A CLASSIFICATION OF THE HYPHOMYCETES

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DURING recent years considerable attention has been given to the Hyphomycetes and it is significant that the main aim of some at least of the leading mycologists interested in this group has been to develop a classification which may serve the needs of pure and applied mycologists better than the current system of classification which is due to Saccardo.[1,2] As is well known, Saccardo classified the Hyphomycetes into four families : the Mucedinaceæ, the Dematiaceæ, the Tuberculariaceæ and the Stilbaceæ, the hallmark of the Tuberculariaceæ being production of sporodochia, that of the Stilbaceæ of synnemata and that of the Mucedinaceæ and the Dematiaceæ of simple conidiophores not aggregated into sporodochia or synnemata. The Mucedinaceæ were delimited by Saccardo as the hyaline counterparts of the Dematiaceæ, the hyphæ or spores or both in the latter being dark-coloured. Thus, the primary criteria used for classification by Saccardo were the solitary nature of the conidiophores or their aggregation to form sporodochia or synnemata and also the colour of the hyphæ, conidiophores and conidia. The mode of formation of spores, as far as it was understood, was given secondary importance. Although as early as 1888 Costantin[3] proposed a classification of about one hundred genera of Hyphomycetes in which he gave primary importance to the mode of insertion of the spore on conidiophores and even distinguished a category in which the spores were stated to be enveloped in slime—the "slimy spores" of Mason[4] and their corollary, the Gloiosporæ of Wakefield and Bisby[5]—his classification was eclipsed by that of Saccardo whose *Sylloge Fungorum*, by its very nature, remained better known. Subsequent work by Vuillemin in France and by Mason at the Commonwealth Mycological Institute, Kew, truly laid the foundations for a new classification of this important group. The acceptance of the type method and its strict application in taxonomy requires a proper understanding of all genera of the Hyphomycetes and more especially of the old and classical ones which have been taken for granted and accepted *sensu* Saccardo who, in treating of the various genera, often excluded the type species from them. The impact of Article 48 of the 1961 International Code on the nomenclature of the genera so treated by Saccardo would be such as to release a number of later homonyms. In the elucidation of generic characters based on types, Mason[4,6,7] made outstanding contributions and, during the past several years, has also inspired much critical work of which special mention may be made of the papers by Hughes.[8,9] Although Hughes contributed considerably to our knowledge of tropical Hyphomycetes represented by numerous African collections which he made and studied, his new approach[8] to classification in which he emphasized the importance of the method of spore formation in taxonomy was illustrated by examples largely of Hyphomycetes commonly found in Europe. There is no doubt that Hughes made a positive approach to a new classification worthy of serious consideration. If there are apparent difficulties in accepting his proposals, these do not stem from his system but reflect our present inadequate knowledge of many generic types which are either imperfectly known or not known at all; but this deficiency applies to Saccardo's system also. It is now generally agreed that the basis on which Saccardo divided the group into families is not sufficiently reliable as a criterion for delimiting families, although these characters would be useful in classification at lower levels.[8,10–12] Hughes has, indeed, clearly set forth the lines on which a new classification may be founded. A classification, like a language, must be used if it were to live and it is therefore worthwhile assessing the usefulness of this classification by using it and putting it to test. Lack of knowledge about precise mode of formation of spores in several genera prevents elaboration of a complete classification, but it would be desirable to apply the new concepts to a classification of the genera which are adequately known.

During the past some years I have collected and studied Hyphomycetes in this country and, during a stay at the Commonwealth Mycological Institute some years ago, have had access (through the very kind courtesy of Dr. S. P. Wiltshire and Mr. E. W. Mason, past Director and Mycologist respectively of the C.M.I.) to type specimens of several Hyphomycetes commonly recorded in Europe. While Hughes recognized eight categories or sections, each with a characteristic method of spore formation, and Tubaki[10] added a ninth category, I believe that several other categories would have to be recognized to properly classify the Indian, or for that matter the tropical Hyphomycetes,

Details of these will be presented elsewhere: the main purpose of this paper is to establish a taxonomic grouping of the Hyphomycetes on the basis of our present knowledge of both temperate as well as tropical forms.

The classification being proposed here is primarily based on the mode of formation of spores. For this purpose, six distinct morphological categories of spores are recognized. They are:

1. the *blastospore*, formed as a blown-out end from any cell on a fertile hypha or, where spores develop in acropetal chains, from the previously formed spore as well;

2. the *gangliospore*, developed by the transformation of the swollen tip of a hypha into a spore: a conidium initial may or may not be delimited,

3. the *phialospore*, abstricted from the tip of a phialide in succession, endogenous or exogenous, sometimes grouped into false heads at the tips of the phialides, sometimes forming basipetal chains. The phialospores are usually thin-walled. The phialide is a unicellular structure which is usually terminal on simple or branched conidiophores and is oval to subcylindrical to flask-shaped or subulate, often with a distinct basal swelling and a narrow distal neck, with or without a terminal collarette;

4. the *porospore*, formed through minute terminal or lateral pores on the wall of the conidiophores: such spores are usually rounded at the base and even in contour except for a basal pore corresponding in position to its point of attachment to the conidiophore;

5. the *arthrospore*, formed as a result of septation and breaking up of simple or branched hyphæ;

6. the *meristem-arthrospore*, formed at the tip of a conidiophore which remains meristematic, and differentiated in basipetal succession: such spores may or may not form chains. The conidiophore is sometimes poorly differentiated and its tip imperceptibly merges with the chain of conidial initials which exhibit a gradual maturation towards the distal end of the chain.

A seventh category, the *spiculospore*, may also be recognized and this is formed at the tip of a pointed structure often elongate and so resembling a spike, as in *Hirsutella* and *Akanthomyces*. More work appears necessary, however, before this spore-category can be used for any formal taxonomic grouping. The following six families are recognized here to take in the bulk of the Hyphomycetes hitherto classified in the Mucedinaceæ, the Dematiaceæ, the Tuberculariaceæ. and the Stilbaceæ of Saccardo's system:

1. **Torulaceae** Corda emend. (Corda, 1837, *Icon. fung.*, 1 : 12). Hyphomycetæ producentes blastosporas. Genus Typicum: *Torula* Pers. ex Fries, 1832, *Syst. Mycol.*, 3 : 501. (Hyphomycetes producing blastospores. Type genus, *Torula* Pers. ex Fries.)
2. **Bactridiaceae** Corda emend. (Corda, 1837, *Icon. fung.*, 1 : 12). Hyphomycetæ producentes gangliosporas. Genus Typicum: *Bactridium* Kunze ex Fries, 1832, *Syst. Mycol.*, 3 : 433. (Hyphomycetes producing gangliospores. Type genus, *Bactridium* Kunze ex Fries.)
3. **Tuberculariaceae** Ehrenb. emend. (Ehrenberg, 1818, *Sylv. mycol.*, p. 12). Hyphomycetæ producentes phialosporas. Genus Typicum: *Tubercularia* Tode ex Fries, 1832, *Syst. Mycol.*, 3 : 464. (Hyphomycetes producing phialospores. Type genus, *Tubercularia* Tode ex Fries.)
4. **Helminthosporiaceae** Corda emend. (Corda, 1837, *Icon. fung.*, 1 : 12). Hyphomycetæ producentes porosporas Genus Typicum: *Helminthosporium* Link ex Fries, 1832, *Syst Mycol.*, 3 : 354. (Hyphomycetes producing porospores. Type genus, *Helminthosporium* Link ex Fries.)
5. **Geotrichaceae** fam. nov. Hyphomycetæ producentes arthrosporas. Genus Typicum: *Geotrichum* Link ex Sacc., 1883, *Sylloge Fungorum*, 4 : 39. (Hyphomycetes producing arthrospores. Type genus, *Geotrichum* Link ex Sacc.).
6. **Coniosporiaceae** fam. nov. Hyphomycetæ producentes meristemat-arthrosporas. Genus Typicum: *Coniosporium* Link ex Fries, 1832, *Syst. Mycol.*, 3 : 256. (Hyphomycetes producing meristem-arthrospores. Type genus, *Coniosporium* Link ex Fries.)

Since considerable differences can be recognized in the mode of insertion of the different types of spores mentioned here, it will be appropriate to divide these families into subfamilies. Details of the delimitation of these subfamilies and the disposition of the genera of which species are known from this country will be presented elsewhere.

Notwithstanding what has been proposed, some difficulties remain: some fungi are known to produce several "imperfect spore forms" and in such cases there is the possibility of the different "states" of the fungus being placed in diverse genera. Thus, several genera such as *Acremoniella* Sacc., *Humicola* Traaen, *Chlamydomyces* Bainier and *Botryotrichum* Sacc. and March. are based on their gangliospore states, but they are also known to produce phialospores.

In these cases, the choice of a generic name would have to be made arbitrarily since, unfortunately, no ideal solution to this difficulty appears possible at present. Mason has admirably discussed these difficulties and stressed the need to study the fungi in their "hochkultur", a concept which has been conveniently and elegantly used in the classification of Fusaria by Appel and Wollenweber and several later workers. There have also been suggestions for developing a classification of the Hyphomycetes *vis-a-vis* their relationship to perfect stages. Indeed, "if we could consistently predict the Perfect genus by an inspection of its conidia, there would be no need for an Imperfect classification at all". As Mason[4] emphasized, "over large tracts of the Fungi Imperfecti, however, we cannot do so, and unless the Perfect classification becomes improved out of all knowledge, it does not appear probable that we ever shall be able to do so".

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3. Costantin, J., *Les Mucédinées simples*, 1888, pp. 210.
4. Mason, E. W., *Mycol. Paps.*, 1937, **4**, 68.
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10. Tubaki, K., *J. Hattori bot. Lab*, 1958, **20**, 142.
11. Subramanian, C. V., *Mem. Indian bot. Soc.*, 1958, **1**, 43.
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ADVANCES IN CANCER RESEARCH*

IN recent years there has been so much work on cancer research that it is almost impossible for any one to keep pace with the findings of various workers. Comprehensive reviews on the different aspects of oncology are therefore most welcome. This need has been fully met by the series of *Advances in Cancer* Research, the first five volumes of which were ably edited by Dr. J. P. Greenstein and Prof. A. Haddow. For the sixth volume Prof. S. Weinhouse joined Prof. Haddow as co-editor owing to the death of Dr. Greenstein. The sixth volume contains reviews on blood enzymes in cancer, enzymes in hepatocarcinogenesis, cancer chemotherapy by perfusion, radiation chimeras, mouse leukæmia and antagonists of purines, pyrimidines and folic acid. A small chapter on plant tumour problem has also been included.

The topic of blood enzymes in cancer and other diseases has been extensively reviewed by Oscar Bodansky. Studies on serum enzymes have been classified into two types: (1) Tissue specific enzymes and (2) Enzymes involved in metabolism. Any defect in the secretion or excretion of tissue specific enzymes is reflected in the serum which is indicative of the pathological process. For example, the elevated levels of acid phosphatase indicates carcinoma of the prostate and those of serum alkaline phosphatase indicate osteogenic sarcomas of hepatobiliary diseases. The potentialities of serum enzymes such as 5-nucleotidase and glucose-6-phosphatase indicating hepatobiliary disease and other hepatic disorders have been rightly stressed by the author. The field opens up possibilities of finding out tissue specific enzymes and those indicating hereditary diseases such as cardiovascular disorders which would be revealed by their alterations in the peripheral blood. The second class is that of the metabolically involved enzymes. Since these enzymes are neither tissue nor disease-specific the alterations of these enzymes in the serum have no significance on the induction of the disease. However although the serum enzyme in this class constitutes a mixture of functionally similar enzymes from different tissues, it is possible to distinguish them by using kinetic electrophoretic and immunological procedures. Their alterations in the serum may then possibly indicate a specific disease or a pathological process. This would, however, need further exploration.

The chapter on blood enzymes has been very well written. It gives details about the properties, assays and significance of the various serum enzymes and should prove of immense value to workers in the field.

Among the biochemical investigations in carcinogenesis the problem of hepatocarcinogenesis has been studied quite extensively This is due to two reasons: (1) The liver is an organ of major metabolic importance and (2) it has afforded appropriate normal tissue for comparison which is very essential for investigations on carcinogenesis. The review on enzymes in hepatocarcinogenesis relates a systematic

* *Advances in Cancer Research*, Vol. 6. By Alexander Haddow and Sidney Weinhouse. (Academic Press, Inc., New York and London), 1961. Pp. 524. Price $ 13·00.