Review: Mitosis and the Cell Cycle

- Please fill in the blanks with the correct term:

______ is the phase of mitosis where the homologous chromosomes separate

The ____ phase of the cell cycle is when DNA replication takes place

The binding of _____ to Cdks is a critical checkpoint in the progression of the cell cycle

The pinching off of the two cell membranes from one another is driven by actin filament polymerization and is called _______

Review: Mitosis and the Cell Cycle

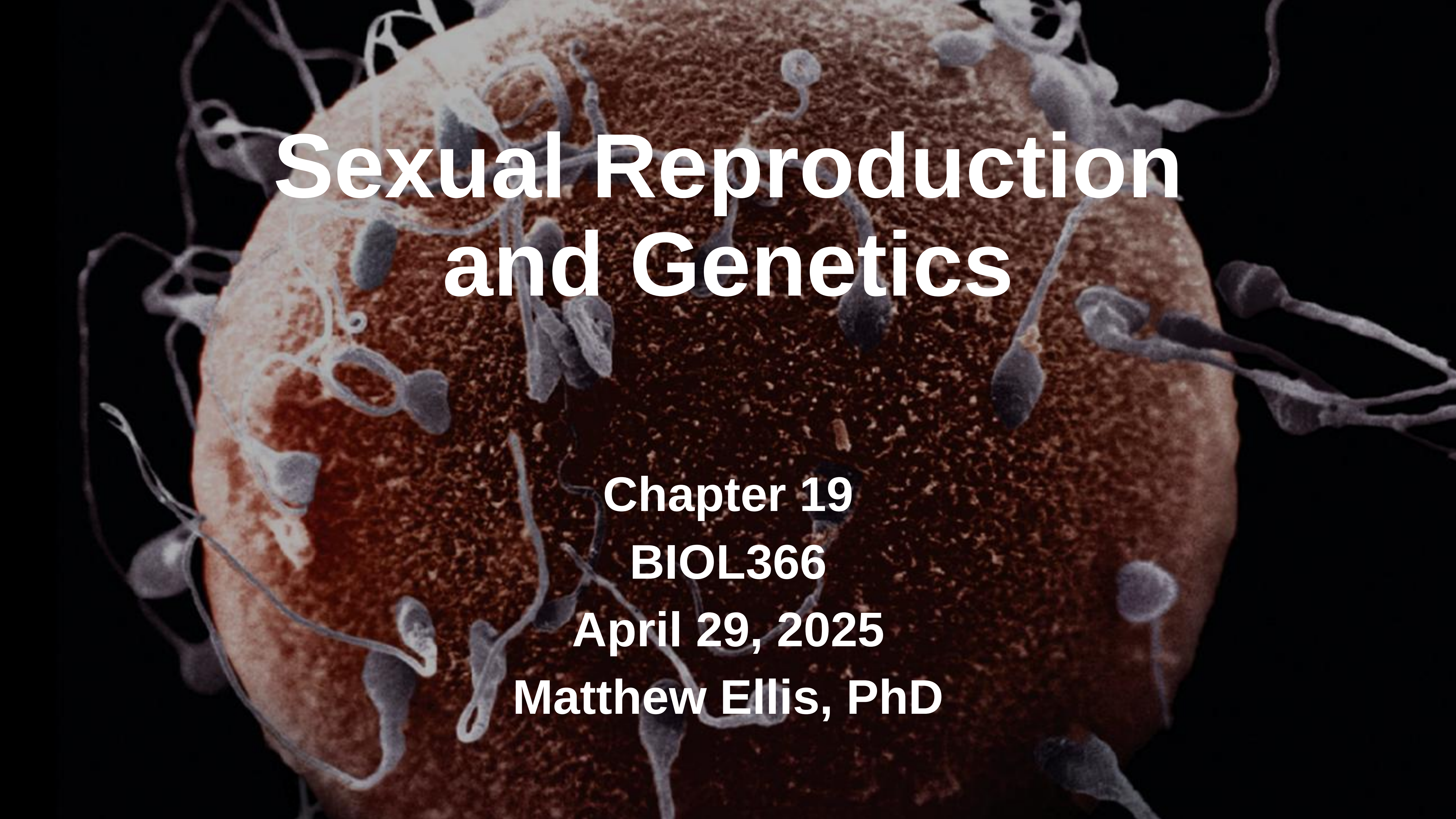
- Please fill in the blanks with the correct term:

Anaphase is the phase of mitosis where the homologous chromosomes separate

The S phase of the cell cycle is when DNA replication takes place

The binding of cyclin to Cdks is a critical checkpoint in the progression of the cell cycle

The pinching off of the two cell membranes from one another at the end of mitosis is driven by actin filament polymerization and is called cytokinesis



Sexual Reproduction and Genetics

Chapter 19

BIOL366

April 29, 2025

Matthew Ellis, PhD

Learning Objectives for Today's Lecture:

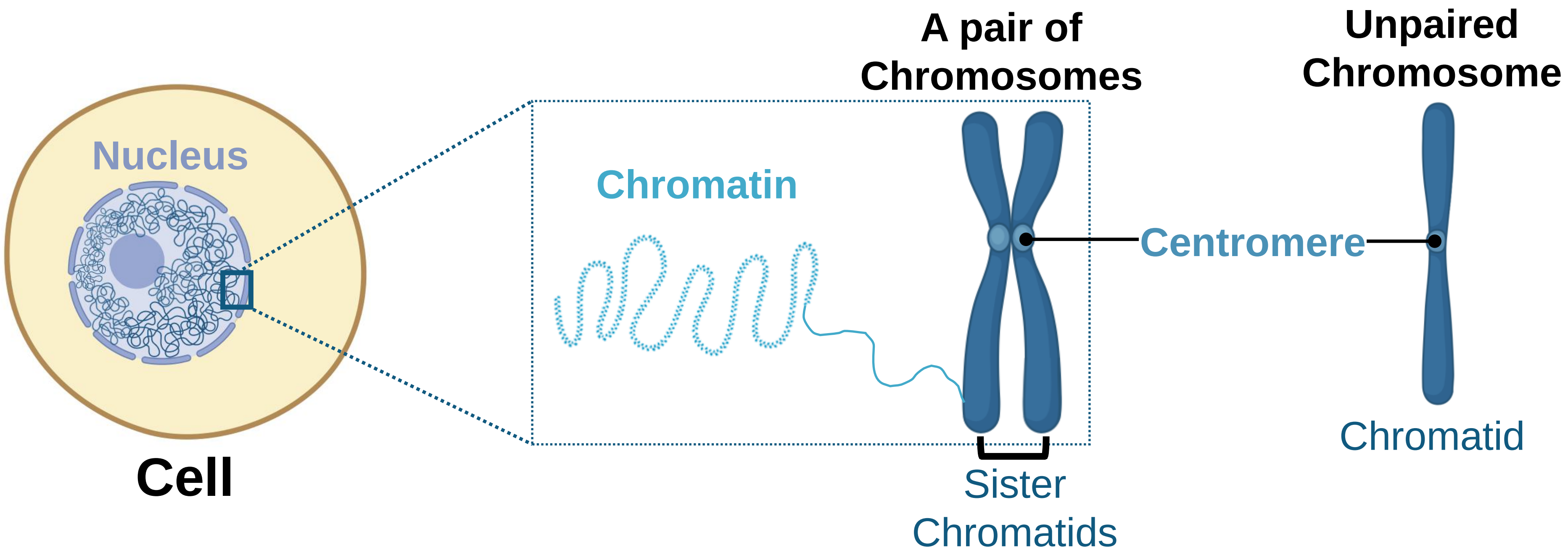
Upon completing this module, **you should be able to**:

- Compare and contrast **asexual** and **sexual reproduction**
- Describe the key steps of **meiosis** that reduce the number of chromosomes and facilitate genetic diversity
- Detail the processes of **spermatogenesis** and **oogenesis**
- Explain how "male" and "female" reproduction cycles lead to **fertilization** and **zygote** formation

Key Terms

- **Asexual reproduction**: offspring that are genetically identical to the parent
- **Sexual reproduction**: the production of new organisms by the combination of genetic information of two individuals of different sexes
- **Meiosis:** cell division process that reduces the total number of chromosomes in half
- **Diploid**: cells with paired chromosomes
- **Haploid**: cells with a single (unpaired) chromosome
- **Gamete**: sex/reproductive cells
- **Somatic cells**: body cells (non-reproductive cells)
- **Allele**: different versions of the same gene
- **Nondisjunction**: a cell division error that occurs when chromosomes fail to separate properly
- **Spermatogenesis:** formation of sperm gamete cells (male reproduction)
- **Oogenesis:** formation of oocytes and ova (female reproduction)
- **Zygote:** Initial diploid cell state following the fusion of haploid gametes during fertilization

DNA is packaged into Chromosomes

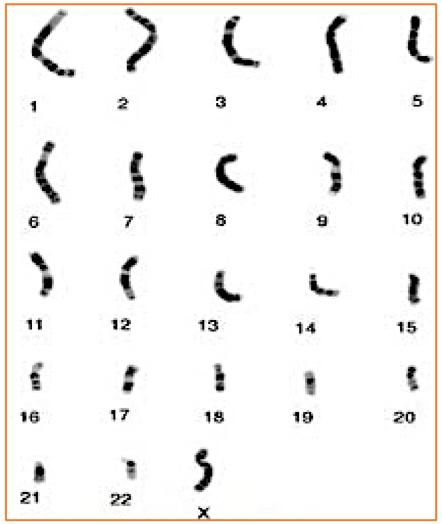


A **chromosome** can consist of either **2 chromatids (sister chromatids)** or **1 chromatid** (unpaired chromosome)

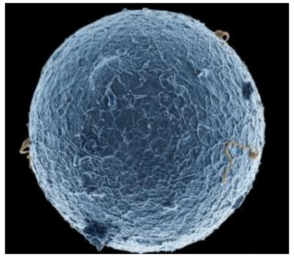
Chromosomes are either haploid or diploid depending on the cell type

Haploid (n)

Cell contains unpaired chromosomes (chromatids)



Human sperm cell



Human egg cell (ovum)

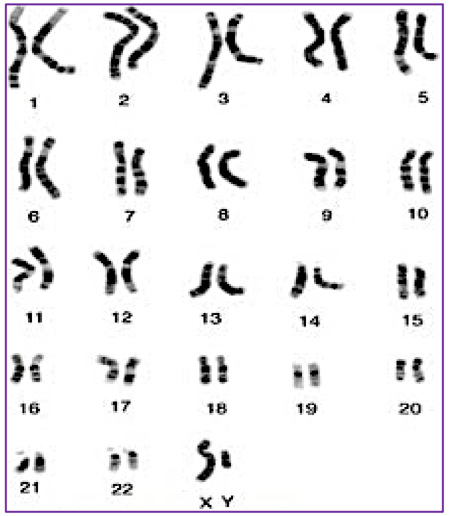
Gametes

"n"= # of chromosomes in the set

Karyotype

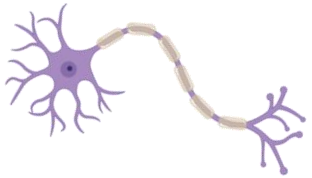
Diploid (2n)

Cell contains **paired** chromosomes

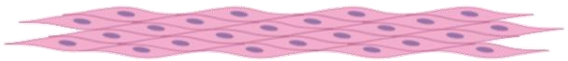


Examples:

Skin



Neurons

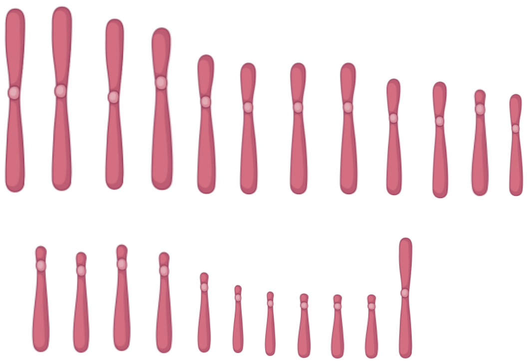


Muscle cells

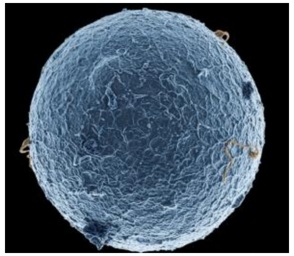
Somatic cells

Human chromosomes are diploid (2n)

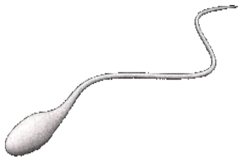
Haploid (n)
23 chromosomes



X

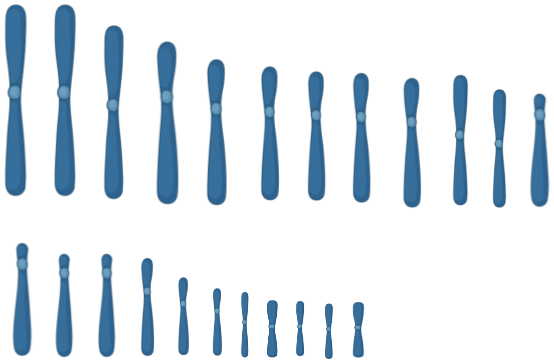


Human egg cell



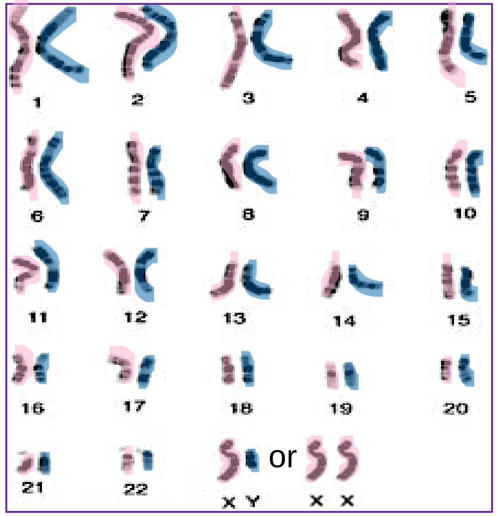
Human sperm cell

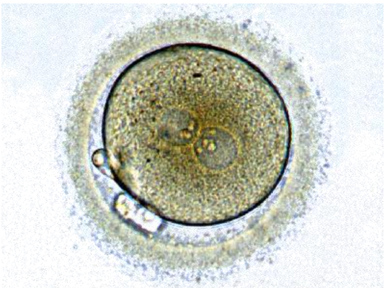
Haploid (n)
23 chromosomes



Y

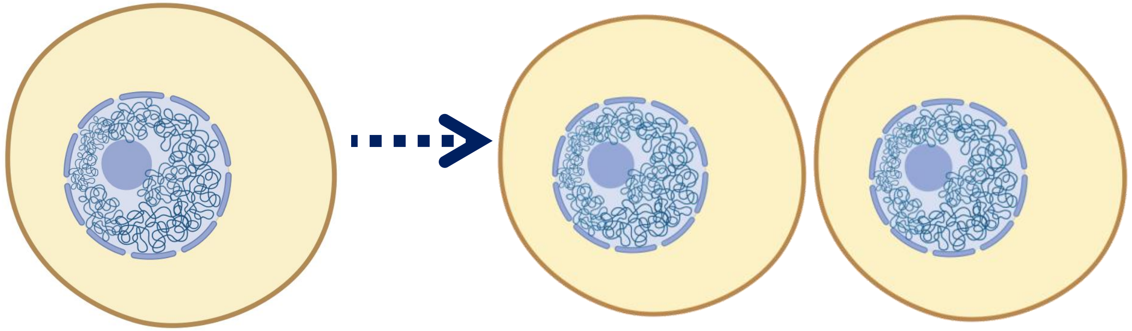
Diploid (2n)
46 chromosomes in 23 pairs





Fertilized egg (zygote)

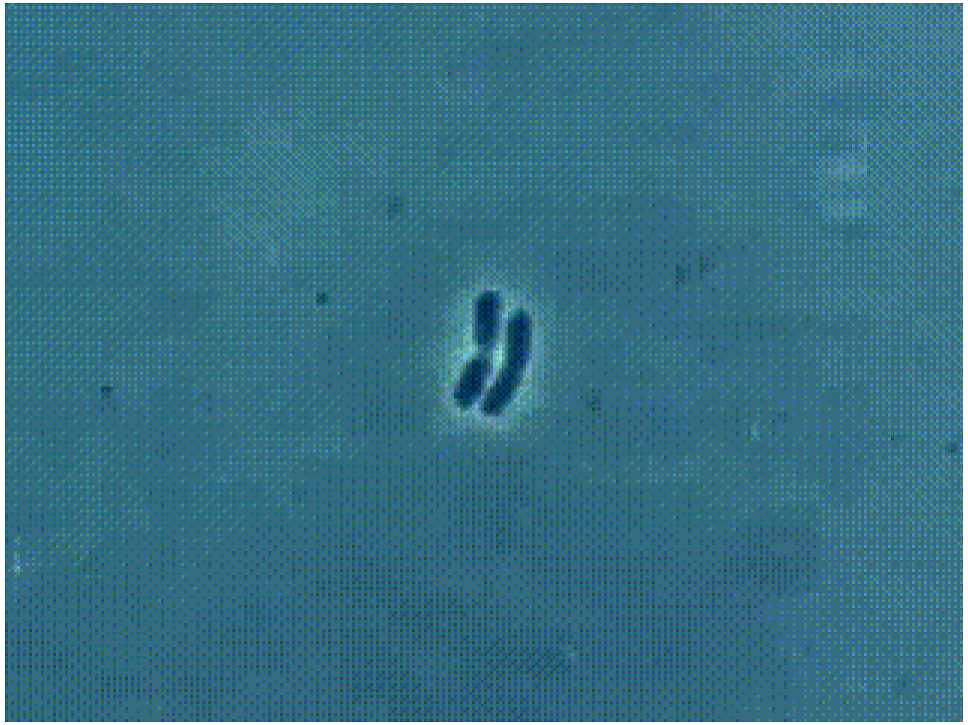
Asexual Reproduction produces genetically identical cells



Parent cell **Daughter cells**

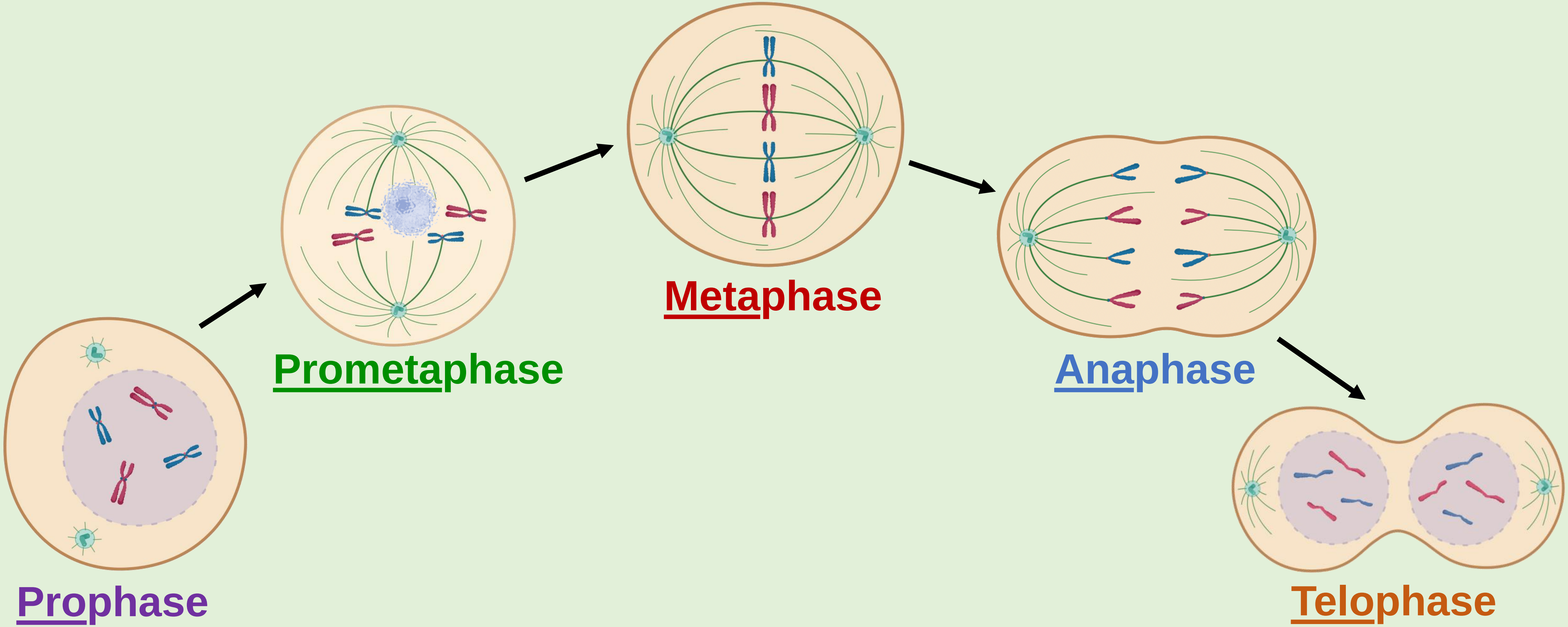
- **Daughter cells** are genetically and physically similar to the **parent cells**

- **Asexual reproduction doesn't involve the fusion of gametes or a change in the number of chromosomes**

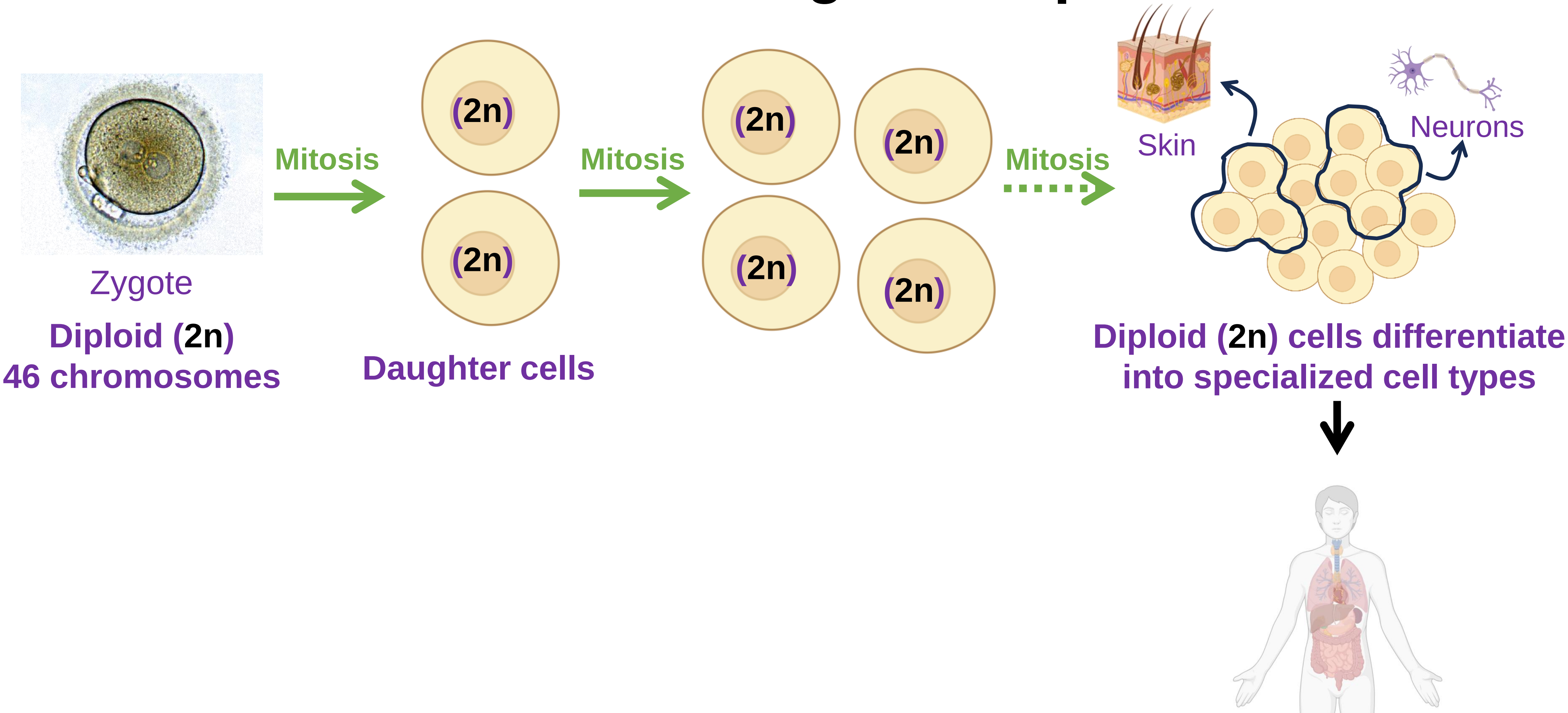


Bacteria reproduce asexually

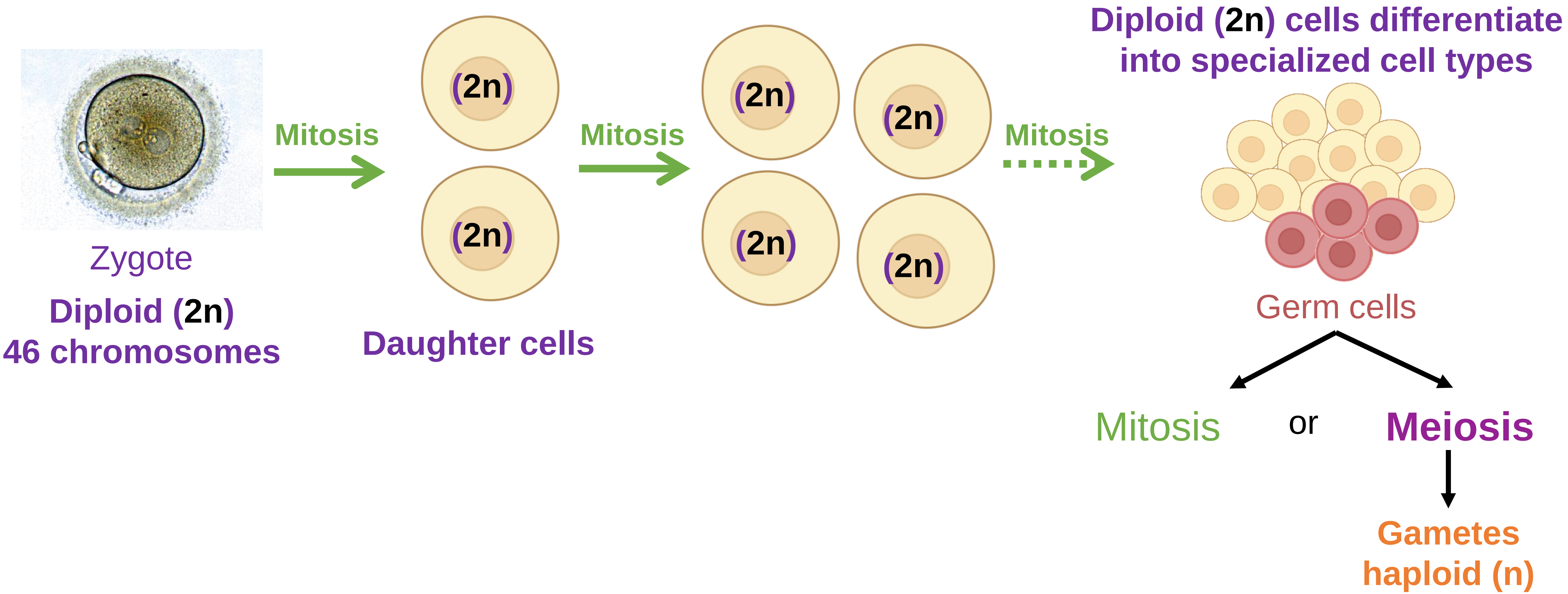
Asexual reproduction uses mitosis for cell division



Human somatic cells undergo asexual reproduction via mitosis during development



Human somatic cells undergo asexual reproduction via mitosis during development



Sexual reproduction relies on the cell division process of meiosis

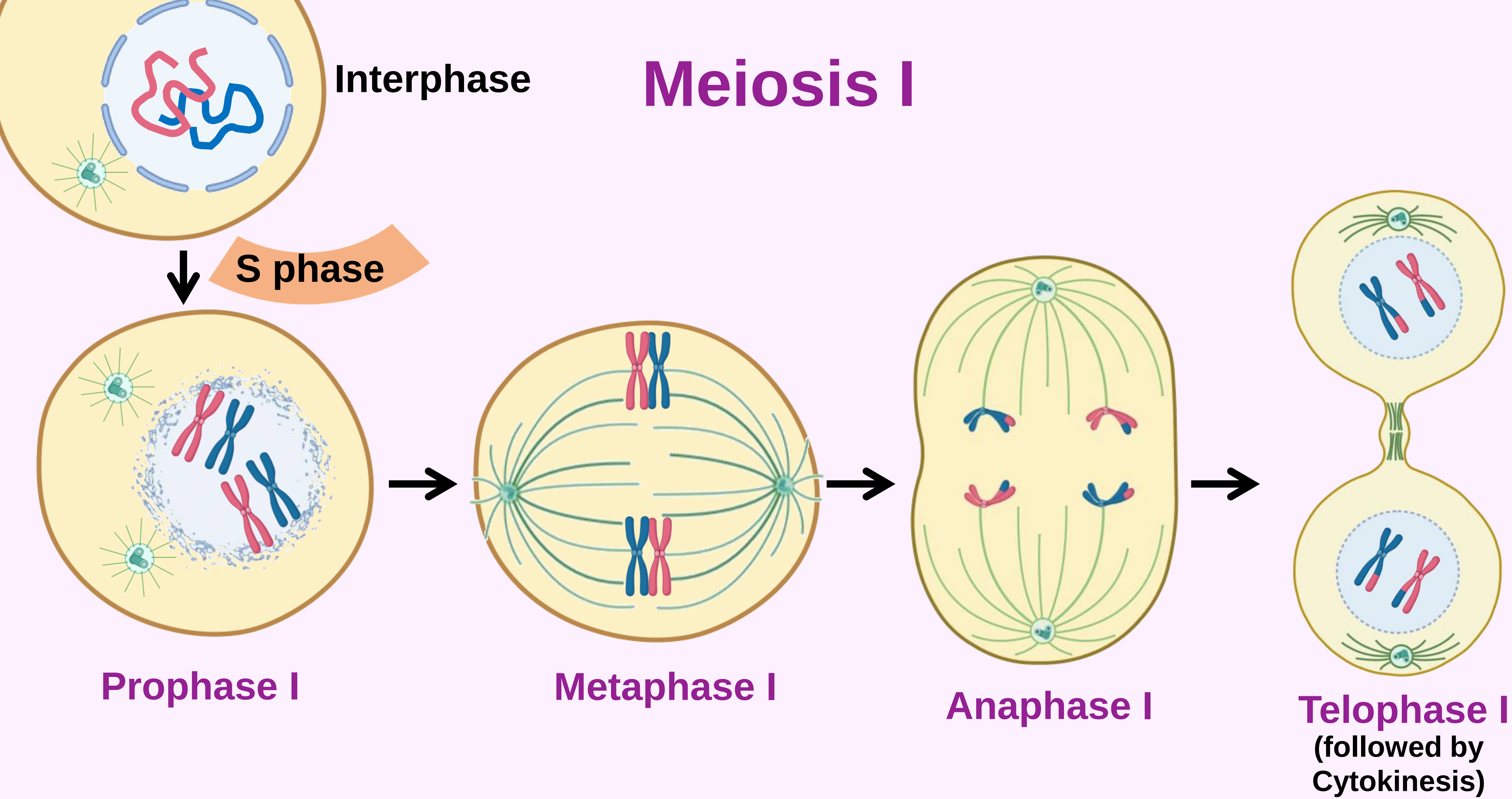
Meiosis I

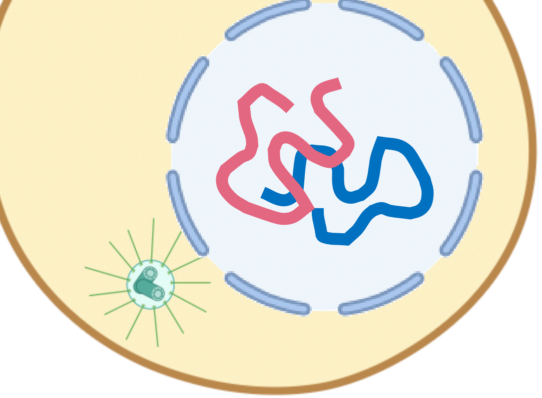
Meiosis II

- **Meiosis** begins in **diploid** (2n) cells

- **The goal of meiosis is for germ cells to produce haploid gametes (n)**

Meiosis I

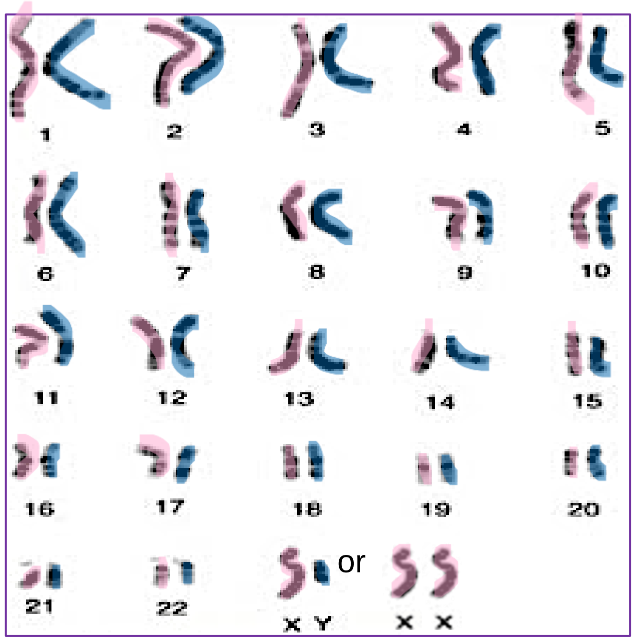

Interphase
S phase
Prophase I
Metaphase I
Anaphase I
Telophase I
(followed by Cytokinesis)



Interphase

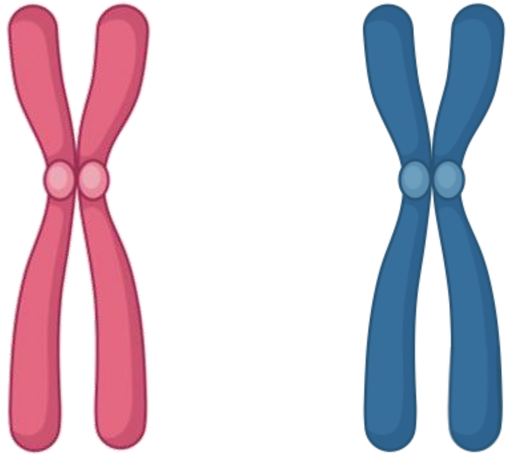
Homologous chromosomes are duplicated during S phase

Homologous chromosomes



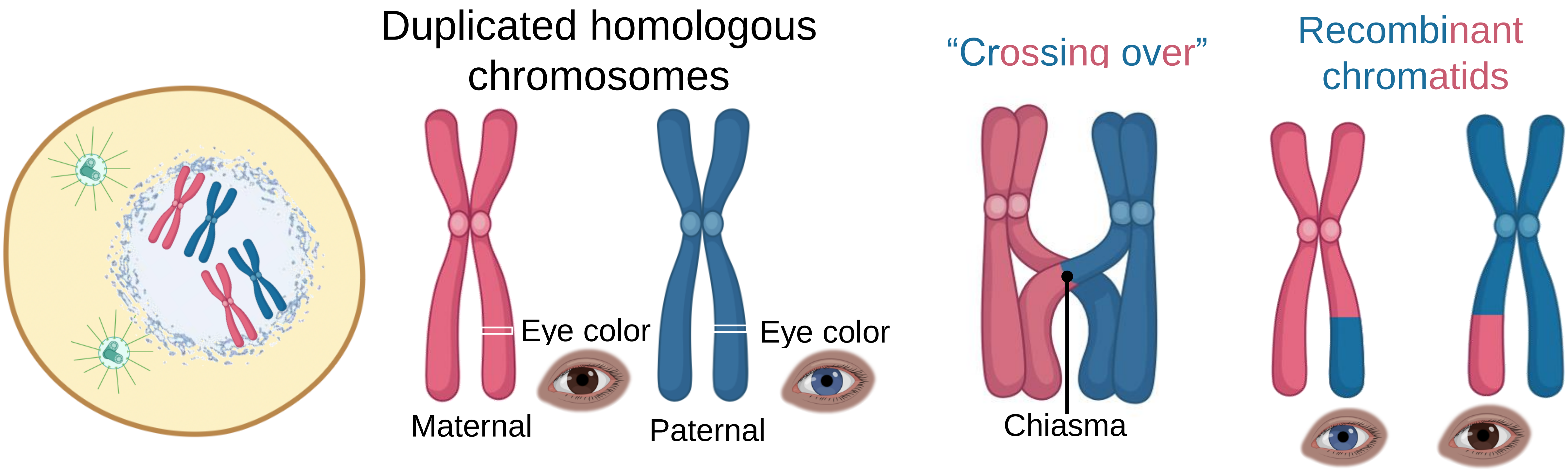
S phase

Duplicated homologous chromosomes



- Pairs of chromosomes that are similar in size and shape
- Homologous chromosomes contain the same genes in the same order

Chromatid recombination "crossing over" occurs during Prophase I



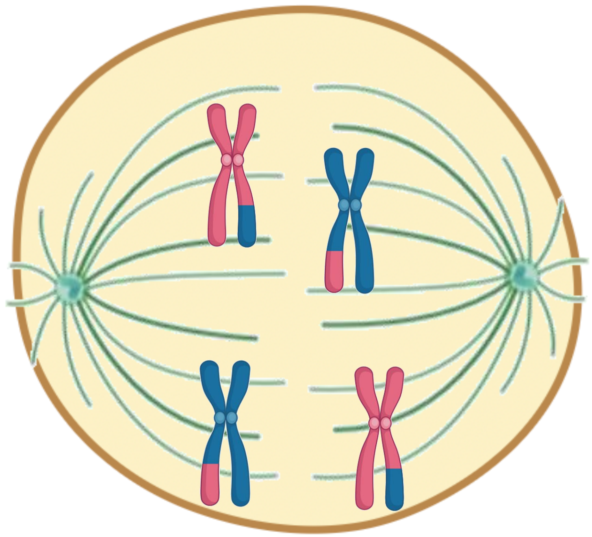
Prophase I

•Chromatid recombination leads to genetically diverse offspring

Offspring inherit two **alleles** for each gene: one from each parent

Independent assortment occurs as a result of random orientation at the metaphase plate

•2 pairs of homologous chromosomes (bivalents) align together at the metaphase plate



Metaphase I

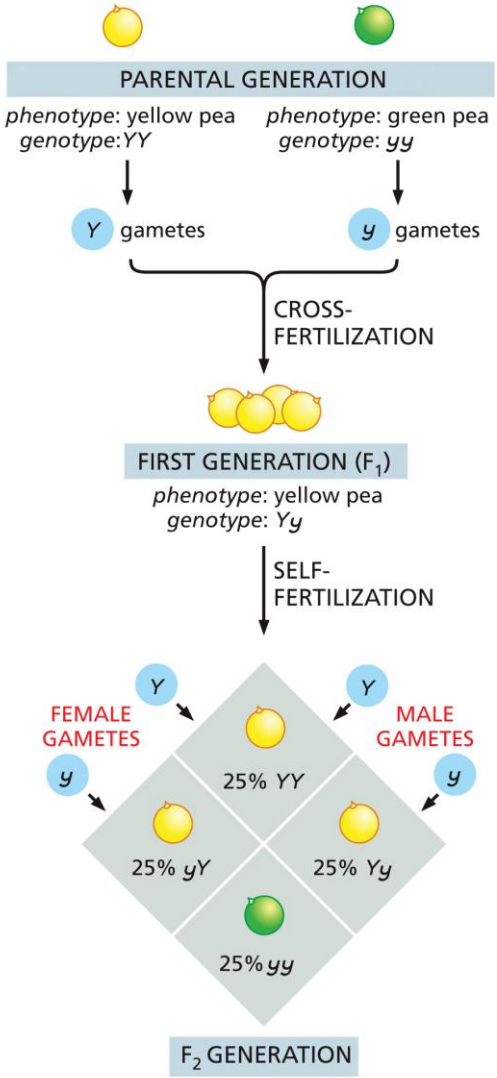
•Homologous chromosome pairs **randomly** orient themselves at the metaphase plate

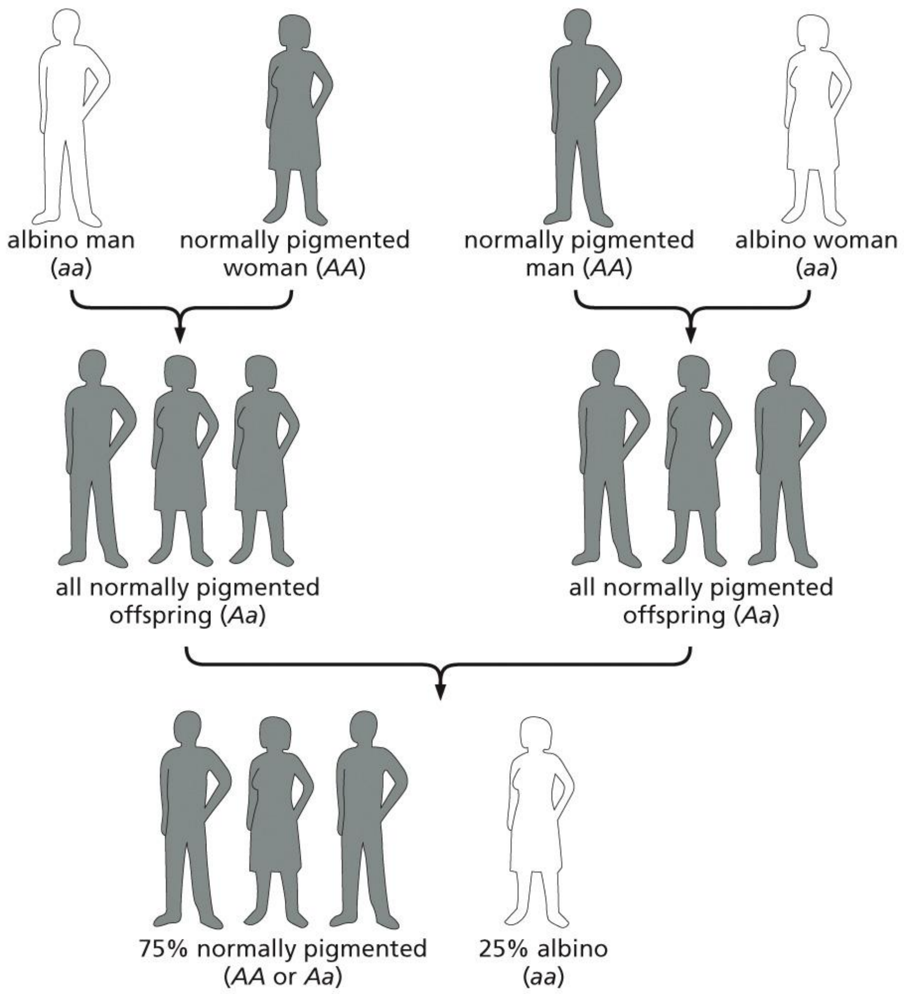
•Leads to **independent assortment:** variety of possible genetic combinations (**genetic diversity**) in resulting **gametes**

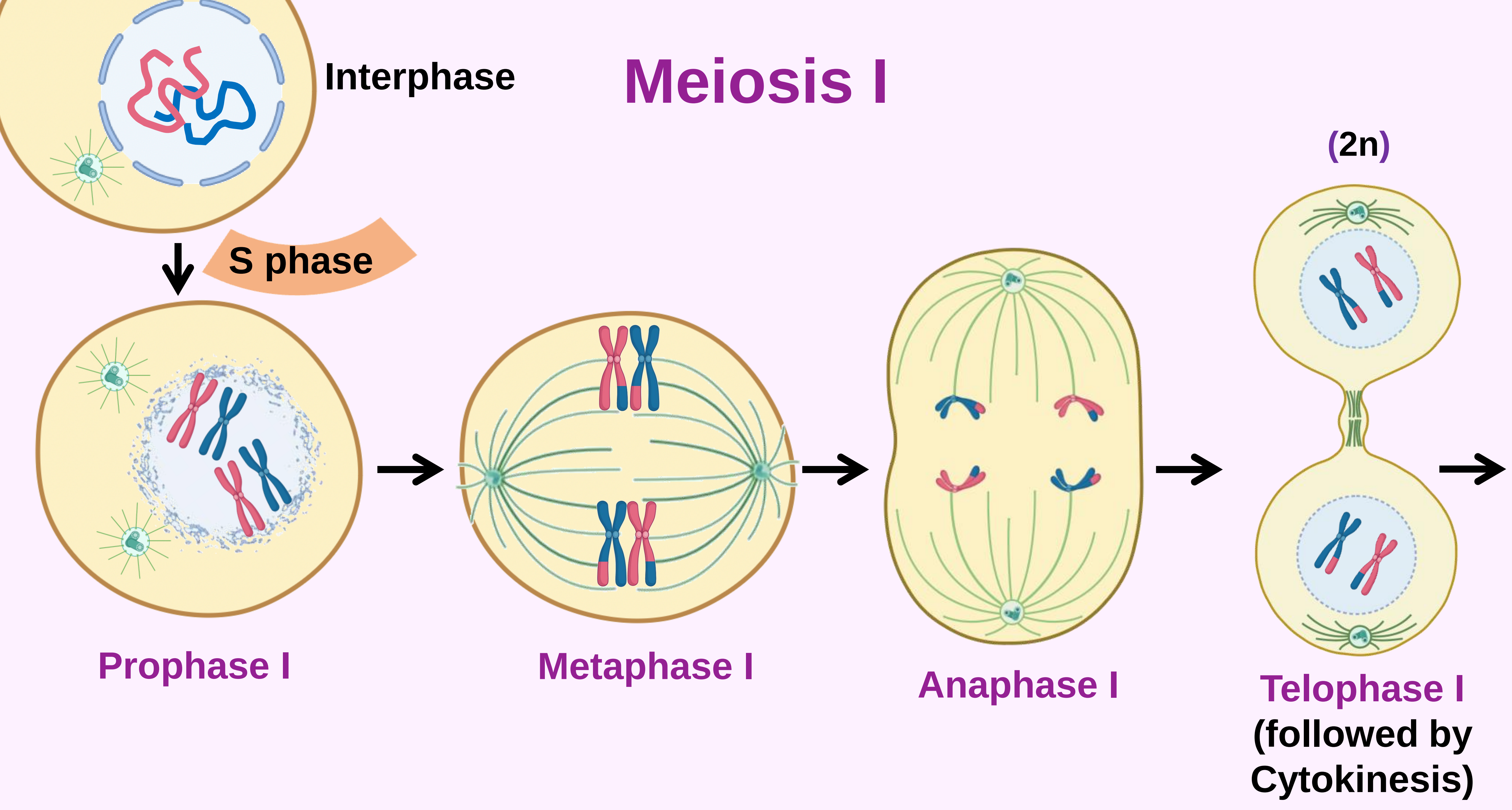
Mendel’s laws of inheritance

<u>Law of segregation</u>:
The two alleles for any given trait separate during gamete formation and unite at random during fertilization. Crossing of two homozygotes yields all heterozygotes. Crossing of heterozygotes yields a 3:1 ratio expression of phenotype

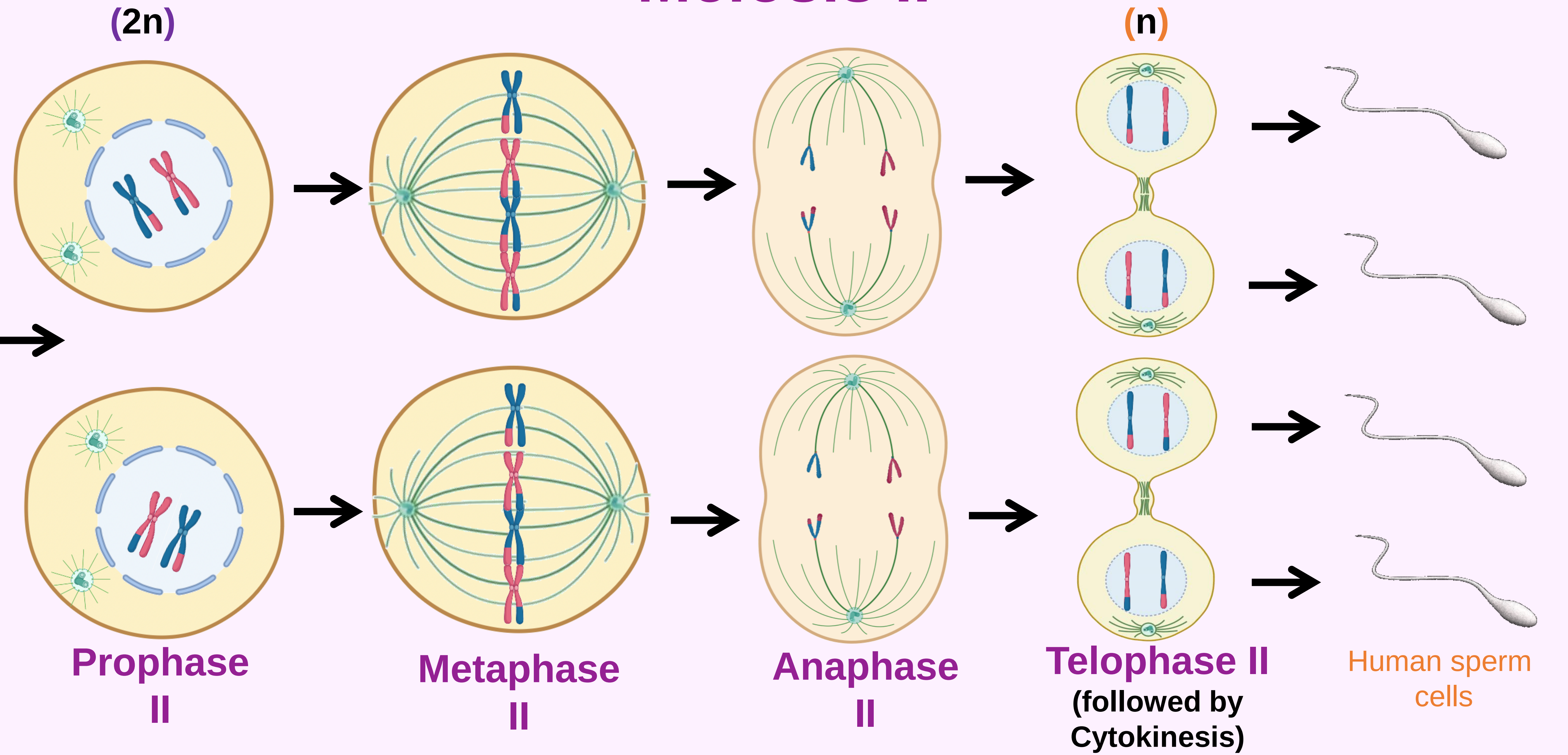
<u>Law of independent assortment</u>:
The two alleles for any given trait get sorted into gametes independently of one another.






Meiosis I
Interphase
S phase
Prophase I
Metaphase I
Anaphase I
(2n)
Telophase I
(followed by
Cytokinesis)

Meiosis II


(2n)
(n)
Prophase II
Metaphase II
Anaphase II
Telophase II
(followed by Cytokinesis)
Human sperm cells

Defects in Meiosis leads to Nondisjunction

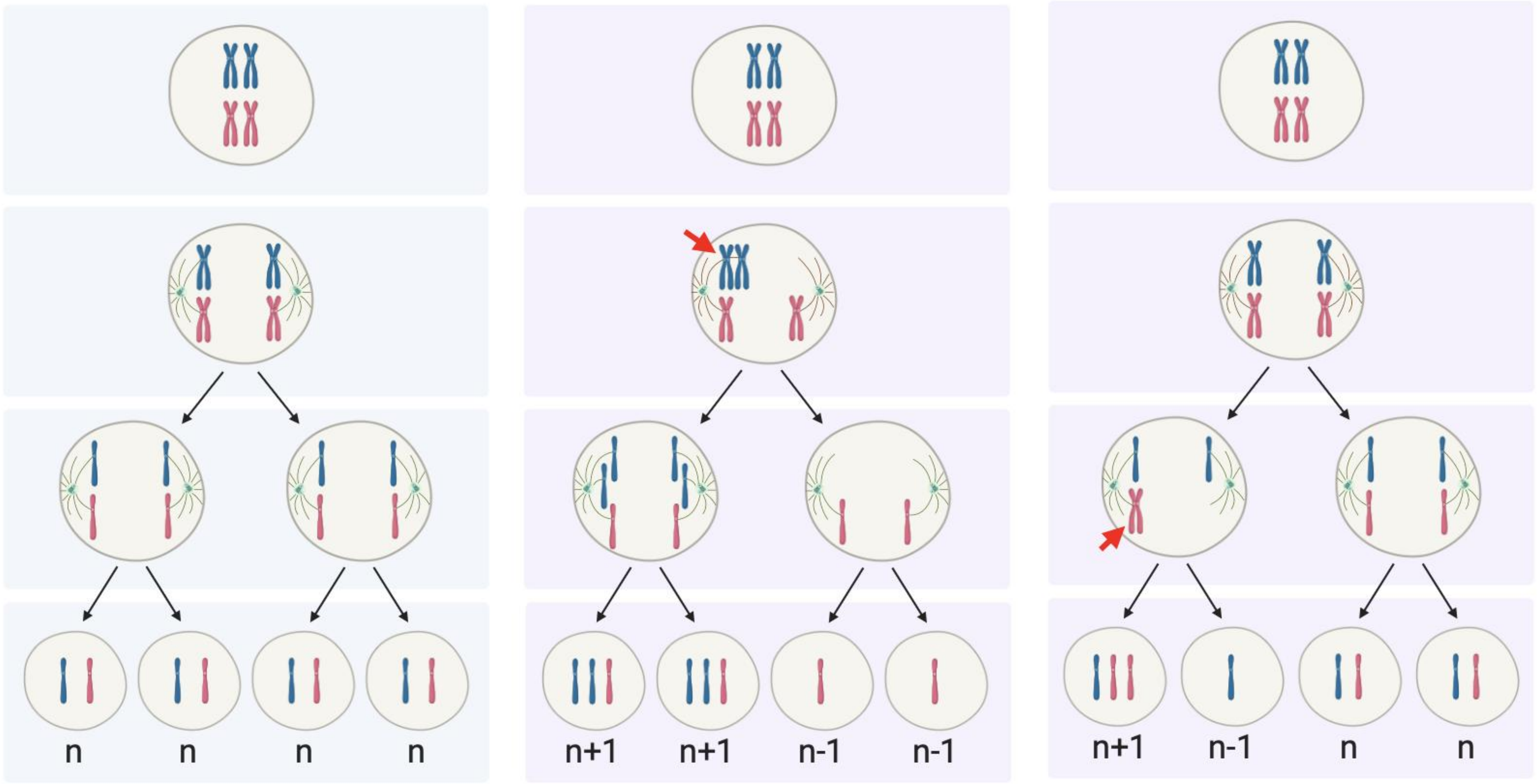
Normal Meiotic Division | Nondisjunction in Meiosis I | Nondisjunction in Meiosis II

Prophase I

Meiosis I

Meiosis II

Gametes

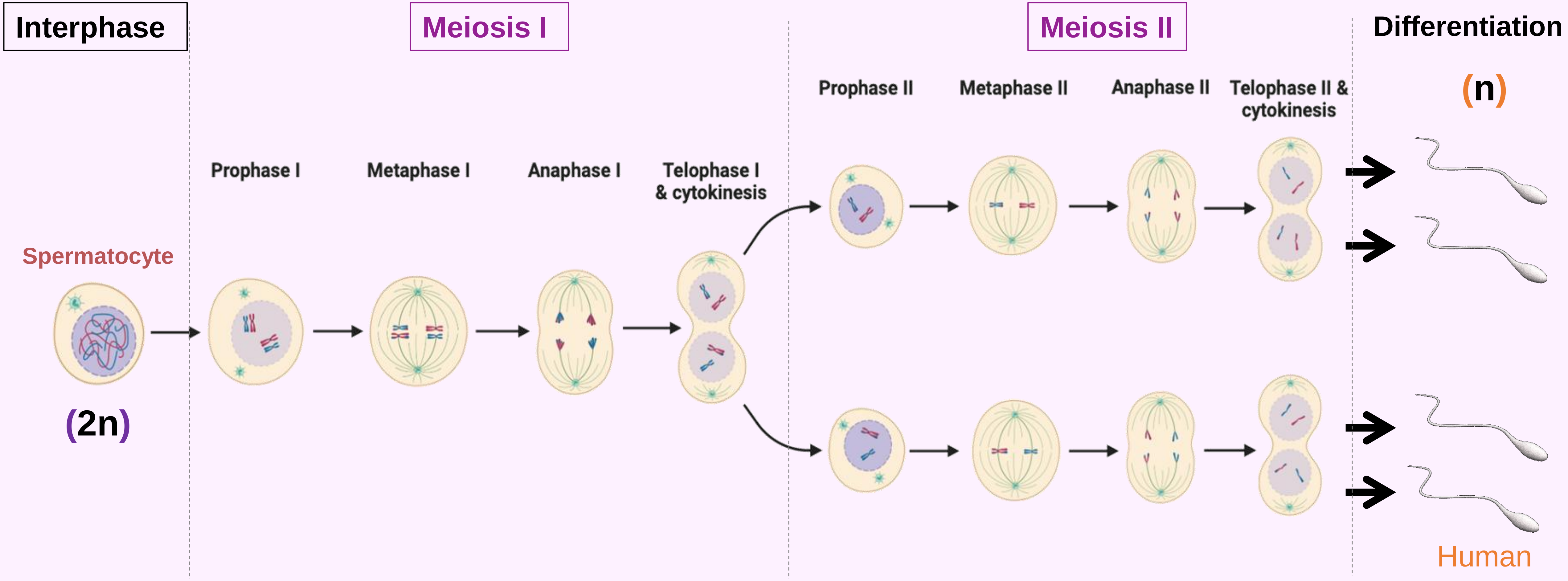


Gametes with n chromosomes

Gametes with more (n +1) or less n (n-1)

50% normal gametes

Meiosis generates 4 sperm cells



•The goal of Meiosis is for germ cells to produce gametes (n)

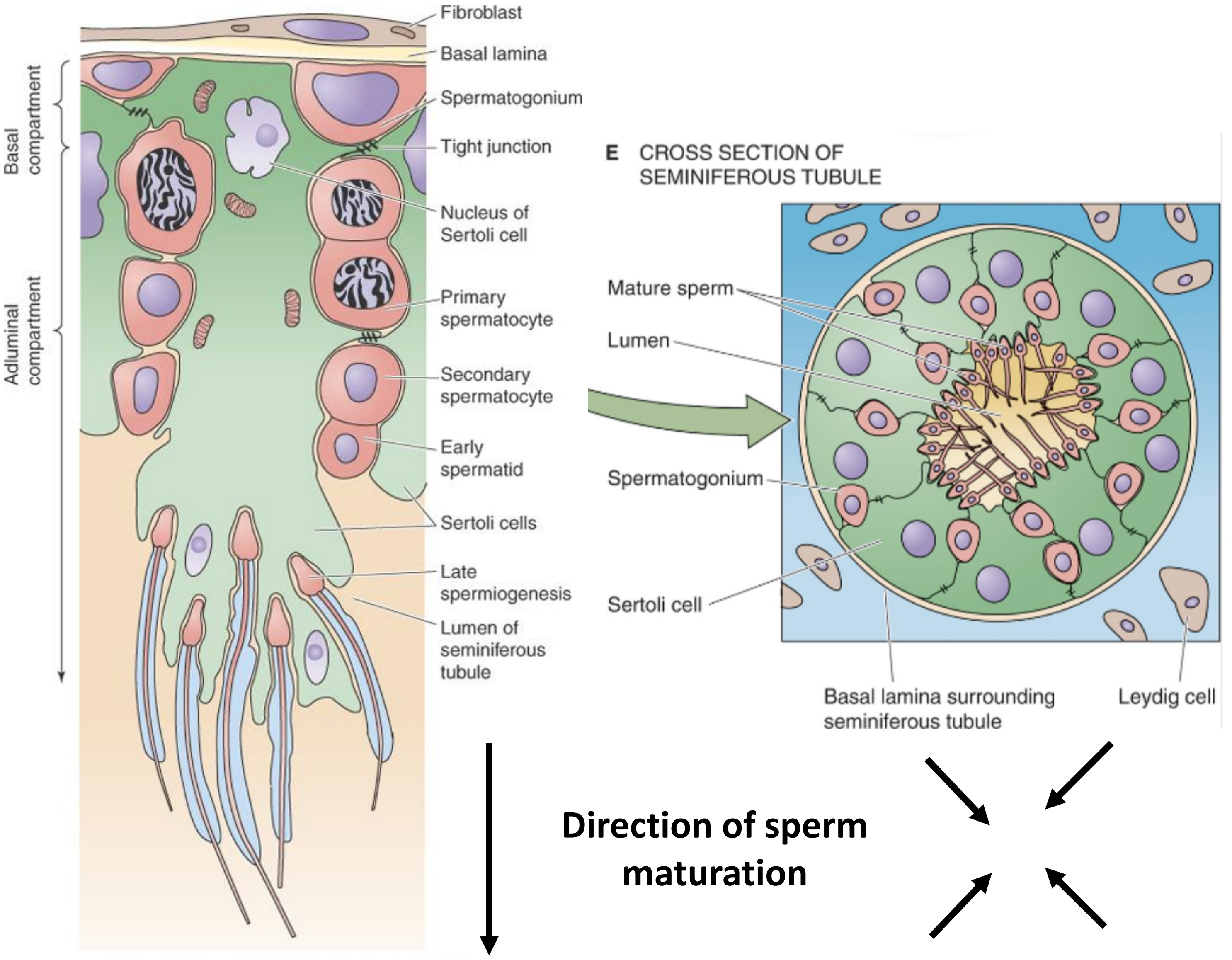
Human
sperm
cells

Spermatogenesis occurs in the seminiferous tubules

- Spermatogenesis is a progressive processing from immature *spermatogonium* (2n, after Meiosis I) to mature *spermatozoa* (n, after Meiosis II) toward the lumen of the tubule

- Transformation of spermatogonium to spermatozoa takes ~74 days

- Production rate 6.5 million sperm/gm testicular parenchyma/day (~200 million/day for average male)

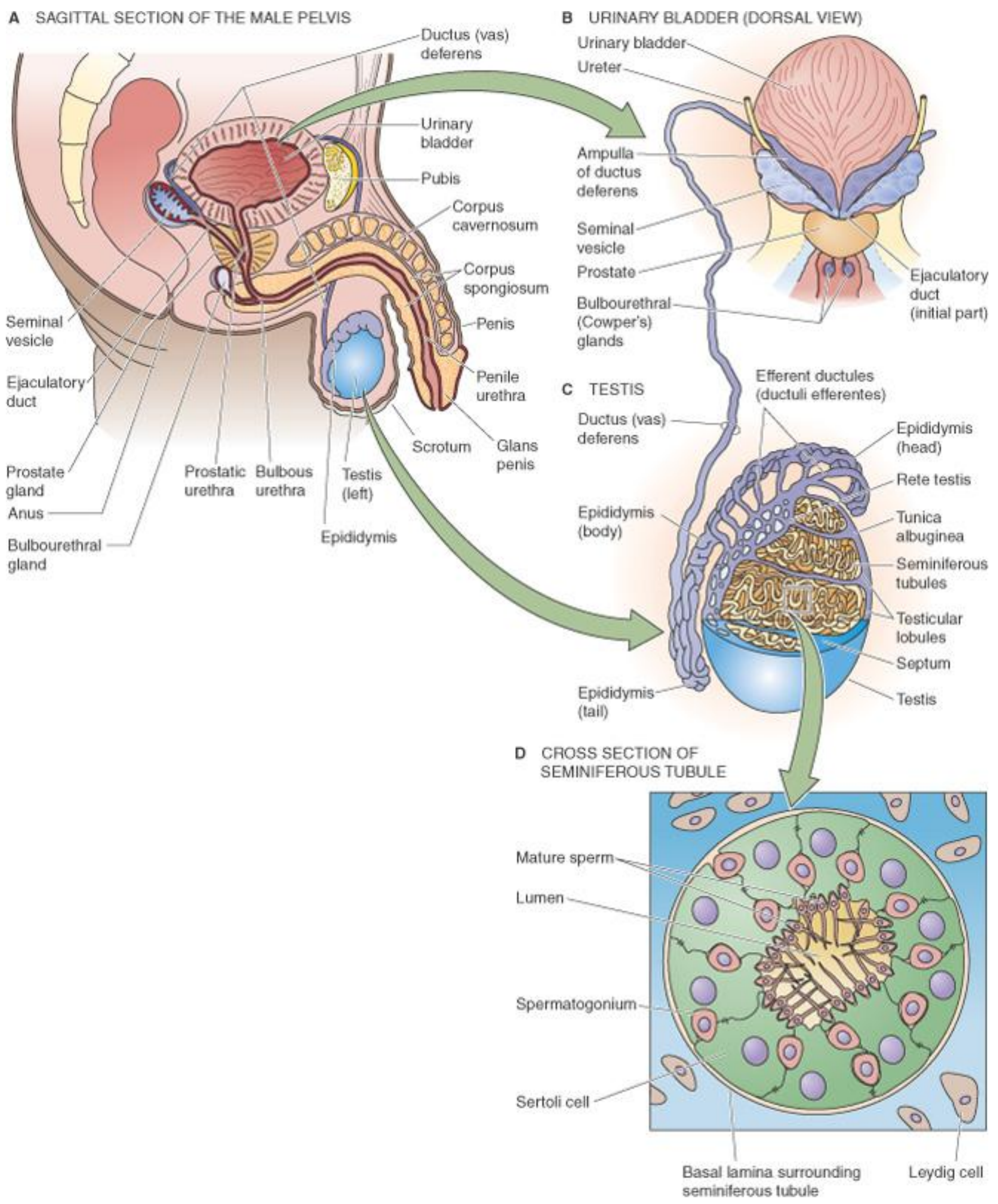


Sperm maturation and transport

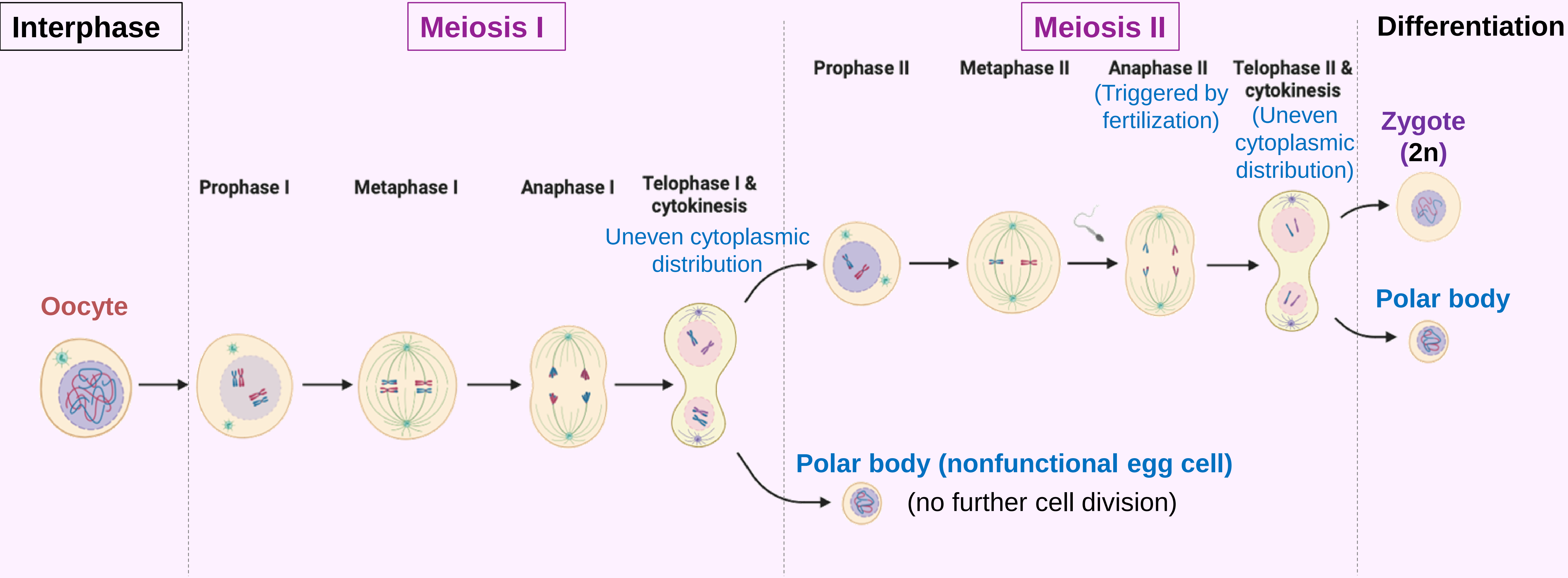
- Seminiferous tubules empty into testes, a reservoir which connects to the epididymis, where sperm maturation occurs (changes in motility, metabolism, morphology)

- Epididymis empties into vas deferens, which forms the ejaculatory duct
  - This is why a vasectomy (surgical closure of the vas deferens) is an effective form of male birth control

- Ejaculate contains *150-600 million* sperm



Meiosis I and II generate a single ovum (mature egg cell)



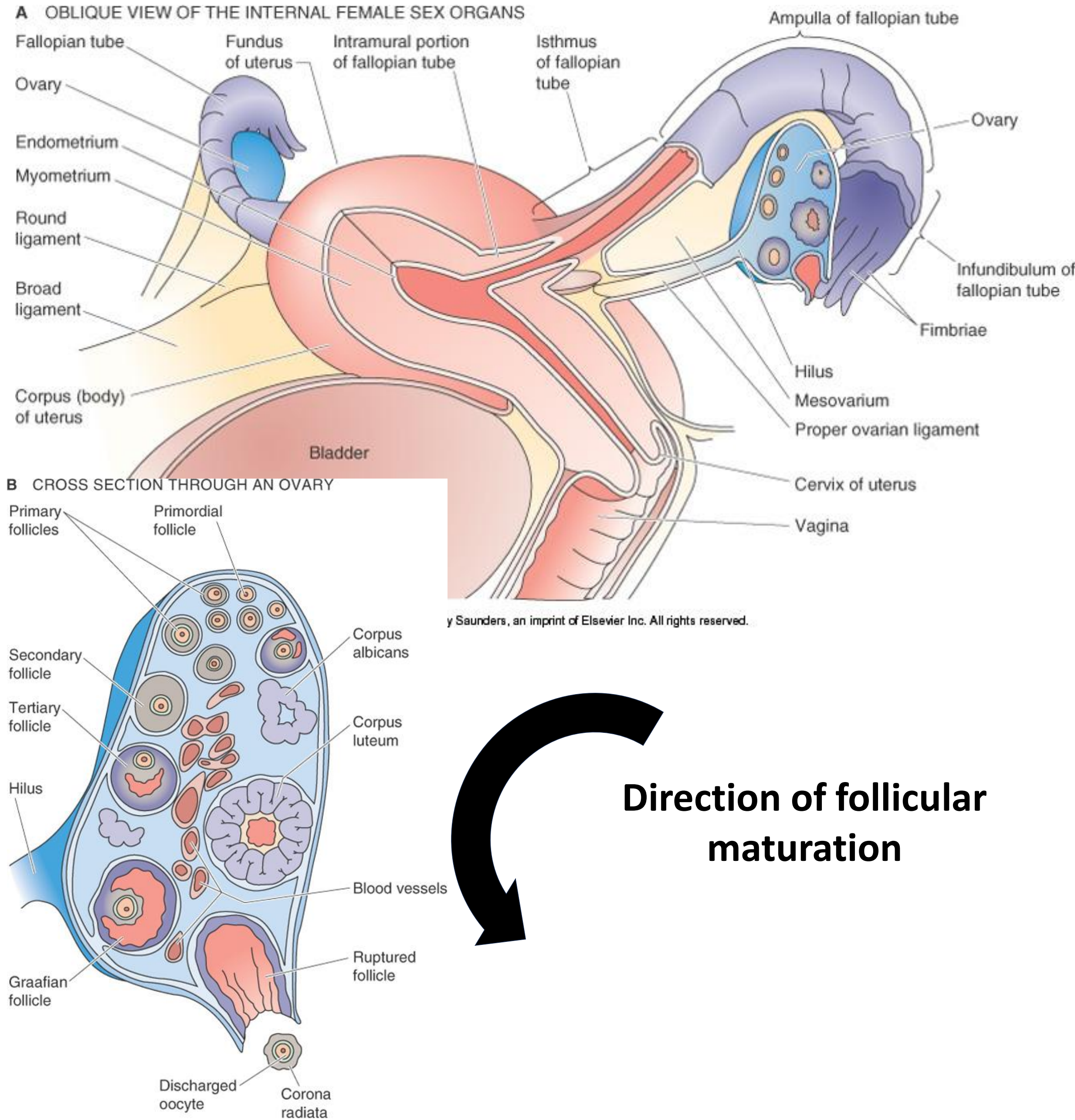
- The goal of Meiosis is for germ cells to produce gametes (n)

Oogenesis occurs in the ovaries

- All germ cell mitotic division occurs before birth in females, and these gametes are arrested in Prophase I of Meiosis I until puberty

- This means that all of the oocytes (immature female egg cells) are already formed by the time of birth and no more will be produced during life

- Follicles contain an oocyte and accessory cells and develop in stages, during which the oocyte increases in size and are stored in the ovaries until puberty



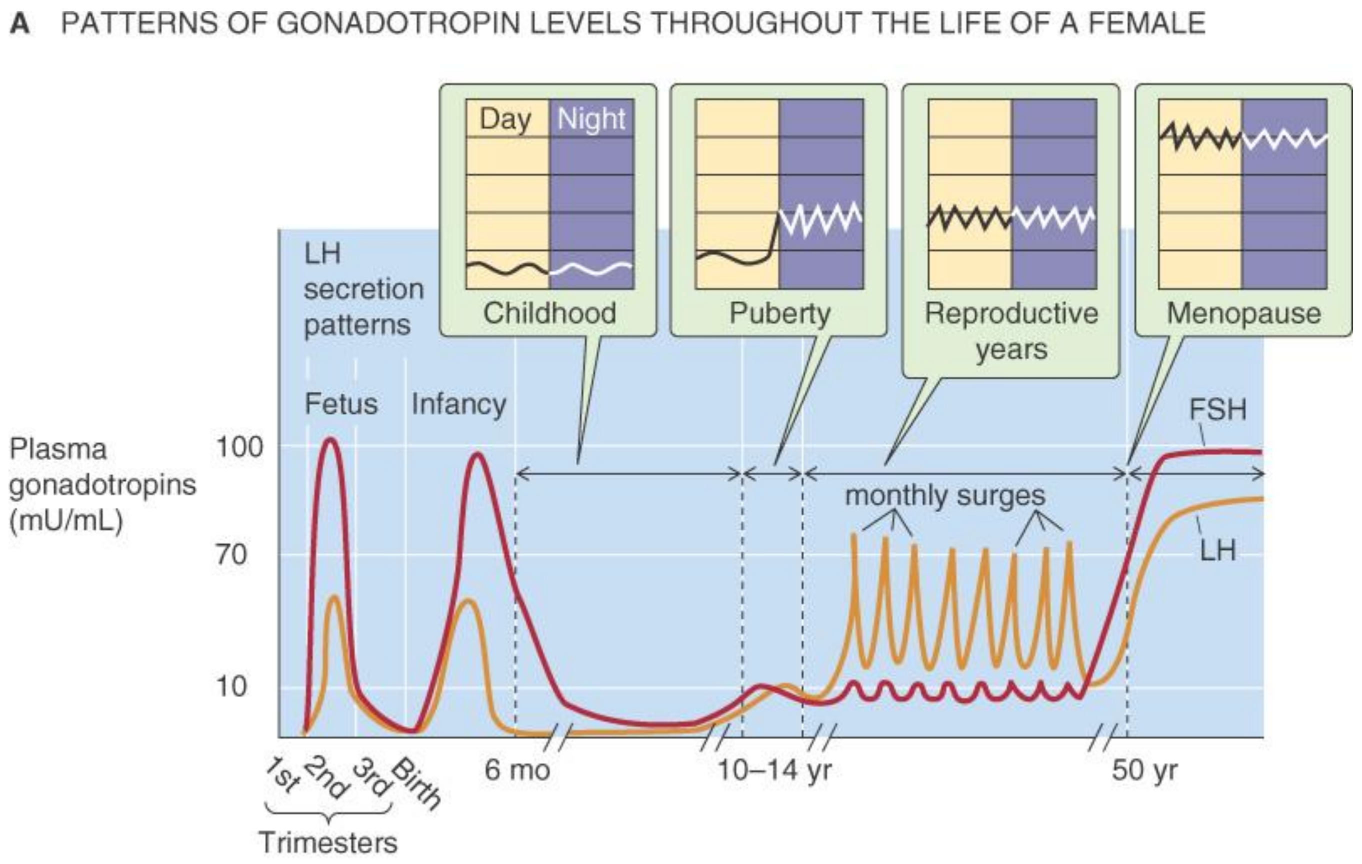
Gonadotropin Levels In Females

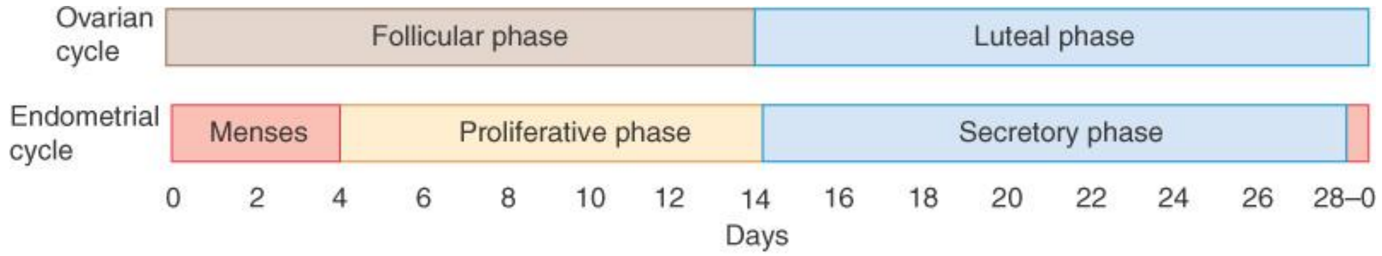
- Surges in levels of both Follicle Stimulate Hormone (**FSH**) and Luteinizing Hormone (**LH**) during intrauterine life and early postnatal period followed by low levels during childhood

- Nighttime pulsatile gonadotropin releasing hormone (GnRH) secretion marks onset of puberty

- Increase in pulsatile GnRH secretion leads to LH surge and first menstrual cycle

- Decrease in sensitivity to gonadal steroid inhibition of LH/FSH release with age (i.e., high levels during menopause)





Hormonal changes during the menstrual cycle

Ovary

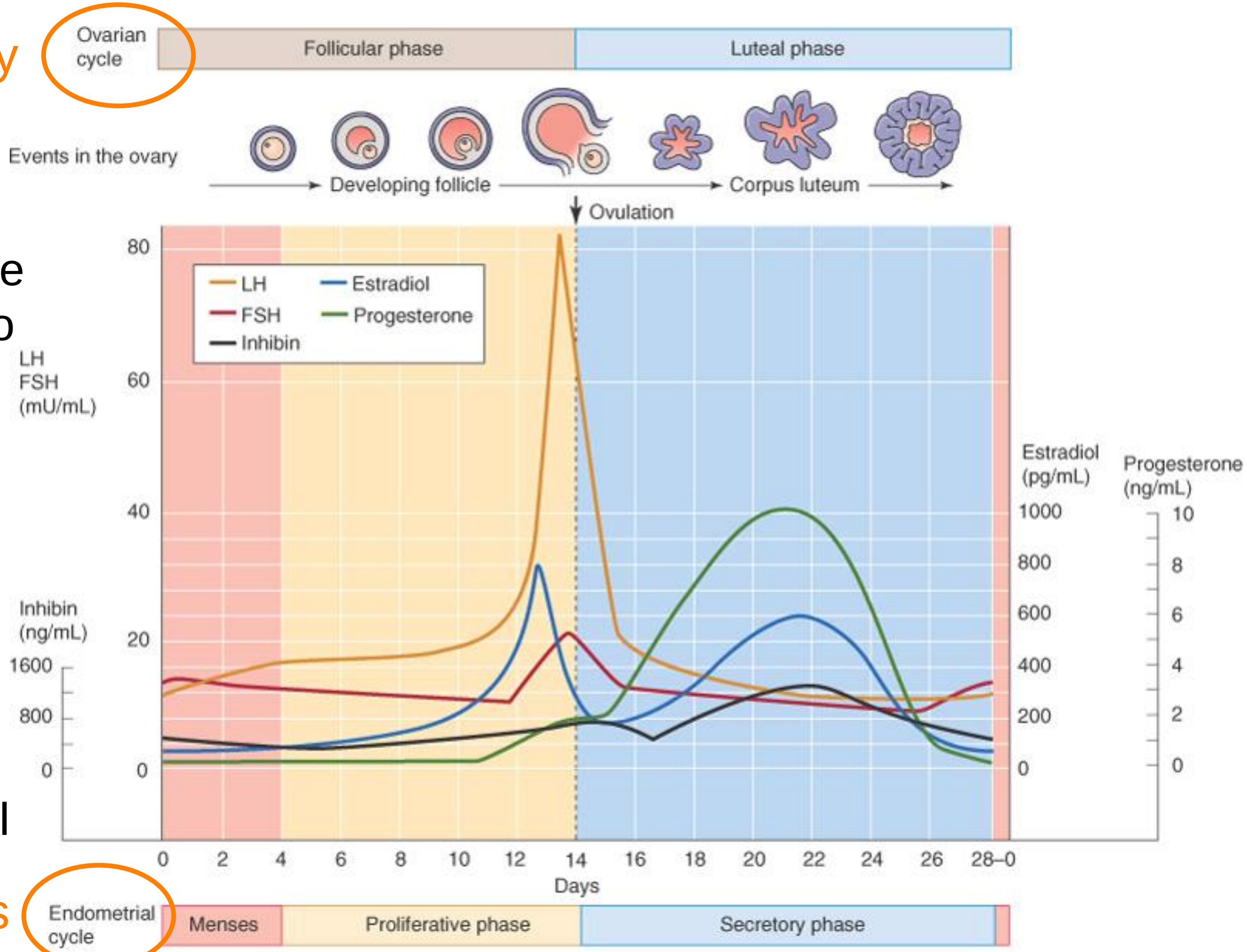
- Folliculogenesis begins with release of FSH

- Slowly rising LH levels rapidly spike following rise of estradiol leading to the luteal phase of the ovarian cycle and the secretory phase of the endometrial cycle

- Following the LH surge, progesterone levels increase to prepare for fertilization

- The cycle ends with the withdrawal of these sex steroids

Uterus



Key Differences Between Spermatogenesis and Oogenesis

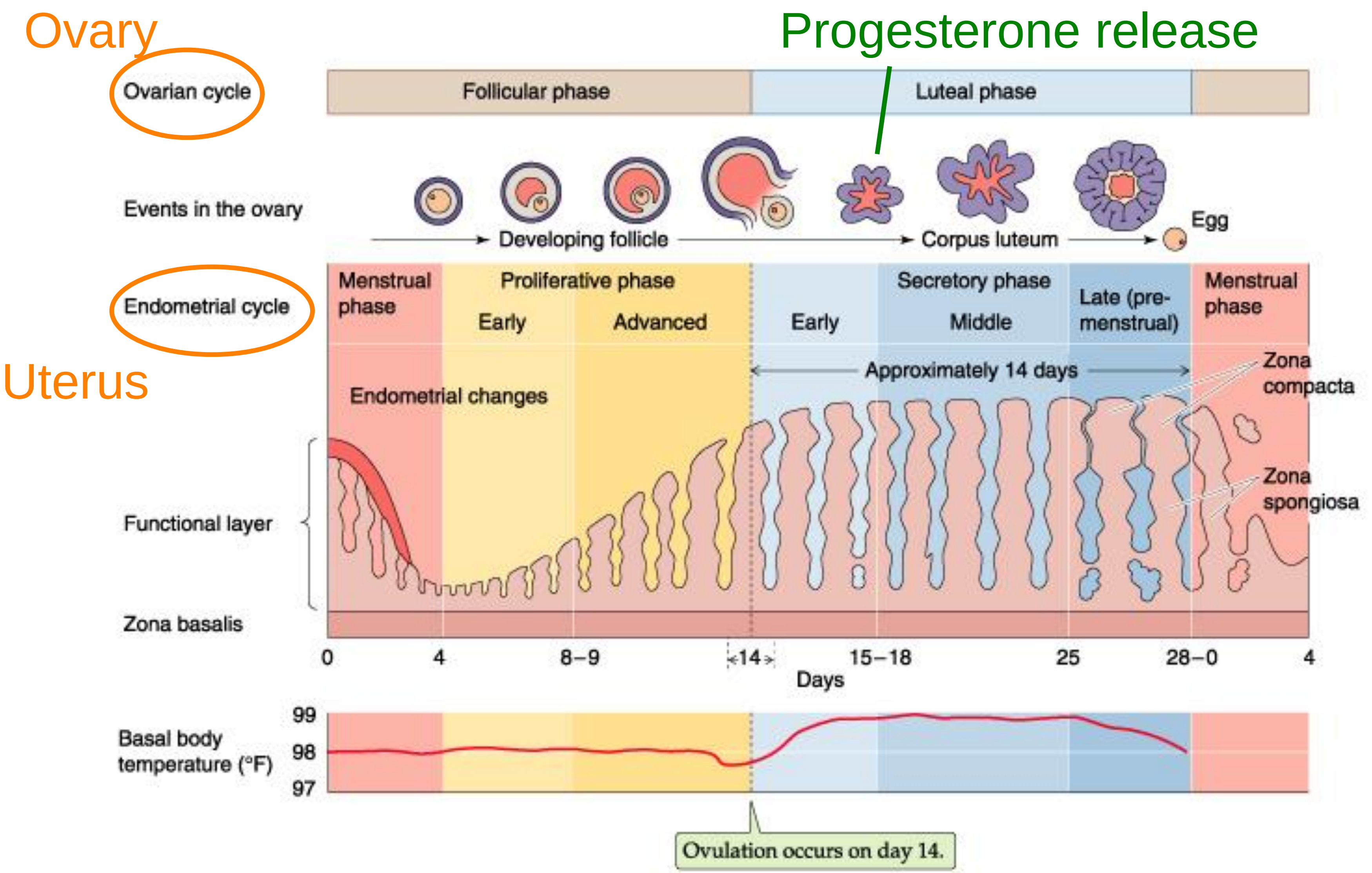
Spermatogenesis

- Proliferation of germ cells occurs after puberty and throughout adult life
- Meiotic divisions produce 4 spermatozoa
- Products of meiosis (spermatozoa) undergo maturation prior to fertilization

Oogenesis

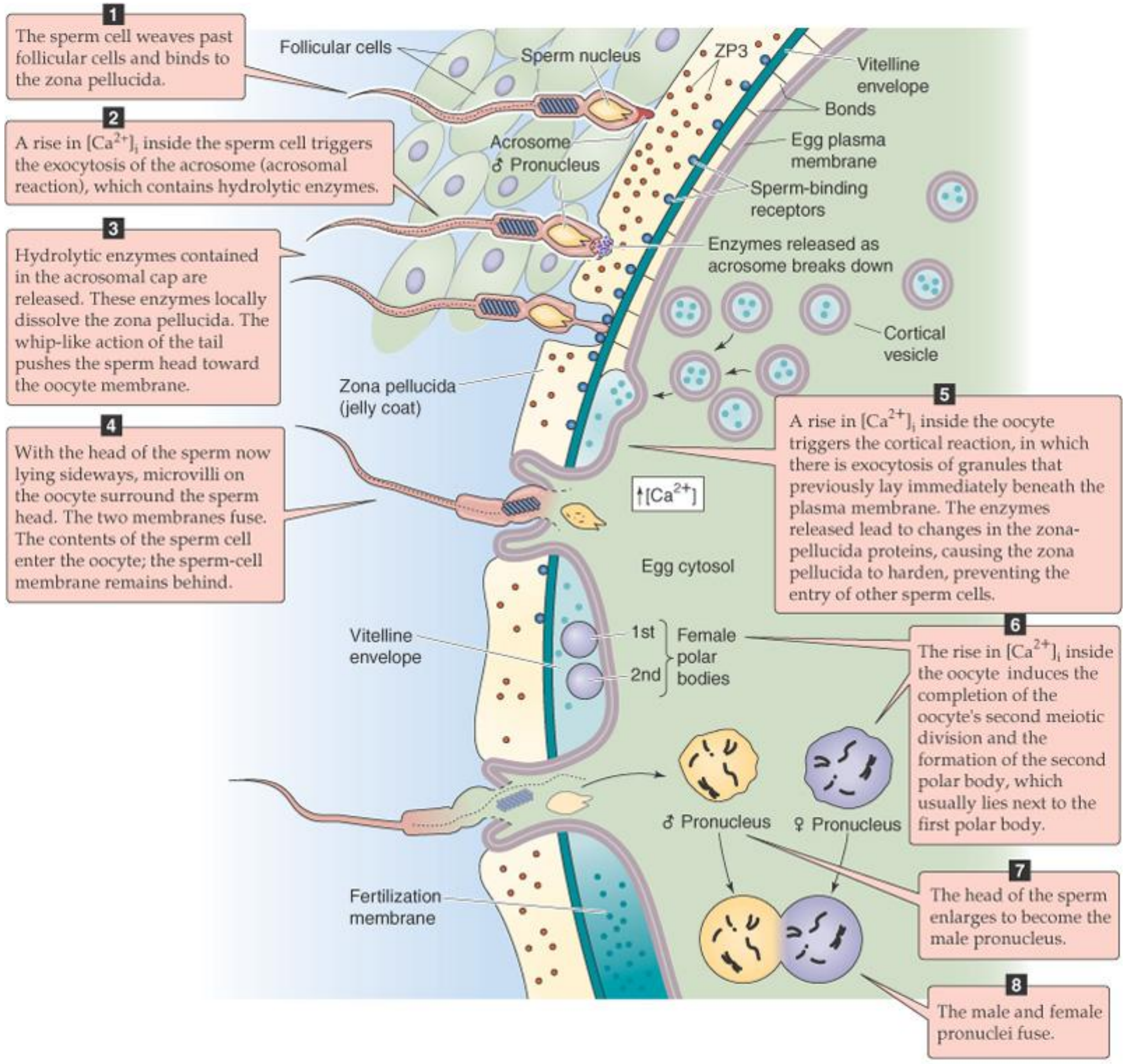
- Proliferation of germ cells occurs before birth
- Meiotic divisions produce 1 ovum
- Meiosis completed after fertilization; no maturation after completion of meiosis

The endometrium develops during the menstrual cycle to facilitate embryonic growth following fertilization

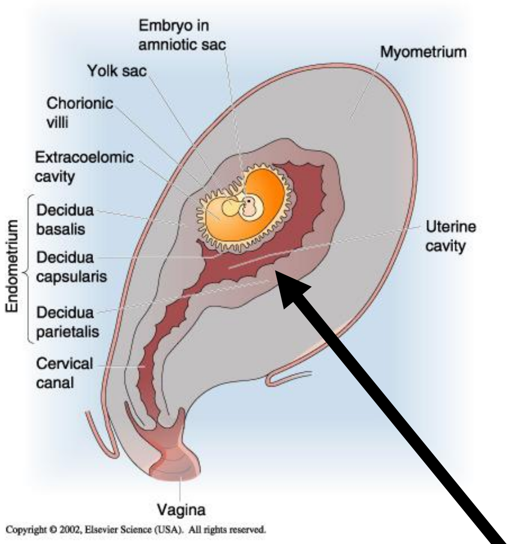


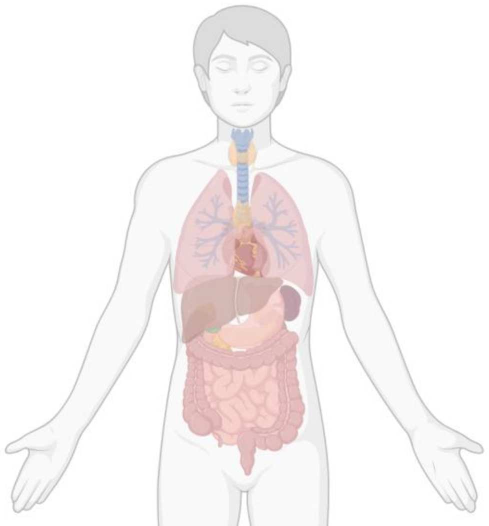
Fertilization: The fusion of haploid gametes

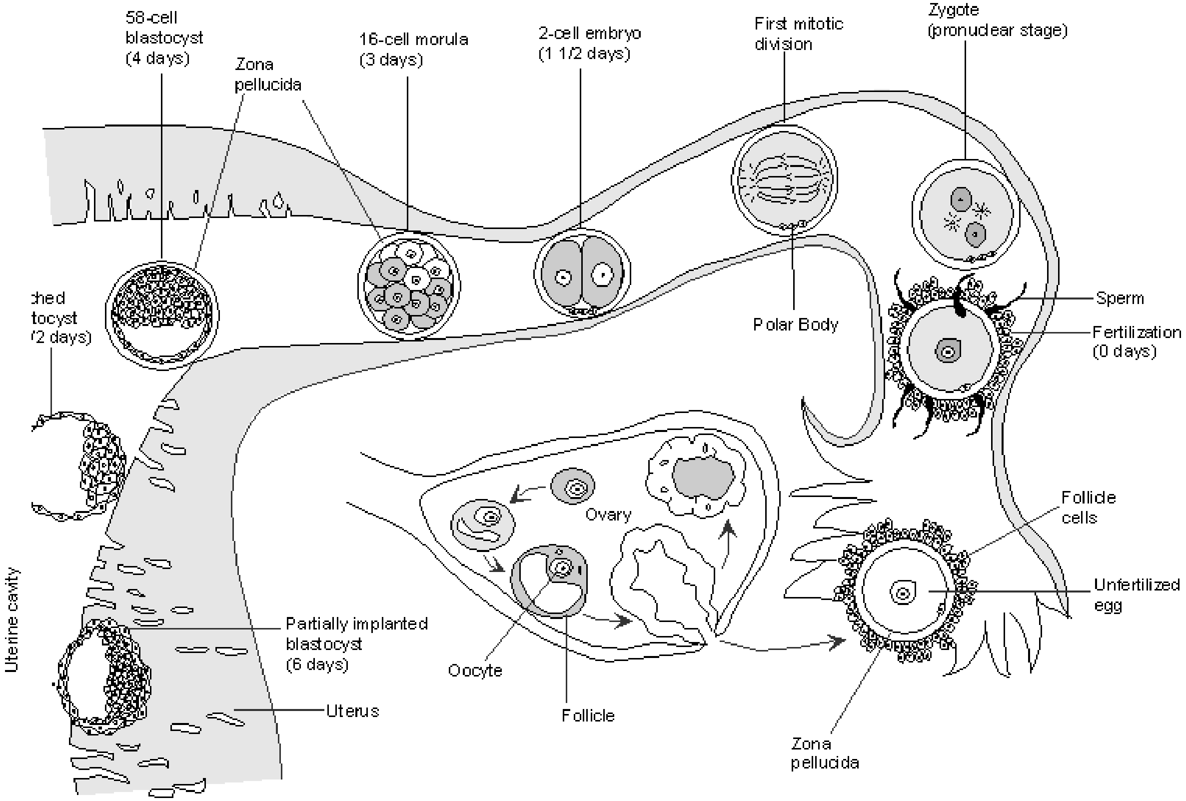
- 150-600 million sperm deposited in the vagina
- 50-100 sperm reach the fallopian tube within 5 min
- Interaction of sperm with egg features a series of chemical reactions leading to:
  - Exclusion of other sperm cell entry
  - Completion of oocyte's second meiotic division
  - Fusion of male and female pronuclei



Following fertilization the diploid zygote undergoes mitotic divisions to form the embryo







Sexual reproduction creates genetically unique individuals

- The sets of genes on each homologous chromosome are the same, but the maternal and paternal versions are not

- <u>Sexual reproduction generates novel chromosome combinations:</u>
  - Inheritance of different combinations of alleles
  - Genetic mixing events in meiosis
  - New fusion events (fertilization) to repeat the process

Metacognitive Reflection Form