Evidences from Cytology-2

Unit 3: Systematics- An Interdisciplinary Science

B. Sc (Hons.) Botany II year Semester IV

CC-10: Plant Systematics

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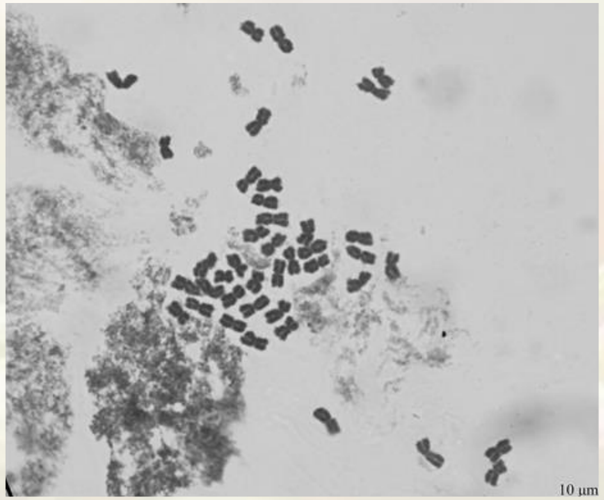
2. Chromosome Size

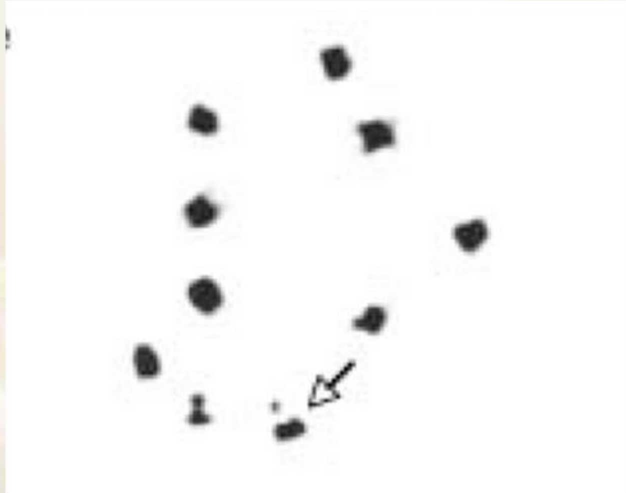
- Other taxonomically useful characteristics of Karyotypes, apart from chromosome number, are found in the gross morphology and size of chromosomes.
- The chromosomes of any one complement often show constant differences in their length at mitotic metaphase.
- The individual chromosomes of some taxa show marked differences in shape and size at mitotic metaphase.
- The size of chromosome varies greatly in different families, and also amongst members of the same family.
- The monocotyledons usually have larger chromosomes than the dicotyledons.
- In general woody plants have smaller chromosomes then the herbaceous relatives.

For instance, nearly all the members of the families **Araceae**, **Commelinaceae**, **Cyperaceae**, **Dioscoreaceae** and **Zingiberaceae** possess small chromosomes; the members of **Iridaceae** reveal small to medium sized chromosomes; while the taxa of **Amaryllidaceae** exhibit large size chromosomes. Members of the family **Liliaceae** are characterized by the presence of all types of chromosomes.

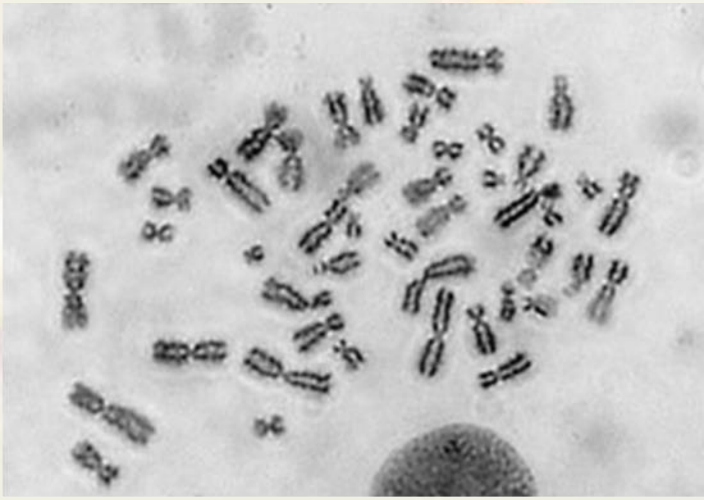
Large chromosomes



medium sized chromosomes



very small chromosomes



mixed type

You must be wondering "HOW can such beautiful spreads of metaphase-chromosomes can be prepared?"
Remember making slides from onion root tips to study the mitotic division stages??
Getting such resolution is NOT EASY……. Believe me !!!

- Chromosome length is usually used to characterize the size of karyotype. However, sometimes chromosome volume expressed as function of DNA content, is used for this purpose.
- The chromosome length in most plants where is from 0.5-30 μ.
- Phylogenetic reduction in chromosome size was described in the genus *Muscari* of the family Liliaceae for the first time. In this genus, species with greater morphological specialization possessed smaller absolute chromosome size as compared to the relatively primitive species.
- Production of chromosome size has also been reported in *Crepis* and in *Dianthus.*
- Similarly phylogenetic increase in chromosome size has been reported in the family Poaceae, in the genera *Galium* and in *Godetia.*
- Largest Chromosomes- genera *Trillium* and *Paris.* The larger chromosome size definitely specialized in their vegetative characteristics and are considered to have descended from Uvularieae
- Members of Uvularieae also have large chromosomes.

3. Chromosome Morphology

- Apart from the number and size of the chromosomes of many genera and families of flowering plants, conspicuous differences in appearance of the karyotype of the chromosome have also been found in species having the same chromosome number.
- The chromosomes are best discernible at mitotic metaphase. The karyotype of the chromosome can be characterized on the following basis:
  - Relative length of the arms of chromosomes
  - Position of the centromere
  - Presence of satellites

Accordingly the karyotypes can be characterized as following types-

- ❑ Symmetrical- karyotype
- ❑ Asymmetrical karyotype

- The most important feature for denoting chromosome structure is the position of the centromere which is median in metacentric, terminal in telocentric and subterminal in acrocentric" chromosomes.

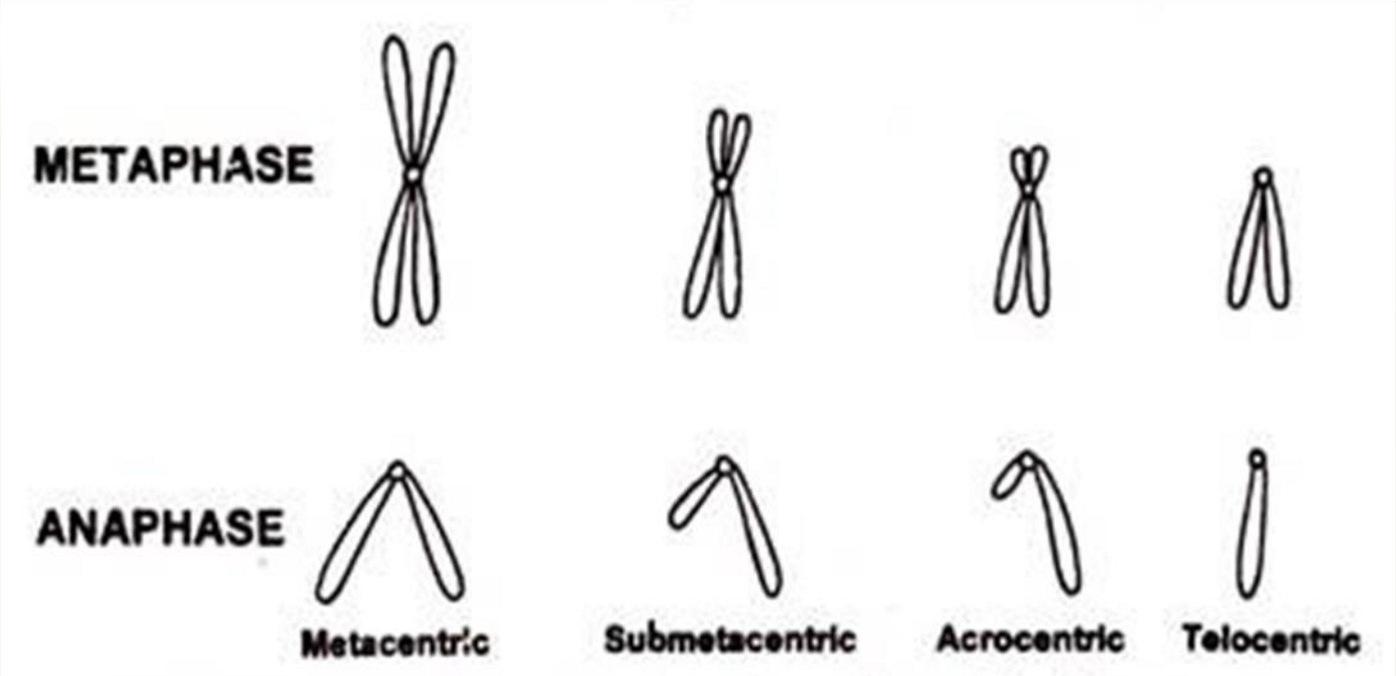
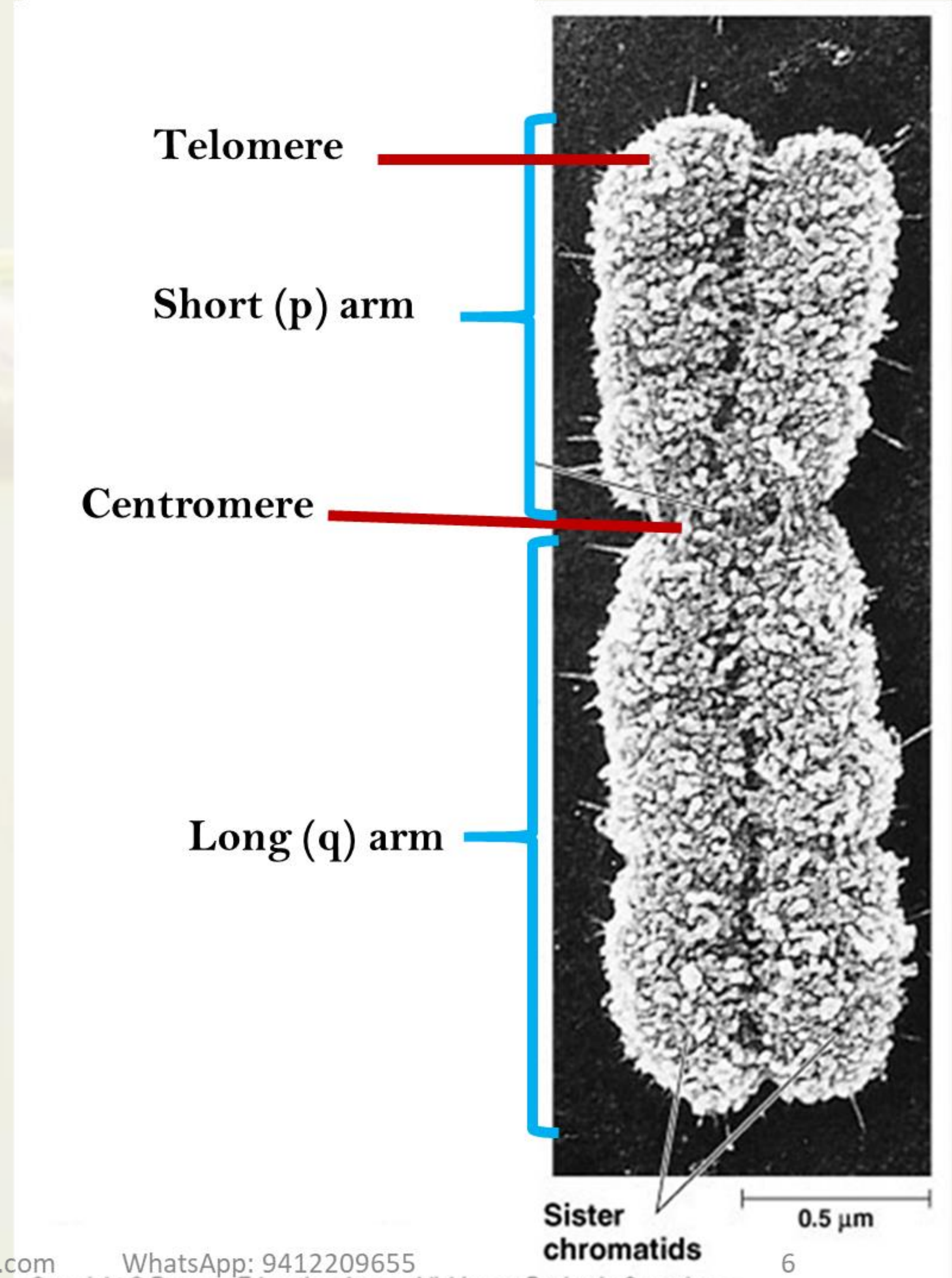


Fig. 1.8. Shape of the chromosome depends upon the position of centromere.

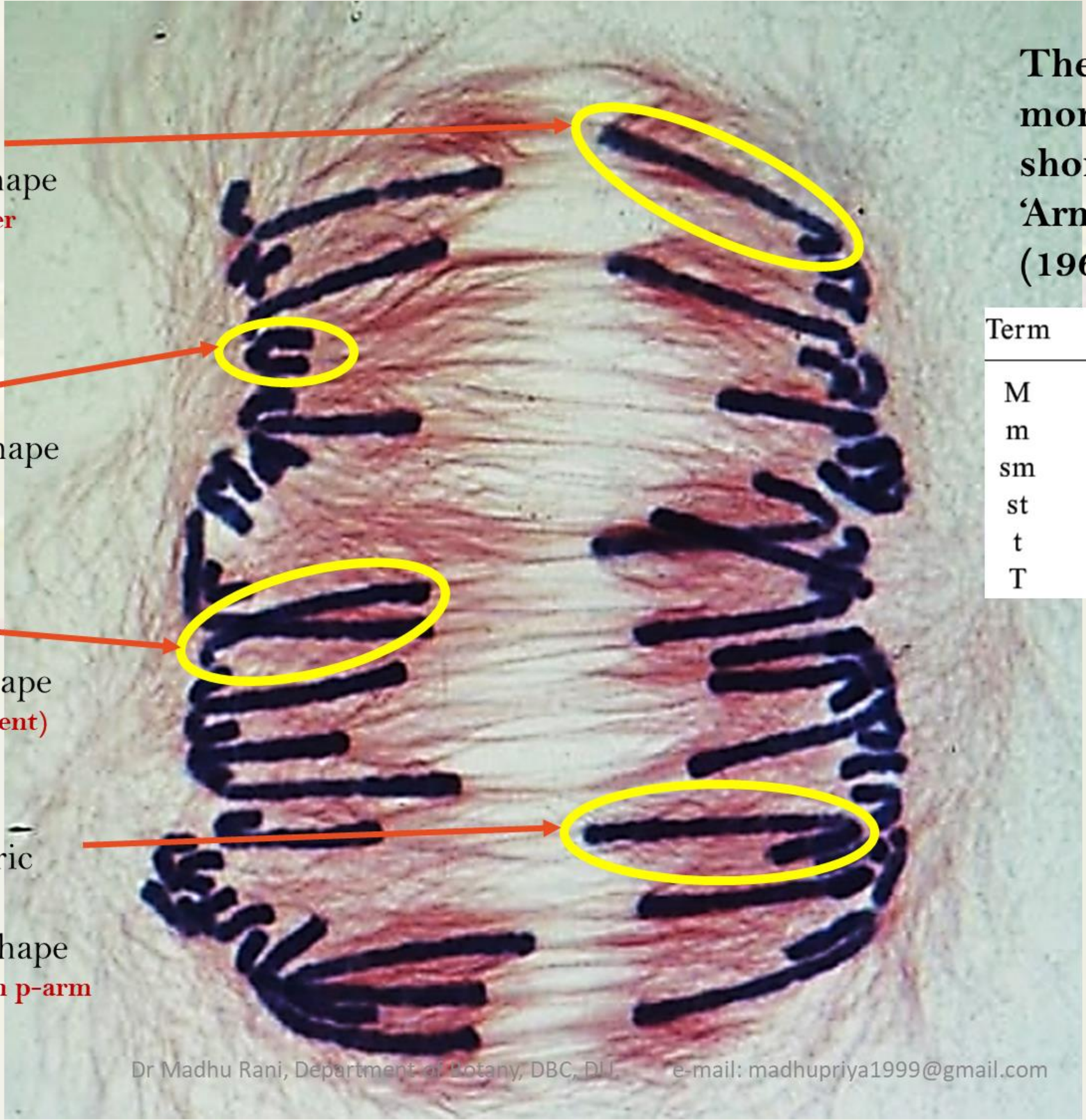


Acrocentric
(Sub-terminal)
Anaphase- J-shape
q-arm much longer than p-arm

Metacentric
(Median)
Anaphase- V-shape
Both arms equal

Telocentric
(Terminal)
Anaphase- I-shape
p-arm (almost absent)

Sub-Metacentric
(sub-median)
Anaphase- L-shape
q-arm longer than p-arm



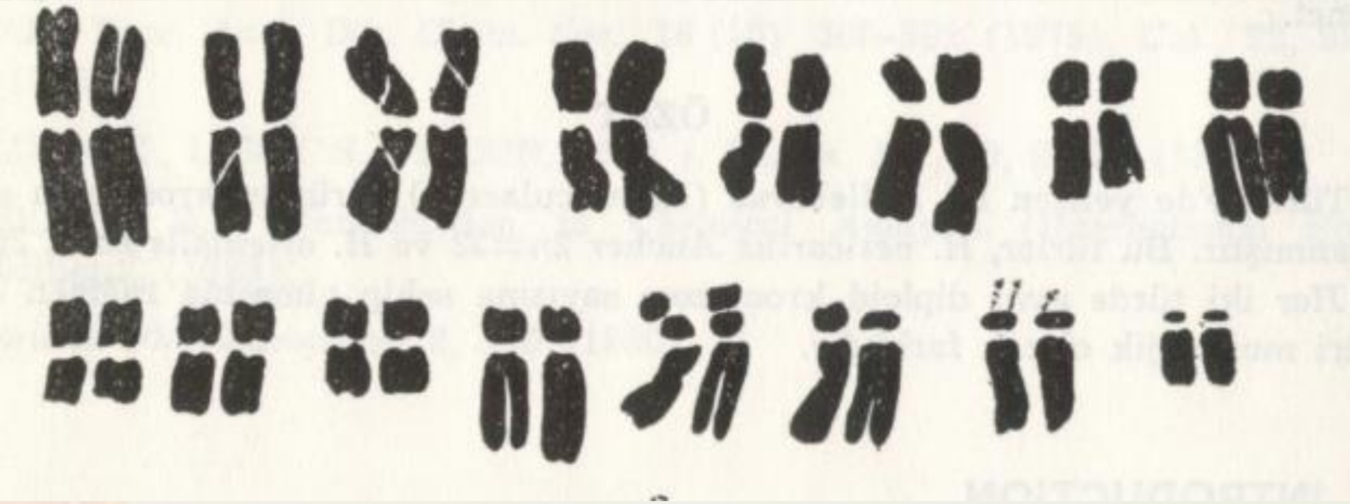
The type of chromosome morphology is based on the ratio of short (p) arm to the long (q) arm- 'Arm ratio". As per Levan *et al.* (1964).

Term	Location	*r* (Arm ratio)
M	Median point	1.0
m	Median region	1.0–1.7
sm	Submedian region	1.7–3.0
st	Subterminal region	3.0–7.0
t	Terminal region	7.0–∞
T	Terminal point	∞

Symmetrical karyotype

Consisting of chromosomes all essentially similar to each other in size and with median centromeres with two equal arms (Metacentric chromosomes) or sub-median centromeres with two arms (Submetacentric chromosome) and are termed as symmetrical chromosomes.

Symmetrical karyotypes are the most commonly found in nature for example chromosomes in the karyotype of the primitive genus *Helleborus* of the family Ranunculaceae differ little from each other in size and most of them are metacentric or submetacentric chromosome.

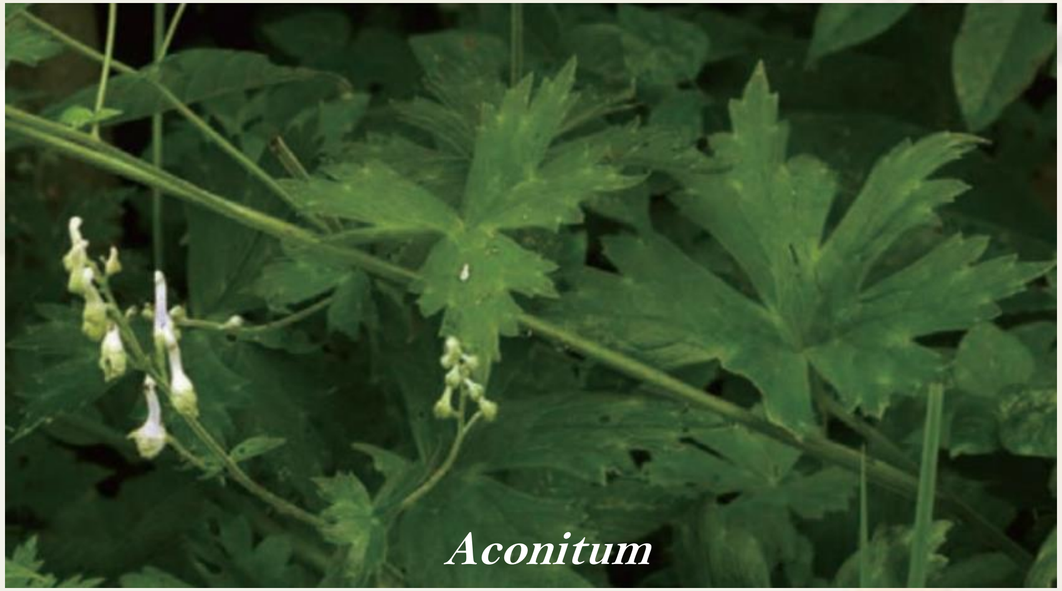


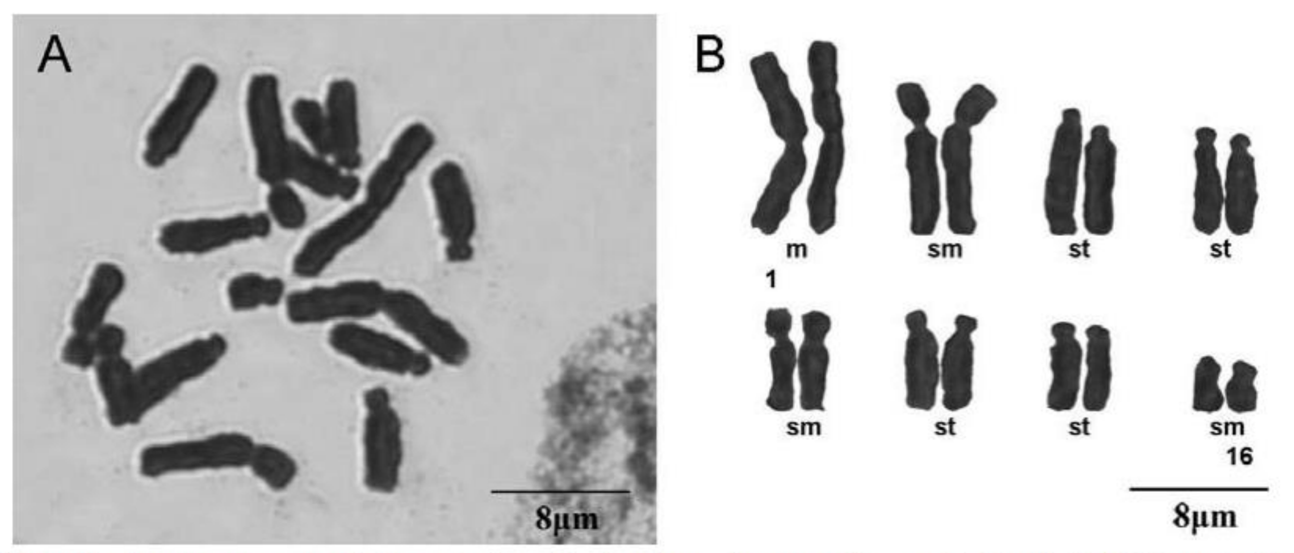
Karyogram of *Helleborus*

http://dspace.marmara.edu.tr/bitstream/handle/11424/1324/5000007282-5000012004-1-SM.pdf?sequence=1&isAllowed=y

Asymmetrical karyotype

Asymmetrical karyotype consist of many chromosomes with sub-terminal position of centromere (Acrocentric chromosome) or terminal centromere (Telocentric chromosome) with great differences in size of the largest and the smallest chromosomes.
Asymmetrical karyotypes are considered as specialized types for example in the advanced genera *Aconitum* and *Delphinium* (Ranunculaceae), the flowers have the largest number of acrocentric chromosome.





Somatic chromosomes at mitotic metaphase in *Aconitum shennongjiaense* Q. Gao & Q. E. Yang. A, Ph

https://ejournal.sinica.edu.tw/bbas/content/2009/2/Bot502-13.pdf

- Mostly the asymmetrical karyotypes are most common in advance species while symmetrical ones are found in comparatively primitive species.
- In general symmetrical karyotypes are taken to reflect primitive status of taxa while various specialized types a symmetrical karyotypes are considered to have been derived from the symmetrical karyotypes.
- However this view has been challenged by many taxonomist by postulating the symmetrical karyotypes original evolved from asymmetrical once by end to end fusion of chromosomes.
- This reverse trend of specialization that is from telocentric chromosome to metacentric chromosomes has been demonstrated in certain members of the Commelinaceae by some taxonomists.

There are few examples of the use of Karyotype studies for differentiating families.

- Daarlington (1963) has provided a diagram showing the potential use of basic numbers for suggesting relationships among the families of woody Angiosperms.
- Warburg (1938) has shown that the Geraniaceae, Oxalidaceae and Tropaeolaceae are cytologically close to each other while the Limnanthaceae differ markedly in chromosome size, number and behaviour. Hence Limnanthineae, with a single family, is separated from the Geraniineae which contains all other families. However, the Balsaminaceae which Warburg found to be cytologically intermediate between the above two groups is now separated in the Sapindales.
- Similarly, a close Karyotype affinity is seen for the closely related Magnoliaceae, Himantandraceae and Degeneriaceae and also for Illiciaceae and Schizandraceae of Annonales which were not thought to be closely related.
- However, there is a marked difference in chromosome numbers of Lauraceae (x=12) and the closely allied Hernandiaceae (nx= 20, 40).

...Examples of the use of Karyotype studies for differentiating families...

- **Karyotype studies within chromosomally uniform families are of not much significant. The taxonomic value of karyotype studies is generally greater at the genus level than at the species level.**
- *Viola tricolor* and *V. arvensis* are the variable species which are often confused.
- <u>Constant chromosome number in this case has indicated constant differences in pollen characters which permit a satisfactory separation of these two species</u>.

Viola tricolor

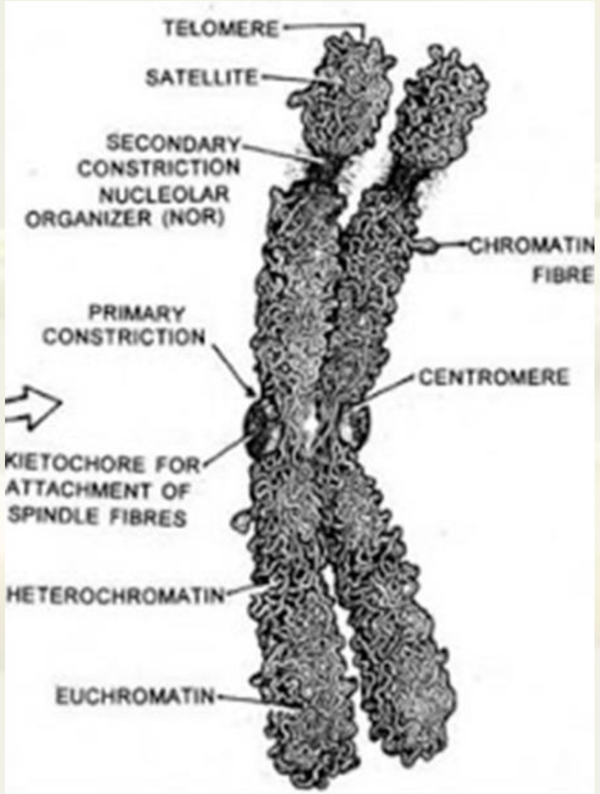
Viola arvensis

...Examples of the use of Karyotype studies for differentiating families...

- Basu and Mukherjee (1975) based on Karyotype analysis have separated Indian spinach from *Beta vulgaris* and have given a distinct species name *B. palonga.*
- Cytotaxonomic studies by Mathew (1958) on Menispermaceae have shown that the genera *Stephania*, *Cyclea*, and *Cissampelos* are grouped under the Cissampelidae by Hooker. While *Cyclea* and *Cissampelos* show reduction in the perianth parts of the female flower, *Stephania* exhibits no such reduction. Cytologically, *Cyclea* and *Cissampelos* are seen to be based on n=12, while *Stephania* shows n= 13. It is seen that n= 13 is characteristic of the tribe Cocculeae, which further shows chromosomes of smaller size. *Stephania* also shows chromosomes of small size, while *Cyclea* and *Cissampelos* have much larger chromosomes. On cytological grounds *Stephania* may be transferred to the tribe Cocculeae.

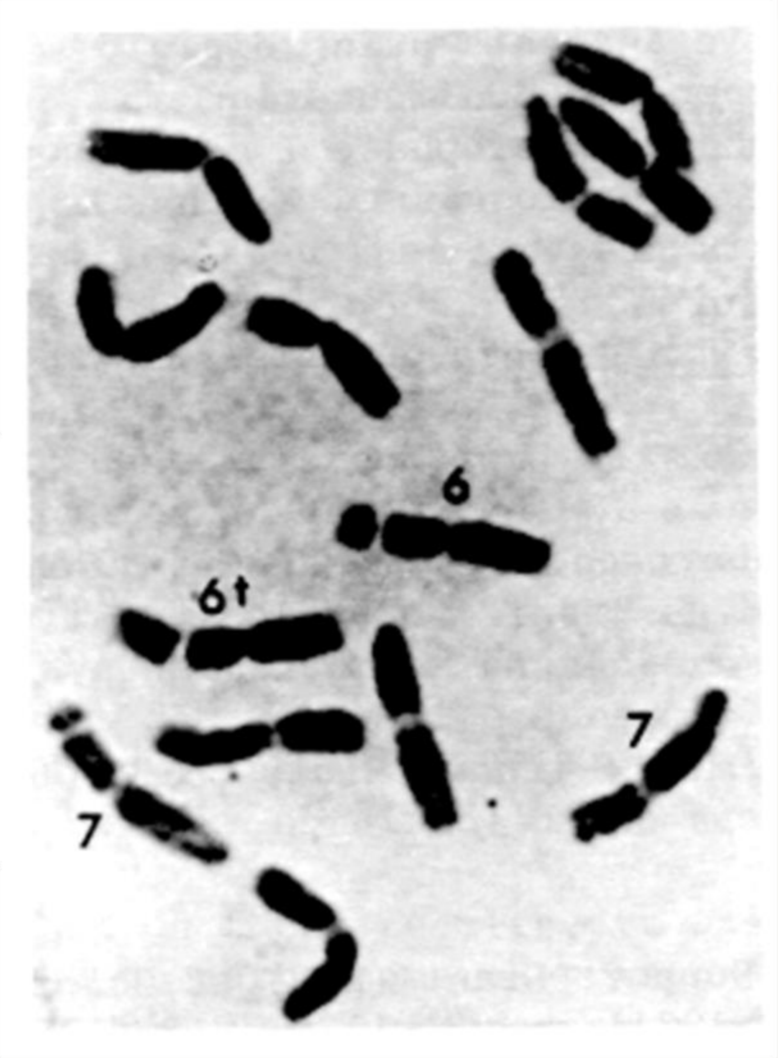
Beta vulgaris

Secondary constructions and satellites



Secondary constructions are constrictions in a chromosomes other than **centromere** (primary constriction) giving the appearance of small bead like appendages occasionally present at the terminal ends of one or more pairs of chromosomes in many species, known as **satellites**.

The somatic chromosomes of diploid hybrid between Shin Ebisu 16 and Utah T3. The photo shows the heterozygous condition of chromosome 6; 6 indicates the normal chromosome 6 and 6^t the translocated chromosome 6.



- These structures are widely distributed in the plant kingdom, which shows that they are a valuable if not essential part of the chromosomal complement.
- Secondary constrictions can also be useful Karyotype characters particularly at or below the species level. Satellites have proved useful for marking the chromosomes carrying them.

4. Chromosome behavior at meiosis

Study of chromosome behavior at meiosis can provide some valuable information about the relationship of populations and species. Pairing behavior at meiosis is mostly determined by chromosome number and chromosome homology.

The kind and degree of pairing can indicate:

- whether hybridization has occurred: the degree of chromosomes homology in hybrids is an indication of the degree of relationship of the parental species.
- structural differences in the parental chromosomes: Meiotic pairing behavior in hybrids can also point to structural differences in the chromosomes of its parents.

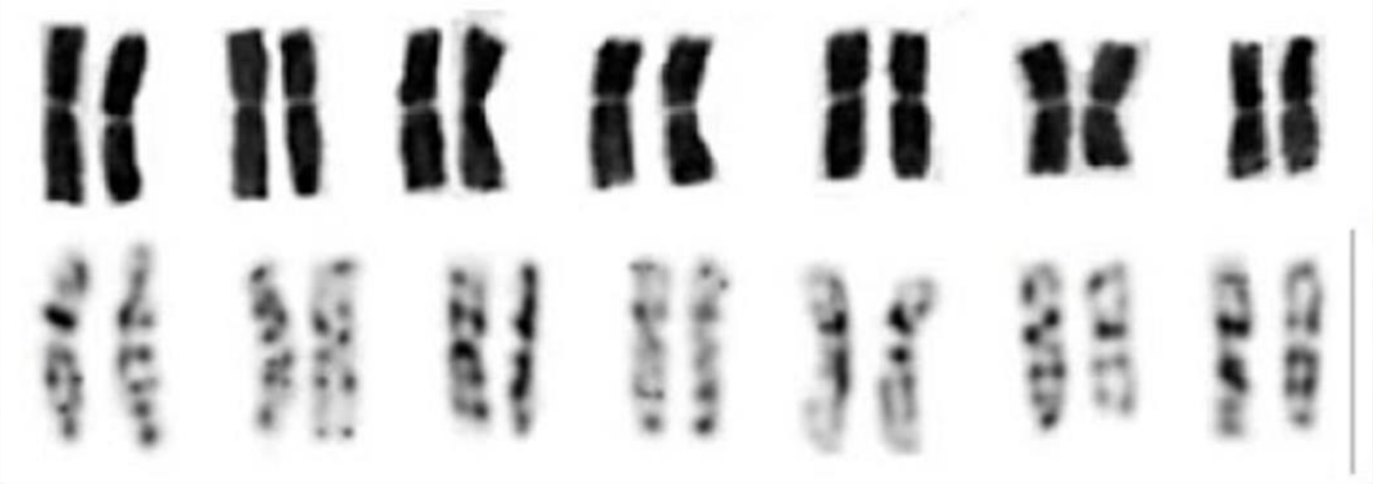
Such differences may be the result of:

- Translocations
- Inversions of segments including paracentric and pericentric inversion
- Deletions
- Duplications

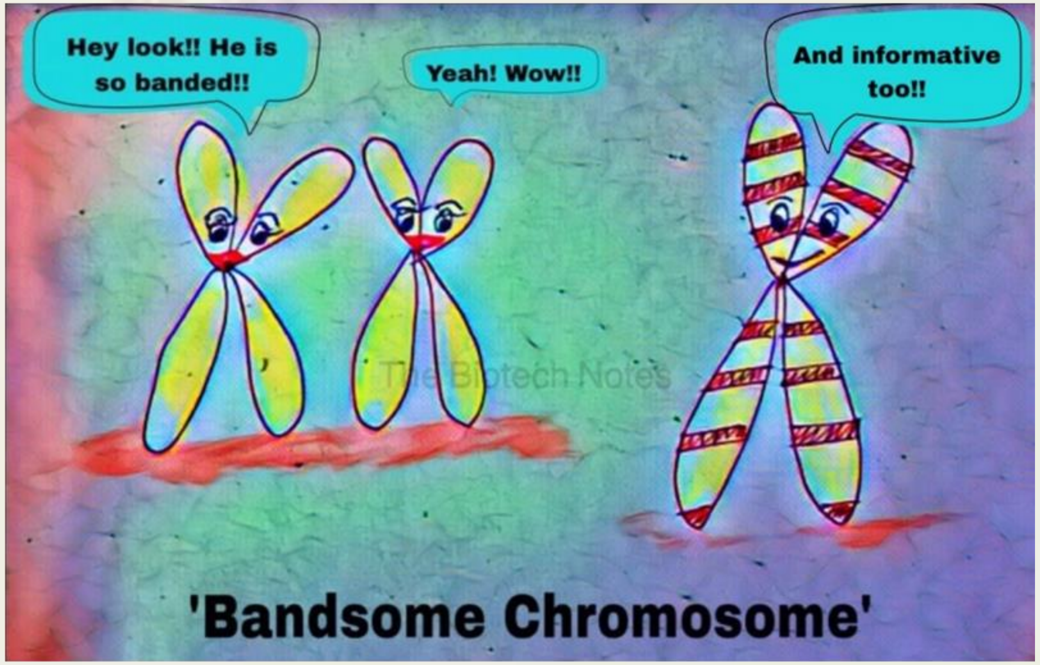
5. Banding Pattern

- In recent years, new staining techniques have been developed, using Giemsa and fluorochrome dyes. These dyes stain chromosomes in a consistent banding pattern.
- Previous staining techniques, for instance use of basic fuchsin (Fuelgen reagent) resulted in uniform staining throughout the whole chromosome.
- DNA is non-homogeneous throughout. During mitosis and meiosis local variations in the degree of condensation of the chromatin to form heterochromatin may be apparent in metaphase preparations. The new techniques have this allowed to distinguish morphologically between chromosomes with enhanced efficiency.

For example- these techniques have been utilized in studying the systematic position of the genus *Anacyclus* which confirms with the results from other fields of study, particularly morphological and phytochemical approaches.



Comparison of usual staining and G-banding
https://scialert.net/fulltext/?doi=pjbs.2007.4160.4163



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- Gurcharan Singh. **PLANT SYSTEMATICS: Theory and Practice.** 3rd edition. Oxford & IBH Publishing Co. Pvt. Ltd.

For a change

Try to recognize these three types of inflorescences….. And identify the family and Genera. Also key features of the family……

Send your answers through WhatsApp (personally)….. Let's see how many of you are studying