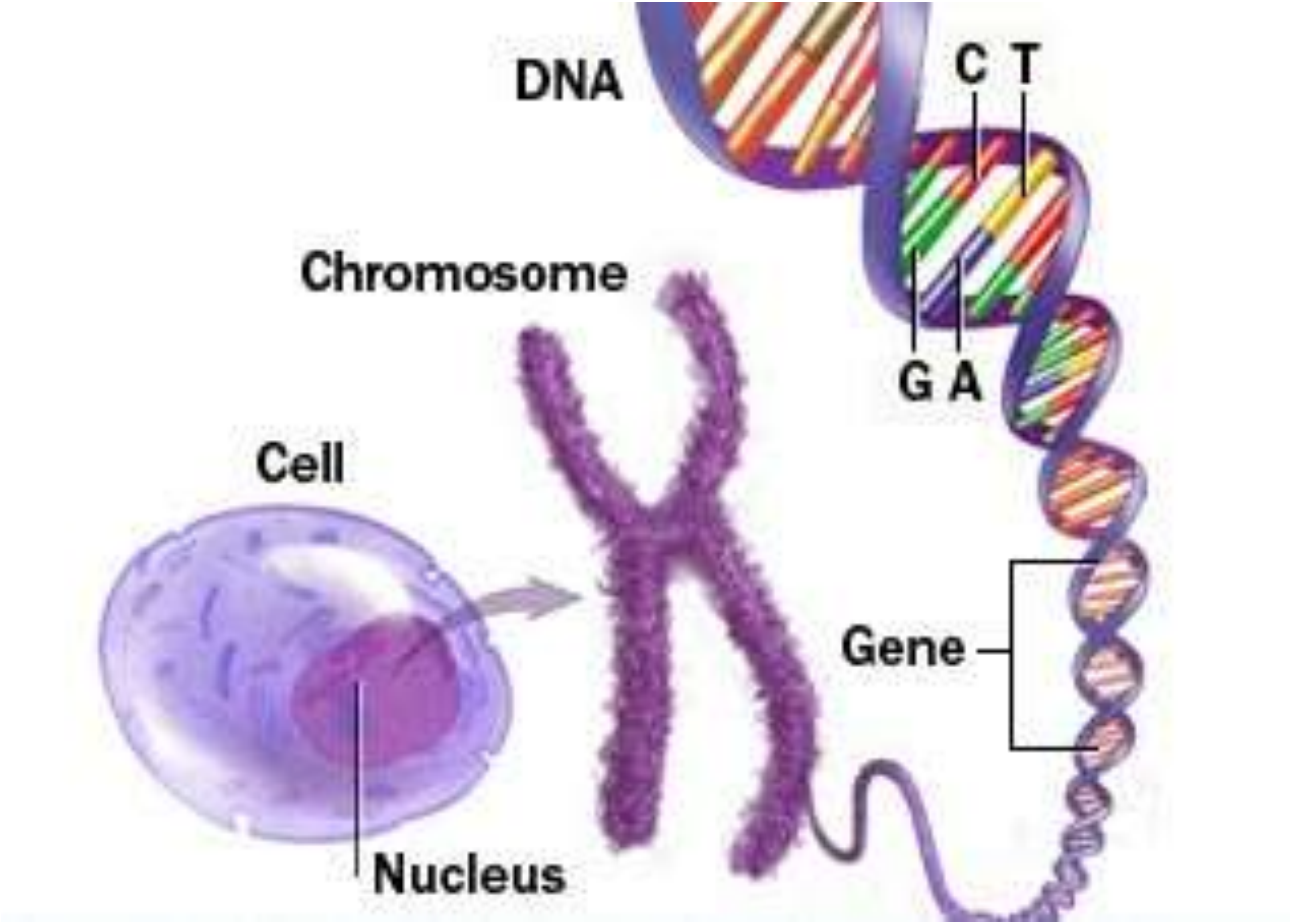
Chromosomes and Karyotypes



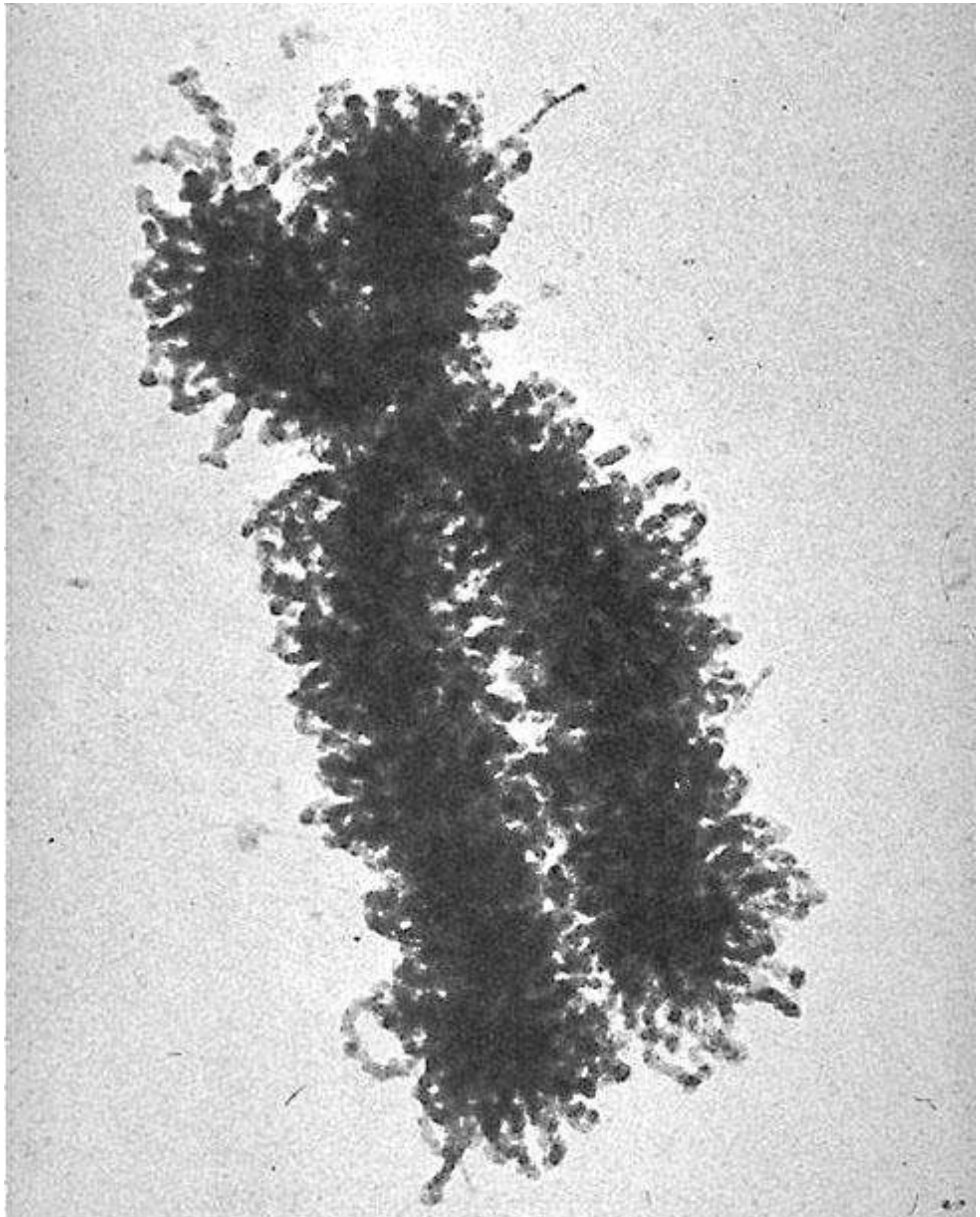
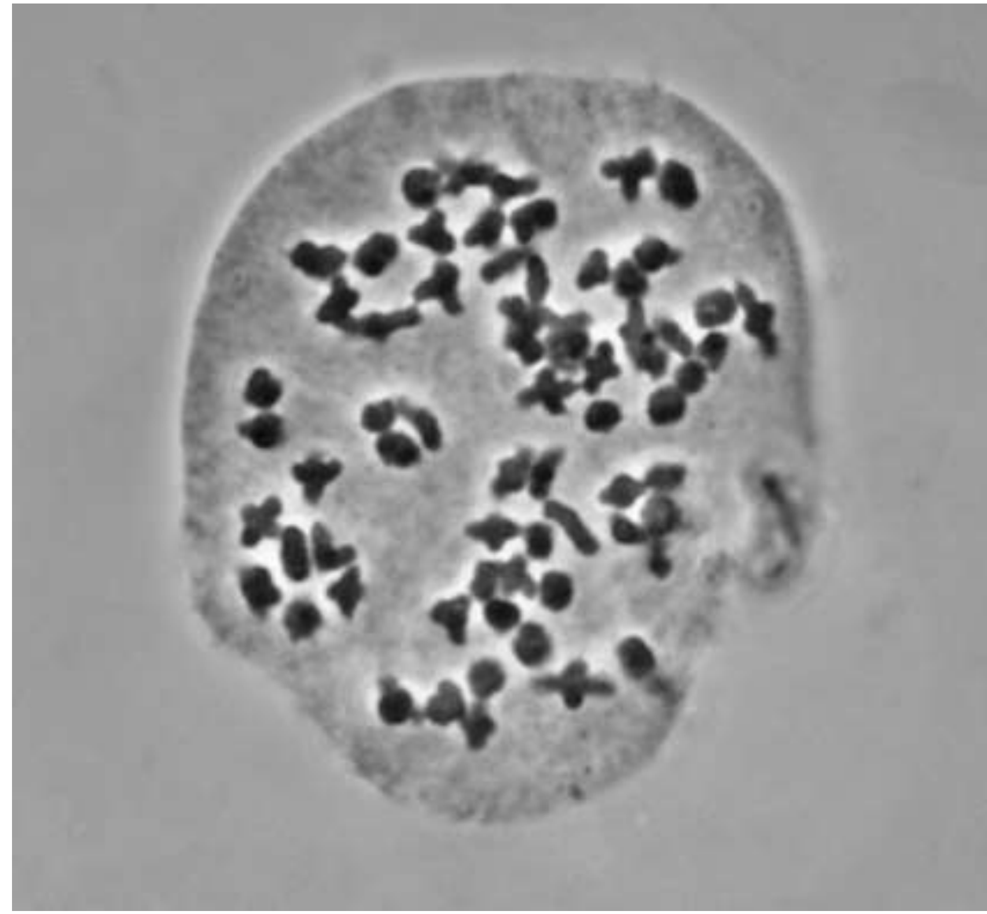


FIGURE 1-14
An electron micrograph of a human chromosome. Chromosome XII from a HeLa cell culture. (Courtesy of Dr. E. Du Praw.)



1838 – Cell Theory, M.J. Schleiden and others (Schwann)
1842 – chromosomes first seen by Nageli
1865 – Charles Darwin, Pangenesis theory, blending inheritance
1865 - Gregor Mendel discovers, by crossbreeding peas, that specific laws govern hereditary traits. Each traits determined by pair of factors.
1869 - Friedrich Miescher isolates DNA for the first time, names it nuclein.
1882 – **Walther Flemming** describes threadlike ’chromatin’ in the nucleus that turns red with staining, studied and named **mitosis**. The term ‘chromosome’ used by Heinrich Waldeyer in 1888.
1902 – Mendel’s work rediscovered and appreciated (DeVries, Corens, etc)
1903 – **Walter Sutton**, the chromosomal theory of inheritance, chromosomes are the carriers of genetic information
1944 - Avery, MacLeod and McCarty show DNA was the genetic material
1953 - James Watson and Francis Crick discover the molecular structure of DNA: a double helix with base pairs of A + T and C + G.
1955 - human chromosome number first established
1999 - The first complete sequence of a human chromosome (22) was published.
2004 - Complete sequencing of the human genome was finished by an international public consortium. **Craig Venter** etc.

Matthias Jakob Schleiden - 1838 proposes that cells are the basic structural elements of all plants.

Cell Theory

1. All living organisms are composed of one or more cells
2. The cell is the basic unit of structure and organization of organisms
3. All cells come from preexisting cells

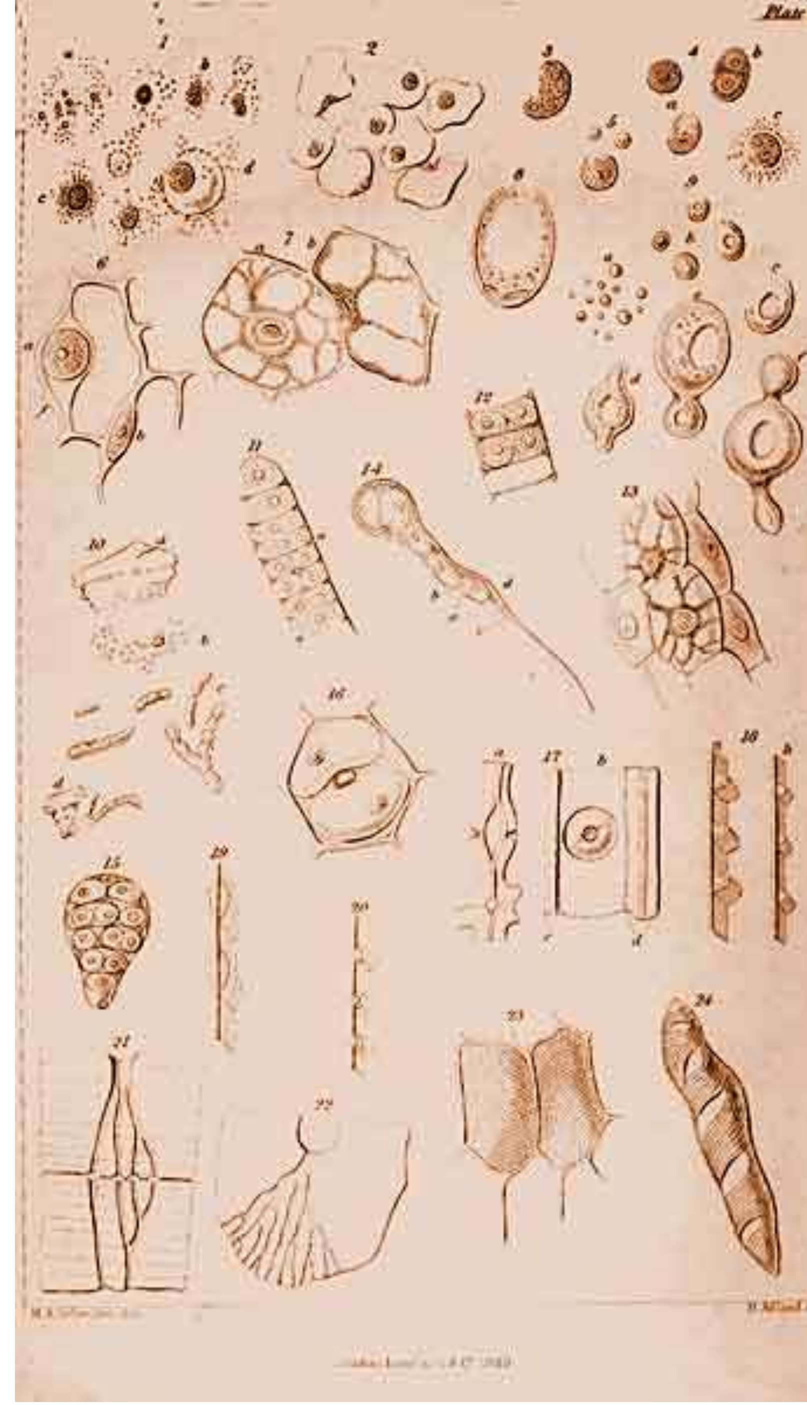
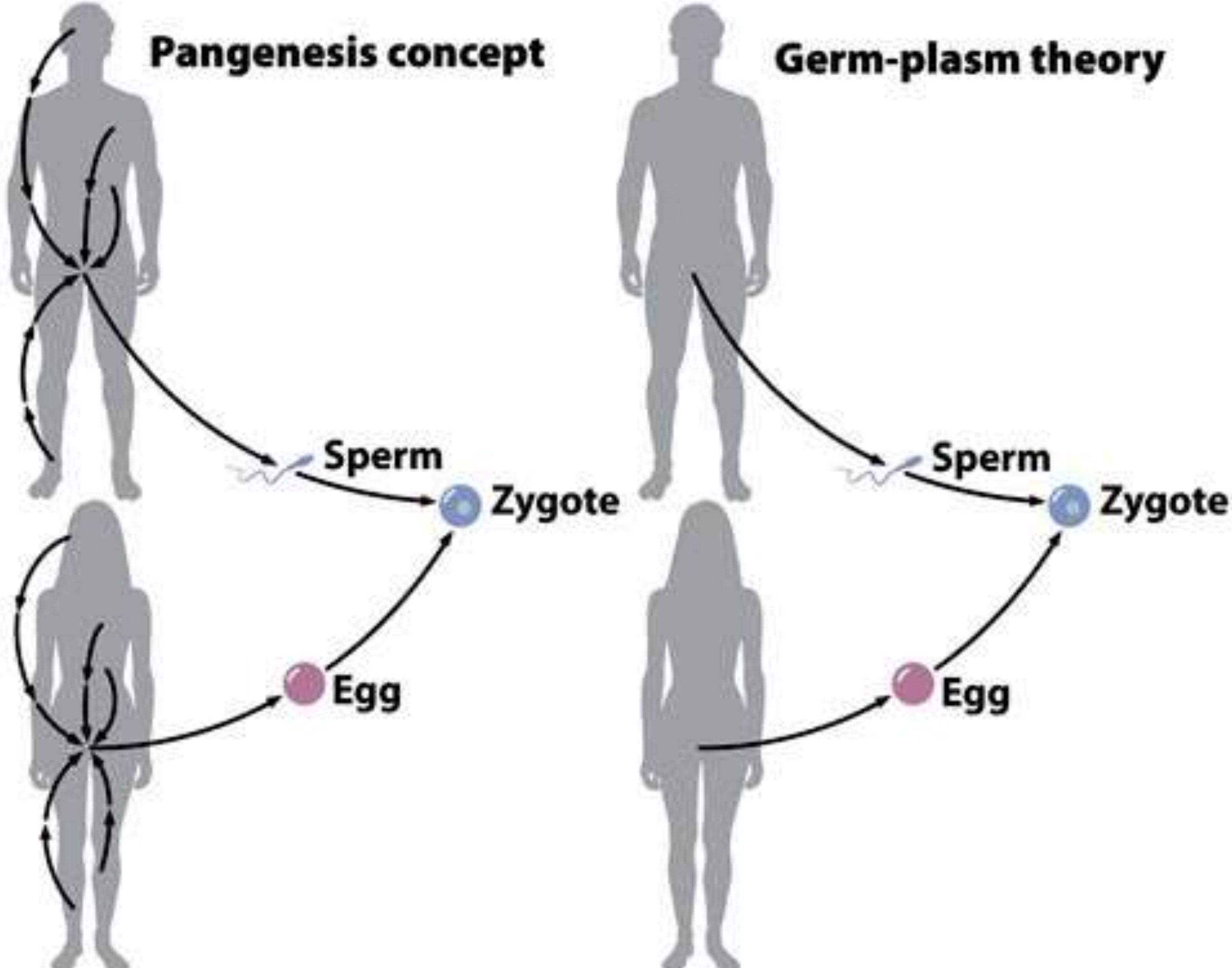
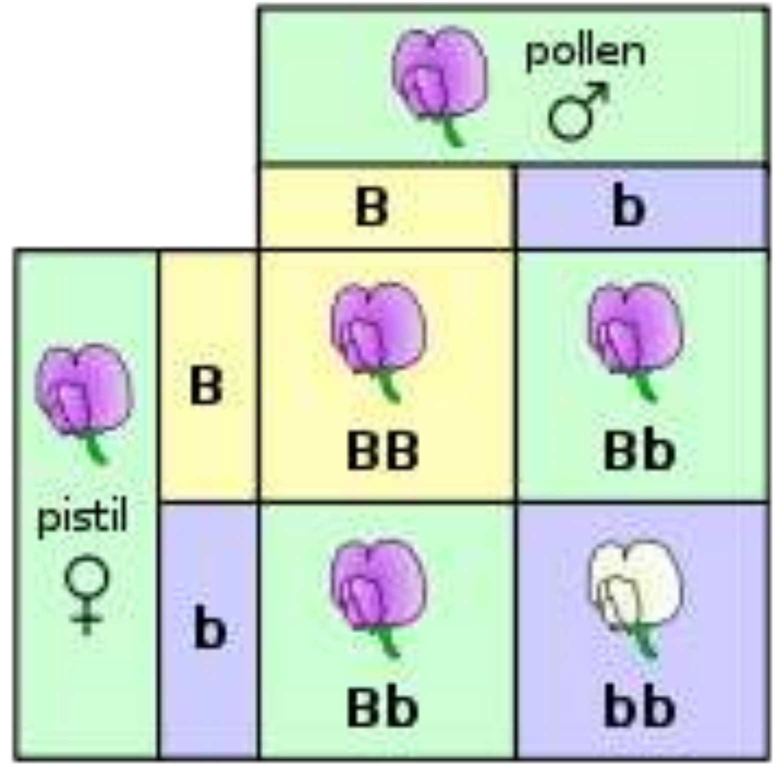


Plate 1 from J. M. Schleiden, Principles of Scientific Botany, 1849, showing various features of cell development



Weismann – Germline
significance of meiosis for reproduction and inheritance - 1890



FIRST LAW:

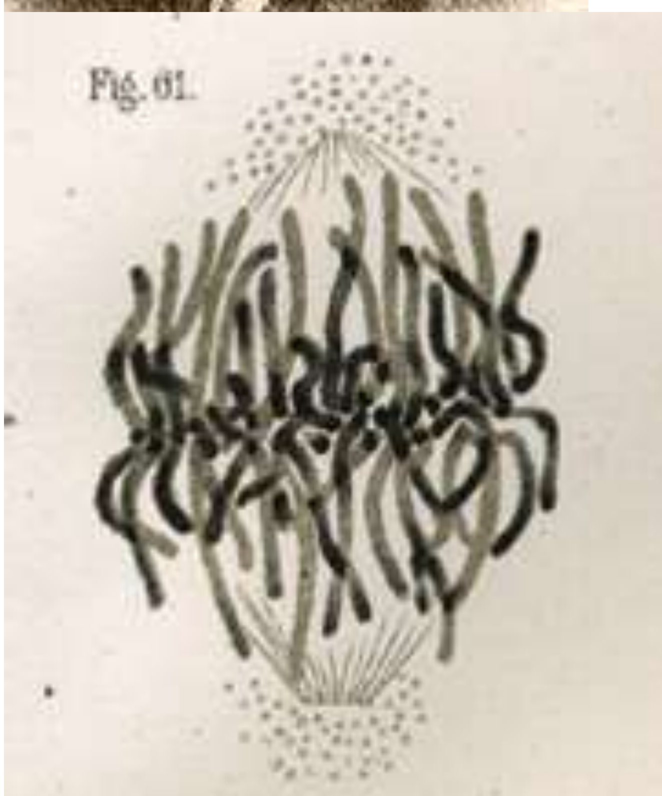
1. Each trait due to a **pair of hereditary factors** which
2. **segregate during gametogenesis**

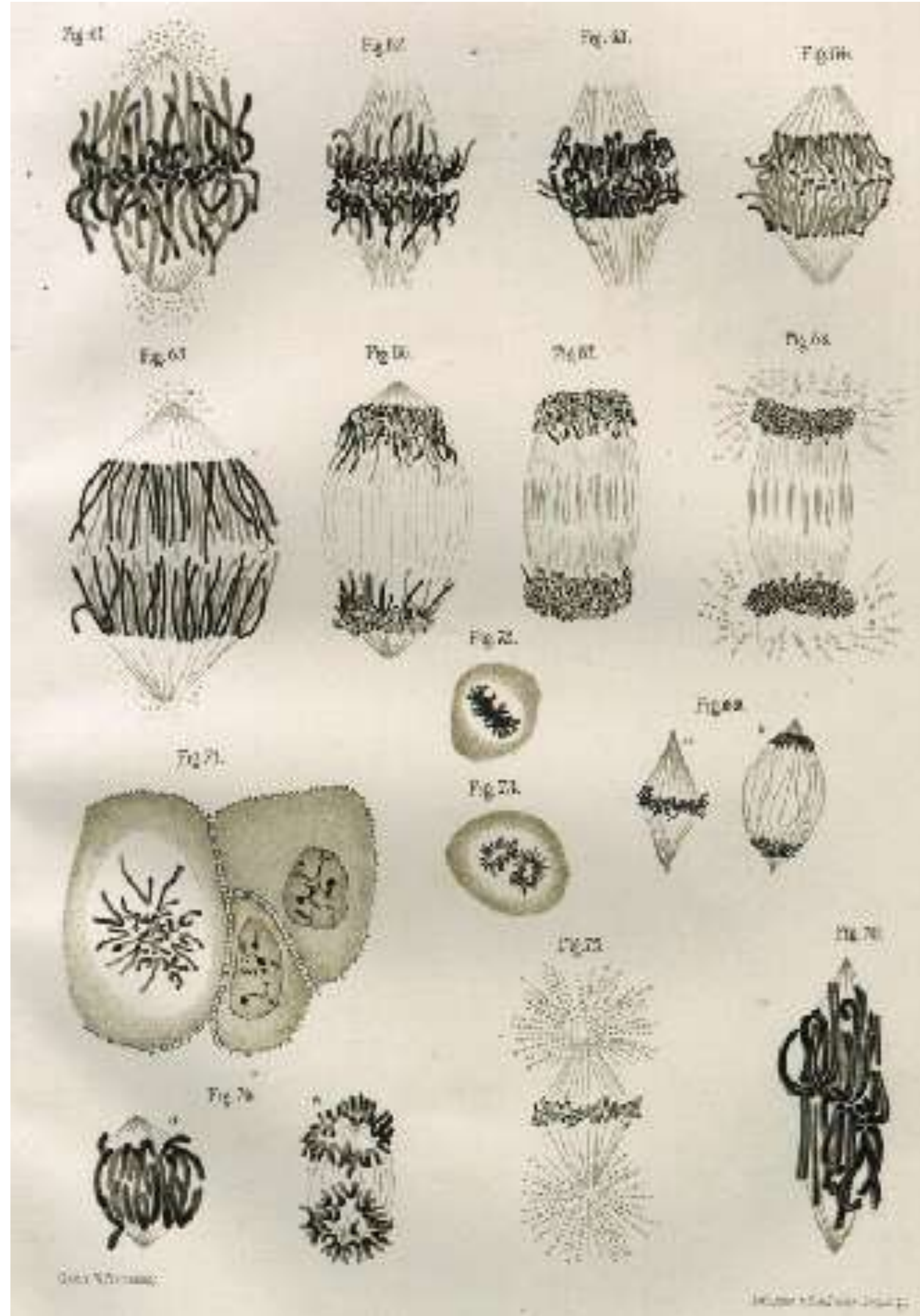
SECOND LAW:

3. Multiple sets of hereditary factors **assort independently**

Mendel‘s work with peas showed that the “blending” explanation was wrong

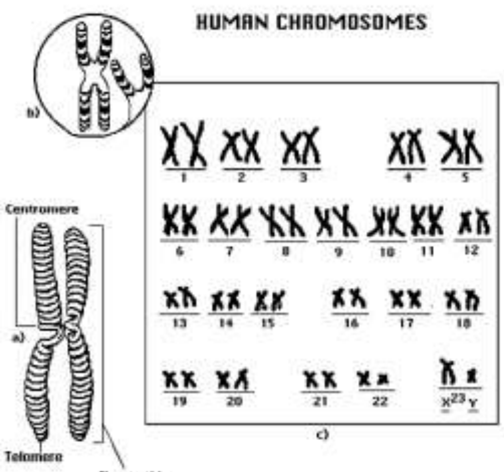
Walther Flemming - Mitosis





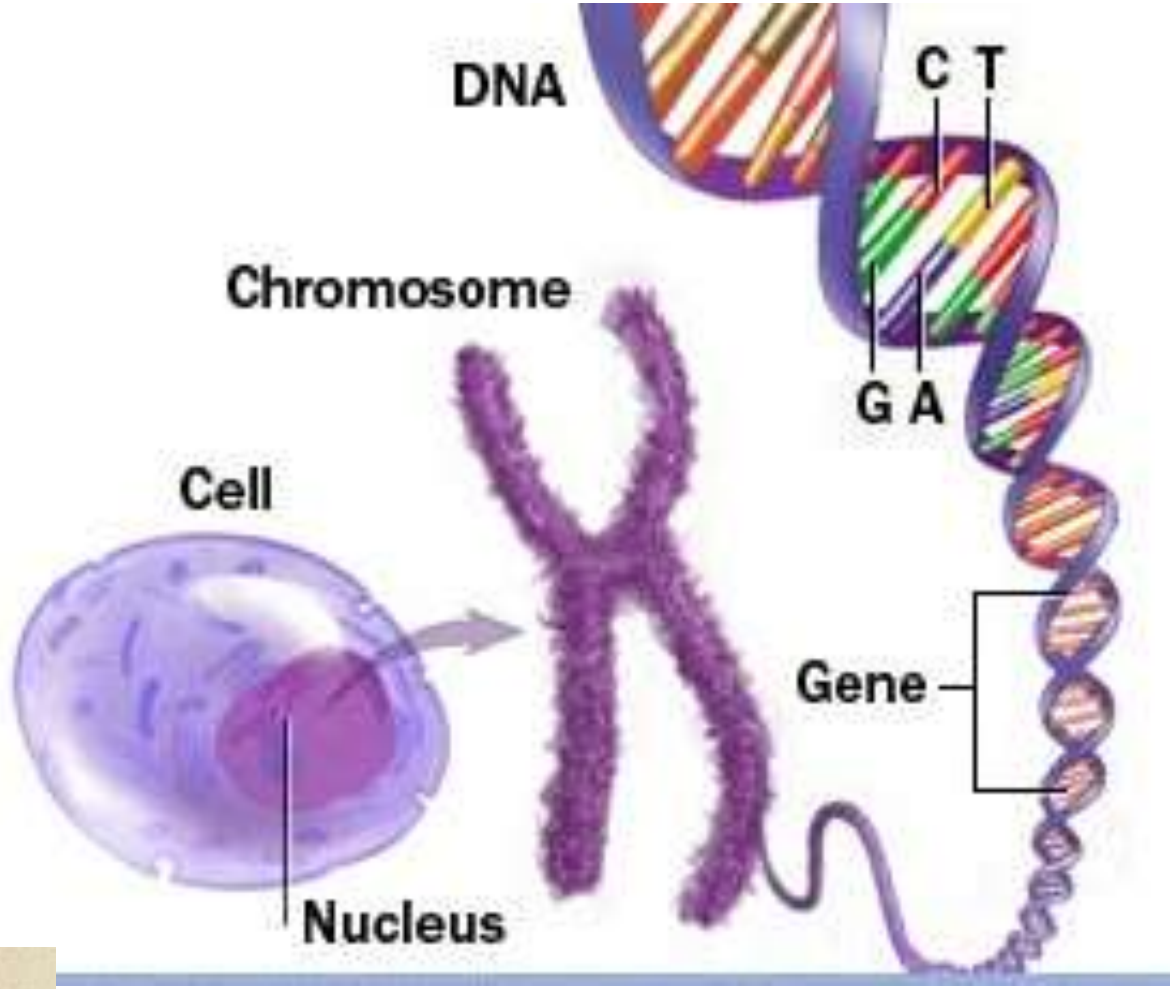
Walter Sutton – Chromosome Theory of Inheritance

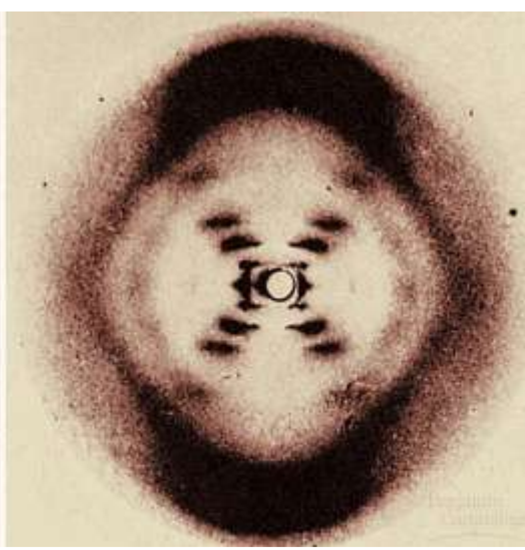
Chromosomes.		Combinations in Gametes.	Combinations in Zygotes.
Somatic Series.	Reduced Series.		
2	1	2	4
4	2	4	16
6	3	8	64
8	4	16	256
10	5	32	1,024
12	6	64	4,096
14	7	128	16,384
16	8	256	65,536
18	9	512	262,144
20	10	1,024	1,048,576
22	11	2,048	4,194,304
24	12	4.096	16,777,216
26	13	8,192	67,108,864
28	14	16,384	268,435,456
30	15	32,768	1,073,741,824
32	16	65,536	4,294,967,296
34	17	131,072	17,179,869,184
36	18	262,144	68,719,476,736



Possible combinations of chromosome pairs at metaphase

Watson and Crick





Rosalind Franklin,
X-ray diffraction of DNA

Basic Definitions

gene - basic unit of heredity; codes for a specific trait

locus - the specific location of a gene on a chromosome (locus - plural loci)

chromosome - elongate cellular structure composed of DNA and protein - they are the vehicles which carry DNA in cells

chromatid - one of two duplicated chromosomes connected at the centromere

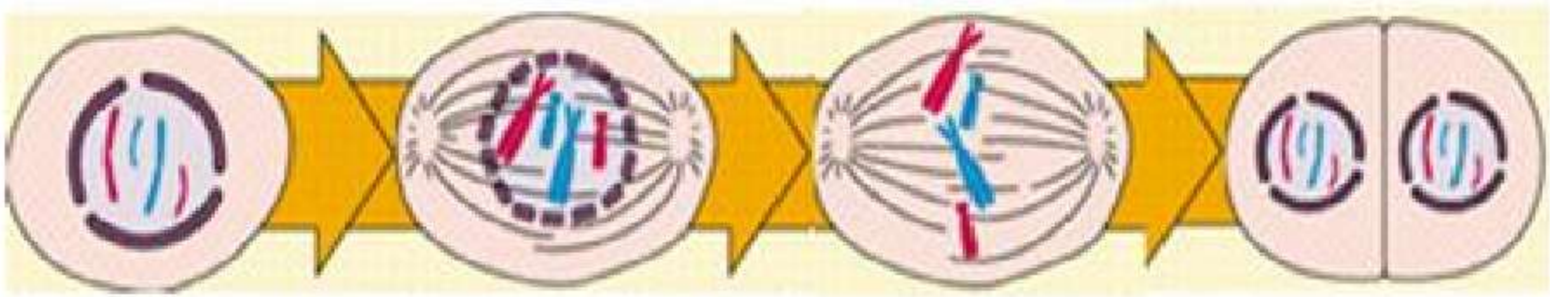
centromere - region of chromosome where microtubules attach during mitosis and meiosis

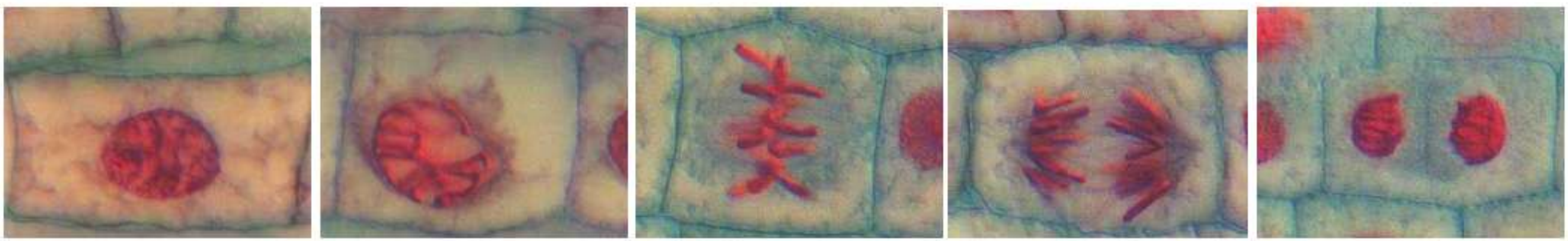
diploid (2n) - cellular condition where each chromosome type is represented by two homologous chromosomes

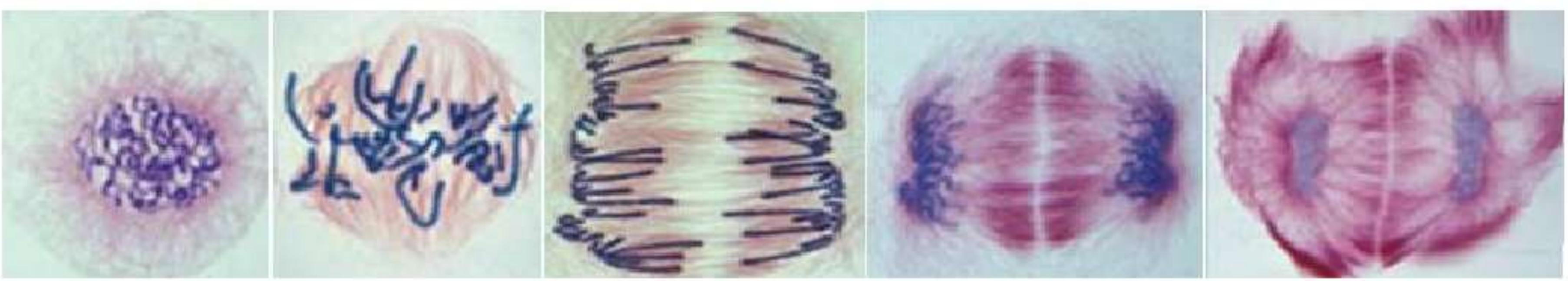
haploid (n) - cellular condition where each chromosome type is represented by only one chromosome

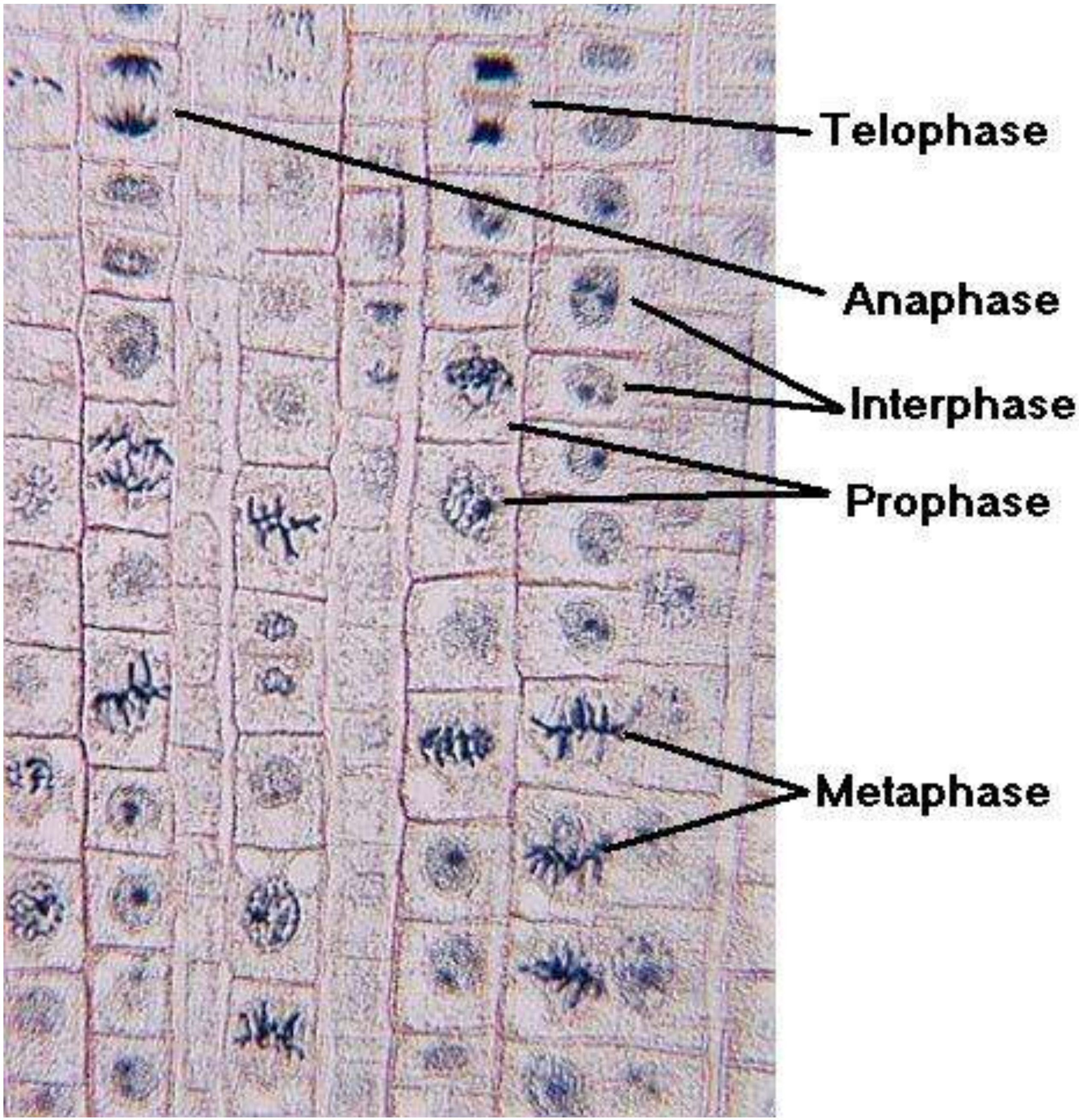
homologous chromosome - chromosome of the same size and shape which carry the same type of genes

Mitosis in Plants and Animals

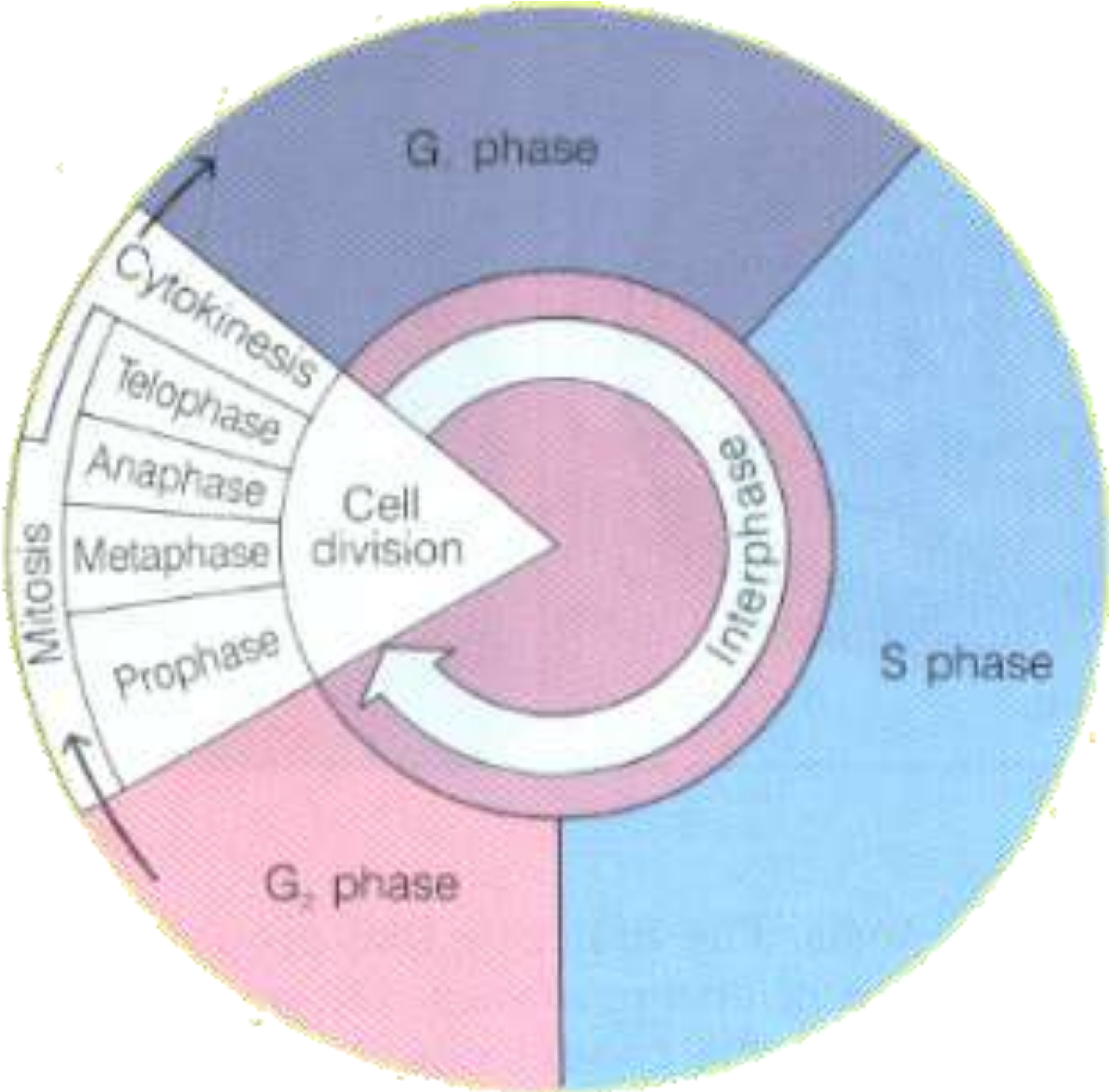






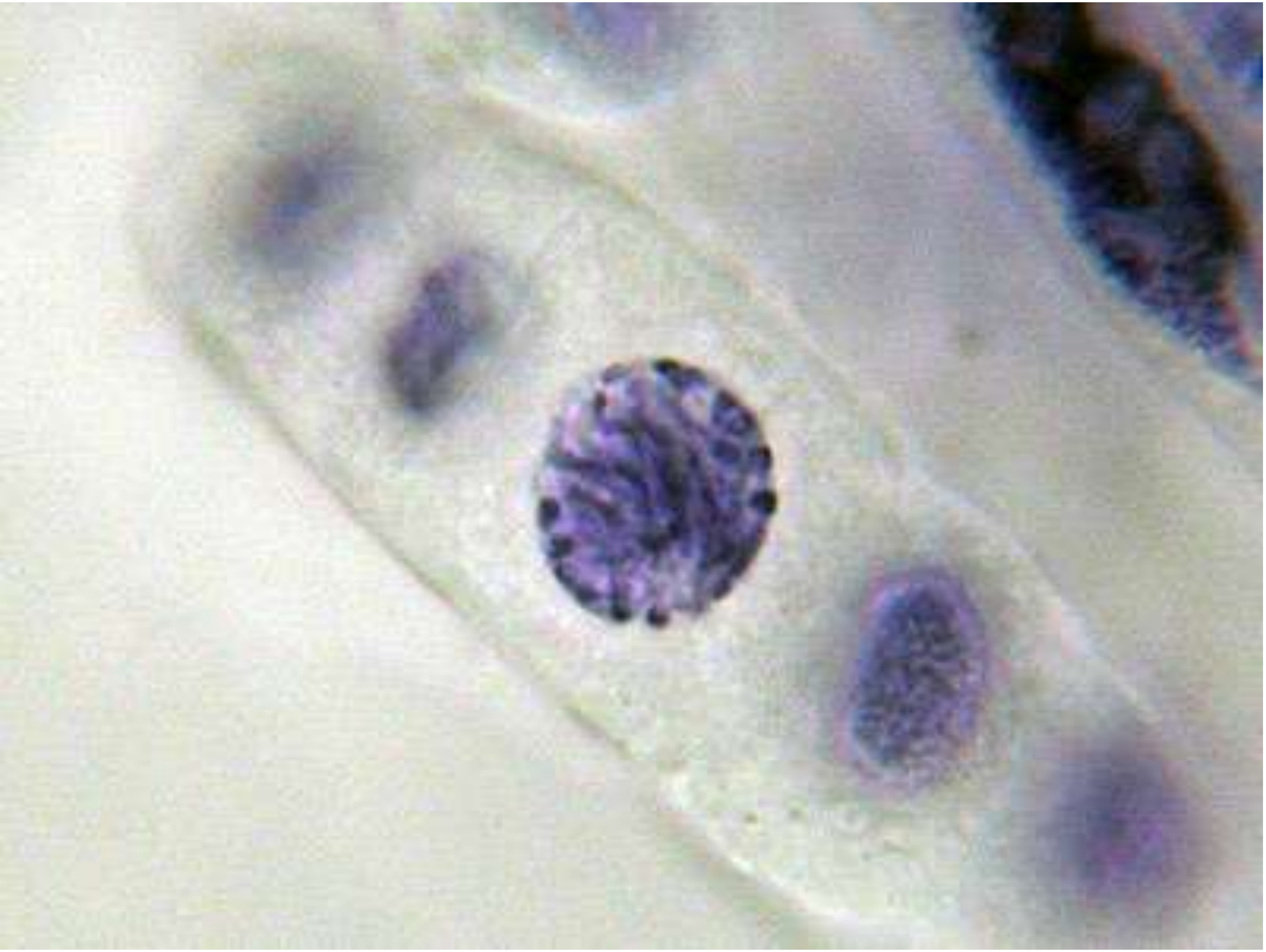

Telophase
Anaphase
Interphase
Prophase
Metaphase

Cell Cycle



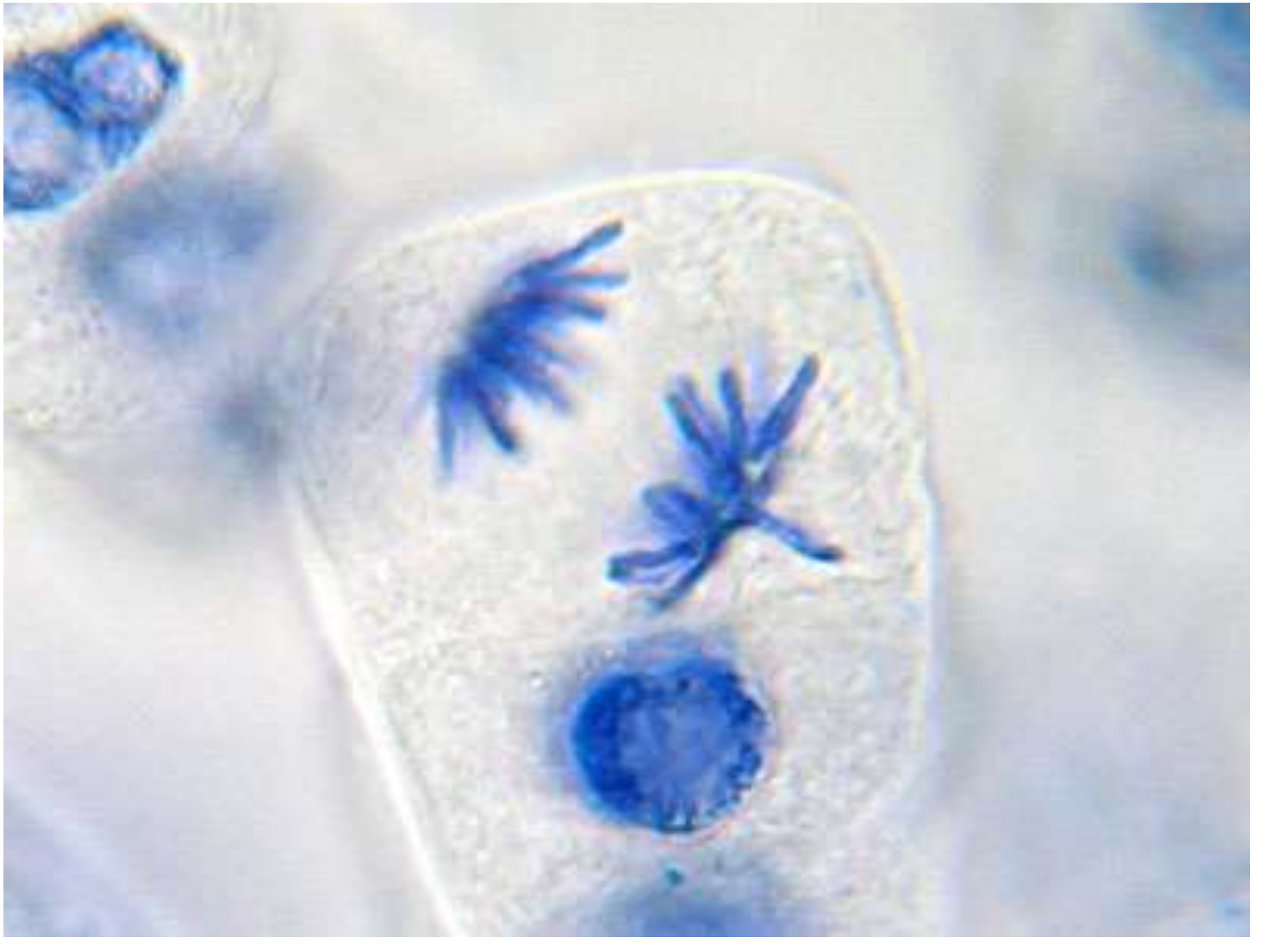
G1 phase
S phase
G2 phase
Cytokinesis
Telophase
Anaphase
Metaphase
Prophase
Mitosis
Cell division
Interphase

Prophase: the chromosomes begin to condense, while around the nucleus spindle fibres develop

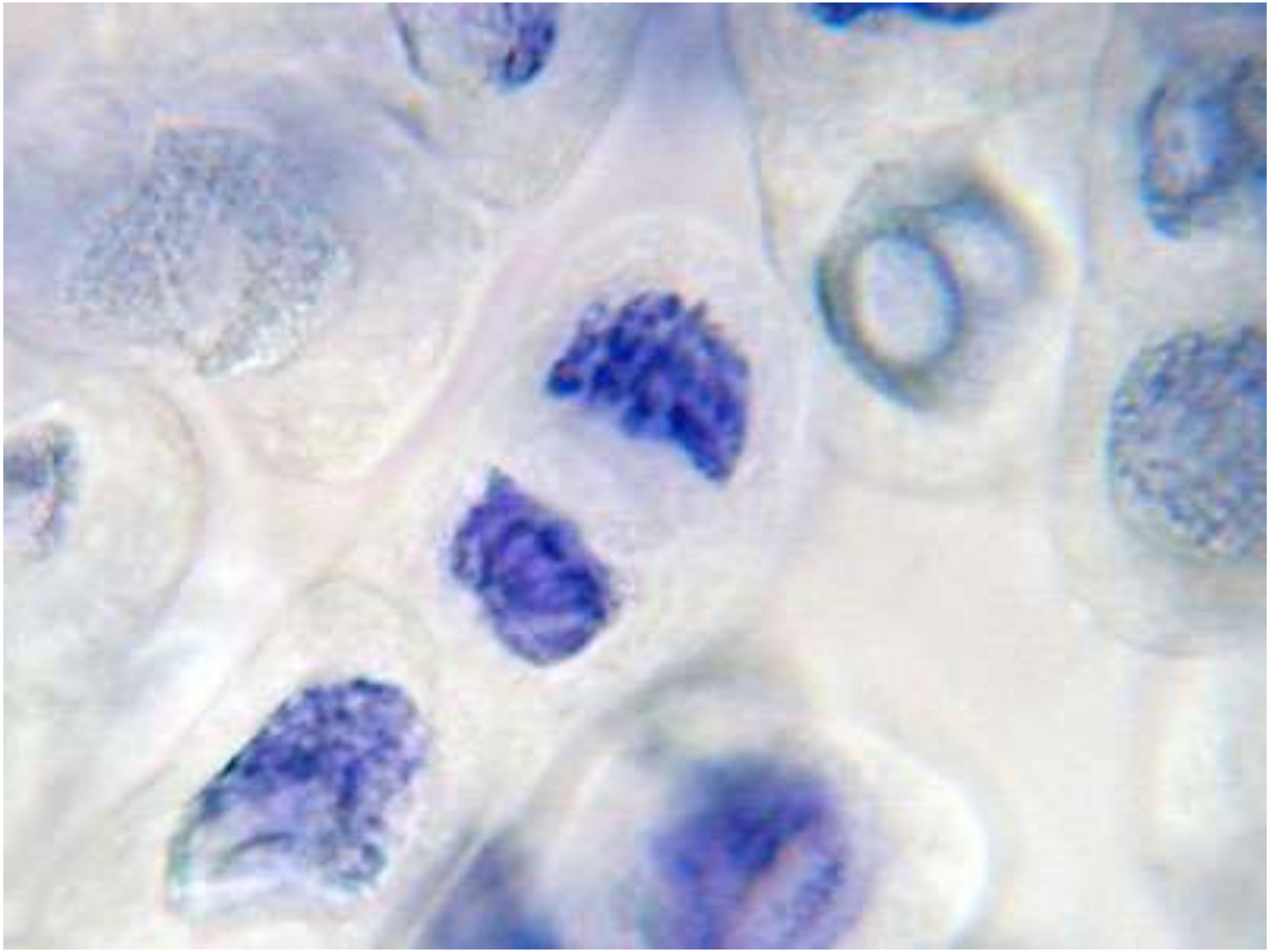


Metaphase: the chromosomes line up along the equatorial plane of the cell

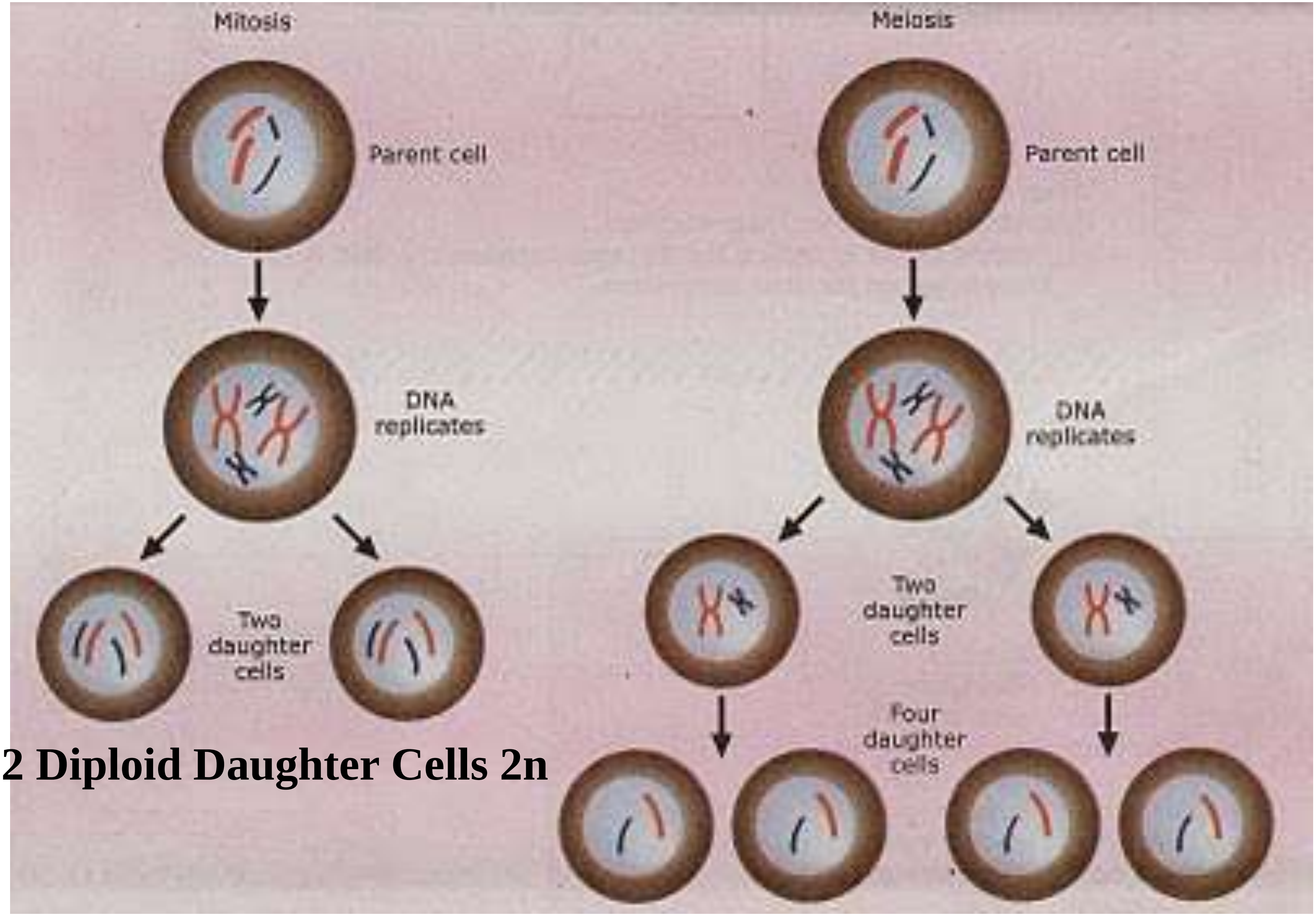
Anaphase: the chromosome pairs divide and the two groups migrate to opposite poles of the cell.



Telophase - a nuclear membrane forms, the chromosomes disperse and can no longer be distinguished. The spindle fibres dissolve. A new cell wall forms and the two cells separate.

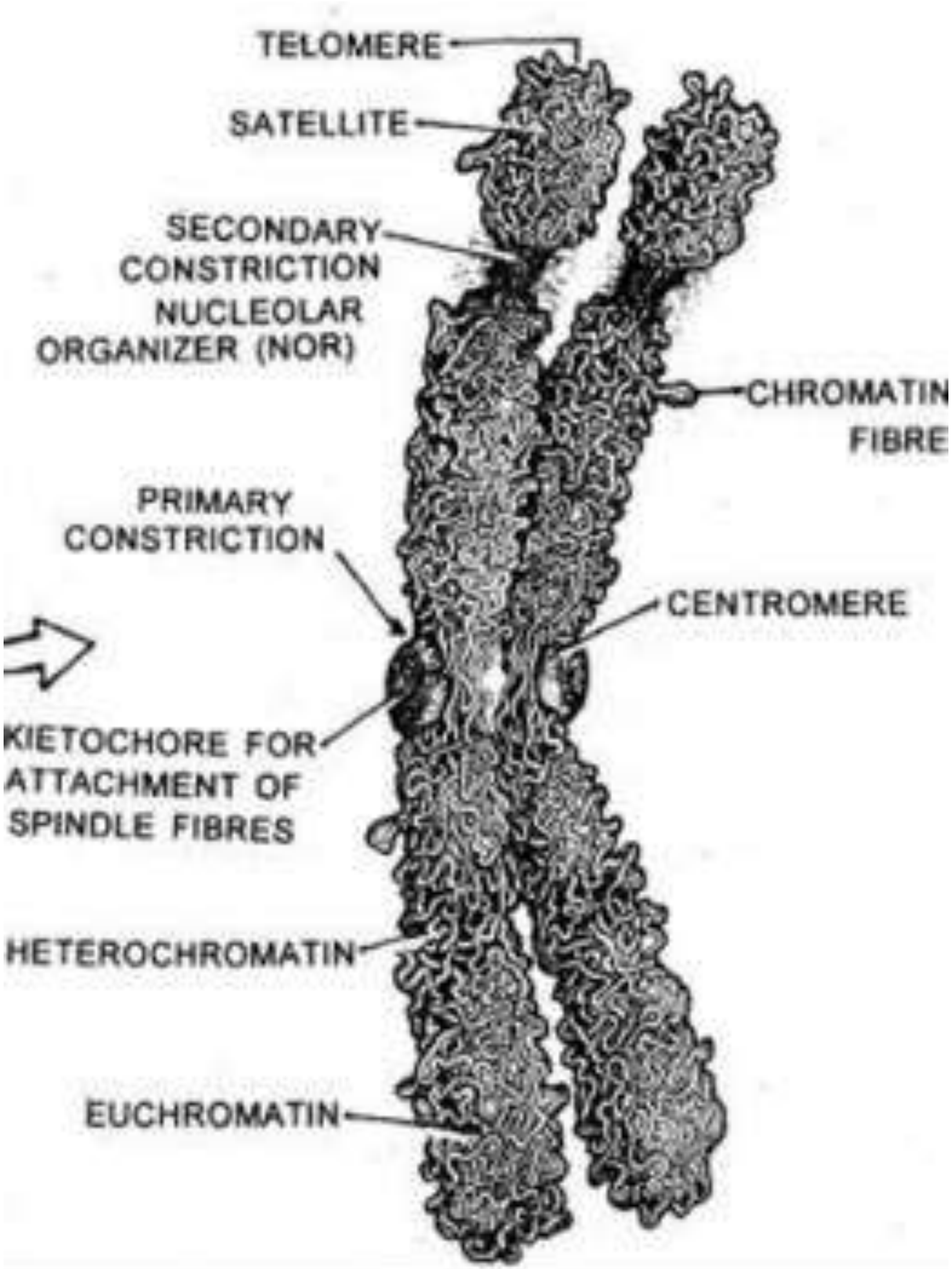


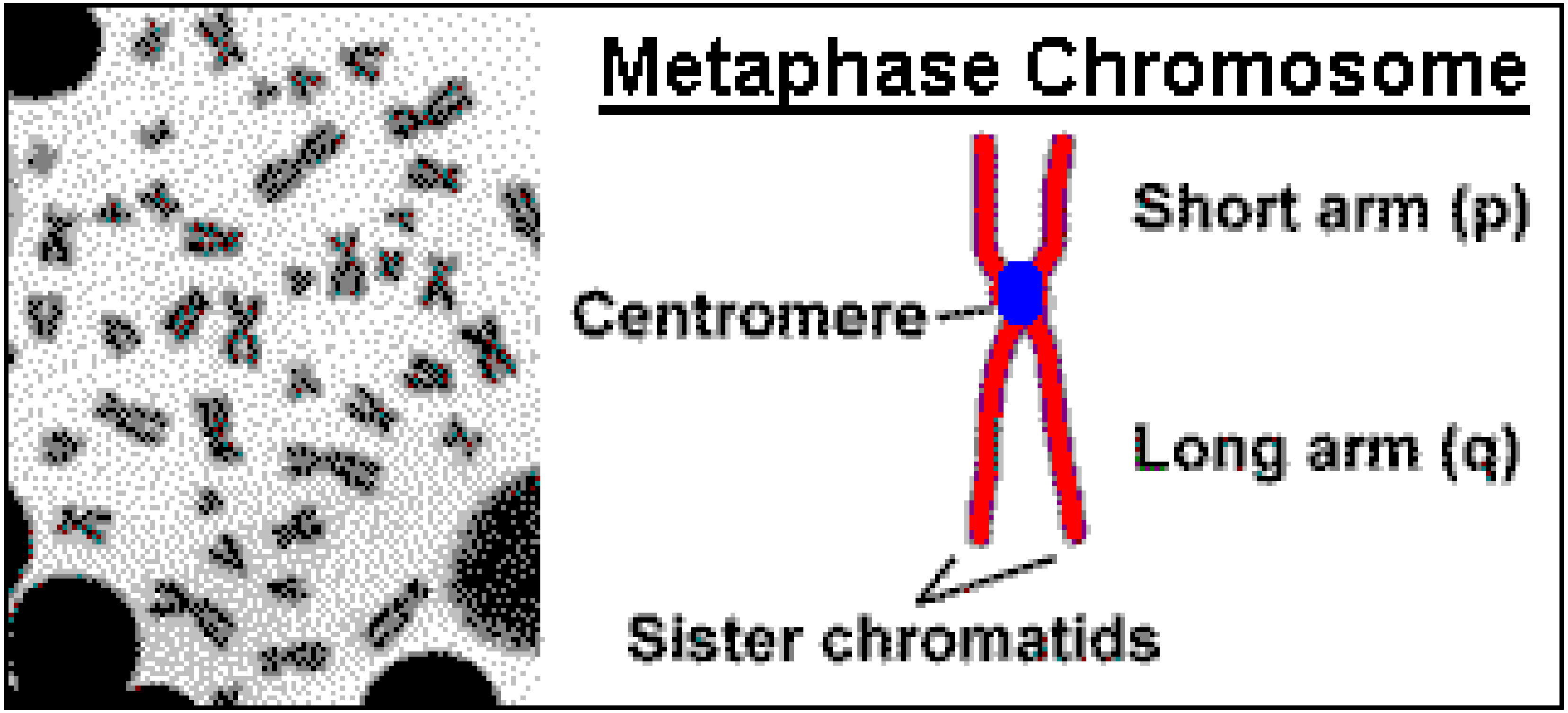
Mitosis **Meiosis**

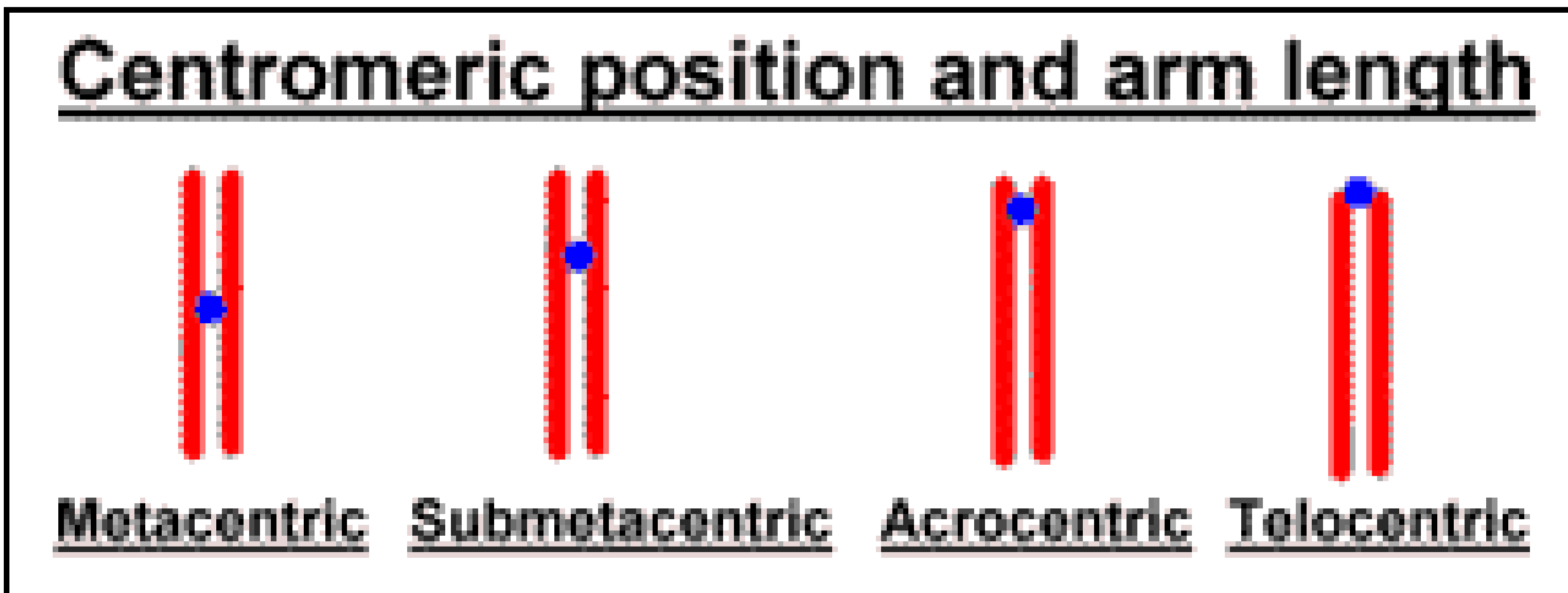


2 Diploid Daughter Cells 2n

4 Haploid Gametes 1n


TELOMERE
SATELLITE
SECONDARY CONSTRICTION NUCLEOLAR ORGANIZER (NOR)
CHROMATIN FIBRE
PRIMARY CONSTRICTION
CENTROMERE
KIETOCHORE FOR ATTACHMENT OF SPINDLE FIBRES
HETEROCHROMATIN
EUCHROMATIN


Metaphase Chromosome
Short arm (p)
Centromere
Long arm (q)
Sister chromatids

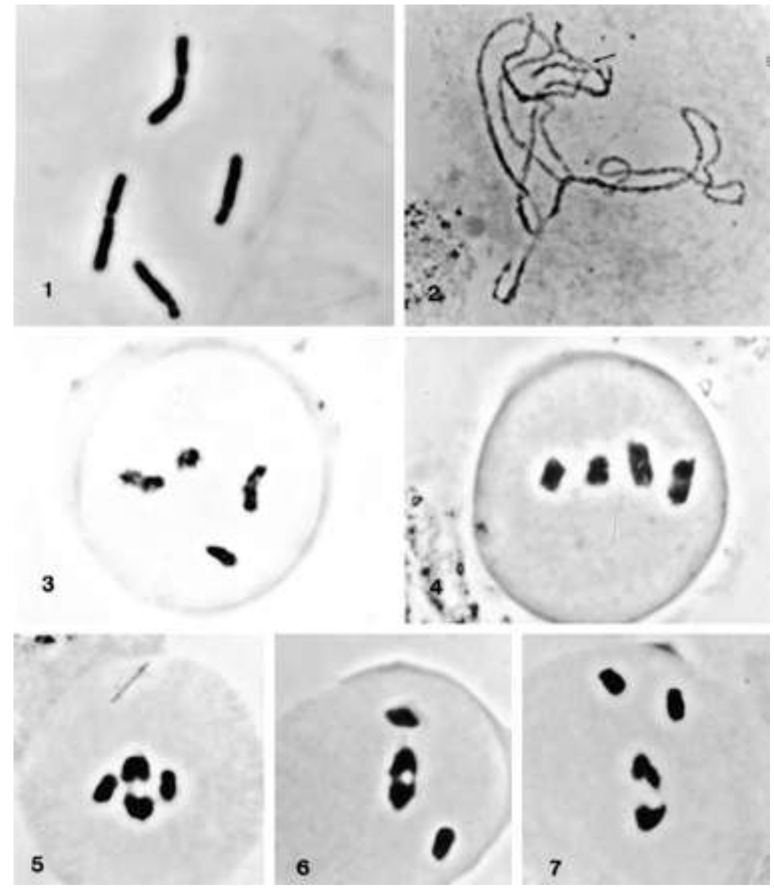

Centromeric position and arm length
Metacentric
Submetacentric
Acrocentric
Telocentric

Chromosome Number

Ophioglossum reticulatum **- 2N = 96X = 1440**

Haplopappus (Machaeranthera) gracilis (Asteraceae)

2N = 2X = 4



IPCN Chromosome Reports

Index to Plant Chromosome Numbers (IPCN)

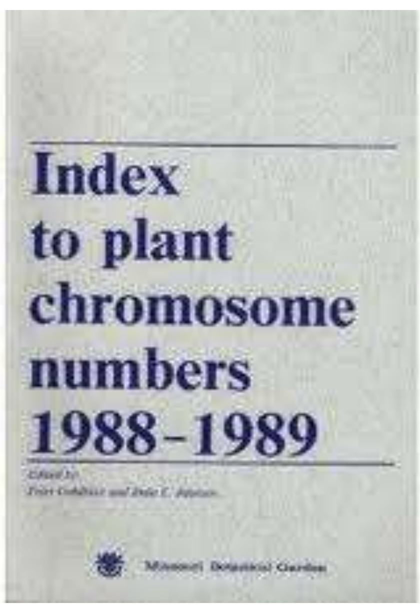
The ***Index to Plant Chromosome Numbers*** is an **NSF funded project** that aims to extract and index original plant chromosome numbers of naturally occurring and cultivated plants published throughout the world. A committee of voluntary contributing editors, located in various parts of the world, reviews sets of serial titles assigned to them and returns the information to the editors for collation in the *Index* and database. Chromosome indexes are published at two or three year intervals. The *Index to Plant Chromosome Numbers* project has been based at the Missouri Botanical Garden since 1978. Data from published indexes from 1979 onward are available for consultation through this facility.

For additional information, see the last supplement by Goldblatt & Johnson 2006. *Index to Plant Chromosome Numbers 2001-2003. Monographs in Systematic Botany from the Missouri Botanical Garden 106.*

An Index covering the years 2004-2006 is in preparation and will be published in the fall of 2008 as: Goldblatt & Johnson 2008. *Index to Plant Chromosome Numbers 2004-2006. Monographs in Systematic Botany from the Missouri Botanical Garden.*

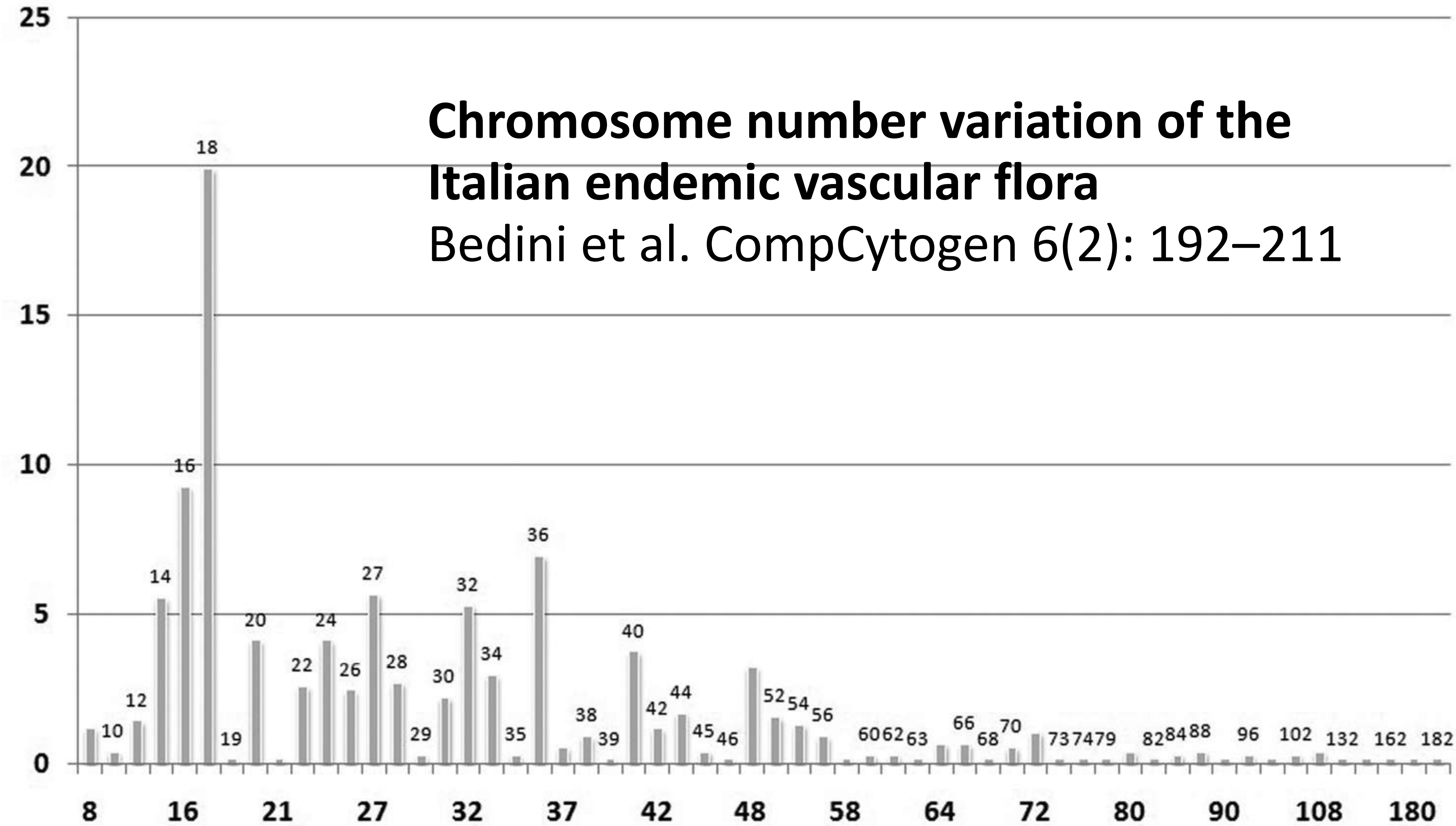
Many but not all data in the printed version of the *Index to Plant Chromosome Numbers* (1979--) are available on the Web in the IPCN database. The printed indexes and the database provide references to chromosome counts reported in the original literature. We therefore request that the IPCN database itself not be cited as the source for chromosome counts. If there is a need to cite the IPCN database, we recommend the following:

Index to plant chromosome numbers. 1979-- . P. Goldblatt & D. E. Johnson, eds. Missouri Botanical Garden, St. Louis.

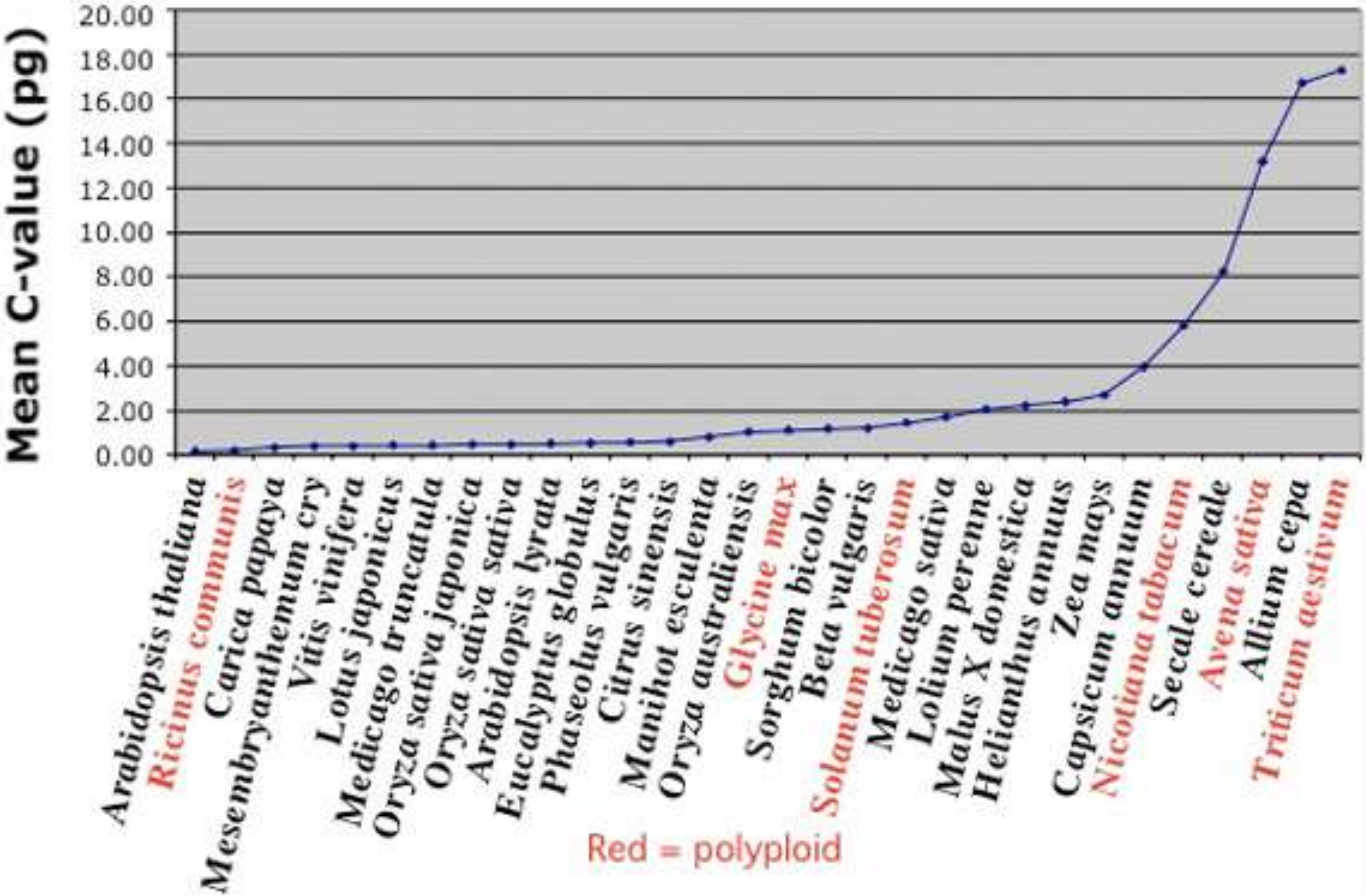


Peter Goldblatt MBG

Chromosome number variation of the Italian endemic vascular flora
Bedini et al. CompCytogen 6(2): 192–211



Known chromosome numbers in Italian endemics range from 2n = 8 to 2n = 182. **Mean chromosome number for Italian endemics is 2n = 30.68** 20.27 (median: 2n = 26, mode: 2*n* = 18).



Mean C-value (pg)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Arabidopsis thaliana
Ricinus communis
Carica papaya
Mesembryanthemum cry
Vitis vinifera
Lotus japonicus
Medicago truncatula
Oryza sativa japonica
Oryza sativa sativa
Arabidopsis lyrata
Eucalyptus globulus
Phaseolus vulgaris
Citrus sinensis
Manihot esculenta
Oryza australiensis
Glycine max
Sorghum bicolor
Beta vulgaris
Solanum tuberosum
Medicago sativa
Lolium perenne
Malus X domestica
Helianthus annuus
Zea mays
Capsicum annuum
Nicotiana tabacum
Secale cereale
Avena sativa
Allium cepa
Triticum aestivum
Red = polyploid

C-Values

Chromosome Number

Variation exists within genera:
Stylidium (2N = 5-16, 26, 28, 30)
Cardamine (2N = 16, 24, 28, 30, 32)

Variation exists within particular species:
Rumex subgenus ***Rumex***: 2N = 2X = 20, 2N = 4X = 40, 2N = 20X = 200.
Chaenactis douglasii: 2N = 12-15, 18, 24-28, 36, 38.

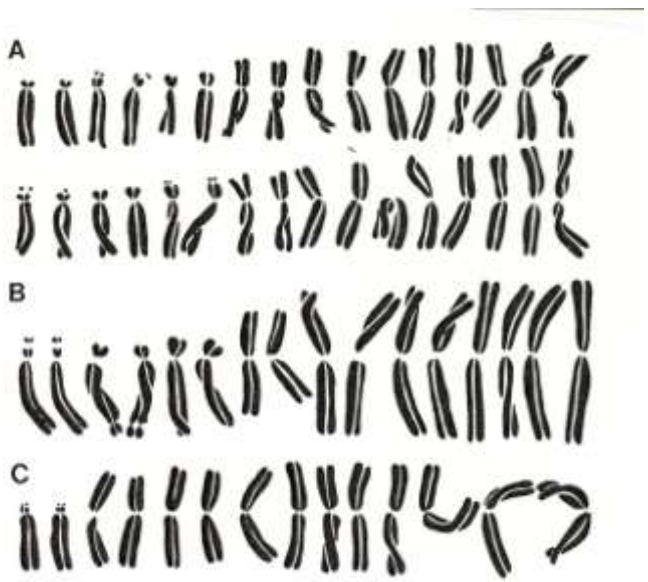
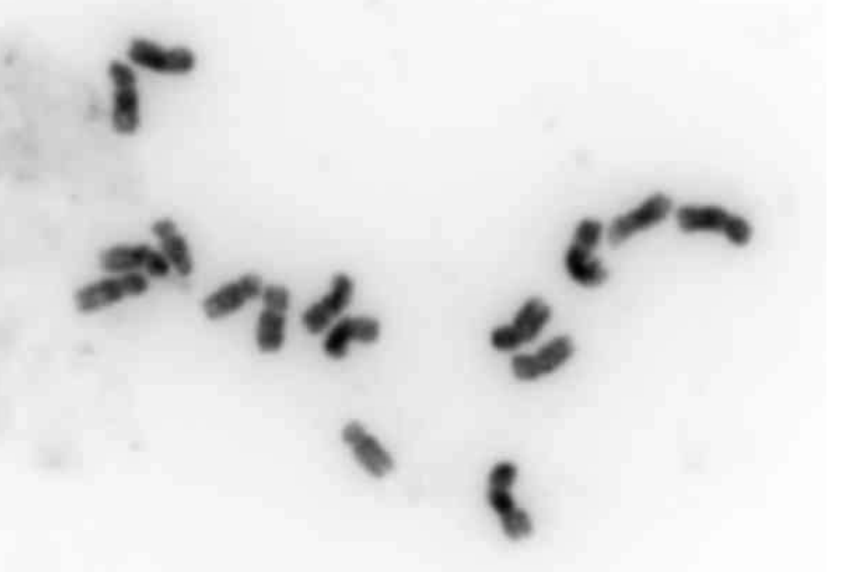


FIGURE 19.4 Drawings of metaphase chromosomes of *Anemone* (Ranunculaceae). A, *A. quinquefolia*, 2n = 32; B, *A. rivularis*, 2n = 16; C, *A. richardsonii*, 2n = 14. x2500. (From Heimburger 1959:592)

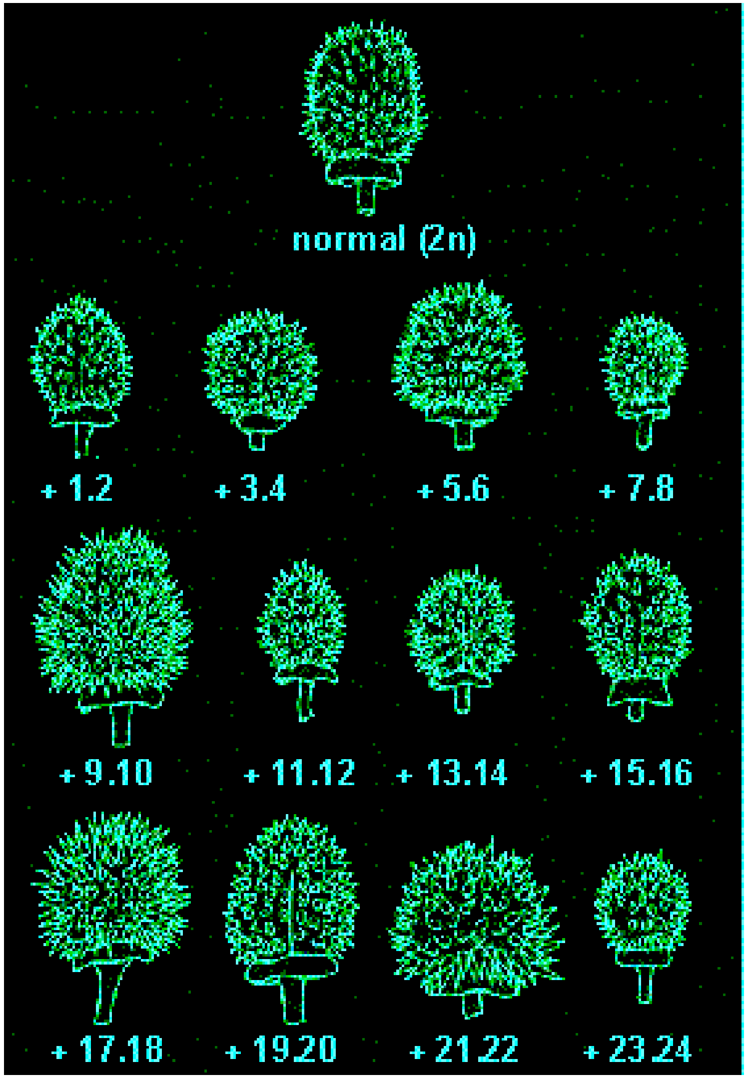
Anemone



Chamaecrista

Aneuploidy

a gain or loss of one or more chromosomes, e.g. 2N -1, 2N + 1, 2N + 2, etc. The most common case are trisomies (sing. trisomy) where a single additional chromosome is present.



Fruits of *Datura*-
Plants On top: Control plant (2n)
Below: Mutants that are characterized by **one additional chromosome** each.

Loss of one or more chromosomes usually has more severe consequences

Aneuploidy

Claytonia virginica
Walter Lewis (1970, 1971).
Plants have different chromosome numbers in different parts of their ranges and even within same population. and within one individual from year to year.

"I would argue that if an organism does not take its chromosome number seriously, there is no reason why the systematist should" (Walter Lewis).

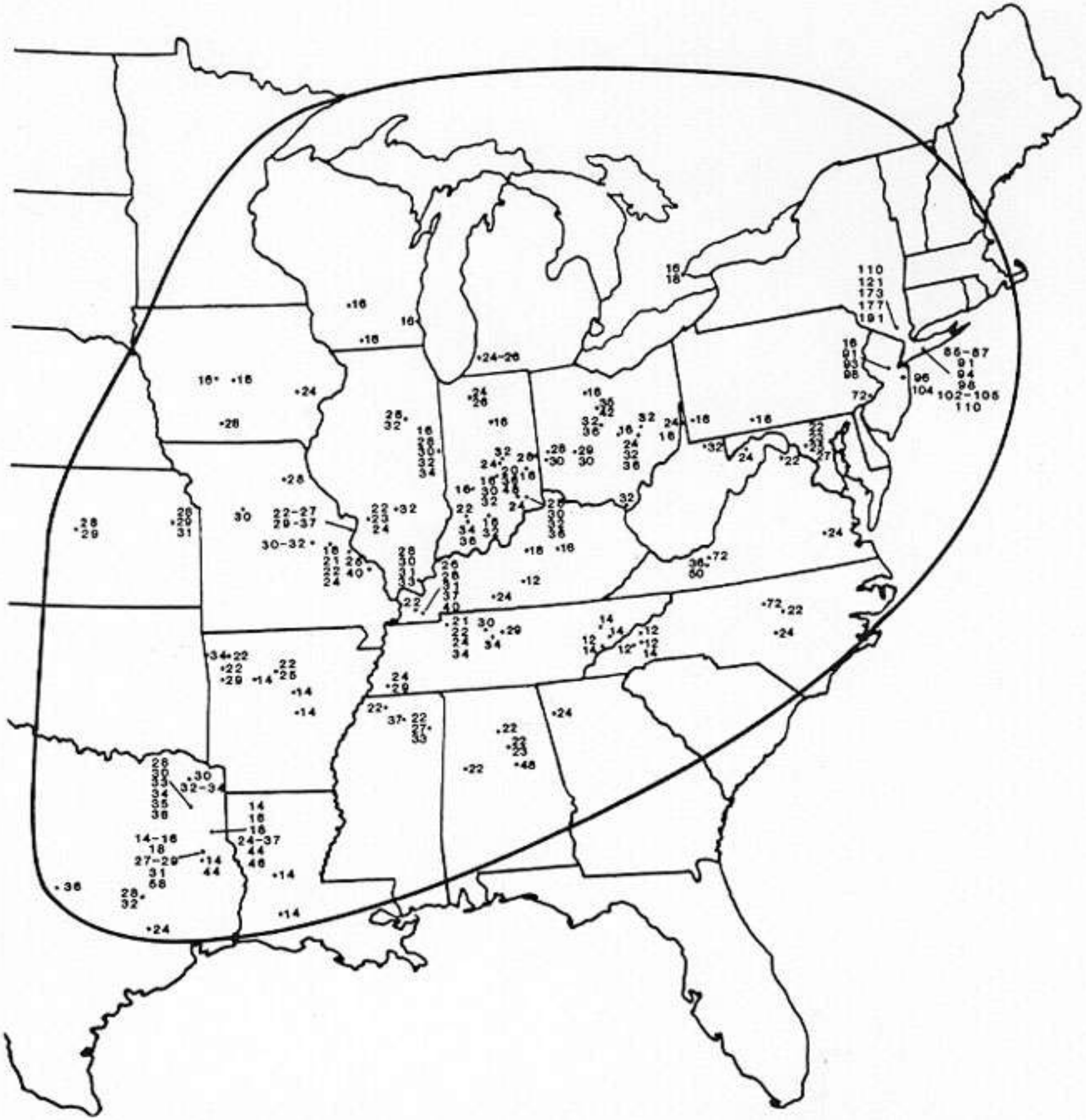
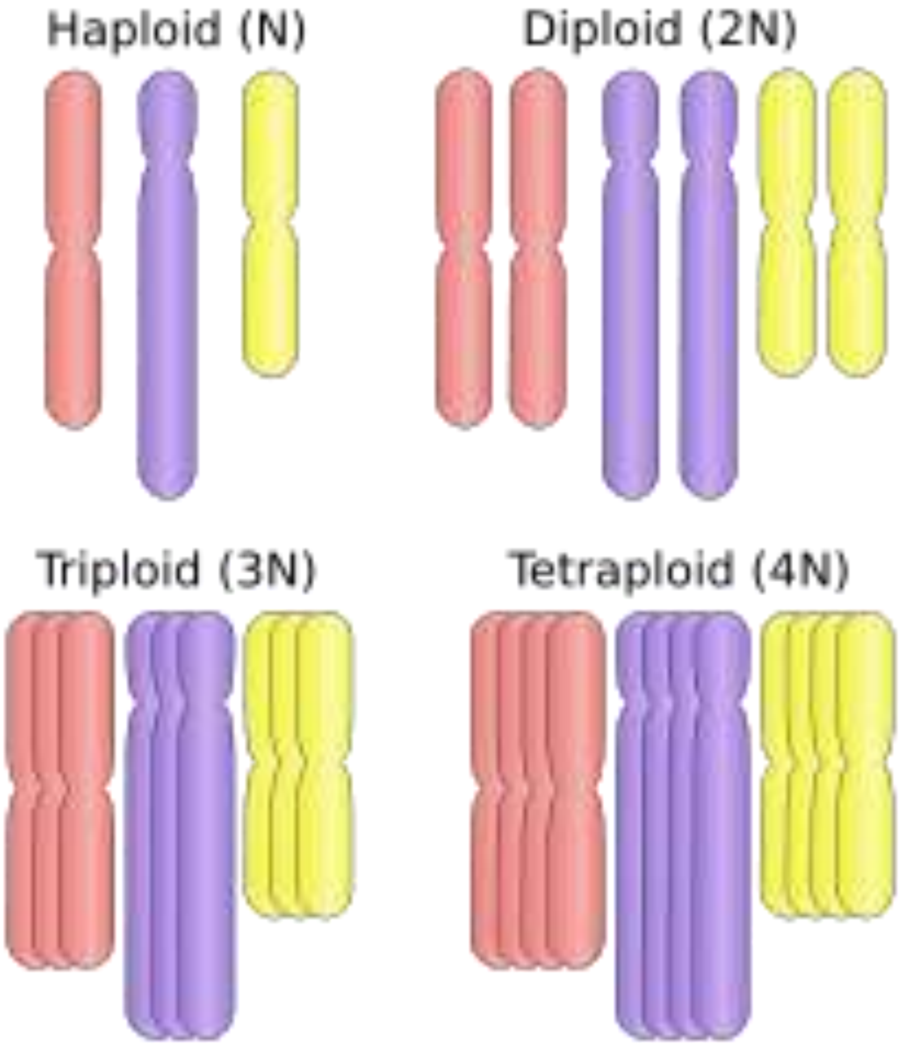


FIGURE 19.2 Variation of diploid chromosome numbers in populations throughout the range (enclosed area) of *Claytonia virginica* (Portulacaceae). (Redrawn from Lewis, Oliver, and Suda 1967:154)

Polyploidy – multiple sets of chromosomes

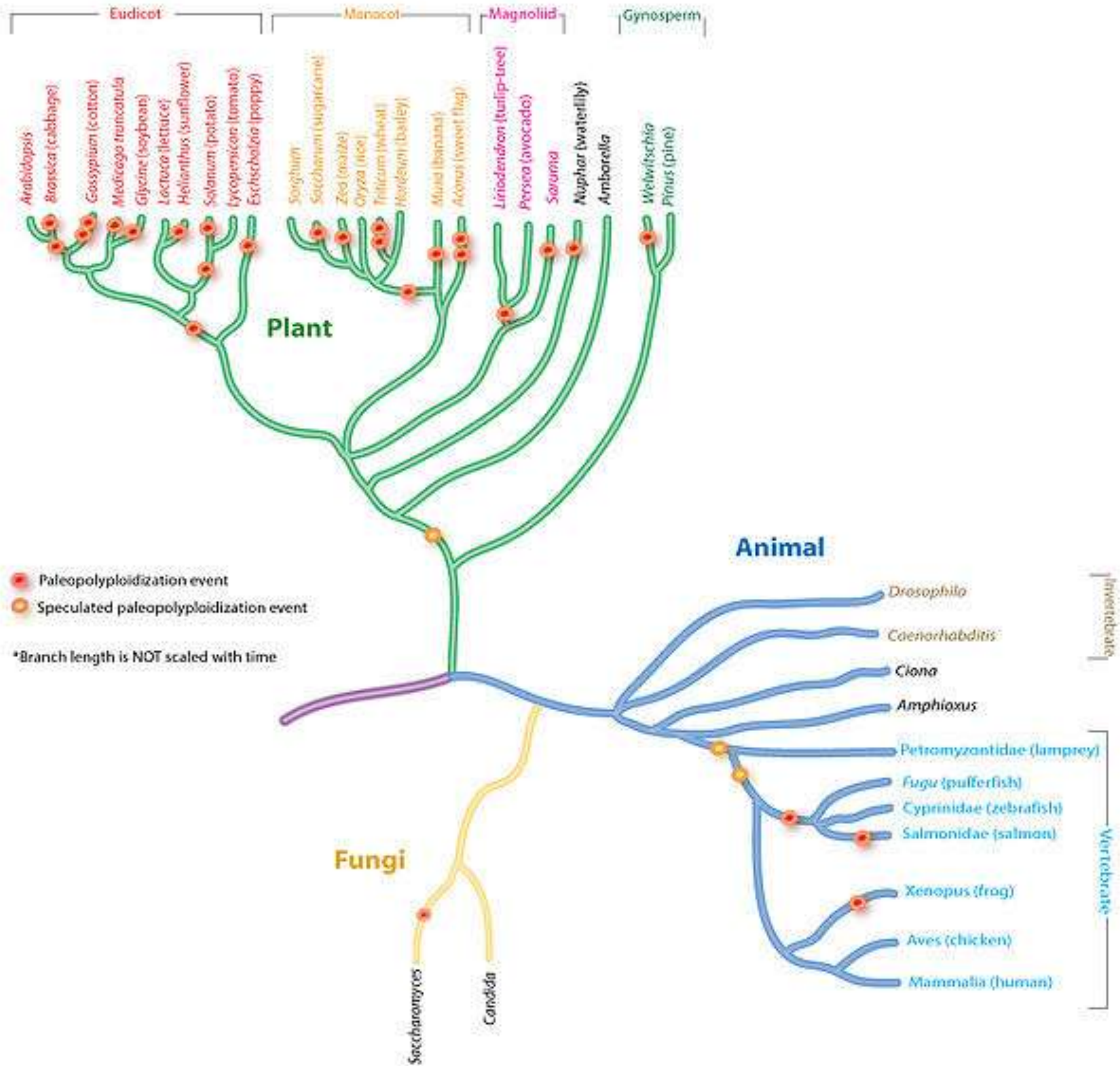


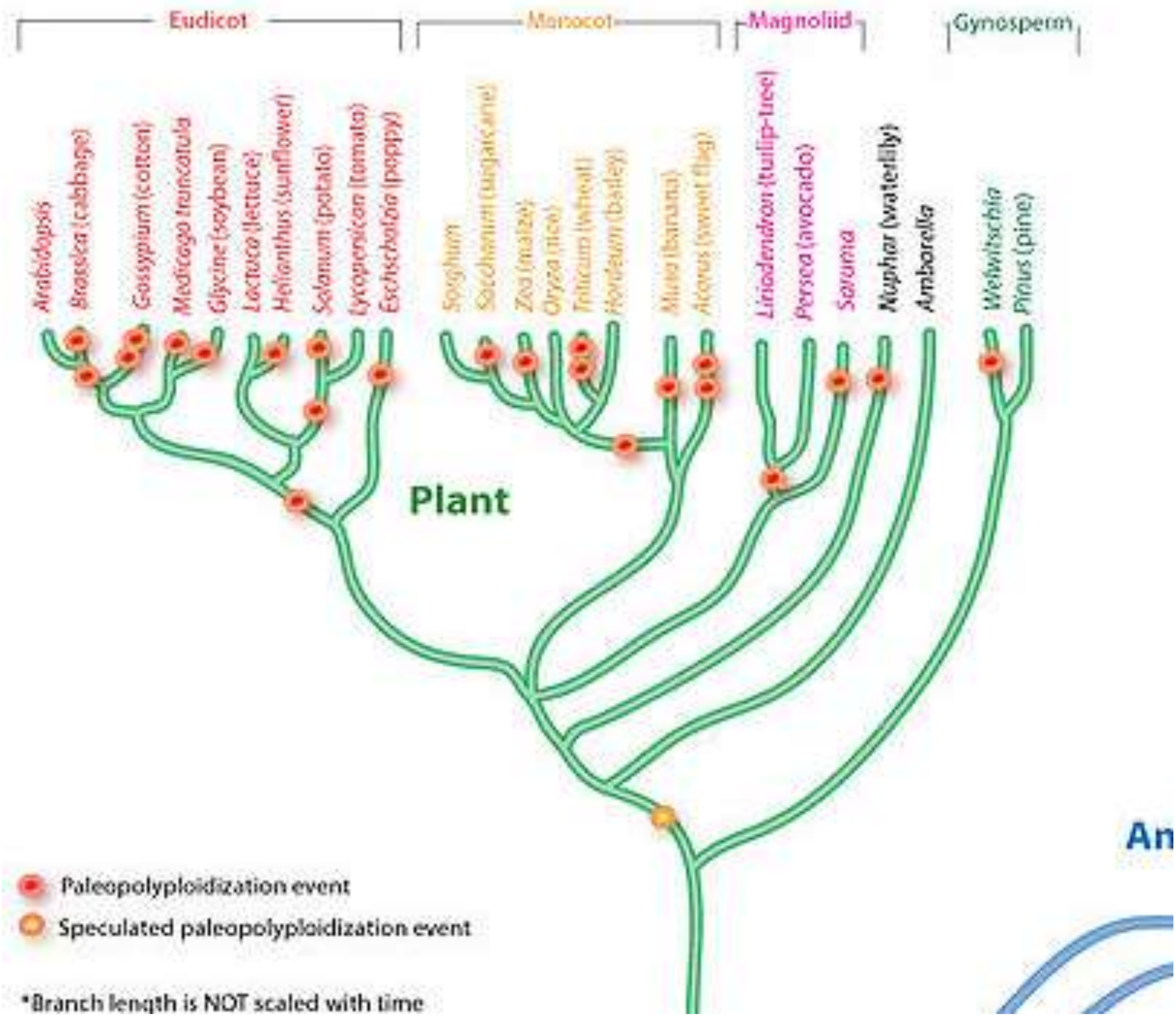
Diploid – 2 sets
Triploid – 3 sets (watermelon)
Tetraploid – 4 sets (cotton)
Hexaploids – 6 sets (wheat)

Autopolyploids: polyploids composed of multiple sets of chromosomes from the <u>same species</u>

Allopolyploids: polyploids that are a new species, composed of multiple sets of chromosomes from <u>closely related</u> species

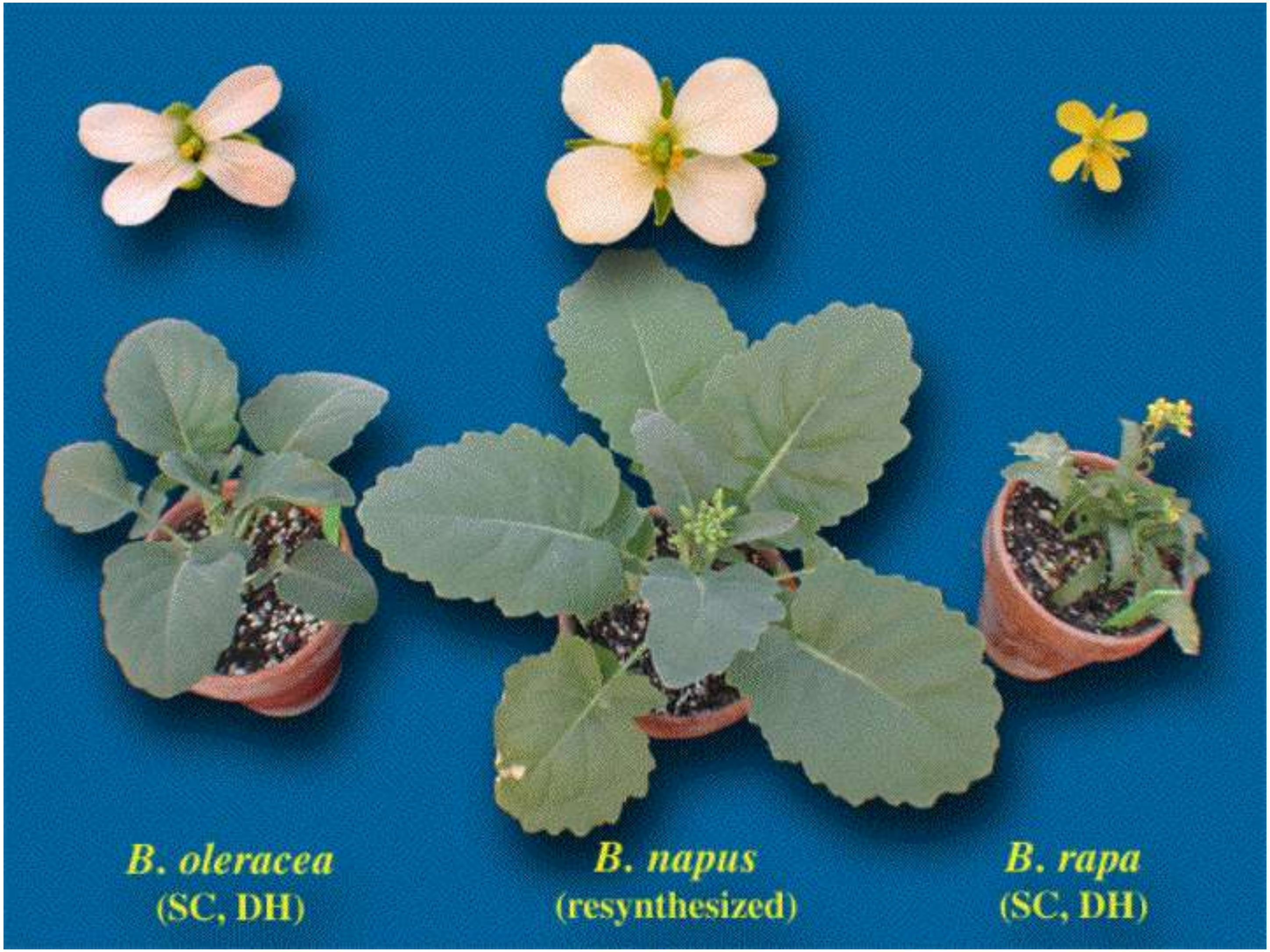
Known Paleopolyploidy in Eukaryotes





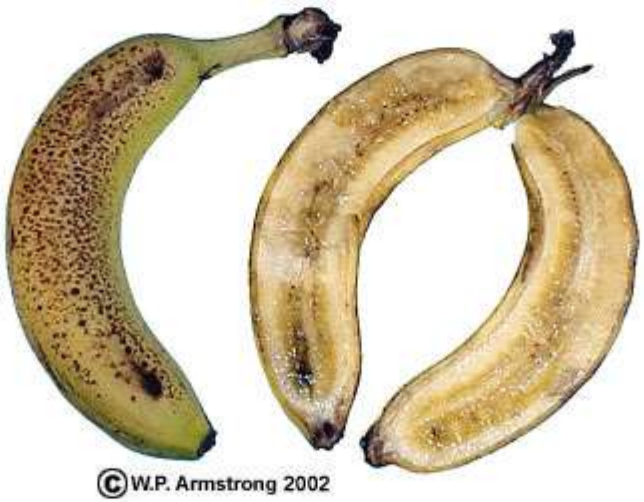
Eudicot
Monocot
Magnoliid
Gynosperm
Arabidopsis
Brassica (cabbage)
Gossypium (cotton)
Medicago truncatula
Glycine (soybean)
Lactuca (lettuce)
Helianthus (sunflower)
Solanum (potato)
Lycopersicon (tomato)
Eschscholzia (poppy)
Sorghum
Saccharum (sugarcane)
Zea (maize)
Oryza (rice)
Triticum (wheat)
Hordeum (barley)
Musa (banana)
Acorus (sweet flag)
Liriodendron (tulip-tree)
Persea (avocado)
Saruma
Nuphar (waterlily)
Amborella
Welwitschia
Pinus (pine)
Plant
An
Paleopolyploidization event
Speculated paleopolyploidization event
*Branch length is NOT scaled with time

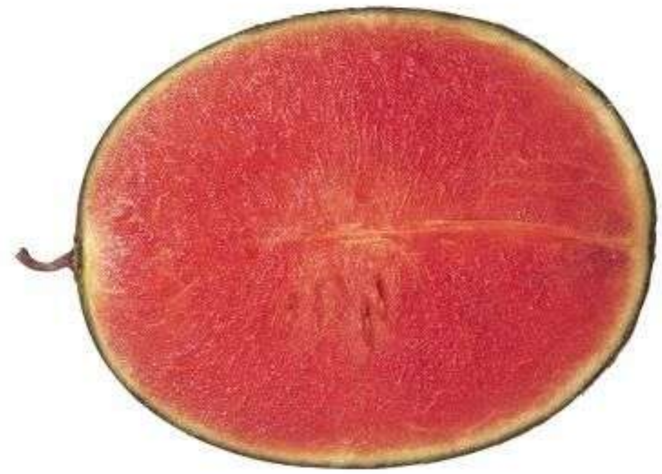
Hybrid Vigor



An example of an allopolyploid that shows hybrid vigor over its diploid progenitors is resynthesized Brassica napus.

Tripoids – 3 sets of chromosomes
Triploid crops: apple, banana, citrus, ginger, watermelon



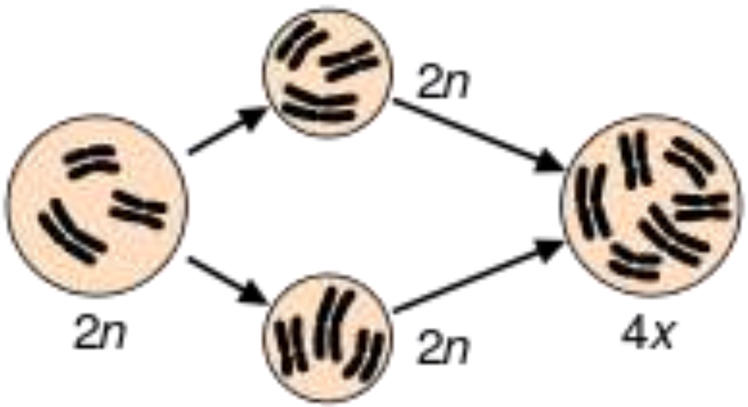


Musa acuminata (Asian Banana)	X	*Musa balbisiana* (Asian Banana)	=	*Musa X paradisiaca* (Hybrid Banana)
AA (fertile)		BB (fertile)		AAB or ABB (etc.) (sterile)

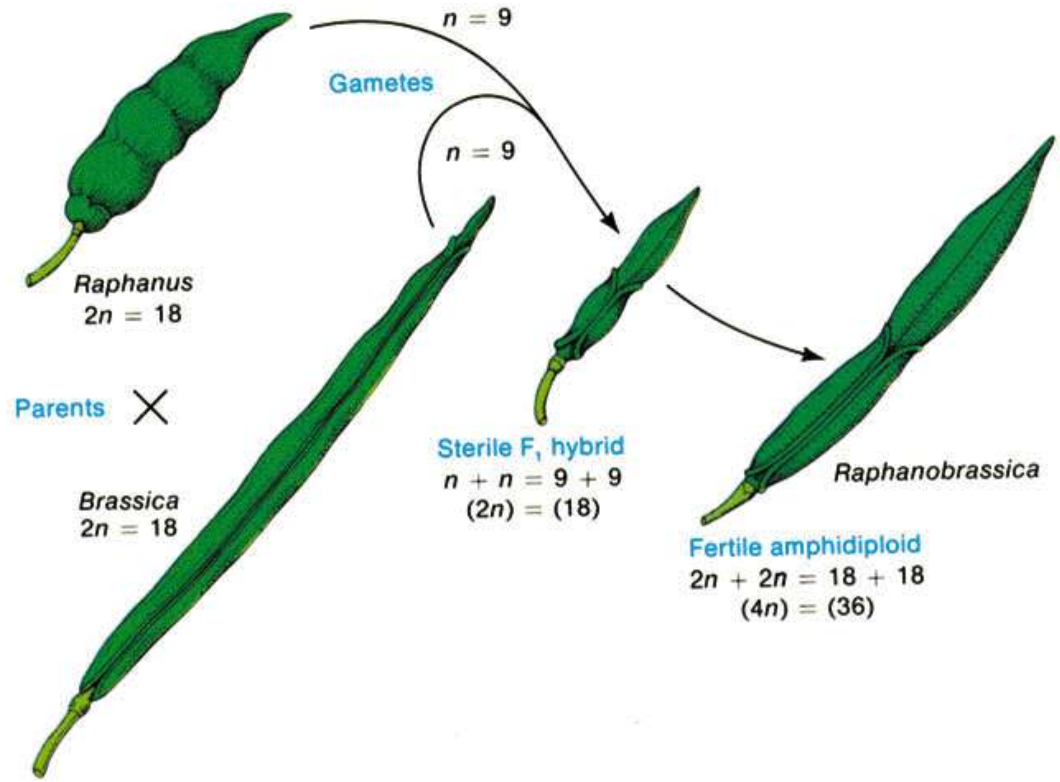
Origin Of Triploid Banana From Asian Parents

A = one haploid set of chromosomes from *M. acuminata*
B = one haploid set of chromosomes from *M. balbisiana*

Tetraploids – 4 sets of chromosomes



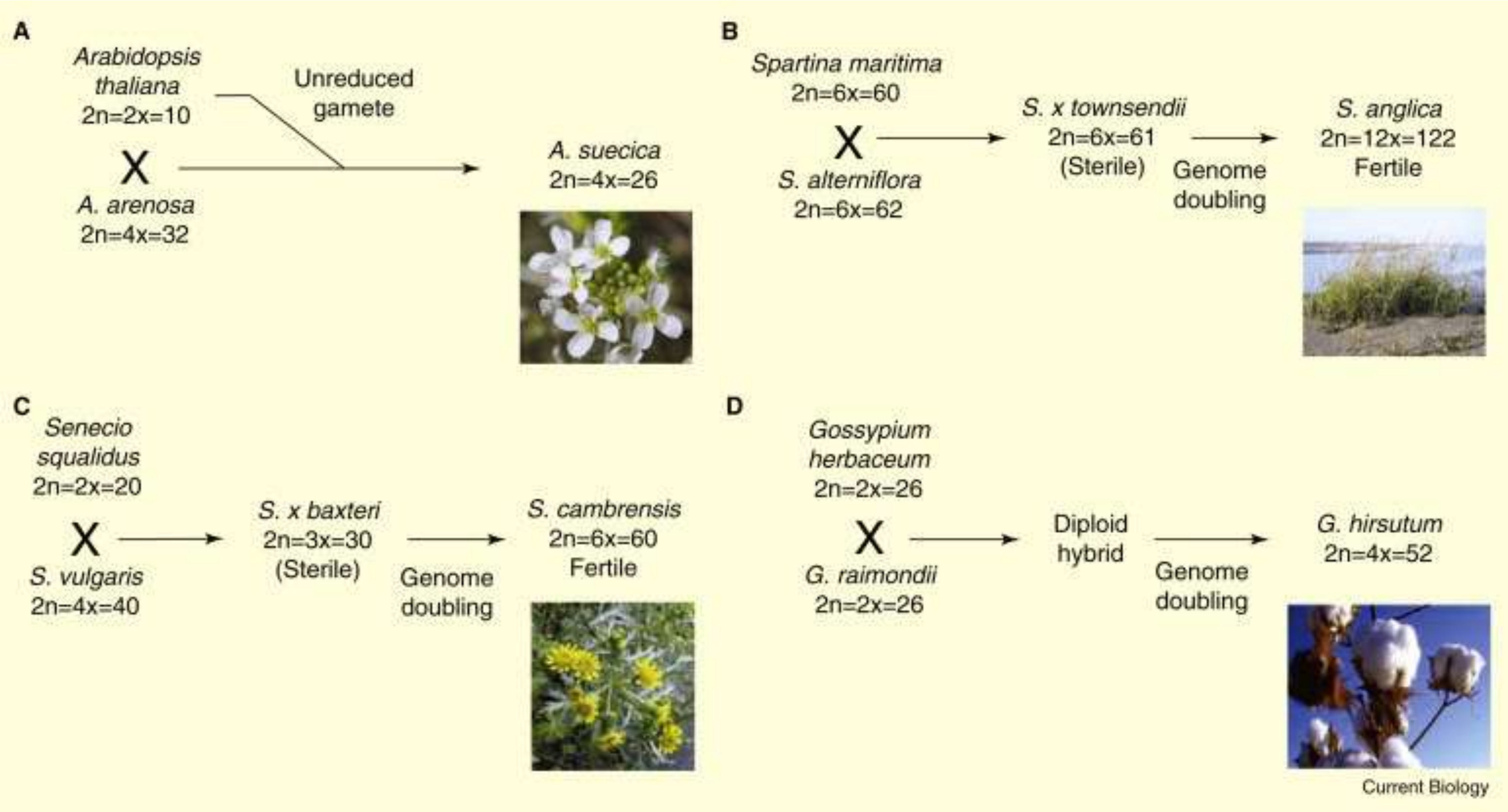
Failed meiosis, gametes 2N



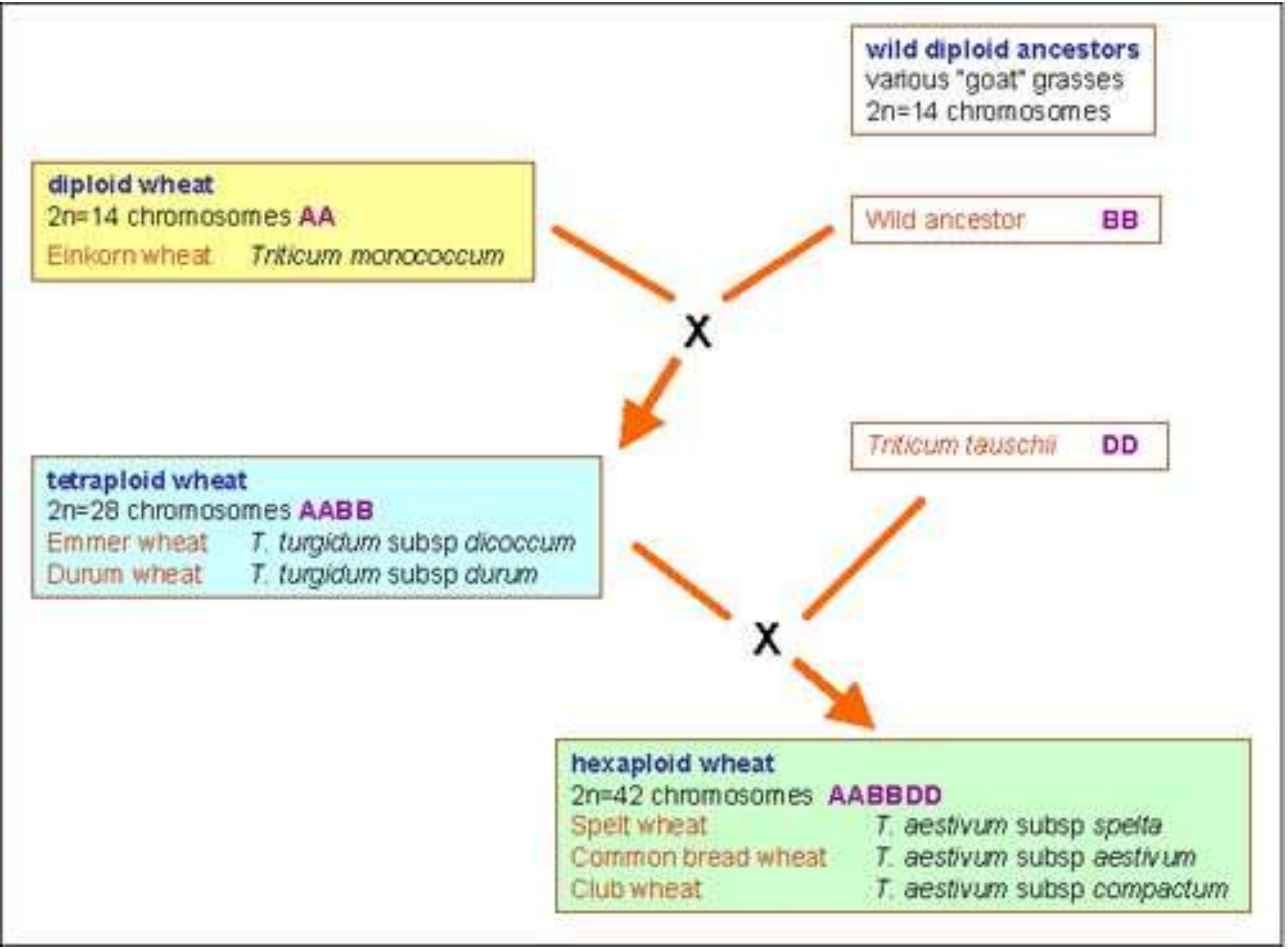
Hybridization followed chromosome doubling

Tetraploid crops: apple, durum or macaroni wheat, cotton, potato, cabbage, leek, tobacco, peanut, Pelargonium

Examples of Polyploidy



Hexaploid – 6 sets of chromosomes



Autopolyploids: polyploids composed of multiple sets of chromosomes from the same species

Allopolyploids: polyploids that are a new species, composed of multiple sets of chromosomes from closely related species

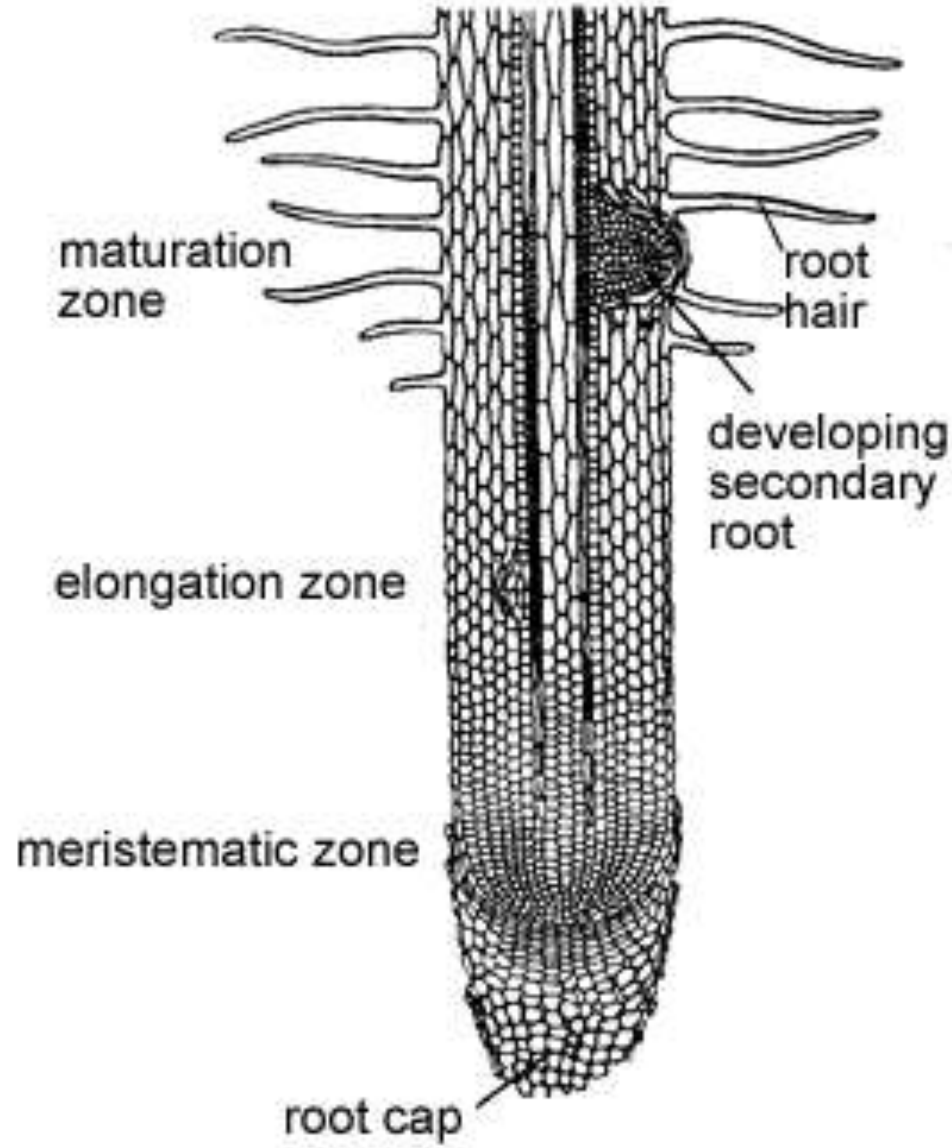
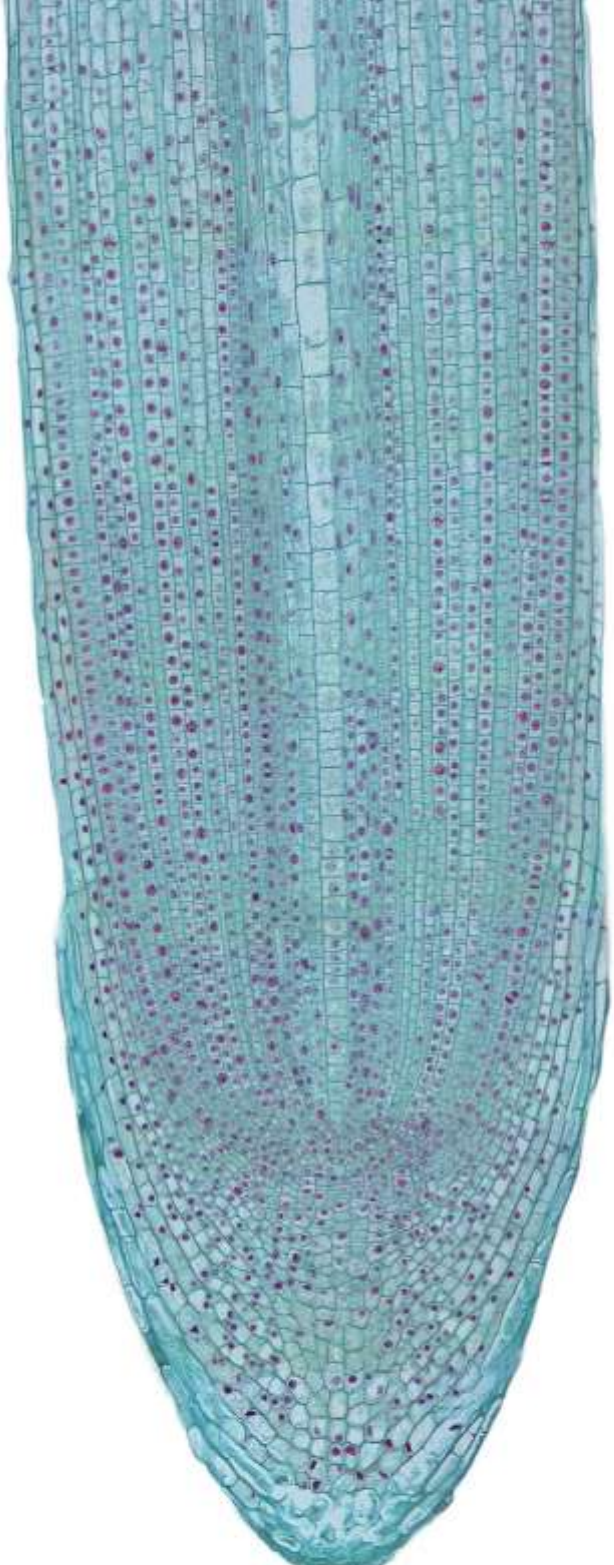
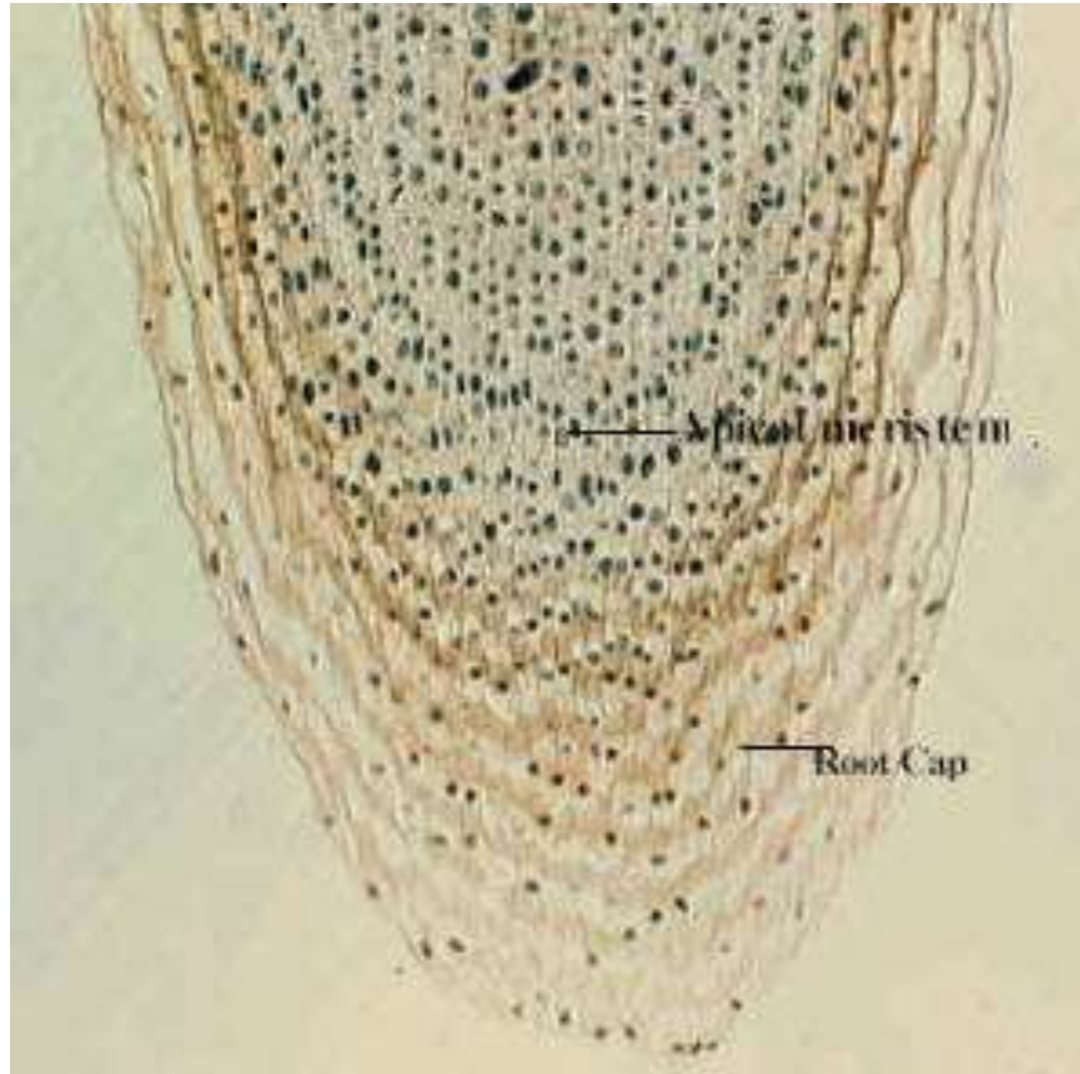

maturation zone
root hair
developing secondary root
elongation zone
meristematic zone
root cap

Figure 6




Apical meristem
Root Cap

Pre-treatment of Roots

8-hydroxyquinoline -cause contraction and improve spreading of chromosomes

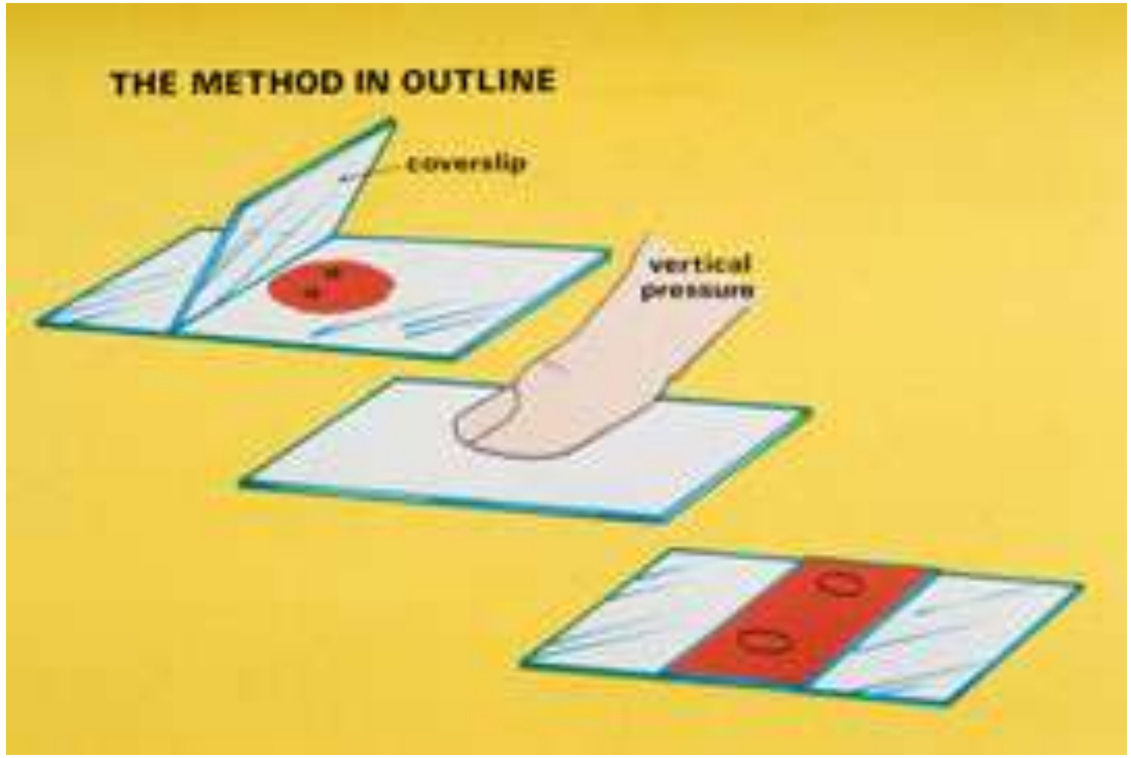
Fixation

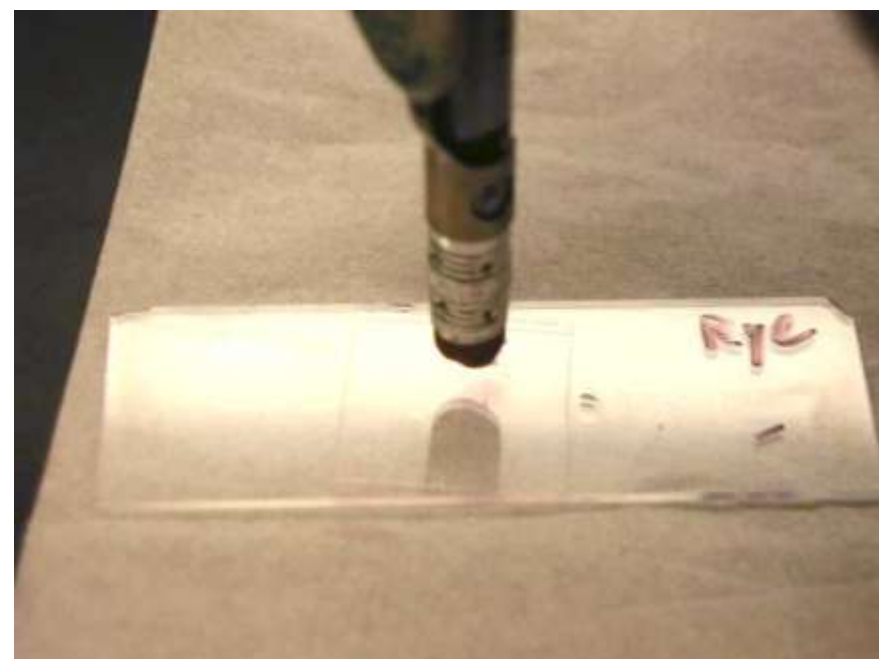
Prevent autolysis of chromosome, denaturation of proteins.
Prevent bacterial decomposition of cells.
Prevents swelling and shrinking of cells and tissues.
Rapid penetration to reach the interior of the cell
Mixtures of chemicals are used, freshly prepared
Carnoy’s: ethanol-acetic acid (3:1) or
Farmer’s: ethanol-chloroform-acetic acid (6:3:1) (2:1:1)
Fixation time 30 minutes- 24 hours – 36 hours (maximum).
After fixation the material is preserved in 70% alcohol

Aceto Carmine
Carmine is a crimson dye, used in solution with 45% acetic acid known as **aceto-carmine**. Acetic acid is a good fixative for chromatin and is rapidly penetrating. The addition of a few drops of ferric chloride or ferric acetate intensifies the color..

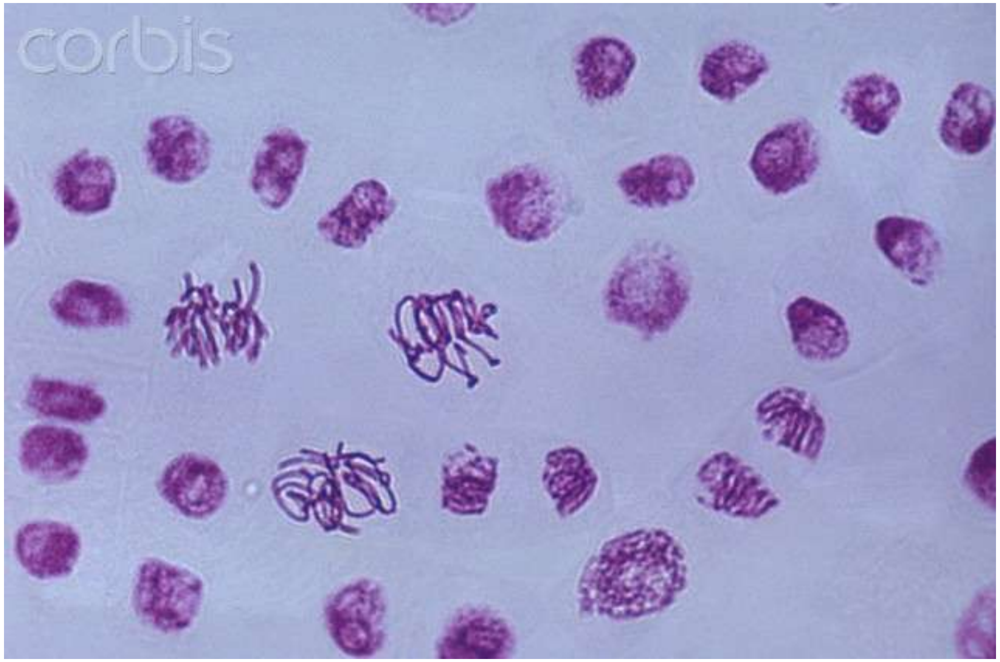
Orcein

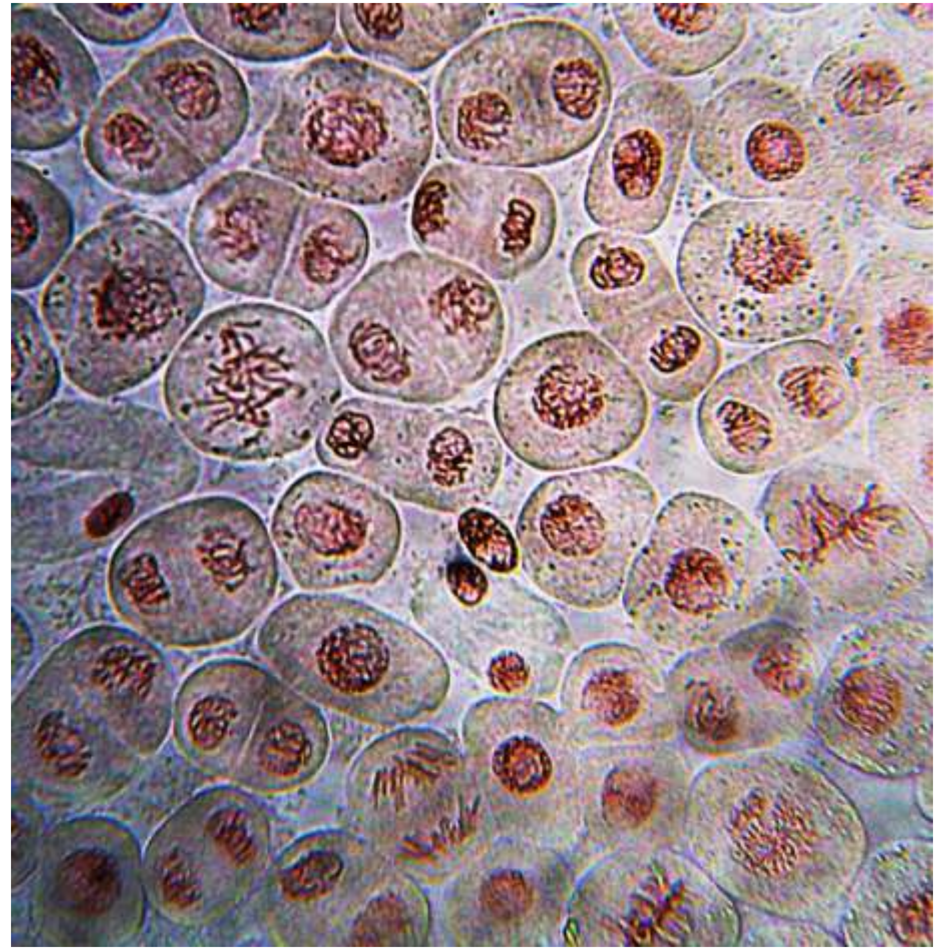
Fuelgen


THE METHOD IN OUTLINE
coverslip
vertical
pressure

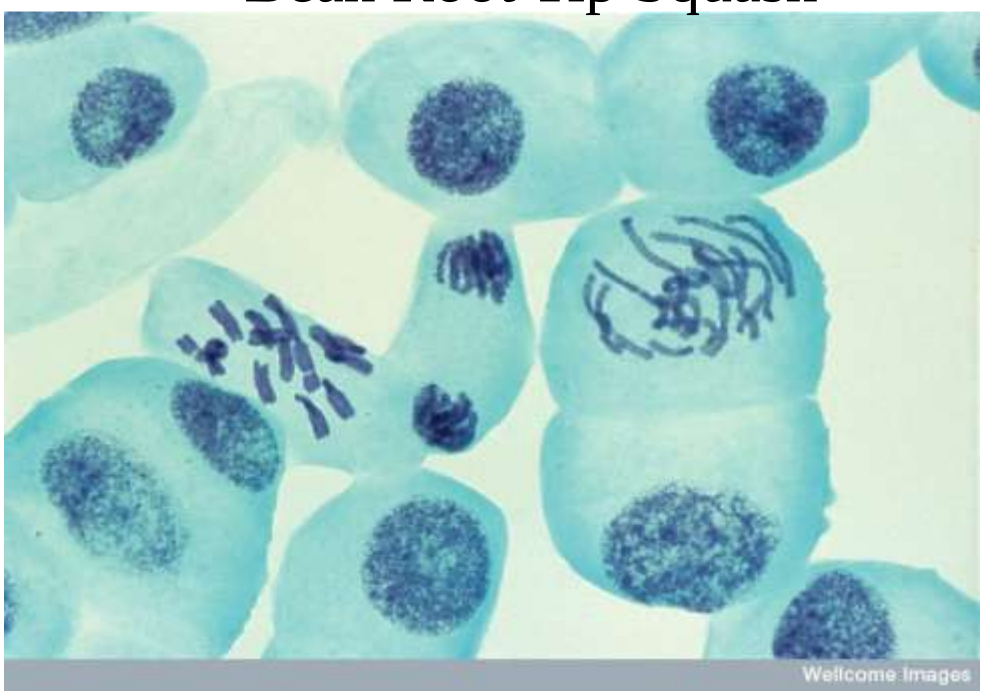

Rye

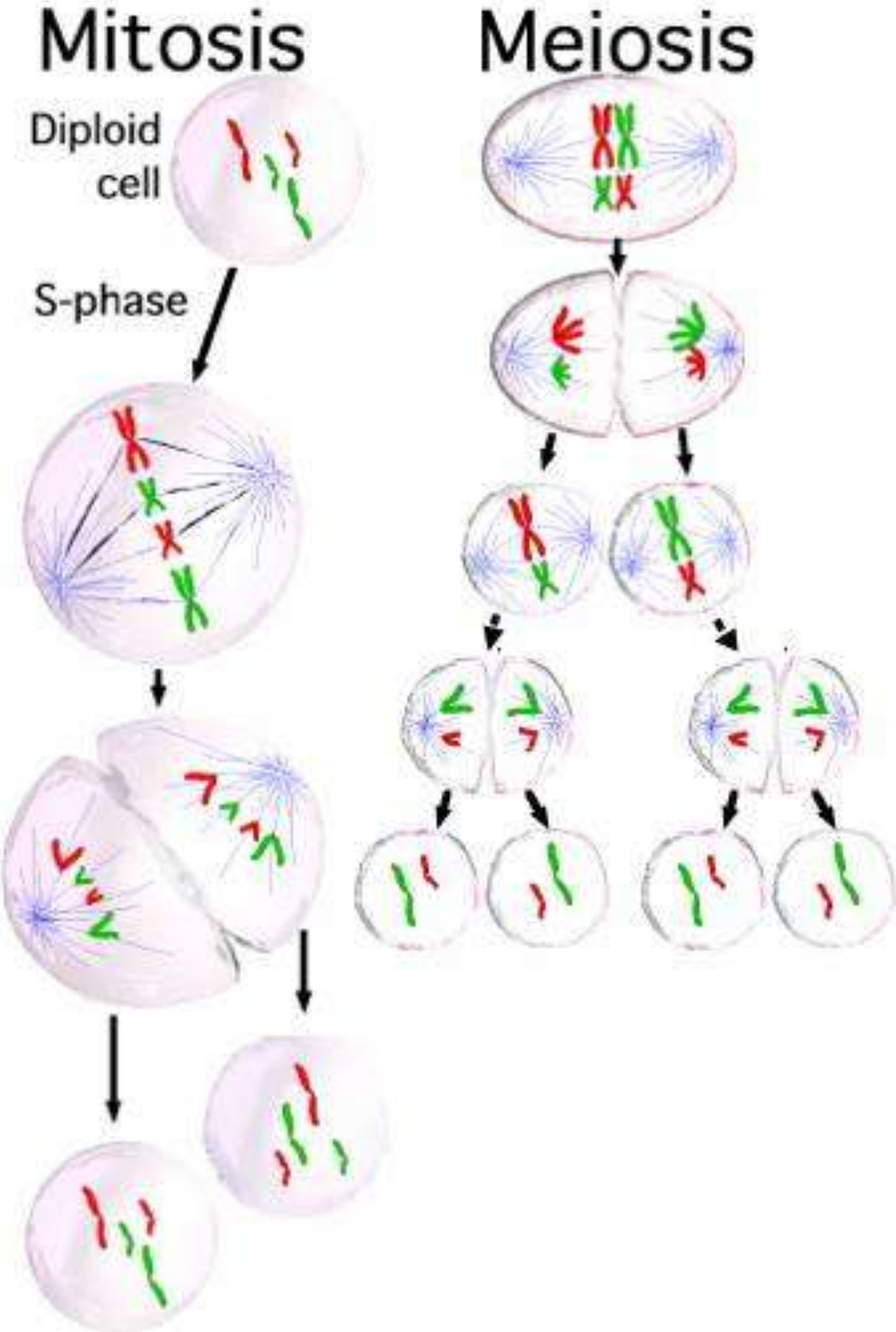
Onion Root Tip Squash

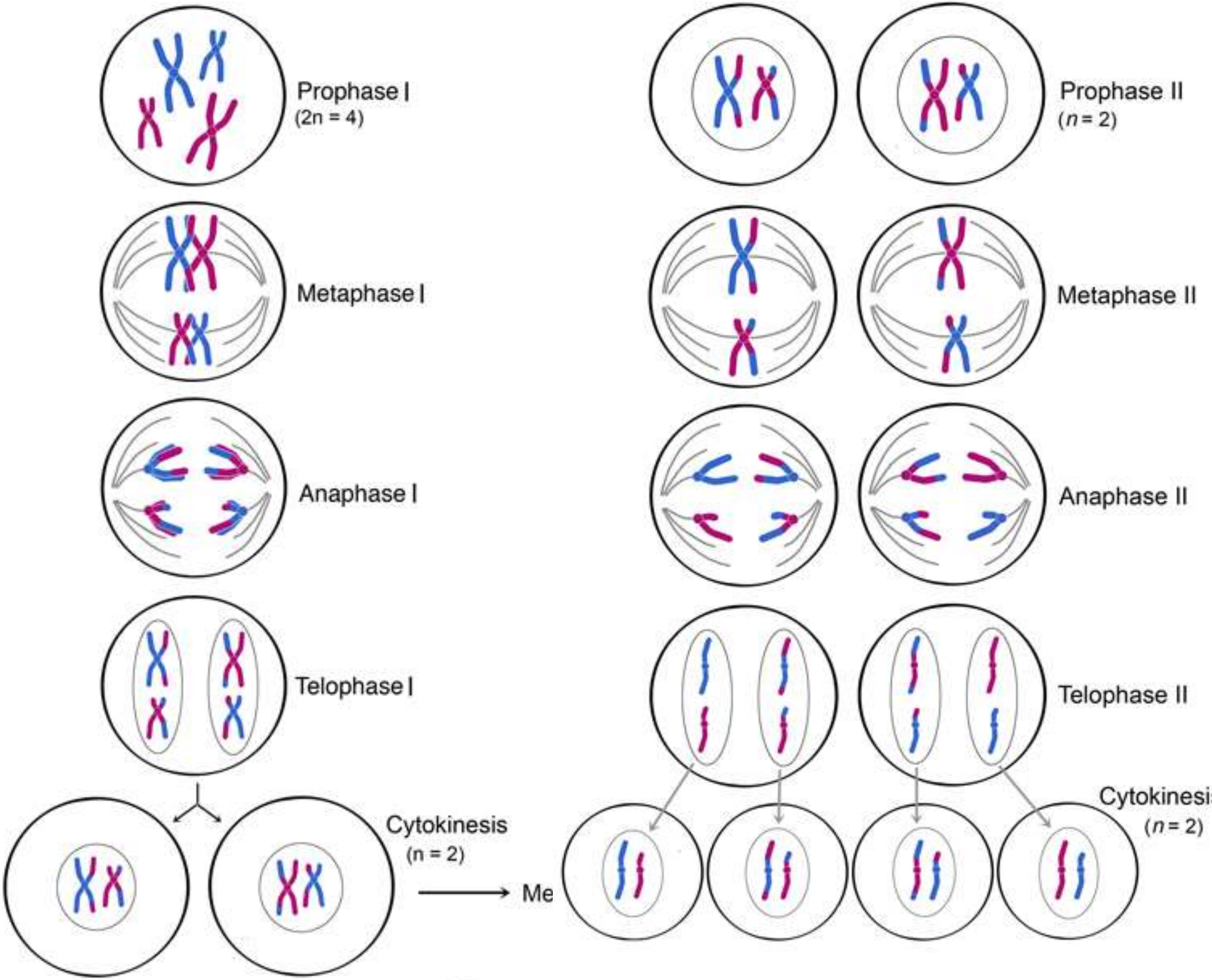




Bean Root Tip Squash




Mitosis
Meiosis
Diploid
cell
S-phase


Prophase I
(2n = 4)
Metaphase I
Anaphase I
Telophase I
Cytokinesis
(n = 2)
Me
Prophase II
(n = 2)
Metaphase II
Anaphase II
Telophase II
Cytokinesis
(n = 2)

End