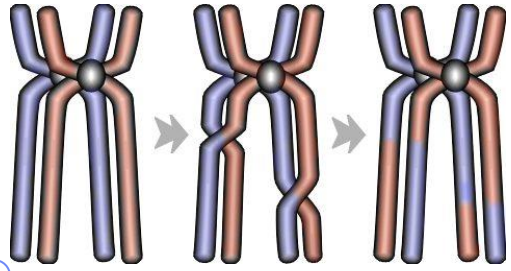
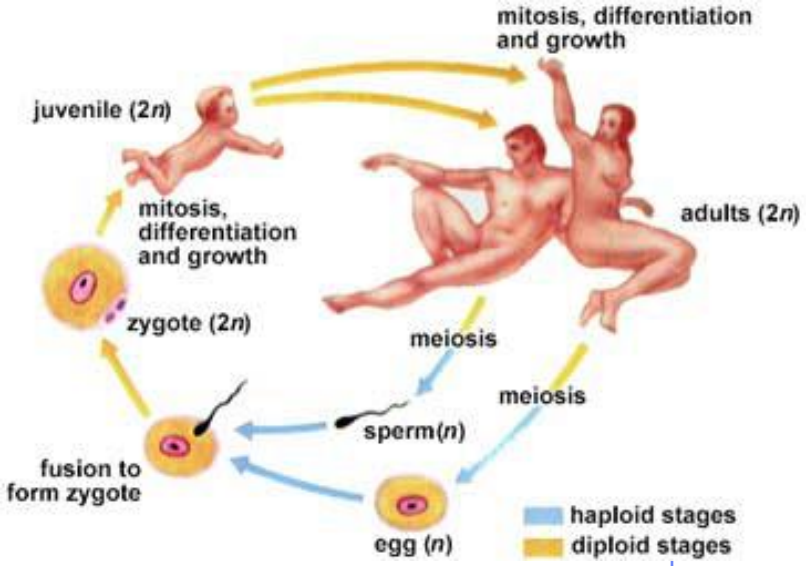
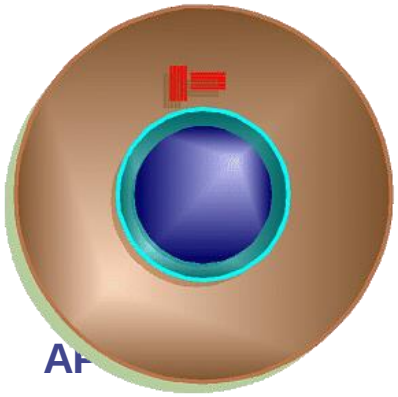
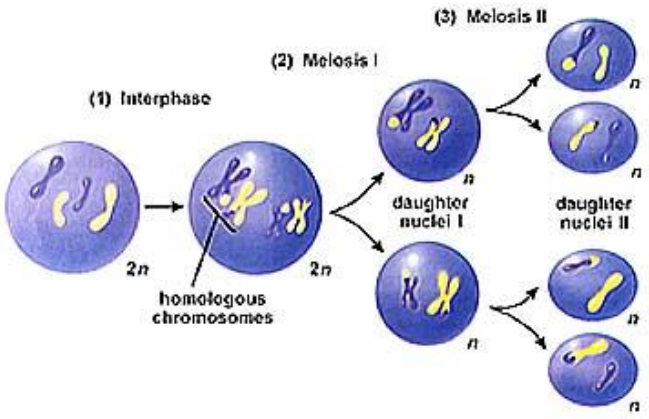




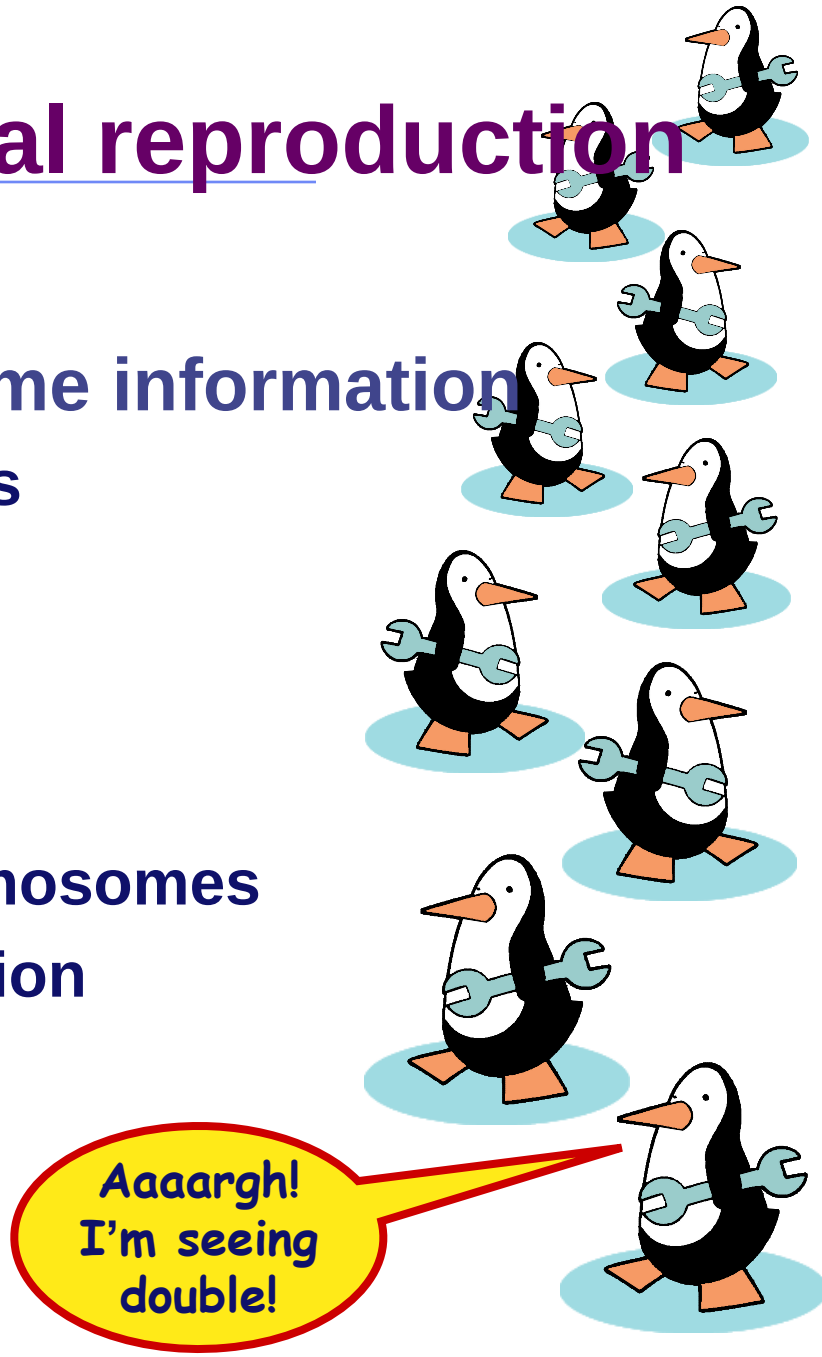
Meiosis & Sexual Reproduction





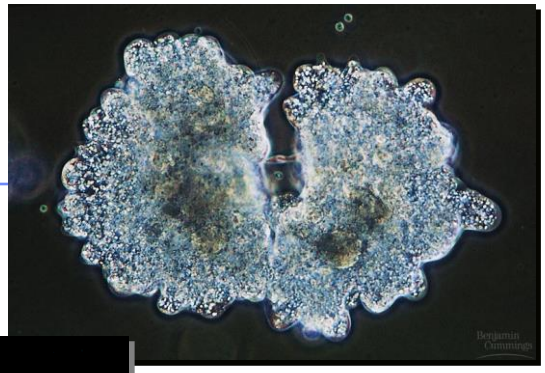
Cell division / Asexual reproduction

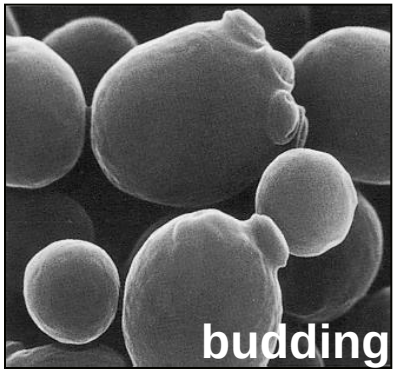
- Mitosis
  - produce cells with same information
    - identical daughter cells
  - exact copies
    - clones
  - same amount of DNA
    - same number of chromosomes
    - same genetic information

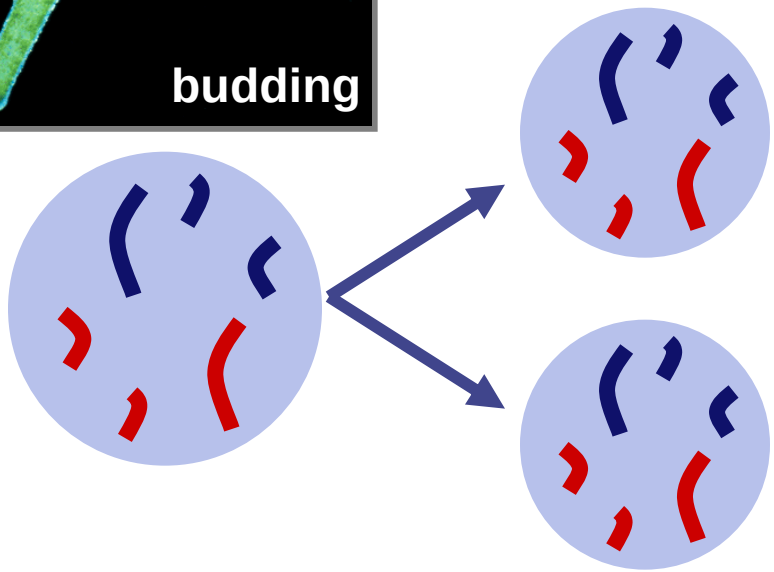


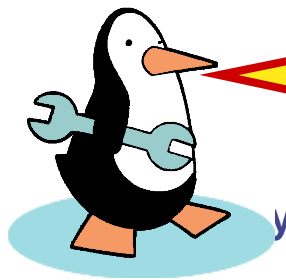
Asexual reproduction

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









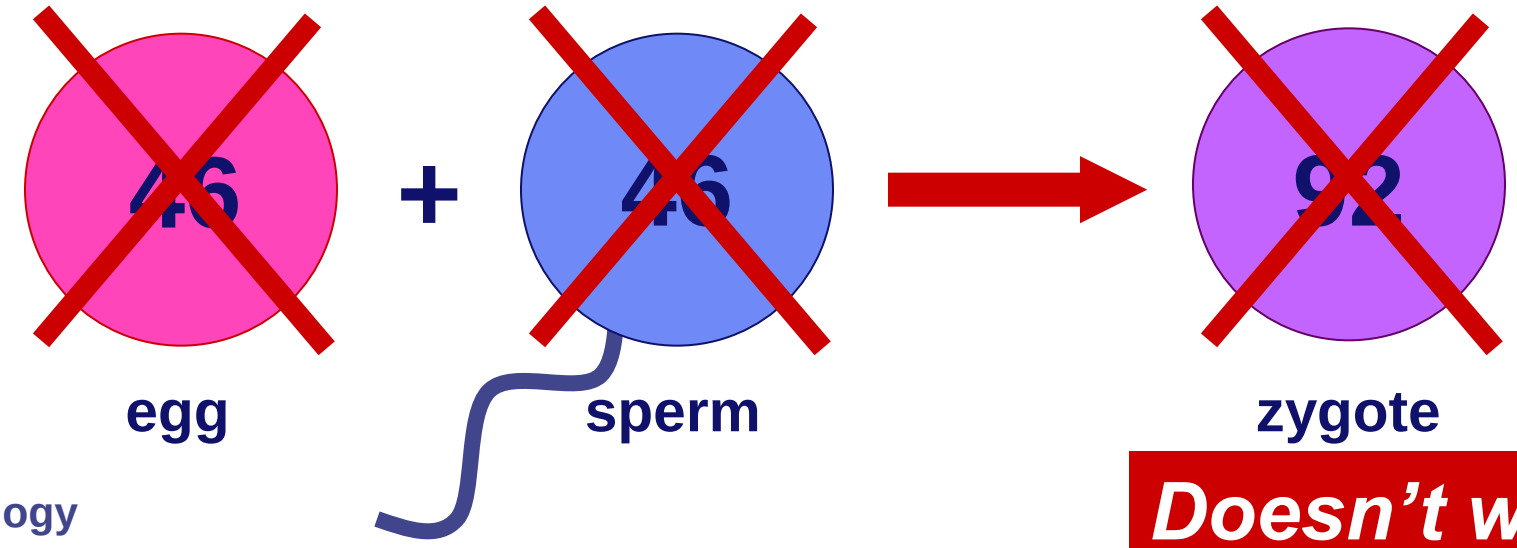
What are the disadvantages of asexual reproduction?

What are the advantages?

How about the rest of us?

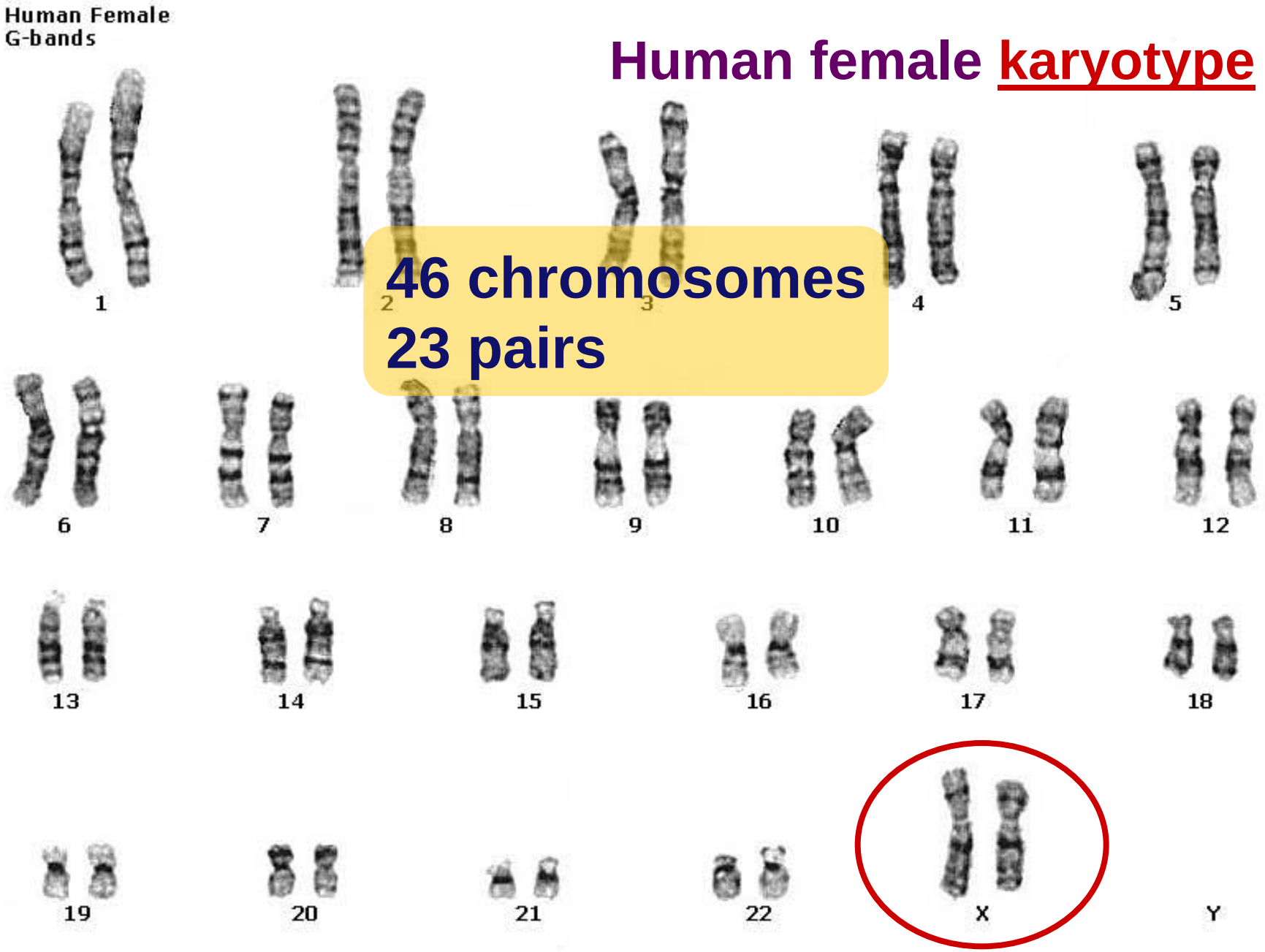
- What if a complex multicellular organism (like us) wants to reproduce?
  - joining of egg + sperm
- Do we make egg & sperm by mitosis?

What if we did, then….



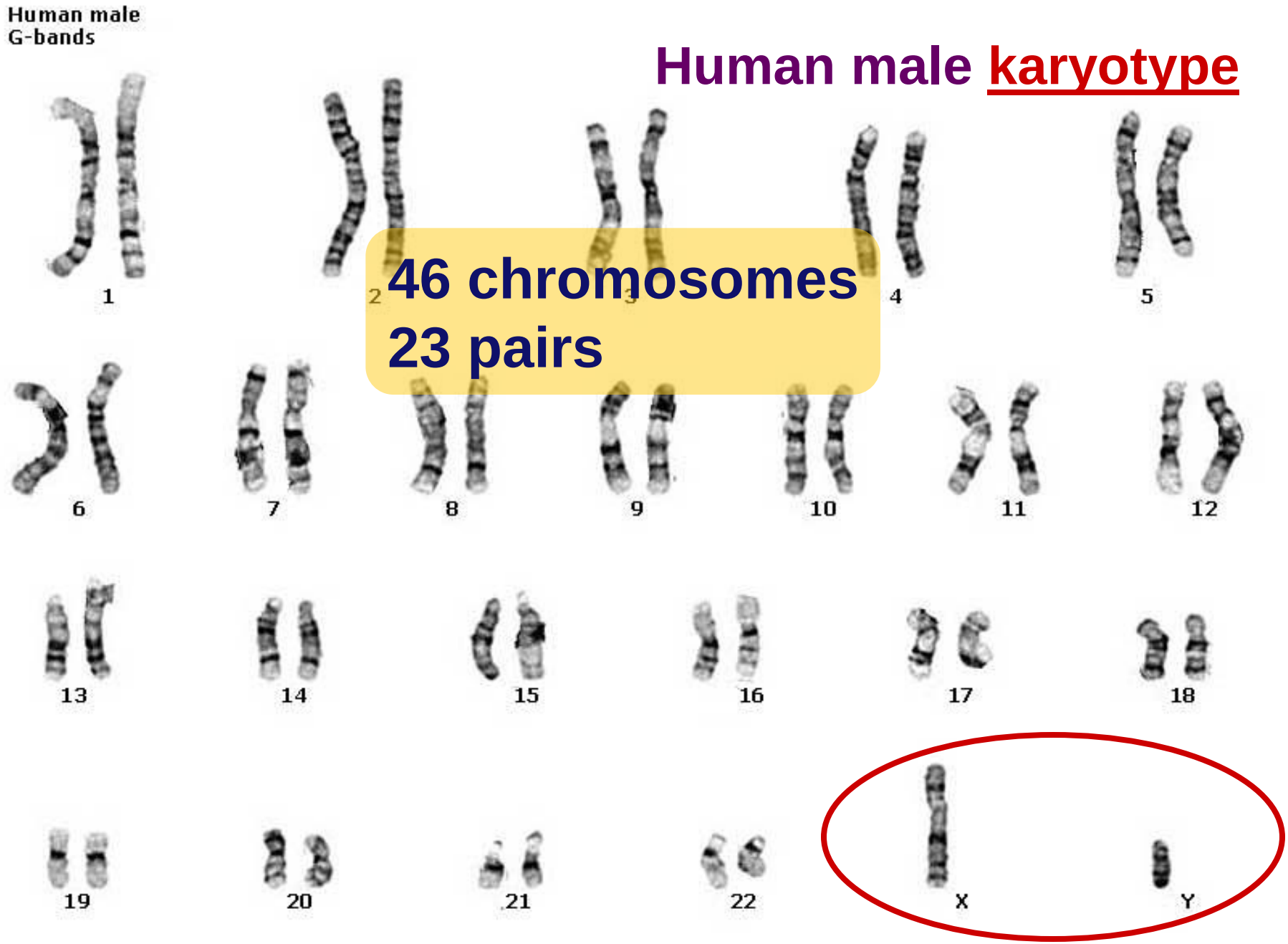
Doesn't work!

Human female karyotype



46 chromosomes
23 pairs

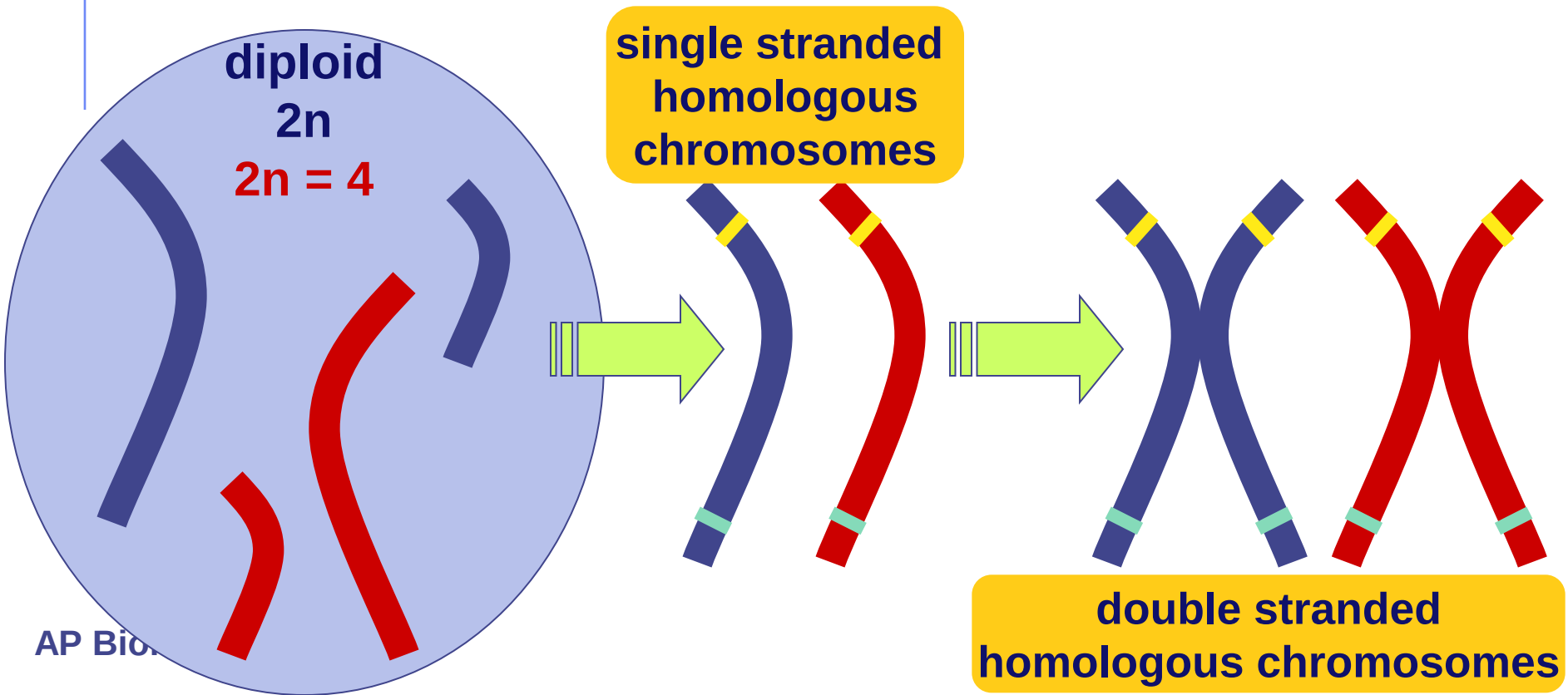
Human male karyotype



46 chromosomes
23 pairs

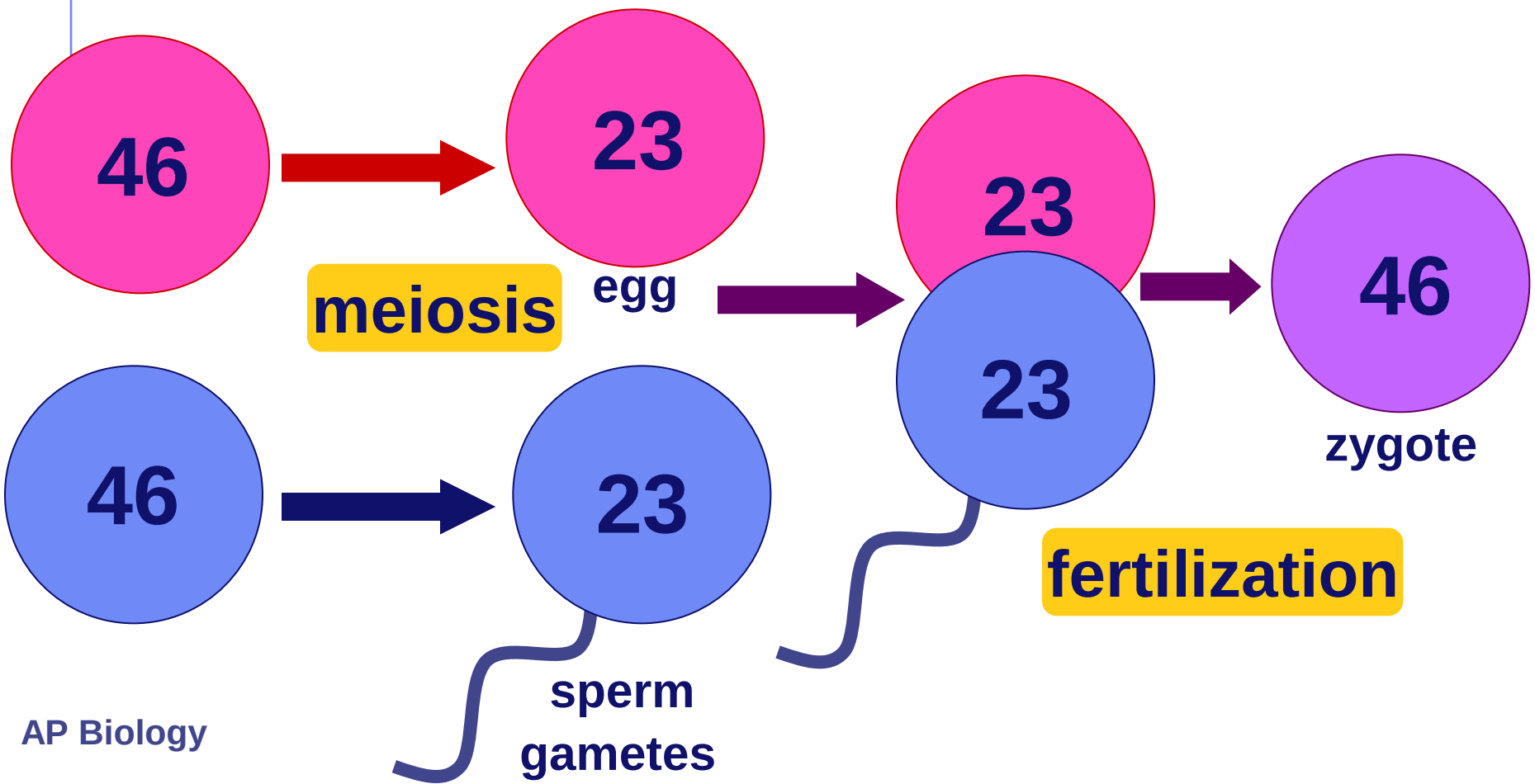
Homologous chromosomes

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



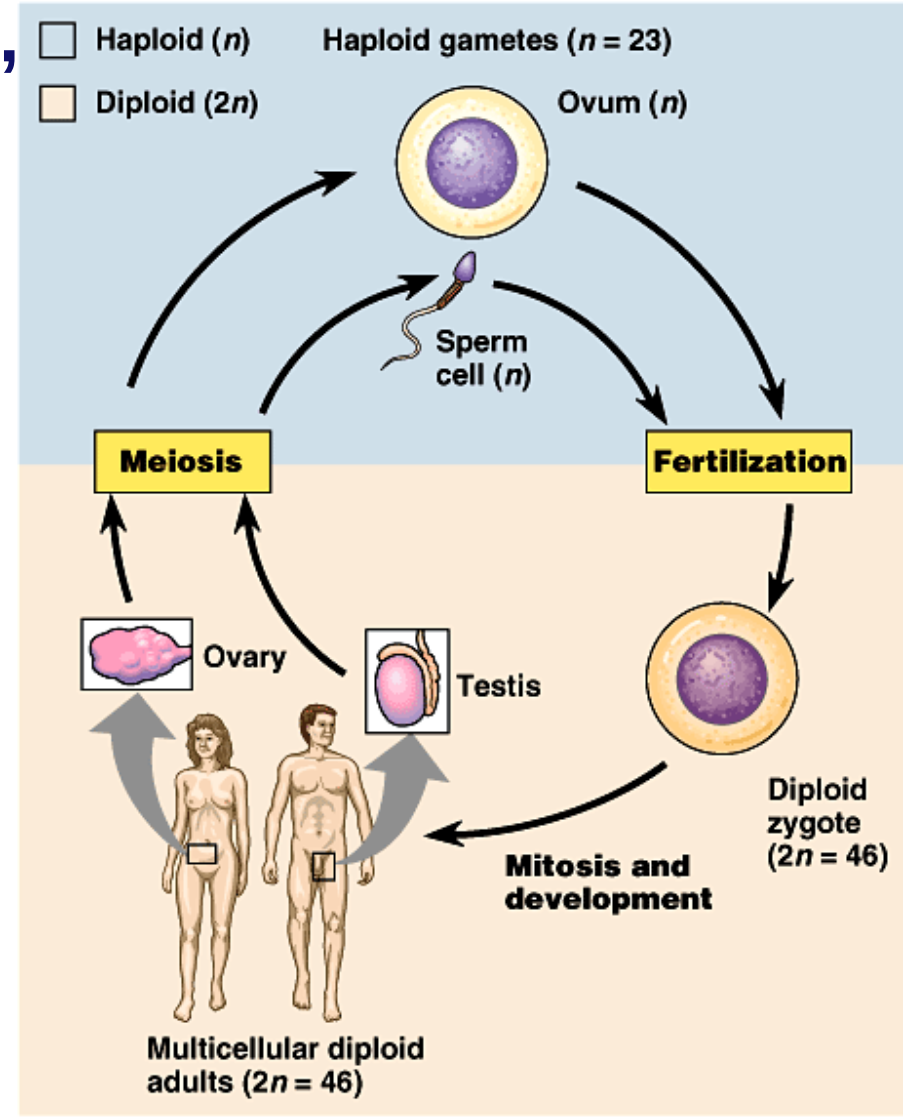
How do we make sperm & eggs?

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



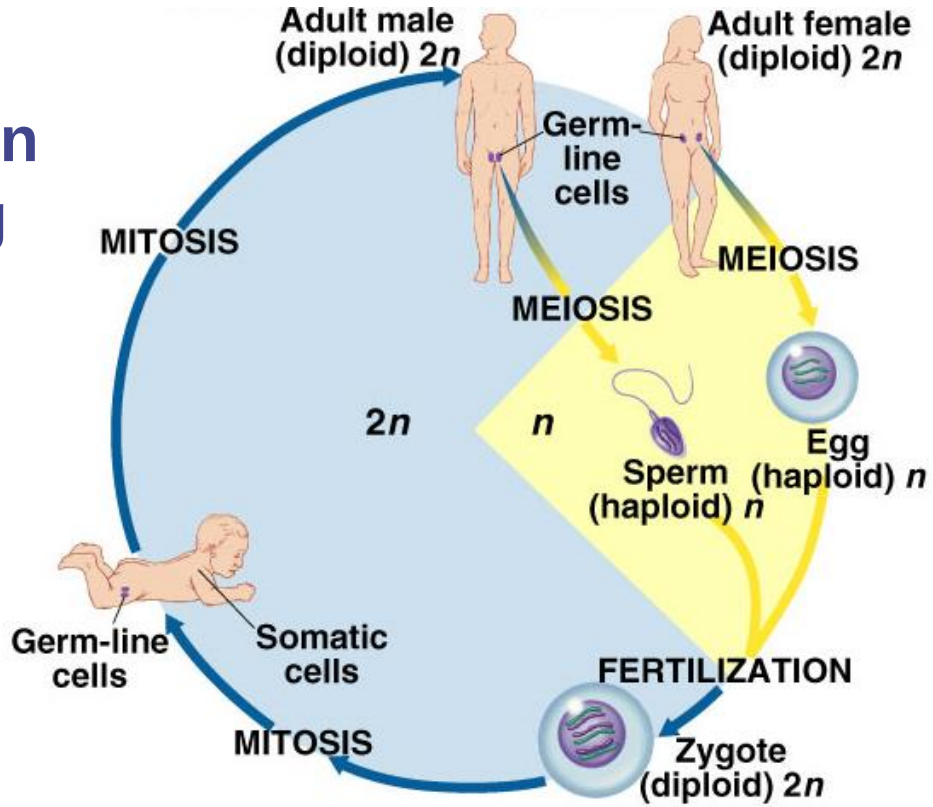
Meiosis: production of gametes

- **Alternating processes, alternating stages**
  - chromosome number must be reduced
    - diploid → haploid
    - 2n → n
      - humans: 46 → 23
    - meiosis reduces chromosome number
    - makes gametes
  - fertilization restores chromosome number
    - haploid → diploid
    - n → 2n



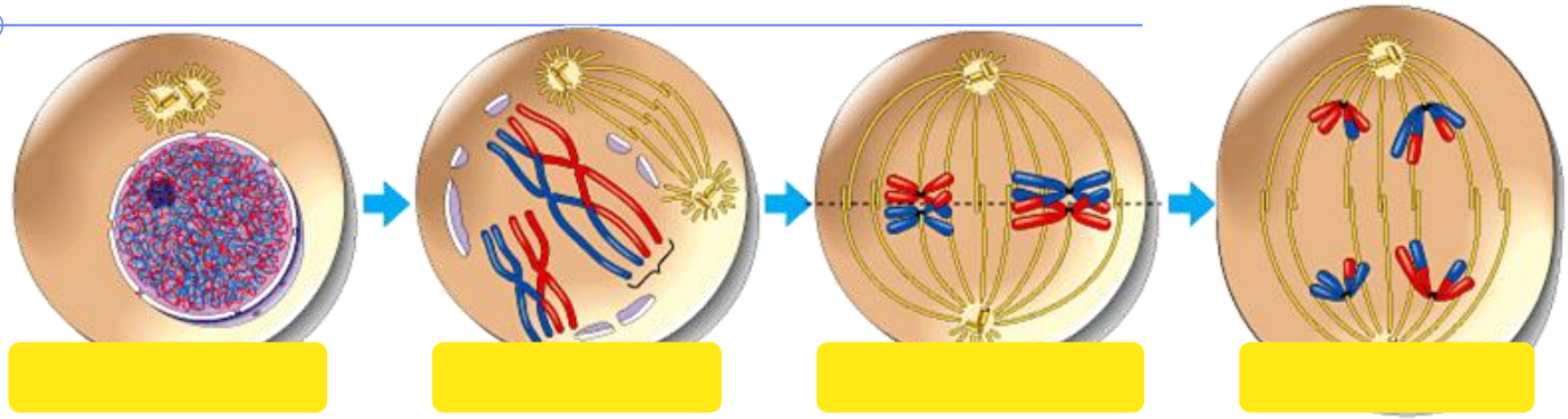
Meiosis

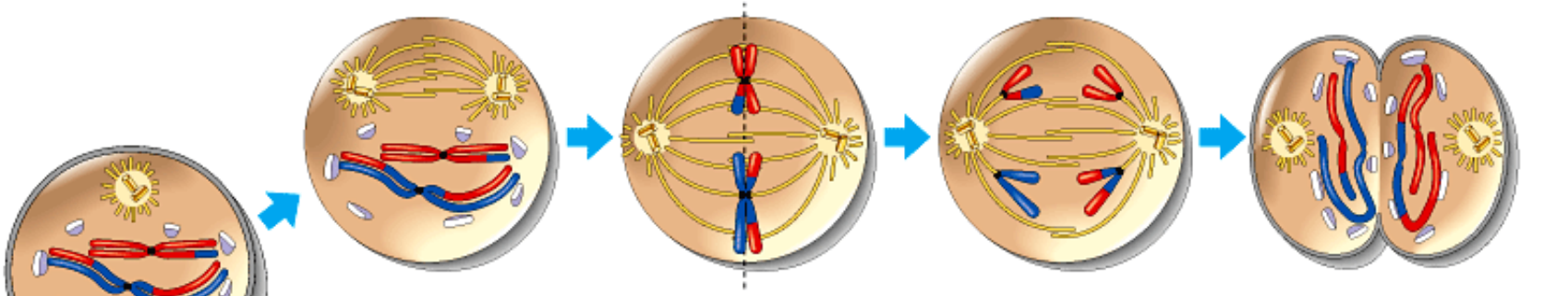
- **Reduction Division**
  - special cell division in sexually reproducing organisms
  - reduce 2n → 1n
  - diploid → haploid
    - "half"
  - makes gametes
    - sperm, eggs



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

Overview of meiosis



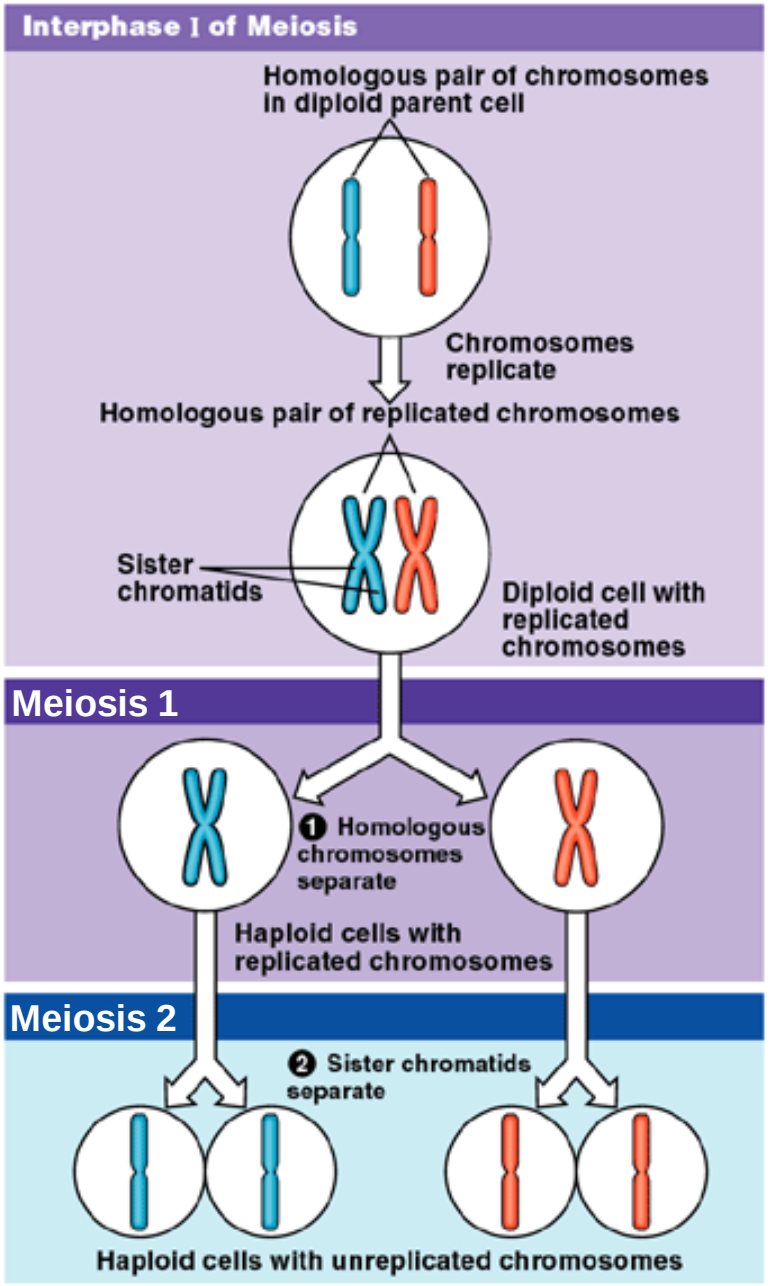


Double division of meiosis

DNA replication

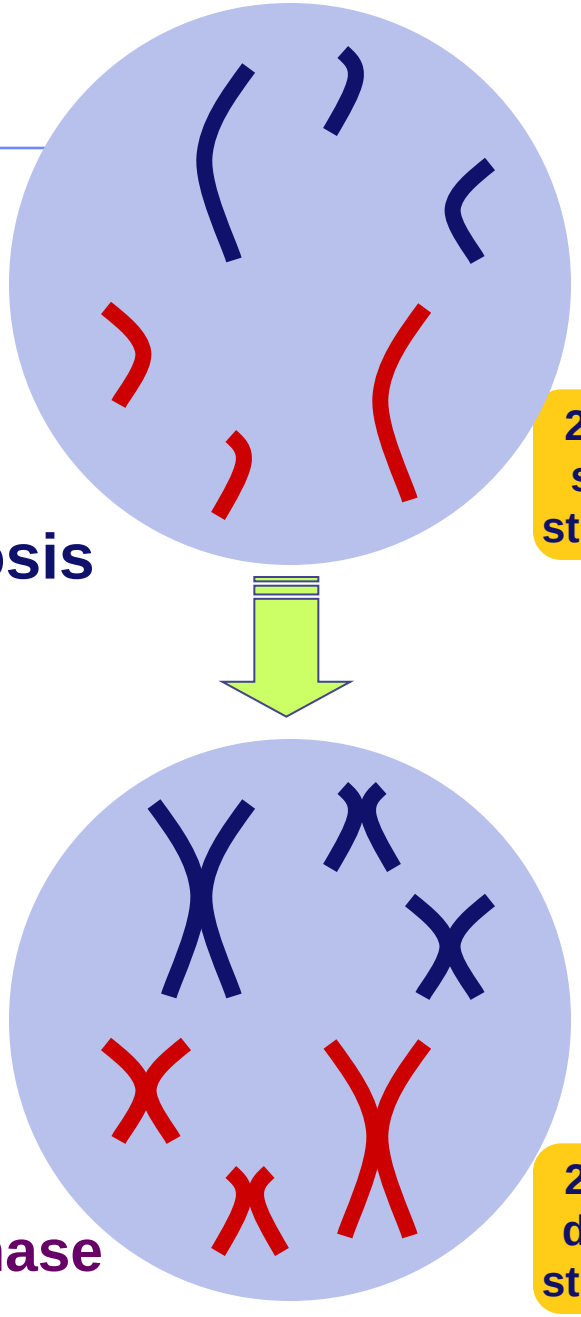
1st division of meiosis separates homologous pairs

2nd division of meiosis separates sister chromatids



Preparing for meiosis

- 1st step of meiosis
  - Duplication of DNA
  - Why bother?
    - meiosis evolved after mitosis
    - convenient to use "machinery" of mitosis
    - DNA replicated in S phase of interphase of MEIOSIS (just like in mitosis)



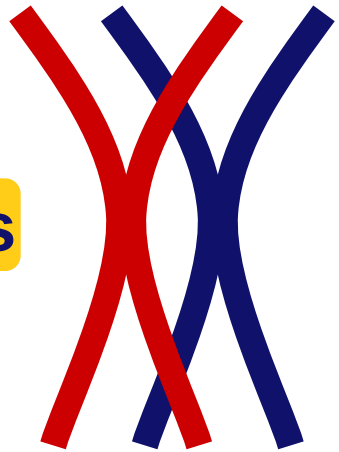
M1 prophase

Meiosis I

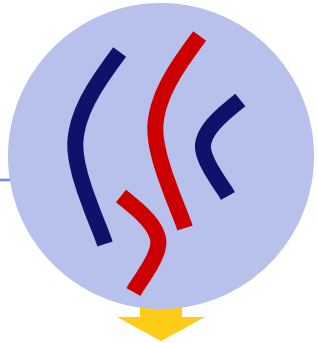
- 1st division of meiosis

chiasmata

synapsis

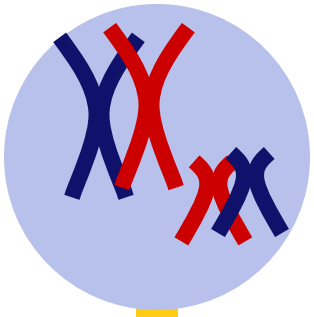


tetrad



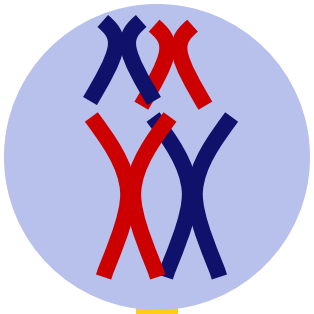
2n = 4 single stranded

prophase I



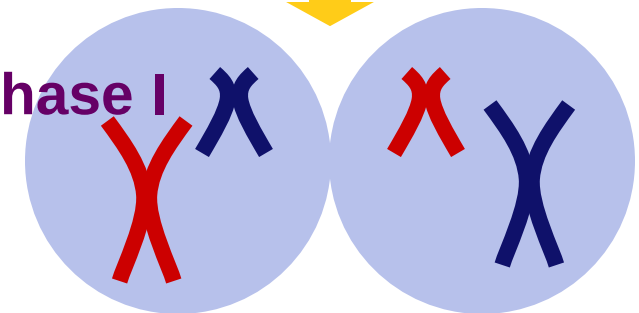
2n = 4 double stranded

metaphase I



2n = 4 double stranded

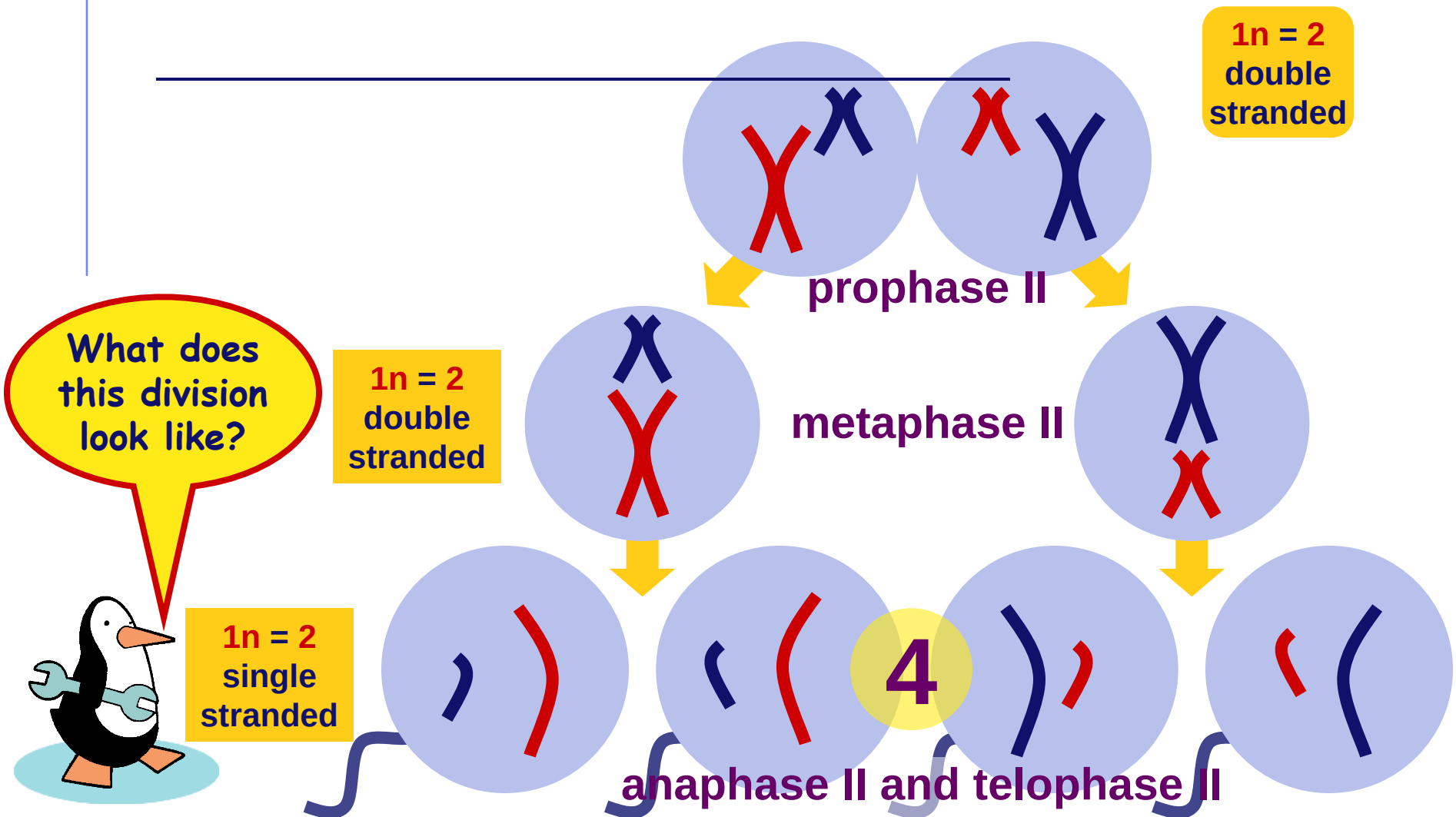
anaphase I and telophase I



1n = 2 double stranded

Meiosis II

- **2nd division of meiosis**



Steps of meiosis

- Meiosis I
  - interphase
  - prophase I
  - metaphase I
  - anaphase I
  - telophase I
- Meiosis II
  - prophase II
  - metaphase II
  - anaphase II
  - telophase II

1st division of meiosis separates homologous pairs

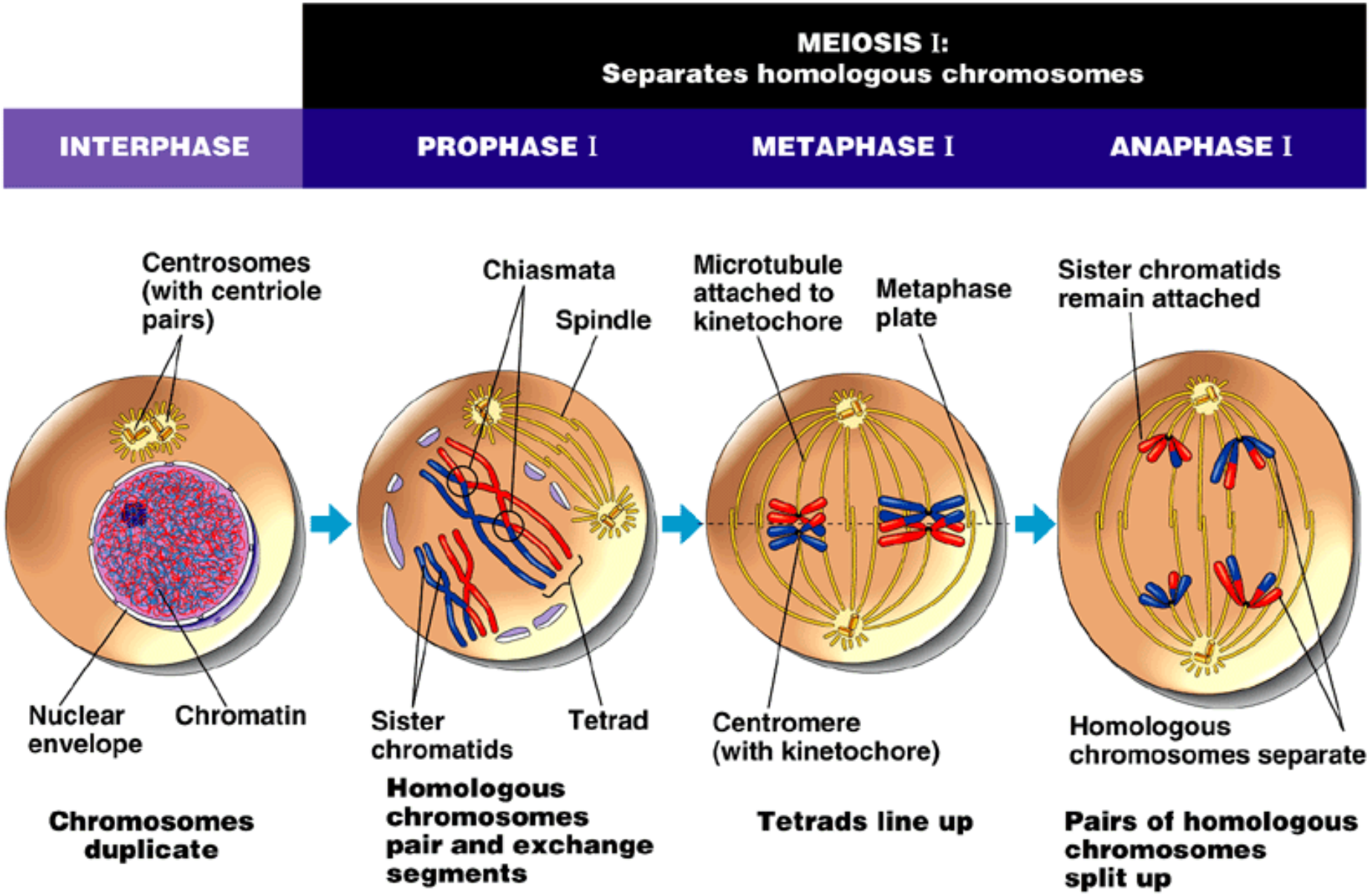
(2n → 1n)

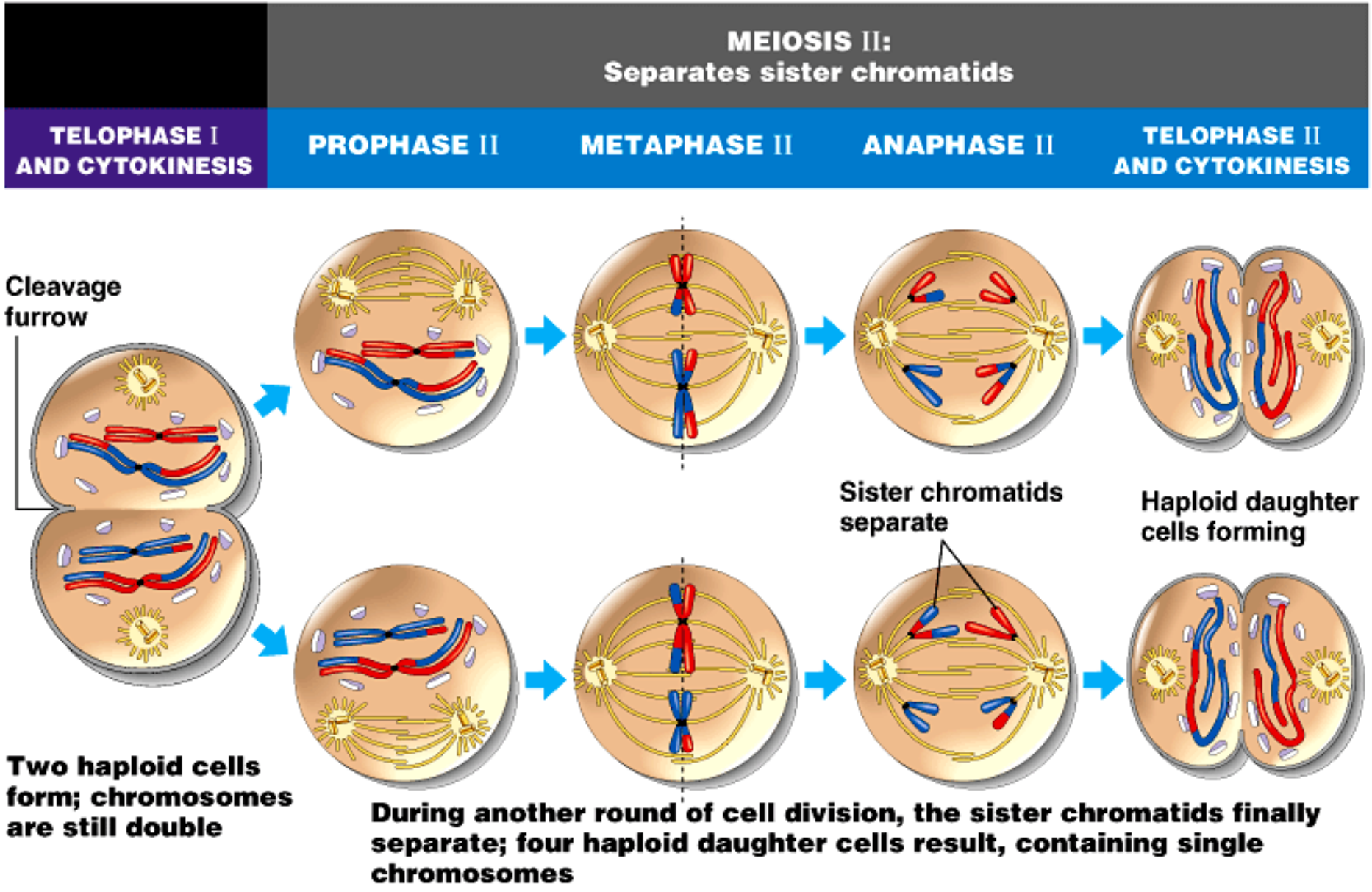
"reduction division"

2nd division of meiosis separates sister chromatids

(1n → 1n)

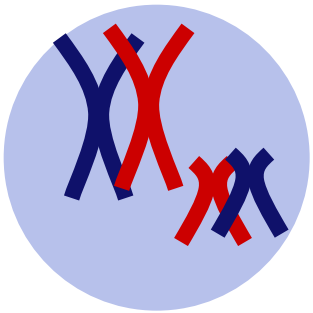
*** just like mitosis ***


MEIOSIS I:
Separates homologous chromosomes
INTERPHASE
PROPHASE I
METAPHASE I
ANAPHASE I
Centrosomes (with centriole pairs)
Nuclear envelope
Chromatin
Chromosomes duplicate
Chiasmata
Spindle
Sister chromatids
Tetrad
Homologous chromosomes pair and exchange segments
Microtubule attached to kinetochore
Metaphase plate
Centromere (with kinetochore)
Tetrads line up
Sister chromatids remain attached
Homologous chromosomes separate
Pairs of homologous chromosomes split up

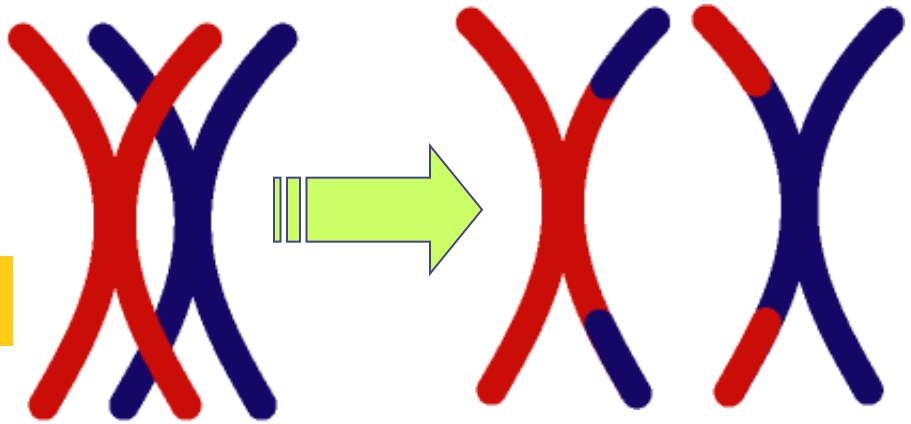

MEIOSIS II:
Separates sister chromatids
TELOPHASE I AND CYTOKINESIS
PROPHASE II
METAPHASE II
ANAPHASE II
TELOPHASE II AND CYTOKINESIS
Cleavage furrow
Sister chromatids separate
Haploid daughter cells forming
Two haploid cells form; chromosomes are still double
During another round of cell division, the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

Trading pieces of DNA

- **Crossing over**
  - during **Prophase I**, sister chromatids intertwine
    - **synapsis** and forms a chiasmata
    - homologous pairs swap pieces of chromosome
      - DNA breaks & re-attaches



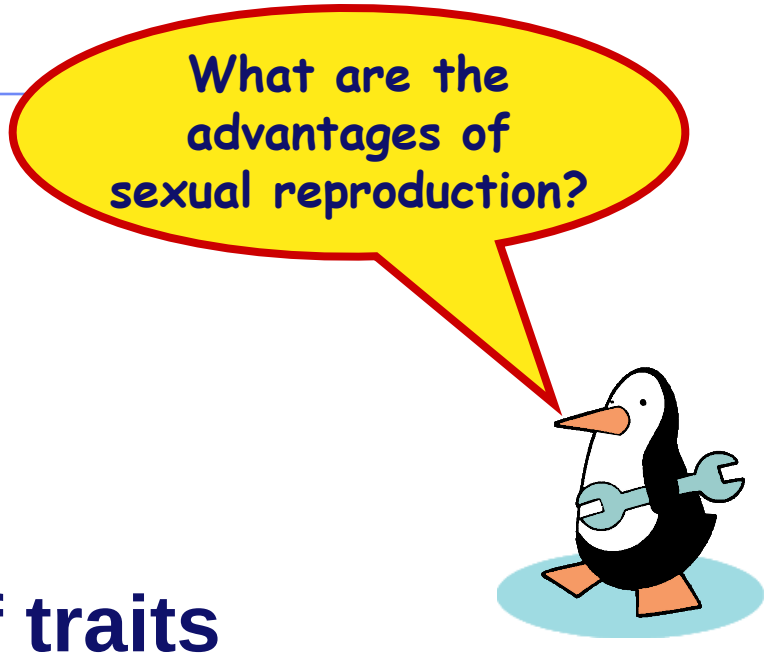
synapsis

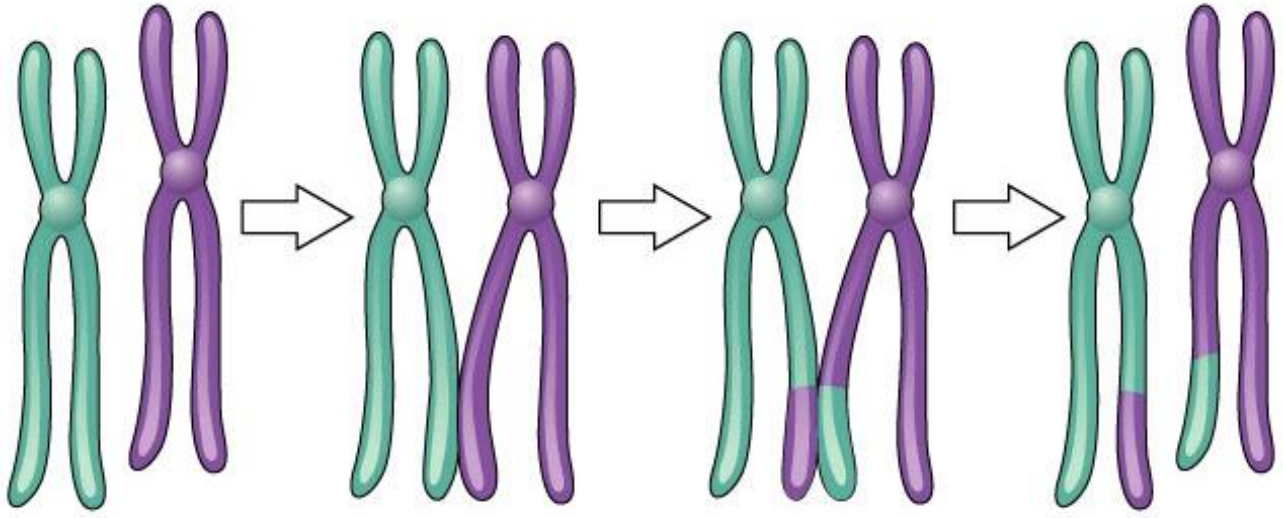


tetrad

Crossing over

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





Meiosis I

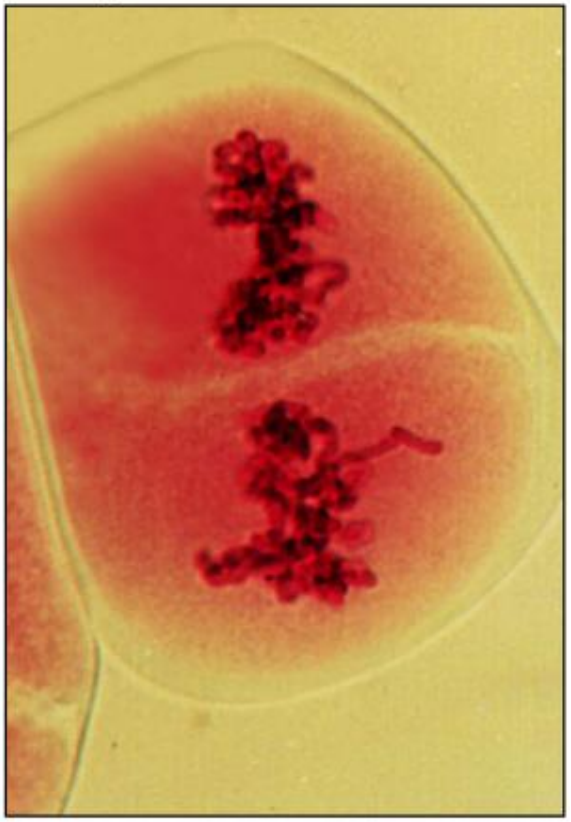
Prophase I

Metaphase I

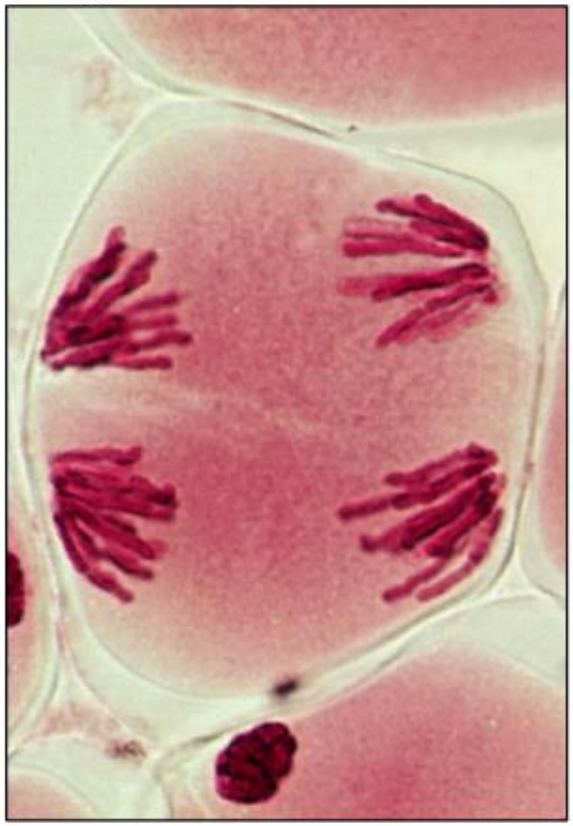
Anaphase I

Meiosis II

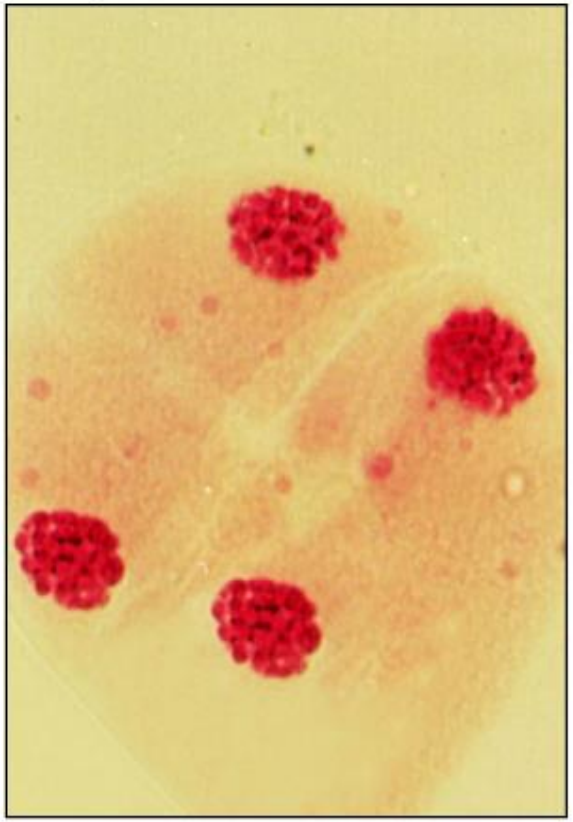
Metaphase II



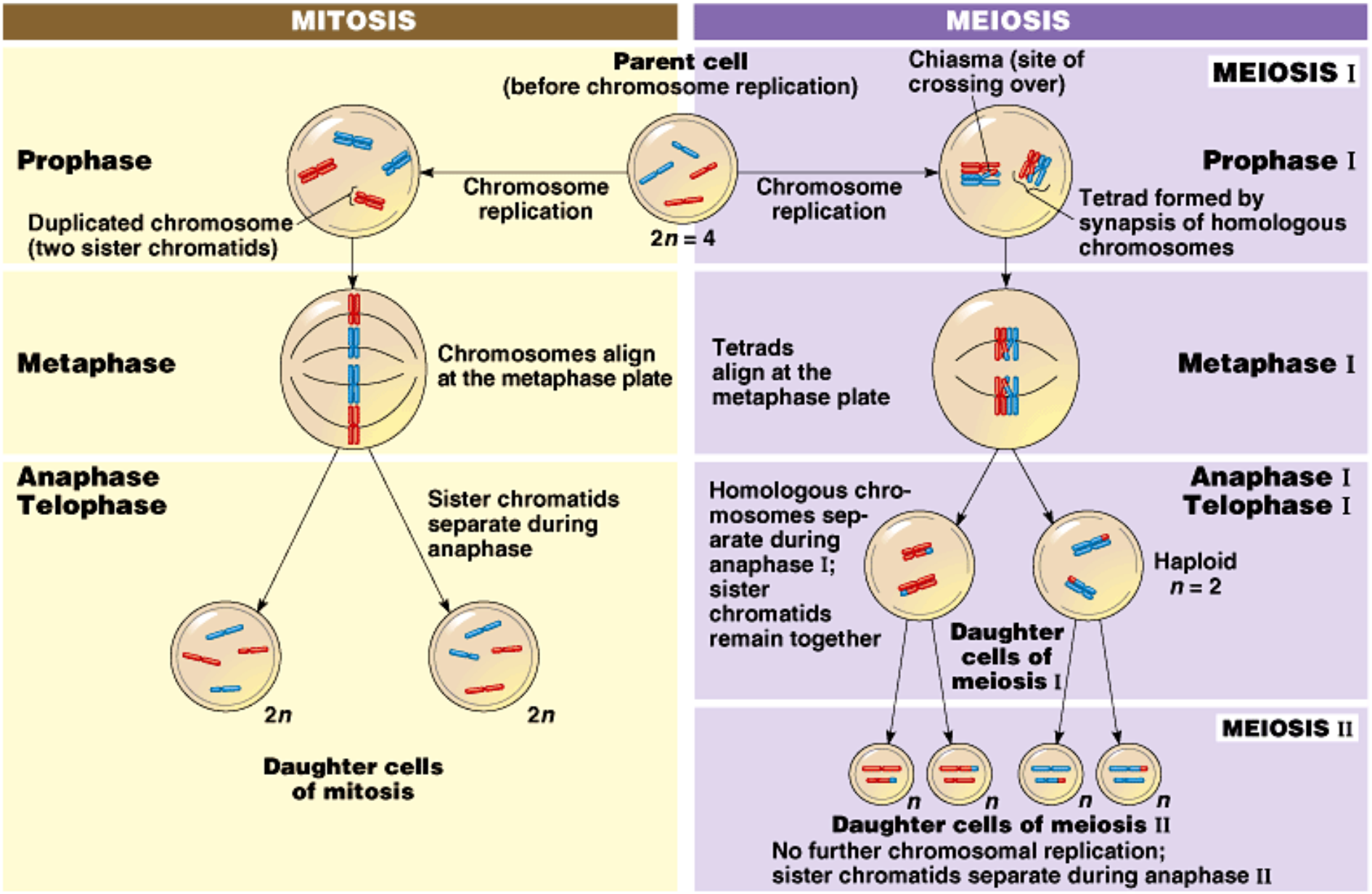
Anaphase II



Telophase II

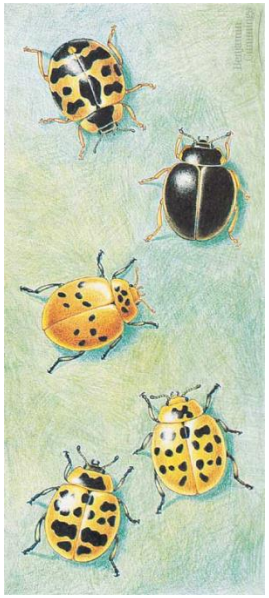


Mitosis vs. Meiosis

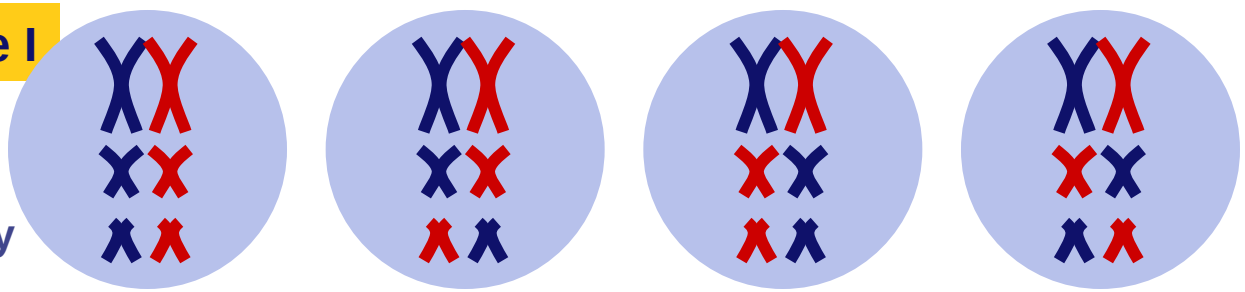


The value of sexual reproduction

- Sexual reproduction introduces genetic variation
  - genetic recombination during meiosis
    - independent assortment of chromosomes
      - random alignment of homologous chromosomes in Meiosis I
    - crossing over
  - random fertilization
    - which sperm fertilizes which egg?
- Driving evolution
  - variation for natural selection

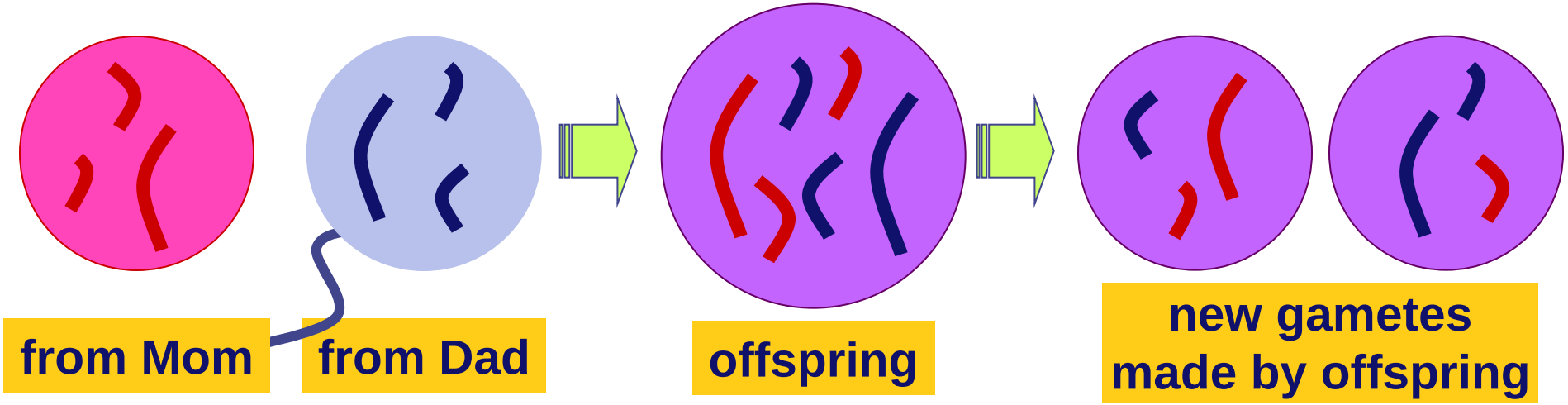


Metaphase I



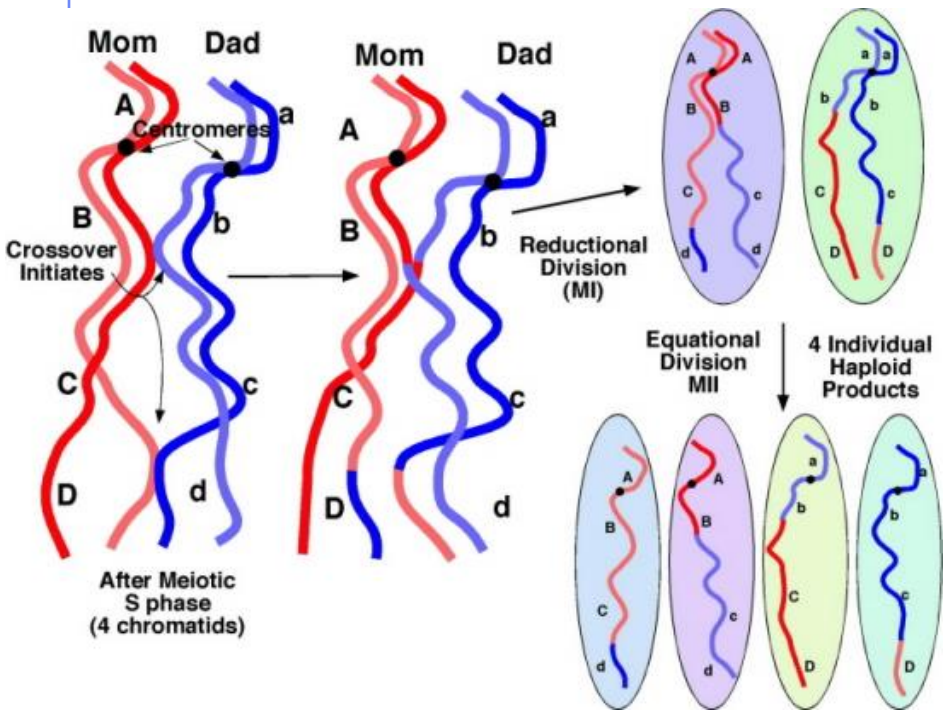
Variation from genetic recombination

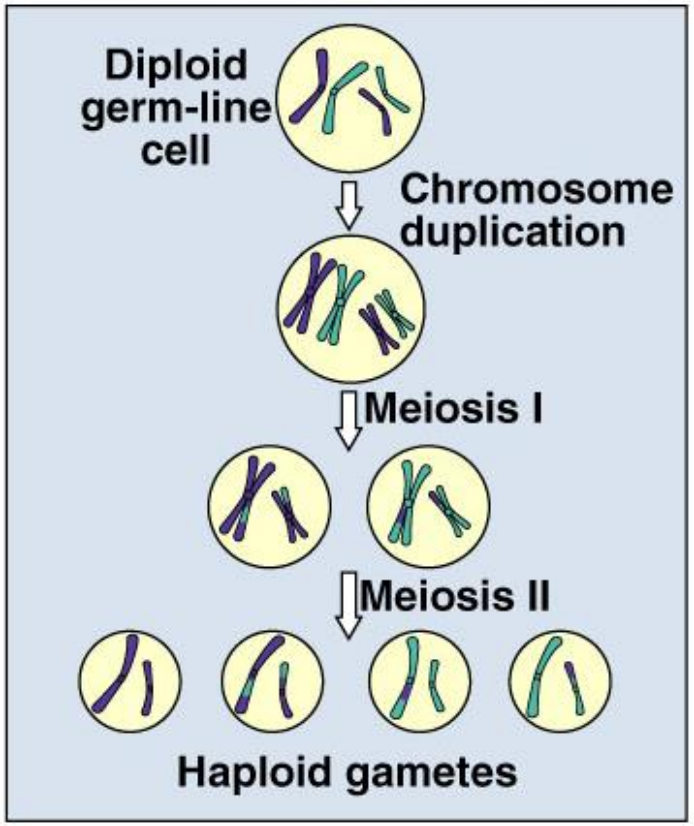
- **Independent assortment of chromosomes**
  - meiosis introduces genetic variation
  - gametes of offspring do not have same combination of genes as gametes from parents
    - random assortment in humans produces 2^{23} (8,388,608) different combinations in gametes



Variation from crossing over

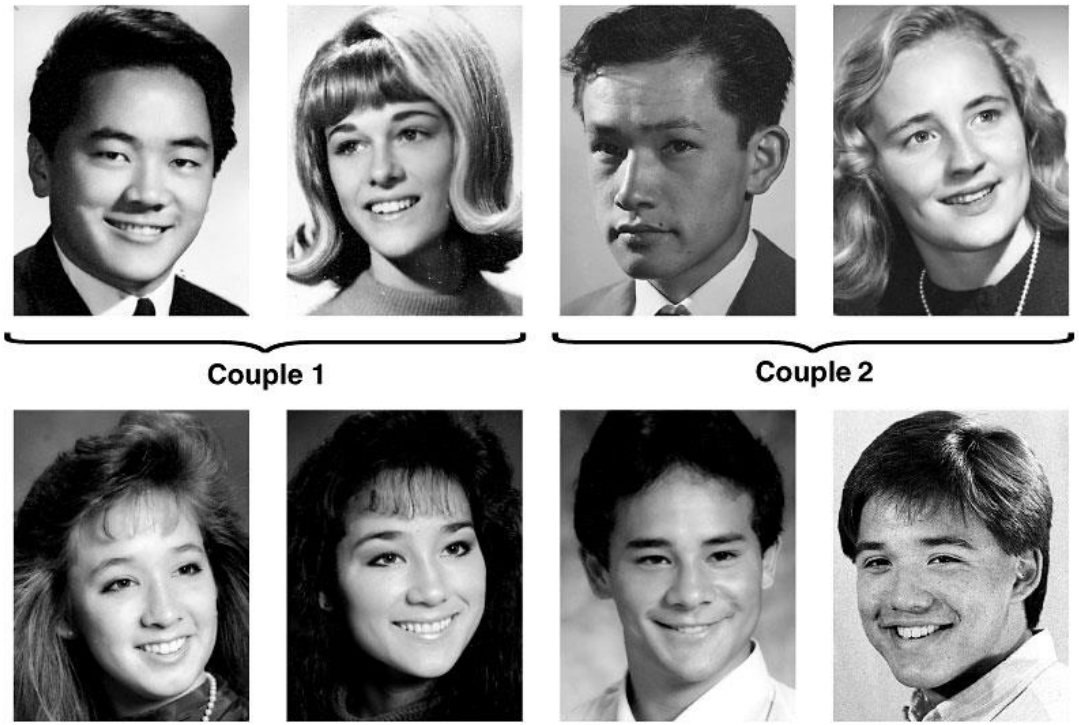
- **Crossing over creates completely new combinations of traits on each chromosome**
  - **from 8 million different gametes → "immeasurable"**

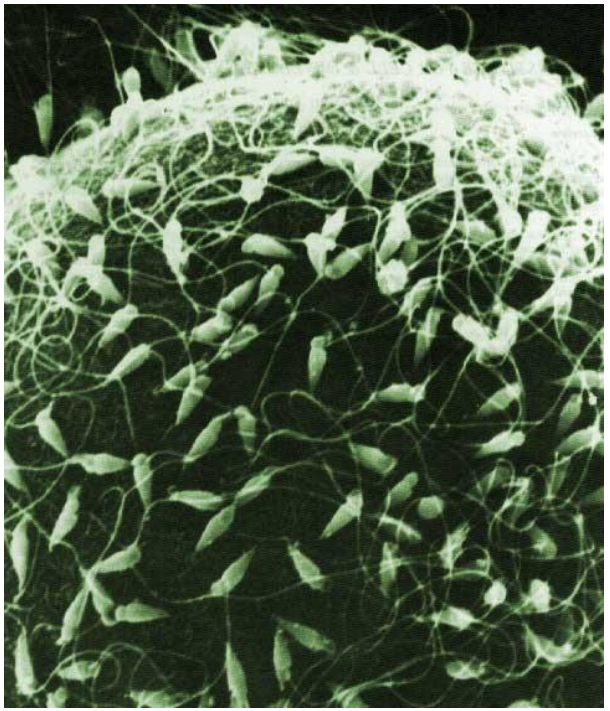




Variation from random fertilization

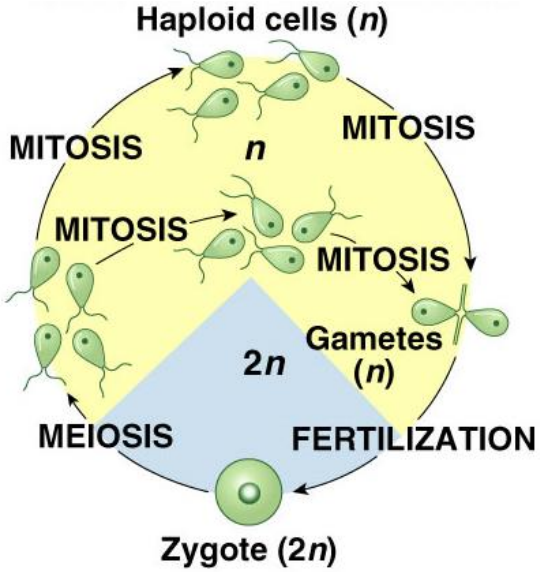
- **Sperm + Egg = ?**
  - **any 2 parents will produce a zygote with over 70 trillion (2^{23} x 2^{23}) possible diploid combinations**



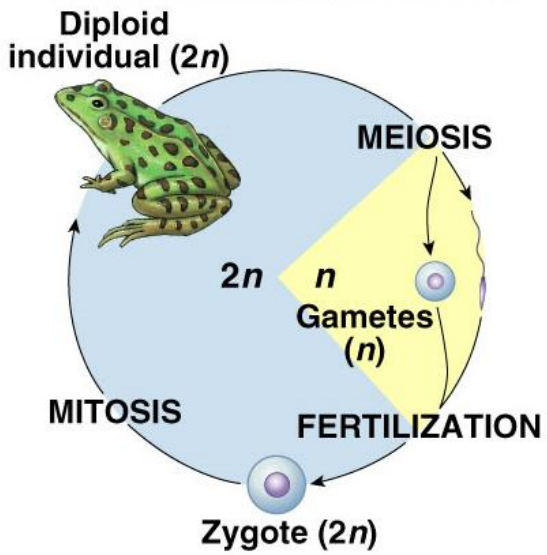


Differences across kingdoms

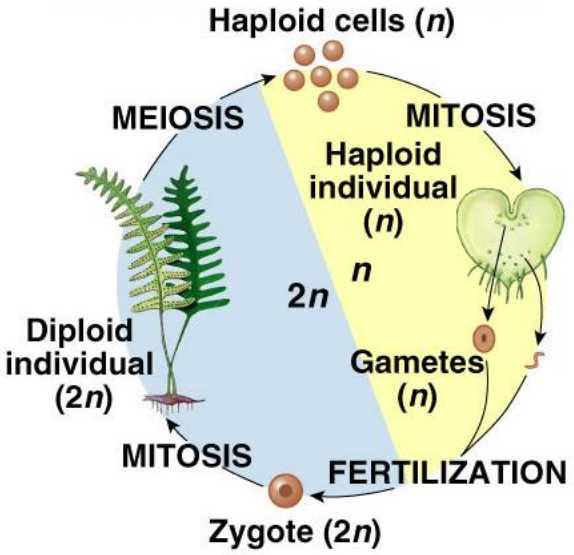
- **Not all organisms use haploid & diploid stages in same way**
  - **which one is dominant (2n or n) differs**
  - **but still alternate between haploid & diploid**
    - **must for sexual reproduction**



(a) Some types of algae



(b) Most animals



(c) Some plants and some algae