

NEW BUD SPORTS IN NEPHROLEPIS¹

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INTRODUCTION

Attention has been called in previous papers to a large number of varieties of *Nephrolepis* derived by bud variation from the commonly cultivated "Boston fern," *N. exaltata bostoniensis*. In one of these articles (BENEDICT 1916) was given the genealogy and brief descriptions of over forty American forms which had arisen by progressive variation, i.e., by divergence in characters from the Boston fern. In a later paper (BENEDICT 1922 a) consideration was given to certain other varieties derived by reversion or regressive variation from a number of the progressive varieties considered in the first paper.

In the present paper, both types of variation are included, but a much smaller number of forms is involved. Two new sports of particular interest in the Boston-fern series form the main subject of the first section; both were derived by progressive sporting from the variety known as *elegantissima-compacta*. With one of these new forms a state of leaf vivipary has been achieved, a condition not heretofore known either among these horticultural varieties or among the wild species of *Nephrolepis*. The second section of the present paper is concerned with a number of varieties, partly new and partly old, which offer excellent examples of parallel variation.

¹ BROOKLYN BOTANIC GARDEN Contributions, No. 32.

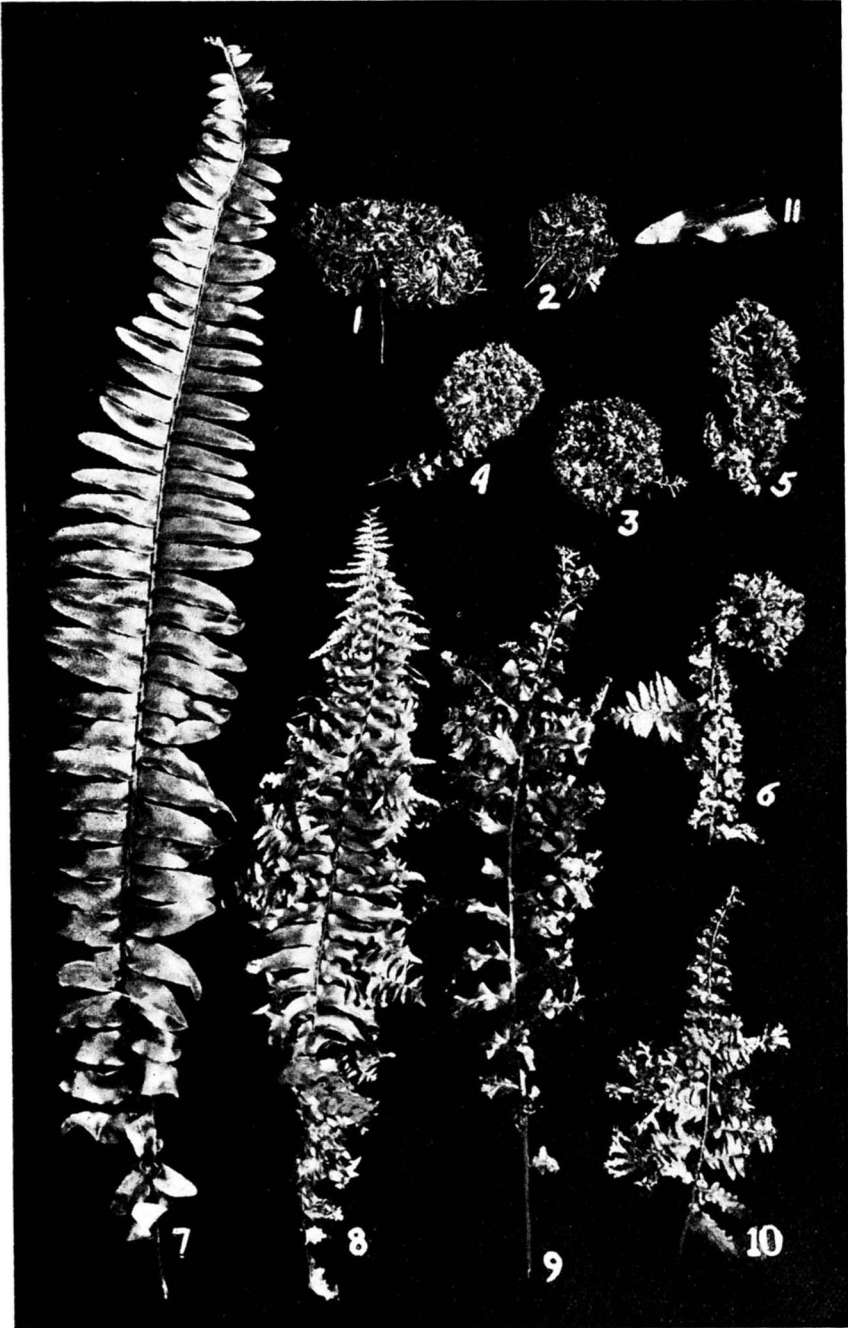
LEGEND FOR PLATE 1

A new viviparous bud sport of *elegantissima-compacta cristata*.

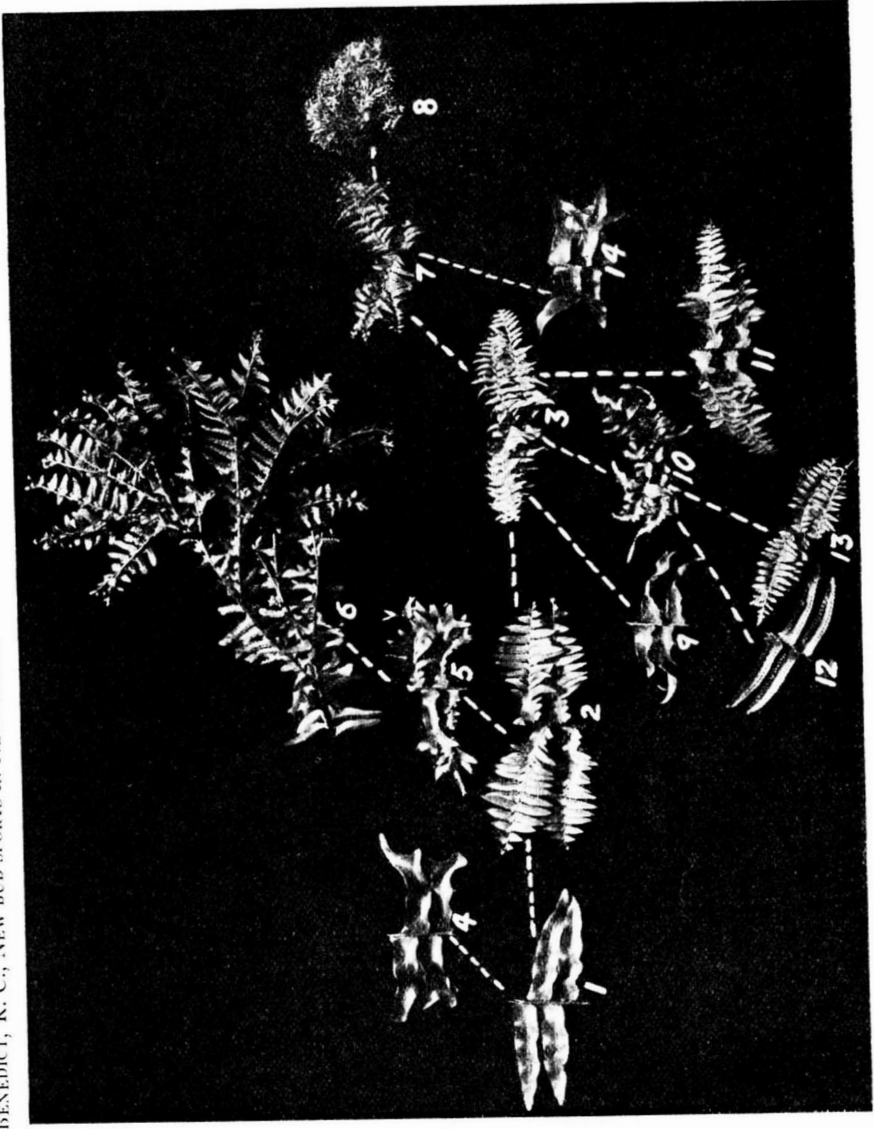
FIGURES 1 to 3.—Typical leaves of new form. Figure 2 shows leaf with a young reverted plant arising viviparously. (Enlarged in text-figure 2.)

FIGURES 4 to 10.—Reverting leaves of new form, showing various expressions of creasing and division.

FIGURE 11.—Single pinna of Boston fern for comparison.



BENEDICT, R. C., NEW BUD SPORTS IN NEPHROLEPIS



LEGEND FOR PLATE 2

Parallel and recurrent variation in *Nephrolepis*. The relationships of varieties described and discussed in the present paper.

- FIGURE 1.—Boston fern.
FIGURE 2.—*Pierstoni*.
FIGURE 3.—*elegantissima-compacta*.
FIGURE 4.—*Gretna*.
FIGURE 5.—*splendida*.
FIGURE 6.—*Baeri* (upper half of leaf).
FIGURE 7.—*elegantissima-compacta cristata*.
FIGURE 8.—New viviparous sport of *elegantissima-compacta cristata* (whole leaf).
FIGURE 9.—“Dwarf Boston.”
FIGURE 10.—*Wanamakeri*.
FIGURE 11.—Unnamed tall two-pinnate revert of *elegantissima-compacta*.
FIGURE 12.—Unnamed dwarf once-pinnate revert of *Wanamakeri*.
FIGURE 13.—Unnamed tall two-pinnate revert of *Wanamakeri*.
FIGURE 14.—Unnamed dwarf, crested, once-pinnate revert of *elegantissima-compacta cristata*.

A NEW FORM WITH VIVIPAROUS LEAVES

As previously described (BENEDICT 1916) the variety *elegantissima-compacta* is a dwarf type with twice-pinnate, pinnatifid leaves, each forming a dense plummy growth (plate 2, figure 3). Occasional reverting leaves once-pinnate or of an intermediate division type, may occur, but on the whole the variety is stable in its characters. Compared with its parent form, *Piersoni*, (plate 2, figure 2) which is tall and simply twice-pinnate, but normally with frequent once-pinnate leaves, *elegantissima-compacta* offers two marked differences; viz., a considerable decrease in size, and a definite increase in division, together also with a greater stability of the division character. There is reason for believing also that this variety, as will be pointed out below, comprises still another difference from *Piersoni*, in the addition of ruffling as a distinct character of the pinnae.

The first of the two new forms to be described represents the addition to the *elegantissima-compacta* complex of characters of an entirely new leaf modification, that of creasing or the forking of the leaf and pinna tips. This is cited as new merely for *elegantissima-compacta*, as it is a common variation among ferns in general, both cultivated and wild. Among the sports of the Boston-fern series it occurs as modifying a considerable number of different types. In this particular case, it was found at the F. R. PIERSON Tarrytown establishment by J. T. TREVILLIAN, the foreman of the greenhouses, as a runner sport, and was first marketed in 1920 under the name, *elegantissima-compacta cristata*, *cristata* being the common technical term for such leaf dichotomy. A section of typical leaf is represented in plate 2, figure 7.

In addition to the creasing, this form shows some decrease in the stability of the twice-pinnate, pinnatifid condition. It appears that the perfect manifestation of both creasing and double division, symmetrically developed throughout a single leaf, is difficult to achieve. The first result is that along a single leaf the pinnae show in varying degrees sometimes both creasing and double division, sometimes only the creasing or only the division type. Reverting leaves present a curious mixture of all possible characteristics from completely crested and divided pinnae through all gradations to entire, undivided, falcate pinnae of the ordinary Boston-fern type (plate 2, figure 1). Whole leaves may show reversion only, retaining the creasing character; others may be simply doubly pinnate without any external sign of creasing. Some leaves are crested along the pinna tips but normal for the leaf tip, and *vice versa*.

From *elegantissima-compacta cristata* a further progressive sport has been detected by TREVILLIAN which represents the most extremely specialized type, (text-figure 1 and 2 and plates 1 and 2) of all known Boston-fern varieties. Described in terms of separate character accretions, it is a sport progressive from *elegantissima-compacta cristata* through an increase in the amount of the pinnate-division character. In other words, from the twice-pinnate pinnatifid type of its parent form, it differs

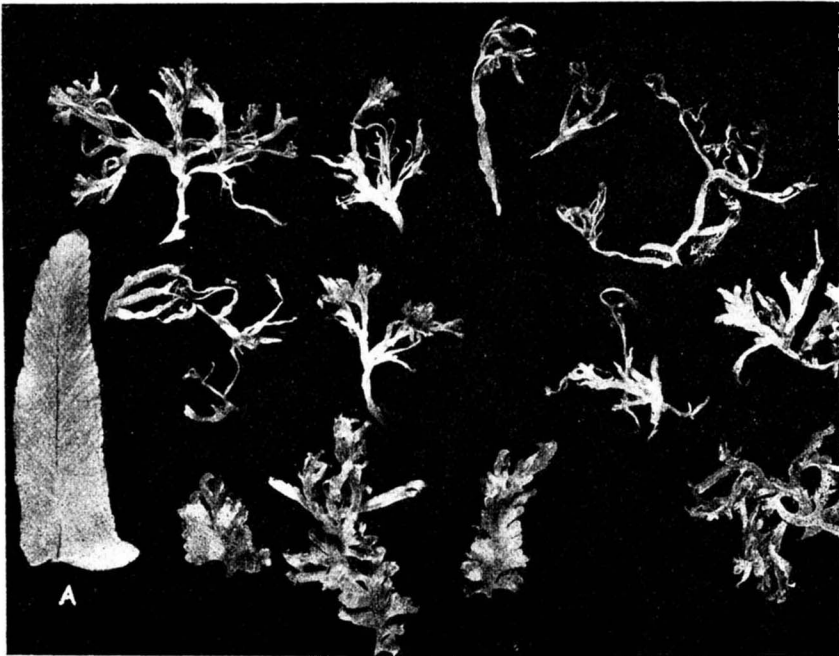


FIGURE 1. Illustrating the forking thalloid segments of a new viviparous sport of *elegantissima-compacta cristata*. A shows a single pinna of *bostoniensis* for comparison.

in being at least four-times pinnate, with the cresting feature retained in combination. So far no other case of a crested "lace" type has come to my attention, although on the basis of the observed and recorded behavior of these sports in general (BENEDICT 1916) it was a logical conclusion that such a combination of characters should occur. As stated earlier (BENEDICT 1916) it has appeared from previous study that any given variety, not at the maximum possible condition for a particular

character if cultivated in sufficient number may be expected to give rise to bud sports showing a greater approximation to that maximum. It is not improbable that such a combination of lace-like division with crested may have occurred more than once and have been discarded as of no commercial value. It is interesting that in this case the combination occurred by the addition of multiple division to a crested form, the latter type being much less common in cultivation, rather than by the discovery among the thousands of three- and four-pinnate varieties grown annually, of a bud sport showing crested.



FIGURE 2.—A single leaf of a new viviparous bud sport, showing production of a new plant from a leaf.

The new form is as yet unnamed. Horticulturally, it is probably valueless, except in the possibility that from it some more easily cultivated, distinct type may arise. The plants are extraordinary in appearance, not only for *Nephrolepis*, but for ferns in general. A single fully developed leaf appears as a dense spherical mass, about an inch in diameter (plate 1, figure 1). Dissected, it is found to consist of irregularly forking, flattened green filaments (text figure 1) of no fixed length or breadth. The wiry red petiole dichotomizes several times within the spherical leaf "blade," and the subdivisions give rise to the green filaments already mentioned.

It is impossible to differentiate between pinnae and pinnulae, if such exist, and the lobes produced by forking.

Added to the interest of this peculiar division type is the fact that these leaf masses seem regularly to produce new plants by the viviparous budding of the leaves. Such young plants may present the typical slender forking filaments of the variety, or may appear completely reverted to a once-pinnate condition (text-figure 2 and plate 1, figure 2). The young reverted plant shown was developed from one of the main forks of the leaf axis or midrib, but in other cases, the new plants seem also to arise from the lesser herbaceous filaments. The stolons typical for *Nephrolepis* appear on the new plants while these are still attached to the parent leaf. Propagation is easily carried on by setting the tiny plants in moist soil. TREVILLIAN believes that reproduction may be artificially induced by taking cuttings of adult leaves without any new plants, and setting these in moist soil, but this has yet to be demonstrated certainly.

Typical adult plants growing in the soil develop stolons normal for the genus, although so far of slight growth. New plants arise along these stolons close to the parent stem. Reversion has appeared in such stem buds, and is illustrated in plate 1, figures 4 to 10. So far the reversion seems to be of the unstable ever-sporting type as shown in the wide variety of leaf forms illustrated, ranging from the simple once-pinnate type of figure 7, through all intergradations of division to the most extreme form of the variety. Presumably the runner progeny of these reverting plants should include new plants typical of the extreme parent form, together with others showing reduced development of the division and creting characters, as well as still others of continued unstable proclivities. So far it appears that with the loss of the dense character in the reverted leaves, although evidence of the combination of creting with reduced division is apparent (plate 1, figures 4 to 6, 9, 10) the ability of the leaves to reproduce viviparously is lost.

Speculation as to the significance of the appearance of viviparity as a character new to the genus and probably present only in one rare species² in the whole fern tribe Davalliae in which *Nephrolepis* belongs, opens up a wide range of interesting possibilities. Dichotomy of leaf has been recognized as probably primitive for ferns, especially on the basis of the

² *Dennstaedtia cicutarioides* (Feé) Hieronymus; FEÉ, Mem. Foug. 11: 95. pl. 25. fig. 2. I am indebted to Mr. W. R. MAXON for this fact and reference.

theory of fern leaf origin from a dichotomously branching thallus frond (homologous alternation of generations). In such a case as the present, assuming as a working hypothesis that the free-forking leaf type is primitive, it is plausible to suppose that other primitive characters might be associated with this, and vivipary, or regeneration, as a result of reduced differentiation of leaf tissue would be explainable on this basis. That dichotomy of leaf division may be considered a primitive character is also indicated by the ontogeny of fern leaves in general. It is a commonplace of fern leaf development that the early leaves, even of species with strongly marked axial venation, are usually forked, or with forking venation (BENEDICT 1911).

The genus *Nephrolepis* offers a fertile field to the student of the organ morphology and vascular morphology of ferns. The normal pairing of leaf and stolon, the fact that these lateral branches are the root-producing organs for the main stem, and the teratological phenomenon, referred to in a previous paper (BENEDICT 1922) in which a stolon by an apparently equal forking may give rise to successive single leaves without associated cauline meristem, deserve further study. The fact that this peculiar behavior is not infrequent in some varieties makes it easy to secure material.

PARALLEL VARIATION SHOWN IN REVERSION AND CRESTING

By parallel variation is here meant the development of similar types of variation from distinct but related forms. The term, parallel variation, may be applied either to the apparently similar changes or mutations, as processes, or to the similar varieties obtained as products of the variations.

Reference has already been made to the fact that these *Nephrolepis* sports behave as if they were produced by the repetition and progressive intensification of only a few types of leaf differences, each of which seems to act as if it were in the nature of a unit difference, presumably based on some specific cytological modification. Reasons for believing that the several characters in which *elegantissima-compacta* diverges from *Piersoni*, its parent form, are to be considered as caused by unit modification of perhaps definite quantitative character, have been advanced in the two papers already cited (BENEDICT 1916, 1922). In particular, evidence for this belief is to be found in the behavior of this variety in its regressive

saltations. As has been described, from *elegantissima-compacta* there have been derived bud sports of several sorts showing various degrees of return toward the characters of *Piersoni* and *bostoniensis*. These regressive forms may be reviewed as follows:

"*Dwarf Boston*," (plate 2, figure 9) a commercial form introduced by F. R. PIERSON, is once-pinnate, semi-dwarf, with the pinnae somewhat revolute, and may be considered as regressive in respect to the division character of *elegantissima-compacta* while retaining the dwarfed condition of that variety, showing that the combination of these two characteristics in the original progressive saltation are separable.

Wanamakeri, (plate 2, figure 10) a commercial form introduced by R. A. CRAIG of Philadelphia, is dwarf like "Dwarf Boston," but shows less complete retrogression in the division character, as its leaves vary from once-pinnate to twice-pinnate, and the pinnae are always considerably ruffled. It is this latter fact that suggests that *elegantissima-compacta* in its original saltation from *Piersoni* may have involved the unit difference of ruffling combined with increased division and dwarfing. Such a combination would be rather difficult to identify on merely vegetative examination, but there is evidence for it in the dense and plummy character of the typical leaves of *elegantissima-compacta*, and also in the behavior of various sports in other lines.

In any case, the ruffling as well as the partial double division of *Wanamakeri* have been lost in a further reversion from *Wanamakeri* which has resulted in a once-pinnate form, like "Dwarf Boston" though probably somewhat taller (plate 2, figure 12). This form was detected by TREVILLIAN but has received no distinctive name. Such reversion of the division character of *elegantissima-compacta* by two successive steps is additional evidence that its twice-pinnate, pinnatifid condition, originally reached through two progressive steps (see chart in figure 4), may be considered to be based on two distinct factors. Further evidence is furnished by the fact that from *Wanamakeri* there has arisen another reversion, resulting in a form much like the original *Piersoni*; i.e., it represents regressive variation in the size factor of *Wanamakeri* and *elegantissima-compacta* without affecting the division character (plate 2, figure 13). A similar revert has appeared directly from *elegantissima-compacta* (plate 2, figure 11) tall and twice-pinnate, but distinguishable from *Piersoni* and the *Piersoni*-like sport of *Wanamakeri* by minor characters of cutting and shape of segments.

In other words, as indicated by these forms and the others described above, modifications in size and division of leaves may occur progressively in separate saltations as more commonly among the described forms (BENEDICT 1916, 1922), or they may appear in combination, united to produce a single new variety as in *elegantissima-compacta*. Likewise in regressive variation, bud sports have occurred in which the two distinct modifications of the *elegantissima-compacta* division were reversed either in a single backward saltation or in two separate steps, and similarly, the dwarfing character has been shown to be lost separately or associated with a reversion in division.

The reversions of another *Piersoni* sport, *superbissima*, furnish even clearer evidence of the separableness of the division and dwarfing characters, largely because *superbissima* offers only a single difference from its parent type, that of dwarfing. The behavior of these reversions has already been set forth (BENEDICT 1922, plate 8, figures 4 to 7) but may be briefly reviewed in chart form.

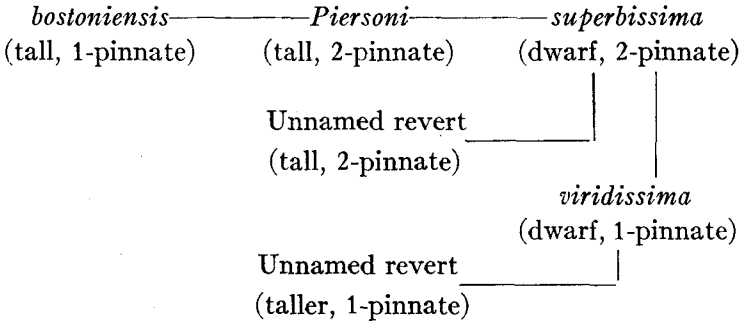


FIGURE 3.—Chart showing reversion of *superbissima*.

The unnamed tall, twice-pinnate reversion is very close in characteristics to regular *Piersoni*, and represents merely a reversion in size from *superbissima*. *Viridissima* leaves are identical with the once-pinnate leaves which occur frequently on *superbissima*; that is, only the division character has been lost. The taller once-pinnate unnamed reversion is intermediate in height between *viridissima* and *bostoniensis*. BLAKESLEE'S intermediate *Portulaca* (BLAKESLEE 1920) dwarfs which proved to be heterozygous for dwarfing and normal size are recalled, but unfortunately these Boston-fern sports are all sterile and unsusceptible of similar genetic analysis.

PROGRESSIVE PARALLEL VARIATION BY CRESTING

Further evidence of parallel variation and of the unit character of these bud sports is supplied by the crested sports of three sequential forms, respectively, *bostoniensis*, *Piersoni* and *elegantissima-compacta*. Crested *elegantissima-compacta* has already been sufficiently described. An earlier example of creusting was furnished by the comparable *Piersoni* sport, *splendida* (plate 2, figure 5). The comments already made as to the variability of the pinnae of *elegantissima-compacta cristata* on a single leaf, apply equally to the leaves of *splendida*, except that the maximum of division is less, only twice-pinnate, and the leaves are longer. Seasonal fluctuation in division will at times show most of the leaves almost entirely once-pinnate and crested, but I have seen no stable plants of this type.

The original Boston fern has also its crested variety, in the variety "Gretna" (plate 2, figure 4) as charted in recent papers (BENEDICT 1922 b). The testimony of the florist who originally introduced this fern (B. M. WICHERS, Gretna, Louisiana) makes it necessary to question the absolute certainty of the relation of this particular crested once-pinnate form to *bostoniensis*, but in its appearance and growth habits (BENEDICT 1921) it is exactly the sort of plant to be expected with this combination of characters, and so may properly be considered in this connection.

Here, then, are three parallel manifestations of creusting affecting three successive related forms, and producing in the resultant new varieties the same type of differences from the parental varieties. Is it not probable that such creusting is caused by some similar cytological modifications in each case; that creusting is a unit character?

Two other variations of interest in this connection remain to be noted. From *splendida* there has come a new bud sport apparently progressive in creusting to a further degree, the variety *Baeri* (plate 2, figure 6) introduced by JOHN LEWIS CHILDS in 1922 and named after CHARLES BAER, the superintendent of the CHILDS Floral Park establishment. So far as I have observed this is the only case in *Nephrolepis* in which creusting has been intensified by a definite new saltation, although such intensification is the rule for the characters of division, dwarfing and ruffling (BENEDICT 1916). Such intensified creusting is, however, not infrequent in other fern genera, as shown by numerous horticultural varieties of hart's-tongue (*Phyllitis*), lady-fern (*Athyrium filix-femina*) and others cultivated widely

in England. These English types indicate that even a third intensification of creusting may be expected.

As manifested in *Baeri*, the increase in creusting is accompanied by a shortening of the leaf, not necessarily, however, representing dwarfing, since the increased dichotomy of the tip gives an increase in leaf tissue compensating for the decrease in length. The twice-pinnate condition of *splendida* and *Piersoni* appears less frequently so far as observed, and in forming the fan-like tasseled leaf tips,—the new form has been called the “fan fern,”—the midrib is thickened almost to the point of fasciation.

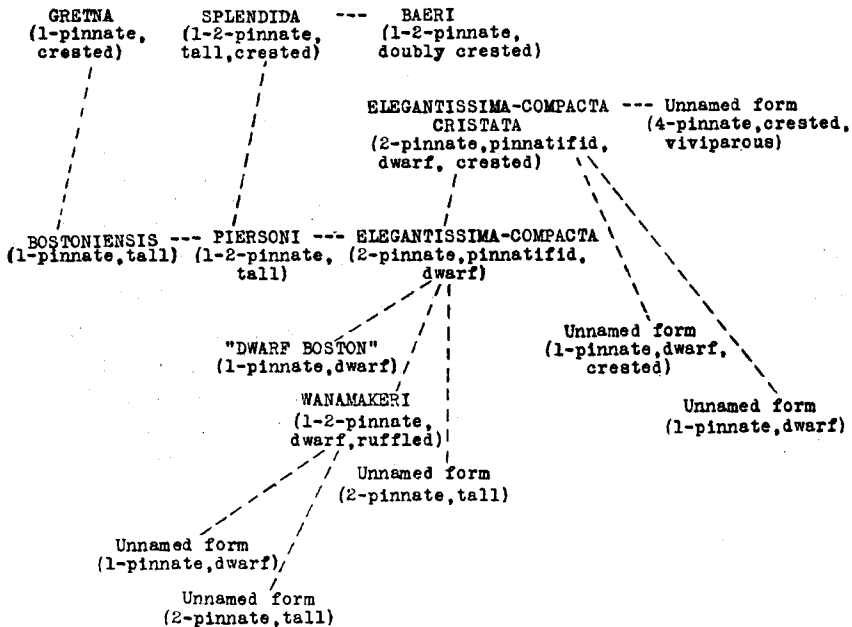


FIGURE 4.—Chart showing the genealogy of the Boston-fern varieties discussed and illustrated in the present paper. Reading from *bostoniensis*, the forms named to the right and above are progressive sports; those below are regressive forms.

Returning to *elegantissima-compacta cristata*, besides the fluctuating reversion of individual leaves, distinct regressive mutations with the loss of both the division character and the creusting character have been detected by TREVILLIAN. One such fern is shown in plate 2, figure 14, by a once-pinnate leaf with crested pinnae and leaf tips. A further reversion, not illustrated, has resulted through the loss of creusting in a simply once-

pinnate dwarf type, like "Dwarf Boston." This type is of particular interest here as showing that the unit character, crestring, may be lost by saltation as well as gained. Similar evidence is at hand in another Boston-fern variety not in the *elegantissima-compacta* series.

To summarize the relationships and characteristics of all the varieties discussed in the preceding pages, a genealogical chart (text-figure 4) is presented, arranged to indicate the parallel variations. Similarly, in one of the illustrations (plate 1) the same chart is reproduced in the form of portions of the leaves of the various types discussed. A collection of all these varieties is maintained at the BROOKLYN BOTANIC GARDEN where excellent facilities for the prosecution of this work have been enjoyed since early in 1915. The investigation has also been partly aided by visits to the establishments of florists growing *Nephrolepis* varieties, the visits being supported by a third grant of money by the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, made at the Toronto meeting, December, 1921.

GENERAL CONSIDERATIONS

Several questions of general interest are suggested in relation to these vegetative variations of *Nephrolepis*, particularly with the recent symposia at the Toronto meeting of the AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE in mind.

1. Are these bud sports of the Boston fern properly to be designated as mutations? EMERSON (1922) raises the point that only such variations should be called mutations as may be shown on genetic analysis to be due to gene changes. As ordinarily applied and originally by DE VRIES, mutations are distinct, true-breeding new forms, produced by germinal changes of autogenous origin, variations due to segregation after hybridization being excluded. Under this conception, the *Datura* variants of BLAKESLEE (1922) associated with the shuffling and duplication of the chromosomes, the *gigas* forms due to doubled chromosomes, the variants in *Drosophila* due to loss or non-disjunction of the chromosomes, would be true mutations, though not in the restricted sense.

Since the word mutation has become fairly common in non-scientific literature, and since, historically, it has been used with several different meanings, it will probably be difficult to bring about a restriction in its meaning, no matter how desirable. If, however, a restriction is to be

accomplished, the proponents will need to supply some acceptable substitute to be used for those variations not clearly due to gene mutation. There are really needed three distinct categories of variation, besides fluctuations; viz., variations proved to be due to gene changes; variations due to redistribution, doubling, loss, etc., of chromosomes; and finally, variations of undetermined identity, such as these bud variations of *Nephrolepis* and of many other plants and animals. For the latter class, the old word saltation seems appropriate and has been so used in this paper.

2. Are these *Nephrolepis* variations illustrations of orthogenesis? Is the parallel variation exhibited by the forms discussed in the preceding pages an example of "definitely directed evolution?"

The papers presented at the recent symposium on orthogenesis at Toronto (GUYER, HENDERSON, LIPMAN, and OSBORN 1922) show such diversity of understanding and definition of the term that its value as connoting a specific type of variation seems open to doubt. Three distinct and divergent points of view appear to be represented in the four discussions. However, no general summary of the meaning of orthogenesis is needed here. A reference to KELLOGG'S comprehensive discussion (1908, pp. 274-326) will obviate the need of further general consideration.

The principal bearing which these fern sports have in relation to orthogenesis lies in the fact that they present evidence, comprised in a series of over one hundred living forms, well differentiated saltations, all of which have arisen within twenty-five years. In other words, the process through which they have arisen is recent, is still continuing, and the connected relationship of these varieties is beyond doubt. The evidence of orthogenesis which they offer seems to agree in all essentials with similar evidence based on comparative studies of collateral species such as EIMER'S butterflies, GUYER'S pheasants, RUTHVEN'S snakes, etc., (GUYER 1922 a, b) as well as on connected series of palaeontological forms (GRABAU 1907).

It may be noted that the actual cause of the variation resulting in these new forms seems at present undiscoverable. The original Boston fern, the parent form, is of somewhat uncertain origin, but there is little chance that it may have been a hybrid. Through its vegetative variations, it has given rise to forms of wide diversity of character, surpassing generic limits as ordinarily understood, but not suggesting any particular hybrid

origin. Through the sporeling forms of the only known fertile strain, to be described in detail later, it shows variation, but not in a way which suggests the segregation of the characteristics of any of the wild forms of *Nephrolepis*.

Whatever the cause originally responsible for the variability of the whole series, there is no present evidence that specific saltations are influenced by environmental conditions. The new types arise independently of adaptation; some of them are hard to grow. It may be pointed out particularly that all the variation types, dwarfing, reversion, ruffling, etc., arise under similar cultural conditions. Possibly HENDERSON'S (1922) conclusion has application:

“Therefore, with due reservations because of incompleteness of biochemical knowledge, it seems reasonable to suppose that apparent instances of orthogenesis may sometimes depend upon a single important chemical change in an organism, followed by slow and progressive modifications, leading up to a definitive morphological result.”

Assuming the origin of the Boston fern as possibly due to a single chemical change in some sword-fern plant, the recurrence of the numerous varieties along a few types of variation may represent the “progressive modifications” HENDERSON suggests. Certainly it cannot be said of these ferns: “No chances or experiments are tried by Nature. The process [orthogenesis] is continuous, adaptive, mechanically perfect . . . ” (OSBORN 1922).

The idea that variations must be adaptive falls to the ground when one considers the multitude of species, some occurring so rarely as to exist in a few counted individuals, and so hard of artificial culture that even the best care does not suffice to maintain them in cultivation. The fact that these Boston-fern saltations are often less well adapted for the struggle for existence than their parent form scarcely argues against accepting them as of evolutionary significance. Such differences in adaptability are common among wild forms. Not every species possesses a maximum of successful growth characteristics else every species would be a weed.

As the matter stands at present, the term orthogenesis is purely descriptive of products, i.e., series of new forms resulting from variation, and indicates that such variations are recurrent. In point of clearness, the words *recurrent* and *progressive* seem to carry all the meaning that may be justifiably assigned to the more imposing word “orthogenetic.”

3. Have these bud sports any significance in relation to the possible mode of origin of new species of ferns? Some consideration has already been given this question in connection with the discussion of their bearing on orthogenesis. It is suggested obviously because of the fact that the characters by which wild fern species are regularly differentiated are paralleled in so many particulars by these bud sports of so few year's standing. Fern species and fern genera are ordinarily established, taxonomically speaking, on differences in growth habits, and leaf cutting; they differ in the shape, conformation, margins of the leaves, and in the position of the pinnae. Of course associated with such differences among wild species there are usually other distinguishing characters, important though often minute, such as variations in the epidermal covering,—scales, hairs, indusia,—differently shaped spores, different positions for the sori, and others. It has not yet been possible to subject these horticultural forms to sufficiently intensive examination to determine whether they also vary with respect to the more critical characteristics above mentioned, but the discovery of the new bud sport with viviparous leaves would seem to indicate that these vegetative types may show quite as extreme types of variations as do wild forms. Moreover, both among these vegetative variations and among the sporeling forms to be described in a later paper are included not a few forms so distinct that their recognition as "new species" if sent in by some collector is scarcely a matter of doubt.

From the standpoint of taxonomy, further, these Boston-fern sports present so confused a tangle of forms that, as a problem to be solved from the study of herbarium material, it would be impossible of complete solution. Forms derived from entirely different parent types not infrequently approximate the same characteristics, and in some cases are difficult to separate even in living condition. As dessicated herbarium material, perhaps collected at different seasons of the year and dried under different circumstances, even their original differences would be lost or confused, but, in this respect, this group is probably no different from many complexes of wild forms, already the bases of different interpretations by systematic botanists. For example, the species of *Nephrolepis* themselves present a most confusing series of forms, all once-pinnate, some reported as pan-tropic, but varying throughout their range in such a way that their differentiation is a matter of extreme difficulty. Every genus, of more than a few species, includes complexes of forms offering

similar difficulties of differentiation. If we may conceive as possible that among wild forms there may exist not infrequently groups of forms in a state of variability like that exhibited by these *Nephrolepis* forms, the difficulties of taxonomy are not rendered any easier. With hybridization as an added confusing factor, the entailed difficulty is almost beyond solution.

With respect to the creasing and ruffling types of variation, it may be noted that these characteristics do not appear to have much weight in the origin of wild forms. Such differences are ordinarily made the basis for taxonomic "form" distinction. Only a few species are separated in which the forking of the leaves is an important difference. It seems probable that the reason for this lies in two facts: first, these characters seem to occur without any associated differences, i.e., as unit differences, while difference in pinnation and in size are almost always accompanied by other characteristics. This is interestingly borne out by EMERSON'S (1921) observation relating to a crinkly-leaved variety of maize: "The leaves of crinkly are not only crinkly but often have prominent lobes at or near the base of the blades." This statement would apply exactly to the ruffled-leaved forms of Boston fern if the word "ruffled" or "crispate" be substituted for "crinkly." Second, mere increase in the vegetative tissue of the leaf as gained by ruffling and creasing would not carry with it any associated advantage and might have some disadvantages. For example, ruffling and creasing furnish folds of leaf tissue from part of which the light would be shut off, and in which water would be retained, the latter a factor in fungus infection.

No attempt to make a comprehensive comparison of these *Nephrolepis* bud variations with similar vegetative sports in other genera will be attempted here. It may be noted, however, that in general they appear to correspond in type, differing mainly in the fact that they show progressive series of as many as five steps in intensification of a single character. The spore sports of ferns in general both cultivated and wild, seem to follow exactly the same lines of variation as are represented by bud sports. A similar observation has frequently been made with respect to the seed and bud sports of flowering plants. Furthermore it may be noted that among flowering plants are to be found variations which appear like those affecting fern leaves, size of plant, etc.,—a condition of ruffling seems to be shown in *Malva crispa*, and in the "curly" varieties of lettuce.

A survey of a considerable number of bud sports in seed plants has recently been given (SHAMEL 1921) comprising variations in size of plant, leaf division, leaf margins, variegation, and others.

SUMMARY

The principal points brought out in the preceding pages may be summarized as follows:

1. New bud sports are to be recognized, viz.,

(a) A new crested, four-pinnate form, the first reported example in which crestring is found combined with lace division. With this combination of characters is associated also vivipary of the leaves, a character new for *Nephrolepis*.

(b) Another new form *Baeri*, presents what appears to be an intensification of crestring, also the first case to be reported in *Nephrolepis*, although known in other fern genera.

2. Regressive variations from *elegantissima-compacta* indicate that it represented originally a sport in three distinct characteristics from its parent form, *Piersoni*, viz., dwarfing, increased division, and ruffling. In the regressive sports, these characteristics are lost separately, producing new forms intermediate between *elegantissima-compacta* and *Piersoni*.

3. Parallel variation in a progressive direction is shown in the crested sports of three sequential sports, *bostoniensis*, *Piersoni*, and *elegantissima-compacta*. Cresting is indicated as a unit difference since the three new forms differ from their parent types only in crestring.

4. Orthogenesis as presented by these fern varieties seems to correspond with reported orthogenetic series of living and fossil species, but is significant as derived within twenty-five years of variation and as represented in all its steps by living plants. The word "orthogenesis" as illustrated by these forms means merely "recurrent" or "progressive" or both.

5. A more accurate classification and terminology for the different types of variation is desirable. At least three categories represented by saltatory variation are to be distinguished: "mutation," for variations due to gene modification; "saltation" for discontinuous variations of undetermined identity; and a third term is needed for variations due to changes in chromosome number.

6. No evidence as to the origin or cause of these variations is available. Apparently all classes occur under similar cultural conditions.

7. Bud variation in *Nephrolepis* parallels spore variation in this and other fern genera, and probably also in seed plants. Accepting these Boston-fern sports as presenting a complex of forms analogous to groups of wild forms, it appears that such wild groups are scarcely susceptible of accurate analysis on ordinary field and herbarium methods.

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