ences to the problems of agriculture. Although it would not seem adaptable under most circumstances, this scheme recognizes the key to the problem. Agricultural research in the commonly accepted sense is not enough. It must be expanded to include far more biological research. In the case of plants and their products, we must direct major rather than incidental efforts toward unraveling the facts of growth, development, and reproduction, and the interrelations of these with soil and climate. When enough such background has been accumulated, then agriculture's practical problems must be reviewed against it.

To gain this critical knowledge we need to make certain changes. Our federal research agencies must be relieved of the requirement to concentrate their efforts on sure-fire, immediately solvable problems, while their scientists defend Congressional mandates for fundamental research. They must expand their research to determine how the green plant combines carbon dioxide and water to produce carbohydrate and then transforms the carbohydrate to thousands of useful substances, and to attack a selected group of other fundamental problems. This calls for a revision of the setup, a new deal from civil service, new types of Congressional authorization and support—all matters of federal government concern. But it calls for other things, too. There must be leaders who can lead, men who can appraise trends in all the sciences and interpret their significance for agriculture, who can recognize the gaps that stop progress, and furnish the individual scientists with charts for action. Such men are likely to come only after a renaissance in teaching and training has directed students in basic biology, chemistry, and physics toward agricultural problems. This calls for reorientation by the colleges and universities with direct or indirect interest in the field, closer cooperation between pure and applied science groups, and the development of programs which will train much more highly and educate more broadly at the same time.

The Significance of Meiosis in *Allomyces*

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TWENTY YEARS AGO Hans Kniep (*7*) described in the water mold *Allomyces* a life cycle and a type of sexuality which were previously unknown in the fungi. The cycle, which now serves to distinguish the subgenus *Euallomyces* (*3*), is outlined in Fig. 1. Sexual reproduction is accomplished

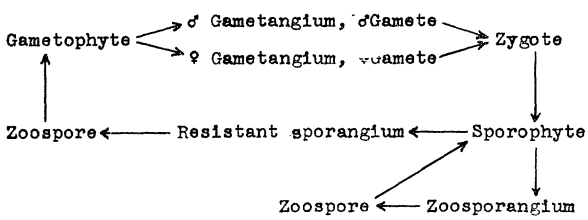

FIG. 1. Life cycle of *Euallomyces*.

by fusion of a small, motile, pigmented male gamete with a somewhat larger, motile, unpigmented female gamete. A year later, having discovered that the nuclei in sporophytic hyphae had about twice the volume of those in gametophytic hyphae, Kniep (*8*), postulated that meiosis occurs in the resistant sporangia of *Euallomyces* and that there is an alternation of haploid gametophytes and isomorphic, diploid sporophytes. Similar studies subsequently led Sörgel (*12, 13*) to accept this concept, and Emerson (*3*) presented genetic evidence, obtained from interspecific crosses, which gave strong indirect support for Kniep's interpretation of the life cycle. Although Hatch (*4*) had made a detailed cytological study of dividing nuclei in zygotes of *Euallomyces* and concluded that meiosis occurred at zygote germination, he later (*5, 6*) denied the validity of his own interpretations and accepted Kniep's hypothesis.

Kniep himself was quick to recognize the unusual possibilities which *Allomyces* presents for experimental investigations of sexuality and reproductive behavior, and subsequent studies by others amply testify to the keenness of his insight. A variety of basic researches using this phycomycete to investigate phenomena of apomixis, sex determination, irradiation action, nutrition, metabolism, and the physiology of spore-maturation, -dormancy, and -germination are under way in a number of laboratories in the United States at the present time. Nearly all of this work

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is directly or indirectly related to chromosome behavior, and the urgent need for exact knowledge of the meiotic divisions has become increasingly apparent. By using the well-known aceto-orcein smear technique, the writers have recently succeeded in completing a critical cytological study of meiosis in *Allomyces*. It is the purpose of the present note, therefore, to give a brief report of the observations which have been made and to emphasize the bearing of these findings on the future use of *Allomyces* in various phases of biological research and teaching.

Resistant sporangia formed by sporophytic thalli grown on slants of yeast-starch agar (*3*) ordinarily become capable of germination three to six weeks after their formation. At this time each sporangium contains about a dozen expanded, diploid nuclei in an advanced prophase stage. These sporangia are fully mature and, if air dried, they will remain viable and their nuclei will remain in prophase without any further detectable change for periods up to at least ten years. When mature resistant sporangia are taken directly from moist agar cultures and placed in water at 20° to 25° C, they form and release spores in 100 to 130 minutes. During this short interval the two meiotic nuclear divisions occur and are immediately followed by cleavage of the cytoplasm and organization of the zoospores. Each of these zoospores is haploid and normally uninucleate, and it has been determined that there are four times the number of zoospores per resistant sporangium as there were diploid nuclei at the start. Hence no haploid mitoses occur in the resistant sporangia. All of the nuclei in a given sporangium undergo meiosis almost simultaneously, and it has been possible to examine many preparations of each of the critical stages in both divisions. Careful analysis of metaphase and early anaphase figures of meiosis I has shown that the haploid chromosome number is probably 7 in *A. arbusculus* and 14 in *A. javanicus* var. *macrogynus*. Preliminary observations of meiosis in the F_1 resistant sporangia from crosses between these two species have revealed pairing of some of the 21 chromosomes and random distribution of the remainder.

The life cycle of *Allomyces cystogenus,* which is in the subgenus *Cystogenes* (*3*), differs strikingly from that of *Euallomyces*. As is shown in Fig. 2, there is no multicellular sexual plant, the zoospores from resistant sporangia becoming transformed directly into gametangial cysts, which release isogametes (*14*). Although various possibilities had been suggested, nothing was known about the place of meiosis in this cycle until it was discovered in the present study. Aceto-orcein smears of resistant sporangia of this species revealed a sequence of events exactly similar to those just described. There are two meiotic nuclear divisions which just precede spore formation. In the entire life cycle, therefore, there is but one mitotic division of haploid nuclei, and this occurs during gametogenesis in the cysts. The haploid chromosome number of *A. cystogenus* appears to be 7.

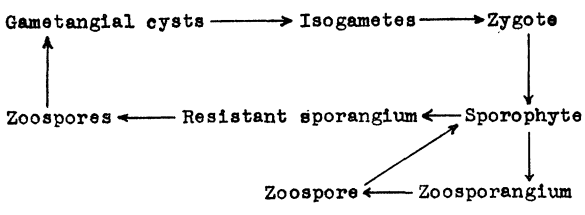

FIG. 2. Life cycle of *Cystogenes*.

The writers wish to focus attention on the relation of the foregoing observations to certain matters of general significance. First, it has been tacitly accepted for more than twenty years that meiosis in the common aquatic phycomycetes such as *Saprolegnia* occurs in the later stages of development of the fertilized egg, that is to say oospore. An examination of the literature, however, shows that virtually all of the evidence is negative, depending on studies which demonstrate that the nuclear divisions which precede gametogenesis are not meiotic. Indeed, although meiotic nuclei have been seen in several genera (*1, 2, 9, 10*), the present investigation appears to be the first critical step-by-step study of meiosis in an aquatic phycomycete. The successful application of the aceto-orcein technique to *Allomyces* indicates that renewed efforts to examine the meiotic processes of other phycomycetes should be revealing, despite the generally small size of the nuclei in these fungi.

Second, it should be understood that the conclusive demonstration of meiosis in the resistant sporangia of *Allomyces* places it, as Kniep (*8*) has already indicated, in the unique category of a filamentous fungus in which there are true diploid nuclei in the vegetative hyphae. The picture becomes even more striking when it is realized that mitoses are diploid throughout the entire cycle of *A. cystogenus,* with the exception of the single haploid division involved in gametogenesis. This nearly complete suppression of the haplophase is remarkably similar to that which occurs in some of the siphonaceous green algae. It is also interesting to note the close parallelism between present concepts of haploidy in the water molds and the situation which existed about twenty years ago, when Schussnig (*11*) and others were demonstrating the fallacy in the belief, generally held at that time, that all green algae are haplonts.

Third, it is obvious that knowledge of meiosis and specific chromosome numbers in *Allomyces* is going to facilitate greatly the planning and interpretation

of genetic studies with this fungus. The feasibility of bringing large numbers of nuclei into meiosis at will on a definite time schedule will be of significance in future irradiation work. Self-fertility of the hermaphroditic sexual plants of *Euallomyces* makes possible in a single karyogamy the production of homozygosity in diploids, while normal dominance relations can be studied in heterozygous diploids.

Fourth, with 7 and 14 as basic haploid numbers, and with a considerable degree of interspecific compatibility, there is a very promising outlook for cytotaxonomic research, a field in which fungi have played little or no part hitherto.

Fifth, establishing the place of meiosis in *Euallomyces* has finally put this water mold in an exceptional position as a laboratory organism with which to demonstrate with diagrammatic simplicity each of the basic structures and processes involved in a generalized, sexual reproductive cycle. Sexual and asexual plants can be grown separately on ordinary laboratory media (*3*) and will produce their respective reproductive structures in profusion without special treatment. The release of gametes, haploid zoospores, or diploid zoospores can be induced at will in a given time simply by placing gametangia or sporangia in water. Arranged in terminal pairs, the male and female gametangia are distinguished by a striking color difference, the females being unpigmented, the males brightly colored with carotene. The difference in size and pigmentation of the gametes themselves makes it possible to identify them after their emergence, and the actual process of syngamy can be followed under the ordinary compound microscopes provided in an elementary laboratory. Surely few other organisms combine so fully and vividly those precise features required for an introduction to concepts and patterns of reproductive mechanisms in living things.

With its ready growth of either diploid or haploid phase in pure culture, its uninucleate motile gametes and zoospores, its colorfully differentiated gametangia, its hermaphroditism and self-fertility, its distinctive resistant sporangia which can so conveniently be used to perpetuate stock strains, and its uniform rapid response to transfer from nutrient agar to water, *Allomyces* is an organism with outstanding possibilities in the fields of biological research and teaching.

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AAAS Recommendation on Atomic Energy Act Amendments

The following memorandum, adopted by the AAAS Executive Committee at its meeting July 7, 1949, was sent to the McMahon Committee of the Senate:

The Executive Committee of the American Association for the Advancement of Science urges upon your Committee and the Congress the exercise of searching scrutiny and objective consideration of any amendments to or revisions of the Atomic Energy Act which would affect seriously if not disastrously the nation's progress in research. Such progress has resulted in the past less from great expenditures of money than from freedom of publication and of communication among scientists. Research has little potential value until its results are public property.

This Committee views with grave misgivings the proposal reported in the press that the export of radioisotopes for research by scientists in other countries be prohibited by statute, on the ground that such research might be applicable to military developments, and its publication might be detrimental to our national interest.

Any basic research has potential applicability to developments of all kinds, including military. This must be regarded as a small "calculated risk." The radioisotopes available to foreign scientists are of a kind not used in weapons, and their utility is preponderantly in tracer studies and medical research. The likelihood of their being employed detrimentally to our interests is practically nonexistent, whereas the potential benefits to mankind are great.

If there is hazard to us in the publication of results obtained abroad with radioisotopes, there is also hazard in publication of results of similar research done in this country with radioisotopes; and the same kind of logic would lead to prohibition of such publication here as of shipments abroad. Prohibition of publication would be highly detrimental to our interests, for research can thrive only in an atmosphere of free interchange among scientists. Without it there is no research. In view of the indisputable fact that research is essential to our leadership, it would be a serious matter indeed to prohibit export of radioisotopes (except those fissionable materials usable in weapons), as it would also to prohibit freedom of publication of results of research in this country, in which radioisotopes are used.