SCIENCE

A WEEKLY JOURNAL DEVOTED TO THE ADVANCEMENT OF SCIENCE, PUBLISHING THE OFFICIAL NOTICES AND PROCEEDINGS OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

FRIDAY, FEBRUARY 6, 1903.

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MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

*THE RISE AND PROGRESS OF ECOLOGY.**

THE extraordinary development of botanical science during the last decade, in which so much hitherto unknown has passed so rapidly into history, fully justifies the usual review of progress at our great annual gatherings. In following this time-honored custom I have ventured to extend the retrospect far enough to contrast some of the aspects of present-day botany with an earlier condition of the science, familiar to a few of us, though known to most of you only by tradition. The outlook, which has also come to be expected, will be limited to a single branch of the science, which has shown remarkable vigor, but the future of which is regarded by some as problematical. The reminiscences will naturally come first.

Twenty-five years ago, in one of our northern universities, a young instructor with a single assistant was engaged in the rather comprehensive task of teaching botany and 'biology.' The botany consisted in part in the analysis of flowering plants by means of Gray's 'Manual,' and in studying the minute anatomy of leaves, stems and other parts of plants, which the literary students pursued under the name of structural botany, while, with a strong

* Presidential address delivered at the Washington meeting of the Society for Plant Morphology and Physiology, December 30, 1902.

flavor of crude drugs, it was administered to the pharmacy class engaged in the study of adulterants. Then, too, there was the so-called cryptogamic botany, and, finally, the general biology, after Huxley and Martin, in which the steps of evolution from protococcus to frog were succinctly unfolded. None of the instructor's colleagues had the slightest suspicion of what it was all about, and the students—well they learned some things in spite of their environment and the teaching they got.

As for the books used—the *Centralblatt* was not in existence, but this mattered little, for neither was the enormous literature it has since recorded. The *Botanische Zeitung* was regularly published, but the library committee had no use for it, and much the same was true of most of the periodicals that every working botanist now finds indispensable; but we had Sachs's 'Text-book of Botany' and the big picture-book of LeMaout and Decaisne, and on the shelves were Sullivant's 'Icones Muscorum,' and dear old Berkeley, and Cooke's 'British Fungi,' with all their impossibilities, and last, but not least, the reports of the government microscopist, of which we can not speak particularly.

The rest of the outfit was in keeping. Microscopes, of a certain sort, there were, but no other apparatus whatever. Razors were sharpened on a well-hacked strap, iodine and sulphuric acid constituted the reagents, and the enthusiasm of fellow adventurers in an unknown country kept up the courage of young men and women who walked by faith and saw but little.

All these untoward conditions harmonized with the stage of development of the science itself. In this country there were only the laboratories of Harvard that had anything to attract special students in botany, and abroad even the laboratories at Leipzig and Bonn had little to offer compared with the magnificent work now associated with the names of Pfeffer and Strasburger; in vegetable pathology the simple methods of DeBary and Brefeld, though coupled with infinite patience and some remarkable results, gave little promise of what has since been achieved. In continental laboratories, for the most part, developmental history began with the *punctum vegetationis* instead of the egg cell. Anatomy was largely a matter of fibro-vascular bundles, and the literature of mitosis was unwritten. In short, botany, as we know it to-day, was as yet only a potentiality.

The men, too, who represented the science in America, how few they were and how isolated. There were Gray and Watson, Eaton, Austin, Prentiss, Engelmann and a very short list of botanists contemporary with them who are still at work. We seldom saw one another, and we had no dreams of gatherings like these, at which the working botanists of the country are numbered by scores, too many already comfortably to hear one another talk.

Now all is changed. With the coming in of the new century the multiplied volumes of the *Centralblatt* and the *Jahresbericht* tell the story of an unequaled productiveness, and a literature which, as measured by number of periodicals, now considerably outranks that of any other science whatever.

And this literature is, much of it, widely different from that of the earlier days. Without essaying the heroic task of reviewing even the main lines of progress, I wish in passing to recall with you certain very significant changes that are taking place. First in systematic botany. You are familiar with the fact that, as the result of observations extending through some seventeen years, De Vries has recorded the actual origin of various species

of plants, 'evolved,' as he puts it, 'with a sudden leap,' not as a result of selection or the struggle for existence. It would seem that, for the species reported, the case is well within the line of positive demonstration, and that some species, at all events, arise by mutation. It is not clear that all species originate in that way, but meantime the whole question of the origin of species is thus coming more and more within the domain of direct observation. Henceforth, positive results are to be attained not by guessing, but by cultivation, and it is an inestimable gain to the science that the issue is thus clearly defined. Students who have been diverted from systematic botany because of its guess-work and its unspeakable nomenclature, have in this new way of species-making a goal worthy of attainment. It is a method that promises definite and final results in a field where hitherto 'judgment' and speculation have unfortunately, though perhaps inevitably, held sway.

The closely related field of experimental morphology, altogether unknown in earlier days, is also making a place for itself in botanical literature. The laboratory study of plastic forms has not thus far presented fully satisfactory evidence of the permanence of forms thus easily evoked, but even if no student of experimental morphology has yet produced a species demonstrably permanent, the accumulation of evidence is pointing more and more clearly to the persistence of character acquired in response to changes of environment. Thus are we coming, as it seems, to conclude that Lamarck, Darwin and De Vries have all, in their own way, gained some insight into the origin of specific characters, but that nature in the beginning took counsel of none of them, and is still working in devious though consistent ways, producing species at her pleasure, meantime laughing at our theories and our narrow range of vision.

In the matter of life histories our literature is beginning to show the inevitable breaking with the past. It has always been interesting, no doubt, to know in how many planes a new series of cell walls are formed, and at what angles and with what indication of relationship to this or that 'type,' but it is certainly encouraging to note the present tendency to ask how constant these phenomena are and what their variations under changed conditions signify.

The time is too short to speak of the phenomenal development of plant physiology since the working days of Sachs, which to a few of us seem not long ago, and of plant pathology in which we have had triumphant demonstration of what scientific spirit and method in America, now happily no longer unknown to European botanists, can accomplish. I hasten to that part of our science that is the last to make for itself a name, though it has long had a place in botanical labor and literature, namely, ecology. It has at the present time a mixed multitude of adherents, and with the double burden of a popular fad and oftentimes the cold shoulder of those who sit in judgment, if there is a survival of the name and the work it stands for, it will be because of its own inherent vitality and fitness, not because of the patronage it has received. Let us pass in review the history of this new name and what it stands for.

It is unnecessary to reproduce or even to condense the erudite etymological discussion carried on in SCIENCE a few months ago, with which, presumably, you are familiar. The word ecology has come to stay. Personally, I should have preferred bionomics, which has the advantage of indicating in its composition that living

things are its subject-matter. This latter term is at all events an acceptable synonym, and as such may properly be used as occasion requires. The question of a name, therefore, is settled and may be dismissed.

Not so, however, with the subject-matter, which represents a growth from many and various sources. The field of bionomics, in one department or another, has been successfully cultivated by Darwin, Warming, Schimper, Kerner v. Marilaun, Bonnier, Engler, Drude, Schwendener, Haberlandt and their co-workers in the Old World, not to enumerate a growing list in the United States. Some of these are known chiefly through their ecological work, others have conducted such work incidentally. In any case these names—not unworthy ones—represent ecology in their publications, much as De Bary, Sachs and Gray, for example, represent primarily morphology, physiology and systematic botany. We may, then, from their own work, better than from definition, form our conception of the subject.

To begin, as we must, with Darwin, every one knows that he was not a systematic botanist; he sent his plants away to have scientific names attached to them. Nor was he a physiologist; at any rate this was the judgment of Sachs, who ought to know. Nor yet was he expert as a plant morphologist; witness his chapter on the morphology of orchids; but he was the great exponent of ecology as it was taking form during the period of his active work and before it had a name. He, more than any other man before or since, worked in such sympathy with living things—not dried in the herbarium, nor tortured on the klinostat, nor pickled in formalin, but living, living in their own way—that they unfolded to him secrets they would tell no other, because he could understand.

The modern criticism of ecological studies seems to involve the implication that final results are only to be attained by experiment; that observation and induction are well enough, but that a plant will never tell its story correctly until it is brought to the rack. But, as a matter of fact, Darwin concerned himself chiefly with plants and animals as he found them. The record of his work is a record primarily of observation. He studied the shapes of flowers as the bees left them. Following the simple operations of the horticulturist, he observed through many generations the effects of cross- and self-fertilization. Such experiments as he performed were largely out of doors, simple or even crude, and had no part nor lot with the refinements of modern physiology. His work from beginning to end was dominated by this one great thought. He would know something of the origin of living forms as we find them. He would formulate a law not so much to express a present reaction as a habit and a history, and while aiming at the elucidation of the great problem he had set for himself, he was engaged, first and last, in studying the origin of adaptations, the study that constitutes ecology.

But there have been new phases and developments that have greatly extended the horizon of ecological study and in various respects changed its immediate object. Consider, for example, plant anatomy as De Bary left it and as it is now pursued. Dusting the volume and glancing through De Bary's great work with its treatment of primary and secondary growth, equivalent and non-equivalent members, anomalous thickenings, and more of life nature, whatever of wearied admiration may be stirred by this monumental record of indefatigable patience, one can not help feeling that it is no longer a thing of the present day. But when there came the great illuminating

principle embodying the relation of structure to function and external factors, with what eagerness even the apparently most trivial fact was gathered and pondered, instead of with the dogged sense of duty which drove us through the old anatomy. Here were spirit and life. True the disciples of Schwendener and Haberlandt, led on by the fascination of the new thought, in more than one instance have run beyond their masters in facile interpretation, but can any one doubt that the science of botany has been permanently advanced by the enlightening inspiration of the 'Physiologische Pflanzenanatomie'?

Morphological studies are coming into the same category. The methods and conclusions of Goebel in the 'Organography' have been criticised, it is true, but it may be well to consider that morphology through such work, as has been well said, is no longer the history of an idealized type, but an account of form as correlated with function and environment. Is there any question that we have gained immeasurably by the change and that this great work has materially contributed to the more scientific view? Most suggestive are recent studies of the orientation of the plant egg and its ecological significance. Surely embryology is in a more hopeful position to-day because a few daring minds have ventured beyond the limits of pure morphology and the bounds of absolute proof, and have suggested relations that may require many years to finally establish.

Still another phase of ecological study, namely, plant distribution as developed by Warming, Schimper and others, has recently come into special prominence. It involves no less than an attempt to account for the present actual distribution and association of plants, through historical and present agencies, and the response of the living organism to its surroundings. More perhaps than any other branch of biological investigation, it calls for the most varied and thorough preparation. There must be a ready knowledge of systematic botany as a working tool, at least good general training in physiology, correct morphological conceptions, and a practical knowledge of physiography. All of these added to sound judgment and conservative habits of thought are essential prerequisites to the successful study of this subject as it is now taking form.

It may be asked whether this branch of science has within itself enough to warrant such preparation and the devotion with which it is pursued by no small number of the rising generation of botanists. There can be, it seems to me, but one reply. If the labors of geologists in bringing to light, piecemeal and often with more or less uncertainty, the past history of the earth is warranted—as it is a thousandfold, whether the progress of science or industrial achievement is considered—then the critical study of this last phase of geological history, a phase which no living geologist is prepared to work out alone, fully justifies the most efficient and persistent effort that botanists trained in the manner indicated are capable of giving. Like the geologists, they are confronted with problems of peculiar intricacy, some of them no doubt insoluble, many that can never be settled in the quiet of the laboratory, others perhaps that can be settled nowhere else, all together involving work that must inevitably attract men who are more than botanists merely, who are willing to grapple with problems of many elements and more than one unknown quantity, and who know how to work patiently when results are both slow in coming and incomplete. Very few, indeed, have possessed, or are likely to possess, all these qualifications, yet some real progress has already

been made. Without attempting to review and estimate this, let us glance at some of the landmarks.

We owe to Warming, more than to any other, the conception now familiar to us under the name of plant society, which in Warming's conception included not merely a collection of plants living together, but, what the name expresses, an association of plants with mutual relations among themselves and common adaptations to their environment. The most conspicuous and useful result of Warming's work was to show so convincingly the predominant influence of water in determining plant societies that his classification, based on this as the chief factor, has been universally adopted, though, as he well knew, so simple a grouping could not serve as a permanent and complete system, however helpful it may have been in the early development of the subject.

Later the great work of Schimper brought us face to face with the tremendous difficulties to be met and overcome in attempting to account for some of the most familiar facts of distribution, but it has greatly broadened our conception of plant relations, presenting with almost the force of a new idea the fact that every plant on the surface of the globe grows where it does because conditions of air, light, temperature, water, soil and the behavior of other plants and animals—not merely in present time, but through an indefinite past, acting not alone but together, not on a lifeless thing, like clay in the hands of a potter, but on living, changing, adaptive beings—have made its presence possible. It is to such a complicated study and to problems so apparently hopeless of complete solution that the student of ecology to-day addresses himself, and it is well, perhaps, that here as in other departments of human activity, there are some daring souls who, for the very joy of treading new ground, do the work of the pioneer, without too close calculation of the probable reward.

If a personal reference may be permitted, I am glad to acknowledge my own great indebtedness to such pioneer work on the part of one of our own botanists. The study of the distribution of plants along shore at Lake of the Woods,* which appeared in 1897, has more than realized the hope of the writer that it 'might be of service in stimulating ecologic study of plants.' It could never have been written in the closet or the laboratory, however much of such labor is still required to verify or supplement the remarkable accumulation of observation and suggestion there recorded. The author has shown the practicability of tracing, here with reasonable certainty, there less perfectly, among most complicated relations, cause and effect.

If it is said that these results are too indefinite to be of scientific value, it may be answered that it is upon precisely such data that for many scores of years the practical operations of forestry have been conducted, and that on this distinctively ecological basis it has become one of the most exact industries of the age, standing perhaps next to life insurance in the certainty with which given results are attained. It is true that individual judgment is here an important factor, and allowance must be made for the personal equation, but this is also true in astronomy, one of the most exact sciences, and in perhaps every other department of human activity that is worth considering.

A still later large and increasing literature, represented by the monographs of Engler and Drude's 'Vegetation der Erde' and many other recent contributions of

* MacMillan, *Minnesota Botanical Studies*, L.

European and American botanists, is perhaps too strictly contemporary for unbiased judgment, but in any case the very mass and rapidity of its accumulation is highly significant. It is expressive of the fact that a large contingent of young and progressive botanists are reaching out far beyond the bounds of systematic botany on the one hand and the limitations of the laboratory on the other and are finding abundant opportunity for productive work.

Without at present referring to others of these more specifically, I gladly pause to do honor to the memory of the great man who, after some 'forty years of sojourn and wanderings' through the state of Alabama, presented three years ago his final contribution to the plant life of that state.* He was seldom seen in gatherings of botanists, and I have heard him lament his lack of training such as it is the fashion now to give, but he had more than the wisdom of the schools, and perhaps studied plant relations more effectually because of his comparative freedom from their traditions. Certain it is that his 'Plant Life of Alabama' has come to us as a noteworthy and acceptable contribution. Through his and similar labors, worthy, if time permitted, of special mention and discussion, the time is drawing nearer when we shall have the data for a satisfactory comparative study of the phytogeography of the whole world.

How shall such an end be attained and how can present methods be improved so as to hasten the desired consummation? Surely not, in the first place, by limiting or diverting into other directions the present output of phytogeographical contributions. All of this and much more is needed. The data for general conclusions are all too slow in coming in. This does not mean, however, that the scattering observations of every summer cruise, with half-baked notions of the 'reasons of things,' need be inflicted on the long-suffering readers of botanical literature.

There must be higher ideals, and only those who have studied, year after year, a limited area and have watched the successive changes that a few seasons bring can quite appreciate what patience and labor the maintenance of such ideals involves.

The accumulation and expression of facts as they really are should take, as it seems to me, nine tenths, possibly ninety-nine one hundredths, of the time that is being given to ecological work. Hypotheses are fascinating, but we have all erred, perhaps, in demanding that those who busy themselves with such observations shall show us promptly their bearing on a theory of the universe. At present it is really the main business of the ecological student to ascertain and record fully, definitely, perfectly and for all time the facts. He is not bound to tell us all their meaning, much as we would like to know; and furthermore, a fact once established is just as good a fact and just as likely to have an important bearing if it is ascertained in a field or garden, in the depths of the Dismal Swamp or in the Sahara, as in a university laboratory. It is just as well for science that Gregor Mendel was working out of doors forty years ago, perhaps even better than if he had known more fully the significance of his own work and had abandoned the field for the laboratory and the microscope. We need to honor more than we do the man who knows how to see living things without complicated apparatus, and we need, cheerfully and without apology to ourselves or others, to give full days of active toil to learning and telling *what is*. It is far more difficult—I speak from personal experience—after these years of laboratory supremacy, to

* Mohr, 'Plant Life of Alabama,' 'Cont. U. S. Nat. Herb.,' VI., 1901.

teach a student to critically report in decent English a direct observation in the field, than to secure from him a tabulated statement of artificially produced reactions.

And yet no true worker in science can go on with his daily task of accumulating data without at least attempting to answer to himself the insistent question 'What does it all mean?' We need and shall always need the thoughtful and original workers who give us not only 'facts well proved,' but also 'conclusions * * * deduced from facts well proved,' and we owe a debt even to those who have the insight sufficient to offer fruitful suggestion.

As a single example, may I refer to a recent paper by Paul Jaccard * in which, from a comparative statistical study of plant distribution in alpine regions, involving an enormous accumulation of data, some most interesting conclusions are drawn. It is shown that, while in the region studied there is an almost mathematical relation between number of species and variety of ecological conditions, the generic coefficient, or ratio of genera to species, is inversely proportional to such variety of conditions; that is to say, in the struggle for existence between the numerous species of a habitat, the species of one and the same genus are in great measure crowded out by species of different genera. Thus it is shown, 'in the course of a purely statistical study, that the struggle for existence works toward the elimination of like elements and selection of unlike, and that, furthermore, the resultant of a number of external factors operates as a selecting cause, not merely on the single species, but on the grouping of species, on the society.' In these studies then, the genus becomes 'a real ecological unity with a definite intrinsic value.'

Whether or not we accept the author's conclusions throughout, we are at all events indebted to him for an ecological study carried out with mathematical precision, from which some at least of the conclusions have been drawn with mathematical certainty. It is, to be sure, a question how far, at present, quantitative results can be looked for in this line of work, but he is not the highest type of scientific worker who demands to know at every step what he shall have for his pains. It is certain, I think, that by just such studies as those of Jaccard we shall be able through careful field work to designate and make increasingly accurate estimates of dominant factors. But many problems must necessarily be taken to the laboratory, and it is to such a union of field and laboratory work that we are to look for the rational development of ecological investigation. Ecology standing alone would present much the same anomaly as physiology getting on without physics and chemistry. But all things in their time. When one of our foremost ecologists declares that ecology must be brought more and more to a physiological basis, he states an obvious truth; it is also true, perhaps, that physiology should take rank as speedily as possible with the exact sciences and record its conclusions more and more in mathematical formulæ. These great consummations, however, are likely to require some little time, and meanwhile those of us who have not yet learned always to think in equations may, nevertheless, find much to do.

It is hardly necessary to call your attention to the need of a settled nomenclature, nor to the fact that we are likely to have a great deal more than we want when we get it. To speak plainly, it seems to the writer little short of scientific

* 'Gesetze der Pflanzenvertheilung in der alpinen Region,' 'Flora,' 90: 349–377, 1902.

crime to load upon willing workers a heavy burden of terminology. Far better than this, however desirable uniformity may be, in itself considered, would it be for each writer to employ, as far as possible, expressions and definitions already current in existing literature, and if forced by the nature of his work to introduce new ones, to do this as infrequently as possible.

It may be permitted to insist once more on the inclusiveness of the training indispensable to success. In phytogeography, to mention only one phase of the subject, the work must be done by the botanist rather than by the physical geographer, but nevertheless by a botanist who is sufficiently at home in physiography to read and understand what is written in the later pages of the physical development of the earth. Like the geologist he must have an instinct for following up a clue and reading history, often as dim and broken as that of some precious manuscript. He must have a conservative judgment, and yet he must freely employ hypotheses to be as freely abandoned or maintained as occasion requires. He must have the spirit of a bold explorer combined with the cautious temper of a trained investigator. He must be at home in the herbarium, but not choked by its stifling atmosphere; he must be a trained experimenter, but not near-sighted. He is aiming to see for himself and to transmit to others a faithful picture of the vegetation of the earth—or of that portion of it which he has studied—and to take account of the various factors that are responsible for what is to-day. He is a writer of history, and considering the broken record and the endless difficulties to be overcome, it must be admitted that the histories written by phytogeographers compare favorably with those that recount the rise and fall of empires.

To a student who has had this broad, thorough and deep training, and who has still a normal vision, there is an inspiring hope. If any fact is borne in upon us with the force of a demonstration, it is that at least in this corner of the universe in which we live we are certainly witnessing the slow but sure evolution of an eternal fitness of things, not realized as yet, but approaching its consummation. Misfits there are, but the exquisite adaptations we see have not always been as nearly perfect as they are to-day. Some day with more perfect adaptation, the ideal of science and the vision of prophecy will be fulfilled.

But workers in science in these days are rightly called upon to show that their work promises something besides the fulfillment of ideals. Modern science, favored as never before with the means of extension and development, should be able to justify its cost to the state by contributing to the betterment of human life. Tested by its capacity to meet this demand, ecology, I think, will not be found wanting. Agriculture, horticulture and forestry are, consciously or not, practical applications of its principles, and their best development has been attained where these principles have been most intelligently observed and applied. It is safe to predict for all these great industries a growth in our own country of which we can at present form but slight conception, and it is equally safe to say that as contributing to this development the study of ecology, now beginning to take definite and permanent form, will abundantly prove its necessity and value. It is unnecessary to remind you that the early dream of science of an exact analysis of the soil, followed by an adequate supply of lacking elements, resulting in fruitful harvests, has never yet been realized in general agriculture, nor can any such analysis, however complete, take the place of that knowledge of the plant itself, its

history, its habits and its needs, that now constitute so large a part of our study, and is an acknowledged factor in practical agriculture.

American horticulture, still more obviously a branch of applied ecology, has already reached a stage of development in which it is hardly an exaggeration to say that desired forms are actually made to order, and some of the men who are contributing to this end are leading promoters of ecological investigations. They are the men we summon when we want to know the real basis of Mendel's laws and the ones who are teaching us from their own studies the course of contemporaneous evolution.

I have already referred to forestry as illustrating the extent and definiteness of application of ecological principles in a great practical industry. It is highly important, particularly in the United States, that this relation should be well understood. We are confronted in many of our states with peculiarly difficult problems of reforestation. Land that has been the greatest source of wealth to the state is now a wilderness, practically worthless until it is clothed again with forests. How this is to be accomplished is one of the serious economic problems that the present generation is called upon to solve. We are gaining the data in part through the suggestions of professional foresters, but there is imperative need of all the light that can be gained by critical and extended study of the natural succession of plant societies. It is fortunate that such studies have already attracted earnest and capable students, and it is fair to say that those who desire to render the state a permanent economic service can hardly find a better field, providing they are fitted for the task.

I make no apology for thus emphasizing the practical value of this branch of scientific work. Service, first wrung from the unwilling slave, then the free-will offering of the citizen and patriot, is now the honorable goal of the worker in science, and there is no higher end to be attained.

Speaking for botanists, I have taken into account only one side of ecological study, that which relates to the habits and adaptations of plants. The habits of animals can not be less interesting and important, and it is a matter of congratulation that zoologists are entering this field with enthusiasm and well-defined aims. We extend to them our hearty greetings for the new year and the new era of biological work. V. M. Spalding.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

SECTION D, MECHANICAL SCIENCE AND ENGINEERING.

TUESDAY MORNING, DECEMBER 30.

Electrical Engineering: J. Burkitt Webb, Stevens Institute, Hoboken, N. J.

Electrical engineering is a branch of engineering which more than any other joins the scientific with the practical, and bases the latter more immediately on theoretical considerations and mathematical calculations. It differs widely in this respect from some other branches of engineering, and for this reason papers which might otherwise come to this section are easily included under the head of physics, just as formerly all papers of scientific affinities went together into one section. Now, since Section D has been in existence, a paper, say, on thermodynamics, has been considered suitable for it, for although its matter was really a branch of physics, its engineering connections would naturally bring it to us. Now, Section B is overloaded with papers and I would suggest that some effort be made to get into this section such papers as may properly be claimed under