow and closed minds of the local medical persons who oppose his theory: "It is by collision alone that truth can be discovered, it will, in the end triumph over every antagonist. If this theory, which I have attempted to reduce to its intrinsic simplicity, proves to be in unison with the undeviating order of nature, the more profoundly it is investigated, the more certainly it will lead to correct views of the origin of diseases, of the method of treating them, and of the manner in which medicines operate. It will also lead to shew where it happens that they so often fail, are sometimes injurious, and so frequently effect the purpose for which they were designed. Is there any knowledge more desirable than what is here proposed? To be emancipated from the wilderness of darkness by which every thing relating to diseases and to medicines has been hitherto obscured, must appear highly interesting. These involve our dearest, our very nearest concerns, and ought to be an object of universal enquiry. Hitherto these pursuits had been confined to a particular class of men, and to men who derived from them their support. Such men are always trammelled by public opinion, and of this they are generally the slaves. Very few indeed dare to deviate from it, because all who have, were the victims of their temerity. They were either vilified, cruelly persecuted, or sunk into neglect. The few sup-

porters of the theory in question, have conspicuously experienced this fate; they have either been stigmatized as quacks, or considered as wild visionaries, and treated with contempt" (*Observer* 2:250). There is no doubt that Crawford was one so treated by his Baltimore colleagues. Further in this essay he says, "In the pursuit of this enquiry, I well know that I shall expose myself to obloquy. I have already experienced it extensively; I have been deemed an innovator; I am accused of having descended from the dignity of my species, and placing myself on a level with the most ignoble of creation. What others may consider as a degradation, I esteem of high value. To be enabled to see with the eyes of my understanding what is hidden from every other species of terrestrial being, must be a high privilege; to be capable of tracing from the lowest, what most nearly concerns the highest order, and what is beyond the reach of every other order, must be a subject of exultation" (*Observer* 2:311). There is much more of this in the same key throughout this paper.

Crawford's main points concerning the cause of infectious disease, as expressed in these two essays, may be summarized: (i) Man's ultimate fate is the same as that of every other living creature, that is, he is a part of nature. (ii) Some animals derive their sustenance from plants, whereas others derive their sole support from preying on their fellow creatures. (iii) Among the most marvelous works of creation are the minutest beings, and in every instance they are employed to divest the superabundance (due to over-reproduction) of those that are a larger size. If we were acquainted with the manner in which this is effected, it would afford a chance for detecting this agency in every other species. (iv) In a multitude of instances, the depredators are wholly unknown to those on whom they prey. Man has invisible, insectlike enemies, numerous and incapable of detection by ordinary senses. (v) Insects and their larvae, because of their mobility and other characteristic habits, are most likely a cause of infectious disease, and their mode of operation may be supposed to be very much similar to that of the ichneumon fly and the gadfly.

In addition to the obloquy and derision that Crawford suffered at the hands of his Baltimore colleagues, his "Observer" essays were more soberly reviewed (2) in the pages of Mitchell and

Miller's *The Medical Repository and Review of American Publication on Medicine, Surgery, and the Auxiliary Branches of Science*, for the year 1807. After briefly alluding to Crawford's belief in the "animalcular hypothesis" and reviewing his contentions that specific diseases were caused by specific insects, the review concludes with the dry statement, "For ourselves, who are believers in the chemical theory, we must refer such of our readers as wish further proofs of Doctor Crawford's learning and ingenuity, to his original dissertation." And prior to this, in a written letter to Benjamin Rush in January, 1806, Crawford complained that, "The premature disclosure (by himself or others) of my opinions has afforded a means to the envious and malignant to prejudice those I had every reason for valuing myself on, so as to deprive me of all the valuable practice in this City. . . . There is one consolation which I felt. I am convinced that we are both of us in earnest in our pursuit of truth, and in so far as our road is the same, we shall necessarily accord. Where we take different directions, I am persuaded also that we shall cordially agree to differ, nor either to hesitate to adopt what appears to us correct. . . ." Rush's concepts were not changed by Crawford's theory, either before or after its appearance in print.

Crawford gamely persisted in attempting to gain notice of his theory when in 1809 he wrote a 41-page essay, published in three parts, for Tobias Watkins' short-lived *The Baltimore Medical and Physical Recorder*. Entitled "Observations on the seats and causes of disease," this work is a formal effort directed to the medical practitioner of his day. The first part, based partly on his Demerara experiences, considers the relationships existing between the actual origin of a disease process and the supposed location based on symptoms. The second and third parts are mostly repetitious, with some additional citations, more examples from the animal kingdom, and rewording of the material in *The Observer* essays. Crawford maintains that there is a plant provided for every animal destined to feed on it, to which it ever resorts in preference. So also, every plant has its suitable insect host which restrains its inordinate luxuriance. Here, there seems to be a hint of what is described today as "species specificity." The pedal point of Crawford's opus continues to sound: "whatever has been created, possesses and exercises the powers of multiplication beyond the

means of support, and that the exigencies of which this want of support must be the consequence, has been obviated by constituting one or more species as food for each other."

There is appended to this essay a letter dated 29 March 1806, from Clement Stanford, concerning discovery of numerous "black bugs and worms" in the stomach contents of a female patient. The letter was addressed to William Winder, Esq., of Baltimore [Oliver (12) has discovered a letter to General William Henry Winder on another subject] and in it Stanford says that, "I am willing to do everything in my power to the advancement of Dr. Crawford's work of which you make mention, although unacquainted with that gentleman." Although Crawford promised to "hereafter produce numerous proofs by which [the theory] is sustained," the above case is the only one cited in his writings.

In 1811, Crawford commissioned Edward J. Coale to publish a 51-page book (7) entitled, *A Lecture, Introductory to a Course of Lectures, on the Cause, Seat and Cure of Diseases. Proposed to be Delivered in the City of Baltimore*. These lectures were to be given at his home at Hanover Street in the fall of 1811, but apparently only one lecture was given. The title suggests the substance of the "Observer" and "Recorder" essays, and indeed the introductory itself is repetitive, discursive, and rambling. In 1812, the regents of the Medical College gave Crawford an appointment with the title "Lecturer on Natural History," but this position was shortly abandoned. He wrote shortly thereafter to Rush that his introductory lecture was poorly received, and that he was treated ungraciously and with illiberality.

Crawford died a disappointed, if undefeated, man. He was heavily in debt, a fact he had mentioned previously (16 November 1808) to Benjamin Rush. He "had lost all his business by propagating an unpopular opinion in medicine, namely that all diseases were occasioned by animalculae."

#### EVALUATION

Most historians have ignored Crawford's work, and, in those rare cases when he is cited, a sentence usually serves to dismiss both him and his theory. Although it might be argued that Crawford is, in fact, a transplanted European and not an American, I maintain that, since his contributions were brought to fruition on the

American scene, we may properly consider him to be an American.

It may be added that American work in this field prior to the Civil War is not documented "in depth." In reintroducing the historic element to this era, it may be instructive to trace the origins of Crawford's theory, a task easily accomplished in his case. It was in Demerara that there were unlimited opportunities for postmortem examinations of persons dead from a variety of diseases. Crawford gradually was forced to the position that current medical theories concerning disease symptoms and origins could not be reconciled with his practical experiences, and thus began the search for a more satisfactory explanation. In Crawford's words, "... I clearly saw that some other plan must be adopted for the explanation of these appearances, than had been hitherto proposed. I perceived a number of changes in the structure of various parts, which it was evident, could not have been effected by any power that could belong to these parts, and that they must have been the work of some influence which was of a foreign nature. I was attracted by the swarms of very minute flies which were visible only when the declining sun emanated its rays in an oblique direction, and, as these were only distinguishable at some distance from me, I asked myself whether the atmosphere by which I was surrounded and continually inhaling, could be less replete with these little beings? If this were so, it necessarily followed that I must be receiving them with my breath in multitudes. My next consideration was whether, when admitted into my lungs it was impossible they could be wholly innoxious to my system" (Observer 1:181-182).

Later, discussions in Leyden revealed to Crawford that a number of authors had suggested, either casually or seriously, that insects might be the cause of infectious disease. Crawford took up the burden of elucidating the detailed mechanics of this process and of supplying proofs of its correctness. There is more to Crawford's theory than the bare statement, "he was also one of those who believed that insects cause infectious disease." It is to Crawford's merit that, by carefully reasoned arguments, together with such field observations as were possible, he was able to erect a theoretical structure to explain how infectious diseases result as a *natural* process, rather than as some accidental concatenation of chemical phenomena. This is why Crawford analyzed in such pains-



taking detail insect-plant and insect-animal relationships. His concept of nature was that of a perfectly coordinated mechanism in which each species performed a specific function and occupied a specific niche. Infectious disease for Crawford was always the resultant of a *natural* process with ultimate positive good in the sense of Malthus, for the race of mankind, even though individuals might suffer or die.

It is curious that Crawford's preoccupation with minute insects seems to have blinded him to consideration of a yet lower level of minute organisms, that is, microorganisms. He seemed satisfied that insects or their larvae (especially those so minute as to be invisible) were the agents of infectious disease, and animalculae, *sensu stricto*, were never considered. Crawford's failure to supply convincing proofs for his theory made his position untenable; yet, he never appeared to actively seek out, by any means at his disposal, the experimental evidence so glaringly lacking. One might have imagined that Crawford would have received some support for his stand against quarantine. After all, Baltimore was a mercantile and maritime city, and bureaucratic interference with the business of a growing and powerful merchant class was not to be brooked. Ackerknecht (1) maintained that the anticontagionists were usually liberals and reformers, but Crawford received no support from these groups during his struggle.

Crawford's essays are tinctured throughout with the same altruistic theme that characterized his public career. There is no doubt that his unorthodox views had a severely adverse effect on his professional and personal affairs. We must admire him for not yielding to the conformist pressures that must have assailed him from all quarters. He was 60 years of age when he began to promulgate his views publicly; one would have imagined that such missionary zeal would characterize a rather younger man.

As to the theory itself, it was sorely out of joint with the times. In his masterful essay, Ackerknecht (1) has shown that anticontagionist doctrines soared highest before their final smashing refutation at the hands of Koch, Pasteur, Lister, and Tyndall. American medical thought and theory in 1800 was essentially European, and the professionals of Baltimore fully echoed those sentiments. Here, for example, are the words of Horatio Gates Jameson (11), written in 1817

about Crawford's "animalcular hypothesis," "... it does not seem to merit notice, yet the many imperfections of diversities of opinion are sufficient ... to humble the most aspiring genius into a cautious reserve how he attempts to trample on opinions supposed to be exploded. ... I may safely say that with our present knowledge of this subject, nothing can be said of any practical use."

Crawford's observations on the geographical limitations of yellow fever were sound. We know now that some insect-borne diseases are not only limited by the distribution of their vectors (yellow fever, malaria, tick-borne diseases), but they are not transmitted from an infected individual to a healthy one. The relationships of insects and ticks as vectors of disease were brilliantly worked out later by Manson, Finlay, Smith, and Ross. Crawford's idea on the specificity of infectious disease agents also was sound. His arguments based on analogy were cleverly and honestly conceived, and were thoroughly consistent with the scientific knowledge of his time. He clearly foresaw the "struggle for existence" that Darwin advocated 53 years later. His philosophy was completely furnished with Malthusian overtones, and doubtless he adopted his views shortly after "The Essay on Population" was published in 1798. The magnitude of the events occurring in the War of 1812, and the short life, poor distribution, and unknown quality of the journals publishing Crawford's work, coupled with failure to attract students or disciples, signified that his unhappy death closed what might have been an auspicious beginning chapter in the history of American medicine. As it was, 19 years elapsed before Daniel Drake seriously reintroduced the question of the relationship between insects and disease, and 35 years passed before Josiah Clark Nott came close to uncovering the connection between yellow fever and mosquitoes.

Crawford may not have deserved the epithet "great," but he was a courageous humanist hacking out a lonely path in a hostile and unexplored jungle; although he traveled but a short distance, he was going in the right direction.

#### ADDENDUM IN PROOF

I have recently discovered an unpublished Master's thesis by W. B. Walker (M.A. Thesis, Johns Hopkins University, Baltimore, Md.). This work, written in 1951, and titled "Dr. John Crawford of Baltimore (1746-1813)," has many

additional details concerning other facets of Crawford's medical work; it should be seen by anyone interested in the history of this period.

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