3. The existence of a continental mass twice greater in elevation than any other continent.

4. Geological data showing the structure of Antarctica.

5. Evidences of a former mild climate and extensive vegetation in the vicinity of the pole.

6. Meteorological data elucidating the atmospheric circulation of the southern hemisphere.

7. The highest tableland of the world, with the location of the south geographic pole on an unbroken ice-cap.

It thus appears that Shackleton has solved the difficult problem of equally satisfying by his expedition the demands of science and the expectations of the public.

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SPECIAL ARTICLES

PREDICTION OF RELATIONSHIPS AMONG SOME PARASITIC FUNGI

A flowering plant which would produce two separate and dissimilar sorts of fruit would indeed be a curiosity, and yet there are some of the common parasitic fungi which exhibit two, three and even four kinds of fruiting bodies or spores. In addition to the variability displayed by many species of fungi in the production of different sorts of spores, a large number of the rust-fungi present a still greater complexity of existence by having the life-cycle divided into two distinct alternating phases, which inhabit wholly different and unlike host plants, such as a sedge and a composite, or a broad-leaved deciduous tree and an evergreen.

In these species which are known to change hosts and on that account are termed heterœcious, the one phase consists usually of æcia, accompanied by one other spore-structure, the pycnium, and the other phase of telia, either alone, or accompanied by uredinia.

The combination in one species of these pleomorphic and heterœcious characters may make the working out of the life-history a very difficult problem. The connection or relation between two alternating phases is best shown by means of cultures. A culture in which a spore from one phase on one host is sown upon another host, and subsequently gives rise to a spore-form of the alternating phase, is the only conclusive evidence that the two phases are related and merely represent different forms of the same parasite. Cultures, therefore, must play an important rôle in the study and investigation of the rust-fungi, especially of those forms which are not only pleomorphic but also heterœcious.

In order that the culture work may be carried on in an expeditious manner, entailing as small an amount of unprofitable labor as possible, it is essential that the experimenter should be guided by some ideas of probable relationships between alternating phases. It often happens that there is nothing in the form or habit of either fungus or host which will give the slightest hint regarding the alternate host. In such instances a notion of relations can be gained only by field observations. The finding of spore-structures of two alternating phases in close proximity in the field is usually the only obtainable factor indicative of a connection between them. This is the case with many of the species of the genera *Puccinia* and *Uromyces,* the common rusts of grasses and sedges. The association of telial and æcial stages is, to be sure, not proof of their affinity, but only a bit of prima facie evidence. The closeness of the association, the abundance of the infection, and the occurrence of stages of other species must all be taken into account. A great deal has already been written[1] emphasizing the value of these observations of association in the field and it seems unnecessary to make further explanation here, suffice it to say that this method of gaining clues to relationships is largely a deductive one. From the fact that related alternating phases are often found associated together, we infer that other associated phases may be related. Association, in

[1] See "Clues to Relationship among Heterœcious Rusts," *Bot. Gaz.*, **33**: 62–66, 1902, and "A Search for Rusts in Colorado," *Plant World,* **11**: 69–77, 1908.

other words, might be considered a general law among heterœcious forms.

In addition to this deductive method, which requires field observations upon which to base its inferences, there is another method by which predictions of relationship may sometimes be inductively made. In some instances there is something peculiar about either host or fungus, or both, which will permit the formation of an hypothesis. These peculiarities may be in form, habit, range or other characteristics, and are usually of such a nature that they may be studied out in the herbarium or laboratory. This second method deals very largely with the principles of analogy and homology.

It is the analogical method of inferring that what is true of one species is probably true of others similar to it which makes us conclude, for instance, that the species of *Coleosporium,* common rusts of the composites especially, are related to leaf-inhabiting forms of *Peridermium* on pine trees, that the species of *Cronartium* are connected to bark-inhabiting forms of *Peridermium* on pine trees, and that the *Gymnosporangia,* the cedar-rusts, have *Rœsteliæ* on members of the apple family as their æcial forms. This general theory for the assignment of certain form-species to their telial genus has already been illustrated in a paper of which the writer was junior author,[2] and subsequent culture work has demonstrated not only the accuracy of the predictions, but also the importance of such theorizing.

The writer wishes now to call attention to still better examples of the application of this analogical process. Perhaps the procedure may be made clearer by a fuller statement of the formula and the consideration of some concrete examples. The examples will be drawn from the group of cedar-apple fungi, *Gymnosporangia,* because of the writer's familiarity with this group.

Analogy has been explained in this way: Two things which are similar in one or more respects are of the same general type or character; therefore a certain proposition which is true of one is likely to be true of the other. In applying this to the fungi, as well as in other cases, it is especially important that the characters selected for comparison should be fundamental ones and not merely of a superficial nature. Some accumulated knowledge in a field, even if it should only be in the form of negative answers to previous conjectures, may not be without value in forming new hypotheses.

The following example may be cited in which cultures have already shown the correctness of an hypothesis formed by the method just explained.

Some time ago what appeared to be a true *Rœstelia* was found upon an herbaceous plant of the rose family. This was considered remarkable because it had always been supposed that all *Rœsteliæ* inhabited only woody plants of the apple family. Upon thorough examination, however, this was found to have all of the morphological characters of the rœstelial forms and it was, therefore, concluded that it was most likely associated with a cedar-rust, as other members of this form-genus are. There was in the range no unattached species of *Gymnosporangium* known which might have such a connection; this discovery called, therefore, for the detection of a new form. From the great resemblance of this rosaceous *Rœstelia* to the æcial form of *Gymnosporangium Nidus-avis,* a rather common and well-known cedar rust, it was predicted that the telial stage, when found, would resemble *G. Nidus-avis.* This new telial stage has been collected and cultures have been made proving the correctness of the assumption as to relationship. The prediction as to structure was also strikingly fulfilled, showing that it is not only possible to show the probable existence of new forms by this method but even to anticipate their characters. This species has been named *Gymnosporangium exterum* and a fuller account of its discovery together with original description and culture record may be found in *Mycologia,* **1**: 226, 227, 253 and 254, 1909.

[2] See "North American Species of *Peridermium*," *Bull. Torrey Botan. Club,* **33**: 403–438, 1906.

The writer ventures to offer the following conjectures of relationship with the hope that cultures may some day prove their correctness. They may turn out eventually to show only the errors which the method of analogical inference may lead to, but they serve well to illustrate its application to this subject and are offered with the hope that they may have some value.

Rœstelia hyalina on a species of hawthorn, *Cratægus*, is a peculiar form which has been very little known up to the present. So far as the writer can make out there is no published record of any but the original collection from South Carolina made in 1860. The writer has recently rediscovered it on some herbarium specimens of the host plant at the New York Botanical Garden and the Arnold Arboretum so that its occurrence is after all not so rare; its distribution is now known from North Carolina to Florida. This adds new zest to the attempt to trace out its alternate phase. Morphologically *R. hyalina* has two very striking characters; first, the entirely smooth walls of the peridial cells, and second, the small wart-like protuberances on the leaves in which the peridia are borne. Only one other known species, *R. Botryapites* on *Amelanchier*, the service-berry, has these characters and it has seemed to the writer for some time that these two forms must be related to similar telial stages. *R. Botryapites* is known to be connected to *Gymnosporangium biseptatum* on the white cedar, *Chamæcyparis thyoides*. *G. Ellisii* is another white cedar rust, similar to *G. biseptatum* in the form of the distortion produced on the host and in the character of the spores, both having 2–4-celled teliospores. *G. Ellisii* has been supposed by some to be connected to *Rœstelia transformans* on *Aronia arbutifolia*, but a careful examination of the culture record shows that this conjecture has never been successfully demonstrated. On the other hand, there are so many negative results that it seems almost safe to conclude that it has been disproved. It seems very probable that since one of these two forms of *Rœstelia*, forms which are in a class by themselves on account of their smooth peridial cells and external anatomy, belongs to a white cedar rust of a certain type, that the other may belong to the only other white cedar rust of the same general type at present known. Recent collections of *G. Ellisii* by Stone in Alabama and Tracy in Florida make its known range from Massachusetts to Alabama so that it is quite feasible to suppose it connected with a form which is known in the heart of that range, North Carolina to Florida.

If an hypothesis provisionally formed either by association or analogy can be supplemented by inferences drawn from homology it is very materially strengthened. Homology might be defined so far as its application to botany is concerned as the morphological likeness existing between elements which may have become adapted to quite different functions. In applying this to the subject under discussion, for instance, if there is an essential structural resemblance between the æciospores and the urediniospores of a species they may be said to be homologous. Some notable examples in which homology in this sense has assisted in detecting genetic relationships have already been recorded by Dr. J. C. Arthur in his first report of "Cultures of Uredineæ"[3] and may be mentioned here.

Field observations had suggested that *Puccinia Vilfæ* on a grass, *Sporobolus longifolius*, was related to *Æcidium verbenicola* on *Verbena*. It was found that the closer the *Verbena* plants stood to tufts of the rusted grass the more thickly they were covered with æcia, and that the plants some distance away were entirely free. This is a good example of the working of the law of association. Before cultures were made, however, a resemblance in form was observed between the æciospores of *Æcidium verbenicola* and the urediniospores of *Puccinia Vilfæ*. The two sorts of spores were similar in shape and surface markings, and both had colorless walls much thickened at the apex. Later successful cultures proved that this homology was not a mere accident in this case and suggested that it might be the sign of relationship in other instances. During the same year a similar morphological correspondence was found between the æciospores of an *Æcidium* on *Fraxinus*, the ash tree, and the urediniospores of a *Puccinia* on *Spartina*, cord-grass, and with this as the only clue cultures were attempted. They were successful and thus

[3] "Cultures of Uredineæ in 1899," *Bot. Gaz.*, **29**: 274–275, 1900.

showed the value of inferences drawn from homology.

The writer now desires to make one other prediction concerning a possible relationship, and the character of a form yet to be discovered, in which both analogy and homology have been employed.

In his paper on "Cultures of Uredinæ" in 1908 Dr. J. C. Arthur reports the establishment of a relationship between *Æcidium Blasdaleanum* and *Gymnosporangium Libocedri*. As explained there *A. Blasdaleanum* is morphologically unlike the other *Rœsteliæ*, having instead, characters like the ordinary æcial forms of *Puccinia* and *Uromyces*. However, it inhabits hosts belonging to the apple family, the hawthorn and service-berry, and these cultures show that it is undoubtedly genetically connected with a cedar-rust. There is, in the Pacific coast region, another æcial form of the same type, on members of the apple family, *Æcidium Sorbi* on the mountain ash and crab-apple. Although *Æcidium Sorbi* is of the same general type as *A. Blasdaleanum*, it has some very pronounced characters which show that it is specifically different. There is in the whole Pacific slope region at present no known *Gymnosporangium* except *G. Libocedri* and it is at once apparent that the telial stage of *A. Sorbi* is still to be discovered. There is, however, within this range a cedar-rust in the form of *Uredo Nootkatensis* on *Chamæcyparis Nootkatensis*, the yellow cedar, from Alaska. That *Uredo Nootkatensis* is the uredinial stage of a *Gymnosporangium*, which has in its life-cycle an æcial stage on hosts belonging to the apple family, has been previously suggested.[4] The basis for such an argument has been furnished by the elucidating researches of Dr. Arthur of which his new classification[5] of the Uredinales is the result. From this work it appears justifiable to assume that the production of all four spore-forms, pycnia, æcia, uredinia and telia, was doubtless the early condition in evolution, and that the suppression of one or more of these forms is a result of later influences. In most of the groups or tribes this four-spored condition not only still persists but usually the larger number of species belong in that class. Arguing from this point of view Dr. Arthur has predicted that sooner or later a *Gymnosporangium* ought to be discovered which would possess uredinia, *i. e.*, have all four spore-forms. Since the uredinial stage is unknown in any of the true *Gymnosporangium-Rœstelia* combinations it seems probable that if it exists at all it is likely to be in a species which has an æcial form like that of the species of *Puccinia* which ordinarily possess uredinia. With the above ideas as a basis the writer suggests the possibility of a relationship between the cedar-rust, *Uredo Nootkatensis* and *Æcidium Sorbi* on the mountain ash and crab-apple. Baranoff Island, Alaska, is the type locality of the *Uredo; Æcidium Sorbi* has also been collected on the same island, an item from geographical distribution which lends further support to the supposition. Arguing from a comparison with *G. Libocedri*, the only cedar-rust known to have the puccinia-type of æcia, the new telial stage should be foliicolous and have spores two or three times septate. If the above contention is true it may well be asked why *G. Libocedri* should not have a uredinial stage if there is anything in analogy. The answer is that it probably does but that it is unknown because no well-directed attempt has yet been made to collect it.

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[4] *Bull. Torrey Botan. Club*, 35: 501–502, 1908.

[5] "Eine auf die Structur und Entwicklungsgeschichte begrundete Klassifikation der Uredineen," *Résult. Sci. Congr. Bot. Vienne*, 331–348, 1906, and "Reasons for Desiring a better Classification of the Uredinales," *Jour. Myc.*, 12: 149–154, 1906.

THE MIOCENE HORIZONS AT PORTERS LANDING, GEORGIA[1]

THE following section of the exposure at Porters Landing is adapted from the description of it given by Mr. Earle Sloan in his "Catalogue of the Mineral Localities of South Carolina," page 273.

[1] Published by permission of the Director of the United States Geological Survey.