Zeitschrift: Berichte der Schweizerischen Botanischen Gesellschaft = Bulletin de la Société Botanique Suisse

Herausgeber: Schweizerische Botanische Gesellschaft

Band: 85 (1975)

Heft: 3

Artikel: Contribution to the cytotaxonomy and cytogeography of the flora of the Western Himalayas (with an attempt to compare it with the flora of the Alps). Part II

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DOI: https://doi.org/10.5169/seals-60179

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Ber. Schweiz. Bot. Ges. *85* (3), 210–252 (1975)

Contribution to the Cytotaxonomy and Cytogeography of the Flora of the Western Himalayas (with an attempt to compare it with the Flora of the Alps). Part II.

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In the first part of this series, cytological studies on species of the families *Gentianaceae* and *Convolvulaceae* were reported. The present paper continues these studies in other families of the Sympetalae.

Boraginaceae

According to Willis (1966), this family consists of 100 genera and 2000 species. The members are distributed in tropical as well as temperate regions of the world. Hooker (1885) has described 185 species from British India, of which a large percentage inhabits the Himalayas. Hegi (1927) has counted 41 species for Central Europe, and Hermann (1956) 79 species for North and Central Europe. Gürke (1897) divided the family into four subfamilies on the basis of flower morphology. They are: *Cordioideae, Ehretioideae, Heliotropioideae* and *Boraginoideae.* He further divided the *Boraginoideae* into seven tribes. Johnston (1924b) rearranged these tribes and genera.

Though *Boraginaceae* is a large family, the chromosome numbers of only about 300 species are known hitherto (Bolkhovskikh, *et al.,* 1969). Among the workers who studied the cytology, the contributions of Strey (1931), Smith (1932), Sugiura (1936), Mulay and Jaisingani (1945), Britton (1951), Pal (1957), Faruqui (1961b), Merxmüller and Grau (1963, 1969), Grau (1964a, b, 1965, 1966, 1967a, b, 1968a, b, 1970, 1971), Chaudhuri (1967) and Blaise (1970, 1972) are particularly significant.

Our cytological results are reported in Table 3.

Discussion

The chromosome number of *Heliotropium eichwaldi* (n = 32) tallies with the earlier finding of Ahuja (1955). *H. strigosum,* with n = 11, falls in line with the identical report of Pal (1964) but differs from the finding of Faruqi (1961) who reported 2n = 32 for this species. The present observation of 2n = 48 in *H. europaeum* (seeds collected in France) is a new chromosome report for the species. Darlington and Wylie (1955) suggested the genus to be polybasic with x = 7–13, while Löve and Löve (1961) attributed x = 8, 9, 10 to this same genus. The current observation indicates that *H. europaeum* from France is a chromosome race at the hexaploid level on the base number x = 8. Of all the genera studied in this family, the genus *Heliotropium* had the greatest variation in chromosome numbers, excepted for the genus *Myosotis.* The different zygotic numbers in the genus (14, 16, 18, 22, 24, 26, 28, 32 and 64) are suggestive of its speciation through aneuploidy or dysploidy accompanied by euploidy. According to Britton (1951), the variation in chromosome number is due to the study of types which are morphologically very diverse. Intraspecific polyploidy does exist in *H. europaeum,* but the exact distribution of the cytotypes or races is unknown.

Trichodesma indicum with n = 22 confirms the observations of Pal (1964) who also reported a diploid cytotype (n = 11) in this species, thereby indicating the presence of chromosome races in *T. indicum.*

The genus *Cynoglossum* consists of sixty species (Willis, op. cit.) spread over subtropical and temperate regions and sometimes found in mountainous regions. During the flowering season, those plants dominate the vegetation in W. Himalayas by virtue of their luxuriant flowering. *C. petiolatum* is confined to alpine W. Himalayas. The author could observe this species only in the Gulmarg region of Kashmir, generally under *Abies* trees.

Of the 8 species of *Cynoglossum,* 3 are reported cytologically for the first time, whereas the chromosome number in the remaining 5 agrees with the report of Britton (1951) (Table 3A). All the 21 species of *Cynoglossum* cytologically known so far (Strey, 1931; Sugiura, 1940b; Britton, 1951; Baksay, 1958; Chaudhuri, 1967 and author) have haploid chromosome number 12 or its multiples. All these data are against Britton's assumption of x = 8 as the basic number for the genus *Cynoglossum.* Darlington and Wylie (1.c.) have proposed x = 12 (6) for this genus, while Löve and Löve (1961) admitted x = 6. The uniformity of 12 as the haploid chromosome number in the genus, except for *C. aequinoctiale* (2n = 48, Britton, 1951), suggests that speciation in the genus is primarily due to structural alterations or gene mutations.

In *C. lanceolatum,* one bivalent is partially attached to the nucleolus at meiosis; in *C. nervosum,* clustering of bivalents and lagging of one bivalent away from metaphase plate were commonly observed. However, the later course of meiosis was found to be normal with regular tetrad formation and well filled pollen grains.

The genus *Lindelofia* Lehm. consists of 10 species (Willis) distributed in the Alpine regions of Central Asia, Afghanistan and Himalayas. *L. spectabilis* occurs in Ladakh of Kashmir and the Garhwal region of Kumaon, between 2700–3000 m. *L. longiflora* ascends to 2700 m in Kashmir. *L. longiflora* with n = 12 agrees with the finding of Strey (1931). *L. angustifolia* with n = 12 is a new report. Basic numbers

10 and 12 are proposed for *Lindelofia.* More cytological data is needed to comment upon the evolutionary pattern of this genus.

Paracaryum glochidiatum (n = 12) is documented cytologically for the first time. This number falls in line with the only other species in which the chromosome number is known (*P. coelestinum,* n = ca. 12, Strey, 1931), on which basis the genus seems to be built. Two populations were observed in the valley of flowers (3600 m) and Gurez (2700 m) in Kashmir. They showed differences in flower colour, the former having pink petals and the latter, white petals. The chromosomes of both varieties were similar (Fig. 44). The differences in flower colour are probably due to either genetic or environmental factors.

The species *Lappula deflexa* from Norway with 2n = 48 is cytologically a new report. *L. echinata* (2n = 48) from three different regions of Europe tallies with the chromosome counts of Löve and Löve (1956) and of Mulligan (1957). *L. microcarpa* (n = 11) from Himalayas is also a new chromosome count. The present findings seem to support the assumption of x = 12, (Darlington and Wylie, 1955) as the basic chromosome number for the genus. The gametic chromosome number 11 of *L. microcarpa* may be an aneuploid derivative of x = 12. In this plant, one bivalent is attached to the nucleolus at meiosis. The present finding of low chromosome number in Himalayas and the count from Tchouksanova (unpublished) in *Lappula barbata* (M.B.) Gürke, support the assumption that the centre of distribution of *Lappula* is Asia.

Eritrichium nanum with n = 23 and 2n = 46 collected from two different places in the Alps agrees with the earlier count of Favarger (1965). But *E. strictum* of W. Himalayas is cytologically a new report. This plant is common in Kashmir at a range of 2000–3000 m, in dry cold regions of Ladakh. The genus *Eritrichium* seems to be polybasic, with x = 12 and x = 11 (Grau, 1968). This fact can explain the gametic number n = 23 for *E. nanum* as coming through amphidiploidy from a taxon with n = 11 and another with n = 12. The polyploid *E. nanum* seems to have a remote Asiatic origin. After Favarger (unpublished), the variety *terglouense* from the Eastern Alps is also polyploid.

The gametic chromosome number 12 found in the material collected from W. Himalayas is a new report for *Asperugo procumbens.* But the higher ploidy (2n = 48) observed in the material collected from Briançon in the French Alps agrees with the earlier findings of Reese (1953) and Löve and Löve (1956). The chromosomes are small. The two reports stand for the intraspecific polyploidy in this species. The higher degree of polyploidy in European material is an interesting fact and seems to prove that in this case also, the plants from Europe have migrated from an Asiatic centre.

Lycopsis orientalis L. with gametic number 8, from Himalayas, agrees with the finding of Strey (1931). This taxon was included by some authors as subspecies in *Lycopsis arvensis* L. European material of the latter is characterized by a polyploid chromosome number. Our observations on plants from Belgium allows to determine more precisely the approximate number ca. 48, counted by Löve and Löve (1956). In all the cases, the size of the chromosomes is very large. Thus, the Asiatic and East European taxon *L. orientalis* seems to be an ancestor of the largely distributed *L. arvensis* from Central and Western Europe.

Nonnea caspica G. Don. was met in the valley of Kashmir on the exposed slopes near water channels. It was absent in the Kumaon regions of W. Himalayas. The chromosome number n = 8 is a new report. The genus seems to be polybasic with n = 7, 8, 10 (Grau, 1971). The majority of species of *Mertensia* reported from India are montane plants representative of Himalayas. *M. elongata* Benth.(1) was sometimes observed in open hill tops at an altitude of 3500 m in Kashmir, but could not be observed in other parts of W. Himalayas surveyed by the author. The chromosome count of n = 12 for this species agrees with the finding of 2n = 24 by Britton (1951). But n = 11, in *M. exserta* (2) (a plant distributed in small patches, in *Abies* forests in Gulmarg but not seen in Kumaon) is documented for the first time for the species. Incidentally, this is the only report of a gametic number differing from 12 or its multiples hitherto recorded for *Mertensia.*

Riedl (1967) had separated, from a morphological point of view, the Central Asiatic species of *Mertensia* from the American and Siberian species and proposed to include the former in a new genus: *Pseudomertensia* H. Riedl. Thus, the genus *P.* seems to be polybasic with n = 12 and n = 11.

Myosotis caespitosa Schultz was met at a range of 1800–2000 m in Kashmir valley, growing in marshy or small water channels and ditches on roadsides. The chromosome number n = 44 (Fig. 50) indicated an octoploid level on basic number x = 11. After Merxmüller and Grau (1963) there are diploid, tetraploid, hexaploid and octoploid taxa in the *palustris* group in Europe. The octoploid taxa are forms from Scandinavia probably belonging to *M. baltica* Sam. and a taxon from the Eastern Pyrénées. Our plants from Kashmir probably represent another octoploid taxon in this group. In a plant from Germany belonging to *M. palustris* (L.) Nath., we have found 2n = 64. This count tallies with those of Strey, Löve and Löve etc. but disagrees with those of Merxmüller and Grau (2n = 66). *M. stricta* Link., grows luxuriantly between 1800–2000 m in the valley of Kashmir in exposed places, in common with grasses. Its distribution is restricted to Kashmir in W. Himalayas. The gametic number n = 18 counted in this species agrees with the oldest counts (for example, Löve and Löve, 1956, on Icelandic material) but not with those of Grau (1968a) who has found 2n = 48 in material from various countries (among which a plant came from Iran). Therefore, Merxmüller (1970) thought that the somatic numbers 36–40 for this species rested on wrong counts! Meanwhile, the present author is sure of both identification of the plant and meiotic chromosome count.

Onosma emodi Wall. was observed in Kedarnath hills, in the midst of bushy shrubs up to 3000 m. The gametic number 9 in *O. emodi* Wall. is the first chromosome report for this species. Another species from Himalayas, *Onosma hookeri* Clarke, has the same basic number (Chaudhuri, 1967). *O. „echioides"* was described by Clarke in Hooker's Flora and it was considered by Riedl (op. cit.) as identical to *O. hispidum* Wall. Grau (1968) had counted 2n = 12 in two plants of this species: one coming from W. Pakistan, and the other from E. Afghanistan. It is difficult to understand the reason of this discrepancy. The chromosomes of *O. „echioides"* are very large compared to those of *O. emodi.*

(1) = *Pseudomertensia elongata* (Decne) H. Riedl.
(2) = *Pseudomertensia parviflora* (Decne) H. Riedl.

The number n = 18 for *Lithospermum arvense* from Himalayas is a new chromosome count for the species. The number 2n = 42 for the same species from Europe, is also a new chromosome report.

In this plant, Grau (1968) had counted 2n = 28 (material from Southern France). The German worker thinks that the older chromosome counts (2n = 24 and 2n = 16) should be considered cautiously. It seems that in this group, European material is built on the chromosome basic number 7 and the W. Himalayan one, on basic number 9.

The cytological conditions in the *Boraginaceae* are extremely complicated. Many genera seem to have more than one basic number, (for example, x = 11 and x = 12 in *Pseudomertensia, Eritrichium, Lappula, Myosotis,* etc.). In was interpreted by Merxmüller and Grau (1969) as dysploidy (aneuploidy with structural changes). This phenomenon can even arise in the same species. The present work brings some new examples of this intraspecific dysploidy such as in *Lithospermum arvense, Myosotis stricta,* and perhaps also in *Onosma hispidum.*

Another interisting feature is the difference observed in some cases between the level of ploidy of certain Himalayan species and the same species in Central Europe, as in *Asperugo procumbens* and *Lycopsis arvensis,* the Himalayan populations having the lowest chromosome number.

Verbenaceae

The family *Verbenaceae* consists of 75 genera and 3000 species (Willis, 1966) distributed in tropical and subtropical regions. Hooker (1885) had reported 129 species from British India. Since most of them are tropical and subtropical, their representation in W. Himalayas is poor. In Central Europe (after Hegi, op. cit. and Hermann, op. cit.), a single wild species is growing.

Clarke (1885) divided the family into six tribes on the basis of joined characters of inflorescence, ovary, fruit and seeds. Briquet (1894) classified the entire family into 7 subfamilies but treated the genus *Phryma* as belonging to a separate family, the *Phrymaceae.*

In this family, the main cytological studies were made by Sugiura (1936b) on the genera *Verbena* and *Callicarpa,* Patermann (1935), Nishiyama and Kondo (1942) and Bowden (1945) on the genus *Clerodendron,* Schnack and Covas (1947), Tjio (1948), and Natarajan and Ahuja (1957) on the genus *Lantana,* Cooper (1941) on the genus *Phryma,* and Sharma (1956) and Sharma and Mukhopadhyay (1963) on other genera of the family. Our cytological results are reported in Table 4.

Discussion

Phryma L.([1]) is a small genus consisting of only one species, reported from Himalayas by Hooker (1885). *P. leptostachya* L. is frequent in W. Himalayas from Kashmir to Kumaon between 700 and 2000 m. The gametic chromosome number counted at meiosis from PMC's is n = 7.

([1]) Tribe Phrymeae in the acception of Clarke (1885). For some authors, this genus belongs to a separate family: *Phrymaceae.*

Lantana camara L. is widly distributed in India. It is very common in plains and outer hills of Himalayas. Various morphological types are noticed with respect to the flower colour. 16 bivalents are clearly discernible at MI of meiosis.

Verbena bonariensis L. is a native of Brazil but was introduced in Himalayas. It is seen, but rarely, in Mussoorie and Sathal regions of Kumaon, with conspicuous absence in Kashmir. 14 bivalents are counted at MI of meiosis. *V. officinalis* L. occurs in Nainital and Mussoorie regions of W. Himalayas at a range between 300 and 2000 m. It is sometimes seen in Kashmir also. This species is common in many parts of Europe. PMC's indicated 7 bivalents at MI of meiosis. *V. bipinnatifida* Nutt. is an exotic species native of California and Mexico. It is cultivated in gardens in Chandigarh. A chromosome count at meiosis shows n = 5 with normal meiosis. Bivalents were comparatively large.

Callicarpa longifolia Lamk. is observed in Almora of Kumaon, but is not very common in W. Himalayas. A chromosome count at MI of meiosis showed 18 bivalents with normal sequence of later stages (fig. 57).

Caryopteris grata Benth. is common in Kumaon in bushy jungles up to 2000 m. The meiotic chromosome number is n = 30 at AI.

Of the seven species of *Verbenaceae* investigated presently, the chromosome number of one species is a new report. The lowest gametic number was found in *Verbena bipinnatifida* (n = 5), whereas the highest one was observed in *Caryopteris grata* (n = 30).

According to the literature, there are two chromosome races in *Phryma leptostachya,* a diploid one studied by Sugiura and by the author, and a tetraploid one with 2n = 28 (Sugiura, Cooper and Sokolovskaja). The plant examined by Sokolovskaja was coming from Siberia (region of Primorye) and the plant examined by Cooper, from the U.S.A. Since Sugiura has studied spontaneous plants from Japan, it is possible to conclude that the monotypical genus *Phryma* was born in Asia, perhaps in Himalayas, and that the tetraploids have migrated to Atlantic North America and to East Siberia. Recently, Hara (1972) has ascertained that in *Phryma,* „The Himalayan, Japanese and Eastern North American plants agree well with each other . . . and have the same chromosome number (2n = 28)." He does not report any of Sugiura's results, and the current finding does not agree with the assertion of Hara.

Lantana camara, a species highly variable in flower colour, showed various chromosome numbers. The present result tallies with the number recorded by Schnack and Covas (1947). It would be interesting to establish a correlation between chromosome numbers and flower colours in *L. camara.* If such a correlation did exist, one would be facing a morphological splitting within the species. Hence intraspecific variation in chromosome numbers may be considered as the main evolutionary trend in this species.

The three different chromosome numbers (n = 5; n = 7; n = 14) found in the presently studied species of *Verbena* refer to two distinct basic numbers, x = 5 and x = 7. These two basic numbers have been recorded in many other species of the genus. From another point of view, it could be mentioned here that karyotypical studies made by Sharma and Mukhopadhyay (1963) enabled them to conclude that *Verbena* is the most primitive genus in the family: a hypothesis based on the long chromosomes and „fairly symmetrical karyotype" observed in this genus.

Callicarpa longifolia (n = 18) has the same chromosome number as *C. japonica* (Patermann, 1935). Hence, it seems that x = 9 is one of the basic numbers of this genus; a secondary gametic number is n = 17. Unpublished data of Bawa (personal communication) indicated that both intraspecific and interspecific polyploidy were prevalent in the genus.

Caryopteris grata, with n = 30 agrees with Mehra and Gill's results (1968). It is difficult, in the present state of knowledge to assign a basic number to this genus.

Although, the author has not made an exact count of the chromosomes of *Stachytarpheta indica,* he could observe in this species a very high number of small chromosomes. Therefore the author agrees with Sharma *et al.* (1963) who have proposed to place this genus in a separate tribe other than *Verbeneae.*

A critical examination of the chromosome numbers of cytologically studied species of *Verbenaceae* clearly reveals a considerable intra- and interspecific variation in chromosome numbers.

The vegetative mode of reproduction of some members of the family perhaps favours speciation through polysomaty (Sharma, 1956).

Solanaceae

The family *Solanaceae* comprises about 90 genera covering about 2000 species (Willis, 1966); it has a wide spread distribution in tropical and temperate regions. Of the 51 species from India recorded by Clarke (in Hooker, 1885), some were found at the montane and subalpine levels of Western Himalayas. The family is poorly represented in Europe: 16 species after Hegi (op.cit.) and 11 after Hermann (op.cit.) of which many are cultivated plants. Some species are common to both Europe and India.

Wettstein (1895) divided the family *Solanaceae* into five tribes on the basis of both flower and embryo characters: *Nicandreae, Solaneae, Datureae, Cestreae,* and *Salpiglossideae.* The most important cytological contributions on non-tuberous members were made by Belling and Blakeslee (1923), Kojima (1925), Lesley (1926), Vilmorin and Simonet (1927), Jörgensen (1928, 1929), Janaki Ammal (1932, 1934), Tokunaga (1934), Nakamura (1937), Nisimura (1939), Ellison (1936a and b), Goodspeed and Avery (1939), Paddock (1942 and 1943), Westergaard (1948), Bhaduri (1933, 1945, 1951) Oinuma (1949), Stebbins and Paddock (1949), Hardas and Joshi (1954), Sinha (1950), Ramprakash and Biswanath Chatterjee (1953), Mehra *et al.* (1954), Swaminathan *et al.* (1953), Sharma and Sharma (1957), Rai (1959, 1960), Soria and Heiser (1961), Magoon *et al.* (1962), Bezbaruah and Bezbaruah (1963), Venkateswarlu and Rao (1963), Rao (1962), Tandon and Rao (1964, 1966), Chennaveeraiah and Krishnappa (1965, 1966), Venkateshwaralu and Bhiravamurthy (1962) and Philomena Madhavadian (1968).

Our cytological results are reported in Table 5.

Discussion

Twenty-nine taxa of *Solanaceae* from W. Himalayas, pertaining to 27 species, are studied in the present work, revealed some interesting cytological features, so far not recorded in the family. Four taxa from Europe were also examined for comparison.

Table 3: *BORAGINACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Heliotropioideae						
Heliotropium eichwaldi Steud.	Lalkuan, 350 m Kumaon	2558	32	–	8x	n = 32, Ahuja 1955 Malik *et al.* 1959
H. strigosum Willd.	Ranikhet, 1900 m	2597	11	–	2x	n = 11, Pal 1964 2n = 32, Faruqi 1961 2n = 26, Malik *et al.* 1959
Subfamily Boraginoideae						
Tribe Cynoglosseae						
Trichodesma indicum Br.	Ranikhet, 1900 m	2599	22	–	4x	n = 11, 22, Pal 1964 2n = 22, Malik *et al. 1959* Baquar *et al.* 1965 n = 22, Chaudhuri 1967
Cynoglossum furcatum Wall.*	Nainital, 1900 m	2555	12	–	2x	
C. lanceolatum Forsk.	Banihal, 2550 m Kashmir	4276	12	–	2x	n = 12, Chaudhuri 1967 2n = 24, Chaudhuri 1967
C. wallichi G. Don	Nainital, 1900 m	2546	12	–	2x	n = 12, Chaudhuri 1967 2n = 24, Chaudhuri 1967
C. microglochin Benth.*	Nainital, 1900 m	2577	12	–	2x	
C. nervosum Benth.	Almora, 2000 m	2095	12	–	2x	2n = 24, Britton 1951
C. petiolatum A. DC*	Gulmarg, 2700 m Kashmir	4240	12	–	2x	
C. zeylanicum Thunb.	Qurez valley, 2700 m Kashmir	4259	12	–	2x	2n = 24, Britton 1951
C. amabile Stapf. and Drumm.	Govindghat, 2100 m Almora	2086	12	–	2x	2n = 24, Britton 1951
Lindelofia angustifolia Brand.*	Sonamarg, 2700 m Kashmir	4231	12	–	2x	
L. longiflora Baillon	Gulmarg, 2700 m Kashmir	4242	12	–	2x	2n = ca. 24, Strey 1931
Paracaryum glochidiatum Benth.	Valley of flowers, 3600 m, Kumaon	2002	12	–	2x	
Tribe Eritrichieae						
Lappula microcarpa (Ledeb.) Gürke *	Dras, 2700 m Ladakh	4269	11	–	2x	
Eritrichium strictum Dcne.*	Zoji La, 3300 m Kashmir	4251	12	–	2x	
Asperugo procumbens L.+	Dras, 2700 m Ladakh	4258	12	–	2x	2n = 48, Reese 1953 Löve & Löve 1956
Tribe Anchuseae						
Lycopsis orientalis L.	Mahagam, 1650 m Kashmir	4227	8	–	2x	2n = 16, Strey 1931
Nonnea caspica G. Don.*	Tangmarg, 2100 m Kashmir	4206	8	–	2x	
Tribe Lithospermeae						
Mertensia elongata Benth.	Lianmarg, 3900 m Kashmir	4261	12	–	2x	2n = 24, Britton 1951
M. exserta I.M. Johnston*	Gulmarg, 2700 m Kashmir	4203	11	–	2x	
Myosotis stricta Link	Pahalgam, 2100 m Kashmir	4218	18	–	?	2n = ca. 36, Löve & Löve 1956 2n = 48, Grau 1968
M. caespitosa Schultz	Pahalgam, 2100 m Kashmir	4228	44	–	?	2n = 22, 44, Merxmüller & Grau 1963 2n = ca. 80, Strey 1931 Tischler 1934 Rohweder 1937
Lithospermum arvense L.+	Sankaracharya Hill, 2100 m, Kashmir	4219	18	–	?	2n = 28, Löve & Löve 1944 Britton 1951 Hanelt & Schultze-Motel 1962 Grau 1968
Onosma „echioides" L.+	Zoji La, 3300 m Kashmir	4248	7	–	2x	
O. emodi Wall.*	Kedarnath Hill, 3600 m Kumaon	2603	9	–	2x	
	Species from Europe studied by the author (B)					
Subfamily Heliotropioideae						
Heliotropium europaeum L.+	Sète-Hérault, France (Bot. Gard. Liège)	–	–	48	6x	2n = 24, Svensson 1925 2n = 32, Britton 1951
Subfamily Boraginoideae						
Tribe Eritrichieae						
Lappula echinata Gilib.	Locality unknown Hungary (Bot. Gard., Gödöllö)	–	–	48	4x	2n = 48, Mulligan 1957 Löve et Löve 1956
	Ceillac, 1670 m France (Prof. C. Favarger)	–	–	48	4x	
	Charrat, 600 m Valais, Switzerland	–	–	48	4x	
L. deflexa Garcke*	Oppland, Lom-Lom Norway (Bot. Gard., Oslo)	–	–	48	4x	
Eritrichium nanum (All.) Schrader	Oberrothorn, 3000 m Valais, Switzerland	–	–	46	?	2n = 44–46, Favarger 1942 2n = 46, Favarger & Huyhn 1964 Favarger 1965
Asperugo procumbens L.	Briançon, 1700 m Hautes-Alpes, France (Bot. Gard., Dijon)	–	–	48	4x	see Table 3A, under the same species
Tribe Anchuseae						
Lycopsis arvensis L.	La Panne, Flandre-occidentale, Belgium (Bot. Gard., Liège)	–	–	48	6x	2n = ca. 48, Löve & Löve 1956 2n = ca. 54, Svensson 1925 Tischler 1934 Rohweder 1937
	Pisse-vache, 470 m Valais, Switzerland (Bot. Gard., Geneva)	–	–	48	6x	
	Quarri-les-Tombes, 390 m Yonne, France (Bot. Gard., Dijon)	–	–	48	6x	
Tribe Lithospermeae						
Myosotis palustris (L.) Nath	Cottbus, Germany (Bot. Gard., Jena)	–	–	64	?	2n = 22, 66, Merxmüller & Grau 1963 2n = 64, Strey 1931 Tischler 1934 Rohweder 1937 Löve & Löve 1942, 1956
Lithospermum purpureocaeruleum L.	Neuchâtel, 700 m Jura, Switzerland	–	8	–	2x	2n = 16, Reese 1952 Grau 1966
L. officinale L.	Lossy, 530 m Haute-Savoie, France (Bot. Gard., Geneva)	–	–	28	4x	2n = 28, Strey 1931 Tischler 1934 Britton 1951 Mulligan 1957 Gadella & Kliphuis 1966
L. arvense L.	Charrat, 650 m Valais, Switzerland (Prof. C. Favarger)	–	–	42	6x	see Table 3A, under the same species

* Chromosome number of the species reported for the first time
\+ A new chromosome report for the species

Table 4: *VERBENACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
Phryma leptostachya L.	Nainital, 1900 m	2588	7	–	2x	2n = 14, Sugiura 1936b 2n = 28, Sugiura 1936a Cooper 1941 Sokolovskaja 1966
Subfamily Verbenoideae Tribe Lantaneae *Lantana camara* L.	Jeolikot, 1400 m Nainital	2504	16	–	4x	2n = 32, 44, Schnack & Covas 1947 2n = 44, Tjio 1948 2n = 22, 33, 44, 66, Natarajan & Ahuja 1957 2n = 44, Raghavan & Arora 1960 Singh 1951 2n = 22, 33, 44, Sen & Sahni 1958
Subfamily Verbenoideae Tribe Verbeneae *Verbena officinalis* L.	Bandipur, 1800 m Kashmir	4260	7	–	2x	2n = 12, Schnarf 1923 Paterman 1935 2n = 14, Junell 1934 Tischler 1934 Dermen 1936 Noack 1937 Schnack & Covas 1944
Verbena bipinnatifida Nutt.	Chandigarh, 300 m	2060	5	–	2x	n = 15, Lewis & Oliver 1961
Verbena bonariensis L.	Bhimthal, 1400 m Kumaon	2572	14	–	4x	2n = 28, Derman 1936 Noack 1937 Schnack *et al.* 1959 Covas & Schnack 1947
Subfamily Viticoideae Tribe Callicarpeae *Callicarpa longifolia* Lamk.*	Almora, 1900 m	2583	18	–	2x	
Subfamily Caryopteridoideae *Caryopteris grata* Benth.	Nainital, 1900 m	2502	30	–	?	n = 30, Mehra & Gill 1968

* Chromosome number of the species reported for the first time

Table 5: *SOLANACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Tribe Nicandreae *Nicandra physaloides* (L.) Gaertn.	Nainital, 1900 m	2519	10	–	2x	2n = 20, Venkateswarlu & Rao 1962, 1963 2n = 19, 20, Darlington & Janaki Ammal 1945 2n = 20, Vilmorin & Simonet 1928 Delay 1947 Gottschalk 1954 2n = 21, Sinha 1951
Tribe Solaneae Subtribe Lyciinae *Atropa belladonna* L.	Gulmarg, 2700 m Kashmir	4223	36	–	6x	2n = 72, Marchal 1920 Vilmorin & Simonet 1928 Delay 1947 Gottschalk 1954 Mehra & Sobti 1954 2n = 50, Homedes Ranquini 1943
Tribe Solaneae Subtribe Hyoscyaminae *Physochlaina praealta* Miers	Kargil, 2500 m Ladakh	4249	41	–	?	2n = 82, Mehra & Sobti 1954
Hyoscyamus niger L.	Gulmarg, 2700 m Kashmir	4224	17	–		2n = 34, Griesinger 1937 2n = 34, Vaarama 1950 Vilmorin & Simonet 1928 Tischler 1934, 1937 Delay 1947 Löve & Löve 1948 Gottschalk 1954 Garajova 1959 n = 17, Mehra & Sobti 1954
H. pusillus L.	Dras, 2700 m Ladakh	4250	34	–	4x	n = 34, Mehra & Sobti 1954
Tribe Solaneae Subtribe Solaninae *Solanum nigrum* L.	Ranibag, 600 m Nainital	2537	12	–	2x	2n = 24, 48, 72, Bhaduri 1933 n = 12, 24, 36, Tandon & Rao 1964 2n = 36, 72, 96, 144, Jörgensen 1928
	Nainital, 1900 m	2507	24	–	4x	2n = 24, 36, 48, Winkler 1921 2n = 72, Vilmorin & Simonet 1928
	Almora, 2100 m	2001	36		6x	Masubuchi 1961
	Lalkuan, 350 m	2553	24	–	4x	Mulligan 1961 etc. (cf. Bolkhovskikh *et al.*, 1969)
S. verbascifolium L.	Almora, 1900 m	2585	12	–	2x	2n = 24, Bhaduri 1933 Ratera, 1943 Bezbaruah & Bezbaruah 1963 Mehra & Gill 1968 Chandola *et al.* 1966
S. khasianum Clarke	Pantnagar, 300 m	2066	12	–	2x	2n = 24, Haiser 1963a Mehra & Gill 1968 Bezbaruah & Bezbaruah 1963
S. torvum Swartz.	Lalkuan, 350 m	2554	12	–	2x	2n = 24, Haiser 1963 Bhaduri 1933 Bezbaruah & Bezbaruah 1963
S. indicum L.	Haldwani, 400 m	2033	12	–	2x	2n = 24, Bhaduri 1933, 1935 Miège 1962 Bezbaruah & Bezbaruah 1963
S. xanthocarpum Schrad. Wendl.	Lalkuan, 350 m	2552	12	–	2x	2n = 24, Jörgensen 1928 Baquar *et al.* 1965 Bhaduri 1933 Mehra & Gill 1968
S. hispidum Pers.	Dehra Dun, 400 m	2077	12	–	2x	n = 12, Haiser 1963
S. incanum L.	Pantnagar, 300 m	2560	12	–	2x	2n = 24, Miège 1962
S. jasminoides Paxt.	Nainital, 1900 m	2562	12	–	2x	2n = 24, Vilmorin & Simonet 1927a, 1968
S. macranthum Dun.	F.R.I., 400 m Dehra Dun	2091	12	–	2x	2n = 24, Nanda 1962
S. pseudocapsicum L.	Someswar, 800 m Kumaon	2547	12	–	2x	2n = 24, Vilmorin & Simonet 1927a, 1928 Bezbaruah & Bezbaruah 1963 Kawano 1965
Lycopersicum pimpinellifolium Dun.	Almora, 1900 m	2036	12	–	2x	2n = 24, Luckwill 1943 Rick 1956 Humphrey 1932, 1937 Upadhya & Majid 1964 2n = 24, 48, Lindstrom 1932
Physalis minima L.	Garampani, 1000 m Nainital	2564	24	–	4x	2n = 48, Bhaduri 1933 Gottschalk 1954 Baquar et al. 1965
P. peruviana L.	Almora, 1900 m	2584	24	–	4x	2n = 24, Yamamoto & Sakai 1932 2n = 48, Menzel 1951 etc. (cf. Bolkhovskikh *et al.*, 1969)
Capsicum frutescens L.	Rajhati, 800 m Nainital	2590	12	–	2x	2n = 24, Sinha 1950 Kapoor & Tandon 1964 etc. (cf. Bolkhovskikh *et al.*, 1969)
Withania somnifera Dunal.	Lalkuan, 350 m	2551	24	–	2x	2n = 24, Mohan Ram & Kamini 1964 2n = 48, Miège 1960 Baquar *et al.* 1965 Bhaduri 1933 Gottschalk 1954
Tribe Datureae *Datura stramonium* L.	Nainital, 1900 m	2521	12	–	2x	2n = 24 (12, 25), Satina *et al.* 1941 2n = 48, Belling & Blakeslee 1922 2n = 24, Bönicke 1911 etc. (cf. Bolkhovskikh *et al.* 1969)
D. fastuosa L.	Almora, 1900 m	2586	12	–	2x	2n = 24, Vilmorin & Simonet 1927, 1928 Bhaduri 1933 Bhaduri & Sharma 1946
D. innoxia Mill.	Haldwani, 400 m	2527	12 + 1	–	2x	2n = 24, Sobti & Singh 1961 Blakeslee *et al.* 1935 Buchholz *et al.* 1935
D. suaveolens Humb.& Bonpl.	Bowali, 1700 m	2523	12	–	2x	n = 12, Gottschalk 1954
Tribe Cestreae Subtribe Nicotianinae *Nicotiana rustica* L.	Haldwani, 400 m	2545	24	–	4x	2n = 48, Goodspeed 1923 etc. (cf. Bolkhovskikh *et al.* 1969)
N. plumbaginifolia Viv.	Haldwani, 400 m	2579	10 + 1B	–	2x	2n = 20, Goodspeed 1945 Gottschalk 1954 etc. (cf. Bolkhovskikh *et al.* 1969)
	Species from Europe studied by the author (B)					
Tribe Solaneae Subtribe Solaninae *Solanum nigrum* L.	Neuchâtel, Switzerland	–	36		6x	see Table 5A, under the same species
Physalis alkekengi L.	Locality unknown Hungary (Bot. Gard., Gödöllö)	–	–	24	2x	2n = 24, Vilmorin & Simonet 1927, 1928 Yamamoto & Sakai 1932 Nakajima 1933 Tokunaga 1934 Menzel 1951 Gottschalk 1954 Murin & Vachova 1967
Subtribe Lyciinae *Atropa belladona* L.	Timisul de Sas, Beasov, Rumania (Bot. Gard., Bucarest)	–	–	72	6x	see Table 5A, under the same species
Subtribe Hyoscyaminae *Hyoscyamus niger* L.	Vallée d'Eyne, East Pyrénées, France (Bot. Gard., Liége)	–	–	34	4x	see Table 5A, under the same species

Table 5C: Summary of distinctive characters of the races of *Solanum nigrum*

Characters	Diploid (n = 12)	Tetraploid (n = 24)	Hexaploid (n = 36)
Locality	Nainital	Nainital	Almora
Habitat	Shady and humid places	Shady and open places	Shady and open places
Habit	Erect and quite branched	Erect and profusely branched, sometimes semi-prostrate	Erect and profusely branched giving bushy appearance
Height	65–98 cm	75–95 cm	50–210 cm with intermediate forms
Stem	Green, non-prominent ribs	Thick dull green with purplish tint, prominent ribs	Green with or without ribs
Leaves	Thin, ovate, serrate	Thick, ovate, serrate margin	Thick, ovate, lanceolate, bigger and fewer serrations, petiole prominently marginate
Length of petiole	1,1–2,3 cm	1,5–4,2 cm	3,0–6,0 cm
Length of lamina	3,0–7,5 cm	5,6–9,8 cm	9,0–13,1 cm
Flowers per inflorescence	4–6	5–6	7–9
Diameter of corolla	4–6 mm	7–8 mm	8–11 mm
Fruit colour	Shiny blue black	Orange red	Purplish black
Fruit size	Small	Small	Large
Seeds per fruit	25	23	45
Size of stomata	20 x 18 μ	24 x 20 μ	32 x 28 μ

Table 6: *SCROPHULARIACEAE*

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
	Species from the Western Himalayas studied by the author (A)					
Subfamily Pseudosolaneae						
Tribe Verbasceae						
Verbascum thapsus L.	Nainital, 1900 m	2518	18	–	?	2n = 34, 36, Håkansson 1926 2n = 36, Mulligan 1961 2n = 36, Packer 1964
Subfamily Antirrhinoideae						
Tribe Antirrhineae						
Linaria ramosissima Wall.	Ranikhet, 1900 m	2598	9	–	2x	n = 9, Verma & Dhillon 1967
L. cymbalaria Mill.	Nainital, 1900 m	2506	7	–	2x	n = 7, Verma & Dhillon 1967
L. bipartita Willd.	Nainital, 1900 m	2513	6	–	2x	n = 6, Verma & Dhillon 1967
L. dalmatica L.	Sankaracharya Hill, 2100 m, Kashmir	4215	6	–	2x	2n = 12, Heitz 1927 Tjebbes 1928 Matsura & Suto 1935
L. subsessilis Pennell *	Anandnag, 1500 m Kashmir	4271	18	–	4x	
Antirrhinum majus L.	Nainital, 1900 m	2508	8	–	2x	2n = 16, Baur 1924, 1932 Propach 1934 et 1935 n = 8, Rieger 1957 2n = 32, Morrison & Rajhathy 1960 n = 8, Verma & Dhillon 1967
A. orontium L.	Pinjore, 400 m	2080	8	–	2x	2n = 14, Sobti & Singh 1961 n = 8, Verma & Dhillon 1967
Tribe Cheloneae						
Scrophularia obtusa Edgew.*	Almora, 1900 m	2570	24	–	4x	
S. scopolii Hoppe +	Gulmarg, 2700 m Kashmir	4225	24	–	4x	2n = 26, Varama & Hiirsalmi 1967
S. edgeworthii Benth.*	Manna valley, 3600 m Kumaon		24 + 1B	–	4x	
S. himalensis Royle *	Nainital, 1900 m	2574	24	–	4x	
	Shervan, 2000 m Kashmir	4234	12	–	2x	n = 10, Mehra & Gill 1968
S. lucida L.	Tangmarg, 2100 m Kashmir	4214	13	–	2x	n = 13, Shaw 1962
S. variegata Bieb.+	Tangmarg, 2100 m Kashmir	4216	24	–	4x	n = 12, Shaw 1962 Vaarama and Hiirsalmi 1967
S. dentata Royle *	Kargil, 2500 m Ladakh	4257	12	–	2x	
Tribe Gratioleae						
Mazus rugosus Lour.	Kuchiathal, 1200 m Nainital	2594	20	–	4x	n = 20, Verma & Dhillon 1967
M. surculosus D. Don *	Nainital, 1900 m	2532	10	–	2x	
Lindenbergia grandiflora Benth.*	Didihat, 1400 m Kumaon	2038	14	–	4x	
L. macrostachya Benth.*	Haridwar, 400 m	2093	16	–	4x	
L. urticaefolia Lehm.*	Lohorkhet, 2100 m Kumaon	2549	25	–	?	
Adenosma capitatum Benth.*	Thal, 1400 m Almora	2042	36	–	?	
Limnophila roxburghii G. Don *	Bageswar, 1400 m Almora	2047	18	–	?	
Bacopa monniera (L.) Wettst. (= *Herpestis monniera* H.B. & K.)	Surajpur, 350 m	2084	32	–	?	n = 24, Srinath 1934 2n = 64, Raghavan 1959b Lewis *et al.* 1962
Bacopa chamaedryoides (H.B.K.) Wettst. (= *Herpestis chamaedryoides* H.B.K.)*	Uttarkashi, 1200 m	2606	10	–	2x	
Torenia cordifolia Roxb.*	Nandaprayag, 1000 m Kumaon	2013	16	–	4x	
Vandellia nummularifolia D. Don *	Almora, 1900 m	2571	12	–	2x	
Bonnaya brachiata Link & Otto *	Sathal, 1200 m Nainital	2568	9	–	2x	
B. veronicaefolia Spreng.*	Sathal, 1200 m Nainital	2566	18	–	4x	
Subfamily Rhinanthoideae						
Tribe Digitaleae						
Wulfenia amherstiana Benth.	Lariakanta, 2000 m Nainital	2538	8	–	2x	n = 8, Verma & Dhillon 1967 n = 8, Mehra & Gill 1968
Veronica ciliata Fisch.*	Lianmarg, 3600 m Kashmir	4262	8	–	2x	
Veronica anagallis L.+	Surajpur, 350 m	2068	27	–	6x	2n = 36, Ehrenberg 1945 n = 27, Verma & Dhillon 1968
	Tangmarg, 2100 m Kashmir	4208	18	–	4x	n = 18, 27, Khoshoo & Khushu 1964 2n = 36, Löve & Löve 1956
Veronica beccabunga L.+	Tangmarg, 2100 m Kashmir	4205	9	–	2x	2n = 18, Schlenker 1936 Gadella & Kliphuis 1963 2n = 18, 36, Sokolowska-Kulczycka *in* Skalinska 1964
V. hederifolia L.+	Tangmarg, 2100 m Kashmir	4222	9	–	2x	2n = 28, Gadella & Kliphuis 1966 2n = 56, Hofelich 1935 Sorsa 1963 Rohweder 1937 Lehmann *et al.* 1954 2n = 18, 36, 54, Fischer 1967
V. polita Fries	Chandigarh, 350 m	2076	7	–	2x	n = 7, Huber 1927 Yamashita 1937
V. persica Poir.	Kasauli, 1500 m	2092	14	–	4x	2n = 28, Borgmann 1964
V. biloba L.	Srinagar, 1650 m Kashmir	4204	14	–	4x	2n = 28, Zündorf 1939
V. laxa Benth.	Pindari glacier, 3500 m, Kumaon	2543	23	–	?	n = 23, Mehra & Gill 1968 Yamasaki 1936
V. verna L.	Sankaracharya Hill, 2100 m, Kashmir	4217	8	–	2x	2n = 16, Hofelich 1935
V. cana Wall.*	Dwali, 3000 m Almora	2544	26	–	?	
V. serpyllifolia L.	Tangmarg, 2100 m Kashmir	4201	7	–	2x	2n = 14, Löve & Löve 1956b Sokolovskaya 1963 Hara 1956 Gadella & Kliphuis 1966
Lagotis glauca Gaertn.	Aporwat, 3900 m Kashmir	4243	11	–	2x	2n = 22, Sakai 1934 Sokolovskaja 1963, 1965
Tribe Gerardieae						
Buchnera hispida Ham.*	Nainital, 1900 m	2021	14	–	2x	
Leptorhabdos benthamiana Walp.**	Nainital, 1900 m	2037	7	–	2x	
Tribe Rhinantheae						
Euphrasia officinalis L.*	Basudhara, 3800 m Kumaon	2004	22	–	4x	
E. platyphylla Pennell *	Khilanmarg, 3000 m Kashmir	4270	22	–	4x	
Pedicularis pectinata Wall.	China peak, 2600 m Nainital	2016	8	16	2x	n = 8, Verma & Dhillon 1967 Mehra & Gill 1968
P. tenuirostris Benth.*	Banihal, 2550 m Kashmir	4265	8	–	2x	

Taxa	Source and altitude	Collection number	Chromosome number n	2n	Level of ploidy	Previous report
P. gracilis Wall.	Badrinath, 3050 m	4265	8	–	2x	n = 8, Mehra & Gill 1968
	Simla Hills, 2600 m Narkunda	–	–	16	2x	n = 8, Mehra & Gill 1968
Pedicularis porrecta Wall.*	Kedarnath, 3600 m	2604	8	–	2x	
P. brevifolia D. Don *	Aporwat, 3900 m Kashmir	4275	–	16	2x	
P. pycnantha Boiss.*	Dras, 2700 m Ladakh	4244	8	16	2x	
P. macrantha Klotzsch *	Kedarnath, 3600 m	2602	7–8	–	2x	
P. megalantha Don *	Valley of flowers, 3600 m, Kumaon	2005	8	–	2x	
P. bicornuta Klotzsch *	Aporwat, 3900 m Kashmir	4245	7	–	2x	
P. siphonantha D. Don	Tangmarg, 2100 m Kashmir	4236	–	16	2x	n = 8, Verma & Dhillon 1967 Mehra & Gill 1968
P. carnosa Wall.	Lariakanta, 2400 m Nainital	2595	6	12	2x	n = 6, Verma & Dhillon 1967
P. rhinanthoides Schrenk *	Aporwat, 3900 m Kashmir	4285	8	–	2x	
P. pyramidata Royle *	Tangmarg, 2100 m Kashmir	4238	8	16	2x	
P. oederi Vahl†	Aporwat, 3900 m Kashmir	4290	–	30	4x	2n = 16, Knaben in Löve & Löve 1948
	Species from Europe studied by the author (B)					
Subfamily Antirrhinoideae Tribe Antirrhineae *Antirrhinum orontium* L. var. *nanum* Gaut.	Roussillon, East Pyrénées, France (Bot. Gard., Versailles)	–	–	16	2x	2n = 16, Heitz 1926, 1927b Tischler 1934 Larsen 1960b 2n = 14, Sobti & Singh 1961 n = 8, Verma & Dhillon 1967
Tribe Cheloneae *Scrophularia scopolii* Hoppe	Gran Sasso, 2250 m Italy (Prof. C. Favarger)	–	13	–	2x	2n = 26, Varaama & Hiirsalmi 1967
Scrophularia scopolii Hoppe	Monkovadolina, 1250 m Belanske, Tatry, Czechoslovakia (Bot. Gard., Komenskeho)	–	–	26	2x	see Table 6A, under the same species
S. nodosa L.	Bottelare, Palus, Belgium (Bot. Gard., Gent)	–	–	36	4x	2n = 36, Scheerer 1939 Löve & Löve 1944b Polya 1949 Löve A. 1954b Shaw 1962 Gadella & Kliphuis 1963
	Simplon Pass, 1400 m Alps, Switzerland	–	18	–	4x	Vide supra
S. umbrosa Dumort.	Angermund, Germany (Bot. Gard., Düsseldorf)	–	–	52	6x	2n = 26, Murin & Vachova 1967 2n = 52, Scheerer 1940
S. canina L.†	Gondo, Simplon Pass, 1300 m Alps, Switzerland	–	12	–	2x	2n = 22, 45, 51, 52, 54–58, ca. 112 Rodrigues 1956 2n = 26, Rodrigues 1953
Subfamily Rhinanthoideae Tribe Digitaleae *Wulfenia carinthiaca* Jack.	Karnische Alpen, Austria (Bot. Gard., Klagenfurt)	–	–	18	2x	2n = 18, Favarger & Huynh 1964
Veronica hederifolia L.	Degeberga, Skane, Sweden (Bot. Gard., Lund)	–	–	54	6x	2n = 54, 36, Nordenstam & Nilsson 1969 Fischer 1967
	Neuchâtel, Switzerland	–	18	–	4x	see Table 6A, under the same species
V. persica Poir.	Landskrona, Skane, Sweden (Bot. Gard., Lund)	–	–	28	4x	see Table 6A, under the same species
V. verna L.	Chaudes Aigues, 800 m Cantal, France (Bot. Gard., Versailles)	–	–	16	2x	see Table 6A, under the same species
V. serpyllifolia L.	Sur-les-Toules, 2000 m Valais, Switzerland (Bot. Gard., Geneva)	–	–	14	2x	see Table 6A, under the same species
	Jura de Neuchâtel, 750 m Switzerland	–	7	–	2x	
V. scutellata L.	Cuisery, Saône-et-Loire, France (Bot. Gard., Dijon)	–	–	18	2x	2n = 18, Scheerer 1939 Hagerup (Löve & Löve 1942b) 1944 Löve & Löve 1956b Gadella & Kliphuis 1963, 1966
V. chamaedrys L.	Neuchâtel, 750 m Jura, Switzerland	–	16	–	4x	2n = 16, Mattick in Tischler 1950 2n = 32, Simonet 1934d Löve & Löve 1944b, 1956b Sorsa 1962 Gadella & Kliphuis 1963, 1966
V. anagallis-aquatica L.	Saby, Skane, Sweden (Bot. Gard., Lund)	–	–	36	4x	2n = 36, Ehrenberg 1945 Löve & Löve 1956b
V. anagalloides Guss.	Salonta, Jud Behor Rumania (Bot. Gard., Cluj)	–	–	36	4x	2n = 36, Schlenker 1936
V. beccabunga L.	Bg-St-Pierre, 1700 m Valais, Switzerland	–	–	18	2x	see Table 6A, under the same species
Tribe Rhinantheae *Tozzia alpina* L.	Lagginthal, 1400 m Simplon Pass, Alps Switzerland	–	10	–	2x	2n = 20, Witsch 1932 Mattick in Tischler 1950
Euphrasia alpina Lam.	Schallberg, 1400 m Simplon Pass, Alps Switzerland	–	11	–	2x	2n = 22, Favarger 1969 n = 11, Yeo 1970
Euphrasia alpina Lam.	Furggstalden, 1900 m Alps, Switzerland (Prof. C. Favarger)	–	11	–	2x	
E. rostkoviana Hayne	Schallberg, 1400 m Simplon Pass, Alps Switzerland	–	11	–	2x	2n = 22, Witsch 1932 Yeo 1956 Holmen in Löve & Löve 1961
Pedicularis oederi Vahl	Gantrisch, 1690–1760 m Bern, Switzerland	–	–	16	2x	2n = 16, Knaben 1950 Hara 1956
P. rostrato-spicata Crantz *	Clausis-de-St-Véran, Hautes Alpes, France (Prof. C. Favarger)	–	–	16	2x	
P. rostrato-capitata Crantz	Schneeberg, 2070 m Östliche Kalkalpen, Austria (Bot. Gard., Vienna)	–	–	16	2x	2n = 16, Mattik in Tischler 1950
P. pyrenaica J. Gay	Massif du Puigmale, East Pyrénées, France (Bot. Gard., Liège)	–	–	16	2x	2n = 16, Küpfer & Favarger 1967
P. recutita L.	Turracher Berge, 2000–2400 m, Nockgebiet, Austria (Alpengarten in Belvedere, Vienna)	–	–	16	2x	2n = 16, Mattik in Tischler 1950
P. kerneri D.T.	Alpjr, 2300 m Simplon Pass, Switzerland	–	–	16	2x	2n = 16, Favarger 1959a

† A new chromosome report for the species
* Chromosome number of the species reported for the first time
** Genus worked out for the first time

Table 6C: Distinctive characters of morphological variants and cytotypes of *Veronica anagallis*

Characters	Tetraploid (n = 18) Variants A	Variants B	Variants C	Hexaploid (n = 27)
Locality and altitude	Tangmarg, 2100 m Kashmir	Tangmarg, 2100 m Kashmir	Kargil, 2500 m Ladakh, Kashmir	Surajpur, 350 m Chandigarh
Habitat	Marshy or wet places on river sides and ponds	Marshy or wet places on river sides and ponds	River sides or damp places	Marshy places, small streams or ponds
Habit	Erect and branched, alternate or opposite, more branches on upper region	Erect and branched, alternate or opposite, more branches on upper region	Erect, less branched	Opposite all over stem
Height	40–75 cm	35–75 cm	16–90 cm	30–70 cm
Hairiness	Hairy all over	Hairy all over	Less hairy	Lower region glabrous, upper sparsely hairy
Internodal length	4–7 cm	3,5–6,5 cm	6–12 cm	2–5 cm
Leaves (shape)	Sessile, pubescent, oblong, cordate	Sessile, pubescent, linear, lanceolate, acute	Oblong, lanceolate, serrate, hairy	Glabrous, sessile, lanceolate, entire, and in some cases, serrate
Length of lamina	3–6,5 cm	3–10 cm	3–6 cm	4,5–7,5 cm
Breadth of lamina	1,7–2,3 cm	1,2–2,1 cm	1,6–3,0 cm	1,7–2,2 cm
Length of inflorescence	15–22 cm	13–25 cm	5–12 cm Pedicels arising from the axil of leaves and branching again forming secondary spikes	15–22 cm
Average number of flowers on inflorescence of same length	30–35	35–40	20–30	35–40
Size of the flower (diam.)	0,4–0,5 cm	0,4–0,48 cm	0,35–	0,25–0,35 cm
Length of petiole	0,75–0.85 cm	0,6–0,8 cm	0,4–0,6 cm	0,3–0,55 cm
Colour of flower	purple-white	purple-white with red streaks on the petal	purple-white	white
Number of seeds per capsule	40–50	40–48	35–42	30–40
Size of stomata	28 x 24 μ	27 x 24 μ	26 x 23 μ	30 x 20 μ

Table 6D: Summary of distinguishing characters of *Scrophularia himalensis*

Characters	Diploid (n = 12)	Tetraploid (n = 24)
Locality and altitude	Kashmir (Sherwan), 2000 m	Nainital, 1900 m
Habitat	Open places between a range of 1700–2100 m	Shady places and on the walls of pedestrian tracks, at a range of 1900 m
Habit	Perennial, erect, mostly unbranched	Perennial, semi-erect and branched
Height in cm	60–300	60–150
Stem	Green, 1–1,5 cm diameter, with ridges	Light green, 0,2–0,4 cm diameter, almost round
Leaf shape	Lanceolate, crenate	Ovate, cordate
Length of petiole cm	1,0–1,5	1,5–4,0
Length of lamina cm	3–10	2–8
Breadth of lamina cm	2–7	2–8
Length and shape of inflorescence cm	50–120, unbranched, erect	20–50, branched
Intensity of flowers on inflorescence	More	Less
Length of pedicel cm	0,2–0,4	0,5–0,9
Diameter of flower cm	0,45–0,5	0,35–0,45
Length of style cm	0,85–0,9	0,9–1,1
Flower colour	Green	Green
Stomatal size	20 x 19 μ	28 x 24 μ

Table 6E: Comparison of karyograms from *Pedicularis* species (description of chromosomes after Levan *et al.*, 1964)

Species	N	M	m	sm	st	t	T	Figs
P. pectinata	8	–	–	5	3	–	–	107, 108
P. brevifolia	8	1	3	1	3	–	–	113, 114
P. pycnantha	8	–	2	4	2	–	–	115, 116
P. siphonantha	8	–	2	5	1	–	–	121, 122
P. carnosa	6	1	2	3	–	–	–	124, 125
P. gracilis	8	–	2	3	3	–	–	110, 111
P. pyramidata	8	–	–	1	5	2	–	128, 130
P. oederi (from Himalayas)	15	–	–	4	11	–	–	131A, 132
P. oederi (from the Alps)	8	–	–	7	1	–	–	133, 134
P. rostrato-capitata (from the Alps)	8	2	1	3	2	–	–	135, 136
P. pyrenaica (from the Pyrénées)	–	–	2	3	3	–	–	138, 139

In the genus *Solanum*, thirteen taxa including the cytological races of *Solanum nigrum* showed a gametic number 12 or its multiple. In the light of the large number of *Solanum* species studied chromosomally (see Bolkhovskikh *et al.*, 1969), predominance of the gametic number 12 undoubtedly indicates this number as the basic number of this genus. This agrees with Ellison (1936), but disproves Wancher (1934) who deduced the number 4 as the true basic number of the genus. Müntzing (1932–33) basing his opinion on the secondary associations in diploid species of *Solanum*, thought that the original basic number was 6 instead of 12, and he was followed by Löve and Löve (1961). If it was the case, the taxa with 2n = 36 would be hexaploids and not triploids. Meanwhile, von Olah (1938) showed that *Solanum commersonii* Dun. (2n = 36) has an irregular meiosis with trivalents and univalents. In the bybrid between the races of *Solanum nigrum* with 2n = 24 and 2n = 48, respectively, Tandon and Rao (1966) noticed meiotic irregularities such as in triploids with three different genomes. Therefore, it seems more likely that 12 would be the basic number for *Solanum*.

We noticed intraspecific polyploidy only in *S. nigrum* (n = 12, 24 and 36). This species has an eurasiatic distribution and is widespread in India. It occurs in plains and ascends up to 2700 m in mountains (Gulmarg). Three cytological races were collected from different places of W. Himalayas. The diploids (n = 12) (Fig. 60) are common in Nainital and Mussoorie; tetraploids (n = 24) (Fig. 61) from Kumaon and hexaploids (n = 36) (Fig. 62) from Gulmarg, Kashmir and Almora Kumaon, were observed. This intraspecific polyploidy is accompanied by morphological distinctiveness with regard to certain characters. The morphological features of these races([1]) are summarized in Table 5C. A hexaploid population noticed in Almora shows extraordinary gigantism. It grows up to about 7 feet and spreads around giving it a big bushy appearance. This form seems to be genetically fixed. The rest of the hexaploids are found to be small in size, comparatively.

The cytological races have been studied in detail by many authors. The main contributors are Jörgensen (1928), Bhaduri (1933, 1945, 1951), Nakamura (1937), Stebbins and Paddock (1949), Swaminathan (1949), Stebbins (1950), Gunther (1959), Magoon *et al.* (1962) and Tandon and Rao (1964 and 1966) (see taxonomic status of cytotypes in general discussion).

Even a genome analysis has been made (Tandon and Rao, 1966). As a result, the hexaploid race has a wider geographical distribution than the other races. The material from Europe investigated in the present work, also revealed the existence of the hexaploid race on this continent.

Another noticeable cytological aspect so far not described in *S. nigrum* is the presence of desynapsis in a tetraploid form of this species. At MI instead of pairing, most of the chromosomes remained as univalents (Fig. 63). Chromosomes were found to be scattered throughout the cytoplasm of PMC's at this stage. An average of 2 or 3 bivalents only were noticed in a large number of cells observed (Fig. 63). Separation of chromosomes at AI is unequal. Some chromosomes were found to be lagging. Non-congression and non-orientation of bivalents were frequent.

([1]) Fig. 168 shows the cytological races of *Solanum nigrum*.

At MII, no polarization of chromosomes was seen. At AII, lagging chromosomes were common (Fig. 64). At Telophase II, micronuclei numbering up to 7 were observed (Fig. 65). Monads, diads, triads and pentads were common as the end product of meiosis, instead of tetrads. Pollen grains varied in size and 97% were sterile. No seed set was observed on the plant. In fact, only 2 to 4 bivalents were observed at the stage of diakinesis and at MI, whereas the other chromosomes remained unpaired. This type of desynapsis may be assigned to the „medium strong" category of Prakken's classification (1943). A more or less similar phenomenon was observed in *Withania somnifera* Dun. (n = 24), a frequent plant in Punjab plains and outer Himalayas. Chromosome number counts at MI give n = 24 (Fig. 66). About 6 to 8 univalents are observed in every PMC's. Lagging chromosomes is noticed at AI and non-orientation of chromosomes is found in MII. Micronuclei, numbering up to 7 are found at Telophase II (Fig. 67). About 15% of pollen sterility is noticed. Thus, the chromosome pairing at MI is comparatively better than in *Solanum nigrum*. This may be attributed to the weak desynapsis suggested by Prakken (1943). Desynapsis has perhaps a genetical basis.

In *Datura innoxia* Mill., chromosomes at MI were found in the form of 2 or 3 chains, each having 4 to 6 bivalents (Fig. 69). Later stages of meiosis were also abnormal with the formation of laggards at AI and AII. In some PMC's, one additional chromosome was noticed (Fig. 68).

Physochlaina praealta (n = 41) is an alpine species met in Ladakh, Kashmir, in open places as small communities. It is not seen in other places of W. Himalayas. In this species, (Fig. 59) three tetravalents were noticed at MI in some PMC's. The rest of the meiosis was normal. The presence of tetravalents seems to indicate a remote autopolyploid origin.

Nicandra physaloides Gaertn. is native from Perou and is found in abundance as cultivated and quasi wild in subtropical Himalayas at a range between 900–1800 m. It is highly variable in its growth habit. Some individuals showed very small size of about half a foot of height, whereas, others are noticed with gigantic growth of about 6 feet of height and profused branching. Cytological studies revealed 10 bivalents (Fig. 58) at MI of meiosis. Plants with various growth habit are found to have the same chromosome number.

Though aneuploid series have not been encountered in *Solanaceae,* accessory chromosomes were reported in many species by different authors: Lesley and Lesley (1930) in *Lycopersicum esculentum,* Blakeslee (1931) in *Datura stramonium,* Rai (1949) in *Solanum melongena,* and Chennaveeraiah and Krishnappa (1965) in 6 species of *Solanum.* In the present investigation, one small accessory chromosome was noticed at AI in *Nicotiana plumbaginifolia* Viv. (Fig. 70), a genus in which this phenomenon was unknown. At the same stage in this plant, there are lagging bivalents. Partial sterility of pollen grains was observed. With the exception of four species, *Solanum nigrum, Withania somnifera, Nicotiana plumbaginifolia* and *Datura innoxia,* with aberrant meiosis, the others revealed normal meiosis.

Another significant finding is the lack of meiotic abnormalities noticed in the present work in diploid species of *Solanum,* contrarily to the findings of Krishnappa (1968). The species with meiotic aberrations mentioned by Krishnappa were found to have normal meiosis in the present material from W. Himalayas.

Under the few species of *Solanaceae* common to W. Himalayas and Europe, *Atropa belladonna* and *Hyoscyamus niger* have the same chromosome number in both regions. *Solanum nigrum* is represented in Europe as tetraploid (= *S. luteum)* and as hexaploid *(S. nigrum).*

After Tandon and Rao (1966a and b), the hexaploid was produced through amphidiploidy between diploid *S. nigrum* and a geographical race of *S. luteum.* Therefore, the origin of hexaploid *S. nigrum* seems to be found in regions where diploid *S. nigrum* grows, for example in W. Himalayas.

Scrophulariaceae

Scrophulariaceae is a large family consisting of 220 genera with 3000 species (Willis, 1966), distributed in all parts of the world. Hooker (1885) has described about 54 genera from the Indian subcontinent, comprising nearly 216 species out of which about 125 species are harboured in Himalayas alone. Hermann (1956) has reported 210 species of *Scrophulariaceae* in his Flora von Nord und Mitteleuropa, and Hegi (1914), 153 species from Central Europe.

In India, they grow from plain level to high alpine level of the Himalayan mountains. Some genera like *Striga, Pedicularis, Euphrasia, Melampyrum* and *Castilleja* are semiparasites growing on grass lands. The genus *Veronica* has got some members with xerophytic as well as aquatic habitat. Some species of *Scrophularia* also adapt well to dry xerophytic conditions. In addition to the intergeneric morphological specialization, intraspecific polymorphism is also a feature in some members of this family (*Veronica anagallis, Scrophularia himalensis,* etc.).

Wettstein (1895) classified this family into 3 subfamilies: *Pseudosolaneae, Antirrhinoideae* and *Rhinanthoideae.*

The most important contributions to the family *Scrophulariaceae* are from Bentham (1846) and Pennell (1943). Many genera of the family are treated separately by different workers. The taxonomic contributions of Stiefelhagen (1910) on *Scrophularia,* Bonati (1918), Prain (1890) and Hui Lin Li (1948) as well as Limpricht (1924) and Tsoong (1956) on *Pedicularis,* Yeo (1968) on *Euphrasia,* Römpp (1931), Lehmann (1941) and Fischer (1920) on *Veronica,* Soo (1927) on *Melampyrum,* Murbeck (1925) on *Celsia* and *Verbascum* (1933), Grant (1924) on *Mimulus* and Keck (1932–1945) on *Penstemon* are some of the praiseworthy contributions besides many other published works on this family.

Though a luxuriant population of *Scrophulariaceae* is present in India especially in the Himalayas, very little cytological work has been done on these plants. After the preliminary study of Raghavan and Srinivasan (1940b and 1941), Srinath (1934), Kumar and Abraham (1941), Iyengar (1937) and Simon and Lowing (1930), there was practically no attempt towards the cytology of Indian *Scrophulariaceae* until Pal (1961) and Khoshoo & Khushu (1966) studied the cytology of *Russelia* species and *Veronica anagallis,* respectively. Chromosome counts were made for some species by Sobti and Singh (1961), Verma and Dhillon (1967), Mehra and Gill (1968). A considerable amount of work on the cytology of *Scrophulariaceae* has been done in different parts of the world (vide Darlington & Wylie, 1955, and Bolkhovskikh *et al.,* 1969). Still the data are insufficient to draw definit conclusions regarding the cytological evolution of this family because of the considerable number of species involved.

The cytological results of the present author are recorded in Table 6.

Discussion

A total of 73 species are cytologically investigated in the family *Scrophulariaceae;* chromosome numbers of 36 species are reported for the first time. The genera *Lindenbergia* and *Leptorhabdos* were not cytologically studied till now. The lowest gametic number of the family recorded currently is n = 6 *(Pedicularis carnosa, Linaria bipartita)* and the highest number noticed is n = 36 for *Adenosma capitatum.* Chromosome size of the genera *Linaria, Leptorhabdos* and *Pedicularis* is comparatively larger in this family.

Pseudosolaneae

Verbascum thapsus L. is extensively populated in W. Himalayas from Kashmir to Kumaon between 1800 and 3200 m. It grows on exposed grassy slopes. The present chromosome count for this species (n = 18) is in line with the zygotic number 36 observed by Håkansson (1926), Mulligan (1961) and Packer (1964) but differs from another chromosome report by Håkansson: 2n = 34. Somatic chromosome numbers in this genus range from 30 to 66. Lawrence (1930) observed a regular polyploid series in the genus and considered 8 as the probable basic number. Both Darlington & Wylie (x = 15, 16 and 18) and Löve and Löve (x = 8, 9, 11, 15 and 17) suggested that *Verbascum* is polybasic. *V. thapsus* with n = 18 can be regarded as a diploid, but the basic number x' = 18 is probably a secondary one and suggests an old phenomenon of polyploidization.

Antirrhinoideae

The chromosome counts made on *Linaria bipartita* (n = 6), *L. dalmatica* (n = 6), *L. supina* (from Europe: 2n = 12) and *L. cymbalaria* (n = 7) agree with the findings of earlier authors. The present observation of n = 9 for *L. ramosissima* which confirms that of Verma and Dhillon (1967), gives an additional proof to the assumption of Valdès (1969) and of Viano (1971) that basic number 9 characterizes the section *Elatinoides.* The new chromosome report n = 18 for *L. subsessilis* indicates its polyploid condition at tetraploid or hexaploid level on a base number 9 or 6 (Fig. 71).

The gametic chromosome numbers of 2 species of *Antirrhinum* (*A. majus* (n = 8) and *A. orontium* (n = 8) studied here, are in line with the earlier reports except 2n = 14 reported by Sobti & Singh (1961) for *A. orontium.* The extensive phenotypic variability of common Snapdragon *(A. majus)* may be due to genic mutations.

The genus *Scrophularia* L. has three hundred species (Willis, 1966) of herbaceous habit distributed in the mountains of northern and temperate regions. Thirteen species are reported from India by Hooker, all being inhabitants of Himalayas. They ascend up to alpine level. Hermann has reported 11 species of *Scrophularia* from North and Central Europe. The wide distribution of *Scrophularia* species in America, Europe and Asia indicates beyond doubt the oldness of the genus.

S. obtusa Edgew. is very common in the Almora region of Western Himalayas but absent in Kashmir. It grows on open places, on roadsides. *S. scopolii* Hoppe was observed in Gulmarg forests near small streams and water channels. This species

was not found in the other parts of Western Himalayas surveyed by the author. It grows also in Central and Eastern Europe and in the Pyrénées. *S. edgeworthii* Benth. grows in abundance between 2500–2900 m in the mountains of Kumaon but was not observed in Kashmir. *S. himalensis* Royle is very widely distributed in the surveyed area from Kashmir to Kumaon at a range between 1700–2300 m. The taxon collected from Nainital reveals 24 bivalents at meiosis, (Fig. 76) whereas the plant from Kashmir has 12 bivalents. In both cases, meiosis is perfectly normal with normal bivalent (Fig. 77) formation. Pollen grains are well filled in both cases. Morphologically both taxa show a lot of differences. A table (6D) showing the salient phenotypic variation of both cytotypes (1) is given. *S. lucida* Linn. was commonly found at about 2000 m in Kashmir while it was very rare in the Kumaon region. *S. variegata* Bieb. is very common at alpine level of Kashmir but rare in the Eastern parts of Western Himalayas. It grows between 2500–3300 m of altitude. *S. dentata* Royle is met in Kargil (Kashmir). It grows on walls of open dry places. Leaves are considerably reduced to fit with xerophytic condition of Ladakh.

Chromosome numbers of *Scrophularia dentata* (n = 12), *S. edgeworthii* (n = 24 + 1B) (2), *S. obtusa* (n = 24) and *S. himalensis* (n = 24) are new reports in this genus. The gametic numbers n = 12 for *S. himalensis* and n = 24 for *S. variegata* are new reports for these species since they differ, respectively, from n = 10 (Mehra and Gill, 1968) and n = 12 (Shaw, 1962, and Vaarama and Hiirsalmi, 1967). The haploid chromosome number 13 of *S. lucida* agrees with that found by Shaw (1962) while *S. scopolii* with n = 24 differs from 2n = 26 reported for this species by Vaarama & Hiirsalmi (1967), and Murin and Vachova (1967). (Figs. 73, 74 for present count).

Small sized chromosomes and relatively high chromosome numbers of many species are general features of the genus *Scrophularia.*

Darlington & Wilie (1.c.) and Löve and Löve (1.c.) recorded the basic chromosome numbers x = 9, 10 and 13 for the genus *Scrophularia.* Vaarama and Hiirsalmi (1967) suggested two additional base numbers, x = 12 and x = 7. The latter number was already mentioned by Larsen (1960).

A confirmation of the existence of a basic chromosome number (x = 12) was given by observing gametic number 12 in *S. himalensis* and *S. dentata* collected from Kashmir. Further proof is brought by the finding in Kumaon, of a tetraploid taxon of *S. himalensis* (n = 24) on the basic number x = 12.

On the basis of x = 12 for the genus *Scrophularia,* only 5 out of 9 taxa studied from Western Himalayas are tetraploids. In this genus, after Carlbom (1969), the polyploidy seems to be directly responsible for migrational stimulus towards more inclement regions in the Northern hemisphere. It is worth mentioning that Stiefelhagen (1910) believed that the major centre of diversity and evolution of the genus was the Himalayan region. He classified the genus into two sections, *Tomiophyllum* and *Anastomosantes,* on the basis of leaf venation, and observed that the former section must be younger on account of its more restricted distribution. The species of the older section *Anastomosantes* have had time to expand and migrate to East

(1) Fig. 169 shows the cytological races of *S. himalensis.*

(2) One small accessory chromosome was observed in few PMC's, which may be a B chromosome. Further course of meiosis is regular.

Asia, Europe and North America; and these migrations were favoured by polyploidy (Carlbom op. cit., p. 300). The species currently studied from Western Himalayas and falling under *Anastomosantes,* group more polyploids than the *Tomiophyllum* section.

Section *Tomiophyllum*		Section *Anastomosantes*	
S. dentata	n = 12	*S. edgeworthii*	n = 24 + 1
S. lucida	n = 13	*S. himalensis*	n = 12, 24
S. variegata	n = 24	*S. obtusa*	n = 24
		S. scopolii	n = 24

If the assumption of Stiefelhagen is correct, the polyploid species from the section *Anastomosantes* actually growing in Eurasia and North America are *rather old polyploids.* But it seems likely too that the section *Tomiophyllum* could be the oldest. This latter hypothesis also gives a good explanation for the presence in Himalayas of several diploid taxa of *Scrophularia* sect. *Tomiophyllum.*

The evolution of the genus *Scrophularia* has been pursued till now by the formation of several neopolyploids, chiefly in the section *Anastomosantes.*

As a matter of fact, intraspecific polyploidy seems to be a rather frequent feature in *Scrophularia.* Vaarama and Hiirsalmi (1967) have reported two races (2n = 26 and 52) in *S. alata* (Gilib.) (= *S. umbrosa* Dum.). The gametic number 12 for *S. variegata* reported by Shaw (1962) and by Vaarama and Hiirsalmi (op. cit.) is not in line with the present author's count from plants of Western Himalayas (n = 24). Unfortunately, the exact origin of Vaarama's material is unknown (Bot. Garden of Copenhagen). Also, the authors's observations of a diploid (n = 12) and a tetraploid (n = 24) taxa in *S. himalensis* give further support to the role of intraspecific polyploidy. As regards the case of *S. scopolii,* the existence of two chromosome races (the diploid with 2n = 26 in Europe, and the hypotetraploid with n = 24 in Himalayas) is not entirely proved and it seems necessary to compare the voucher specimen from the Himalayan plants with samples from Europe. Gametic number 12 (Fig. 80) is a new report for *S. canina.*

Out of the two species of the genus *Mazus* studied here (Figs. 81, 82) chromosome number of *M. surculosus* (n = 10) is a new report, while *M. rugosus* (n = 20) agrees with the finding of Verma and Dhillon (1967). Since n = 10 is the lowest haploid number observed in this genus, x = 10 is considered as the basic number. The chromosome numbers present in *M. radicans* (n = 52) and *M. pumilio* with 2n = 38 (Hair & Beuzenberg, 1960) are an indication that chromosome evolution in genus *Mazus* has taken place through aneuploidy. However, after Index Kewensis, *Mazus radicans* was transferred in *Mimulus.*

The genus *Lindenbergia* has not been cytologically studied hitherto. The chromosome number of 3 species is, hence, reported here for the first time. Two basic numbers: x = 7 and x = 8 can be tentatively proposed for this genus, but the gametic number 25 speaks for an aneuploid alteration of the chromosome set. The two

species *L. grandiflora* and *L. macrostachya* are probably paleopolyploids, and *L. urticaefolia* a mesopolyploid. Again the perennial growth habit of *L. grandiflora* and *L. macrostachya* and the annual habit of *L. urticaefolia* point out the possibility of a recent origin for the latter. (See Figs. 83, 84, 85 for chromosome numbers).

Chromosome numbers of the marshy species *Limnophila roxburghii* (n = 18) and *Adenosma capitatum* (n = 36) are reported for the first time. The relatively high chromosome numbers of these species (Figs. 87, 86) probably point out again their polyploid nature (paleopolyploids). It is interesting to mention that in tropical or subtropical genera of *Scrophulariaceae,* such as *Limnophila, Adenosma* and *Lindenbergia,* one can observe only high secondary basic numbers, exactly as in the *Acanthaceae.*

In *Bacopa monniera* (L.) Wettst. (= *Herpestis monniera* H.B. and K.), the gametic chromosome number observed (n = 32) is perfectly in agreement with the report of Lewis *et al.* (1962), but it differs from the finding of n = 24 for this species, by Srinath (1934). In the Himalayan plants, 6–8 univalents were observed at MI (Fig. 88). Few laggards were noticed at AI. The fertility of pollen reached about 85%. In *Bacopa chamaedryoides* (H.B. & K.) Wettst. not yet cytologically studied, the gametic number is n = 10. (Fig. 89). This species was probably introduced from America, but grows as quasi wild in open grassy grounds at low altitudes. It is a diploid one with basic number 10, whereas *B. monniera* is probably a paleopolyploid belonging to another section of the genus *Bacopa.*

The chromosome number n = 16 of *Torenia cordifolia* is a new report (Fig. 90). Darlington and Wylie have recorded x = 8,9 as basic numbers and in this case, the taxon is at the tetraploid level.

The genus *Vandellia* is represented here by only one species: *V. nummularifolia* with n = 12 is a new report (Fig. 91). The documentation of 2n = 42 for *V. crustacea* (Raghavan, 1940) is a pointer to show the polyploid evolution in this genus. The present findings may suggest the possible occurrence of another basic number, x = 6, in this genus, besides x = 7 already recorded by Darlington and Wylie.

The chromosome number of two species of the genus *Bonnaya* namely, *B. brachiata* (n = 9) and *B. veronicaefolia* (n = 18), is reported for the first time. The basic number of this genus seems to be x = 9 and, on this basis, *B. veronicaefolia* is a tetraploid. The report of a large number of morphotypes (Hooker, l.c.) in *B. veronicaefolia* again emphasizes the active state of evolution of the species. (See Figs 92 and 93).

The small genus *Wulfenia* consists of 4 species, one in W. Himalayas and Afghanistan *(W. amherstiana),* one in Syria *(W. orientalis),* another in Albania *(W. baldaccii)* and the last one in the South-Eastern Alps and in Montenegro *(W. carinthiaca).* This extremely wide and disrupted distribution gives a proof of the genus' old age. According to Merxmüller (1962), *W. carinthiaca* is a relict species from the Tertiary. *W. amherstiana* is distributed from Kashmir to Kumaon at an altitude range of 2000–3000 m, especially in Nainital and Mussoorie regions. It grows on walls on roadsides. At AII of the meiosis, eight chromosomes are distributed on each pole. This number is in agreement with the previous workers' counts. Though *W. carinthiaca* was already studied by Favarger (1965) and by Fischer (1969), its cytological features were explored anew by the present author. The number is 2n = 18; two chromosomes of the somatic complement were found to be larger than the others. It is astonishing that the Himalayan and the Alpic species, which seem to be true

vicarious species, do not have the same chromosome number. However, both are diploids. Perhaps these species, geographically separated for a very long time, have endured a divergent chromosomal evolution through such events as translocations with loss or gain of 1 chromosome. It does not hinder to consider both as schizo-endemic taxa (Favarger and Contandriopoulos, 1961).

Out of the 15 species of *Veronica* studied both from Himalayas and Europe in the course of this investigation, chromosome number of *V. cana* (n = 26), and *V. ciliata* (n = 8) are documented for the first time. In this genus, the lowest chromosome number observed in the region surveyed by the author is n = 7 *(V. polita, V. serpyllifolia)* and the highest number, n = 27 *(V. anagallis).* In every case, regular bivalent formation and normal meiosis were noticed. Chromosome size is comparatively small in all the species.

Veronica is a polybasic genus, showing an even more complicated cytological evolution than the genus *Scrophularia.* Darlington & Wylie (1.c.) have recorded x = 7, 8, 9, x_2 = 15, 17 and x_3 = 26 as basic numbers, while Löve and Löve (1961) suggested x = 7, 8, 9, 13(?) and 17. Wanscher (1934) opined that in this genus, a 8 series exist from which the other numbers evolved through aneuploidy. He believed that in *Veronica,* there was a descending series 8–7, in basic chromosome numbers.

In Western Himalayas, species representing the three primary basic numbers, x = 7, 8 and 9 have been found, besides species with n = 23 and n = 26, which seem to be secondary polyploids.

The counts of chromosomes in *Veronica polita* Fr. and *V. biloba* L. are in agreement with those of the earlier authors on material from Europe and Japan *(V. polita)* and from India (*V. biloba,* cf. Lehmann, 1940).

Veronica ciliata Fisch. is an annual plant growing at high altitudes; it was found in isolated groups, in exposed alpine mountain peaks of Kashmir between 3300–3800 m. At AI of meiosis, 8 chromosomes can be seen at each pole (Fig. 94). Römpp (1931) has placed this species in the *Beccabunga* section, but he said that it had been set by Ledebour in the *Pentasepalae.* The present author believes that the chromosome number n = 8, which does not exist in the section *Beccabunga,* but is very frequent in the *Pentasepalae,* allows to transfer *V. ciliata* to the section *Pentasepalae.* Moreover, the plant seems to have 5 sepals!

Veronica laxa is a conspicuous species with blue coloured flowers found in Kashmir and Phurkia in Kumaon. The gametic number n = 23 already counted by Yamazaki (1936) is surprising in the *Multiflorae* group, to which belong for example, *V. chamaedrys* (n = 16[1]) and n = 8, see Fischer, 1970) and *V. melissifolia* n = 21 (Afanisiyeva and Meschkowa, 1961). The number n = 23 can proceed from n = 24 through aneuploidy; the gametic number of *V. melissifolia* needs to be confirmed. On the other hand, a possible evolution of a species with n = 23 from ancestors with n = 16 and n = 7 is conceivable. *V. cana* was met near the Pindari glaciers as well as in the Kedarnath mountains in Kumaon. It was totally absent from Kashmir. The gametic number n = 26 is unusual in the genus *Veronica.*

(1) The number n = 16 was confirmed by the author on plants growing in the Jura mountains, near Neuchâtel.

As *V. montana* and *V. scutellata,* from the same group, both have x = 9, it is likely that *V. cana* is a hypohexaploid. (Fig. 100).

The chromosome number of *V. serpyllifolia, V. persica, V. verna* and *V. beccabunga* from different localities in Europe, is in agreement with the chromosome counts of the same species from Himalayas.

Like many other species of *Veronica, V. hederifolia* also forms a polyploid complex with an Eurasiatic distribution. The present observations of chromosome number on plants from Europe, agree with the finding by Nordenstam and Nilsson (1969) of a (Fig. 99) hexaploid (2n = 54) besides a tetraploid race of *V. hederifolia* (2n = 36) in Scandinavia. The tetraploid race is found in (Fig. 98) Switzerland too. The current observations of a diploid race (n = 9) in Western Himalayas are in line with Fischer's count (1967) in a population from Pakistan. As Nordenstam and Nilsson (1969) could not establish a good correlation between morphological characters and ploidy level, they treated the two main taxa from Scandinavia as subspecies: ssp. *hederifolia* (2n = 54) and ssp. *lucorum* (2n = 36). Fischer (1967) proceeded to search for morphological characters distinguishing the cytotypes. His findings led him to determine five taxa, to which he gave the rank of species. In Western Himalayas, *V. hederifolia* occurs in exposed places in Kasauli, in outer Himalayas and in the Kashmir valley under the shade of coniferous trees. The plants of Kashmir are bigger than the samples from Kasauli, but these populations are diploid with n = 9 (Fig. 97). Fischer's separation of a Himalayan taxon (2n = 18) as a new species, *V. hederoides,* seems to be more realistic on account of the morphological features and the different chromosome number, which hold the Himalayan populations apart from the tetraploid and hexaploid taxa. A map of the distribution of the taxa from this group was given by Fischer (op. cit.). It can be supposed that the whole complex has an Asiatic (perhaps Himalayan) origin. But now, some diploid populations *(V. triloba)* are found in Europa too.

V. anagallis Linn. sensu lato is one of the most common species in the genus *Veronica.* It occurs frequently in Punjab plains, Kumaon and Kashmir in India, where it ascends to 2700 m. The populations found in Kashmir differ from other populations of the species in several morphological characters. The meiotic study shows that plants growing in the Kashmir valley are tetraploids (n = 18) (Fig. 96), while the plants in the Punjab plains as well as Nainital are hexaploids (n = 27) (Fig. 95). Among the tetraploids, morphological variants could be observed. A chart (Table 6C) comprising morphological features of cytological races(1) and morphotypes among them, is given.

The current observations are in complete agreement with those of Khoshoo and Khushu (1966) who have detected for the first time in India, two cytotypes of *V. anagallis:* a tetraploid one, in Kashmir, and a hexaploid one in the Punjab plains. Moreover, striking morphological differences were found by the present author between the various populations of the tetraploid in Kashmir. Some of these variants grow in the same habitat side by side with the normal tetraploids, which rules out the possibility of their ecological specialization. Since the differences seem to be genetically fixed, they can be due to structural changes or to genic

(1) Figs 170 and 171 show the cytological races and varieties among tetraploids of *V. anagallis.*

mutations. One of these variants, with long narrow leaves, could belong to *V. anagalloides*. This last taxon was found to be diploid by Schlenker (1936) and by Afanisiyeva and Meschkowa (1961) (see Bolkhovskikh *et al.*), but Meschkova (1965) reported a tetraploid too, likewise a plant from Rumania studied by the present author (see Table 6B). As shown by Khoshoo and Khushu, all the cytotypes of the *V. anagallis* complex in Western Himalayas seem to be allopolyploid on account of their regular meiosis without multivalents, which was confirmed by the present author. Khoshoo and Khushu supposed that one ancestor of the hexaploid race should be a plant „with more or less lanceolate type of blad". It is likely that the tetraploid narrow leaved population from Kashmir which perhaps belongs to *V. anagalloides,* is one ancestor of the hexaploid race from Punjab. More work is needed before one can obtain a clear picture of the whole complex in W. Himalayas and of its relation with European populations. Until now, the distribution of the hexaploid race of *Veronica anagallis* is limited to North-Western India.

The process of reduction in floral parts of *Veronica* is still in progress today, with the result that many species must be in an unstable state. The frequency of intraspecific polyploidy, the great number of species complexes with incomplete separation of the taxa, all this points out the active state of evolution in which the genus *Veronica* is involved.

The genus *Leptorhabdos* is cytologically investigated for the first time. *L. benthamiana* (n = 7) is the only species (Fig. 103) observed in the area of the present investigation. The basic number x = 7 can be assigned to the genus. *Buchnera hispida* (Fig. 102) with n = 14 is also a new report. This species is a tetraploid on basic number x = 7, whereas *B. americana* (2n = ca. 42) is a hexaploid.

Lagotis glauca Gaertn. is an Arctic Alpine species distributed in mountains from Central and North Asia, and Arctic Asia and America, but not in Europe. This small herb is noticed on the mountains of Kashmir above 3300 m from sea level, on exposed slopes. Haploid chromosome number is determined as n = 11 at AI with equal distribution of chromosomes on either pole (Fig. 101). Chromosome size is small. The same number has been counted by earlier authors on Japanese and Siberian material (see Bolkhovskikh *et al.*).

The genus *Euphrasia* L. was intensively studied in Europe and splitted into many microspecies with narrow ranges of distribution. Hooker has reported one species from temperate Himalayas. Another one was described more recently by Pennell.

E. officinalis occurs in temperate Himalayas from Kashmir to Kumaon between an altitudinal range of 2100–3600 m. Fig. 104 shows 22 bivalents at MI of meiosis. The chromosome size is small. This species is tetraploid on basic number x = 11. In comparison with *Euphrasia rostkoviana* from the Alps (n = 11), the plants from W. Himalayas are taller (20–40 cm high).

E. platyphylla Pennell is a small herb of hardly 5–8 cm, growing in abundance in the alpine meadows of Khilenmarg and nearby Lianmarg regions of Kashmir, at an altitude of about 3300 m. Chromosome number has been ascertained as n = 22 at AI. (In the Fig. 105 the two plates of anaphase were brought in the same plane by squashing). This tetraploid species seems to be endemic to W. Himalayas. According to Yeo (1956), the evolution of the genus *Euphrasia* proceeded in part through polyploidy, in part through hybridization, between diploids and tetraploids too, which allows some degree of introgression. Some recombinants of the very

variable progeny can grow in new habitats to which they become narrowly adapted. Such a phenomenon was not studied until now in Himalayas. Fig. 106 shows n = 11 for *E. alpina* from the Alps.

The genus *Pedicularis* L. is one of the largest genus of the family *Scrophulariaceae* with beautiful flowers of pink, pale violet, white or yellow colours. It belongs to the Arctic-Alpine flora and consists of about 600 species (Sprague, 1962), both annuals and perennials. Almost half of the species (282) are confined to China (Hui Lin Li, 1948). Hooker (1885) has reported 37 species of *Pedicularis* from India, of which 35 are distributed in the Himalayas and 2 species on the Nilgherry Hills, in the south of India. This genus with a wide geographical distribution is characterized by a high amount of endemism. Prain (1890) reported for example, 52.5% of endemic *Pedicularis* in the circumpolar „province", 89% in the Himalayan province and 85% in Europe. In the Alps, about 20 species are growing as orophytes, of which 42% are endemic. (Favarger, oral communication).

This semiparasitic genus „exhibits a variety of corolla forms that may be unparalleled in any other genus" (Sprague, 1962). The flowers, like those of all members of the tribe *Euphrasiae,* are among those most highly specialized for insect pollination.

As pointed out by Sprague (1962), the species of „Bombus" are principal pollinators. Corollas are of various size to suit the size of different pollinators as *Lepidoptera* and humming birds. Prain (1890) in his monograph on *Pedicularis* has considered the yellow colour and the absence of a beak on corolla as more archaic characters. Hui Lin Li (op. cit.) believed that the alternate leaves are more advanced than the opposite or verticillate arrangement.

Fourteen species from W. Himalayas and five species from Europe were cytologically studied in the course of this investigation. In eleven cases, an idiogram could be established based on pollen mitosis or on dividing cells of root tips made available by germinating seeds in the laboratory.

The cytological data are reported on Table 6A & B and Table 6E. Course of meiosis is regular in all the cases, with the exception of *P. megalantha.* In this species, transfer of chromatin material from one pollen mother cell to the neighbouring one was observed (Fig. 118, 119). As a result of this cytomixis, some PMC's are observed with less chromosomes while the others possess more than the normal haploid set. Subsequent stages of meiosis showed irregular behaviour such as laggards at AI and micronuclei at telophase, culminating in polyads and sterility of pollen as the end product of meiosis. Perhaps the plant investigated was a hybrid. In *P. rhinanthoides,* an anaphase bridge is clearly seen in a PMC, but the meiotic course is found to be undisturbed. (Figs. 126, 127).

The chromosome number of 9 species from the Himalayas and 1 from Europe are new reports. The other counts are in agreement with those of earlier authors with the exception of *P. oederi* (Himalayan material). In the last species, the number 2n = 16 was ascertained by several workers and was confirmed by the present author on plants from the Swiss Alps. The plant from Kashmir (Fig. 131) revealed the somatic number 2n = 30 which could have arisen through aneuploidy (32→30). However, in looking at the idiogram, one can observe rather striking differences between the Alpic plant and the Himalayan one, the latter having eleven pairs of chromosomes with a subterminal centromere while the former had only one pair. This case needs further investigations to know if the plant from Kashmir had perhaps

arisen through hybridization between the normal cytotype (n = 8) and another very different cytotype of *P. oederi* with n = 7.

The great majority of Pedicularis species cytologically investigated till now possess the basic number n = 8. Favarger (1953) discovered the basic number n = 6 in *Pedicularis verticillata.* This number is represented in *P. carnosa* from the Himalayas too. Moreover a gametic number n = 7 became evident according to the present investigations. It characterized *P. bicornuta* and *P. macrantha* (1). Therefore, it seems logical to attribute to the genus *Pedicularis* the basic numbers x = 6, 7 and 8. Polyploidy is very unfrequent in *Pedicularis:* three cases were reported in Bolkhovskikh *et al.,* to which the report of *P. oederi* from Kashmir can be added. See Figs 109, 112, 137 for new chromosome reports.

The relatively large size of the chromosomes was already mentioned: this gives the opportunity to study the karyotype.

Each species seems to be characterized by a special karyotype but in such cases as *P. pectinata, P. brevifolia* and *P. siphonantha,* the idiograms are rather similar. The karyotype of *P. carnosa,* having only chromosomes with median or submedian centromere, is more symmetrical and perhaps gives the proof of the archaic character of the species belonging to the *Rhyncholophae* (2). On the contrary, *P. pyramidata* seems to be more advanced on account of its karyotype showing a majority of subtelocentric and acrocentric chromosomes. It belongs to the more advanced section *Orthorrhynchae.*

As regards *P. oederi,* the karyotype of the plants from Kashmir is very asymmetrical but this feature can proceed from a recent event, and the karyogram of the Swiss plant is more like those of other species with chromosomes more or less symmetrical. If *Pedicularis carnosa* (n = 6) and *P. verticillata* (n = 6; *Anodontae*) are relatively archaic species, it is not unlikely to suppose that the basic number 6 is the oldest in the genus.

As to the origin of the genus, the opinion of the authors are greatly divergent. Prain (op. cit.) and more recently Tsoong (1956) thought it originated from the Arctic region, and migrated along some meridians, at the end of the Tertiary and showed a striking, mostly divergent, evolution in the mountains of the southern parts of the Northern Hemisphere. On the other hand, Limpricht (1924) believed that the mountains of Central Asia (Altaï and Sayan) are the center of origin, and Hin-Lin-Li (op. cit.) was of the same opinion.

The presence of a large amount of species in the Himalayan and Chinese provinces, the existence of species with x = 6, 7 and 8 in the Himalayas and of some types bearing a primitive karyotype perhaps bring some support to the hypothesis of a Central Asiatic origin.

(1) In the latter species, the presence of seven bivalents at meiosis is not entirely proved. (Fig. 117).
(2) Size of chromosomes is larger in *P. carnosa* than in the other species (3,3 μ for the shortest and 5,8 μ for the longest).

Summary

Cytological studies on species of *Boraginaceae, Verbenaceae, Solanaceae,* and *Scrophulariaceae* from the Western Himalayas and from Europe are presented. Some chromosome numbers were determined for the first time; others differed from earlier determinations. Intraspecific polyploidy was observed in *Solanum nigrum* (n = 12, 24, 36), *Scrophularia himalensis* (n = 12, 24) and *Veronica anagallis* (n = 18, 27) in populations from W.Himalayas. Our own observations joined to those of various authors showed the existence of chromosome races in other species from the Himalayas or from India.

In several species growing in the Himalayas as well as in Europe (especially in the Alps) the chromosome number is the same in both regions (e.g. *Atropa belladonna, Veronica serpyllifolia, V. persica*). In some other cases the Himalayan taxon is diploid whereas the corresponding taxon (or the same species) in the Alps is polyploid (*Asperugo procumbens, Lycopsis arvensis, Veronica* grex *hederifolia*); in a few other groups the opposite situation was found *(Pedicularis oederi, Scrophularia scopolii).* In *Phryma leptostachya,* the Himalayan population is diploid whereas those from North America and Japan are (in part) polyploid.

The intrageneric cytological evolution of all genera studied was tentatively explained (see discussion of the families). An analysis of the karyotype in *Pedicularis* (with comparatively large chromosomes) was made and the cytological basis of species evolution discussed. New basic numbers (x) were suggested for many genera. The bibliography will be given at the end of the series.

Zusammenfassung

Cytotaxonomische und cytogeographische Untersuchungen an Pflanzen aus dem Himalaya im Vergleich zu verwandten Pflanzen aus den Alpen. Teil II.

Aus den Familien der *Boraginaceae, Verbenaceae, Solanaceae* und *Scrophulariaceae* wurden zahlreiche Arten aus dem westlichen Himalaya und aus den Alpen cytologisch untersucht. Manche Chromosomenzahlen wurden erstmals bestimmt; andere waren von früheren Bestimmungen verschieden. Intraspezifische Polyploidie wurde bei *Solanum nigrum* (n = 12, 24, 36), *Scrophularia himalensis* (n = 12, 24) und *Veronica anagallis* (n = 18, 27) aus dem Himalaya beobachtet. Eigene Beobachtungen und solche anderer Autoren zeigten das Vorkommen von Chromosomenrassen bei anderen Arten aus dem Himalaya und Indien.

Bei verschiedenen Arten, die im Himalaya und in Europa (v.a. in den Alpen) vorkommen, ist die Chromosomenzahl in beiden Regionen gleich (z.B. *Atropa belladonna, Veronica serpyllifolia, V. persica*). In anderen Fällen ist die Art aus dem Himalaya diploid und die gleiche oder entsprechende Art aus den Alpen polyploid (*Asperugo procumbens, Lycopsis arvensis, Veronica* grex *hederifolia*); andere Arten verhalten sich

umgekehrt *(Pedicularis oederi, Scrophularia scopolii). Phryma leptostachya* aus dem Himalaya ist diploid; die Populationen aus Nordamerika und Japan sind teilweise polyploid.

Die intragenerische cytologische Entwicklung wird diskutiert (siehe Diskussion der Familien). In der Gattung *Pedicularis* (mit relativ grossen Chromosomen) wird der Karyotyp analysiert und die cytologischen Grundlagen der Artbildung diskutiert. Für mehrere Gattungen werden neue Grundzahlen (x) vorgeschlagen. Die Literatur wird am Ende der Reihe zusammengestellt werden.

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Fig. 34: Cuscuta lupuliformis Krock. 2n = 28 MI.
Fig. 34A: Cuscuta lupuliformis Krock. 2n = 28 idiogram.
Fig. 35: Cuscuta alba Presl. n = 15 Diakinesis.
Fig. 36: Cynoglossum furcatum Wall. n = 12 MI.
Fig. 37: Cynoglossum lanceolatum Forsk. n = 12 Late Diakinesis.
Fig. 38: Cynoglossum wallichi G.Don n = 12 MI.
Fig. 39: Cynoglossum microglochin Benth. n = 12 MI.
Fig. 40: Cynoglossum nervosum Benth. n = 12 MI.
Fig. 41: Cynoglossum nervosum, showing one bivalent lying away from metaphase plate.
Fig. 42: Cynoglossum petiolatum A. DC n = 12 Late Diakinesis.

Fig. 43: Lindelofia angustifolia Brand. n = 12 MI.
Fig. 44: Paracaryum glochidiatum Benth. n = 12 MI.
Fig. 45: Lappula microcarpa (Ledeb.) Gürke n = 11 Diakinesis.
Fig. 46: Lappula reflexa Garcke 2n = 48 MI.
Fig. 47: Eritrichium strictum Dcne. n = 12 MI.
Fig. 48: Asperugo procumbens L. 2n = 48 MI.
Fig. 49: Mertensia exserta I.M.Johnston n = 11 MI.
Fig. 50: Myosotis caespitosa Schultz n = 44 MI.
Fig. 51: Lithospermum arvense L. 2n = 42 MI.
Fig. 52: Lithospermum arvense L. (W.Himalayas) n = 18 Late Diakinesis.
Fig. 53: Onosma echioides L. n = 7 MI.
Fig. 54: Onosma emodi Wall. n = 9 Late Diakinesis.

Fig. 55: Lycopsis orientalis L. n = 8 MI.
Fig. 56: Nonnea caspica G.Don. n = 8 Diakinesis.
Fig. 57: Callicarpa longifolia Lamk. n = 18 MI.
Fig. 58: Nicandra physaloides Gaertn. n = 10 MI.
Fig. 59: Physochlaina praealta Miers n = 41 MI. See the quadrivalents.
Fig. 60: Solanum nigrum L. n = 12 MI.
Fig. 61: Solanum nigrum L. n = 24 MI.
Fig. 62: Solanum nigrum L. n = 36 MI.

Fig. 63: Solanum nigrum L. n = 24 revealing univalents at MI.
Fig. 64: Solanum nigrum L. n = 24 showing lagging chromosomes at Anaphase II.
Fig. 65: Solanum nigrum L. n = 24 showing 8 micronuclei (1600x).
Fig. 66: Withania somnifera Dunal. n = 24, many univalents are seen at MI.

Fig. 67: Withania somnifera Dunal. n = 24 show 9 chromatin groups at telophase II.
Fig. 68: Datura innoxia Mill. Amixed telophase II shows 24 + I Chromosomes.
Fig. 69: Datura innoxia Mill. n = 12, shows 2 ring bivalents of 3 each and one ring of three chromosomes.
Fig. 70: Nicotiana plumbaginifolia Viv. n = 10, shows one additional chromosome at AI.
Fig. 71: Linaria subsessilis Pennell n = 18 Diakinesis.
Fig. 72: Scrophularia obtusa Edgew. n = 24 AI.

Fig. 73: Scrophularia scopolii Hoppe (W.Himalayas) n = 24 MI.
Fig. 74: Scrophularia scopolii Hoppe n = 13 Diakinesis.
Fig. 75: Scrophularia edgeworthii Benth. n = 24 + 1 MI.
Fig. 76: Scrophularia himalensis Royle n = 24 MI.
Fig. 77: Scrophularia himalensis Royle n = 12 MI.
Fig. 78: Scrophularia variegata Bieb. n = 24, some bivalents are secondarily associated.
Fig. 79: Scrophularia dentata Royle n = 12 MI.

Fig. 80: Scrophularia canina L. n = 12 AI.
Fig. 81: Mazus rugosus Lour. n = 20 MI.
Fig. 82: Mazus surculosus D.Don. n = 10 MI.
Fig. 83: Lindenbergia grandiflora Benth. n = 14 Diakinesis.
Fig. 84: Lindenbergia macrostachya Benth. n = 16 MI.
Fig. 85: Lindenbergia urticaefolia Lehm. n = 25 MI.
Fig. 86: Adenosma capitata Benth. n = 36 MI.
Fig. 87: Limnophila roxburghii G.Don n = 18 Diakinesis.
Fig. 88: Herpestis monniera HB and K. n = 32 MI, four to six univalents are observed.
Fig. 89: Herpestis chamaedryoides HB and K. n = 10 MI.

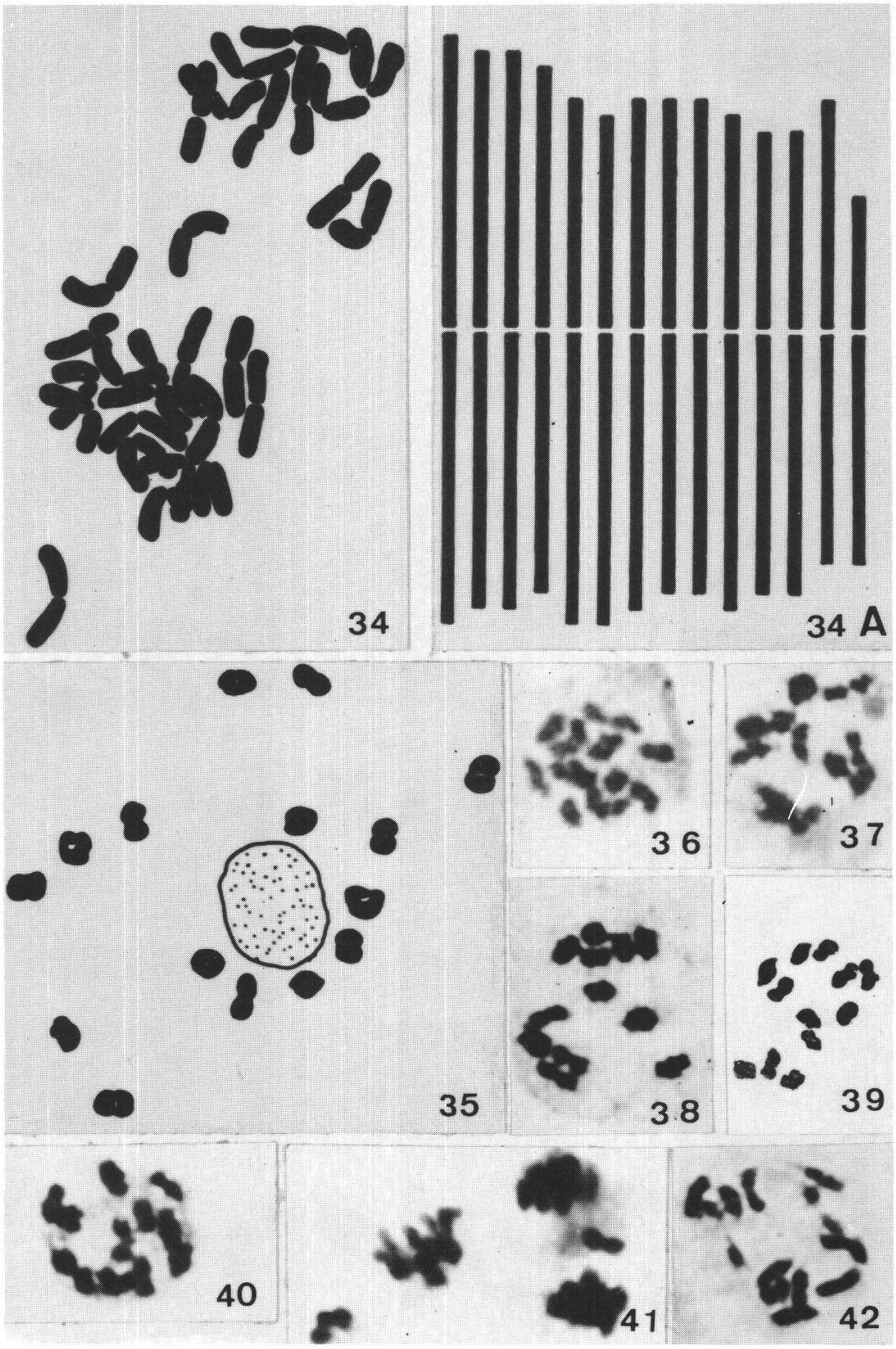
Fig. 90: Torenia cordifolia Roxb. n = 16 MI.
Fig. 91: Vandellia nummularifolia D.Don n = 12 MI.
Fig. 92: Bonnaya brachiata Link and Otto n = 9 MI.
Fig. 93: Bonnaya veronicaefolia Spreng. n = 18 MII.
Fig. 94: Veronica ciliata Fisch. n = 8 AI.
Fig. 95: Veronica anagallis L. n = 27 MI.
Fig. 96: Veronica anagallis L. n = 18 MI.
Fig. 97: Veronica hederifolia L. n = 9 AI (one pole only).
Fig. 98: Veronica hederifolia L. (Europe) n = 18 AI.
Fig. 99: Veronica hederifolia L. (Europe) 2n = 54 MI.

Fig. 100: Veronica cana Wall. n = 26 Diakinesis.
Fig. 101: Lagotis glauca Gaertn. n = 11 AI (one pole only).
Fig. 102: Buchnera hispida Ham. n = 14 MI.
Fig. 103: Leptorhabdos benthamiana Walp. n = 7 MI.
Fig. 104: Euphrasia officinalis L. n = 22 MI.
Fig. 105: Euphrasia platyphylla Pennell n = 22 Mixed anaphase I.
Fig. 106: Euphrasia alpina Lam. n = 11 AI.
Fig. 107, A: Pedicularis pectinata Wall. 2n = 16 MI.
Fig. 108: Pedicularis pectinata Wall. 2n = 16 MI (idiogram).
Fig. 109: Pedicularis tenuirostris Benth. n = 8 MI.

Fig. 110: Pedicularis gracilis Wall. 2n = 16 MI.
Fig. 111: Pedicularis gracilis Wall. 2n = 16 idiogram.
Fig. 112: Pedicularis porrecta Wall. n = 8 MI.
Fig. 113: Pedicularis brevifolia D.Don. 2n = 16 MI.
Fig. 114: Pedicularis brevifolia D.Don. 2n = 16 idiogram.
Fig. 115: Pedicularis pycnantha Boiss. n = 8 (pollen mitosis)
Fig. 116: Pedicularis pycnantha Boiss. n = 8 idiogram.
Fig. 117: Pedicularis macrantha Klotzsch n = 7 (?) MI.
Fig. 118: Pedicularis megalantha Don. n = 8 MI.
Fig. 119: Pedicularis megalentha Don. n = 8 showing cytomixis.

Fig. 120: Pedicularis bicornuta Klotzsch n = 7 MI.
Fig. 121: Pedicularis siphonantha D.Don. 2n = 16 MI.
Fig. 122: Pedicularis siphonantha D.Don 2n = 16 idiogram.
Fig. 123: Pedicularis carnosa Wall. n = 6 Diakinesis.
Fig. 124: Pedicularis carnosa Wall. 2n = 12 MI.
Fig. 125: Pedicularis carnosa Wall. 2n = 12 idiogram.
Fig. 126: Pedicularis rhinanthoides Schrenk n = 8 MI.
Fig. 127: Pedicularis rhinanthoides Schrenk n = 8 showing bridge formation at AI.
Fig. 128: Pedicularis pyramidata Royle 2n = 8 MI.
Fig. 129: Pedicularis pyramidata Royle 2n = 16 MI.
Fig. 130: Pedicularis pyramidata Royle 2n = 16 idiogram.
Fig. 131, 131A: Pedicularis oederi Vahl (W.Himalayas) 2n = 30 MI.

Fig. 132: Pedicularis oederi Vahl 2n = 30 idiogram.
Fig. 133: Pedicularis oederi Vahl (Europe) 2n = 16 MI.
Fig. 134: Pedicularis oederi Vahl (Europe) 2n = 16 idiogram.
Fig. 135: Pedicularis rostrato-capitata Crantz 2n = 16 (3000 x).
Fig. 136: Pedicularis rostrato-capitata Crantz 2n = 16 idiogram.
Fig. 137: Pedicularis rostrato-spicata Crantz 2n = 8 (3000 x).
Fig. 138: Pedicularis pyrenaica J.Gay 2n = 16 (3000 x).
Fig. 139: Pedicularis pyrenaica J.Gay 2n = 16 idiogram.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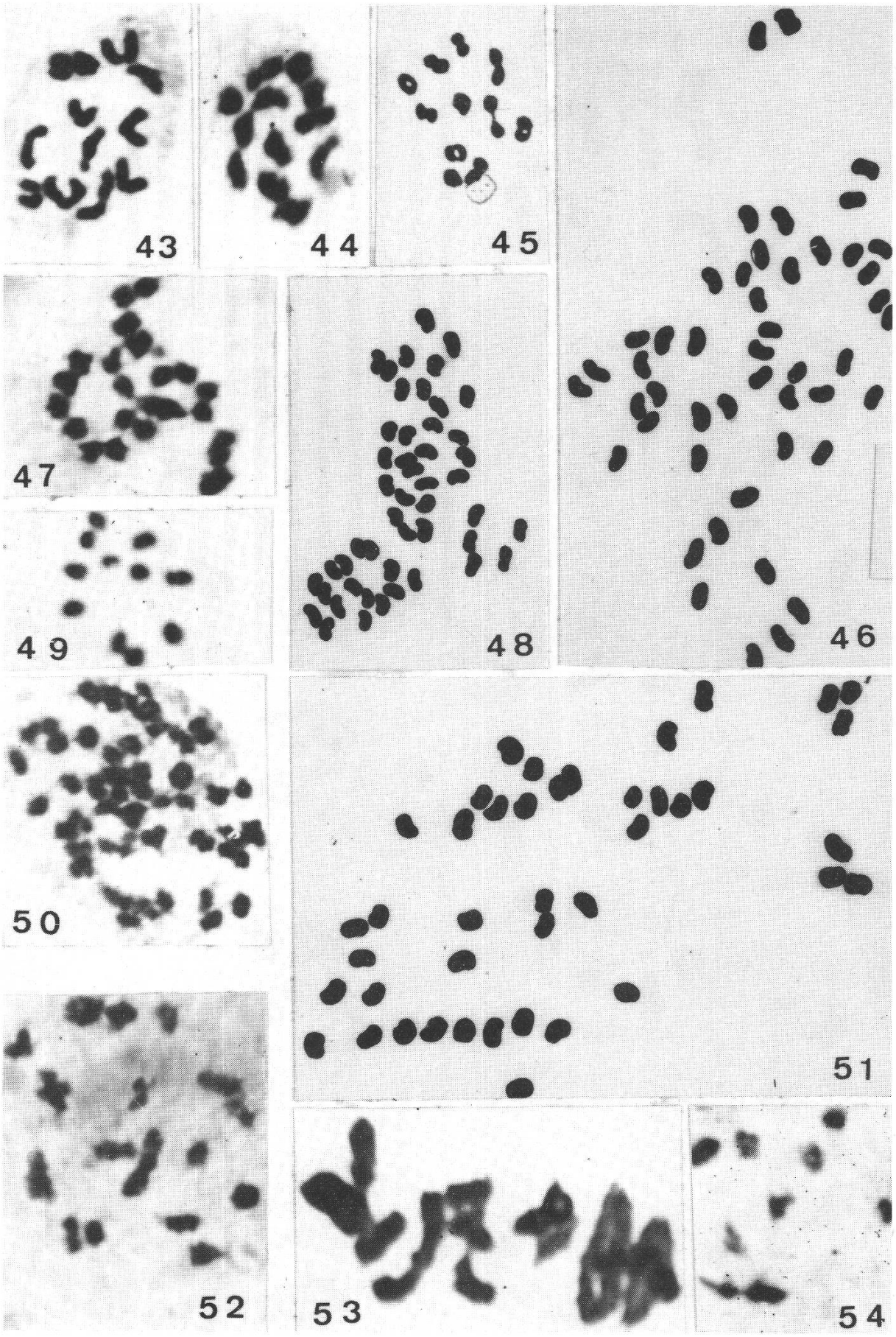
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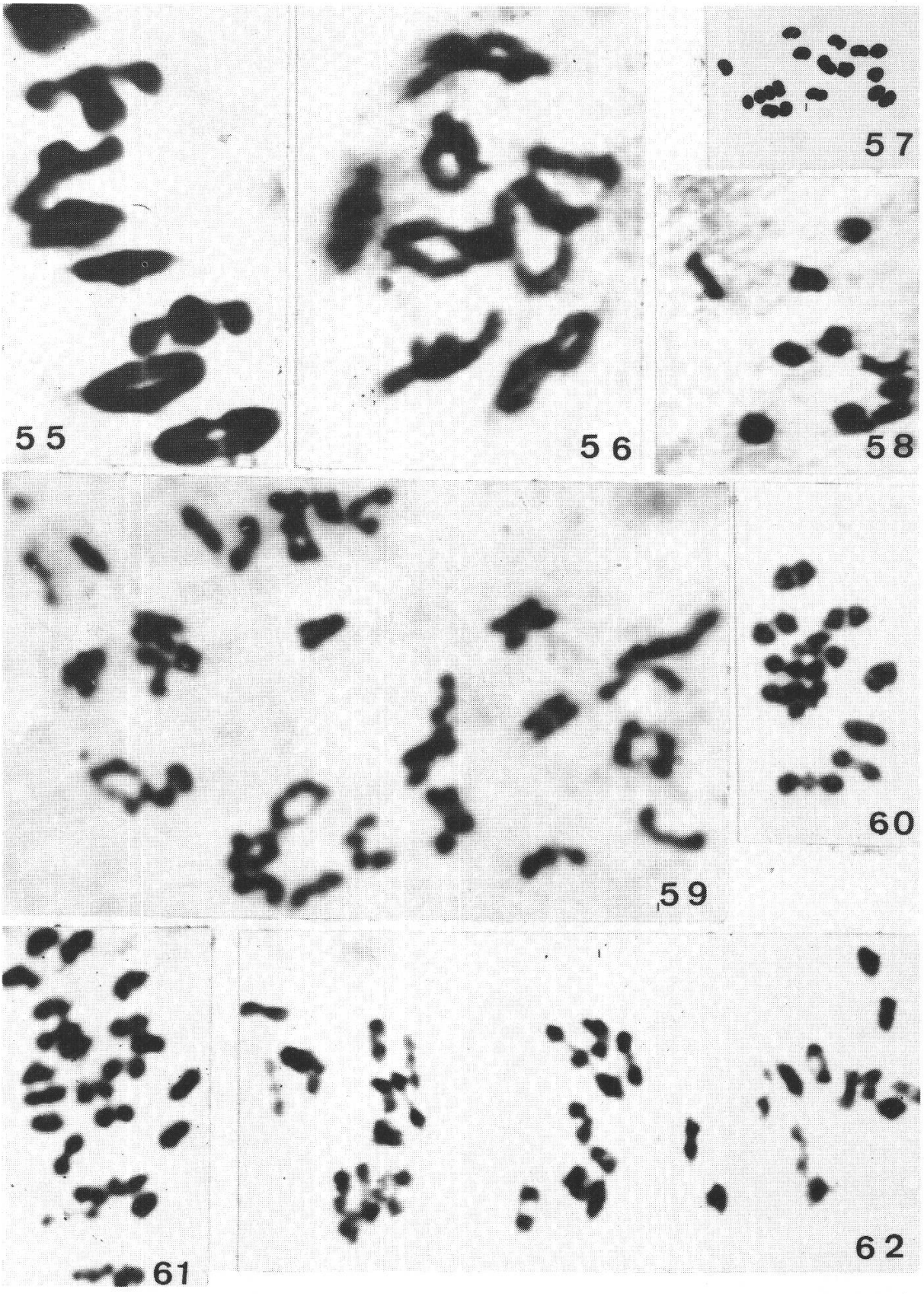
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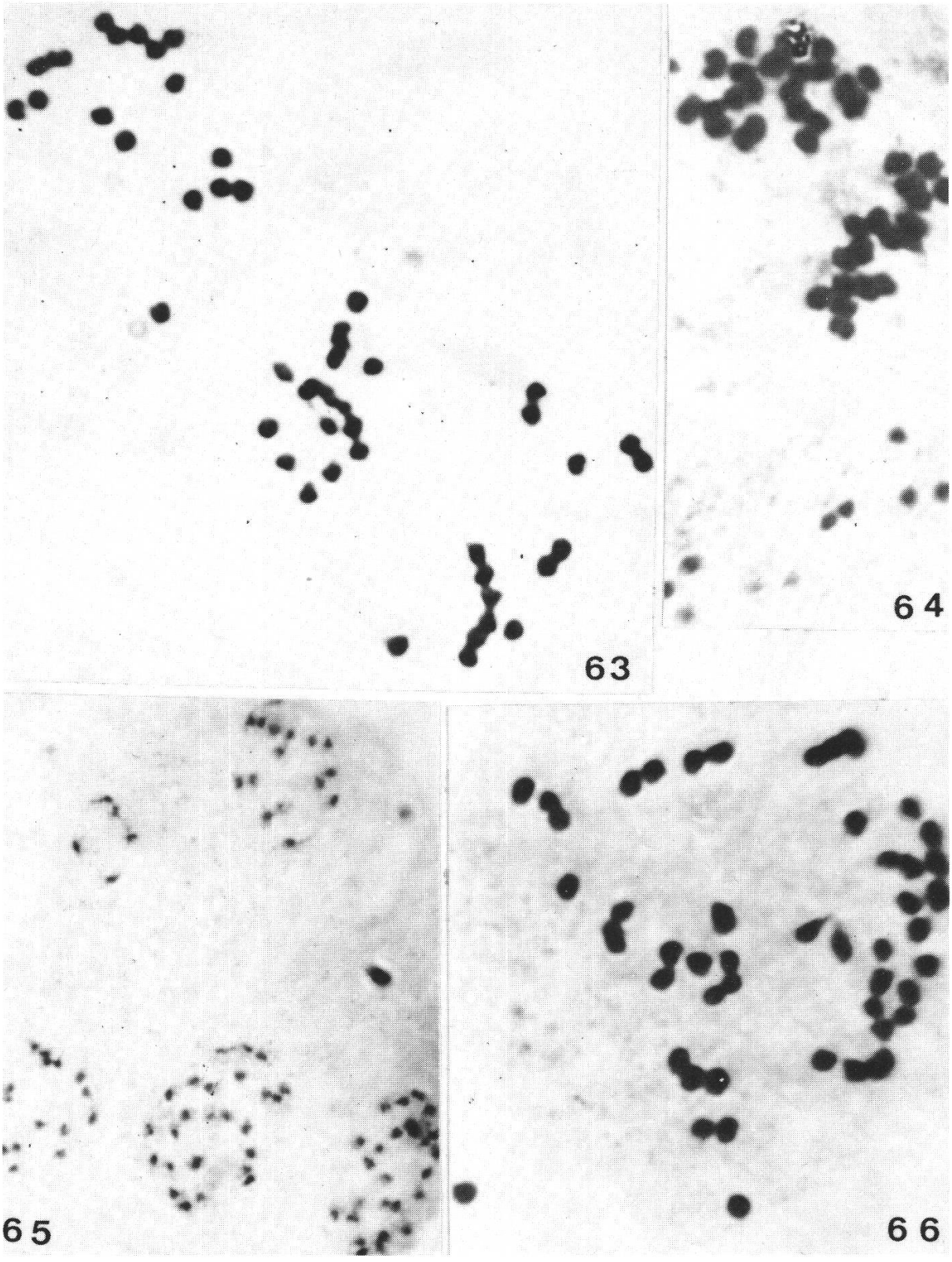
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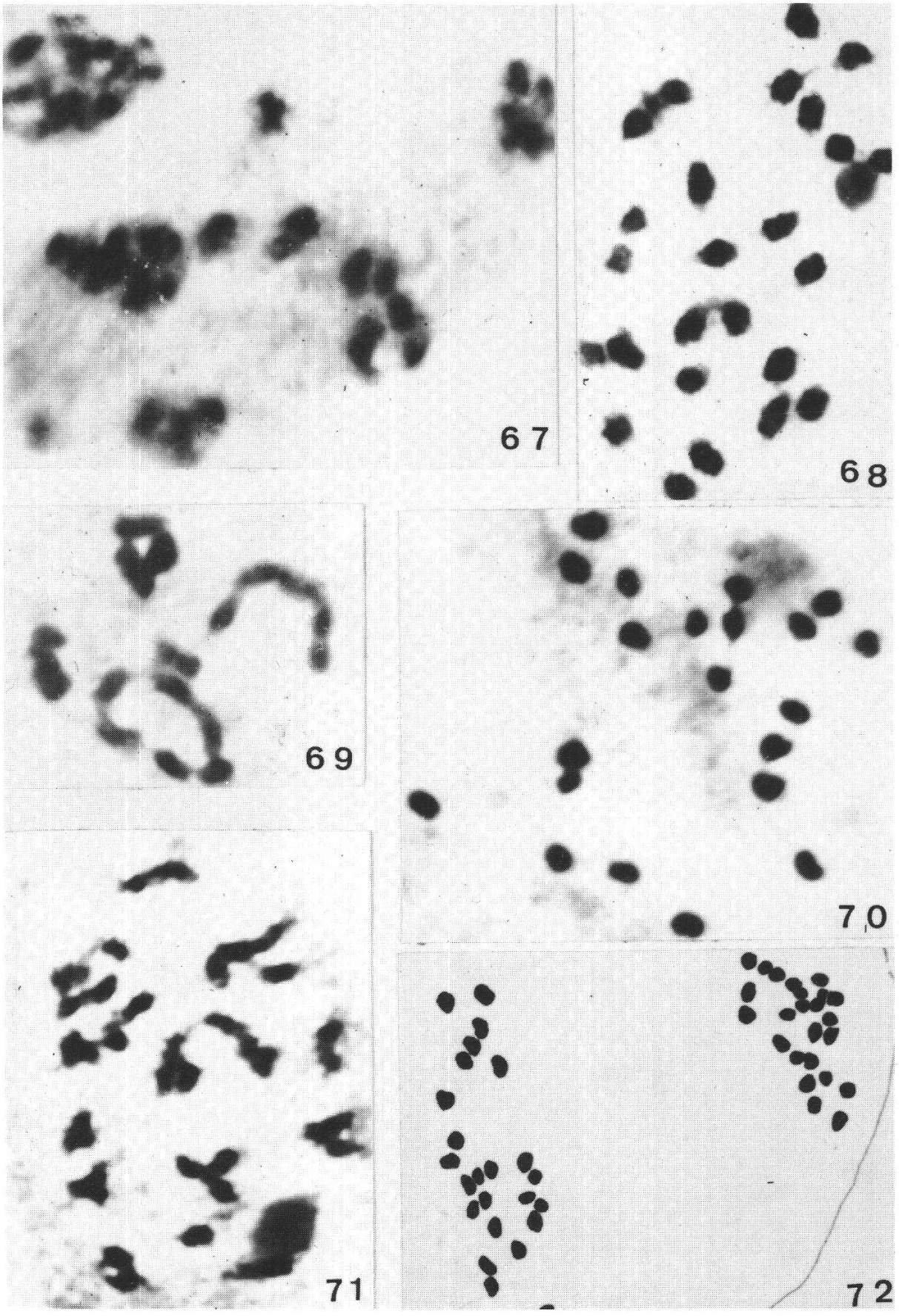
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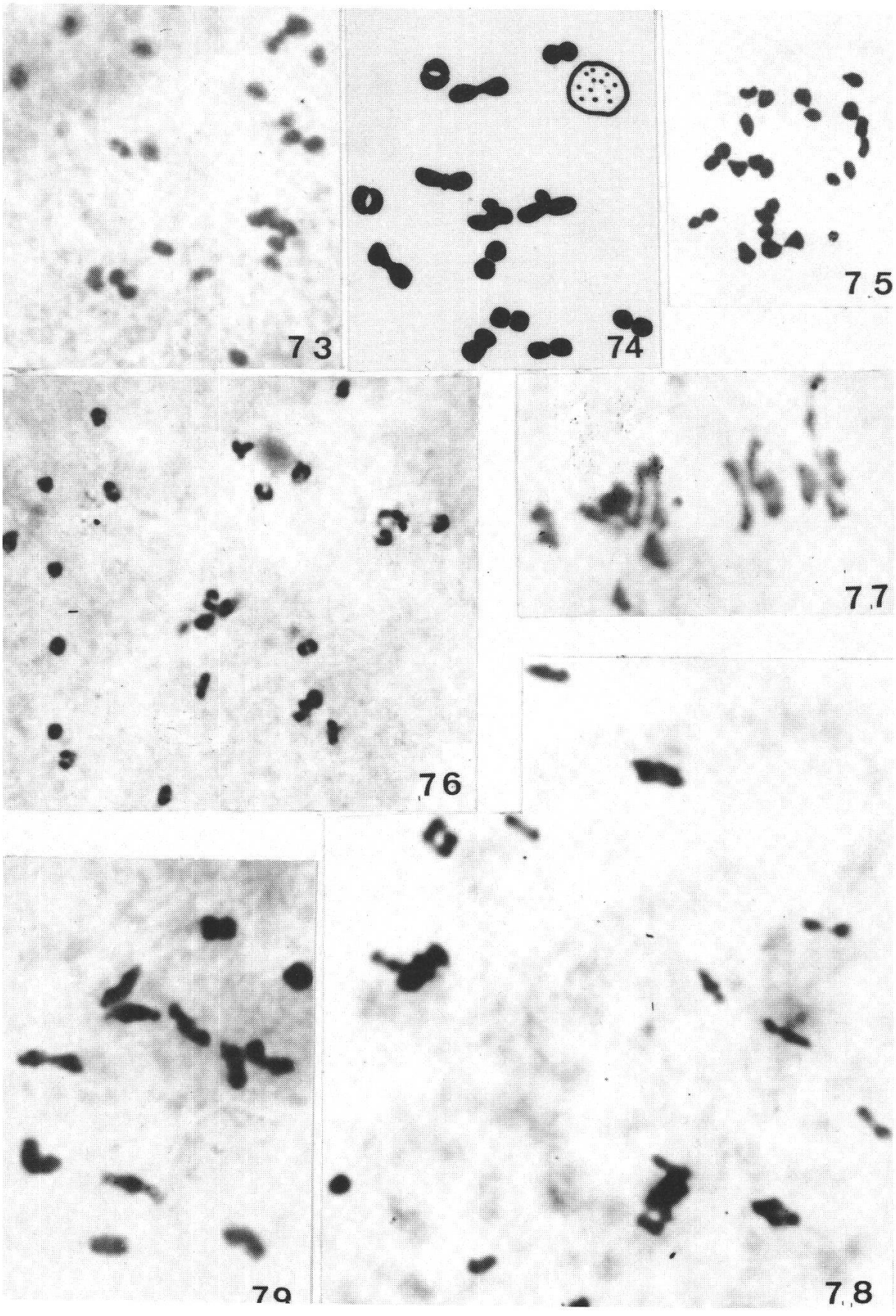
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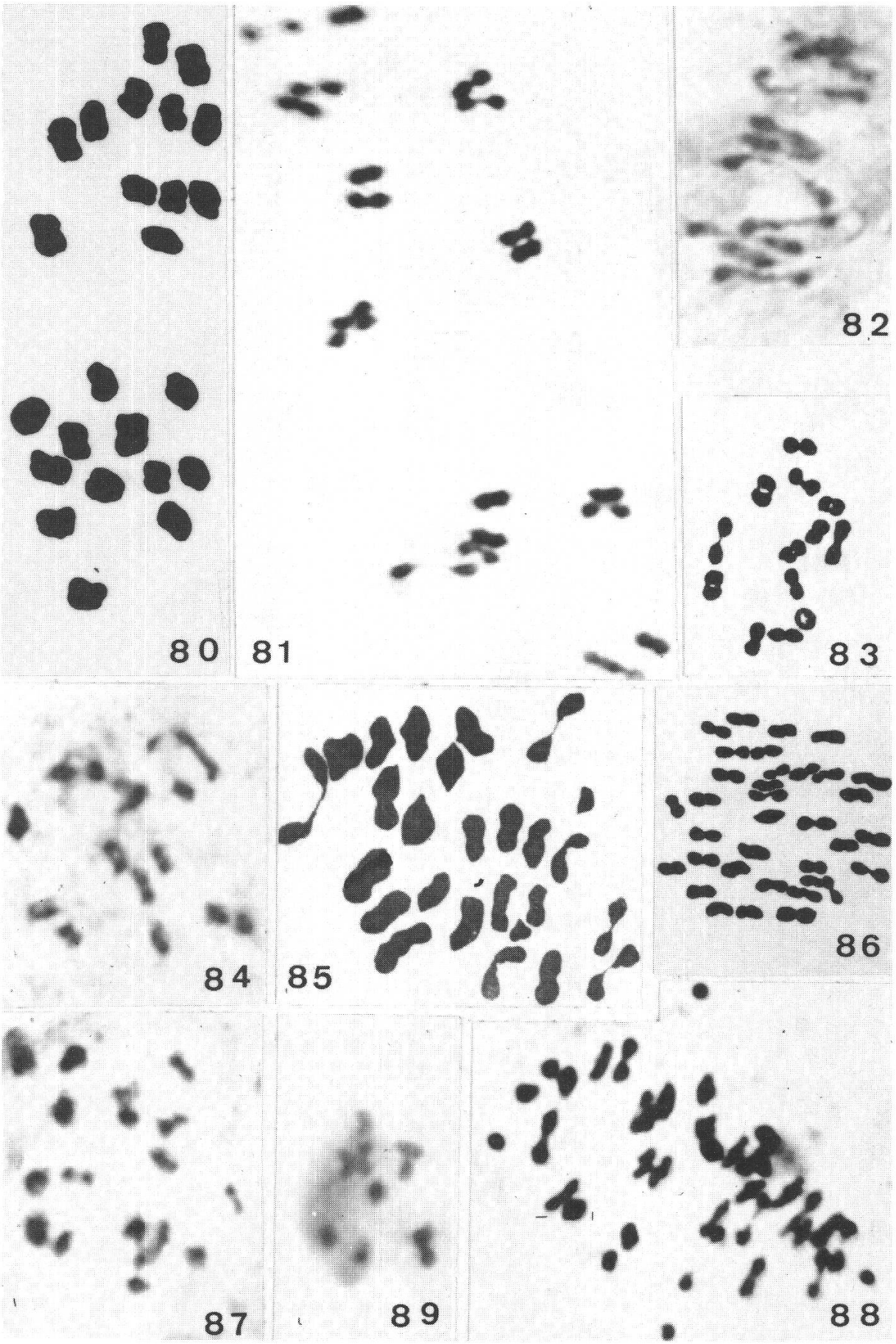
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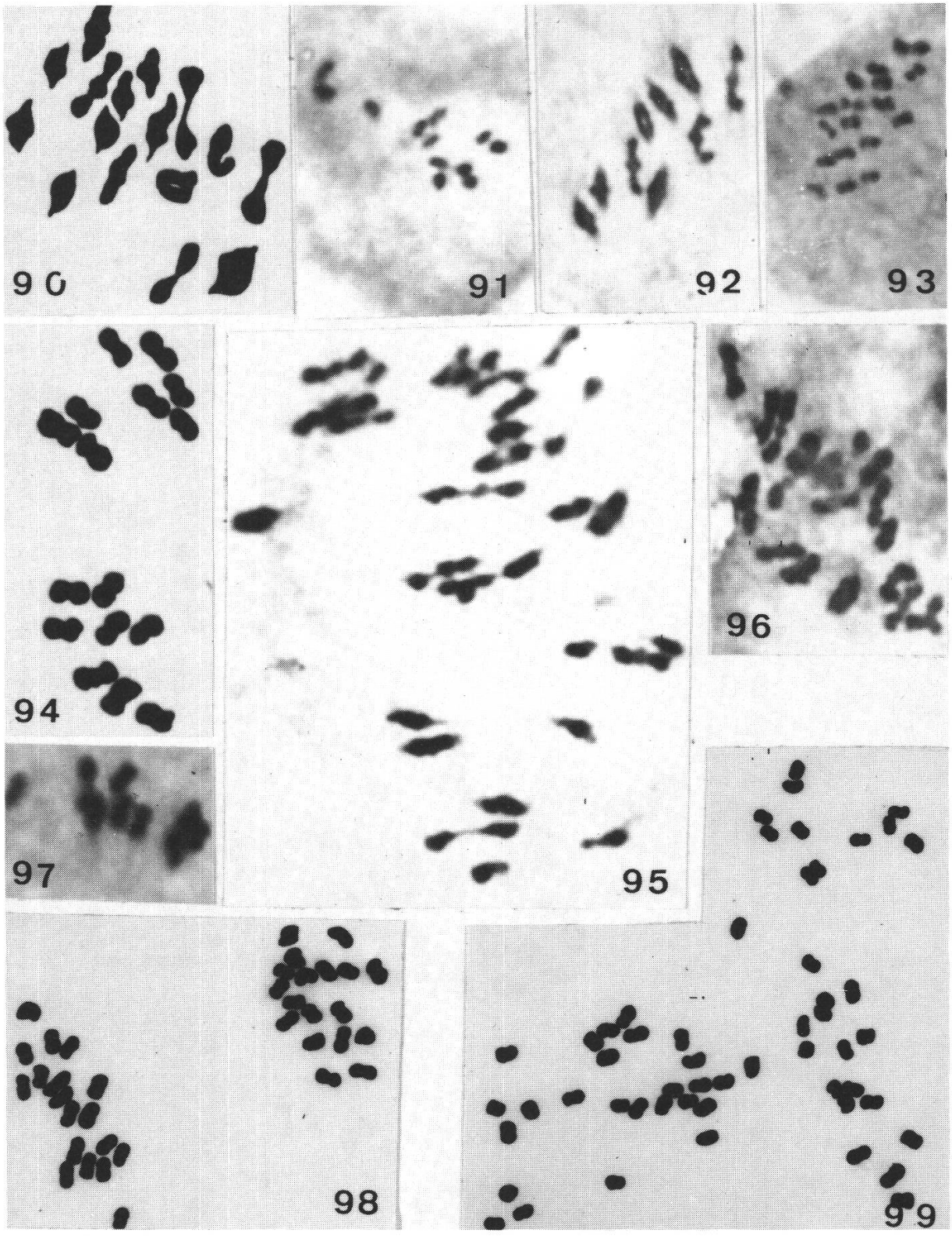
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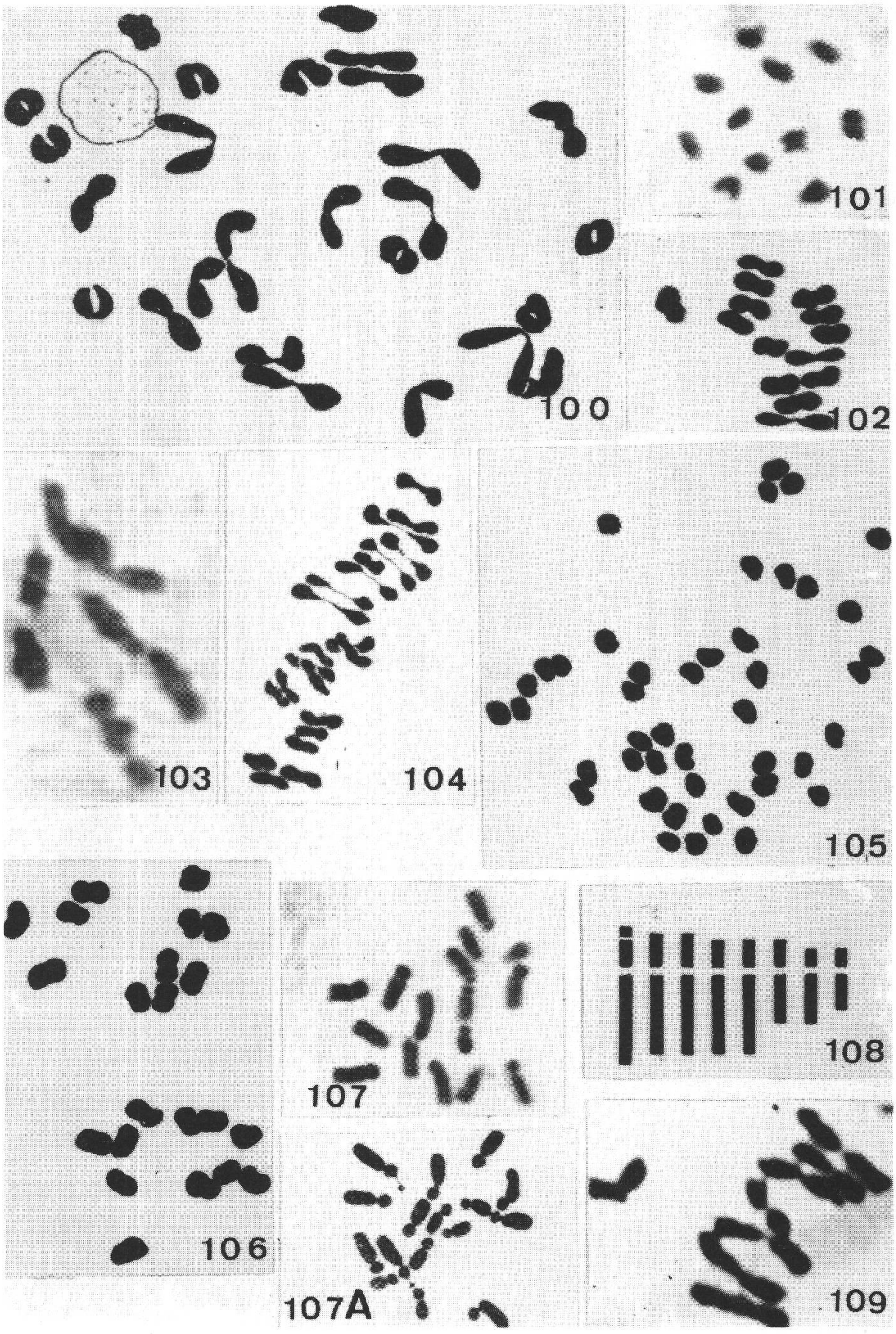
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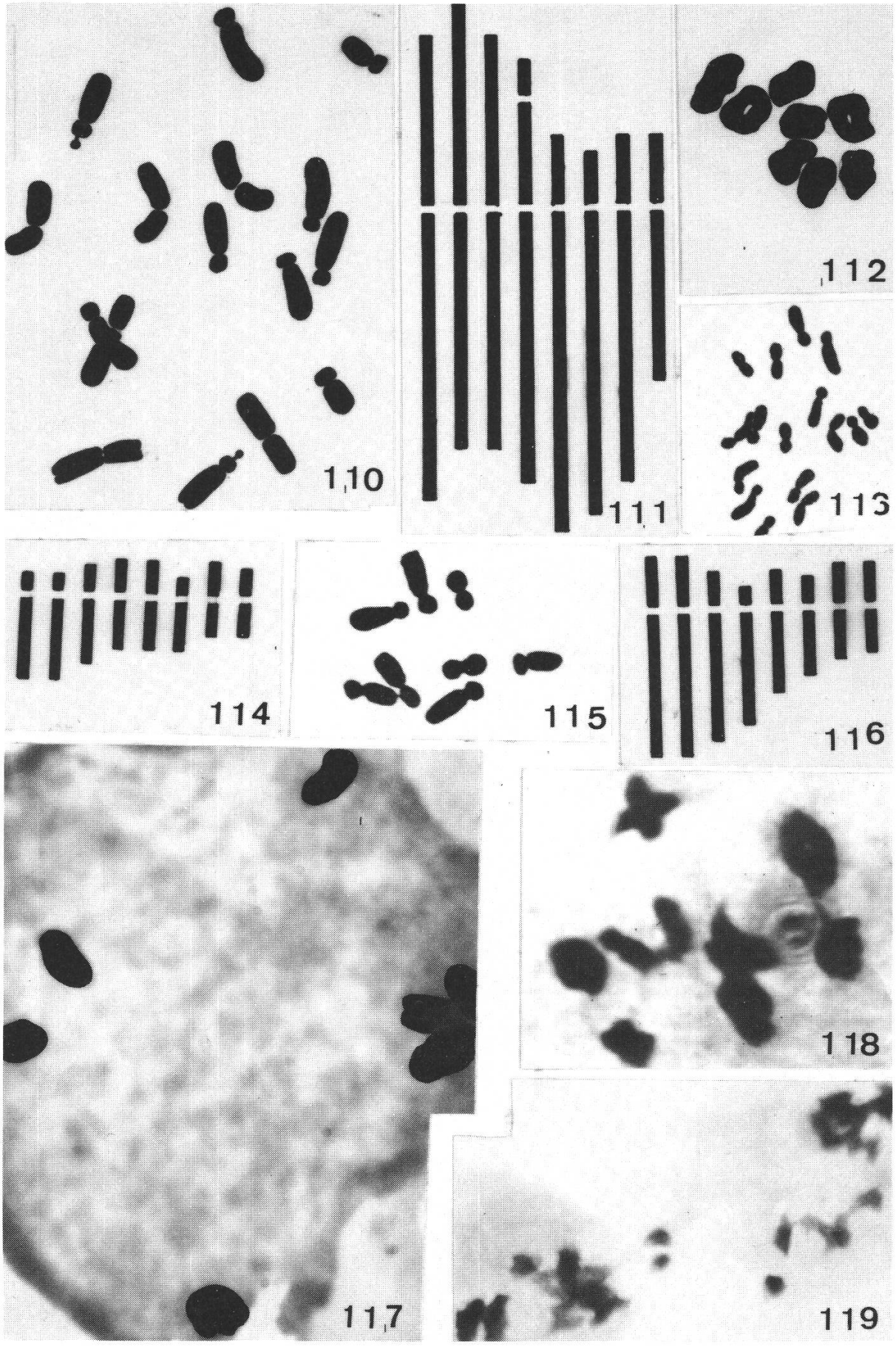
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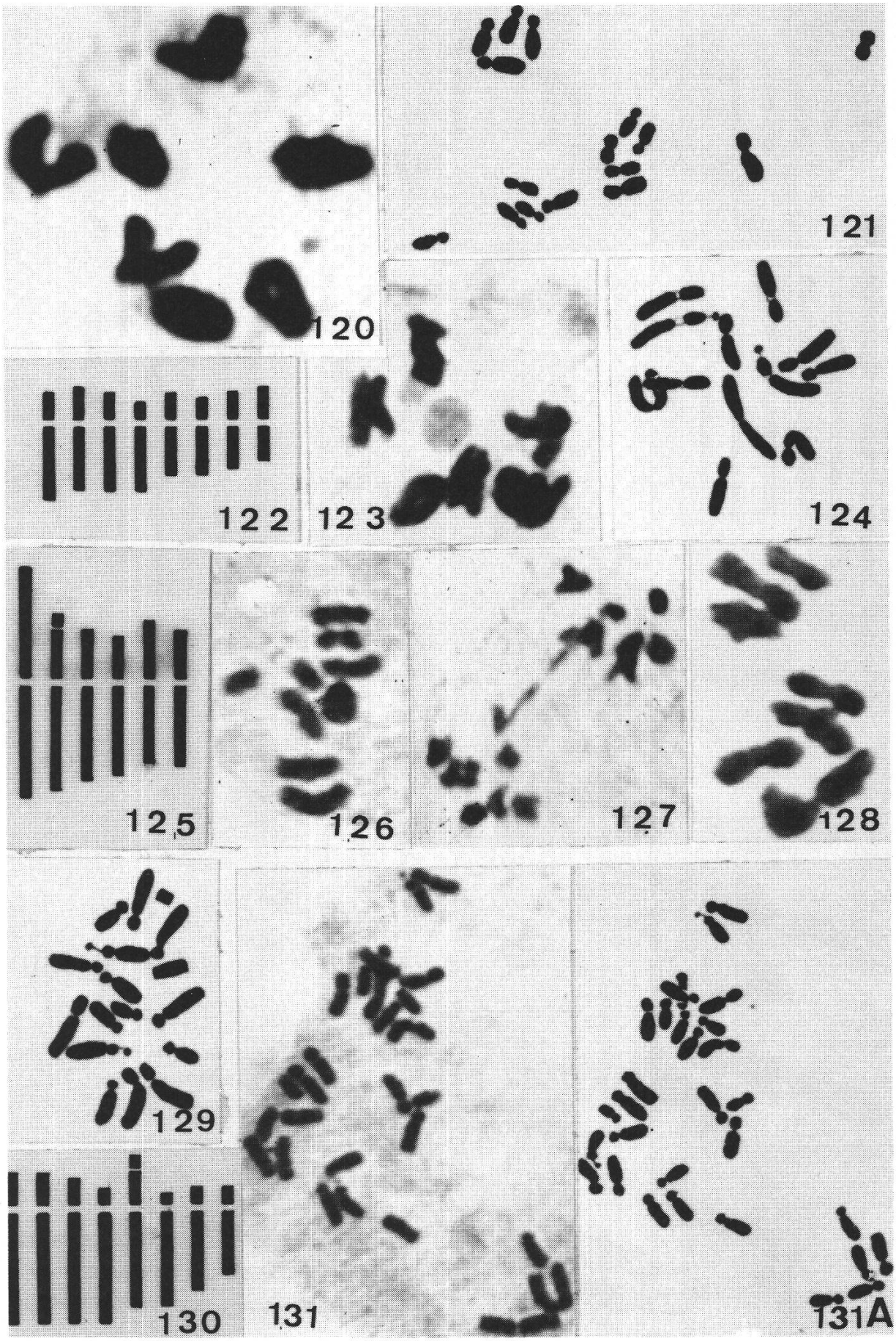
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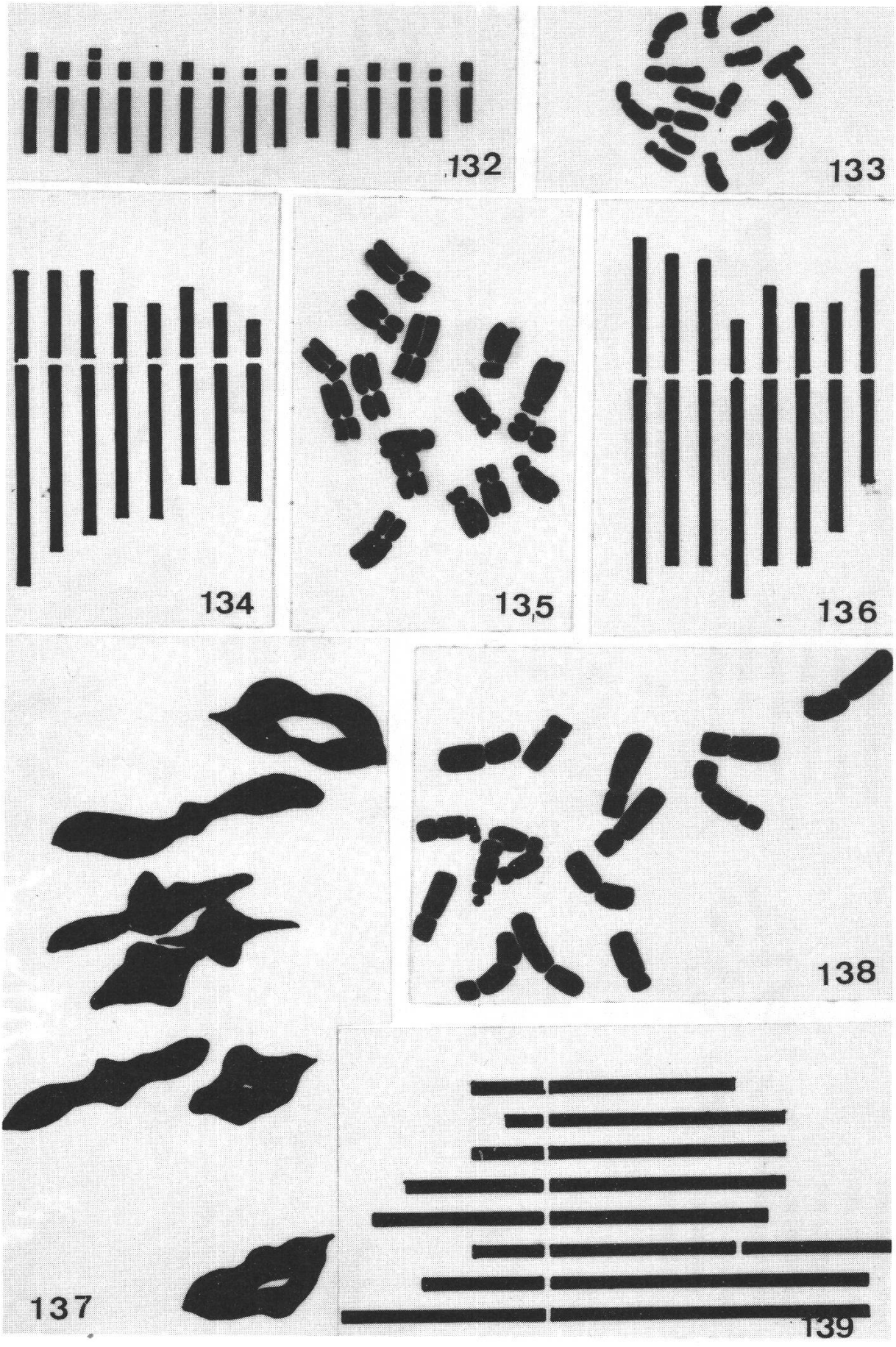
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