

FLOWER ABNORMALITIES

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Introduction	165
Metamorphosis of floral organs	166
Phylloidy and Bracteody	166
Sepalody	168
Petalody	169
Staminody	170
Carpellody	171
Change of sex	173
Dioecious plants	173
Monoecious plants	174
Development of pollen in ovules	174
Embryo-sac-like pollen grains	174
Agents causing abnormal differentiation	174
Unusual climatic conditions	174
Heritable abnormalities	178
Parasitism	180
Chemical treatment	181
Discussion and conclusions	183
Literature cited	187

INTRODUCTION

Because of its possible importance for future research, it seemed advisable to begin a study of the available information on abnormal flowers. Most references to abnormal structure of plants are in papers dealing primarily with other subjects. Obviously, study of all contributions relating to flowering plants is an impossible task. The primary concern of this review is to collect information about the various external and internal factors which can cause development of sepals, petals, stamens, or pistils, or of their constituent parts, particularly their development in parts of the plant or parts of the flower where they normally do not occur. Although published reports of abnormal flowers are few and widely scattered after 1900, only papers of exceptional interest are discussed if they appeared before that date, when the science of genetics began to develop. Because there are several excellent reviews of the literature on male-sterility of plants, papers dealing exclusively with that subject will be omitted.

Among the unexplored areas in the field of biology, organ differentiation may well be the most challenging. Abnormal flowers could be particularly useful for studying the process of differentiation, for the following reasons. (1) Most Angiosperms produce many flowers. In nearly all instances the flowers of any one plant are genetically identical. Consequently, it is possible to study variability within one genotype as a single plant differentiates sets of reproductive organs (flowers) over and over. (2) Many flower abnormalities are heritable. Thus it is possible to study gene interactions and gene dosage effects when they influence the degree of abnormality expressed by the plant. (3) In many

situations cytoplasm has significant effects on the expression of floral abnormalities. In some reciprocal crosses the different cytoplasm produce entirely different phenotypes. (4) The external environment can be very important. For some plants, abnormal differentiation can be promoted or suppressed at will by control of cultural conditions. (5) Given a combination of the four points listed above, i.e., an ever-blooming plant with a genetically controlled flower abnormality subject to modification by cytoplasm and environment, it should be possible to obtain new kinds of data about the processes and conditions which determine whether the apical meristem uses its genetic information for differentiating a leaf or for differentiating a carpel.

METAMORPHOSIS OF FLORAL ORGANS

All of the organs of the flower are capable, in some plant or other, of developing in the form of any of the other organs present in the normal flower. Goethe's essay on metamorphosis (1790) is the best-known early statement of the theory that all appendices of the leafy shoot—leaves, bracts, sepals, petals, stamens, and pistils—are homologous. The ability of organs to undergo transformation was important in Darwin's development of his theories of natural selection and evolution. Masters quotes Darwin frequently in his "Vegetable Teratology" (1869), still one of the most useful check-lists for species likely to furnish structural surprises. Penzig's "Pflanzen-Teratologie" (1890), although incomplete, gives an exhaustive treatment of the abnormalities reported in the plant families discussed. Even though Worsdell's "The Principles of Plant Teratology" (1916) was published after the rediscovery of Mendel's laws of heredity, it too is entirely Nineteenth Century in outlook; nevertheless, his discussions of the phylogenetic implications of organ metamorphosis argue points still being raised in botanical literature. Table I lists the plants for which floral abnormalities have been reported. Bailey's classification of plants by families in "The Standard Cyclopedia of Horticulture" (1941) was used as the structural basis for the list. In nearly all instances the plants are listed under the names assigned to them by the original authors, even though the names often are known to be obsolete or suspected to be incorrect. Wherever possible, the original paper reporting the abnormality was checked, but in many older papers the literature citations are haphazard, incomplete, or entirely lacking. Author citations are frequently, perhaps usually, lacking from species names in the older papers. Because there is no way to determine what species a man actually studied in 1830, authorities for species have been omitted from the text wherever they could not be stated with confidence. For the same reason, and also because Table I is intended to suggest genera and perhaps families likely to furnish abnormalities, the species are listed in Table I without authors' names. Particular emphasis is given to reports published after 1900 in the following discussions of the various types of metamorphosis of floral organs.

PHYLLODY AND BRACTEODY

Phyllody is leaflike development of floral organs. In the most extreme form the organ involved is replaced by a foliage-type leaf. Any floral organ, even the

ovule, may become leafy in form or color. Of all organs in the flower, the stamen is least likely to become phylloid. Since many authors do not distinguish between phyllody and bracteody in their reports, the two abnormalities will be considered together.

In photoperiodic plants the induction of flowering "switches" the meristems from vegetative growth to the production of flowering shoots and floral organs. Harder (1948), working with *Kalanchoë blossfeldiana*, found that with low stimulus for floral initiation the scalelike bracts of the inflorescence are subject to phyllody. However, among the thousands of flowers examined during his experiments, none of the floral parts were ever transformed to leaves. Raghaven (1961) and Raghaven and Jacobs (1961) reported the production of sterile structures resembling the cones of *Selaginella* when buds of *Perilla frutescens* (L.) Britt. grown in culture were maintained under long days. Indoleacetic acid in the medium produced similar effects. In preliminary experiments with *Petasites hybridus* (L.) Gaertn., Warldaw (1963) found that if an early transition apex was bisected it reverted to the vegetative state. Primordia which would have developed into bracts became normal leaves up to 10 cm. in width. Treatment with gibberellin partially or completely prevented reversion to the vegetative state.

Cold-requiring plants are also likely to develop phylloid floral organs under threshold levels of induction, or under treatment conditions which counteract some of the effects of the cold treatment. Thompson (1939) reports that sugar beets become vegetative at high temperatures even after the flower stem has grown to full height and the buds have developed. Chroboczek (1934) showed that when grown at 50-60°F. the garden beet developed seedstalks under a photoperiod of eight hours, but the seedstalks were barren. Detjen (1927) reported annual reversion of floral organs of cabbage to the vegetative state at irregular intervals. Tschermak (1932) found foliose calyces in over-wintered *Primula*. Hillman and Smith (1965) induced flowering in a vegetative clone of hybrid *Nicotiana* by a combination of gibberellic acid, low temperature, and short days. The abnormal petals shown in their illustrations are obviously phylloid. In the "green rose," a frondescent variety of *Rosa indica* Lindl. still commercially available, all of the organs of the flower are replaced by small, simple leaves which do not resemble the ordinary foliage-leaves of the plant.

Heritable phyllody has been reported for few genera. Recessive genes produce the phyllody reported in *Antirrhinum majus* L. by Baur (1924), *Torenia fournieri* Linden by Simon (1924), and *Zea mays* L. by Postlethwait and Nelson (1964).

Phyllody (also bracteody, chloranthy, or virescence) has been reported in the following genera:

Entire flower: Acer, Actaea, Agrostemma, Alyssum, Anagallis, Anchusa, Anemone, Angelica, Anthriscus, Apium, Aquilegia, Arabis, Arenaria, Barbarea, Begonia, Brassica, Brownea, Bunias, Cakile, Calendula, Capsella, Cardamine, Cerastium, Chelidonium, Corchorus, Corydalis, Crotalaria, Daucus, Delphinium, Desmodium, Dianthus, Dielytra, Dionaea, Diplotaxis, Dipsacus, Draba, Drosera, Epilobium, Erica, Erucastrum, Eryum, Erysimum, Eudianthe, Euphorbia, Fragaria, Galanthus, Galega, Geranium, Geum, Gilia, Gronovia, Helleborus, Hesperis, Isatis, Juncus, Lavatera, Lathyrus, Lilium, Lunaria, Lupinus, Lychnis, Lysimachia, Mathiola, Matricaria, Medicago, Melianthus,

Melilotus, Myosotis, Myrrhis, Nicotiana, Nigella, Nymphaea, Pelargonium, Peltaria, Petasites, Pisum, Polygala, Potentilla, Poterium, Primula, Prunus, Ranunculus, Raphanus, Reseda, Rhamnus, Rhus, Rosa, Rubus, Rumex, Saxifraga, Scabiosa, Scrophularia, Sedum, Selinum, Sempervivum, Silene, Sisymbrium, Spiraea, Stachys, Stellaria, Thlaspi, Torenia, Torilis, Trifolium, Trillium, Triumphetta, Tropaeolum, Turritis, Verbascum, Vicia, Viola, Vitis.

Bracts: Actaea, Ajuga, Amorpha, Centaurea, Corydalis, Glyceria, Heracleum, Hypericum, Kalanchoë, Lythrum, Norantea, Oenanthe, Parthenium, Perilla, Plantago, Rosa, Taraxacum.

Calyx: Anemone, Athamanta, Brassica, Cakile, Caltha, Campanula, Carduus, Carum, Cattleya, Centranthus, Cheiranthus, Cirsium, Clematis, Colchicum, Convallaria, Convolvulus, Cucumis, Cucurbita, Daucus, Delphinium, Diplotaxis, Epilobium, Eschscholtzia, Fragaria, Fuchsia, Galanthus, Gentiana, Geranium, Geum, Helenium, Heteropteris, Hypericum, Hypochaeris, Kalanchoë, Lagenaria, Laurus, Lycium, Mespilus, Papaver, Peltaria, Petunia, Philadelphus, Potentilla, Primula, Prunus, Pyrus, Ranunculus, Ribes, Rosa, Scorzonera, Senecio, Sisymbrium, Spiraea, Thlaspi, Tragopogon, Trifolium, Tulipa.

Corolla: Actaea, Alyssum, Anagallis, Anemone, Anthriscus, Antirrhinum, Aquilegia, Begonia, Brassica, Calendula, Campanula, Cattleya, Cerastium, Cheiranthus, Cirsium, Daucus, Delphinium, Dictamnus, Diplotaxis, Epilobium, Erysimum, Galanthus, Gentiana, Geranium, Geum, Gilia, Helenium, Heracleum, Hesperis, Lathyrus, Lonicera, Lychnis, Malva, Nicotiana, Oenothera, Peltaria, Petunia, Phyteuma, Polemonium, Potentilla, Primula, Prunus, Ranunculus, Raphanus, Reseda, Rosa, Rubus, Scabiosa, Senecio, Sisymbrium, Spiraea, Stachys, Stellaria, Symphytum, Thlaspi, Trifolium, Triumphetta, Tropaeolum, Turritis, Verbascum.

Stamens: Anagallis, Anemone, Anthriscus, Antirrhinum, Araucaria, Daucus, Delphinium, Dielytra (Dicentra), Dictamnus, Epilobium, Euphorbia, Glyceria, Heracleum, Jatropha, Lonicera, Nymphaea, Petunia, Primula, Rosa, Salix, Trifolium, Tropaeolum.

Carpels: Adonis, Anchusa, Aquilegia, Brassica, Cardamine, Carduus, Cerastium, Cheiranthus, Daucus, Delphinium, Dianthus, Diplotaxis, Epilobium, Heracleum, Lathyrus, Lonicera, Lychnis, Medicago, Melilotus, Nymphaea, Paeonia, Primula, Prunus, Ranunculus, Reseda, Rosa, Salix, Saxifraga, Scrophularia, Sisymbrium, Sterculia, Trifolium, Triumphetta, Tulipa.

Ovules: Adonis, Agrostemma, Alliaria, Anagallis, Anemone, Anthriscus, Aquilegia, Brassica, Carum, Cheiranthus, Crepis, Cupressus, Delphinium, Desmodium, Dictamnus, Drosera, Erucastrum, Fragaria, Gaillardia, Gilia, Hesperis, Hyacinthus, Lonicera, Lysimachia, Medicago, Melilotus, Nasturtium, Nigella, Pastinaca, Phyteuma, Primula, Prunus, Raphanus, Reseda, Rosa, Rumex, Scrophularia, Sisymbrium, Stachys, Stellaria, Symphytum, Thlaspi, Trifolium, Triumphetta, Tropaeolum, Turritis.

SEPALODY

Sepalody is a relatively uncommon abnormality. Sepalody of entire flowers has been reported only for *Dianthus* and *Erica*. Penzig (1890) reported sepaloid bracts in *Aconitum* and *Anemone*. Sepaloid petals have been found in *Anemone*, *Aquilegia*, *Cheiranthus*, *Delphinium*, *Origanum*, *Primula*, *Prunus*, *Pyrus*, *Rosa*, and *Silene*. Sepaloid anthers have been reported only for *Aquilegia*, *Delphinium*, *Nigella*, and *Trollius*; sepaloid carpels for *Anemone*, *Delphinium*, and *Rosa*.

The only two instances of sepaloid petals known to Masters (1869) were the St. Valery apple, and de Candolle's report of a calyx-like corolla in *Primula*

auricula L. Heinricher (1931) found two calyx-like corollas in the flowers of one seedling of *Primula kewensis* W. Wats. Germination of its seeds was very poor, and none of the seedlings had sepaloid corollas. Appl (1933) found a wild clone of *Origanum vulgare* L. with the corolla transformed into a second calyx and all of the stigmas carpelloid. The plants could not be selfed, but some of the seedlings of the abnormal plant had a double calyx, and one had a triple calyx. Crosses of the corollaless mutant with garden marjoram always gave 100 per cent plants with corollas. The petals are sepaloid or lacking in the mutant *Cheiranthus cheiri* L. which will be discussed under carpelloidy. Worsdell (1916) reports that in "rogue" roses, in which a second flower forms within the first, the carpels of the mother flower become superior, green, and inversely oriented, and serve as the calyx of the second flower. Many of the reports of organ transformation in the Ranunculaceae appear due to the fact that the plants were more flexible than the taxonomists. A flower with fewer petals and more sepals than usual was quite likely to be reported as an instance of sepalody.

PETALODY

Petalody is by far the commonest flower abnormality. The stamens are the organ which most commonly becomes petaloid, but the calyx and the pistils may also be affected. There is one record of petaloid ovules in *Begonia* (Worsdell 1916), and Penzig (1890) describes one case of petaloid leaves of *Rosa centifolia* L. Penzig also lists species of *Anemone*, *Hydrangea*, and *Prunus* reported to have petaloid bracts.

A petaloid calyx produces the "hose-in-hose," "catacorolla," or "calycanthema" flower, as reported for *Gloxinia*, *Mimulus*, *Nicotiana*, *Primula*, and *Rhododendron*. For *Campanula*, the petaloid calyx is normal in some species. In the Ranunculaceae, as mentioned above, the number of petals and sepals may vary, and this may be reported as either sepalody or petalody. A petaloid calyx in the orchids or *Calceolaria* may produce a second "lip."

Petaloid stamens are so common that they can hardly be considered an abnormality. Any good general seed catalog will list at least a hundred examples of heritable petalody (double flowers), and new double flowers are released by plant breeders each year. Development of petaloids is sometimes affected by environmental conditions, and this is discussed on page 178.

In many flowers with extreme doubling, the carpels as well as the stamens are affected. Rolfe (1890) reports the occurrence of an *Epidendrum* in which all four whorls present were petaloid. Worsdell notes that a petaloid carpel, or part of it, is normal in *Iris*. In this instance the style becomes petaloid and has well-developed median lamellae. The terminal portions of the lamellae form the upper bifid lip of the stigma in this genus.

Petalody has been reported in the following genera:

Calyx: *Aceras*, *Anagallis*, *Anemone*, *Aquilegia*, *Brassica*, *Calceolaria*, *Campanula*, *Carum*, *Clematis*, *Crataegus*, *Crocus*, *Delphinium*, *Fuchsia*, *Galanthus*, *Gloxinia*, *Helianthemum*, *Helleborus*, *Mimulus*, *Nicotiana*, *Nigella*, *Orchis*, *Peltaria*, *Philadelphus*, *Primula*, *Ranunculus*, *Rhododendron*, *Robinia*, *Rosa*, *Rubus*, *Silene*, *Syringa*, *Trollius*.

Stamens: Abutilon, Achimenes, Adonis, Aesculus, Allamanda, Althaea, Alyssum, Anagallis, Anemone, Anthyllis, Antirrhinum, Aquilegia, Arabis, Arbutus, Asphodelus, Atragene, Azalea, Barbarea, Begonia, Berberis, Bignonia, Brassica, Calceolaria, Calcepinia, Calluna, Caltha, Camellia, Campanula, Cardamine, Carum, Catasetum, Cattleya, Cereus, Cheiranthus, Chelidonium, Citrus, Clarkia, Clematis, Clerodendron, Clitoria, Colchicum, Commelina, Convallaria, Convolvulus, Cornus, Coronilla, Corydalis, Crataegus, Crocus, Cyclamen, Cypripedium, Cytisus, Datura, Daucus, Delphinium, Deutzia, Dianthus, Digitalis, Epilobium, Erica, Fragaria, Fritillaria, Fuchsia, Galanthus, Gardenia, Genista, Gentiana, Geranium, Geum, Gladiolus, Gloxinia, Godetia, Gossypium, Gratiola, Helleborus, Helianthemum, Hemerocallis, Hesperis, Hibiscus, Hippeastrum, Hyacinthus, Hydrocharis, Iberis, Impatiens, Ipomoea, Iris, Ixora, Jasminum, Kerria, Knautia, Lathyrus, Laurus, Leucojum, Lilium, Linaria, Lonicera, Lotus, Lychnis, Malva, Mathiola, Medicago, Melandrium, Melianthus, Miltonia, Mimulus, Mirabilis, Myrtus, Narcissus, Nelumbium, Nerium, Nesaea, Nicotiana, Nigella, Nymphaea, Orchis, Orobanche, Oxalis, Paeonia, Papaver, Pelargonium, Petunia, Philadelphus, Photinia, Prunus, Punica, Ranunculus, Rhododendron, Ribes, Robinia, Rosa, Rubus, Ruta, Sagina, Sagittaria, Sambucus, Sanguinaria, Saxifraga, Scabiosa, Scilla, Serissa, Silene, Solanum, Sparmannia, Spartianthus, Spiraea, Sternbergia, Streptocarpus, Syringa, Tabernaemontana, Thalictrum, Thea, Tofieldia, Torenia, Tradescantia, Trifolium, Trollius, Tropaeolum, Tulipa, Ulex, Veronica, Viburnum, Vinca, Viola.

Carpels: Althaea, Anemone, Arabis, Camellia, Dianthus, Fragaria, Hibiscus, Impatiens, Iris, Lonicera, Melandrium, Miltonia, Narcissus, Nigella, Papaver, Potentilla, Primula, Prunus, Ranunculus, Robinia, Trichosporum, Viola.

STAMINODY

Staminody is less common than one might expect, in view of the fact that many authors consider all of the floral organs within the calyx to be phylogenetically derived from sporophylls. Staminody of the sepals is extremely rare. A report by Gris (1858) of such staminody in *Philadelphus* was the only case known to Masters. Worsdell (1916) reported only a few additional examples: (1) *Crocus*, laterally lobed sepals, which Worsdell regards as imperfect reversions to the stamens from which they originally sprang, (2) *Trifolium*, one or two semi-petaloid sepals bore anthers, and (3) *Tulipa*, sepals had lateral lobes, and one bore an anther.

Penzig (1890) describes Licopoli's (1867) illustrations of inflorescences of *Melianthus major* L., in which the lower flowers were entirely normal, the upper ones progressively reduced until at the tip of the inflorescence there were only rosettes of bracts partially or entirely transformed to anthers. Penzig also cites a report by Guillard of *Sinapis* (*Brassica*) *arvensis* L. with petals completely lacking, stamens partly fused with sepals, and the carpels free from each other and open.

In contrast to the hundreds of genera with petaloid stamens, staminoid petals have been found in only a few genera:

Amelanchier, Aquilegia, Asphodelus, Avena, Berberis, Capsella, Cardamine, Crocus, Daucus, Digitalis, Fuchsia, Geum, Gloxinia, Heracleum, Melilotus, Monarda, Myosurus, Narcissus, Odontoglossum, Ophrys, Orchis, Papaver, Phaseolus, Prunus, Saxifraga, Solanum.

Worsdell reports (1916) that in *Alpinia* the petaloid labellum resulting from the union of two anterior stamens of the inner whorl resolved into its original constituents and the stamens became fertile.

Staminoid pistils are also quite unusual. They have been reported in:

Allium, Armoracia, Begonia, Bunias, Campanula, Chamaerops, Cochlearia, Colletia, Euphorbia, Gentiana, Geum, Hyacinthus, Impatiens, Linaria, Mathiola, Ophrys, Paeonia, Prunus, Ruta, Saxifraga, Scilla, Sempervivum, Tofieldia, Tulipa.

In a few instances normal stamens have replaced ovules inside of the ovary. Masters (1869) pictures and describes at length normal-appearing flowers of *Baekia* which he dissected, and which had normal stamens growing from the inside walls of the carpels, many of the stamens shedding pollen. Worsdell (1916) cites Agardh's report of a double hyacinth with an open ovary, in which anthers were borne on the same placenta as ovules. Buchenau (1903) described abnormal flowers of *Melandrium*; a calyx and a central placenta were lacking, and a circle of stamens formed inside the ovary at the base. Worsdell's Fig. 136 is a photograph of a tulip with a 9-merous pistil. The ovary is split open on one side, and two carpels are transformed into stamens. Worsdell's Plate 49 shows a carpel of *Begonia* bearing an anther. Martz (1928) reports that tulips sometimes bear carpels in which the rows of ovules are replaced by pollen sacs.

CARPELLODY

Carpellody is one of the more frequent floral abnormalities. Not only may any of the floral organs become carpelloid, but Marx and Mishanek (1964) report the formation of rudimentary carpels on the foliage leaves of photoperiodic peas maintained in the vegetative condition for six months or longer. The only other report of carpelloid leaves seems to be Kirschleger's (1866) description of transformation of the leaflet of *Astragalus cicer* into a carpel, with ovules on the suture.

Lutz (1897) described flowers of *Crocus* in which stamens, perianth-leaves, and even the bracts, bore stigmas. Worsdell (1916) states, "It is not rare for the sepals of tulip and crocus to become partially carpelloid, bearing ovules on their margins; in these cases all transitions have been found between carpels and sepals." Masters (1869) also reports pistillody of the perianth to be frequent in the tulip. Penzig (1890) mentions carpelloid sepals of *Pyrus*. Duchartre (1860) described alternating whorls of sepals and carpels of *Delphinium*, with numerous transitions between the two. Gottschalk (1961) produced a recessive gene mutation by irradiating pea seeds; petals were reduced or absent, and extra carpels formed from anther and calyx tissue.

Besides the carpellody of the perianth already described for *Crocus* and *Tulipa*, petals of the following genera develop some or all of the structure normal for carpels. Flowers of a highly abnormal plant of *Gossypium hirsutum* L. have all of the stamens, and frequently some of the petals, replaced by beaked carpels (Meyer, unpublished). Graf (1919) described the floral anatomy of a *Linaria* collected by Geisenheyner (1919); carpels replaced the stamens, and sometimes replaced the nectaries. C. Schimper (1829) reported carpellody of the corolla for *Paeonia moutan* Sims., *Rhinanthus*, and *Stachys*. Dahlgren (1932) cites Correns' report of the *polycarpa* strain of *Silene*. Not only stamens, but also petals, are transformed to carpels. Only a bundle of stigmas protrudes from the calyx.

Carpelloidy of the androecium occurs in many genera. It ranges in degree from stigma-like extensions on the connectives of otherwise normal anthers to development of carpels with typical stigma and style, bearing ovules capable of development into normal, viable seeds. In Baur's (1924) *Globosa* strain of *Antirrhinum majus*, the plants form a branched shoot instead of a single flower, each shoot ending in a number of irregularly formed flowers. The flowers usually contain a many-carpelled ovary surrounded by a thick sheath of calyx-like leaves. Among hundreds of these plants, an occasional fertile anther may develop. Tepfer (1953) discovered teratological flowers and fruits of *Aquilegia formosa* Fisch., in which there were numerous open, pedicellate carpels and also abnormal stamens of similar general structure, but with "submarginal" pollen sacs instead of ovules. Bateson and Sutton (1919) were apparently the first to report the occurrence of masses of exposed ovules at the base of the petals of *Begonia* flowers in the terminal position normally occupied by male flowers. Worsdell (1916) reports that petaloid stamens of *Caltha* occasionally bear marginal ovules. Usteri (1907) states that when stamens of *Carica papaya* L. are converted into carpels, the normal ovary aborts. *Cheiranthus cheiri* has probably furnished more reports of carpelloid stamens than any other species. Allman (1851) first reported transformation of the anthers to a ring of carpels. He discusses the anatomy and homology of the floral organs, as illustrated by the abnormal flowers. Later reports (Masters 1869, Chittenden 1914, Worsdell 1916, Sirks 1924, Nelson 1928-1929) discuss the development of viable seeds in the supernumerary carpels, and also the recessive inheritance of the abnormality. Worsdell cites Smith's (1908) report of a coconut palm, in the Buitenzorg Botanic Garden, which "bore, instead of the few ordinary fruits at the base of the spadix, great numbers of small, crowded, narrow (quite banana-like) fruits, which created wonderment until it was found that the phenomenon was due to the transformation of many or all of the male flowers into female." Masters (1869) discusses replacement of stamens by carpels: "One of the most curious cases of this kind recorded is one mentioned by Mr. Berkeley, wherein a large white seeded gourd presented a majority of flowers in which the pollen was replaced by ovules . . ." Martz (1928) described hybrids of *Digitalis* species, in which the androecium, normally of four stamens, was reduced and partially fused with the corolla. Anotropous ovules were scattered around the filament, along the line of anther dehiscence, and at the base of the anther next to the ovary. Meyer and Buffet (1962) found external ovules on carpel-like tissue at the tip of the androecium of *Gossypium* interspecific hybrids. Rehder (1911) discovered *Hypericum* flowers with three to ten pistillodes per flower, between the pistil and stamens, and bearing numerous exposed ovules on each margin. Pistillodes with fertile anthers were rare. Worsdell (1916) reports that *Larix* and *Pinus* stamens are sometimes seen to bear ovules. Graf (1919) and Geisenheyner (1919), in companion papers, report and describe a collection of *Linaria* with carpels, outside of the normal two-celled ovary, replacing stamens and sometimes nectaries. Martz (1928) states that in some varieties of cultivated *Narcissus* the same anther simultaneously bears pollen and ovules. Pistilloid stamens of *Nicotiana*, sometimes bearing ovules, have been reported by Costerus (1907), White (1914), Avery (1929), Goodspeed (1930), and Goodspeed and Avery

(1934). In *Nicotiana* some types of pistillody are very uniform in expression, others exceedingly variable. Both genes and cytoplasm affect development of the stamens in *Nicotiana* hybrids. Von Mohl (1837) discussed pistillody of the stamens in *Papaver* as evidence for the foliar origin of stamens. Transformation of the inner stamens to fertile carpels or stamino-carpels is common in the genus (See Table I). For *Primula*, Masters (1869) reports carpeloidic stamens varying from petaloid to those bearing ovules and stigmas. The petaloid carpels had ovules not only on their margins, but also on their upper surfaces. (Other reports are listed in Table I.) Tukey (1922) and Smith (1927) describe two different *Prunus* hybrids in which stamens were replaced by pistils. Masters (1867) describes an example in *Rosa* in which stamens exhibited almost every conceivable gradation between their ordinary form and that of the carpels, whereas some of the ovules contained pollen in more or less abundance. Bremer (1928) found carpeloidic stamens, some bearing ovules, on seedlings of a *Saccharum* usually propagated vegetatively. Apparently the first published report of pistillody of the stamens in any plant was by Du Petit-Thouars (1807), for *Sempervivum*. The transitional stages between stamen and carpel have been described many times since then (see Table I). Worsdell (1916) cites a report by Miss D. G. Scott (1906) of potato stamens with normal anthers, and with ovules on the filament and in an internal cavity of the filament. Leighty and Sando (1924), Calder (1930), and Porter, Lahr, and Atkins (1965) report carpeloidy of wheat stamens. Worsdell cites Roepers' description of a tulip in which the inner whorl of stamens was transformed to three carpels which alternated with the three outer stamens, the normal whorl of carpels being suppressed. Carpeloidy of the stamens is common in *Zea mays*. Table I lists some of the many reports of genetic and environmental effects on "tassel-seed."

Penzig (1890) notes K. Schimper's illustration of virescent carpels in *Desmodium canadense* (L.) DC., with ovules transformed to little carpels.

Carpeloid stamens have been reported in: *Amaryllis*, *Antirrhinum*, *Aquilegia*, *Asphodelus*, *Bambusa*, *Barbarea*, *Begonia*, *Bocconia*, *Caltha*, *Campanula*, *Carica*, *Cheiranthus*, *Citrus*, *Cochlearia*, *Cocos*, *Crocus*, *Cucumis*, *Cucurbita*, *Delphinium*, *Dianthus*, *Digitalis*, *Dionaea*, *Epilobium*, *Erica*, *Euphorbia*, *Fuchsia*, *Gentiana*, *Glochidion*, *Gossypium*, *Helleborus*, *Hypericum*, *Ipomoea*, *Larix*, *Lilium*, *Linaria*, *Magnolia*, *Myrtus*, *Narcissus*, *Nicotiana*, *Papaver*, *Pinus*, *Pisum*, *Platanthera*, *Polemonium*, *Primula*, *Prunus*, *Pyrus*, *Ranunculus*, *Ribes*, *Rosa*, *Rumex*, *Saccharum*, *Salix*, *Saxifraga*, *Scabiosa*, *Sedum*, *Sempervivum*, *Solanum*, *Spiraea*, *Stachys*, *Thalictrum*, *Triticum*, *Tropaeolum*, *Tulipa*, *Zea*.

CHANGE OF SEX

DIOECIOUS PLANTS

Diocious plants frequently produce either hermaphrodite flowers or flowers of the opposite sex. It is now generally accepted that all flowers are potential hermaphrodites. Even such genera as *Melandrium* and *Spinacia*, with distinct sex-chromosomes, are subject to modification of developing primordia through the effects of environment, modifier genes, or chemicals. These are discussed further in subsequent sections.

Modification of sex has been reported for the following dioecious or diclinous plants:

Acer, Aesculus, Aucuba, Begonia, Breynia, Bryonia, Callitriche, Cannabis, Carex, Cleistanthus, Cluytia, Conceveiba, Crozophora, Cucumis, Cucurbita, Empetrum, Fagus, Gunnera, Hermesia, Humulus, Juniperus, Leitneria, Lychnis, Melandrium, Mercurialis, Mozinna, Myrica, Myristica, Phyllanthus, Pistacia, Populus, Restio, Ricinus, Rumex, Salix, Schismatophora, Sedum, Spinacia, Stauntonia, Suregada, Taxus, Urtica, Zea.

MONOECIOUS PLANTS

Monoecious plants occasionally are subject to suppression of development of either anthers or carpels. In most such instances the male organs are non-functional or lacking. This could well be due to the fact that female-sterility would be more of a disadvantage than male-sterility in natural selection. Entirely male or entirely female flowers or plants have been reported in the following usually bisexual genera:

Arisaema, Callitriche, Cleome, Fragaria, Hippurus, Honckenya, Hymenanchera, Juglans, Lathyrus, Leptospermum, Morus, Origanum, Ranunculus, Sedum, Spiraea, Streptocarpus, Thymus, Trinia.

DEVELOPMENT OF POLLEN IN OVULES

This abnormality has been reported in three genera. Goebel (1908) found pollen grains inside the nucellus of *Begonia*. Salter (1863) is cited by Masters as reporting the formation of pollen within the ovules of two species of *Passiflora*. Masters himself (1867) found pollen in greater or lesser abundance in some of the ovules of a form of *Rosa arvensis* Huds. in which the stamens showed every possible transition between stamen and carpel.

EMBRYO-SAC-LIKE POLLEN GRAINS

Giant pollen grains with the appearance and nuclear arrangement of embryo-sacs have been reported in anthers of *Hyacinthus* by Nemec (1898), Naithani (1937), Stow (1930, 1933), and de Mol (1933). Geitler (1941) found similar embryo-sac-like giant pollen grains in *Ornithogalum*. He states that the other authors' drawings and descriptions agree with his findings, so they are probably correct. Nakamura (1936) found giant pollen grains in anthers of *Impatiens* exposed to high temperatures.

AGENTS CAUSING ABNORMAL DIFFERENTIATION

UNUSUAL CLIMATIC CONDITIONS

Unusual climatic conditions frequently cause or modify abnormal flower development. Other factors of the external environment, such as available nutrients or soil moisture, can also affect differentiation. The first authors to attribute abnormal differentiation to the effects of unusual environmental conditions observed a suddenly higher incidence of "a teratological phenomenon" following some particularly noticeable weather. A few of the more recent papers on plant differentiation report experiments with plants in growth chambers, or with precise measurements of field environments correlated with plant

development. In some of the experiments the chemical basis of the environmental response has been investigated also. No sharp boundary can be drawn between the environmental agent, the chemical or physical process it affects, and development of the plant organ which is suppressed or stimulated. Nevertheless, for discussion purposes it is desirable to examine each major influence separately, before briefly considering the complex interactions which finally produce a more or less abnormal flower.

The effects of environment on production of stamens and pistils are particularly noticeable in dioecious plants, or in monoecious plants with unisexual flowers distributed in some definite pattern. Atkinson (1898) controlled the sex of inflorescences of *Arisaema* by varying the nutritional level of the plant. Camp (1932) stated that *Arisaema triphyllum* (L.) Torr. is not a true dioecious plant, and that the sexual states are relatively unstable. He found that plants producing staminate flowers arose from corms light in weight and high in catalase activity whereas those producing carpellate flowers came from heavier corms with a lower catalase activity. Transitional or monoecious plants had intermediate corm weight and catalase activity.

Cannabis sativa L., the hemp plant, has been the basis for many experiments in sex reversal. Gasparriani (1862) was probably the first to report monoecious plants in this unusually dioecious species. Another genus in the same family, *Humulus*, was frequently used in parallel experiments by the same authors. Tournois (1911) reported transformation of stamens into carpels on the first flowers of early-planted hops. Seed planted at the usual time produced only normal flowers, and the early-planted hops also produced normal flowers during the normal flowering season. Tournois attributed the observed phenomenon to early sowing and to atmospheric conditions the plants were subject to at the beginning of their development. Schaffner (1921, 1923, 1925, 1931) found the relative length of daylight to induce sex reversal of hemp in a high degree. He also found that for any given daylength, percentage of reversal was greater in soil with abundant nitrogen than in a poor substratum low in nitrogen. In an experiment with greenhouse plants grown under natural short day in winter, percentage of male plants producing female organs rose gradually with decreasing daily illumination from zero to 100, and then fell again to zero with increasing daily illumination. Hemp was particularly troublesome during the first stages of developing a genetic theory of sex determination for dioecious plants. In nearly every instance the ratio of male:female plants was 1:1, and yet sex reversal occurred under some conditions. Black (1945) found fertilizer to have little effect on sex ratios of hemp. Talley (1934) and Borthwick and Scully (1954) pointed out that the tendency to produce male or female plants was undoubtedly determined genetically, but that the actual determination of sex for any one flower depended to some extent on environmental conditions. Borthwick and Scully noted that time of flowering and incidence of intersexual flowers on monoecious plants was modified to varying degrees by the interaction of other environmental factors with photoperiod. Köhler (1958) stated that sex expression of hemp seemed correlated with leaf size, since the flowers formed in regions with primarily large leaves were male, and those in regions with primarily small leaves were female.

Corn (*Zea mays*) frequently produces spikes with some or all of the flowers showing sex reversal. Schaffner (1927) found that 75 per cent of the corn plants grown in a winter greenhouse produced carpellate tassels, but the same variety showed no such reversal when grown under summer field conditions. Richey and Sprague (1932) produced partially or completely pistillate tassels on corn plants grown in the greenhouse during the winter in an environment of short days, low light intensity, normal growing temperatures, and abundant water. Increasing either temperature or light decreased the number of silks in the tassels. A difference of 10° F. in temperature was about as effective as four and one-half hours of illumination.

As early as 1869, Masters was concerned with the role of environmental factors in differentiation. "Knight and other vegetable physiologists have been of the opinion that a high temperature favours the production of stamens, while a lower degree of heat is considered more favorable to the production of pistils . . . Mr. Darwin cites from various sources the following details relating to strawberries which it may be useful to insert in this place, as throwing some light on the production of unisexual flowers. 'Several English varieties, which in this country are free of any such tendency, when cultivated in rich soils under the climate of North America commonly produce plants with separate sexes. Thus a whole acre of Keen's seedlings in the United States has been observed to be almost sterile in the absence of male flowers . . .'" Masters continues his discussion, "*Stratiotes aloides* has been said to produce its carpels with greater abundance towards the northern limits of its distribution, and its stamens, on the other hand, are stated to be more frequently developed in more southern districts . . . *Honckenya peploides* affords another illustration of the sexual arrangements in the flower being altered as it would seem by climatal conditions. Thus, in the United States, according to Professor Asa Gray, the flowers are frequently hermaphrodite, while in this country they are usually sub-dioecious . . . Treviranus says that the flowers of *Hippurus* and *Callitriche* are apt to be hermaphrodite in summer, but female at a later period."

Perhaps the first experimental study of environmental effects on differentiation was performed by Shattuck in 1910. He prevented the formation of megaspores in *Marsilia*, a fern, by means of a spray of cold water. Many observations and experiments since that time have concerned a wide range of plant species, organs affected, and climatic factors involved. Meade (1913) reported supernumerary carpels at the center of cotton bolls from widely separated locations (Maryland, California, Texas). He attributed the formation of supernumerary carpels to unusually low night temperatures. Tukey (1922) was uncertain whether the pistillody he described in a hybrid plum was a varietal characteristic or the result of a frost which occurred at the time of blossoming. Simon (1924) found that maximum development of flower abnormalities occurred in mutant *Torenia* plants grown under the hot, dry conditions of the cactus-house, and nearly normal plants were produced under warm, moist, shady conditions. Transferring either group of plants to the other environment reversed the expression of the abnormality. Detjen (1927) reported that reversion of carpels and other organs of cabbage to a vegetative stage occurred annually at irregular intervals. Appl (1929) found formation

of perfect flowers of marjoram to be suppressed to some extent early in the season or under conditions of poor nutrition. As noted earlier, the formation of giant pollen grains depends on abnormally high temperatures during differentiation (see p. 174). Goodspeed (1930) reports considerable variation in pistilloid *Nicotiana tabacum* L.: "At the start of the flowering season practically no viable pollen is produced in flowers of this type, whereas towards its close the anthers uniformly exhibit less structural abnormality and contain a considerable proportion of viable pollen."

Tschermak (1932), in studies of *Primula*, found that even for one individual, calycanthemy and doubling were at a different level in summer than in winter flowers. Foliose calyx, accompanied by vestigial sex organs, occurred in some of his overwintered *Primula* stocks. Later flowers of the same plants were entirely normal, so apparently this was an example, not of heritable abnormality, but of one produced by cold. Chroboczek (1934) states that favorable conditions of light and temperature are essential to the development of a fertile inflorescence of beets, as well as to the initiation of the flower primordia. The results of Harder's experiments, involving phyllody in *Kalanchoë*, are discussed on page 167. Kihara (1951) found that environment had important effects on fertility in *Triticum*, material grown at Kyoto being considerably more fertile than that sown on the same date in Sapporo. The lower fertility was due to two kinds of defects in reproductive organs—pollen abortion and pistillody of stamens. Pistillody was more frequent in late maturing plants. Daylength seems to play an important role in producing pistillody; in Sapporo, where the summer days are longer than at Kyoto, pistillody was always very conspicuous, and the fertility of the *Aegilops* backcrosses to *T. vulgare* Vill. was very low. Lang (1952) reported that low light intensity may block development of anthers of *Lycopersicon* or *Bryophyllum*.

Galun (1956) found that cold treatment would reduce the number of nodes before the first female flower was produced by some, but not by other, cucumber varieties. Shifriss, George, and Quinones (1954) found the varying sex expression of different cucumber strains to be controlled by weak or strong male-determining genes which acted by speeding or slowing the normal transition from male to female flowers as the plant aged. Thomas (1956) delayed production of female flowers in *Cucurbita pepo* L. and in *Ambrosia* by growing plants at high temperatures and under long photoperiods. In natural summer conditions monoecious plants of *Mercurialis ambigua* L. fil. produce one female flower and a cluster of male flowers in each leaf axil, but long days significantly delayed production of female flowers, as did increasing the temperature from 15.5° to 24°C. Male flowers were produced at the lowest flowering node of female plants grown in continuous light for 45 days at a day temperature of 21-26° C. and a night temperature of 15.5-21° C. and then transferred to eight-hour photoperiods at the same temperature. Thomas states, "These results are particularly interesting as they indicate the possibility that growth of female as well as monoecious plants through a male phase before they produce female flowers is a general phenomenon. Female plants normally reach the female phase before flowers develop and usually produce no male flowers, but by artificially delaying the attainment of femaleness, male flowers are produced."

Zabka (1961) found that, although *Amaranthus caudatus* L. will initiate flower primordia on long days, normal development of the inflorescence requires short photoperiods. Noack (1962) reported that in two successive years there was a distinct positive correlation between hours of daily sunshine and the number of perfect flowers replacing male *Begonia* flowers. Semeniuk (1964) carried out growth-chamber experiments with rose seedlings. The maximum number of petals was formed at 62° F., whereas at 82° and 92° F. the number of petals was reduced to five, the basic number in the wild rose species. Also, stamens were fewer and pistils and filaments relatively longer at lower temperatures. His results probably account for the observation published by Violle (1911). A partial translation follows: "During the holidays, I had the opportunity of observing an occurrence which appears noteworthy to me. This was produced by a magnificent rose plant of *Gloire de Dijon* planted in the open ground at Fixin, about ten years ago, remarkable in development and vigor: all by itself it forms an arbor above a large door and for months at a time produces an abundant and constantly renewed flowering of superb roses. However it did not undergo the torrid heat of last summer without suffering, and during the month of August flowers were less beautiful and less numerous than usual. Then, suddenly, about September 12, it produced on all of its branches a complete flowering of absolutely single roses, which were succeeded 8 days later on the same branches by a full crop of the beautiful roses usual for it, and which were still being produced by the plant when I left a few days ago."

Wijewantha and Stebbins (1964) found the expression of the *agropyroides* gene, affecting the number and type of appendages differentiated in the barley spike, to be greater under field conditions than in the greenhouse. Meyer (1965) found a negative correlation between minimum daily temperature 17-18 days before anthesis and the number of external ovules produced by cotton plants with the EO gene; there was also a significant positive correlation between relative humidity 23 days before anthesis, and the number of anthers per flower produced by Upland cotton and its hybrids with the EO gene.

HERITABLE ABNORMALITIES

Heritable abnormalities are responsible for the majority of the reports of abnormal differentiation during the past 50 years. Strictly speaking, virtually any mutant gene interferes in some way with normal differentiation. The old-fashioned reports of singular occurrences of teratological phenomena have been replaced by studies of the mode of action of mutant genes. A non-heritable abnormality is unlikely to be reported in modern journals, unless it can be either reproduced by physiological manipulation or propagated vegetatively.

Recessive genes are responsible for anomalous flowers in many genera. Baur (1924) discusses the inheritance of 40 different factors in *Antirrhinum*, most of them recessive mutants, six of them producing highly abnormal flowers. The many reports of pistilloid stamens in *Cheiranthus cheiri* all agree that the property seems due to a single recessive gene. Either the same gene must mutate rather often, or the anther primordia of *Cheiranthus* must respond

similarly to many different mutant genes. Corn, tobacco, and *Primula* have several different flower abnormalities attributed to single genes. Other recessive abnormalities are known in *Hordeum*, *Lathyrus*, *Papaver*, and *Pisum*. Chromosome abnormalities seem to be associated with the carpellody of *Saccharum*.

A disproportionately high number of aberrations occurs in interspecific hybrids. In some instances the two sets of chromosomes may not cooperate as well as chromosomes from within one species; in others the genes of one species are unable to function effectively in another cytoplasm. Bateson and Sutton (1919) had considerable difficulty explaining the results they got from crosses between normally monoecious *Begonia* species. When they crossed pollen of a single-flowered *B. davisii* on a double *B. lloydii* all plants were at least partially double-flowered. The reciprocal cross and the self of *B. davisii* were single. The double flowers were in the terminal position ordinarily occupied by male flowers in the *Begonia* inflorescence, but in this example the double flowers bore masses of exposed ovules at the bases of the petals. In *Begonia lloydii* the terminal double flowers are male, and they readily produce pollen if the plants are grown under stress conditions. Bateson and Sutton (1919) state: "The view that plants e. g. Graf Zeppelin, in which the terminal flowers are female, instead of male as normally, may be *homozygous* females is rather attractive, but we see no means of testing it; nor if such an idea could be entertained, would it at all account for the fact that in a full double which must certainly be accepted as a recessive, homozygous in doubleness, the normal female flowers standing in the lateral positions are single . . . Since *B. davisii* is a genuine wild species and bears exclusively single flowers, the conclusion to which our observations have led us, namely that its male side is genetically all double, seems not a little remarkable." Noack, working with *Begonia* hybrids (1962a), and observing essentially the same sort of flowers as did Bateson and Sutton, found that the results could be quite simply explained by assuming a combination of segregating nuclear and plasmatic factors and pollen-tube competition.

Heilbronn and Basarman (1942) found sex determination of *Bryonia* hybrids to be complex. *B. alba* cytoplasm prevents formation of fertile germ cells in the hybrid, but *B. dioica* cytoplasm does not. Sex determination within the species is controlled by different genes. They conclude that phylogenetic development of a mixed-sex species into a separate-sexed one with genotypic sex determination can occur in different ways, through mutation in different chromosomes; the finally-fixed method of sex determination can vary, even in closely related forms, i.e., unifactorial, bifactorial (or plurifactorial?).

Rainio (1927) is of the opinion that interspecific hybridization may be a factor involved in all of the monoecious plants of *Populus* and *Salix*. Since most such reports concern single trees found growing spontaneously in various parts of the world, and since the genera are wind-pollinated, that seems a reasonable assumption. Peto (1938), Seitz (1952), and Schlenker (1953) all state that perfect flowers occur regularly in experimental hybrids of *Populus*. Arnal's (1952) report of an androgynous *Salix* concerns *S. sepulcralis* Simonkai, believed to be a hybrid between *S. alba* L. and *S. babylonica* L.

Other floral abnormalities reported for interspecific hybrids include external ovules in *Gossypium* (Meyer and Buffet 1962), petaloid and pistilloid

Nicotiana (White 1914, Burk 1960), corollaless *Origanum* (Appl 1933), phyllody and calycanthemy in *Primula* (Heinricher 1931, Ernst 1931), pistillody and staminody in *Prunus* (Tukey 1922, Smith 1927), deformed and indehiscent flowers in *Solanum* (Grun, Aubertin, and Radlow 1962), pistillody in *Sireptocarpus* (Oehlkers 1940), and pistillody in *Triticum* (Kahara 1951).

Some monotypic genera also apparently have cytoplasmic differences which can affect gene action to produce abnormal flowers or flowering. At least one of the pistillate varieties of *Ricinus* requires both "pistillate" cytoplasm and the proper dominant genetic factor to produce entirely pistillate plants (Parkey 1957). Although Stein (1965) is dubious about possible cytoplasmic influences in the expression of "everted ovule" gene in *Ricinus*, some of the mutant genes affecting fertility are expressed differently in cytoplasm from different sources within the genus. The extreme variability of Simon's (1924) mutant *Torenia*, together with its virtually complete disappearance in the F_2 and later generations from some test-crosses with normal plants, suggests that cytoplasmic abnormalities may be involved in this case also.

PARASITISM

Parasitism was one of the first causes of abnormal differentiation to be widely recognized. Goethe (1790) mentions its effects on flower development, but specifically excludes description and discussion of such abnormalities from his essay on metamorphosis. Peyritsch (1881) observed many cases of aphid-caused phyllody in crucifers. He also produced phyllody artificially in *Cerastium glomeratum* Thuill. by infestation with *Psylla cerastii*. Worsdell (1916) lists many reports of petalody as a result of infestation by parasites: stamens of *Knautia arvensis* (L.) T. Coulter changed to violet petals as a result of attack by *Peronospora violacea*; double flowers of *Saponaria officinalis* L. caused by the smut fungus *Ustilago saponariae*; petaloid stamens of *Primula officinalis* Hill caused by presence of the fungus *Dematium* in the roots; double-flowered plants of *Saponaria officinalis* L. infected in their rhizomes with *Fusarium*, while single-flowered plants were free of it; petalody in *Scabiosa columbaria* due to galls of *Heterodera radicolica*—normal plants transplanted to the same location became double. Molliard (1904) describes a phylloid gynoeceium of *Trifolium repens* L. due to presence in the stem of an insect larva, probably *Hylastinus obscurus*; in *Melilotus arvensis* all plants with phylloid flowers had larvae of *Apion melilotii* in the neck and branches of the stem. The same author also found abnormal flowers resulting from insect infestation in *Senecio jacobaea* L. and *Cardamine pratensis* L. Allan and Zotov (1930) found that the rust *Aecidium otagense* produced female flowers in male inflorescences of *Clematis*. Erlenmeyer and Geiger-Huber (1935) report a smut fungus which causes development of anthers in female flowers of *Melandrium album* Garcke; spores of the fungus are then formed within the anthers instead of the normal pollen of the plant. Loehwing (1938) notes the development of stamens in pistillate flowers of *Lychnis dioica* L. infested with *Ustilago*, and the hermaphroditism of staminate willow trees, induced by Eriophid mites. Heslop-Harrison (1959) discusses the formation of female flowers in the normally male terminal inflorescence of *Zea mays* as a result of infection by *Ustilago zeae*.

CHEMICAL TREATMENT

Chemical treatment has been used in many ways to modify plant development, including that of the inflorescence. The auxins were the first group of chemicals to be used for intensive studies. Later studies involved many single compounds, of known and of unknown structure, and other groups of substances, such as gibberellins and cytokinins. Important information has resulted from experiments to determine effects of growth substances when they are applied to growing plants at particular stages of differentiation.

Löve and Löve (1940) performed one of the earliest experiments on the chemical modification of sex in plants. They applied animal sex hormones to young growing points of *Melandrium rubrum*. Treatment of normal female plants with testosterone increased development of the rudimentary staminate normally present in the flowers. Gynohermaphrodite plants treated with oestrin became purely female with no staminate. Normal male plants have no rudimentary gynoeceium, but in a few instances a very small hairlike formation is to be found in the flower. By treating normal male plants with oestron such hair develops, grows, and sometimes forms a little gynoeceium with two stigmas. An andro-hermaphrodite treated with oestron produces a large gynoeceium with no staminate. In most situations oestron on female plants and testosterone on male plants exercised a poisonous effect and often killed the sprouts.

Wittwer and Hillyer (1954) reported that a single application of maleic hydrazide to cucurbits resulted in a high percentage of plants with only pistillate flowers. Repeated applications produced many male-sterile plants. Pistillate flowers on such plants were normal and fertile.

Laibach and Kribben (1950) found that β -indoleacetic acid (IAA) could cause development of female flowers on nodes of cucumber plants which normally have only male flowers. Heslop-Harrison (1956) used α -naphthaleneacetic acid (NAA) to cause formation of female flowers in genetically male plants of hemp. Galun (1956) reduced the number of nodes preceding the first pistillate cucumber flower by applying NAA after cold treatment. Brantley and Warren (1958), working with NAA on muskmelon, increased the number of staminate and perfect flowers and the ratio of perfect to staminate flowers. J. and Y. Heslop-Harrison (1958) treated *Silene pendula* L. with NAA; all of the plants grown in long days were male-sterile to some extent. A feature of the auxin-induced male-sterile flowers was precocious development of the gynoeceium. Flowers of this type were mostly female-fertile and gave a normal crop of seed when pollinated artificially. Raghaven (1961) added IAA to the culture medium for photoinduced apical buds of *Perilla*. Flowering was inhibited in two ways — by delay in appearance of the first signs of flowering at the apex, and by a gradual transition from flower-like structures at lower concentrations of IAA to sterile cones in higher doses. Orr and Postlethwait (1964) prevented complete expression of the fasciated ear gene of maize by the addition of either IAA or NAA.

Peterson and Anshder (1960) induced formation of staminate flowers on gynoeceious cucumber plants by gibberellin (GA) treatment. Similar results with cucumbers have been reported by Wittwer and Bukovac (1962b), and Shifriss and George (1964). Shifriss and George report varietal differences

in the sensitivity of female plants to sex reversion by gibberellin treatment. Shifriss (1961) found that gibberellin treatment of castorbeans produced a response diametrically opposite to that for cucumbers—a marked increase in female tendency. Wardlaw (1963) used gibberellin to partially or entirely prevent reversion of injured floral apices of *Petasites* to the vegetative state. Hillman and Smith (1965) used a combination of GA, low temperature, and short days to induce flowering in a clone of tobacco which had previously been entirely vegetative.

Carbon monoxide induces auxin-like symptoms in plants. No pure-sexed female plants of *Mercurialis ambigua* exist. J. and Y. Heslop-Harrison (1957) increased the proportion of female flowers by treatment with carbon monoxide.

Wijewantha and Stebbins (1964) found that the effect of barley of the *agropyroides* gene could be partly neutralized by the addition of arginine or one of its precursors, glutamic acid. Tyrosine and adenine sulphate also caused significant changes toward normality in expression of the *agropyroides* character.

Roark, Pfrimmer, and Merkl (1964) studied effects on flower initiation of various chemicals sprayed on cotton. First fruiting branches developed at a higher node of the main axis on plants sprayed with methyl parathion than on control plants sprayed only with solvent + emulsifier. Plants sprayed with phosphorodithoate I also developed first fruiting branches from a higher node of the main axis than on control plants.

Since 1961 experiments have been carried out on the combined or contrasted effects of various groups of chemicals, and of modifications of photo- or thermal- induction by various groups of chemicals. Mitchell and Wittwer (1962) increased pistillate flower formation in monoecious cucumber plants by adding allyl trimethylammonium bromide to the aerated culture solutions used as the root medium. By contrast, gibberellin induced staminate flower formation on gynoeceous cucumber plants. The two chemicals also have diametrically opposite effects in tendril formation and vegetative extension.

Wittwer and Bukovac (1962a) comment on the marked species specificity of compounds which affect flowering and fruit setting in higher plants. The N-arylphthalmic acids effect flower formation only in the tomato and possibly the strawberry; 2,3,5-triodobenzoic acid in the bean, tomato, and only one or two other species; hydrazine derivatives only in the pineapple; 2,4-D only in pineapple and sweet potato; maleic hydrazide only on celery; furfuryl alcohol only on *Rudbeckia speciosa* Wenderoth; and 2-chloroethyl-trimethylammonium chloride (CCC) only on tomato and *Azalea*. The gibberellins appear to be the only group of chemicals which exercise predictable and consistent control of flowering over large segments of the plant kingdom. Phenocopies of five recessive genetic characters in the tomato may be induced by treatment with N-m-tolylphthalmic acid. These include determinate growth, fasciation of the flowers, branching of the flower cluster, leafy flower clusters, and blindness. Auxins and CCC shortened the time to anthesis for tomato seedlings; maleic hydrazide, phosphon D, and gibberellin either delayed first anthesis or increased the number of nodes subtending the first inflorescence. An even greater delay occurred with kinetin. Gibberellin delays flowering of peas; kinetin has the

reverse effect. The promotive effects of kinetin on flowering of peas appeared light-dependent.

Nitsch (1962) states that applied growth regulators can modify the development of the flower parts as do environmental factors. Auxins can inhibit development of male flowers and stimulate that of female ones. Gibberellins, on the other hand, increase the male/female ratio not only by delaying the formation of the first pistillate flower, but by actually causing the development of male flowers on genetically 100 per cent female cucumber lines. A substance with the biological properties of a gibberellin has been isolated from photo-induced *Rudbeckia* plants, and can induce flowering of other rudbeckias maintained under non-inductive short days. An endogenous growth substance different from the indolic auxins and the nine first gibberellins has been isolated from cold-requiring plants (chrysanthemum, biennial hollyhock). Although this substance causes flowering of rudbeckias under short days, it did not produce any flowers on unvernallized hollyhocks, but it did cause their bolting.

Tepfer *et al.* (1963) extended the developmental limits of *Aquilegia* buds at nearly all stages by adding indoleacetic acid, gibberellic acid, and kinetin to the basic culture medium.

DISCUSSION AND CONCLUSIONS

Surprisingly little experimental work has been done on controlled variation of plant form. Many plant species deviate frequently from their normal pattern of flower development. Some physical and chemical treatments are known to affect flower organ formation. Several authors have pointed out that *the phenotype of a plant results from interaction of its genes and cytoplasm with each other and with its internal (physiological) and external environment.* An experimental approach would seem to be a good starting point for trying to determine what basic mechanism actually causes differentiation.

In 1790 Goethe attributed the serial production of cotyledons, leaves, bracts, calyx, corolla, stamens, and carpels to refinement of the sap as the crude liquid moved from the ground upward and became more ethereal. In 1965 we have other ideas than Goethe did about the process of differentiation, but not many more actual data. The information which is available is fragmentary, contradictory, and scanty. There is so little of it that there are not even opposing theories about the basic mechanisms of flower differentiation.

Few theoretical concepts have been so generally and so quickly accepted as the idea that plant meristems function as reaction systems, with "switch mechanisms" to turn on and turn off the gene-controlled processes involved in producing the various appendages. Wardlaw's (1957) original statement of the theory included the idea that a particular gene only becomes active when the physiological situation has become appropriate to its activity, and that the changes induced by it in the reaction system (or in the protoplasmic substratum) prepare the way for the action of certain other genes. Wardlaw concludes, "Experimental tests of the theory will consist essentially in interfering with the floral reaction system at critical stages in a known manner, followed by observation of such morphological modifications as may be induced. The main

impediment to crucial experiments lies in the fact that so very little is known of the factors that are at work in the reaction system."

Zeevaert (1962) assumes that the reaction of an organism to its environment must be completely determined by its genotype. The sequential turning on and off of genes during differentiation he calls programming. His experiments with *Pharbitis* suggest that the photo-periodic stimulus activates the floral genes directly. From the suppression of flowering by specific chemical metabolic inhibitors, reversal of the inhibition by precursors of DNA, and the different effects obtained by varying the time of application of the various chemicals, he concludes that the floral genes can be activated during the multiplication of DNA.

Brink (1964) discusses the process of activation and repression of genes in multicellular organisms. He states that (1) activation of a gene is dependent upon the sequential operation of two sets of factors, one at the chromosomal level, the other at the individual gene level. (2) Two processes are involved at the chromosome level, uncoiling of the chromosome, and dissociation of DNA from the histone sheath which prevents its action. (3) Gene action is repressed in a coiled chromosome segment, and formation of its RNA copy requires absence of the histone sheath. (4) General nuclear processes, not the genes activated, control chromosome uncoiling and histone dissociation. (5) Heterochromatin may act as a non-specific repressor substance by blocking uncoiling. (6) Definitive activation of a gene follows uncoiling of a chromosome segment and dissociation of the histone. It occurs in response to some sort of signal from the cell, specifically related to the locus in question. "The basic requirement to be fulfilled is a mechanism that recognizes the uniqueness of each gene." Brink concludes that the known examples of genetic repression in multicellular organisms provide inadequate evidence for the individual regulation of gene action in accordance with the requirement for orderly development. The mechanism that effects the latter process must be co-specific with the genes themselves.

Wijewantha and Stebbins (1964) treated barley carrying the *agropyroides* character with arginine or its precursors, and produced a significant change of expression toward normality. Apparently the altered biochemical information produced by this gene affects arginine metabolism at all stages in the life cycle of the plant. The visible effect of the gene is probably not due to a time limited initial action of the gene, but to effects of unbalanced arginine metabolism on critical stages of cellular differentiation. They suggest that the connection between the primary effect of the gene on arginine metabolism and its final effect on differentiation is via an abnormal or deficient synthesis of histone proteins.

There is considerable evidence that phytochrome may sometimes trigger the switch mechanism which changes differentiation of the apical meristem from leaf production to flower production (Borthwick 1962, Nitsch 1963). Other evidence suggests that sometimes the auxin level may be of critical importance in the differentiation of the various organs (Heslop-Harrison 1957). In still other examples a competition between two antagonistic substances of different origin and chemistry seems to determine which of two alternative

structures will occur (Wittwer and Tolbert 1960, Tolbert 1961).

Every new development in plant physiology or genetics has probably been seriously considered in at least one theory which attempts to correlate the obvious external differences in plant organs with an internal variance during differentiation. Because they are so close together in time and space, and yet so obviously distinct, the male and female organs of flowers have frequently been subjected to comparative analyses or experiments.

Laurent (1906) associated differences in sex of plants with osmotic pressure. He found rootstocks of female hop plants to be heavier than those of male plants in the same plots, female poplars several days earlier than males, lush growth in general associated with female flowers.

After sex chromosomes were discovered in animals, there was an intensive (occasionally successful) search for such chromosomes in dioecious plants. The early workers on genes and chromosomes associated with sex determination in plants frequently had serious doubts that sex of dioecious plants was genetically determined, because environmental factors could alter the usual ratio of 1:1. Emerson (1924) was one of the earliest to point out that the fact that a property is influenced by environmental factors does not mean that a gene makes no contribution to its development. He states that what is inherited is merely the possibility—indeed the necessity—of reacting in a particular way to a particular external and internal environment. In typically hermaphroditic forms where both male and female tendencies are exhibited in the same individual, factors for maleness or femaleness are thought of as being in so delicate a balance that influences analogous to those responsible for the differentiation of vegetative characters effect a more or less regular differentiation of sex organs. Sharp (1925) came to essentially the same conclusions. He considered *determination* of the heritable characters exhibited by an organism to involve reaction of the genic mechanism with other factors in and through the cytoplasm during the course of the ontogeny.

Allen (1932) also distinguished between sex inheritance and sex determination. He noted that in dioecious bryophytes only one set of sex possibilities is represented in each haploid chromosome complement. Richey and Sprague (1932) point out that although genes which produce a given end product under a wide range of environments are used by most geneticists, the geneticist recognizes clearly that other types of genes exist, and regularly uses a more or less controlled environment in working with such genes. Naithani (1937) endorses the theory advanced by Emerson and Sharp. Sex reversal occurs in the anthers of 'Yellow Hammer' hyacinths, but not in other varieties similarly treated. He attributes this to the genetical balance, which is such in other varieties that the environmental condition which disturbs the balance in 'Yellow Hammer' is not effective. Erlanson and Hermann (1927) reported the production of perfect flowers by *Populus tremuloides* Michx., a normally dioecious species. "Since the perfect flowered *Populus* is heterogametic with an XY-sex pair such as found in the normal male, this seems to be another case in which some factor upsets the internal balance which geneticists claim determines the external manifestations of sex."

Camp (1929) found a distinctly higher catalase activity in male than in

female plants of dioecious species, with floral structures generally showing a greater difference than vegetative parts. Talley (1934) found that male hemp plants had values for reducing sugars two to three times as high for male as for female hemp plants. Staminate plants also had a relatively lower nitrogen content than female plants. Joyet-Lavergne (1935) attributed sexual differences to physico-chemical differences in metabolism.

Goldschmidt (1938) considered Oehlkers' *Streptocarpus* hybrids to be subject to sex determination in the same way as his *Lymantria* intersexes. The various degrees of intersexuality were due to balances between genic and cytoplasmic sex determiners of differing strengths, distributed at meiosis and at fertilization.

Loehwing (1938) believed flowering to be induced by hormones. He considered the sex processes to be as different from one another metabolically as are the vegetative from the fruiting phase of plants as a whole. He discussed the Manoilov technique for measuring differences in oxidation potential, and noted that female tissues are generally more reducing in character.

Arnal (1952, 1954) found evidence for a sexual gradient in willows. In his theory of sex determination there are three fundamental types of gradient: simple, double (female-male-female), and multinodal (a gradient at each bud). When the gradient is weak, the switch from one sex to the other is subject to external control; when it is strong, external factors have little effect. Arnal considers the usual hermaphrodite flower of the Angiosperms as only a special example of high-level sexual gradient always oriented in the same direction. When the level of the gradient is diminished, stamino-carpels may appear.

Heslop-Harrison (1957) presents a theory based on initiation of flowering through the agency of an auxin-controlled, self-duplicating nucleoprotein. "The course of floral morphogenesis, once initiated, is established by genetic factors at the reacting apex, and the activity of these is to some extent regulated by auxin levels there. The growth of stamen and pistil primordia is governed by auxin in the characteristic manner, the response following an optimum curve. The concentration promoting maximal stamen growth is lower than that promoting maximal pistil growth, so that auxin level at the differentiating apex determines the sex balance of the flowers produced. In some plants this level is susceptible to local control in the apex by such influences as temperature, and through the auxin economy of the whole plant, by such factors as nutrition and photoperiodism. Through these agencies the sex balance of the flowers may be modified." Beuzenberg's (1961) observations of sex differentiation and cytotaxonomy in some New Zealand *Violaceae* are in accordance with Heslop-Harrison's theory. In some of the dioecious species of *Melicytus* and *Hymenanthera* the developmental pattern of the flower reflects a gradient pattern. Anthers are well developed and sporogenous cells sharply defined before ovular development is even apparent. Late and almost mature flowers in some male plants show much more extensive female development. The bisexual potentiality in a genotypically male plant can be realized, during growth, through a gradual increase in available auxin, especially if the sex balance is near equilibrium.

It is probably more than coincidence that the early authorities on "vegetable teratology" were closely associated with botanical gardens, and that fewer abnormalities seem to appear in modern botanical collections. Collections of newly discovered species from throughout the world were grown in the temperate zone gardens of northern Europe. Several factors which would favor development and discovery of floral abnormalities were much more common then than now. First, although skilled labor was available for giving exotic plants individual care and attention which are rarely possible today, close control of daylength and temperature was not attempted. Plants which had evolved under very different climatic conditions were maintained in a relatively lush state; species which required particular conditions of daylength or temperature for initiating flowers were under inductive conditions only by chance, and frequently only for a short time. The abnormal flowers which sometimes occur under threshold conditions of induction would consequently appear fairly often. Also, collections of new species were likely to originate from a few seeds or bulbs; any seed obtained from these plants would be used to maintain the collection, and to send stocks to other botanical gardens. Consequently, species which were normally outcrossed in their original habitat were subject to a rather close inbreeding, and recessive genes became homozygous. Then too, collections of species from different habitats and different continents were frequently grown side by side, with the result that interspecific hybridization could occur either intentionally or by chance. Another favorable factor was the new theory of natural selection, and the resulting theoretical importance to scientists of deviations from the normal structure, particularly heritable deviations.

Further studies of abnormal flowers would seem most likely to be of value in two very widely separated fields: first, the series of processes by which a particular gene is "turned on," a particular cytoplasmic structure is instructed to carry out a chemical process, the upper and lower limits of the reaction rate are determined, the resulting substance moves to other parts of the cell and perhaps other parts of the plant, and finally a structure recognizable as a petal or a carpel is produced; second, the means by which the heritable components of the genes and cytoplasm adjust to either the short-term fluctuations of climate to which an individual plant must adapt in order to survive, or to the long-continued climatic changes which have occurred several times during the evolution of the species we know.

LITERATURE CITED

- ALLAN, H. H., and V. D. ZOTOV. 1930. A case of malformation in *Clematis foetida*. New Zealand Jour. Sci. Tech. **11**(6): 362-365.
- ALLEN, C. E. 1932. Sex-inheritance and sex-determination. Amer. Nat. **66**: 97-107.
- ALLMAN, G. J. 1851. On the morphology of the fruit in the Cruciferae, as illustrated by a monstrosity in the wallflower. Report Brit. Ass. Adv. Sci. **21**(2): 70.
- APPL, JOHANN. 1929. Weitere Mitteilungen über die Aufspaltung eines Bastards zwischen *Origanum majorana* L. ♀ und *Origanum vulgare* ♂ in der F₂ und F₃-Generation. Genetica **11**: 519-558.
- . 1933. Artkreuzungen, Geschlechtsvererbung und Nondisjunction bei Lip-

- penblütlern aus der Thymiengruppe. *Blätter für Pflanzenzücht.* **11**(3/4): 51-56.
- ARNAL, C. 1952. Remarques sur le déterminisme du sexe à propos d'un saule androgyne. *Ann. Univ. Saraviensis* **1**: 80-86.
- . 1954. Gradients sexuels chez les Phanérogames. *Rapp. et Comm.* 8^m Congr. Int. Bot. (Paris), Sects. 7 & 8, p. 291.
- ATKINSON, G. F. 1898. Experiments on the morphology of *Arisaema triphyllum*. (Abstr.) *Bot. Gaz.* **25**: 114.
- AVERY, PRISCILLA. 1929. Chromosome number and morphology in *Nicotiana*. IV. The nature and effects of chromosomal irregularities in *N. alata* var. *grandiflora*. *Univ. Calif. Publ. in Bot.* **11** (15): 265-284.
- BAILEY, L. H. 1941. The Standard Cyclopedia of Horticulture. (Key to the families and genera, pp. 80-85.) The Macmillan Company, New York, xxiv + 3639 pp.
- BATESON, W., E. R. SAUNDERS, and R. C. PUNNETT. 1905. Experimental studies in the physiology of heredity. Report II. Sweet pea, Types of pollen. Reports to the Evolution Committee of the Royal Society (London) **2**: 1-154 (pp. 80-83).
- , and I. SUTTON. 1919. Double flowers and sex-linkage in *Begonia*. *Jour. of Genet.* **8**: 199-207.
- BAUR, ERWIN. 1924. Untersuchungen über das Wesen, die Entstehung und die Vererbung von Rassenunterscheiden bei *Antirrhinum majus*. *Bibliotheca Genetica* **4**: 170 pp. + 5 plates and linkage maps. Geb. Borntraeger, Leipzig.
- BEUZENBERG, E. J. 1961. Observations on sex differentiation and cytotaxonomy of the New Zealand species of the Hymenantharinae (Violaceae). *New Zealand Jour. Sci.* **4**(2): 337-349.
- BLACK, C. A. 1945. Effect of commercial fertilizers on the sex expression of hemp. *Bot. Gaz.* **107**: 114-120.
- BLARINGHEM, L. 1904. Sur une monstruosité de *Zea Mays tunicata* D.C. provoquée par un traumatisme. *Compt. Rend. Soc. Biol.* **50**: 555-557.
- . 1905. Anomalies héréditaires provoquées par des traumatismes. *Compt. Rend. Acad. Sci.* **140**: 378-380.
- BORTHWICK, H. A. 1962. Effects of light intensity and quality on flowering and fruit set. Campbell Soup Co., Proc. Plant Science Symposium, Camden, New Jersey, pp. 189-200.
- BORTHWICK, H. A., and N. J. SCULLY. 1954. Photoperiodic responses of hemp. *Bot. Gaz.* **116**: 14-29.
- BRANTLEY, B. B., and G. F. WARREN. 1958. The effect of nitrogen, photoperiod and auxin on sex expression in the muskmelon. *Plant Physiology* **33**(Suppl.): xix.
- BREDEMANN, G., K. GARBER, W. HUHNKE, and R. VON SENGBUSCH. 1961. Die Züchtung von monözischen und diözischen, fasertragreichen Hanfsorten (Fibrimon und Fibridia). *Zeitschr. Pflanzenz.* **46**: 235-245.
- BREMER, G. 1928. Chromosomal mutations in *Saccharum*. *Rec. Trav. Bot. Neerlandais* **v25A**: 82-91.
- BRINK, R. A. 1964. Genetic repression in multicellular organisms. *Amer. Nat.* **98**: 193-211.
- BUCHENAU, F. 1903. Entwicklung von Staubblättern im Innern von Fruchtknoten bei *Melandryum rubrum* Garcke. *Ber. Deutsch. Bot. Ges.* **21**: 417-424.
- BURK, L. G. 1960. Male-sterile flower anomalies in interspecific tobacco hybrids. *Jour. Hered.* **51**: 27-31.
- CALDER, J. W. 1930. Carpellody in the wheat flower and its inheritance. *Trans. & Proc. New Zealand Inst.* **61**: 391-401.
- CAMP, W. H. 1929. Catalase activity and sex in plants. *Amer. Jour. Bot.* **16**: 221-224.
- . 1932. Sex in *Arisaema triphyllum*. *Ohio Jour. Sci.* **32**: 147-151.
- CHITTENDEN, F. J. 1914. The rogue wallflower. *Jour. Bot.* **52**: 265-269.
- CHROBOCZEK, EMIL. 1934. A study of some ecological factors influencing seed-stalk development in beets (*Beta vulgaris* L.). *Cornell Univ. Agr. Exp. Sta. Mem.* **154**, 84 pp.

- CLAVIER, C. 1961. Etudes sur la sexualité du ricin (*Ricinus communis* L.). Cah. Rech. Agron. Rabat 1961: No. 13: 111-176.
- CLOS, D. 1859. Fascicule d'observations de tératologie végétale. IV. Cératomanie d'*Orchis laxiflora* L. Mém. Acad. Sci. Toulouse, sér. 5, 3: 103-105.
- COSTERUS, J. C. 1907. Pistillody of the stamens in *Nicotiana*. Rec. Trav. Bot. Neerl. 4: 221-230.
- DAHLGREN, K. V. O. 1932. Über eine Form von *Primula officinalis* mit pistilloiden Staubgefäßen und ihre Vererbung. Hereditas 17: 115-130.
- DAVEY, A. J., and C. M. GIBSON. 1917. Note on the distribution of sexes in *Myrica gale*. New Phytol. 16: 147-151.
- DETJEN, L. R. 1927. Sterility in the common cabbage (*Brassica Oleracea*). Mem. Hort. Soc. New York 3: 277-280.
- DUCHARTRE. 1860. Sur une monstruosité de *Delphinium Ajacis*. Bull. Soc. Bot. France 7: 483-485.
- EMERSON, R. A. 1924. A genetic view of sex expression in the flowering plants. Science 59: 176-182.
- ERLANSOHN, E. W., and F. J. HERMANN. 1927. The morphology and cytology of perfect flowers in *Populus tremuloides* Michx. Mich. Acad. Sci. 8: 97-110.
- ERLENMEYER, H., and M. GEIGER-HUBER. 1935. Reversal of sex in *Melandrium album* caused by a fungus. Helv. Chim. Acta 18: 921-923.
- ERNST, A. 1931. Weitere Studien über die Vererbung der Calycanthemie bei *Primula*. Archiv Julius Klaus-Stiftung Vererbungsforschung 6: 277-375.
- FIGDOR, W. 1911. Übergangsbildungen von Pollen zu Fruchtblättern bei *Humulus Japonicus* Sieb. et Zucc. und deren Ursachen. Sitzber. Kais. Ak. Wiss. Wien 120: 689-707.
- FOURNIER, E. 1861. Deux anomalies développées sur le *Cakile maritima*. Bull. Soc. Bot. France 8: 696-697.
- GALUN, E. 1956. Effect of seed treatment on sex expression in the cucumber. Experientia 12: 218-219.
- GASPARRINI, G. 1862. Ricerche sulla embriogenia della canape. Atti Accad. Sci. Fis. e Mat. 1: 1-44.
- GEISENHEYNER, L. 1919. Über eine monströse *Linaria vulgaris*. Ber. Deutsch. Bot. Ges. 37: 479-484.
- GEITLER, L. 1941. Embryosäcke aus Pollenkörnern bei *Ornithogalum*. Ber. Deutsch. Bot. Ges. 59: 419-423.
- GIARD, A. 1898. Les variations de la sexualité chez les végétaux. Compt. Rend. Soc. Biol. Paris 10: 730-731.
- GOEBEL, K. 1908. Einleitung in die Experimentelle Morphologie der Pflanzen. Leipzig & Berlin.
- GOETHE, J. W. VON. 1790. Versuch die Metamorphose der Pflanzen zu erklären. Translation by Emily M. Cox. 1863. Essay on the metamorphosis of plants. Jour. Bot. 1: 327-345, 360-374.
- GOLDSCHMIDT, R. 1938. A *Lymantria*-like case of intersexuality in plants (Oehlkers' work) and its meaning for the theory of sex determination in plants. Jour. Genet. 36: 531-535.
- GOODSPEED, T. H. 1930. Inheritance in *Nicotiana tabacum*. IX. Mutations following treatment with X-rays and radium. Univ. Calif. Publ. Bot. 11: 285-298.
- , and P. Avery. 1934. The cytogenetics of fourteen types derived from a single X-rayed sex cell of *Nicotiana tabacum*. Jour. Genet. 29: 327-353.
- GOTTSCHALK, W. 1961. Über die zeitliche Aufeinanderfolge bestimmter Gestaltungsprozesse bei der Ausdifferenzierung von Vegetationskegeln zu Blüten. Naturwissenschaften 49: 59.
- GRAF, J. 1919. Eine abnorme Blütenbildung bei *Linaria vulgaris*. Ber. Deutsch. Bot. Ges. 37: 485-489.
- GRIS, A. 1858. Note sur quelques cas de monstruosité et spécialement sur la rose verte. Ann. Sci. Nat., IV^e Sér. (Bot.) 9: 76-83.

- GRUN, P., M. AUBERTIN, and A. RADLOW. 1962. Multiple differentiation of plasmons of diploid species of *Solanum*. *Genetics* 47: 1321-1333.
- , and A. RADLOW. 1960. The gene-plasmon interactions of *Solanum phureja* and *S. chacoense*. (Abstr.) *Genetics* 45: 990.
- GUBLER, A. 1862. Des anomalies aberrantes et régularisantes, à propos de deux cas tératologiques, l'un de géantisme et l'autre d'hermaphroditisme, observés sur le *Pistacia lentiscus*. *Bull. Soc. Bot. France* 9: 81.
- HALL, MARION TRUFANT. 1961. Teratology in *Trillium grandiflorum*. *Amer. Jour. Bot.* 48: 803-811.
- HARDER, R. 1948. Vegetative and reproductive development of *Kalanchoë blossfeldiana* as influenced by photoperiodism. *Symp. Soc. Exp. Biol.* 2: 117-137.
- HARSHBERGER, J. W. 1907. An unusual method of vegetative reproduction in *Dionaea muscipula*. *Torreya* 7: 181-183.
- HEILBRONN, A., und M. BASARMAN. 1952. Über die F₂ der Bryoniabastarde und ihre Bedeutung für das Problem der Geschlechtsrealisation. *Rev. Fac. Sci. Univ. Istanbul* 7: 138-144.
- HEINRICHER, E. 1891. Neue Beiträge zur Pflanzenteratologie und Blütenmorphologie. Eine Blüthe von *Cypripedium Calceolus* L. mit Ruckschlagserscheinungen. *Oester. Bot. Zeitschr.* 41: 41-45.
- . 1931. Untersuchungen über die Nachkommenschaft der *Primula Kewensis* und ihre Vielgestaltigkeit. *Denkschriften Akad. Wiss. Dien, Mathem. naturw. Kl.* 102: 69-112.
- HENSLOW, G. 1882. Note on staminiferous corollas of *Digitalis purpurea* and *Solanum tuberosum*. *Gard. Chron., Ser. 3*, 19: 216-218.
- HESLOP-HARRISON, J. 1956. Auxin and sexuality in *Cannabis sativa*. *Physiologia Plantarum* 9: 588-597.
- . 1957. The experimental modification of sex expression in flowering plants. *Biol. Rev. (Cambridge Phil. Soc.)* 32: 38-90.
- . 1959. Growth substances and flower morphogenesis. *Jour. Linn. Soc. London Bot.* 56: 269-281.
- , and Y. HESLOP-HARRISON. 1957. The effect of carbon monoxide on sexuality in *Mercurialis ambigua* L. fls. *New Phytologist* 56: 352-355.
- , and ———. 1958. Long-day and auxin induced male sterility in *Silene pendula* L. *Port. Acta Biol. Ser. A*, 5: 79-94.
- HEUFLER. 1843. Monströse Blumen von *Linaria vulgaris*. *Linnaea* 17: 10-14.
- HILLMAN, W. S., and H. H. SMITH. 1965. Induced flowering in a vegetative tobacco hybrid. *Jour. Hered.* 56: 2-6.
- JOYET-LAVERGNE, Ph. 1935. Que faut-il penser des lois de sexualisation cytoplasmique? *Rev. Gén. Sci. Pures et Appl.* 64: 47-51.
- KAJANUS, BIRGER. 1918. Genetische Studien über die Blüten von *Papaver somniferum* L. *Arkiv för Botanik* 15(18): 1-87 + 3 plates.
- KIHARA, H. 1951. Substitution of nucleus and its effects on genome manifestations. *Cytologia* 16: 177-193.
- KIRSCHLEGER, FR. 1866. Nouveaux faits tératologiques. *Ann. Ass. philomatique vogésorhénane*; 6^{me} livraison.
- KÖHLER, D. 1958. Die Entwicklung von *Cannabis sativa* unter dem Einfluss verschiedener Tageslängen. *Physiol. Plantarum* 11: 249-259.
- KOOPMANS, A. 1955. Changes in sex in flowers of the hybrid *Solanum rybinii* × *S. chacoense*. III. Data about the reciprocal cross *Solanum chacoense* × *S. rybinii*. *Genetica* 27: 465-471.
- LAIBACH, F., and J. KRIBBEN. 1950. Über die Bedeutung der β-Indolylessigsäure für die Blütenbildung. *Ber. Deutsch. Bot. Ges.* 63: 119-120.
- LANG, A. 1952. Physiology of flowering. *Ann. Rev. Plant Physiol.* 3: 265-306.
- LAURENT, M. J. 1906. Une nouvelle hypothèse sur le déterminisme du sexe. *Ass. Franç. Adv. Sci.* 35: 413-418.
- LAXTON. 1866. Double-blossomed peas. *Gard. Chron., 1866*, p. 901.

- LEIGHTY, C. E. and W. J. SANDO. 1924. Pistillody in wheat flowers. *Jour. Hered.* **15**: 263-268.
- LEWIS, D., and L. K. CROWE. 1952. Male sterility as an outbreeding mechanism in *Origanum vulgare*. *Heredity* **6**: 136.
- LICOPOLI, G. 1867. Osservazioni teratologiche sul fiore del *Melianthus major*. *Annali Accad. Aspiranti Natur. Napoli*.
- LOEHWING, W. F. 1938. Physiological aspects of sex in Angiosperms. *Bot. Rev.* **4**: 581-625.
- LÖVE, A., and D. LÖVE. 1940. Experimental sex reversal in plants. *Svensk bot. Tidskr.* **34**: 248-252.
- LUTZ. 1897. Note sur un safran monstrueux. *Bull. Soc. Bot. France* **44**: 95-98.
- MARSDEN-JONES, E. M., and W. B. TURRILL. 1931. Flower mutations in the primrose. I. Origins and genetics. *New Phytol.* **30**: 284-289.
- MARTZ, M. 1928. Anomalies de l'androcée chez un hybride du genre *Digitalis*. *Compt. Rend. Acad. Sci.* **186**: 642-643.
- MARX, G. A., and W. MISHANEK. 1964. The "spontaneous" formation of rudimentary carpels on leaf tissue. *Bioscience* **14**: 40-41.
- MASTERS, M. T. 1867. On polliniferous ovules in a rose (*Rosa arvensis*). *Jour. Bot.* **5**: 318-322.
- MASTERS, M. R. 1869. *Vegetable Teratology*. Robert Hardwicks, London, xxxviii + 534 pp.
- McPHEE, H. C. 1925. The genetics of sex in hemp. *Jour. Agr. Res.* **31**: 935-943.
- MEADE, R. M. 1913. Supernumerary carpels in cotton bolls. *U.S. Dep. Agr. Circ. No.* **111**: 25-28.
- MEEHAN, T. 1878. Notes on *Acer rubrum*. *Proc. Acad. Nat. Sci., Philadelphia, 1878*: 122-123.
- MEYER, J. R., and V. G. MEYER. 1961. Cytoplasmic male sterility in cotton. (Abstr.) *Genetics* **46**: 883.
- MEYER, V. G. 1965. Environmental effects on the differentiation of abnormal cotton flowers. (Abstr.) *Amer. Jour. Bot.* **52**: 620.
- , and M. BUFFET. 1962. Cytoplasmic effects on external-ovule production in cotton. *Jour. Hered.* **43**: 251-253.
- MITCHELL, W. D., and S. H. WITTEW. 1962. Chemical regulation of flower sex expression and vegetative growth in *Cucumis sativus* L. *Science* **136**: 880-881.
- MOHL, H. VON. 1837. Sur la métamorphose des anthères en carpelles. *Annales Sci. Nat.* 2^e Sér. **8**: 50-75.
- MOL, W. E. DE. 1933. Die Entstehungsweise anormaler Pollenkörner bei Hyazinthen, Tulpen und Narzissen. *Cytologia* **5**: 31-63.
- MOLLIARD, N. 1896. Homologie du massif pollinique et de l'ovule. *Rev. Gén. Bot.* **8**: 271-283.
- . 1901. Fleurs doubles et parasitisme. *Compt. Rend. Acad. Sci.* **133**: 548-551.
- . 1904. Virescences et proliférations florales produites par des parasites agissant à distance. *Compt. Rend. Acad. Sci.* **139**: 930-932.
- . 1905. Deux cas de duplicature florale provoqués par une nutrition déficiente, et hérédité de cette anomalie. *Bull. Soc. Bot. France, sér. 4*, **52**: 13-15.
- MONTFORD, H. M. 1931. Flower mutations in the primrose. II. Morphology and anatomical investigation. *New Phytol.* **30**: 289-297.
- MURNEEK, A. E. 1927. Physiology of reproduction in horticultural plants. II. The physiological basis of intermittent sterility with special reference to the spider flower. *Missouri Agr. Exp. Sta. Res. Bull.* **106**, 37 pp.
- NAITHANI, S. P. 1937. Chromosome studies in *Hyacinthus orientalis* L. III. Reversal of sexual state in the anthers of *Hyacinthus orientalis* L., var. Yellow Hammer. *Ann. Bot. (London) N. S.* **1**: 369-377.
- NAKAMURA, M. 1936. Experimental and cytological studies on the instability of the meiotic division of the pollenmothercells of *Impatiens balsamina* L. caused by the effect of high air temperature. *Mem. Fac. Sci. Agr. Taihoku Imp. Univ.* **17**, 121 pp.

- NELSON, ALEXANDER. 1928-1929. The inheritance of sex in an abnormal (carpellodic) wallflower. *Papers & Proc. Roy. Soc. Tasmania* 1928-1929: 119-122.
- NEMEC, B. 1898. O pylu petaloidnich tycinek hyacintu (*Hyacinthus Orientalis* L.). *Rozprawy Ceska Akad. Prag* II, 7, 18 pp. + plates.
- NITSCH, J. P. 1962. Basic physiological processes affecting fruit development. Campbell Soup Co., Proc. Plant Science Symposium, Camden, New Jersey, 1962, pp. 5-23.
- . 1963. The mediation of climatic effects through endogenous regulating substances. *Environmental Control of Plant Growth*. (Ed. by L. T. Evans.) Proc. of Symposium, Canberra, Australia, Aug. 1962, pp. 175-193.
- NOACK, R. 1962a. Plasmatische Vererbung in der Gattung *Begonia*. *Zeitschrift für Botanik* 50: 52-59.
- . 1962b. Die zwittrigen und eingeschlechtlichen Blüten von *Begonia cathayana*. II. Der Einfluss äusserer Faktoren auf die Zwitterblütenbildung und deren Fruchtbarkeit. *Zeitschr. Botanik* 50: 22-33.
- NYPELS, P. 1897. Notes pathologiques. *Bull. Soc. Roy. Bot. Belg.* 36: 274.
- OEHLKERS, F. 1940. Bastardierungsversuche in der Gattung *Streptocarpus* Lindley. III. Neue Ergebnisse über die Genetik von Wuchsgestalt und Geschlechtsbestimmung. *Ber. Deutsch. Bot. Ges.* 58: 76-91.
- ORR, A. R., and S. N. Postlethwait. 1964. Chemically induced phenocopy of a normal inflorescence in fasciated ear (Fa), a maize mutant. (Abstr.) *Amer. Jour. Bot.* 51: 666.
- PARKEY, W. 1957. Cytoplasmic influence in the production of the pistillate sex expression in castorbeans. *Agron. Jour.* 49: 427-428.
- PENZIG, O. 1886. Note teratologica. I. Peloria terminale di *Acanthus mollis*. II. Anomalie fiorali di Orchidee. *Malpighia* 1: 125-131.
- . 1890. Pflanzen-Teratologie. A. Ciminago, Genua, 540 pp.
- PETERSON, C. E., and L. D. ANHDER. 1960. Induction of staminate flowers on gynoeceous cucumbers with gibberellin A₈. *Science* 131: 1673-1674.
- PETIT-THOUARS, A. DU. 1807. Sur un changement d'étamines en pistils dans la Joubarbe des toits. *Nouveau Bull. Soc. Philomat. Paris* I: 30-31.
- PETO, F. H. 1938. Cytology of poplar species and natural hybrids. *Canad. Jour. Res. Sect. C*, 16: 445-455.
- PEYRITSCH, J. 1881. Zur aetiologie der chloranthieen eniger arabis-arten. *Pringsheim's Jahrb. für Wissensch. Botanik* 13(1).
- PHIPPS, I. F. 1928. Heritable characters in maize. XXXI. Tassel seed—4. *Jour. Hered.* 19: 399-404.
- PORTER, K. B., KEITH A. LAHR, and I. M. ATKINS. 1965. Cross-pollination of malesterile winter wheat (*Triticum aestivum* L.) having *Aegilops caudata* L. and *Aegilops ovata* L. cytoplasm. *Crop. Sci.* 5: 161-163.
- POSTLETHWAIT, S. N., and O. E. NELSON. 1964. Characterization of development in maize through the use of mutants. I. The polytypic (Pt) and Ramosa-1 (ra) mutants. *Amer. Jour. Bot.* 51: 238-243.
- PRITCHARD, F. J. 1916. Change of sex in hemp. *Jour. Hered.* 7: 325-329.
- RAGHAVEN, V. 1961. Studies on the floral histogenesis and physiology of *Perilla*. III. Effects of indoleacetic acid on the flowering of apical buds and explants in culture. *Amer. Jour. Bot.* 48: 870-876.
- , and W. P. JACOBS. 1961. Studies on the floral histogenesis and physiology of *Perilla*. II. Floral induction in cultured apical buds of *P. frutescens*. *Amer. Jour. Bot.* 48: 751-760.
- RAINIO, A. J. 1927. Über die Intersexualität bei der Gattung *Salix*. *Annales Societatis Zoolog.-Botanicae Fennicae, Vanamo*, 5: 165-276.
- REHDER, A. 1911. Pistillody in stamens of *Hypericum nudiflorum*. *Bot. Gaz.* 51: 230-231.
- RICHEY, F. D., and G. F. SPRAGUE. 1932. Some factors affecting the reversal of sex expression in the tassels of maize. *Amer. Nat.* 66: 433-443.
- ROARK, B., T. R. PFRIMMER, and M. E. MERKL. 1964. Effects of some insecticide formulations on fruiting of the cotton plant. *Crop. Sci.* 4: 97-98.

- ROLFE, R. A. 1890. A double orchid: *Epidendrum vitellinum* fl. pl. Gard. Chron., ser. 3, 8: 123.
- RYTZ, W. 1921. Blütenanomalien. Sitzungs-Ber. Bern. Bot. Ges. v. 17 Okt. in Mitteil. d. Naturf. Fes. Bern aus D. Jahre 1921: xxv-xxvi.
- SALTER, S. J. A. 1863. On a sexual monstrosity, consisting in the development of polleniferous ovules, in two species of *Passiflora*. Trans. Linn. Soc. 24: 143-150.
- SAUNDERS, E. R. 1911. On inheritance of mutation in the common foxglove (*Digitalis purpurea*). New Phytol. 10: 47-53.
- SCHAFFNER, J. H. 1921. Influence of environment on sexual expression in hemp. Bot. Gaz. 71: 197-219.
- . 1922. Control of the sexual state in *Arisaema triphyllum* and *Arisaema dracontium*. Amer. Jour. Bot. 9: 72-78.
- . 1923. The influence of relative length of daylight on the reversal of sex in hemp. Ecology 4: 323-334.
- . 1925. The influence of substratum on the percentage of sex reversal in winter-grown hemp. Ohio Jour. Sci. 25: 172-176.
- . 1927. Control of sex reversal in the tassel of Indian corn. Bot. Gaz. 84: 440-449.
- . 1929. Progeny resulting from selfpollination of staminate plant of *Morus alba* showing sex reversal. Bot. Gaz. 87: 653-659.
- . 1931. The fluctuation curve of sex reversal in staminate hemp plants induced by photoperiodicity. Amer. Jour. Bot. 18: 424-430.
- SCHIMPER, C. 1829. Correspondenz. Flora 12: 423.
- SCHLENKER, G. 1953. Beobachtungen über die Geschlechtsverhältnisse bei jungen Graupappeln und Aspen. Zeitschr. Forstgenetik 2: 102-104.
- SCOTT, D. G. 1906. On abnormal flowers of *Solanum tuberosum*. New Phytol. 5: 77-81.
- SEITZ, F. W. 1952. Zwei neue Funde von Zwitterigkeit bei der Aspe. Zeitschr. Forstgenetik 1: 70-73.
- SEMENIUK, P. 1964. An effect of temperature on development and differentiation of rose flowers. Amer. Hort. Mag. 43: 177-180.
- SERINGE. 1830. Notice sur une monstruosité du *Diploaxis tenuifolia*. Bull. Bot. Genève, No. 1, pp. 5-8.
- SHARP, L. W. 1925. The factorial interpretation of sex-determination. La Cellule 35: 195-235.
- SHATTUCK, C. H. 1910. The origin of heterospory in Marsilia. Bot. Gaz. 49: 19-39 + 6 plates.
- SHIFFRIS, O. 1961. Gibberellin as sex regulator in *Ricinus communis*. Science 133: 2061-2062.
- , and W. L. GEORGE, JR. 1964. Sensitivity of female inbreds of *Cucumis sativus* to sex reversion by gibberellin. Science 143: 1452-1453.
- , ———, and J. A. QUIÑONES. 1964. Gynodioecism in Cucumbers. Genetics 49: 285-291.
- SHULL, G. H. 1910. Inheritance of sex in *Lychnis*. Bot. Gaz. 49: 110-125.
- SIMON, S. V. 1924. Über eine spontan entstandene Blütenvergrünung von *Torenia* und das genetische Verhalten ihrer Nachkommenschaft. Jahrb. wiss. Bot. 63: 172-230.
- SIRKS, M. J. 1924. Die gynanthere form des Goldlacks und ihre Vererbung. Genetica 6: 537-548.
- SMITH, B. W. 1963. The mechanism of sex determination in *Rumex hastatules*. Genetics 48: 1265-1288.
- SMITH, C. O. 1927. A pistillate *Prunus*. Jour. Hered. 18: 537-541.
- SMITH, J. J. 1908. Een merkwaardige Klapper. Teysmannia 19: 8-10.
- STEIN, H. 1965. A gene for unfruitfulness in the castorbean plant and its utilization in hybrid seed production. Crop Sci. 5: 90-93.
- STOW, I. 1930. Experimental studies on the formation of the embryosac-like giant pollen grains in the anthers of *Hyacinthus orientalis*. Cytologia 1: 417-439.

- . 1933. On the female tendencies of the embryosac-like giant pollen grain of *Hyacinthus orientalis*. *Cytologia* 5: 88-108.
- TALLEY, P. J. 1934. Carbohydrate-nitrogen ratios with respect to the sexual expression of hemp. *Plant Physiol.* 9: 731-748.
- TEPPER, S. S. 1953. Floral anatomy and ontogeny in *Aquilegia formosa* var. *truncata* and *Ranunculus repens*. Univ. Calif. Publ. Bot. 25: 513-648.
- , R. I. GREYSON, W. R. CRAIG, and JOSEPH L. HINDMAN. 1963. In vitro culture of floral buds of *Aquilegia*. *Amer. Jour. Bot.* 50: 1035-1045.
- THOMAS, R. G. 1956. Effect of temperature and length of day on the sex expression of monoecious and dioecious angiosperms. *Nature* 178: 552-553.
- THOMPSON, H. C. 1939. Temperature in relation to vegetative and reproductive development in plants. *Proc. Amer. Soc. Hort. Sci.* 37: 672-679.
- THOUARS, DU PETIT. 1807. see Petit-Thouars.
- TIBEAU, M. E. 1936. Time factor in utilization of mineral nutrients by hemp. *Plant Physiol.* 11: 731-747.
- TOLBERT, N. E. 1961. Alteration of plant growth by chemicals. *Bull. Torrey Bot. Club* 88: 313-320.
- TOURNOIS, J. 1911. Anomalies florales du houblon japonais et du chanvre déterminées par des semis hatifs. *Compt. Rend. Acad. Sci. (Paris)* 153: 1017-1020.
- TSCHERMAK, E. 1932. Über einige Blütenanomalien bei Primeln und ihre Vererbungsweise. *Biologia Generalis* 8: 337-350.
- TUKEY, H. B. 1922. A case of pistillody and staminody in the plum. *Torreya* 22: 28-29.
- USTERI. 1907. Studien über *Carica Papaya* L. *Ber. Deutsch. Bot. Ges.* 25: 485-495.
- VELENOVSKY. 1909. Die vergleichende Morphologie der Pflanzen, Teil iii. Prag, 1909.
- VIOLLE, J. 1911. Sur un retour momentané des fleurs doubles d'un rosier à la forme simple. *Compt. Rend. Acad. Sci.* 153: 121.
- VUILLEMIN, PAUL. 1916. Modifications de l'androcée et extension du pistil dans le genre *Papayer*. *Bull. Soc. Bot. France* 63: 164-171.
- WARDLAW, C. W. 1957. The floral meristem as a reaction system. *Proc. Roy. Soc. Edinb., Sec. B*, 66: 394-408.
- . 1963. Experimental investigations of floral morphogenesis in *Petasites hybridus*. *Nature* 198: 560-561.
- WEATHERWAX, P. 1925a. Anomalies in maize and its relatives.—II Many-flowered spikelets in maize. *Bull. Torrey Bot. Club* 52: 87-92.
- . 1925b. Anomalies in maize and its relatives.—III Carpellody in maize. *Bull. Torrey Bot. Club* 52: 167-170.
- WHITE, O. E. 1914. Studies of teratological phenomena in their relation to evolution and the problems of heredity. I. A study of certain floral abnormalities in *Nicotiana* and their bearing on theories of dominance. *Amer. Jour. Bot.* 1: 23-26.
- WHYTE, R. O. 1929. Studies in *Ranunculus*. II. The cytological basis of sex in *R. acris* L. *Jour. Genet.* 21: 183-191.
- WIGAND. 1856. Beiträge zur Pflanzenteratologie. *Flora* 39: 713.
- WIJEWANTHA, R. T., and G. L. STEBBINS. 1964. Developmental and biochemical effects of the agropyroides mutation in barley. *Genetics* 50: 65-80.
- WITTMER, S. H., and M. J. BUKOVAC. 1962a. Exogenous plant growth substances affecting floral initiation and fruit set. Campbell Soup Co., *Proc. Plant Science Symposium*, Camden, New Jersey, 1962, pp. 65-87.
- , and ———. 1962b. Staminate flower formation on gynoecious cucumbers as influenced by the various gibberellins. *Naturwissenschaften* 49: 305-306.
- , and I. G. HILLYER. 1954. Chemical induction of male sterility in Cucurbits. *Science* 120: 893-894.
- , and N. E. TOLBERT. 1960. 2-chloroethyl trimethylammonium chloride and related compounds as plant growth substances. V. Growth, flowering, and fruiting responses as related to those induced by auxin and gibberellin. *Plant Physiol.* 35: 871-877.

- WORSDELL, W. C. 1916. The principles of plant-teratology. Vol. II. The Ray Society, London, xvi + 296 pp. + plates.
- YAMPOLSKY, C. 1919. Inheritance of sex in *Mercurialis annua*. Amer. Jour. Bot. **6**: 410-442.
- ZABKA, G. G. 1961. Photoperiodism in *Amaranthus caudatus*. I. A reexamination of the photoperiodic response. Amer. Jour. Bot. **48**: 21-28.
- ZEEVAART, J. A. D. 1962. Physiology of flowering. Science **137**: 723-731.

TABLE I
SPERMATOPHYTES FOR WHICH FLORAL ABNORMALITIES
HAVE BEEN REPORTED

Key to classes of abnormalities:

ABNORMALITY	ORGAN INVOLVED	TYPE OF CHANGE
I. Phyllody	A. Entire flower	J. To male flowers only.
II. Bracteody	B. Leaves	K. To female flowers only.
III. Sepalody	C. Bracts	L. To male and female flowers on same plant.
IV. Petalody	D. Sepals	M. To male and female flowers in same inflorescence.
V. Staminody	E. Petals	N. To some or all hermaphrodite flowers.
VI. Carpellody	F. Stamens	O. Complete sex reversal.
VII. Change from monoecism	G. Carpels	P. Unspecified flower deformities.
VIII. Change from dioecism or dicliny	H. Ovules	

FAMILY

Genus and Species	Abnormality	Author	Year
RANUNCULACEAE			
<i>Aconitum lycococtinum</i>	III-C	Penzig	1890
<i>Actaea spicata</i>	I-E	Masters	1869
"	I-A, I-C	Penzig	1890
<i>Adonis amurensis</i>	I-G	Worsdell	1916
<i>autumnalis</i>	I-G, IV-F	Masters	1869
<i>Anemone</i> spp.	IV-F, IV-G	Masters	1869
"	III-G	Worsdell	1916
<i>alpina</i>	III-C, IV-F	Penzig	1890
<i>baldensis</i>	III-C	Penzig	1890
<i>coronaria</i>	I-D, I-F	Masters	1869
"	I-A, I-D, III-C, IV-F, IV-G	Penzig	1890
<i>dichotoma</i>	I-D	Penzig	1890
<i>fulgens</i>	IV-F	Penzig	1890
<i>hortensis</i>	I-D	Masters	1869
"	I-A, III-C, IV-F, IV-G	Penzig	1890
<i>nemorosa</i>	I-D, I-F	Masters	1869
"	I-A	Penzig	1890
"	IV-E	Velenovsky (in Worsdell)	1909 1916
<i>patens</i>	III-C	Penzig	1890
<i>pratensis</i>	I-D, IV-F	Penzig	1890
<i>pulsatilla</i>	I-D	Masters	1869
<i>ranunculoides</i>	I-E	Worsdell	1916
"	I-D, IV-F	Penzig	1890
<i>rivularis</i>	I-A	Penzig	1890
<i>sylvatica</i>	I-F	Penzig	1890
<i>sylvestris</i>	I-D	Masters	1869
"	IV-F, IV-G	Penzig	1890
<i>vernalis</i>	IV-C	Penzig	1890
<i>vulgaris</i>	I-D, I-H, III-C, III-F	Penzig	1890
<i>Aquilegia</i> spp.	I-H, III-E, IV-D, IV-F, V-E	Worsdell	1916
<i>atrata</i>	I-A	Penzig	1890

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>canadensis</i>	IV-F	Penzig	1890
	<i>coerulea</i>	III-E, III-F	Penzig	1890
	<i>formosa</i>	I-G, V-H	Tepfer	1953
	<i>skinneri</i>	I-H	Masters	1869
	<i>vulgaris</i>	I-A, E, G, H; IV-F	Masters	1869
	"	I-A, III-E, III-F, IV-F	Penzig	1890
	<i>Atragene</i> spp.	IV-F	Penzig	1890
	<i>Caltha palustris</i>	I-D, IV-F	Masters	1869
	"	IV-F, VI-F	Worsdell	1916
	<i>Clematis</i> spp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890
	<i>flammula</i>	IV-F	Penzig	1890
	<i>foetida</i>	VIII-O	Allan & Zotov	1930
	<i>florida</i>	IV-F	Penzig	1890
	<i>fortunei</i>	I-D	Worsdell	1916
	<i>integrifolia</i>	IV-C	Penzig	1890
	<i>patens</i>	IV-F	Penzig	1890
	<i>viticella</i>	I-D	Worsdell	1916
	<i>Delphinium</i> spp.	IV-F	Masters	1869
	"	IV-D, IV-F	Worsdell	1916
	<i>ajacis</i>	I-D, E, G, H	Masters	1869
	"	III-G, VI-D	Worsdell	1916
	"	I-H, IV-A, IV-F, VI-F	Penzig	1890
	<i>amoenum</i>	I-G	Masters	1869
	<i>consolida</i>	I-A, II-A	Penzig	1890
	<i>crassicaule</i>	I-E, F, G, H	Masters	1869
	<i>dictyocarpum</i>	I-H	Masters	1869
	<i>elatum</i>	I-F, G, H	Masters	1869
	"	I-A, VI-F	Penzig	1890
	<i>montanum</i>	I-A	Penzig	1890
	<i>orientale</i>	II-A, III-E, III-F	Penzig	1890
	<i>staphisagria</i>	I-E	Penzig	1890
	<i>Helleborus</i> sp.	VI-F	Martz	1928
	<i>foetidus</i>	I-A, VI-F	Penzig	1890
	<i>niger</i>	IV-F	Penzig	1890
	<i>olympicus</i>	IV-D	Masters	1869
	<i>Hepatica</i> sp.	IV-F	Masters	1869
	<i>Myosurus</i> sp.	V-E	Worsdell	1916
	<i>Nigella</i> sp.	IV-D	Worsdell	1916
	<i>damascena</i>	I-H, IV-F, IV-G	Masters	1869
	"	I-A	Penzig	1890
	<i>Paeonia moutan</i>	VI-E	Schimper	1829
	<i>officinalis</i>	I-G, IV-F, V-G	Masters	1869
	<i>Ranunculus</i> spp.	IV-F, IV-G	Masters	1869
	"	IV-F	Penzig	1890
	<i>abortivus</i>	III-E	Penzig	1890
	<i>acris</i>	I-D	Masters	1869
	"	I-D, IV-F	Penzig	1890
	"	VII-K	Whyte	1929
	<i>asiaticus</i>	IV-A	Penzig	1890
	"	I-G	Worsdell	1916

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>auricomus</i>	I-A, IV-D, V-G, VI-F	Penzig	1890
	"	IV-D	Masters	1869
	<i>bulbosus</i>	IV-F, VII-J	Penzig	1890
	<i>californicus</i>	I-A	Penzig	1890
	<i>nemosus</i>	IV-D	Penzig	1890
	<i>philonotis</i>	I-E, IV-F, IV-G	Penzig	1890
	<i>repens</i>	I-E, I-G	Masters	1869
	"	I-A	Penzig	1890
	<i>tuberosus</i>	I-A	Penzig	1890
	<i>Thalictrum</i> sp.	IV-F	Masters	1869
	<i>anemonoides</i>	I-A, IV-F	Penzig	1890
	<i>minus</i>	VI-F	Masters	1869
	<i>Trollius</i> sp.	IV-F	Masters	1869
	"	IV-D	Worsdell	1916
MAGNOLIACEAE				
	<i>Magnolia fuscata</i>	VI-F	Masters	1869
BERBERIDACEAE				
	<i>Berberis</i> sp.	IV-F	Masters	1869
	<i>canadensis</i>	V-E	Penzig	1890
	<i>Podophyllum</i> sp.	IV-F	Masters	1869
	"	VI-F	Penzig	1890
LARDIZABALACEAE				
	<i>Stauntonia latifolia</i>	VIII-L	Masters	1869
NYMPHAEACEAE				
	<i>Nelumbium</i> spp.	IV-F	Masters	1869
	<i>Nymphaea</i> spp.	IV-F	Masters	1869
	<i>dentata</i>	I-F, I-G	Masters	1869
	<i>lotus</i>	I-A	Masters	1869
PAPAVERACEAE				
	<i>Bocconia (Macleya)</i>			
	<i>cordata</i>	VI-F	Gris	1858
	"	VI-F	Masters	1869
	<i>Chelidonium</i> sp.	IV-F	Masters	1869
	"	IV-F	Molliard	1905
	<i>majus</i>	I-A	Masters	1869
	"	I-A	Penzig	1890
	<i>Eschscholtzia crocea</i>	I-D	Masters	1869
	<i>Papaver</i> spp.	VI-F	von Mohl	1837
	"	IV-F, IV-G	Masters	1869
	"	VI-F	Penzig	1890
	"	VI-D, VI-E	Vuillemin	1916
	"	VI-F	Martz	1928
	<i>bracteatum</i>	VI-F	Masters	1869
	<i>malvaeflorum</i>	V-E	Worsdell	1916
	<i>nudicaule</i>	VI-F	Masters	1869
	"	VI-F	Worsdell	1916

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
<i>orientale</i>	I-D, IV-F	Masters	1869
"	I-D, VI-F	Penzig	1890
"	IV-F	Chittenden	1914
"	VI-F	Worsdell	1916
<i>rhoeas</i>	I-A, IV-F, VI-F	Penzig	1890
"	VI-F	Molliard	1905
"	VI-F	Worsdell	1916
<i>somniferum</i>	VI-F	Masters	1869
"	VI-A	Penzig	1890
"	IV-F	Chittenden	1914
"	IV-F	Kajanus	1918
<i>Sanguinaria</i> sp.	IV-F	Masters	1869
FUMARIACEAE			
<i>Corydalis aurea</i>	I-A	Masters	1869
<i>solida</i>	I-C	Masters	1869
"	I-C, I-D, IV-F	Penzig	1890
<i>Diclytra (Dicentra)</i> sp.	I-A	Penzig	1890
"	I-F	Worsdell	1916
<i>Fumaria officinalis</i>	I-A	Penzig	1890
CRUCIFERAE			
<i>Alliaria officinalis</i>	I-H	Masters	1869
"	I-H	Penzig	1890
<i>Alyssum incanum</i>	I-E	Masters	1869
"	I-A, IV-F	Penzig	1890
<i>Arabis alpina</i>	I-A, VI-F	Penzig	1890
"	IV-F, IV-G	Worsdell	1916
<i>Armoracia rusticana</i>	V-G	Masters	1869
<i>Barbarea</i> sp.	IV-F	Masters	1869
<i>stricta</i>	I-A	Penzig	1890
"	I-A	Worsdell	1916
<i>vulgaris</i>	VI-F	Masters	1869
"	I-A, IV-A, IV-F, VI-F	Penzig	1890
<i>Brassica (Sinapis)</i> spp.	IV-F	Masters	1869
<i>alba</i>	I-A	Penzig	1890
<i>arvensis</i>	I-A, E, G, H	Masters	1869
"	I-A, I-H, IV-F, V-D	Penzig	1890
"	I-F	Molliard	1896
<i>napus</i>	I-H	Masters	1869
"	I-A, I-H	Penzig	1890
<i>nigra</i>	I-A	Penzig	1890
<i>oleracea</i>	I-A, D, E, G, H	Masters	1869
"	IV-D	Penzig	1890
<i>Rapa</i>	I-A	Penzig	1890
<i>Bunias</i> sp.	I-A	Masters	1869
"	I-A, V-G	Penzig	1890
<i>orientalis</i>	I-A	Penzig	1890
<i>Cakile maritima</i>	I-D	Fournier	1861
"	I-A	Penzig	1890
<i>Calepina corvini</i>	IV-F	Penzig	1890

TABLE I, Continued

FAMILY				
Genus and Species	Abnormality	Author	Year	
<i>Capsella bursa-pastoris</i>	V-E	Masters	1869	
"	I-A, III-E, IV-F, V-E	Penzig	1890	
"	V-E	Worsdell	1916	
<i>Cardamine</i> sp.	IV-F	Masters	1869	
<i>amara</i>	IV-F, IV-G	Penzig	1890	
<i>matthiola</i>	I-A	Penzig	1890	
<i>pratensis</i>	I-A, IV-F, IV-G, IV-H, V-E	Penzig	1890	
<i>Chieranthus cheiri</i>	VI-F	Allman	1851	
"	I-D, E, H; IV-F, VI-F	Masters	1869	
"	I-G, IV-F, VI-F	Penzig	1890	
"	VI-F	Chittenden	1914	
"	VI-F	Worsdell	1916	
"	VI-F	Sirks	1924	
"	VI-F	Nelson	1928-9	
<i>fruticulosus</i>	IV-A, IV-F	Penzig	1890	
<i>incanus</i>	I-D	Masters	1869	
<i>Cochlearia</i> spp.	VI-F, V-G	Penzig	1890	
<i>Armoracia</i>	VI-F	Masters	1869	
<i>Diplotaxis</i> sp.	I-D	Masters	1869	
<i>erucoides</i>	I-A	Penzig	1890	
<i>muralis</i>	I-E	Masters	1869	
"	I-A	Penzig	1890	
<i>tenuifolia</i>	I-A	Seringe	1830	
"	I-A, I-G	Masters	1869	
"	I-A	Penzig	1890	
<i>Draba</i> spp.	I-A	Penzig	1890	
<i>Erucastrum canariense</i>	I-A	Masters	1869	
"	I-A	Penzig	1890	
<i>pollichii</i>	I-H	Masters	1869	
<i>Erysimum barbarea</i>	I-E	Masters	1869	
<i>canescens</i>	I-A	Penzig	1890	
<i>cheiranthoides</i>	I-E	Masters	1869	
"	I-A	Penzig	1890	
<i>officinale</i>	I-E	Masters	1869	
<i>Hesperis</i> sp.	I-H	Worsdell	1916	
<i>matronalis</i>	I-A, I-E, IV-F	Masters	1869	
"	I-A, I-H, IV-F	Penzig	1890	
<i>Iberis</i> sp.	IV-F	Masters	1869	
"	IV-F	Penzig	1890	
<i>Isatis tinctoria</i>	I-A	Penzig	1890	
<i>Lunaria annua</i>	I-A	Penzig	1890	
<i>Mathiola</i> sp.	IV-F, V-G	Masters	1869	
<i>annua</i>	I-A, IV-F	Penzig	1890	
<i>incana</i>	I-A, IV-A	Penzig	1890	
<i>Nasturtium</i> sp.	I-H	Masters	1869	
"	I-A	Penzig	1890	
<i>Peltaria alliacea</i>	I-D, I-E	Masters	1869	
"	I-A, IV-D	Penzig	1890	
<i>Raphanus</i> sp.	I-H	Worsdell	1916	
<i>sativus</i>	I-E	Masters	1869	
"	I-A	Penzig	1890	

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>Sisymbrium</i> sp.	I-H	Worsdell	1916
	spp.	I-A, II-A	Penzig	1890
	<i>officinale</i>	I-A, D, H	Masters	1869
	<i>tenuifolium</i>	I-E	Masters	1869
	<i>Thlaspi arvense</i>	I-D, I-H	Masters	1869
	"	I-A	Penzig	1890
	<i>bursa-pastoris</i>	I-E	Masters	1869
	<i>Turritis</i> sp.	I-H	Masters	1869
	<i>glabra</i>	I-E	Masters	1869
	"	I-A	Penzig	1890
CAPPARIDACEAE				
	<i>Cleome spinosa</i>	VII-K	Murneek	1927
RESEDACEAE				
	<i>Reseda</i> spp.	I-A	Penzig	1890
	<i>lutea</i>	I-E, I-H	Masters	1869
	<i>odorata</i>	I-A	Masters	1869
	<i>phyteuma</i>	I-E, I-G	Masters	1869
CISTACEAE				
	<i>Helianthemum</i> sp.	IV-D	Masters	1869
	<i>amabile</i>	IV-F	Penzig	1890
	<i>vulgare</i>	IV-F	Penzig	1890
VIOLACEAE				
	<i>Hymenanchera</i> spp.	VIII-N	Beuzenberg	1961
	<i>Viola</i> sp.	IV-F, IV-G	Masters	1869
	<i>alba</i>	I-A	Penzig	1890
	<i>altaria</i>	IV-F	Penzig	1890
	<i>grandiflora</i>	I-A	Penzig	1890
	<i>odorata</i>	IV-F, I-A	Penzig	1890
	<i>tricolor</i>	IV-F	Penzig	1890
POLYGALACEAE				
	<i>Polygala vulgaris</i>	II-A	Penzig	1890
CARYOPHYLLACEAE				
	<i>Agrostemma githago</i>	I-H	Masters	1869
	"	I-A, I-H	Penzig	1890
	<i>Arenaria</i> sp.	I-A	Penzig	1890
	<i>Cerastium</i> sp.	I-G	Masters	1869
	<i>glomeratum</i>	I-A	Masters	1869
	<i>triviale</i>	I-A, I-E	Masters	1869
	<i>vulgatum</i>	I-E	Masters	1869
	"	I-A	Penzig	1890
	<i>Dianthus</i> spp.	I-G, IV-F, IV-G	Masters	1869
	<i>barbatus</i>	I-A, II-A, IV-F	Penzig	1890
	<i>carthusianorum</i>	IV-D	Penzig	1890
	<i>caryophyllus</i>	II-A, IV-F, IV-G, IV-H	Penzig	1890
	"	II-A, III-A	Worsdell	1916
	<i>sinensis</i>	IV-F, VI-F	Penzig	1890

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>Eudianthe Coeli Rosa</i>	I-A	Penzig	1890
	<i>Lychnis</i> spp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890
	<i>dioica</i>	I-A, I-E, I-G	Masters	1869
	"	VIII-O	Shull	1910
	<i>sylvestris</i>	I-E	Masters	1869
	<i>Melandrium album</i>	VIII-J	Erlenmeyer & Geiger-Huber	1935
	<i>pratense</i>	IV-F, IV-H	Penzig	1890
	<i>rubrum</i>	V-H	Buchenau	1903
	"	VIII-N	Löve & Löve	1940
	<i>Sagina</i> sp.	IV-F	Masters	1869
	<i>Saponaria</i> sp.	IV-F, IV-G	Masters	1869
	"	IV-F, IV-G	Penzig	1890
	<i>Silene</i> sp.	IV-D	Masters	1869
	<i>armeria</i>	VI-E, VI-F	Dahlgren	1932
	<i>inflata</i>	I-A, III-E	Penzig	1890
	<i>maritima</i>	IV-F	Penzig	1890
	<i>pendula</i>	IV-F, IV-H	Penzig	1890
	<i>sericea</i>	I-A	Penzig	1890
	<i>Spergularia media</i>	I-G, I-H	Penzig	1890
	<i>Stellaria (Alsine)</i>			
	<i>media</i>	I-A, I-E, I-H	Masters	1869
	"	I-A	Penzig	1890
PORTULACACEAE				
	<i>Portulaca</i> sp.	IV-F	Masters	1869
HYPERICACEAE				
	<i>Hypericum nudiflorum</i>	VI-F	Rehder	1911
	<i>perforatum</i>	I-C, I-D	Penzig	1890
TERNSTROEMIAACEAE				
	<i>Camellia</i> sp.	IV-F, IV-G	Masters	1869
	<i>Norantea brasiliensis</i>	I-C	Penzig	1890
	<i>Thea</i> sp.	IV-F	Masters	1869
MALVACEAE				
	<i>Abutilon</i> spp.	IV-F	Penzig	1890
	<i>Althaea</i> sp.	IV-F, IV-G	Masters	1869
	"	IV-F, IV-G	Penzig	1890
	<i>Gossypium</i> hybrids	IV-F	Meyer & Meyer	1961
	"	VI-F	Meyer & Buffet	1962
	<i>Hibiscus</i> sp.	IV-F, IV-G	Masters	1869
	"	IV-F, IV-G	Penzig	1890
	<i>Lavatera trimestris</i>	IV-A	Penzig	1890
	<i>Malva</i> spp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890
	<i>silvestris</i>	I-E	Masters	1869
STERCULIACEAE				
	<i>Sterculia platanifolia</i>	I-G	Penzig	1890

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
TILIACEAE			
<i>Corchorus</i> spp.	I-A	Penzig	1890
<i>Honckenya peploides</i>	VII-L	Masters	1869
<i>Sparmannia africana</i>	IV-F	Penzig	1890
<i>Triumfetta</i> spp.	I-A, I-E, I-H	Masters	1869
MALPIGHIACEAE			
<i>Heteropterys chrysophylla</i>	I-D	Penzig	1890
RUTACEAE			
<i>Citrus aurantium</i>	VI-F	Masters	1869
"	IV-F	Penzig	1890
<i>Dictamnus albus</i>	I-F, I-H	Masters	1869
"	I-A	Penzig	1890
"	I-F	Molliard	1896
<i>fraxinella</i>	I-A, I-E, I-H	Masters	1869
<i>Ruta</i> spp.	IV-F, V-G	Penzig	1890
GERANIACEAE			
<i>Geranium</i> sp.	I-D, I-E, IV-F	Masters	1869
<i>columbinum</i>	I-A	Penzig	1890
<i>molle</i>	IV-F	Penzig	1890
<i>Robertianum</i>	I-A	Penzig	1890
<i>sylvaticum</i>	IV-F	Penzig	1890
<i>Pelargonium</i> sp.	IV-F	Masters	1869
<i>zonale</i>	I-A, IV-F	Penzig	1890
TROPAEOLACEAE			
<i>Tropaeolum</i> sp.	I-A, E, F, H; IV-F	Masters	1869
"	I-A, IV-F	Penzig	1890
<i>majus</i>	VI-F	Masters	1869
OXALIDACEAE			
<i>Oxalis</i> sp.	IV-F	Masters	1869
spp.	IV-A, IV-F	Penzig	1890
BALSAMINACEAE			
<i>Impatiens</i> sp.	IV-F	Masters	1869
"	IV-F, IV-G, V-G	Penzig	1890
RHAMNACEAE			
<i>Colletia spinosa</i>	V-G	Penzig	1890
<i>Rhamnus fragula</i>	I-A	Masters	1869
VITACEAE			
<i>Vitis vinifera</i>	I-A	Masters	1869
ACERACEAE			
<i>Acer platanoides</i>	I-A	Penzig	1890
<i>saccharinum</i>	VIII-L	Meehan	1878
MELIANTHACEAE			
<i>Melianthus major</i>	II-A, IV-F, V-C	Penzig	1890

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
ANACARDIACEAE				
	<i>Pistacia lentiscus</i>	VIII-N	Gubler	1862
	<i>Rhus copallina</i>	I-A	Penzig	1890
	<i>glabra</i>	I-A	Penzig	1890
HIPPOCASTANACEAE				
	<i>Aesculus</i> sp.	IV-F	Masters	1869
	<i>hippocastanum</i>	VII-K	Penzig	1890
LEGUMINOSAE				
	<i>Amorpha fruticosa</i>	I-C	Masters	1869
	<i>Anthyllis cotonilla</i>	IV-F	Masters	1869
	<i>Astragalus cicer</i>	VI-B	Kirschleger	1866
			(in Penzig	1890)
	<i>Brownea</i> sp.	I-A	Penzig	1890
	<i>Clitoria</i> sp.	IV-F	Masters	1869
	<i>Coronilla</i> sp.	IV-F	Penzig	1890
	<i>Cytisus</i> sp.	IV-F	Masters	1869
	<i>Desmodium canadense</i>	I-H	Masters	1869
	"	I-A, VI-H	Penzig	1890
	<i>Ervum hirsutum</i>	I-A	Penzig	1890
	<i>Galega officinalis</i>	I-A	Penzig	1890
	<i>Genista</i> sp.	IV-F	Masters	1869
	<i>Lathyrus (Orobus) sp.</i>	IV-F	Masters	1869
	<i>latifolius</i>	I-G	Masters	1869
	"	I-A	Penzig	1890
	<i>odoratus</i>	VII-K	Bateson, Saunders, Punnett	1905
	<i>Lotus</i> sp.	IV-F	Masters	1869
	<i>Lupinus</i> sp.	I-A	Masters	1869
	"	I-A	Penzig	1890
	<i>Medicago</i> sp.	I-G, IV-F	Masters	1869
	spp.	I-A	Penzig	1890
	<i>maculata</i>	I-H	Masters	1869
	<i>Melilotus</i> sp.	I-G	Masters	1869
	spp.	I-A	Penzig	1890
	<i>alba</i>	I-G, V-E	Penzig	1890
	<i>macrorhiza</i>	I-H	Worsdell	1916
	<i>Ononis</i> spp.	I-A	Penzig	1890
	<i>Phaseolus</i>	IV-F	Masters	1869
	<i>Pisum</i> sp.	IV-F	Masters	1869
	<i>sativum</i>	VI-D	Laxton	1866
	"	II-A	Penzig	1890
	"	VI-D, VI-F	Gottschalk	1961
	"	VI-B	Marx & Mishanek	1964
	<i>Robinia pseudoacacia</i>	IV-D, IV-F, IV-G	Penzig	1890
	<i>Spartianthus</i> sp.	IV-F	Masters	1869
	<i>Trifolium</i> sp.	I-D, IV-F	Masters	1869
	spp.	I-A	Penzig	1890
	<i>elegans</i>	I-A	Penzig	1890
	<i>hybridum</i>	I-G	Masters	1869
	"	I-A	Worsdell	1916

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
<i>repens</i>	I-A, D, E, F, G, H	Masters	1869
"	II-E, V-D	Worsdell	1916
<i>Ulex</i> sp.	IV-F	Masters	1869
<i>Vicia biennis</i>	I-A	Penzig	1890
ROSACEAE			
<i>Amelanchier oblongifolia</i>	V-E	Worsdell	1916
<i>Crataegus</i> sp.	IV-F	Masters	1869
spp.	IV-D, IV-F	Penzig	1890
<i>Cydonia</i> sp.	IV-F	Masters	1869
<i>Fragaria</i> sp.	I-D, IV-F, VII-K	Masters	1869
"	VII-K	Schaffner	1925
spp.	I-A, IV-F	Penzig	1890
<i>alpina</i>	I-H	Masters	1869
<i>vesca</i>	I-A	Masters	1869
<i>Geum rivale</i>	I-A, D, E	Masters	1869
spp.	I-A, IV-F, V-E, V-G	Penzig	1890
<i>Kerria</i> sp.	IV-F	Masters	1869
<i>Mespilus germanicus</i>	I-D	Penzig	1890
<i>Photinia</i> sp.	IV-F	Masters	1869
<i>Potentilla</i> sp.	I-D, IV-F	Masters	1869
spp.	I-A, IV-F, IV-G	Penzig	1890
<i>argentea</i>	I-A	Masters	1869
<i>nepalensis</i>	I-A, I-E	Masters	1869
<i>Poterium polygonum</i>	I-A	Masters	1869
<i>Prunus</i> spp.	IV-F, V-G	Masters	1869
"	I-H, IV-F	Penzig	1890
spp. hyb.	V-E, VI-F	Tukey	1922
"	VI-F	Smith	1927
<i>amygdalus</i>	I-D, I-E, IV-F, IV-G	Masters	1869
"	IV-C, IV-F, IV-G	Penzig	1890
<i>avium</i>	I-G	Masters	1869
<i>cerasus</i>	I-D, I-E, I-G	Masters	1869
"	I-A, IV-F	Penzig	1890
"	I-G, IV-F	Worsdell	1916
<i>persica</i>	I-D, I-E	Masters	1869
"	I-D, IV-G	Worsdell	1916
<i>Pyrus communis</i>	I-D, III-E, IV-F	Penzig	1890
<i>malus</i>	I-D, II-E, IV-F, IV-G	Masters	1869
"	I-D, III-E, IV-F, VI-D	Penzig	1890
"	III-E	Worsdell	1916
<i>Rosa</i> spp.	I-D, E, F, G; IV-F	Masters	1869
"	I-D, III-E, IV-D, IV-F	Penzig	1890
"	I-D, I-H, III-G	Worsdell	1916
"	IV-F	Semeniuk	1964
<i>arvensis</i>	VI-F	Masters	1867
<i>centifolia</i>	IV-B	Penzig	1890
<i>diversifolia</i>	I-A	Masters	1869
<i>indica</i>	I-A	Worsdell	1916

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>Rubus</i> sp.	I-E	Masters	1869
	spp.	I-A, II-A, IV-F	Penzig	1890
	<i>caesius</i>	I-A, IV-D	Masters	1869
	<i>fruticosus</i>	I-A	Masters	1869
	"	I-D	Worsdell	1916
	<i>Spiraea</i> sp.	IV-F	Masters	1869
	spp.	I-A, I-D, IV-F, VI-F, VII	Penzig	1890
	<i>oblongifolia</i>	I-E	Masters	1869
DROSERACEAE				
	<i>Dionaea muscipula</i>	VI-F	Masters	1869
	"	I-A	Harshberger (in Worsdell)	1907 1916
	<i>Drosera intermedia</i>	I-H	Masters	1869
CRASSULACEAE				
	<i>Kalanchoë blossfeldiana</i>	I-C	Harder	1948
	<i>Sedum</i> sp.	VIII-N	Masters	1869
	<i>Semperivivum</i> spp.	I-A, V-G, VI-F	Penzig	1890
	<i>montanum</i>	VI-F	Masters	1869
	<i>tectorum</i>	VI-F	Thouars	1807
	"	VI-F	von Mohl	1837
	"	VI-F	Masters	1869
	"	VI-F	Martz	1928
SAXIFRAGACEAE				
	<i>Deutzia</i> sp.	IV-F	Masters	1869
	<i>Hydrangea</i> sp.	IV-C	Penzig	1890
	<i>Philadelphus</i> sp.	V-D	Gris	1858
	"	IV-F	Masters	1869
	"	I-D, IV-D, IV-F	Penzig	1890
	<i>Ribes</i> sp.	IV-F	Masters	1869
	"	I-A, IV-F, VI-F	Penzig	1890
	<i>Saxifraga</i> spp.	I-A, IV-F, V-E, VI-F	Penzig	1890
	<i>aizoides</i>	I-G, IV-D, V-G	Penzig	1890
	<i>cotyledon</i>	I-A	Worsdell	1916
	<i>crassifolia</i>	VI-F	Masters	1869
	<i>foliosa</i>	I-A	Masters	1869
	<i>granulata</i>	V-E	Masters	1869
HALORAGIDACEAE				
	<i>Callitriche</i> sp.	VIII	Penzig	1890
	<i>Gunnera</i> sp.	VIII-L	Masters	1869
	<i>Hippuris</i> sp.	VII-K	Masters	1869
MYRTACEAE				
	<i>Baeckia diosmaefolia</i>	V-H	Masters	1869
	<i>Leptospermum</i> sp.	VII-L	Penzig	1890
	<i>Myrtus</i> sp.	IV-F, VI-F	Masters	1869
PUNICACEAE				
	<i>Punica</i> sp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
LYTHRACEAE				
	<i>Lythrum salicaria</i>	I-C	Penzig	1890
	<i>Nesaea verticillata</i>	IV-F	Penzig	1890
ONAGRACEAE				
	<i>Clarkia</i> sp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890
	<i>Epilobium</i> spp.	I-A, IV-F	Penzig	1890
	<i>hirsutum</i>	I-A, D, E, F, G	Masters	1869
	<i>Fuchsia</i> sp.	I-D, IV-F, VI-F	Masters	1869
	"	I-D, IV-D, IV-F, VI-F	Penzig	1890
	"	V-E	Worsdell	1916
	<i>Godetia</i> sp.	IV-F	Masters	1869
	"	IV-F	Penzig	1890
	<i>Oenothera striata</i>	I-E	Masters	1869
	"	I-A	Penzig	1890
LOASACEAE				
	<i>Gronovia scandens</i>	I-A	Penzig	1890
PASSIFLORACEAE				
	<i>Passiflora</i> spp.	V-H	Salter	1863
CARICACEAE				
	<i>Carica papaya</i>	VIII-N	Masters	1869
	"	VII-K	Usteri (in Worsdell 1916)	1907
CUCURBITACEAE				
	<i>Acanthosicyos</i> sp.	VIII-N	Penzig	1890
	<i>Bryonia</i> spp. hyb.	VIII-L, VII-K	Heilbronn & Basarman	1942
	<i>Cucumis</i> sp.	VI-F	Masters	1869
	spp.	I-D, VI-F, VII-N	Penzig	1890
	<i>melo</i>	J, K, L, N	Brantley & Warren	1958
	<i>sativus</i>	O	Laibach & Kribben	1950
	"	VII-K	Wittwer & Hillyer	1954
	"	O	Peterson & Anhder	1960
	"	VII-J, VII-K	Mitchell & Wittwer	1962
	"	VIII-J	Nitsch	1962
	"	VIII-J	Wittwer & Bukovac	1962
	"	O	Shifriss & George	1964
	<i>Cucurbita</i> spp.	VIII-N, VI-F	Masters	1869
	"	I-D, VI-F, VIII-N	Penzig	1890
	spp.	O	Thomas	1956
	<i>pepo</i>	VI-F	Masters	1869
	"	VII-J, VII-K	Nitsch	1962
	<i>Ecballium</i> sp.	VIII-N	Penzig	1890
	<i>Lagenaria leucantha</i>	I-D	Penzig	1890
	<i>Thladiantha dubia</i>	O	Giard	1898
	<i>Trichosanthes</i> sp.	VIII-N	Penzig	1890

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
BEGONIACEAE				
	<i>Begonia</i> spp.	IV-F, VIII-M	Penzig	1890
	"	V-H	Goebel	1908
	"	IV-H, V-G	Worsdell	1916
	<i>cathayana</i>	VI-F	Worsdell	1916
	"	N	Noack	1962
	<i>frigida</i>	VI-F	Masters	1869
	<i>lloydii</i> hyb.	VI-E, VI-F	Bateson & Sutton	1919
	hyb.	VI-E, VI-F	Noack	1962
	<i>pearcei</i>	I-E, IV-F, IV-G	Worsdell	1916
CACTACEAE				
	<i>cereus</i> spp.	IV-F	Penzig	1890
UMBELLIFERAE				
	<i>Angelica</i> sp.	I-A	Penzig	1890
	<i>Anthriscus</i>			
	(<i>Torilis</i>) sp.	I-A, E, F, H	Masters	1869
	"	I-F	Molliard	1896
	<i>Apium</i> sp.	I-A	Penzig	1890
	<i>Athamanta cervaria</i>	I-D	Masters	1869
	<i>Carum carvi</i>	I-H, IV-D	Masters	1869
	"	I-A, IV-D, IV-F	Penzig	1890
	<i>Daucus</i> sp.	I-G	Worsdell	1916
	<i>carota</i>	I-D, E, F, G; IV-F, V-E	Masters	1869
	"	I-A, IV-F, V-E	Penzig	1890
	<i>Echinophora</i> sp.	I-A	Penzig	1890
	<i>Heracleum</i> sp.	I-F, I-G	Masters	1869
	"	I-C, V-E	Penzig	1890
	<i>spondylium</i>	I-E	Masters	1869
	<i>Myrrhis</i> (<i>Seseli</i>) sp.	I-A	Masters	1869
	<i>Oenanthe</i> sp.	I-C	Penzig	1890
	<i>Pastinaca</i> sp.	I-H	Masters	1869
	<i>Selinum caruifolium</i>	I-A	Masters	1869
	<i>Trinia</i> sp.	VII	Penzig	1890
CORNACEAE				
	<i>Aucuba</i> sp.	VIII-N	Masters	1869
	<i>Cornus</i> sp.	IV-F	Penzig	1890
CAPRIFOLIACEAE				
	<i>Lonicera</i> sp.	I-H, IV-F, IV-G	Masters	1869
	<i>periclymenum</i>	I-E, I-F, I-G	Masters	1869
	"	I-E	Worsdell	1916
	<i>xylosteum</i>	I-E	Masters	1869
	<i>Sambucus</i> sp.	IV-F	Masters	1869
	<i>Viburnum</i> sp.	IV-F	Masters	1867
RUBIACEAE				
	<i>Gardenia</i> sp.	IV-F	Masters	1869
	<i>Ixora</i> sp.	IV-F	Masters	1869
	<i>Serissa</i> sp.	IV-F	Masters	1869

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
VALERIANACEAE				
	<i>Centranthus macrosiphon</i>	I-D	Masters	1869
DIPSACACEAE				
	<i>Dipsacus fullonum</i>	I-A	Masters	1869
	<i>Knautia arvensis</i>	IV-F	de Bary (in Worsdell)	1884
	<i>Scabiosa</i> sp.	IV-F, IV-G	Masters	1869
	<i>agrestis</i>	I-E	Masters	1869
	<i>Columbaria</i>	I-A, I-E	Masters	1869
	"	I-A, I-E	Masters	1869
	"	IV-F	Worsdell	1916
COMPOSITAE				
	<i>Ambrosia</i> sp.	VIII-J	Thomas	1956
	<i>Calendula officinalis</i>	I-A, I-E	Masters	1869
	<i>Carduus heterophyllus</i>	I-D, I-G	Masters	1869
	<i>tataricus</i>	I-D, I-G	Masters	1869
	<i>Centaurea jacea</i>	I-C	Masters	1869
	<i>Cirsium arvense</i>	I-D	Masters	1869
	<i>tricephalodes</i>	I-E	Masters	1869
	<i>Crepis</i> sp.	I-H	Masters	1869
	<i>Gaillardia</i> sp.	I-H	Masters	1869
	<i>Helenium autumnale</i>	I-C, I-E	Worsdell	1916
	<i>Hypochaeris radicata</i>	I-D	Masters	1869
	<i>Matricaria parthenium</i>	I-A	Masters	1869
	<i>Parthenium inodorum</i>	I-C	Masters	1869
	<i>Petasites hybridus</i>	I-A	Wardlaw	1963
	<i>Scorzonera octangularis</i>	I-D	Masters	1869
	<i>Senecio vulgaris</i>	I-D, I-E	Masters	1869
	<i>Taraxacum officinale</i>	I-C	Masters	1869
	<i>Tragopogon orientale</i>	I-D	Masters	1869
	<i>pratense</i>	I-D	Masters	1869
	"	I-C	Worsdell	1916
CAMPANULACEAE				
	<i>Campanula</i> sp.	I-D	Masters	1869
	<i>glomerata</i>	I-E	Masters	1869
	<i>medium</i>	IV-D	Worsdell	1916
	<i>persicifolia</i>	IV-D, IV-F, V-G	Masters	1869
	"	IV-D	Worsdell	1916
	<i>pyramidalis</i>	I-A	Masters	1869
	<i>rapunculoides</i>	VI-F	Masters	1869
	<i>Phyteuma odorata</i>	I-H	Masters	1869
	<i>spicatum</i>	I-E	Masters	1869
	<i>Platycodon</i> sp.	IV-F	Masters	1869

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
ERICACEAE				
	<i>Arbutus</i> sp.	IV-F	Masters	1869
	<i>Azalea</i> sp.	IV-F	Masters	1869
	<i>Calluna</i> sp.	IV-F	Masters	1869
	<i>Erica</i> sp.	IV-F	Masters	1869
	<i>cinerea</i>	III-A	Worsdell	1916
	<i>tetralix</i>	VI-F	Masters	1869
	"	II-A	Worsdell	1916
	<i>Rhododendron</i> sp.	IV-F	Masters	1869
	<i>indicum</i>	IV-D	Worsdell	1916
PRIMULACEAE				
	<i>Anagallis arvensis</i>	I-A, I-F, I-H, IV-D, IV-F	Masters	1869
	<i>phoenicea</i>	I-E, I-H	Masters	1869
	<i>webbiana</i>	I-A	Masters	1869
	<i>Cyclamen</i> sp.	IV-F	Masters	1869
	<i>Lysimachia</i>			
	<i>epheumerum</i>	I-A, I-H	Masters	1869
	<i>Primula</i> sp.	IV-F, IV-G	Masters	1869
	"	I-H	Worsdell	1916
	"	I-D	Tschermak	1932
	<i>acaulis</i>	I-D, VI-F	Masters	1869
	"	IV-F, IV-G	Tschermak	1932
	<i>auricula</i>	I-H, III-E	Masters (de Candolle)	1869
	<i>calycanthema</i>	IV-D	Masters	1869
	<i>elatior</i>	I-D	Masters	1869
	"	IV-F, IV-G	Tschermak	1932
	<i>keawensis</i>	I-E, IV-F	Heinricher	1931
	<i>officinalis</i>	I-D, IV-D	Masters	1869
	"	IV-F	Molliard (in Worsdell)	1901
	"	IV-F, VI-F	Marsden-Jones & Turrill	1931
	"	IV-D, VI-F	Montford	1931
	"	VI-F	Dahlgren	1932
	"	IV-F, IV-G	Tschermak	1932
	<i>praenitens</i>	I-H	Masters	1869
	<i>sinensis</i>	I-A, I-E, I-F	Masters	1869
	<i>veris</i>	VI-F	Rytz	1921
	<i>vulgaris</i>	VI-F	Masters (in Worsdell)	1878
	"	I-D, IV-D	Worsdell	1916
OLEACEAE				
	<i>Jasminum</i> sp.	IV-F	Masters	1869
	<i>Syringa</i> sp.	IV-F	Masters	1869
	<i>persica</i>	IV-D	Masters	1869
GENTIANACEAE				
	<i>Gentiana</i> sp.	IV-F	Masters	1869
	<i>amarella</i>	I-E, VI-F	Masters	1869
	<i>campestris</i>	I-D, V-G	Masters	1869

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
APOCYNACEAE			
<i>Allamanda</i> sp.	IV-F	Masters	1869
<i>Nerium</i> sp.	IV-F	Masters	1869
<i>Tabernaemontana</i> sp.	IV-F	Masters	1869
<i>Vinca</i> sp.	IV-F	Masters	1869
POLEMONIACEAE			
<i>Gilia capitata</i>	I-A	Masters	1869
<i>glomeruliflora</i>	I-E, I-H	Masters	1869
<i>Polemonium coeruleum</i>	I-E, VI-F	Masters	1869
"	IV-F	Chittenden	1914
BORAGINACEAE			
<i>Anchusa ochroleuca</i>	I-A, I-G	Masters	1869
<i>paniculata</i>	I-G	Masters	1869
<i>Myosotis caespitosa</i>	I-A	Masters	1869
<i>Symphytum officinale</i>	I-E, I-G, I-H	Masters	1869
<i>zeyheri</i>	I-H	Masters	1869
CONVOLVULACEAE			
<i>Convolvulus</i> sp.	IV-F	Masters	1869
(<i>Calystegia</i>)			
<i>sepium</i>	I-D	Masters	1869
<i>Ipomoea</i> sp.	IV-F	Masters	1869
<i>imperialis</i>	VI-F	Correns (in Dahlgren)	1932
SOLANACEAE			
<i>Datura</i> sp.	IV-F	Masters	1869
<i>Lycium europaeum</i>	I-D	Masters	1869
<i>Nicotiana affinis</i>	VI-F	Costerus	1907
<i>alata</i>	VI-F	Avery	1929
<i>langsdorffi</i> hyb.	IV-D, IV-D, VI-F	White	1914
<i>rustica</i>	I-A	Masters	1869
<i>rustica</i> hyb.	I-A, I-G	Hillman & Smith	1965
<i>tabacum</i>	VI-F	Goodspeed	1930
"	VI-F	Goodspeed & Avery	1934
<i>tabacum</i> hyb.	P	Burk	1960
<i>Petunia</i> spp.	I-F, IV-F	Masters	1869
<i>violacea</i>	I-D, I-E	Masters	1869
<i>Solanum</i> sp.	V-E	Henslow (in Worsdell)	1882
"	VI-F	Scott (in Worsdell)	1906
"	V-E	Worsdell	1916
spp. hyb.	P	Koopmans	1955
"	P	Grun & Radlow	1960, 62
SCROPHULARIACEAE			
<i>Antirrhinum majus</i>	I-E, IV-F	Masters	1869
"	I-A, III-E, III-F, I-E, III-A	Baur	1924

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
<i>Calceolaria</i> sp.	IV-D, IV-F	Masters	1869
<i>Digitalis</i> sp.	IV-F	Masters	1869
<i>purpurea</i>	V-E	Masters	1869
"	V-E	Saunders (in Worsdell)	1911
<i>purpurea</i> ×			
<i>lutea</i>	IV-F, VI-F	Martz	1928
<i>Gratiola</i> sp.	IV-F	Masters	1869
<i>Linaria</i> sp.	IV-F	Masters	1869
<i>vulgaris</i>	IV-F	Heufler	1843
"	V-G, VI-F	Worsdell	1916
"	VI-F	Geisenheyner	1919
"	VI-F	Graf	1919
<i>Mimulus</i> spp.	IV-D, IV-F	Masters	1869
"	IV-D	Worsdell	1916
<i>Rhinanthus</i> sp.	VI-E	Schimper (in Worsdell)	1829
<i>Scrophularia</i> sp.	I-H	Worsdell	1916
<i>aquatica</i>	I-A, I-G	Masters	1869
<i>nodosa</i>	I-A	Masters	1869
<i>Torenia fournieri</i>	I-A, I-G, IV-F	Simon	1924
	all transitional forms		
<i>Verbascum</i> sp.	I-E	Masters	1869
<i>pholomoides</i>	I-A	Masters	1869
<i>Veronica</i> sp.	IV-F	Masters	1869
BIGNONIACEAE			
<i>Bignonia</i> sp.	IV-F	Masters	1869
GESNERIACEAE			
<i>Achimenes</i> sp.	IV-F	Masters	1869
<i>Gloxinia</i> sp.			
(<i>Sinningia</i>)	IV-D, IV-F	Masters	1869
"	V-E	Worsdell	1916
<i>Streptocarpus</i> sp.	IV-F	Worsdell	1916
sp. hyb.	VI-F	Oehlkers	1940
<i>Trichosporum</i> sp.	IV-G	Masters	1869
VERBENACEAE			
<i>Clerodendron</i> sp.	IV-F	Masters	1869
LABIATAE			
<i>Ajuga reptans</i>	I-C	Masters	1869
<i>Monarda fistulosa</i>	V-E	Masters	1869
<i>Origanum majorana</i>			
× <i>vulgare</i>	K, L, M	Appl	1929
<i>Origanum vulgare</i>	III-E, VI-F, III-F	Appl	1929
"	VII-K	Lewis & Crowe	1952
<i>Perilla frutescens</i>	II-A	Raghaven & Jacobs	1961
<i>Stachys germanica</i>	VI-F	Masters	1869

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>sylvatica</i>	I-A, I-E, I-G	Masters	1869
	"	VI-E	Schimper (in Worsdell)	1829
	<i>Thymus vulgaris</i> × <i>T. ovatus</i>	VIII-K, VIII-N	Appl	1933
PLANTAGINACEAE	<i>Plantago</i> spp.	I-C	Masters	1869
CHENOPODIACEAE	<i>Spinacia</i> sp.	VII-N	Masters	1869
NYCTAGINACEAE	<i>Mirabilis</i> sp.	IV-F	Masters	1869
POLYGONACEAE	<i>Rumex arifolius</i>	I-A, I-H	Masters	1869
	<i>crispa</i>	VI-F	Masters	1869
	<i>hastatulus</i>	VII-J, VII-K	Smith	1963
	<i>scutatus</i>	I-A, I-H	Masters	1869
MYRISTICACEAE	<i>Myristica</i> sp.	VIII-L	Masters	1869
LAURACEAE	<i>Laurus</i> sp.	IV-F	Eichler (in Worsdell)	1853
	"	IV-F	Masters	1869
	<i>cerasus</i>	I-D	Masters	1869
MORACEAE	<i>Cannabis sativa</i>	VIII-N	Gasparrini (in Figdor)	1862
	"	VIII-L, VIII-N	Masters	1869
	"	O	Molliard	1896
	"	VIII-N	Pritchard	1916
	"	VIII-N, O	Schaffner	1921, 1923, 1925, 1931
	"	VIII-N	McPhee	1925
	"	VIII-N	Talley	1934
	"	J, K, N	Tibeau	1936
	"	VIII-J	Borthwick & Scully	1954
	"	VIII-K	Heslop-Harrison	1956
	"	VIII-L	Köhler	1958
	"	VIII-J, VIII-K	Bredemann <i>et al.</i>	1961
	<i>Humulus japonicus</i>	VIII-J	Nypels	1897
	"	VIII-L	Giard	1898
	"	VIII-N	Figdor	1911
	<i>lupulus</i>	VIII-L	Masters	1869
	"	VIII-L	Worsdell	1916
	<i>Morus</i> sp.	VII-J, VII-K	Masters	1869
	<i>alba</i>	VIII to J, K, L	Schaffner	1929

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
JUGLANDACEAE			
<i>Juglans</i> sp.	VII-K	Masters	1869
LEITNERIACEAE			
<i>Leitneria floridana</i>	VIII-L	Masters	1869
MYRICACEAE			
<i>Myrica gale</i>	VIII-L, VIII-N	Davey & Gibson	1917
EUPHORBIACEAE			
<i>Bryonia</i> sp.	N	Masters	1869
<i>Cleistanthus</i>	N	Masters	1869
<i>Cluytia semperflorens</i>	N	Masters	1869
<i>Conceveiba</i>			
<i>macrophylla</i>	N	Masters	1869
<i>Crozophora tinctoria</i>	N	Masters	1869
<i>Euphorbia</i> sp.	VI-F	Schmitz (in Worsdell)	1871
<i>esula</i>	VI-F	Masters	1869
<i>geniculata</i>	I-F	Masters	1869
<i>palustris</i>	V-G	Masters	1869
<i>segetalis</i>	I-A	Masters	1869
<i>Glochidion</i> sp.	VI-F	Masters	1869
<i>Hermesia</i>			
<i>castaneifolia</i>	VIII-N	Masters	1869
<i>Jatropha pohliana</i>	I-F	Masters	1869
<i>Mercurialis</i> sp.	VIII-L and N	Masters	1869
<i>ambigua</i>	VIII-L	Yampolsky	1919
"	J	Thomas	1956
"	J & L	Heslop-Harrison	1957
<i>Mozinna peltata</i>	VIII-L	Masters	1869
<i>Phyllanthus</i> sp.	N	Masters	1869
<i>Ricinus communis</i>	N, V-G	Masters	1869
"	VII-K	Parkey	1957
"	VIII-L	Clavier	1961
"	VII-K	Shifriss	1961
"		Shifriss & George	1964
"	Everted ovule	Stein	1965
<i>Schismatophora</i>			
<i>distichophylla</i>	VIII-L	Masters	1869
<i>Suregada</i> sp.	N	Masters	1869
FAGACEAE			
<i>Fagus sylvatica</i>	N	Masters	1869
SALICACEAE			
<i>Populus alba</i> hyb.	VIII-L	Peto	1938
<i>tremula</i> hyb.	VIII to L & N	Runquist (in Seitz)	1951
"	VIII to L & N	Seitz	1952
"	VIII to L & N	Schlenker	1953
<i>tremuloides</i>	VIII-N	Erlanson & Hermann	1927

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>Salix</i> sp. hyb.	V-G, VI-F, N	Rainio	1927
	"	IV	Heribert-Nilsson (in Dahlgren)	1932
	sp.	V-G	Masters	1869
	"	VIII-L	Wigand (in Worsdell)	1916
	<i>alba</i>	VIII to L & N	Worsdell	1916
	<i>andersoniana</i>	VI-F	Masters	1869
	<i>babylonica</i>	I-G, VI-F	Masters	1869
	<i>capraea</i>	I-H	Masters	1869
	<i>cinerea</i>	VIII-L	Worsdell	1916
	<i>fragilis</i>	V-G	Zimmerman (in Worsdell)	1911
EMPETRACEAE				
	<i>Empetrum</i> sp.	N	Masters	1869
TAXACEAE				
	<i>Taxus</i> sp.	N	Masters	1869
PINACEAE				
	<i>Cupressus</i> sp.	I-H	Worsdell	1916
	<i>Juniperus virginiana</i>	VIII-L	Masters	1869
	<i>Larix</i> sp.	VI-F	Worsdell	1916
	<i>Pinus</i> sp.	VI-F	Worsdell	1916
HYDROCHARITACEAE				
	<i>Hydrocharis</i> sp.	IV-F	Masters	1869
ORCHIDACEAE				
	<i>Aceras anthropophora</i>	IV-D	Masters (in Worsdell)	1916
	<i>Catasetum</i> sp.	IV-F	Masters	1869
	<i>Cattleya loddigesii</i>	I-D, I-E	Worsdell	1916
	<i> trianae</i>	IV-D	Worsdell	1916
	<i>Cypripedium</i> spp.	IV-F	Masters (in Worsdell)	1916
	"	IV-F	Penzig (in Worsdell)	1916
	<i>calceolus</i>	IV-F	Heinricher (in Worsdell)	1891
	<i>lawrencianum</i>	IV-D	Heinricher (in Worsdell)	1891
	<i>Epidendrum</i>			
	<i> vitellinum</i>	IV-A	Rolfe (in Worsdell)	1890
	<i>Mitonia vexillaria</i>	IV-F, IV-G	Worsdell	1916
	<i>Odontoglossum</i>			
	<i> crispum</i>	III-E	Worsdell	1916
	<i>Ophrys</i> sp.	V-E	Masters	1869
	<i> insectifera</i>	V-G	Masters	1869

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
<i>Orchis</i> sp.	IV-F	Masters	1869
<i>mascula</i>	V-E	Masters	1869
<i>morio</i>	IV-D	Penzig (in Worsdell)	1886
<i>Platanthera bifolia</i>	VI-F	Rytz	1921
IRIDACEAE			
<i>Crocus</i> sp.	IV-F	Masters	1869
"	all transitions between carpels and sepals	Worsdell	1916
<i>graecus</i>	VI-C, VI-E, VI-F	Lutz (in Worsdell)	1897
<i>nudiflorus</i>	VI-E	Masters	1869
<i>sativus</i>	VI-C, VI-E, VI-F	Lutz (in Worsdell)	1897
<i>zonatus</i>	V-D, V-E	Worsdell	1916
<i>Gladiolus</i> sp.	IV-F	Masters	1869
<i>Iris</i> , all species	IV-G	Worsdell	1916
sp.	IV-F	Masters	1869
<i>kaempferi</i>	IV-F	Worsdell	1916
<i>sieboldii</i>	IV-F	Worsdell	1916
AMARYLLIDACEAE			
<i>Amaryllis</i> sp.	VI-F	Masters	1869
<i>Galanthus nivalis</i>	IV-F	Masters	1869
"	II-A, IV-D, I-A	Worsdell	1916
<i>Hippeastrum</i> sp.	IV-F	Masters	1869
<i>Leucojum</i> sp.	IV-F	Masters	1869
<i>Narcissus</i> sp.	IV-F	Masters	1869
"	IV-F, IV-G	Worsdell	1916
<i>pseudo-narcissus</i>	VI-F	Molliard	1896
"	VI-F	Martz	1928
<i>tazetta</i>	IV-F	Celakovsky (in Worsdell)	1916
<i>Polianthes</i> sp.	IV-F	Masters	1869
<i>Sternbergia</i> sp.	IV-F	Masters	1869
ZINGIBERACEAE			
<i>Alpinia</i> sp.	V-E	Worsdell	1916
LILIACEAE			
<i>Allium</i>			
<i>scorodoprasum</i>	V-G	Masters	1869
<i>Asphodelus</i> sp.	IV-F, V-E	Masters	1869
<i>ramosus</i>	VI-F	Masters	1869
<i>Colchicum</i>			
<i>autumnale</i>	I-D, IV-F	Masters	1869
<i>Convallaria maialis</i>	I-D, IV-F	Masters	1869
<i>Fritillaria</i> sp.	IV-F	Masters	1869
<i>Hemerocallis</i> sp.	IV-F	Masters	1869
<i>Hyacinthus</i> sp.	I-G, IV-F, V-G	Masters	1869
"	V-H	Worsdell	1916

TABLE I, Continued

FAMILY	Genus and Species	Abnormality	Author	Year
	<i>orientalis</i>	IV-F		
	"	embryo-sac-like pollen	Nemec	1898
	"	IV-F		
	"	embryo-sac-like pollen	Stow	1930
	"	IV-F		
	"	embryo-sac-like pollen	de Mol	1933
	"	IV-F		
	"	embryo-sac-like pollen	Naithani	1937
<i>Lilium</i> sp.		IV-F	Masters	1869
<i>candidum</i>		I-C	Worsdell	1916
<i>longiflorum</i>		VI-F	Masters	1869
<i>tigrinum</i>		VI-F	Masters	1869
<i>Ornithogalum</i>				
<i>nutans</i>		embryo-sac-like pollen	Geitler	1941
<i>Scilla</i> sp.		IV-F	Masters	1869
<i>nutans</i>		V-G	Worsdell	1916
<i>Tofieldia</i> sp.		IV-F	Masters	1869
<i>calyculata</i>		V-G	Masters	1869
<i>Trillium</i>				
<i>grandiflorum</i>		I-A, O	Hall	1961
<i>Tulipa</i> sp.		VI-F	Clos	1859
"		I-G, IV-F	Masters	1869
"		VI-F	Molliard	1896
"		VI-D, VI-E, V-G, I-D, V-D	Worsdell	1916
"		V-H	Martz	1928
<i>gesneriana</i>		I-D, VI-E	Masters	1869
COMMELINACEAE				
	<i>Commelina</i> sp.	IV-F	Masters	1869
	<i>Tradescantia</i> sp.	IV-F	Masters	1869
JUNACEAE				
	<i>Juncus lamprocarpus</i>	I-A	Masters	1869
	"	II-A	Worsdell	1916
	<i>uliginosus</i>	I-A	Masters	1869
PALMACEAE				
	<i>Chamaerops humilis</i>	V-G	von Mohl	1837
	"	V-G	Masters	1869
	<i>Cocos</i> sp.	O-K	Smith (in Worsdell)	1908, 1916
ARACEAE				
	<i>Arisaema triphyllum</i>	J-K or M	Atkinson	1898
	"	J-K or M	Schaffner	1922
	"	J-K or M	Camp	1932
ALISMACEAE				
	<i>Sagittaria</i> sp.	IV-F	Masters	1869

TABLE I, Continued

FAMILY			
Genus and Species	Abnormality	Author	Year
CYPERACEAE			
<i>Carex</i> sp.	VIII-L	Masters	1869
GRAMINEAE			
<i>Avena chinensis</i>	V-E	Masters	1869
<i>Bambusa</i> sp.	VI-F	Masters	1869
<i>Glyceria fluitans</i>	I-D, E, F	Wigand (in Worsdell)	1856
<i>Hordeum</i> sp.	O	Wijewantha & Stebbins	1964
<i>Saccharum spontaneum</i>	VI-F	Bremer	1928
<i>Triticum</i> sp. hyb.	VI-F	Leighty & Sando	1924
"	VI-F	Kihara	1951
<i>aestivum</i>	VI-F	Porter, Lahr, & Atkins	1965
<i>vulgare</i>	VI-F	Leighty & Sando	1924
"	VI-F	Calder	1930
<i>Zea mays</i>	VI-F, N	Masters	1869
"	O	Blaringhem	1904, 1905
"	M, O	Worsdell	1916
"	M, VI-F	Weatherwax	1925a, 1925b
"	M	Schaffner	1927
"	M	Phipps	1928
"	M	Richey & Sprague	1932
"	M	Heslop-Harrison	1959
"	I	Postlethwait & Nelson	1964
"	II, VI-H	Orr & Postlethwait	1964