STUDIES IN THE SOUTH INDIAN CHILLIES

I. A Description of the Varieties, Chromosome Numbers and the Cytology of some X-rayed Derivatives in *Capsicum annuum* Linn.

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I. Introduction

The cultivation of the genus *Capsicum* is more or less widespread in South India. Its home is said to be South America, growing wild on the banks of the Amazon and in Eastern Peru. Its exotic nature could be gathered not

only by its not being mentioned in ancient Sanskrit literature but also by the fact that for religious Hindu rituals, *Capsicum* is not used for culinary purposes.

The earlier workers like Roxburgh (1832) recognised a large number of species of Indian Chillies. But Irish (1898) reduced the number of species to two—*Capsicum annuum* Linn. and *Capsicum frutescens* Linn. These are divided into a number of varieties. The species of Roxburgh, like *C. purpureum*, *C. grossum*, etc., and those of earlier writers, come under *C. annuum* as varieties.

Not much work seems to have been done on the Indian Chillies. Shaw and Abdur Rahman Khan (1928) studied 52 types of Indian Chillies. Of these the bulk belonged to Northern India, only a few were South Indian varieties. Dixit (1933) described mitosis in *Capsicum*. He has, however, paid no attention to the morphology of the chromosomes.

Shaw and Khan recognised only two types of *C. frutescens*, whilet he rest were varieties of *C. annuum*. In the present study, an attempt has been made to collect the various types of South Indian Chillies. By the kindness of the Director of Agriculture, Madras, seeds from various parts of the Presidency were got, and grown in the University Botanic Gardens; a few were got from Pochas, Poona.

In the classification of the South Indian varieties, only such characters have been employed as have already been utilized and wherever possible these varieties have been assigned to type forms already described by Shaw and Rahman Khan. This is adopted with a view to avoid multiplication of types. And varieties not coming within those already described are specified by their localities. Also very minor characters have not been employed as this would also lead to a multiplication of the types. Table I gives an account of the data collected from the various localities, in respect of the time of sowing, transplantation and the first and last pickings.

TABLE I

Varieties	Sowing	Transplanting	1st picking	Last picking
1. Chodavaram	August	October	January	April
2. Erode	June	August	November	March
3. Chandragiri ..	January	March	..	..
4. Cheparupalli	July September	August December	December	March
5. Tiruttani	January	..	..	..
6. Nandyal	July	August	November	
7. Allagadda	July	..	..	..
8. Madura	August	September	December	March
9. Paramakkudy	September	..	..	April
10. Sattur	August	..	December	March
11. Periyakulam	February	March	..	..
12. Musiri	August	October	January	April
13. Kulittalai	August	October	January	April
14. Tanjore	August	September	..	February
15. Atmakur	September	October	January	April
16. Kandukur	August	..	January	April
17. Kaveli	November	December	March	April
18. Nellore	October	November	March	..
19. Gudiyattam	December	Feburary	May	July
20. Walajah	June	August	..	..

III. Short Description of Some Types of South Indian Capsicum

All the varieties belong to *Capsicum annuum* (flowers solitary). In all the varieties the flowers are white.

Kadiri 1. Plants are 1½ to 2 feet high; not bushy. Fruits are thin and long (3 to 3½″), pendent, red wrinkled; calyx embracing the base of the fruit; similar to type 44 of Shaw and Rahman Khan.

Thiruvannamalai, Guntur 398 and *Bellary* varieties are like the above.

Kadiri 2. Plants slightly bigger; fruits medium sized 2 to 2½″ long, conical, red pendent, smooth surface; calyx embracing; similar to type 36.

Cheparupalli varietiy is similar to above.

Gudyattam like Kadiri 2 but fruits shorter; about 1″ long.

Nandyal like Gudyattam.

Perambalur 2 like Gudiyattam.

Paramakkudy plants about 2 feet; fruits globular large, red smooth surface; calyx not embracing.

Cape medium 2 like Paramakkudy but the fruits are orange coloured.

Pithapuram. Plants 2 feet high; fruits are long (3 to 3½″), smooth orange coloured, circular in transverse section; calyx not embracing; similar to type 13.

Sunnybrook. Leaves bigger than the rest as also the flowers. Fruits large, globular, angular in cross-section, corrugated base, pendent.

Californian Wonder. Similar to above but with erect fruits.

Atmakur. Small, globular, circular in cross-section, pendent, orange colour; calyx not embracing.

Kulittalai 2 and *Kandukkur* are similar to above, but the fruits red.

Chodavaram. Similar to above.

Sattur. Plants about 4 feet high; leaves light yellow; fruit 1½ to 2″ long, red not wrinkled; calyx embracing; like type 38.

Thiruthony and *Thirumangalam* are similar to Sattur.

Local (Chidambaram). Plants about 2 feet high; fruit 1½ to 2″ long, red, pendent; calyx not embracing.

Kaveli, Kulittalai 1, *Cape* 1 and *Puthoor* are similar to the local variety.

Tanjore. Fruits are globular, large, completely corrugated, pendent red and calyx not embracing.

Travancore. Fruits short about an inch long, somewhat blunt, red; calyx not embracing.

Musiri and *Walajah* 1 are similar to Travancore.

Guntur 380. Fruits short, pendent about an inch long, orange coloured and calyx embracing.

Nellore. Fruits about 2″ long, orange and calyx embracing.

Perambalur 1. Fruits long, 2 to 2½″, red, acute tip; calyx embracing.

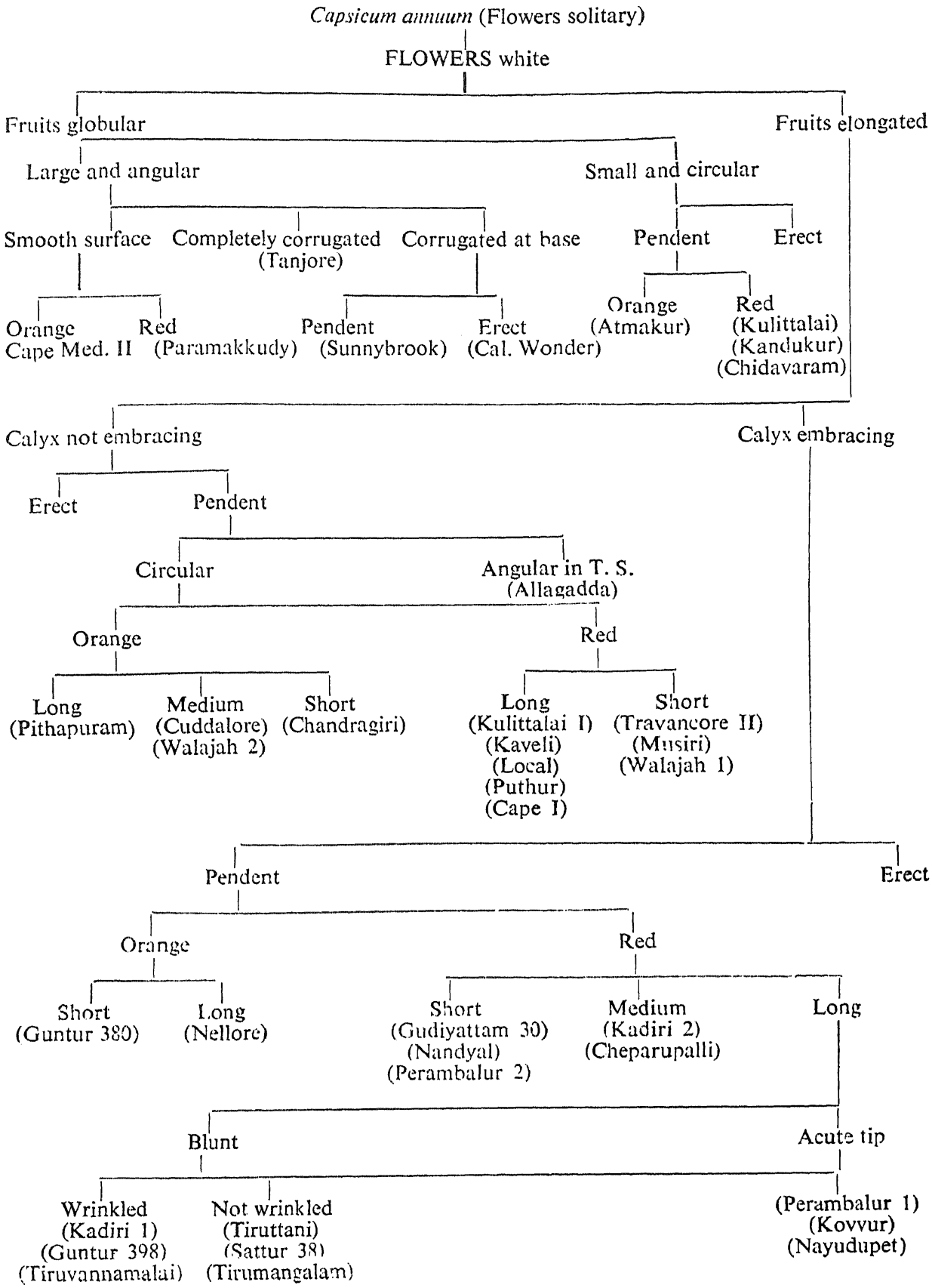
Kovoor and *Nayadupet* varieties are just like Perambalur 1.

Chandragiri. Short conical about an inch, pendent, orange and calyx not embracing.

Allagadda. Long, 2 to 2½″, wrinkled, angular and calyx not embracing.

Cuddalore. Fruits medium-sized, 1 to 1½″ long, orange; calyx not embracing. *Walajah* 2 *is similar* to above.

IV. Classification of the Varieties



V. X-ray Treatment and Origin of Material

Seeds of a pure line of Paramakkudi were exposed to X-rays. They were treated in a dry state and the treatment consisted of unscreened exposure under a water-cooled Coolidge tube in the copper anticathode operated at 53 *kv* and a tube current of a 10 m. A., at a target distance of 17 cms. for one hour. We are indebted to Capt. T. W. Barnard for this.

Several types of mutations affecting size of plant, branching, chlorophyll content of leaves, size of leaves, nature of fruit—pendent or erect—, size of the fruit were noticed in the X–1 generation. Of these six have been isolated for further study. They are shown in the accompanying photographs. They are *Pa* X–1 "*large-leaved giant*" which is twice the size of the normal plant, bushy and leaves very large (7″ × 4″). Fruit pendent and normal (Pl. I, Fig. 4).

Pa X–2 "*narrow-leaved giant*". Similar to *Pa* X–1 but the leaves are very narrow. Fruit pendent and normal (P. I, Fig. 4).

Pa X–3 "*lean erect*" plants are very lean about 20 inches high and a spread of 9″. There is a conspicuous absence of branches from the base. The fruits are erect, of normal size rounded and arising singly (Pl. I, Fig. 3).

Pa X–4 "*bushy erect*". The plant was nearly 2 feet high and a foot across; branching profuse from the base. Fruits erect (Pl. 1, Fig. 1).

Pa X–5 "*nigroides*". Short spreading, dark green leaves like those of *Solanum nigrum* (Pl. I, Fig. 5).

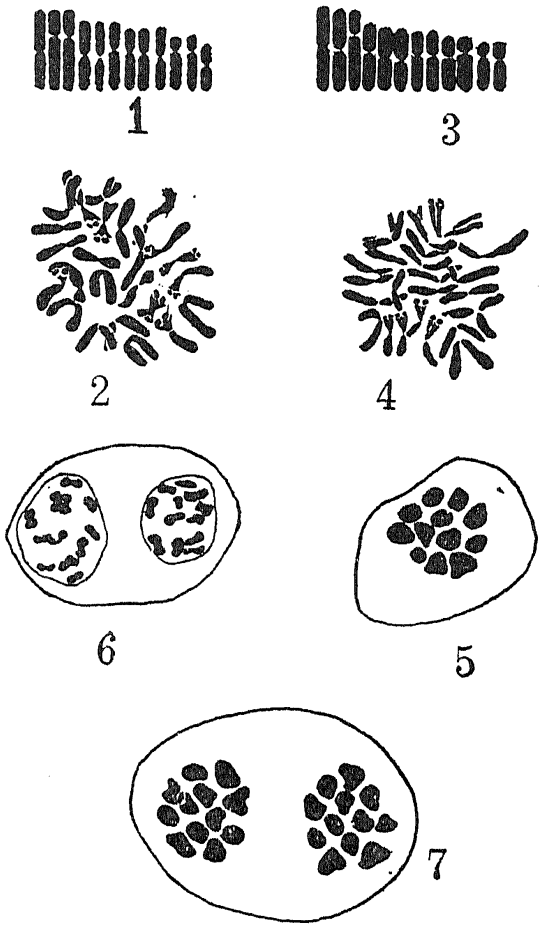
Pa X–6 "*dwarf*". Short, no branches at the base (Pl. I, Fig. 2).

The bulk of the cytological data herein presented relate to those of a 'semi-sterile mutant of the X–2 generation' and of a normal looking plant of the X–1 generation.

Anthers were fixed in Navashin after acetocarmine examination and sections were made in the usual way using Genetian violet as the stain.

VI. Observations

(*a*) *Somatic Chromosomes.*—The somatic chromosome number in all the varieites, is 24. The complement in two such widely different varieties as Paramakkudi and "Sunnybrook" are analysed and it will be seen that the range of size is small in both cases (Text-Figs. 1–4). The cetromeres are of the median and sub-median type. There are three pairs of long chromosomes in both. In Paramakkudi one of these has median constriction while in "Sunnybrook" two have it. In the other chromosomes there is slight

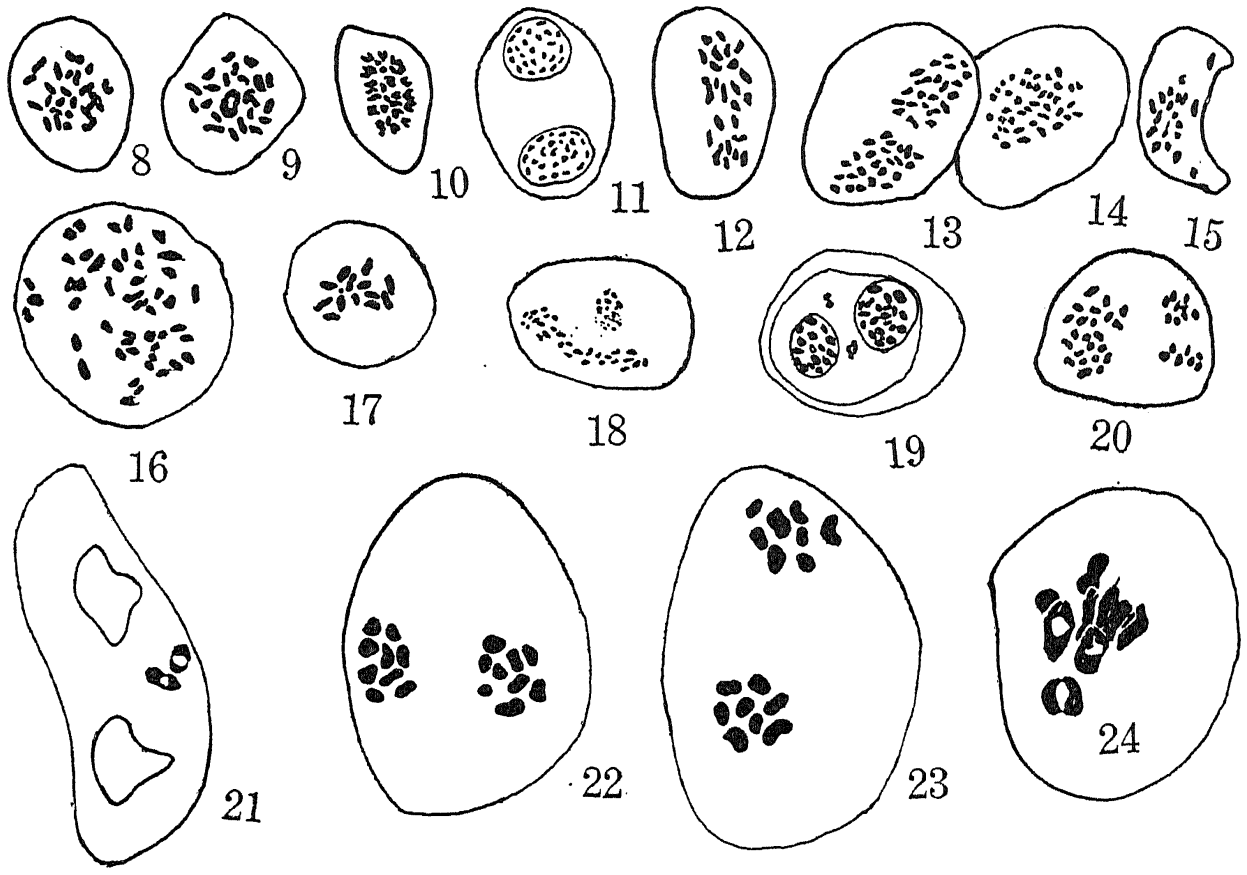


variation in the position of the centromere. It is obvious that change in chromosome number has not played any part in the form of the varieites, however different they are, and one has to look to structural changes rather than number of even morphology of chromosomes.

Meiosis of the un-X-rayed plant is normal and this was found to be true in half a dozen varieties. Fig. 5 shows M I with 12 bivalents and Fig. 7 shows M II plate with 12/12 arrangement. Pollen is formed in the normal manner. Fig. 6 shows interphase nuclei with 12 univalents in each.

(*b*) *Asynapsis.*—This was very common in a semi-sterile mutant of the X–2 generation. In many cases, the full diploid number of chromosomes is seen at diakinesis (Fig. 8). This could arise from a restitution nucleus formed at first division including all the 24 chromosomes. This, however, is improbable because, restitution nuclei are usually irregular in shape and do not generally include all the chromosomes. This appears to be a case of complete failure of pairing. This asynapsis has been frequently recorded as a result of X-rayed mutation. Goodspeed (1929) has described a first metaphase with 48 univalents in place of 24 bivalents. In Fig. 9, there is a tendency for bivalent formation, there being a single ring bivalent and the rest are univalents.

The occurrence of full diploid number of univalents without any pairing whatsoever, is common in interspecific hybrids. In *Narcissus*, Nagao (1933) found no pairing of parental chromosomes at all. Partial or absence of pairing in hybrids is regarded as indicating distant relationship of parental species. The chromosomes of the parental species are considered to be structurally dissimilar and therefore incapable of pairing at meiosis. Though this general principle was found to be true in *Nicotiana* (Goodspeed, 1934), *Crepis* (Babcock and Emsweller, 1936), etc., there are a number of other cases where this is not revealed. Crew and Koller (1935) consider this abnormality along with others to be genotypic rather than structural. Sapehin (1933) opines that if the genotype is kept constant other changes like the change of environment may induce failure of conjugation of chromosomes



as the response of a particular genotype to the new condition. To this category according to him must belong the abnormalities in meoisis induced by external agencies like temperature X-rays, etc. In *Capsicum* there is evidence of structural changes, however slight, having been induced by X-rays. The not infrequent occurrence of chromosome rings of four, is a sure indication of this. Asynapsis has been recorded in a number of other plants in some of which it has been traced to the presence of recessive genes. Since this paper

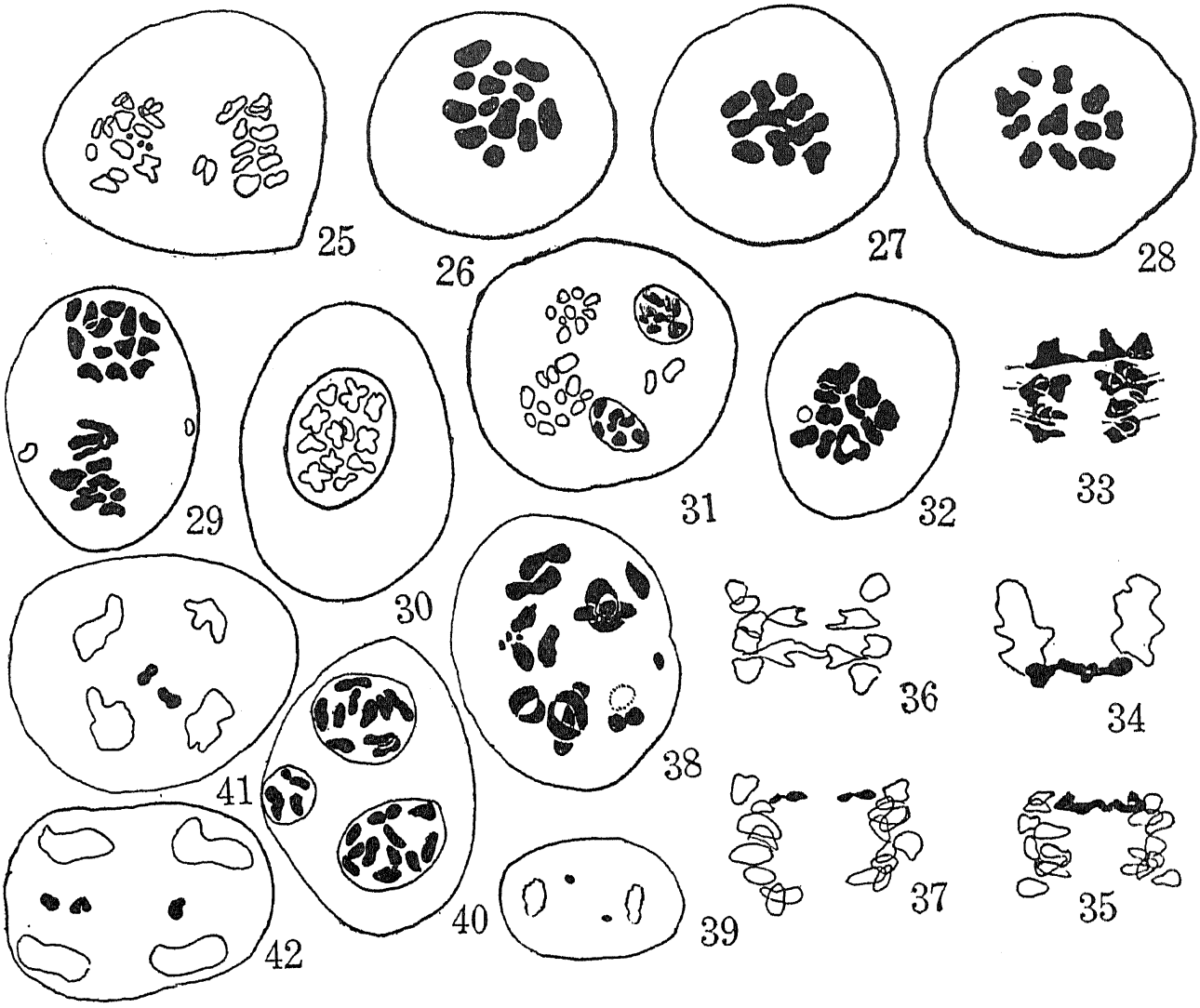
was being prepared for the press we have seen a note by Pal and Ramanujam (1940) describing the occurrence of asynaptic chilly in a natural population.

The behaviour of the unpaired univalents is varied. Sometimes no further division takes place and a membrane is organised and presumably a monad with 2 *n* chromosome is formed (Fig. 10). Frequently, these univalents assort themselves at random (Fig. 12) and nuclei with irregular chromosome numbers are found. Fig. 46 is a cell with such irregularly formed nuclei. Sometimes a cross-wall is formed separating these and the nuclei of different sizes are seen in the two cells (Fig. 48). Fig. 18 shows an earlier stage where these univalents are in a process of assortment into groups prior to organisation into irregular nuclei. Fig. 20 shows another type of irregularity. The prevailing method seems to be, however, for these univalents to undergo mitotic division. Fig. 16 shows nearly 48 bodies and these appear to have been derived by the splitting of each univalent prior to separation. There may be irregularities in this separation also. Fig. 19 shows two interphase nuclei organised in such a manner. There are a few univalents left out also. Occasionally, this equational division is regular (Fig. 11) and in Fig. 13 we see M II each plate having the diploid number. Though we have not seen stages later than this, it is presumed four diploid tetrads will be organised ultimately. Whether these pollen grains are viable cannot be said, but their origin would appear to be through double division. In normal sexually reproducing plants, this is rather rare. In apomictic forms, like *Hieracium* (Rosenbergh, 1927) equational splitting of all the chromosomes takes place in both the divisions, giving rise to diploid gametes. A few other cases are also known. Clausen (1926) found in *Viola* some of the univalents dividing twice. In Ribes (Meurman, 1928) found that in a few cells there was complete absence of synapsis and these univalents divided twice regularly to give gametes with diploid number of chromosomes. There were, however, no data to show that these were functional in producing polyploids.

There is extensive degeneration. Many assume a shrivelled up crescent-shaped form with univalents spread all through (Fig. 15).

(*c*) *Fusion of M II Plates.*—Fig. 14 shows a cell with 48 chromosomes. This could have arisen in either of two ways. If in a P.M.C. both the first and second divisions are interrupted, a nucleus containing a tetraploid number may be formed. This would be a restitution nucleus and it is not likely to have operated in the formation of the present cell. Firstly, such a nucleus would be of irregular shape and the size of the cell itself will be bigger. Moreover, in a restitution nucleus loss of a few chromosomes is

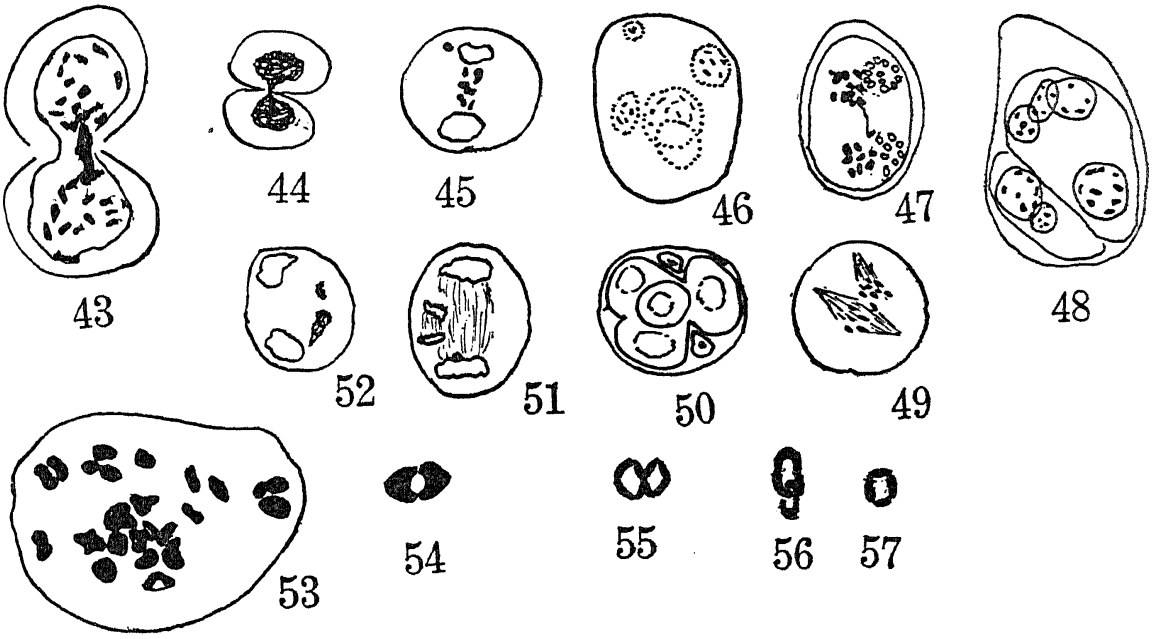
almost the rule and the fact that the entire 48 chromosomes are seen rules out the possibility of this cell having been formed in such a manner. The probability is that two M II plates each with the diploid number have fused and resulted in this tetraploid cell. Such fusions are reported to be very common in X-rayed *Nicotiana* (Goodspeed, 1929). In Fig. 53 the M II plates cannot be distinguished because of lack of proper orientation and the consequent even distribution of all the chromosomes.



(*d*) *Non-disjunction.*—The phenomenon of bivalents reaching the poles without disjunction was commonly met with (Figs. 21 and 24 and Pl. I, Figs. 7–9). In such cases, these bivalents reach the poles earlier, where they naturally increase the number of chromosomes in the poles they reach. In Pl. I, Fig. 7, a ring bivalent has already reached the pole. In Pl. I, Fig. 9, a bivalent is recognised in telophase. It is only by such a method that we can explain the occurrence of 13 univalents in some cases. Fig. 24 is that of M I where the bivalent is reaching the pole earlier. In some cases, however, it would appear that these bivalents are not included in the poles so that

they remain as bivalents till the end, having been cast into the surrounding cytoplasm and not taking part in the divisions. They become lost. Presumably because of such losses, we get very often M II plates showing numbers smaller than 12. Fig. 23 shows 8/8 and in Fig. 22 9/9. It is interesting that we get the same number in each plate of a particular cell. This confirms the assumption that three bivalents in the one case and four in the other have not taken part in the division. Hence the deficiency.

Rarely these extruded bivalents have separate spindles which are very much smaller than the normal ones. In Fig. 51 we see a cell in anaphase I showing two spindles, the smaller representing the spindle of the bivalents which were off the plate. We also find very often chromosomes spread out and orientated in all directions. In Fig. 49 we find tripolar spindles in the first division. The frequency with which these occur shows that the spindle is a compound structure as suggested by Gates (1932).



(*e*) *Interlocking.*—Occasionally at diakinesis the phenomenon of interlocking was observed (Fig. 56 and Pl. I, Fig. 14). The interlocking was either between two bivalents or between a ring of four and a bivalent. The interlocking is due to the peculiar distribution of threads at zygotene. When synapsis between two homologues is taking place, a third chromosome from another pair may come between the pairing threads and the formation of chiasmata on either side in the chromosome pairs will naturally result in the interlocking of bivalents in the succeeding diakinesis and metaphase. Interlocking has been reported to occur among others, in *Allium* (Levan, 1933).

(*f*) *Cytomixis.*—Frequently, cases of cytomixis have been met with and this at various stages of meiosis. Fig. 44 shows it at early prophase. Fig. 43

in diakinesis. This phenomenon was first described by Gates (1911) in *Oenothera*, where he observed the transference of chromatin between two adjacent cells, through gaps in the cell walls by means of protoplasmic connections. This phenomenon has since been reported in many plants. Kattermann (1933) gives a list of these works and describes cytomixis in P.M.C. of *Triticum* × *Secala* hybrids. Though in the present case, cytomixis is confined to the first division stages, cases are known where, this takes place in the second division also. Gates and Latter (1927) described such a behaviour in various stages of meiosis. It is not unlikely that in the present case where, cytomixis is frequent, the result is an increase in chromosome number. The cell with 48 chromosomes was interpreted to have arisen by the fusion of M II plates. Such cells may also arise by the passage of the whole of the nuclear contents from one mother-cell to another. Such a passage has been reported before and in rice Nandi (1936) found one case in which both the nuclear contents passed from one mother-cell to another and forming a binucleate P.M.C. at diakinesis.

(*g*) *Ring Formation.*—Though bivalent formation is more or less the rule, some cases were met with where rings were seen to be formed. Fig. 57 and Pl. I, Fig. 17 show a ring of four at diakinesis. Afify (1933) found in *Aconitum* rings forming very occasionally, the normal behaviour being regular bivalent formation. This shows that only small segments have interchanged. The association of four chromosomes in the semi-sterile plant which being a diploid, forms normally only bivalents, is due to interchange of segments between non-homologous chromosomes as first suggested by Belling (1925). In trisomic *Daturas*, Belling and Blakeslee (1926) found ring formation and inferred the occurrence of an interchange of segments between non-homologous chromosomes. This has since been used in interpreting ring formation in plants arising from hybridisation or irradiation and also in naturally occurring forms. Chromosome ring formation was first recorded by Gates (1908) in *Oenothera rubrinervis*. Parthasarathy (1938) found ring formation in the X–1 generation of X-rayed rice seeds and this was exhibited also by a semi-sterile plant as in the present case. Fig. 55 and Pl. I, Fig. 16 show orientation of this ring prior to anaphasic separation and it appears that disjunction will be of the AB, CD, and BC, DA type giving viable gametes. Random orientation also occurs disjoining on the AB, BC, and CD, DA basis. And this would give rise to inviable gametes due to deficiency of D and B segments.

(*h*) *Other Abnormalities.*—A variety of abnormal meiotic conditions other than those already described include chromosome fragmentation, and lagging chromosomes. Fig. 39 shows two chromosomes lagging in division I,

Figs. 41 and 42 show them at division II. Occasionally we find chromosomes lagging throughout the spindle (Fig. 45). Often in diakinesis, we get bodies less than 12 in number, due to formation of trivalents (Figs. 28 and 32 and Pl. I, Fig. 11). Consequently, a variable number of univalents also arise. In Fig. 26 and Pl. I, Fig. 13, we see 13 bodies, 11 bivalents and 2 univalents. There is also a marked tendency for these bodies to fuse (Fig. 27 and Pl. I, Fig. 15). The behaviour of the univalents is very irregular. Some are extruded; they either get lost or organise themselves into cells of their own (Fig. 40). On account of irregular divisions groups of univalents of varying numbers are formed and each group comes to be invested by a wall, and the result is a number of cells of different sizes are formed. Fig. 50 shows 6 such cells, while Fig. 31 shows them at earlier stages leading to the ultimate formation of these different-sized cells. Anaphasic separation of the chromosomes is abnormal. A proportion separate normally, while the remainder lag. Fragments are seen sometimes (Fig. 38). Fig. 17 is A I with 13 chromosomes and a fragment. The separating chromosomes are drawn out into threads (Figs. 34–36) and this is common in second division also (Fig. 47). The bulk of the chromatin reaches the poles but some remain in the plate and disintegrate. In Fig. 52 masses of disintegrating chromatin are seen. At interphase, the chromosomes show a marked split. In Fig. 30 we see one of the interphase nuclei. Most of the bridges (Figs. 33–37) that are seen seem to be the result of the stretching of the chromosomes, on account of incomplete treminilisation of the chiasmata especially of the trivalents which are formed as an abnormality. Separation takes place in some cases so violently that the torn ends can be seen clearly (Fig. 36). It seems that none of these bridges is to be regarded as inversion bridges. The second division is equally irregular. In Pl. I, Fig. 10 *a*, we recognise two univalents lying off the M II plates, while in Fig. 41 two univalents are lagging in second telophase. There is also indication of non-simultaneous division. In Fig. 25 two univalents are lagging and in one pole can be recognised three fragments. In Fig. 29 and Pl. I, Fig. 10 *a* which is a M II, two univalents are off the spindle. In one pole there are 13 chromosomes and the other 10. Obviously, the two bodies lying outside the spindle cannot be two univalents but the product of the division of a single univalent, which must have been cast out in division I. Laggings in second division are represented in Figs. 31, 41 and 42.

VII. General Considerations

Experiments on the application of radiation to plants have been carried out by numerous workers. Goodspeed (1929), Goodspeed and Avery (1930)

have described chromosome alteration induced by X-rays in *Nicotiana*, Katayama (1935) in wheat, Catechside (1935) in *Oenothera*. The cytological changes involved were found to be gene mutation, translocation, inversions and deficiencies and these were later confirmed by genetical results. Most of these induced mutations were useless from the economic point of view. The changes induced are so varied that the possibilities of obtaining desirable types are great, though it must be admitted that the results cannot be anticipated. In the present case, most of these gene mutations except inversion have been described and an interesting mutant with erect fruits has occurred. Normally pendant is dominant to erect. Further progenies of these erects are being studied. In the meantime it is interesting to record that a similar mutation has been obtained by Colchicine pretreatment of seeds, perhaps a case of parallelism in mutation.

There would appear to be ample scope of obtaining polyploids through X-ray treatment in Capsicum. Besides asynapsis, which has been previously recorded, Cytomixis which has been described in the present paper would appear to play an important part in the establishment of polyploids. The importance of polyploids in plants of economic importance like chilly, cannot be over-estimated. In the words of Blakeslee (1937)· · · ·" It is our belief that in the future extra chromosomes will be consciously utilized as a source of desirable variations in plants of economic importance. · · · · · To the geneticist who is specializing in any economic form and who desires to be most practical, our advice would be 'know your chromosomes'."

VIII. Summary

A number of varieties of South Indian Chillies have been described. They are all found to be varieties of *Capsicum annuum*. All have $2n = 24$. The somatic complement of two widely differing types have been analysed and it is suggested structural rather than numerical and morphological variations have played a part in the evolution of the various varieties. Meiosis is found to be regular. Seeds from a pure line of Paramakkudy were exposed to X-rays and mutants in X–1 and X–2 generations have been isolated. Meiosis in a semi-sterile mutant of the X–2 generation is described. It is found to exhibit asynapsis, cytomixis and chromosome ring formation. A number of other meiotic abnormalities are also described. The importance of X-ray treatment in the evolution of polyploid forms either through asynapsis or through cytomixis is indicated.

LITERATURE CITED

Afify, A. .. "Chromosome form and behaviour in diploid and triploid *Aconitum*," *Journ. Genet.*, 1933, **27**, 293.

Babcock, E. B., and Emsweller, S. L. "Meiosis in certain interspecific hybrids in *Crepis* and its bearing on taxonomical relationship," *Univ. Calif. Publ. agri. Sci.*, 1936, **6**, 325.

Belling, J. .. "A unique result in certain species crosses," *Z. indukt. Abstamm-u. Vererb Lehre*, 1925, **39**, 286.

———, and Blakeslee, A. F. "On the attachment of non-homologous chromosomes at the reduction division in certain 25-chromosome *Daturas*," *Proc. Nat. Acad. Sci., Wash.*, 1926, **12**, 7.

Blakeslee, A. F. .. *Studies in the behaviour of chromosomes.* (*Year-book*), 1937, 1.

Catcheside, D. G. .. "X-ray treatment of *Oenothera* chromosomes," *Genetica*, 1935, **17**, 313.

Clausen, J. .. "Genetical and cytological investigations on *Viola tricolour* L. and *Viola arvensis* Murr.," *Hereditas, Lund.*, 1926, **8**, 1.

Crew, F. A. E., and Koller, P. C. "Genetical and cytological studies of the inter-generic hybrid of *Cairina moschata* and *Anas platyrhyncha*," *Proc. Roy. Soc. Edin.*, 1935, **54**, 210.

Dixit, P. D. .. "Cytological study of *Capsicum annuum*," *Ind. Jour. Agri. Sci.*, 1933, **1**, 419.

Gates, R. R. .. "A study of reduction in *Oenothera rubrinervis*," *Bot. Gaz.*, 1908, **45**, 1.

———— .. "Pollen formation in *Oenothera gigas*," *Ann. Bot.*, 1911, **25**, 909.

———— .. "Nuclear Structure," *Journ. Roy. Micro. Soc.*, 1932, **52**, 1.

———, and Latter, J. .. "Observations on the pollen development of two species of *Lathræa*," *ibid.*, 1927, **47**, 209.

Goodspeed, T. H. .. "Effects of X-rays and Radium," *Journ. Heredity*, 1929, **20**, 243.

———— .. "*Nicotiana phylesis* in the light of Chrono., and morph. behaviour," *Uni. Cal. Bot.*, 1934, **11**, 369.

———, and Avery, P. .. "Nature and significance of structural chromosome alterations induced by X-rays and Radium," *Cytologia*, 1930, **1**, 308.

Irish, H. C. .. "Revision of the genus *Capsicum*," *Missouri. Bot. Gard. Report*, 1898, 9.

Katayama, Y. .. "On a chromosomal variant induced by X-ray treatment in *Triticum monococcum*," *Proc. Imp. Acad. Japan*, 1935, **2**, 110.

Kattermann, A. .. "Ein Beitrag zur Frage der Dualität der Bestandteile des Bastardkerns," *Planta*, 1933, **18**, 751.

Levan, A. .. "Cytological studies in *Allium fittulosum*," *Svensk. Bot. Tidskr.*, 1933, **27**, 211.

Meurman, O. .. "Cytological studies in the genus *Ribes* L.," *Hereditas Lund.*, 1928, **2**, 289.

Nagao, S. .. "Number and behaviour of chromosomes in the genus *Narcissus*," *Mem. Coll. Sci. Kyoto*, (B), 1933, **8**, 81.

Nandi, H. K. .. "The chromosome morphology, secondary association and origin of cultivated rice," *Journ. Gen.*, 1936, **33**, 315.

Pal, B. P., and Ramanujam, S... "Asynapsis in Chillies," *Curr. Sci.*, 1940, 9, No. 3, 126.

Parthasarathy, N. .. "Cyto-genetical studies of some X-ray derivatives of Rice," *Journ. Gen.*, 1938, 37, 1.

Rosenberg, O. .. "Die Semiheterotypische Teilung and ihre Bedeutung fur die Entstehung verdoppelter chromosomenzahlen," *Hereditas, Lund.*, 1927, 8, 305.

Roxburgh, W. .. *Flora indica*, 1832, 1, 573.

Sapehin, L. A. .. "The genes of the reduction division," *Bull. Appl. Bot. Genet. pl. Breed. ser.*, 1933, 2, D. No. 5, p. 43.

Shaw, F. J. F., and Khan, A. R. "Studies in Indian Chillies," *Mem. Dept. Agr. Ind.*, 1928, 16, No. 2, p. 59.

EXPLANATION OF PLATE I

Figs. 1-6: Photographs

Fig. 1.—Photograph of 'Bushy erect' (Pa X-4)

Fig. 2.— ,, 'Dwarf' (Pa X-6)

Fig. 3.— ,, 'Lean erect' (Pa X-3).

Fig. 4.— ,, 'Narrow-leaved giant' (Pa X-2).

Fig. 5.— ,, 'Nigroides' (Pa X-5).

Fig. 6.— ,, 'Large-leaved giant' (Pa X-1).

Figs. 7-17: Photomicrographs

Figs. 7-9.—Non-disjunction; note the ring bivalent going to the pole without disjunction.

Fig. 10—M II with one univalent off the spindle.

Fig. 10*a*.—One of the plates in polar view and two univalents extruded.

Fig. 11.—M I showing eleven bodies.

Fig. 12.—First telophase showing formation of bridge through delayed disjunction of trivalents.

Fig. 13.—First metaphase, eleven bivalents and two univalents.

Fig. 14.—Interlocking; same as Text-fig. 56.

Fig. 15.—First metaphase-bivalents extruding tendency to fuse; same as Text-fig. 27.

Fig. 16.—Ring of four prior to disjunction; similar to Text-fig. 55 which is however another ring.

Fig. 17.—Ring of four and also a chain; same as Text-fig. 57.

Text-Figs 1-57

Text-figs 1-7.—× Ca 3,300 except Figs. 5 and 6 which are × 2,500.

Figs. 1 and 2.—Idiogram and somatic complement of 'Paramakkudy'.

Figs. 3 and 4.—Idiogram and somatic complement of 'Sunnybrook'.

Fig. 5.—M I Paramakkudy, 12 bivalents.

Fig. 6.—Interphase; note prominent constrictions of the chromosomes.

Fig. 7.—M II; both plates polar view 12/12.

Text-figs. 8-24.—× *a* 1,650 except Fig. 16 which is × 2,500; Figs. 21-24 × 3,300.

Fig. 8.—Asynaptic P.M.C; note complete failure of pairing and the consequent diploid number of univalents.

Fig. 9.—Asynaptic P.M.C., with only one ring bivalent.

Fig. 10.—Organization of a monad with 2 *n* chromosomes.

FIG. 11.—Interphase regular equational divisional of the 2 *n* P.M.C.

FIG. 12.—Random assortment of univalents.

FIG. 13.—M II with 2 *n* number in each plate—a result of regular equational divisional division.

FIG. 14.—Mother cell with about 48 chromosomes, presumed to have arisen by the fusion of M II plates.

FIG. 15.—Shrivelled up crescent-shaped cells with univalents spread all through.

FIG. 16.—Mother cell showing 48 bodies derived by the splitting of each univalent.

FIG. 17.—First anaphase, 13 chromosomes and a fragment.

FIG. 18.—Early stage in the assortment of univalents into groups prior to organization of irregular nuclei.

FIG. 19.—Interphase nuclei organized by irregular division of a 2 *n* P.M.C. Note some univalents left out.

FIG. 20.—Another type of irregular division of an asynaptic P.M.C.

FIG. 21.—First telophase with two bivalents extruded.

FIG. 22.—M II polar view nine in each plate.

FIG. 23.—M II polar view eight in each plate. Both these have arisen by the deletion of bivalents.

FIG. 24.—M I side-view; note one bivalent migrating to a pole earlier than the rest without disjunction; same as Plate I, Fig. 7.

Text-figs. 25–42.—× Ca 3,300 except Fig. 40 which is × 1,650 and Fig. 42 which is × 2,500.

FIG. 25.—M II. Note two univalents un-included and the presence of three fragments.

FIG. 26.—M I with 13 bodies.

FIG. 27.—M I; same as Plate I, Fig. 15.

FIG. 28.—M I eleven bodies; same as Plate I, Fig. 11.

FIG. 29.—M II two univalents off the spindle, presumably the product of the division of a single univalent.

FIG. 30.—Interphase, 12 chromosomes with deep constrictions.

FIG. 31.—Univalents, assorting irregularly to form different sized cells.

FIG. 32.—M I eleven bodies; note the trivalent and the univalent.

FIGS. 33–37.—Various types of bridge formation owing to delayed disjunction of trivalents.

FIG. 38.—Diakinesis with 13 bodies and three fragments.

FIG. 39.—First telophase with two lagging univalents.

FIG. 40.—Irregular behaviour of the univalents; three different sized cells are formed. This is a later stage than Fig. 31.

FIGS. 41–42.—Lagging chromosomes in the second division.

Text-figs. 43–57.—Figs. 43–52 × Ca 1,650; Figs. 53–57 × Ca 3,300.

FIG. 43.—Cytomixis at diakinesis.

FIG. 44.—Cytomixis at early prophase.

FIG. 45.—First telophase; no. of chromosomes spread throughout the spindle.

FIG. 46.—5 nuclei of different sizes are formed by the random assortment of the univalents of an asynaptic P.M.C.

FIG. 47.—Second division, separating chromosomes drawn into threads.

FIG. 48.—Same as 46, six irregular nuclei are formed but the division of the cell into two has taken place.

FIG. 49.—Tripolar spindle.

FIG. 50.—Six cells of different sizes formed by the random assortment and organization of the univalents.

FIG. 51.—P.M.C. in the first division, showing two spindles, the smaller spindle being that of the extruded bivalents.

FIG. 52.—First division shown extruded masses of degenerating chromatin.

FIG. 53.—Fusion of M II plates.

FIG. 54.—A typical ring bivalent.

FIG. 55.—Ring of four assuming the zig-zag configuration prior to disjunction.

FIG. 56.—Interlocking; same as Plate I, Fig. 14.

FIG. 57.—Ring of four; same as Plate I, Fig. 17.