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Viruses of Orchids and Their Control

Orchids have more virus disease problems than most crops. The commercial value of an orchid can be reduced considerably when it becomes diseased, and hence viruses are greatly feared, particularly by breeders and growers of cut flowers. Much information about viruses of orchids has accumulated since 1947, when the first orchid virus was described (15). Nevertheless, viruses remain widespread in cultivated orchids, even though the requisite control technology is now available.

Characteristics of Orchids

The Orchidaceae is perhaps the largest and most diverse plant family, consisting of more than 25,000 species in 800–900 genera. Orchids grow naturally throughout the world, except in arctic zones and the major deserts, as epiphytes, lithophytes, terrestrials, and even mycotrophs. Orchids are best known for their attractive flowers (Fig. 1A). More than 25,000 orchid hybrids have been described, and many of them are multigeneric. Few orchids are edible; however, vanilla flavoring is derived from an orchid seed capsule (Fig. 1B). Some orchids that are not normally cultivated are valued as wild flowers (Fig. 2), some of which (e.g., *Cypripedium calceolus, Isotria medeoloides*, and *Platanthera integrilabia*) in the United States have received federal and state protection as endangered species.

The most important orchids from a commercial standpoint are those grown for cut flowers; these include species of *Arachnis, Ascocentrum, Cattleya, Cymbidium, Dendrobium, Laelia, Oncidium, Paphiopedilum, Phalaenopsis, Renanthera*, and *Vanda* and their hybrids. Such orchids are grown in many parts of the world but are especially important in Southeast Asia (Fig. 3A). Thailand, the largest producer, has a $35 million export industry. Cut flower orchids in the tropics are generally field-grown with minimal maintenance. The *Vanilla* orchid is also field-grown (Fig. 3B) and in recent years has become increasingly important as a source for vanilla. At $20 to $70 per kilogram on the international wholesale market, vanilla is the second most expensive spice after saffron. The largest vanilla producers are Madagascar, Comoro Islands, and Indonesia, which collectively produce about 1,400 t of dried "beans" for export.

In the temperate zones, most orchids are grown in greenhouses (Fig. 3C), but some (e.g., *Bletilla* and *Cypripedium*) can be grown outdoors as garden plants. Greenhouse-grown orchids are generally marketed as potted plants for hobbyists. In Florida, for example, where there are about 3,000 active hobbyists, over 4.5×10^5 m^2 of structural space is devoted to growing orchids, which have an estimated annual sales value of $3 million.

Viruses of Orchids

At least 25 viruses of orchids have been listed (2,12,23) (Table 1). Of these, cymbidium mosaic virus (CyMV) and odontoglossum ringspot virus (ORSV), which belong to the potexvirus and tobamovirus groups, respectively, have received the most attention. ORSV has been confused with tobacco mosaic virus (TMV), but TMV may not be an important orchid pathogen (4). TMV has not been detected in surveys, even though greenhouse-grown orchids are frequently exposed to TMV inoculum from infected members of the Gesneriaceae, which are often commercially grown with orchids (22).

Both CyMV and ORSV infect orchids of many genera of old- and new-world origin (Table 2), but CyMV seems to be more common. These viruses can infect other plants that are inoculated experimentally, but only orchids sustain economic damage. Since there are no confirmed reports of natural infection by

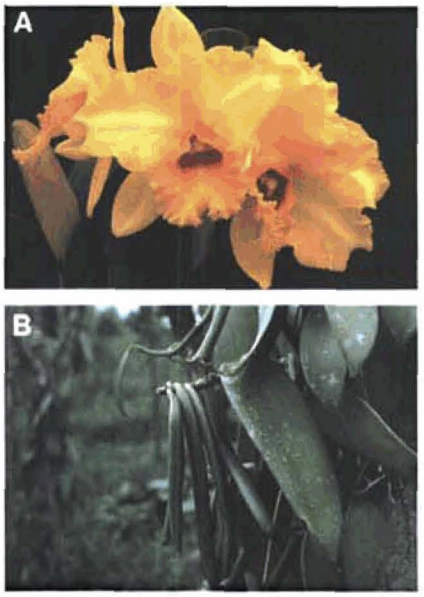

Fig. 1. Ornamental and edible orchids: (A) Inflorescence of the *Cattleya* hybrid, *Brassolaeliocattleya* Lorraine Malworth 'Orlando'. (Courtesy P. I. Stafford) (B) Immature seed capsules ("beans") of *Vanilla planifolia* grown in Costa Rica.

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either CyMV or ORSV in wild orchids (Table 2), the origins of these viruses remain unknown. The high incidences of these viruses in cultivated orchids can be largely attributed to their stability and the ease of their transmission by horticultural tools used to divide plants and to cut flowers. Seed transmission of neither virus has been proved, nor has any natural vector been identified. Accordingly, incidences of both viruses are correlated with the length of time plants remain in cultivation and the frequency with which they are handled. Species of *Paphiopedilum*, although susceptible to CyMV, are seldom infected because pruning tools are rarely used in the division and propagation of these plants (18).

It is not known when CyMV and ORSV became established as major pathogens of cultivated orchids. Clearly, this occurred before the early 1950s, when these viruses were first described definitively. A color plate of a *Cattleya* hybrid published in 1900 shows flower symptoms resembling those induced by ORSV (17). The first commercial orchid nursery was established in 1821 near London, England, but commercial orchid production did not come into vogue until the turn of the century. Since then, orchids of all kinds have been shipped throughout the world and are grown in close contact with one another. The typical orchid hobbyist endeavors to have a varied assemblage of orchids consisting of many species. The probability is high, therefore, that many plants are infected by viruses (18). Vanilla plantations in French Polynesia, not previously exposed to CyMV and ORSV inoculum, are now being threatened by recent importations of infected ornamental orchids and experimental vanilla germ plasm accessions (19).

Fig. 2. Orchids growing in native habitats: (A) *Cypripedium acaule*, a terrestrial orchid native to the United States. (B) *Anguloa virginalis* growing in a mountain forest habitat in southern Ecuador. (Courtesy W. M. Whitten)

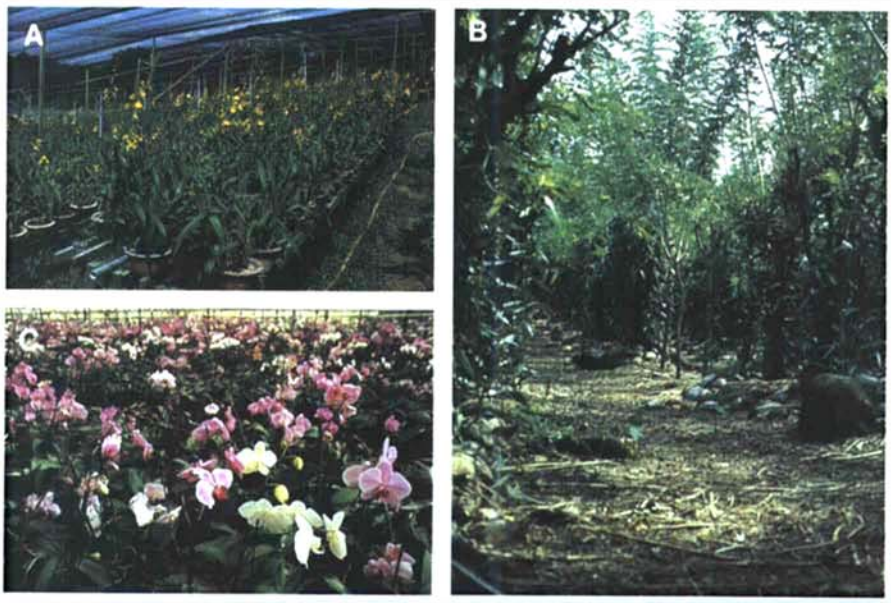

Fig. 3. Commercial production of orchids: (A) Commercial shadehouse production of *Oncidium* in Singapore. (B) *Vanilla tahitensis* vines growing on support trees in Moorea, French Polynesia. (C) Greenhouse production of *Phalaenopsis* hybrids in Florida. (Courtesy P. I. Stafford)

Symptoms induced either by CyMV or by ORSV can be severe (Fig. 4A and B). Unfortunately, infected plants often produce normal-looking foliage, and reliable diagnoses cannot be based on visual symptoms alone. Thus, collectors unwittingly expose healthy plants to infected ones as they seek to enrich their collections. Another factor contributing to high incidence of CyMV and ORSV, particularly among the sympodial orchids, is the use of tissue culture for orchid propagation. This technology facilitates production of larger numbers of a given orchid than would be possible by conventional propagation methods. Originally developed as a means to obtain CyMV-free *Cymbidium* plants using minute, virus-free shoot tips, the procedures were soon modified for the sole purpose of rapid propagation. Accordingly, much larger shoot tips, often infected with virus, were routinely used. Ironically, virus-infected orchids were then produced in large numbers and distributed to collectors everywhere. Today, many orchid growers are aware of this problem, and conscientious ones endeavor to index their plants before propagating them by tissue culture.

In contrast to the much studied CyMV and ORSV, considerably less is known about other viruses that infect orchids. Several of these viruses that are well known in other crops do not seem to be widespread in orchids. The potyviruses bean yellow mosaic, clover yellow vein, and turnip mosaic are reported to infect *Calanthe, Masdevallia*, and *Orchis* grown in Germany, Japan, and the United States, respectively. Cucumber mosaic virus has been detected in *Dendrobium* and *Miltonia* grown in Japan and in *Phalaenopsis* from Taiwan (Fig. 4C). Likewise, the nematode-transmitted tobacco rattle and tomato ringspot viruses have been found in *Orchis* grown in Germany and in *Cymbidium* grown in the United States, respectively (12,14,23).

Cymbidium ringspot virus, a member of the tombusvirus group, has a rather wide host range and has been detected in the United Kingdom in both *Cymbidium* and white clover (*Trifolium repens*). However, this virus does not appear to be widespread in orchids, even though it is readily transmitted by foliar contact, plant handling, and contaminated soil and water (7).

Other viruses of orchids also appear to be of restricted distribution. Dendrobium vein necrosis virus, a presumed closterovirus, has been detected only in *Dendrobium* plants grown in Europe and the United States (Fig. 4D). Potyviruses of *Cypripedium, Dendrobium, Spiranthes*, and *Vanilla* (Fig. 4E) have been found in Europe, Japan, Korea, and French Polynesia, respectively (2,12,19, 23). Various bacilliform viruses have been found in orchids grown in Brazil, Europe, Japan, and the United States (Fig. 4F). Some of these viruses appear to be rhabdoviruses (e.g., laelia ringspot, orchid fleck, and phalaenopsis chlorotic spot viruses), but their relationships to one another have not yet been clearly established (12).

Since most diagnostic techniques are specifically designed to detect CyMV and ORSV, other orchid viruses may be more prevalent than is perceived. On the other hand, CyMV and ORSV induce less conspicuous and persistent foliar symptoms than some of the other viruses and thus are more difficult for growers to recognize and eradicate from their collections.

Techniques for Detecting Orchid Viruses

Many reliable techniques have been developed for detecting viruses in orchids. The information necessary to apply these techniques is available to orchid growers through publications and meetings sponsored by various orchid societies (11–13,18,20). In addition, private and state-supported agencies provide services for diagnosing viruses of orchids. However, attitudes vary considerably among orchid growers with respect to the necessity of indexing their collections and identifying infected plants. Many growers are reluctant to divulge or guarantee the health status of their plants, and some prefer to index their own plants or to have them checked by diagnostic laboratories under conditions of anonymity.

Orchid growers must consider several factors when deciding whether or not to index their plants. Because few growers can afford to index every plant in their collection, they are selective in choosing which plants to test, such as those destined for propagation by tissue culture. Seedling orchids are seldom indexed, because none of the orchid viruses appears to be seedborne and because the horticultural merits of seedling orchids have not yet been evaluated.

Bioassay techniques have been widely used for many years to index orchids for CyMV and ORSV. *Cassia occidentalis* is the indicator plant most frequently used for CyMV, and *Chenopodium amaranticolor* and *Gomphrena globosa* are recommended for ORSV. Although reliable under the proper conditions, bioassays are time-consuming and require greenhouse space.

The leaf dip technique has been used for diagnosing CyMV, ORSV, and certain other viruses, but this technique is available only to those with access to electron microscope facilities. Light microscopes also have been used (10) and may be helpful when a virus is not readily identified by other methods.

Serological techniques have recently become widely used for diagnosing CyMV, ORSV, and other viruses for which antisera are available (1,8,9, 12,18,21). Liquid precipitin tests have been used for orchid viruses but are much less frequently used today than immunodiffusion and ELISA tests. The latter two serological methods have been modified so that orchid growers can

Table 1. Twenty-five orchid viruses, probable taxonomic affinities, and natural means of transmission[a]

Virus	Group	Natural vector
Bean yellow mosaic	Potyvirus	Aphids
Brazillian bacilliform	(Rhabdovirus)	(Aphids)
Clover yellow vein	Potyvirus	Aphids
Cucumber mosaic	Cucumovirus	Aphids
Cymbidium mild mosaic	(Rhabdovirus)	(Aphids)
Cymbidium mosaic	Potexvirus	Unknown
Cymbidium ringspot	Tombusvirus	Unknown
Dendrobium rhabdovirus	Rhabdovirus	(Aphids)
Dendrobium mosaic	Potyvirus	Aphids
Dendrobium vein necrosis	(Closterovirus)	(Aphids)
Filamentous Cypripedium	(Potyvirus)	(Aphids)
Filamentous Orchis	Unknown	Unknown
Grammatophyllum bacilliform	(Rhabdovirus)	(Aphids)
Isometric Masdevallia	Unknown	Unknown
Laelia red leafspot	Rhabdovirus	(Aphids)
Long orchid rhabdovirus	(Rhabdovirus)	(Aphids)
Odontoglossum ringspot	Tobamovirus	Unknown
Orchid fleck	Rhabdovirus	(Aphids)
Phalaenopsis chlorotic spot	Rhabodovirus	(Aphids)
Spiranthes mosaic	(Potyvirus)	Aphids
Short orchid rhabdovirus	(Rhabdovirus)	(Aphids)
Tobacco rattle	Tobravirus	Nematodes
Tomato ringspot	Nepovirus	Nematodes
Turnip mosaic	Potyvirus	Aphids
Vanilla potyvirus	(Potyvirus)	Aphids

[a] Viruses in parentheses have been tentatively assigned to groups and are not officially listed as such by the International Committee for Taxonomy of Viruses in 1982. Vectors in parentheses also are not yet established conclusively.

Table 2. Relative incidence of cymbidium mosaic (CyMV) and odontoglossum ringspot (ORSV) viruses in wild and cultivated orchids

	Number of infected plants[a]		
		Cultivated	
Genus	Wild	CyMV	ORSV
Angraecum	0/16	2/34	0/34
Arachnis	ns	11/30	2/30
Cattleya	0/85	75/200	14/200
Cymbidium	0/2	3/50	21/50
Dendrobium	0/21	102/535	10/535
Epidendrum/Encyclia	0/232	38/159	3/159
Laelia	0/19	7/21	0/21
Oncidium	0/66	26/67	4/67
Paphiopedilum	0/3	4/139	0/139
Phaius	0/1	25/38	14/38
Phalaenopsis	0/8	19/37	0/37
Renanthera	ns	19/30	0/30
Spathoglottis	0/51	ns	ns
Vanda	0/30	56/101	3/101
Miscellaneous[b]	0/105	468/1,101	61/1,101
Total	0/639	885/2,542	132/2,542

[a] Ratios are number infected of total samples. Values represent pooled data compiled by the authors from serological tests (ELISA and immunodiffusion). ns = No samples collected.

[b] *Aerides, Aerangis, Aranda, Ascocentrum, Brassia, Brassocattleya, Brassolaeliocattleya, Catesetum, Cycnoches, Grammatophyllum, Laeliocattleya, Maxillaria, Odontoglossum, Pleurothallis, Potinara, Spathoglottis, Sophrolaeliocattleya*, and *Spiranthes*.

index their own plants or avail themselves of testing services provided by several private companies.

More recently developed techniques may soon be significant for virus detection in orchids. For example, monoclonal antibodies are effective for detection of ORSV and other viruses, and nucleic acid probes are being developed for many viruses, including some known to infect orchids (3,6,16).

Transmission of Orchid Viruses

Recognizing that viruses can be spread by mechanical transmission, most experienced orchid growers now routinely dip pruning tools in solutions of virus-inactivating compounds, such as trisodium phosphate. Likewise, use of sterilized pots and soil mixes is a further deterrent to the spread of virus (7,12,18). Such practices are especially effective against CyMV, ORSV, and cymbidium ringspot virus, which have no known vectors. Controlling other orchid viruses, however, may be contingent upon eliminating their known or putative vectors. Studies of vectors for viruses in orchids have been limited, but aphids are known to transmit bean yellow mosaic, clover yellow vein, cucumber mosaic, dendrobium mosaic, spiranthes mosaic, and turnip mosaic viruses and the virus of *Vanilla* (2,6, 19,23). Twenty-three of the 25 viruses listed in Table 1 can be placed at least tentatively into recognized taxonomic groups. Eighteen of the 25 viruses are in groups with members known to be transmitted by arthropods, and two are in groups transmitted by nematodes (Table 1).

Millipedes, mites, nematodes, slugs, snails, and eight insect orders are listed as common orchid pests. The main insect pests are aphids, an ambrosia beetle, caterpillars, a chalcid wasp, cockroaches, fungus gnats, springtails, thrips, scales, and mealybugs. Aphids are the likely candidates as vectors of most orchid viruses (23). Although certain beetles and thrips can transmit several important viruses (i.e., bromoviruses, comoviruses, sobemoviruses, tymoviruses, and tomato spotted wilt virus), none of these viruses is known to infect orchids.

Although the nematode-transmitted tomato ringspot and tobacco rattle viruses can infect orchids, they are not likely to be major problems. Nematode populations are low in most collections because most epiphytic and many terrestrial orchids today are grown in soilless media that are not conducive to the development of high nematode populations (23). Aphids are occasionally found in orchid collections, particularly on inflorescences, but are not necessarily conspicuous because they seldom form extensive colonies. The high probability of aphids being vectors of orchid viruses is based on transmission data for viruses associated with other crops. Indeed, the majority of cucumoviruses, potyviruses, and closteroviruses are aphid-transmitted, as are some of the rhabdoviruses. Some rhabdoviruses can also be transmitted by leafhoppers and planthoppers, but these insects are unlikely to occur on cultivated orchids (23).

Control of Orchid Viruses

Viruses are likely to be persistent problems in cultivated orchids for the foreseeable future. Collectively or individually, ornamental orchids are probably the most expensive plants grown. Retail prices of potted, flowering-sized orchids range from about $5 to over $100 each. Certain *Cymbidium, Paphiopedilum*, and *Vanda* clones have been valued in excess of several thousand dollars. Also, many other orchids, not normally sold commercially, are treasured as rare botanical specimens. Because such plants would be retained in a collection despite being virus-infected, few orchid growers would agree to a concerted effort to

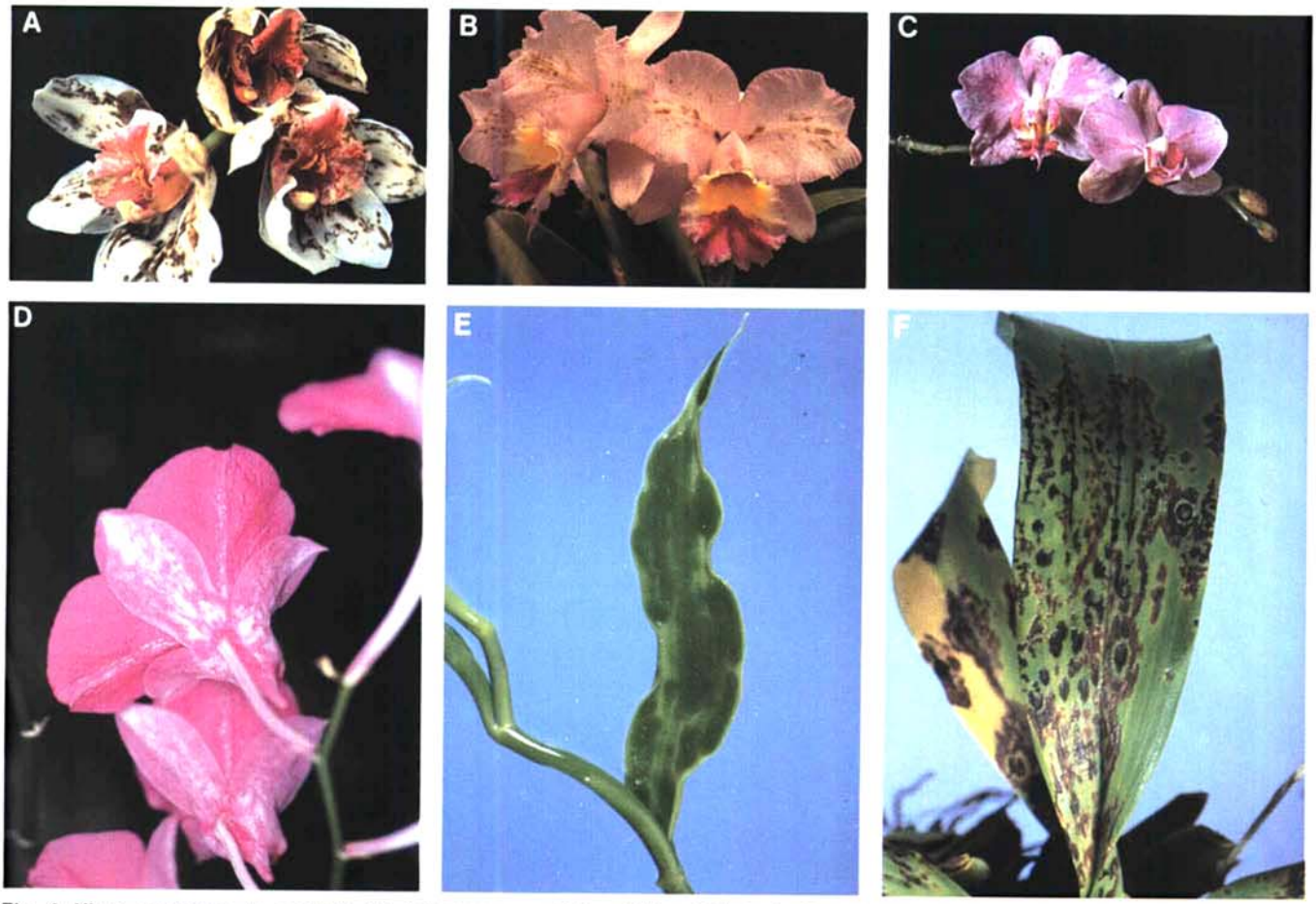

Fig. 4. Virus symptoms in orchids: (A) Inflorescence of *Cymbidium* infected with odontoglossum ringspot virus. (B) Flowers of *Cattleya* alliance hybrid with necrotic symptoms of cymbidium mosaic virus. (Courtesy P. I. Stafford) (C) Inflorescence of *Phalaenopsis* infected with cucumber mosaic virus. (D) Inflorescence of *Dendrobium phalaenopsis* infected with a closterovirus (5). (E) Leaf of *Vanilla tahitensis* infected with the *Vanilla* potyvirus. (F) Leaf of *Brassia* infected with a rhabdovirus described by Ko et al (10).

purge virus-infected plants from their collections. Nor would they agree to Draconian quarantine measures that would preclude or interfere with the international exchange of plant material. Monopodial orchids such as *Aranda* and *Vanda*, which comprise most of Southeast Asia's cut flower production, are difficult to propagate in vitro, which limits the tissue culture option for producing large quantities of virus-indexed replacement stock.

The incentive is lacking for commercial orchid growers to provide routinely certified, virus-indexed stock to their customers. Progressive growers of ornamental orchids will continue to avail themselves of information from symposia and publications. Growers will continue to test individual plants and take precautionary measures to avoid contaminating healthy ones. In so doing, most growers will probably continue to succeed in preventing viruses from pervading their collections, although few will eliminate them altogether.

The outlook for virus elimination may be worse for the less showy orchids such as *Vanilla* and endangered species maintained in germ plasm collections. Indeed, despite the recent attention being directed toward preservation of germ plasm of wild orchids and other plants, there appears to be little or no concerted effort to safeguard them from virus infections once they are put into cultivation.

Acknowledgments

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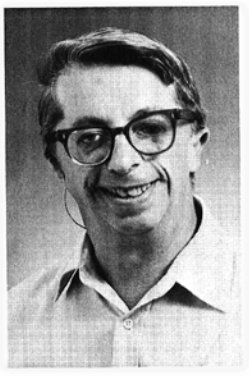

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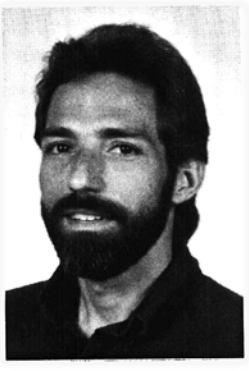
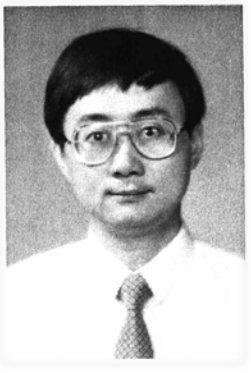


Mark S. Elliott



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