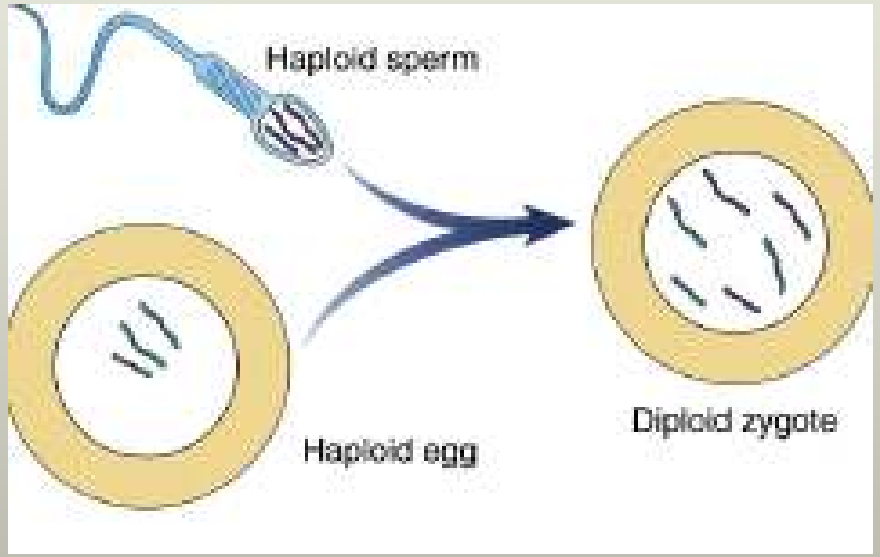
Meiosis and Sexual Life Cycles

Asexual reproduction vs. Sexual Reproduction

- The goals of each type:
  - Asexual
  - Sexual

Sexual reproduction

- Two parents produce a genetically unique individual
  - A new, never before seen combination
- Gametes are required – egg and sperm
  - Meiosis
- Then what?
- Fertilization



Take home message

- Sexual life cycles produce genetic variation
- That's a good thing

Sexual reproduction

- What's so special about gametes?
- They have half the number of chromosomes of any other cell in the body

Two types of cells

- Somatic cells- all cells of the body except gametes
  - 2 sets of chromosomes
- Gametes- sex cells (egg and sperm)
  - 1 set of chromosomes

Diploid and Haploid

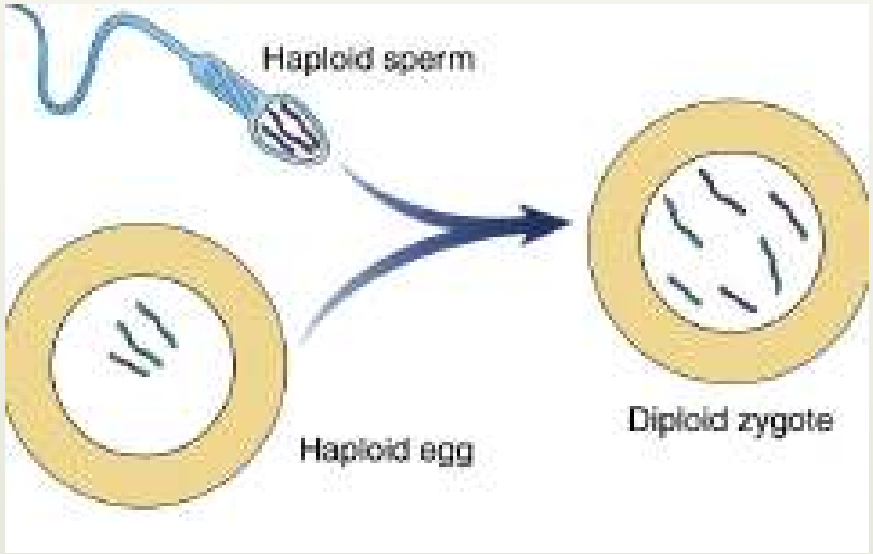
- How many chromosomes do we find in a human somatic cell?
  - Humans are diploid with 23 pairs of chromosomes for a total of 46
- Number of chromosomes in a set is **n**
- Diploid: 2 full sets of chromosomes: 2n
- Haploid – 1 set of chromosomes: n

How do we get cells with half of the normal number of chromosomes?

- Meiosis!!

- The purpose of meiosis is to divide a cell, producing daughter cells that have half of the number of chromosomes as the original
  - These cells become gametes

FERTILIZATION



- Fusion of two gametes
- Produces a diploid zygote
- After the formation of a zygote, the resulting cell divides through mitosis to produce all the somatic cells needed for organism
- Once the organism is mature, meiosis will again produce haploid gametes

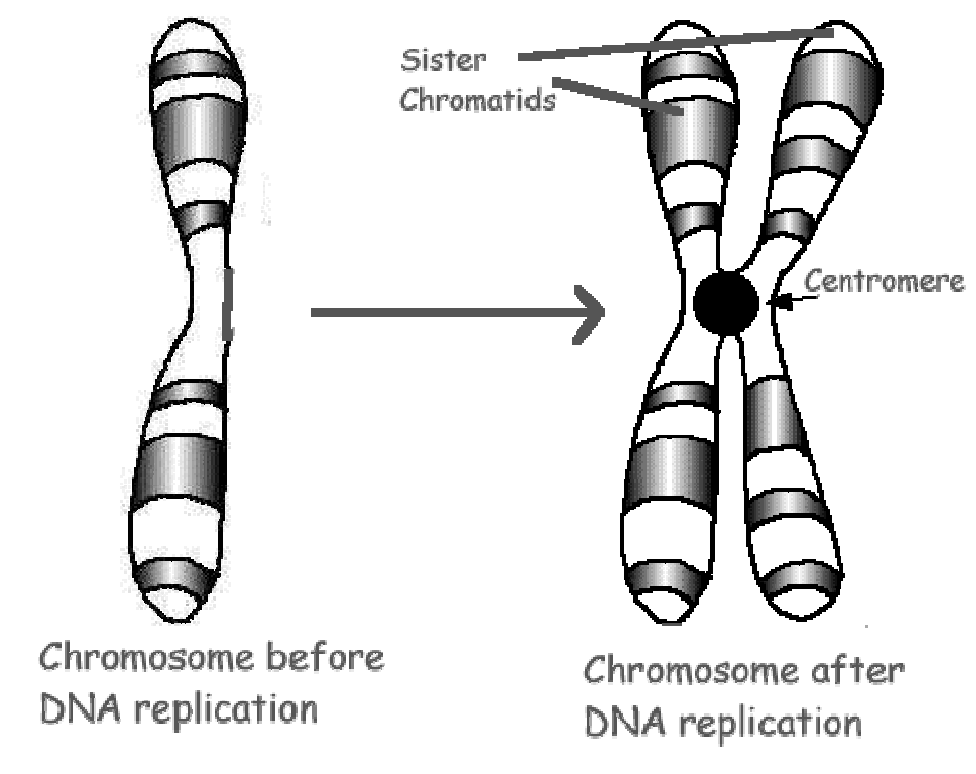
- And the cycle continues…

Quick review

- Heredity: transmission of traits from generation to generation
- Variation: ?
- Genetics: the study of heredity and hereditary variation

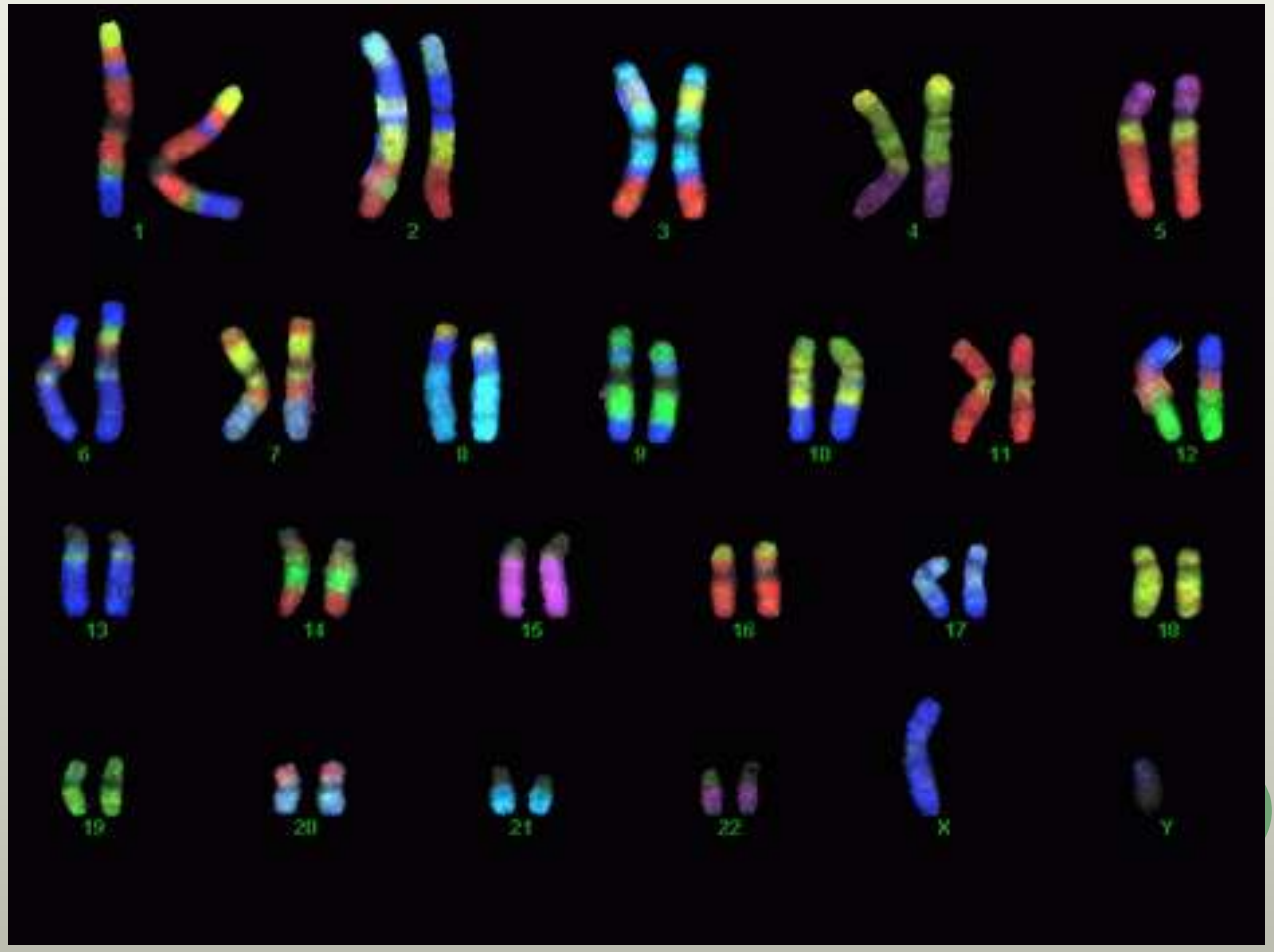
CHROMOSOMES

- Each species has a characteristic number of chromosomes
- Chromosomes carry hundreds to thousands of genes
- Each gene has a specific locus

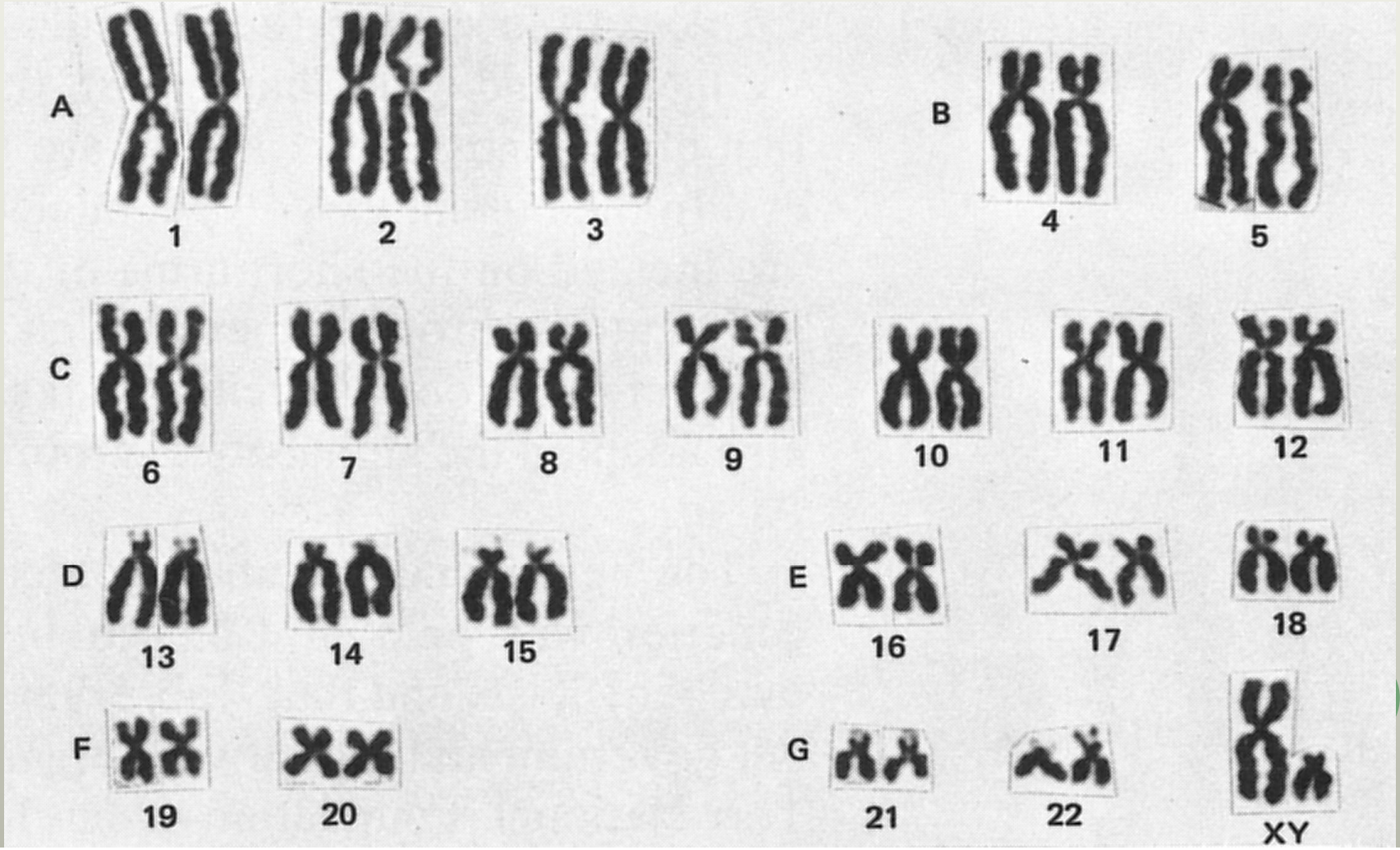


KARYOTYPE

- Somatic Cells – all the cells of the body, except gametes
- Sex chromosomes
- Autosomes

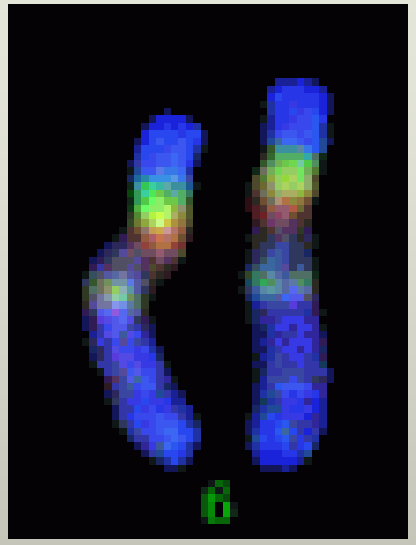


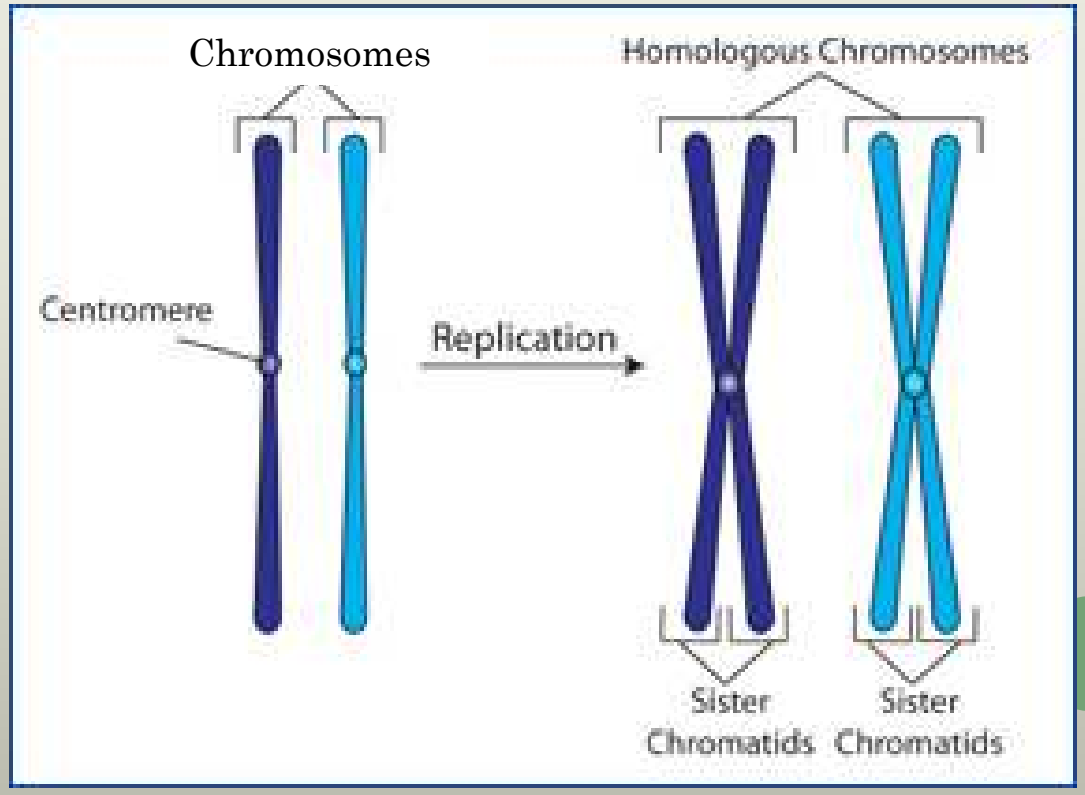
Karyotype



HOMOLOGOUS CHROMOSOMES

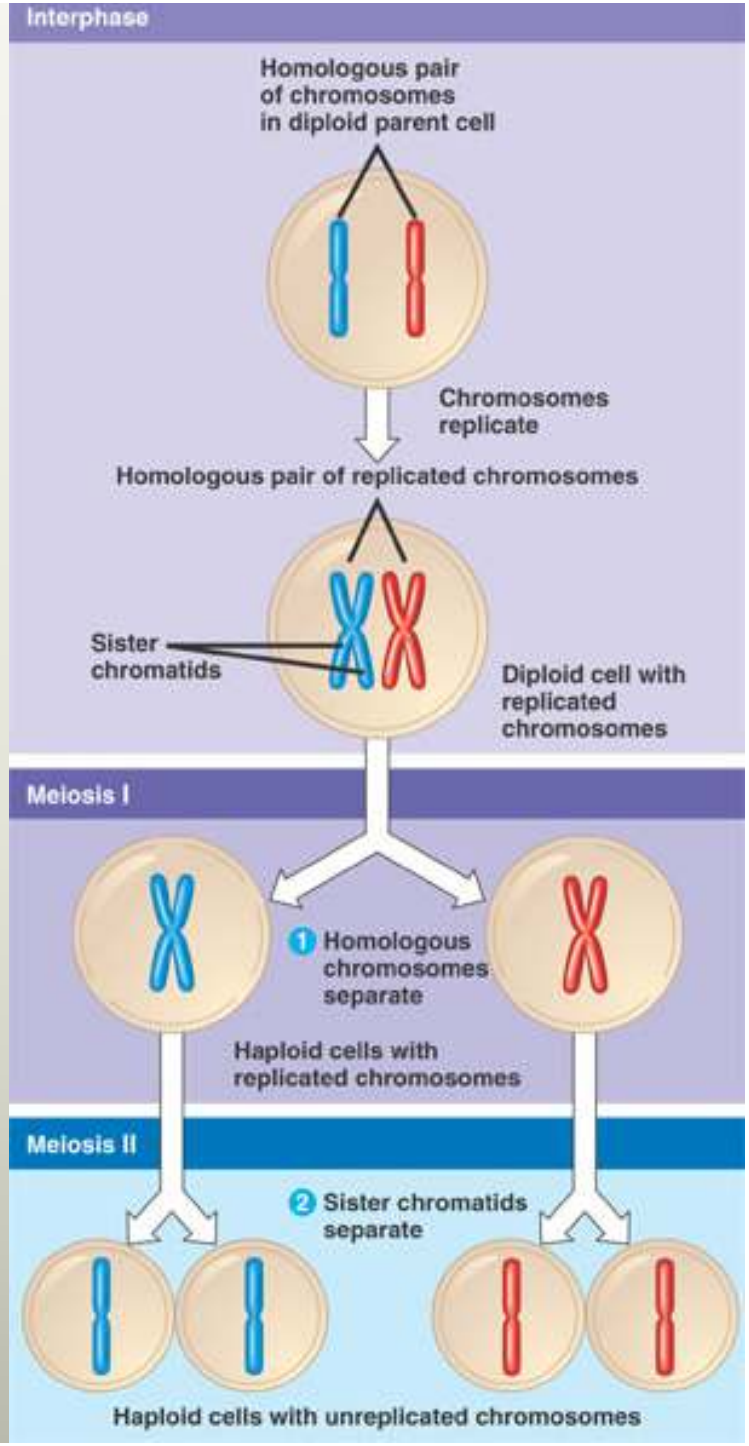
- Chromosomes that have the same length, centromere position and banding pattern
- Carry the same loci





What happens in meiosis?

- It's like mitosis but more complex
  - Two stages of division
    - Meiosis I
    - Meiosis II
- Replication of chromosomes still occurs first
- Reduces chromosome number from diploid to haploid
- Produces 4 haploid gametes



Key concepts of meiosis

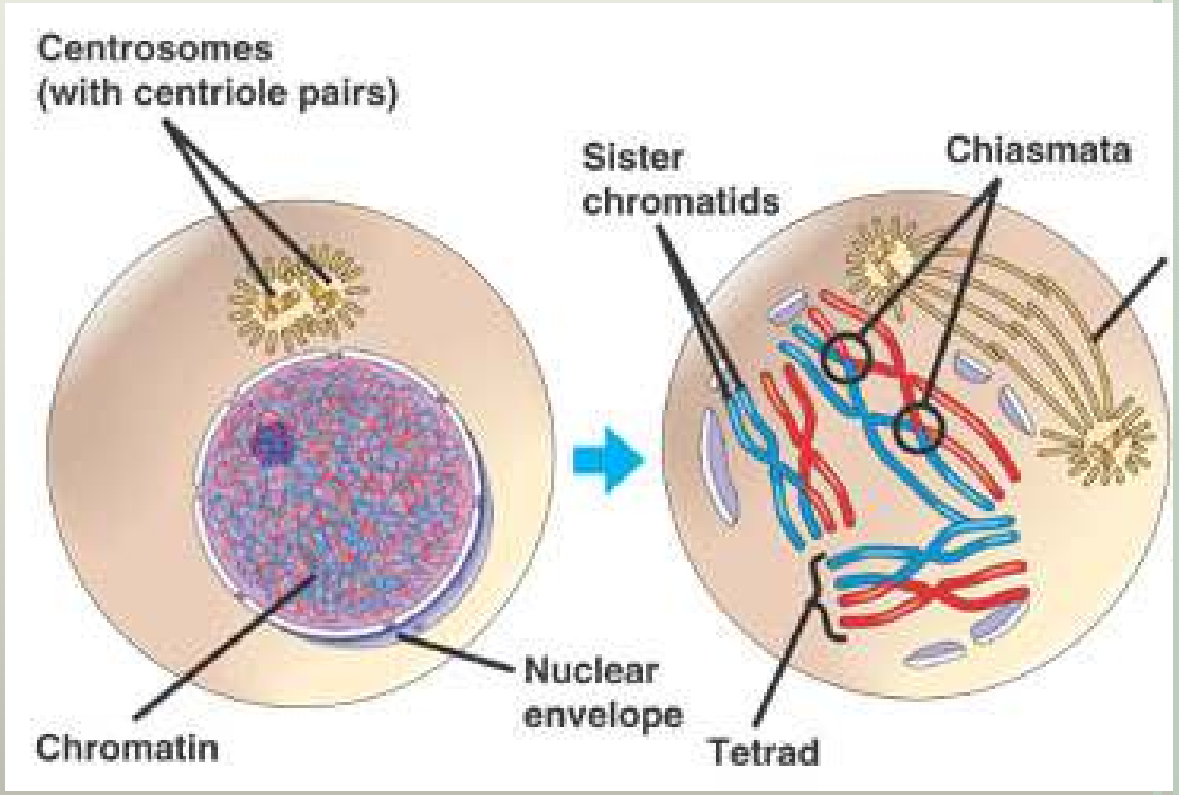
- Chromatin condenses to chromosomes, nucleus dissolves, spindle apparatus forms
- Homologous chromosomes pair up (synapsis) and become connected (tetrads)
- Crossing over occurs
  - Non-sister chromatids exchange DNA
- Tetrads align on the metaphase plate
- Tetrads separate and sister chromatid pairs move towards opposite poles
- Nucleus re-forms
- Cytokinesis - two haploid cells are formed
  - Sister chromatids still linked
- End of Meiosis I followed by Interphase-like stage
  - No additional DNA replication

Key concepts of meiosis

- Meiosis II is EXACTLY like mitosis
  - Except:
    - Sister chromatids are no longer identical
    - Fewer chromosomes in each cell (haploid)
- Nucleus dissolves, spindle apparatus forms
  - Remember, this is happening in two separate cells!
- Chromosomes line up on the metaphase plate
- Sister chromatids separate and move to opposite ends of the cell
- Nuclei re-form, chromosomes decondense
- Cytokinesis
  - Results in 4 daughter cells, each genetically unique from the parents and from each other

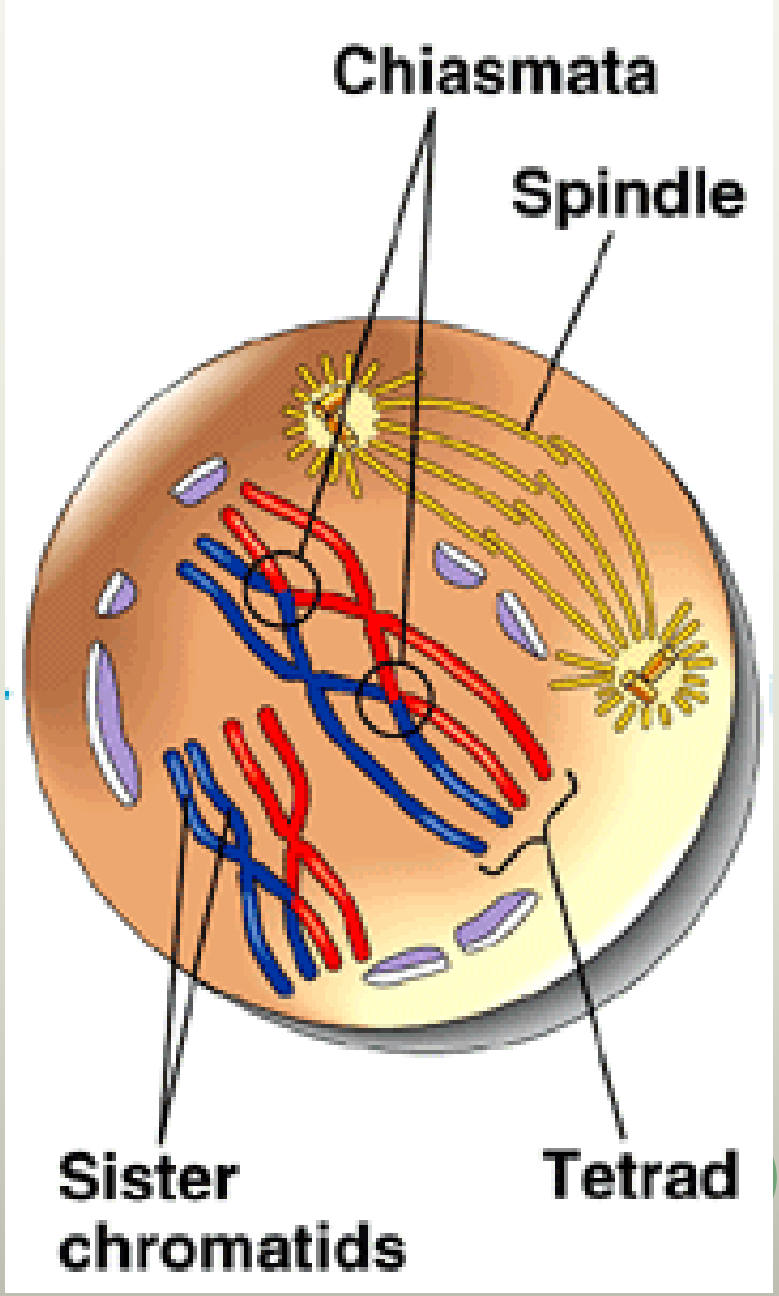
Meiosis I

- Chromatin condenses to chromosomes, nucleus dissolves, spindle apparatus forms



Meiosis I

- Homologous chromosomes pair up (synapsis) and become connected (tetrads)



Meiosis I

- Crossing over occurs
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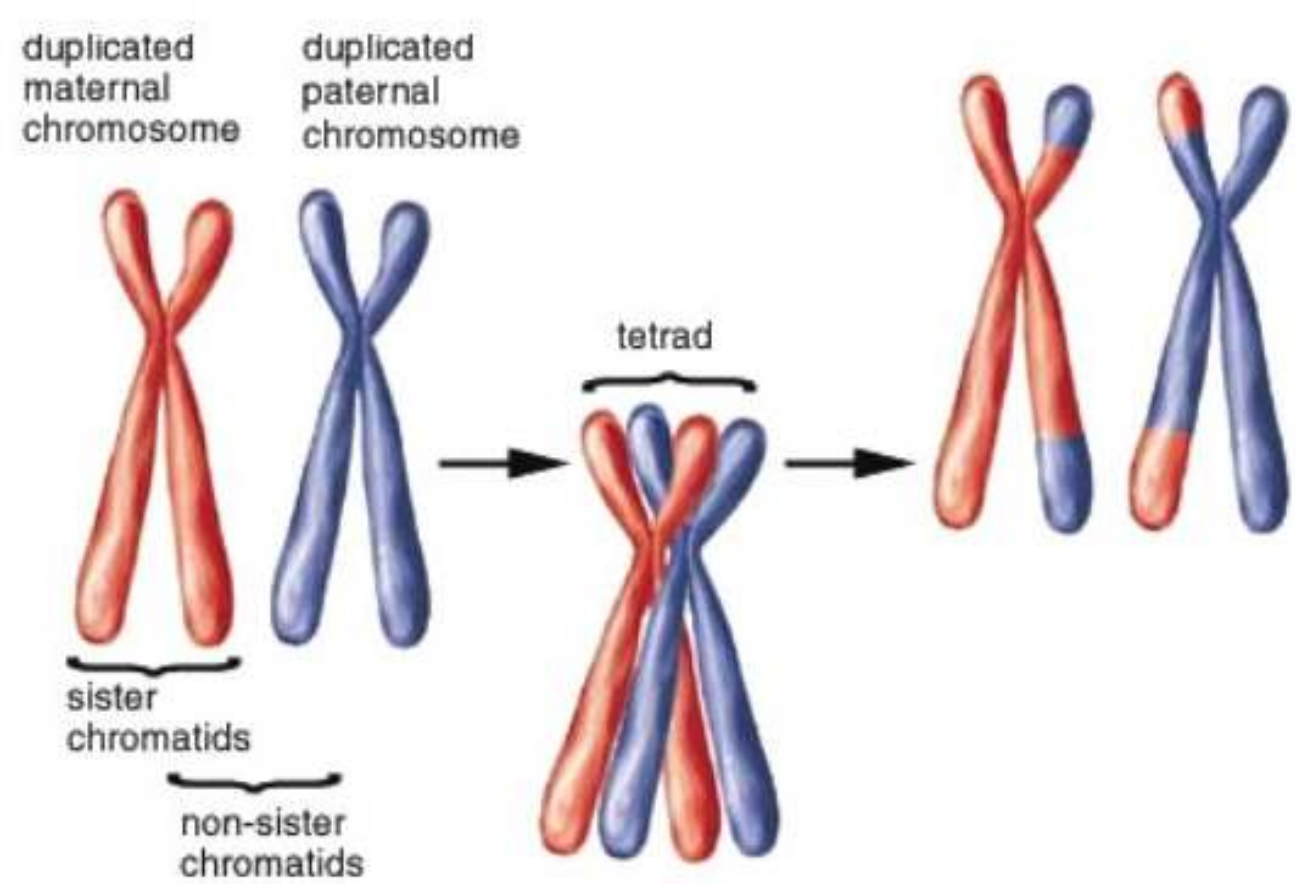
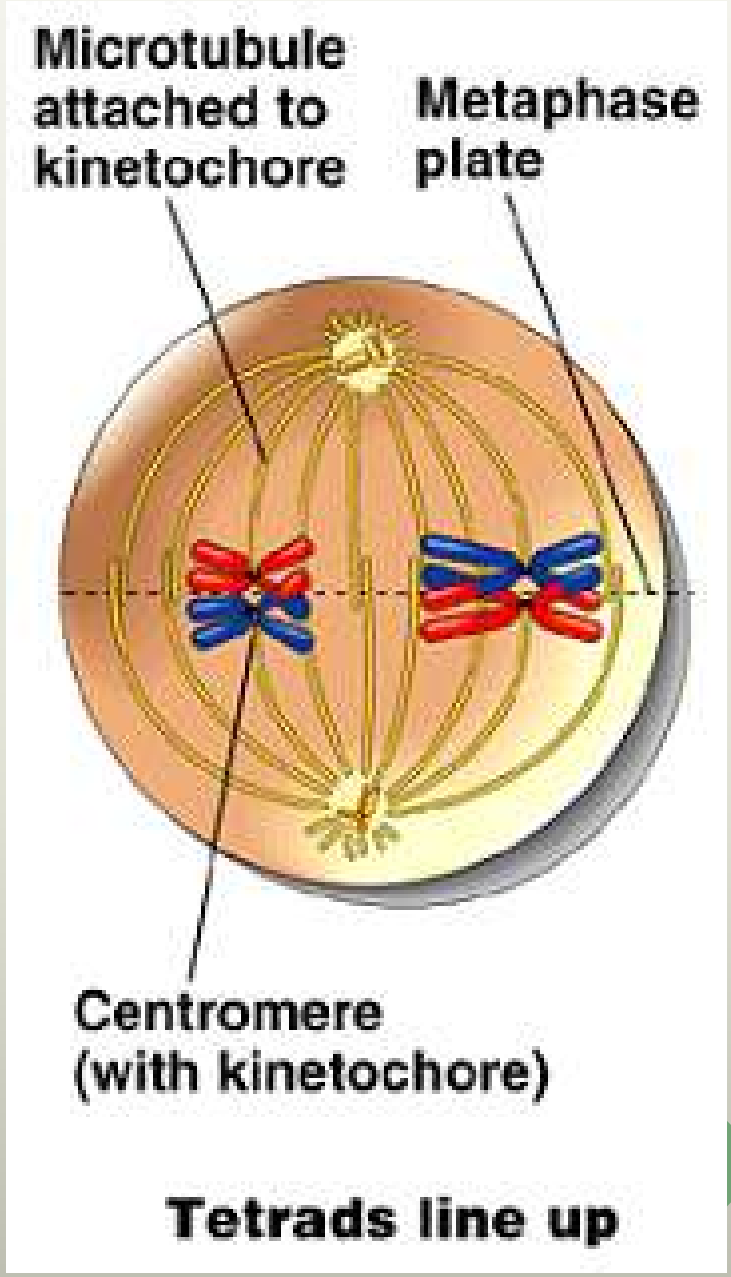


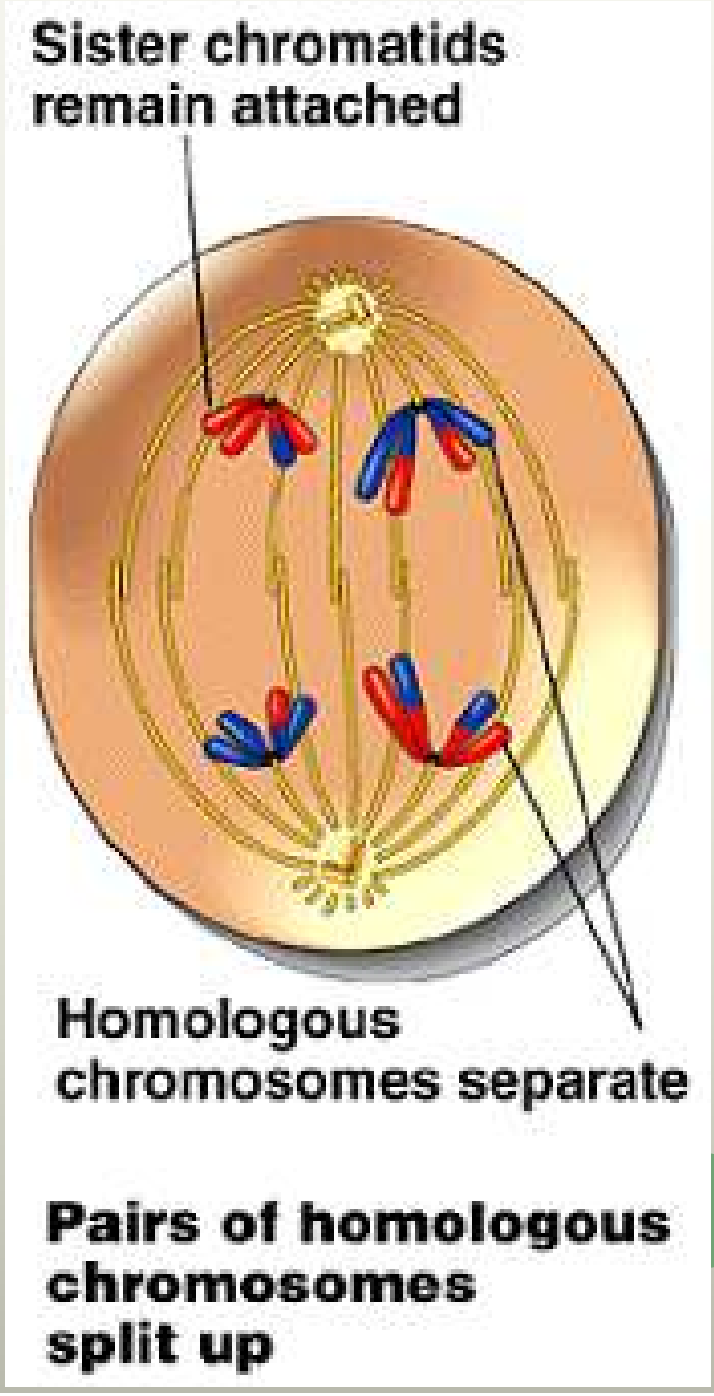
Meiosis I

- Tetrads align on the metaphase plate



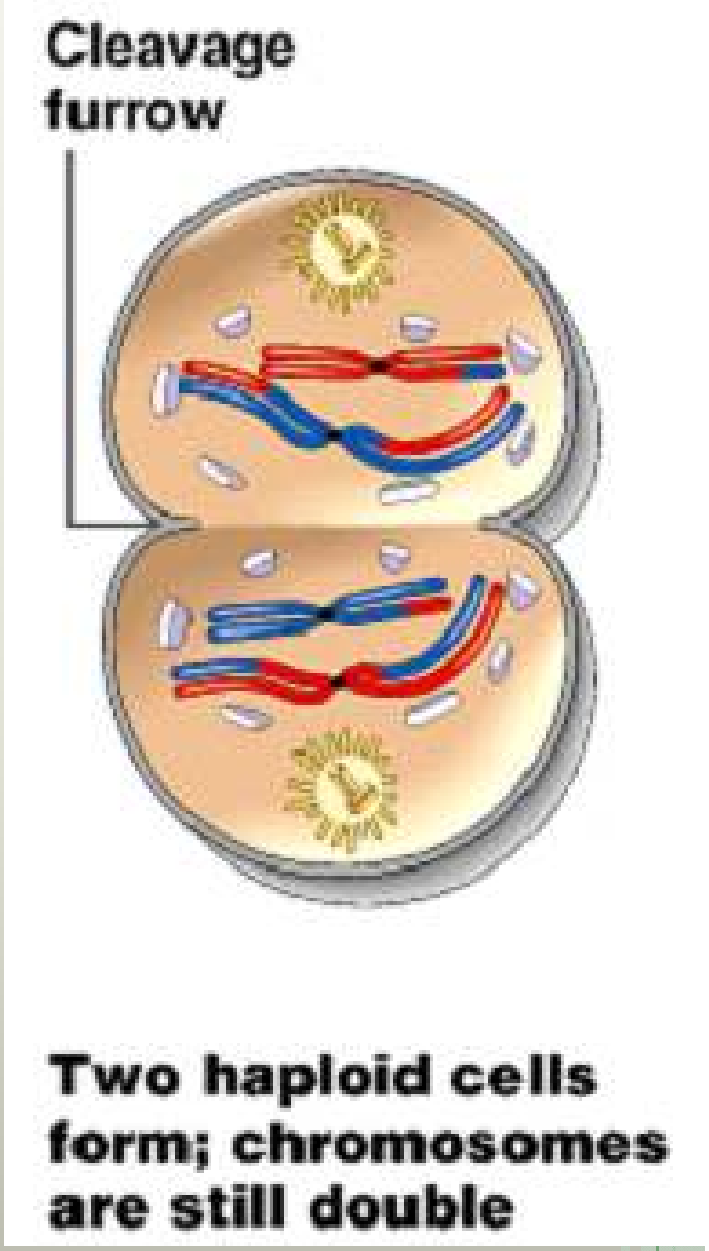
Meiosis I

- Tetrads separate and sister chromatid pairs move towards opposite poles
- Separation of homologous pairs



MEIOSIS I

- Nucleus re-forms
- Cytokinesis - two haploid cells are formed
  - Sister chromosome still linked
- End of Meiosis I followed by Interphase-like stage
  - No additional DNA replication



Meiosis II

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    - Sister chromatids are no longer identical
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- Nucleus dissolves, spindle apparatus forms
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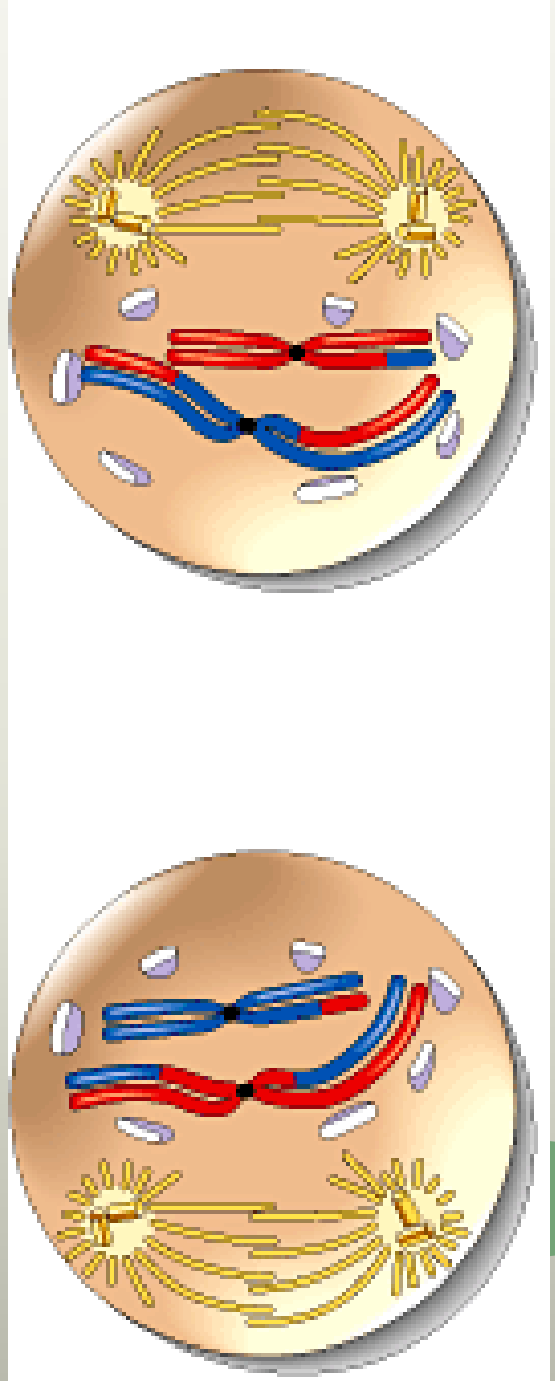
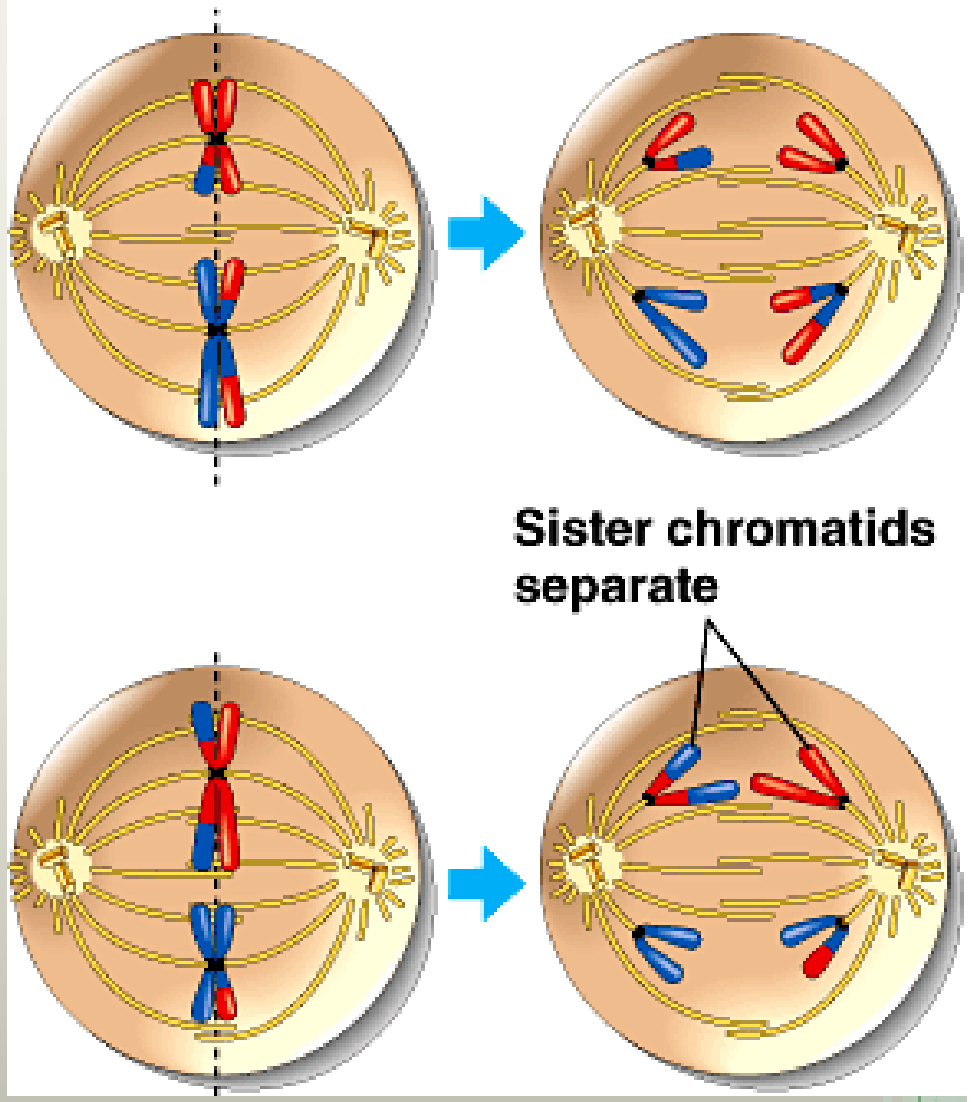


Meiosis II

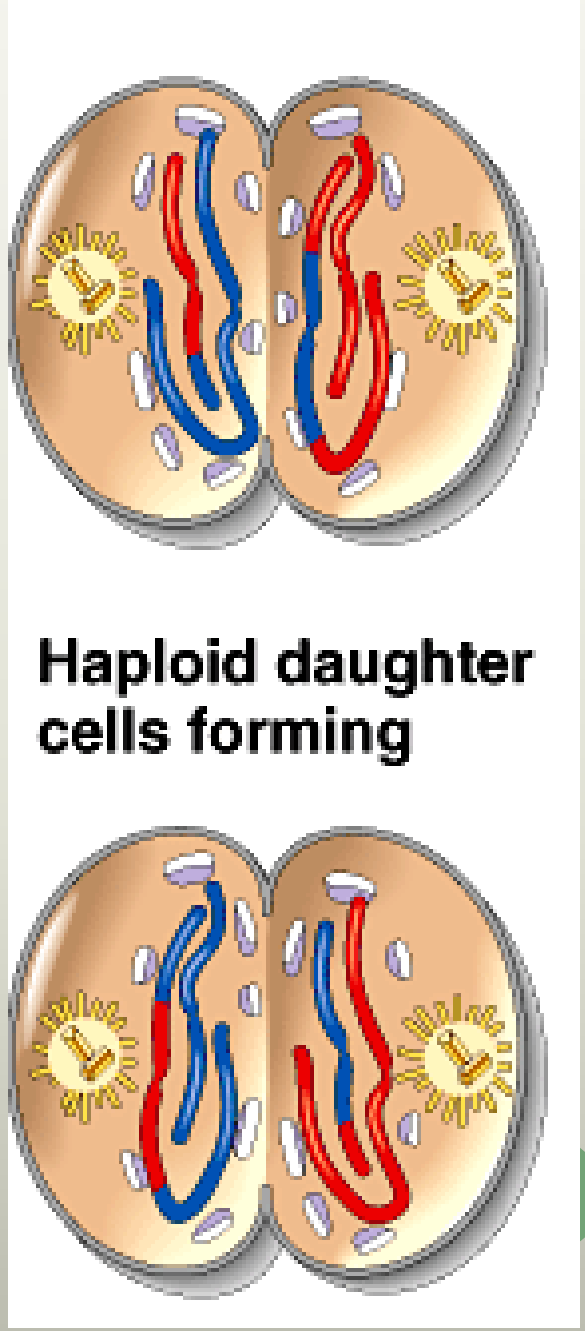
- Chromosomes line up on the metaphase plate
- Sister chromosomes separate and move to opposite ends of the cell



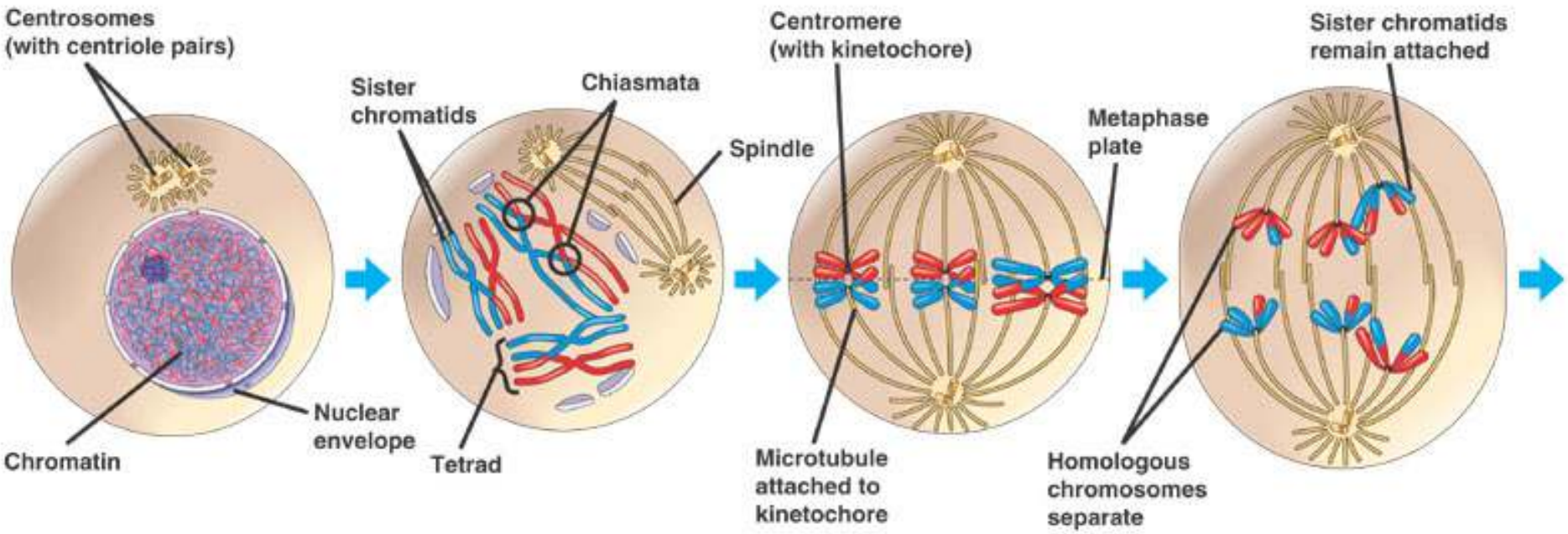
Meiosis II and Cytokinesis

- Nuclei re-form, chromosomes decondense

- Cytokinesis
  - Results in 4 daughter cells, each genetically unique from the parents and from each other
  - Haploid cells



INTERPHASE	MEIOSIS I: Separates homologous chromosomes		
	PROPHASE I	METAPHASE I	ANAPHASE I

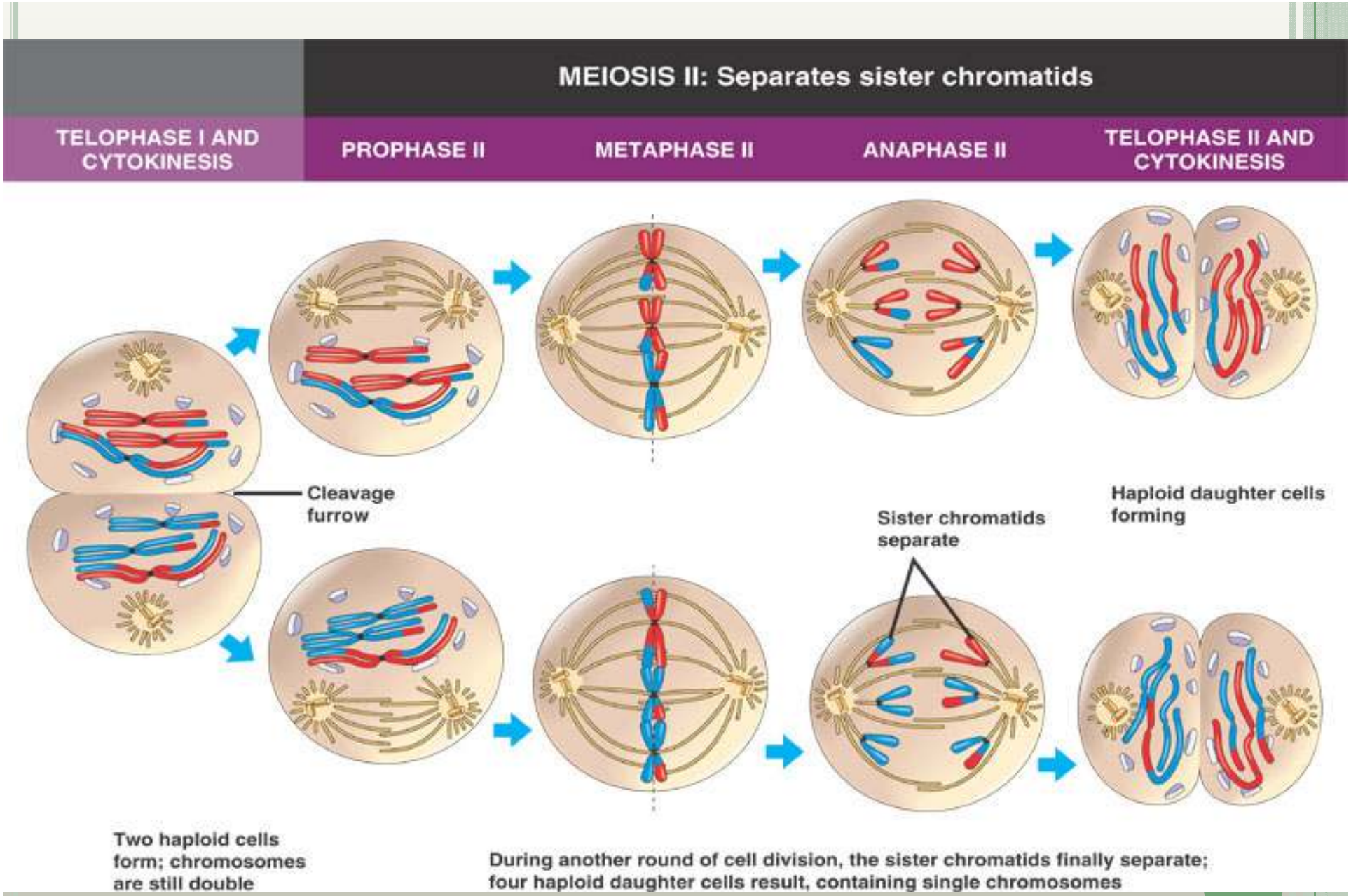


Chromosomes duplicate

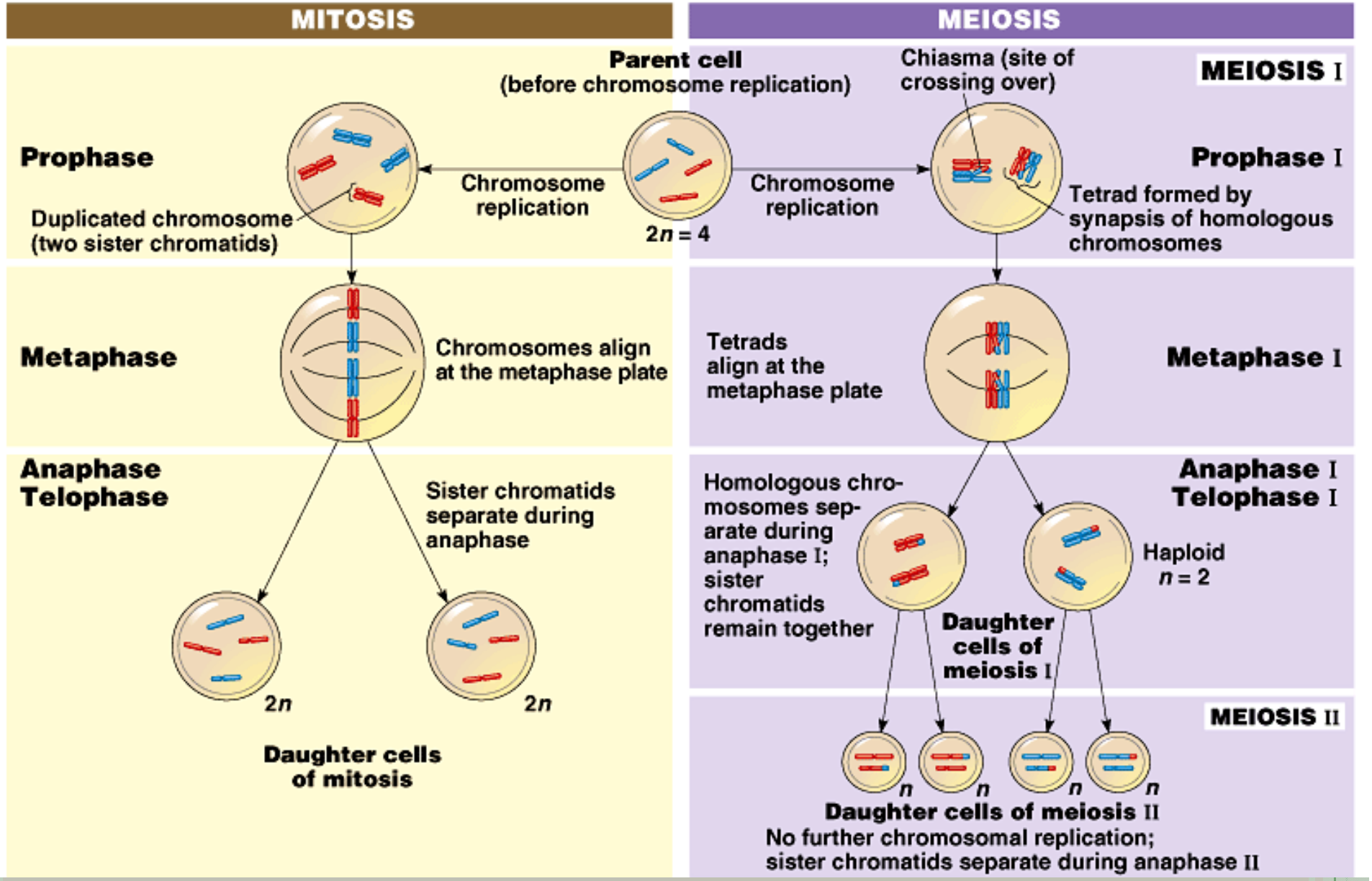
Homologous chromosomes (red and blue) pair and exchange segments; $2n = 6$ in this example

Tetrads line up

Pairs of homologous chromosomes split up


MEIOSIS II: Separates sister chromatids
TELOPHASE I AND CYTOKINESIS
PROPHASE II
METAPHASE II
ANAPHASE II
TELOPHASE II AND CYTOKINESIS
Cleavage furrow
Sister chromatids separate
Haploid daughter cells forming
Two haploid cells form; chromosomes are still double
During another round of cell division, the sister chromatids finally separate; four haploid daughter cells result, containing single chromosomes

In what ways are mitosis and meiosis similar and different?


MITOSIS
MEIOSIS
Parent cell
(before chromosome replication)
Chiasma (site of crossing over)
MEIOSIS I
Prophase
Chromosome replication
Chromosome replication
Prophase I
Duplicated chromosome (two sister chromatids)
2n = 4
Tetrad formed by synapsis of homologous chromosomes
Metaphase
Chromosomes align at the metaphase plate
Tetrads align at the metaphase plate
Metaphase I
Anaphase
Telophase
Sister chromatids separate during anaphase
Homologous chromosomes separate during anaphase I; sister chromatids remain together
Anaphase I
Telophase I
Haploid
n = 2
Daughter cells of meiosis I
2n
2n
Daughter cells of mitosis
MEIOSIS II
n
n
n
n
Daughter cells of meiosis II
No further chromosomal replication; sister chromatids separate during anaphase II

SUMMARY

Event	Mitosis	Meiosis
DNA replication		
Number of divisions		
Synapsis of homologous chromosomes		
Number of daughter cells and genetic composition		
Role in the animal body		

What was the take home message about meiosis?

How does meiosis introduce genetic diversity?

- Independent assortment
- Crossing over
- Random fertilization

Genetic Variation

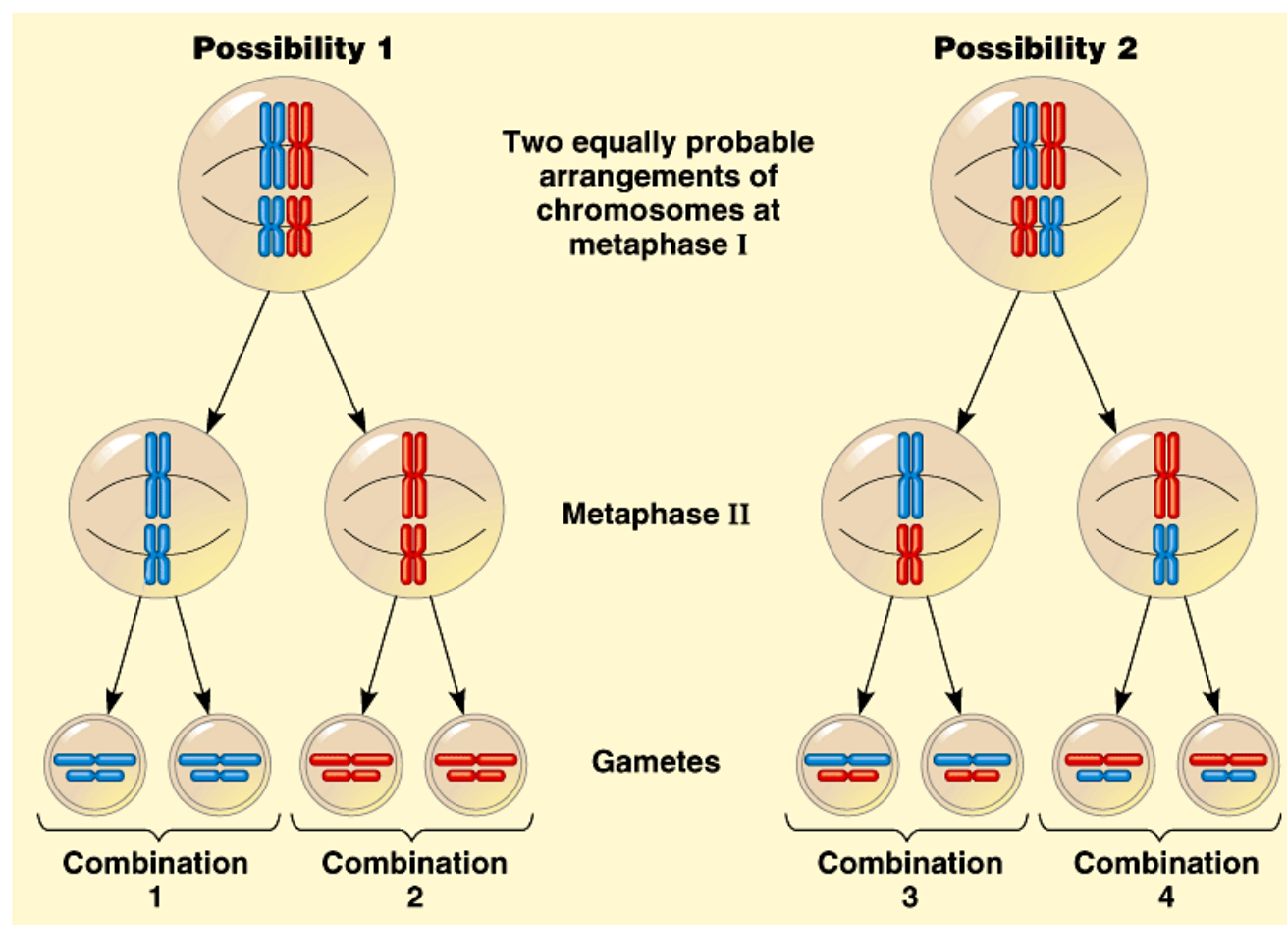
- Why is genetic variation so important?

- Ultimate source of variation is mutation which creates different allele varieties for genes

- Meiosis is like reshuffling a deck of cards and dealing a new hand

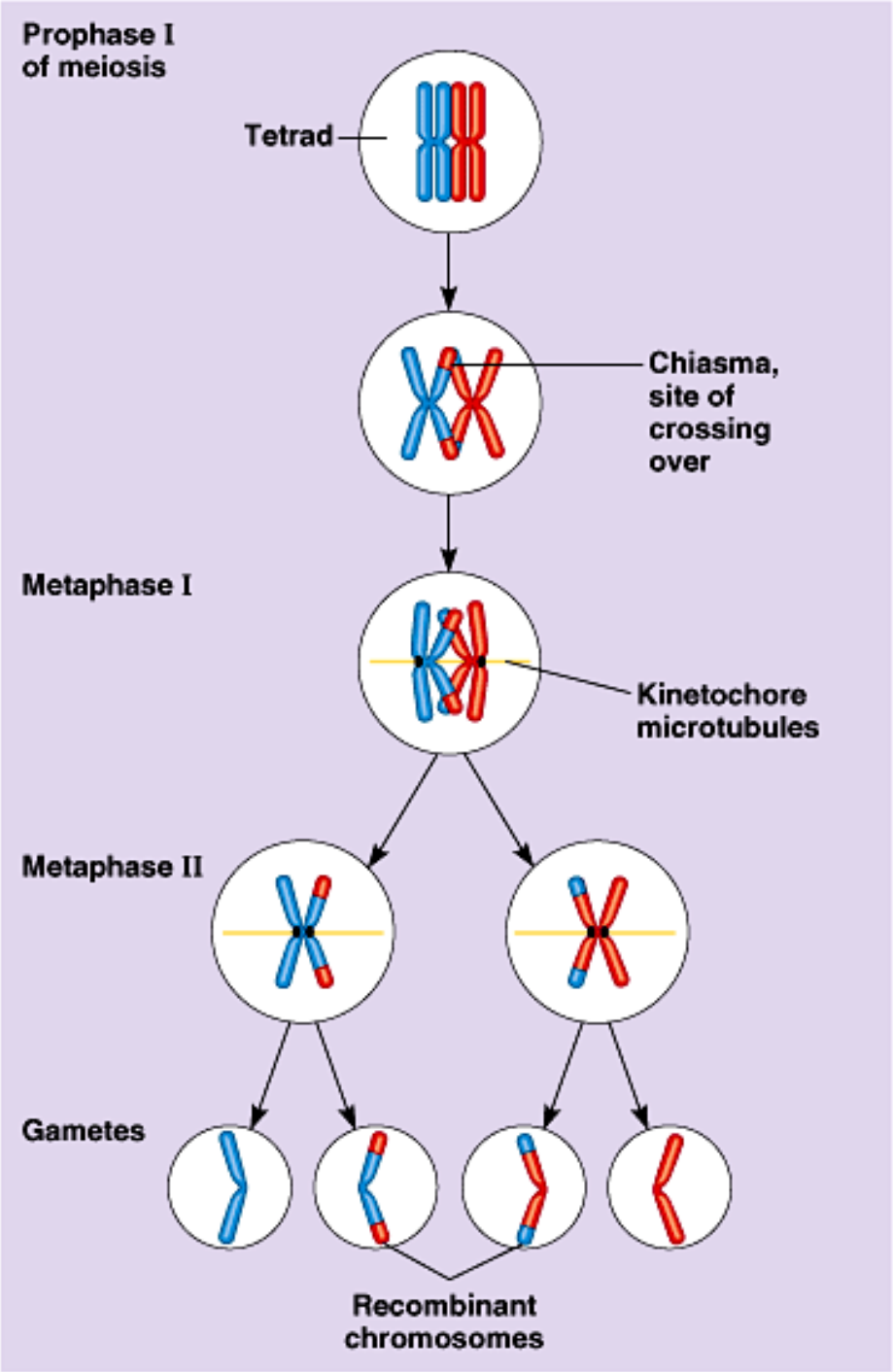
Independent Assortment

- Random line up
- Homologous pairs separate
- Maternal and paternal chromosomes move into separate daughter cells
- 2^n possibilities



Crossing Over

- Mixes parental DNA to form new combinations
- 2-3 events per chromosome



Random Fertilization

- Male and female gametes from different individuals combine to form new combinations
- Brings back diploid state

- That's 2^{23} x 2^{23} = over 70 trillion possible combinations!

- You are so unique!!!

Evolution