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Chromosome Arrangement in the Heterotype Division of Pollen Mother Cells in *Narcissus tazetta*, L. and *Lilium japonicum* THUNB.[1]

By

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With 5 Text-figures

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Contents

INTRODUCTION

In a previous series of papers (Chromosome Arrangement I—IX, 1929), it was reported that while in the cases where all the chromosomes are relatively small and uniform in size, there is a certain clear resemblance between the arrangement of chromosomes and that of MAYER's floating magnets, in the cases where there are some differences

[1] Chromosome Arrangement X.

in size and behaviour among chromosomes, the tendency towards having a smaller number of inner chromosomes in the arrangement than that which we expect increases, except in the case of a variety of *Lythrum salicaria* studied by SHINKE (Chrom. Arrang. IV). In this exceptional case the number was greater by one instead of less than expected. In any attempt to compare the arrangement of chromosomes with that of MAYER's floating magnets, it seems highly important to investigate those cases of chromosome sets with elements of different sizes and their behaviour in division. With this object in view, *Narcissus* and *Lilium* which have chromosomes of different sizes were taken as materials.

It is my pleasant duty here to record my indebtedness to Prof. Y. KUWADA for his kind suggestions and criticisms.

SHORT DESCRIPTIONS OF THE CHROMOSOMES IN *Narcissus* AND *Lilium*

All the observations were made in the heterotype division of pollen mother cells with fixed materials.

I. *Narcissus tazetta*, L.[1]

1) *A variety called "Franklin."* This variety shows 10 gemini or chromosomes, in the wide sense of the term, in the heterotype metaphase. 6 chromosomes of the 10 are distinctly larger than the remaining 4 (*cf.* Fig. 2, NAGAO, 1930).

2) *A variety belonging to "albae" type.* The somatic number of chromosomes of this variety is 22 (NAGAO, 1929). In the heterotype metaphase there can be found two kinds of pollen mother cells, one with 10 chromosomes and the other with 11. The latter number of chromosomes is derived from the former by the cross segmentation of a chromosome which consists of two bivalents and forms a tetrapartite

[1] A preliminary report on the meiotic division in this plant is to be published in the Japanese Journal of Genetics vol. V, 1929—'30.

complex. In the case where there are 10 chromosomes, 5 of them (including the tetrapartite chromosome) are large and the other 5 are small, while in the other, where the number of chromosomes is 11, the large ones are 4 in number and the small 7 (*cf.* Figs. 13—15, NAGAO, 1930).

II. *Lilium japonicum*, THUNB.

12 chromosomes are counted in the heterotype metaphase of pollen mother cells as in the other species of *Lilium* studied by many earlier investigators (*cf.* TISCHLER, 1922). There are two large chromosomes and two small ones, the remaining eight being of intermediate sizes of different degrees (*cf.* Fig. 4). These differences in size are slight and continuous so that it is frequently impossible to determine to which category of size a chromosome belongs. In 10 chromosomes of the 12 the spindle fiber attachment is terminal, and in the remaining two, which may classified in either category of size, the small or the intermediate, it is median.

CHROMOSOME ARRANGEMENT

I. *Narcissus tazetta*, L.

1. "*Franklin*" ($n=10$)

The statistical results obtained from 217 pollen mother cells of this variety are as follows:—

Case I. 1 chromosome occupies an inner position, and the other 9 peripheral (Fig. 1*a—b*).....22 (10.1%)

Case II. 2 chromosomes occupy inner positions, and the remaining 8 peripheral (Fig. 1*c—e*) 143 (65.9%)

Case III. 3 chromosomes occupy inner positions, and the remaining 7 peripheral (Fig. 1*f—h*).....46 (21.2%)

Case IV. The form of arrangement is more or less irregular, and falls under none of the above three Cases 6 (2.8%)

When the number of floating magnets is 10, two magnets occupy the inner positions in the stable form and the other 8 the peripheral,

forming an octogon (MIDZUNO, 1916; CANNON, 1923). The statistical data just given above show that in "Franklin" the majority of the chromosome arrangements resemble the stable form of the floating magnets. The frequency of occurrence of the resembling case (Case II) amounts to 65.9%, a result which is similar to those obtained in the other plants studied having chromosomes of the same size and shape. When we consider the size of the chromosomes which occupy

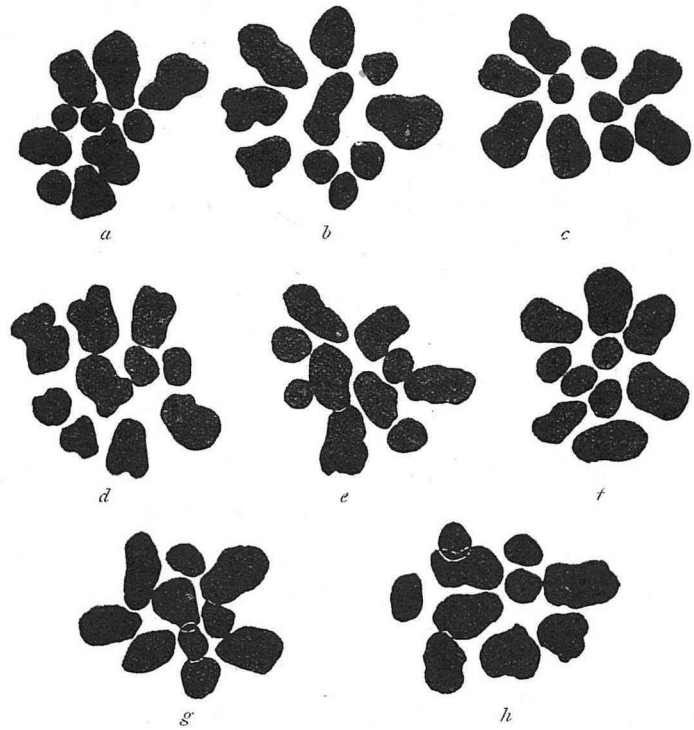

Fig. 1*a*–*h*. Heterotype nuclear plates in the variety "Franklin" of *Narcissus tazetta*, L. Explanation in the text. x1710.

inner positions in the arrangement, all the cases given above can be divided into some number of different types of chromosome combination in regard to size. Possible types that we can expect for Cases I, II and III and their frequency of occurrence are as follows :—

Case I { Type *a*. A small chromosome (Fig. 1*a*) 10
Type *b*. A large chromosome (Fig. 1*b*) .....12 } 22 (10.1%)

Case II
- Type *a*. Both small chromosomes (Fig. 1*c*) 71
- Type *b*. 1 small and 1 large chromosome (Fig. 1*d*)···69
- Type *c*. Both large chromosomes (Fig. 1*e*) 3

} 143 (65.9 %)

Case III
- Type *a*. All 3 small chromosomes (Fig. 1*f*).....32
- Type *b*. 2 small and 1 large chromosome (Fig. 1*g*)...11
- Type *c*. 1 small and 2 large chromosomes(Fig. 1*h*... 3
- Type *d*. All 3 large chromosomes 0

} 46 (21.2%)

If we assume that there is not any other special factor nor action than mere chance which influences the combination of the inner chromosomes in the arrangement, we may expect the following frequencies of occurrence of these types of combination from the point of view of probability :—

Case	Type	Number of combinations	Expected frequency	Observed frequency
I	*a*	${}_4C_1\ {}_6C_0 = 4$	8.8	10
	b	${}_4C_0\ {}_6C_1 = 6$	13.2	12
II	*a*	${}_4C_2\ {}_6C_0 = 6$	15.6	71
	b	${}_4C_1\ {}_6C_1 = 24$	62.4	69
	c	${}_4C_0\ {}_6C_2 = 25$	65.0	3
III	*a*	${}_4C_3\ {}_6C_0 = 4$	1.9	32
	b	${}_4C_2\ {}_6C_1 = 12$	5.75	11
	c	${}_4C_1\ {}_6C_2 = 60$	28.75	3
	d	${}_4C_0\ {}_6C_3 = 20$	9.6	0

Comparing these expectable frequency values with those obtained by the actual observations, we can find that the small chromosomes have a greater tendency towards occupying the inner positions than expected. In both Case II and Case III, the observed frequencies of type *a*, in which only small chromosomes occupy the central regions, are 71 and 32 respectively, and are greater than those expected, which are 15.6 and 1.9 respectively. In Case III, furthermore, we see that, while such is also the case in type *b* where only one of the 3 occupying

the inner positions is the large chromosome, in type *c*, where there are found 2 large chromosomes among the 3, the observed frequency 3 is much less than the expected frequency 28.75. In type *d* where all the 3 chromosomes are large ones it is zero, while, on the basis of the assumption we made above, we should expect 9.6 cases of this type. It is a very interesting fact that the greater the number of the small chromosomes occupying the inner positions, the greater is the excess of the frequency value over that expected, and the more such chromosomes are replaced by the large chromosomes, the less it is, and when they are all replaced by the latter it is zero. When there is only one chromosome which occupies the central position (Case I) we have no such relation. In both type *a* where the chromosome is a small one and type *b* where it is a large one, the two frequencies, expected and observed, are nearly equal.

2. *A variety belonging to "albae" type*

a. The case where the number of chromosomal elements is 10

In this case 5 chromosomes (including the tetrapartite one) of the 10 are larger than the remaining 5. It is of interest to compare the forms of arrangement of the chromosome with those of the variety "Franklin" where 6 chromosomes of the 10 are large and the other 4 small. The results obtained from the observation at metaphase in 386 pollen mother cells of this variety are as follows :—

Case I. 1 chromosome occupies an inner position, and the remaining 9 peripheral ..... **22** (5.7 %)

Type *a*. A small chromosome occupies the central position (Fig. 2*a*)..... 7

Type *b*. Instead of the small chromosome a large one occupies this position (Fig. 2*b*).....15

Case II. 2 chromosomes occupy inner positions and the other 8 peripheral..... ..... **222** (57.5 %

Type *a*. Both small chromosomes (Fig. 2*c*) 115

Type *b*. 1 large and 1 small chromosome (Fig. 2*d*) 104

Type *c*. Both 2 large chromosomes (Fig. 2*e*) 3

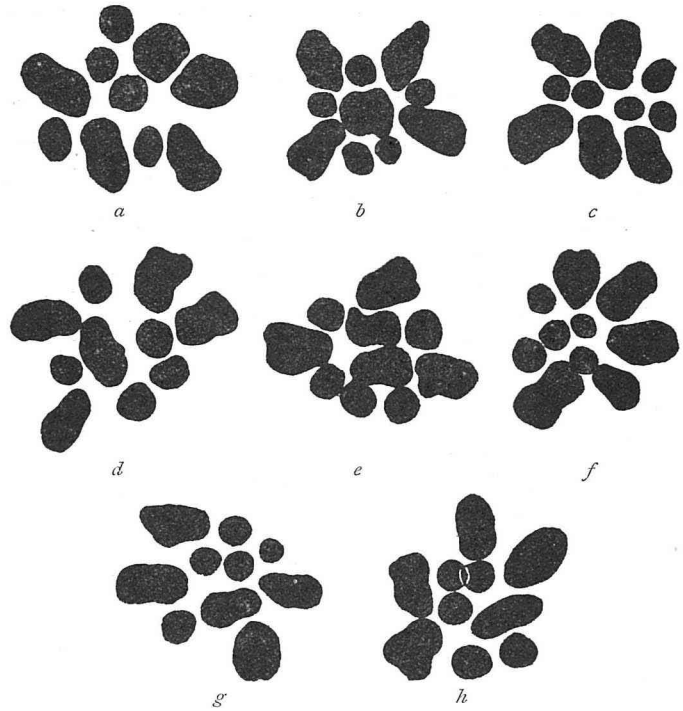

Fig. 2*a–h*. Heterotype nuclear plates in a variety of "albae" type of *Narcissus tazetta*, L. with 10 chromosomal elements. Explanation in the text. x1710.

Case III. 3 chromosomes occupy inner positions and the other 7 peripheral ... .**104** (26.9 %)

Type *a*. All 3 small chromosomes (Fig. 2*f*) 85

Type *b*. 1 large and 2 small chromosomes (Fig. 2*g*) 19

Type *c*. 2 large and 1 small chromosome 0

Type *d*. All 3 large chromosomes 0

Case IV. 3 small and 1 large chromosome occupy inner positions, and the remaining 6 peripheral (Fig. 2*h*) .....**1** (0.3 %)

Case V. The form of arrangement is more or less irregular, and falls under none of the above four Cases .....**37** (9.6 %)

In these results we see again that the case where 2 chromosomes occupy the inner positions (Case II) is most common, being 222 (57.5%) in number out of 386. This indicates that there is a certain resemblance between the chromosome arrangement and the stable form of floating magnets in this case of the variety too, but we find here

that Case III forms a second maximum, its frequency of occurrence, 26.9%, standing out prominently among the other cases (Cases I, IV, V) in all of which the frequency values are under 10%.

In the present case too, we see that the small chromosomes have a greater tendency towards occupying the inner positions than we should expect. A comparison may be made from the following table.

Case	Type	Combination of chromosomes	Number of combinations	Expected frequency	Observed frequency
I	*a*	a small chromosome	${}_5C_1 = 5$	11	7
	b	a large chromosome	${}_5C_1 = 5$	11	15
II	*a*	2 small chromosomes	${}_5C_2 = 10$	49.3	115
	b	1 large and 1 small	${}_5C_1\ {}_5C_1 = 25$	123.3	104
	c	2 large chromosomes	${}_5C_2 = 10$	49.3	3
III	*a*	3 small chromosomes	${}_5C_3 = 10$	8.6	85
	b	1 large and 2 small	${}_5C_1\ {}_5C_2 = 50$	43.3	19
	c	2 large and 1 small	${}_5C_2\ {}_5C_1 = 50$	43.3	0
	d	3 large chromosomes	${}_5C_3 = 10$	8.6	0

In type *a* of Case II where both the inner chromosomes are small ones, the observed frequency is 115, while the expected frequency is 49.3. In type *c* where both the inner small chromosomes are replaced by large chromosomes, however, the observed frequency is only 3 while the expected is so high as 49.3. In Case III too, the same fact with regard to what kinds of chromosomes tend to occupy the inner position in the arrangement is observed. In this case the observed frequency of types *c* and *d* is even zero, while we should expect 43.3 and 8.6 respectively. In type *a*, where 3 small chromosomes occupy inner positions, it is markedly greater than the frequency expectable, the numerical value of the observed frequency being 85 and that of the expected only 8.6. But in type *b* where one of the 3 inner chromosomes is replaced by a large chromosome it decreases to 19,

which is much less than the expectable frequency, 43.3. In short, in both Case II and Cases III it is shown that the type having no large chromosomes in the inner region of the arrangement is of the most frequent occurrence, and the greater the number of large chromosomes occupying the inner positions, the less frequent is the occurrence of such a type.

It is also a noteworthy fact that in Case I, where one chromosome occupies the central position, the large chromosome has a greater tendency towards occupying this position than the small one. Our results show that this type of arrangement (type *b*) is found in 15 cases, while in the case of the type where a small chromosome takes the inner position (type *a*) only 7 are found, or about half as many as in the case of the former type.

The question whether the tetrapartite chromosome has a special tendency towards occupying the inner position or not could not be determined, because in metaphase its tetrapartite nature was hardly discernible in many cases. In his observation in *Lythrum*, SHINKE has shown that there is no recognizable special tendency in the tetrapartite chromosome to occupy the central region. It seems to be likely that the same is also true in the case of the narcissus plant.

b. The case where the number of chromosomal elements is 11

The results obtained from the observation of 69 heterotype nuclear plates in pollen mother cells are as follows:—

Case I. 1 chromosome occupies the central or inner position, the other 10 forming the peripheral ring 3

Type *a*. A small chromosome occupies the central position 0

Type *b*. A large chromosome instead of the small one (Fig. 3*a*).....3

Case II. 2 chromosomes occupy the inner positions, the other 9 forming the ring ...11

Type *a*. Both small chromosomes (Fig. 3*b*) 6

Type *b*. 1 large and 1 small chromosome (Fig. 3*c*).....5

Type *c*. Both large chromosomes.....0

Case III. 3 chromosomes occupy the inner positions, being surrounded by the

other 8.....47

Type *a*. All 3 small chromosomes (Fig. 3*d*) 41

Type *b*. 2 small and 1 large chromosome (Fig. 3*e*).....6

Type *c*. 1 small and 2 large chromosomes.....0

Type *d*. All 3 large chromosomes 0

Case IV. 4 small chromosomes occupy the inner region being surrounded by the other 7 (Fig. 3*f*).....4

Case V. The arrangement of the chromosomes is irregular or determination of the number of chromosomes in the inner position is difficult 4

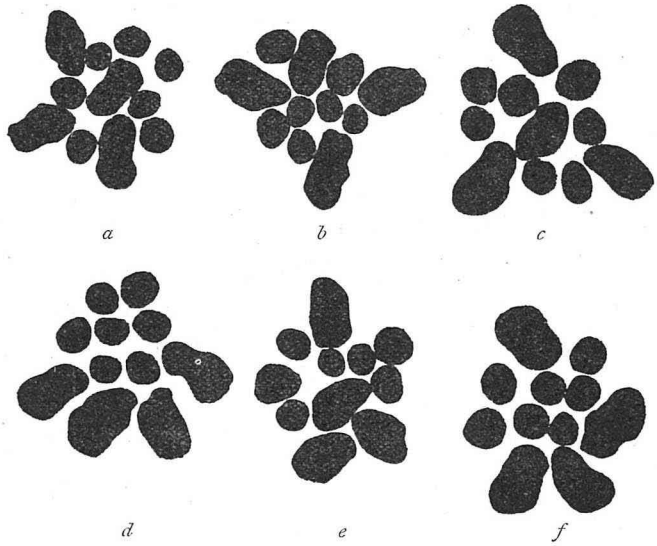

Fig. 3*a–f*. Heterotype nuclear plates in a variety of "albae" type of *Narcissus tazetta*, L. with 11 chromosomal elements. Explanation in the text. x1710.

From the data given above we see that in the case of 11 chromosomes the arrangement of the chromosomes resembles very closely that of the floating magnets. The number of the resembling cases (Case III) is 47 out of the 69 pollen mother cells observed. The frequency curve of the different forms of chromosome arrangement obtainable from the data is leptokurtic in nature as in those cases where the chromosomes are all of nearly the same size and shape (KUWADA, Chrom. Arrang. I, p. 208), and we find no second maximum of frequency such as is found in "Franklin" as well as in the case of the 10 chromosomal elements in this variety.

II. *Lilium japonicum*, THUNB.

The size relations of chromosomes to one another described above in this plant resemble those in *Cycas revoluta* and thus the comparison of the chromosome arrangements in this plant with those of *Cycas revoluta* observed by NAKAMURA (Chrom. Arrang. IX) may be interesting. The results of observation of the heterotype nuclear plates in 103 pollen mother cells are as follows :—

Case I. 1 chromosome is found in the central position, the remaining 11 forming the peripheral ring **10** (9.7%)

Type *a*. A small chromosome occupies the central position (Fig. 4*a*) 5

Type *b*. A large chromosome instead of the small one (Fig. 4*b*).....5

Case II. 2 chromosomes are found in the inner reglon, being surrounded by the other 10 .....**52** (50.5%)

Type *a*. Both small chromosomes (Fig. 4*c*) 21

Type *b*. 1 small chromosome and 1 large or intermediate (Fig. 4*d–e*) ...25

Type *c*. Both large, or both intermediate sized chromosomes or 1 large and 1 intermediate (Fig. 4*f*) 6

Case III. 3 chromosomes are found in the inner region, the remaining 9 forming the ring.....**21** (20.4%)

Type *a*. 2 small chromosomes and 1 intermediate (Fig. 4*g*).....9

Type *b*. Other combinations of chromosomes of various sizes[1] which differ from type *a* (Fig. 4*h–i*).....12

Case IV. 4 chromosomes are found in the inner region, the remaining 8 taking the peripheral positions (Fig. 4*j*) **3** (2.9%)

Case V. The arrangement of the chromosomes is irregular or determination of the number of chromosomes in the inner position is difficult **17** (16.5%)

In the case of floating magnets, when we have 12 floating magnets 3 magnets of the 12 occupy the inner positions in the arrangement. Our cytological data show, however, that the case where 2 chromosomes occupy the inner positions (Case II) is most common, its frequency value being 50.5%, and the arrangement which resembles the stable configuration of the floating magnets (Case III) forms only a second

[1] The case where one of the 3 inner chromosomes was a small chromosome was most common.

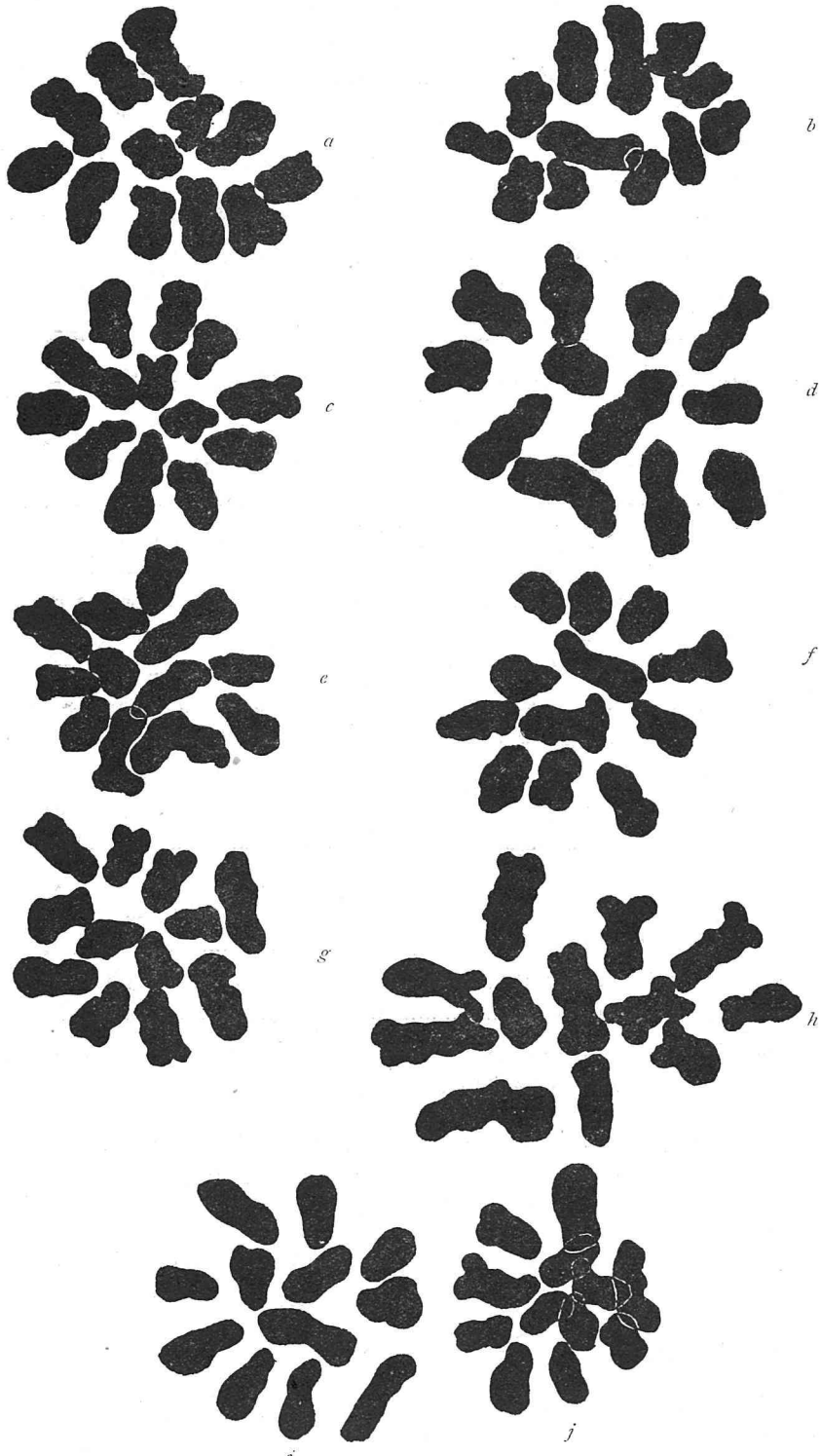

Fig. 4*a–j*. Heterotype nuclear plates in *Lilium japonicum*, THUNB. Explanation in the text. x1710.

maximum (20.4%). This result is quite similar to that obtained in *Cycas revoluta* by NAKAMURA, in which the size relations of the chromosomes to one another are quite similar to those of this plant.

The higher tendency of the small chromosomes than the large ones to occupy the inner position is also seen in this plant. In the following table a comparison of the observed frequencies in Case I and Case II with the corresponding expected frequencies obtained on the basis of the assumption made above in the case of *Narcissus* is shown :—

Case	Type	Combination of chromosomes	Number of combinations	Expected frequency	Observed frequency
I	*a*	a small chromosome	${}_2C_1 = 2$	5	5
	b	a large chromosome	${}_2C_1 = 2$	5	5
II	*a*	2 small chromosomes	${}_2C_2 = 1$	0.78	21
	b	1 small and 1 large or intermediate	${}_2C_1\,{}_2+{}_8C_1 = 20$	15.76	25
	c	1 large and 1 intermediate	${}_2C_1\,{}_8C_1 = 16$	35.46	6
		2 intermediate chromosomes	${}_8C_2 = 28$		
		2 large chromosomes	${}_2C_2 = 1$		

The comparison shows that the numerical relations between the expected and observed frequencies of the types of arrangement in respect to the size of the inner chromosomes are quite the same as those we saw in the case of *Narcissus*.

CONSIDERATION OF THE RESULTS

It was pointed out by DONCASTER (1920) that especially when the chromosomes are short and of nearly uniform size, the arrangement of the chromosomes has a remarkable resemblance to that of MAYER's floatnig magnets. The results of our previous investigations show that the resemblance is remarkable not only in those cases pointed out by DONCASTER, but also in those cases where one of the chromosomes is

markedly larger than the others of nearly uniform size and shape (*Spinacia* and *Vicia* by MAEDA and KATÔ, Chrom. Arrang. VII). In

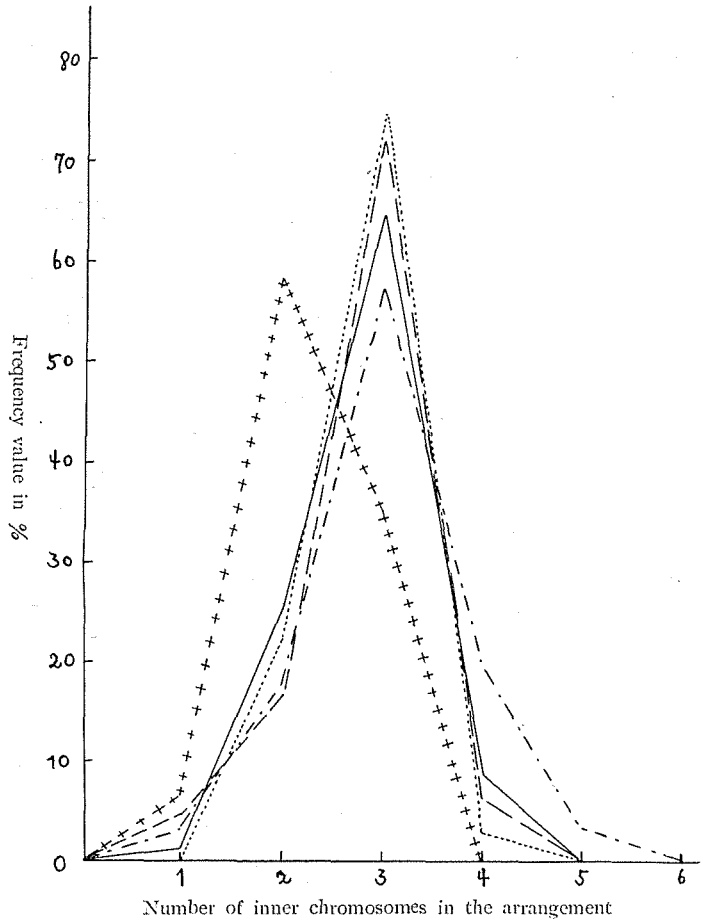

Fig. 5. Frequency polygons showing variation in the number of chromosomes occupying the inner region of the arrangement in plants with 11 chromosomes. In all the plants except *Cycas* the maximum frequency values are found in those cases where 3 chromosomes of the 11 occupy the inner regions, the cases which resemble the stable form of arrangement of floating magnets.

—·—·—· *Phaseolus*
..... *Peucedanum* } All the 11 chromosomes are of nearly uniform size.

——— *Sagittaria* 1 of the chromosomes is large and another one small, the remaining 9 being intermediate.

— — — — — — *Narcissus* 4 large and 7 small chromosomes.

+ + + + + + + + + *Cycas* The 11 chromosomes form a continuous graded series in size.

the present investigation it has further been shown in *Narcissus* that the resemblance is also remarkable even when there are some chromosomes of large sizes among others of small sizes, if the chromosomes can be divided into two distinct categories of size. When, however, there is a continuous gradation in the size and shape of the chromosomes from the smallest to the largest, as in *Cycas revoluta* and *Lilium japonicum*, such a resemblance as that seen in the case of chromosomes of uniform size is recognizable only frequently enough to form a second maximum. In Fig. 5, frequency polygons from plants, the case where the number of chromosomes of the plant is 11 being taken as an example, are given to show how the shape of the polygon differs in different combinations of chromosomes.

In the cases of *Cycas* and *Lilium* the first maximum of frequency is presented by the form of arrangement in which the number of inner chromosomes is less by one than that of the form resembling the stable form of floating magnets. This tendency is also recognizable in the other plants investigated, such as in the homotype division in *Peucedanum japonicum* by OGAWA (Chrom. Arrang. V) and *Sagittaria Aginashi* by SHINKE (Chrom. Arrang. IV), though in these cases this form can present only the second maximum. In the case of the variety "Franklin" of the narcissus plant, on the other hand, the tendency towards forming a second maximum is found in the case where the inner chromosomes are more by one instead of less than that of the stable form of floating magnets (Case III). A similar phenomenon was found by SHINKE in the case of 14 chromosomal elements in a variety of *Lythrum salicalia*, and this was the only exception to the rule which we were able to formulate from the results we obtained in our previous investigations (*cf.* KUWADA, Chrom. Arrang. I, p. 221). Now we have in "Franklin" another example of this type of shifting of frequency to the form having a greater number of inner chromosomes than that of the stable form of floating magnets. In SHINKE's variety of *Lythrum salicaria* there is a chromosome with the tetrapartite constitution which can divide itself into two independent free chromo-

somes, and in the group of *Narcissus* to which 'Franklin" is classified as belonging we have a variety of "albae" type, in which a chromosome may similarly divide into two independent mero-chromosomes, so that the plant may have a greater number of chromosomes than we expect from the basal number of chromosomes of the group. These two facts lead us to the conclusion that the occurrence of the *Lythrum* type of shifting of frequency in "Franklin" may show the potentiality of cross-segmentation in a "Franklin" chromosome into two mero-chromosomes. In the variety of 'albae" type, in fact, when the tetrapartite chromosome remains undivided, the frequency curve of chromosome arrangements is quite similar to that obtainable from SHINKE's results in the case of *Lythrum*, although, while in *Lythrum*, when the tetrapartite chromosome separates into two independent chromosomes, the arrangement still shows a high tendency to have the same number of inner chromosomes as that found in the case where no such separation takes place, in the variety of "albae" type such a tendency is no longer marked, the frequency curve being leptokurtic (Case II). But the curve is so far in accord with that of *Lythrum* that Case II stands next Case III in frequency.

Further investigation may lead us to the conclusion that the study of chromosome arrangement can disclose the potentiality of cross segmentation of a chromosome in a plant, but we wish at present to explain the present case by simply comparing it with the behaviour of floating magnets in the matter of arrangement, because in the present case the second maximum is very low as compared with that found in the case of *Lythrum*.

According to MIDZUNO (1916) and CANNON (1923), in the stable form of floating magnets two of the 10 take the inner positions in the ring, the remaining 8 forming an octogon. According to MAYER, however, this form is less stable, and the stable form is that where 3 of the 10 occupy the inner positions (*cf.* KUWADA, Chrom. Arrang. I, p. 203). In my own experiments with floating magnets the stable form was the same as that given by MIDZUNO and CANNON. From

these facts it may be considered that if the arrangement of chromosomes is comparable with that of the floating magnets, the form with 3 inner chromosomes may also occur besides the form with 2 of these, because in the case of the chromosome arrangement, it is obvious that the medium in which the chromosomes move is more viscous than the medium in which the magnets float, so that unstable forms of arrangement may be less easily transformable (KUWADA, Chrom. Arrang. I, p. 208). The high frequency of occurrence of Case III in the varieties of the narcissus plant may thus be simply explained, and the case of " Franklin " seems to be comparable with the case of *Torilis Anthriscus* studied by OGAWA (Chrom. Arrang. V) rather than with the case of *Lythrum*.

Finally we wish to consider the greater tendency of the small chromosomes to occupy the inner position than that of the large chromosomes. According to the results of our previous investigations, the frequency with which a large chromosome occupies the central position of arrangement is different in different cases. In *Spinacia* (MAEDA and KATÔ) it is nearly equal to the frequency to be expected from the point of view of chance. In *Sagittaria* (SHINKE) and *Cycas* (NAKAMURA) it is less, and in *Vicia* (MAEDA and KATÔ) it is greater than the frequency expectable. Small chromosomes show, on the other hand, a greater tendency to take the inner positions (*Sagittaria* and *Cycas*). This greater tendency of the small chromosomes is seen also in *Narcissus* and *Lilium*. In the large chromosomes it is very low in both *Narcissus* and *Lilium*, and it was found in the narcissus plants that the greater the number of small chromosomes occupying the inner positions, the greater is the excess of the frequency of that type of arrangement over the expected frequency, and the more such small chromosomes are replaced by the large ones, the less the frequency becomes.

In both " Franklin " and *Lilium japonicum*, in Case I where only one chromosome occupies the inner position, the frequency of occurrence of both the small and the large chromosome in the central position

is nearly equal to that expectable from the point of view of chance. In the variety of "albae" type it is much greater in the large chromosome and less in the small chromosome than we should expect. They may appear to form exceptional cases, but we can not draw any definite conclusion from these data, because of the fact that the case in question represents only a transitional stage and also that the observed data of frequency of occurrence are too meager.

As one of the chief causes of the greater tendency of small chromosomes to occupy the inner positions than the larger chromosomes, the viscous nature of cytoplasm as compared with water, which is used as the floating medium in the case of experiments with the floating magnets, may be mentioned, as emphasized by KUWADA (1929). Small chromosomes have a lesser mechanical resistance to the cytoplasm than large ones, and thus the small chromosomes may migrate through the cytoplasm faster than the large ones if they carry a sufficient electrical charge, and will have a greater chance of occupying the inner positions.

SUMMARY

The results of observation made in the heterotype division of pollen mother cells in two garden varieties of *Narcissus tazetta*, L. and *Lilium japonicum*, THUNB. may be summarized as follows.—

1. Two garden varieties of *Narcissus tazetta*, L.

a. The form of chromosome arrangement with two inner chromosomes or the form which resembles the stable form of floating magnets occurs most frequently in both varieties.

b. The form of arrangement with 3 inner chromosomes stands next in frequency making a second maximum both in "Franklin" and in the variety of "albae" type with 10 chromosome elements.

c. The small chromosomes have a greater tendency to enter inside the chromosome ring of arrangement than we should expect as a mere matter of chance and the greater the number of the small chromosomes occupying the inner positions is, the greater is the excess

of this frequency value over that expected, and the more such chromosomes are replaced by the large chromosomes, the less is the frequency of occurrence of such a type.

d. In the case of a variety of "albae" type with 11 chromosomal elements, the frequency curve of the various forms of chromosome arrangement is leptokurtic in nature as in the case where all the chromosomes are of nearly uniform size and shape.

2. *Lilium japonicum*, THUNB.

a. There are 12 gemini or chromosomes in the heterotype division of pollen mother cells as in all the other species of *Lilium* hitherto investigated.

b. In this plant, the maximum frequency value is found in the case where 2 of the 12 chromosomes occupy the inner positions instead of 3 which is the number of such chromosomes in the form resembling the stable form of the floating magnets, though the latter form still maintains a high value of frequency, forming a second maximum. This is analogous to the case of *Cycas revoluta* investigated by NAKAMURA and is regarded as due to the marked difference in the size of the chromosomes in a group as in *Cycas*.

c. A greater tendency of the small chromosomes and a lower tendency of the large chromosomes to occupy the inner positions in the arrangement are found also in this plant as in the case of *Narcissus*.

3. Both in *Narcissus* and *Lilium*, when only 1 chromosome takes the central position, the observed frequency of occurrence of the large chromosome in the central position is nearly equal to the expected frequency (*Lilium*, "Franklin") or even greater than it ("albae" type of the narcissus variety), though we can not draw any conclusion from these facts alone, because, in addition to the fact that the observed data of frequency of occurrence are too meager, the case in question must be regarded as representing only a transitional stage.

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LITERATURE CITED

1. Chromosome arrangement, I—IX.

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