Meiosis

Learning Targets

- Explain the purpose of meiosis.
- Explain the process of meiosis.
- Compare mitosis and meiosis.

Mendel

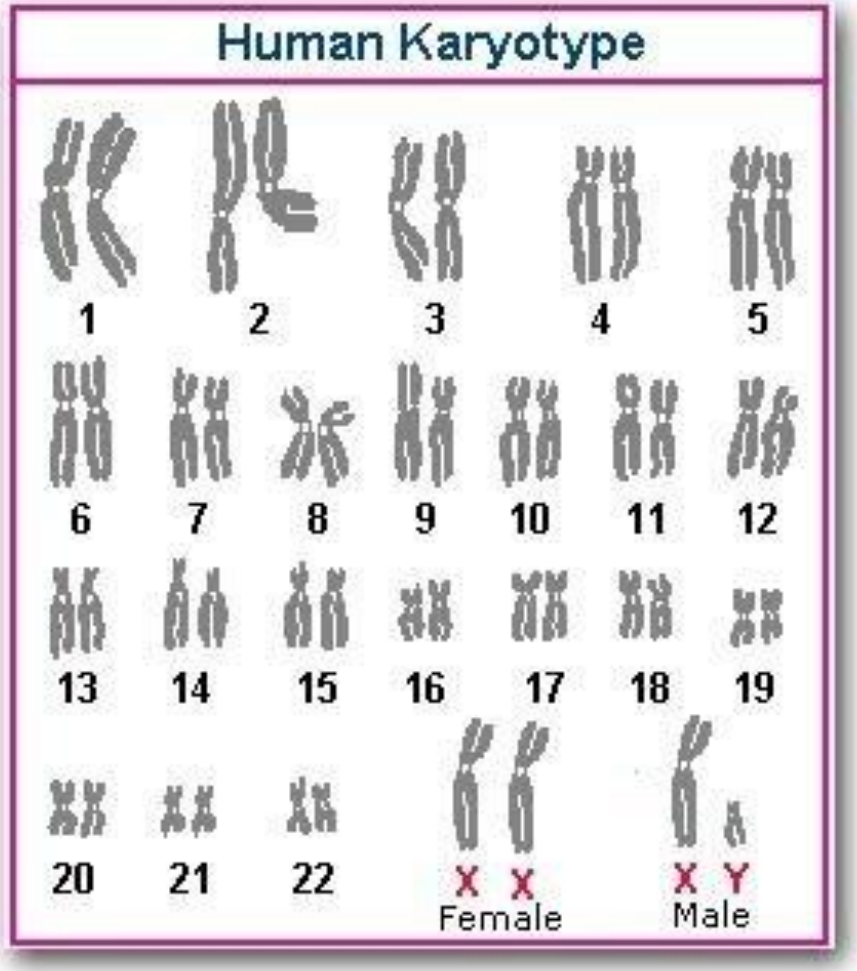
- Mendel learned that organisms carry two copies of each gene, one coming from each parent.
- But organisms only pass *one* of their copies of each gene to their offspring.
- When organisms produce gametes, their two copies of each gene separate so that each gamete contains just <u>one</u> set of genes.

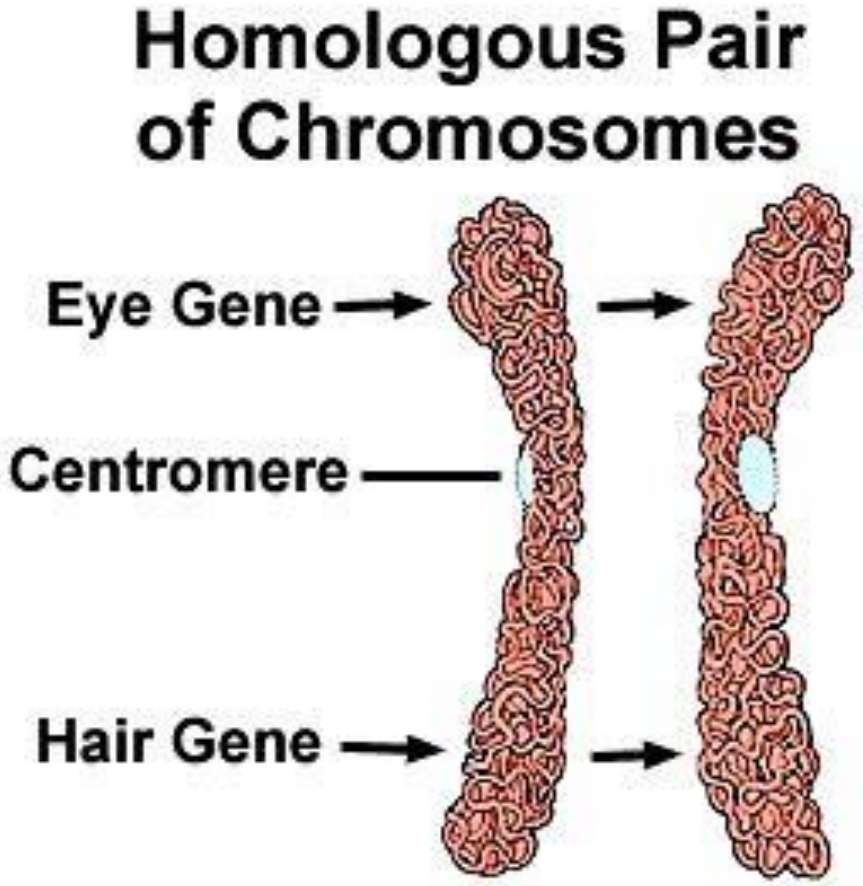
Chromosome Number

- In fruit flies, each body cell contains 8 chromosomes.
- Four of the chromosomes came from the fruit fly's male parent, and 4 came from its female parent.
- These two sets of chromosomes are homologous, meaning that each of the 4 chromosomes that came from the male parent has a corresponding chromosome from the female parent.
- A **homologous chromosome** is one that has a corresponding chromosome from the opposite-sex parent.

Homologous Chromosomes

Humans have 46 chromosomes in 23 homologous pairs.





Chromosome Number – Diploid Cells

- A cell that contains both sets of homologous chromosomes is said to be **diploid**, which means “two sets”.
- The number of chromosomes is a diploid cell is represented by the symbol 2N.
- For fruit flies, the diploid number is 8, which can be written 2N = 8.
- Diploid cells contain two complete sets of chromosomes and two complete sets of genes.

Chromosome Number – Haploid Cells

- The gametes of sexually reproducing organisms contain only a single set of chromosomes, and therefore only a single set of genes.
- These cells are said to be **haploid**, meaning “one set”.
- For fruit flies, this can be written N = 4, meaning that the haploid number is 4.

Human Cells

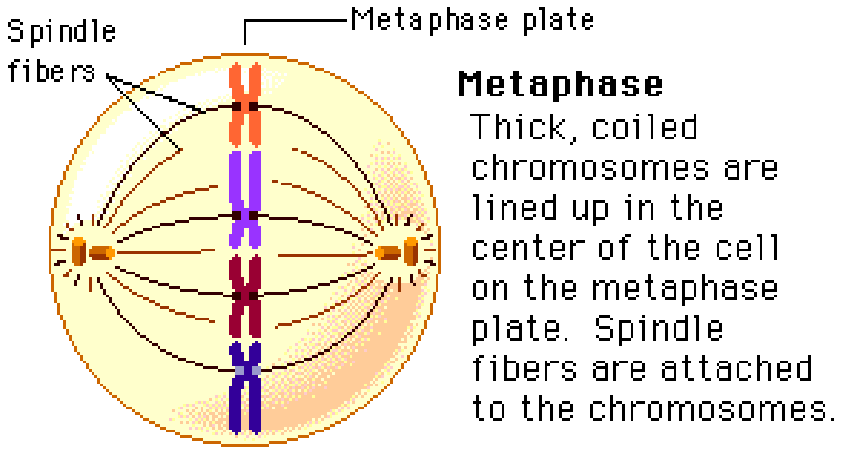
- Humans have 46 chromosomes in their body cells. What would be the diploid chromosome number for humans?
- 2N = 46
- What would be the haploid chromosome number for human gametes (sperm and egg cells)?
- N = 23

Meiosis

- **Meiosis** is the process of reduction division in which the number of chromosomes per cell is cut in half through the separation of homologous chromosomes in a diploid cell.
- Meiosis involves two distinct divisions, called meiosis I and meiosis II.
- By the end of meiosis II, the diploid cell that entered meiosis has become 4 haploid cells.

Prior to Meiosis I – Interphase I

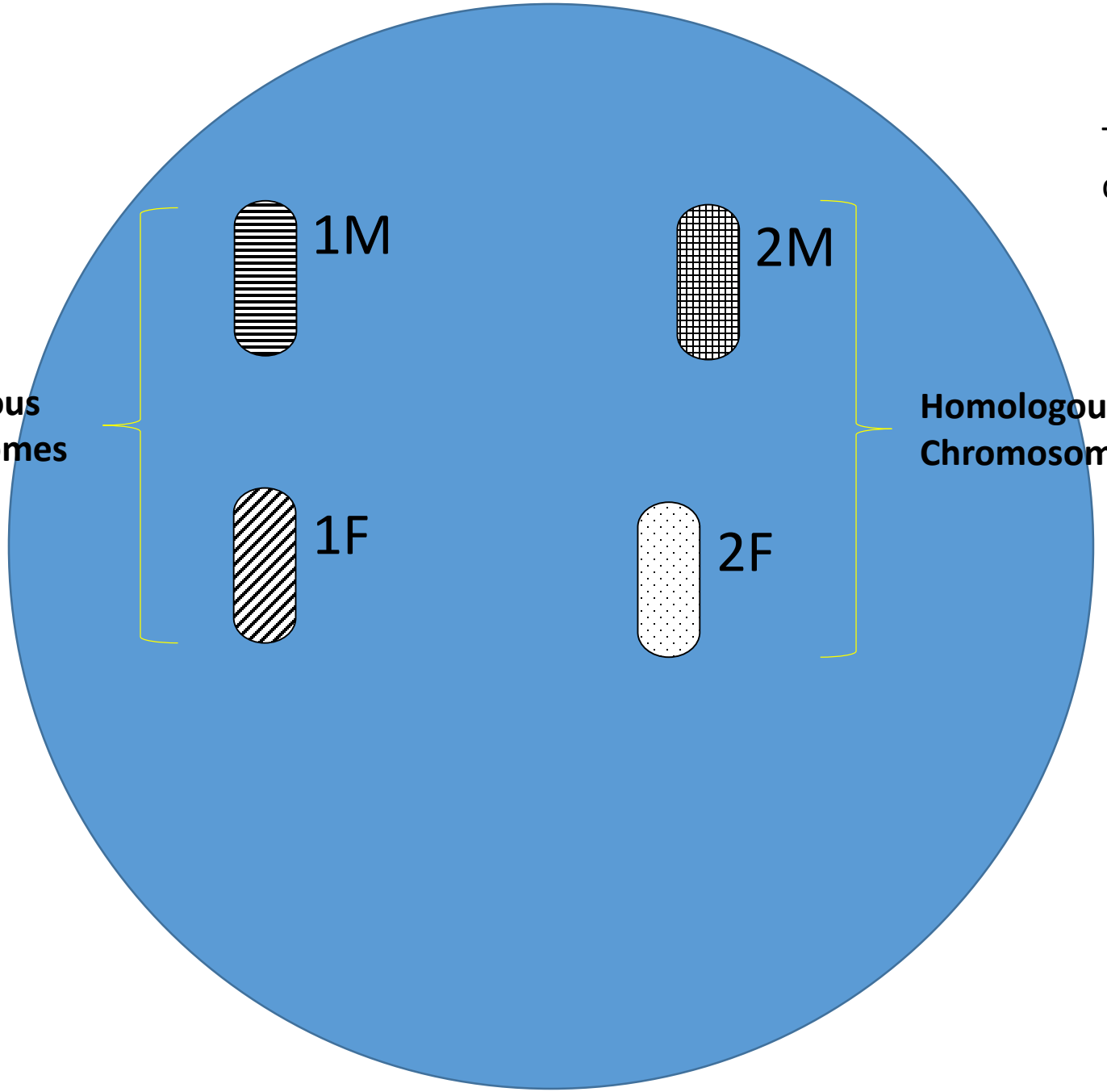
- Prior to meiosis I, during interphase I, each chromosome is replicated.
- The cells then begin to divide in a way that looks similar to mitosis. In *mitosis*, the chromosomes (made of 2 sister chromatids) line up *individually* in the center of the cell and then the two sister chromatids that make up each chromosomes separate from each other.



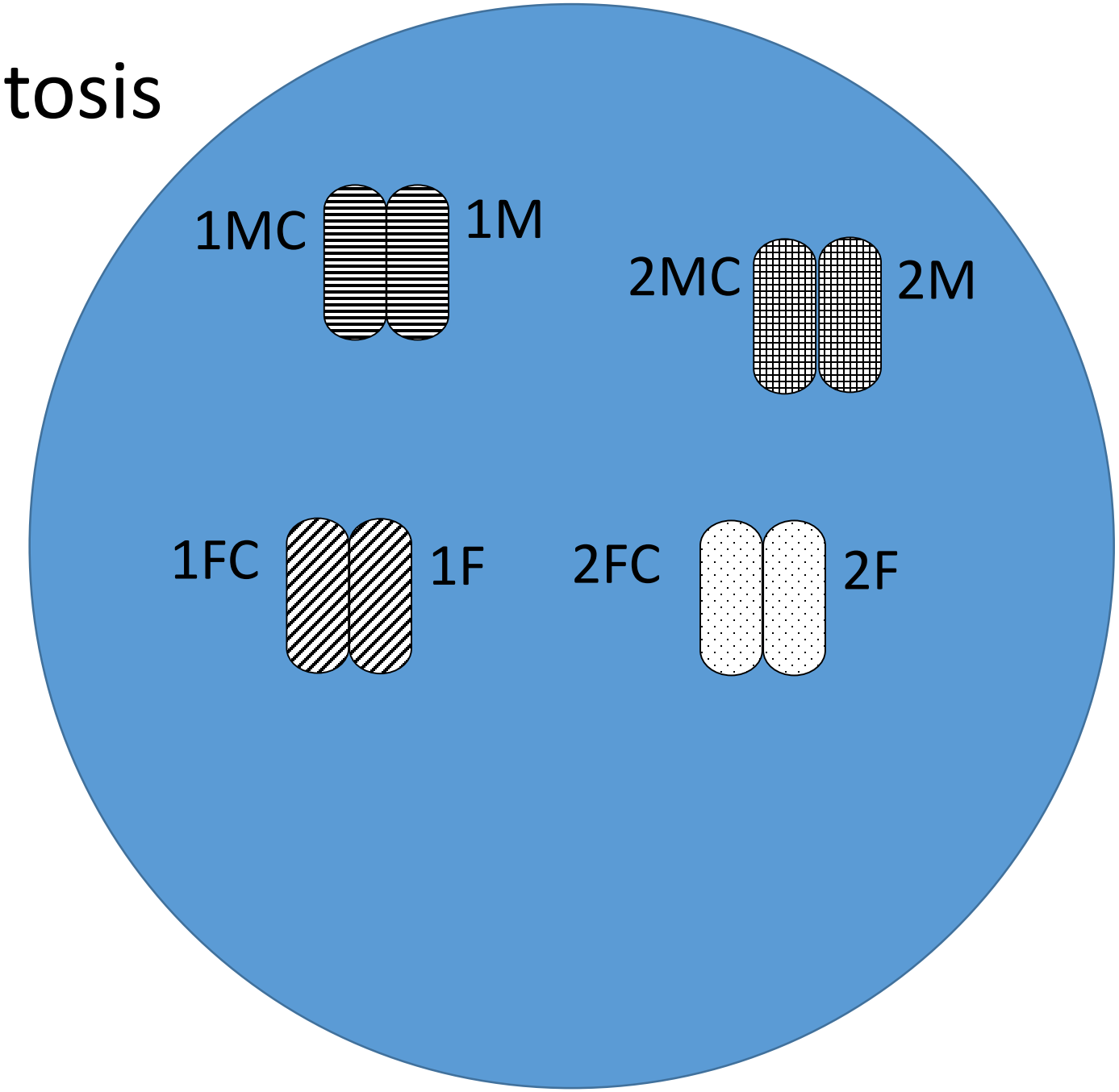
Remember, each chromosome consists of two sister chromatids. How many chromosomes are shown in the picture Above?

Mitosis

The diploid cell has 4 chromosomes. 2N = 4



Mitosis



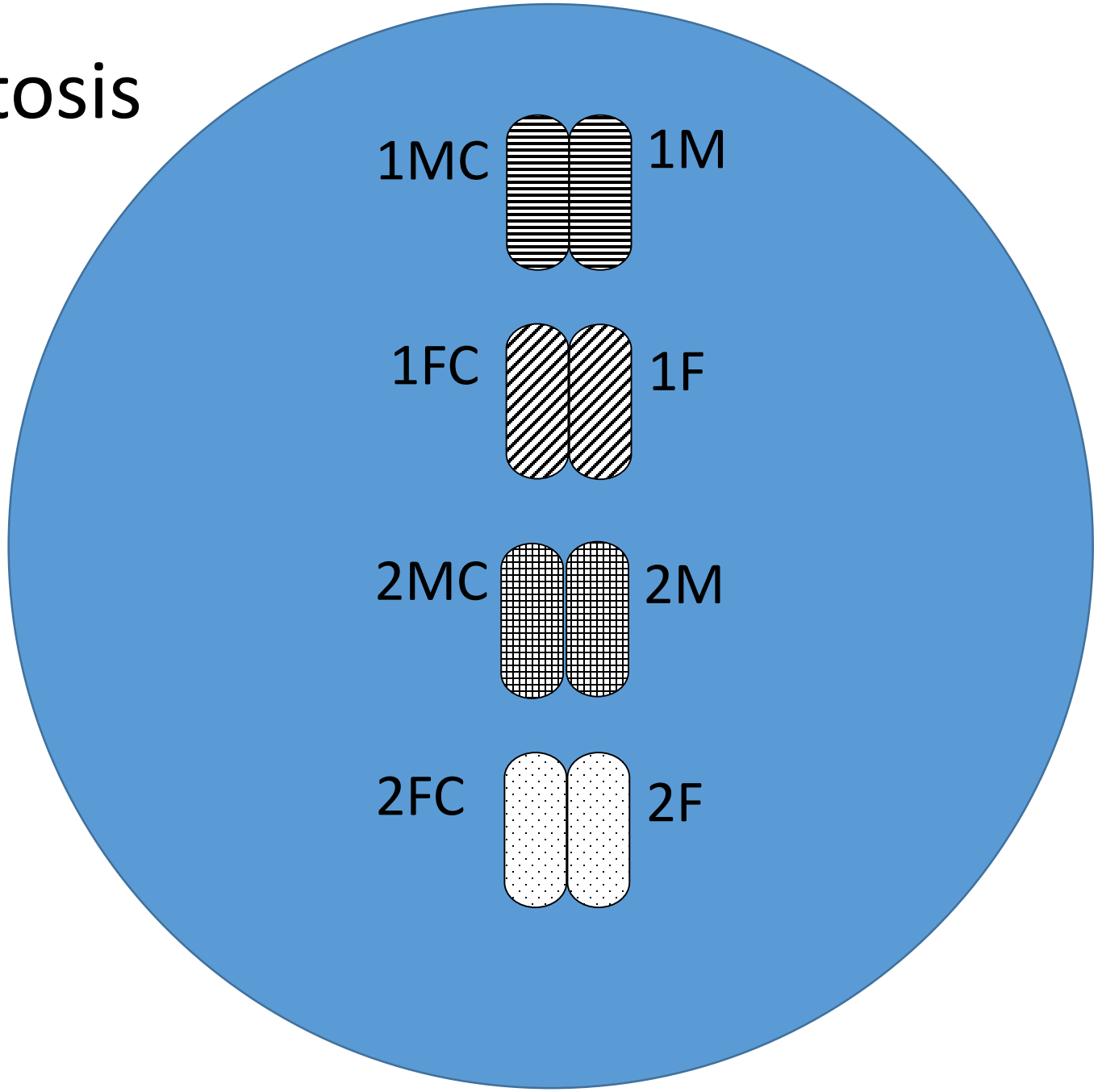
Chromosomes are replicated.

After replication, each chromosome consists of two chromatids.

Each pair of chromatids is considered one chromosome.

Which chromosomes are homologous?

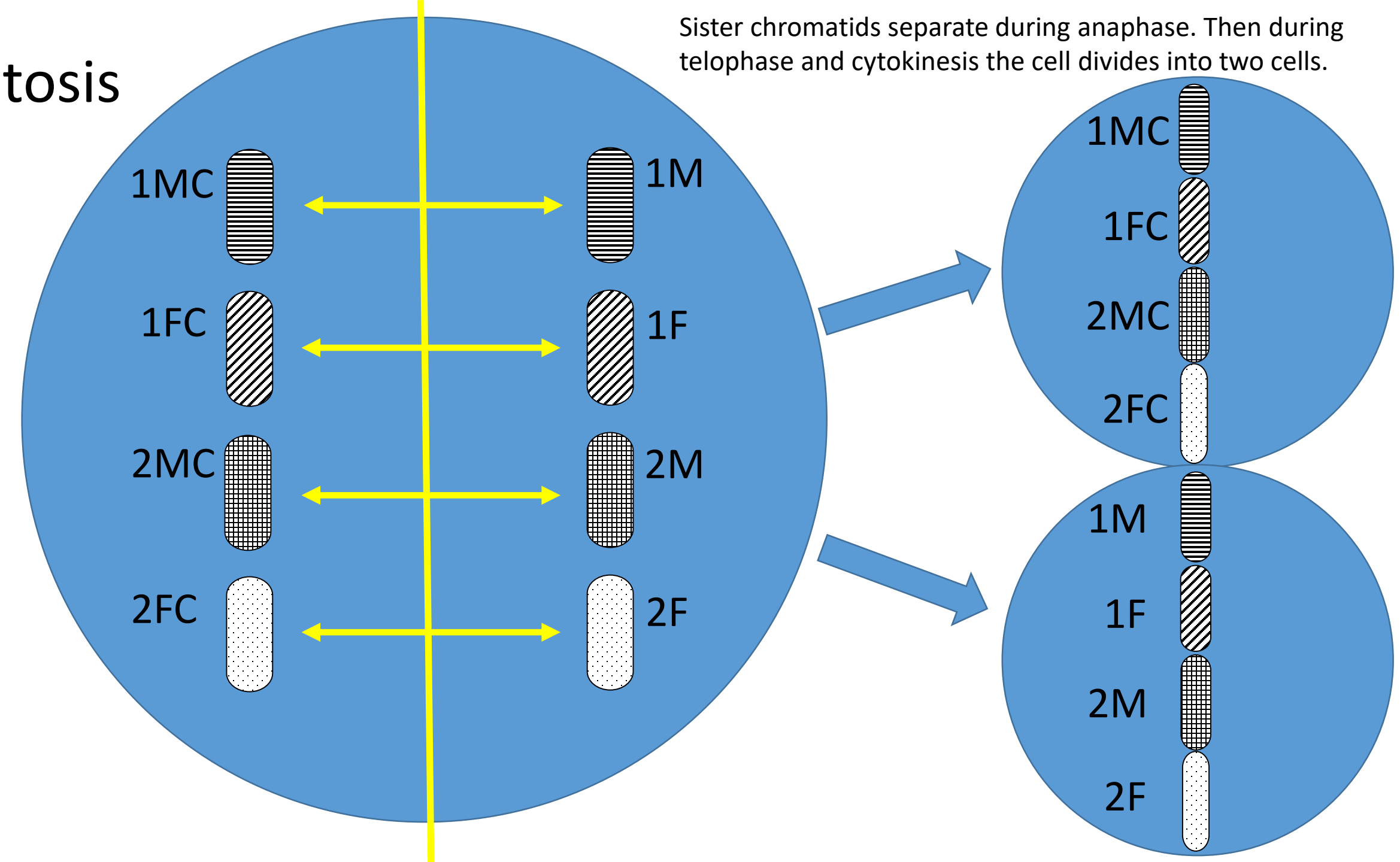
Mitosis



During metaphase, chromosomes (made of two chromatids) line up in the middle of the cell **INDIVIDUALLY.**

Mitosis

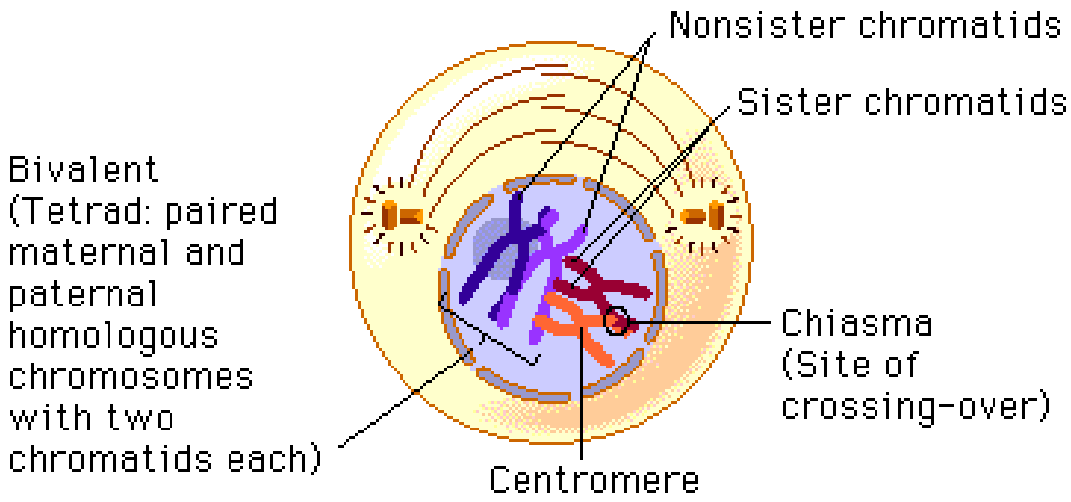
Sister chromatids separate during anaphase. Then during telophase and cytokinesis the cell divides into two cells.



Meiosis I

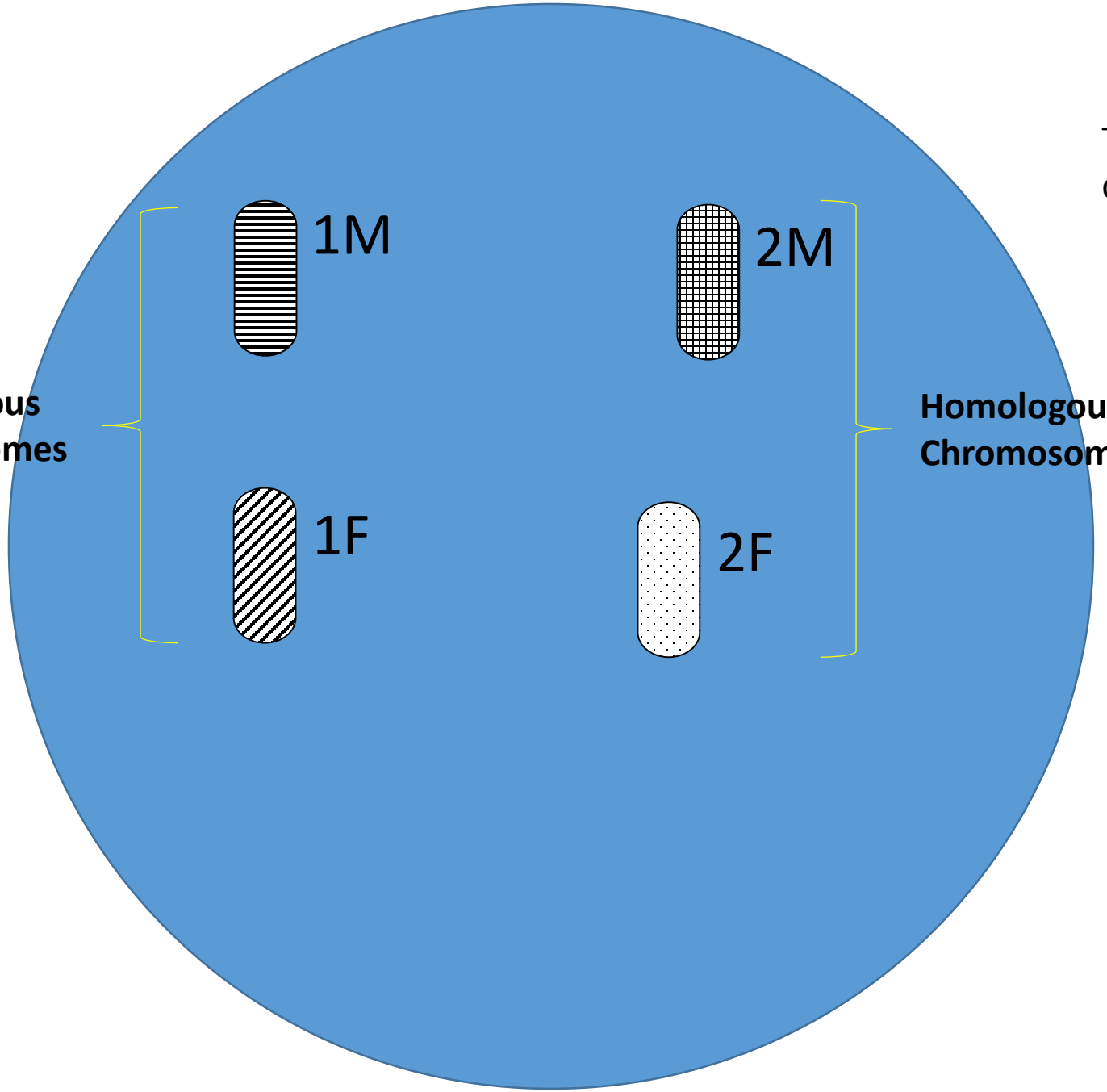
Meiosis I – Prophase I

- In prophase I, however, each chromosome pairs with its corresponding homologous chromosome, in a process called **synapsis**, to form a structure called a **tetrad**.
- There are 4 chromatids in a tetrad.
- **THIS IS KEY TO UNDERSTANDING MEIOSIS!!!**

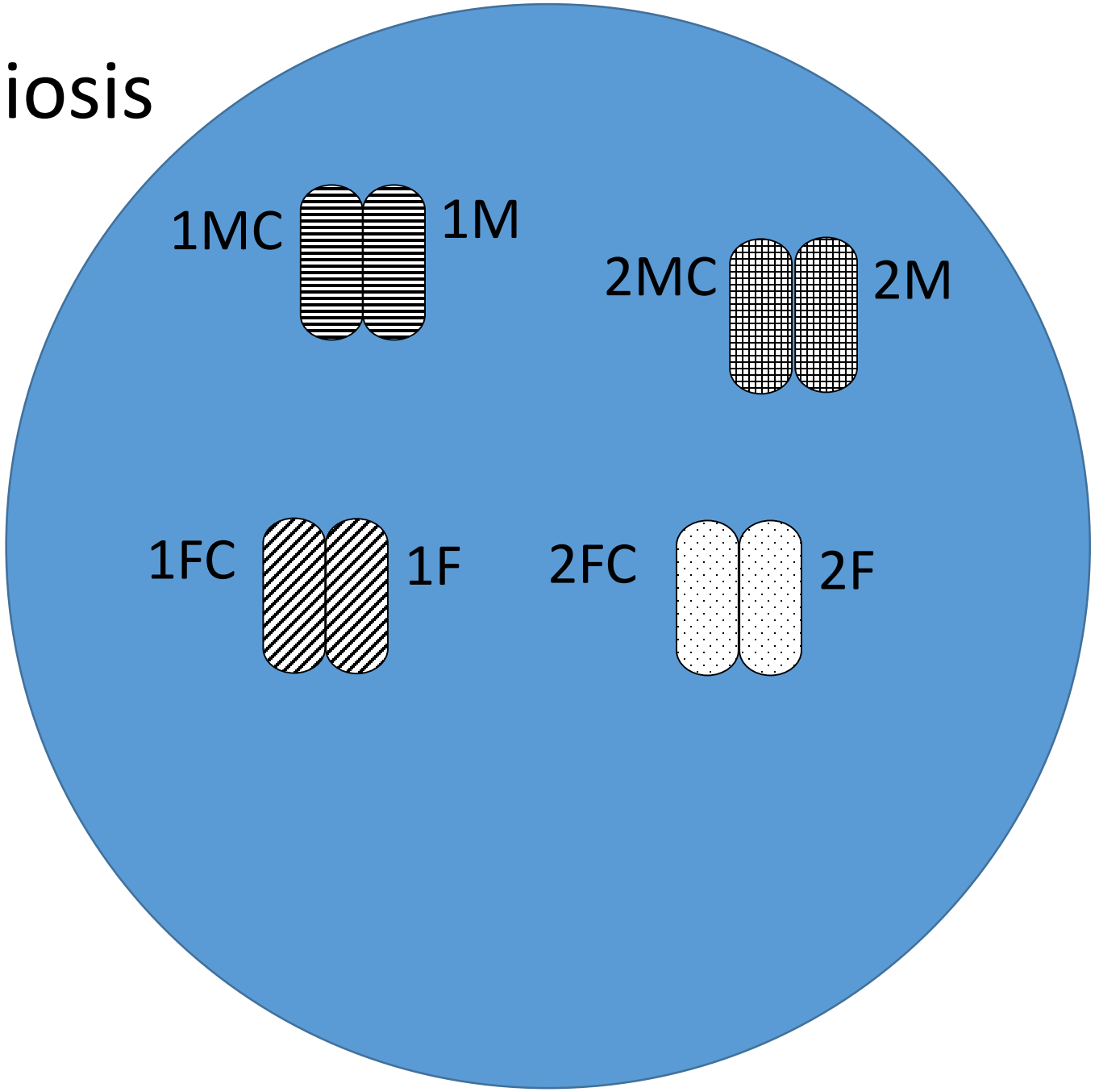


Meiosis

The diploid cell has 4 chromosomes. 2N = 4



Meiosis

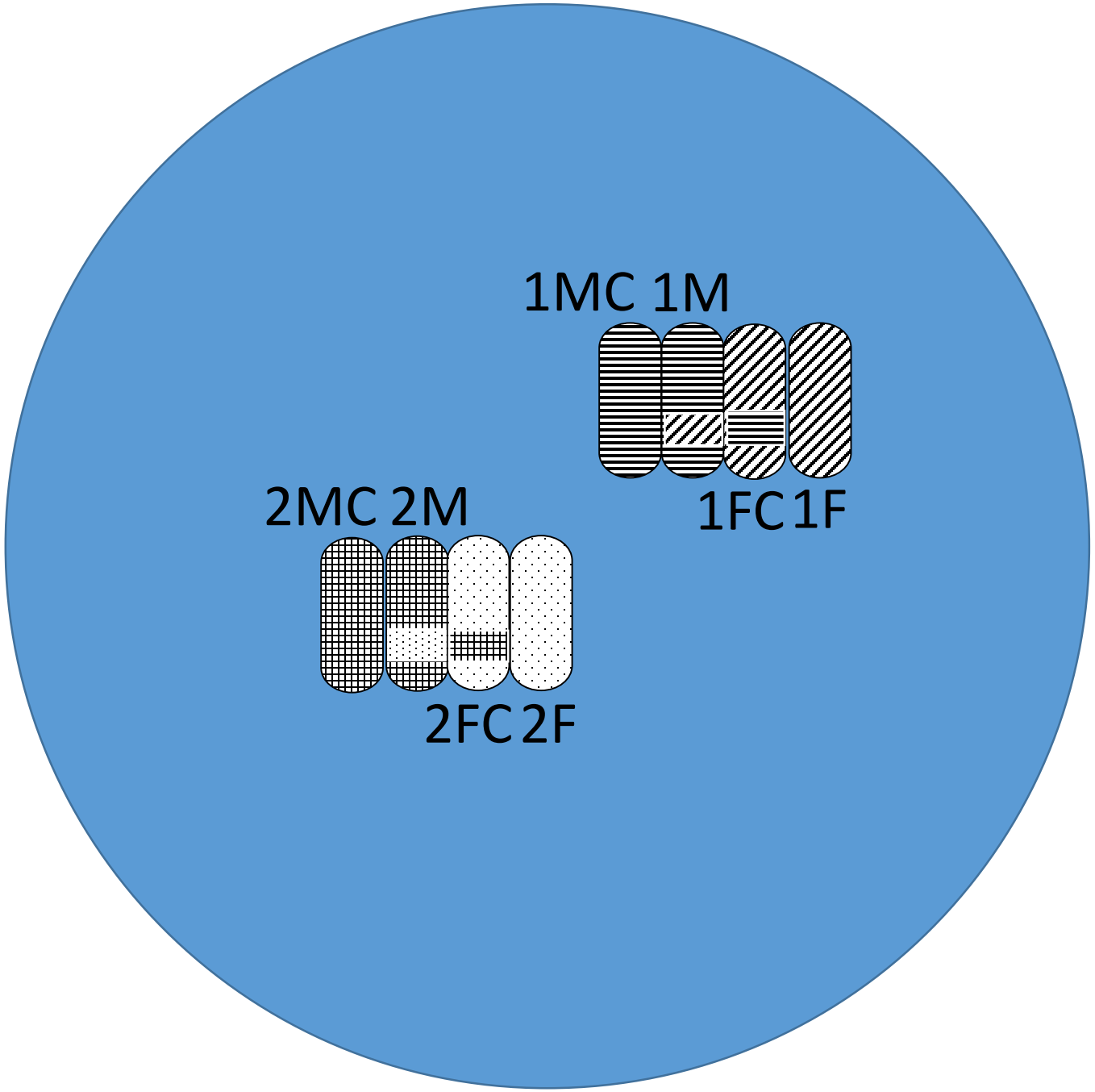


During interphase, chromosomes are replicated.

After replication, each chromosome consists of two chromatids.

Each pair of chromatids is considered one chromosome.

Which chromosomes are homologous?



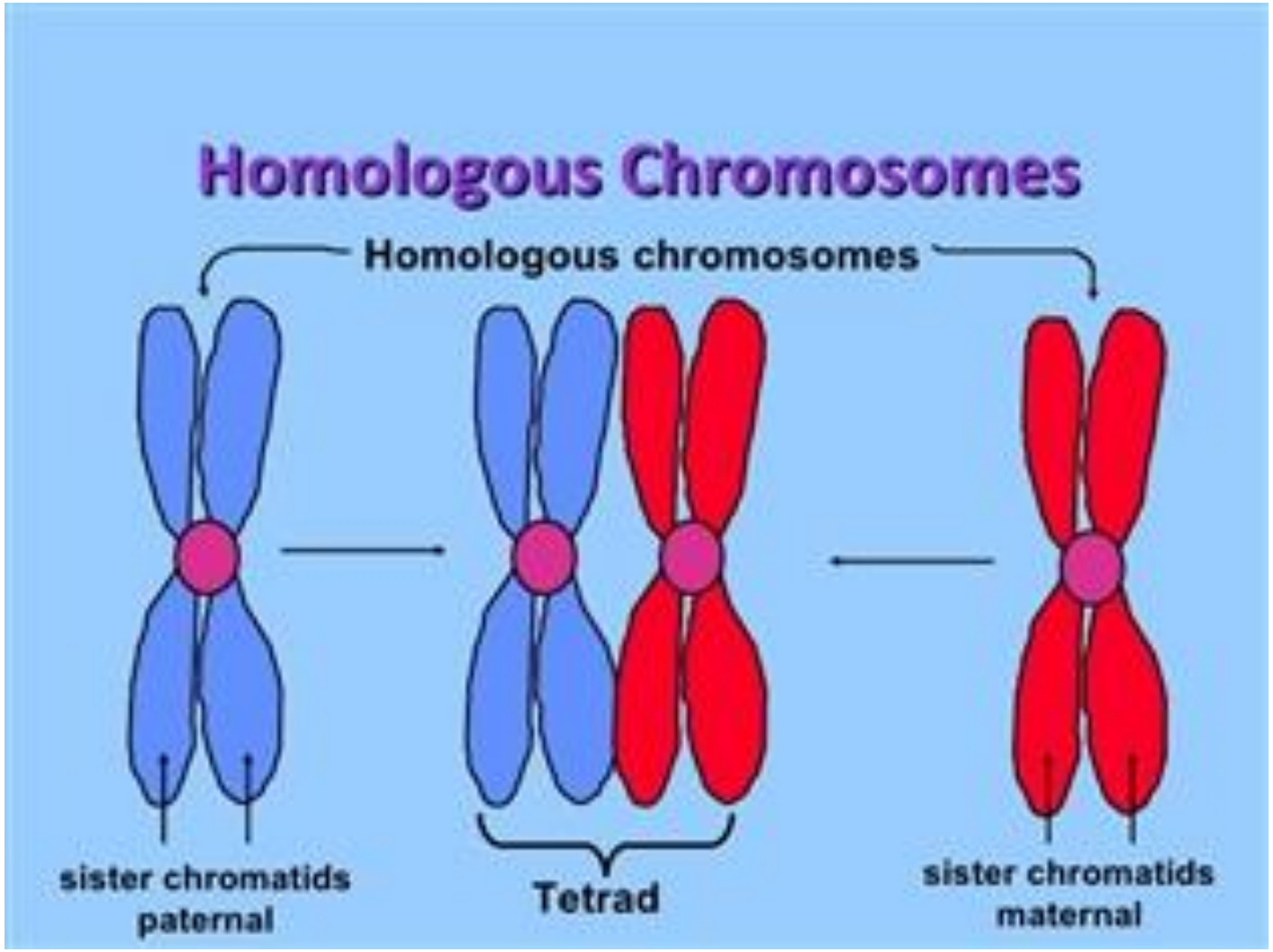
During Prophase 1, homologous chromosomes pair together in a process called synapsis to form tetrads.

Each tetrad consists of 4 chromatids.

Crossing over occurs.

Synapsis and Tetrads

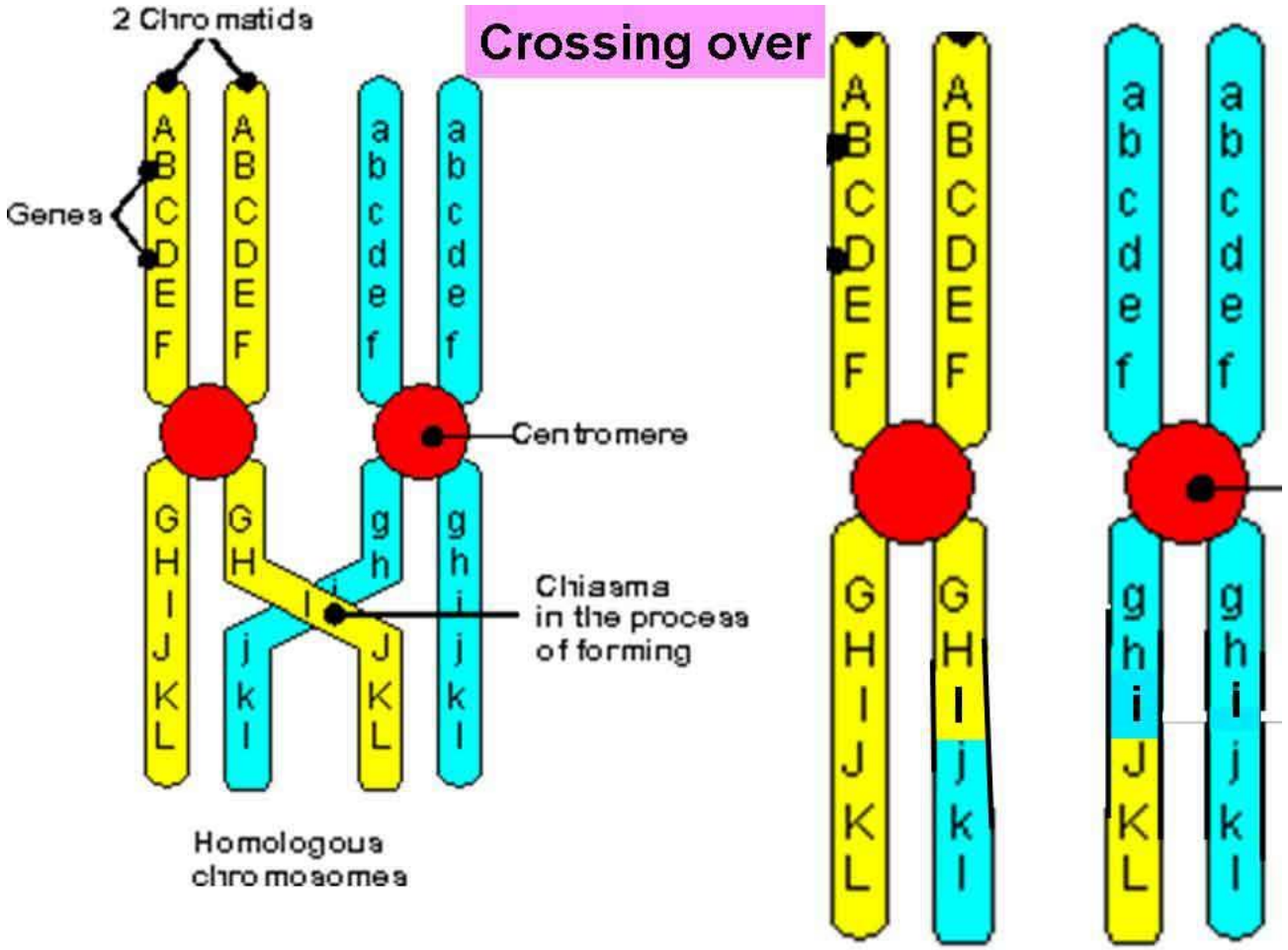
- **Synapsis**: the pairing of homologous chromosomes.
- **Tetrad**: a pair of homologous chromosomes, made of 4 chromatids.



Crossing Over

- As homologous chromosomes pair up and from tetrads, they randomly exchange portions of their chromatids in a process called **crossing-over**.
- Crossing-over results in the exchange of alleles between homologous chromosomes and produces new combinations of alleles.
- This increasing genetic variation.

Crossing Over



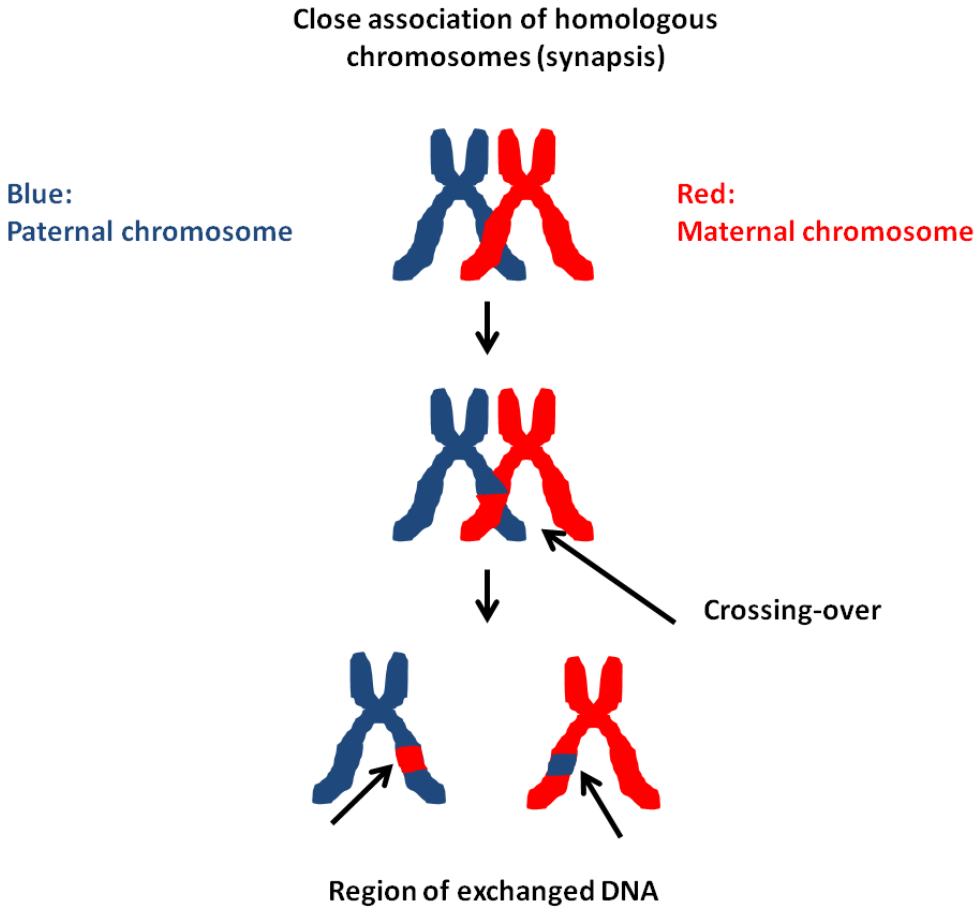
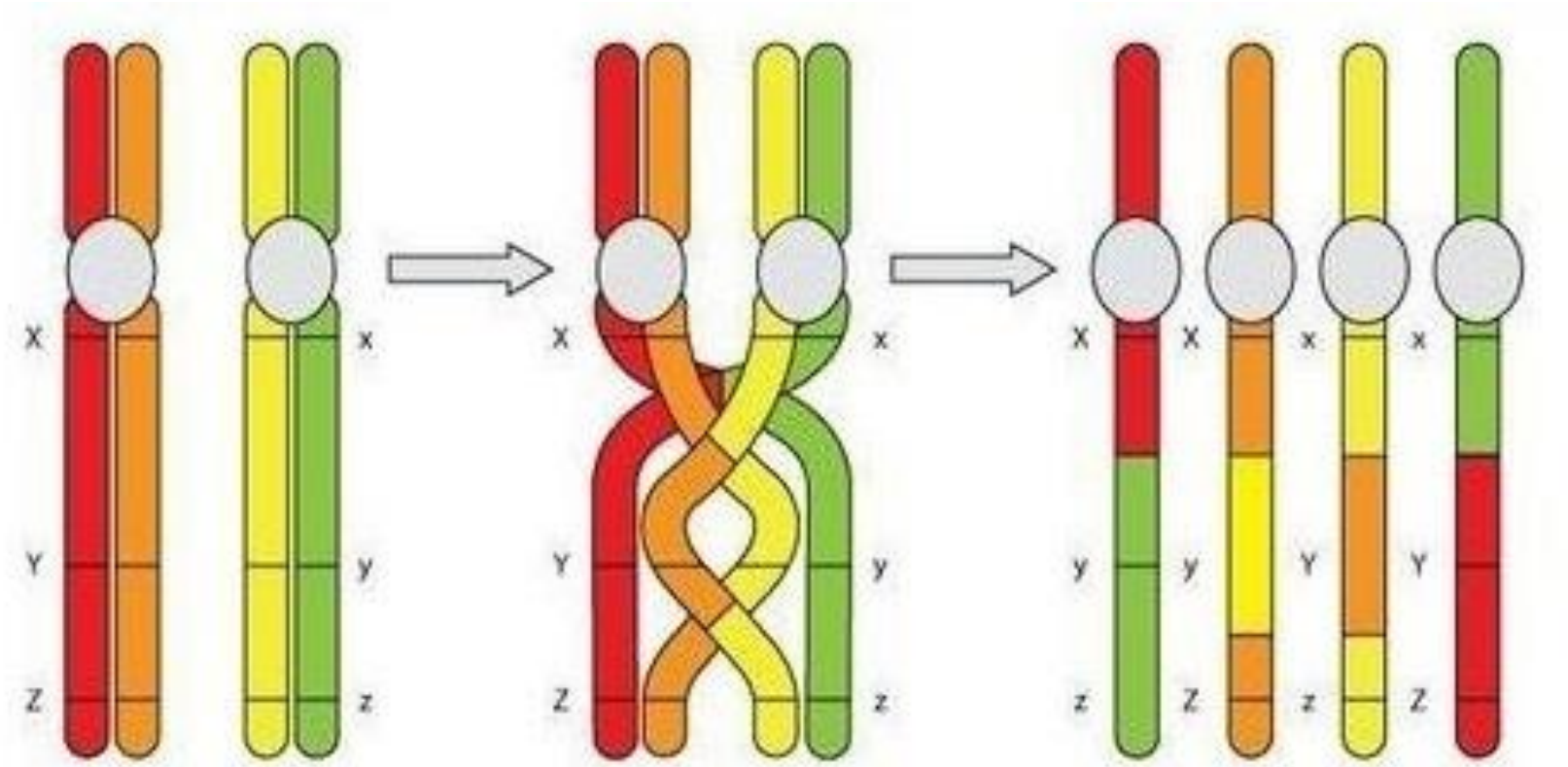


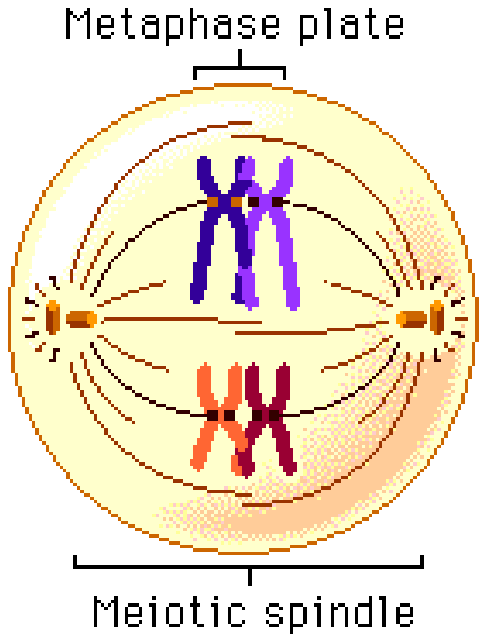
Figure 8.1. Meiotic Prophase
During synapsis, homologous chromosomes from each parent align in close association. The regions proximal to each other exchange, so that when the two homologous chromosomes separate, they contain portions of DNA from the other parent.

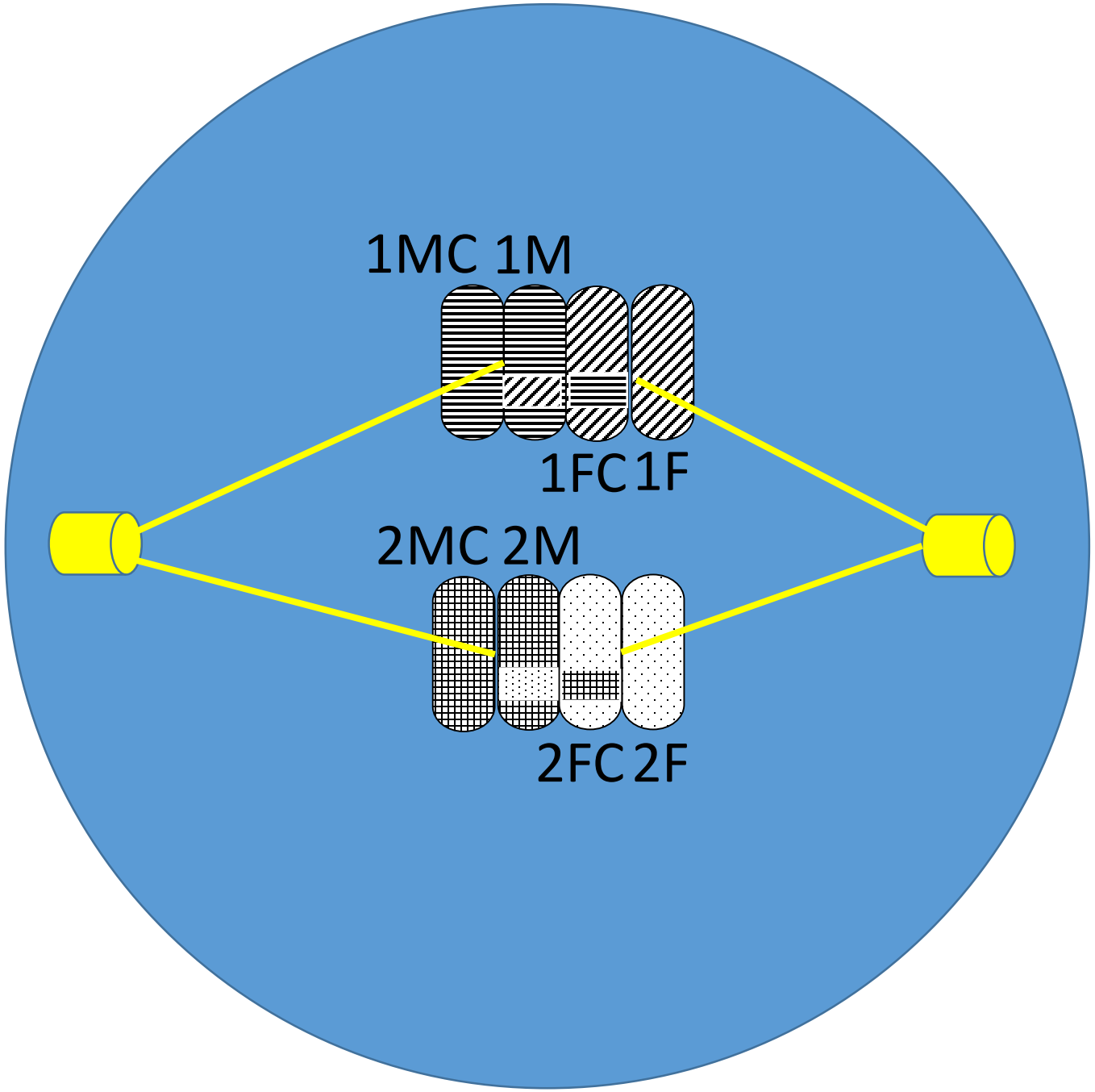
Crossing Over



Meiosis I – Metaphase I

- Chromosomes (each made of 2 chromatids) line up in the middle of the cell.
- Spindle fibers attach to the chromosomes.



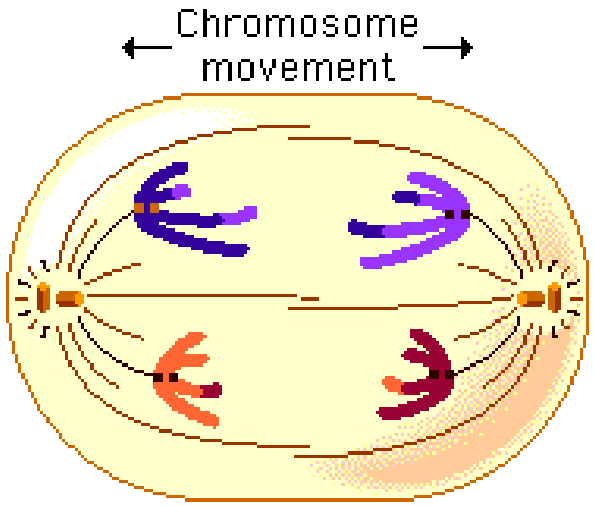


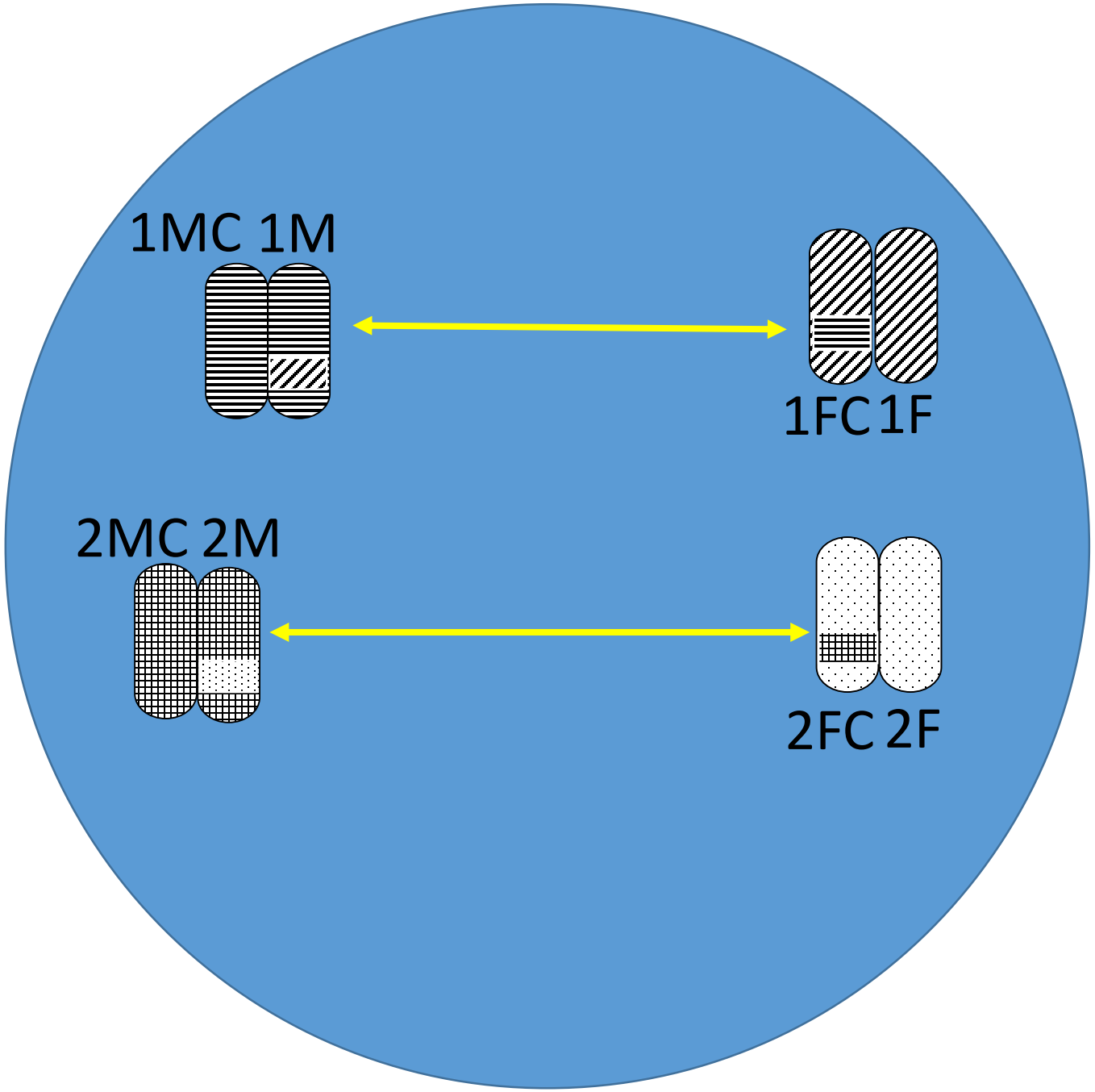
During metaphase 1, homologous chromosomes line up in the middle of the cell.

Spindle fibers attach.

Meiosis I – Anaphase I

- The spindle fibers pull each of the homologous chromosomes (each still composed of 2 chromatids) toward opposite ends of the cell.



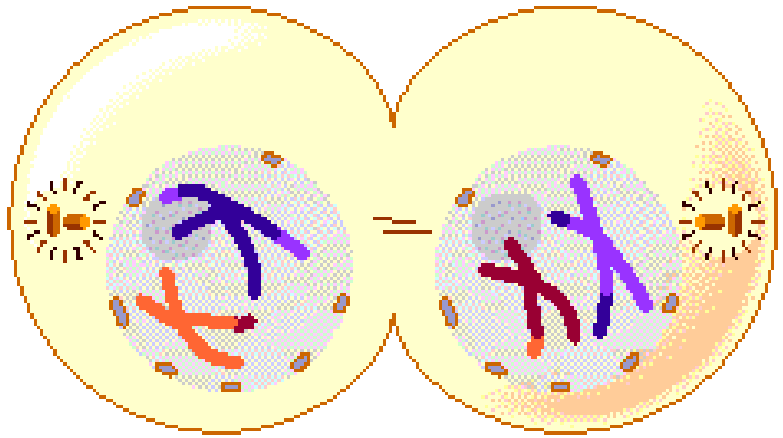


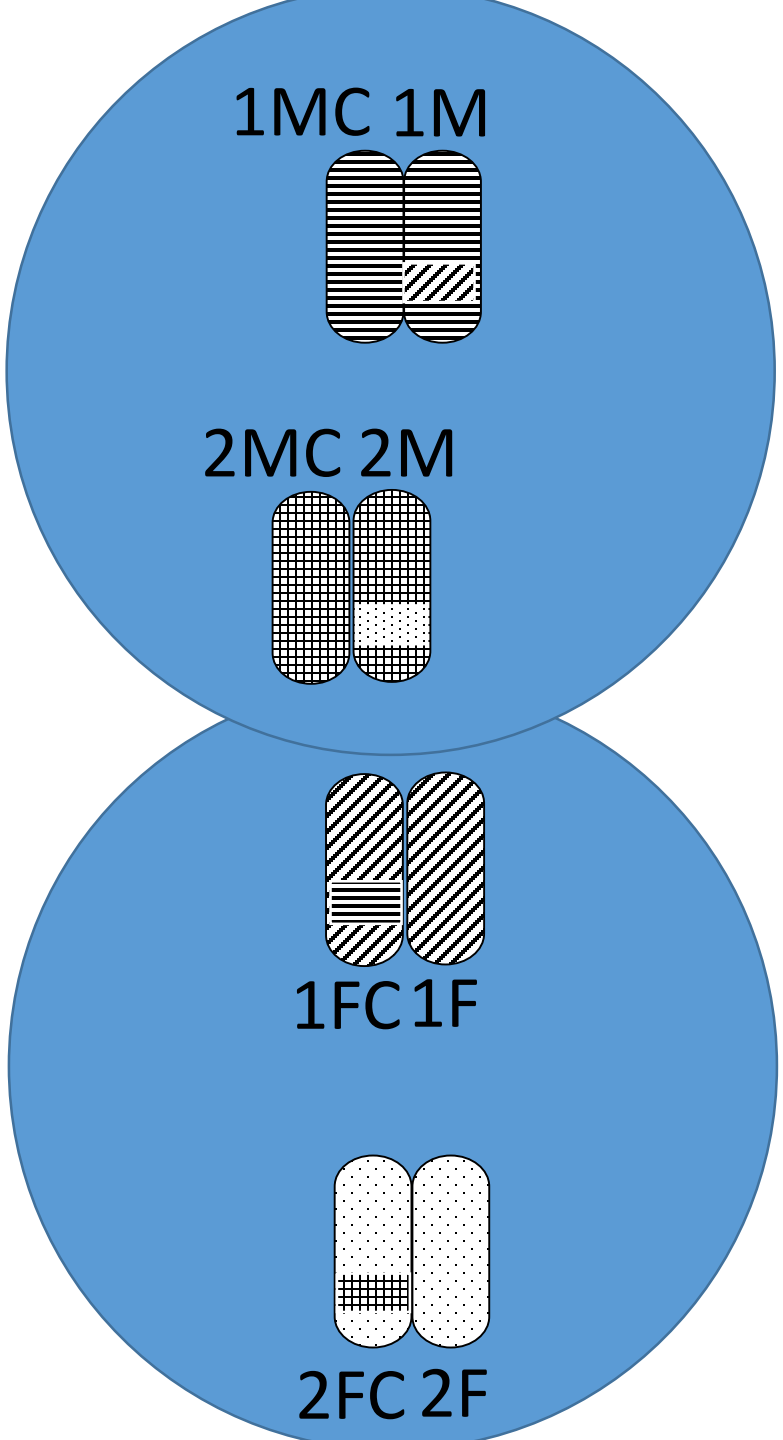
During anaphase I, homologous chromosomes are separated.

Each chromosome still consists of two chromatids.

Meiosis I – Telophase I and Cytokinesis

- Nuclear membranes form.
- The cell separates into two cells.





During telophase I and cytokinesis, the cell divides into two cells.

Each cell contains two chromosomes, each made of two chromatids.

After Meiosis I

- Each new cell has 4 chromatids, as it would after mitosis, but there are differences.
- Because each pair of homologous chromosomes was separated, neither of the daughter cells has the two complete sets of chromosomes that it would have in a diploid cell.
- Those two sets have been shuffled and sorted almost like a deck of cards.
- The two cells produced by meiosis I have sets of chromosomes and alleles that are different from each other and from the diploid cell that entered meiosis I.

Mitosis vs. Meiosis I

- How are mitosis and meiosis I different?
- Mitosis splits chromatids
- Meiosis I splits homologous chromosomes.

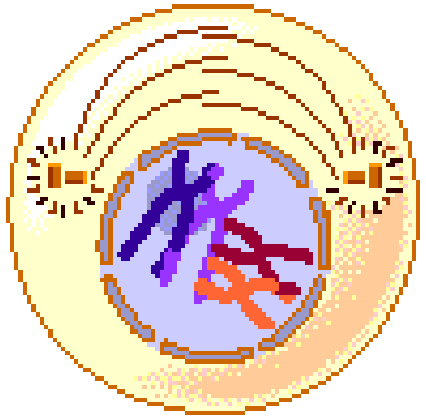
Meiosis II

Meiosis II – Prophase II

- Meiosis I results in two haploid (N) daughter cells, each with half the number of chromosomes as the original cell.
- But… each chromosome is still composed of two chromatids.
- The two cells produced by meiosis I now enter a second meiotic division which will separate the chromatids.
- Unlike the first division, neither cell goes through a round of chromosome replication before entering meiosis II.

Meiosis II – Prophase II

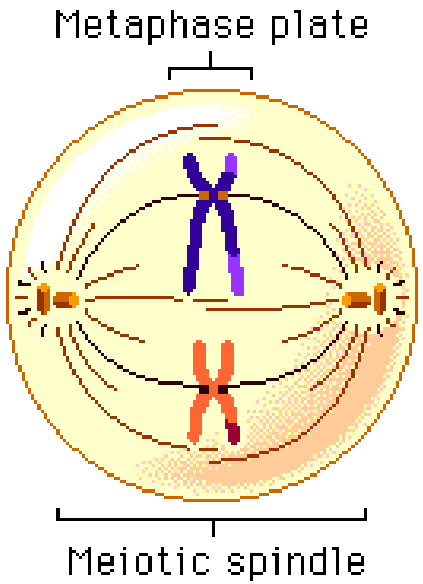
Prophase I

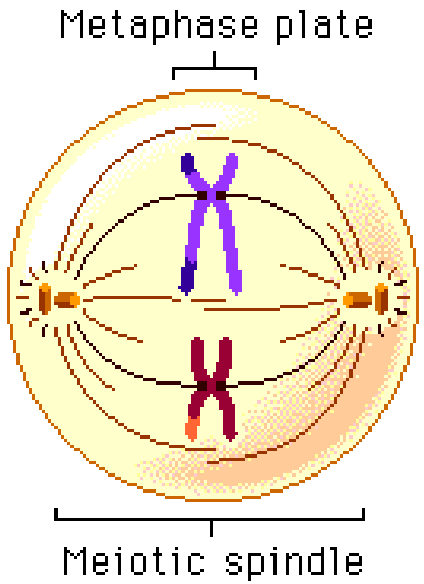


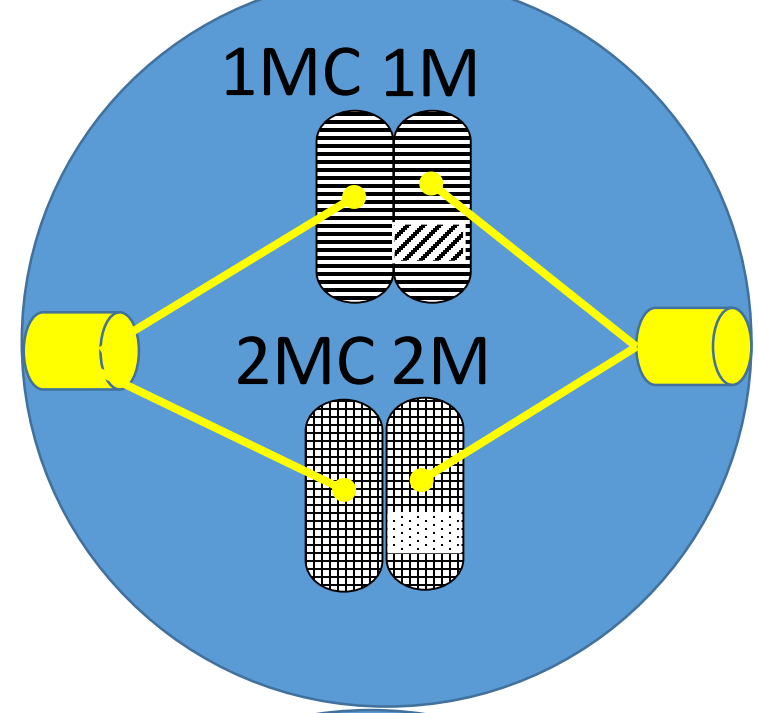
Prophase II

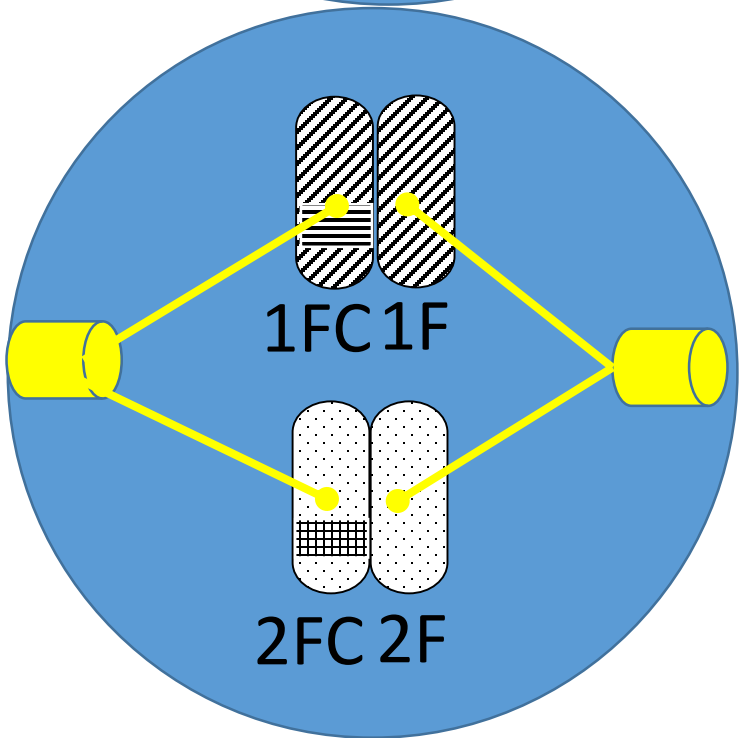
Meiosis II – Metaphase II

- The chromosomes line up in a similar way to the metaphase stage of mitosis, in the middle.





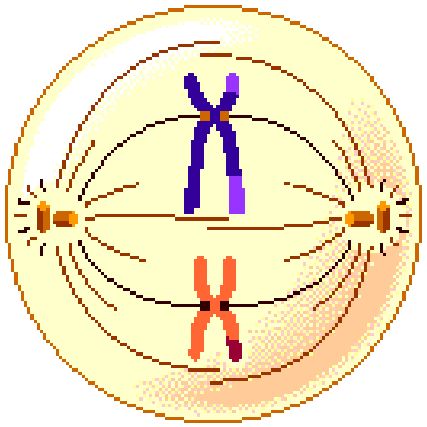


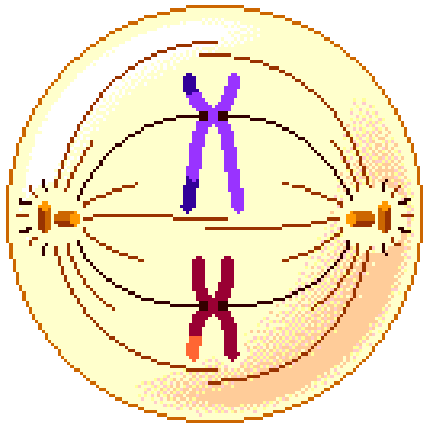


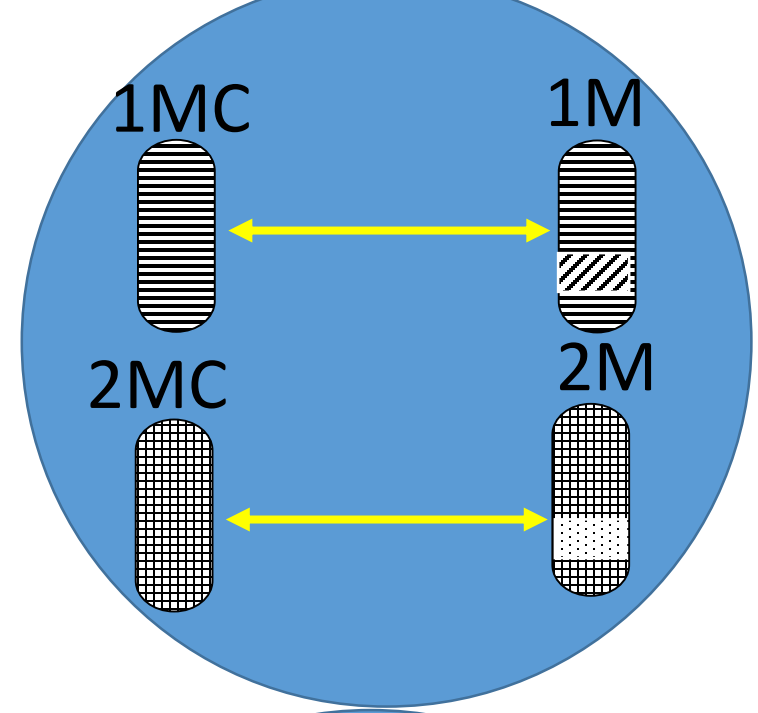
During metaphase II the homologous chromosomes line up in the middle of the cell.

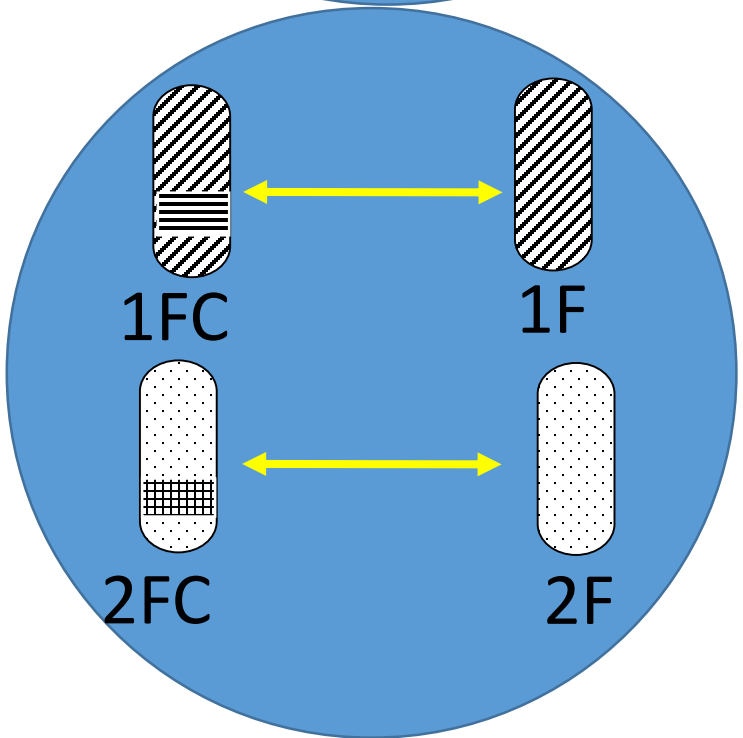
Meiosis II – Anaphase II

- The chromatids that compose each chromosome separate and move toward opposite ends of the cell.





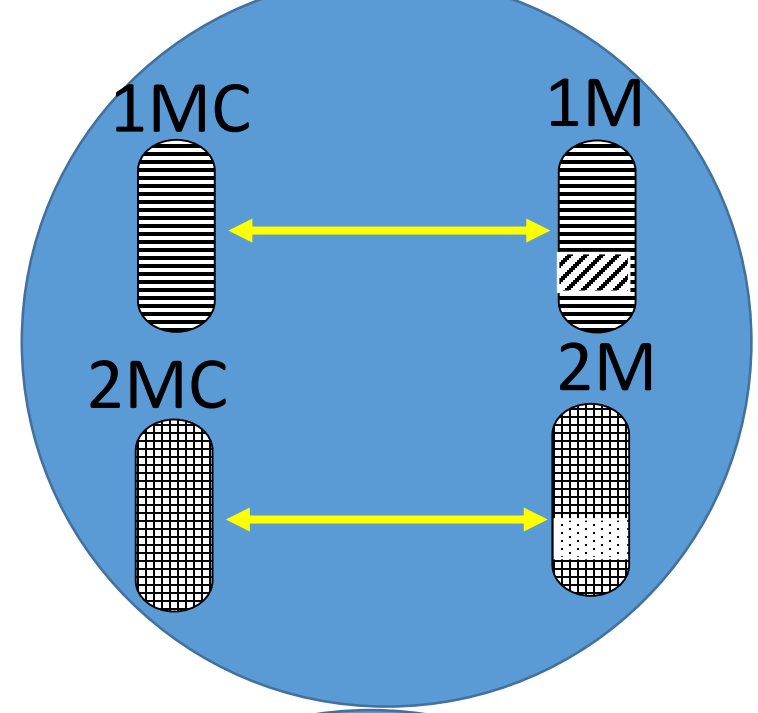


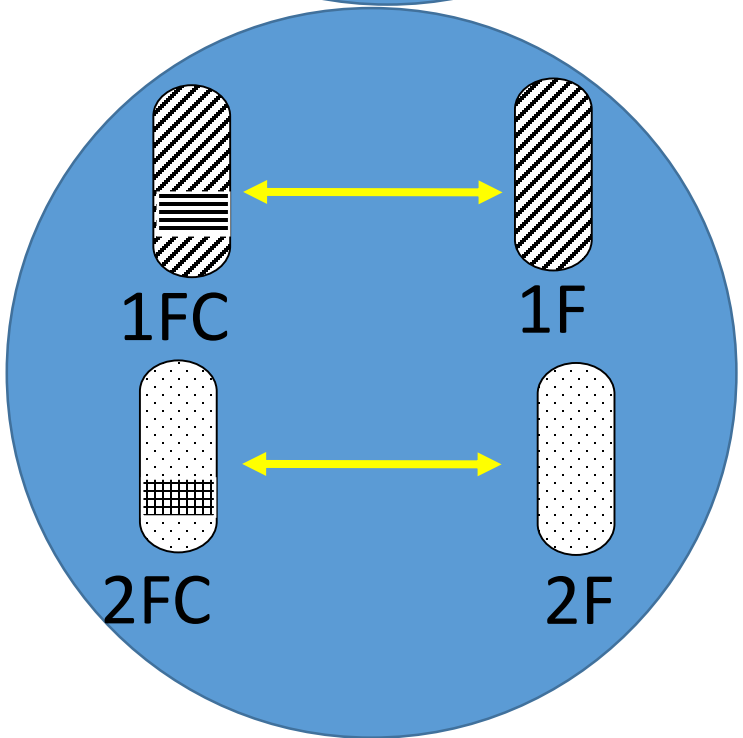


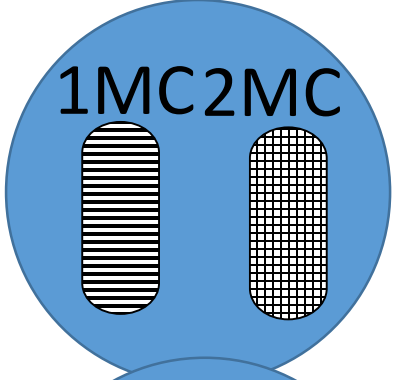
During anaphase II the chromatids that make up each homologous chromosome separate.

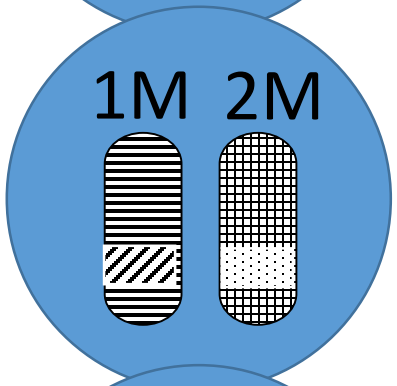
Meiosis II – Telophase II and Cytokinesis

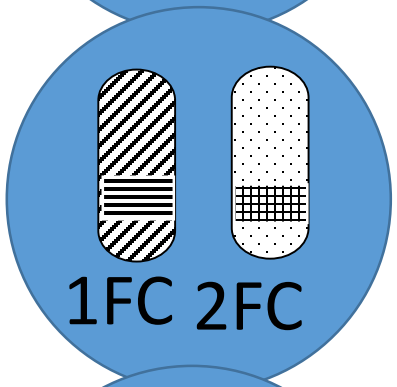
- Meiosis II results in four haploid (N) daughter cells.

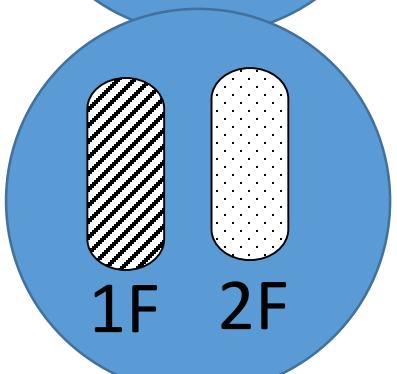










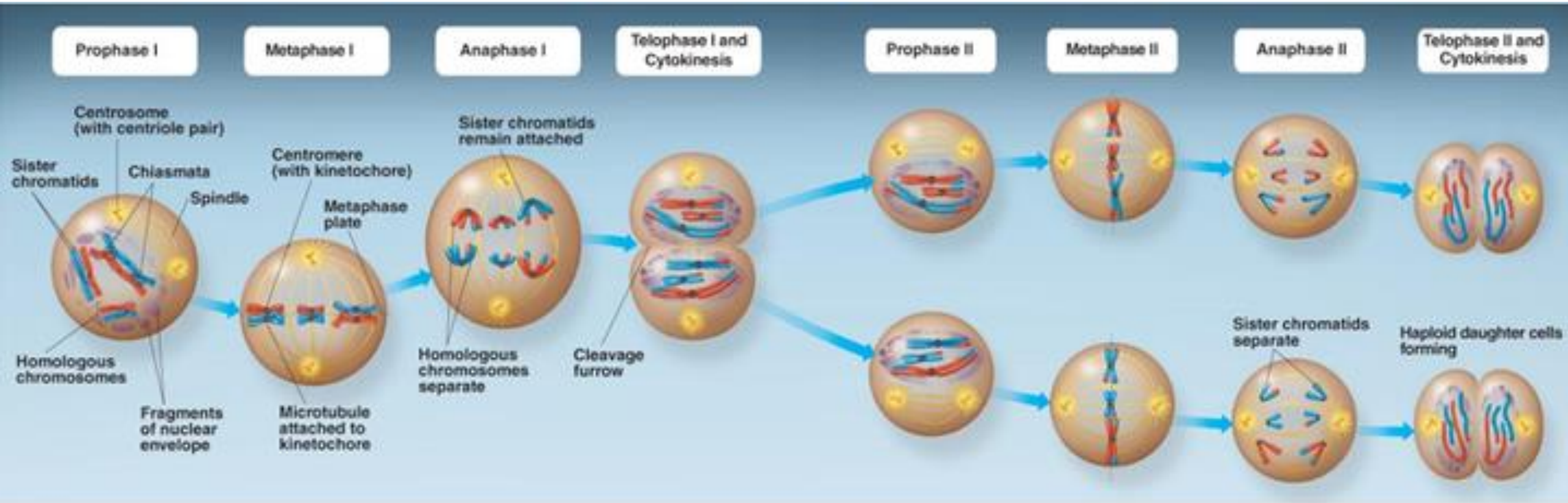


During telophase II and cytokinesis four haploid gametes, with half the number of the original chromosomes, are formed that are genetically different than the diploid cell that entered meiosis and genetically different from each other.

Crossing over results in some genes received from the female parent being transferred to the chromosome received from the male parent and vice versa.

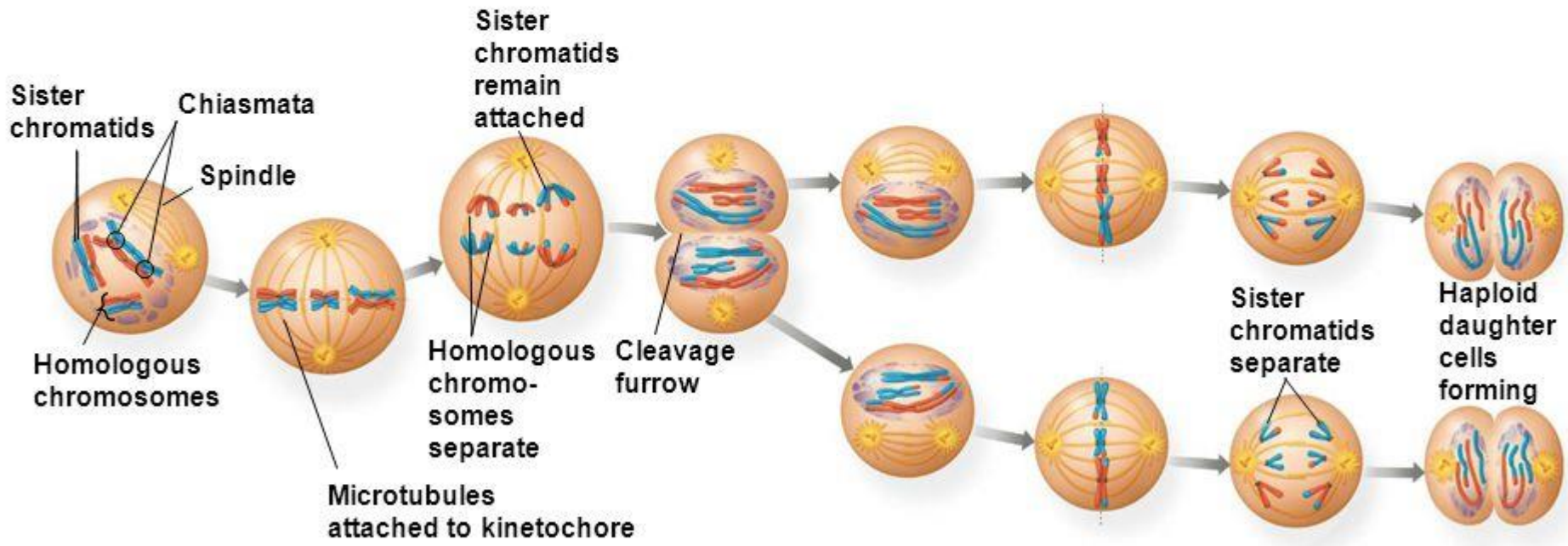
Meiosis I vs Meiosis II?

- What is the difference between meiosis I and meiosis II?
- Meiosis I separates homologous chromosomes.
- Meiosis II separates chromatids.



Overview of Meiosis

MEIOSIS I: Separates homologous chromosomes				MEIOSIS II: Separates sister chromatids			
Prophase I	Metaphase I	Anaphase I	Telophase I and Cytokinesis	Prophase II	Metaphase II	Anaphase II	Telophase II and Cytokinesis

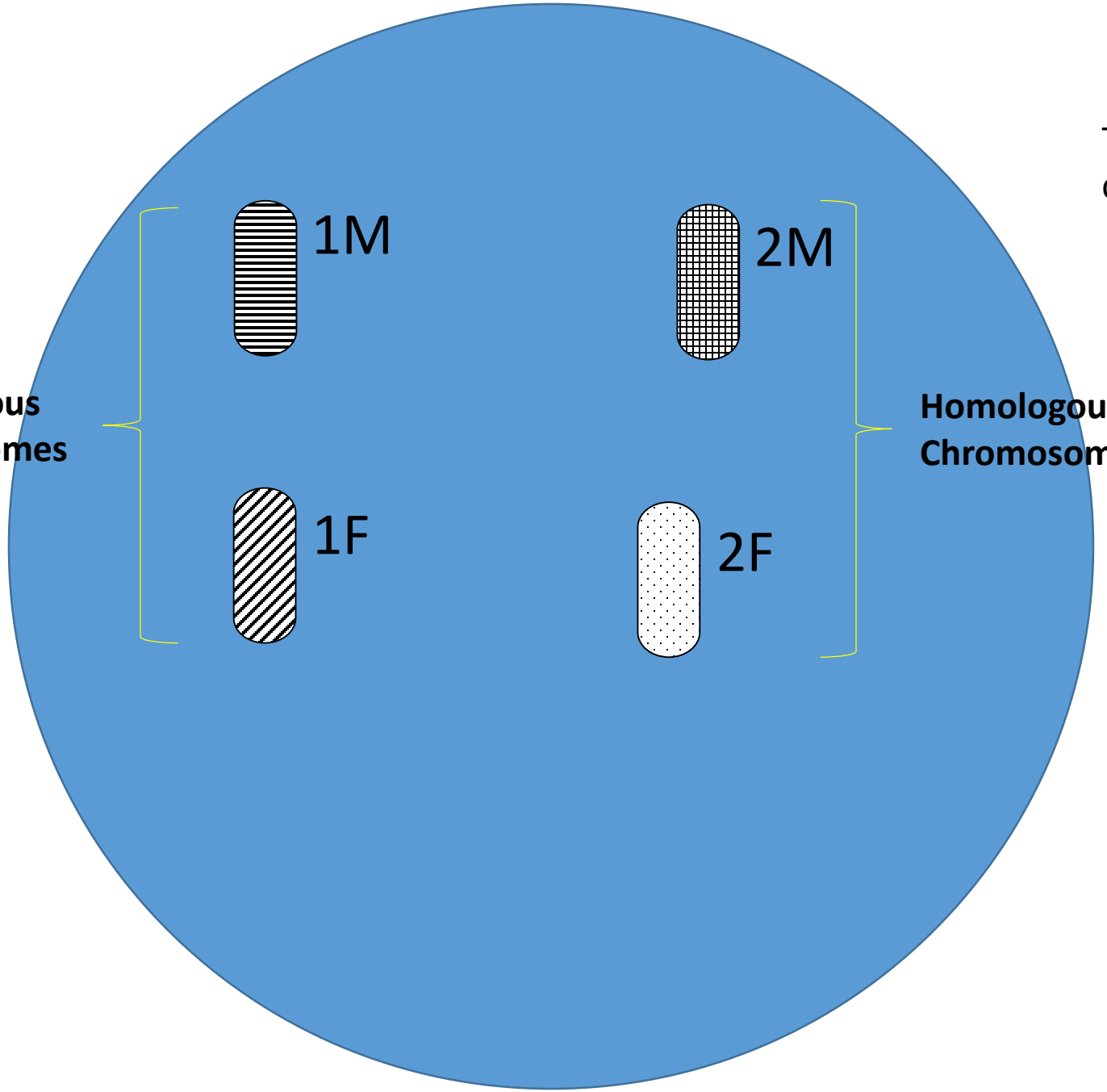


Meiosis I = **"reductional division"** as chromosome number goes from **diploid to haploid**

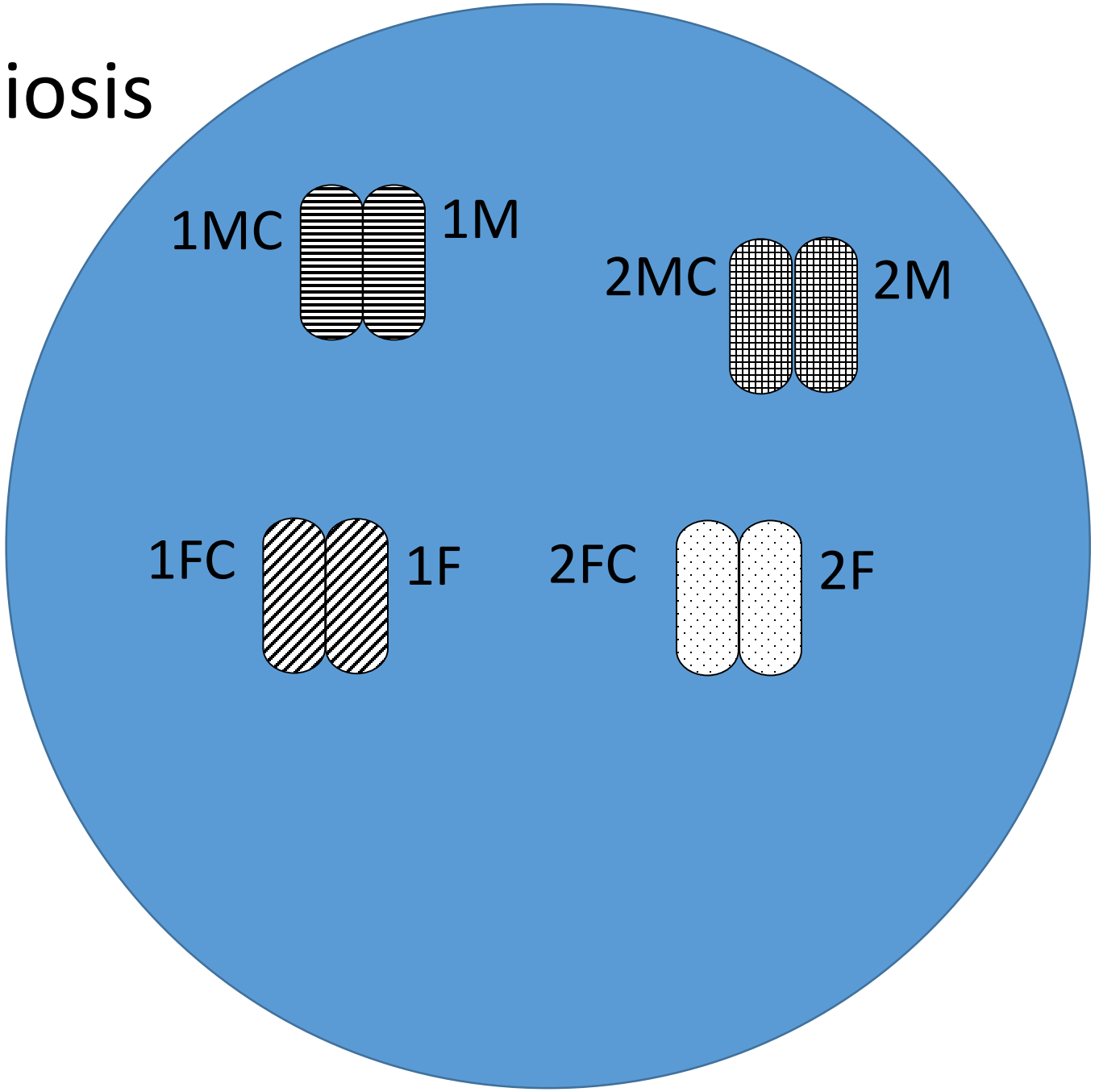
Meiosis II = **"equational division"** as sister chromatids separate (start double-stranded, **centromeres break and become single-stranded)**

Meiosis

The diploid cell has 4 chromosomes. 2N = 4



Meiosis

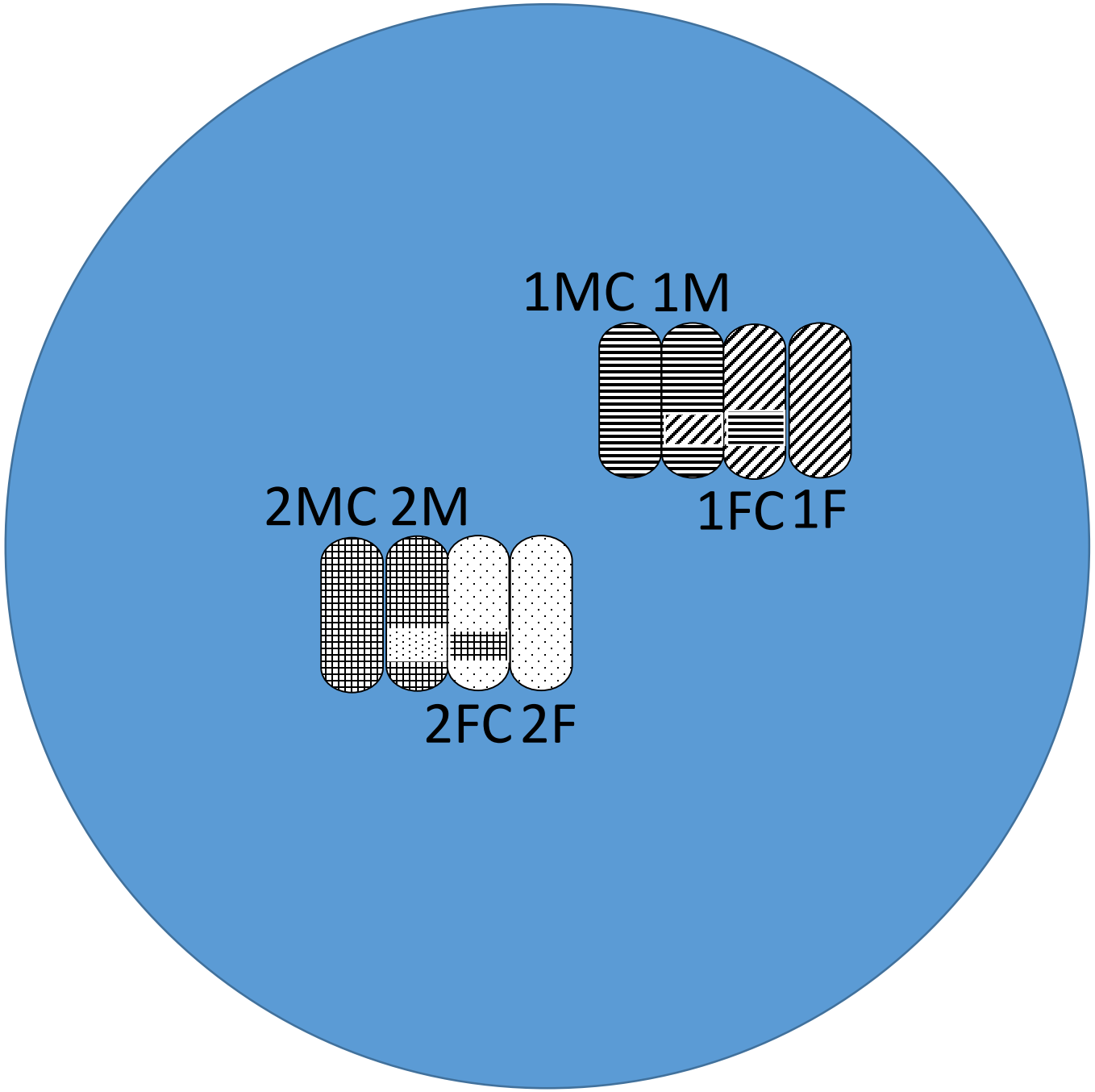


During interphase, chromosomes are replicated.

After replication, each chromosome consists of two chromatids.

Each pair of chromatids is considered one chromosome.

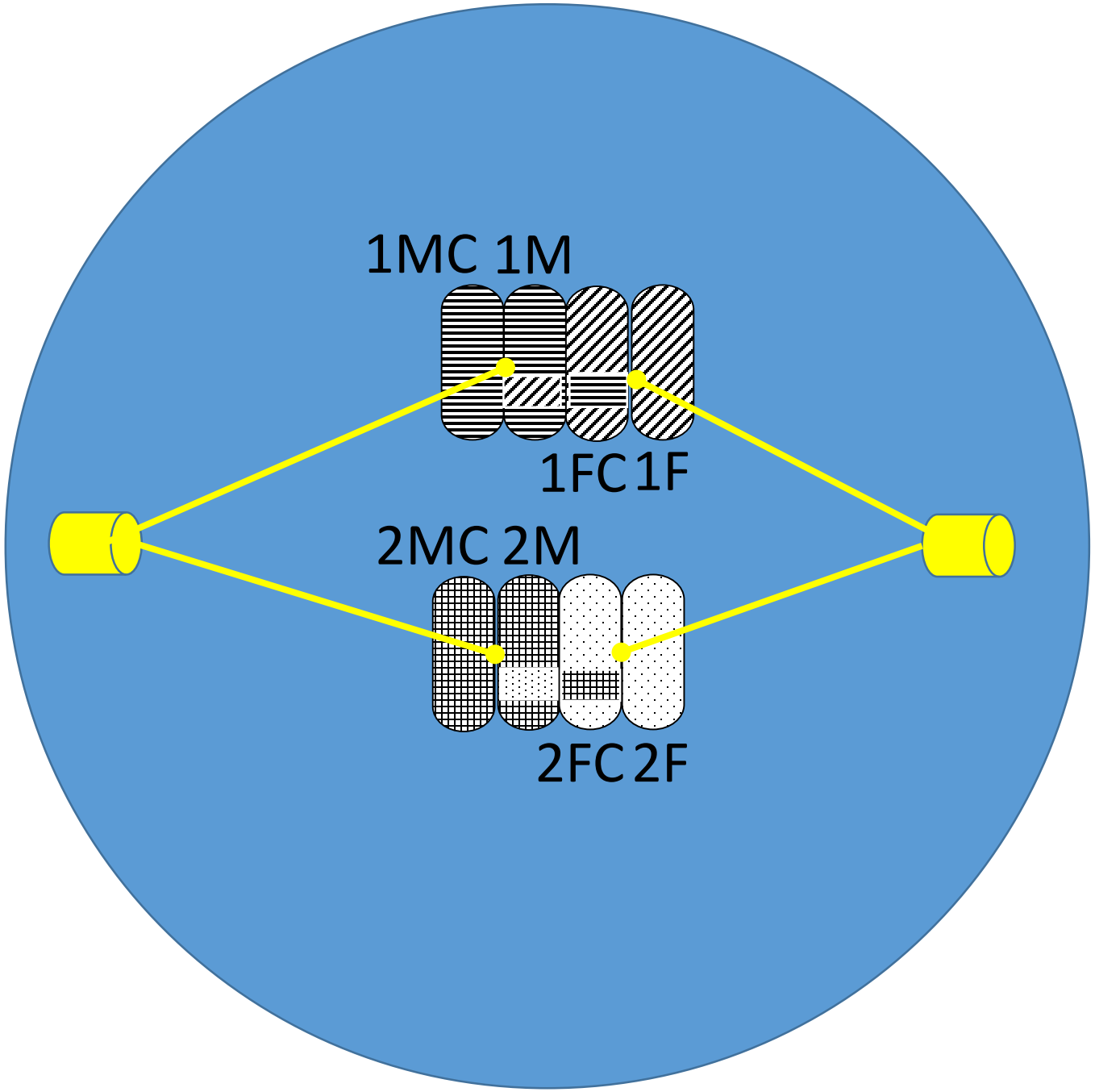
Which chromosomes are homologous?



During Prophase 1, homologous chromosomes pair together in a process called synapsis to form tetrads.

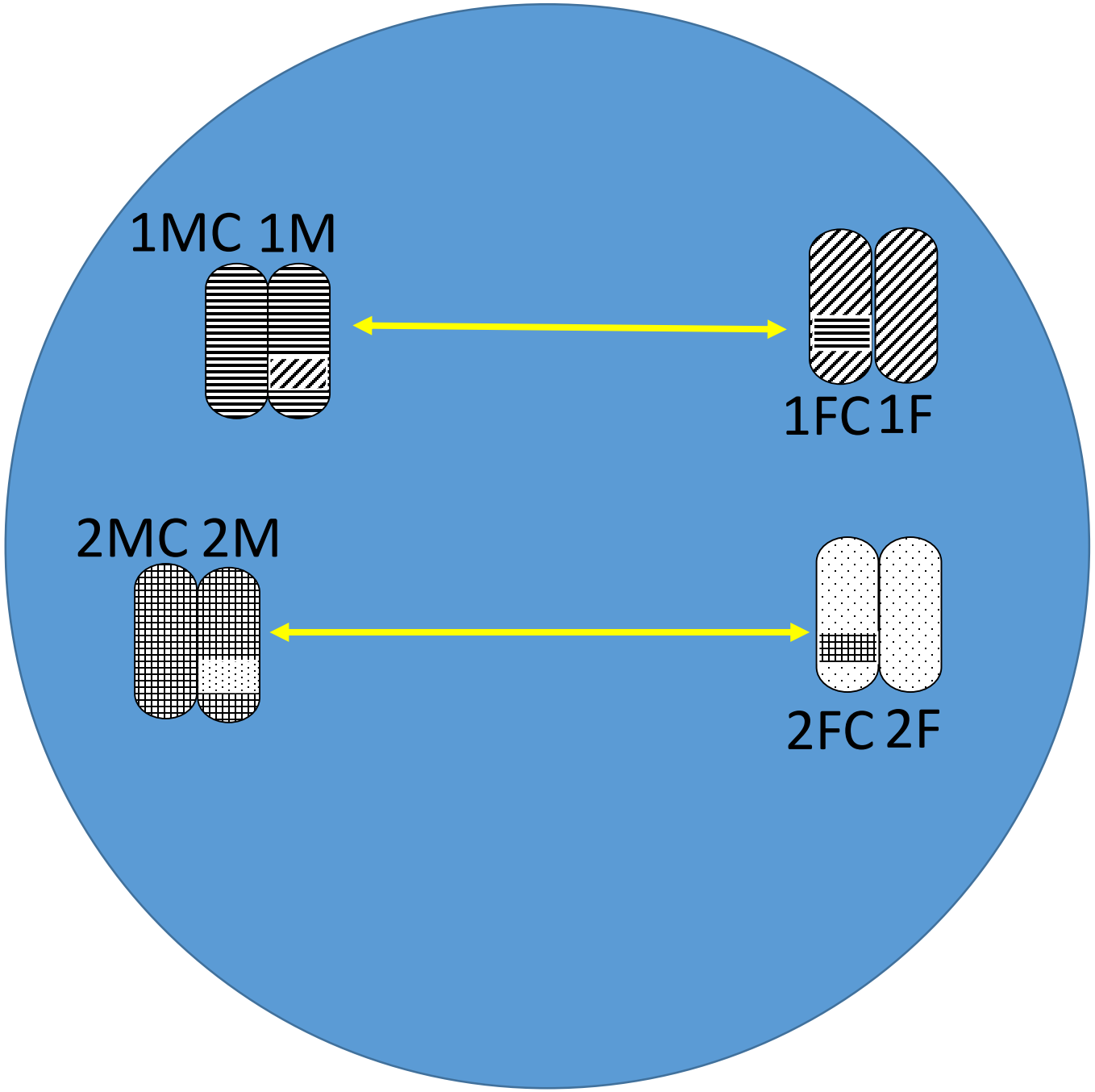
Each tetrad consists of 4 chromatids.

Crossing over occurs.



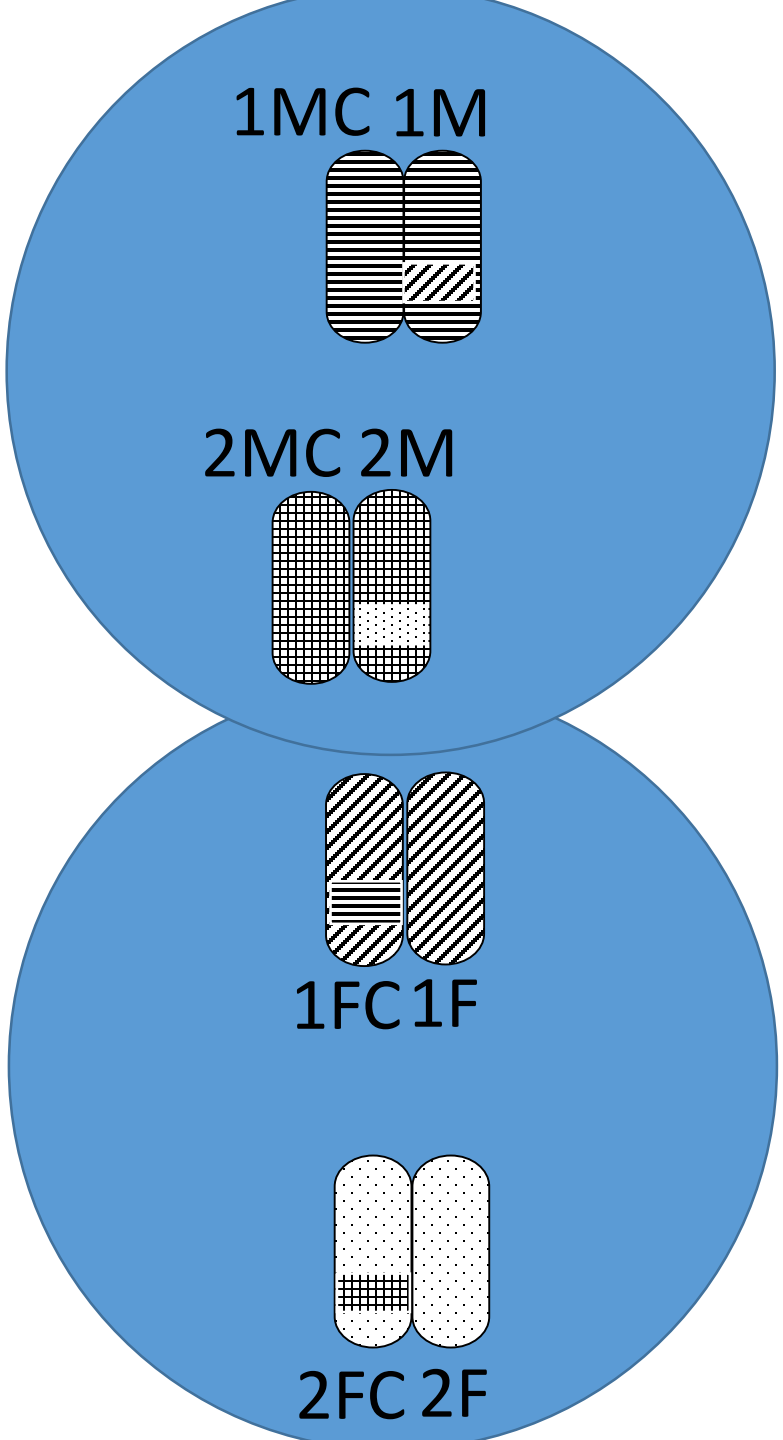
During metaphase 1, homologous chromosomes line up in the middle of the cell.

Spindle fibers attach.



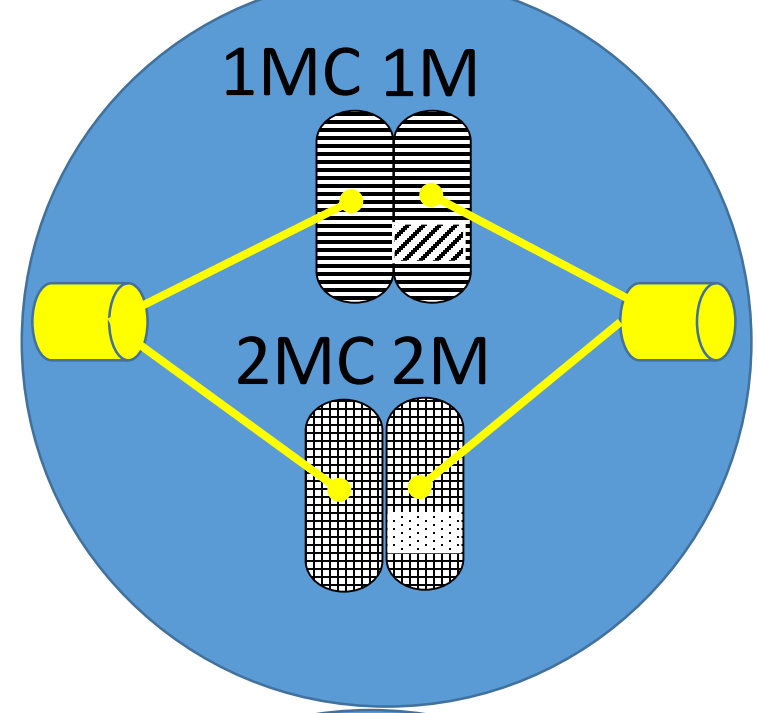
During anaphase I, homologous chromosomes are separated.

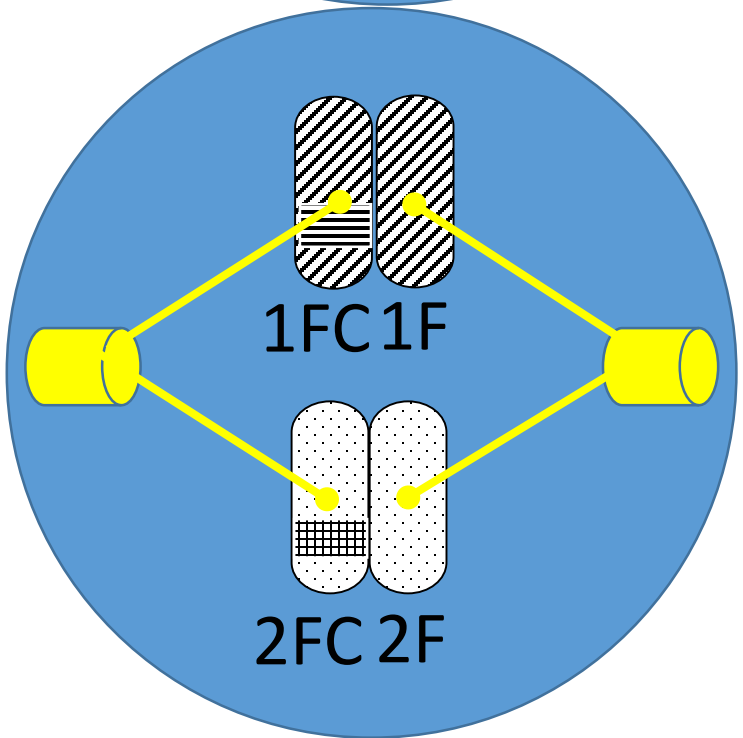
Each chromosome still consists of two chromatids.



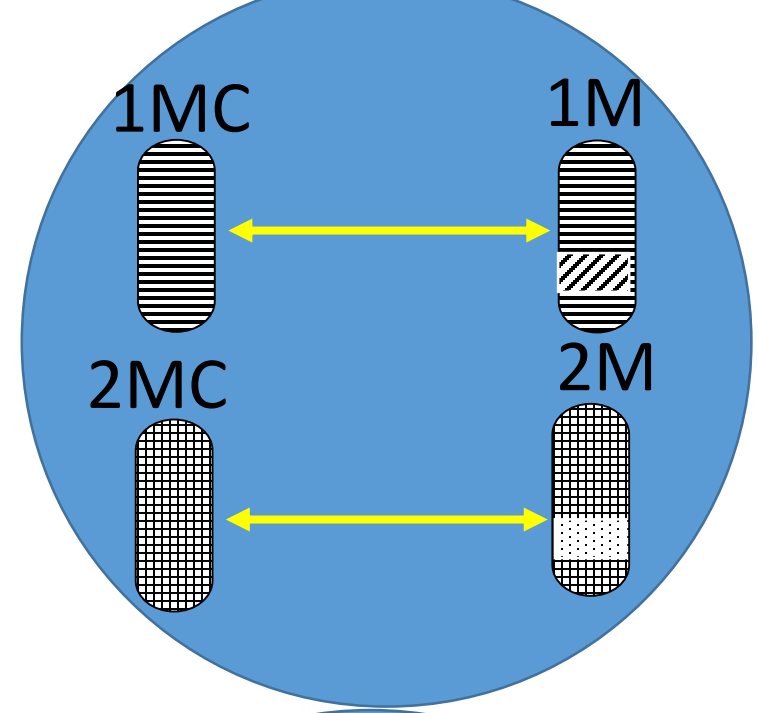
During telophase I and cytokinesis, the cell divides into two cells.

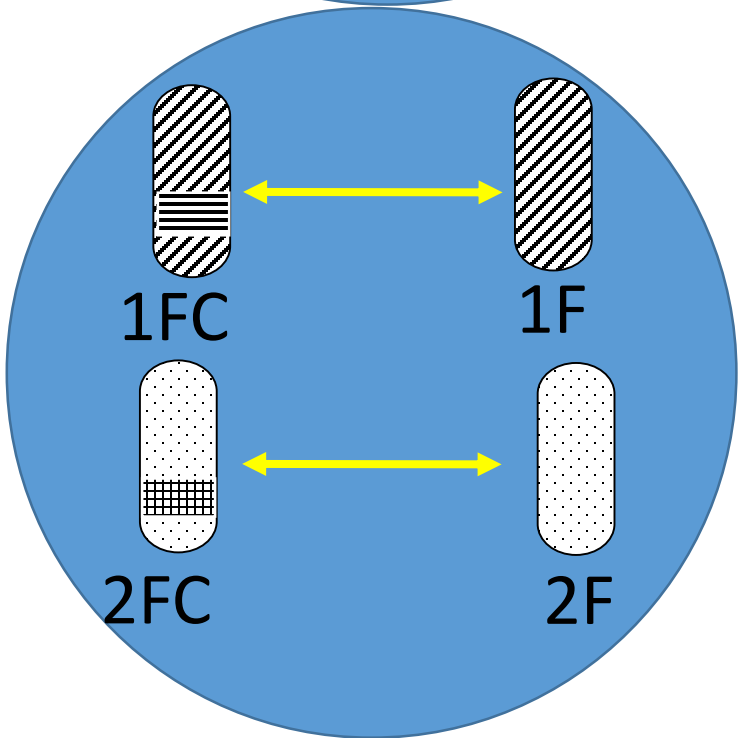
Each cell contains two chromosomes, each made of two chromatids.



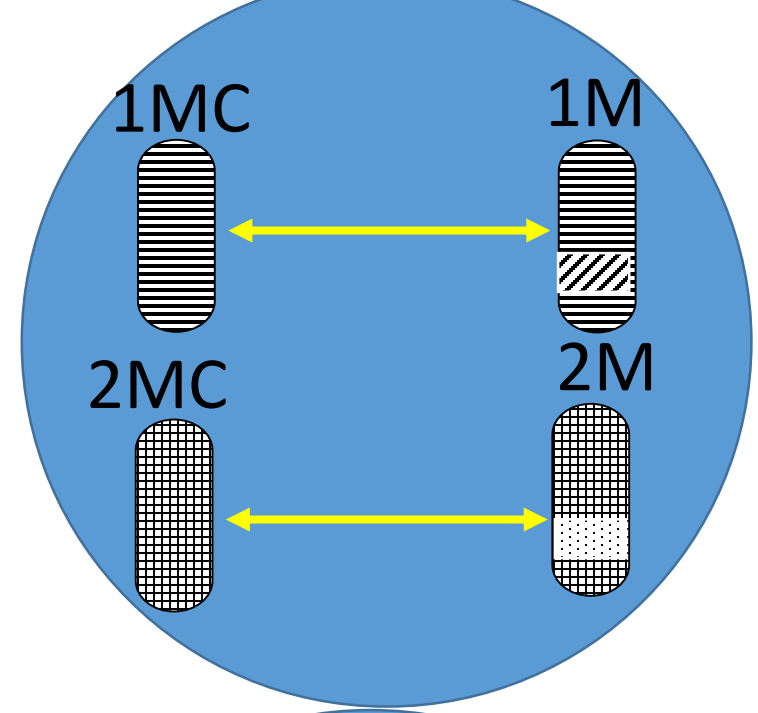


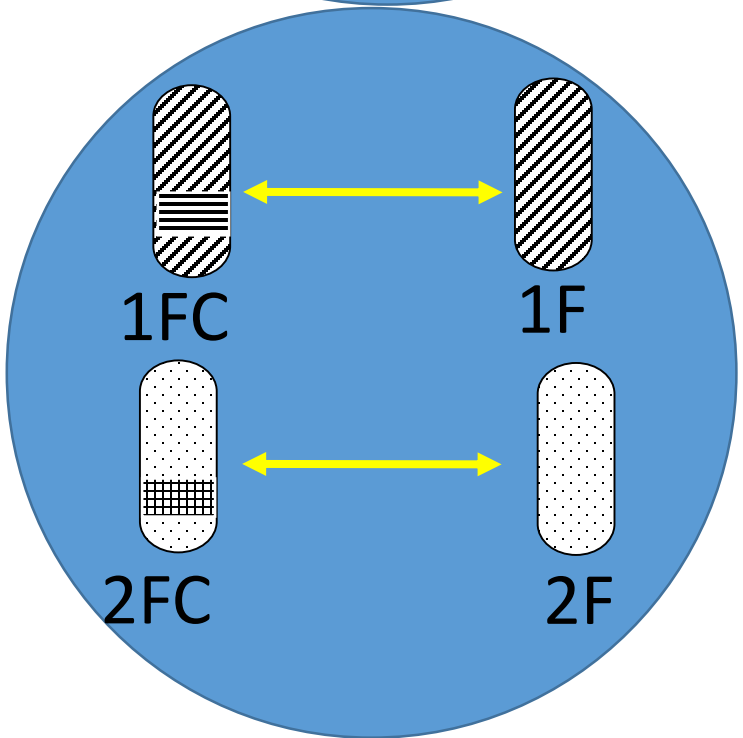
During metaphase II the homologous chromosomes line up in the middle of the cell.

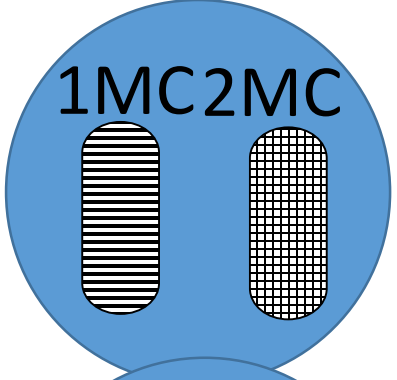


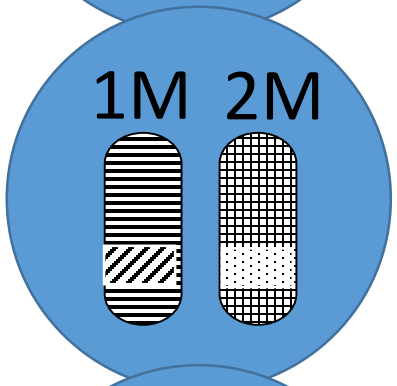


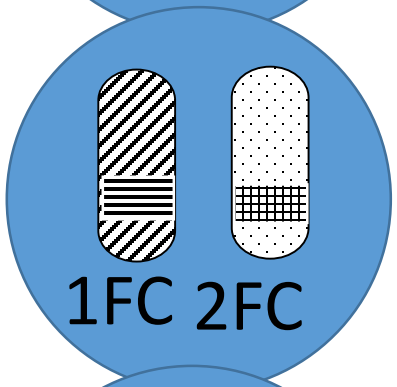
During anaphase II the chromatids that make up each homologous chromosome separate.

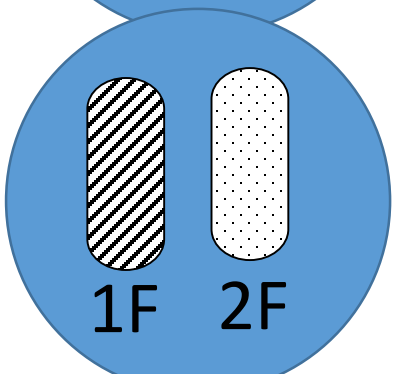












During telophase II and cytokinesis four haploid gametes, with half the number of the original chromosomes, are formed that are genetically different than the diploid cell that entered meiosis and genetically different from each other.

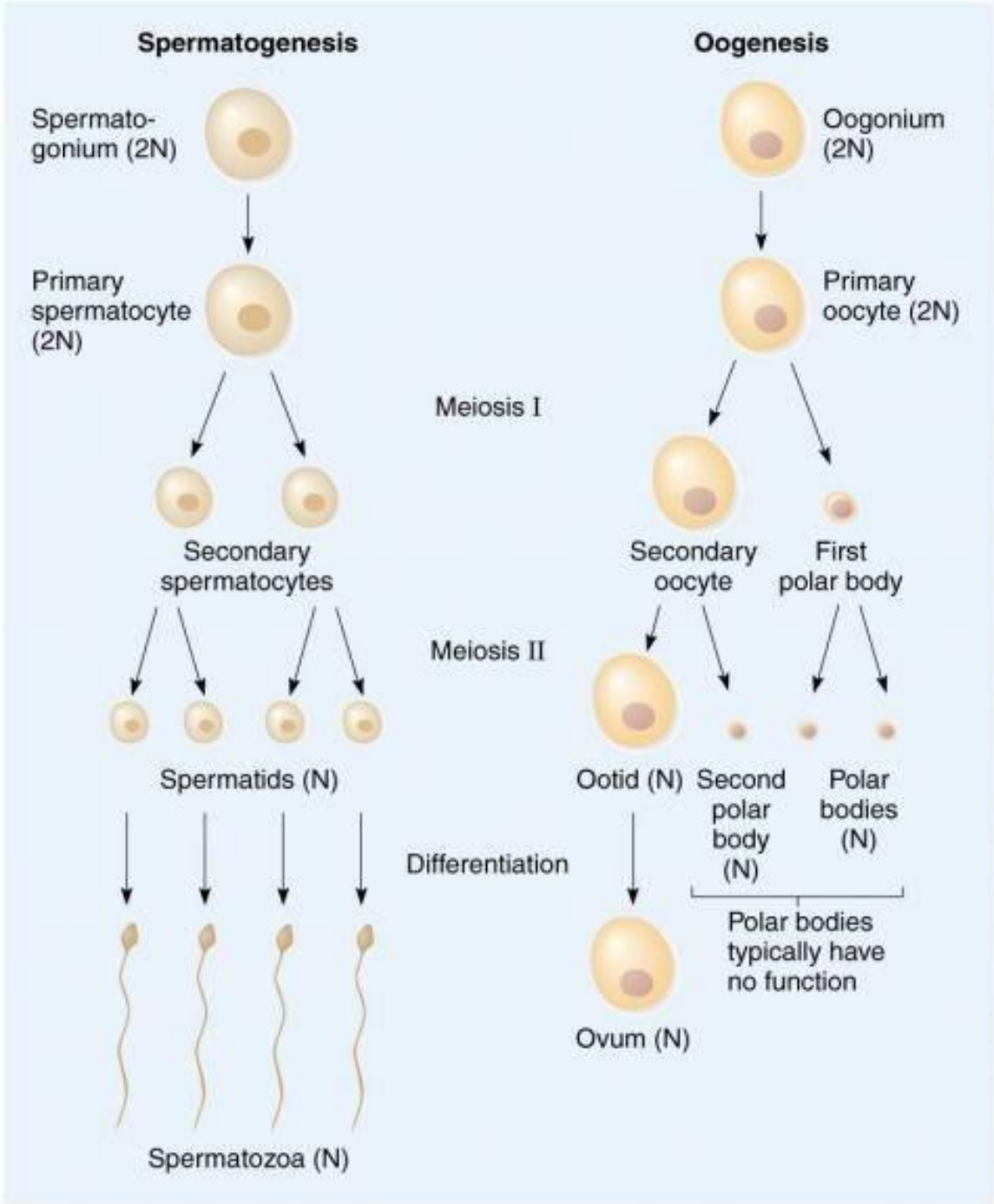
Crossing over results in some genes received from the female parent being transferred to the chromosome received from the male parent and vice versa.

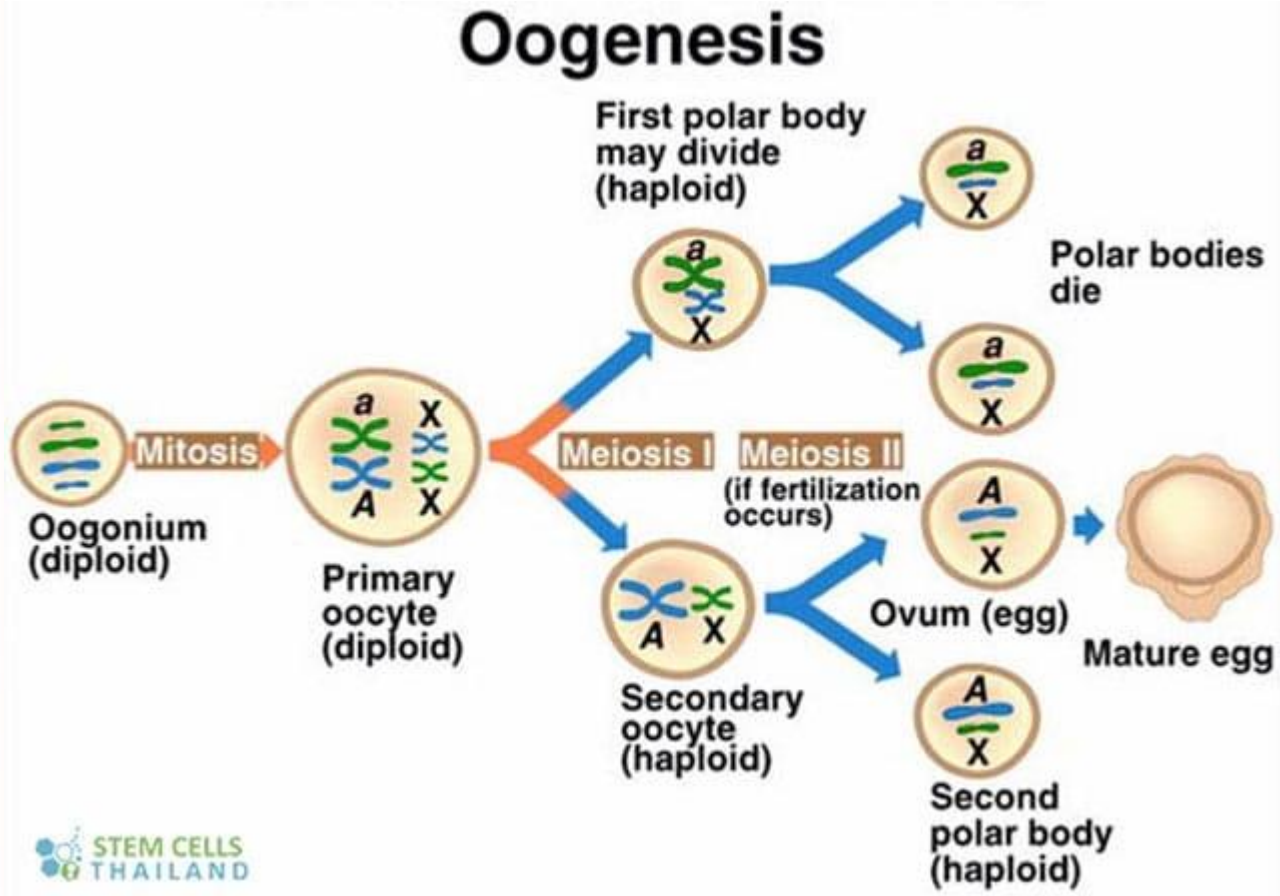
Gamete Formation

- In male animals, the haploid gametes are called sperm.
- In some plants, pollen grains contain haploid sperm cells.

Gamete Formation

- In female animals, generally only one of the cells produced by meiosis is involved in reproduction.
- This female gamete is called the egg in animals and in some plants.
- In many female animals, the cell divisions at the end of meiosis I and II are uneven, so that a single cell, which becomes an egg receives most of the cytoplasm.
- The other three cells are called polar bodies and usually do not participate in reproduction.





Comparing Mitosis and Meiosis

- Mitosis results in the production of two genetically identical diploid cells.
- Meiosis produces four genetically different haploid cells.

Mitosis

- A diploid cell that divides by mitosis results in two diploid (2N) daughter cells that have sets of chromosomes and alleles that are identical to each other and to the original parent cell.
- Mitosis allows an organism's body to grow and replace cells.
- In asexual reproduction, a new organism is produced by mitosis of the cell or cells of the parent organism.

Meiosis

- Meiosis begins with a diploid cell but produces four haploid (N) cells.
- These cells are genetically different from the diploid cell and from each other.
- Meiosis is how sexually reproducing organisms produce gametes.

Mitosis vs. Meiosis