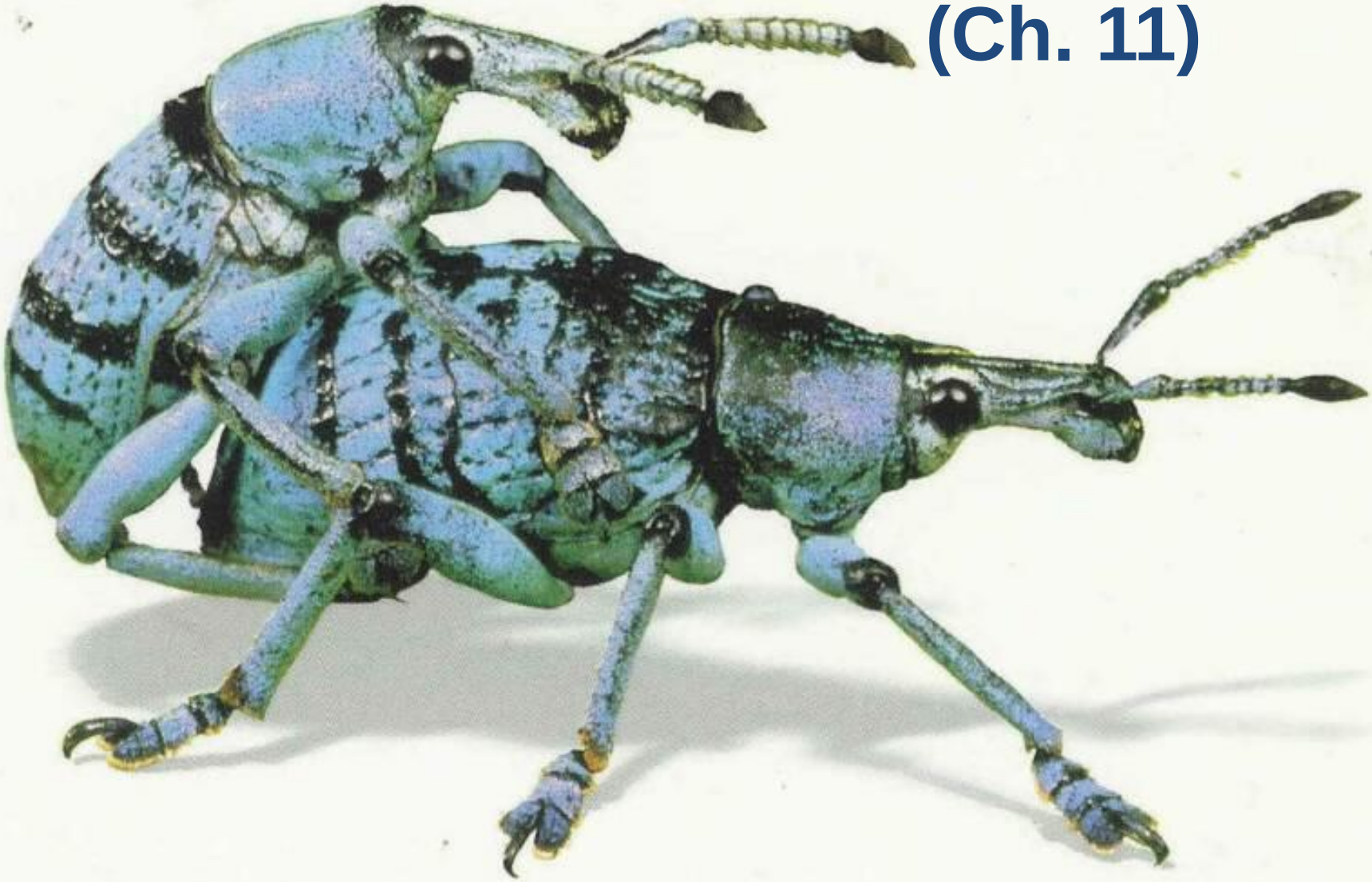
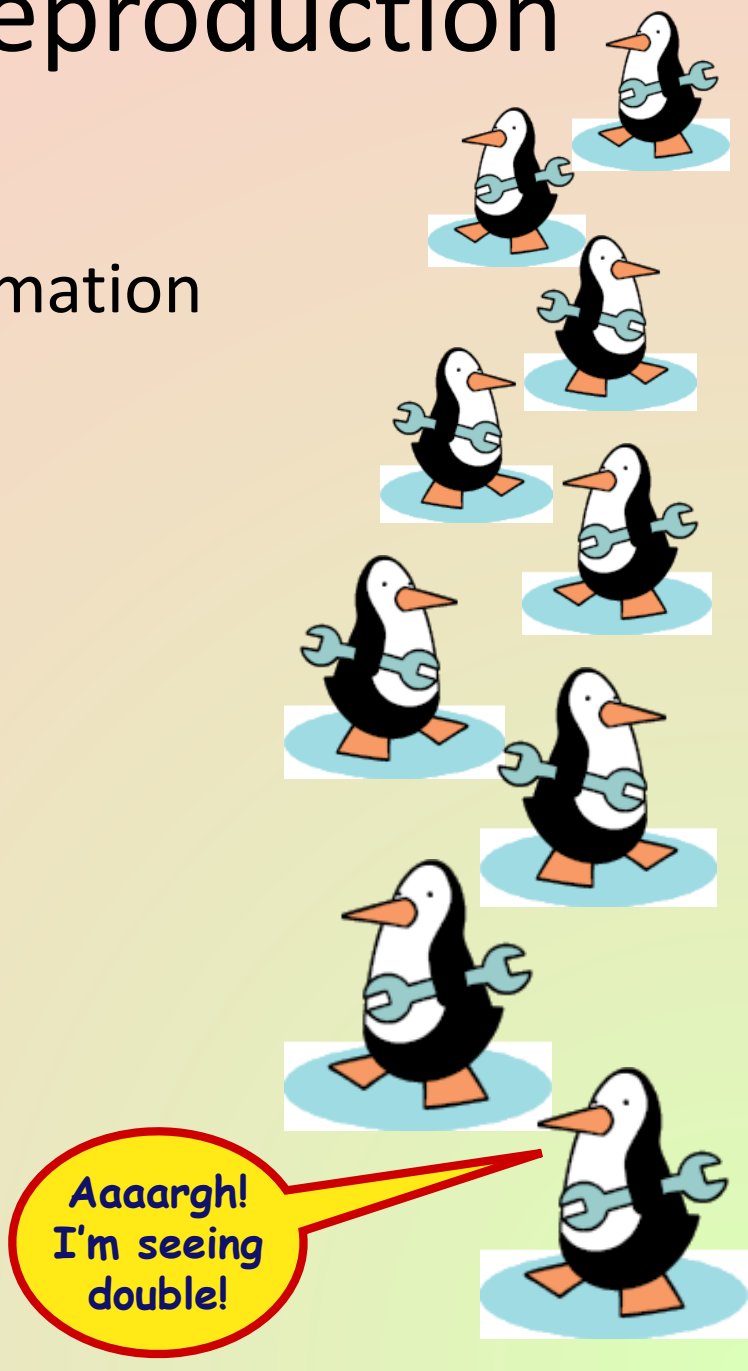
Meiosis & Sexual Reproduction (Ch. 11)



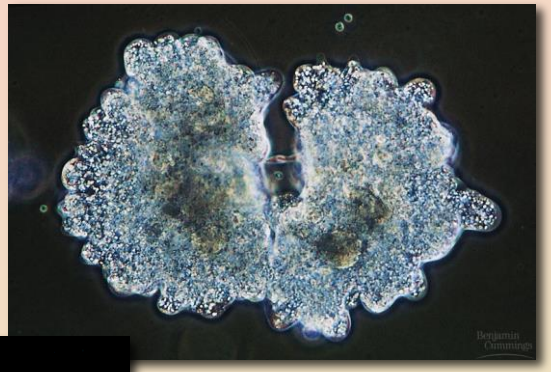
Cell division / Asexual reproduction

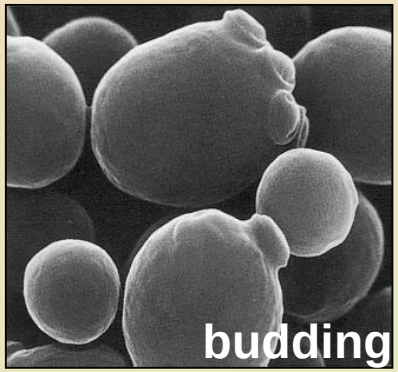
- Mitosis
  - produce cells with same information
    - identical daughter cells
  - exact copies
    - clones
  - same DNA

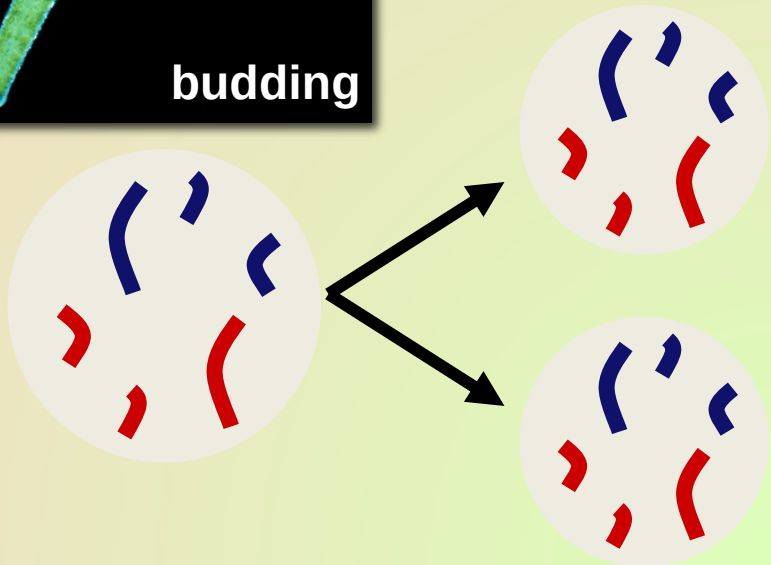


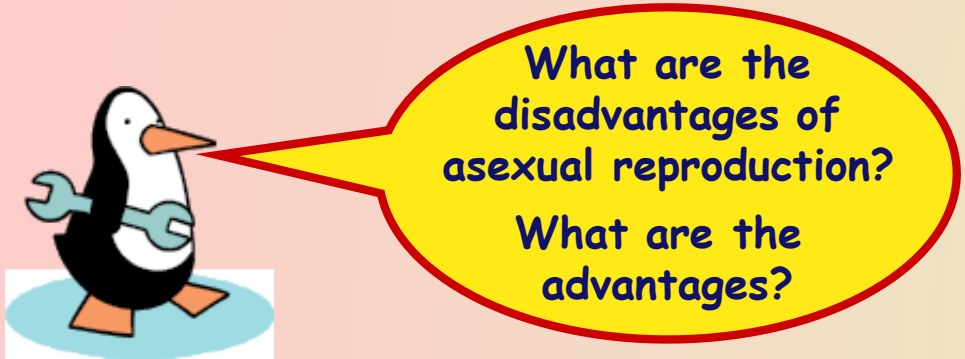
Asexual reproduction

- Single-celled eukaryotes
  - yeast (fungi)
  - Protists
    - *Paramecium*
    - *Amoeba*
- Simple <u>multicellular</u> eukaryotes
  - *Hydra*







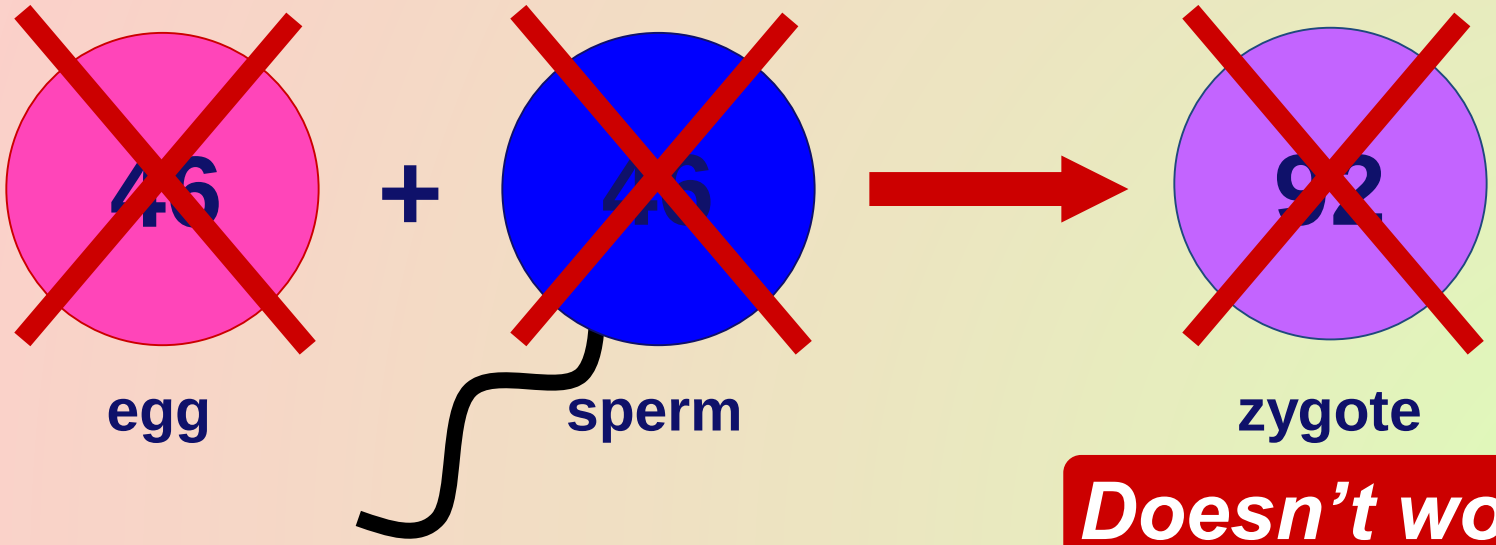


How about the rest of us?

- What if a complex multicellular organism (like us) wants to reproduce?
  - joining of egg + sperm
- Do we make egg & sperm by mitosis?

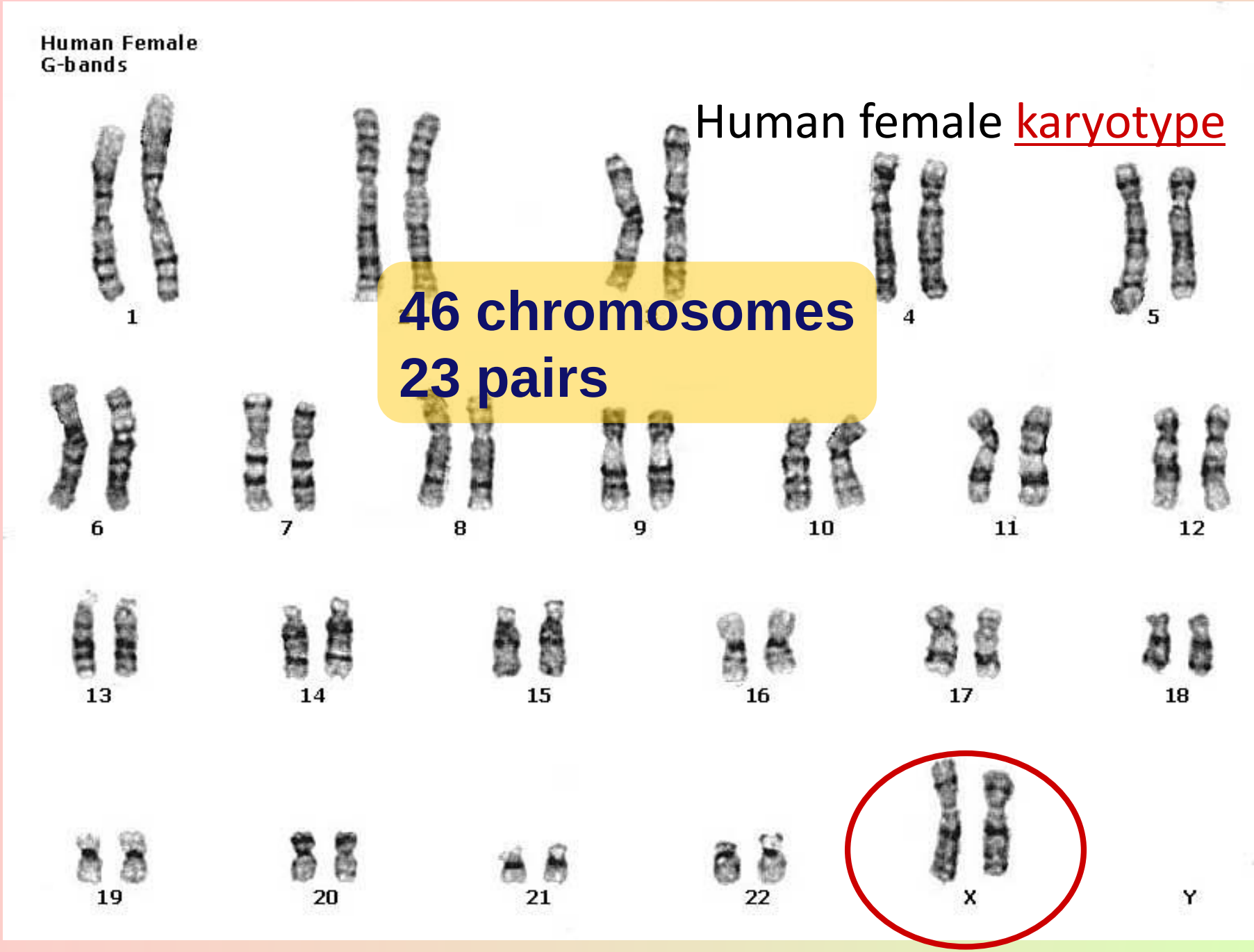
No!

What if we did, then….



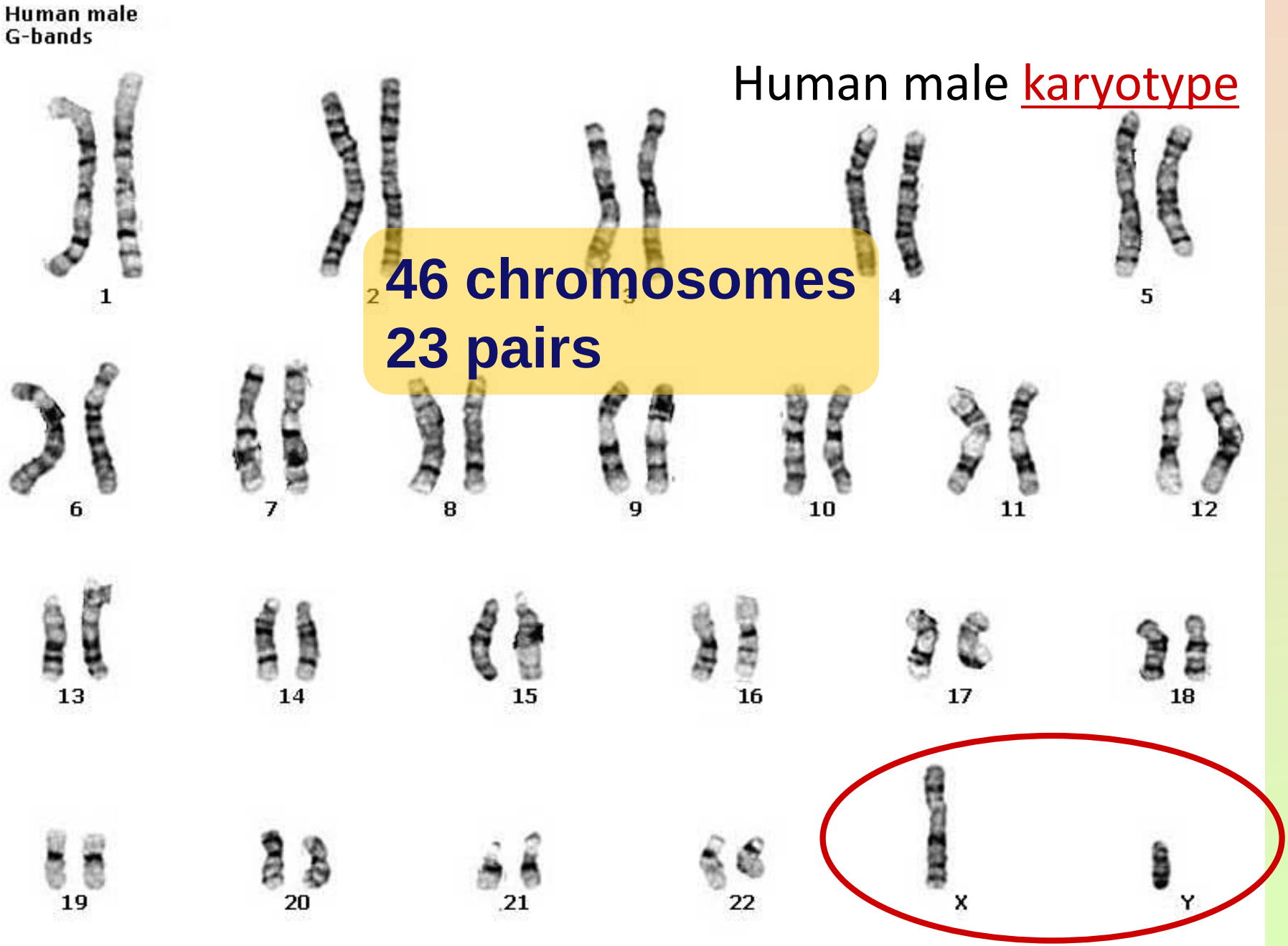
Doesn't work!

Human female karyotype



46 chromosomes
23 pairs

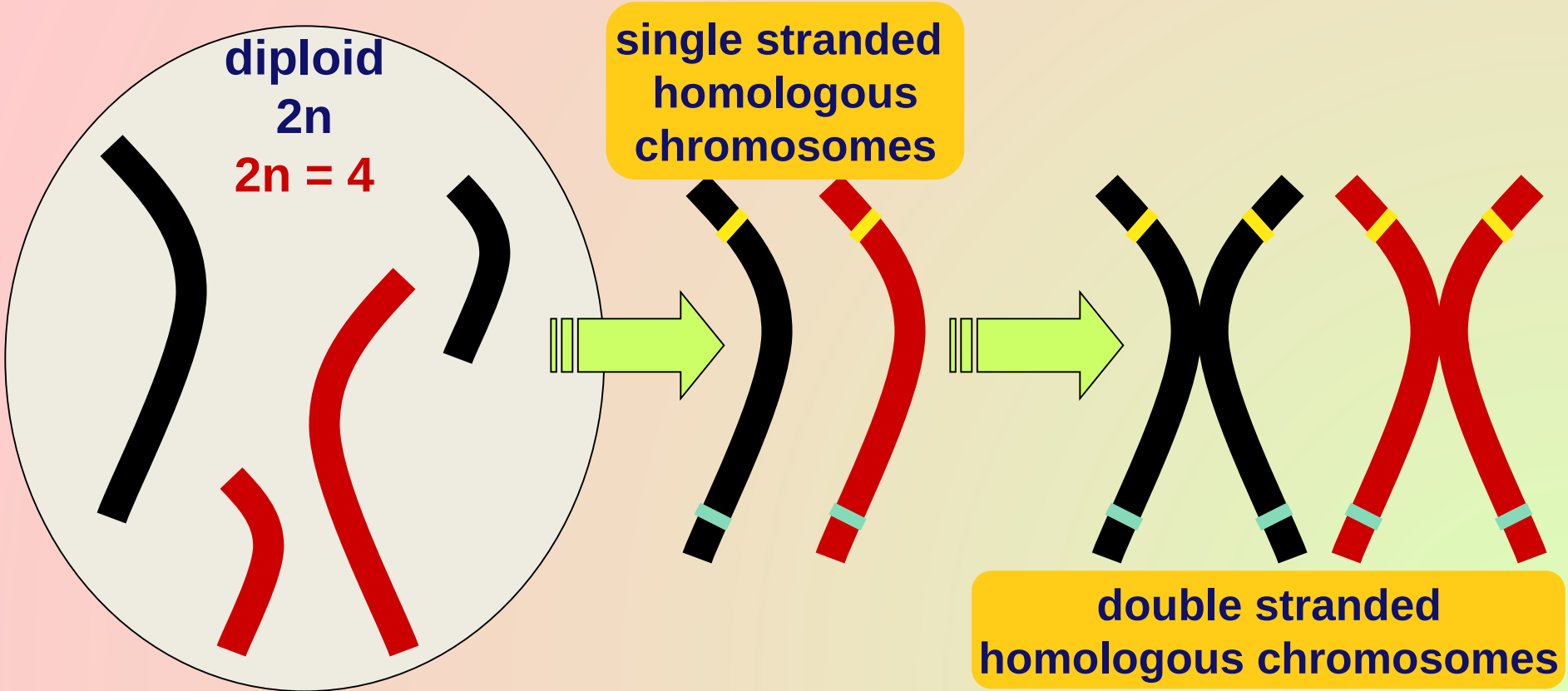
Human male karyotype



46 chromosomes
23 pairs

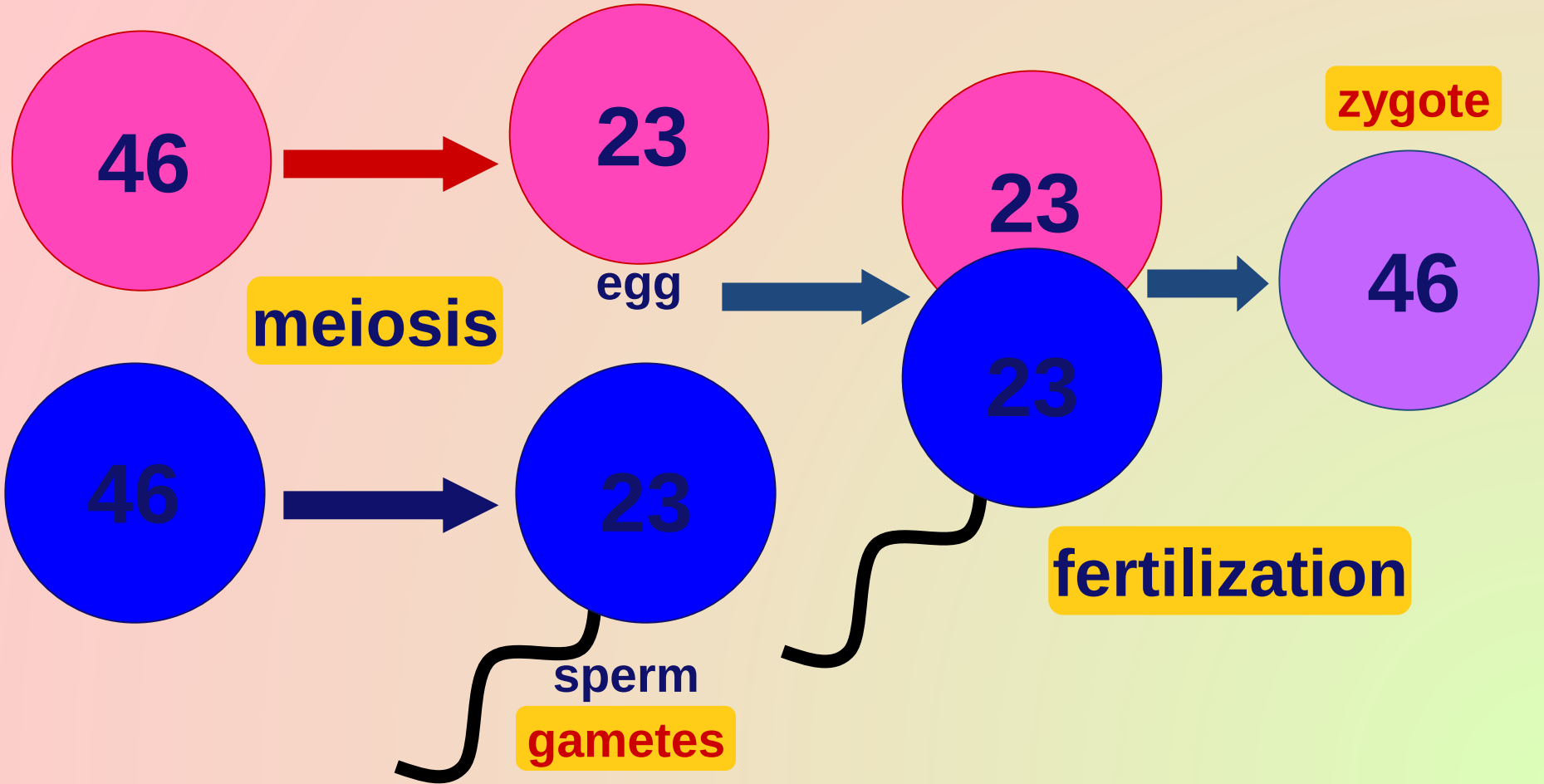
Homologous chromosomes

- Paired chromosomes
  - both chromosomes of a pair carry “matching” genes
    - control same inherited characters
    - homologous = same information



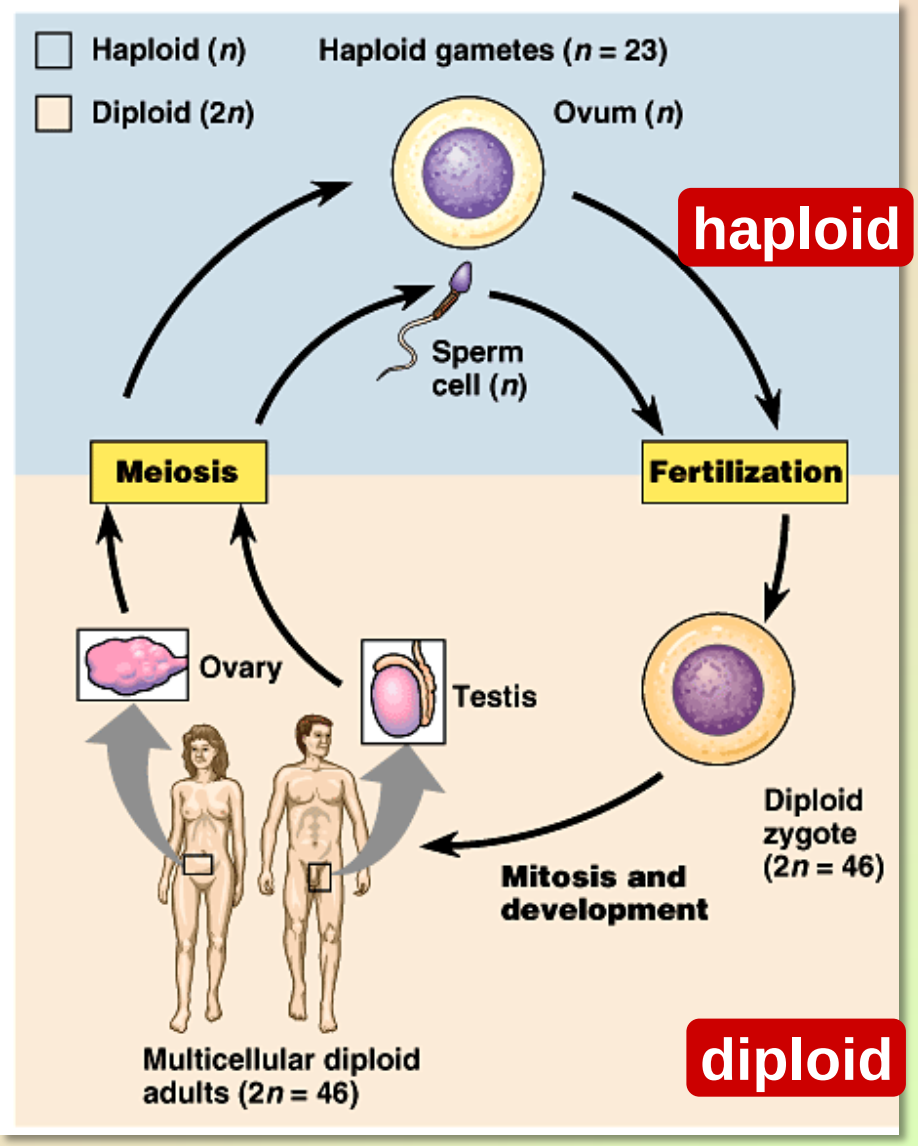
How do we make sperm & eggs?

- Must reduce 46 chromosomes → 23
  - must reduce the number of chromosomes by half

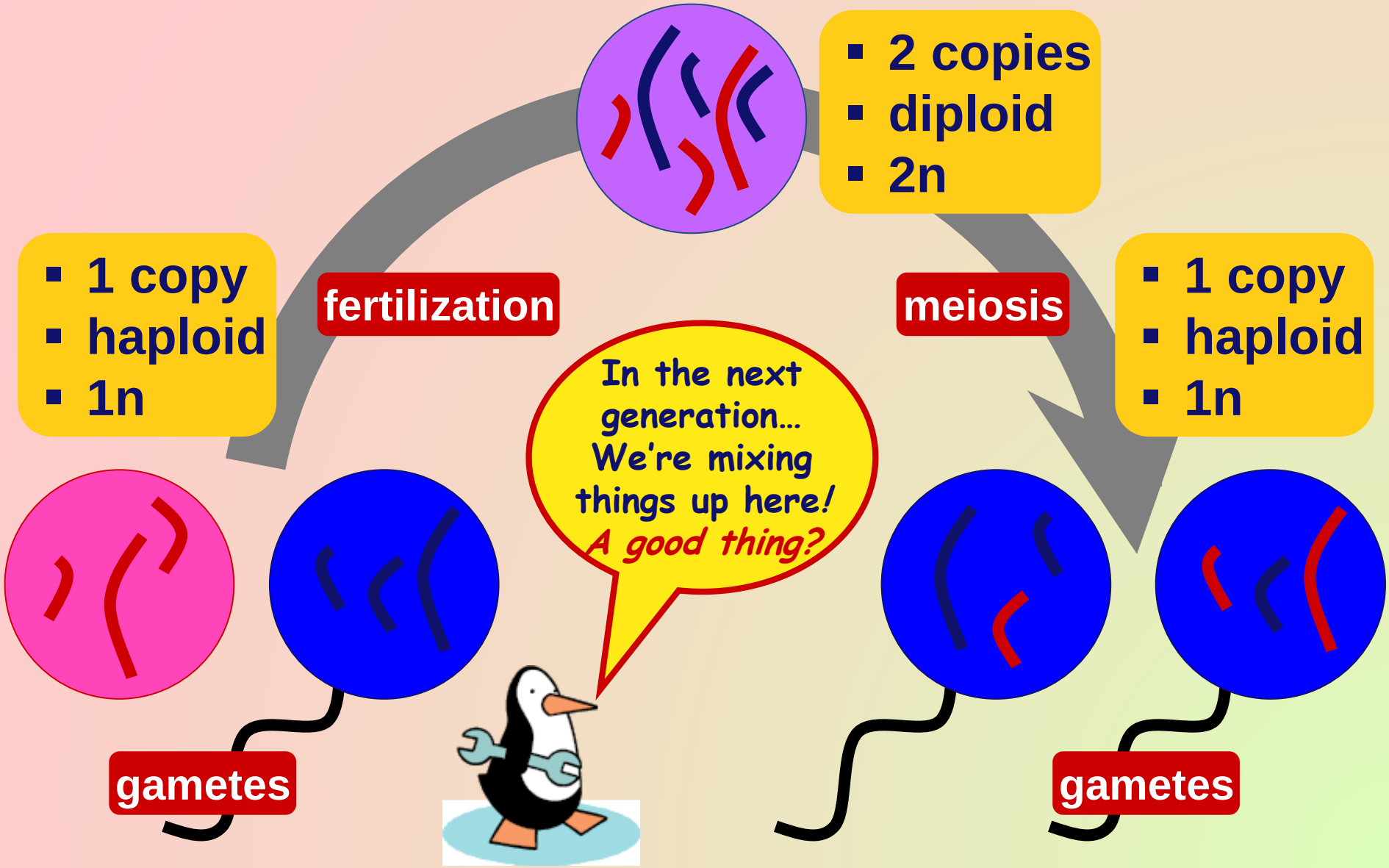


Meiosis: production of gametes

- Meiosis
  - chromosome number must be reduced
    - diploid → haploid
    - 2n → n
      - humans: 46 → 23
    - makes gametes
  - fertilization restores chromosome number
    - haploid → diploid
    - n → 2n

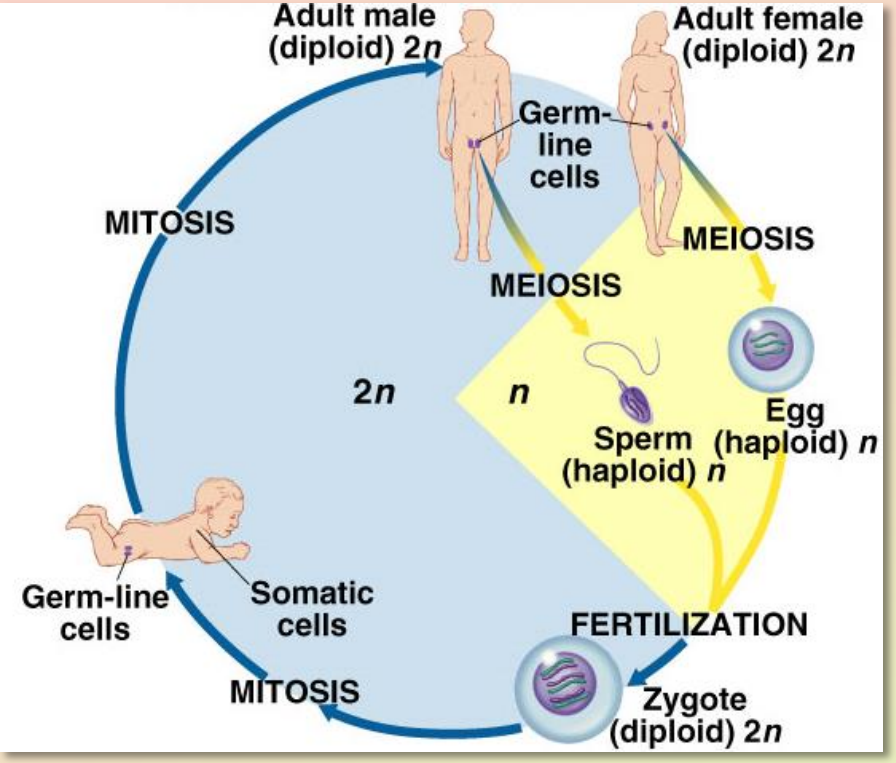


Sexual reproduction lifecycle



Meiosis

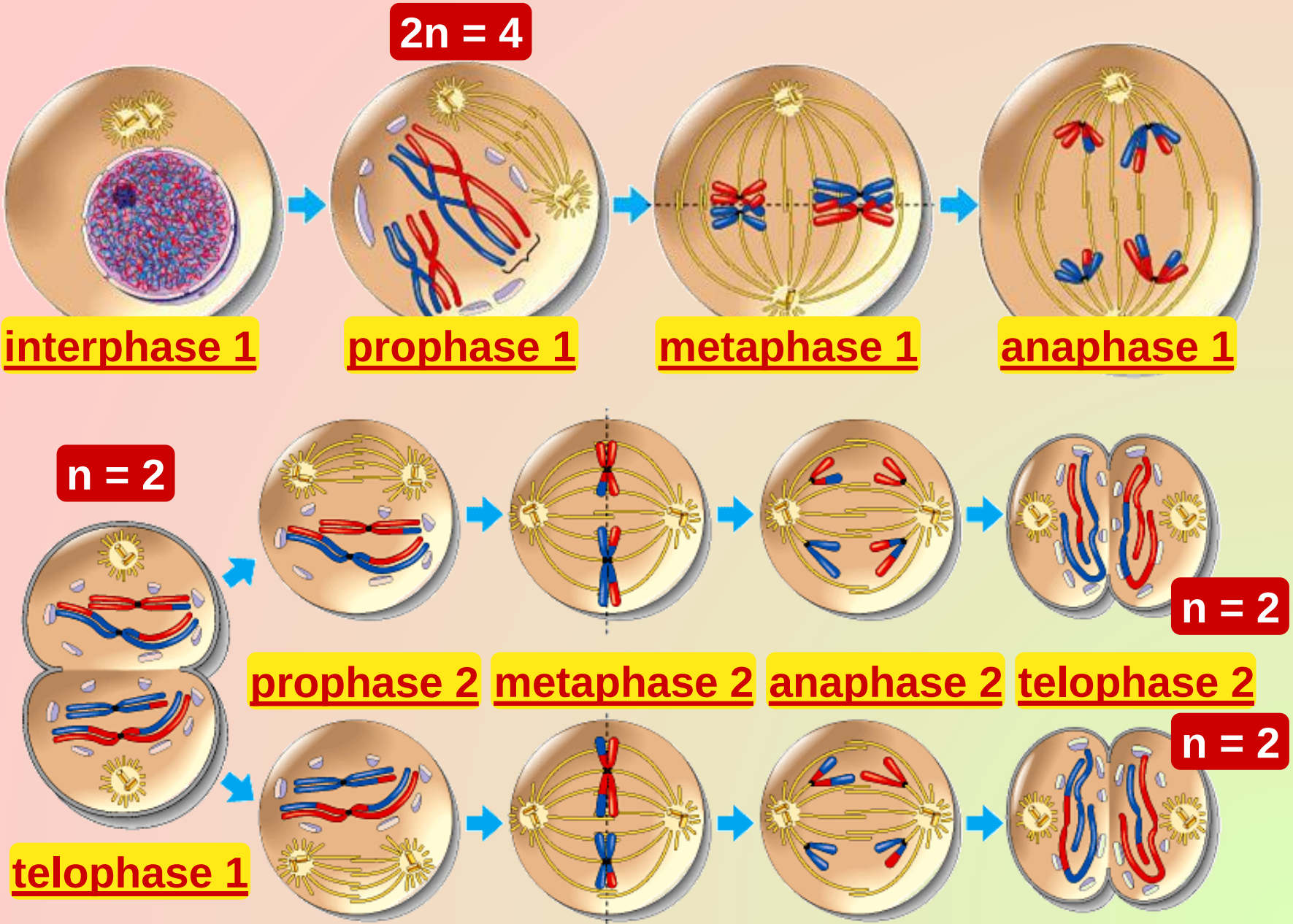
- Reduction Division
  - special cell division for sexual reproduction
  - reduce 2n → 1n
  - diploid → haploid
    - "two" → "half"
  - makes gametes
    - sperm, eggs



Warning: meiosis evolved from mitosis, so stages & "machinery" are similar but the processes are radically different. Do not confuse the two!

Overview of meiosis

I.P.M.A.T.P.M.A.T

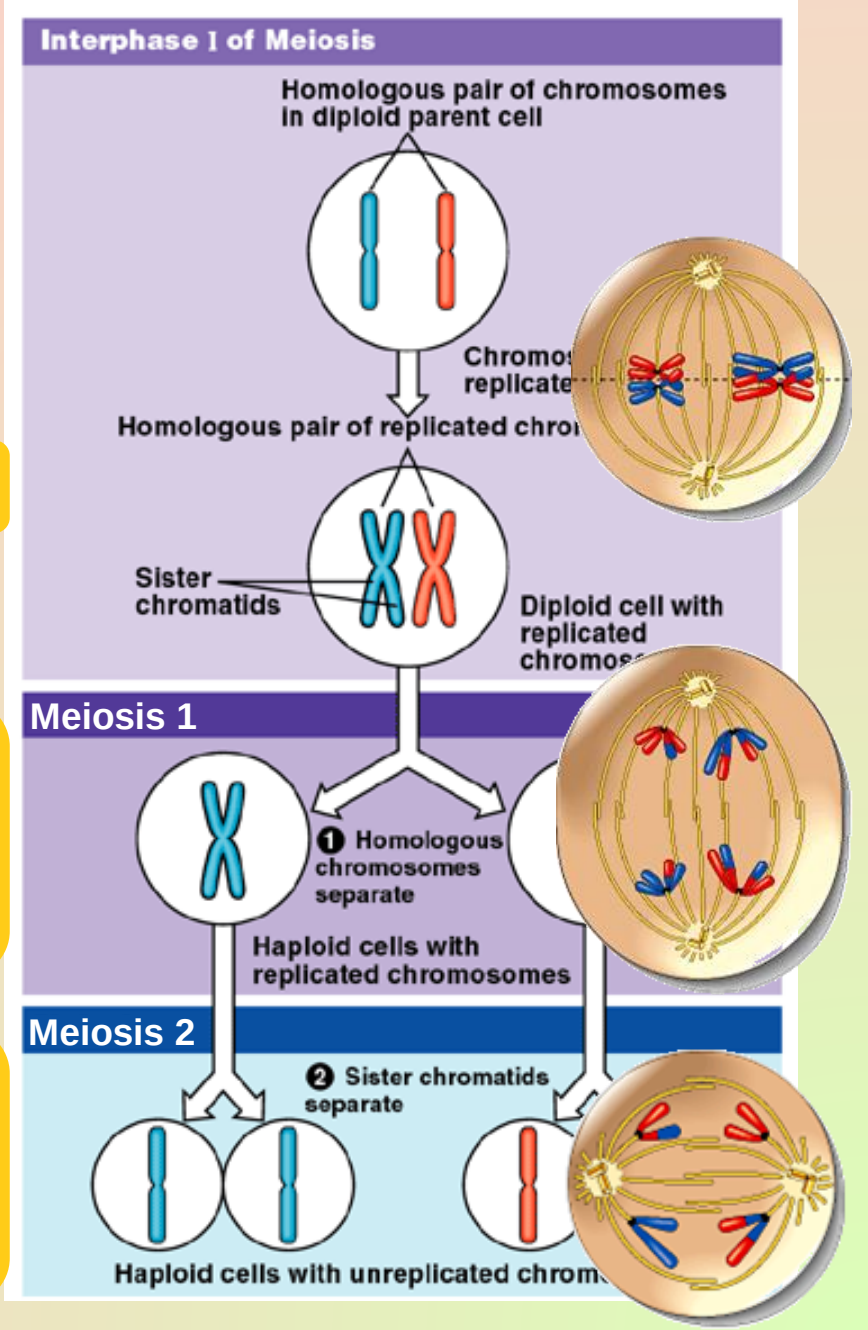


Double division of meiosis

DNA replication

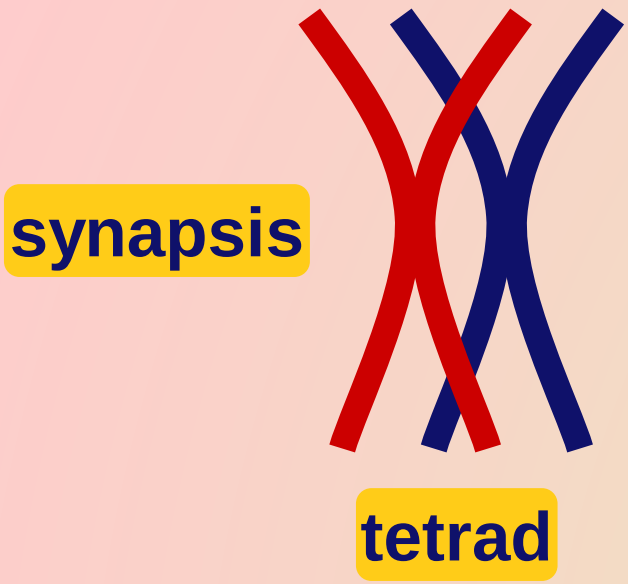
1st division of meiosis separates homologous pairs

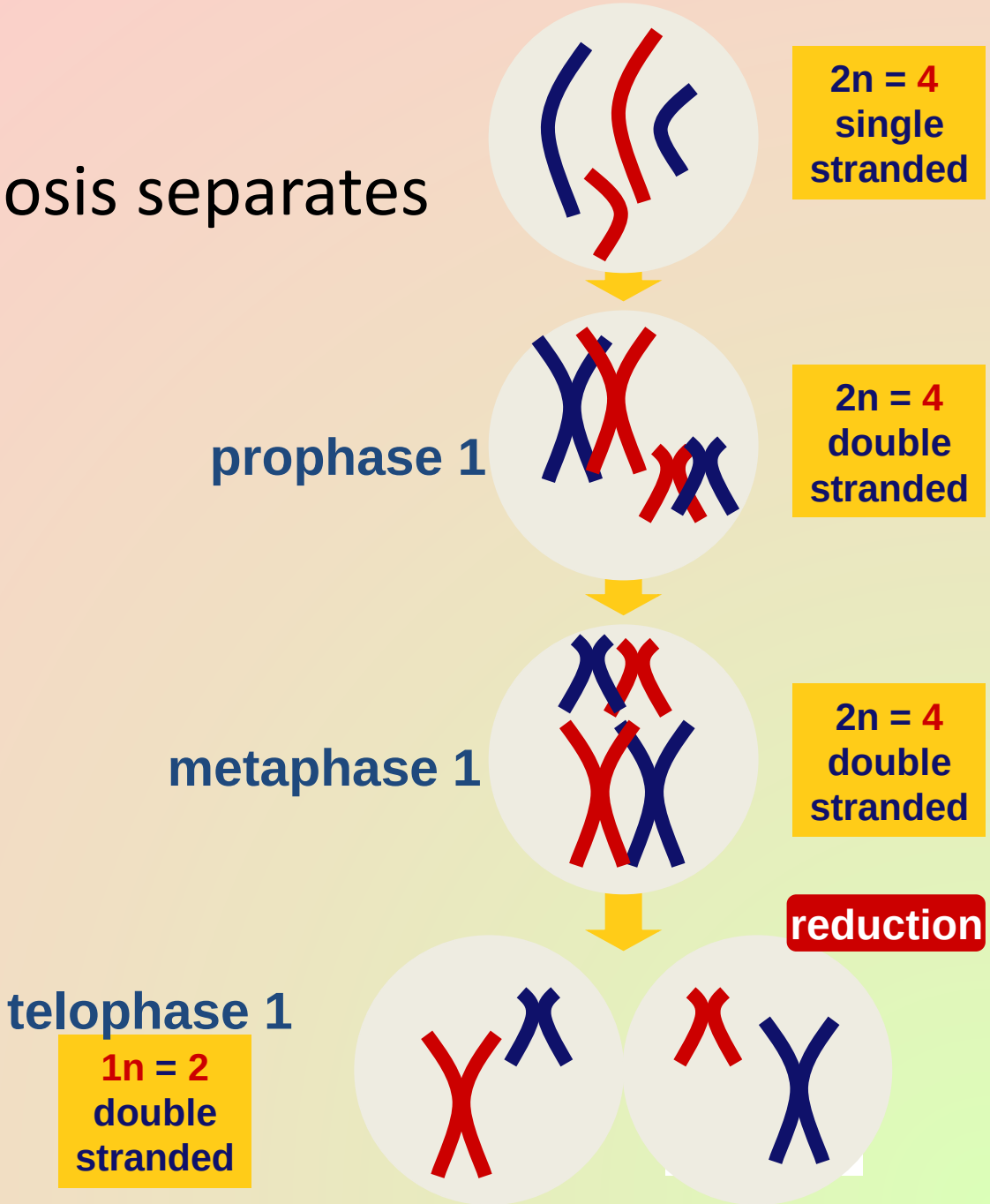
2nd division of meiosis separates sister chromatids



Meiosis 1

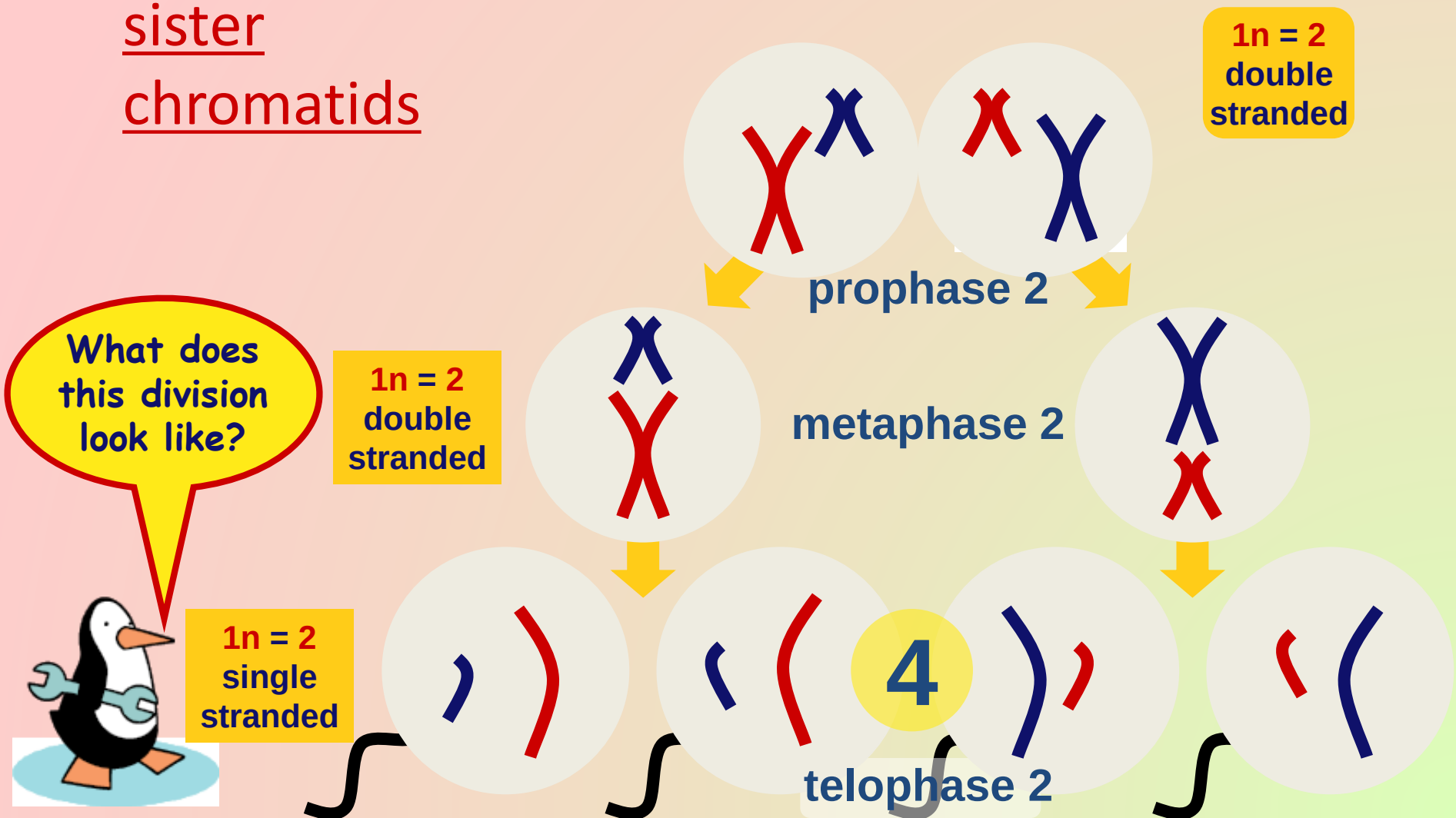
- 1st division of meiosis separates homologous pairs





Meiosis 2

- 2nd division of meiosis separates <u>sister chromatids</u>



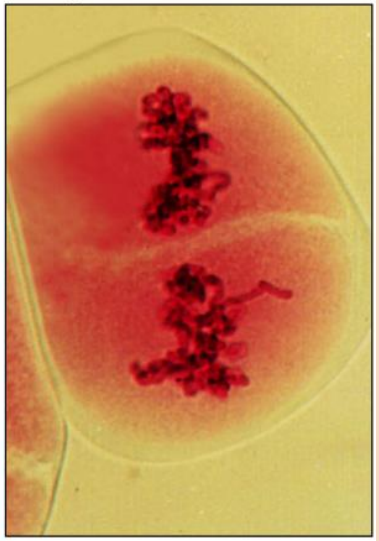
Meiosis 1 & 2

Prophase I

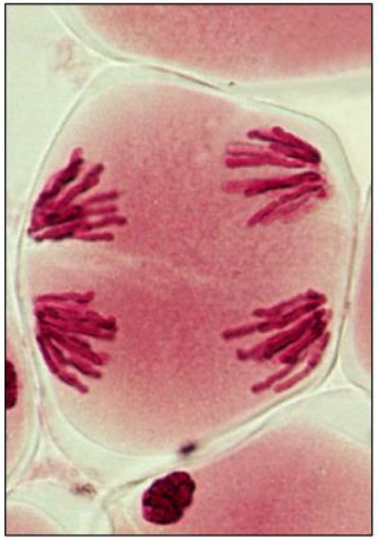
Metaphase I

Anaphase I

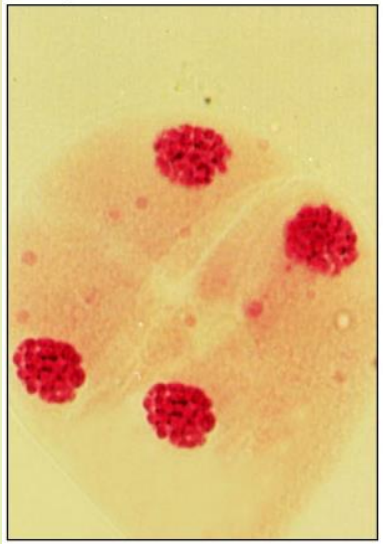
Metaphase II



Anaphase II

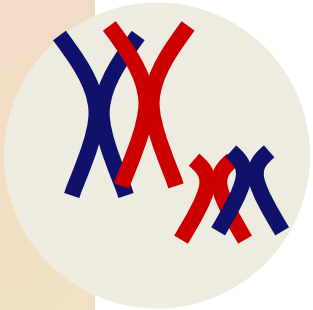


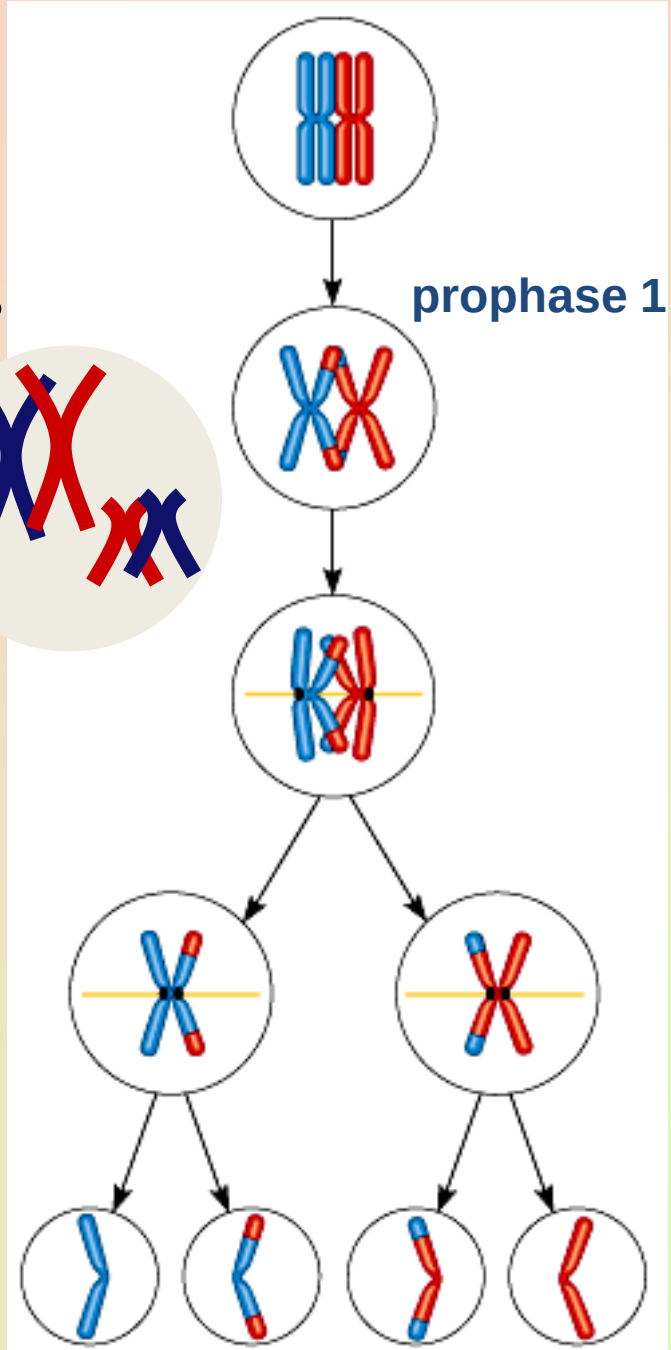
Telophase II

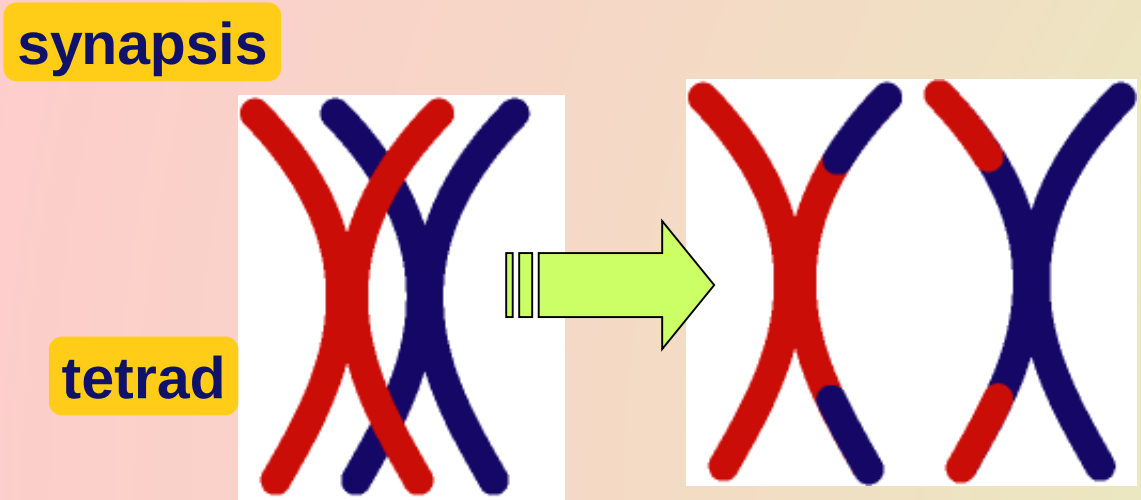


Trading pieces of DNA

- Crossing over
  - during Prophase 1, sister chromatids intertwine
    - homologous pairs swap pieces of chromosome
      - DNA breaks & re-attaches

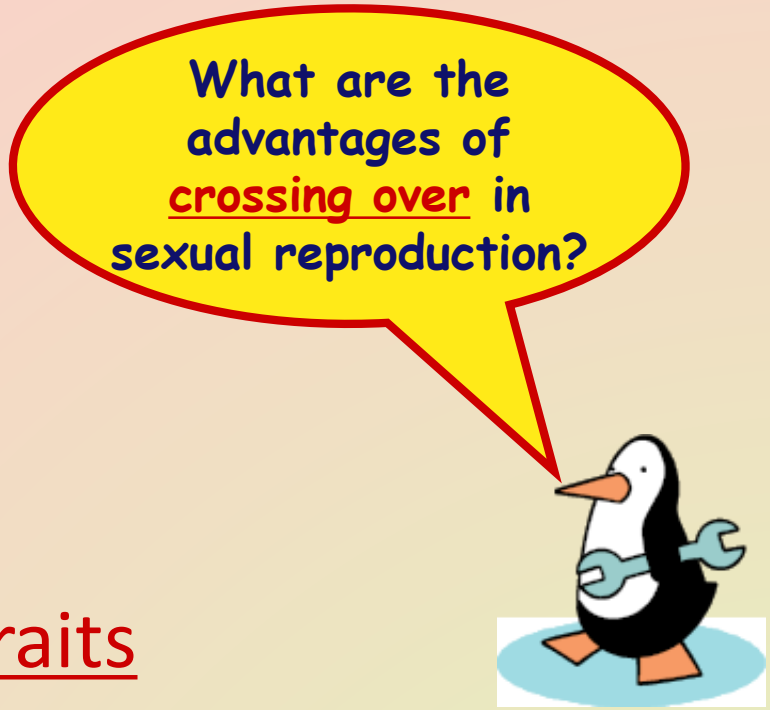


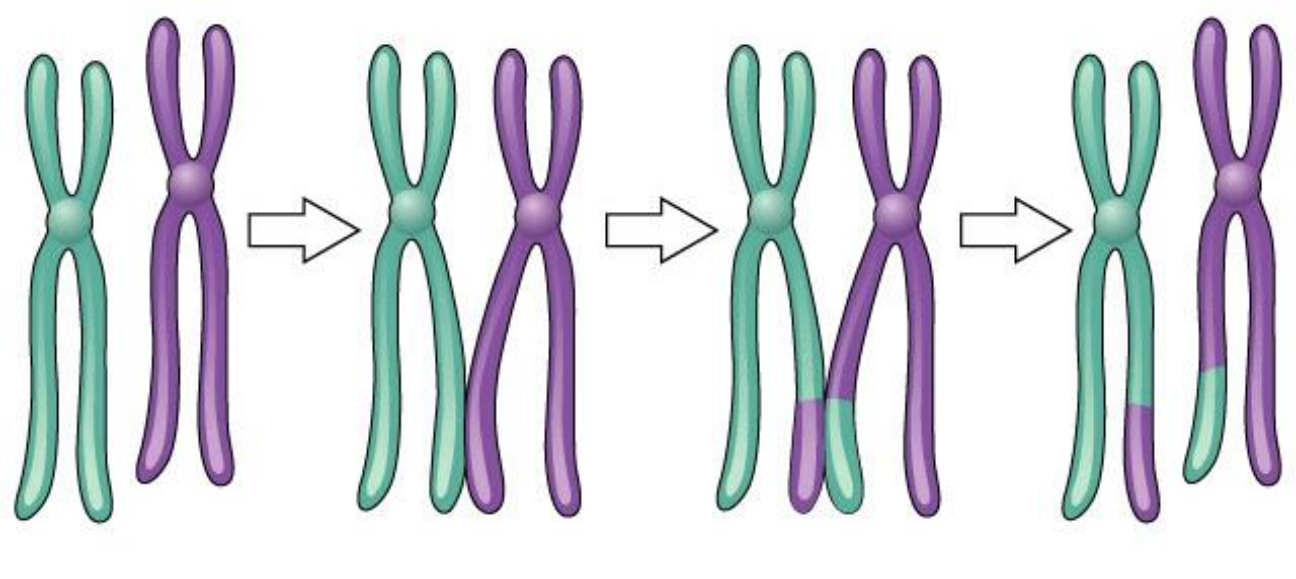




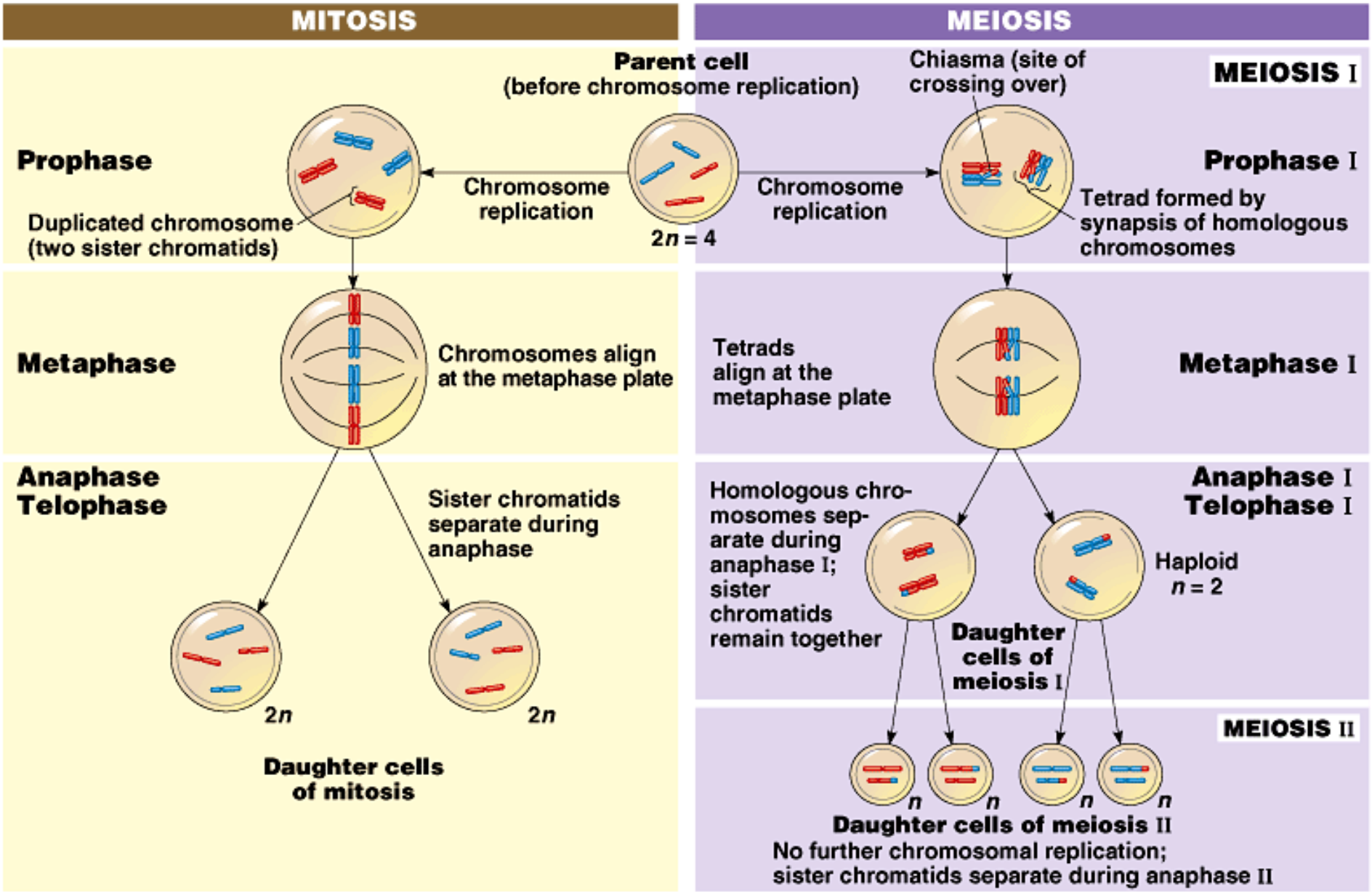
Crossing over

- 3 steps
  - cross over
  - breakage of DNA
  - re-fusing of DNA
- New combinations of traits





Mitosis vs. Meiosis



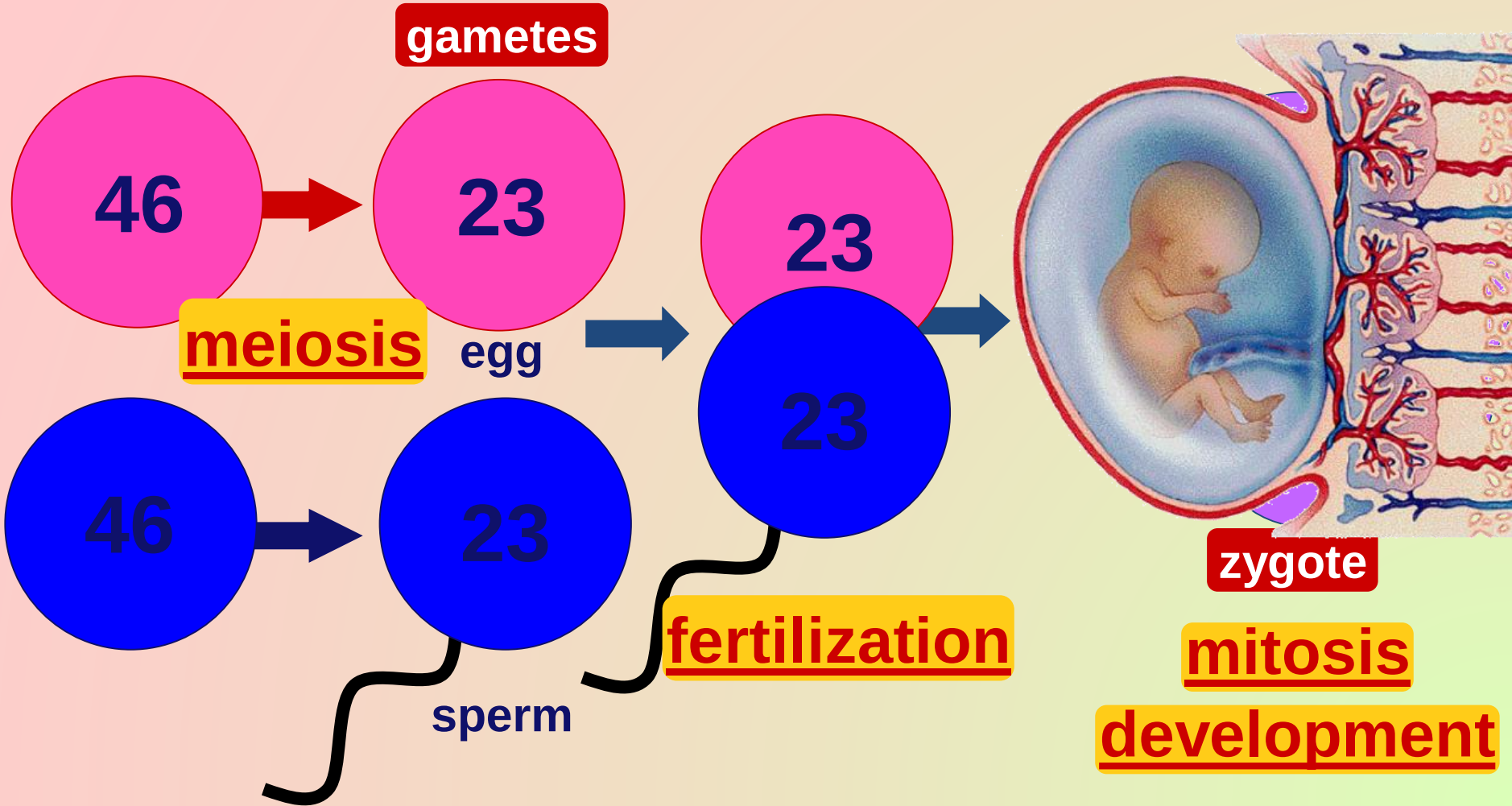
Mitosis vs. Meiosis

- Mitosis
  - 1 division
  - daughter cells genetically identical to parent cell
  - produces 2 cells
  - $2n \rightarrow 2n$
  - produces cells for growth & repair
  - no crossing over

- Meiosis
  - 2 divisions
  - daughter cells genetically different from parent
  - produces 4 cells
  - $2n \rightarrow 1n$
  - produces gametes
  - crossing over

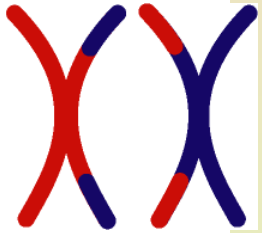
Putting it all together…

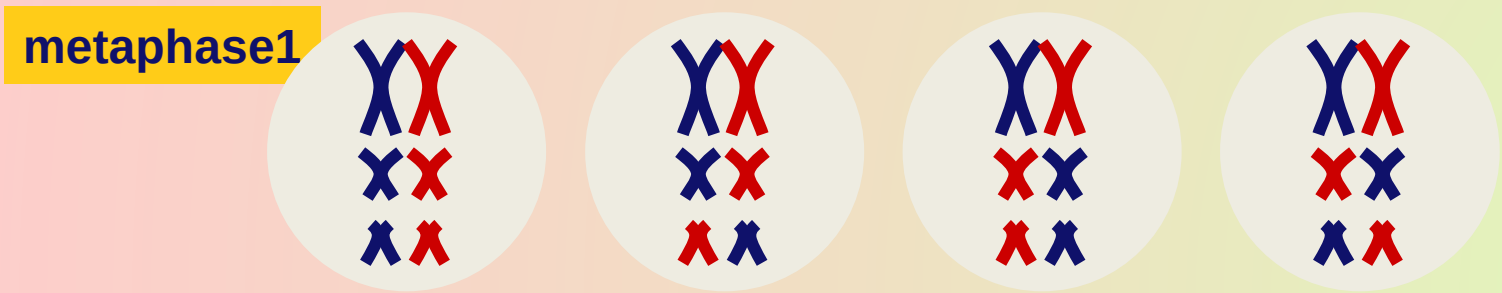
meiosis → fertilization → mitosis + development



The value of sexual reproduction

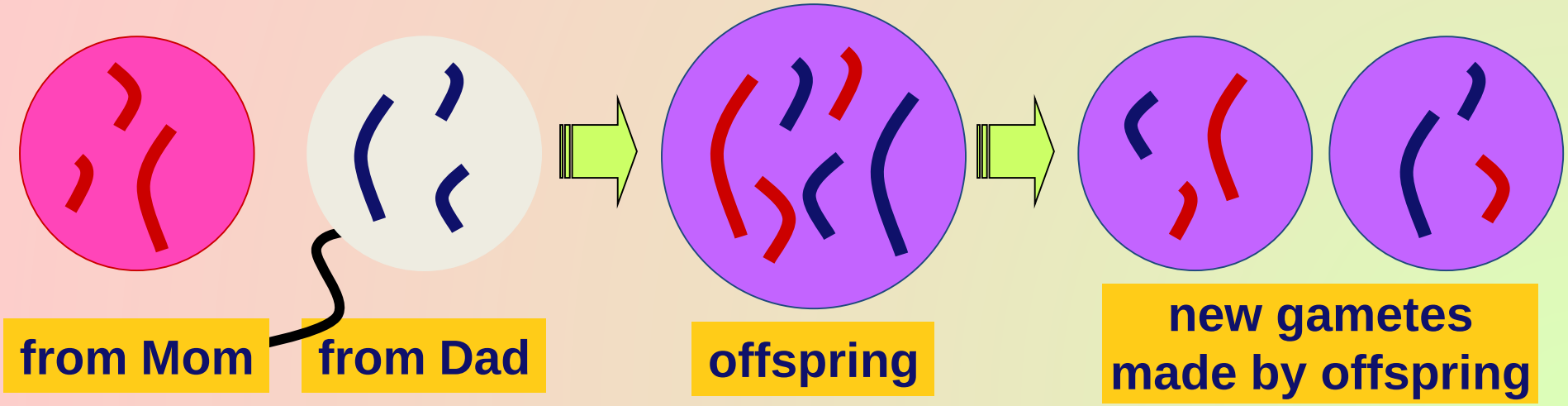
- Sexual reproduction introduces genetic variation
  - genetic recombination
    - independent assortment of chromosomes
      - random alignment of homologous chromosomes in Metaphase 1
  - crossing over
    - mixing of alleles across homologous chromosomes
  - random fertilization
    - which sperm fertilizes which egg?
  - providing variation for natural selection





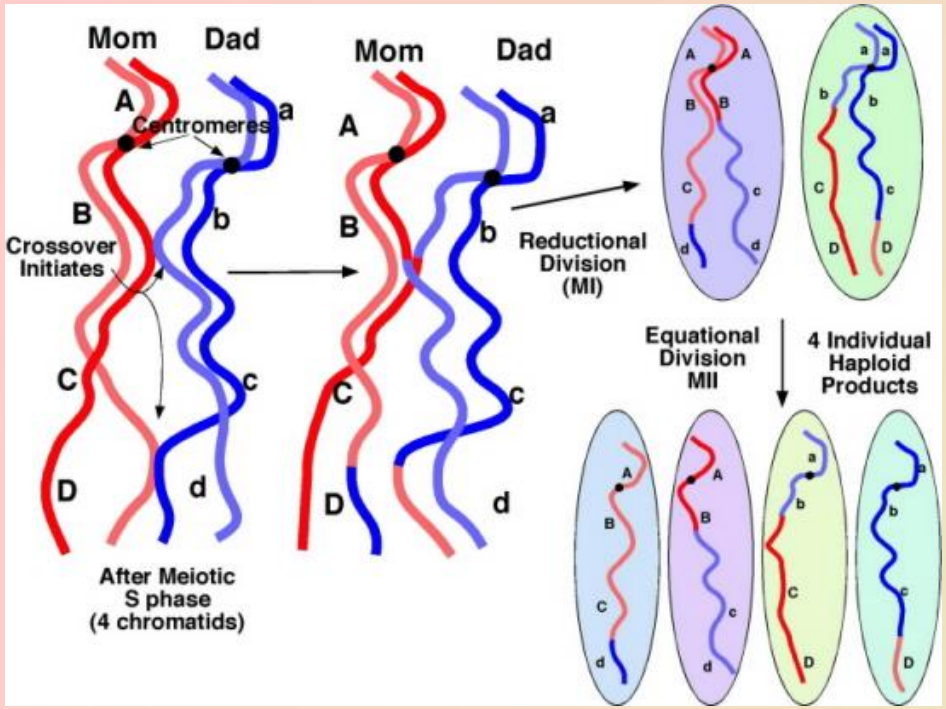
Variation from genetic recombination

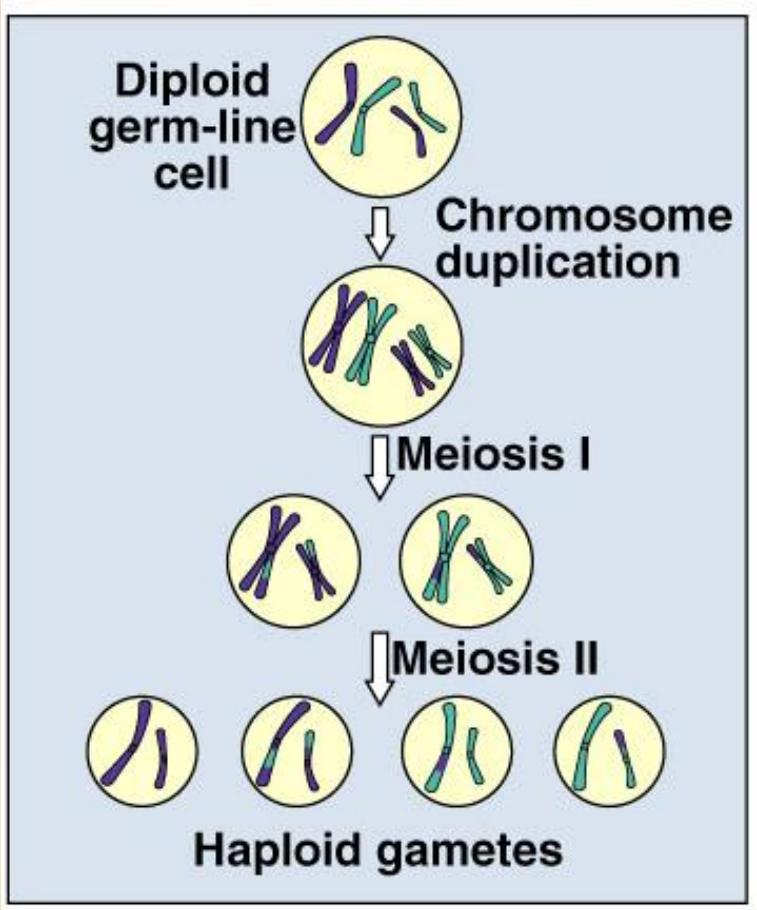
- Independent assortment of chromosomes
  - meiosis introduces genetic variation
  - gametes of offspring do not have same combination of genes as gametes from parents
    - random assortment in humans produces 2^{23} (8,388,608) different combinations in gametes



Variation from <u>crossing over</u>

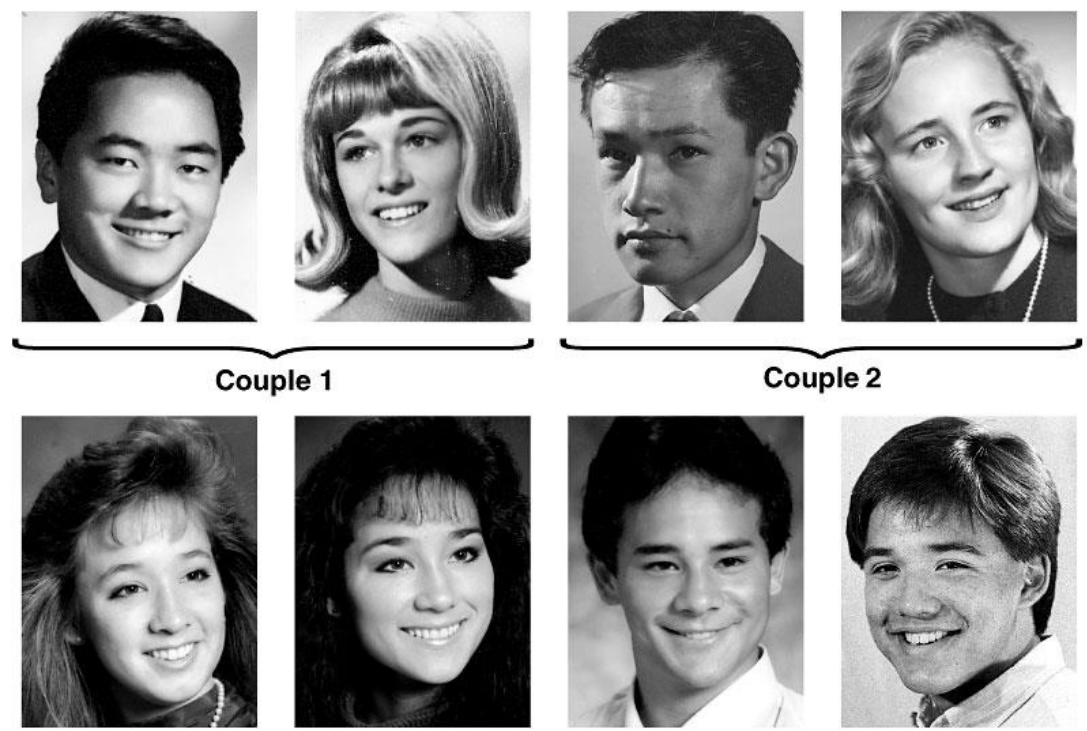
- Crossing over creates completely new combinations of traits on each chromosome
  - creates an <u>infinite</u> variety in gametes

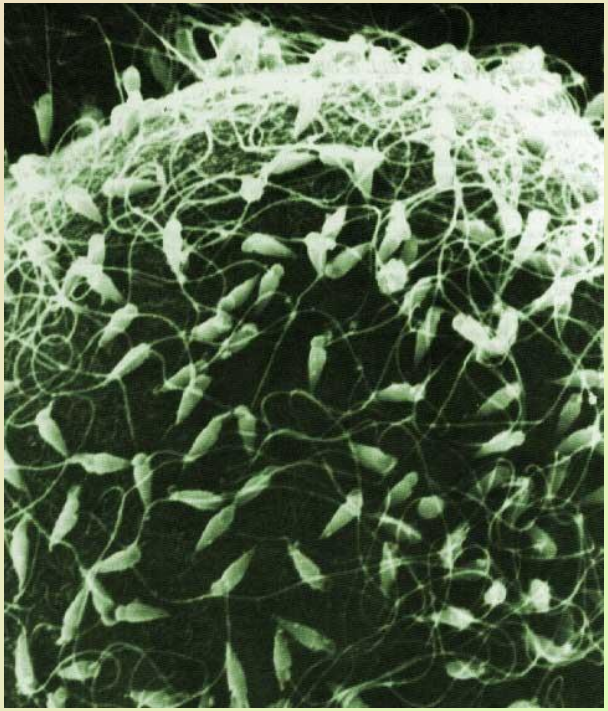




Variation from random fertilization

- Sperm + Egg = ?
  - any 2 parents will produce a zygote with over 70 trillion (2^{23} x 2^{23}) possible diploid combinations (not even counting crossing over!!!!!!!!!)



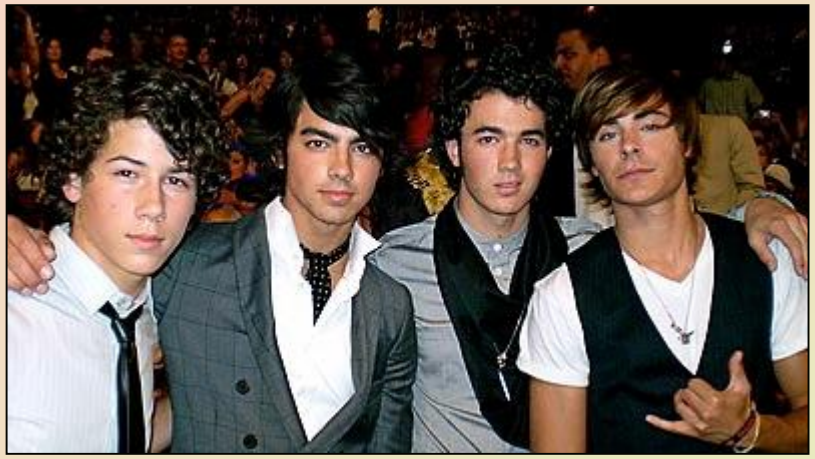


Sexual reproduction creates variability

Sexual reproduction allows us to maintain both genetic similarity & differences.

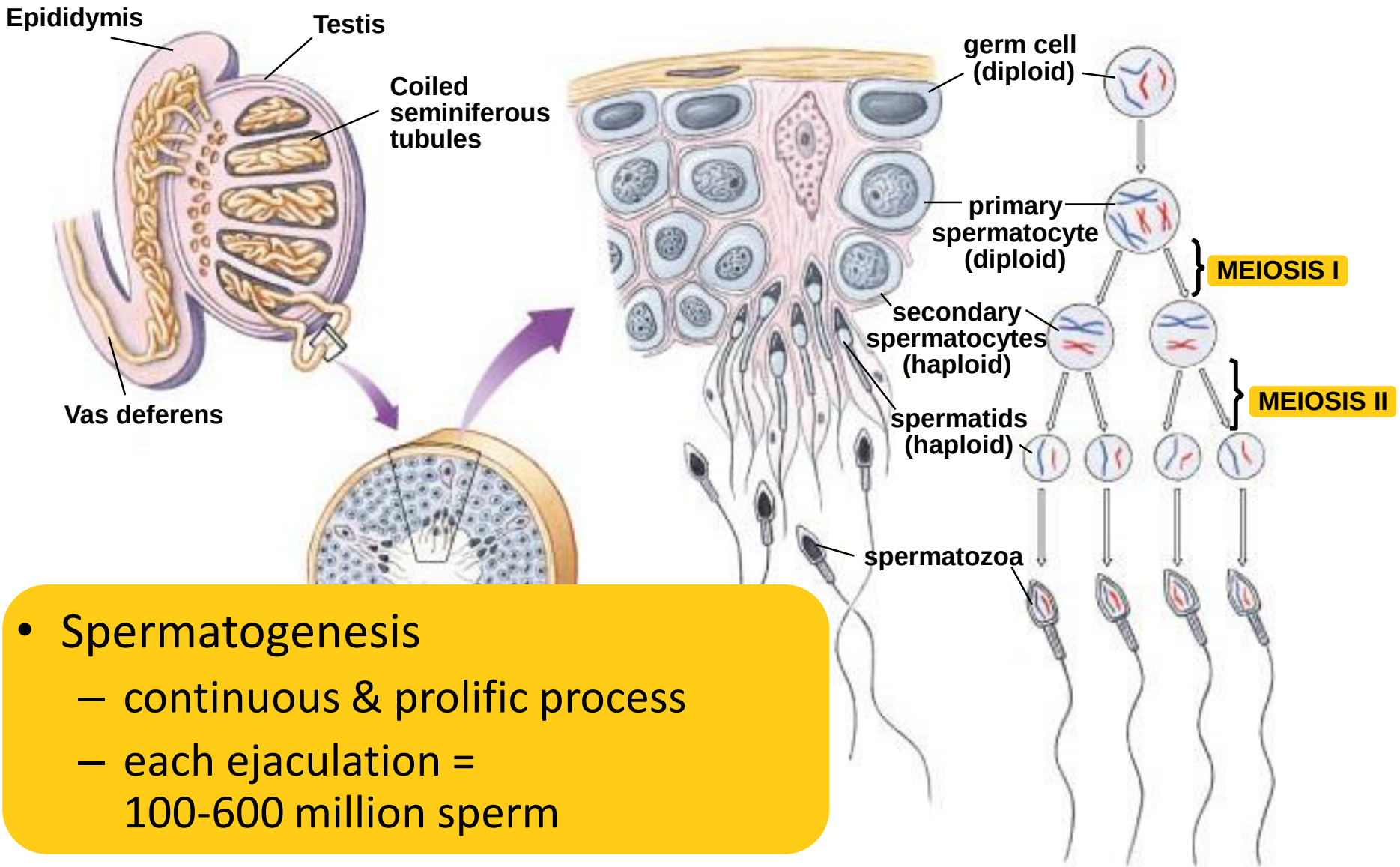
Baldwin brothers

Jonas Brothers



Martin & Charlie Sheen, Emilio Estevez

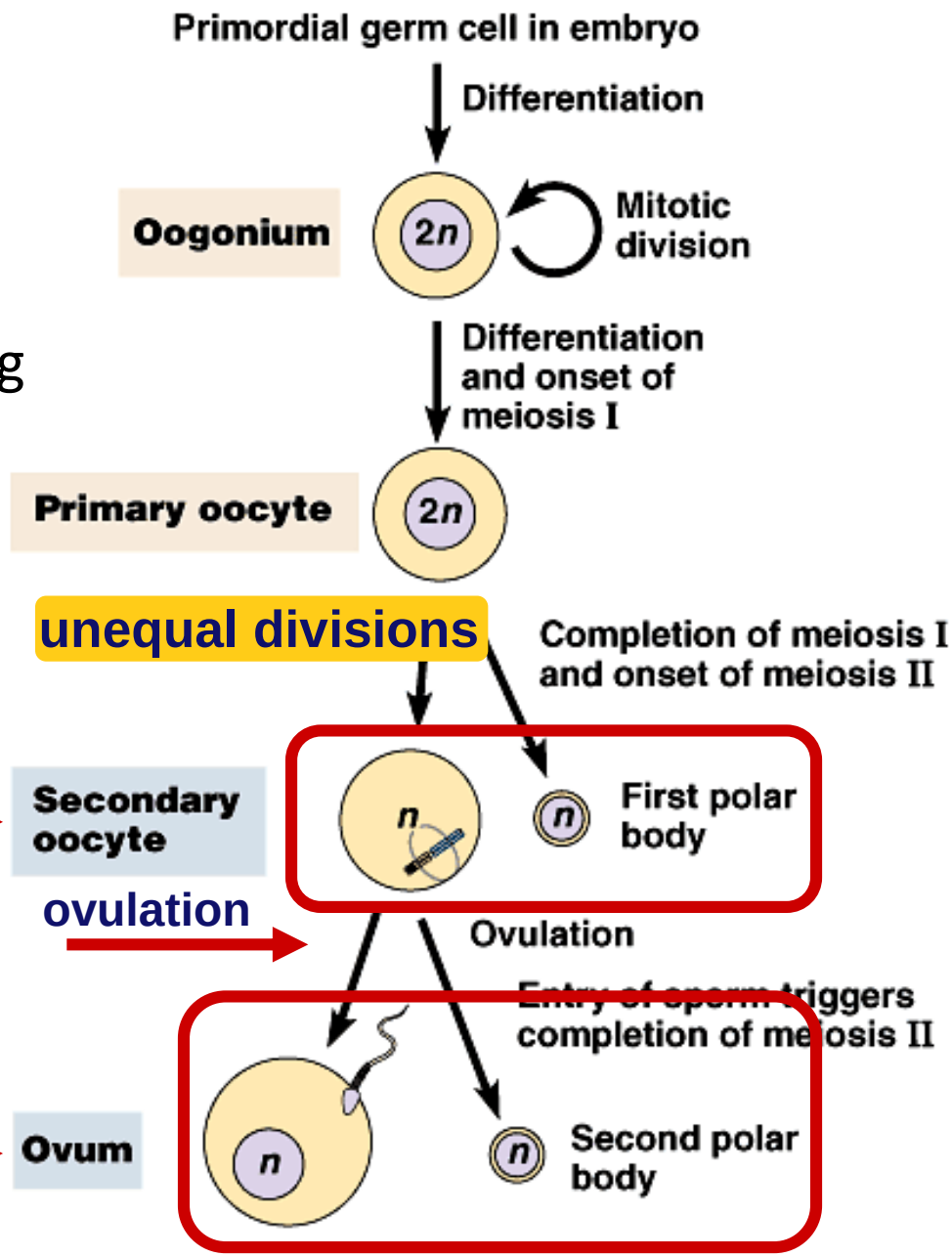
Sperm production



- Spermatogenesis
  - continuous & prolific process
  - each ejaculation = 100-600 million sperm

Egg production

- Oogenesis
  - eggs in ovaries halted at Metaphase 1
  - Meiosis 1 completed during maturation
  - Meiosis 2 completed after fertilization
  - 1 egg + 2 polar bodies



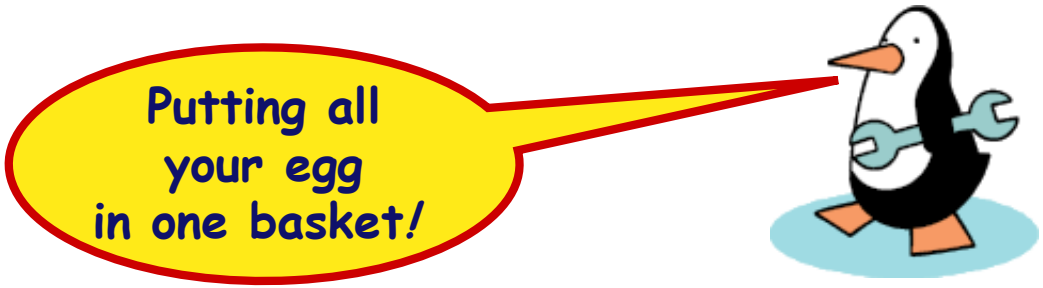
Meiosis 1 completed during egg maturation

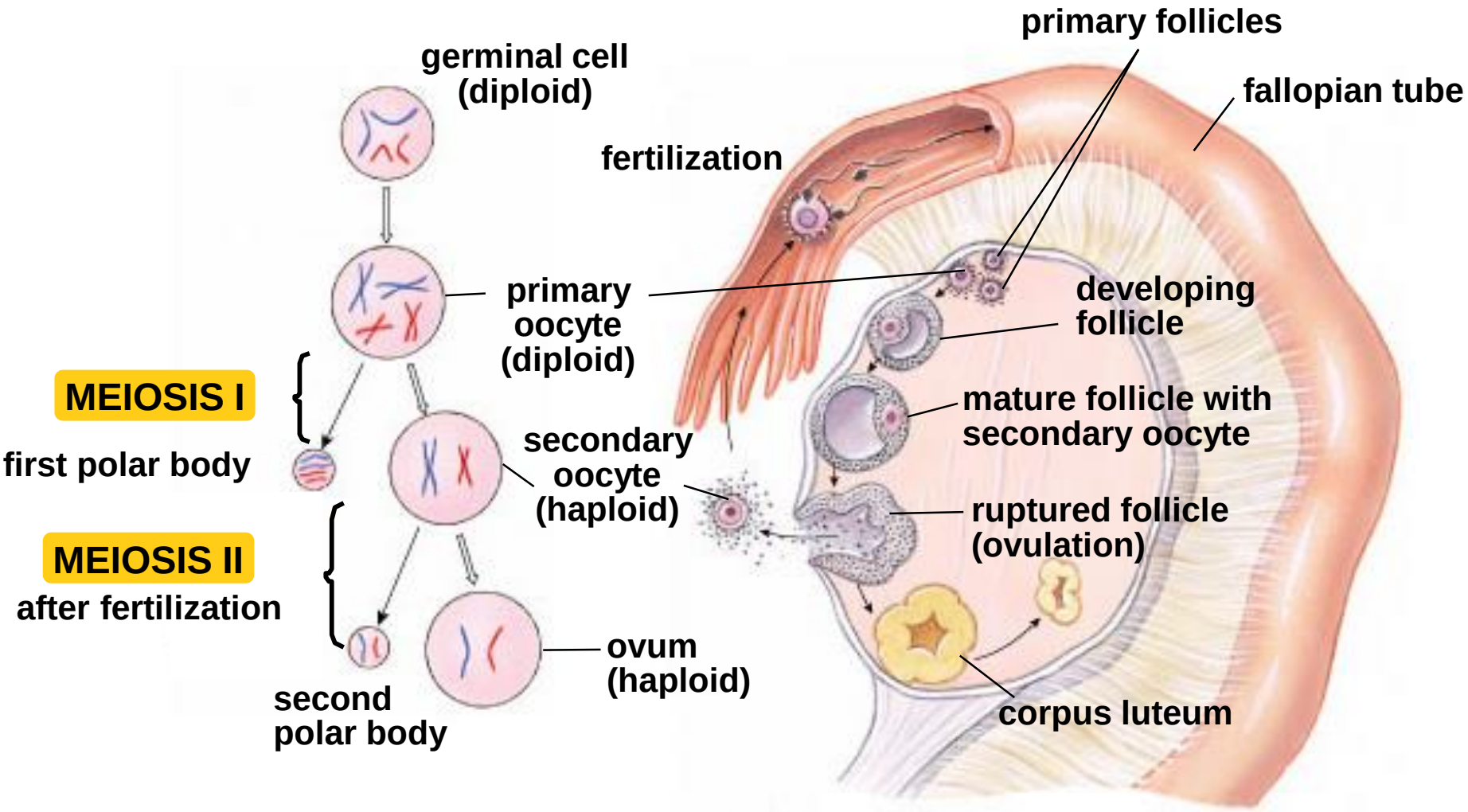
What is the advantage of this development system?

Meiosis 2 completed triggered by fertilization

Ovum

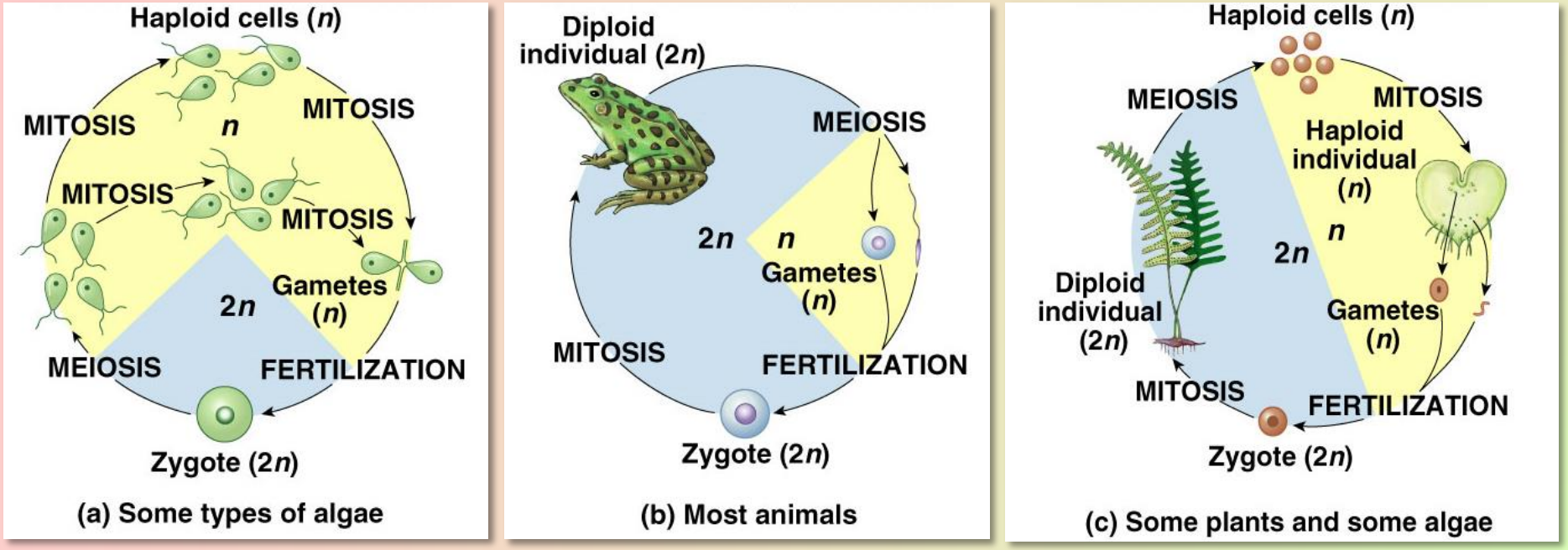
Oogenesis


Putting all your egg in one basket!


germinal cell (diploid)
fertilization
primary oocyte (diploid)
MEIOSIS I
first polar body
secondary oocyte (haploid)
MEIOSIS II
after fertilization
ovum (haploid)
second polar body
primary follicles
fallopian tube
developing follicle
mature follicle with secondary oocyte
ruptured follicle (ovulation)
corpus luteum

Differences across kingdoms

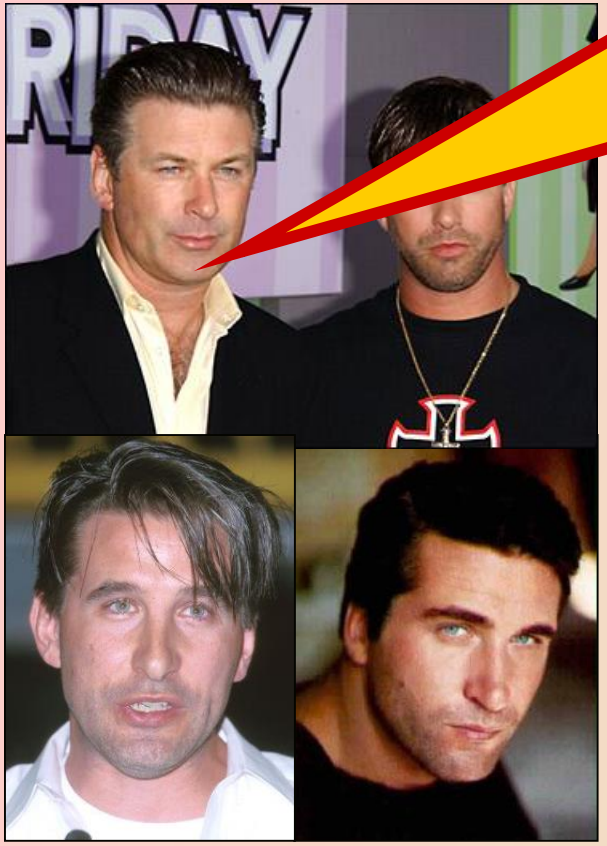
- Not all organisms use haploid & diploid stages in same way
  - which one is dominant (2n or n) differs
  - but still alternate between haploid & diploid
    - <u>must</u> for sexual reproduction



Eggs are Precious,

Sperm is Cheap.

Any Questions??



What are the <u>DIS</u>advantages of sexual reproduction?

Review Questions

1. How do cells at the completion of meiosis compare with cells that have replicated their DNA and are just about to begin meiosis?

A. They have twice the amount of cytoplasm and half the amount of DNA.

B. They have half the number of chromosomes and half the amount of DNA.

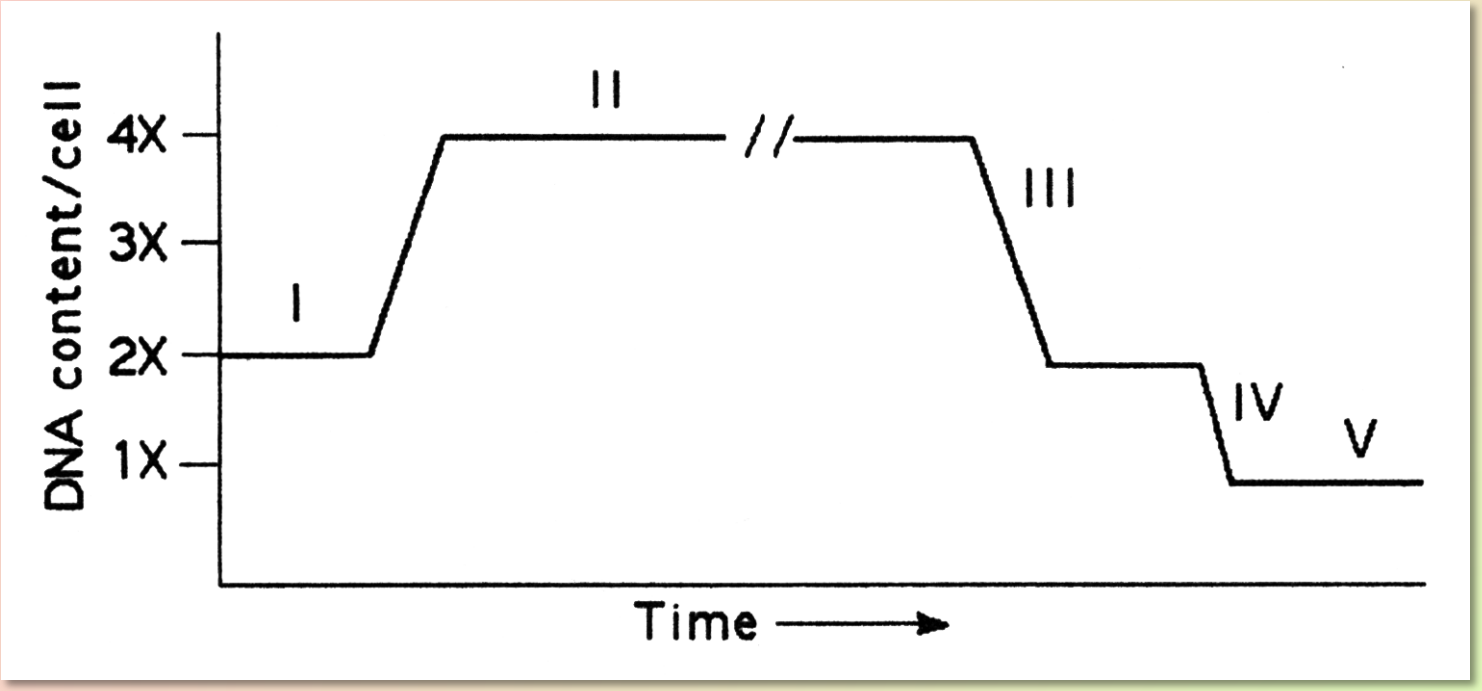
C. They have the same number of chromosomes and half the amount of DNA.

D. They have half the number of chromosomes and one-fourth the amount of DNA.

E. They have half the amount of cytoplasm and twice the amount of DNA.

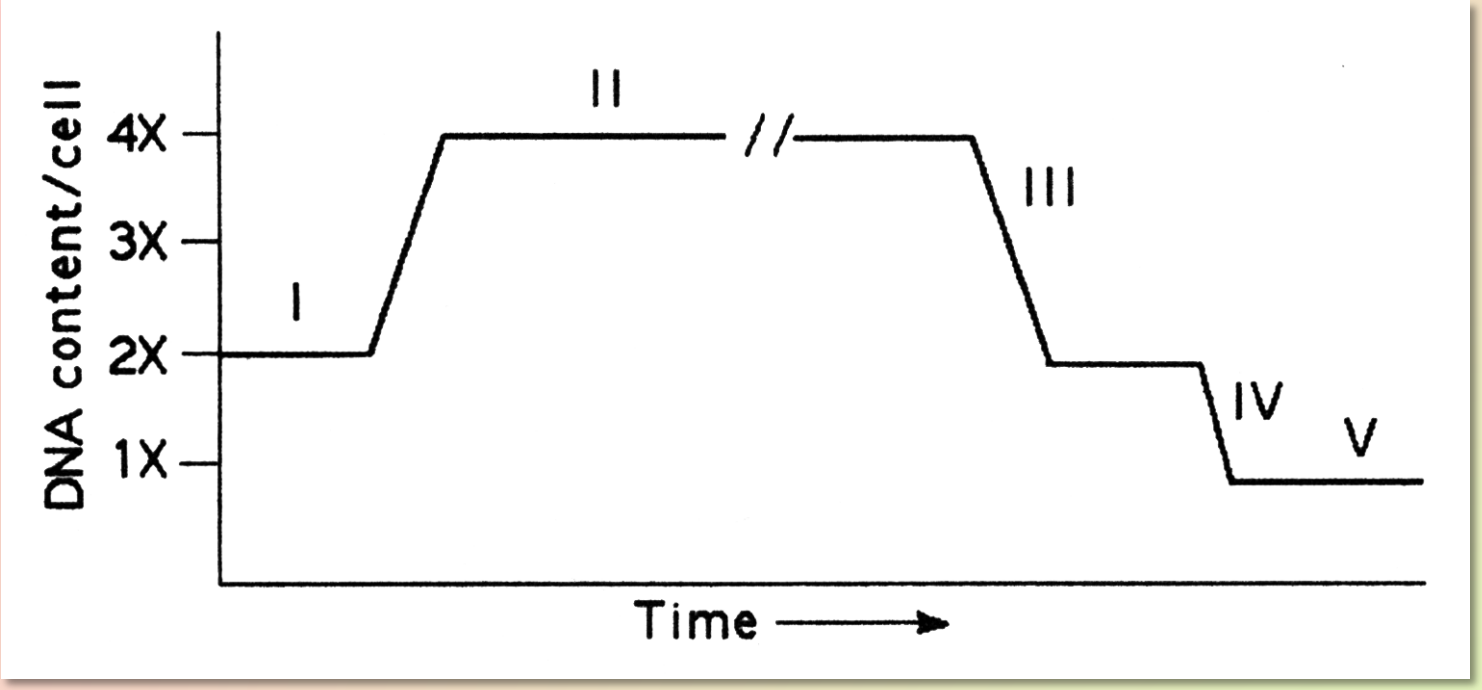
2. Which number represents G_2? *

A. I
B. II
C. III
D. IV
E. V



3.. Which number represents the DNA content of a sperm cell?

A. I
B. II
C. III
D. IV
E. V



4. Which of the following would not be considered a haploid cell?
   A. daughter cell after meiosis II
   B. gamete
   C. daughter cell after mitosis in gametophyte generation of a plant
   D. cell in prophase I
   E. cell in prophase II

5. A cell in G_2 before meiosis compared with one of the four cells produced by that meiotic division has

A. twice as much DNA and twice as many chromosomes.

B. four times as much DNA and twice as many chromosomes.

C. four times as much DNA and four times as many chromosomes.

D. half as much DNA but the same number of chromosomes.

E. half as much DNA and half as many chromosomes.