THE FUNGAL BIODIVERSITY AGENDA 2013: THE IMPERATIVES

C V SUBRAMANIAN
Past President, International Mycological Association (IMA)
A-8 Damayanthi Apts, 17 South Mada Street,
Nungambakkam, Chennai 600 034, Tamilnadu, India.
E-mail: cvsubra1952@yahoo.co.in

This paper is an expression of our concern about protecting and conserving our fungal resources, and learning more about the biology and life-style of fungi and harnessing the knowledge gained to the good of plants, animals and man, in our effort to contribute to sustainability. Lacking chlorophyll, fungi have spread everywhere by their chemistry, impinging on all human activity, and the activity of biota in the biosphere. We are aware of their contribution to agriculture, forestry, public health and medicine, biotechnology and industry, and sustainability which is so crucial for survival. Fungi do immense good, but can do incalculable harm. There are no accurate estimates of the total number of fungal species on a global or regional basis. The distinguished tropical botanist, E J H Corner said that 'there are as many species of fungus as there are species of flowering plant, if not of all seed plants, multiplied by the number of their parts.' Further, he explained: 'The variety of fungi is a measure of the chemical differences in plant tissues.' While many biotrophs and parasites are host-specific, there are many that are not, and can attack many host species/genera. There are also countless substrates that are colonized by a diversity of species and genera in a succession that is characteristic for a given substrate in a given habitat. If we now take into consideration just the many species of flowering plants, and the many species of insects, which serve as hosts or substrates, we can only view with awe the number of fungal species in relation to the number of species of flowering plants or insects. We arrive at a staggering number and realize how little we know about them. We must know what they do in their habitats, and must ponder the implications of their presence and their activity. Every fungus has an individuality and yet the importance lies not merely in their individuality, but in their togetherness and their collectivity. Nothing exists by itself. Coexistence and mutualism are the essence of life. They are also the essence of biodiversity.

In dealing with the Agenda, I shall first highlight the relevance of fungi in our lives, and then deal with the points and issues on our Fungal Biodiversity Agenda: designation of biodiversity-rich areas, exploration and inventorying, documentation, establishment of mycogenome banks and a centre for fungal taxonomy and biology, besides conservation of our fungal resources.

Key words: Fungi: diversity, exploration, inventory, fungal taxonomy and biology, tropical forests

Every fungus has relevance. We may not know it, but time will tell. Thus, fundamental discoveries in science have come from intuitive and intelligent studies on many of them. For example, *Monilia sitophila*, a little known asexually propagated mould used by the Javanese to make a fermented product from soybeans or peanuts, was described by the Dutch mycologist F A F C Went early in the last century from Java (now Indonesia). Persistent efforts by that great mycologist, B O Dodge, led to the discovery of the sexual state of this and related moulds, heralding the establishment of the genus *Neurospora* in a landmark paper which Dodge published jointly with Cornelius Shear of the USDA in 1927. The rest of the *Neurospora* story, its adoption for genetic studies by George Beadle and Edward Tatum at Stanford and by Carl Lindegren at Cal Tech, are well known. Beadle and Tatum, from their work on *Neurospora*, proposed the one-gene-one-enzyme (more precisely,one-polypeptide)

Footnote: This is a slightly modified and updated version of the talk given at the Symposium on Biodiversity organized by Sectional President Dr Umesh C Lavania in the Plant Sciences Section of the 100th Session of the Indian Science Congress Association at Kolkata, and published in the Proceedings, Part II, Section XIV, pages 35-46. I am grateful to Dr Lavania for inviting me to speak at the Symposium and for his initiative in having this updated version published in this Journal.

hypothesis for which they were given the Nobel Prize. We should note here that but for the landmark study of the life cycle of *Neurospora* by Dodge, genetic studies on the fungus would not have come up at the time they did. And this depended on the accidental discovery by Dodge of the need for heat treatment of ascospores for germination. This correlated well with the fact that *Neurospora*'s natural home was burnt ground and bark. The discovery of heterothallism in the common bread mould by A F Blakeslee in 1904 proved fundamental to understanding fungal life cycles, fungal perpetuation and fungal variability. Studies on another mould, *Aspergillus nidulans*, were key to our knowledge of parasexuality and parasexual recombination in fungi. Our knowledge of fungal chemistry began with the pioneering studies on the common mould, *Aspergillus niger* and other ubiquitous species of that genus by Louis Pasteur and his students. Significantly, Pasteur's epochal studies on fermentation centred on the yeast, *Saccharomyces cerevisiae*, the fungus, alongside the ciliate *Paramoecium*, that contributed preeminently to our knowledge of the role of cytoplasm in inheritance and our current concepts of what has come to be known as epigenetics. *Penicillium* and penicillins, and *Aspergillus* and aflatoxins ushered in studies on antibiotics and mycotoxins of great relevance in human and animal health and in medicine. Plant pathogens such as *Puccinia graminis* on wheat, and *Phytophthora infestans* on potato, devastated our crops and led us to devise methods to stem their assaults and methods to assess their virulence and breed crop cultivars for resistance. E C Stakman at Minnesota pioneered these epochal studies on wheat rust. One of Stakman's students, John Niederhauser did the same for *Phytophthora infestans*. [Though *Phytophthora* is no longer considered a fungus, I mention it as it is very much part of the story of mycology and plant pathology] Ergot (*Claviceps purpurea*) and ergotism led to fundamental studies in pharmacology, epidemiology, chemistry and medicine, and even psychology and psychotherapy, with the discovery of LSD. The discovery of histamine and acetylcholine, and the then startling discovery by Henry Dale, Otto Loewi, and their co-workers, that neural transmission of stimuli is mediated chemically, are part of the great ergot story. Dale and Loewi were awarded the Nobel Prize for their discovery. The discovery of gibberellins by Japanese scientists studying the bakanae disease of rice plants caused by the fungus *Gibberella fujikuroi* in Formosa (now Taiwan) led not only to understanding host-pathogen interaction in plant disease but also to fundamental studies in plant physiology. Thus, it turned out that flowering plants themselves produce gibberellins. Finally, it was found that gibberellin synthesis is not unique to *Gibberella* among fungi and is synthesized by a variety of moulds and even by some bacteria. Fundamental discoveries often emerge in succession. The use of moulds to make fermented foods and drinks was pioneered by the Japanese. The ancient Egyptians knew how to make wine. Edible, poisonous and hallucinogenic mushrooms were known and used by many ancient cultures and peoples and ethnic groups and tribes. The essential hallucinogenic and even chemical properties of the fly-agaric (*Amanita muscaria*) were known to ethnic groups in Siberia long before chemists took up their study. There are countless others about which we know nothing.

We must recognize the known, and inspect the unknown. Strange moulds lurk in strange places, awaiting discovery. A lowly *Allomyces* , first described from soil in Pusa in India, an *Olpidium* infecting root systems of Brassica, first described from Japan, or a *Coelomomyces* on a mosquito larva first described from Malaysia, or a *Saksenaea* first described from soil from Saugor, India, or a *Neocallimastix* from the rumen of sheep, are just five examples. When these novelties were discovered, their importance was not known. All of them turned out to be taxonomically or otherwise unique, thus contributing to our science. *Allomyces* was found to have a life cycle (of isomorphic alternation of generations) not known in any other fungus, though common in the algae. *Coelomomyces* was found to complete its life cycle on two unrelated hosts, an insect and a copepod, simulating somewhat the wheat black rust fungus which completes its normal life cycle on two unrelated hosts, the telial phase on wheat (a grass) and the aecial phase on barberry (a dicot). *Neocallimastix frontalis* whose taxonomy was in doubt when first described, turned out to be a fungus unique in being anaerobic, and inhabitant of rumen of herbivores. It is monotypic, lacks mitochondria, has hydrogenosomes, and currently is classified in the Family Neocallimastigaceae. As for *Saksenaea*, it has not only turned out to be monotypic, but its sexual state is yet to be discovered. What is more, its uniqueness among the fungi necessitated its accommodation in a separate Family, *Saksenaeaceae*. Further, *Saksenaea vasiformis* turned out to be a pathogen of humans and a pathogen of whales and dolphins. *Coelomomyces* has potential use in biological control of the malarial parasite transmitted by mosquitoes. *Olpidium brassicae* was described from Japan by Shimsuki Kusano early in the last century. Kusano studied the life cycle of this fungus but, except for mention in some textbooks, this lowly fungus received no attention until suddenly in the early 1960s it was found to transmit tobacco necrosis virus and its importance in virology and plant pathology was established. These examples highlight the significance of such discoveries. Let me add: the discoveries were made by scientists with a passion for objects of their study and required practically no funding.

The Agenda

Designation of Biodiversity-rich Areas

Biodiversity-rich areas must be designated, protected and conserved. From data available, the forest-cover in India is estimated to be 67.83 million hectares which is 20.64% of the country's geographical area. The Western Ghats and Eastern Himalayas are among the thirty-two hot spots on our planet. Five States lead in the extent of forest cover in the following sequence: Madhya Pradesh (7.64 million hectares), Arunachal Pradesh (6.8 million hectares), Chhatisgarh (5.6 million hectares), Orissa (4.83 million hectares) and Maharashtra (4.68 million hectares). The forest cover in these States needs special survey. The Botanical Survey of India and the Zoological Survey of India have been engaged in making inventories of the flora and fauna respectively, but few forest types have been systematically combed for fungi. There are regions with very high rainfall, and there are deserts. There is a variety of forest types. Being a mega-diversity country, there is a high level of endemism, more marked in the flora than in the fauna. About 4-5% of the total geographical area of the country is protected (viz. the Forest Conservation Act of India, 1980). The Western Arunachal Landscape (WAL) in eastern Himalayas and the South Western Ghats Landscape (SWGL) are already designated. Other obvious areas, notably, the Terai Arc Landscape, the Kanchanjunga Landscape and the Sundarbans Landscape are in the same category.

The different forest types with their characteristic floristic and faunal components are distributed across the country. The evergreen tropical forests in the Andamans and Nicobar, the Western Ghats, and the North-eastern States, the dry alpine scrub high in the Himalayas to the north, the semi-evergreen rain forests, and the monsoon forests across the country need to be considered in this context. Wetlands hold unique flora and fauna. They are also distributed across the country. Chilka Lake in Orissa, Kealodeo National Park in Bharatpur, freshwater marshes of the Gangetic Plain, the rivers and lakes of montane Kashmir, the mangroves in the south-eastern coast in Porto Novo, and the mangroves and other wetlands in Andamans-Nicobar, need special mention. There are also the lagoons and other wetlands on the southern west coast, and the vast saline waters of Gujarat and the Gulf of Kutch.

Exploration, Inventorying Fungi

The study of fungi in our country essentially began with two army medical men sent over here from Britain, men, as it happened, imbued with the spirit of science and service. D D Cunningham, posted in Calcutta, published possibly the first ever detailed account of air spora from studies he carried out in Calcutta in the early 1870s. The numerous fungal and other spora he beautifully illustrated are an index of the diversity of sporulating fungi. Cunningham and the other medical man, Arthur Barclay, collected and described rust fungi from the Himalayan region. The posting of another medical man, Edwin J Butler, as Cryptogamic Botanist stationed at Calcutta in 1901, moved to Dehra Dun in 1905, and appointed Imperial Mycologist at the Agricultural Research Institute at Pusa in Bihar a year later, must be considered a key event in the development of the twin disciplines of mycology and plant pathology in India. Butler initiated studies on fungi as fungi (mycology) and on fungi as plant pathogens (plant pathology). He compiled a list of Indian fungi jointly with G R Bisby, wrote a monograph on the genus *Pythium* and allied fungi, and authored a book, Fungi and Disease in Plants, a classic. While mycology has many ramifications, its kinship with plant pathology in its development in India has never been in doubt. Their kinship has been to enormous mutual advantage. We have a good inventory of plant disease fungi, and information on their epidemiology and their biology, a follow-up of the Butler legacy. Following Butler's departure from India in 1920, Indian mycologists trained by him took over and continued the tradition. We have done well but we certainly could have done better. We can do great things if we want to. It is this spirit that I like to see when we are discussing an Agenda.

I shall sketch briefly the broad approach and methodology of exploration and inventorying fungi. There are three obvious approaches which can be categorized as (i) the regional, (ii) the ecological, and (iii) the taxonomic. The regional approach calls for exploration of the different regions based on geography. It is pertinent here to refer to an exploratory study we carried out some years ago in ten different locations in the Western Ghats, collecting and studying microfungi. We recorded 255 species of hyphomycetes belonging to 152 genera. Of these, 142 species (55.4% of the total) and 95 genera (62.5% of the total) turned out to be new. These included tropical species recorded earlier from other parts of India, besides species from tropical Africa, Sri Lanka, Malaysia, and some species till then known only from Hawaii, New Zealand and Europe. In the little known Coronophorales, also from the Western Ghats, of the 23 species represented in 12 genera, ten species and two genera turned out to be new. These figures are an indication of the richness of the fungal flora in our dense forests in the country. Those who have collected in tropical rain forests know the travails they have to contend with: leeches, snakes, stinging nettles and such others. And, precisely, these are habitats where fungi abound. The ecological approach, notwithstanding the overlap with the regional, calls for exploration of different ecosystems, and the diverse habitats such as birds' nests, cave dwellings of bats, termite mounds, lagoons holding retting coconut husks and fibre such as are found on the southwestern coasts, bird sanctuaries, and many more. There are also microhabitats such as the rhizoplane in root systems, the phylloplane of leaves, the haemocoel of insects and the rumen of herbivores. There are many ecological groups of fungi, not always strictly definable, such as soil fungi, coprophilous fungi, litter fungi, fungi on wood and bark, thermophilic fungi, fungi on burnt ground or burnt substrates, and freshwater, and marine fungi. Entomogenous fungi (on insects) and predacious fungi (on nematodes and other soil-dwelling animals) are other categories. Freshwater and marine ecosystems hold a vast array of fungi, also inadequately explored. There are plant pathogens, and the symbiotic mycorrhizal fungi, besides endophytes. The taxonomic approach has its emphasis on taxonomic groups of fungi. Many taxonomic groups are poorly studied. The three approaches complement each other, and are the gateway to at least a modestly complete inventory. Fungal host species must be identified correctly and in this fungal taxonomists should seek the best expertise (e.g.

angiosperm taxonomists, insect taxonomists) available in the country or outside. In the identification of dead wood, bark, twigs and leaves, anatomy might help.

Methodology is important. Regional surveys will bring forth material that relate to the second and third approaches and will need to be dealt with accordingly. Looking for fungi and collecting them is an art that comes by experience. On a collecting trip to Kambakkam Hills, north of Chennai, the great M O P Iyengar stopped at the sight of what he exclaimed to be desmids in a piece of stagnant freshwater, and collecting it, asked us to view it under a field microscope. And indeed, they were desmids! Only an M O P Iyengar can spot desmids in this way. A Roland Thaxter, a Tom Petch or a Yosio Kobayasi will never miss a fungus on insect, though often hidden from easy view. There is a way to locate predacious fungi, as first demonstrated by Charles Drechsler, who pioneered the study of these fungi at the USDA. While many common moulds are easily isolated from soil by the common dilution plate method, special pre-treatment such as soil steaming is required to isolate ascomycetous and basidiomycetous species as first shown by J H Warcup, working in Cambridge. The remarkable pioneering work on chytrids and other aquatic fungi was accomplished by the use of hemp seeds and other baits. John Karling used cellulose, chitin, and keratin, and substrates such as snake skin to isolate aquatic moulds. Baits can be endless in their variety. So much innovation is possible. Apart from canopy of foliage and wood and branches on which they are borne, fallen and decaying litter are home to an extraordinary diversity of fungi and the richness of one's collection is in inverse proportion to the time one spends in a single location with a hand lens. When asked about the hand lens which he always carried around, my mentor in Kew, E W Mason replied “I am naked without it!” Apart from foliicolous fungi on living leaves, leaves in senescence and decay in terrestrial and aquatic habitats carry a succession of fungi of extraordinary variety. Many dark stromata on wood and bark, and dark black velvetty or powdery colonies are easily seen and collected, not so the countless light-coloured, hyaline fungi which abound in nature, but are difficult to collect, preserve and study. For this reason, they are the least noticed, the least studied and described. We know very little about them and so their study is especially important. Scanning electron microscopy would be useful in studying such fungi. As far as possible, sufficient material must be collected for distribution and assured keeping in International repositories, but not more. The natural habitat should not get depleted. We should try and bring into culture the fungi collected and pure cultures maintained in a Culture Collection (see below).

Documentation

We must have names and descriptions for all our fungi and information on their biology. Names should be in conformity with updated nomenclature and descriptions should be accurate. Nomenclature could be a matter of opinion, but not description. The first ever list of Indian fungi was that provided by E J Butler and G R Bisby in 1930, a compilation of great accuracy, and authoritative. Following additions to it by B B Mundkur, it was updated by R S Vasudeva on the pattern of the first list. Since then, there have been other compilations from time to time. Thanks to the initiative and vision of M S Randhawa, several monographs of fungi (and algae) were published by the Indian Council of Agricultural Research (ICAR). As a first priority on our Agenda we need to update the List of Indian fungi and holdings in our culture collections, such as there are. The importance of monographing fungi was highlighted by E J Butler, by example, when he published the monograph on *Pythium* in 1907. We need monographs of genera and higher taxonomic groups in the hierarchy. Revision of monographs, alongside updating of lists, must be taken up with a view to consolidate available information on fungal biodiversity. Monographs should carry concise and accurate descriptions of taxa supported by illustrations and data such as hosts, substrata, distribution and cladistics based on molecular data, where available. The recently published Genera of Hyphomycetes by Seifert, Morgan-Jones, Gams and Kendrick (see Curr. Sci. 101(6): 729-730) should serve as a model.

A major concern in taxonomy and nomenclature of fungi relates to their polymorphism wherein different morphs have received separate names in the past. The sexual morph (teleomorph) and the asexual morph (anamorph), when not originally found connected, were given different names. Several anamorphs have been connected and thus enjoy a single name which corresponds to the teleomorph name which takes precedence under the International Code. Article 59 of the Code as accepted at the Seventh International Botanical Congress held at Stockholm in 1950 which permitted use of anamorph names where a connection with a sexual state is not known has been in practice ever since, giving some stability in nomenclature. Concurrently, much effort has gone into connecting anamorphs and teleomorphs, but by its very nature, this is a never-ending process. Unfortunately, a recent development and event, intended to mitigate the problem of nomenclature of morphs, has now led to confusion making the problem worse. At the Melbourne International Botanical Congress held in August 2011, Article 59 was repelled. Instead, the new provisions (Art. 59.1) make it mandatory that there will hereafter be a ONE FUNGUS-ONE NAME wherein the ONE-NAME will be the oldest name, be it that of the anamorph or teleomorph, all legitimate names being treated equally for purposes of establishing priority. The application of this provision will require lectotypification and study of elements associated with the names in the original and/or sanctioning sources of countless teleomorph and anamorph names which will be a herculean task, diverting the attention of taxonomists from more serious and important work. Names to be accepted or rejected will rest on decisions to be taken by Committees and Sub-committees and will be final, with no provision for appeal. And we do not know how committees and subcommittees will be constituted and how they will function. The implications of the precipitate action taken on Article 59 at the Melbourne Congress are much deeper than what I have briefly mentioned here and will only stagger the progress of our Agenda.

The Fungal Herbarium [Herb.Crypt. Indiae Orientalis] founded by E J Butler and at what is now the Indian Agricultural Research Institute, Delhi could serve as the repository of fungal collections envisaged in our Agenda. I would recommend the Commonwealth (now International) Mycological Institute at Egham in the UK as a good model to emulate in the arrangement of herbarium specimens and live cultures so that they reflect the current taxonomy and nomenclature of any given specimen or culture, although admittedly there may not always be agreement among taxonomists!

Culture Collection, Mycogenome Banks

We should have a Culture Collection on the model of the Belgian Collection, the oldest in the world, the CBS collection in Utrecht in the Netherlands, the CAB collection at Egham in the UK, and the USDA Collection at Peoria, Illinois in the USA. The fungal collection should necessarily be in charge of competent fungal taxonomists. They should have expertise in traditional approaches to taxonomy and should have training in using modern approaches such as molecular techniques and cladistics. The Culture Collection will be a repository for all fungi brought into culture, but should have those of relevance in agriculture, forestry, human and veterinary medicine and public health, industry and biotechnology, and fundamental scientific research. It is never easy to build and maintain a good culture collection to be useful to the variety of users and for scientific research. But where there is the will, there will be a way.

Centre for Fungal Taxonomy

To achieve our goals we need to have a Centre of Excellence in Fungal Taxonomy with the responsibility of mapping our fungal resources, maintaining Reference Fungal material and Culture Collections, documentation of resources, and service and training facilities/programmes. We need competent and dedicated taxonomists. It is not easy to find them. If we do not have born taxonomists, we can have trained ones. Although there are always loud proclamations of the importance of taxonomy and conservation of biodiversity, support for taxonomy and taxonomists is hard to come by, a worldwide phenomenon. We need positive action on our proclamations of the need for taxonomy and taxonomists. Such positive action will, I am sure, encourage students to take to taxonomy and pursue a career in taxonomy which is a global need. The Centre will carry out research on fungi in the broadest sense, but specially on taxonomy, and serve as a training ground for fungal taxonomy. It is advisable to recruit a few competent taxonomists with expertise in different fungal groups to begin with and gradually expand the activity. There is always an optimum size for any institution or organization beyond which there is only a point of no return. We can determine the optimum size in terms of our current needs. The Centre should be equipped to meet international standards of study on traditional and more modern lines. There should be provision of having two or three internationally known taxonomists from other countries come and work in the Centre for periods, say three to six months annually, and a similar provision for the scientists in the Centre to go and work with counterparts in centres in those countries. Such collaboration would be of mutual benefit.

Conservation

Culture collections serve as mycogenome banks of our fungal resources and it is imperative we maintain them in the best possible way to prevent genetic modification and change. Protection and conservation of natural habitats and natural forests is not easy. In the final analysis, it is a collective responsibility of we the people. We need to act collectively as a people to achieve what we want to. For this, we need to inculcate in our people a love and concern for nature. The attitude to protect and conserve must come from within. As John Bright told the British Parliament about ruling India, force is no remedy.

I am grateful to Dr U C Lavania for inviting me to participate in the Symposium on Biodiversity organized by him in the Plant Sciences Section of 100th Indian Science Congress held at Kolkata during 3-7 January, 2013 and his initiative in having this modified version of my talk published in this Journal. Permission given by the Indian Science Congress Association for publication in this Journal is acknowledged.

SELECTED REFERENCES

Beadle G W & Tatum E L 1941 Genetic control of biochemical reactions in *Neurospora*. *Proc. nat. Acad. Sci.*,USA **27** 499-506

Bhat, D Jayarama 2010 *Fascinating Microfungi (Hyphomycetes) of Western Ghats – India.* Broadway Book Centre, Panjim, Goa, India, 221 pp.

Blakeslee A F 1904 Sexual reproduction in the Mucorineae. *Proc.Amer.Acad. Arts Sci*. **50** 205-319

Bycroft B W & Shute R E 1987 Chemistry and biosynthesis of Penicillins and Cephalosporins In John F Peberdy (ed.) *Penicillium* and *Acremonium*, Plenum, N.Y.,pp.113-160

Cadman C H 1963 Biology of soil-borne viruses. *Annu. Rev. Microbiol*. **1** 143-172

Corner E J H 1968 Mycology in the tropics – apologia pro monographia sua secunda. *New Phytol*. **67** 219-228

Couch J N & Bland C E (eds) 1985 *The Genus Coelomomyces*. Academic Press, Orlando, Florida, 399 pp.

Dale H H 1953 *Adventures in Physiology*. The Wellcome Trust, London (reprint 1965, 498 pp.)

Das Gupta S N 1958 Part **I**. Mycology and Plant Pathology In *History of Botanical Researches in India, Burma and Ceylon,* Indian Bot.Society, Bangalore, 118 pp.

Emerson R 1941 An experimental study of the life cycles and taxonomy of *Allomyces*. *Lloydia* **4** 77-144

Gams W, Humber R A, Jaklitsch W, Kirschner R and Stadtler M 2012 Minimizing the chaos following the loss of Article 59: Suggestions for a discussion. *Mycotaxon* **119** 495-507

Gams W, Jaklitsch W M & 77 others 2011 [Fungal Nomenclature} 3. A critical response to the 'Amsterdam Declaration'. *Mycotaxon* **116** 501-512

Garrett S D 1944 Root Disease Fungi. *Chronica Botanica*, Waltham, 177 pp.

Hansford C G 1946 The foliicolous ascomycetes, their parasites and associated fungi. *Mycol. Pap*. **15** 1-240

Harley J L & Smith S E 1983 *Mycorrhizal Symbiosis*. Academic Press, London, 334 pp.

Haslam Edwin 1985 *Metabolites and Metabolism. A commentary on secondary metabolism*. Clarendon Press,

Oxford, 172 pp.
Hawksworth D L 1991 The fungal dimension of biodiversity: magnitude, significance, and conservation. *Mycol.Res*. **95** 641-655
Hawksworth D L, Minter DW, Kinsey G C & Cannon P F 1997 Inventorying a Tropical Fungal Biota. Intensive and Extensive Approaches. In K K Janardhanan, C Rajendran, K Natarajan & D L Hawksworth (eds.) *Tropical Mycology*, Oxford and IBH Publishing Co, New Delhi, pp.29-50
Ho Y W & Barr D J S 1995 Classification of anaerobic gut fungi from herbivores with emphasis on rumen fungi from Malaysia. *Mycotaxon* **47** 285-293
Hofmann A 1970 The discovery of LSD and subsequent investigations on naturally occurring hallucinogens, In P J Ayd & B Blackwell (eds.) *Discoveries in Biological Psychiatry*, J P Lippincott, Philadelphia, pp.91-106
Hughes S J 1976 Sooty Moulds. *Mycologia* **68** 693-820
Ingold C T 1942 Aquatic hyphomycetes of decaying alder leaves. *Trans. Br. mycol. Soc*. **25** 339-417
Karling J S 1966 The chytrids of India with a supplement of other zoosporic fungi. *Beih. Sydowia* **6** 1-125
Kusano S 1912 On the life-history and cytology on a new *Olpidium* with special reference to the copulation of motile isogametes. *J. Coll. Agric. Imp. Univ*. *Tokyo* **4** 141-199
Lindegren C C 1945 Mendelian and cytoplasmic inheritance in yeasts. *Ann. Mo. bot. Gdn* **32** 107-123
Meredith D S 1962 Some fungi on decaying banana leaves. *Trans. Br. mycol.Soc*. **45** 335-347.
Nanney David L 1958 Epigenetic control systems. *Proc. nat. Acad. Sci*. USA **44** 712-717
Norvell L L 2011 Fungal Nomenclature I. Melbourne approves new Code. *Mycotaxon* **116** 481-490
Pandit A & Maheshwari R 1996 Life history of *Neurospora intermedia* in nature. *Fungal Genet. Newslett*. **21** 57-79
Pontecorvo G 1956 The parasexual cycle in fungi, *Annu. Rev. Microbiol*. **10** 393-400
Saksena S B 1953 A new genus of the Mucorales. *Mycologia* **45** 426-436
Shear C L & Dodge B O 1927 Life histories and heterothallism of the red bread-mold fungi of the *Monilia sitophila* group. *J. agric. Res.* **34** 1019-1042
Subramanian C V 1982 Tropical mycology: future needs and development. *Curr.Sci*. **51** 321-325
Subramanian C V 1983 *Hyphomycetes*: *Taxonomy and Biology*. Academic Press, London, 502 pp.
Subramanian C V 1986 The progress and status of mycology in India. *Proc.Indian Acad.Sci. Pl.Sci*. **96** 379-392
Subramanian C V 1992 Tropical mycology and biotechnology. *Curr.Sci.* **63** 167-172
Subramanian C V 1992 Mycogenome Banks: Strategies for Asian and Global development. *Proc. Asian Mycology Symp.*, Seoul, South Korea, 1-4 Oct.1992, pp.7-17
Subramanian C V 1995 Mushrooms: Beauty, Diversity, Relevance. *Curr.Sci*. **69** 986-998
Subramanian C V 1996 Tropical Mycology: Achievements, Objectives, Priorities. *Fungal Science* **11(3 & 4)** 135-136
Subramanian C V 2007 *The fungal biodiversity agenda: emerging trends in taxonomy*. 1st World Conference on the conservation and sustainable use of wild fungi, Spain, pp.119-121
Takahashi N, Phinney B O & Macmillan J (eds.) 1991 *Gibberellins.* Springer Verlag, N.Y.,426 pp.
Tansey E M 2003 Henry Dale, histamine and anaphylaxis: reflections on the role of chance in the history of allergy. Studies in History and Philosophy of Science Part **C** *Studies in History and Philosophy of Biological and Biomedical Sciences* **34** 455-472