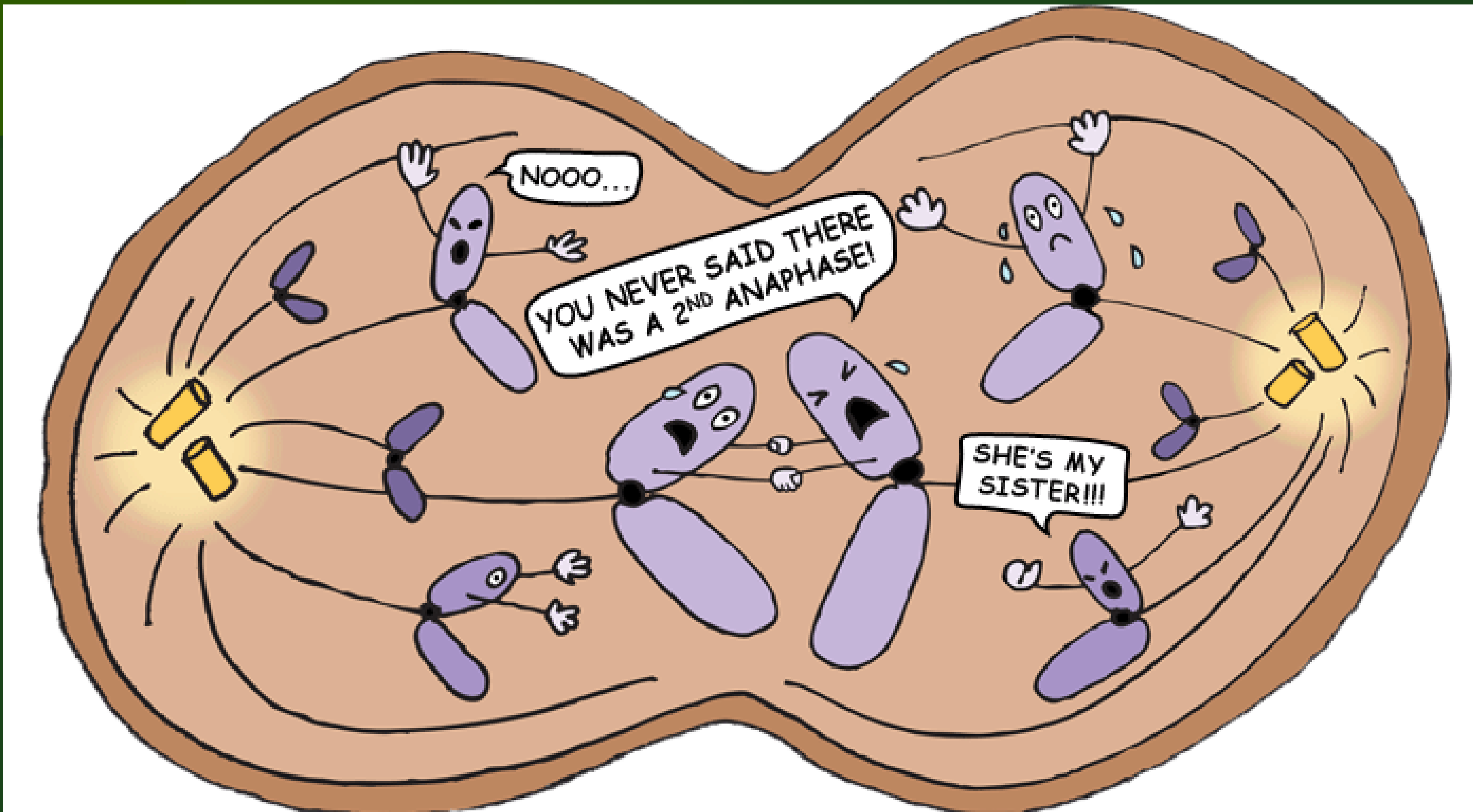
Meiosis



Maria Jose Calasanz / Pintertest

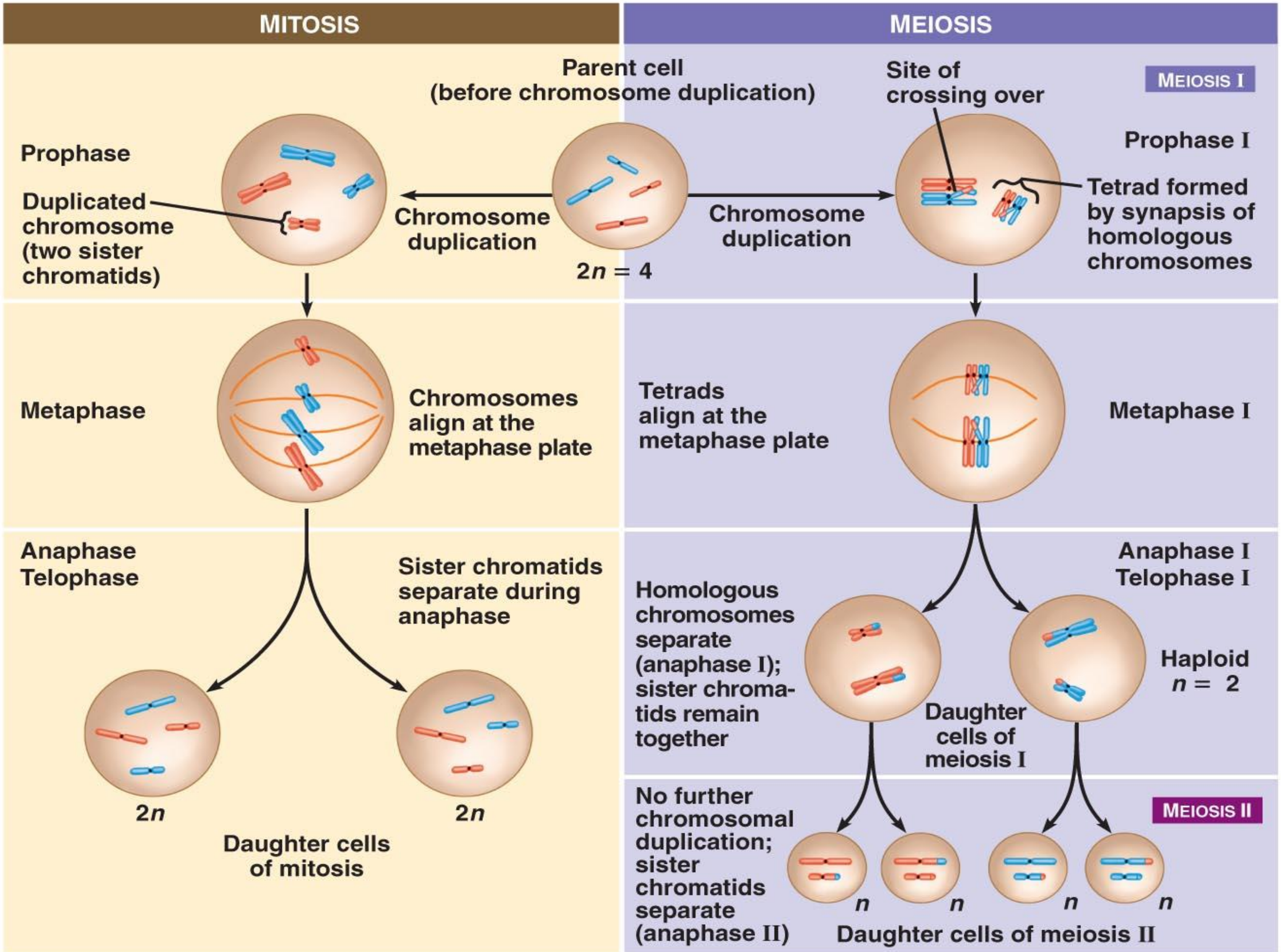
Genetic information is transmitted from the maternal to the daughter cells by cell division. There are two types of cell division – mitosis and meiosis. Mitosis produces daughter cells identical to maternal. It is a way for asexual reproduction of somatic cells. During sexual reproduction two cells – spermatozoa and oocyte fuse to form new diploid cell – zygote. Gametes have to be haploid to produce new diploid organism by their fusion. For this aim gametes need special type of cell division – meiosis.

Meiosis includes two consecutive cell divisions to produce haploid cells from the diploid maternal cell. Before the first meiotic division DNA duplicates like in mitosis. Between first and second division however, interphase is brief without DNA replication. In this way DNA is replicated only once for both of divisions. It ensures producing of haploid cells at the end of the process. That's why meiosis can start from diploid maternal cell only. Mitosis produces identical daughters and one haploid maternal cell can divide into two haploid daughter cells.

During meiotic division we differentiate the same phases – interphase, prophase, metaphase, anaphase, telophase and cytokinesis. Meiotic spindle is formed to attach the chromosomes by their centromeres.

MITOSIS vs MEIOSIS

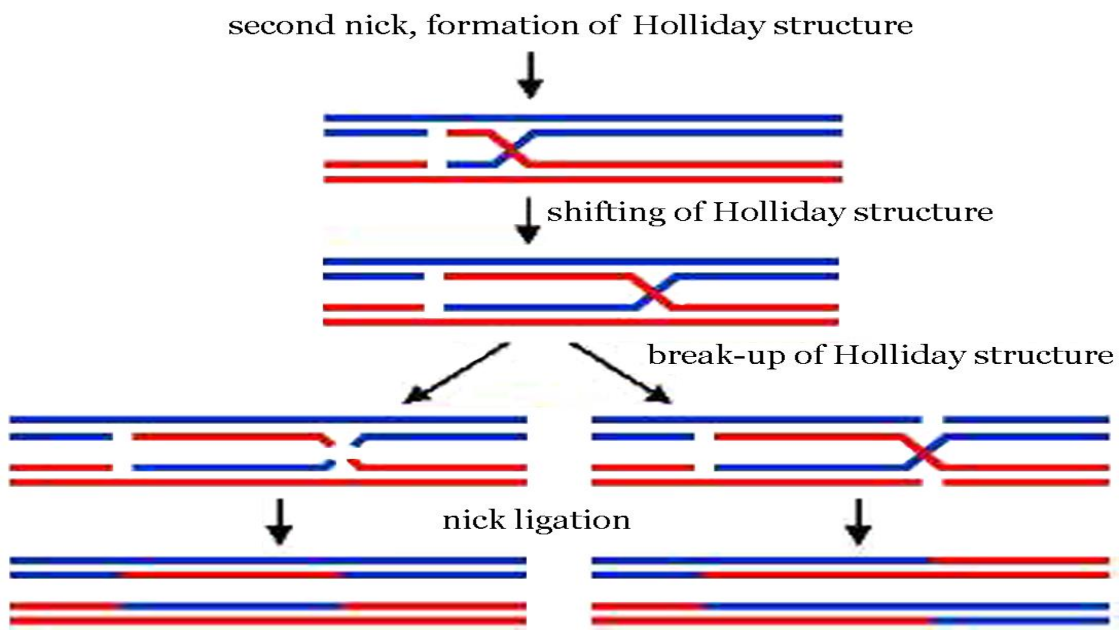
Mitosis	Meiosis
Mitosis takes place within somatic cells (cells that make up the body).	Meiosis takes place within gamete cells (sex cells).
One single division of the mother cell results in two daughter cells.	Two divisions of the mother cell result in four meiotic products or haploid gametes.
A mitotic mother cell can either be haploid or diploid.	A meiotic mother cell is always diploid.
The number of chromosomes per nucleus remains the same after division.	The meiotic products contain a haploid (n) number of chromosomes in contrast to the (2n) number of chromosomes in mother cell.
It is preceded by a S-phase in which the amount of DNA is duplicated.	In meiosis, only meiosis I is preceded by a S-phase.
In mitosis, there is no pairing of homologous chromosomes.	During prophase I, complete pairing of all homologous chromosomes takes place.
There is no exchange of DNA (crossing-over) between chromosomes.	There is at least one crossing-over or DNA exchange per homologous pair of chromosomes.
The centromeres split during anaphase.	The centromeres do separate during anaphase II, but not during anaphase I.
The genotype of the daughter cells is identical to that of the mother cells.	Meiotic products differ in their genotype from the mother cell.
After mitosis, each daughter cell has exactly same DNA strands.	After meiosis, each daughter cell has only half of the DNA strands.


MITOSIS
MEIOSIS
Parent cell
(before chromosome duplication)
Site of
crossing over
MEIOSIS I
Prophase
Duplicated chromosome (two sister chromatids)
Chromosome duplication
$2n = 4$
Chromosome duplication
Prophase I
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 (anaphase I); sister chromatids remain together
Anaphase I
Telophase I
Haploid
$n = 2$
Daughter cells of meiosis I
$2n$
$2n$
Daughter cells of mitosis
No further chromosomal duplication; sister chromatids separate (anaphase II)
MEIOSIS II
n
n
n
n
Daughter cells of meiosis II

Unique events during meiosis

- First meiotic prophase is very long because in this stage crossing over occurs. During first prophase homologous chromosomes recognize each other and join together by special proteins. Chromosomes have to stay close to exchange fragments. Homologous chromosomes are aligned side by side and they exchange alleles of the same genes.
- Crossing over occurs between non-sister chromatids – one from the paternal and one from the maternal chromosome. Sister chromatids are absolutely identical and crossing over between them is aimless. Maternal and paternal chromosome could have different alleles of the same gene. Crossing over creates new combinations of alleles in the gametes and contributes to genetic variability of next generations. Crossing over is made by special enzymes that break DNA double helix. Then other enzymes join the broken ends to their opposite partner. Double helices are reformed and each contains a part of the foreign DNA molecule.

Mechanism of crossing over



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After crossing over homologous chromosomes continue to be connected at the places where exchanging took place. Homologous chromosomes align together on the equator of the first spindle. During first metaphase bivalents (tetrads – four chromatids of the two chromosomes) arrange together on the spindle equator.

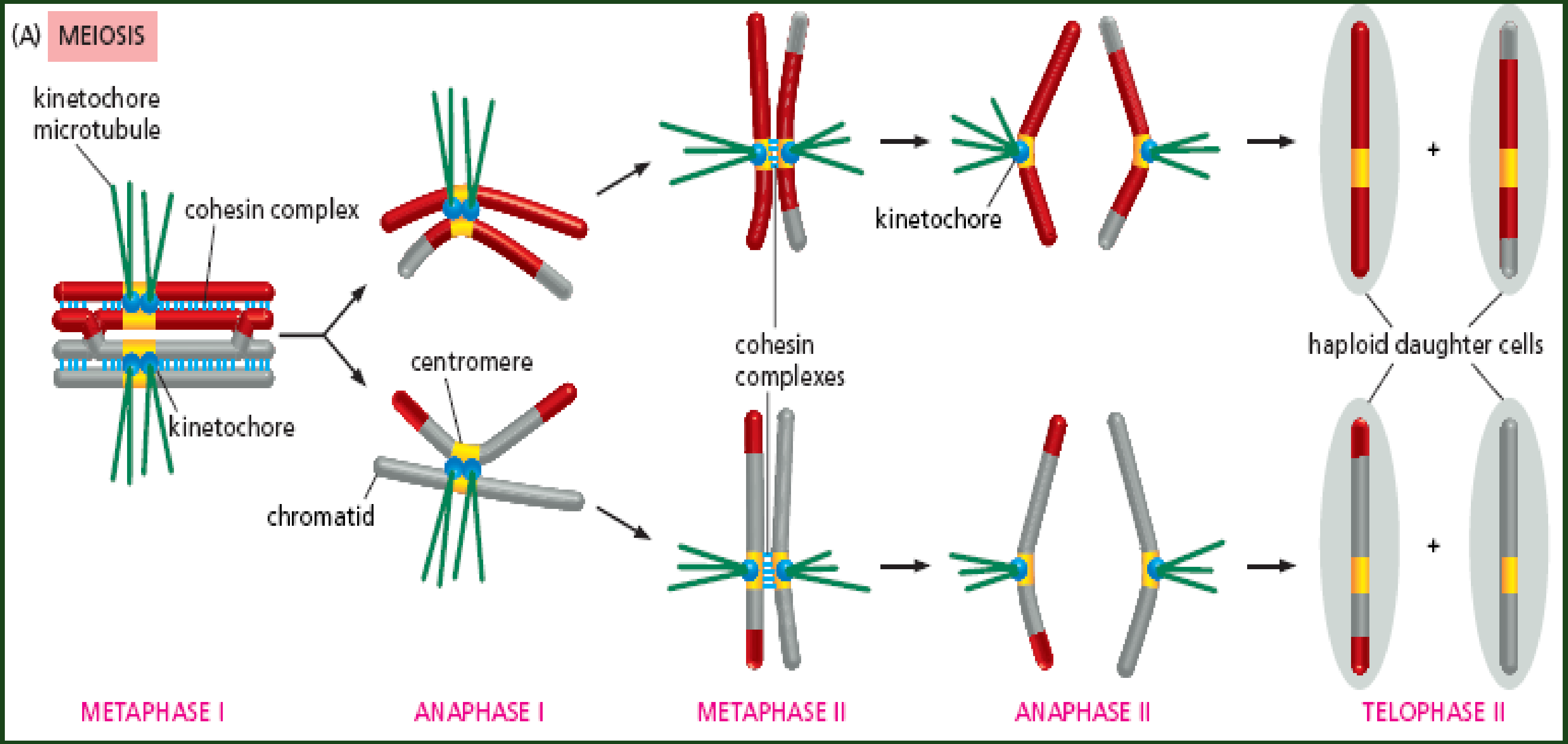
During first anaphase homologous chromosomes separate. Centromeres of the chromosomes remain intact and not individual chromatids, but whole chromosomes move to the opposite spindle poles. That’s why daughter cells become haploid after the first meiotic division. One of the daughters possesses paternal chromosome only and the other – maternal only. The definition for diploid cell is to have two copies of each chromosome – one maternal and one paternal. After anaphase first, this is not valid and daughter cells are haploid. First meiotic division is called reductional, because it reduces the diploid number of chromosomes of the maternal cell to haploid in the daughters.

During second meiotic division sister chromatids separate and each chromatid becomes an individual chromosome. Second division is called equational, because it maintains the same ploidy level of the cell. The aim of this division is to balance the amount of DNA in the daughter cells. After the first division chromosomes are still consisting of two sister chromatids. As we know, during interphase each chromosome has only one chromatid. Second meiotic division recovers the interphase amount of DNA in the cell.

Scheme of chromosomal segregation during meiosis

Kinetochores (blue balls on the picture) are protein complexes which assembly around centromeres of the chromosomes. Kinetochores attach chromosomes to the spindle fibers. In the picture is visible that kinetochores of the sister chromatids are fused during meiosis I. It results both of sisters to move to the same pole, because the common kinetochore is captured by fibers one pole fibers.

During second meiotic division each chromatid has its individual kinetochore and the sisters separate.



THREE MAJOR CONTRIBUTIONS OF SEXUAL REPRODUCTION TO GENETIC VARIABILITY

- Exchanged segments of homologous chromosomes and re-assorted genes in individual chromosomes
  - crossing over during prophase I.

- Independent assortment of the maternal and the paternal homologues
  - takes place in anaphase I;
  - it makes 2^n possible combinations of maternal and paternal chromosomes in gametes (2^{23} in human);

  n = number of chromosome pairs – 23 in human.

- Genetic variability in sexually reproduced organisms is increased also by fusion of random gametes during fertilization.