not to laud his contributions but to speak in simple terms of him as a person. There is very clear in memory his act of kindness to the speaker who was a young experimenter in another laboratory. It betrayed a genuine human interest that, wherever found, compels admiration. His mind was keen and full of suggestions to the students in this Jefferson Physical Laboratory. Although kind and generous, he was intensively a just man. Never aggressive in a bold sense, others sought him out. He was essentially modest, but he had confidence in his mental powers. He was fine in spirit, outwardly highly acceptable and, withal, a splendid type of gentleman. One can not forget him as a person.

G. W. Stewart

University of Iowa

THE ORIGIN AND STRUCTURE OF PLANT GALLS[1]

The study of the histology of pathological tissues of plants has been very much neglected, especially in America. It is true that more or less extensive studies have been recorded and discussed in the papers on the various diseases of plants but nothing has been done towards bringing this data together into a comprehensive whole. In recent years this phase of botany has begun to attract attention, especially in the case of abnormal growths, which have been referred to under many names, such as cecidia, galls, cancers, hypertrophies and various terms which are more or less indefinite. It is the purpose of this paper to give a brief historical review of the phase of plant pathoanatomy which is involved in these abnormal structures. The fact that the author has made rather extensive studies of those plant galls which are the result of insect stimuli may be a sufficient excuse for attempting to discuss this very broad subject involving similar abnormal plant structures which are attributed to other organisms. Abnormal growths on plants are caused by insects, nematodes, fungi, slime molds, bacteria and chemical and mechanical irritations. Similar growths are also produced on animals; but, in general, it may be said that the causes are not nearly so well understood as in the case of plants. On the other hand the histology of abnormal animal growths has been the subject of much more extensive studies than that of those found on plants.

The plant galls which are caused by insects were among the first to attract attention and the early Greek literature contains many references to them. However, very little real progress was made until Malpighi published his "De Gallis" in 1686. This work was primarily descriptive but the author also advanced the theory that the excitation was due to a poison secreted by the mother insect. Although this idea was disproved long ago, there are some text-books which still retain this so-called "chemical theory" of more than two hundred years ago. The next great advance was about fifty years ago and was marked by Adler's "Ueber den Generations-wechsel der Eichen Gallwespen," a work dealing entirely with oak galls caused by insects. The works of Adler, Beyerinck and their contemporaries gave us very definite information concerning the life history of some of the causal insects and the structures of certain insect galls, and disproved the theory that the excitation was due to a fluid secreted by the mother insect.

The European literature is much more extensive than the American. In this country the major part of the work has been by entomologists but within recent years has attracted the attention of several botanists and papers have been published by Cosens, Rosen and Wells. Felt's "Key to Insect Galls" is the most complete and usable work in our American literature for the determination of these plant growths. He lists and describes more than 1,400 species, a number which is no doubt insignificant when compared with the number of undescribed species. In most cases each species of insect cecidium is confined to a single specific host plant and those that occur on more than one host are restricted to closely related species.

A few species of nematodes are well known as the causes of abnormal plant growths. They are widely distributed throughout the world,

[1] Address of the vice-president and chairman of Section G, Botany, American Association for the Advancement of Science, Boston, December, 1922.

especially in the tropical and subtropical climates and the literature is voluminous. It appears that the Reverend M. J. Berkeley, the mycologist, was the first to describe and figure the nematode root galls and to recognize that they were due to an animal organism (1855).

Fungi are the causes of many abnormal structures, such as cedar apples, peridermium growths on conifers, witches' brooms and other hyperplasias of various types which are so well known to botanists that it is not necessary to more than mention them at this time, although they will receive further consideration in the course of this discussion. Slime molds are the causes of some few abnormal growths; the most important being the well-known "club root" disease of cruciferous plants caused by *Plasmodiophora brassicæ* which will be referred to later.

Bacteria are recognized as the causes of such well known abnormalities as crown gall and hairy root, olive knot and legume tubercles. The first of these has received a great deal of attention in recent years because of certain resemblances to animal cancers. Crown gall attracted the attention of the European workers more than sixty years ago but the American literature contains practically no references of importance previous to 1891. Interest in this line of study received a very great impetus in 1907 when Smith and Townsend announced the discovery of the causal organism which they designated as *Bacterium tumefaciens.* The later work of these authors and of Hedgcock, Levine and others of the last quarter of a century is well known to this audience. The studies of the olive knot have been much less extensive. The legume tubercles have been the subject of extensive studies with reference to the organisms producing them and their economic value, but comparatively little attention has been given to their origin and structure. It is very well known that the abnormalities designated as "œdemas" are the results of chemical irritations; and that calluses and some other enlargements are frequently due to mechanical irritations. They have received very little attention.

Many problems have been suggested in connection with the study of plant galls. One of the earliest had to do with the nature of the irritant and has never been answered satisfactorily although centuries have elapsed since it was first proposed. Another and more recent inquiry involved the relationship of these growths, especially the crown gall, to animal cancers. Unfortunately the workers on these various groups of galls have very generally possessed but little knowledge of the other groups. It appears to the writer that it is desirable to correlate our knowledge of these various groups of galls as a basis for future study in this very interesting and important branch of botany.

We have previously stated that the old idea that insect galls were due to a chemical secretion by the mother insect is no longer accepted by the students of the subject, except possibly in the case of a few Nematus galls. Adler also showed that there was no cell division or growth until the larva emerged from the egg. Whether the very rapid growth and cell division which follows this event is due to the voracious feeding of the larva or to a chemical secreted by it is a problem which is likely to remain unsolved for some time to come. Küster is of the opinion that the excrement of the larva of *Pontania salicis* is capable of causing cell division in the host plant and this idea is supported by Cosens in his study of our American species, *P. pomum.* Both of these workers have also carried on experiments demonstrating that the larvæ of some of the Cynipidæ secrete enzymes capable of changing starch to sugar. The most generally accepted views at the present time are: (1) that the stimulus is purely mechanical; this may possibly be true sometimes, but certainly is not true in the majority of cases, (2) that the stimulus is due to a chemical action; this is more plausible in the light of modern research. However, in the case of insect galls the stimulus must come from the larva rather than from the mother insect. In the case of some insects the egg is within the tissues of the host plant and the emerging larvæ attacks the meristematic cells. In the case of some other insects the egg is placed on the surface of an incipient organ and there is no gall formation until the young insect emerges, when a more or less well defined pocket gall is produced. In this case we have no positive evidence as to whether the gall is the result of a chemical or a mechanical irritant. However, there is undoubtedly a growth beyond the point of irritation. It is also generally believed that the stimulus endows the protoplasm with the power to develop new tissues or organs, but Cosens has advanced the more plausible theory that these new tissues and organs "are due to the awakening of dormant characters in the protoplasm." The characters are already present and the stimulus enables them to develop.

Nematodes work their way through the tissues and no doubt stimulate growth during their journeys and after coming to rest, but we do not know whether the stimulus is mechanical or chemical. However, cells not directly in contact with the organisms are stimulated to activity. Our data on galls caused by fungi with reference to this phase of the subject are very limited and unsatisfactory. It is very evident that the stimulus must be applied to meristematic cells. The ramifications of a fungus through the tissues extends the area of stimulation and development, but it also appears that cells not in contact with the fungus enlarge and divide. The slime mold, *Plasmodiophora brassicæ,* penetrates the cells, causing both cell enlargement and cell division, but in this case the neighboring cells which have not been attacked also undergo division, apparently due to some substance passing from the infected to the uninfected cells. Division also occurs in cells which are not in direct contact with the infected cells and may be due to pressure in both cases.

Galls caused by bacteria show considerable variation and may be divided into three groups as follows: (*a*) those in which the bacteria occupy small pockets and stimulate the surrounding cells, as in the case of the olive knot; (*b*) those in which the bacteria are within the cells as in the case of the legume nodule forming bacteria; (*c*) those of the crown gall type which are not well understood, although it is known that they are not in the vessels or in the intercellular spaces. Smith at first attributed the formation of the crown gall to bacterial products or toxines which escape from the infected cells. But in 1917 after successfully producing abnormalities by the use of a number of chemicals, both acid and alkaline, and also with distilled water, he came to the conclusion that "any soluble substance whatever, except a killing, a plasmolyting or an oxygen absorbing substance, if continually liberated in excess locally in tissues, would be competent to induce tumor formation." He also says "that dilute ammonia causes intumescences and have rendered it probable that ammonia liberated within the cell in small quantities by the imprisoned bacteria must be one of the causes of the excessive and abnormal cell proliferation in crown gall. Probable amin compounds also help to determine it. Since an acid and an alcohol are likewise produced by crown gall bacteria and this alcohol and this acid (as well as other acids) in pure dilution and also in combination with ammonia caused galls or intumescences in my experiments the acid (or acids), the alkalies and the alcohol must, I believe, act together in producing tumors, and *osmotically rather than chemically.*"

The reactions of host plants to parasites are many and various, but we are dealing with those which have to do with stimulations and hyperplasias. These structures appear on a great number of species of plants and are caused by organisms belonging to a very large variety of different species of animals, plants and bacteria. They are produced on all parts of the host plants and the external forms of these growths are very numerous but the histological structures are few and harmonious, regardless of the causal organisms or the species of the host plant. In fact it is doubtful if there are any new histological structures. The writer has repeatedly called attention to the fact that there are three well-defined stages in the formation of plant galls: (1) cell enlargement or cell division or both, (2) the failure of the affected part to differentiate into the characteristic tissues of the normal plant organ on which the gall is formed, and (3) the differentiation into the characteristic tissues of the gall. The writer and others have also called attention to the fact that in the Cynipidous galls which show the most complex histological structures, the tissues are organized into four well defined concentric zones surrounding the larval chamber.

The first stage in the development of the gall, regardless of host plant or causal organism, is cell growth—either cell enlargement or cell division or both. The result is the development of parenchyma tissue from which differentiations into other tissues may or may not arise. A number of years ago the writer called attention to the fact that plant galls caused by insects could be grouped into four classes on basis of the complexity of their structure; also that the more highly developed galls pass through all the stages represented in the simpler galls during their development. Later studies on galls due to other causes and a study of the recent papers by other workers lead me to believe that most and possibly all of the various types of plant galls can be placed in some one of the four classes just referred to regardless of causal organisms, although in some cases the distinctions are not so well defined as in the most highly developed of the insect galls. These views have been very generally confirmed by the later investigations of Cosens and Wells.

Adler as a result of his studies on the Galls of the Cynipidæ, which are the most complex, believed that the egg must be placed so that the emerging larva would feed on the cambium; otherwise it would perish and a gall would not be formed. This is probably true of the galls which he studied but is not true of the galls which are due to many other organisms.

Küster has classified galls on the basis of presence or absence of cell differentiation into two great groups: (1) *kataplasmas* or those in which the structure is undifferentiated parenchyma and (2) *prosoplasmas* in which there is a differentiation into other tissues. In the prosoplasma group we find all gradations from galls with very slight differentiation of tissues to those in which the structures are very complex. Wells calls our attention to the fact that galls caused by Rotifera, Copepoda, Nematoda, Orthoptera, Neuroptera, Coleoptera, Lepidoptera, Musidæ, Chalcidæ and Tenthrenidæ must be classed as kataplasmas; while the Acarina, Psyllidæ, Aphidiæ, Coccidæ, Itonididæ and Cynipidæ include many galls which are kataplasmas and many others which are prosoplasmas. To these may be added the galls of *Plasmodiophora brassicæ* on the Cruciferæ, which are true kataplasmas and the bacterial and fungus galls which include kataplasmas and simple prosoplasmas, and also the intumescences and callous growths which are very simple kataplasmas. When the cell growth of the plant is stimulated, we find cell enlargements or cell division or both and great reduction of intercellular spaces; in fact, these changes take place before there is any visible enlargement of the organ. In many cases, the leaf-inhabiting aphids cause abundant cell division resulting in a compact mesophyll of very small cells and sometimes a division of the palisade cells without any thickening or other abnormality of the leaf.

Since the galls which are formed as a result of animal injuries give us the greatest range for study we will give them first consideration and the other types of galls will be compared with them. Since the Rotifera and Copepoda galls are represented by one species each and both are classed as the kataplasmas we will omit them from consideration. We will also omit most of the galls caused by insects, taking only those which are necessary to demonstrate the facts. Members of the Acarina are the causes of the simplest of the leaf galls. The first effect of the attack of these organisms is increased cell division. In some cases it is followed by the development of numerous trichomes, forming the socalled Erineums, and in others by the formation of pocket galls lined with trichomes. Some of them never pass beyond the kataplasma stage while others show a slight differentiation and may be considered as the simplest of the prosoplasmas.

The members of the Aphidæ are the causes of large numbers of plant galls which are especially prominent on the foliage. They are mostly of the pocket type and originate by increased cell activity. In some cases the cells tend to form zones but without differentiation. Some of them are strictly kataplasmas while others are prosoplasmas in which there has developed a considerable amount of fibrous tissue.

The Itonididæ (Diptera) contain a larger number of species of insects which cause galls than any other group. The galls also present a much greater variety of forms than those of any other group, but none of them show as high a degree of structural complexity as the galls of the Cynipidæ. Some of them are distinct kataplasmas while others are well developed prosoplasmas; many of them have the protective zone of sclerenchyma and the nutritive zone of parenchyma which are so characteristic of the Cynipidæ.

Species of the Cynipidæ are the makers of most of the oak and rose galls which have attracted so much attention. Some few of them are kataplasmas but most of them are highly developed prosoplasmas. They are more complex in structure and the tissues are more highly developed than the galls produced by the members of any other group of organisms. These galls originate in all cases from the most active meristematic tissues and the first stage involves very active cell division. Some of these galls never develop beyond this point and are true kataplasmas but most of them undergo very rapid differentiation resulting in the development of four well-defined zones. The innermost zone is composed of very rich parenchyma cells on which the larva feeds and is known as the nutritive zone. It is surrounded by a zone of sclerenchyma cells which is very thick in the small galls and correspondingly thin in the large galls. This is surrounded by a zone of parenchyma cells, in which fibrous structures are sometimes intermingled. It is thin in small and thick in large galls. The epidermis is the fourth and outer zone.

In recapitulation of these insect galls we can say that they all originate from the meristematic cells and are at first true kataplasmas. Many of them pass into the prosoplasma stage in which fibrous and sclerenchyma tissues are more or less prominent. In most cases the sclerenchyma is new to the organ on which the gall is produced. The fibrous tissues may or may not be new and in many cases this point is difficult to determine. In many cases I am satisfied that the fibrous tissues of the plant organs, especially the roots and stems, are merely pushed out of place by the development of other cells and that sometimes these misplaced tissues have been mistaken for new ones. So far as the writer is able to determine, insect galls never originate on mature plant organs but always during early periods of very active growth.

The literature on the nematode galls is very conflicting but it is evident that the point of excitation is less definite than in the insect galls. The writer is inclined to believe that the excitation must be restricted to tissues which are more or less meristematic and it is doubtful if the xylem tissues are ever changed except as they may be distorted by pressure exerted by the growth of other cells or possibly in some cases crushed or torn. If this interpretation is correct, these galls must be classed as kataplasmas. It also appears that the form and character of the abnormality depends largely upon the age of the root at the time of the infection and the number of individual worms attacking it.

Our knowledge of the origin, structure and development of galls due to fungi is more satisfactory than that of galls due to other causes. In the various papers on galls which are caused by fungi, the discussions have to do with the fungus rather than with its effect on the tissues of the host plant. However, it appears that the reaction is restricted to the tissues that are not highly differentiated and in most cases to those that are decidedly meristematic. Some of them are readily classed as kataplasmas while others are prosoplasmas of various degrees of complexity. The most satisfactory studies are found in the cases of the cedar and apple rust fungi, although there are some galls caused by fungi which are less complex and others which are more highly developed. Unfortunately, their structures have received very little attention. In all cases the direct modifications are mainly in the parenchyma tissues. The modifications of the fibrous structures appear to be indirect. The cedar galls have been studied by a number of investigators whose ideas are extremely divergent and confusing. Alban Stewart believes that galls of *Gymnosporangium juniperi-virginianæ* arise from axillary buds. He finds that each gall contains two fibrovascular systems, one derived from the incipient stem and the other from the leaves. The parenchyma tissues predominate and the fibro-vascular structures are dwarfed and modified. He finds practically the same condition in the galls of *G. globosum*. Reed and Crabill, who studied *G. juniperi-virginianæ* at about the same time, believe the galls arise from the leaf but otherwise their conclusions are not materially different. They further say: "The parenchyma of the leaf is stimulated to excessive growth, the fibro-vascular system, which is close to the point of infection, becomes much contorted and branched and radiates through the forming cedar apple." Again they say: "The fibro-vascular system is a modified continuation of the fibro-vascular system of the cedar leaf. From or near the base of the cedar apple, where the vascular systems are contorted, arise many branches which extend radially almost to the cortex." This description indicates that the origin and structure of these galls are similar to those of the Cynipidous galls. In their description of the effect of the fungus on the structure of the apple leaf, they say: "The hypertrophy of the apple leaf is due almost entirely to an excessive enlargement and multiplication of the spongy parenchyma cells. These cells become elongated, stand perpendicular to the upper epidermis, and form what at first glance appears to be a continuation of the palisade layer. The palisade layer, though, always remains intact and its cells, which are much smaller and more uniform in size and shape than those of the hypertrophied spongy parenchyma, are only slightly if at all enlarged. The intercellular spaces of the spongy parenchyma are entirely obliterated." This description is in harmony with that of the simple galls or kataplasmas which are due to insects. The writer has studied a number of other plant galls due to fungi and has found them to conform quite well in origin, development and structure to galls in general. Some of them are true kataplasmas while others are prosoplasmas. However, much work is necessary before it will be possible to classify these galls in their true morphological relationship.

The galls caused by *Plasmodiophora brassicæ* have been the subject of considerable research in recent years by Lutman, Chupp and Kunkel and the data concerning their development and structure is much more accurate than that of the fungous galls. They are true kataplasmas and it is evident that the cortex of the host reacts to the organism, that the cambium is especially susceptible, and that the cells of the medullary rays between the xylem also respond to the stimulus. The organism is sometimes found in the xylem but has very little if any effect upon it. The distortions of the xylem are evidently due to the force exerted by the infected rays and other parts. Instead of increasing the amount of woody tissue the action of the organism on the cambium tends to prevent the formation of vascular elements.

The bacterial galls so far as studied must be classed as kataplasmas, or possibly in some cases very low forms of prosoplasmas. The tubercles formed on the roots of the leguminous plants due to the action of *Bacillus radicicola* appear to originate and develop in the cambium of the cortical tissue and are true kataplasma galls. The so-called olive knot appears to be a true kataplasma originating in or very near the cambium, but the literature is indefinite on this point. The crown galls have received more attention than any other of the bacterial galls in recent years. The studies up to date indicate that all meristematic cells react to this organism but the character of the galls evidently depends largely on the activity of these cells at time of infection. The cells divide rapidly and therefore are very small as in galls due to other causes, more especially those in which the organism acts on the cambium of the host. It is very evident that in the formation of the crown gall, the irritant must be in the tissues which are more or less meristematic. Smith found that the dormant and old, hard, slow growing tissues were unfavorable for inoculation; but that when he used young, rapidly growing organs, he obtained good results; sometimes 100 per cent. infection. He also found that shallow inoculations into the cork cambium gave small galls while inoculations into the region of the true cambium gave vigorous tumors. The writer is inclined to believe that the size and character of the gall depend largely on the tissues infected and that the xylem seldom if ever reacts to stimulation from *B. tumefaciens,* although it is very possible that the sheath cells do respond to stimulation. The most complex and definite galls arise from the cambium, the less complex galls may arise from other meristematic tissues. The development of rather weak fibrous tissues in the galls indicates that the crown gall is a low type of prosoplasma. However, there is much greater variation in the amount of fibrous tissue in different crown galls than in more highly developed galls due to other causes. The crown gall agrees very generally in its origin, development and mature structure with other plant galls regardless of the causal organism. However, there is certainly one and possibly three marked differences between some of the bacterial galls and galls due to other causes: (1) The presence of the tumor strands in the crown gall, (2) Possibly the stimuli in the bacterial galls are more prolonged or more variable in location than in galls due to other causes, (3) The formation of embryomas or tumor containing leaf shoots or roots which have been attributed to the crown gall. The first appears to be a very clear and well-defined feature of crown gall but not of other types of bacterial galls; the second and third are open to question and should receive further study. In considering the second point we must call attention to the fact that a gall passes through periods of youth, maturity and old age, the same as any organism or organ of a normal plant. In some species, the period of stimulation is short and in others it is very long. In discussing the third we must call attention to the tendency of most of our higher plants to produce buds and shoots in or near the nodes when stimulated or injured. Furthermore, abnormally large fruits are frequently formed as a result of decortication of the stems. It is well known that similar conditions may arise as a result of winter injury, insect and fungous injuries. One of the most striking is the formation of aerial tubers on potato plants as a result of attacks of *Rhizoctonia solani*. In all these cases the conditions appear to be due to a physiological disturbance, which interferes with the descent of elaborated foods through the phloem and cortex. The question naturally arises as to whether the pathologic conditions arising from the injuries referred to above are comparable to the pathologic conditions arising from infection with *B. tumefaciens*. That is, are excessive shoot growths following injuries, enlarged fruits following decortications and other injuries, aerial tubers following attacks of *Rhizoctonia solani* comparable to embryomas following inoculations with *B. tumefaciens?*

In answer to a series of questions by the writer, Dr. Smith defined embryomas as "crown galls containing aborted shoots, often in great numbers," and stated that they differed from aerial tubers on potatoes resulting from attacks of *R. solani* in "that the aerial shoots from these aerial tubers have no disoriented tumor tissues in them and come from normal situations, *i. e.*, from eyes, while the crown gall shoots are adventitious." He also stated that the shoots which resulted from inoculations with *B. tumefaciens* do not differ from shoots which arise as a result of other injuries, except that the tumor tissues mingle with them and that as the tumor tissues grow the shoots are injured and aborted.

Levine after working with the crown gall on *Bryophyllum calycinum* says that the leafy shoots do not occur until after the galls are established; that *B. tumefaciens* is not the cause of the formation of the leafy shoots but inhibits and retards normal development. In brief the formation of the leafy shoot is mechanical and secondary to the formation of the gall. This idea is in harmony with the prevailing opinion concerning the formation of aerial tubers on the potato plants following attacks of *R. solani*. In this connection we must take into consideration that the production of buds where they do not normally occur as a result of stimulation by *Plasmodiophora brassicæ* has been reported by Woronin, Favorsi and Kunkel. The latter author says: "The tissues of such buds are always infected. In most cases they grow into short fleshy shoots. The leaves are thick, distorted and abnormally succulent. In other cases the buds grow and give rise to sprouts of considerable size. Such sprouts may push above the surface of the ground and become green. One interesting thing shown by the diseased buds is that they are often unable to respond normally to gravity. Sometimes they arise on the under side of a root and grow directly downward. In other cases they arise laterally and turn downward like the young sprout. They have also been observed to grow out horizontally, but this is not common as downward growth." However, the fungous, slime mold and bacterial galls differ from the more highly developed insect galls in that in the case of the more complex insect galls the development ceases very suddenly with the maturity of the larva while in the case of the other galls there is no such sharp and well-defined cessation of cell activity.

In this discussion the writer has repeatedly called attention to the fact that all galls originate in practically the same manner regardless of the stimulus which excites their growth; that although some are more complex than others, the complex types pass through the stages found in the lower forms. This very naturally leads us to look for the key for our interpretation. This subject has been discussed in an interesting paper by Wells who takes as the foundation of his studies the following statement by the writer: "The morphological character of the gall depends upon the genus of the insect producing it rather than upon the plant on which it is produced. The families show parallel lines of development from a low form to a high form." This statement was published twenty years ago and attracted more attention in Europe than in America, because the workers of Europe have given much more attention to the anatomy of pathologic plant structures than the workers in America.

Wells takes Beyerinck's division of galls into indefinite and definite growths, which was advanced in 1877, and amplified by Küster in 1911 into kataplasmas and prosoplasmas and presents phylogenetic lines of development which are very suggestive. The results of his studies reaffirm the following statements of the writer as published nearly twenty years ago: "(1) Within each family we find certain morphological resemblances, (2) The families show parallel lines of gall structure to a high form." Wells's studies reaffirm the idea expressed by the writer that all galls originate with the excessive development of parenchyma tissue. His studies may be summarized as follows: (1) He accepts Küster's groupings into kataplasmas and prosoplasmas as the basis of his work. (2) He points out that prosoplasmas have arisen from the kataplasmas by evolutionary processes. (3) Kataplasmic evolution is the result of progressive inhibition of differentiation ending with tissue homogeneity. Prosoplasmic evolution begins when homogeneity has been attained, and is the development of new tissue characters.

The most important facts in gall formation may be summarized as follows:

(1) The original theory that insect galls were formed as a result of a chemical injected by the mother insect was disproved many years ago.

(2) In most cases the stimulus is probably due to an excretion by the organism; in the case of insects, by the larva. In some cases the stimulus may be due to pressure or other mechanical factors.

(3) The stimulus must be applied to the meristematic tissues. The reaction depends largely on the degree of activity of the meristematic tissue.

(4) The reaction of cells to the stimuli is remarkably similar regardless of the stimulating factor involved.

(5) Cells that are well advanced and that under normal conditions undergo very little division may respond to the stimulation, divide and grow rapidly.

(6) Galls of indefinite and irregular form and structure may arise from older tissues which still retain some meristematic power. This appears to depend somewhat on the age and activity of the meristematic tissue.

(7) Galls may be classified in one of two groups regardless of the causal organism. The kataplasma group consists of galls which are made up of parenchyma tissue. In the prosoplasma group, the tissues have reached varying degrees of differentiation.

(8) Complex galls, such as those due to the Cynipidæ, always arise from very young and very active meristematic tissue.

(9) Galls of complex structure pass through the stages found in the galls of less complexity.

(10) Insect galls have by far the greatest regularity of structure and development. Some of them are very simple while others present the highest development and greatest complexity of any of the plant galls.

(11) The most complex insect galls show four stages of growth; others pass through one, two or three stages of development.

(12) The organism causing the insect gall is stationary but in the case of most other galls the causal organism may pass by processes of growth or otherwise to points other than their original location.

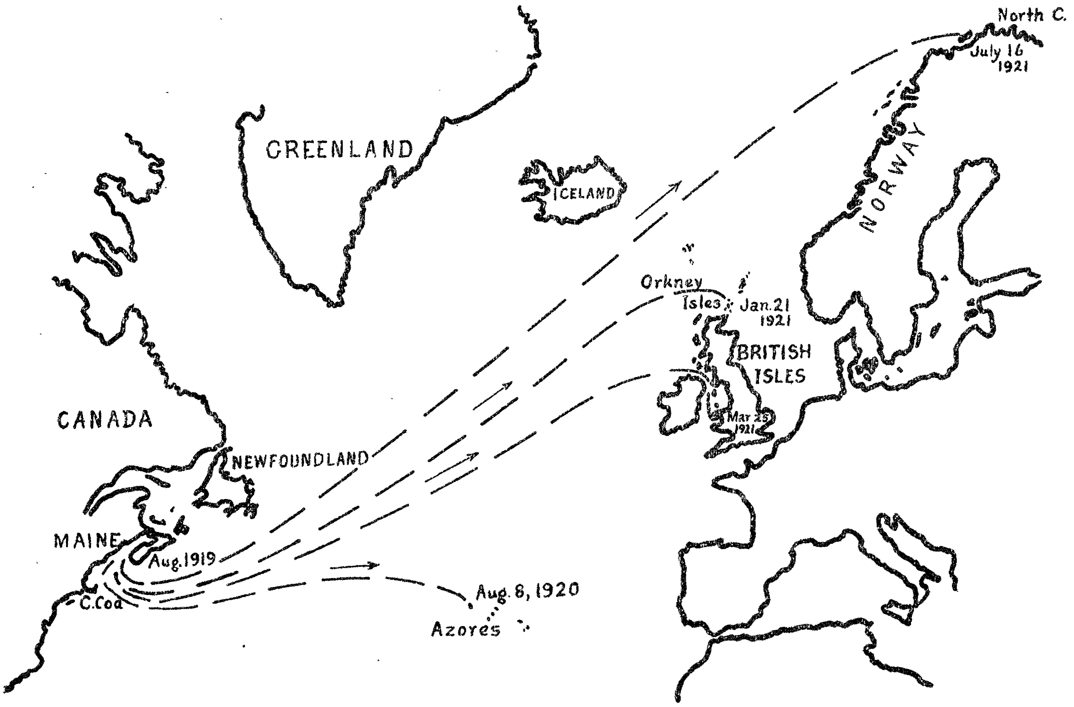

FIGURE 1. Chart on Mercator's projection of the positions of setting out and finding of drift bottles in the North Atlantic, 1919-21.

(13) The stimulus in all cases may pass beyond the location of the causal organism.

(14) Abnormal shoots and other growths (sometimes referred to as embryomas) are frequently formed in connection with many galls. Their status can not be determined from our present knowledge of the subject.

MELVILLE T. COOK

NEW BRUNSWICK, N. J.

THE COURSE OF THE GULF STREAM IN 1919-21 AS SHOWN BY DRIFT BOTTLES

IN several short notes published in this journal,[1] the writer has recorded the results of drift bottle experiments conducted for the Biological Board of Canada. Since the publication of these notes additional data has been obtained and it seems advisable to bring together to date that part of the data which bears on the course and rate of flow of the North Atlantic Wind Drift, the so-called Gulf Stream.

During the summer of 1919 some four hundred bottles were set adrift in the Bay of Fundy. Each bottle contained a postcard offering a reward to the finder who wrote in the spaces provided on the card the answers to the questions, "Where found? When found? By whom found?" Up to the present time no records have been received of bottles being found south of the Cape Cod peninsula. The records of the seventy-three bottles which were found on this side of the Atlantic during the year 1919 have already been published[2]. Four of the bottles have been found on the European side of the Atlantic. They were set adrift in the latter part of August, 1919, and the records of the finding of them follow:

No. 198. Azores, Island of Flores, August 8, 1920.

No. 230. Orkney Islands, Island of Papa Westray, January 21, 1921.

[1] Science, N. S., Vol. LII, No. 1349, page 442, November 5, 1920, Vol. LIII, No. 1365, page 187, February 25, 1921, Vol. LIII, No. 1373, page 289, April 22.

[2] Proceedings of the American Fisheries Society, 1920, page 334. Contributions to Canadian Biology, New Series, Vol. I, No. 8, page 103, 1922.