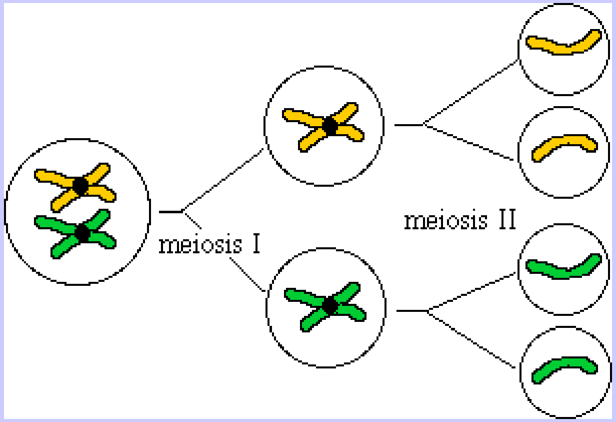
For a species to survive,

it must REPRODUCE!



Ch 13 NOTES – Meiosis

Genetics Terminology:

Autosomes

Somatic cell

Gamete

Karyotype

Homologous chromosomes

Meiosis

Sex chromosomes

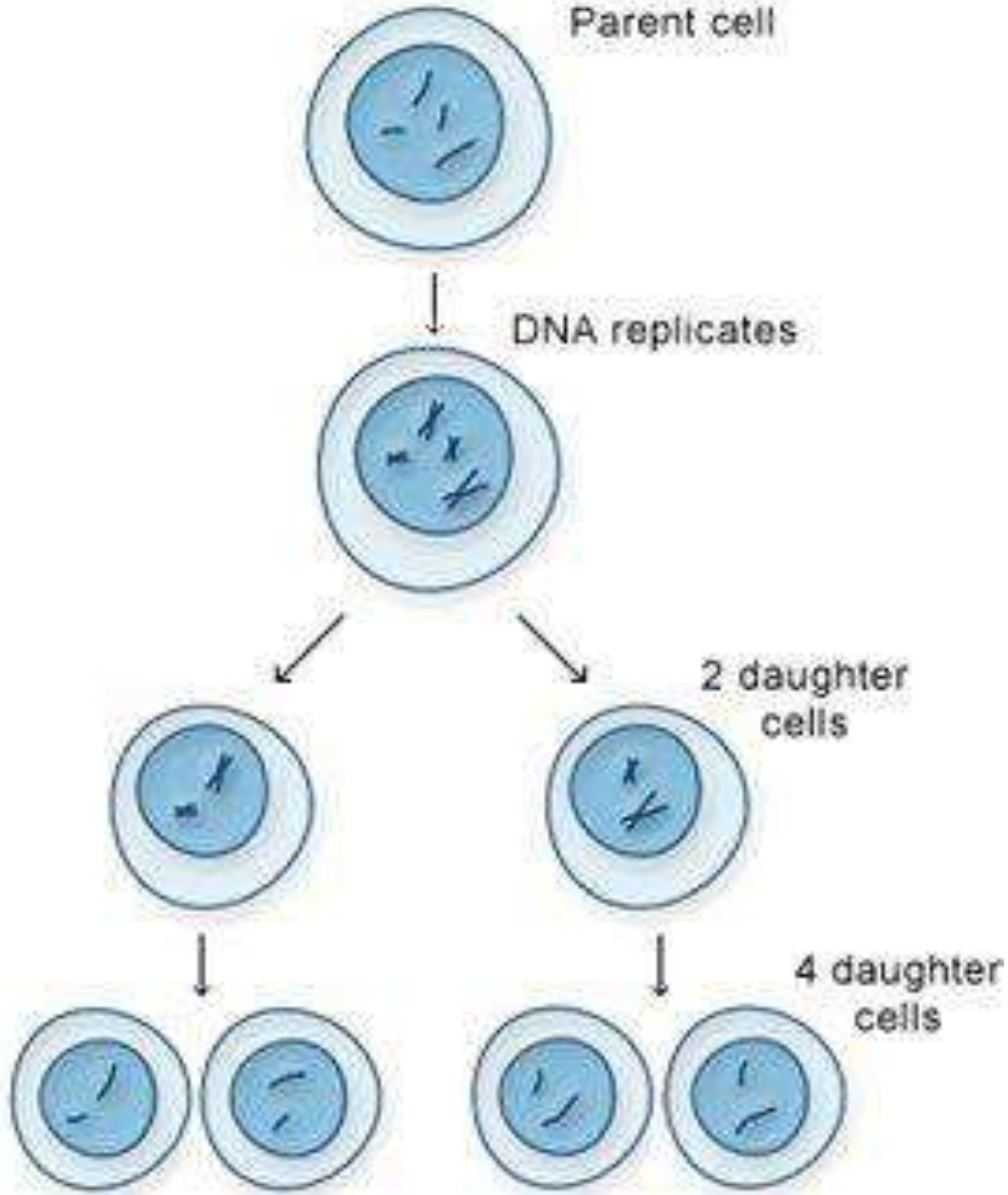
Diploid

Haploid

Zygote

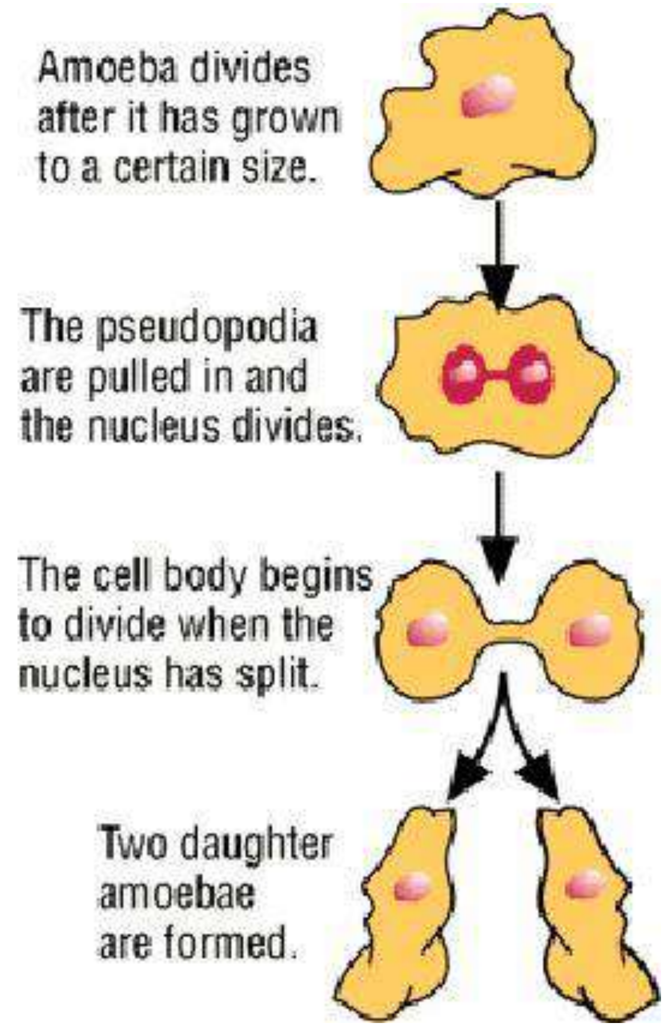
Synapsis

Crossing over


Parent cell
DNA replicates
2 daughter cells
4 daughter cells

1) ASEXUAL REPRODUCTION:

- each new organism gets a set of chromosomes identical to parents
- DNA from generation to generation remains the same
- therefore, no differences or variations occur in the offspring (difficult to adapt!)

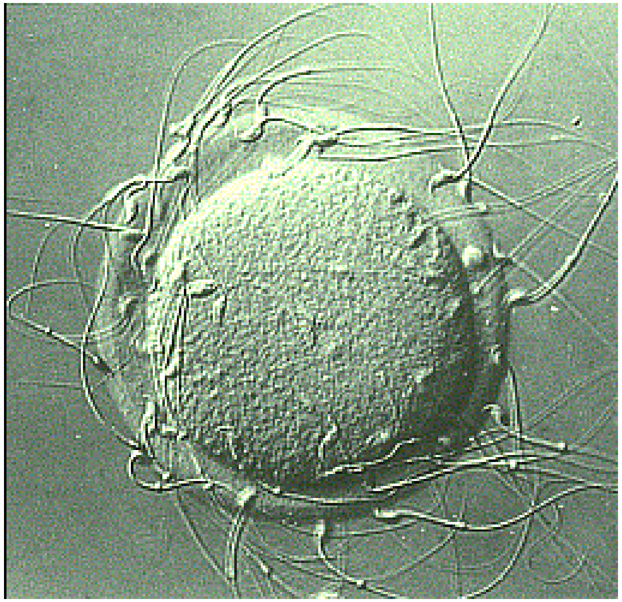


<u>2) SEXUAL REPRODUCTION:</u>

● fusion of nuclei from 2 special cells: <u>**GAMETES**</u>
(female gamete = <u>**egg**</u>; male gamete = <u>**sperm**</u>)

● with 2 parents, offspring receive half of their chromosomes from the female parent and half from the male parent.

● therefore, the offspring will <u>show new combinations of characteristics</u>

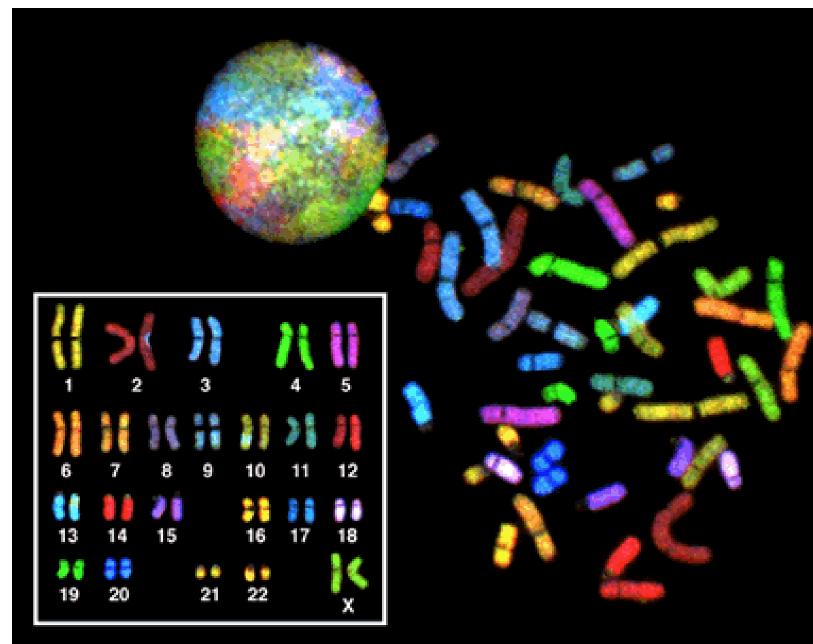


***Sexual reproduction leads to <u>VARIATION!</u>*
(this ensures the survival of a species)

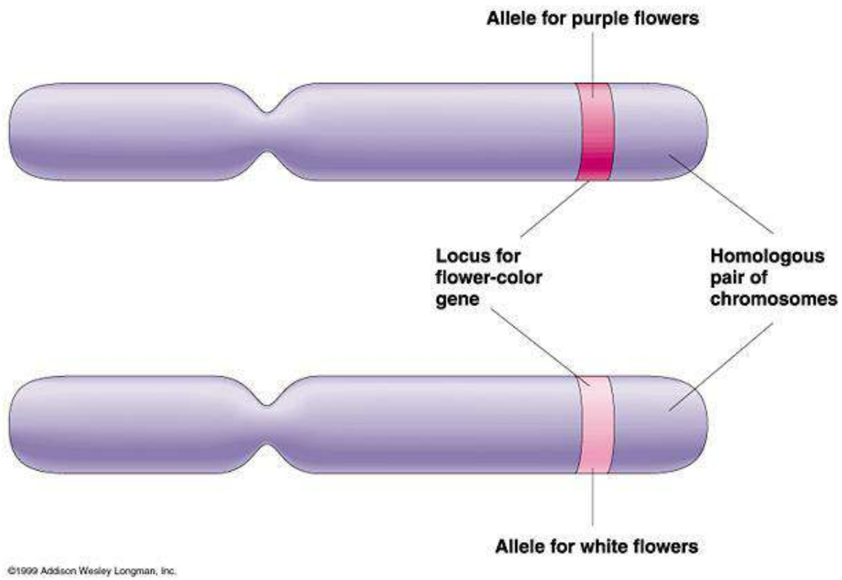
- ***<u>SOMATIC CELLS</u>*** = *<u>all cells EXCEPT the gametes</u>*
- each somatic cell of an organism contains a specific # of chromosomes (<u>humans = 46</u>)

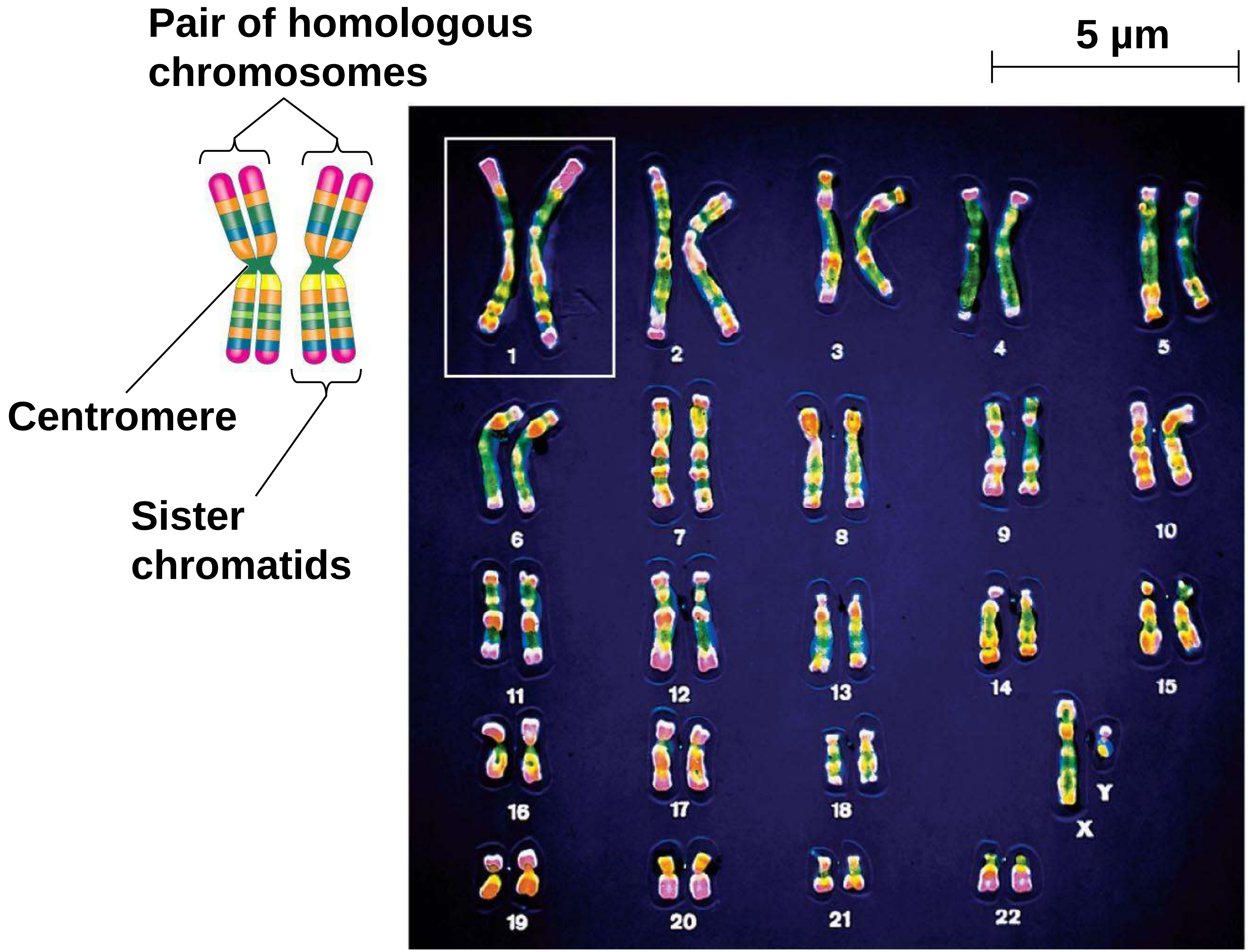
Sets of Chromosomes in Human Cells

- Each human somatic cell (any cell other than a gamete) has 46 chromosomes <u>arranged in pairs</u>
- A <u>**KARYOTYPE**</u> is an <u>ordered display</u> of the pairs of chromosomes from a cell



- the chromosomes occur in “matching pairs” (1 member of each pair came from the egg and 1 member came from the sperm)
- these pairs of chromosomes are called **<u>HOMOLOGOUS PAIRS</u>**
- Both chromosomes in a pair carry genes <u>controlling the same inherited characteristics</u>





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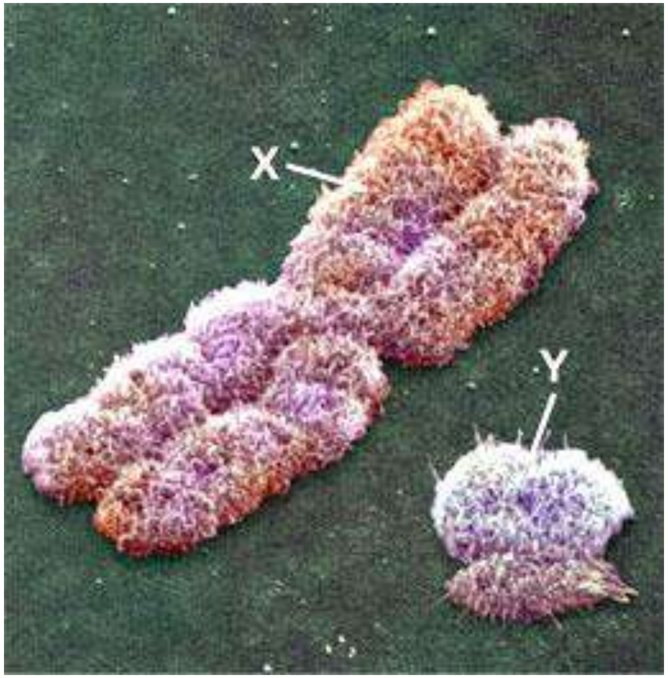
- The sex chromosomes are called X and Y
- Human females have a homologous pair of X chromosomes (**XX**)
- Human males have **one X and one Y** chromosome
- The 22 pairs of chromosomes that do not determine sex are called **AUTOSOMES**

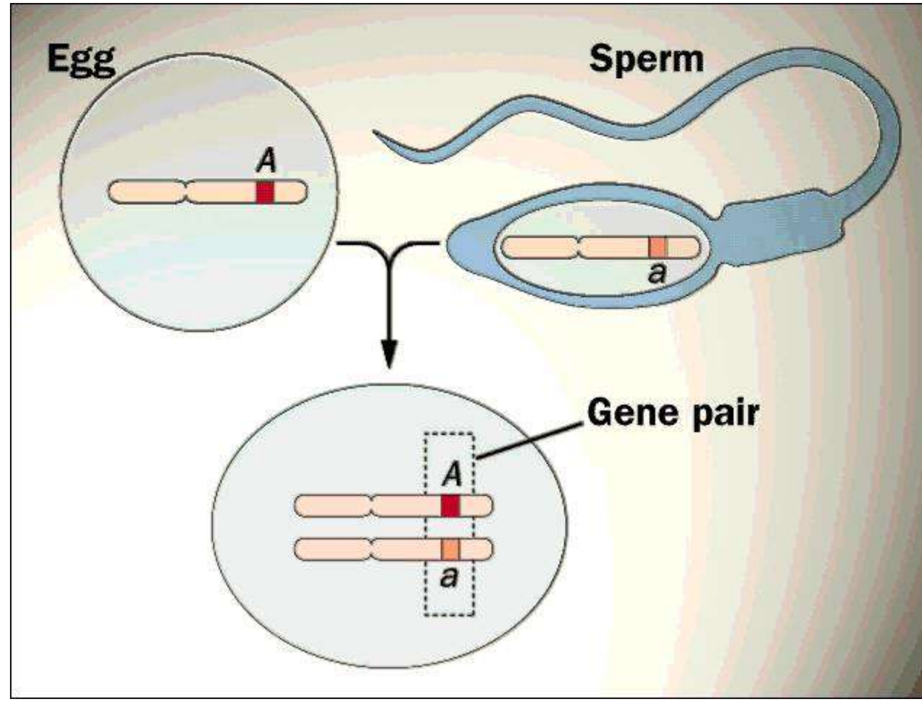


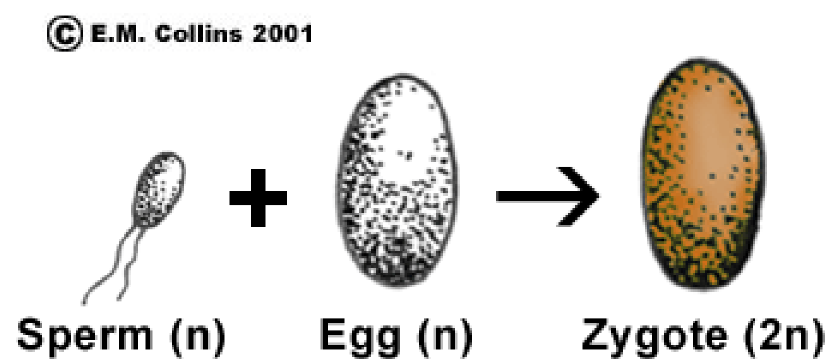
Human Gamete

~cells with half the # of chromosomes are **HAPLOID (n)**

Human Somatic Cell

~cells with full # of chromosomes are **DIPLOID (2n)**



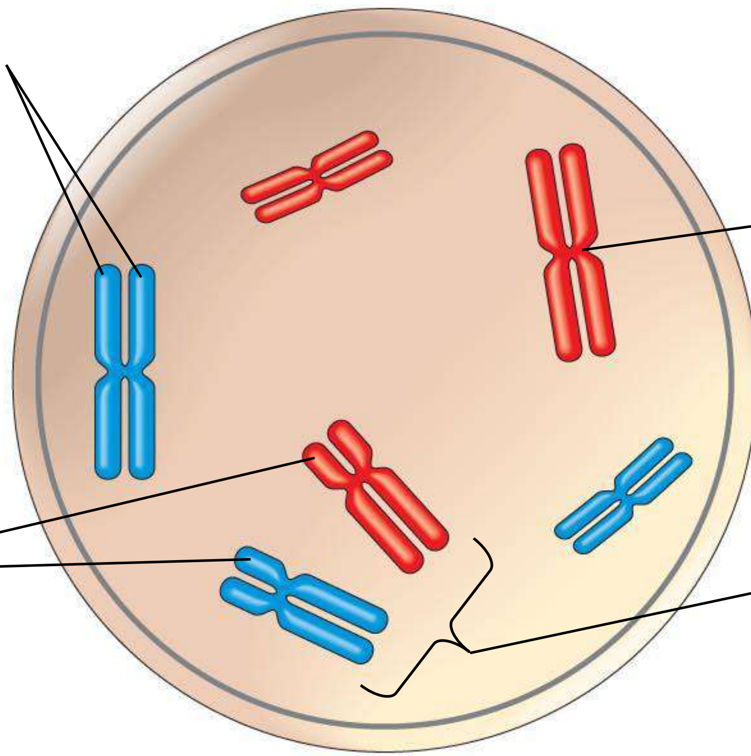


Key

2n = 6

Maternal set of chromosomes (n = 3)

Paternal set of chromosomes (n = 3)



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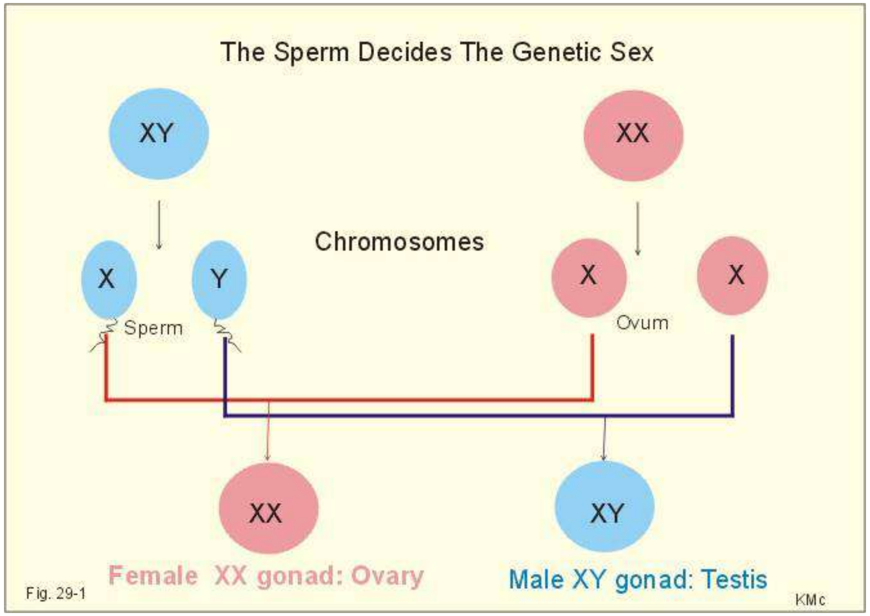
- Gametes are <u>haploid cells</u>, containing only one set of chromosomes
- For humans, the haploid number is 23 (n = 23)
- Each set of 23 consists of <u>22 autosomes and a single sex chromosome</u>
- In an unfertilized egg (ovum), the <u>sex chromosome is X</u>
- In a sperm cell,

the sex chromosome

may be either X or Y



- the <u>union of 2 haploid gametes</u> restores the diploid # of chromosomes ***(<u>Fertilization</u>!)***

- **<u>MEIOSIS</u>**: cell division in which daughter cells <u>receive only ½ of the chromosomes</u> of the parent cell
  - ***RESULT:*** ***<u>formation of gametes</u>!***

- occurs only in <u>reproductive tissues</u>

male = <u>testes</u> **female = <u>ovaries</u>**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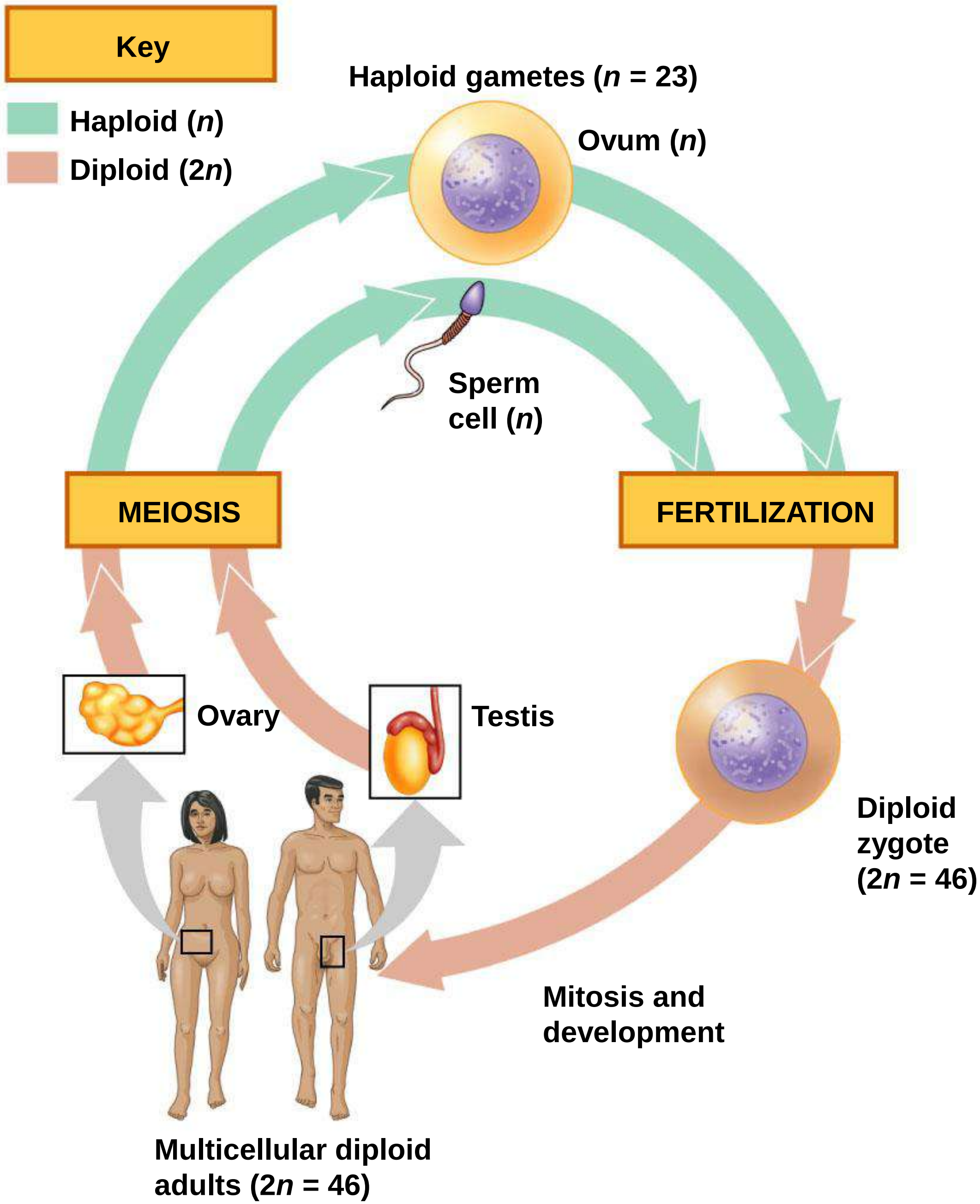
Behavior of Chromosome Sets in the Human Life Cycle - OVERVIEW

- At sexual maturity, the ovaries and testes produce haploid gametes
- Gametes are the only types of human cells produced by meiosis, rather than mitosis
- Meiosis results in <u>one set of chromosomes in each gamete</u>
- Fertilization, the <u>fusing of gametes</u>, restores the diploid condition, forming a zygote
- The diploid zygote <u>develops into an adult</u>



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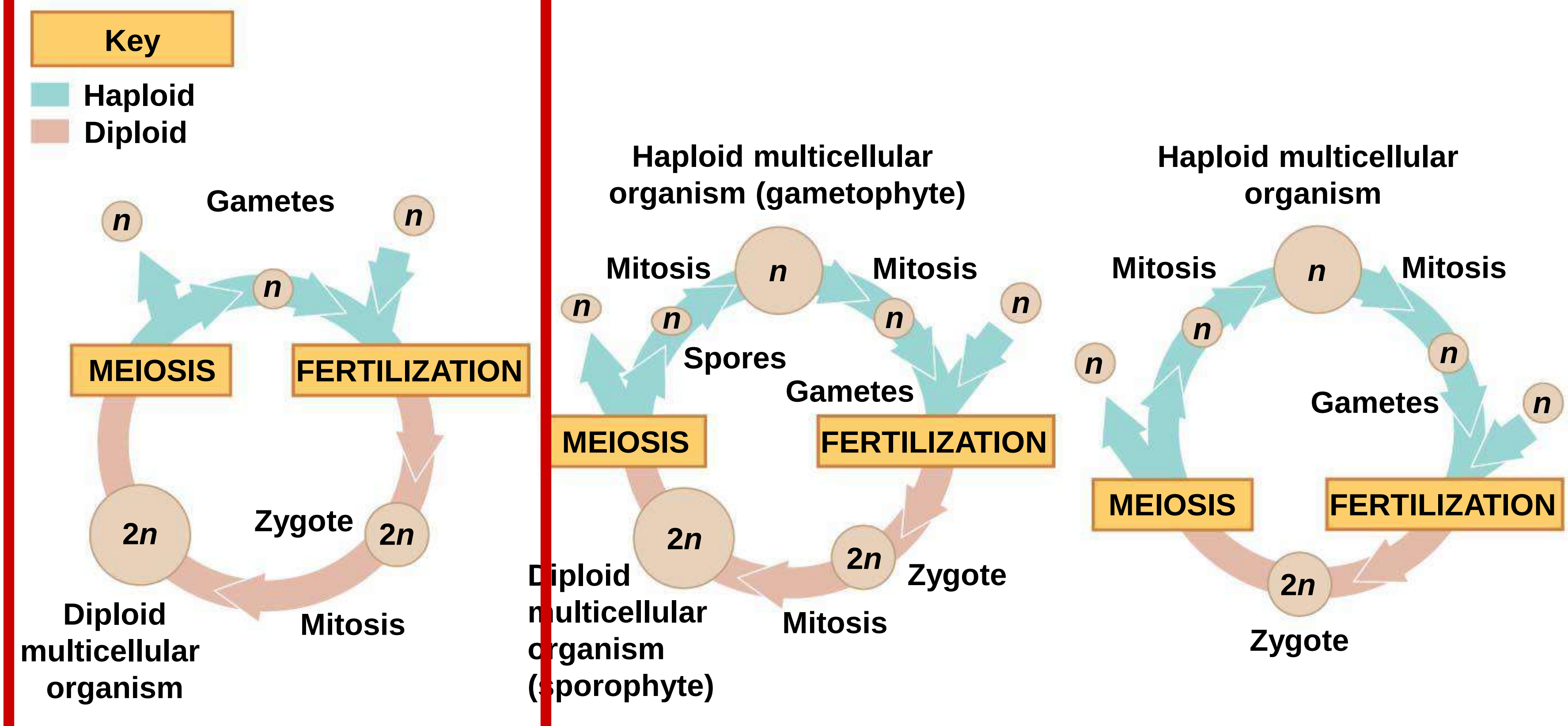
The Variety of Sexual Life Cycles

- The alternation of meiosis and fertilization is common to all organisms that reproduce sexually
- The three main types of sexual life cycles differ in the timing of meiosis and fertilization

<u>ANIMALS</u>

- In animals, <u>meiosis produces gametes</u>, which undergo no further cell division before fertilization
- Gametes are the only haploid cells in animals
- Gametes fuse to form a <u>diploid zygote</u> that <u>divides by mitosis</u> to develop into a <u>multicellular organism</u>



(a) Animals (b) Plants and some algae (c) Most fungi and some protists

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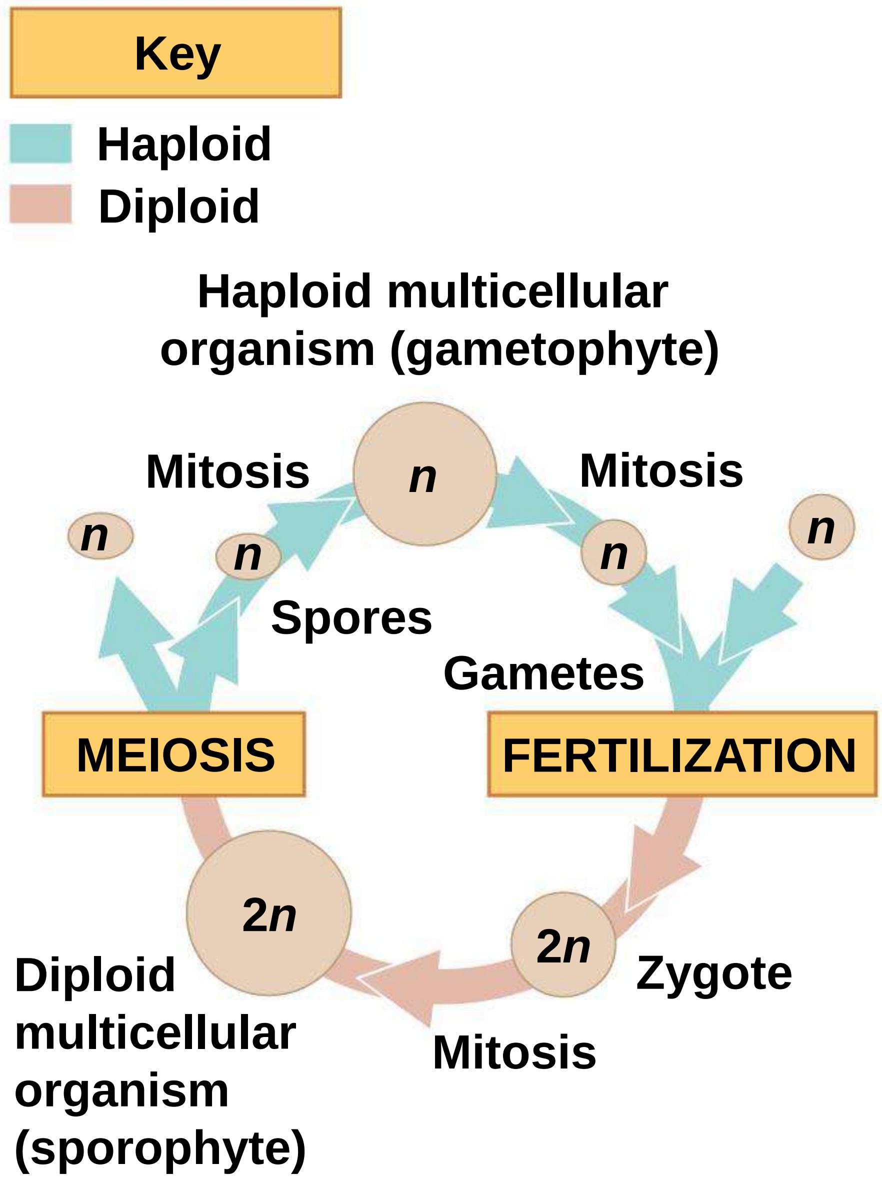
PLANTS

- Plants and some algae exhibit an alternation of generations
- This life cycle includes two multicellular generations or stages: one diploid and one haploid
- The diploid organism, the **SPOROPHYTE**, makes haploid spores by meiosis
- Each spore grows by mitosis into a haploid organism called a **GAMETOPHYTE**
- A gametophyte makes haploid gametes by mitosis



(b) Plants and some algae

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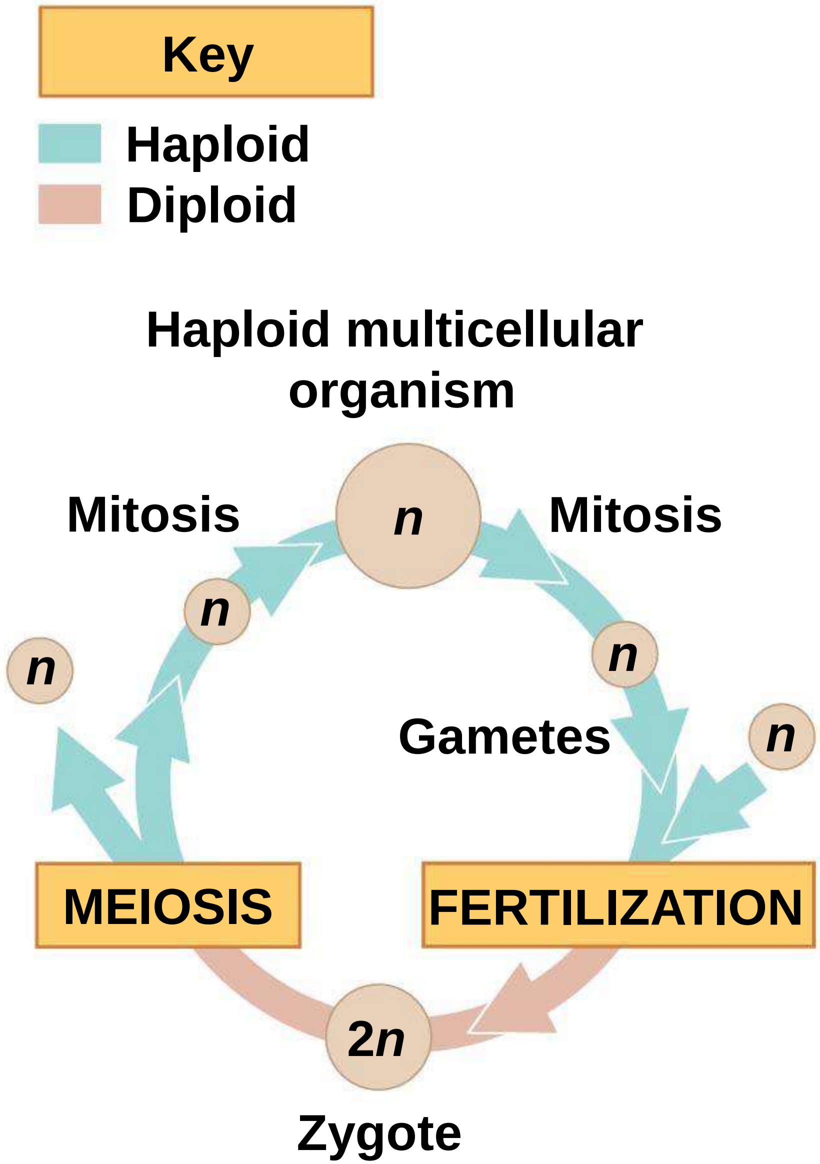
FUNGI and PROTISTS

- **In most fungi and some protists**, the only diploid stage is the single-celled zygote; there is no multicellular diploid stage
- The zygote produces haploid cells by meiosis
- Each haploid cell grows by mitosis into a haploid multicellular organism
- The haploid adult produces gametes by mitosis



(c) Most fungi and some protists

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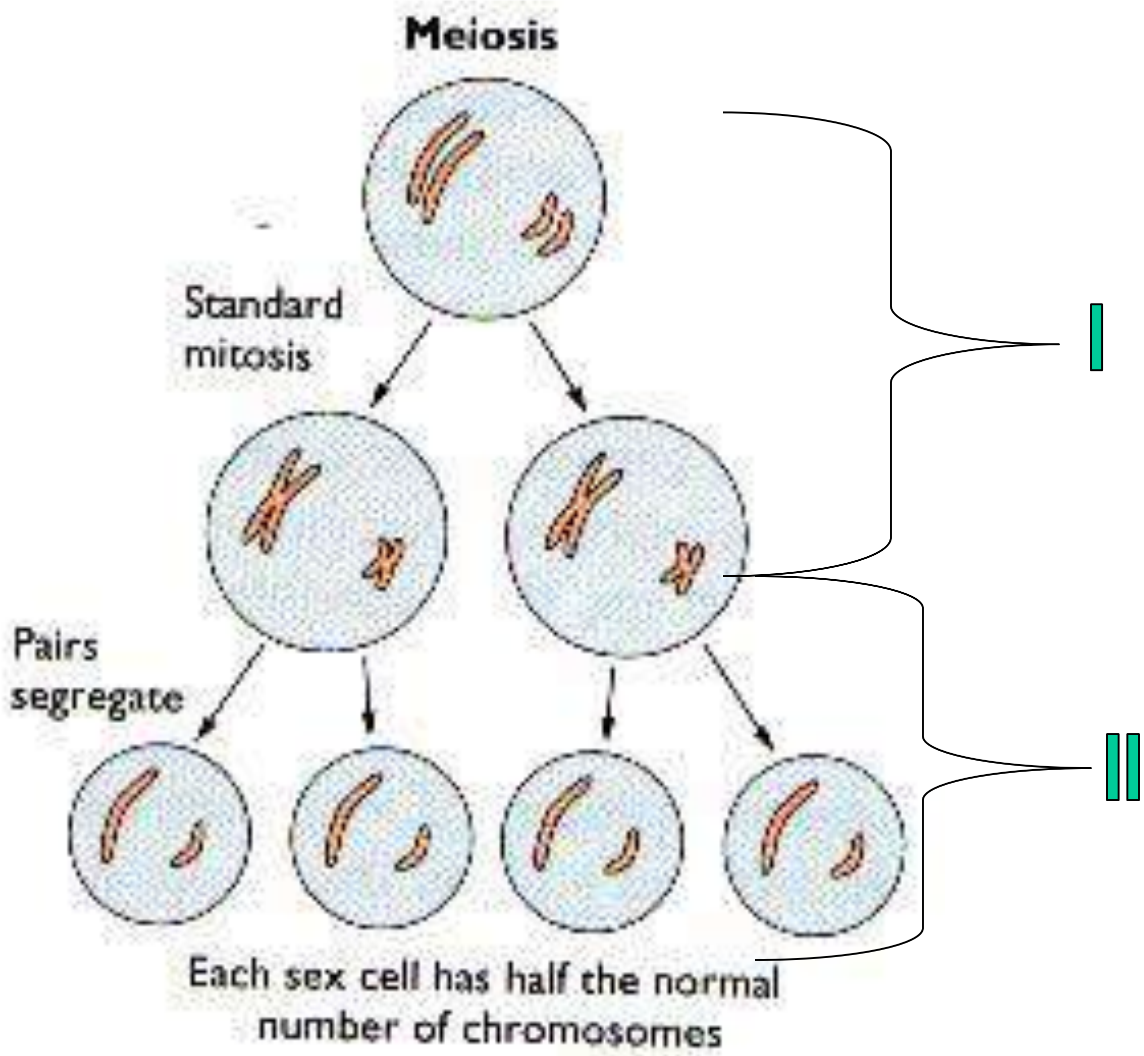
Meiosis takes place in 2 stages:

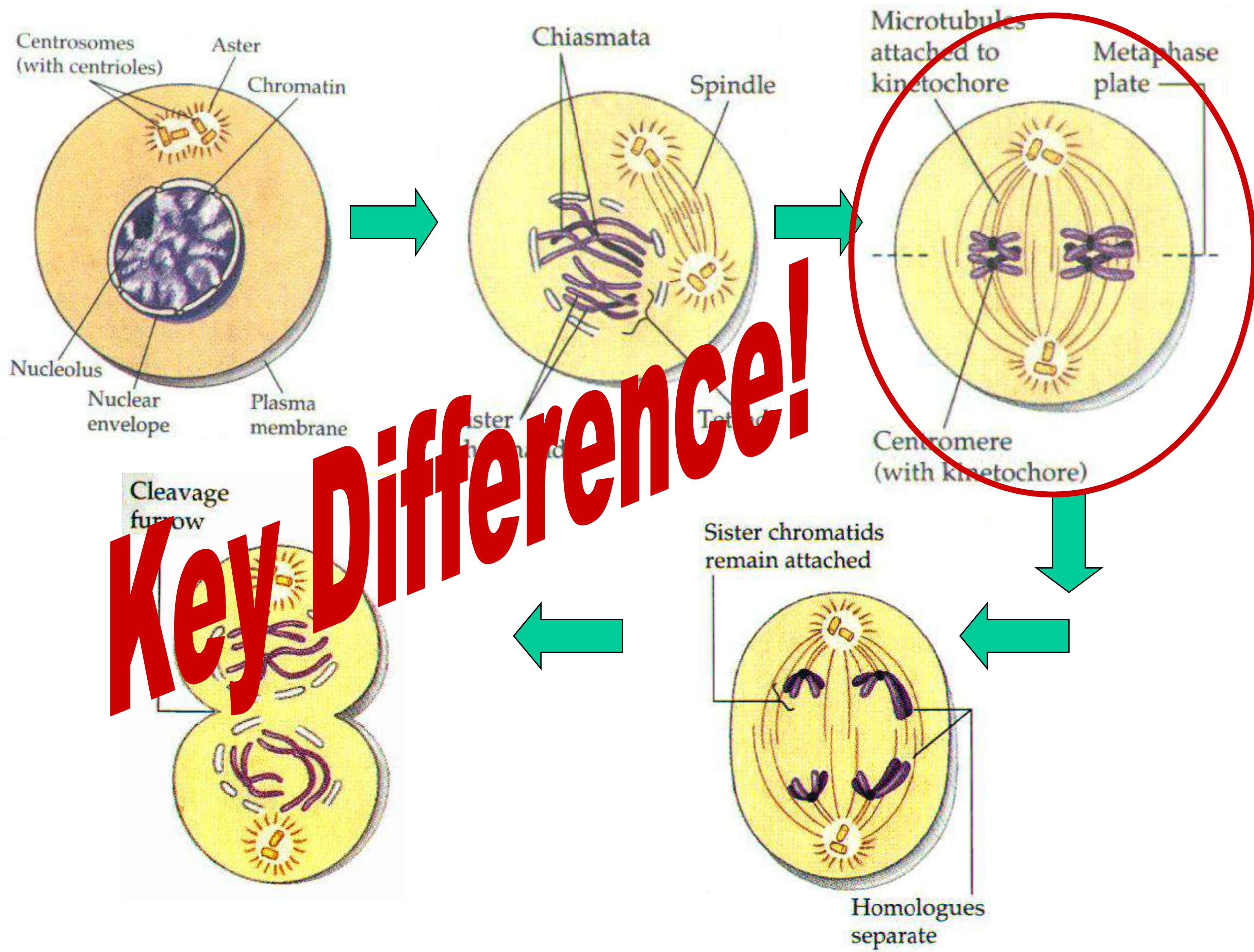
1) **<u>Meiosis I</u>**

2) **<u>Meiosis II</u>**



1) Meiosis I

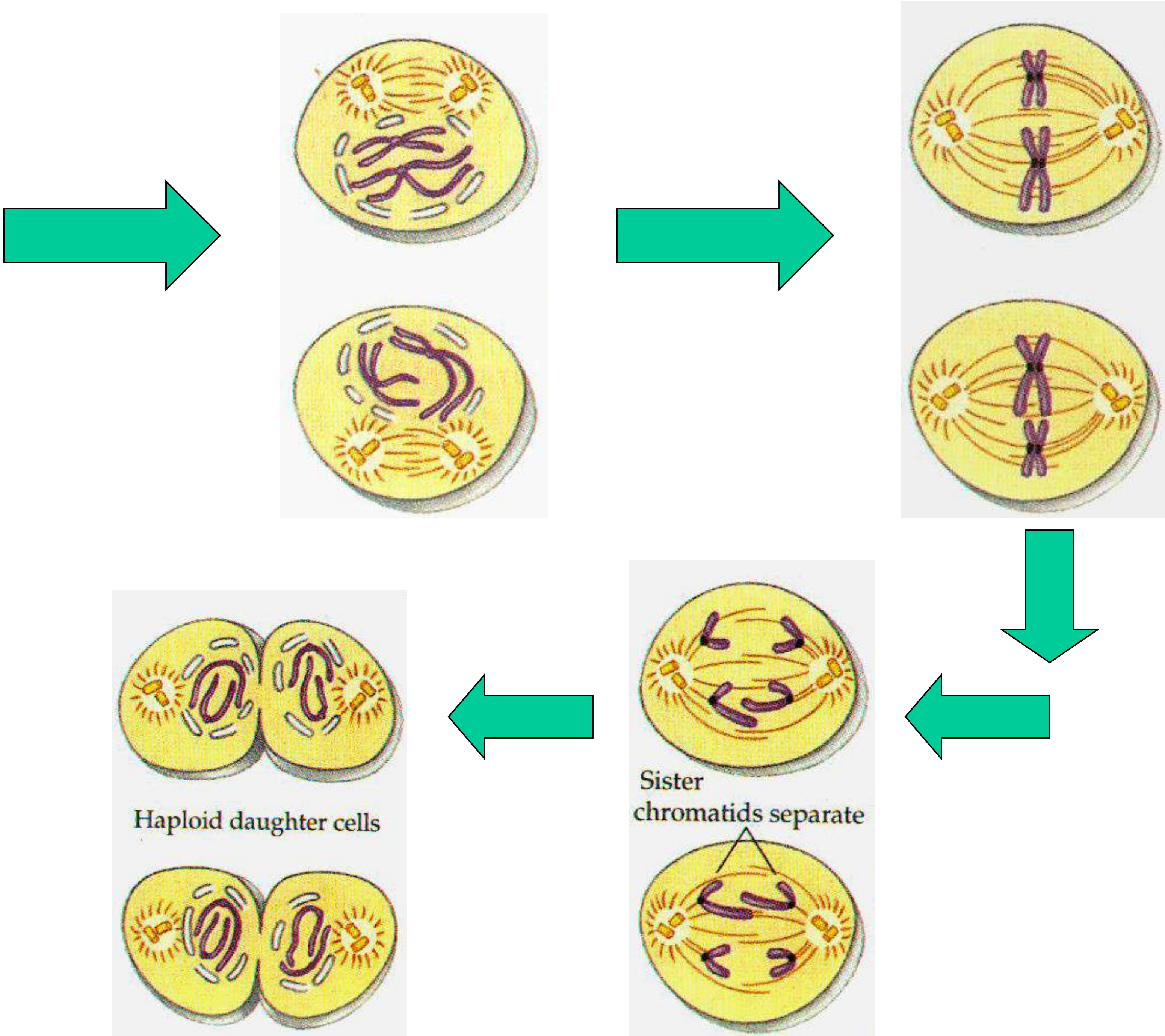
- preceded by ***Interphase***: DNA is copied
- ***Prophase I***: each chromosome pairs up with its homologous chromosome to form a **TETRAD** (4 chromatids)
- ***Metaphase I***: tetrads line up in the center of the cell
- ***Anaphase I***: homologous chromosomes are pulled apart from one another
- ***Telophase I***

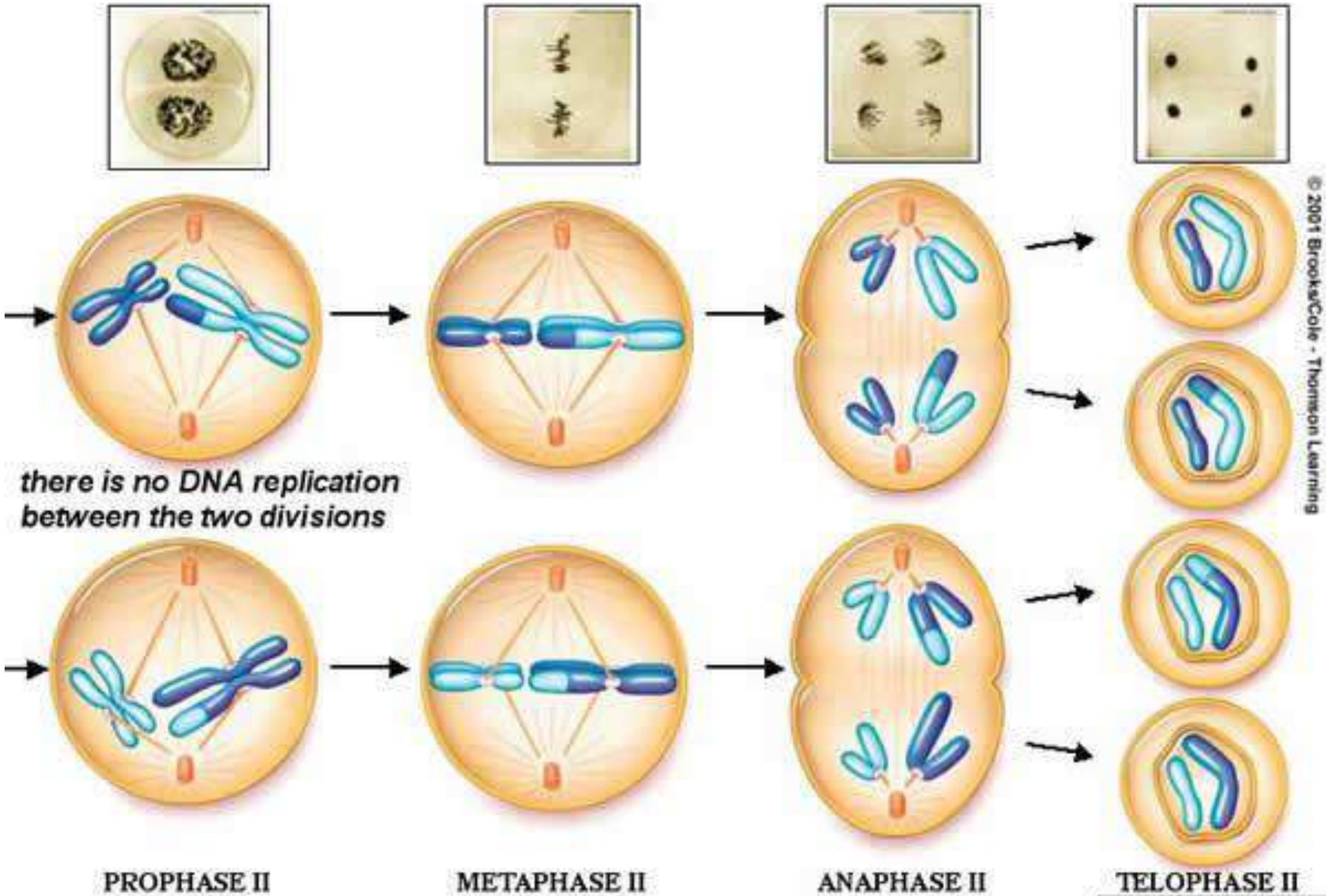

Centrosomes
(with centrioles)
Aster
Chromatin
Nucleolus
Nuclear
envelope
Plasma
membrane
Chiasmata
Spindle
Microtubules
attached to
kinetochore
Metaphase
plate
Centromere
(with kinetochore)
Sister chromatids
remain attached
Homologues
separate
Cleavage
furrow
Key Difference!

***no DNA replication occurs before the 2nd round of division**

2) Meiosis II

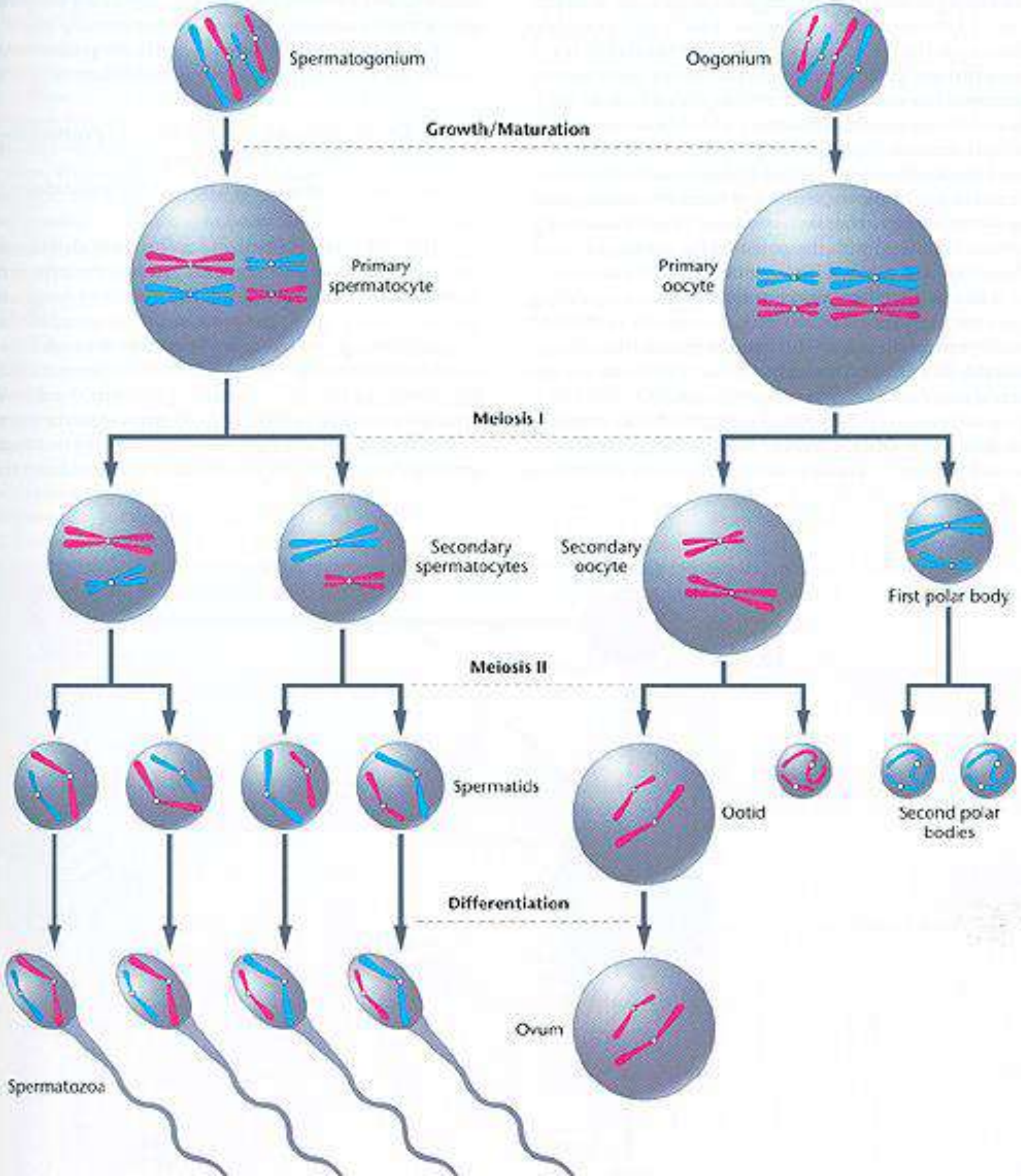
- the 2 cells produced in meiosis I undergo a second division (PMAT - II)
- the result: 4 haploid daughter cells!


Sister
chromatids separate
Haploid daughter cells



MEIOSIS II: Separate the Sister Chromatids (by mitosis)

Slide 6



Spermatogonium
Oogonium
Growth/Maturation
Primary spermatocyte
Primary oocyte
Meiosis I
Secondary spermatocytes
Secondary oocyte
First polar body
Meiosis II
Spermatids
Ootid
Second polar bodies
Differentiation
Ovum
Spermatozoa

A Comparison of Mitosis and Meiosis:

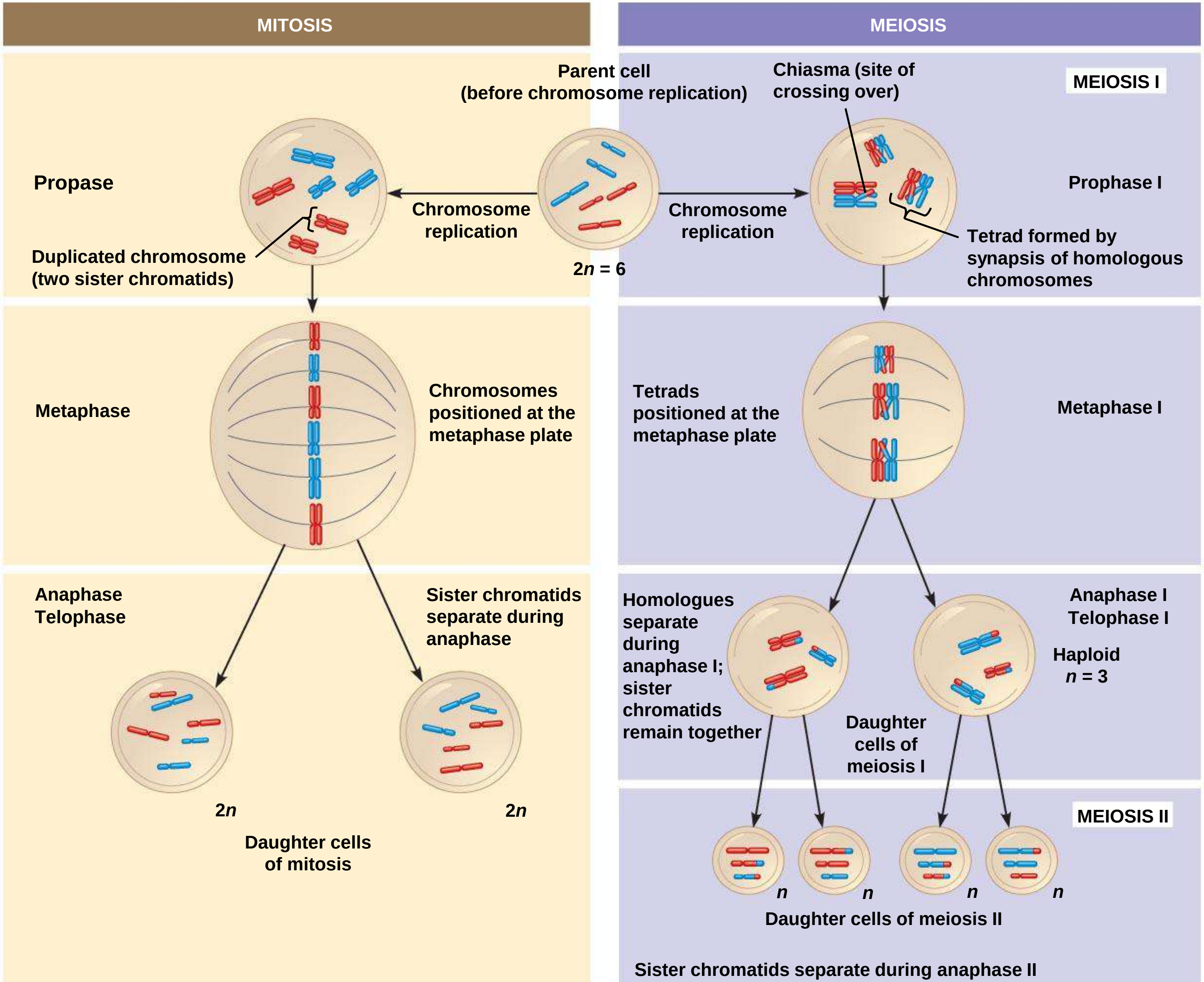
- Mitosis conserves the number of chromosome sets, producing cells that are genetically identical to the parent cell
- Meiosis reduces the number of chromosomes sets from two (diploid) to one (haploid), producing cells that differ genetically from each other and from the parent cell
- The mechanism for separating sister chromatids is virtually identical in meiosis II and mitosis

Three events are unique to meiosis, and all three occur in meiosis I:

1) <u>Synapsis and crossing over in prophase I</u>: Homologous chromosomes physically connect and exchange genetic information

2) At the metaphase plate, there are paired homologous chromosomes (tetrads), instead of individual replicated chromosomes

3) At anaphase I, it is homologous chromosomes, instead of sister chromatids, that separate and are carried to opposite poles of the cell



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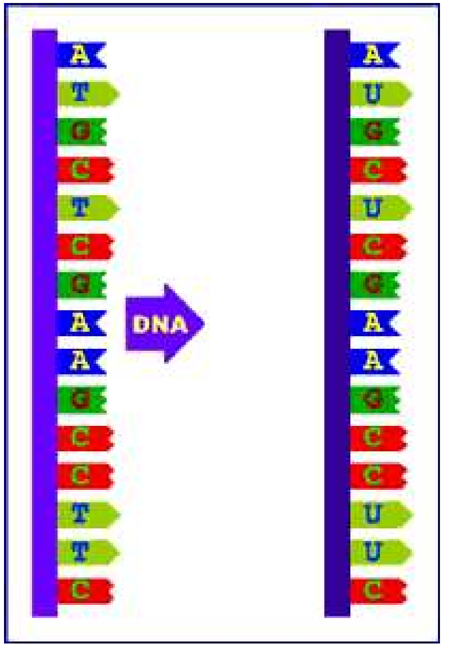
Property	**Mitosis**	**Meiosis**
DNA replication	During interphase	During interphase
Divisions	One	Two
Synapsis and crossing over	Do not occur	Form tetrads in prophase I
Daughter cells, genetic composition	Two diploid, identical to parent cell	Four haploid, different from parent cell and each other
Role in animal body	Produces cells for growth and tissue repair	Produces gametes

Genetic variation produced in sexual life cycles contributes to evolution

- Mutations (changes in an organism's DNA) are the original source of genetic diversity
- Mutations create different versions of genes
- Reshuffling of different versions of genes during sexual reproduction produces genetic variation



Origins of Genetic Variation Among Offspring

- The <u>behavior of chromosomes</u> during meiosis and fertilization is responsible for most of the variation that arises in each generation
- Three mechanisms contribute to genetic variation:

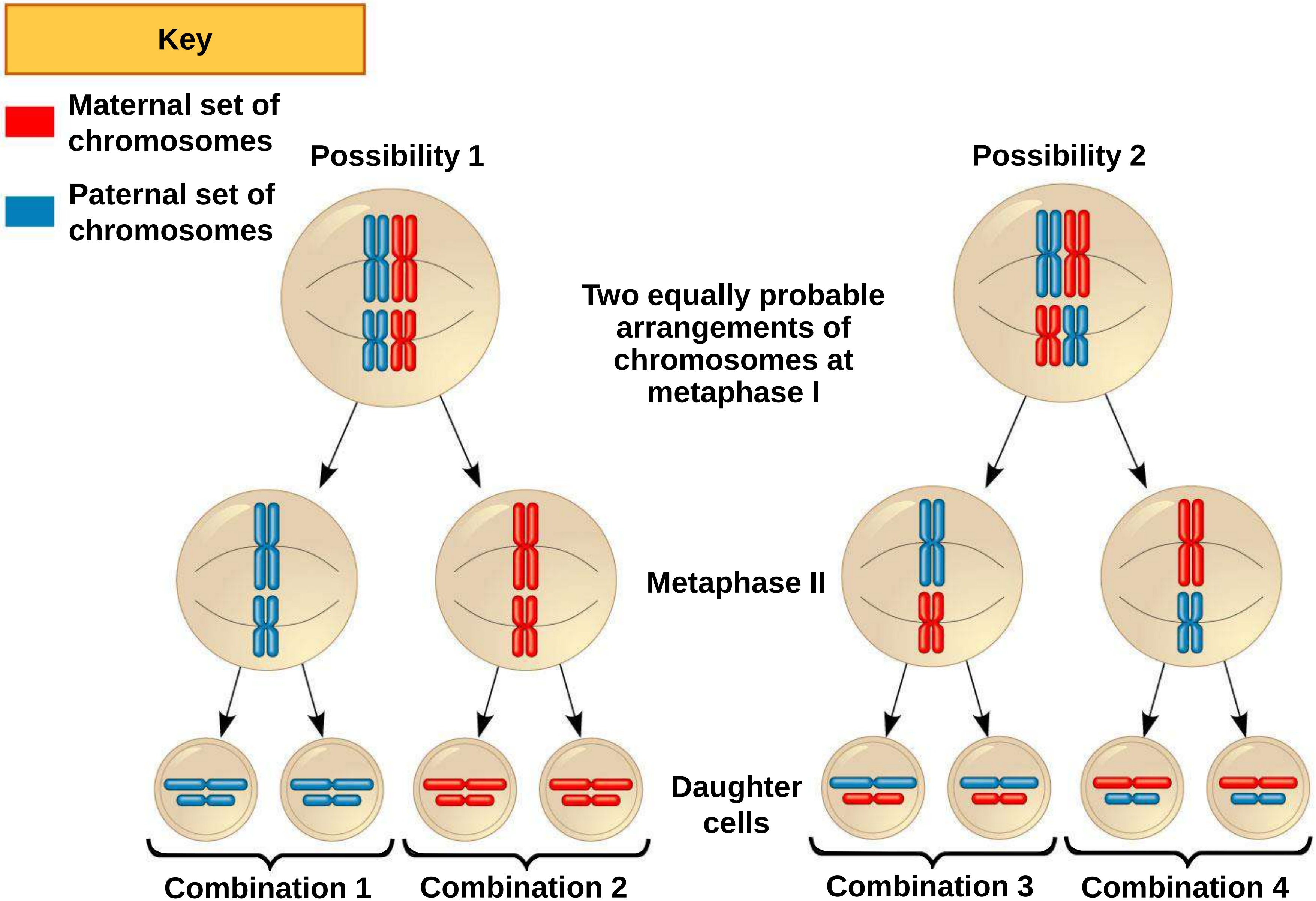
  1) Independent assortment of chromosomes

  2) Crossing over

  3) Random fertilization

1) Independent Assortment of Chromosomes

- Homologous pairs of chromosomes orient randomly at <u>metaphase I of meiosis</u>
- In independent assortment, **each pair** of chromosomes sorts maternal and paternal homologues into daughter cells <u>independently of the other pairs</u>
- The number of combinations possible when chromosomes assort independently into gametes is 2^n, where <u>n is the haploid number</u>
- For humans (n = 23), there are more than 8 million (2^{23}) possible combinations of chromosomes!



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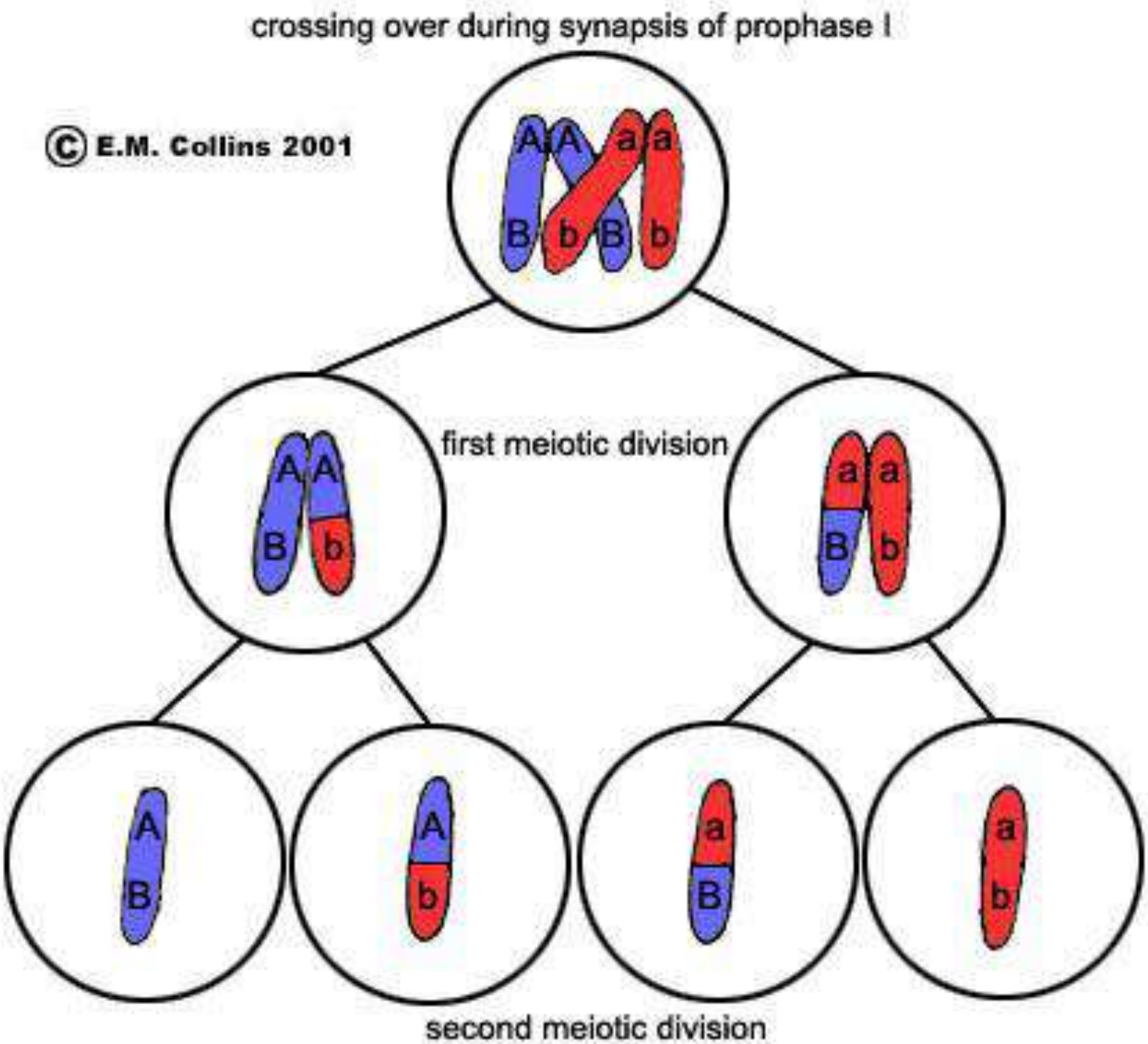
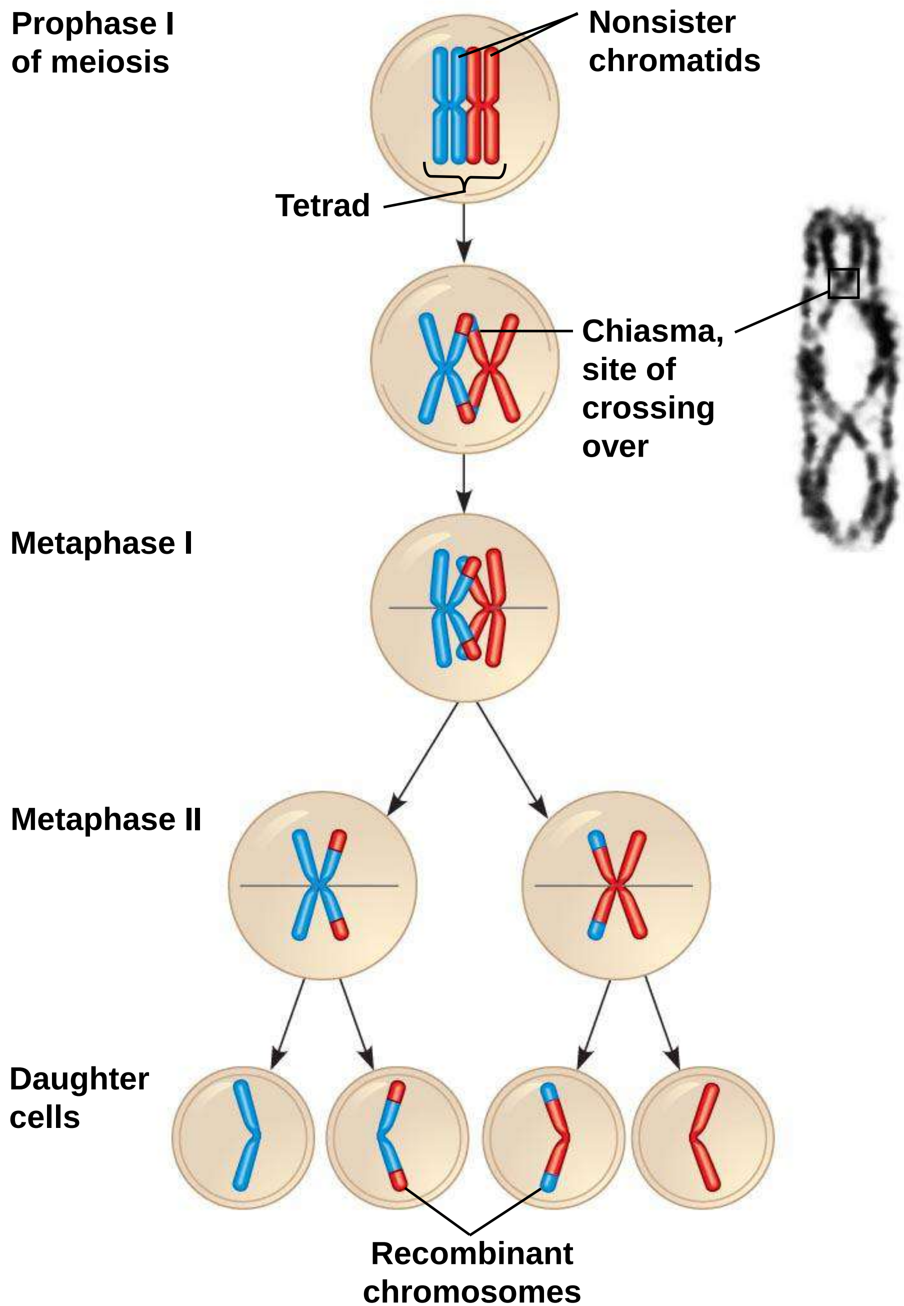
<u>2) Crossing Over</u>

- Crossing over produces **<u>recombinant chromosomes</u>**, which combine genes inherited from each parent
- Crossing over begins very early in prophase I, as homologous chromosomes pair up gene by gene
- In crossing over, homologous portions of two nonsister chromatids trade places
- Crossing over contributes to genetic variation by <u>combining DNA from two parents into a single chromosome</u>


crossing over during synapsis of prophase I
© E.M. Collins 2001
A A a a
B b B b
first meiotic division
A A
B b
a a
B b
A
B
A
b
a
B
a
b
second meiotic division



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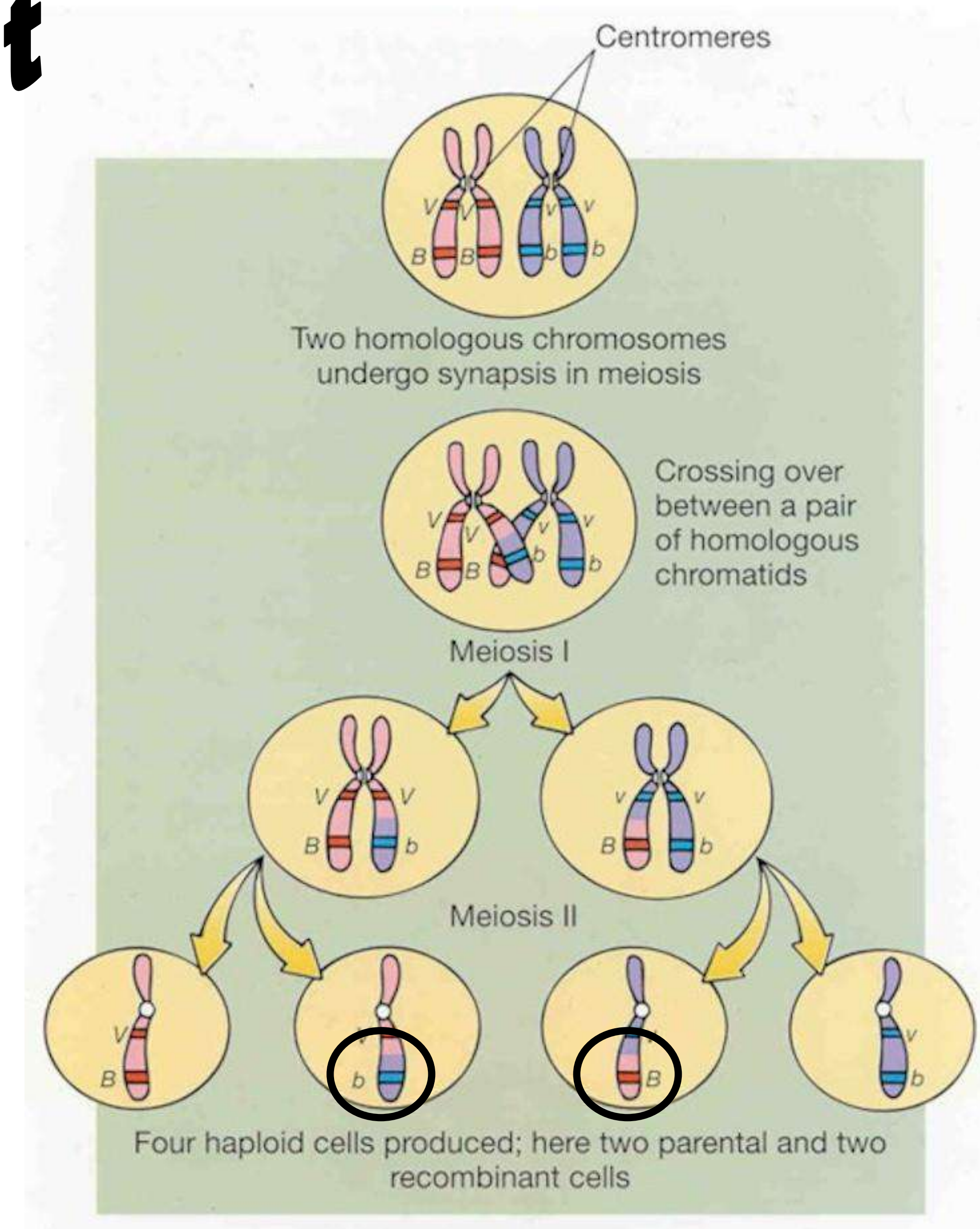
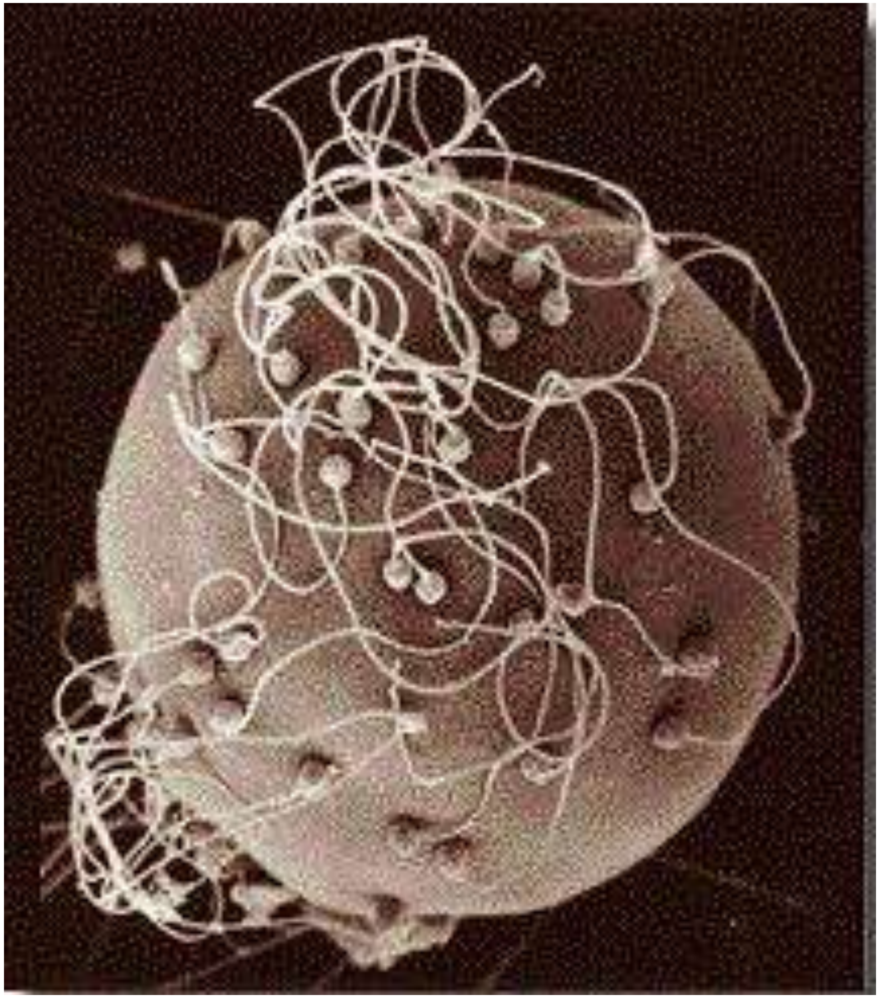
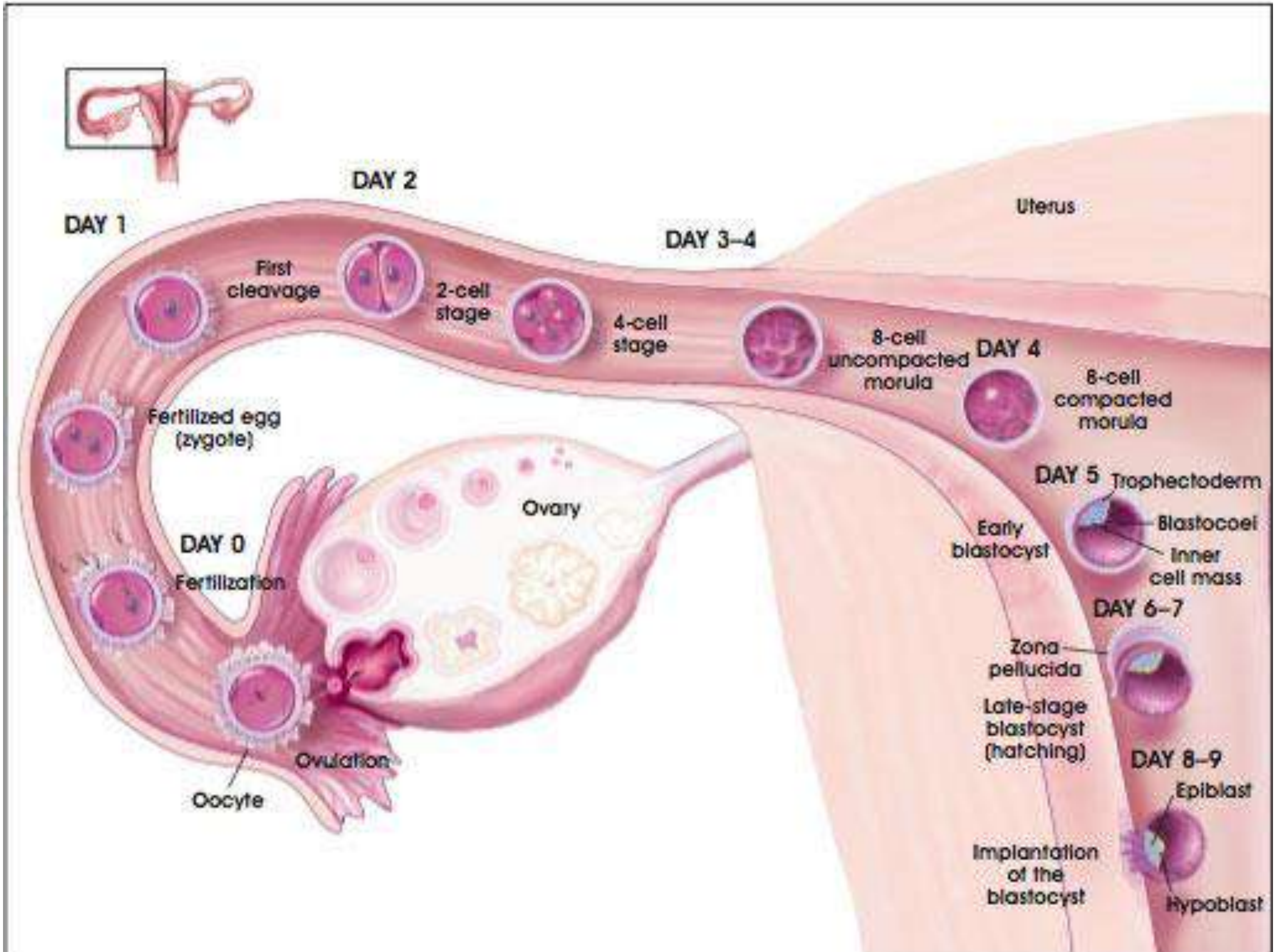
4 different cells!



3) Random Fertilization

- Random fertilization adds to genetic variation because any sperm can fuse with any ovum (unfertilized egg)
- The fusion of gametes produces a zygote with any of about 64 trillion diploid combinations
- Crossing over adds even more variation
- Each zygote has a **unique genetic identity**




DAY 2
DAY 1
Uterus
DAY 3–4
First cleavage
2-cell stage
4-cell stage
8-cell uncompacted morula
DAY 4
8-cell compacted morula
Fertilized egg (zygote)
DAY 5
Trophectoderm
Ovary
Blastocoel
Early blastocyst
Inner cell mass
DAY 0
Fertilization
DAY 6–7
Zona pellucida
Late-stage blastocyst (hatching)
Ovulation
DAY 8–9
Epiblast
Oocyte
Implantation of the blastocyst
Hypoblast

Evolutionary Significance of Genetic Variation Within Populations

- Natural selection results in accumulation of genetic variations favored by the environment
- Sexual reproduction contributes to the genetic variation in a population, which ultimately results from mutations