universally, and form part of the education of every liberal-minded and intelligent man. Dr. Draper's books show that he was a deep thinker in the department of the philosophy of history and human progress, and that he aimed to exalt the intellectual development of man.

The "*History of the Conflict of Religion and Science*," a work which many readers consider is incorrectly represented by the title, proves how broad and liberal were Dr. Draper's views, and it may surprise many to learn, that such opinions were not considered by him inconsistent with religious belief. The materialists appear to have written and published in vain for him, as we are told in the "*American Journal of Science*," that "it is a satisfaction to affirm that he was a theist and a firm believer in a future state of existence, for which the present is only a preparation."

On the 4th of January last, Dr. Draper peacefully surrendered his life, honored and respected by all nations, for his fame had been diffused throughout the civilized world by reason of the translation of his works into both European and Asiatic languages.

Dr. Draper leaves two daughters and three sons, the latter having already achieved distinction in pursuits kindred to the work of their father. As the work of Herschell was continued by his son, so in Professor Henry Draper we find all the special qualities for maintaining the high prestige of the family name; his recent success in photographing such difficult celestial objects as nebulous matter, and the important discovery of the presence of oxygen in the sun, have placed him in the foremost rank of original scientific workers, and the furthur development of his investigations are anticipated with keen interest by physicists, both in this country and abroad.

VEGETABLE PATHOLOGY.

By T. J. Burrill, Ph. D.

It is not an easy accomplishment to separate physiology from pathology when, instead of dealing with the definitions of words, we attempt to classify the operations taking place within a living object, by placing them in the one or the other category of activities and effects. Indeed there is no well marked and uniformly acceptable line of division. We may speak of one as normal and healthful and the other as abnormal and injurious; but these vary with the standpoint from which our judgment is made, and with the conditions which modify, this way and that, the results.

If these things are true as regards the vital processes of animals, they are much more evidently true concerning those of plants. In the latter, the standards of health and disease are not so well agreed upon; less attention has been given to the life processes and their results; the individuality of the plant has been less recognized, and its own particular good or injury less regarded. If an apple-tree produces for *us* a crop of good sized, highly flavored, richly colored fruit, we do not stop to ask whether these luscious pippins are the results of physiological or pathological operations, judged from the standpoint of the *tree*. If a cabbage has its terminal bud enormously developed so as to be called a head, the monstrosity never calls forth a compassionate word of sympathy as *we* enjoy the crisp and savory production, for a New Year's dinner. The ink with which we preserve our thoughts, flows no less freely because of a peculiar wound in a particular tree by a particular insect, and a most wonderful malformation of the growing tissues in consequence. We have not listened to the masterly disquisition of a learned and betitled oak upon *septicemia* or the curiosities of *traumatic tumors*. We have heard no complaints from suffering, bleeding grape vines; no uneasy groans from plants perishing through the withering effects of blight and mildew.

But the terms physiology and pathology do have a meaning answering to the operations and conditions of health and disease in plants as well as in animals. The grasses of the fields and meadows may flourish in the luxuriance of bountiful supply and perfect adaption, their vital forces being attuned and harmonized into combinations of causes and consequences, all conspiring to the good of the individual and the welfare of the species; or these members of the vegetable kingdom, may, through unfavorable conditions, through privation, through the attack of enemies, become dwarfed or distorted, weak or disproportioned, unfruitful or incapable of growth and self-perpetuation.

Without attempting to give in this place a classification of the diseases of plants, much less a description of the many that are now known and more or less clearly understood as to origin and progress, we proceed to give some account of a few of the more general facts and phenomena connected with our subject.

THE PROCESSES OF PHYSIOLOGY AND PATHOLOGY IN PLANTS ARE SLOW.

Except in the case of violently disturbing causes, like fire, frost, caustic chemicals, etc., disease or death never attacks a plant in the sudden and unheralded manner frequently known in animals. It is true that what has been called "blight," a very indefinite and loosely applied term, is usually supposed to be the work of a day or a night, perhaps of an hour; but the facts have not been known by those who make this supposition. If by "blight" is meant the results of a tornado or even of a sirocco, with which we of Illinois can claim some acquaintance after the last summer's experience—if these are meant, we cannot say that "blight" is not sudden; but the effects of such agencies should be classed as injuries rather than as diseases, There are really no exceptions to the rule that true pathological operations in plants are slow in their progress. The healing of wounds offers us a good illustration, if we examine the process in plants compared with that in animals. If from a healthy, rapidly growing tree, we cut off a limb close to the trunk, making a wound one inch in diameter, a whole year will scarcely suffice for complete healing, while in most animals a clean cut of this kind may be covered with newly produced tissue in a fortnight. We talk about the *circulation* of the sap; but in plants the fluids do not circulate in any proper sense. The slow movement which does take place is at best a process of *soaking*. When water is most rapidly ascending in the stem of a leafy plant to supply the loss by transpiration, one foot per hour is more than is commonly gained; and this is altogether exceptional speed for movements in plants generally. This feeble distribution of the fluids in living vegetation is no doubt one of the reasons for the slow workings of disease. Again the want of sympathetic action of one part with another, so common in animal bodies, is almost or entirely wanting in plants, due probably to the absence of a well developed nervous system. Nothing is more common than to find a leaf dotted here and there with diseased parts, while the intervening tissues remain active and healthy. No organ suffers because another is affected, unless there is a direct dependence in the way of food supply or other similar reason. Hence diseased action can not be rapidly communicated from part to part. The tree never becomes flushed with fever because some one or more of its members have met with disaster. In order that disease may spread at all, it is necessary that the disease producing agent shall itself spread from its original point of attack.

INHERITANCE, OR CONTINUANCE OF PECULIAR EFFECTS.

The protoplasm of the cells is "the physical basis of life" in plants. From this flows the issues of life. Not only all other material products are secreted by the more or less plastic, often semifluid, substance known by this name, but the peculiar and unexplained products of vitality are due to the same source. Whatever potential difference exists in the seed of a thistle separating it from that of a turnip; in a bit of a twig of a Bartlett pear, used as a scion, from the worthless stock on which it is set; whatever difference there may be between health and disease, considered as a constitutional affectation, resides in this wonderful, ever-present, ever-important constituent of living plants—protoplasm.

There is nothing more wonderful in the phenomena of plant life than the peculiar tenacity with which an impression once made is held by living protoplasm. We may not be able, with all our skill, to introduce or cause a change to take place; but when an effect is produced, the changed cell may by reproduction become tens of thousands of similar cells, all having the same peculiarity of vital potency and power. It is upon this principle that horticulturists depend in the propagation of special varieties of plants by grafting, budding, cuttings, etc. It is because of this mysterious but interesting quality of the "germinal matter" of the tissues of plants that Baldwins among apples, Bartletts among pears, Marechal Niel's among roses, etc., are possible.

Now any deviation from the normal character of the plant by which it is rendered less capable of succeeding in the struggle for existence on its own account, and by its own forces must be considered a disease. Usually our highly prized fruits are produced as abnormal growths, and the trees that produce them are notoriously liable to seriously suffer from enemies and unfavorable surroundings and conditions, which, to their rough, hardy progenitors would have been as the summer shower and the smiling sun.

So the blotched leaves and variously colored foliage of many decorative pets of the garden, are but indications of a protoplasmic impression continuing itself as a disease. When it happens that these disease changes of the plant are beneficial to us, or when they in any way please our fancy, we do not think of them as pathological conditions and effects; but when through the operations of the same law the opposite is true, we quickly enough talk of failure through disease. Our potatoes all go to vines with no tubers, our strawberries blossom profusely but the flowers are "blasted," our sweet corn becomes too big and coarse, our melons lose their sugar, etc. How the impressions originally occur we do not usually know, but that they are made we cannot doubt, nor too clearly see their permanence, if we would study the causes of health and disease, and try to learn how to profit thereby.

Connected with this topic is a most peculiar phenomenon not yet well understood on the botanical side and perhaps not yet adequately studied. Who can explain why it is that a certain and regular abnormal growth takes place on a given plant after the sting of a certain insect forming what is called a gall? Anyone who has seen the leaves of a jack oak ornamented with "oak apples," especially if he has broken them open and examined the complexity and regularity of their structure, can hardly have helped wondering at the peculiar something which could produce in an abnormal, diseased growth so close an imitation of a true and proper fruit. What can be more strange with our knowledge of the constancy of form and character in plant growth generally, than that a tiny wound with the injection perhaps of a minute drop of a special kind of poison by a particular insect, should entirely modify this growth and produce, not a distorted, irregular knot, but an uniform, constant and thoroughly characteristic though abnormal multiplication and shaping of cells, producing thereby an organic structure so peculiar and so uniformly the same that it may be subjected to all the procedures of natural classification and of specific identification! Though the subject has not been studied from the botanist's stand-point, especially in its physiological or pathological bearings as its importance would seem to justify and demand, it is at least questionable whether the microscope would reveal anything tending to explain the marvelous result. The structure is, like other plant tissues, formed of cells which through inherent forces and properties, rather than through external agencies, shape themselves, and by their co-ordinated and united impulses give form and character to the resulting production. It is also here as elsewhere, the living protoplasm that receives and bears the directing impulse. The cell walls passively bend and swell under its silent and incomprehensible, but dominating power. The wonder is increased when we remember that the growth is not a continued reproduction of the same thing, but that certain cells of the new structure are shaped and modified to form the external wall with its various and inter-differentiated layers, others to form the core or nucleus and still others widely differing from any of the former to make up the mediary parts of the gall. What subtle influence, what magic power is it, that thus toys with the vitalized forces and substances of the plant? What invisible barrier turns the usually inflexible current of life from its healthful and appropriate course and converts the onward rush into swelling pools with their own peculiar currents and eddies and waves, and self-controlled depths and boundaries? A gall produced by a plant in obedience to a particular act of an insect is certainly a most remarkable thing, and merits the closest and most profound study. Why should not man be able to effect as great a modification in the growth of a tender plant, as a buzzing insect? If we knew how why should we not gather grapes from thorns and figs from thistles?

But we must not lose sight of the fact that so far as the plant is concerned, a gall is a disease and sometimes a very serious one. If there is anything whatever, in plant pathology to support Dr. Lionel Beale's theory of "disease germs" being the degraded but still living cells of the ordinary tissues, it is this of insect galls. Is it not possible that a careful study of the latter might be of service to the specialist in gaining more and better knowledge of the origin and development of cancer in the human body?

PLANT DISEASES ARE DUE TO SPECIFIC AGENCIES.

There is no more important item of knowledge connected with vegetable pathology than that each disease has its own predisposing cause, or, in other words, that each disease is a specific thing itself, in the same sense and manner as a particular plant belongs to a species bearing relations to, but unlike every other species.

There is no clearer illustration of the truth of the foregoing than in the matter just before us of insect galls. Entomologists have given these structures much attention, and it is found as easy to recognize the gall as a species, as it is the insect that causes the growth. A skillful specialist in this matter will give us the name of the insect on seeing its domicile, as readily as upon seeing the winged inhabitant itself. Each one of the hundreds of these curious structures differs from every other one, and owes its existence to a different agent from that of any other one. There are a very few possible exceptions to this if we limit the difference in insects to specific distinctions, for it is known that at least one species produces several kinds of galls on the same parts of the same plant, while others make somewhat different galls on different parts of a given plant, as in the case of the devastating *Phylloxera*. But every one knows that the individuals of a species vary much among themselves, so that our rule should be strengthened rather than broken by these apparent exceptions. There are at least one hundred kinds of galls known upon oaks; hence we may say there are one hundred specific agents, each working after its own fashion and producing its own peculiar results.

Much might also be said of diseases of plants caused by insects which do not form galls, illustrating the same thing; but these are passed without remark to save time and room for those more particularly falling under my own observation and the subjects of more personal investigation, viz: those caused by parasitic fungi.

Though having had a very good chance to find out, I do not know of a single flowering plant in our country which is not more or less injuriously affected by one or more fungi, living as parasites on, or in, its substance. Sometimes numerous species dwell on (or in) one host plant; sometime the same parasite preys on many kinds; but very often a particular fungus is found only upon a particular supporting plant. Nearly all of these myriads of thieves are so small that they cannot be seen, certainly are not usually seen by the unaided eye, except as they occur in masses. Many are at times exceedingly destructive, as witness the wholesale rotting of potatoes during certain seasons, while yet in the ground and attached to the stems of the plants; and the dreaded rust of wheat, which apparently cuts off the farmer's returns for a year's labor in a week or a day. We pay less attention to the diseases and death of uncultivated plants, but these, too, suffer as severely. I have observed great areas of thickly springing smart weed (Polygonum Pennsylvanicum and P. hydropiper) destroyed almost as effectually as by fire, by a vegetable parasite (Helmin thosporium) whose corrosive action caused the leaves, long before frost in autumn, and before the maturity of the plant, to shrivel and die, after which the entire plants soon succumbed.

Though these mischief-makers are usually invisible to untrained and unaided eyes, their peculiar effects are ordinarily recognizable at once, by an expert, even without his magnifier. Each has its own characteristic influence upon the host—one causing yellowish spots on the leaves, another a curled and distorted growth, another little cracks on the stems, another swellings like insect galls, etc., etc. A closer examination brings into clearer relief the different injuries or modifications of growth, caused by each different parasite. Each faded spot, each tumid projection, each rupture of the epidermis, each blister and canker, each puncture and corrosion, has its own more or less clearly marked characteristics; and each parasite has, as well, its own pathological influences and effects. The grapevine alone has at least thirty species of parasite fungi peculiar to it and all more or less injurious, while an entire book of some hundred and fifty pages has been filled with generic and specific descriptions of fungi, known to occur on the cultivated vine. (Thümen, Die Pilze des Weinstockes, Wien, 1878.) The list of specific and separate causes of disease in plants thus immeasurably exceeds that known to the wisest practitioner of medicine for man, for the illustration from the grapevine, though a strong example, is not exceptional. Of fungi, as a class, there are many more species growing in Illinois than there are flowering plants, putting the native and introduced together,—at least double as many. Large numbers of these, however, never grow on living plants; they are the scavengers of the vegetable world.

Two questions may now be raised. (1.) Are all these fungous growths really divisible into good specific forms? in other words, can the term species be applied to these various productions in the same sense as it is used for the higher plants and animals? (2.) Do those kinds known to inhabit living plants really cause disease, or are they mere concomitants of pathological conditions, due to other influences?

These questions are continually pressing for answer, founded on careful observation and skillful investigation. The first one has been, and must be, answered unhesitatingly in the affirmative by every botanist who has made, or may make, a special study of the plants. There are curious alternations of generation, as among the lower animals—a given species presenting itself under two, three, or even four forms. There are also deviations from the recognized type, and modifications due to circumstances and conditions; but it is doubtful whether these fluctuations are greater than in the species of higher and better known organisms. It does require, perhaps, keener perceptions to distinguish allied species than among those having greater differentiation of parts, as root and stem and leaf and flower and fruit; but none of these affect the general question. We admit the probability of evolution of species in the world, and should be theoretically disposed to look for greater plasticity in these low forms than in the higher; yet, except in the particulars cited, observation does not apparently support the deduction. I am sure that any botanist, equally familiar with the two, will as positively recognize *Puccinia graminis*, the rust, or, rather, one of the rusts of wheat, as he will *Triticum vulgare*, though the former is very variable for a fungus. The same may be said for *Ustilago maydis*, the smut of corn, and *Zea mays;* but, in this case, there seems to be no variableness nor shadow of turning in the characteristics of the parasite. Hundreds of even better illustrations might be given, all conspiring to enforce the opinion upon the skeptical, that these low, mostly microscopical plants, have specific distinctions as characteristic and rigid as those found among the higher organized, if not more respectable and reputable members of the vegetable kingdom. It is yet to be proved whether or not hybrids ever occur among the fungi; the very fact that none are positively known, or even reported as suspected, helps to indicate the goodness of the species to botanical eyes. Still there is much to be done in the way of experiment, by sowing spores and watching the development of the plants, before much confidence should be placed in the slight distinctions now used in many cases for specific separation.

Passing to our second question, a direct answer cannot be given. In the interdependence and complexity of relations existing among all living organisms, it is exceedingly difficult to pronounce upon the exact effect of any one of them, considered in and of itself. Cold water is not regarded as poisonous to man, yet individuals have severely suffered, even died, from the effects of a reasonable (so far as amount is concerned) draught. Arsenic is poisonous, yet there are those who swallow what would ordinarily be deadly doses, with impunity. Poisonous doses of opium are merely nerve restorers to the habitual eater of the drug. Shall we then say that water causes death when taken to allay thirst, and arsenic and opium are not poisonous? Shall we not rather say that whatever proves seriously injurious to man in a normal condition, under the usual circumstances of his life, is the poisonous thing, and the one which *causes* death; while we assign the peculiar and abnormal condition as the cause in other cases,—as the over-heating instead of the water.

Measured by this standard there are many parasitic fungi which must always be acknowledged as a "cause" of disease in the higher plants, for they germinate and grow under the usual conditions of our summer weather, and penetrate and develope in and at the expense of otherwise healthy plants. Under these conditions it is only necessary to place the matured spores on the parts of the plants inhabited by the fungus to ensure its growth, and, in consequence, the disease. It is, however, even in these cases, evident that much must depend upon the peculiarities of the weather, etc., whether the host or the parasite is specially favored or repressed, and so whether or not the disease is seriously injurious.

Rust spores on young wheat leaves in spring time are as certain to germinate and penetrate the tissues as arsenic is to poison mammals. In this case development goes on but slowly however, unless specially favorable conditions occur for the parasite, when, in the latter case, it makes its presence easily recognized by the disastrous results too often witnessed. Smut in wheat is less affected by peculiar states of the climate. The spores send their germinal tubes into the tissues of the seedling plants; the fungus grows with the host, and finally, just before harvest time, matures its spores again in the aborted wheat grains. Blight-bacteria, again, need only to be introduced in few numbers into the living bark cells of a healthy pear tree, during ordinary Summer weather, to insure their reproduction and multiplication in myriad numbers, and the death of the invaded cells in consequence of their deleterious action. It is by on means true that plants must be in an enfeebled condition that such parasites may grow upon them. The very vigor of the host often adds, by furnishing more assimilable food, to the extreme development of the parasites.

On the other hand there are many fungi that only grow on the higher plants when these have been injuriously affected by something else, or when the conditions are peculiar and altogether unfavorable for their proper development or growth. Thus apples become "scabby" by a fungus belonging to the preceding class, but they often rot while hanging on the trees through the effects of other fungus never injurious to perfectly sound fruit with an unbroken skin or epidermis. Peaches rot upon the trees under the effect of a mould-like fungus which produces myriads of spores that readily float like dust in a dry atmosphere, but these do not germinate except in moisture, and, as their duration of vitality is very short, few succeed in reproducing the plant except during rainy weather, when one decaying peach may be a source of contagion for hundreds of others. There are too great numbers of leaf-dwelling fungi which only grow upon these organs when from old age or other causes they have lost their powers of existence through the diminution of their vital forces, so that the mycologist learns to look upon old and fading leaves for numerous specimens. In the descending scale we find vast numbers of still other fungi which only grow upon really dead organic matter; these however have no share in the title parasitic.

It may therefore be concluded that, in the struggle for existence, many species of fungi have acquired the physiological power of overcoming the defensive forces of certain higher plants in a state of health under ordinary conditions of plant life and growth, while others, truly parasitic in their nature, are obliged to seize upon favorable chances to take advantage of slight or serious misfortunes happening to their hosts, thus giving the kick to one already going down hill.

I have thus endeavored to point out some of the general truths of vegetable pathology as they appear to one who accounts himself a student but not a master of the subject. I enter the open gateway of a great field, and make little incursions here and there, gathering now and again from the abundance offered, material for many odd hours of microscopical work, which again furnishes "food for thought" when the lamp has been extinguished and the scalpels laid away. There is much room for many better workers, and much interest for those who will work.

CROTON WATER OF NEW YORK.

It is admitted on all sides that an improved supply of water for New York city, both in regard to quantity and quality is imperatively demanded by its citizens, and the subject in one form, will shortly be discussed by the legislature at Albany.

In regard to quantity, the solution appears a simple one, as the present supply is adequate for all legitimate purposes; in fact, if it were not for the great waste of water now practised, the supply would exceed all demands of the present population.

It is claimed by the "*Sanitary Engineer*" that this waste is due to imperfect plumbing, and the facts and figures given, show that such a supposition is, in part, correct. Every householder, however, knows that a wasteful use of the water, due to the whole supply of the city being at the command of every individual, must lie at the root of the evil.

Much printers ink has been wasted in printing proclamations from the authorities to the people, counselling economy in the use of the water, but the time has, perhaps, now arrived when the legislature should decide to employ some remedy and make radical changes in the method of distributing the supply.

The method of running the main supply direct into every house, is certainly the most primitive and least scientific or practical of all means at command. It is an invitation for waste and extravagance, and has proved an utter failure, as the means for thus distributing a supply are so defective that, while one family in a house can draw on the Croton river at will, others, less fortunate, on another level endure a constant water famine.

The whole evil of this imperfect distribution of the water could be remedied, if the supply were made by cisterns only. This system has always been in use in London and answers admirably. Every householder under this system has one or more cisterns filled twice daily, and is not restricted either to the number, capacity or location of the cisterns. Thus each householder pays *pro rata* for the actual amount of water he consumes annually, which, beyond doubt, is the only equitable method of charging a water rate. In the case of manufacturers a meter is substituted, if desired.

A natural accompaniment of this system is a universal high pressure of water throughout the city, which provides that cisterns in the highest part of every house shall receive its supply daily. This mitigates the evil under the present system, of pumping and carrying water above the first and second stories, now necessary in most houses in New York city.

The economy of the cistern system is self evident for no one would call for more water than he could legitimately use and increase the annual water tax. Thus a premium for economy rather than waste is offered. In a sanitary point of view many advantages are attached to the use of cisterns, as the large amount of impurities have time to subside and the water is consumed in an improved condition. It is usual to construct one of the cisterns with slate, which is reserved for drinking purposes.

The plea that such a system curtails the proper use of water has no foundation in fact. The writer lived in a house in London for many years, under this system of supplying water, and found he received not only abundance for family use, but sufficient to water a large garden. If the system here described were put in practice in New York city, and the plumbing perfected, the present supply of water would be found ample, and part of the money now proposed to be wasted in making new storage reservoirs might be profitably used in building pumping stations, which would give a high pressure of water to all the upper rooms in the city, and increase the efficiency of the means now at command for extinguishing fires.