WALDO IRVING BURNETT , EARLY AMERICAN HISTOLOGIST

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I. The Evolution of Histology in the United States and Waldo Irving Burnett

By the middle of the nineteenth century, young American medicine had made important practical contributions, such as anesthesia, Sims' vesicovaginal fistula operation, Gerhardt's differentiation of typhus and typhoid, and, through the work of Beaumont, even an important contribution to medical science.

In the field of microscopical anatomy, on the other hand, one can point to no American contribution of significance during the period. Even the mere assimilation of European discoveries and techniques, usually very rapid in the United States, seems to have badly lagged in this field. We are therefore all the more interested in the few individuals who did histological work in the United States at that time. Amont these few we are especially concerned with Waldo Irving Burnett, most active of these early American microanatomists.

In Burnett's famous monograph on the cell, he himself refers to the histologists Drs. Wyman, Agassiz, and Joseph Leidy.[1] Leidy in 1848 contributed to the library of the American Academy of Arts and Sciences an article on "Comparative structure of the Liver and on Some Bodies in the Boa

Constrictor Resembling the Pacchinian Corpuscles."[2] At about this time Leidy made his discovery of trichinois in the pig and microscopically studied the bacterial flora of the intestines. Leidy is reported to have taught in the 1840's a class in microscopical anatomy.[3]

Some references to microscopy or microscopical work can be found in the periodicals of the 1840's and early 1850's, but these contribution generally stem from men devoted to other subjects who chanced to do some microscopy in the course of their work. There are noted some references to minor microscopical work by Holmes, of literary fame,[4] and, indeed, in the very issue of the American Medical Association Transactions wherein included Burnett's lengthy treatise on the cell there is reference in a preceding article to some microscopic work on tumors. But in spite of the extistence of an extensive European literature on the micropathology of tumors, the bulk of this voluminous publication on neoplasms is devoid of attempts at microscopic examination of the pathology discussed.[5]

Waldo, Irving Burnett, the subject of this study, appears to have been the first in the United States to attempt to fully assimilate the European literature on microscopy and histology and to devote his energies throughout a brief but active life to the study of this field. His record of accomplishment is particularly remarkable when one considers his few productive years.

Waldo Irving Burnett was born in Southborough, Massachusetts on July 12, 1827, the son of a physician, Dr. Joel Burnett. We know little about him until the age of 16, at which time he bagn visiting patients with his physician father. In March of 1845 his father died[6] and Burnett began to teach school for support, concurrently studying medicine under the preceptorship of Dr. Joseph Sargent of Worchester. Burnett then entered the Tremont Medical School, graduating, however, from Harvard Medical School. In the mean time he had obtained a microscope from a relative and had acquired some knowledge of Greek, Latin, Spanish, French, German, and Swedish. He graduated from medical school in 1849 and thereafter went to Europe for four months, ill health forcing his return. Subsequent to his return he became, "as it were, a pilgrim in America."[7]

That he acquired early in life a scientific reputation seems to be reflected in the fact that in 1848 Burnett, not yet titled doctor, is listed as a member of the American Association for the Advancement of Science. At a second meeting on August 18, 1849, Burnett, now the possessor of a doctor's degree, was secretary of the section of zoology.[9]

In 1851, though but 24, he was elected to membership in the Academy of Arts and Sciences, and continued to contribute to this body until his death. The esteem in which his work was held is shown in the publication of his reports at some length.[10]

He is said to have published some sixty articles during his life, his major work being a publication in the A. M. A. Transactions of 1853. This lengthy essay, in reality a book printed within the confines of a journal, is a compendious work summarizing his research on the cell. He did, in addition, microscopical work on embryology and entomology. Burnett died from consumption on July 1, 1854, not yet 27 years of age at the time of his death.[11]

His death was commented upon in the proceedings of the American Academy of Arts and Sciences by Agassiz, who said of him that "the American Academy has sustained a severe loss by the death of W. I. Burnett. Burnett, though ill throughout his active life, was unceasingly active and industrious. Perhaps the realization of the necessarily short span of his life made him even more eager to accomplish that which he could during his lifetime. He was one of the few among us," said Agassiz, "who was extensively conversant with the whole range of foreign publications upon the subjects with which he was engaged. Modest, unpretending, and ever willing to aid others, true and open as a friend."[12]

Though but 27 years old at the time of his death, Burnett had evidently gained during a brief scientific life the respect and affection of his colleagues, and had triumphed over illness to perform a significant task in the advancement of the science of his time.

II. The Histology of Waldo Irving Burnett

Waldo Irving Burnett did not anticipate any startling theories or discoveries. His contribution to histology consisted primarily in the assimilation of the work of European authors, in the repetition and confirmation of their research (often including their errors) with minor emendations and discoveries. Such a contribution should, of course, be seen against the background of contemporary American indifference towards the field, and should not be underestimated. It should not be overlooked that Burnett died before he reached the age at which most scientists made their discoveries.

The first paper by Burnettt which I am able to trace was read in 1849 to the American Association for the Advancement of Science. Burnett, then a recent medical school graduate, presented a discourse on the morphology of cells. In this study he proposed what he considered a new description of cell-formation. He disputed the Schwannian doctrine of the formation of cells in a cytoblastema with the initial manifestation of a nucleus within the cytoblastema and the secondary development of the cell itself around this nucleus by a process, as it were, of precipitation. Burnett concurred in the doctrine of cytoblastema as the medium of cell formation but he felt that the mechanism was other than claimed.

Burnett describes the appearnce of 'points' within the

cytoblastema. These points, vesicular in nature, grow in size, acquiring a more granular nature with the increased size. Eventually there occurs within each of these vesicles the condensation of a nucleus. Allied with this doctrine is that of the essential similarity in matter of cell and nucleus. Further cell formation takes place, according to this belief, by the enlargement of the nucleus and endogenous formation of the cell in the same manner. Perhaps one of the reasons for Burnett's acceptance of this thesis is the explanation it affords for the disappearance of the nucleus during cellular reproduction. In this same study Burnett also admitted the production of cells by fission, but this was not stated as a personal discovery.[13] Reproduction of cells by fission had long been known to occur in plants, Schleiden himself having admitted the reproduction of cells by division. As early as 1837 Mohl had definitely stated the division of the cell by formation of cell walls.[14]

In his next article Burnett, in accepting the Ascherson theory of utricular formation from oil and albumen, reverted in a measure to the pre-Schwannian era. He postulated the formation of cells by expansion of these utricles and nuclear precipitation within the utricle. He also stated that these utricles could line themselves up and form fibrillated tissue or could arise in pathological blastema and form fibrillae. Burnett believed too that muscular cells acquired strength by reversion to the utricular state, and that prior to the

formation of the embryo or the sperm cell there was reversion of the mother cell to the utricular state. This thesis is based largely on Ascherson's observation that oil and albumen would together form little vesicles. Though most scientists claimed that this was as far as these vesicles would progress, Burnett fell back upon a vital principle theory to explain the further evolution of these droplets into living matter. Burnett proposed a vital principle with which these utricles were infused to become living cells.[15]

This theory of the formation and composition of tissues by utricles was by no means new. Raspail had long before this written of the formation of all tissue from utricles, and J. H. Bennett, the great Scottish physician, believed as late as 1849 that all tissue was of utricular composition.[16] Burnett accepted a middle road between the theories of these men and the Schwannian cell doctrine. That Burnett knew about Ascherson is not to be doubted, but whether he knew about Bennett's work it is difficult to say, for he gives no references in this paper.

At the same meeting he read an abstract on the "Origin, Development, and Nature of Spermatic Particles." In this study he speaks of the epithelial nature of the testicular tissue and of its hyperplasia during puberty. He describes in some detail the formation of the sperm and compares the sperm to the ovum; the sperm, he states, is itself capable of division, whereas the ovum requires the intercession of

the male for division, though it can divide several times without the aid of the male particle. He shows in this article recognition of the method of sperm formation of spermatocytes.[17]

The subject of 'spermatology' continued to interest Burnett and in 1851 at the meeting of the American Association for the Advancement of Science he reported on the "Relations of Embryology and Spermatology to the Fundamental Doctrines of Physiological Science." Burnett at that time directed his knowledge of what he called 'spermatology' towards a subject of no little interest to him, that of 'vital force.' He was of the opinion that the microscopist must be impressed with the presence of a 'vital force.' Cells, he states, have a similar appearance throughout the animal kingdom and yet we see the production of diverse organisms from superficially similar cells, and must therefore recognize the presence of a modifying principle, the 'vital force.' Within the sperm and ovum, according to the concept of Burnett, there is embodied 'the idea' of the child to result, and, therefore, the child resembles the parents. This 'vital force' he conceived of as no less logical than many of the physical forces recognized by all, such as that of affinity.[18] (see the "philosophy of Waldo Irving Burnett", this paper p. ff.)

In this intensive study of sperm Burnett derives a method of classification of animals. He would classify animals as

far as genera on the basis of the appearance of their sperm, though he admits the failure of this appraoch for further classification.[19]

Burnett presented numerous other histological studies to the American Association for the Advancement of Science and the American Academy of Arts and Sciences. Almost all of his work in histology and pathology is summarized, however, in the prize essay which was to be, in essence, the parting work of his life.

This work, entitled, "The Cell: Its Physiology, Pathology, and Philosphy", begins with a history of the cell theory. This history is still considered adequate for use as reference by two contemporary authors.[20] He follows this with his theory of cell formation and his opinions on sperm and ovum formation, both reported above.

Next he discusses in some detail blood cell formation, disagreeing with Wharton Jones' concept of erythrocyte formation from chyle corpuscles, Jones had expressed his concept of the origin of nucleated colored corpuscles, as seen in the lower animals, from the chyle-corpuscles. Jones felt that these burst and the nucleus became the colored corpuscle in the higher animals.

Though Burnett is in accord with the doctrine of erythrocyte development from chyle-corpuscles, he doesn't agree with this hypothesis of their formation, at least in higher animals. Nucleated cells are not seen in sufficient quanti-

ties in the adult to justify such a belief, he writes. He here finds 'corroboration' of his theory of cell origin in his observation of the chyle (lymphatic) system. From the small particles (apparently the fat particles seen in the abdominal lymphatics) seen in the abdominal area the chyle-corpuscles, he says, are formed during the passage of the chyle up the lymph stream. This is 'proven' by the observation of so many more fully developed chyle-corpuscles in the thoractic duct. The small particles within the abdominal lymphatics are, to Burnett's way of thinking, the utricles from which the chyle-cells are formed.

That the erythrocyte should not be formed from the chyle-corpuscle is inconceivable to him, but, though accepting the hypothesis of erythrocyte formation around the chyle-corpuscle in animals with a nucleated colored cell, he postulates an original theory of erythrocyte formation in the case of animals such as mammalia. He hypothesizes that the granules of the 'multi-nucleated chyle corpuscle' (apparently he could not differentiate the lymphatic and neutrophilic cells) serve as nidus for the formation of the erythrocyte. He states that in the embryo the method of formation is different, but he felt that the erythrocytes in the mammalian embryo were just provisional until the mother's corpuscles came into the embryo.

It is interesting to note that Burnett here (and in a report to the Am. Ass. for the Adv. of Science) disagreed

with Koelliker's statement of the spleen as a blood-destroying organ. Koelliker, according to Burnett, observed brownish bodies which he felt to be the blood-destroying bodies within the spleen, and which Burnett felt to be simply accidental productions, extravasations of blood into the splenic parenchyma. Burnett noticed oval bodies containing pigment on some of the small arteriolaed of the spleen and felt these to be pigment producers. In one of his erroneous generalizations, Burnett put the spleen in the class of the ductless glands, such as thyroid, thymus and adrenal, but whereas the latter were active during embryonic life, the former (the spleen) was active during the adult life of the animal.[21]

The spleen, Burnett felt, is rather connected with erythrocyte production, being the site wherein the plastic materials of the blood are made ready for conversion into red cells and chyle-corpuscles formed and eliminated for the formation of red cells. This is why, Burnett said, the spleen is found in animals with erythrocytes in the blood.[22]

Burnett then goes on to describe the 'fixed tissues' of the body, as he calls the other tissues, in contrast to the 'moving tissues' such as blood. The nervous tissue he conceived of as the 'grand tissue' among the fixed tissues of the body. His conception was that of the separate origin of the ganglion (cell body) and tubes, and he didn't believe in their connection. He thought of the tubes as originating from a number of cells lined up one by one with the merging

of the cells, and cells walls remaining only as the sheath, with the nuclei of the cells becoming the nuclei of the sheath. The failure of connection between ganglion and tube had been confirmed, he stated, by Prof. Wyman. Burnett knew of the grey fibers, as described by Remak, but considered them as being simply fibrous tissue, although he admitted the presence of a sympathetic nervous system. Apparently there was considerable confusion at that time as regarded the grey fibers and the sympathetic system.

Burnett next dealt with the muscle cells and muscular tissue. He felt that one could best study muscle action in the lower animals, where the pedicle could be seen to contract in the radiata by virtue of the affinity of the granules in the pedicle. He theorized that in the higher animals muscle was formed by the process of lining up of a number of cells, and, much the same as in nerve formation, subsequent coalescence. The granules, physiologically the same as those in the lower animals, then line up to form the striated musculature. The fiber, therefore, and not the fibrilla, was to be considered the true unit. The cellular character of muscle can be seen, he stated, when the muscle breaks down, as when boiled or when undergoing pathological degeneration.

This, was an advance in Burnett's thought over what he had written only three years previously. Then he had spoken of muscle as being a tissue which had to retrogress into the

utricles from which it arose to be effective in performing its action.[23] Now he spoke of it as being a cellular tissue with the loss of cell demarcation by coalescence.

At this point Burnett also spoke of having observed a type of muscle rather elongated and narrowed towards the ends. This "celloid" tissue, Burnett wrote, is found in dermis, areola, and other tissue, the histological and local peculiarities having been worked out by Koelliker.

Burnett next discussed fibre-cells and fibrous tissue. After beginning with a historical survey, he pointed out the existence of two kinds of fibers, yellow and white.

The white fibers, he wrote, consist of inelastic bands and often present a wavy aspect, allowing retraction and expansion. This is a cell product, the cells becoming elongated and fusing together to form this type of connective tissue. The yellow fibers are long, smooth fibers, curled upon one another when extension is made. Though these fibers are believed by some to be of cell origin also, Burnett feels that they are rather of utricular origin, being fibrillar tissue by nature and formed by the lining up and coalescence of utricles.

He next dealt with adipose cells, saying that some felt that adipose cells were developed as were other cells and contained nuclei. Schwann himself was an adherent of this view. Burnett was of the opinion that these cells did not as a rule possess nuclei, and that others had not really seen

a nucleus toward the wall as often as they said. Occasionally, he admitted, a nucleus might form within the adipose tissue cell by the Ascherson method of nucleus formation, but this was to be considered the exception rather than the rule.

Bone and cartilage he took up togehter, because of their close association. Bone, other than membrane bone, is formed from cartilage. There are two kinds of cartilage, cellular cartilage, consisting of well-defined cells lying in a semi-solid punctiform stroma, and fibro-cartilage, consisting of the same kind of cell within a network of fibrous tissue.

All cartilage is originally cellular in nature. Some of the cells then condense into a puntiform stroma, leaving groups of one to three or four cells within this stroma. Gradually the cell walls blend with this stroma and leave a cavity in which the nucleus of the cell persists. In fibro-cartilage this same kind of cell lies within a network of fibrous tissue.

When bone is to form, a liquefaction of the stroma takes place, and the cartilage cells line up in parallel rows, parallel also to the long diameter of the bone.

Gradually there is the replacement of the liquefactive material by calcareous salts and the formation of the typical bony structure as it is seen in the more developed bone. The cartilage cells become the Purkinjean corpuscles of the

bone. When these cartilage cells, begin to shrink there are seen radiating lines running out from one cartilage cell to another. While there is considerable discussion as to the meaning of these lines, and while Schwann believes that they are prolongations of the cell membrane, Burnett believes that these are actually canals for the escape of gases as the cells die.

Thus the process of bone formation is essentially one of substitution, though Burnett admits that membranous bone can be formed independently of cartilage. In lower animals the cartilage can become ossified without the formation of the type of bone seen in the higher animals, simply by the deposition of 'calcareous matter' within the cartilage.

Burnett appears to have based his exposition of bone development on the synthesis of numerous references, and observation. His exposition seems better organized and more advanced than that of a contemporary work of Koelliker.[24]

Burnett discusses last the formation of crystalline lens tissue, which he feels forms in the same manner as muscle and nerve tissue, by the lining up of cells and their coalescence.

Burnett was not content to discuss merely the histology of the cell, but went on to discuss cell function; the physiology of the cell.

The epithelial cell he describes as the secreting agent of the animal economy. Nutrition and secretion rest upon the

animal cell as their basis. Secretion is accomplished, according to his impression, by the cell-wall; the liver cell, for example, elaborates bile from plasma which has passed through the cell wall and is "changed" to bile by contact with the nucleus. Why the different cells produce different secretions he does not even attempt to explain.

As part of the subject of the function of the epithelial cell Burnett discusses the ciliated cell, looking upon the cilia as finger-like protrusions of the cell-membrane. He also comments upon the tactile and prehensile cells; these contain a long filament within the cell which is thrown out and winds around the object to be cuaght. The process here, as burnett appreciates it, is one of "intracellular cilia" formation. He distinguishes two types of prehensile cells; one containing a filament alone, and the other type possessing a stigma and a filament arising from the stigma. Burnett's careful approach is illustrated by this distinction.

A subject of no little interest to Burnett is that of chyle and blood-cell function. In the lower animals the chyle carries only nutritive materials, while oxygen carriage is performed by a separate and inherently crude system, unsuited to the needs of higher vertebrates. In the vertebrates, accordingly, the circulatory system carries both food and oxygen, the oxygen transport being performed by the colored corpuscle. This is proven by the change in

color of the blood upon oxygenation, a change due to the presence of a constituent named haematin.

The nervous tissue serves for the origination and distribution of mental force, the cells originating, the tubes distributing this 'force'. Little is known, however, Burnett admits, of the mechanism of action by which the transmission of these nerve impulses is accomplished. Such a complex phenomenon as the transmission of immaterial images from eye to mind can be but poorly understood.

In the summary of his histology Burnett reiterates the Schwannian credo of the unity in all organization. The cell is the ground upon which simple matter and life find their union. However, in this summary of his histological thought Burnett repeats also Schwann's greatest of errors, which was just being overcome by Remak and Virchow: the belief that tissues are formed from granules or utricles rather than from nucleated cells.

According to his theories, Burnett points out, there is truly unity, for nucleus and cell are composed of essentially the same material. Thus, among the diversity of life we see the unity of the cell. In this unity amid diversity there is that truth and beauty, says Burnett, which has been prophesied by the highest philosophy.

III. The Pathology of Waldo Irving Burnett

"In a general way," Burnett wrote in his prize essay in the American Medical Association Transaction of 1853, "it may be stated that pathology is but an erring physiology."[25] We must consider health and disease, he felt, as a kind of continum for there is no absolutely positive method of establishing one as compared to another. Sometimes, indeed, disease may not even have a material expression, and we may refer to diseases of this sort as being functional.

The main difference between the normal and pathological cell, according to Burnett, was the lack of future and "determinate result" of the pathological cell, as compared with the purpose of the normal. There is about the pathological an "absence of teleology" which distinguishes it from the physiological. Burnett divided the pathological into two types, the heteromorphous and the homeomorphous. The later resembles normal tissue in appearance but has no purpose; the former is of most importance, because so widely separated from the normal. Among the heteromorphous types of pathology are cancer, the tubercle, and pus. Gluge, in an Atlas of Pathology translated into English by Leidy at about this time, employed generally similar classification, but was far less specific in its ramification than was Burnett.[26]

To Burnett the basis of all physiology was nutrition, by which he meant all types of "decay and repair." All

tissue is constantly undergoing this simultaneous decay and repair. Accordingly, pathology being but perverted physiology, the seat of all pathology lies in perverted nutrition. This had been said by Virchow at about the same time: "All pathological processes are primarily disturbances of nutrition."[27]

Burnett wrote of the plasma effusing through the wall of the capillary and coming in contact with the tissue to be repaired, then taking on the characteristics of this tissue. This plasmatic formation of utricles, the appropriation of this plasma by the tissue, and the impression upon the plasma of the characteristics of the tissue Burnett referred to as nutrition; all of pathology was encompassed within the perversions of this normal mechanism.

As can be pictured, there were thus established two classifications within the realm of the pathological: one in which the derangement is within the plasma; a second in which the tissue did not possess the proper power to impress its characteristics upon the plasma. The power of a tissue to cause the formation of its own type by the plasmatic utricles is referred to as the type-power.

The perversion of the plasma Burnett considered to be the cause of what he referred to as the heteromorphous products, among which he included cancer, pus, and tubercle. Cancer was the result of a plasma approaching normal, pus and tubercle the result of a "lower" plasma. Even if perverted

plasma is utilizable, the type-power of the tissue may be modified by this poorer plasma, as in an indolent ulcer.

The second type of pathological classification, by the same token, was that of perversion of type-power. This produced homeomorphous pathology, such as epithelioed tissue, which Burnett felt was erroneously referred to as cancer. The homemorphous product, as previously mentioned, has a histological resemblance to normal tissue, but is not a true hypertrophy. True hypertrophy is, produced by a simple increase in type-power rather than perversion. A decrease in type-power produced retrograde metamorphosis, or return to the utricles from which the tissue was formed.

It is interesting to note what is in essence somewhat of a synthesis of the Rokitansky dyscrasia doctrine and the cellular pathology which was to arise.[28] The heteromorphous tissue pathologies were essentially the result of a dyscrasia much the same as that which Rokitansky had proposed as the solution to all the problems of pathology. The type-power classification more closely resembles the cellular pathology which was to be expressed more or less definitively by Virchow.

In his discussion of pathology, Burnett discusses inflammation, which he felt to be the forerunner of heteromorphous product formation. Stasis and congestion occur, he says, and then the exudation of plasma and hyaline products into the tissues takes place. From this there is

formed the utricles and granules which are heteromorphous.

He discusses in some detail the heteromorphous pathological conditions. The most simple of these is that in which the plasma cannot even give rise to a 'low' product. Such is the effusion of a serious blister. In our "ascent" up the ladder of the heteromorphous we find that next is that plasma which is a little more active and can produce utricles but no cells. Such, for example, is a scrofulous inflammation. The utricle, he says, is the embroyonic cell, but in these conditions few cells are formed and there is little occasion for the utricles to pass on to the cellular stage.

The higest of the heteromorphous conditions are those in which cells are produced. But these too have degrees of "height." Nearest to the utricle is the tubercle cell. In tuberculosis the utricles are low in cell power and few cells are formed. Even once formed, many of these "low" cells regress to their utricular state. The tuberculous plasma is the result of a tuberculous dyscrasia, and though its expression may be local, the dyscrasia is general.

Yet higher in the heteromorphous series is the pus cell. This is formed in the plasma effused due to inflammation. In the highest forms of inflammation we see cells which are true "pus-corpuscles", while in lower forms we see cells which are large and round and contain no nuclei.

The highest product of the heteromorphous, according

to Burnett, is cancer. This Burnett regarded as "a form of inflammation, being general though having a local appearance." This is distinguished from other types of heteromorphous products by its high degree of organization. It has no particular form or structure, though the microscopist can, with experience, recognize the cancer by the lack of "type-peculiarities."

Burnett states that cancer has an almost limitless power of expansion due to a capability for self-propagation and perpetuation. Yet, he says, when the cancer is entirely removed the locality is not any more liable to reappearance than it was previous to the first invasion. Malignancy, is, therefore, due to a high power of cell-reproduction.

"I look upon the subject of cancer", wrote Burnett, "as a histological product, the expression of a constitutional dyscrasia, under the form of the highest pathological cell with which we are acquainted."[29]

Burnett then discusses the homeomorphous cell products, deviations of the type-power rather than of the plasma. He refers to them as epigeneses.

First he discusses the epithelial epigeneses, among which are tumors of skin, mucous membranes, and ovaries. Among these he includes the dermoids and cystic disease of the ovary. Yet he believes that dermoids are actually part of a forming embryo, for, as he says, it is impossible to believe that a human being, or parts therefrom, can be formed

without the aid of the fertilizing fluid of the male, even though the virgin aspect of the sexual organs is often insisted upon."[30]

He then hastily surveys the subject of vascular epigeneses and denies the presence of muscular epigeneses, saying that muscle does not even regenerate when injured, but scar tissue forms at the site of injury.

Burnett feels that nervous tissue likewise never regenerates even though replaced by a tissue capable of exerting nerve-power. The tumors of nervous tissue, he says, are fibrous in type rather than nervous.

Burnett is of the opinion that tissues give rise only to their own types and believes that the report of cartilage being seen in tumors other than endochondroma is wrong because it would mean origin of cartilage from another tissue. Origin of one tissue from another can no more occur, reports Burnett, than can spontaneous generation, each tissue having an individuality which precludes the occurrence of a situation such as this.

Burnett discusses the osseous epigeneses and differentiates simple calcification from true osseous epigeneses.

Among the epigeneses which from his previous descriptions would appear to be benign, Burnett includes the fibroplastic or sarcomatous tumor, which he feels is a member of the group of fibroid epigeneses.

As the last of the epigeneses, he discusses the adipose

epigeneses, saying that they are always benign and when they endanger life do so only on the basis of size and location rather than malignancy.

Burnett admits the incomprehensive nature of his discussion of pathology, saying that he has omitted a number of diseases from consideration, particularly diseases of the blood.

He summarizes his pathology in the statement that "the part which cells play in pathological products is certainly very extensive; they may be said to constitute the chief but not the sole actors."

"Pathology" he says "we have seen to be not an entirely distinct, but only an erring, fallen condition of physiology ... these pathological cells often have the exact physical semblance of those in health, but if their imperfection is not traceable in their physical organization, it is manifested in their meaningless destiny."[31]

Burnett recognized the importance of cellular pathology and the importance of microscopic study of tissue, but recognized too the limitations of this pathological study, at least as it was done at the time.

He seems to have accepted in great measure the widespread dyscrasia theory of the time, but to have modified it with a theory of the ability of the cell itself or the tissue to become pathological.

It is difficult to state what influence, if any, Burnett

had on the course of American pathology. Certainly his very obscurity would militate against the belief that he exerted any considerable influence on the main stream of pathology. Yet it is interesting to observe his theories of the pathological in the light of past and modern thought.

IV. The Philosphy of Waldo Irving Burnett

Burnett chooses to discuss the "philosophy of the cell" as the concluding portion of his monograph on the cell but quite apart from the formal exposition of his philosophical views, one cannot avoid meeting the philosphy of W. I. Burnett throughout his works. There is interwoven in the pattern of his science a philosphical thread which is far from being inconspicuous.

Burnett was, first of all, a vitalist. To him there is an extraneous, indefinable, vital force which separates the domain of the inorganic from the realm of the organic. This vitalist attitude he expresses, for example, in his article on the utricular theory, in which he states that the difference between the albumen and oil particles of Ascherson and the live, organic utricles of his (Burnett's) theory is essentially one of vitalization. He felt that "vitalization" is no more occult a force than the physical forces of the physicist.[32]

Burnett also believed strongly in a special creation, and directed the facts which he discovered in the course of his study of embryology, spermatology, and parasitology to the proof of special creation. Certainly it is difficult to assess the matter, but it seems as though he entered the field with a preconceived notion and strained points to collaborate scientifically his faith in a special creation.

In the course of his microscopic work, he studied parasitology and in 1850 wrote an article on the relation of the distribution of lice to the different faunas. If the theories of the appearance of animals by "metamorphotic changes" were true, says Burnett, then similar animals should have similar parasites, but such is not the case. Each species tends to have its own parasites. Further, says Burnett, if animals were produced on the basis of environment, what is the explanation for the presence of various parasites on the same animal, in an obviously similar environment.

"I think," he writes, "that the analogous species of animals of the different continents were created as such and therefore have their proper parasites instead of emanating from parent stocks." As to man having origin in the lower animals, he expounds, there is a point against that in the fact that monkeys have different parasites then do man.[33]

Similarly he brings to bear his entomological knowledge to sustain his belief in the process of special creation rather than "metamorphotic change" as an explanation for the multiplicity of animal types.

He considers the fact that the numbers of seventeen year-locusts appear to be about the same in every appearance, according to recollections. We know, therefore, he states, that though a number do not survive there are just enough

survivors to produce an equal number at each appearance. Also, he points out, the female has the proper number of egss to insure the survival and numerical stability of the species. To Waldo Burnett this is evidence incontrovertible of the "design in nature".

He points out too that in some areas there are crops of seventeen-year locusts appearing in different years. "Since we have faith in their cycle," he writes, "we must also believe in special local creations and special creation at different periods in the same locality."[34]

We also find his attitude toward special creation exemplified in an article on the relations of embryology and spermatology to animal classification. Burnett realized that in the embryology of higher animals one could see the lower animals reproduced. Though others had pointed this out as evidence of "metamorphotic change," Burnett postulated that this merely shows the tendency of "nature" to be retrospective in her works. In the course of creation there has been a succession of types. Nature, once having created a simpler animal, uses this form in creating a higher animal. One of the prime proofs of evolution thus becomes in Burnett's hands evidence of special creation.[35]

One could point out other evidences throughout his works of Burnett's philosophy and religious attitude, but the final expression of his philosophical beliefs, as of his scientific beliefs, is found in his prize essay on

the Cell.

Having discussed previously the histology and pathology of the cell, Burnett feels the necessity of integrating these with his religious attitude, and as the third major portion of his work discusses in short the "philosophy of the cell."

The cell, he says, is the altar upon which life and matter are married-the meeting point of the two in nature.

There are, Burnett states, two views of organization. One is the "teleological view", the view that all exists by virtue of a pre-existent idea and that there is an end to everything and an end in view to every existence. The second is the "physical view", the view that organic life and existence occur only through the chance combination of pre-existent inorganic forces.

To Burnett the second view is totally untenable. The inorganic, he says, may indeed be a result of simple chance, as the inorganic is simply in harmony with nature, but the organic is not only in harmony with the present but also in harmony with the future. This, he believes, cannot be simply the result of chance. As an example he proposes again the observation that the number of animals of a specific species remains essentially stable. He looks upon this from the viewpoint that when one sees the reproductive faculties of animals so 'geared' to the liabilities of destruction, one cannot but believe in a pre-existent idea according to which the formation of animals occurs.

We see an example of the occurrence of the idea prior to its concrete realization when we see an animal possess the faculties of its father, for the sperm carries within itself the idea of the formation of a certain type of animal. Within nature the idea is similarly present before creation of an animal.

He also discusses within this section the question of the nervous cells as mediators of thought and will. The cells connected with thought, says Burnett, must be different in type from all other cells. "The capacity of these cells which terminate in intellectual manifestation," he says, "must belong to them per se."[36]

Perhaps we can express the thought of Burnett in a statement made towards the end of his work on the cell, a statement expressive of the religious attitude of Burnett and his attitude toward the special status of man in creation. He writes:

> "Man's nobility lies in his exclusive possession of a deeply mysterious power, inseparably connected with, yet quite different from, his consciousness. A power to do or not do as may be; a power which may induce mental action in this or that direction without limit....This is the will-the immortal Psyche-which the innermost depths of our consciousness tells us holds no relation to matter, for it never grows weary or becomes borne down with labor, but when the intellectual acts have ceased to become distinct, it retains that freshness of action belonging to its unearthly nature. Physiology and psychology ... do not even pass into each other. By physiology we learn the necessary relations of cell life and action to the conditions of the simple intellectual act; whereas, by psychology, we seek to learn the ever-varying changes of his intellectual act due to the

> agency of the immortal will. Physiology as connected with cells would be sadly deficient did it not indicate to the humble student, as he stands upon the confines of his domain, the necessity of condition and springs of action connected with our mental life which lie above and beyond any mere conditional, relations of ever-changing, decaying matter."[37]

We see here the attitude towards man as a special creation of God and of man's possession of a will and soul peculiar to him alone.

We find the expression of his faith in a statement made at a meeting of the American Association for the Advancement of Science in 1851. Having spoken in favor of special creation he said:

> "In studies of this kind we ultimately rest on the confines separating the scientific from the higher world of thought; and if the mind is rejoiced in looking back upon the realities of the one, it has much more reason to do so in looking forward to the anticipations of the other. If, in pure science, we are to have reasons and demonstration, and not faith, it is here that the latter takes our hand and it is a faith too, not blind, but intellectual, and which is constantly leading us on to the full appreciation of that highest and most stable of mental facts, which is the existence of a First Great Cause, who laid the foundations of the earth, and by special fiats, at different epochs, created all therein."[38]

V. The Importance of Burnett

In this necessarily short discussion of Waldo Irving Burnett we have to limit ourselves to the consideration of only his most important work: his work in histology and pathology and to his general philosophy. Yet, as the preceding chapters and the bibliography show, Burnett wrote also on embryology, entomology, parasitology, and even on climatology in disease.

Burnett was not one of the greats among histologists such as Henle, Koelliker, Hassall or Donne. He made no great discovery and his mistakes are multifarious, often in fields in which others had previously enunciated the truth as we believe it today. His love for generalization often led him into error in the attempt to encompass too much within a single theory, and his religious beliefs no less led him to deny what his scientific conscience should have led him to accept.

Yet, even his errors are often not without interest, and there is a significance about Burnett which should be pointed out.

Burnett rose to histological study from an American atmosphere virtually barren of histological interest or achievement. As has been pointed out, American scientists had played no role in the progress of histology and the few who employed the microscope for study had done so only on occasion and, as a rule, in no serious manner. Burnett,

on the other hand, concerned himself mainly with histology throughout his scientific life, studied the European literature, and sought to confirm by personal observation what he read and to discover the new. His publications reveal the background which he possessed and the personal observations which he made.

Burnett thus became one of the lonely precursors of an orientation towards the laboratory, a method of approach that did not become powerful in American medicine until thirty years after his death. He is therefore an important and interesting figure in American medical and cultural history. Some of his philosophy points towards the famous English Bridgewater treatises, and some even more towards the German influences which were also so conspicuous in Emerson.

Although Burnett contributed no important solutions in science, he showed an amazing flair for relevant problems, problems which were to become the dominant ones in medicine and biology. Thus he concentrated on cellular pathology as well as on evolution before the appearance of the classic works of Virchow and Darwin.

In the final evaluation of Burnett's achievement we must consider too the circumstances of his life. Ill from youth with the ailment which was to kill him, and realizing full well the inevitably brief duration of his life, he nevertheless wrote some 60 articles before his death at the

age of 27. Even his own illness served as a basis for at least two articles, one on "A Consideration on a Change of Climate by Northern Invalids and on the Climate of Aiken, South Carolina" and another on "Considerations on Some of the Relations of Climate to Tubercular Disease." The scientific spirit of Burnett was always active, even his own misfortunes and tribulations serving him as a source of material for research.

Certainly Burnett's prize essay on the cell should be given a place among the classics of American histology, for this essay seems to be the first American attempt to comprehensively consider the cell, its physiology and pathology. Indeed, insofar as mere arrangement is concerned, this prize essay is more comprehensive and orderly than are even the European treaties up to the time of Virchow's Cellular Pathology.

Burnett played a role in the growth of American histology through his numerous appearances before scientific groups, through his numerous writings, and through his comprehensive prize essay on the cell. The then young science of histology in America suffered a severe blow in the death of Waldo Irving Burnett, for though young in years at the time of his death, Burnett had accomplished much and held forth much promise for future contributions. Devoted, industrious, and active, Burnett had earned an honored place among the scientists of his time.

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