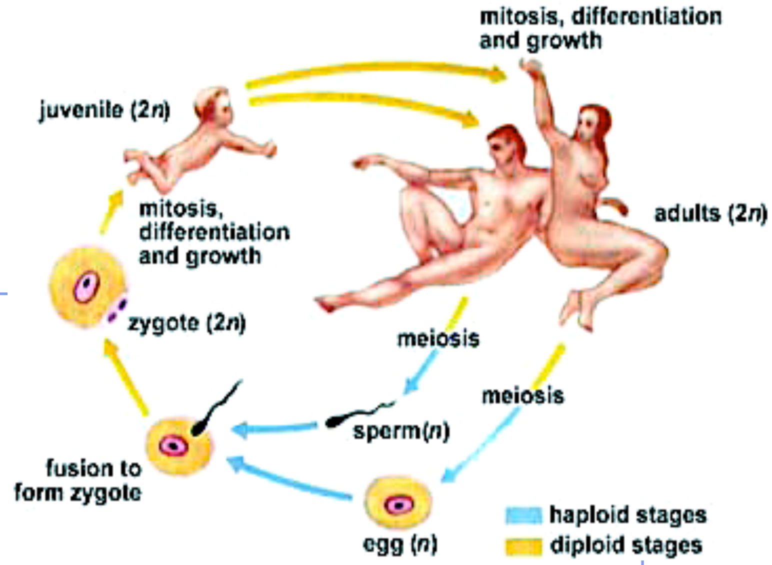
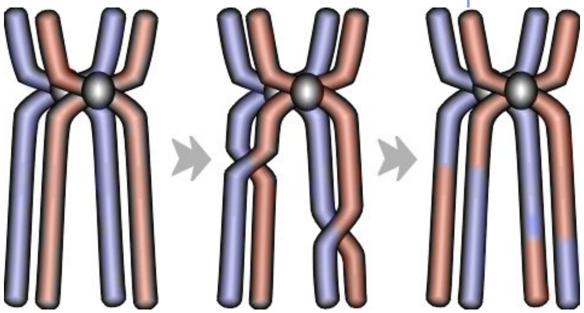


Chapter 13:

Meiosis & Sexual Reproduction

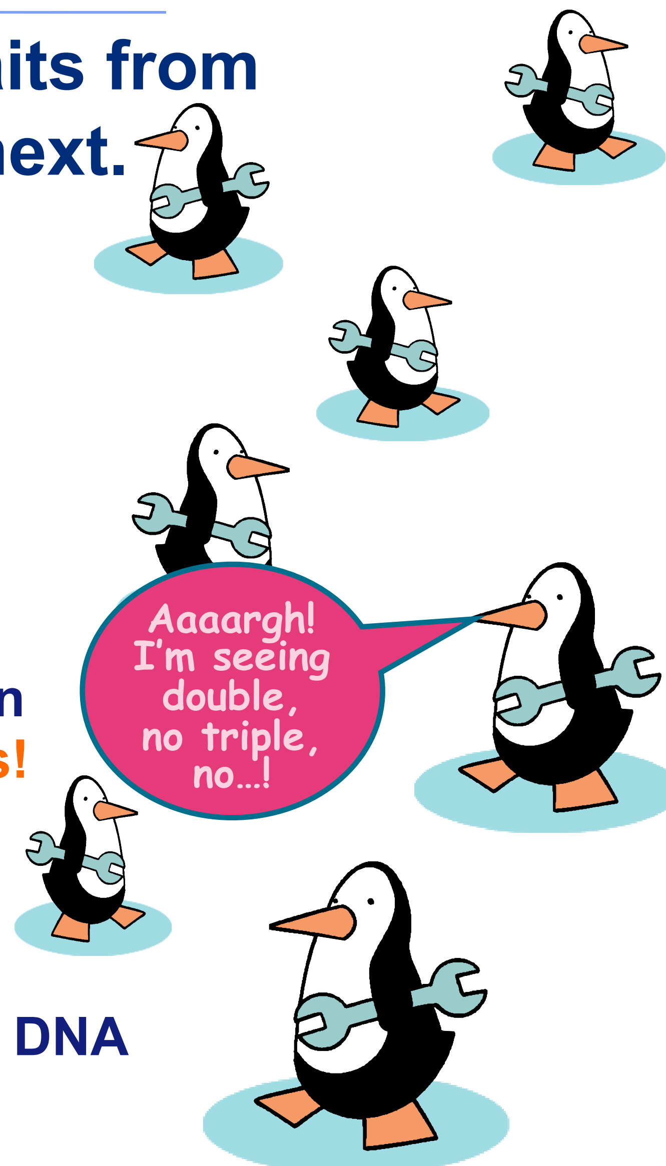


Reproduction *(Making Offspring)*

- **Heredity: The transmission of traits from one generation to the next.**
  (Latin "heres" meaning heirs)

- **Genetics: The study of heredity.**

- **Asexual Reproduction:**
  - Via Binary Fission (in prokaryotes) & Mitosis (in eukaryotes)
    - Produces cells with same information
      - produces identical daughter cells!
    - Daughter cells are exact genetic copies of the parent cell!!!
      - the daughter cells are clones!
    - Cells have same amount & type of of DNA
      - same number of chromosomes
      - same genetic information



Asexual Reproduction - Prokaryotes

Single individual is the sole parent

- Binary fission is the process of asexual reproduction (cell division) which takes place in prokaryotic cells, like bacteria.
  - Advantages:
    - it is fast *(approx. 20 min generation time for some bacteria under optimal conditions)*
    - it only requires a single organism *(sexual reproduction requires two)*
    - offspring inherit that one parent's gene versions and, thus, have the same traits of the parent which is a positive if the characteristics of the parent work well in a given environment.

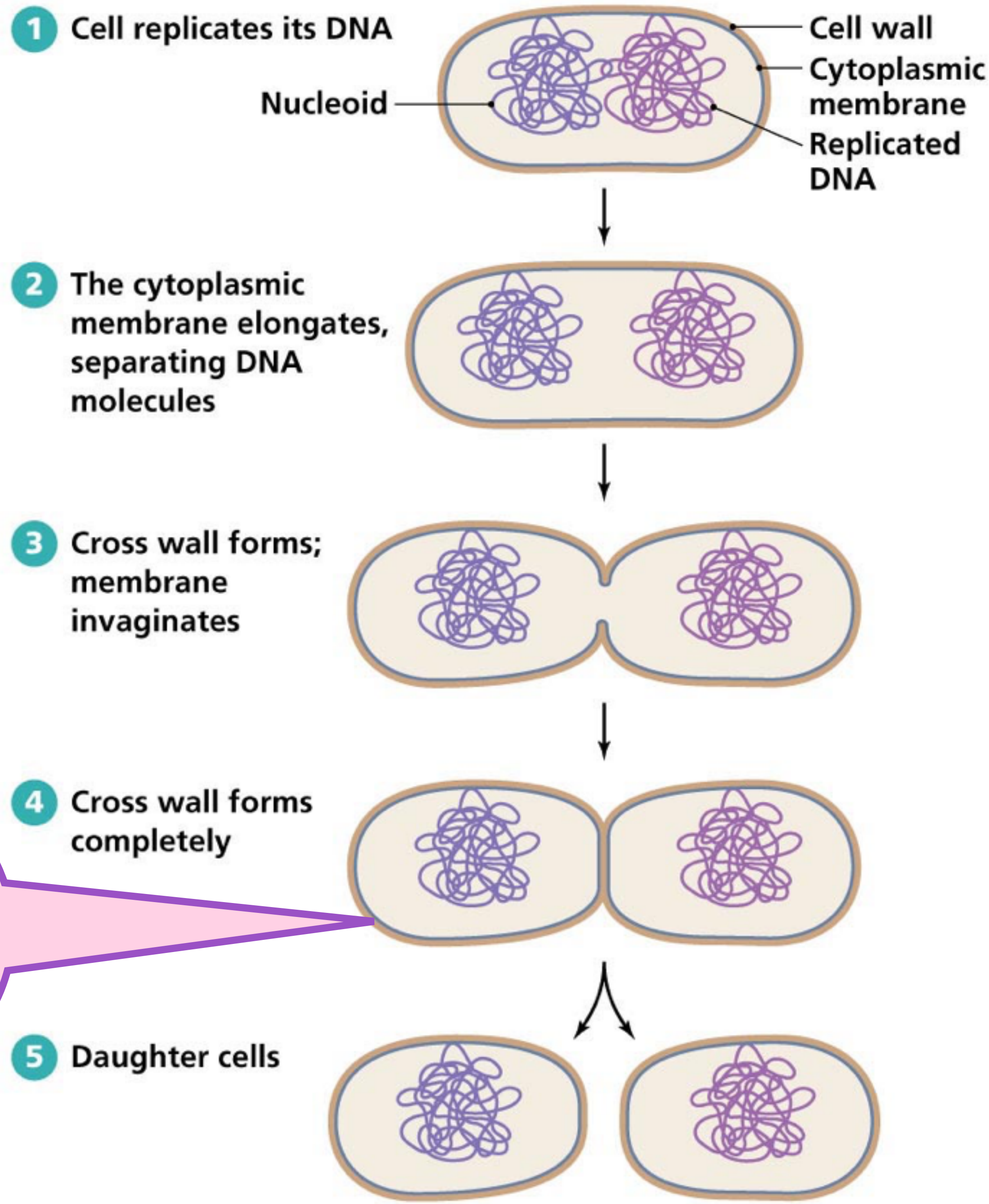
- Recall: Gene = a segment of DNA that contains the information for making a specific type of RNA *(tRNA, rRNA etc..)* or for making polypeptides and, thus, proteins *(via mRNA)*
- Recall: Mutations in the DNA of genes has resulted in various versions of a gene, called alleles, sometimes existing between organisms in a population, alleles of a particular gene differing slightly in their DNA sequences.

Binary Fission

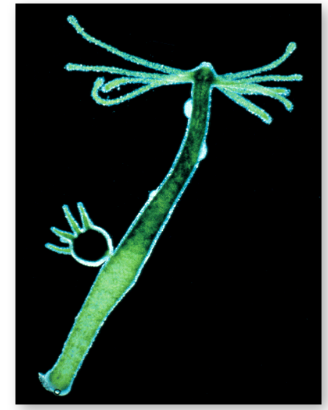
Disadvantages:

- NO genetic variation is introduced into offspring, which are clones of the parent, except if an error is made when copying the parental DNA resulting in a DNA mutation

Some types of bacteria have evolved ways of increasing their own genetic variation through processes such as transformation and conjugation (Ch.27)

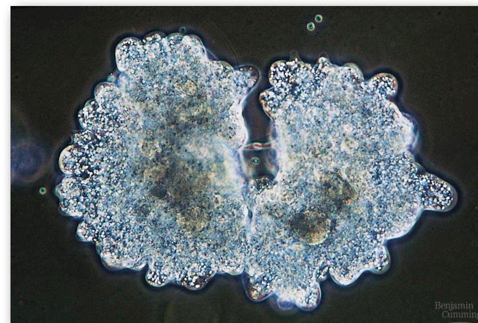


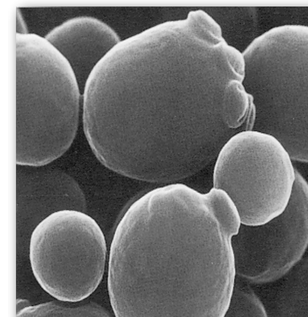
Asexual Reproduction - Eukaryotes

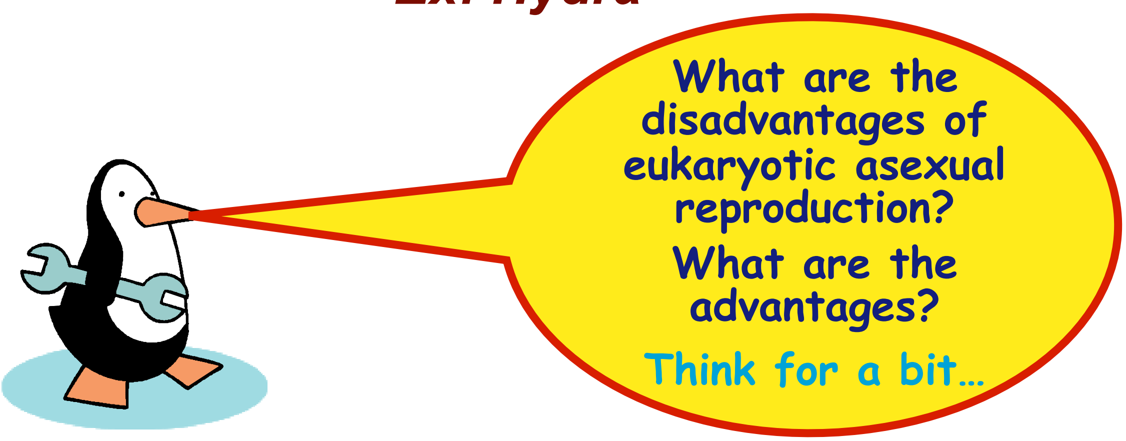


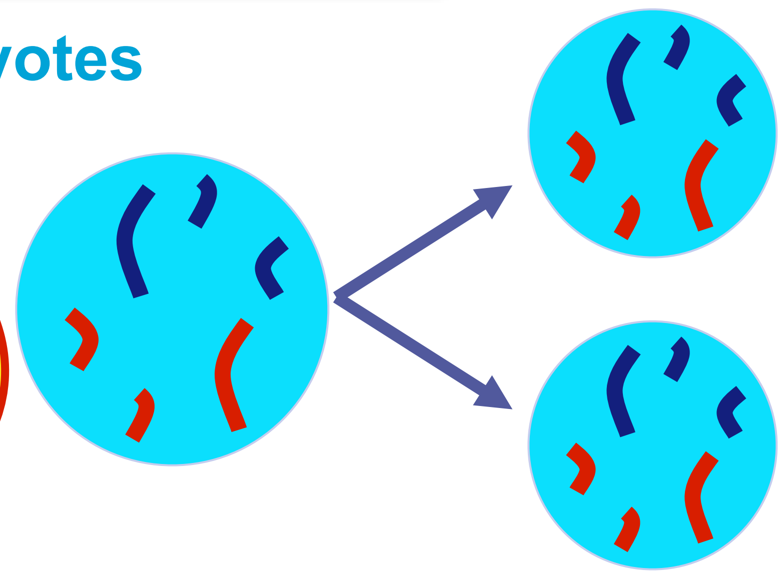
Single individual is the sole parent

- Passes, *through mitosis & cytokinesis*, ALL its genes to offspring
  - Single-celled eukaryotes
    - Ex: *Protists*
      Paramecium
      Amoeba
  - Simple multicellular eukaryotes
    - *Ex: Hydra*





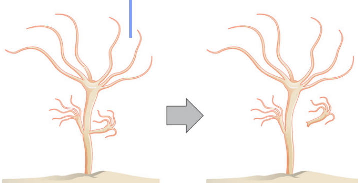


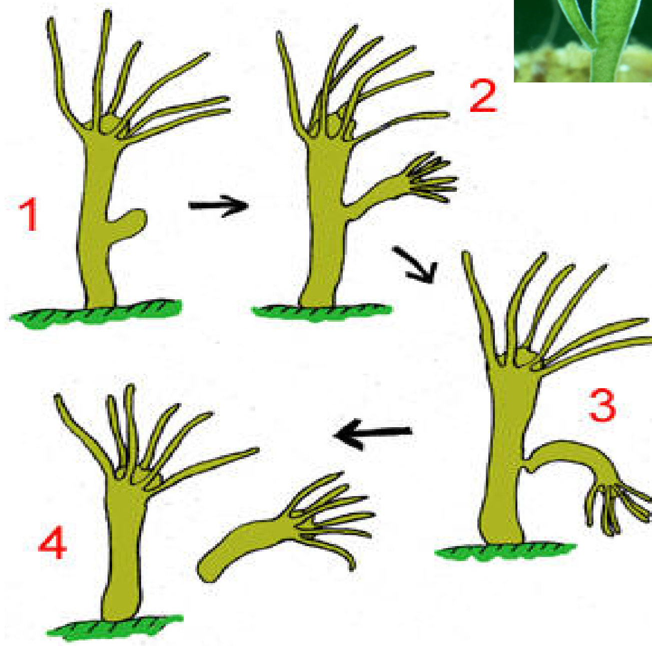


Asexual Reproduction

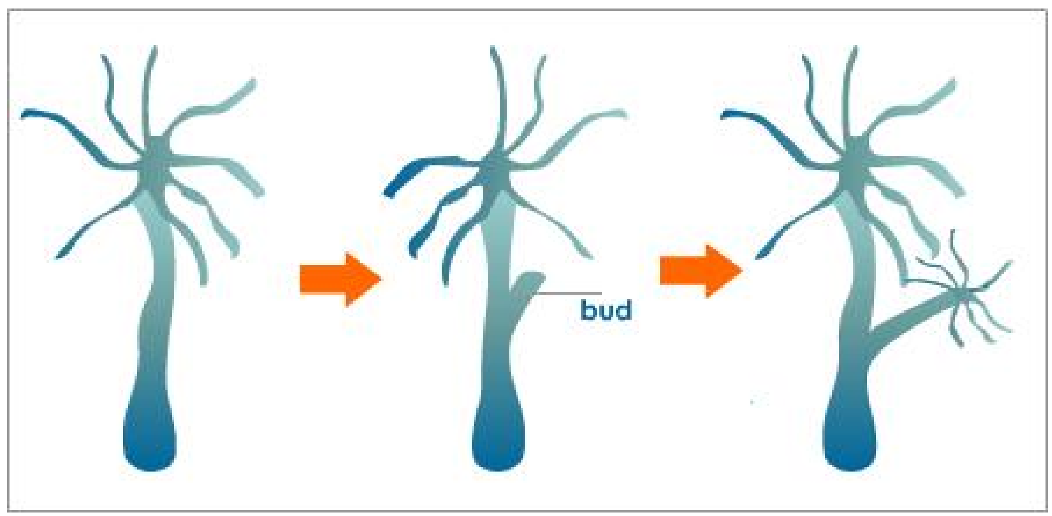
Single individual is the sole parent

- ***Ex: Hydra***
  - Relies on a budding, a form of asexual reproduction via mitosis & cytokinesis
    - Hydra develops an outgrowth through mitosis, which when detached from the parent, becomes a new individual.





  - This is perfect for the Hydra, which doesn't move, so its chances of finding a partner to mate with are slim.

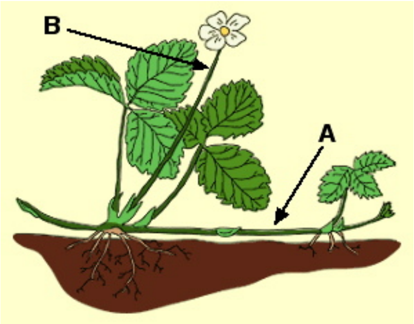


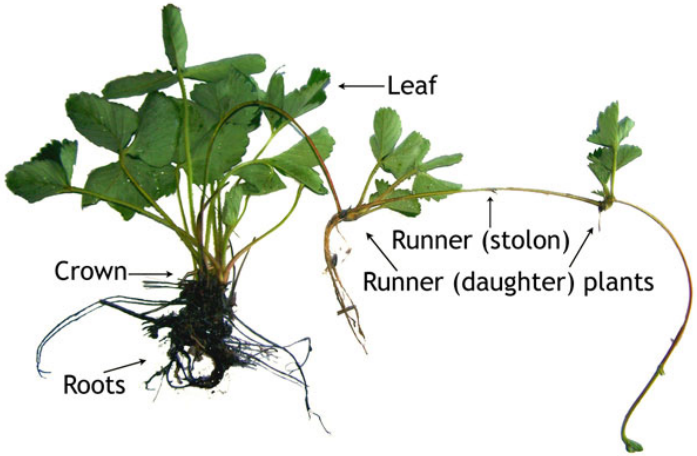
Asexual Reproduction

- Vegetative reproduction is a form of asexual reproduction in plants, where parts of the plant fall off and develop into new plants or the plant sprouts a new plant from certain existing parts.

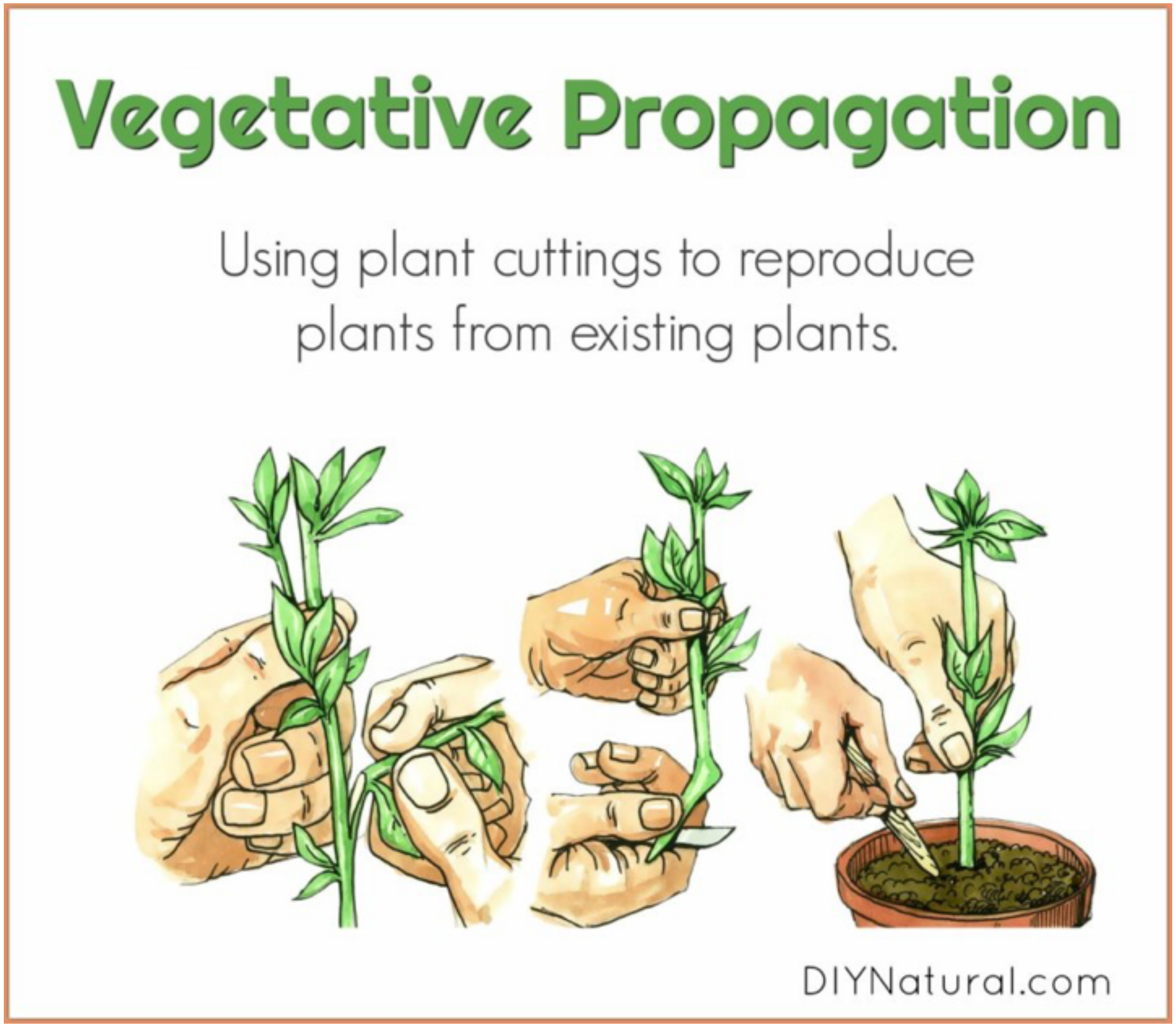
- Since asexual reproduction doesn't require another partner, or pollen transfer, it is very quick and is guaranteed.
- The main disadvantage of this form of reproduction, is that the new plants will all grow very close to each other and to the parent.
  - This will cause a struggle/competition for soil, nutrients and light.

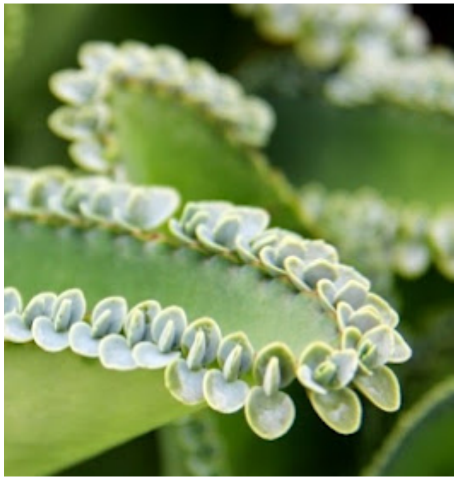
- Ex: potato tubers and redwoods are examples of a plant that used this form of reproduction where new plants grow around and from the parent plant
- Ex: Strawberries produce runners over the ground, irises and ferns produce rhizomes underground, daffodils and hyacinths produce daughter bulbs.



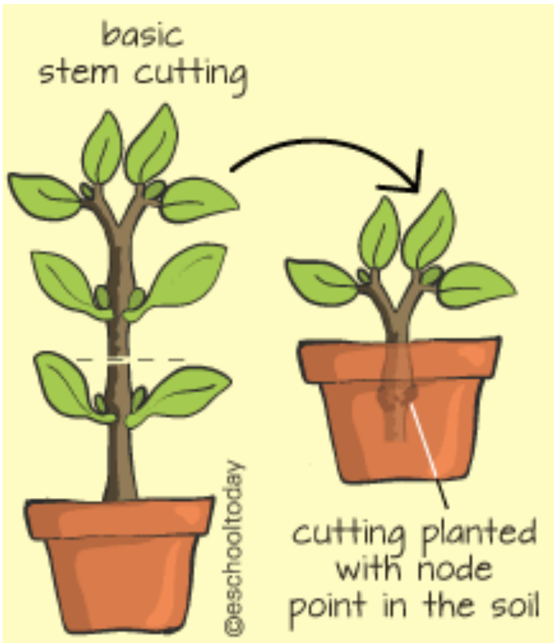


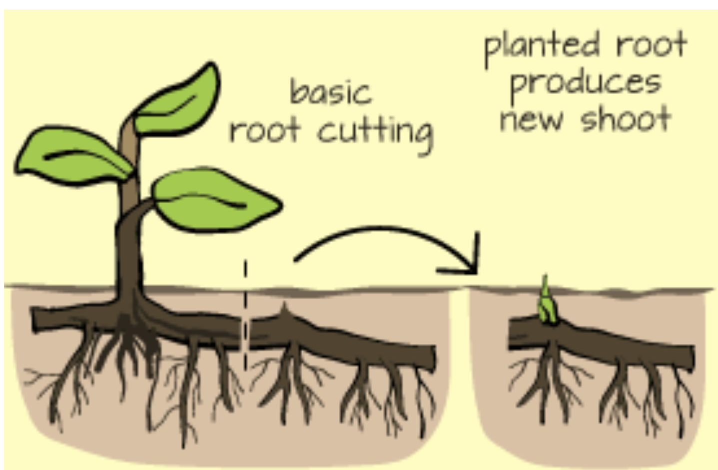
Asexual Reproduction

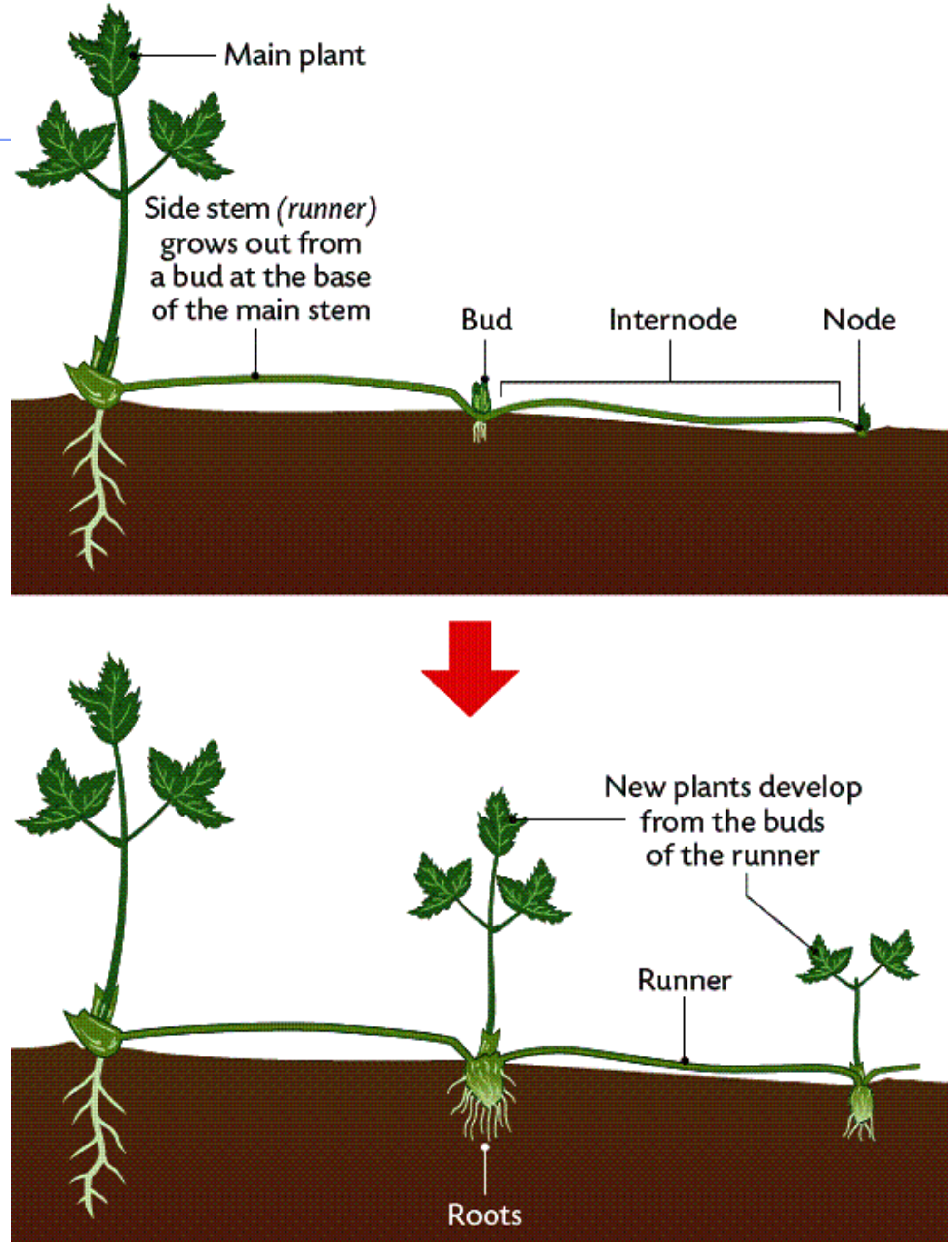




Asexual Reproduction

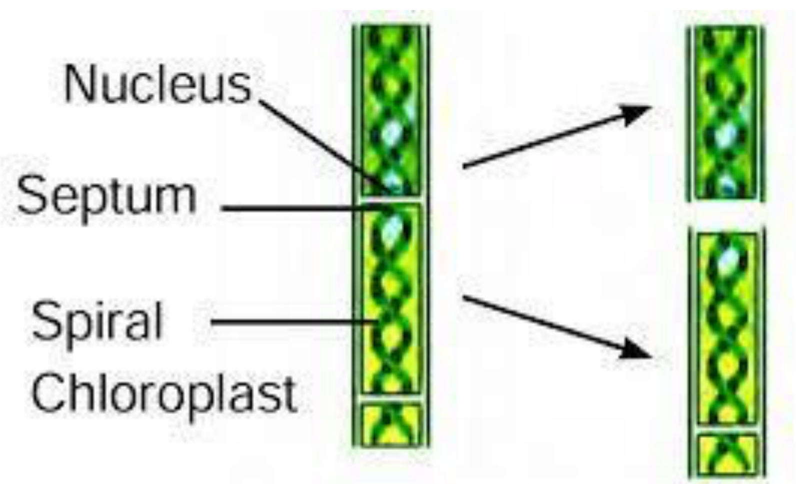




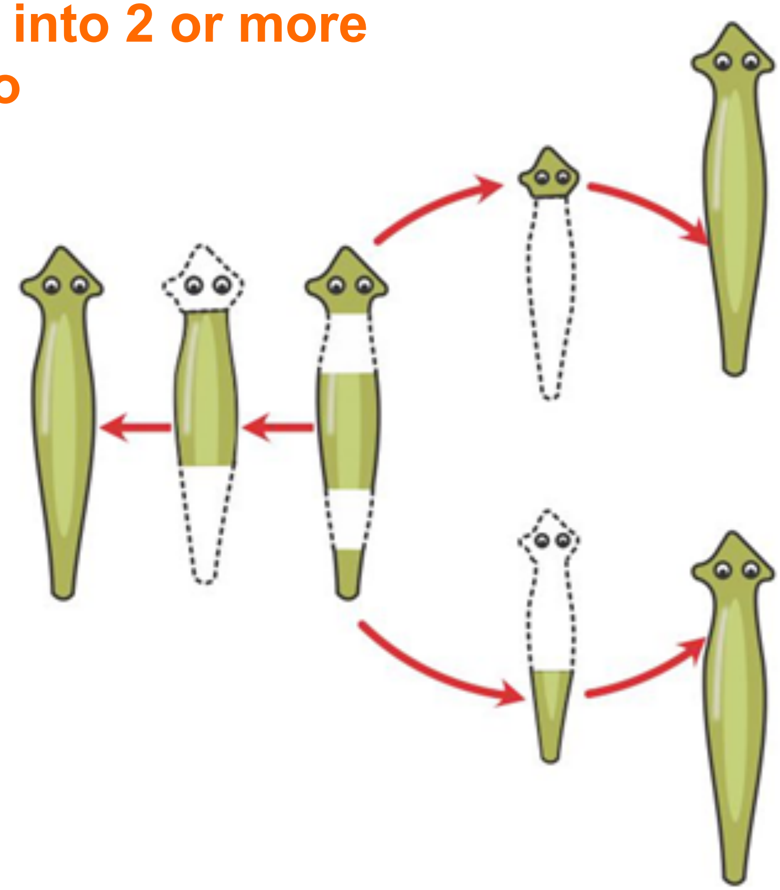


Asexual Reproduction

- Fragmentation is another form of asexual reproduction in plants, some alga, and lower animals such as some worms, planaria, hydra, sponges.
  - When an organism is broken into 2 or more pieces, each piece grows into a separate new individual.

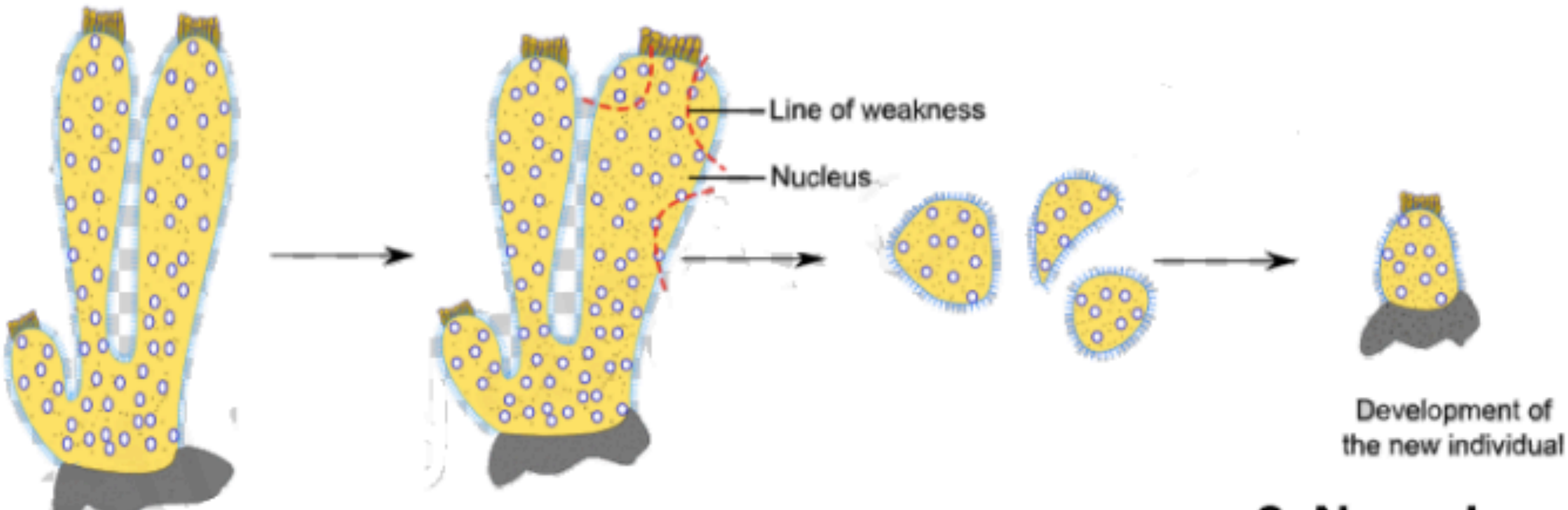


Fragmentation in spirogyra



Asexual Reproduction

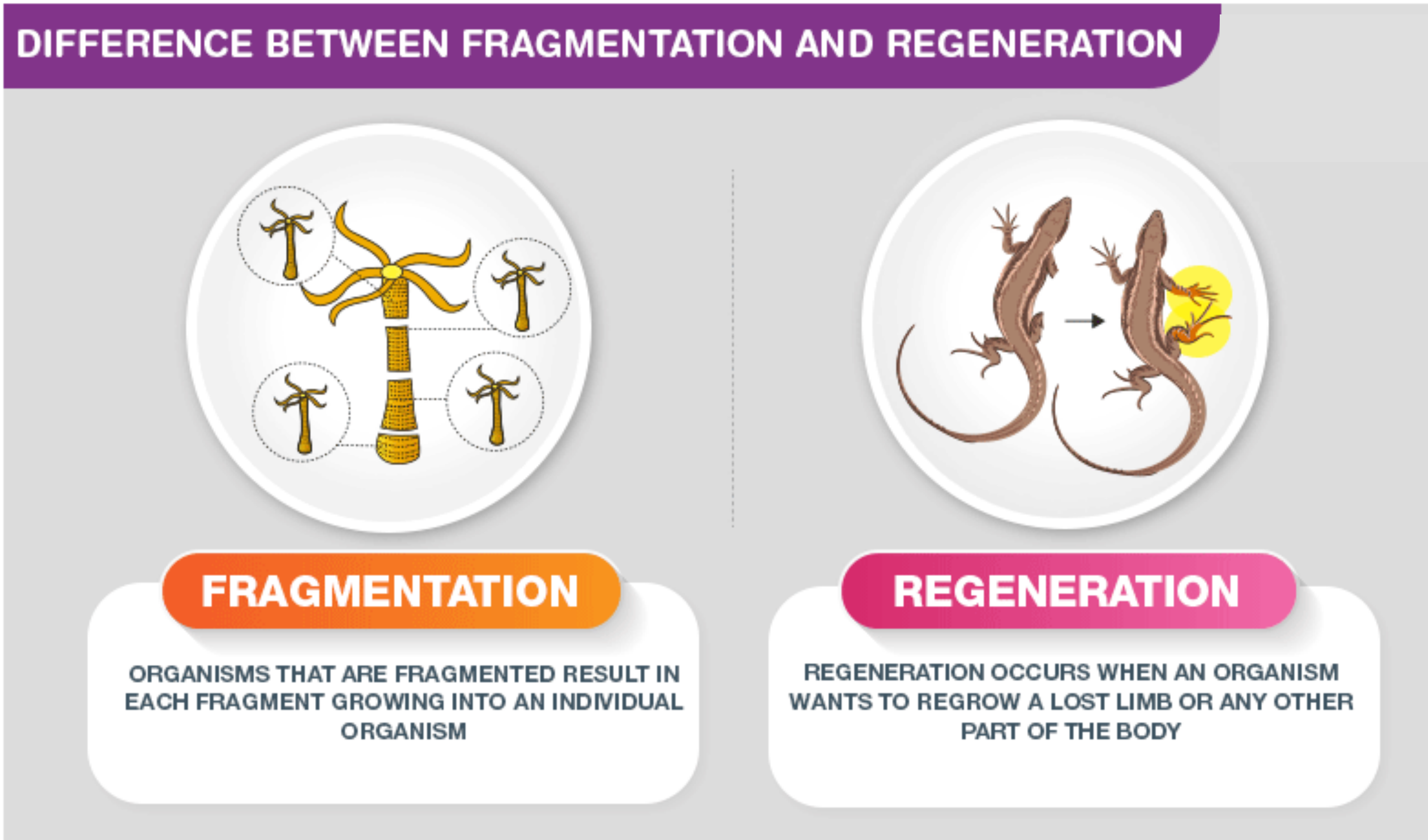
Asexual Reproduction - Fission/fragmentation



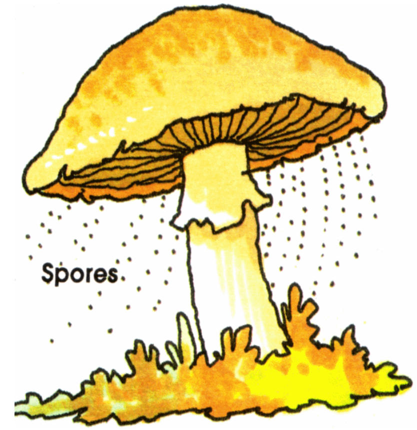
1. Sponge is split or broken into pieces (accident - fragmentation, purpose - fission)

2. New clones attach to a surface and begin to grow

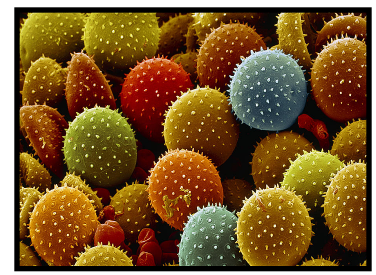
Asexual Reproduction: Fragmentation results in reproduction. Regeneration does not.



Asexual Reproduction



- **Spores** are cells, formed by the parent organism to carry out reproduction directly or indirectly.
  - Eukaryotes like plants make spores via *meiosis* and use them in their *sexual* life cycle but….
  - Certain eukaryotic Fungi make spores *asexually (via mitosis)*
  - And bacterial prokaryotes make endospores *asexually* too (via a modified form of binary fission).



Fungal Spores

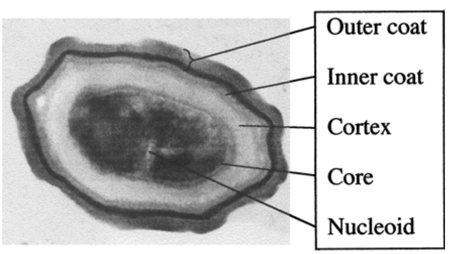
- If environmental conditions are suitable, **spores of fungi and endospores of bacteria** develop into new individual organisms.
  - Disadvantage: A spore developing into an active adult cell will only occur under good conditions.
  - Advantage: Spores are very effective, because they are small and light, and so can be carried to new locations by wind, water or animals so they can travel far away from the parent, perhaps to better conditions.
  - Advantage: Some spores have thick walls which can give them protection against unfavorable conditions (high heat or drought) that may kill the adult cells that made the spores

Germinating Fungal Spores

Asexual Reproduction - Bacterial Endospores

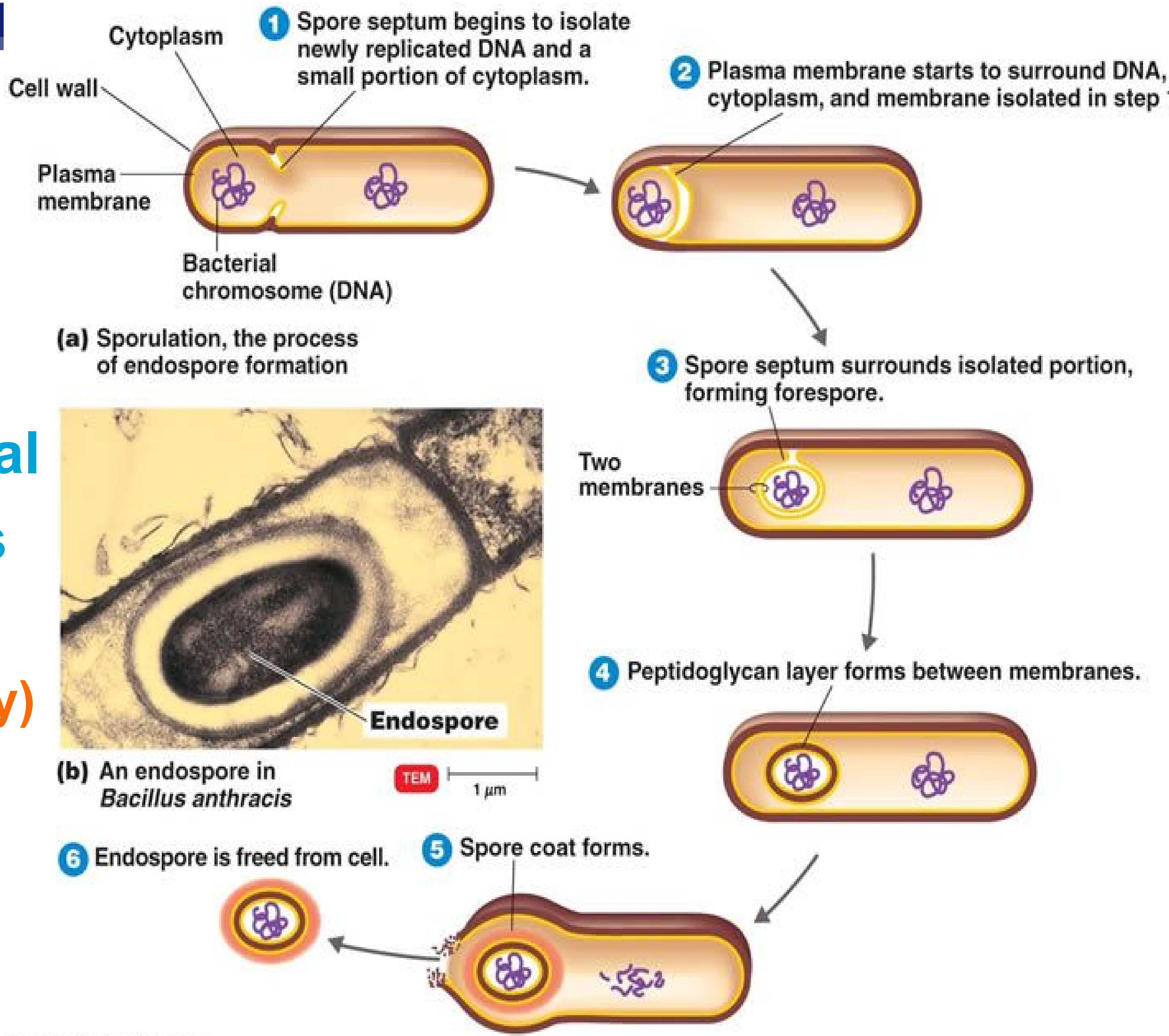
- Certain bacteria have evolved strategies to help the species survive temporary damaging conditions in their environment
  - Microorganisms sense and adapt to changes in their environment.
    - When favored nutrients are lacking, some bacteria may become motile to seek out nutrients elsewhere, or they may turn on certain genes to produce enzymes to exploit alternative nutrients.
    - One example of an extreme survival strategy employed by certain bacteria is the formation of endospores.

      - This complex developmental process is often initiated in response to nutrient deprivation or other extreme condition.
      - It allows the bacterium to produce a dormant and highly resistant cell to preserve the cell's genetic material in times of extreme stress *(when the active bacterial cell would otherwise die)*



        - While these environmental stressors would kill an active bacteria, the endospore can survive exposure to high temperature, high UV irradiation, desiccation (dehydration), chemical damage and foreign enzymatic destruction.

Bacterial Spores (Made Asexually)

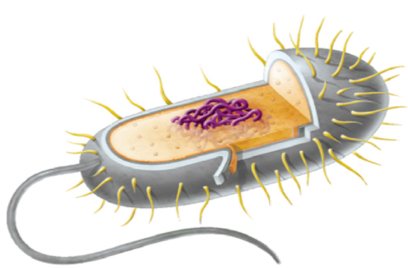


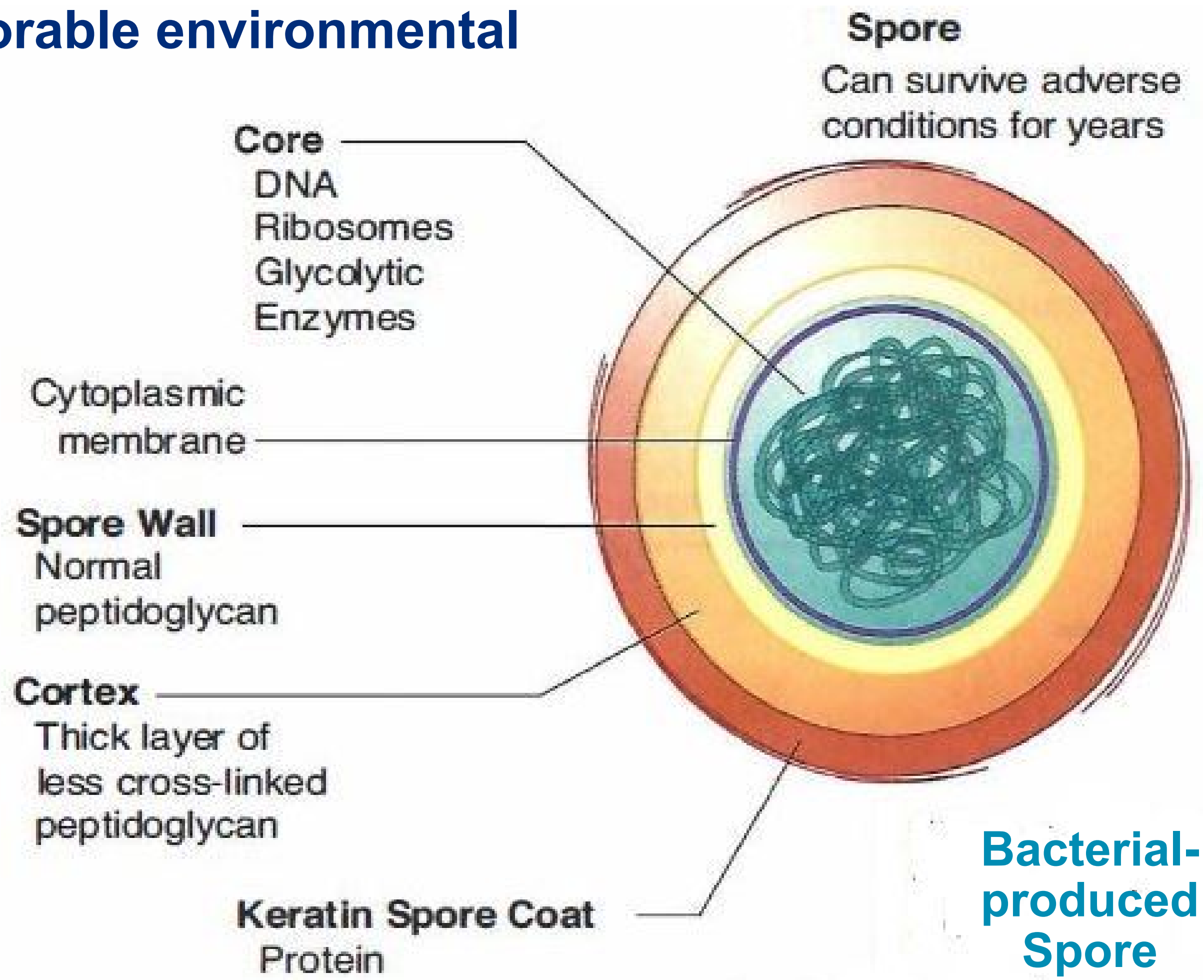
(a) Sporulation, the process of endospore formation

(b) An endospore in *Bacillus anthracis*

Asexual Reproduction

- **Bacterial Endospores**
  - **Lie dormant sometimes for YEARS [metabolically - *chemically* - inactive] until favorable environmental conditions return, allowing them to survive extreme conditions like dryness, lack of nutrients, and heat that that would kill the active bacterial cells normally.**

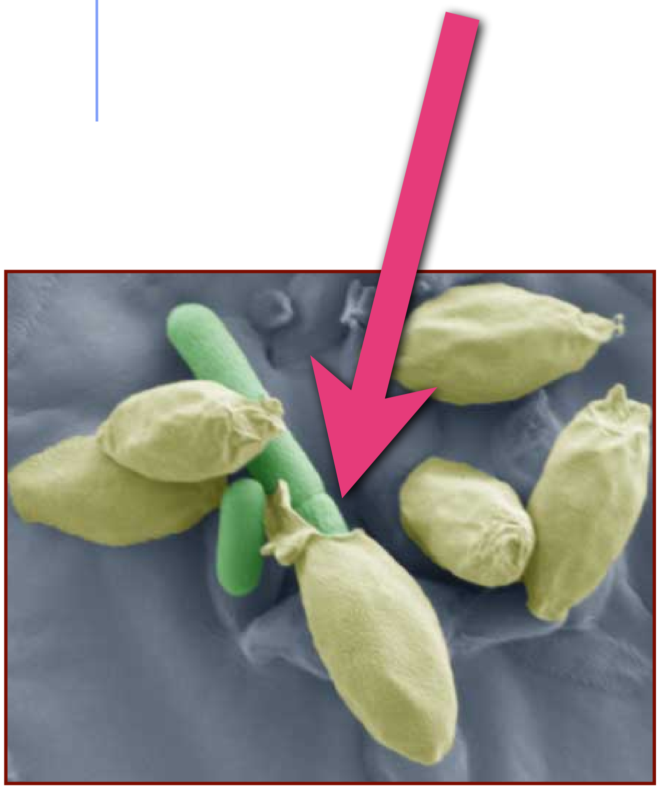


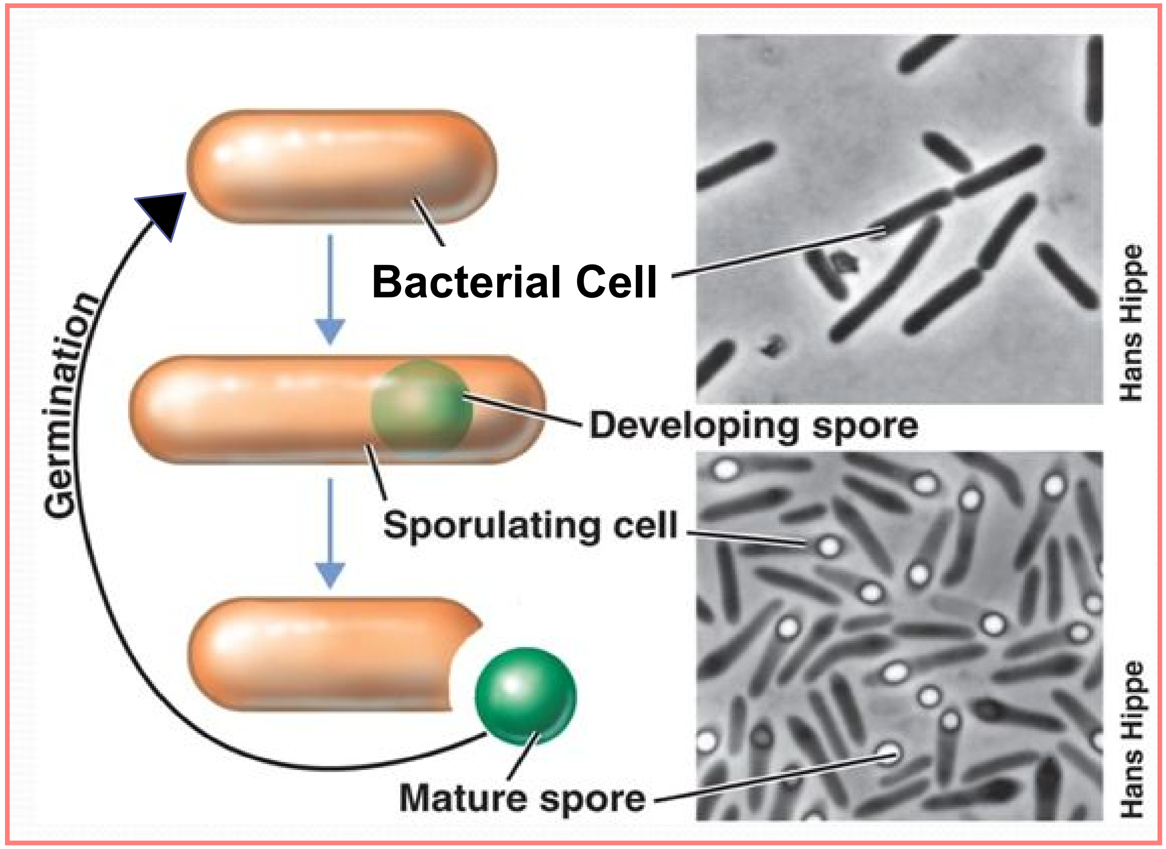


Bacterial-produced Spore

Bacterial Spores [Made Asexually]

Under good conditions, the inner portion of the spore matures into a new active bacteria, which emerges from the spore (break out of the spore coat) through a process called germination.





Asexual Reproduction

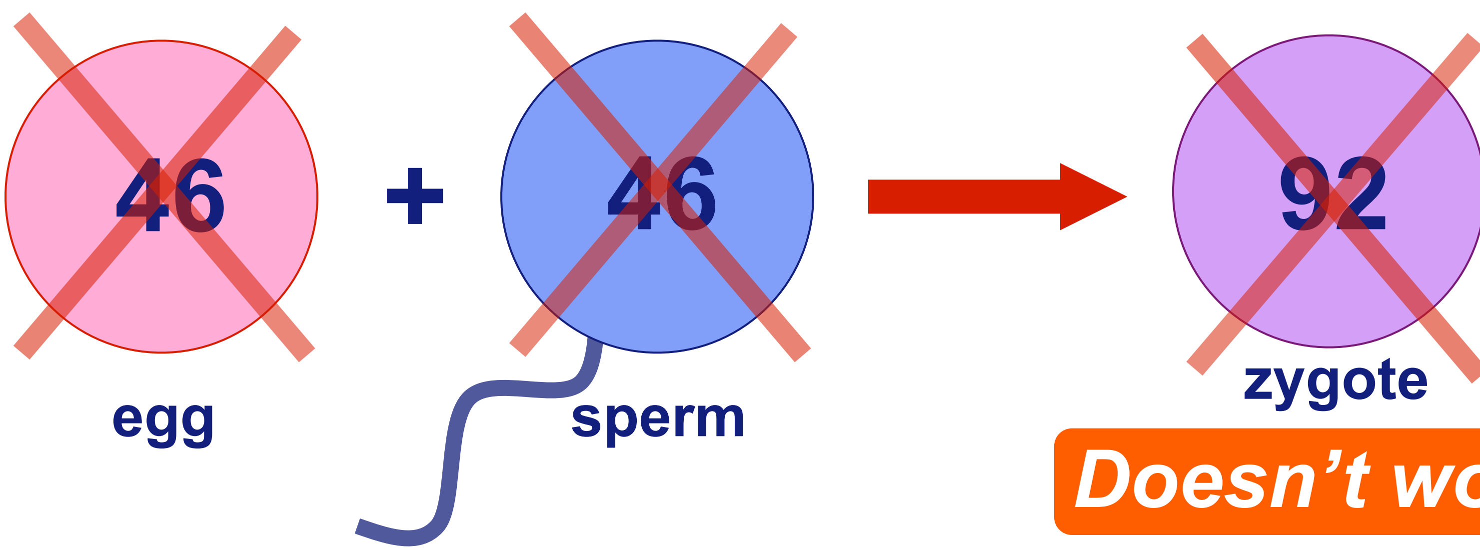
- **Advantages:**
  - No gestation period
  - No mate needed
    - No energy spent on this task
  - If you are unicellular, two offspring are made each time
  - Large number of offspring produced very quickly under right conditions
  - Large number of organisms means that species may survive when conditions are favorable
- **Disadvantages:**
  - Any negative mutation in the DNA can weaken or destroy all offspring as they are clones of the one parent that made them
  - Some methods of asexual reproduction produce offspring that live close together and so compete for nutrients and space (resources)
  - No genetic variation for natural selection to act on in case of environmental changes
    - Individuals have no genetic variation that may help some, and thus the species, survive changing environmental variables.

Sexual Reproductive: How about the rest of us?

- What if a complex multicellular organism (like a human) wants to reproduce?
  - Involves joining gametes (reproductive cells) from two different parents.
    - For us that's an egg + sperm
- Do we make egg & sperm by mitosis? **No!**

What if we did, then….

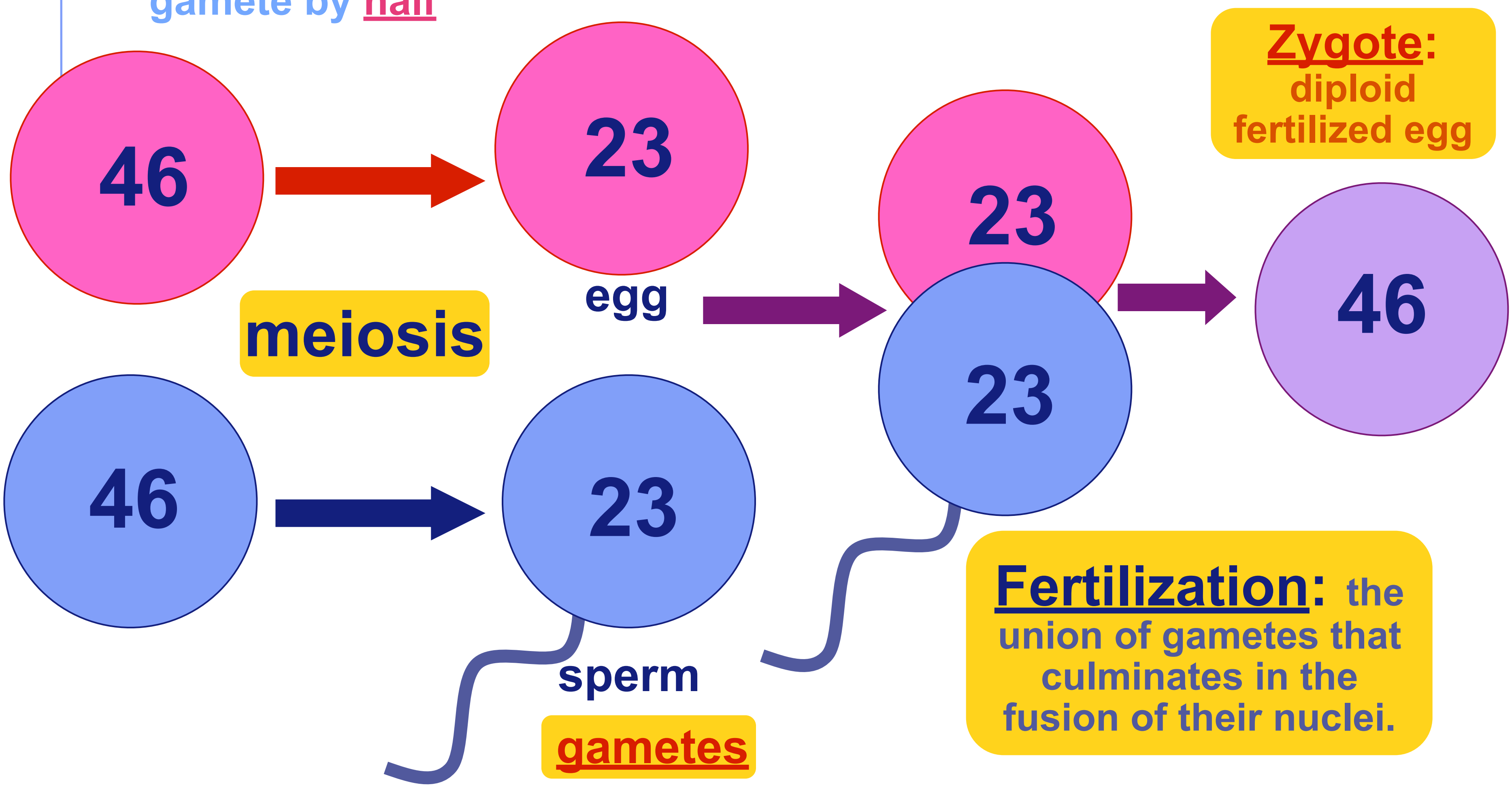
Wrong "Gene Dosage"



Doesn't work!

How do humans make sperm & eggs?

- **Must reduce the # of 46 chromosomes to 23 per gamete**
  - must reduce the number of chromosomes in each gamete by half

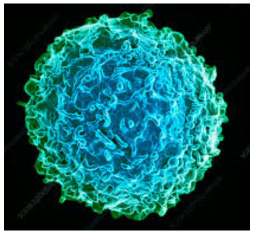


Every species has a specific number of chromosomes that make up one set, and a specific number of sets of chromosomes in their cells.

Two types of cells can be distinguished in sexually reproducing organisms:

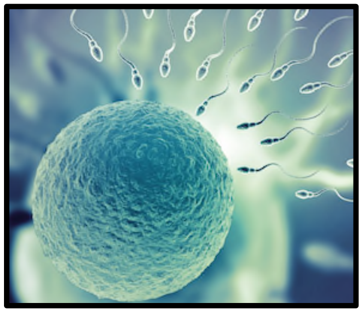
Somatic Cells are cells of the body which usually undergo *mitosis* in order to make exact copies of themselves, the daughter cells containing the same # of sets of chromosomes as the parent cell.

- In humans most somatic cells contain 2 sets of chromosomes
  - They are considered diploid, ploidy referring to the number of chromosome sets present in a cell. Diploid = 2 Sets of Chromosomes.



Each human set containing 23 different types of chromosomes (DNA molecules) for a total of 46 in total per diploid somatic cell.

Certain somatic cells though can undergo *meiosis* in order to produce **reproductive cells (gametes)**, which contain half the number of sets of chromosomes of somatic cells and which will be involved in fertilization events to make offspring.

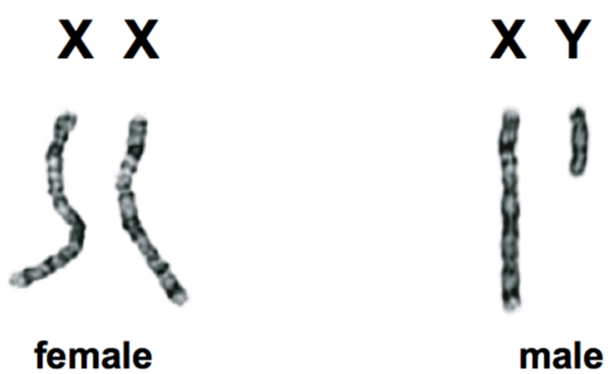


- In humans gametes contain 1 set of chromosomes
  - They are thus considered haploid.

The Linear Chromosomes in Sexually Reproducing Eukaryotes

Chromosome Names:

Sex Chromosomes: Help determine an individual's physical sex *(Chromosomes #23 in a human set)*



X or Y chromosomes are the sex chromosomes in humans, somatic cells having two sex chromosomes per cell.

XX = female
XY = male

Females can only produce gametes that carry X chromosome
Male can produce gametes that carries either an X or a Y

Autosomes: all other types of chromosomes

(Chromosomes #1-22 in a human set)

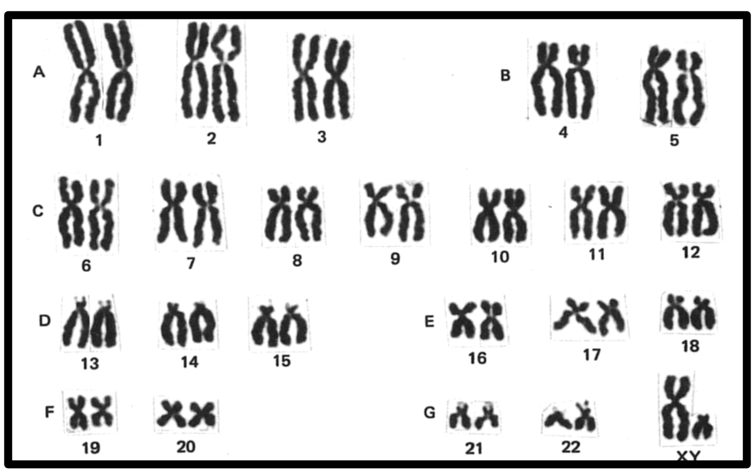
Remember we inherit one set of chromosomes from mom and another set from dad.

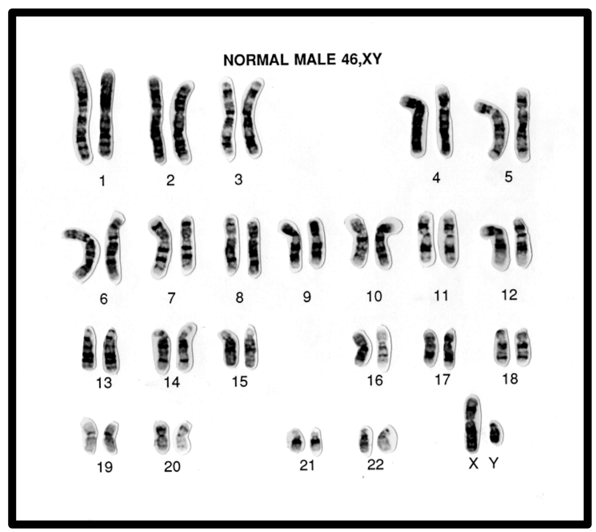
Karyotypes

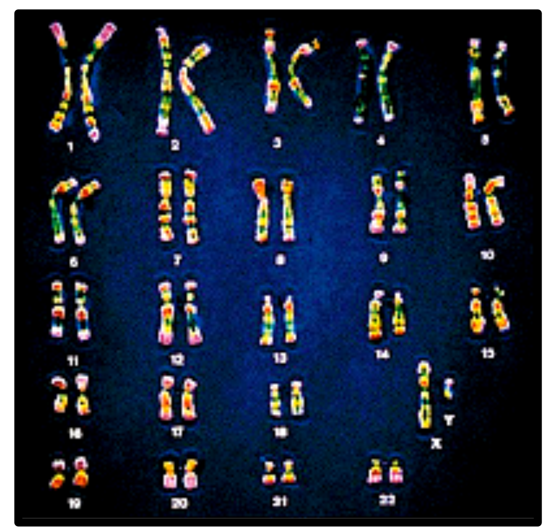
Karyotype: Ordered display of chromosomes used to screen for abnormal numbers of chromosomes or defective shaped chromosomes (like one that is missing a portion)

Made by:

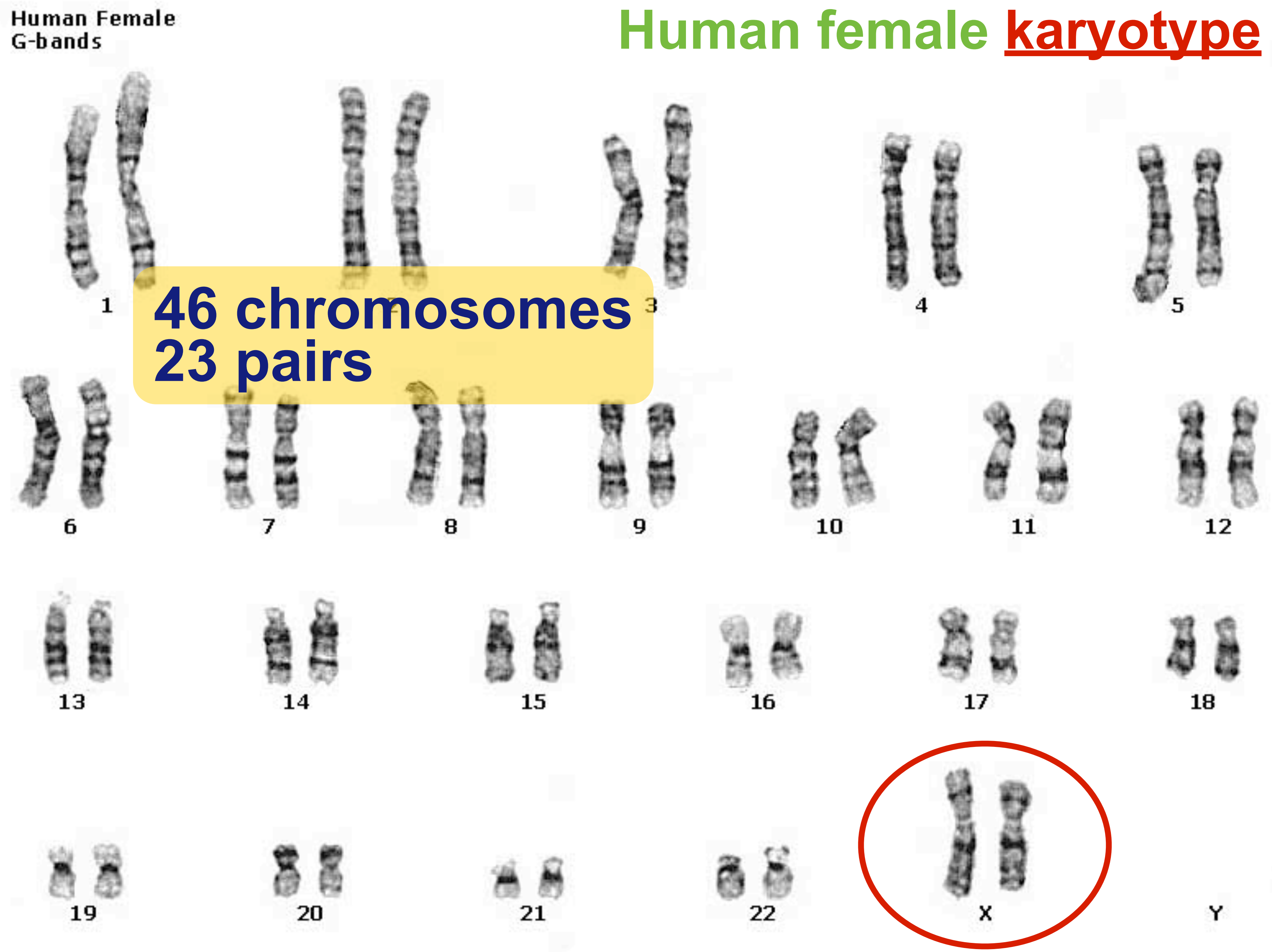
1. Staining chromosomes of a cell in metaphase
2. Then pairing up homologous chromosomes
3. Then arranging them from largest to smallest





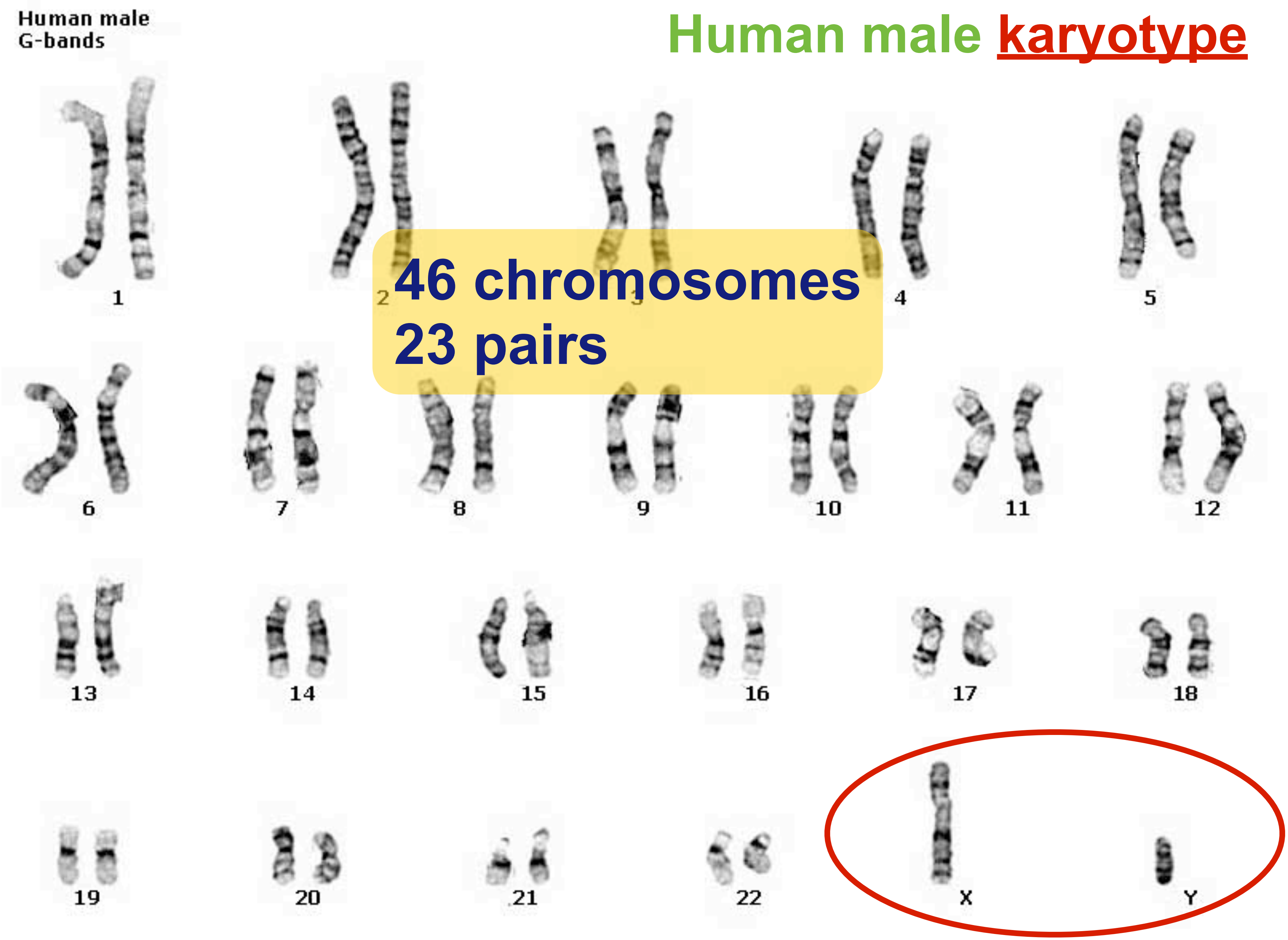


Human female karyotype



46 chromosomes
23 pairs

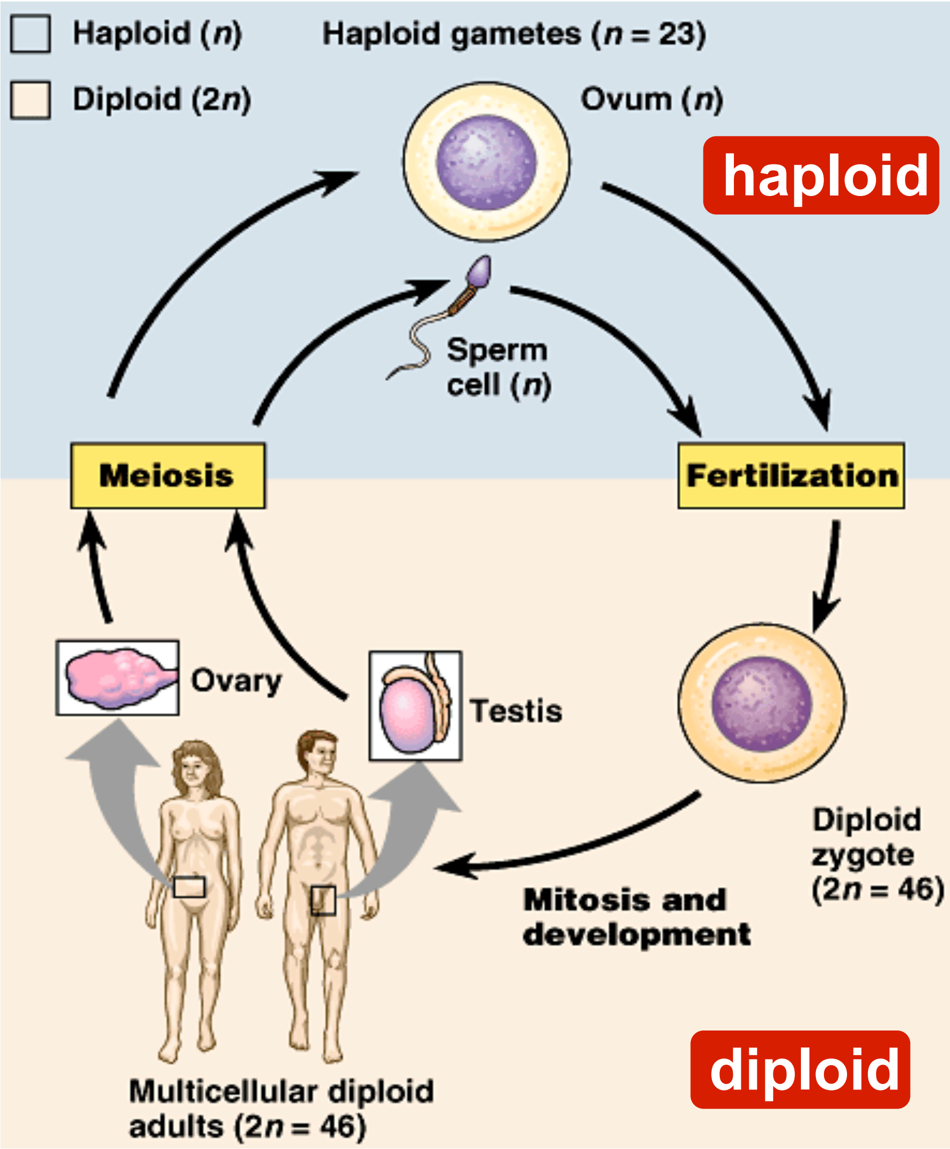
Human male **karyotype**



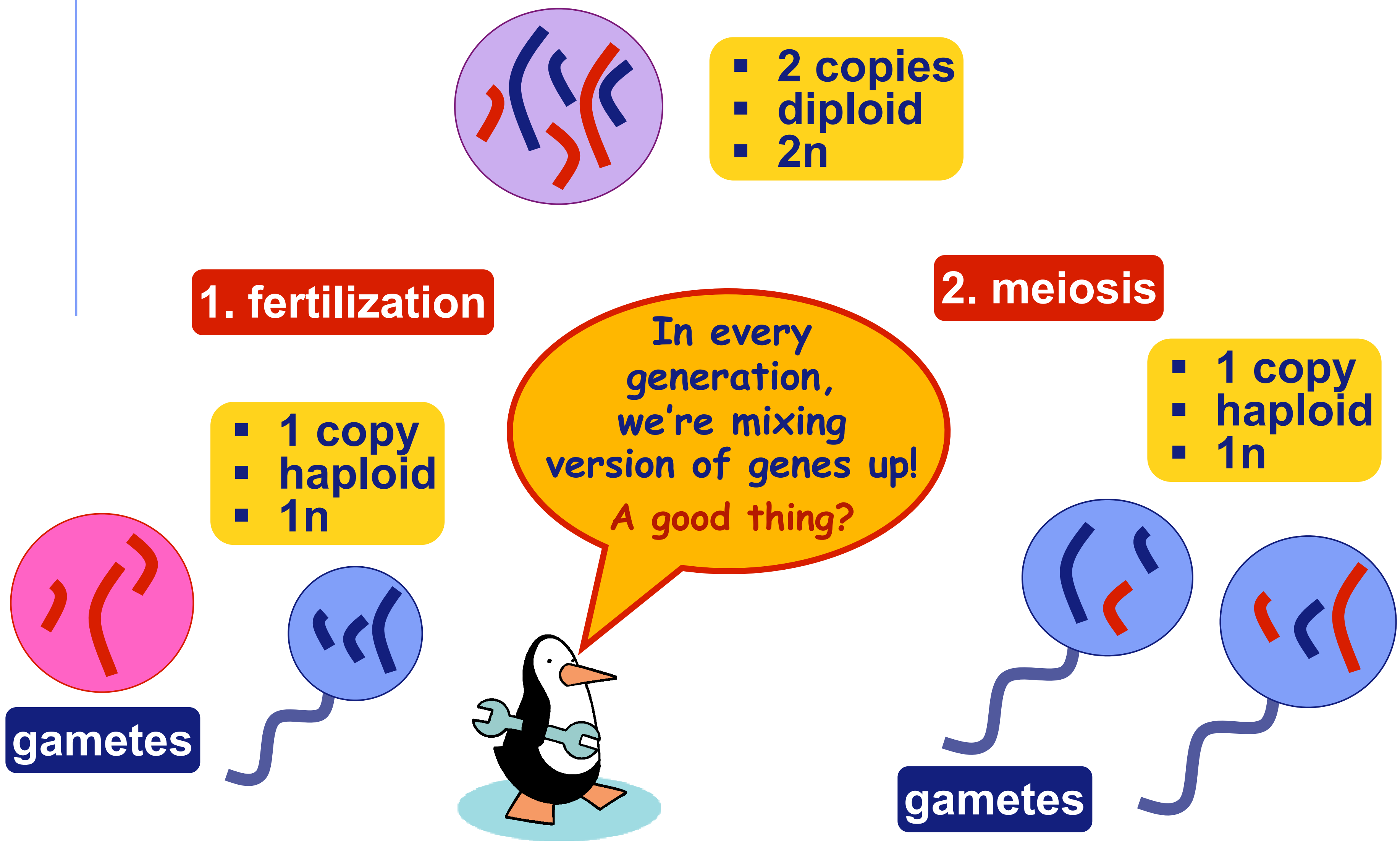
46 chromosomes
23 pairs

Meiosis: production of gametes through a type of cell division that yields non-identical haploid daughter cells (with half as many chromosomes as the parent)

- Alternating stages of Animal Reproductive Life Cycles
  - chromosome number must be reduced
    - diploid → haploid
    - 2n → n
      - In humans: 46 → 23
  - meiosis reduces chromosome number
    - makes gametes
  - fertilization restores chromosome number
    - haploid → diploid
    - n → 2n
      - In humans: Two haploid gametes, a sperm and an egg, combine to form one diploid cell, zygote.

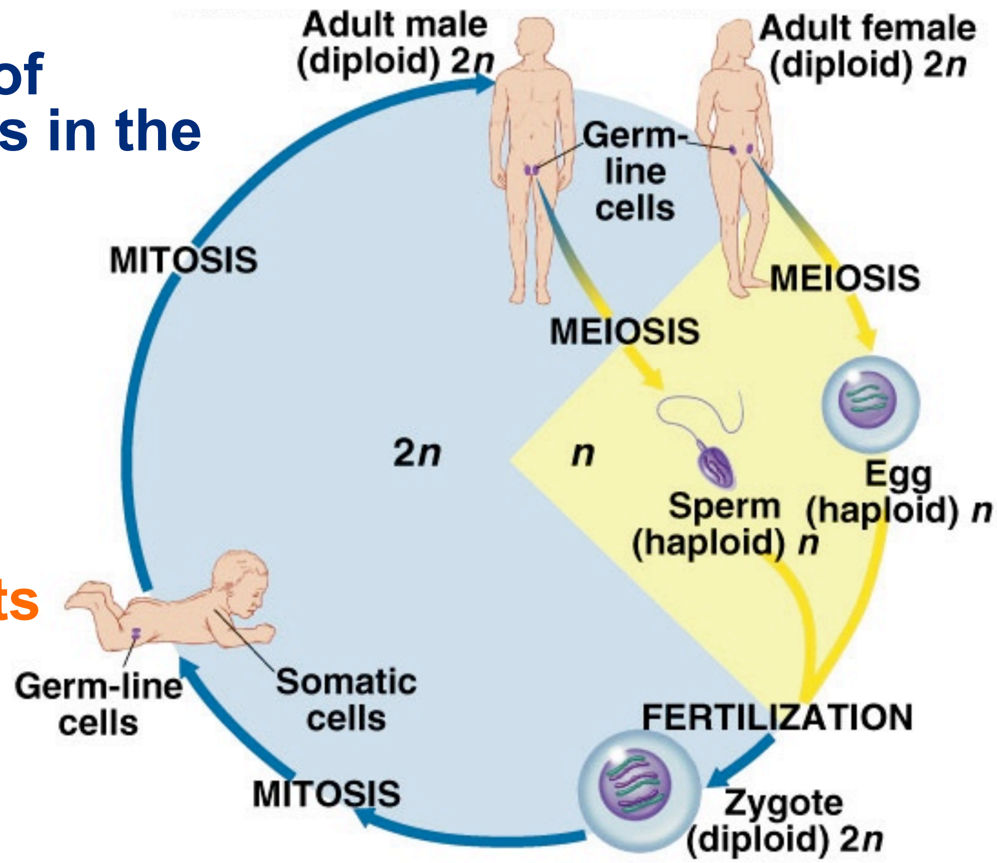


Sexual reproduction lifecycle



Meiosis

- "Reduction Division"
  - special cell division for sexual reproduction
    - Reduce the number of sets of chromosomes in the cells formed by half:
      - 2n → 1n
    - Make a diploid cell into a haploid cell
      - "two" sets → "half" the # of sets
  - makes gametes
    - sperm, eggs



Review: Goals of Meiosis & Cytokinesis

1. **Make a reproductive cell (gamete) with half the number of sets as the somatic parent cell !!!**

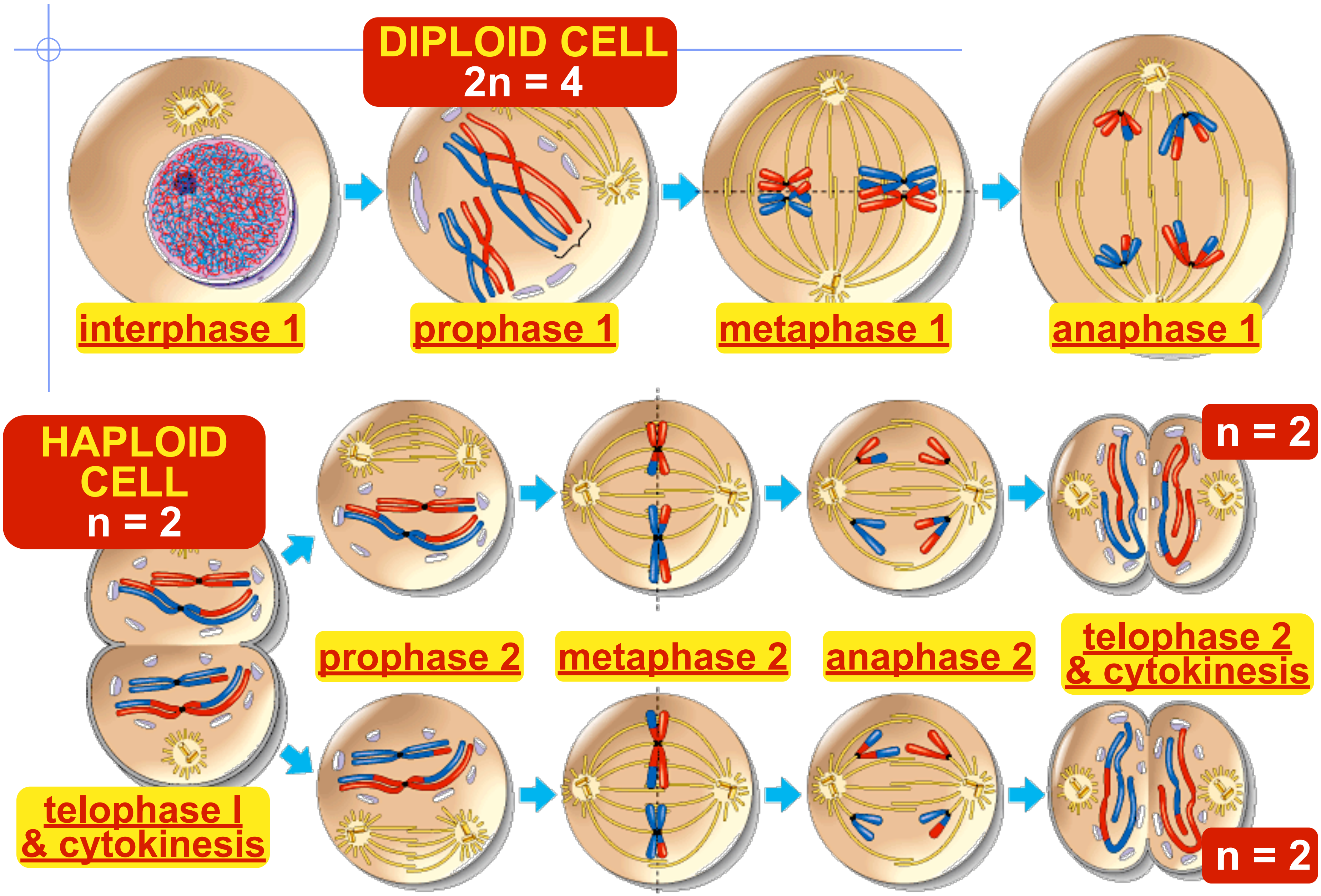
2. **Make daughter cells that are genetically different from the parent cell**

3. **Make daughter cells that are genetically different from each other !!!**

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

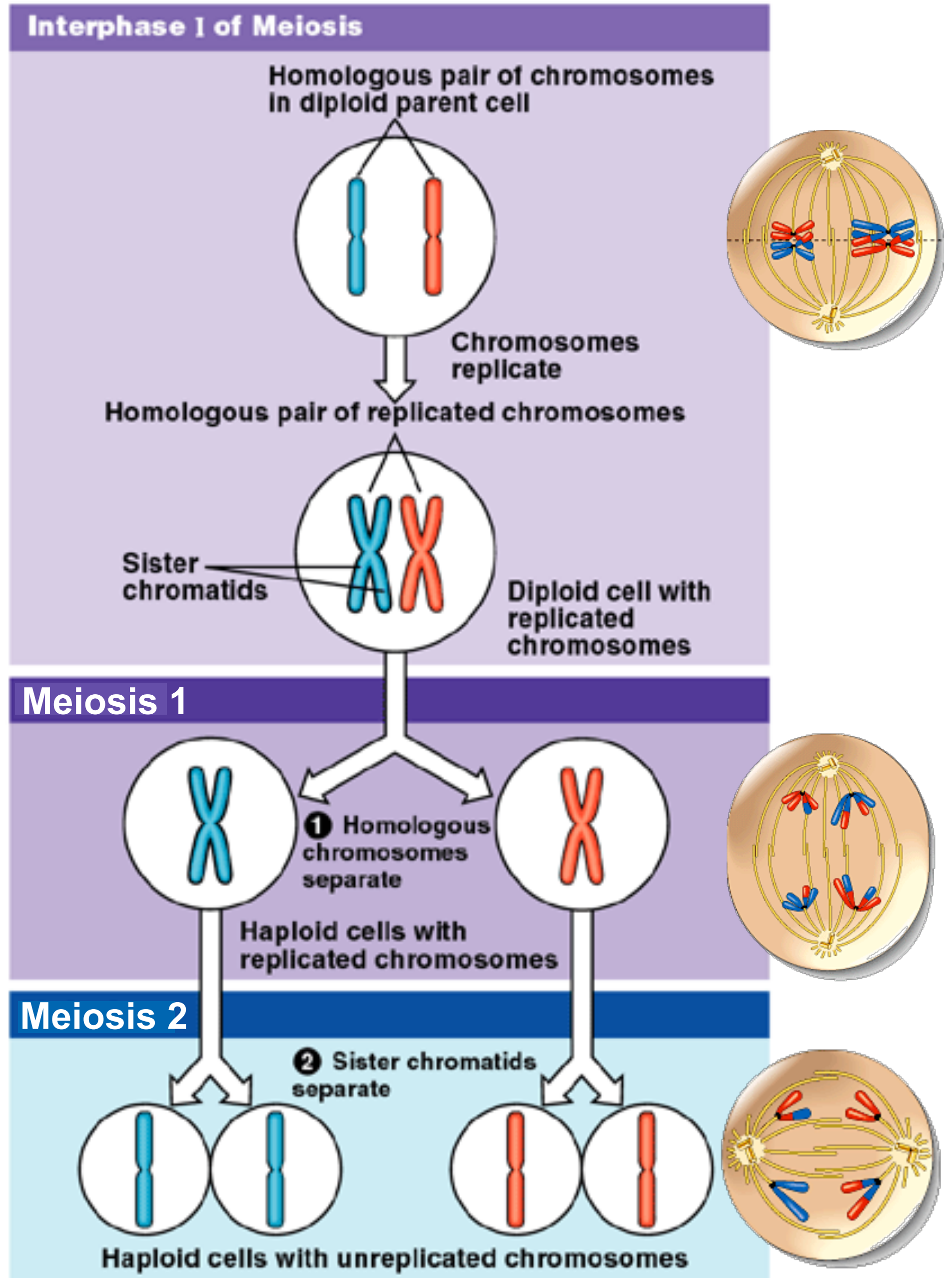


The Double Division of Meiosis

Interphase:
DNA replication

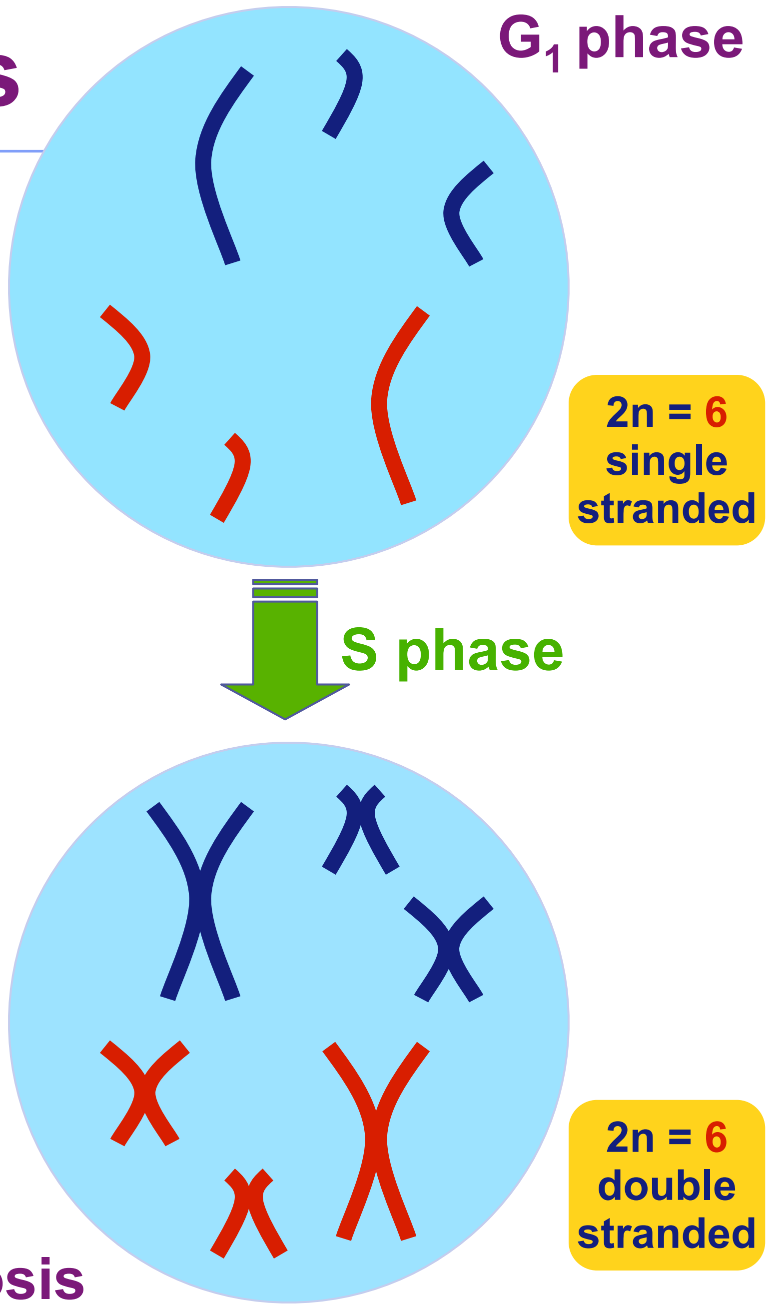
<u>1st division</u> of meiosis separates <u>homologous pairs</u>

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



Preparing for meiosis

- 1st step in preparing for meiosis during M phase:
  - Duplication of DNA, which happens during S phase of interphase of the cell like (just like before Mitosis)
  - Why?
    - meiosis evolved after mitosis
    - it evolved when new proteins evolved, which worked with the "machinery" already in place



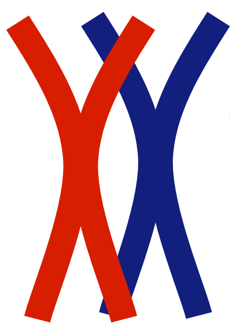
Prophase 1 of Meiosis

Meiosis 1

1st division of meiosis' M phase separates homologous pairs

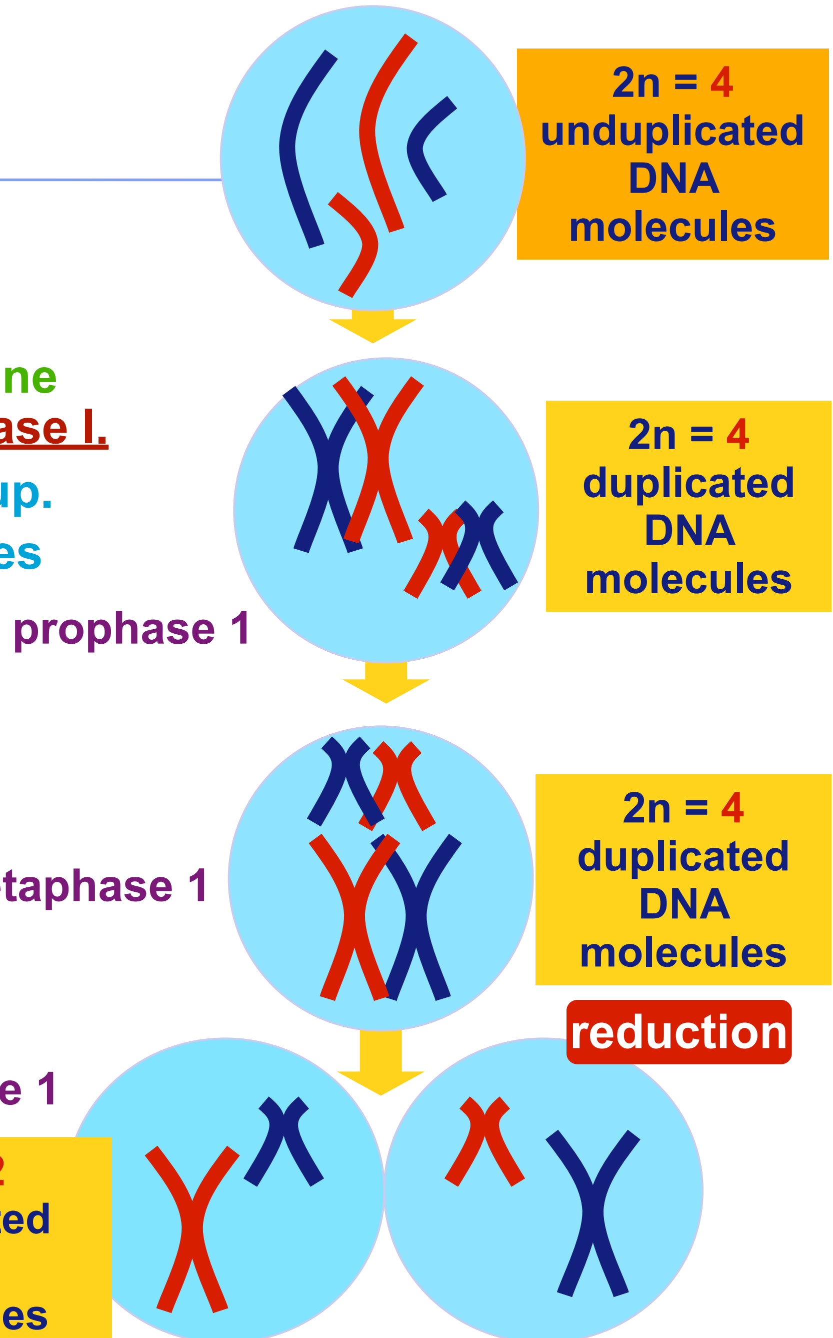
- Homologs pair up in prophase I and line up on the metaphase plate in metaphase I.
  - In mitosis, homologs do not pair up.
  - In mitosis, individual chromosomes line up on the metaphase plate and sister chromatids separate.

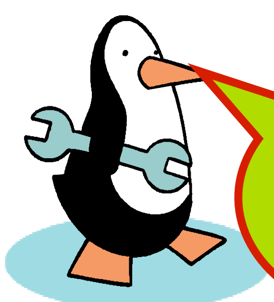
Synapsis: The pairing up of homologs during Prophase I



Synapsis results in the formation of a:

tetrad



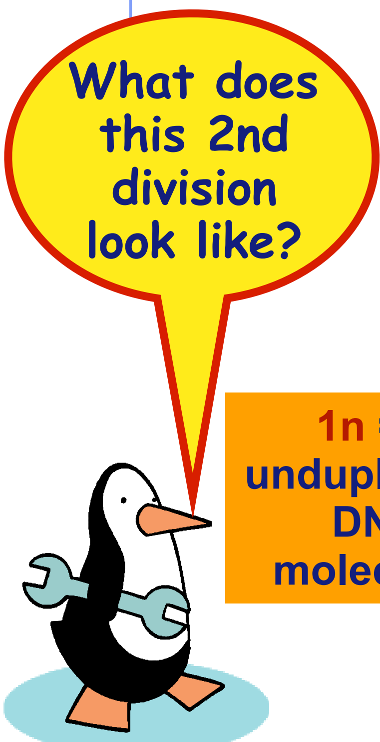


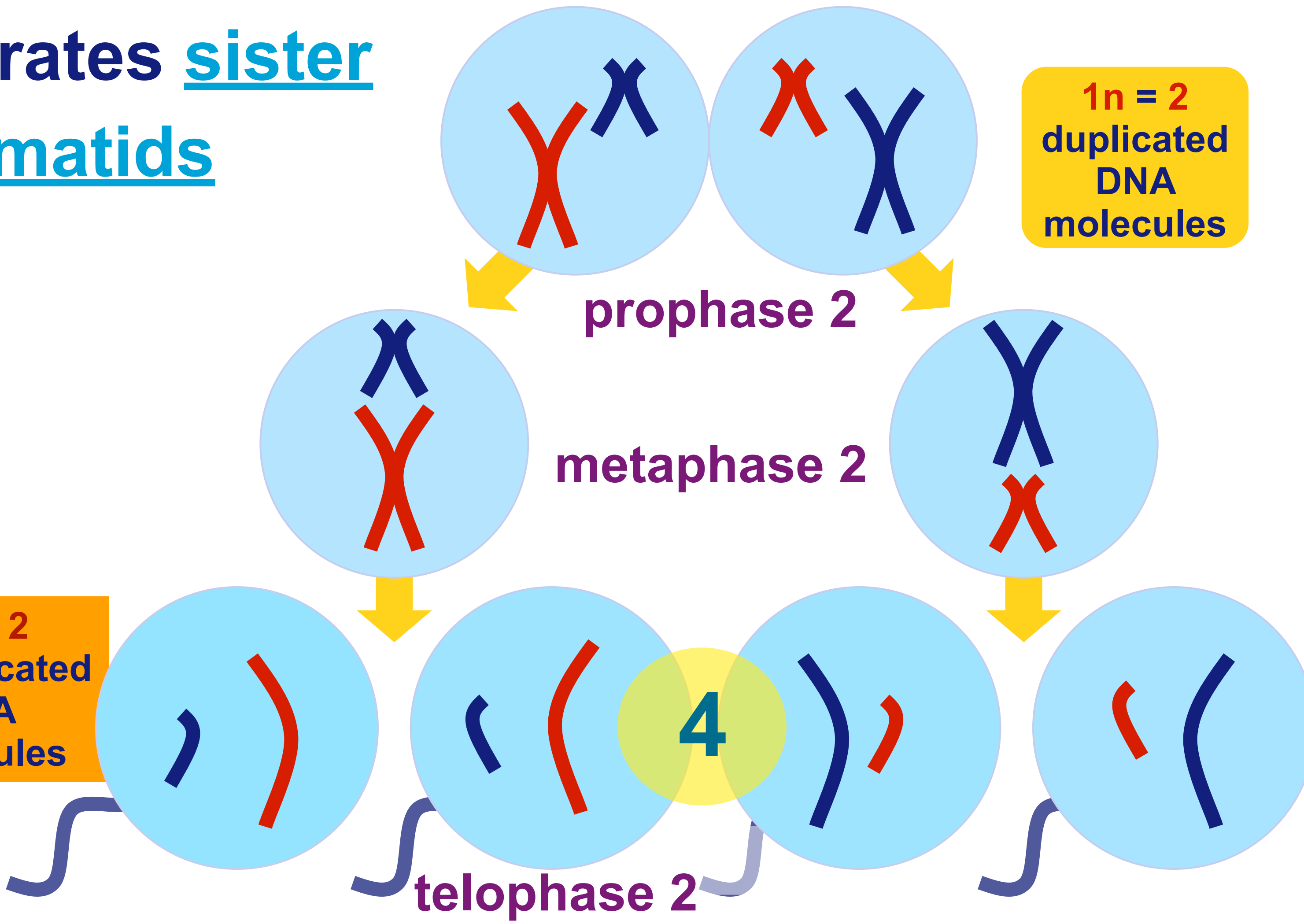
Daughter cells are haploid not diploid

Meiosis I = reduction division. Why?

Meiosis 2

- **2nd division of meiosis separates sister chromatids**





Review: Steps of meiosis

- **Meiosis 1**
  - interphase
  - prophase 1
  - metaphase 1
  - anaphase 1
  - telophase 1
    - Cytokinesis
- **Meiosis 2**
  - prophase 2
  - metaphase 2
  - anaphase 2
  - telophase 2
    - Cytokinesis

1st division of meiosis separates homologous pairs

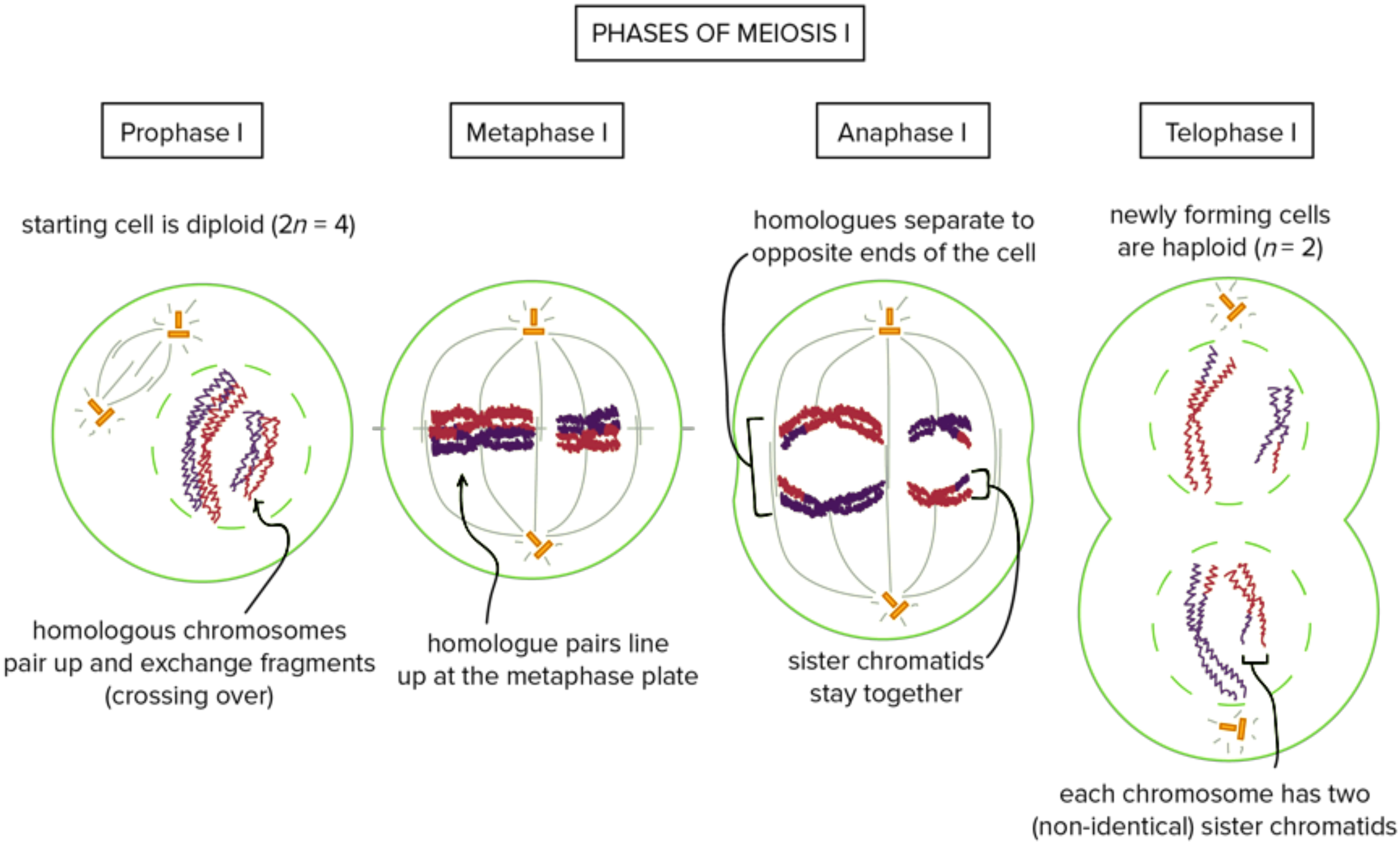
(2n → 1n)

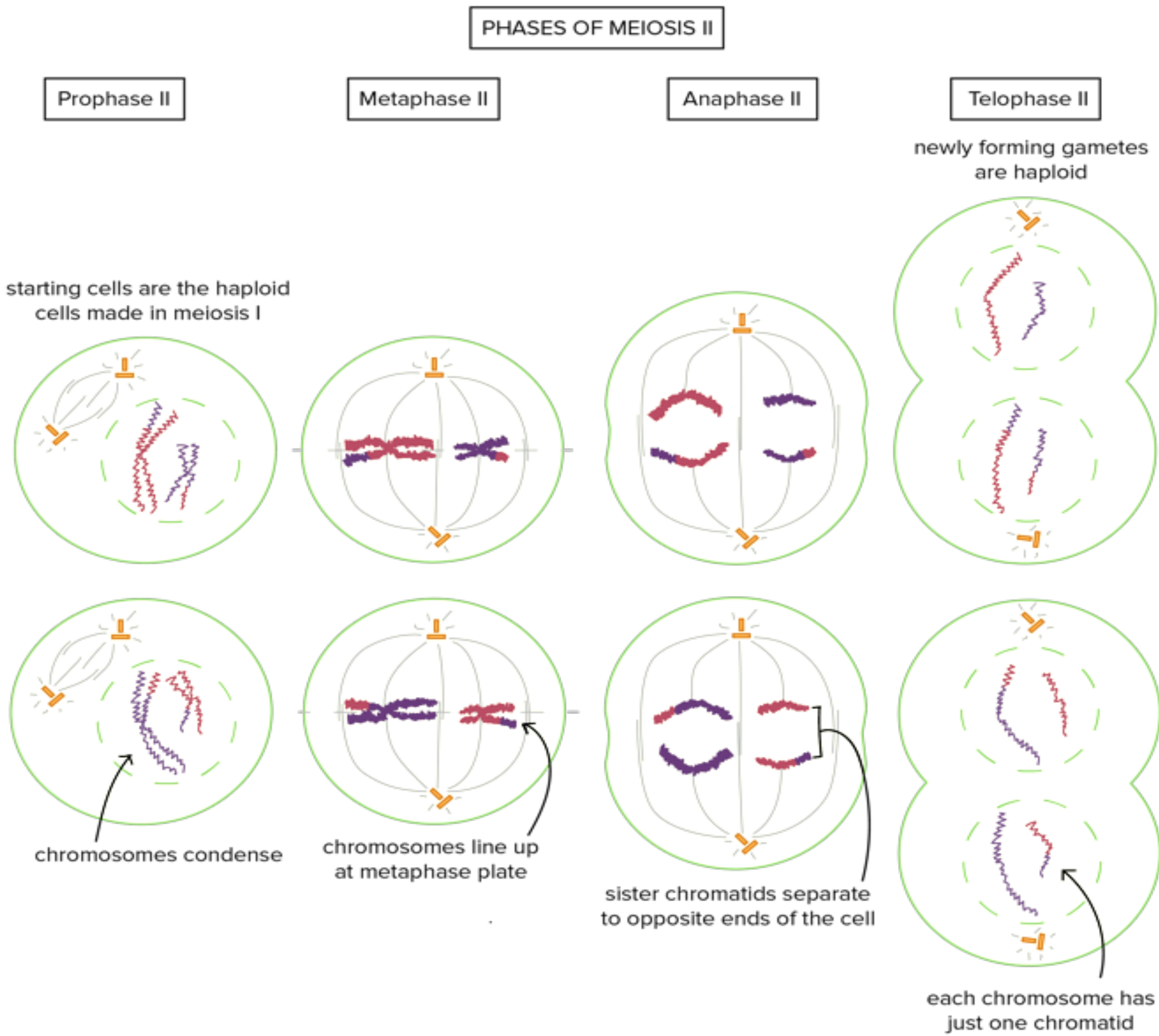
“reduction division”

2nd division of meiosis separates sister chromatids

(1n → 1n)

*** just like mitosis ***


PHASES OF MEIOSIS I
Prophase I
Metaphase I
Anaphase I
Telophase I
starting cell is diploid (2n = 4)
homologues separate to
opposite ends of the cell
newly forming cells
are haploid (n = 2)
homologous chromosomes
pair up and exchange fragments
(crossing over)
homologue pairs line
up at the metaphase plate
sister chromatids
stay together
each chromosome has two
(non-identical) sister chromatids

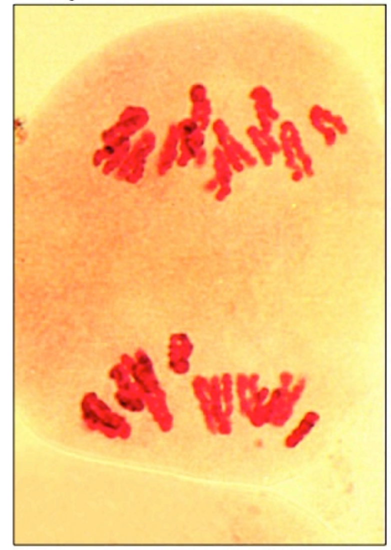

PHASES OF MEIOSIS II
Prophase II
Metaphase II
Anaphase II
Telophase II
newly forming gametes are haploid
starting cells are the haploid cells made in meiosis I
chromosomes condense
chromosomes line up at metaphase plate
sister chromatids separate to opposite ends of the cell
each chromosome has just one chromatid

Meiosis 1 & 2

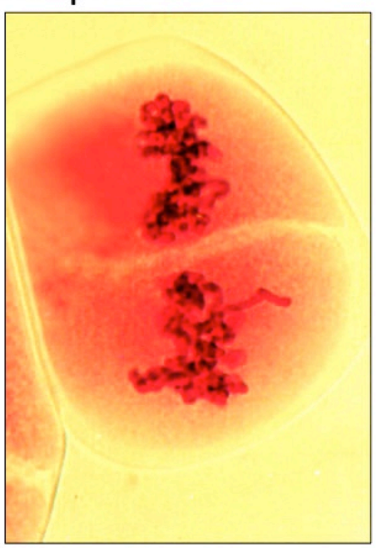
Prophase I

Metaphase I

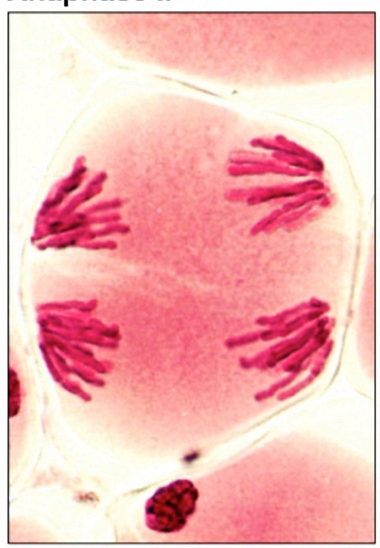
Anaphase I



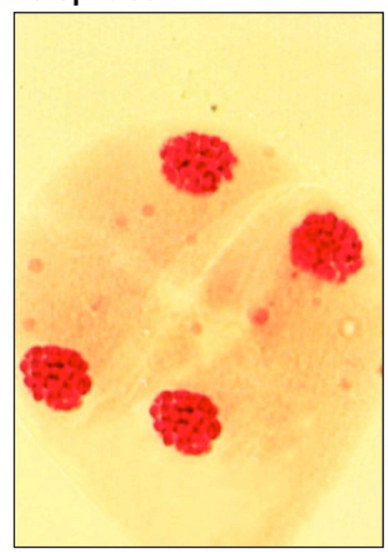
Metaphase II



Anaphase II

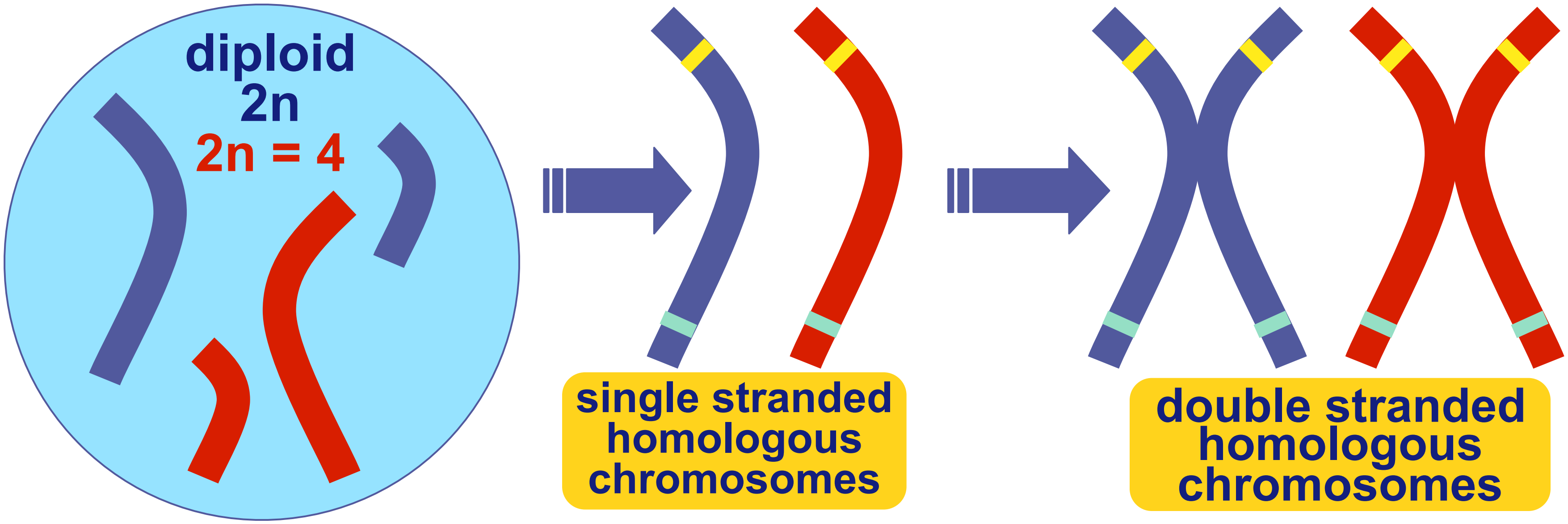


Telophase II



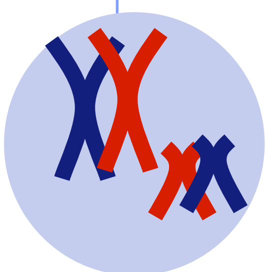
Homologous chromosomes

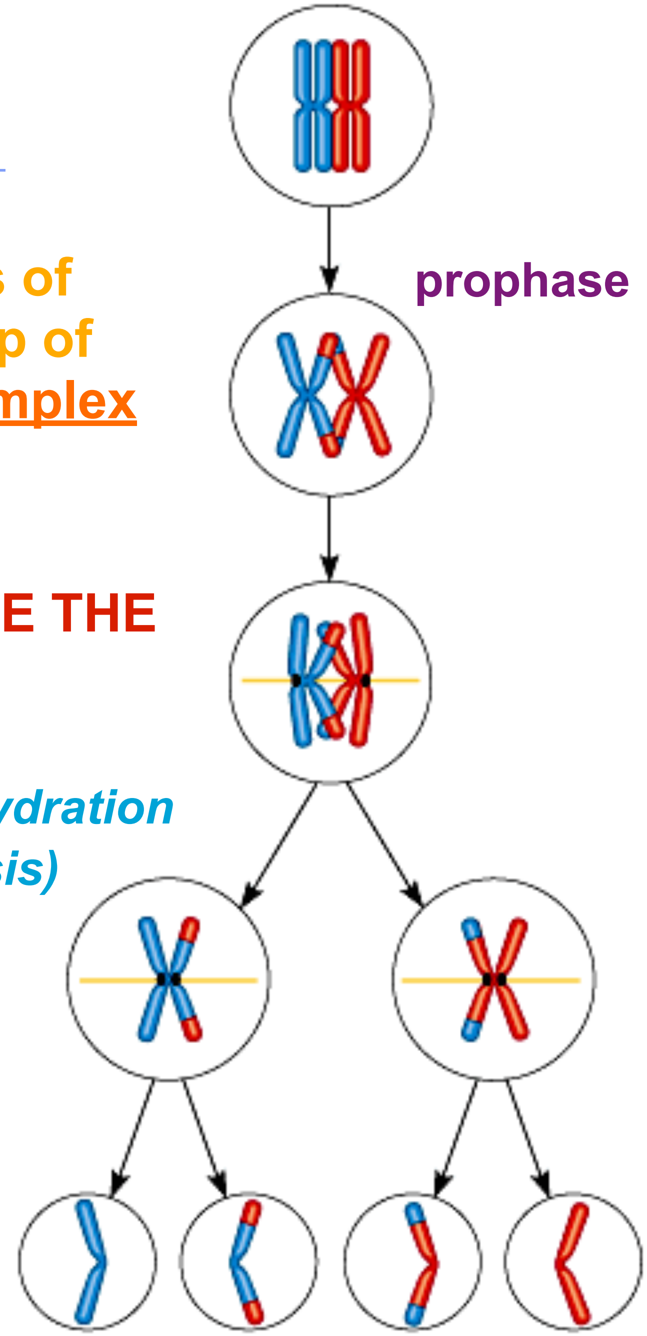
- **Paired chromosomes carry the genes for the same characteristics**
  - **Genes come in different versions called alleles.**
    - **Ex: in peas there exists a gene for controlling flower color**
    - **One allele codes for white flowers**
    - **The other type of allele codes for purple flowers**
    - **One diploid pea plant inherits one allele from each parent (so 2 copies of this type of gene in total) they may be the same or different versions of the gene.**
  - **Alleles of a gene control same inherited characters**
  - **homologous = same information**



Trading pieces of DNA

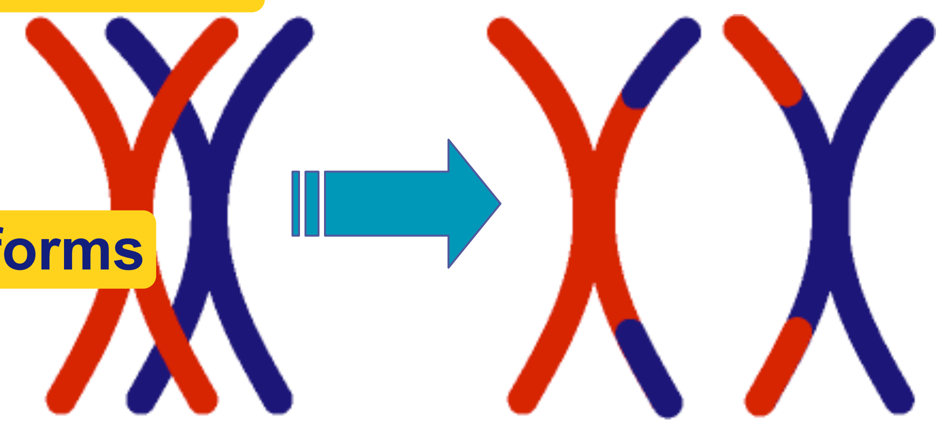
- **Crossing over**
  - during **Prophase 1**, sister chromatids of paired homologs pair up with the help of proteins forming a **synaptonemal complex**
    - homologous pairs swap pieces of chromosome
    - **NON-SISTER CHROMATIDS TRADE THE SAME SEGMENTS OF DNA!**
      - DNA breaks *(via hydrolysis)*, gets exchanged, & re-attaches *(via dehydration synthesis)*





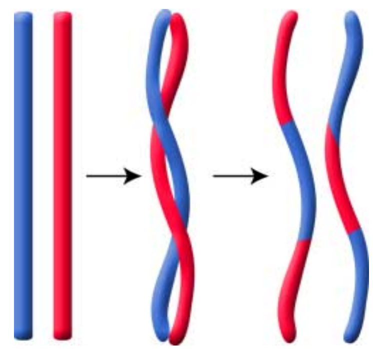
Synapsis occurs

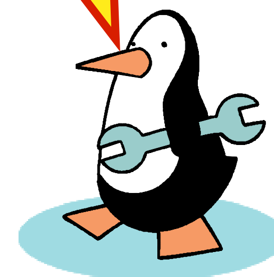
Tetrad forms

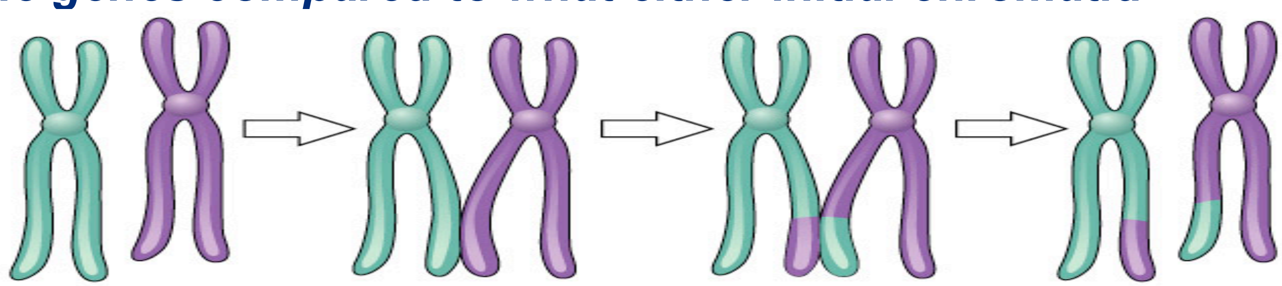


Crossing over

- **Three steps involved in Crossing Over:**
  1. Non-sister chromatids overlap & intertwine during synapsis
  2. breakage of DNA
  3. re-fusing of DNA
- **Results in a new combinations of alleles for the genes located on the chromatids involved**
  - **Alleles for genes trade places**
    - **Material alleles move onto paternal chromatid**
    - **Paternal alleles move onto maternal chromatid**
  - **Get RECOMBINANT chromatids *(with a new combination of alleles for several of the genes compared to what either initial chromatid originally had)***



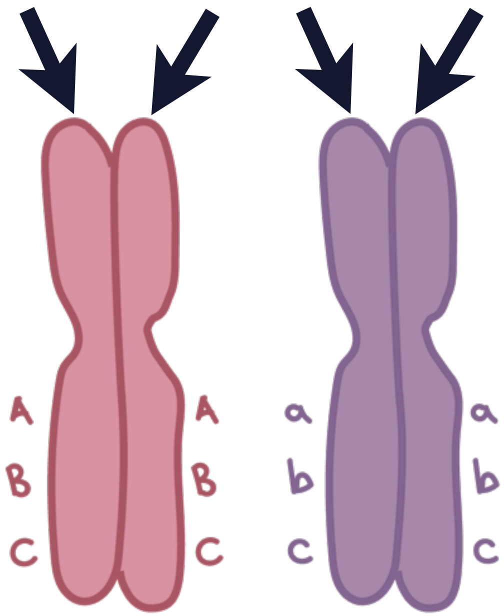




The Benefits of Crossing Over: Producing four gametes that are genetically different from each other

- EACH chromatid of a homologous pair of duplicated chromosomes (2 chromatids in one duplicated homolog and 2 chromatids in the other duplicated homolog) will eventually become a separate chromosome in each of the four gametes that result at the end of meiosis
  - In this example, this type of chromosome contains 3 types of genes, but the genes each come in two possible versions or alleles.
    - Here, homolog 1 starts off with both sister chromatids containing the A B C combination of alleles for the three different genes and both sister chromatids of homolog 2 have the a b c combination of alleles for the same three genes for the same three characteristics.

Future chromosomes the 4 gametes

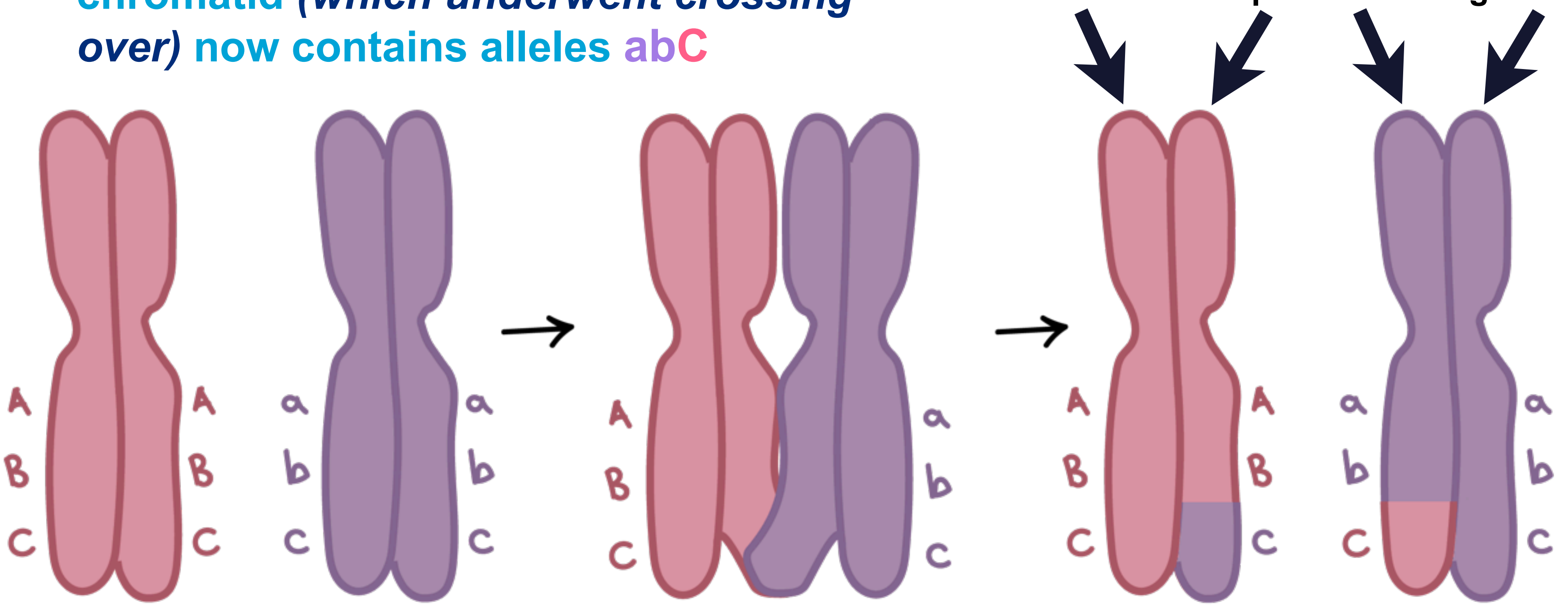


- If NO crossing over occurred between this homologous pair of chromosomes:
  - The future gametes would inherit either a chromosome that contained alleles A, B, C for the three genes or that contained alleles a, b, c for the three genes.
    - Two types of gametes would be possible if this cell had only this 1 type of homolog pair

The Benefits of Crossing Over: Producing four gametes that are genetically different from each other

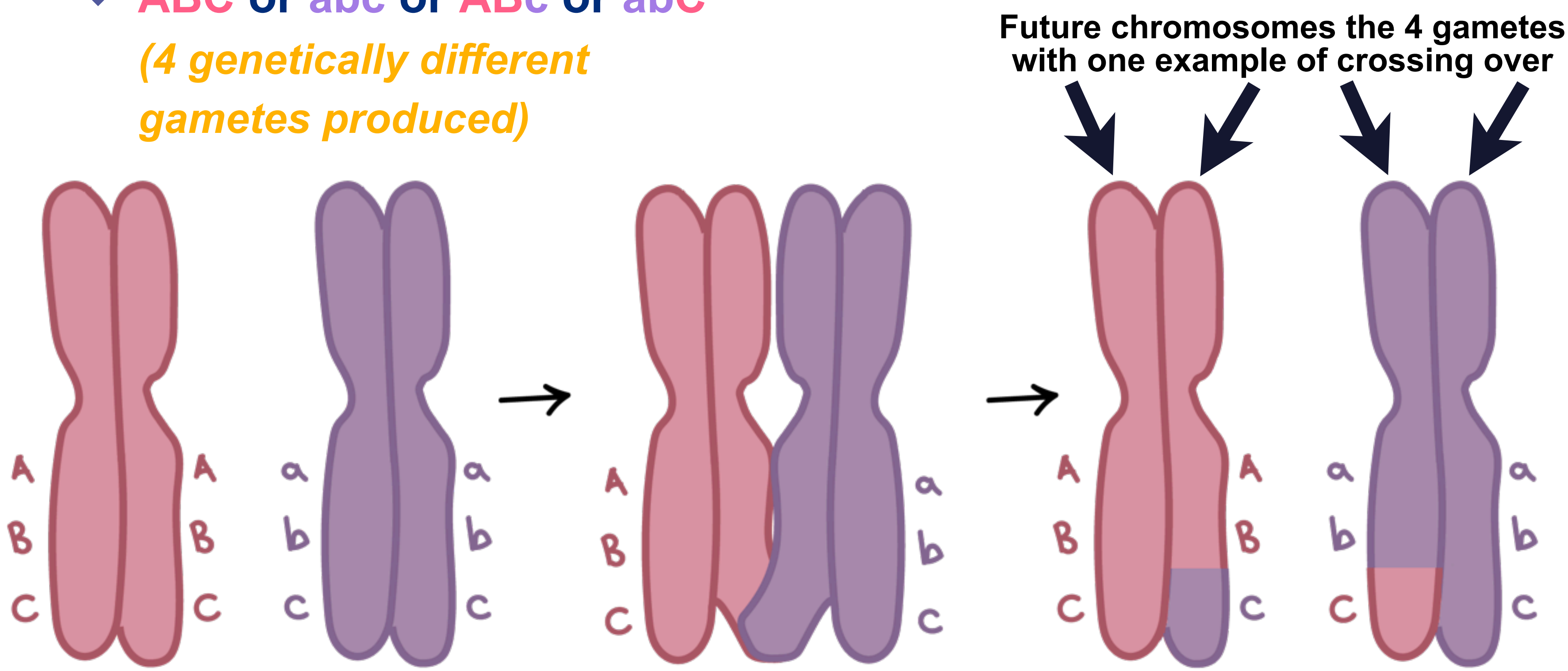
- **If crossing over DID occur between two of the nonsister chromatids however, the cell could create a hybrid (recombinant) chromatids that contain a new and different combination of alles for the three genes.**
  - **Here, in homolog 1, one non-recombinant sister chromatid still contains allele combination ABC, but its sister chromatid *(which underwent crossing over)* now contains alleles ABc.**
  - **Here, in homolog 2, one non-recombinant sister chromatid still contains allele combination abc, but its sister chromatid *(which underwent crossing over)* now contains alleles abC**

Future chromosomes the 4 gametes with one example of crossing over



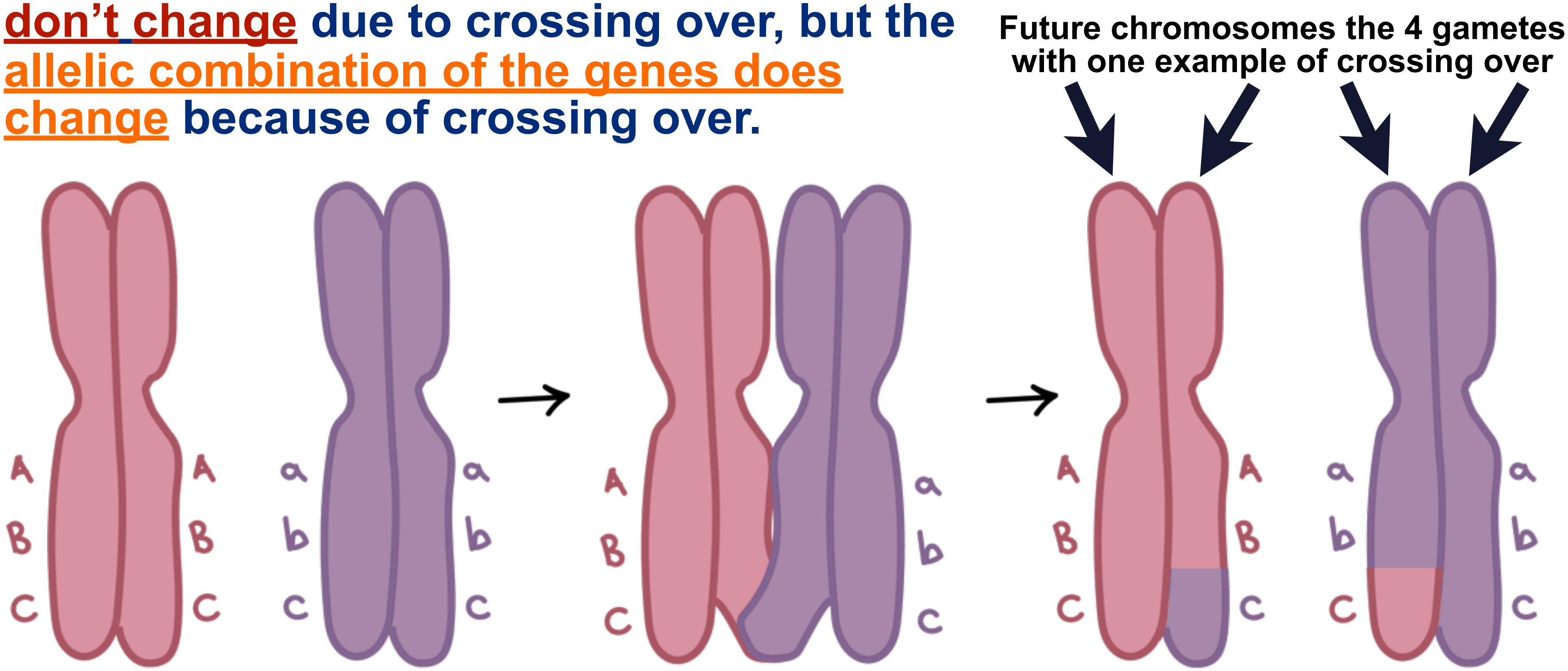
The Benefits of Crossing Over: Producing four gametes that are genetically different from each other

- Without crossing over, gametes with the following allele combinations for the three genes were possible:
  - ABC or abc *(2 genetically different gametes produced)*
- With crossing over, gametes with the following allele combinations for the three genes are possible:
  - ABC or abc or ABc or abC *(4 genetically different gametes produced)*

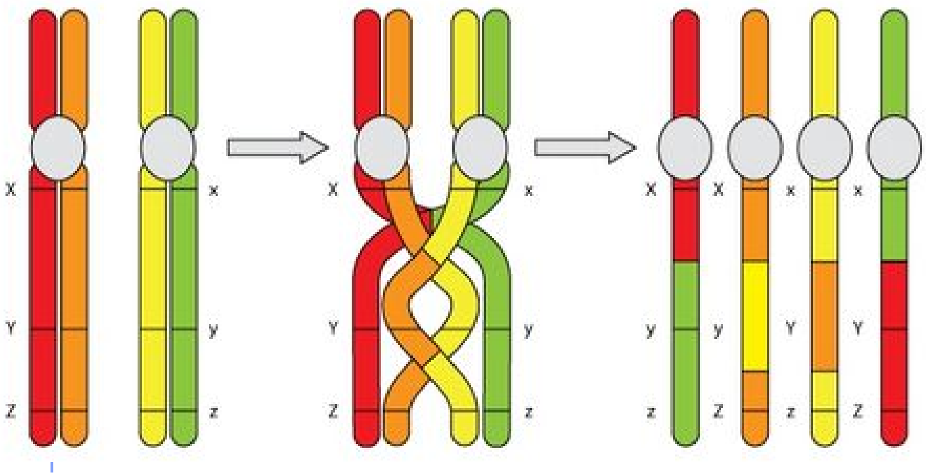


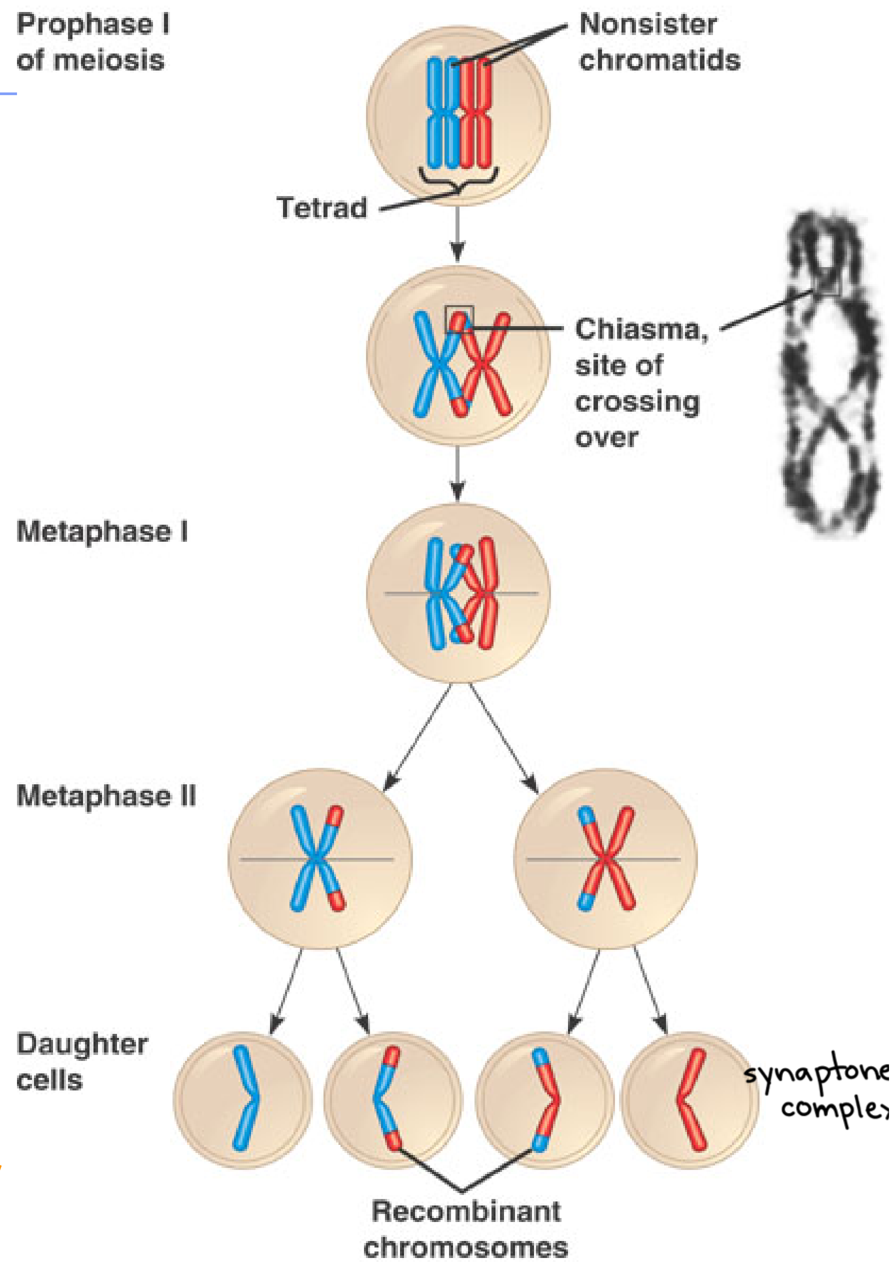
The Benefits of Crossing Over: Producing four gametes that are genetically different from each other

- Chromosomes contain several 100 to 1000 genes for different characteristics.
  - Every time a cell engages in meiosis, 1 to 3, even up to 25, crossing over events will happen between non-sister chromatids in a tetrad.
  - Crossing over events do not occur in the same locations along non-sister chromatids when a new cell undergoes meiosis, compared to the last cell that underwent meiosis. Crossing over locations are semi-random.
- The type or number of genes located of the chromosomes don't change due to crossing over, but the allelic combination of the genes does change because of crossing over.



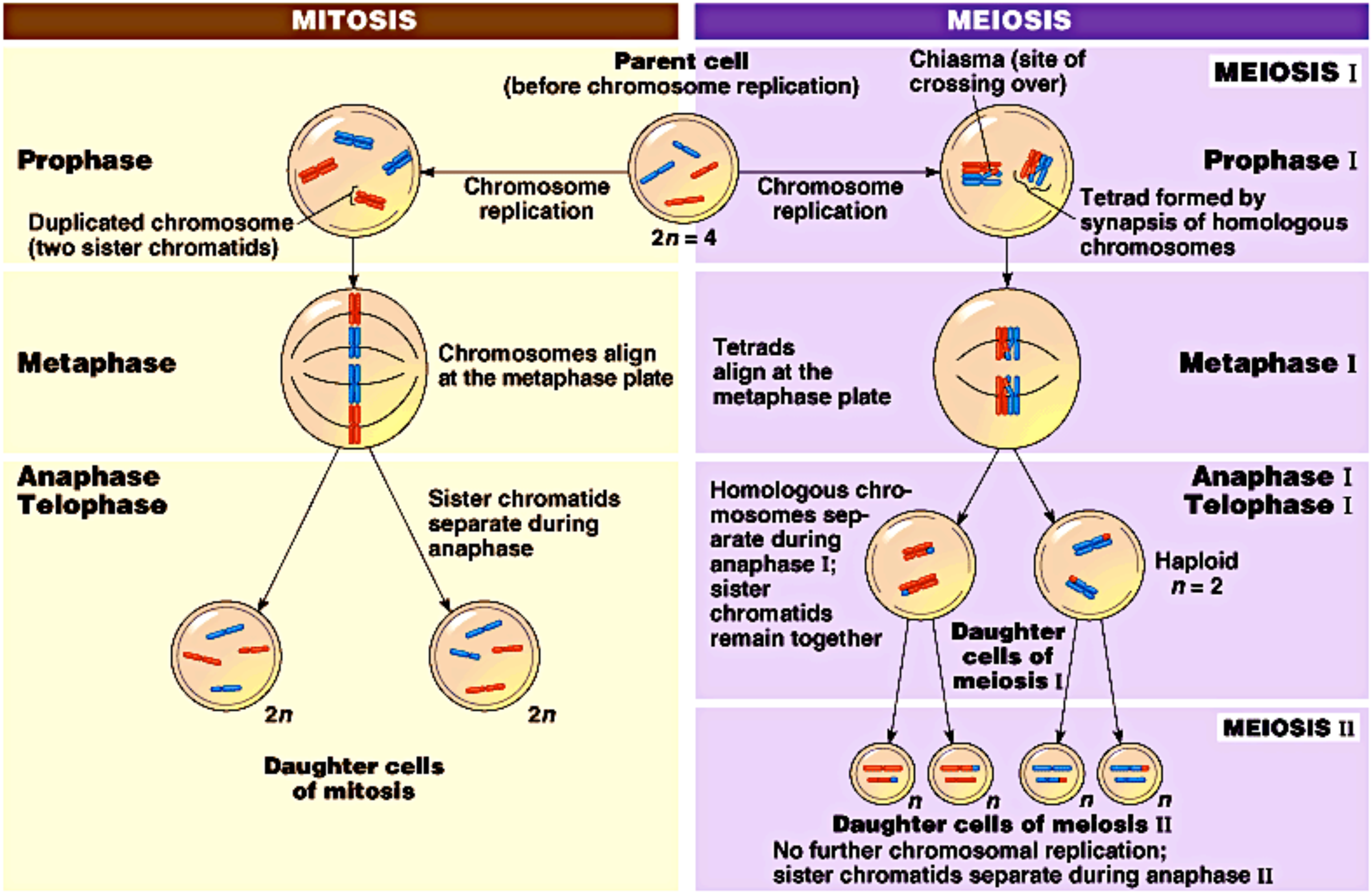
Crossing over produces chromosomes with new allelic combinations





- Each chromatid ends up in a <u>separate</u> gamete
- After crossing over, each chromatid still contains the same # and types of genes as before, <u>BUT</u> now the <u>allelic versions of some genes may have been changed</u>.
- Chiasma (plural *chiasmata*)
  - Physical sites of crossing over
    - After crossing over is completed, the two homologs pull apart a bit but remain connected at the points where non-sister chromatid crossing over occurred.

Mitosis vs. Meiosis

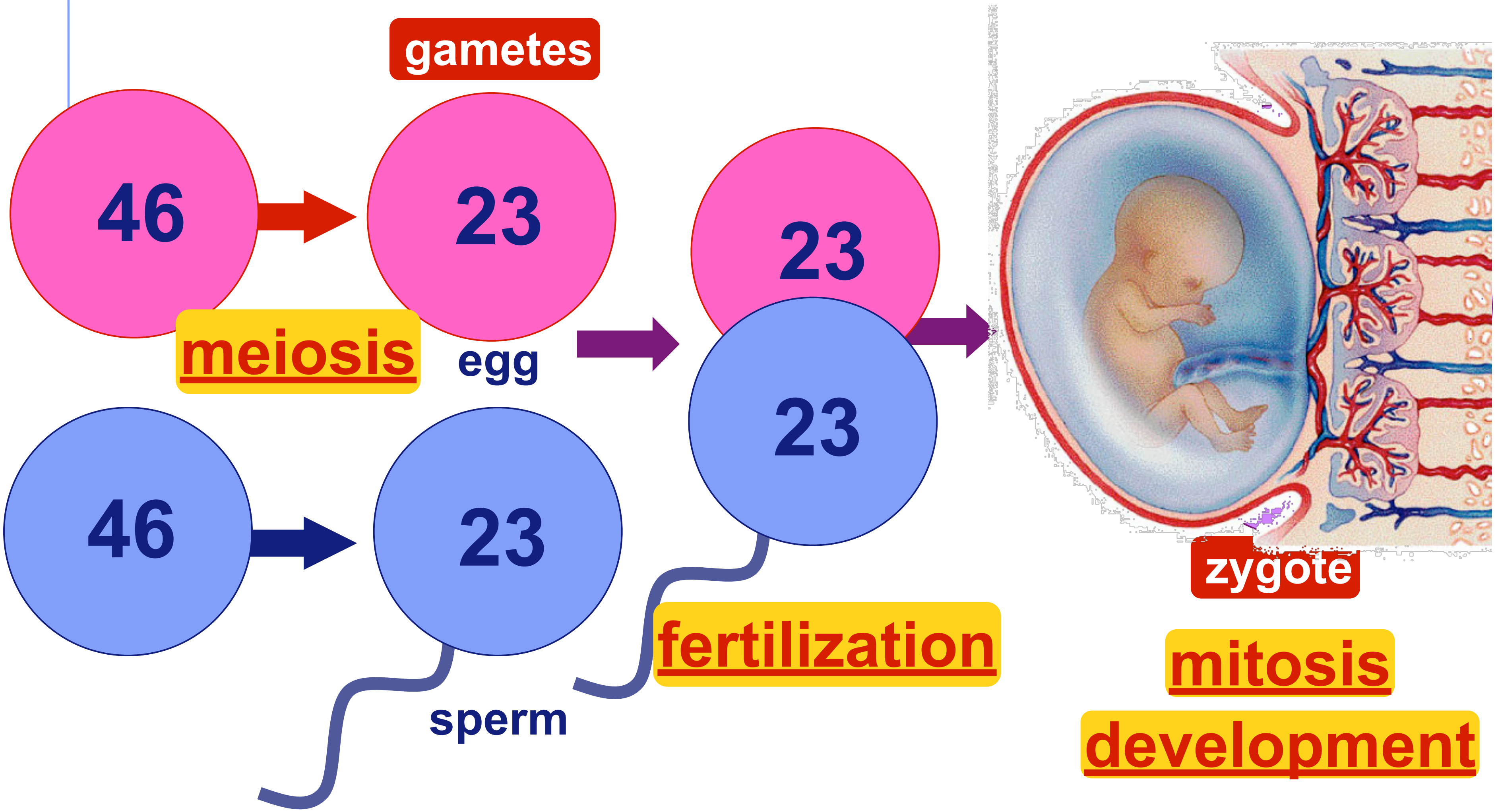


Mitosis vs. Meiosis

- Mitosis
  - 1 division
  - daughter cells genetically identical to parent cell
  - produces 2 cells
  - 2n → 2n
  - produces cells for growth & repair *(and reproduction in single celled eukaryotes)*
  - no crossing over
- Meiosis
  - 2 divisions
  - daughter cells genetically different from parent and each other
  - produces 4 cells
  - 2n → 1n
  - produces gametes
  - crossing over *(daughter cells inherit chromosomes that have a different combination of alleles for the genes than the original parental chromosome had)*

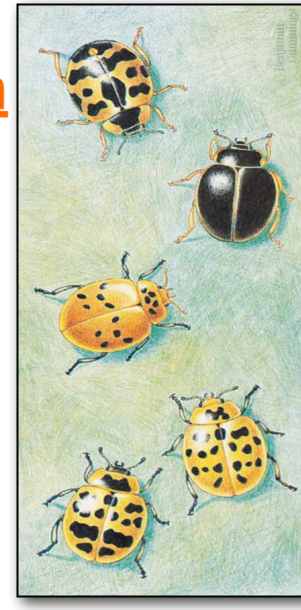
Putting it all together…

meiosis → fertilization → mitosis + development



The value of sexual reproduction

- **Sexual reproduction introduces genetic variation** **because of the genetic recombination** **(new combinations of alleles for genes)** **that occurs during meiosis and fertilization**

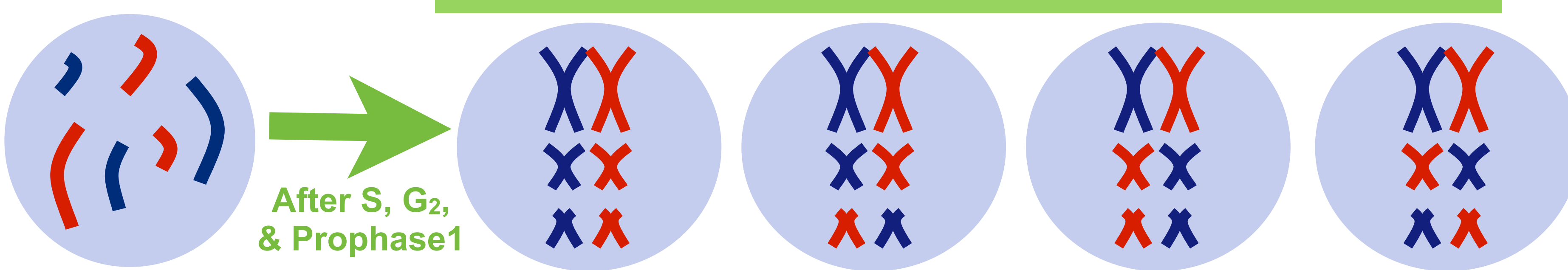


Three mechanisms play a key role in creating this genetic diversity:

1. **independent assortment of chromosomes**
   - **due to the random alignment of EACH pair of homologous chromosomes along the metaphase plate in Metaphase 1...**
     - **Daughter cells may receive either a paternal or maternal chromosome 1, either paternal or material chromosome 2 etc...**

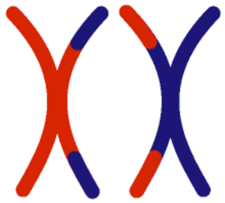
Nucleus When it Was in G_1

Metaphase 1 Possible Scenarios



The value of sexual reproduction

2. **crossing over**



- Each individual chromosome is not made up of only maternal or paternal alleles at the end of meiosis, but is actually a RECOMBINANT CHROMOSOME, made up of genes derived form two different parents
  - Crossing over mixes alleles across homologous chromosomes
  - Every time a new somatic cells undergoes meiosis, genetically different gametes are produced than what was made by the previous somatic cell that underwent meiosis.

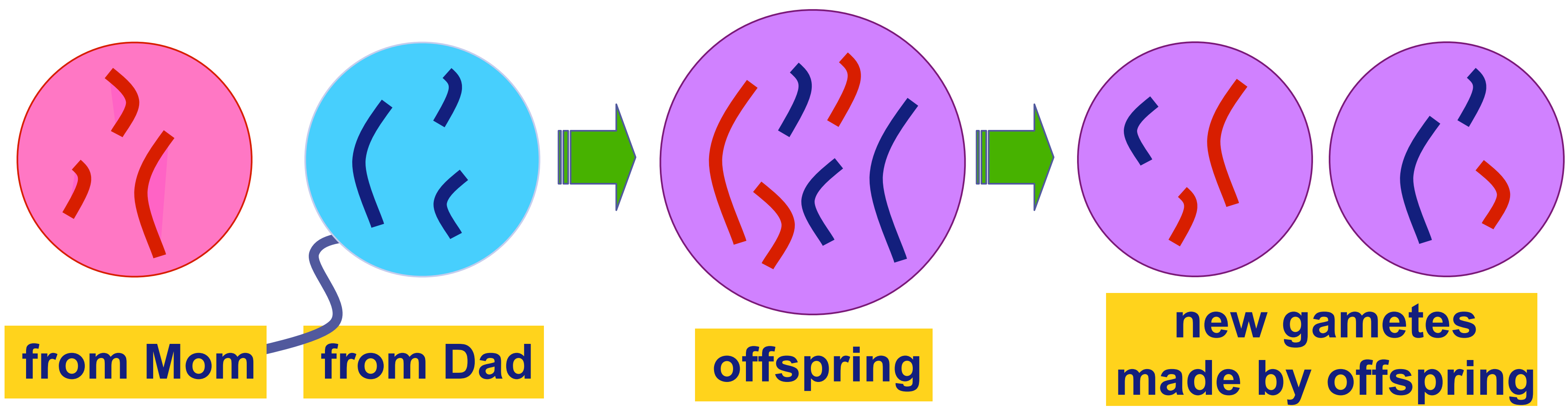
3. **random fertilization**

- which sperm fertilizes which egg?
  - Each gamete contains one of 8.4 million possible chromosome combinations and any two of these can combine during fertilization to produce ~70 trillion possible zygotes.

- **Genetic Variation drives evolution!!!!!**
  - provides the genetic variation for natural selection to act upon!!

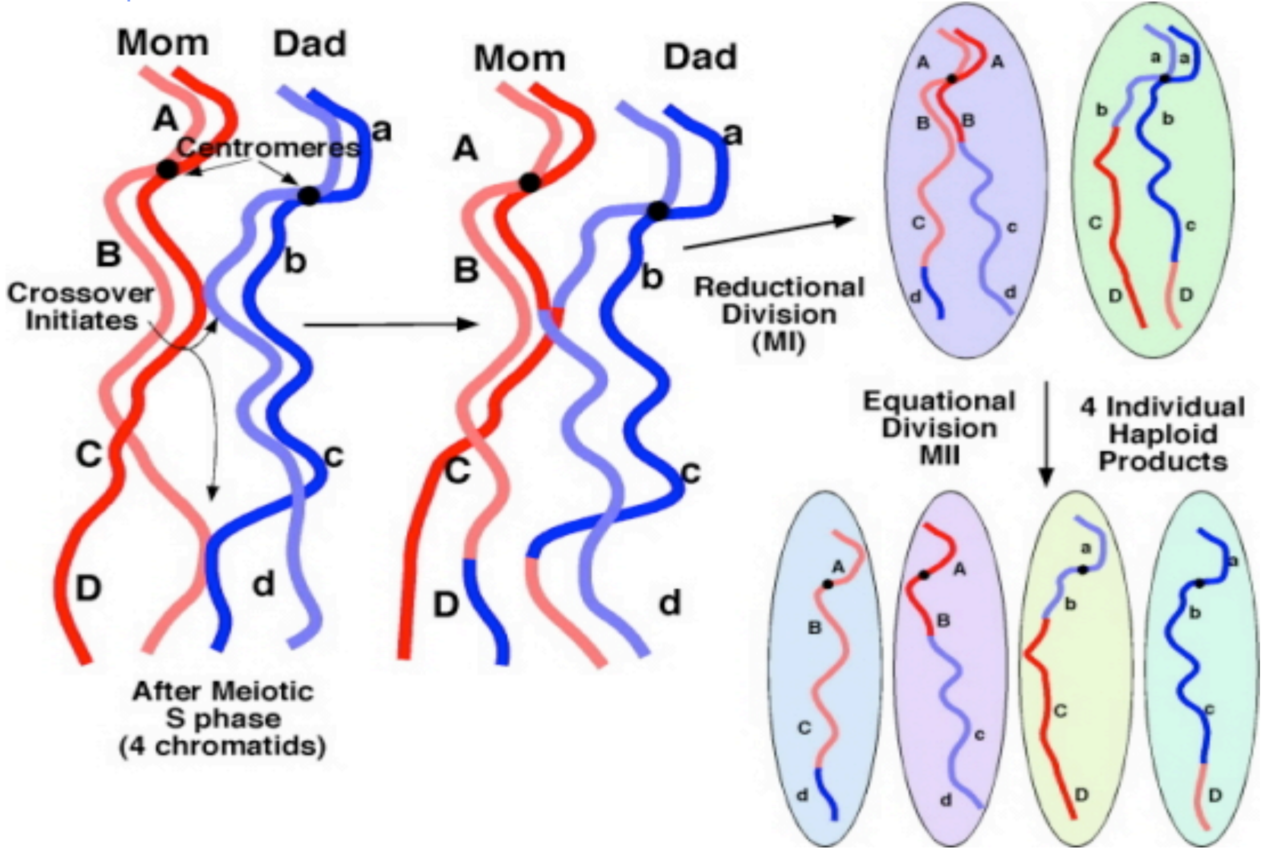
Variation from genetic recombination

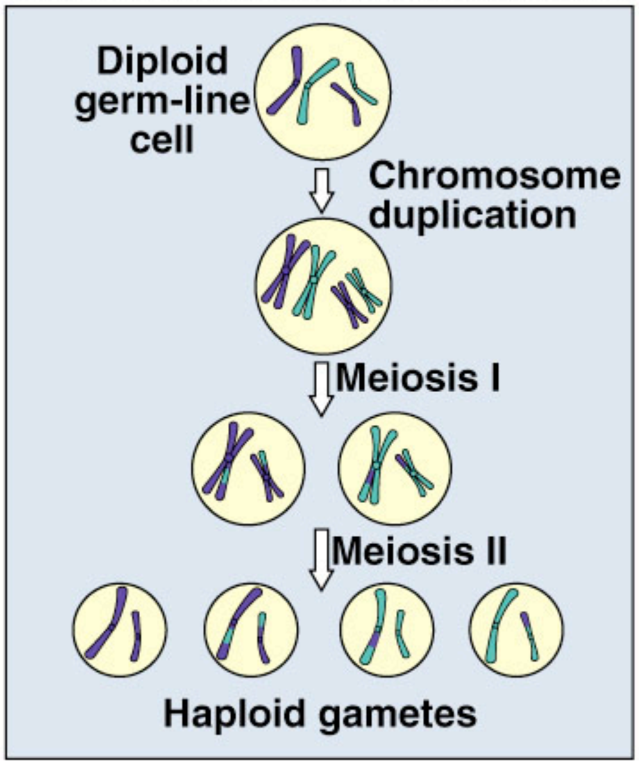
- Independent assortment of chromosomes
  - meiosis introduces genetic variation
  - gametes of offspring do not have same combination of genes as gametes from parents
    - random assortment in humans produces 2^{23} (8,388,608) different combinations in gametes



Variation from crossing over

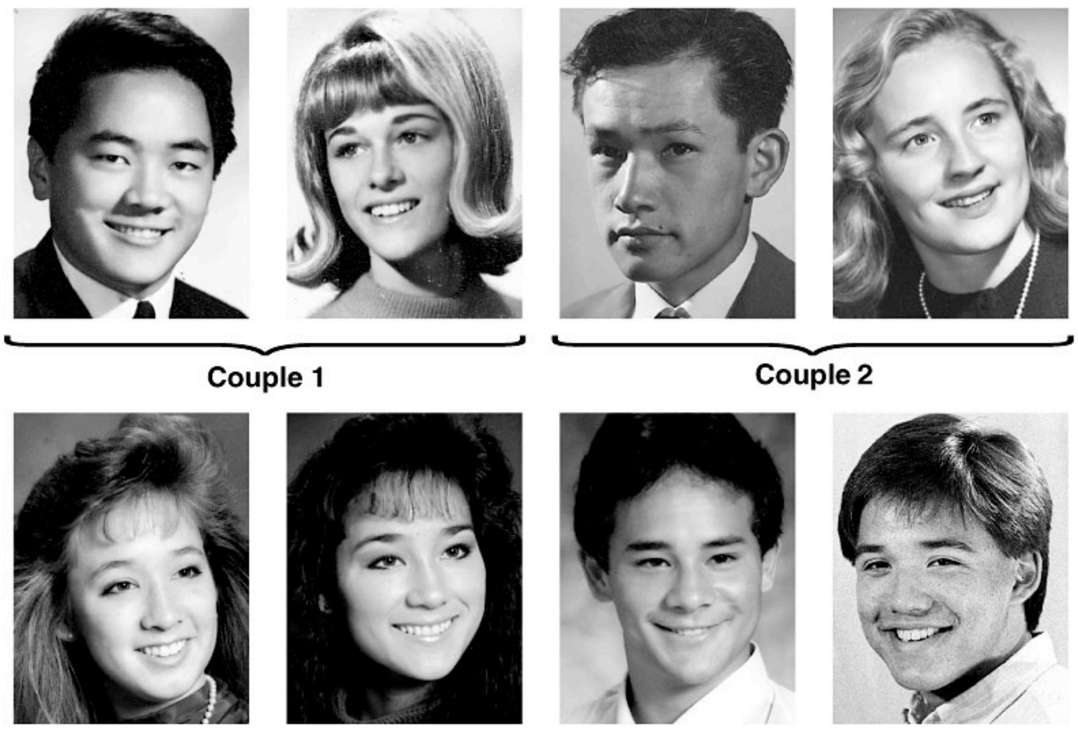
- Crossing over creates completely new combinations of traits on each chromosome
  - creates an "infinite" variety of gene version combinations on each chromosome in a gamete





Variation from random fertilization

- Sperm + Egg = ?
  - any 2 parents will produce a zygote with <u>over 70 trillion</u> (2^{23} x 2^{23}) possible diploid combinations *(and that's while ignoring crossing over)*

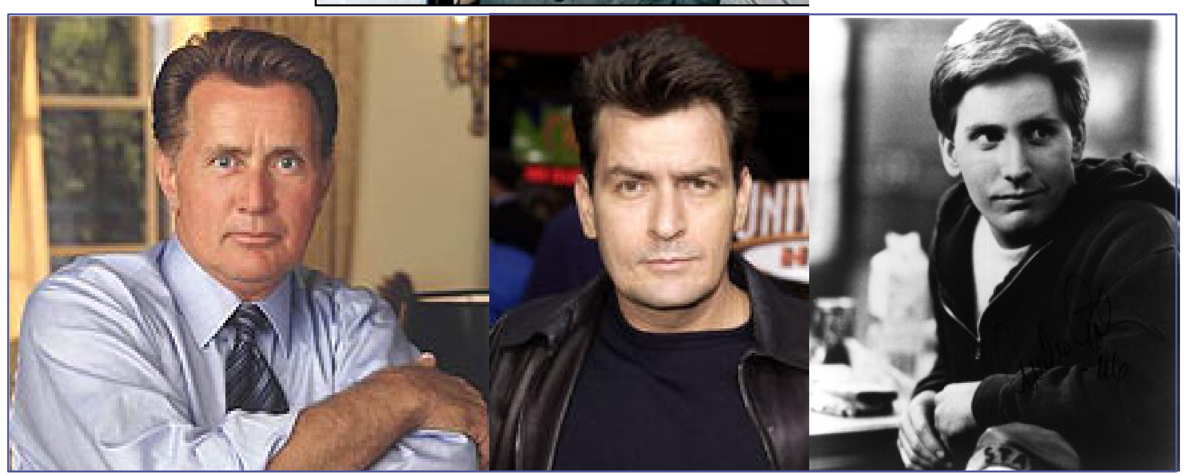


Sexual reproduction creates variability

Sexual reproduction allows us to maintain <u>both genetic similarity & differences.</u>

Jonas Brothers

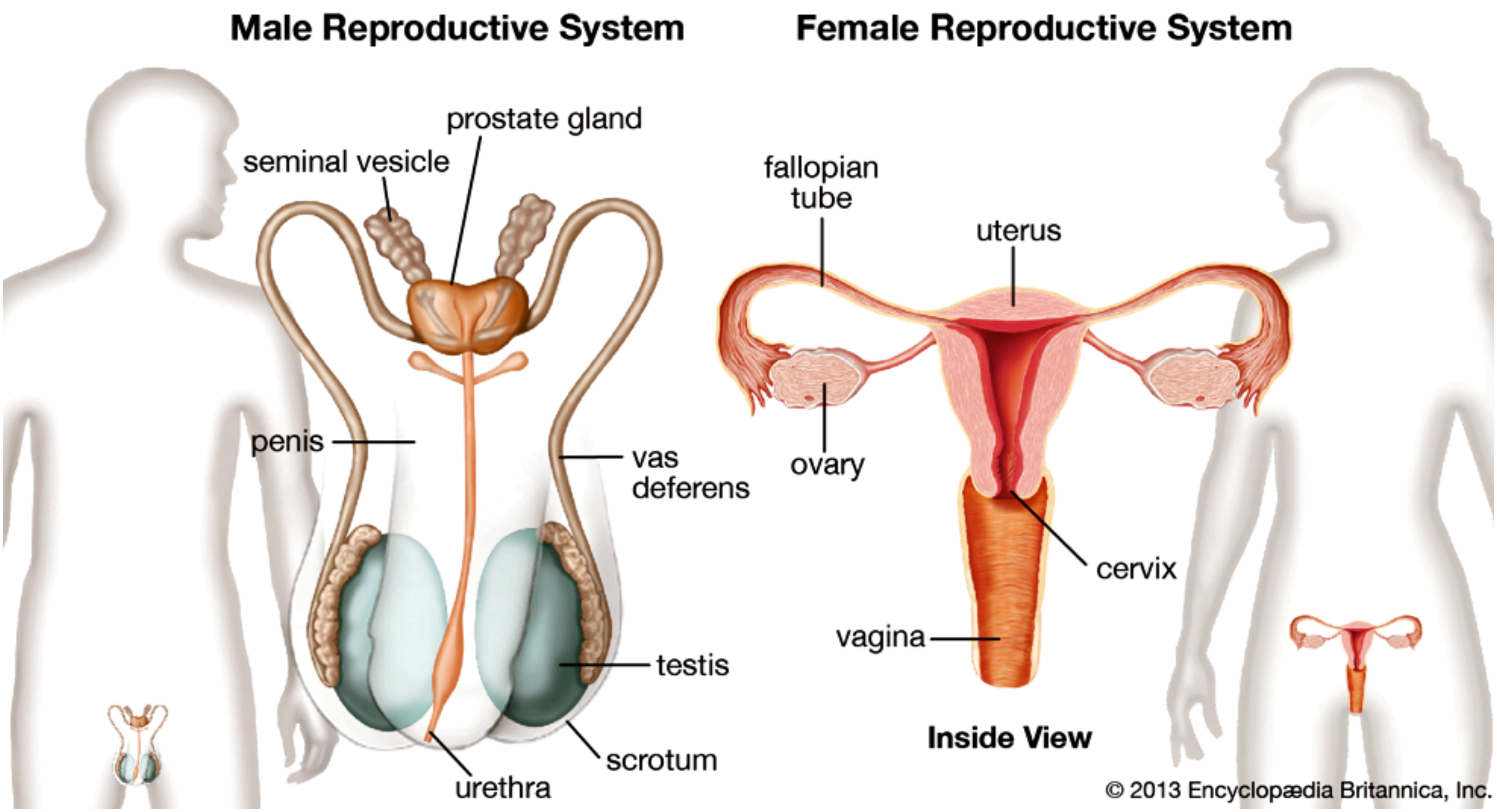
Baldwin brothers



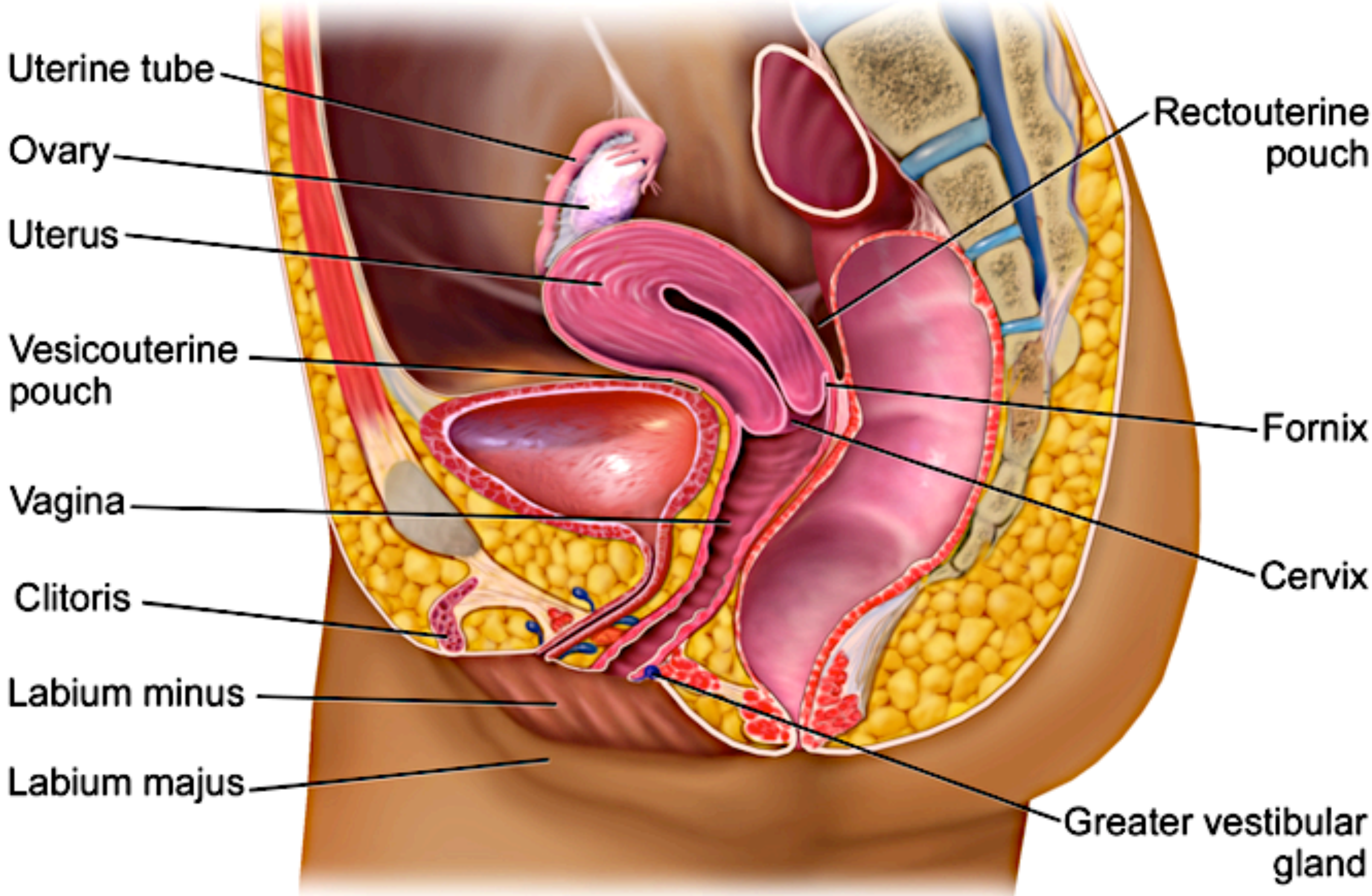
Martin & Charlie Sheen, Emilio Estevez

Male & Female Reproductive Anatomy

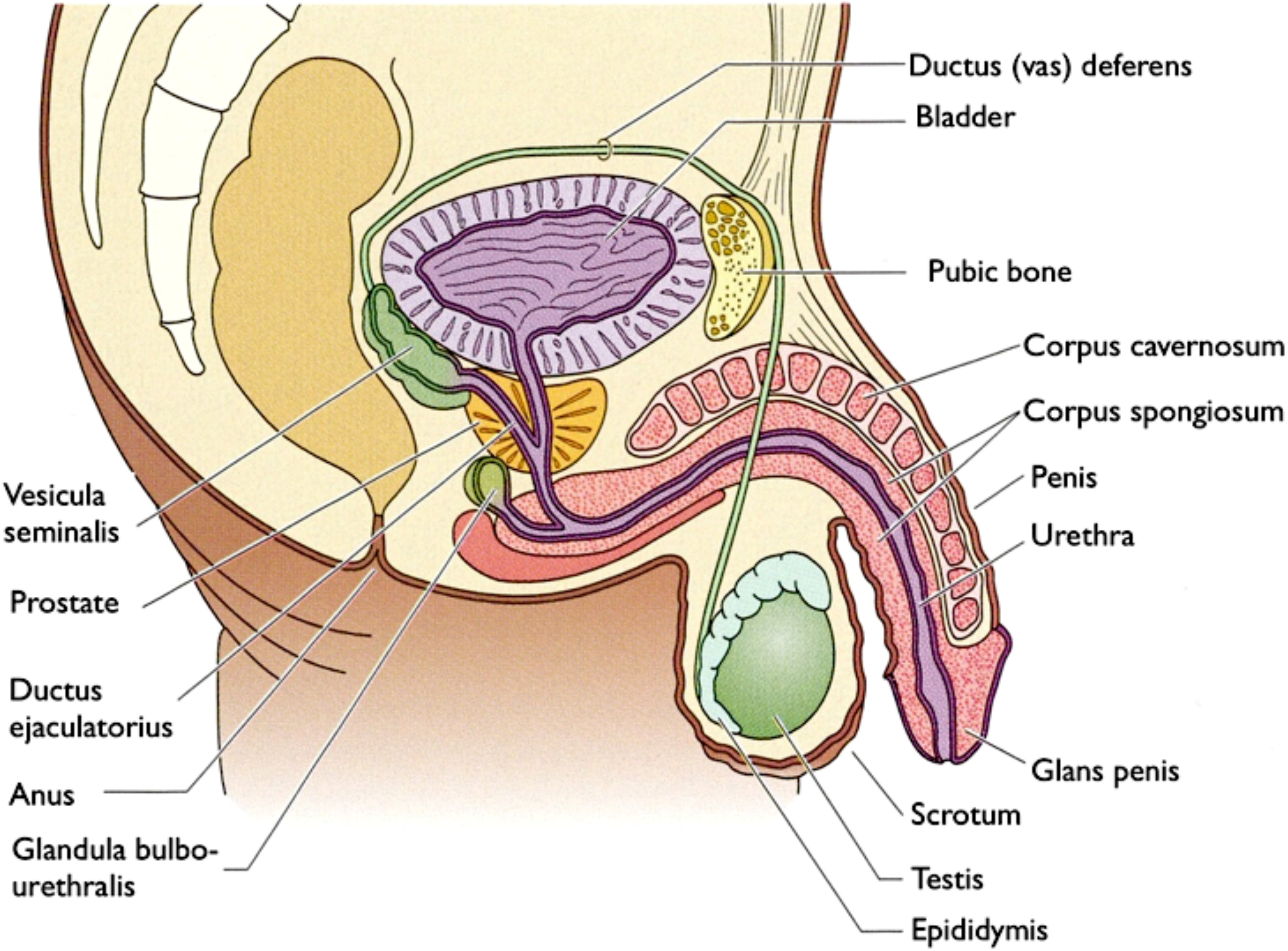
The gonad where meiosis will take place is the testis (testicle) in males and the ovary in females.



Female Reproductive Anatomy



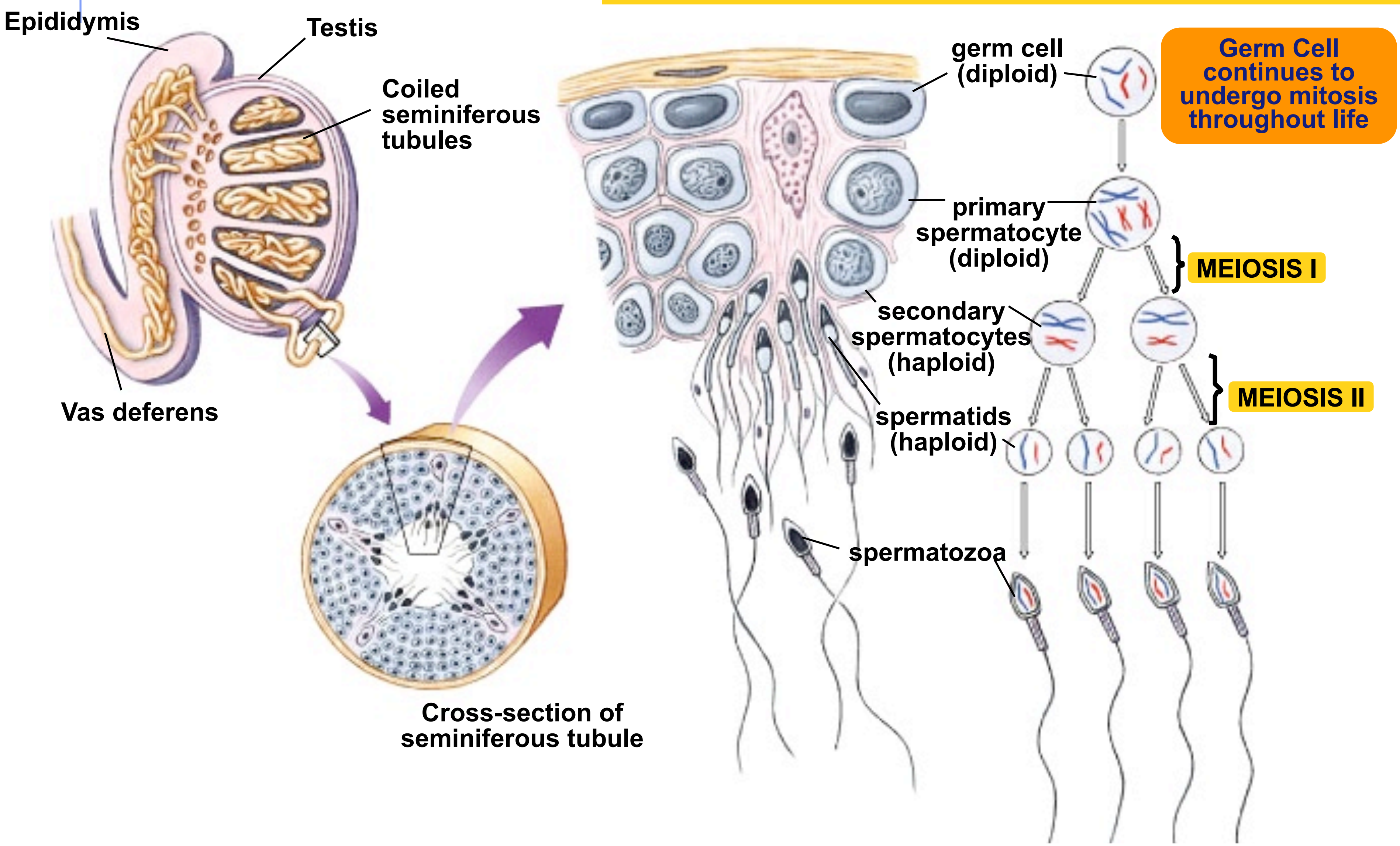
Male Reproductive Anatomy



Sperm production

Spermatogenesis (the birth of sperm)

- continuous & prolific process
  - Starts at puberty
- each ejaculation = 100-600 million sperm



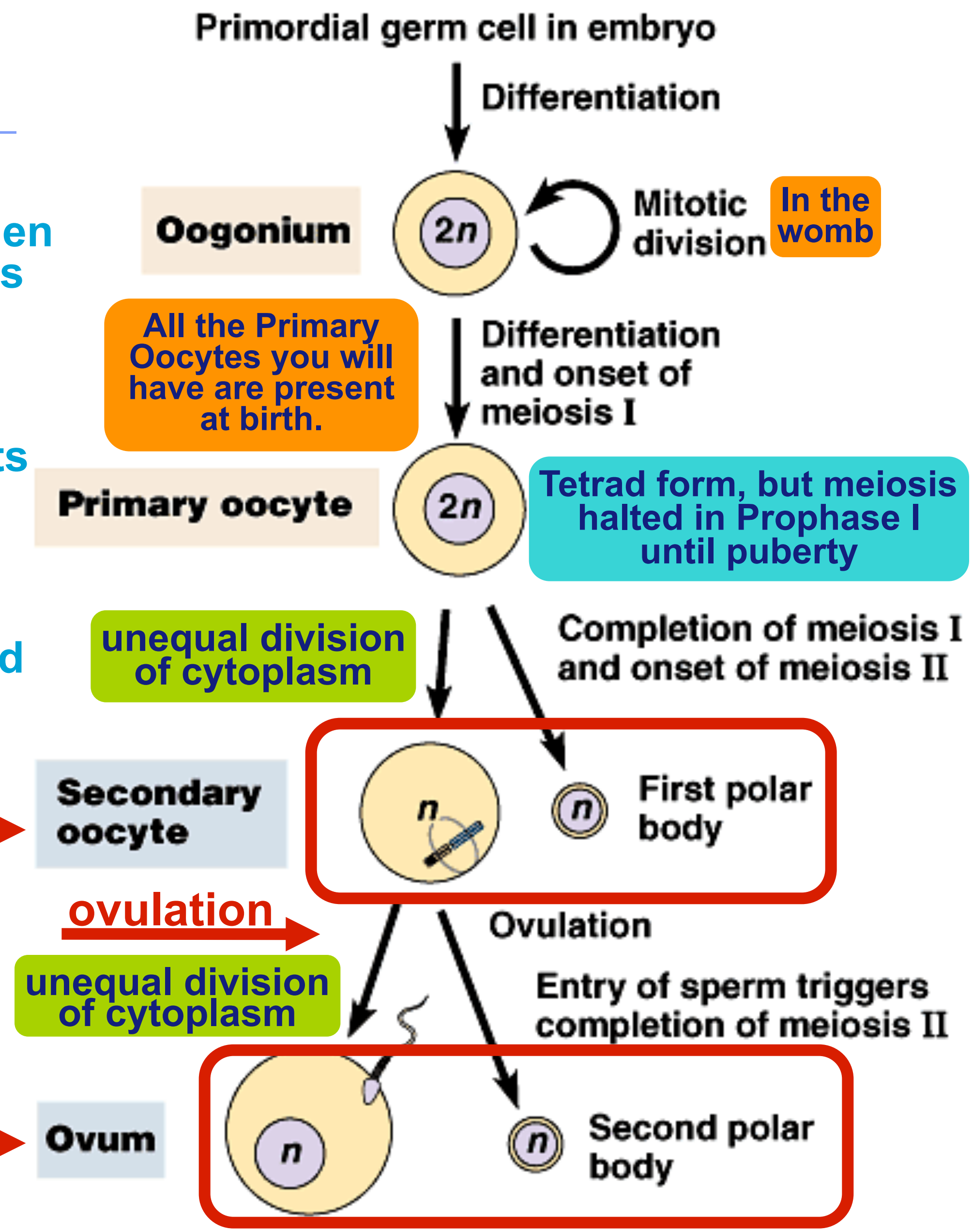
Egg production

- **Oogenesis**
  - eggs in ovaries start meiosis when you are a fetus but the process is <u>halted before anaphase 1 & telophase 1</u>
  - <u>Meiosis 1</u> is completed during maturation of an egg which starts at puberty and on
  - <u>Meiosis 2</u> completed after fertilization by sperm cell
  - For each somatic cell that started meiosis, we end up with: <u>1 egg + 2 polar bodies</u>

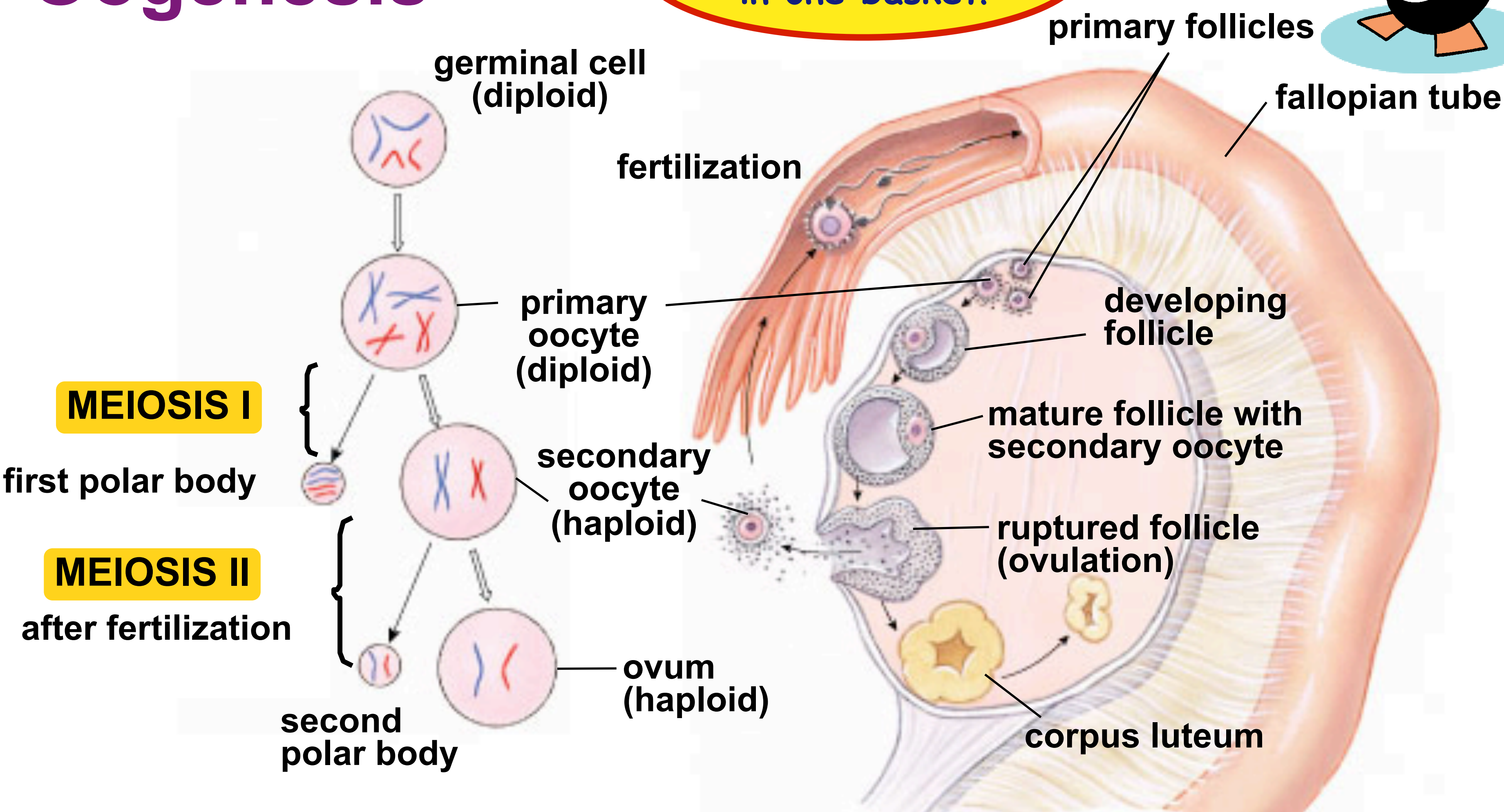
Meiosis 1 completed during egg maturation

Meiosis II starts but is halted in metaphase II until after fertilization

Meiosis 2 completed triggered by fertilization



Oogenesis

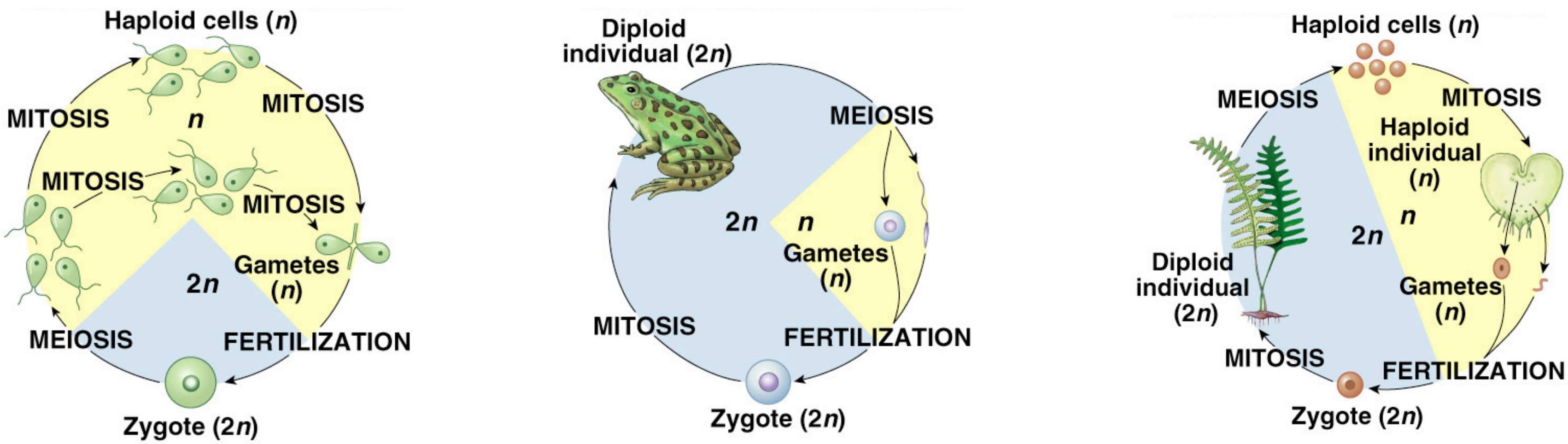


Ovum is the egg. **Through the unequal division of cytoplasm during Meiosis, it is a large cell. This cell, once fertilized, can undergo many mitotic divisions initially without having to spend time growing in the G1 phase to grow into a large enough cell before heading back into S phase. It thus passes through the cell cycle very rapidly initially.**

Polar bodies are discarded.

Differences across kingdoms

- Not all organisms that sexually reproduce use haploid & diploid stages in same way
  - Which one is dominant (2n or n) differs by kingdom
  - Each differs in the timing of Meiosis & Fertilization
    - Both meiosis and fertilization events contribute to the genetic variation among offspring
  - In all kingdoms though, there is still an alternation between haploid & diploid cells
    - a must for sexual reproduction

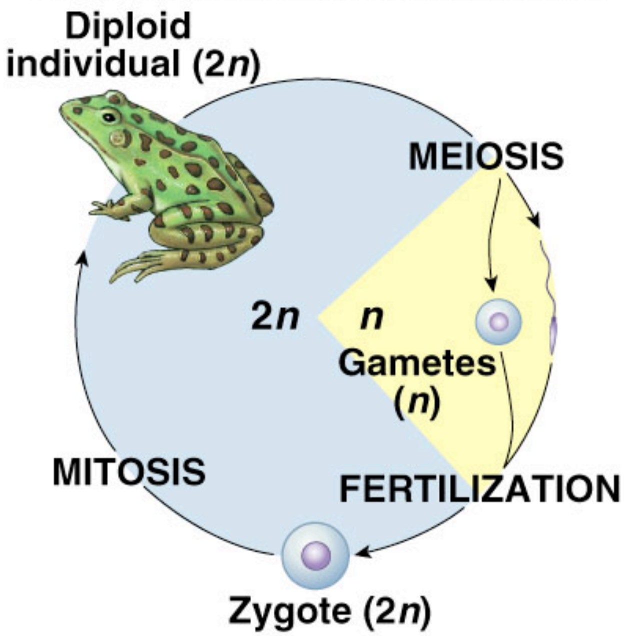


(a) Some types of algae (b) Most animals (c) Some plants and some algae

Most Animals

- Cells can divide by mitosis whether or not they are haploid or diploid.
  - Haploid cells produce more haploid daughter cells
  - Diploid cells produce more diploid daughter cells
    - Haploid cells cannot divide by meiosis however.
      - We cannot end up with half of one set of chromosomes.

- In Animals:
  - Diploid cells undergo meiosis to make gametes
  - Gametes are the only haploid cells in these organisms
  - The gamete does not undergo any mitosis before fertilization
  - After fertilization, the diploid cell divides by mitosis to make a multicellular diploid organism

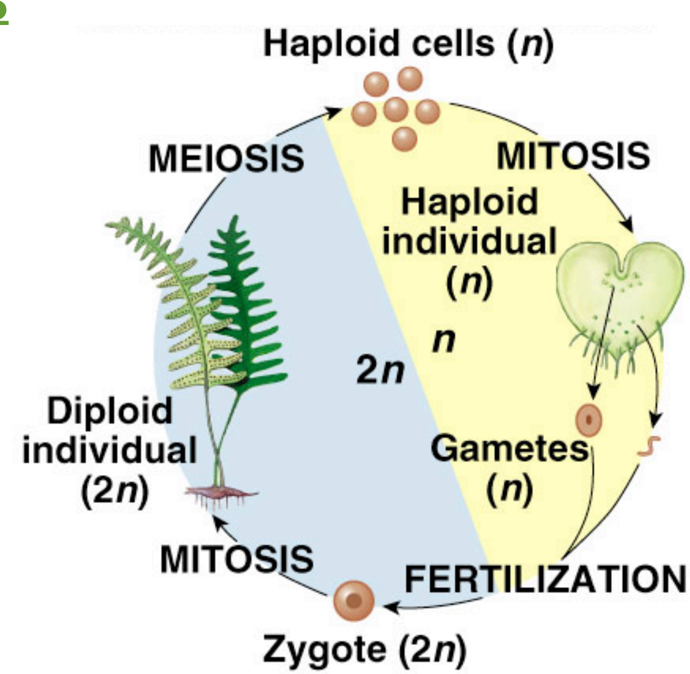


(b) Most animals

Some Plants and Algae

Some Plants and Algae display a life cycle called "Alternation of Generation"

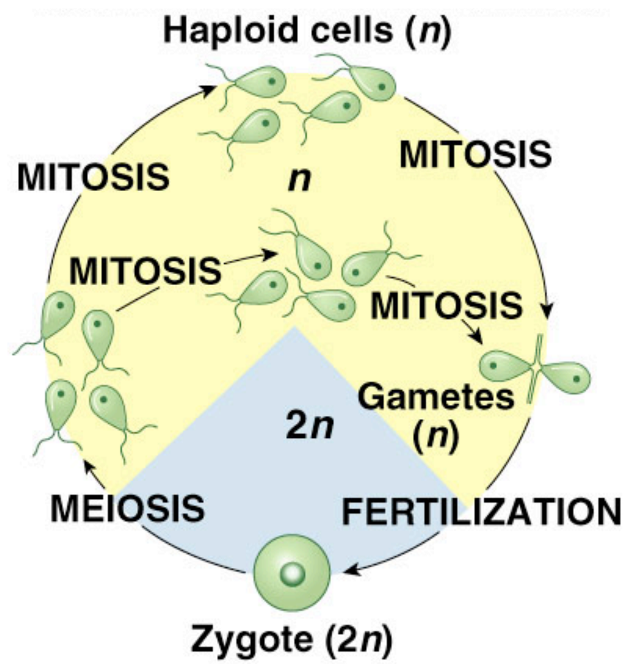
- **This life cycle involves multicellular stages of haploid cells and multicellular stages of diploid cells**
  - The multicellular diploid organism is called the SPOROPHYTE.
  - Sporophytes undergo meisosis to produce haploid cells called SPORES
    - Haploid spores do not combine in fertilization right away.
    - They begin mitosis and produce a multicellular haploid body called a GAMETOPHYTE
  - GAMETES are eventually produced by gametophytes through mitosis ***NOT*** meiosis *(since they are already haploid)*
    - Gametes from two parent gametophytes combine in fertilization, producing a diploid cell
  - This diploid cell undergoes mitosis to become a diploid sporophyte again



(c) Some plants and some algae

Some Algae & Most Fungi

- Haploid gametes fuse to produce diploid zygote
  - Zygote does NOT undergo mitosis and form a multicellular organism
- Diploid zygotic cell goes straight through meiosis, producing haploid cells
  - These cells are not gametes and do not combine through fertilization
- Instead, they undergo mitosis producing many single celled haploid cells or one multicellular haploid body
  - Later gametes are made through mitosis from these haploid cells
  - Gametes combine through fertilization into a diploid zygote which immediately undergoes meiosis again

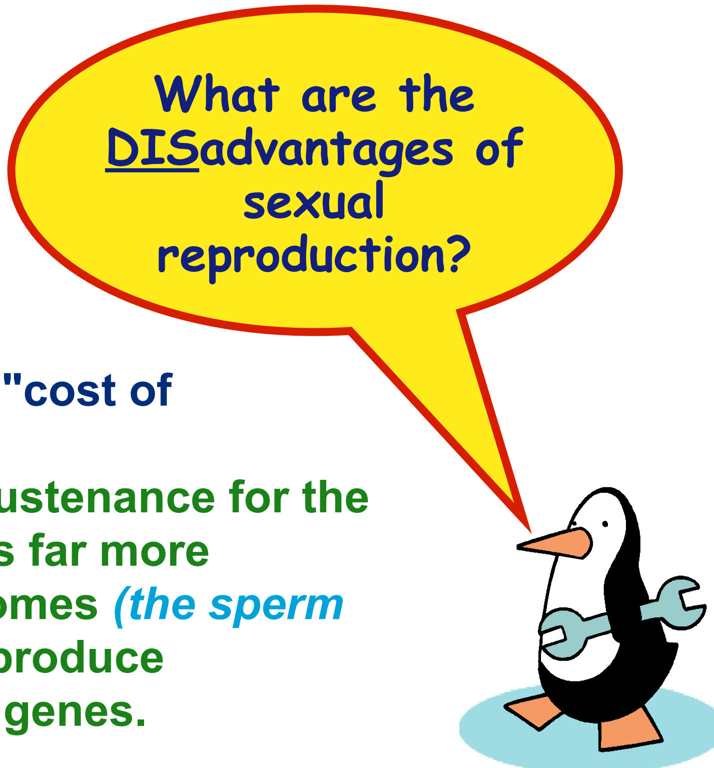


(a) Some types of algae

Sexual Reproduction

DISADVANTAGES

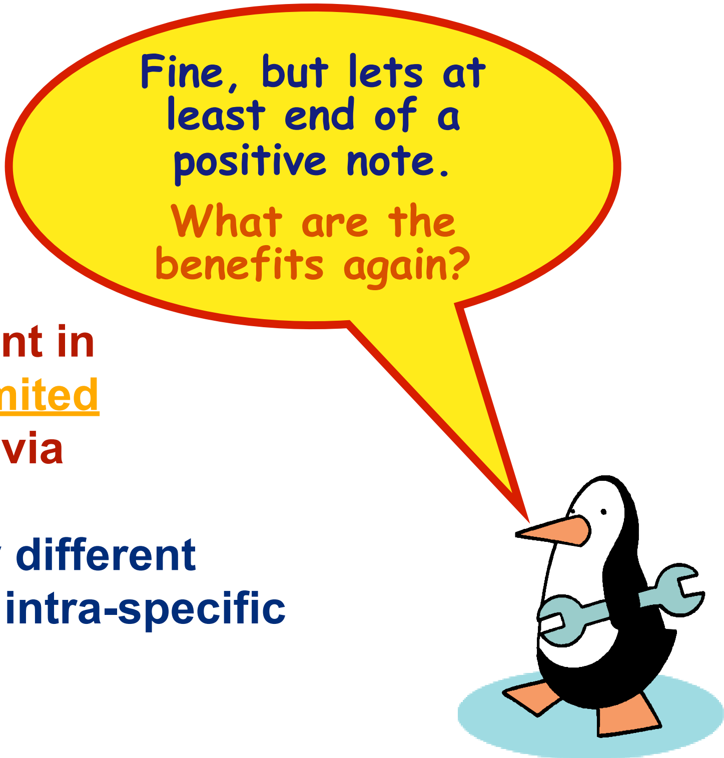
- Sexual reproduction takes time at the cellular level.
  - The process of Meiosis takes considerably longer than two mitotic divisions
- Gamete fusion and combining their DNA takes time
- The major features of Meiosis (chromosomal recombination and independent assortment) mean that good allelic combinations *(individuals have two copies of most genes on autosomes)* may be disrupted on a haphazard basis both within and between chromosomes.
- Individuals must find and/or attract mates
  - Expenditures of time and energy.
  - Individuals may encounter predators
  - Contact between individuals during mating is an ideal mechanism by which parasites and pathogens may be transmitted.
- For the individual there is a "the 50% cost" or a "cost of genome dilution"
  - The sex which invests in the cytoplasmic sustenance for the embryo *(the egg producing females)* invests far more than the sex which only provides chromosomes *(the sperm producing males)*. In other words, females produce offspring, while males only contribute their genes.



Sexual Reproduction

ADVANTAGES:

- Asexual lineages may accumulate many mutations independently of each other
  - While recombination of chromosomes and random mating during sex will produce recombinant genomes that have fewer mutant alleles.
- Sex guarantees that every generation will be a diverse sample of all the genotypes
  - Genotypic variation will enable the population to respond to future selection pressures.
- Beneficial alleles can only be introduced into asexual lineages by successive mutation.
  - Similar combinations of favorable alleles could be produced in a single generation in sexual populations.
- Asexual offspring will all utilize the environment in exactly the same manner, and in a resource limited environment, will reduce their average fitness via internal competition.
  - Sexually produced offspring have slightly different resource requirements, and the impact of intra-specific competition will not be as great.



Sexual Reproduction

ADVANTAGES:

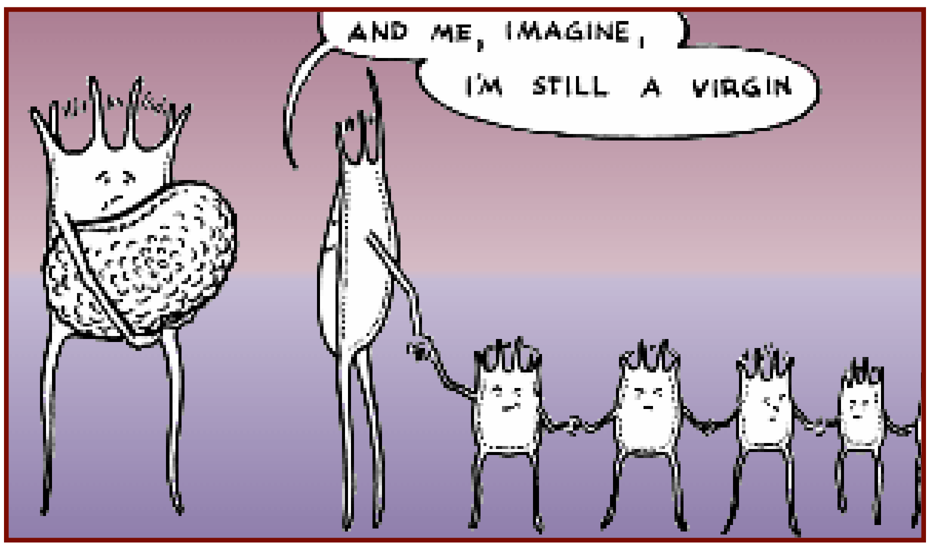
- "Red Queen" hypothesis.
    - This concept takes its name from the Alice in Wonderland character who had the opinion that one must run as fast as one can in order to stay in the same place.
  - There is a frequency-dependent relationship between hosts and parasites.
    - Parasites and pathogens are assumed to cause a significant reduction in host fitness
    - Susceptibility to a given parasite is a function of genotype.
    - Novel, parasite-resistant genotypes will have a high fitness when they first appear
      - Their selective advantage will decline as they increase in frequency and the parasite evolves to circumvent their resistance.

Obviously, any mechanism which produces new genotypic variants will be favored.

- DNA damage can be repaired through recombination during sexual reproduction

P.S. Now that you understand meiosis, you can understand one final complicated form of ASEXUAL Reproduction

- Parthenogenesis (from the Greek for "virgin" + "birth") means the growth and development of an animal embryo or plant seed without fertilization of the female egg by a male.
- Parthenogenesis occurs naturally in some lower plants, invertebrate animals (e.g. water fleas, aphids) and some vertebrates (e.g. lizards, salamanders, some fish, and even turkeys).
  - Populations of animals that undergo reproduction by parthenogenesis mostly are typically all-female!



Asexual Reproduction

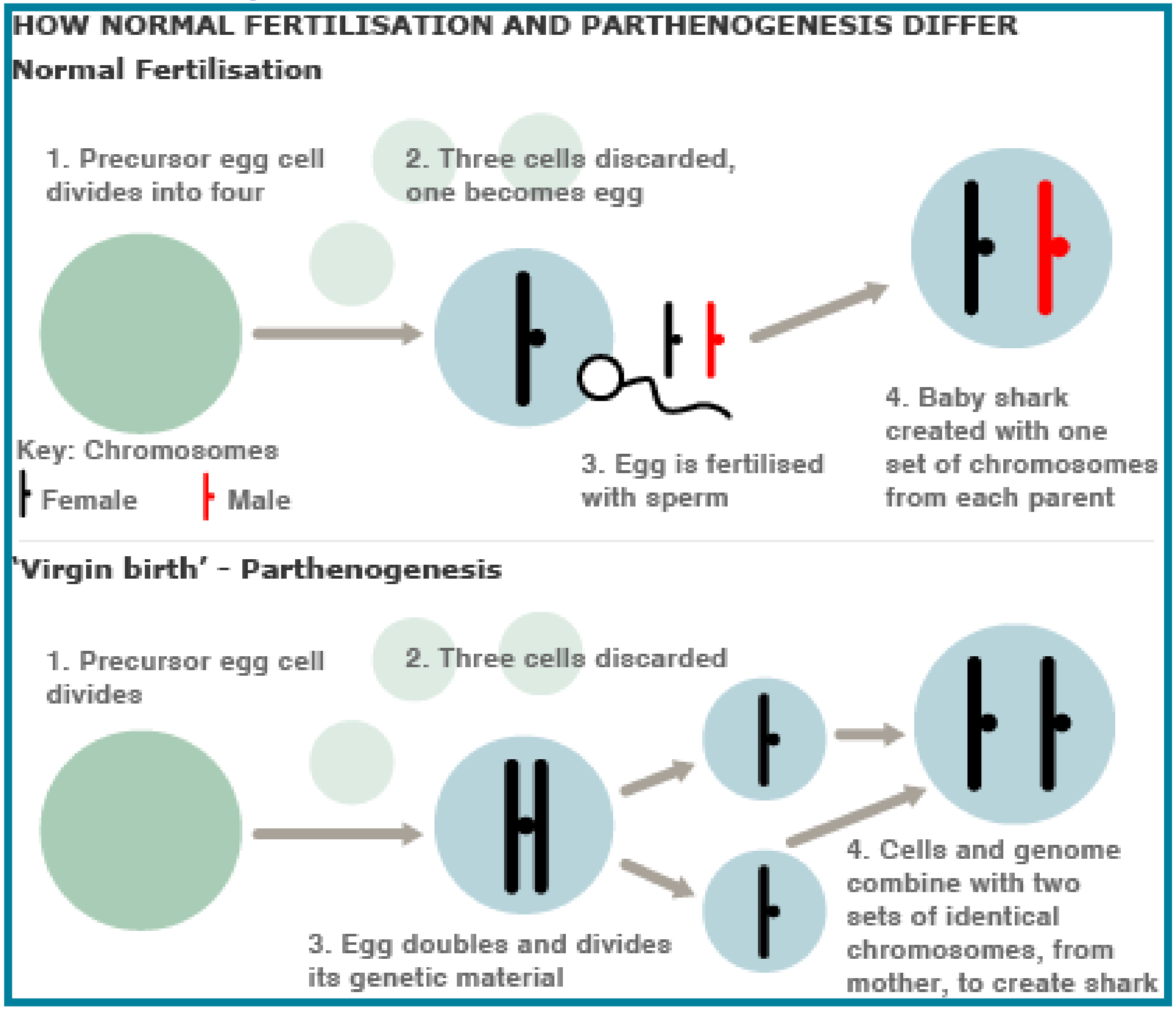
Parthenogenesis even witnessed among sharks!

Female hammerhead sharks *can* reproduce without having sex, scientists confirm. The evidence comes from a shark at Henry Doorly Zoo in Nebraska which gave birth to a pup in 2001 despite having had no contact with a male.

Genetic tests by a team from Belfast, Nebraska and Florida prove conclusively the young animal possessed no paternal DNA *(no DNA from a male).*

The type of reproduction exhibited had been seen before in bony fish but never in cartilaginous fish such as sharks.

Shark offspring were produced not by mitosis but by combining two haploid female reproductive cells made by the mother *via meiosis* in a process that looks like fertilization between male and female gametes, except here the gametes are both made by ... *the mother!!!*



Asexual Reproduction

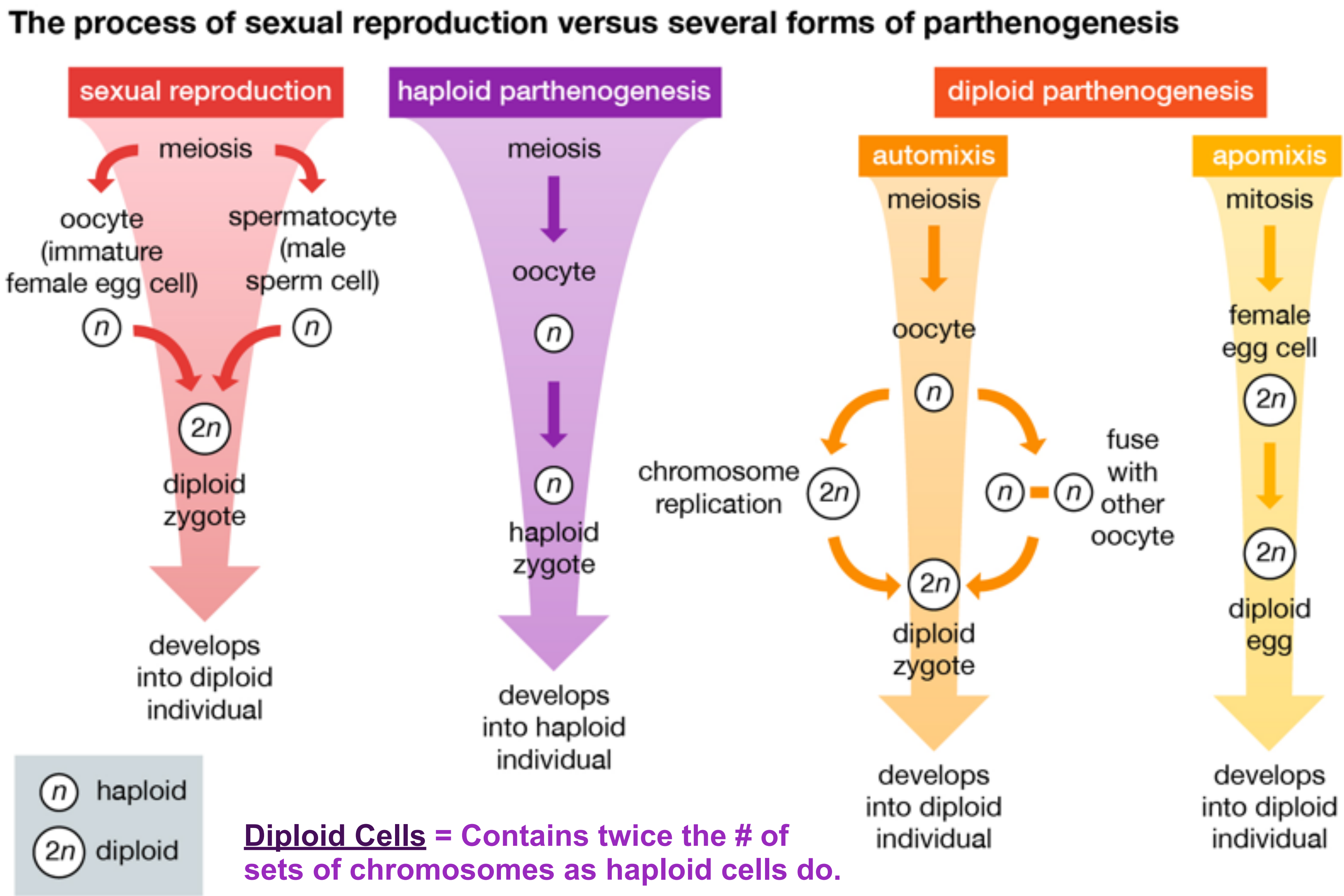
In the wild, these sharks have come under extreme pressure through over-fishing and many species have experienced sharp declines.

If dwindling shark groups resort to **parthenogenesis** to reproduce because females have difficulty finding mates, this *is likely to weaken populations* still further. The reason is that asexual reproduction **reduces genetic diversity** *(the male's DNA version is not passed down)* and this makes it harder for populations of the organism to adapt to changing environmental conditions or the emergence of a new disease, for example.

- With normal sex, the mixing of maternal and paternal DNA introduces novel genetic combinations of genes in the offspring, which can give animals new varieties of traits that might be advantageous in new circumstances.
  - Dr Paulo Prodohl: "Vertebrates in general have evolved away from parthenogenesis to boost genetic diversity among their offspring and enhance evolutionary potential for survival of the species."

The concern for sharks is that not only could we be reducing their numbers but we could be making the species less biologically **"fit"** *(less able to survive & reproduce)* as well.

Actually, various forms of parthenogenesis have been identified, all having in common that offspring are made by only one parent!



Diploid Cells = Contains twice the # of sets of chromosomes as haploid cells do.


Any Questions??