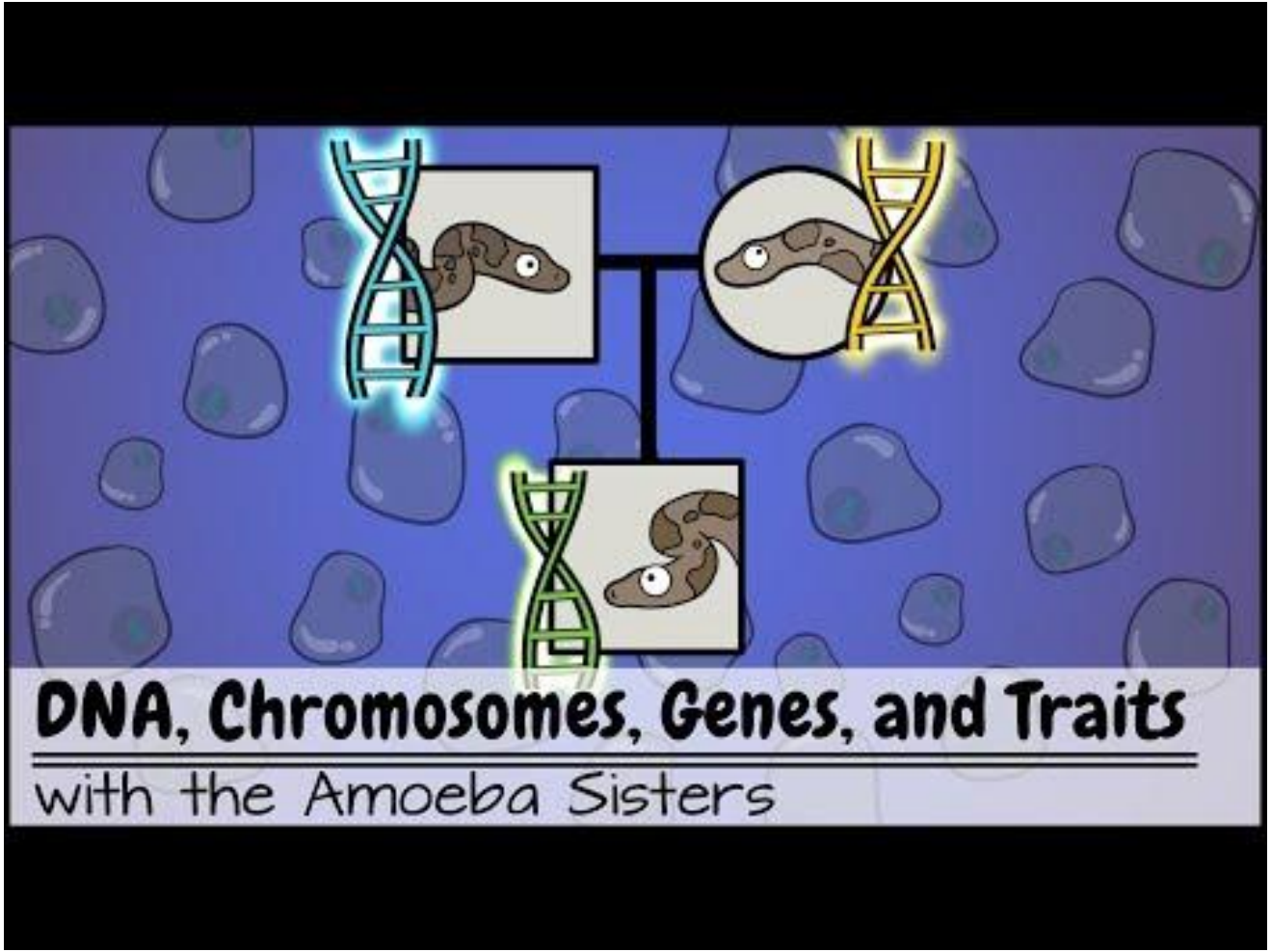
4.1 The Nature of Heredity

P. 138 - 141

Cell Division

- Process that is **fundamental to life**
  - Unicellular species use this process to **reproduce**
  - Multicellular species use this process for **growth and repair**

- Through the process, **chromosomes** are passed onto daughter cells (heredity).



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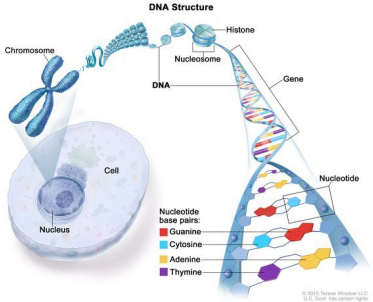
Terms Associated with Genetics



Genetics: the study of heredity and variation.

Heredity: the passing of traits from parents to their offspring.

- **Chromosomes** are long coiled strands of DNA (deoxyribonucleic acid)found in the nucleus of eukaryotic cells
  - Each chromosome contains **thousands of genes.**
  - Genes are segments of DNA (distinct sequences) that code for a **particular trait.**

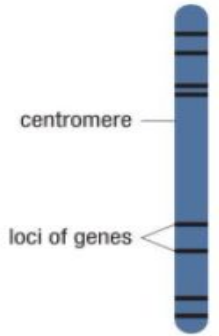


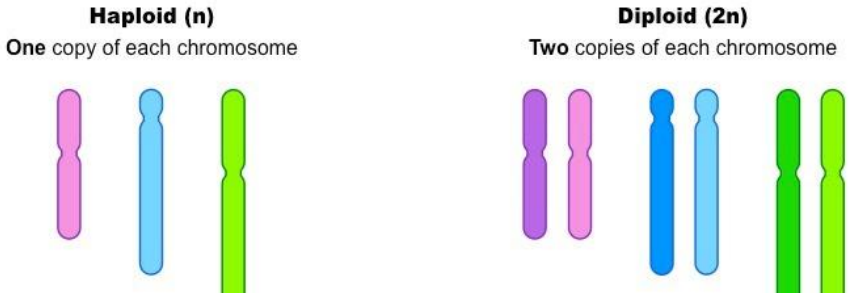
Figure 2 A typical human chromosome contains thousands of genes. Each gene is located at a different locus.

Species	*Parascaris equorum*	*Oryza sativa*	*Homo sapiens*	*Pan troglodytes*	*Canis familiaris*
Chromosome #	4	24	46	48	78
Common Name	 Roundworm	 Rice	 Human	 Chimpanzee	 Dog

Species vary in terms of the number, shapes and sizes of their chromosomes.

Chromosomes

- Occur mostly in **sets** in multicellular organisms.
- In humans…
  - **diploid** cells contain **double** the number of chromosomes **(2n)**. This is considered “normal number” of chromosomes for **body/somatic cells**
  - **haploid** cells (i.e. sex cells/gametes) have **half** the “normal” number **(n)**
  - **polyploid** have more than two sets of chromosomes.



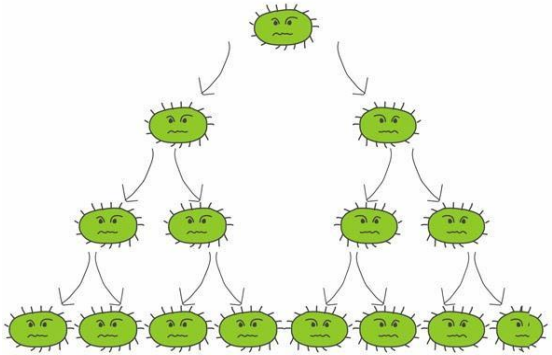
Reproduction

Asexual vs. Sexual Reproduction

Asexual reproduction results in an offspring that is a copy of/ identical to the parent.

Sexual reproduction results in an offspring that is a combination of both parents.

Asexual Reproduction



- The production of offspring from a single parent by cell division (without the use of sex cells)
- Results in **genetically identical** individuals

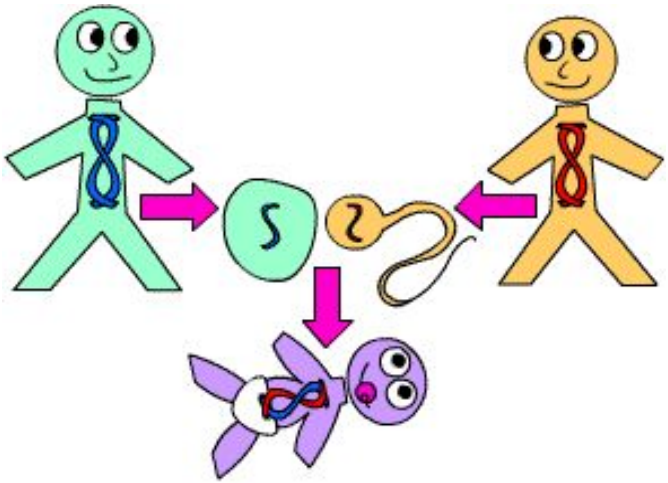
Advantages:

- Do not need to seek out a mate (limit energy expenditure and risky activity)
- Nothing left to chance - identical (invariability of offspring)

Disadvantages:

- Little variation - if the environment changes, individuals may no longer be well adapted

Sexual Reproduction



- Offspring are produced from the fusion of two sex cells, usually coming from two different parent organisms.
- Results in offspring that are genetically variable.

Advantages:

- Variation of offspring (non-identical)
- If the environment changes, some individuals may be better able to adapt.

Disadvantages:

- Need to have different sexes, mating calls or mating dances, etc…
- Requires more energy
- Sex is biologically costly - attracting a mate can also attract predators (ie bright coloured peacock).

ASexual VS Sexual Reproduction

Homework:

Pg 141: # 1,5,6 & 7

4.1 Textbook Review

4.1 Summary

- A fundamental aspect of reproduction is the passing on of genetic information from one generation to the next.
- Genetic information is stored in DNA molecules within the chromosomes of cells.
- Portions of the DNA molecule, called genes, carry heritable information and are found at distinct locations on a chromosome.
- Chromosome number, shape, and size vary from species to species.
- Asexual reproduction results in offspring that are genetically identical to their single parent.
- Sexual reproduction results in offspring that are genetically variable. Offspring inherit half of their genetic information from each of two parents.

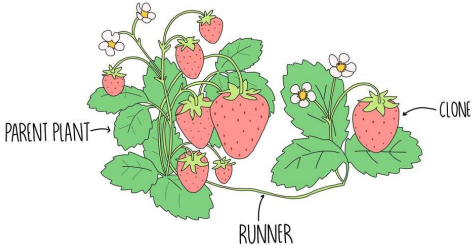
4.2 Asexual Reproduction

P. 142 – 151

Modes of Asexual Reproduction

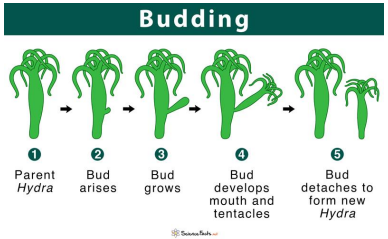
Copies and clones!

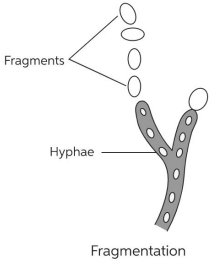
Strawberry plants can send out "runners".



Female aphids produce female offspring (without a male)in the spring through the spontaneous development of an embryo from an unfertilized egg cell. This allows rapid population growth!

Hydra can produce offspring by outgrowths of their bodies called "budding."

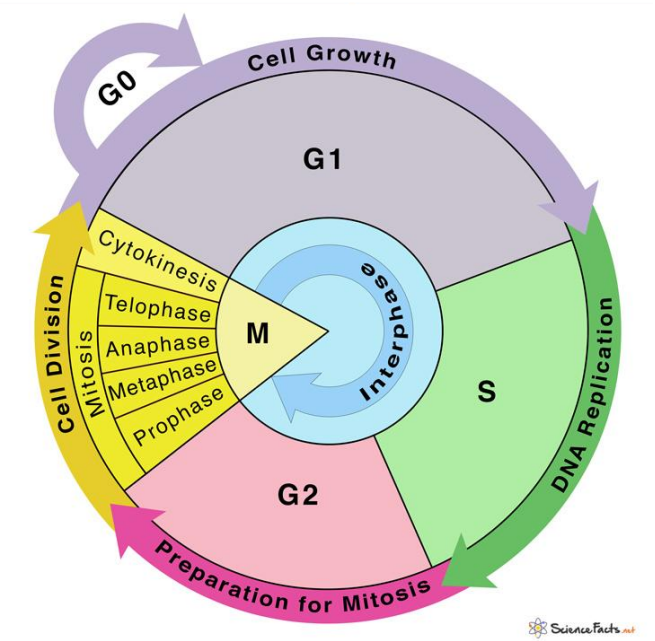




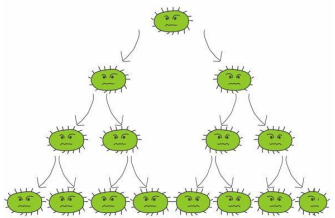
Fungi can reproduce through fragmentation, when a piece breaks off and becomes independent.

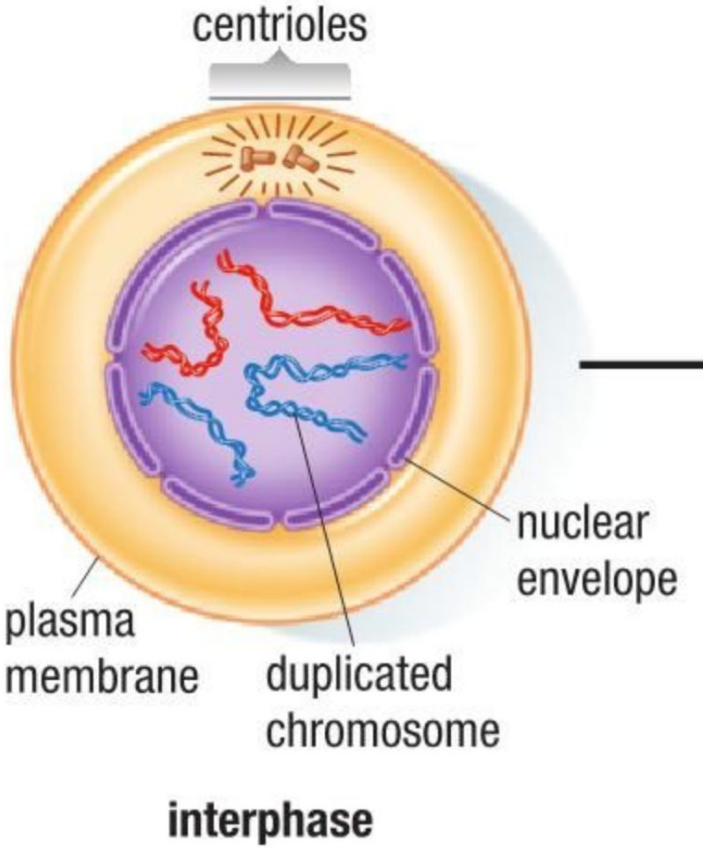
(all rely on cell division)

Cell Division



- Cell division consists of both mitosis and cytokinesis
  - Mitosis: nuclear division
  - Cytokinesis: cytoplasmic division

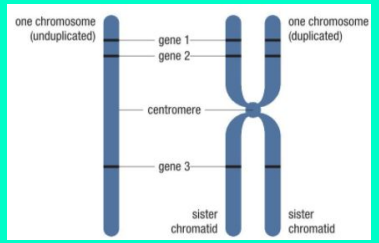


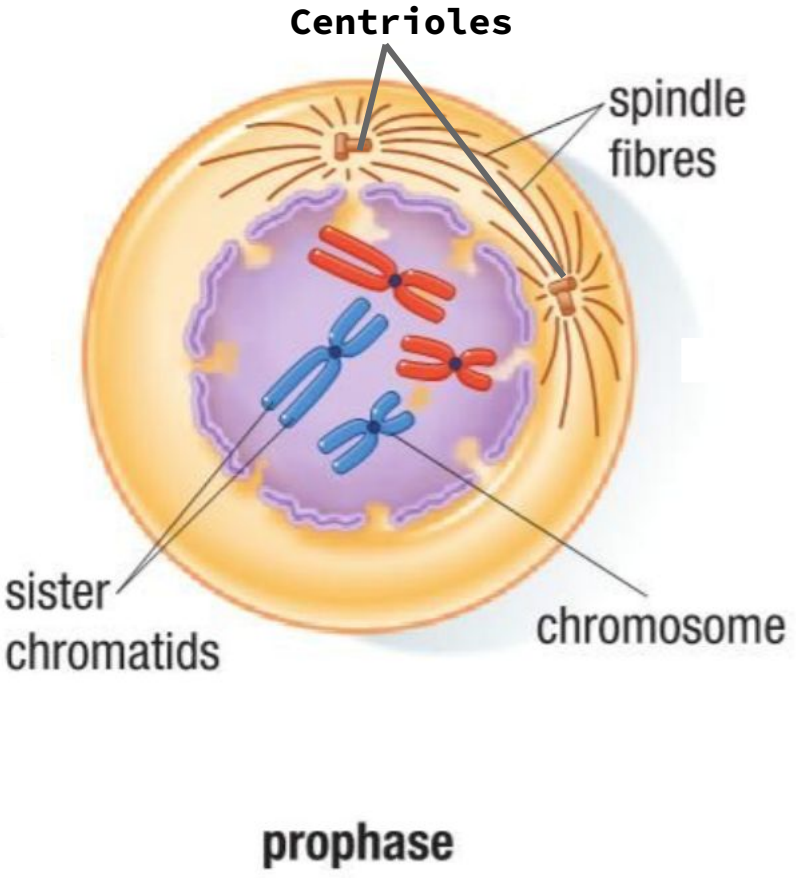


Interphase:

(longest phase of cell cycle)

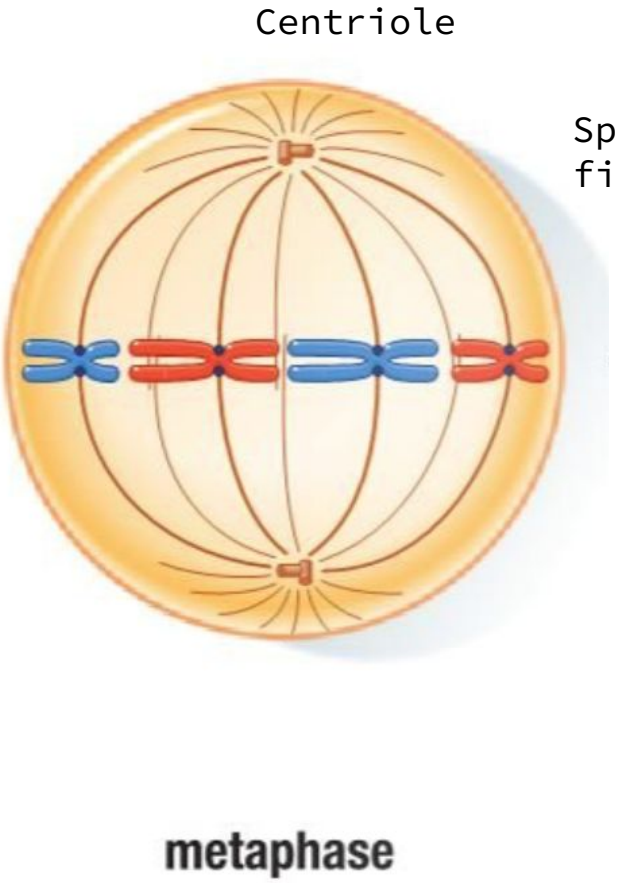
- Cell grows and carries out normal functions
- Genetic material is in the form of thread-like chromatin
- Replication of chromosomes results in pairs of sister chromatids attached at the centromere.





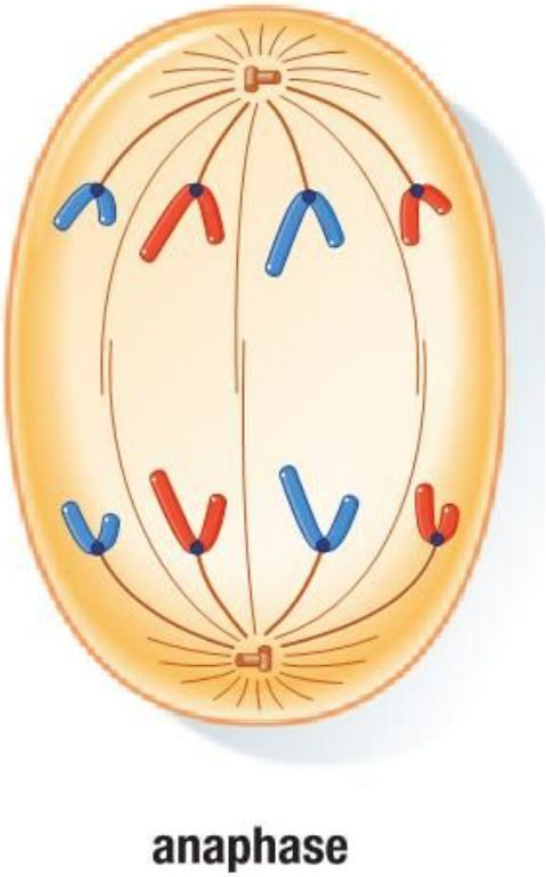
Prophase:

- Prophase is the first phase of mitosis
- During prophase the chromosomes condense and are visible under a microscope.
- Centrioles (in animal cells) separate and move to opposite ends of the cell
- Nuclear membrane starts to dissolve



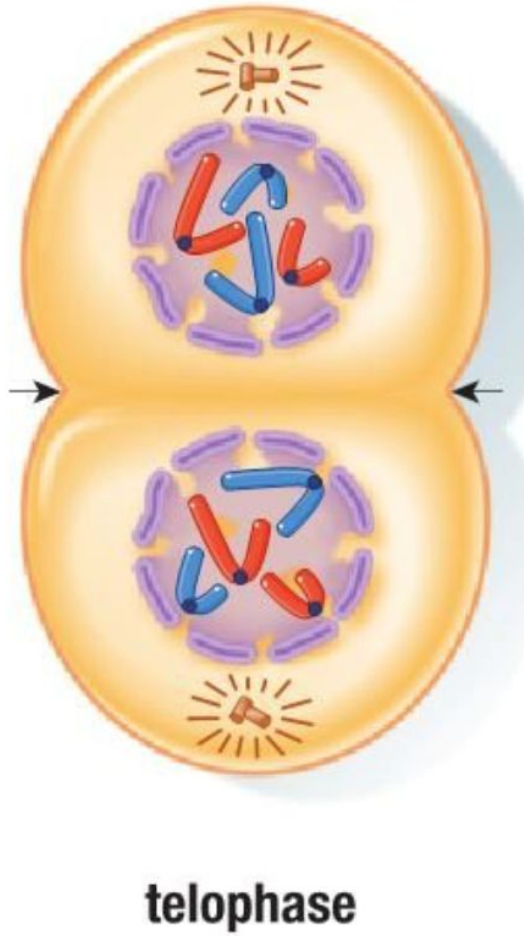
Metaphase:

- Metaphase is the second phase of mitosis
- Spindle fibers move and align chromosomes (each composed of sister chromatids) at the centre (equator) of the cell.



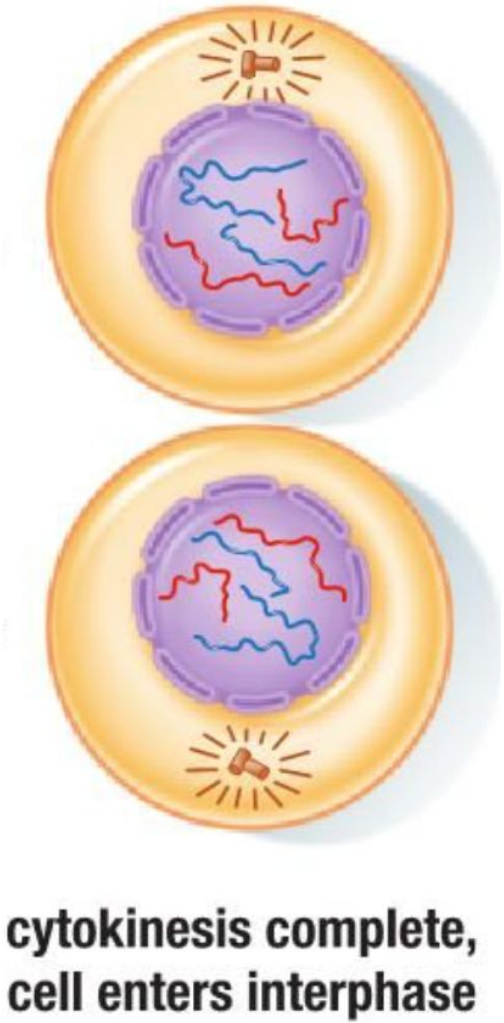
Anaphase:

- Centromeres divide
- Sister chromatids (chromosomes) separate and move to opposite poles of the cell
- If mitosis proceeds correctly, the same number and type of chromosomes will be found at each pole of the cell.



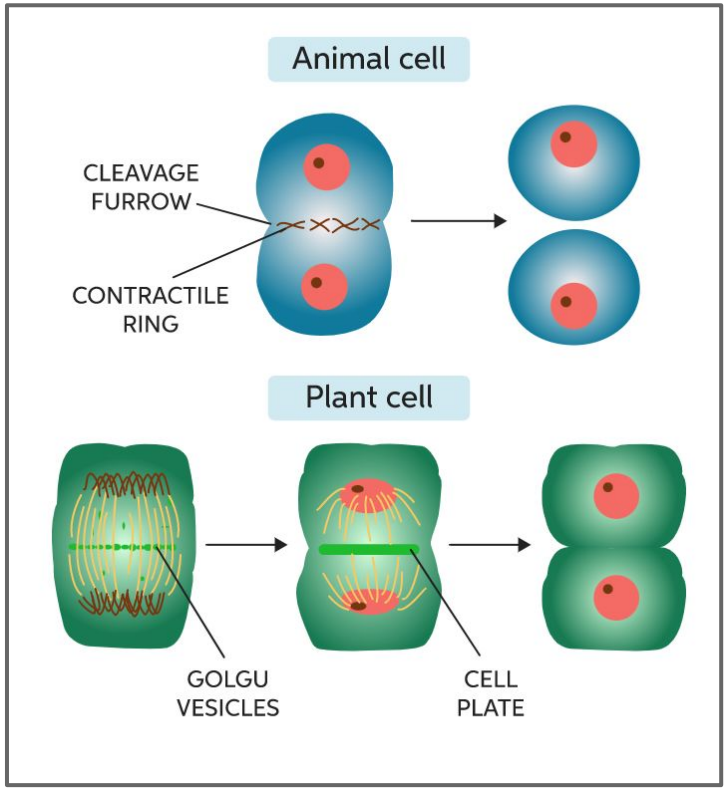
Telophase:

- Final phase (of nuclear division)
- Chromosomes reach opposite poles of the cell and begin to unwind
- Spindle fibres dissolve
- Nuclear membrane starts to reform
- Two daughter **nuclei** are now present



Cytokinesis (cellular division):

- The cell divides its cytoplasm and organelles, into two new daughter cells



Differences in cytokinesis

- In many cells (protist, fungi and animal) a furrow develops and the cytoplasm divides
- In plant cells, **vesicles** produced by Golgi apparatus **gather, then fuse**, on both sides of the equator; this **cell plate** will then become the cell wall
- Along with the organelles, the cells organelles are separated evenly

Cloning is not limited to natural processes...

Humans have been able to create clones of cells/organisms using the knowledge behind asexual reproduction

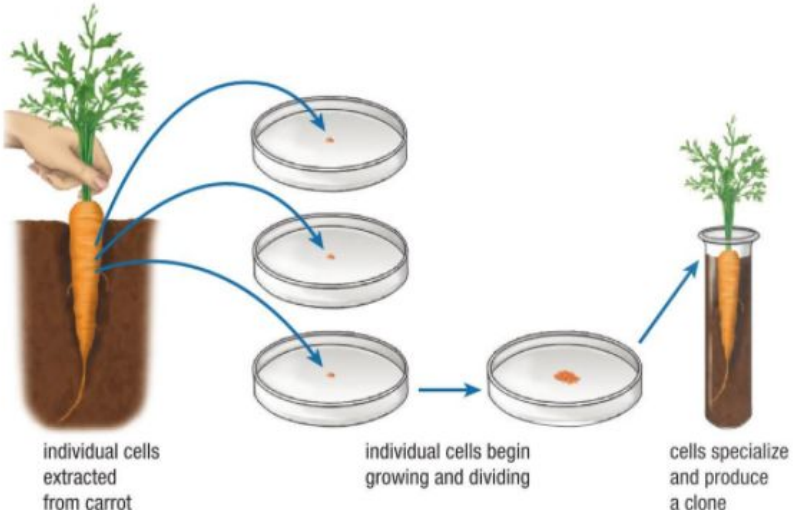
➔ (biotechnology)

Biotechnology - Applications

- Biotechnology is the field of biology that involves the use of living things in engineering, industry and medicine

Plant Cloning

- In 1958, carrot plants were first cloned using single carrot cells placed in a medium with hormones
- Commonly used to produce strains of plants with identical characteristics



- Mature/specialized root cells were extracted
- Special hormones/growth medium cause the cells to return to their undifferentiated (unspecialized state)
- Process of growth, specialization and development was kick started!

Animal Cloning

- In 1996, Dolly was the first **mammal to be cloned**
- Removed **body cell** from sheep to be **cloned**
- **Removed nucleus** from egg cell of an **egg donor**
- **Fused** body cell with enucleated egg cell
- Stimulated the egg cell to **divide, grow and differentiate**
- Inserted cells **into the uterus** of third sheep (surrogate mother)
- Dolly born 5 months later!

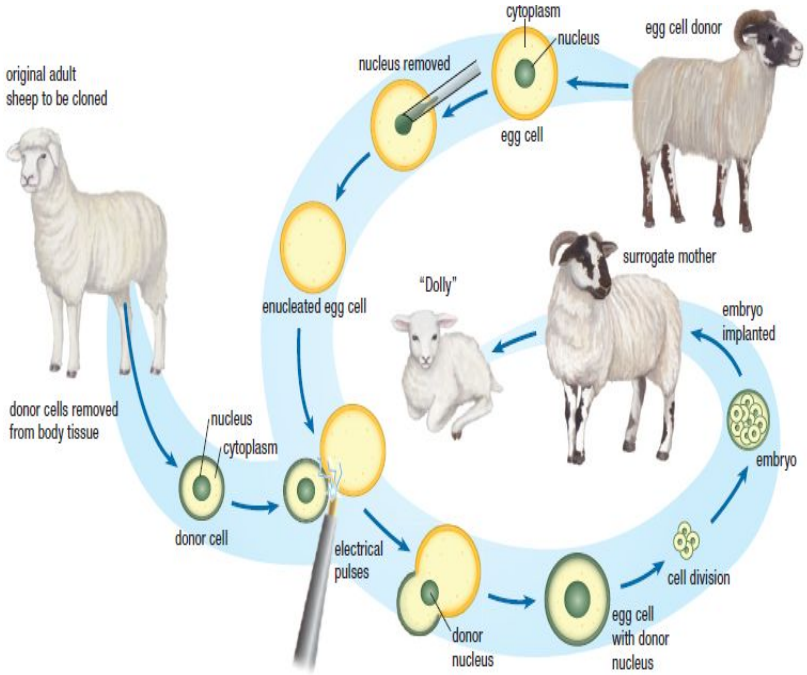


Figure 7 In 1996, Dolly was the first mammal to be cloned from an adult body cell. The process involved transferring an adult cell's nucleus into an egg cell in place of the original nucleus.

Animal Cloning - Implications

- Shorter lifespan
- Suffer from a variety of health implications (e.g. Dolly had lung problems)
- Premature aging
  (Dolly had arthritis)

Cloning can be used to mass produce organisms (e.g. livestock and crops) with favoured characteristics.

Applications and implications of Cloning

- Mass production of high quality livestock and crop plants
  - Implications: expensive, lack variation (vulnerable to environmental changes and disease)
- Cloning genetically modified organisms
  - Human insulin gene inserted into safflower plants

Figure 9 (a) Humulin is identical to human insulin and is produced by genetically engineered micro-organisms. (b) Now researchers have genetically engineered safflowers to produce the same substance. They hope this will reduce the cost of this very valuable drug.

- Cloning endangered species
- Cloning extinct organisms difficult because of lack of DNA

4.2 Textbook Review

4.2 Summary

- Asexual reproduction results in offspring that are genetically identical to a single parent.
- Cell division produces two daughter cells that are genetically identical to each other and to the original parent cell.
- Clones have little or no genetic variability.
- Mammals have been cloned from adult cells, but only with limited success.
- Applications of biotechnology include the production of valuable pharmaceutical and commercial products, high-quality plants and livestock, and prize individual animals.
- Cloned plants and animals are more vulnerable to changes in the environment and new diseases than are populations that exhibit genetic variability.
- Cloning may prove valuable in the fight to protect endangered species.

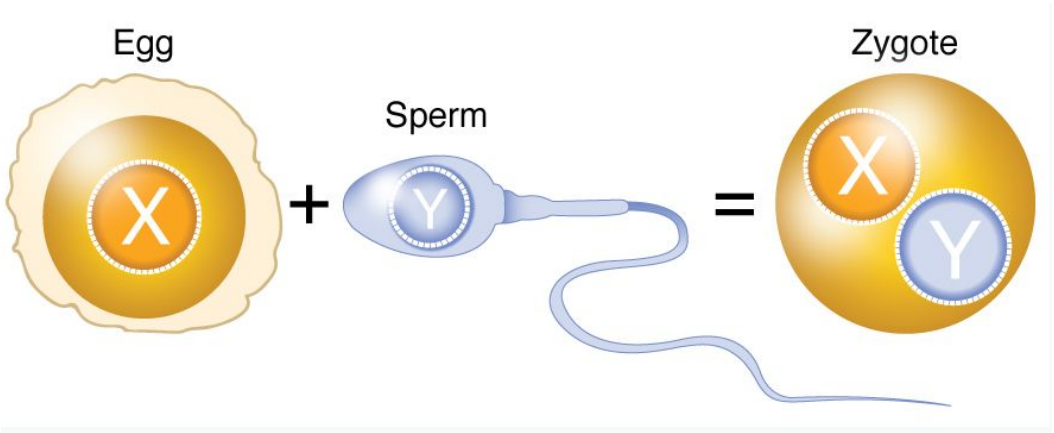
Homework:

Pg 151: #1,2 & 6

4.3 Sexual Reproduction

Sexual Reproduction

- Unlike asexual reproduction, sexual reproduction produces **genetic variety**.
- It involves two key processes:
  - 1. Formation of haploid sex cells called gametes (meiosis)
  - 2. Fertilization - when the sex cells join to form a zygote



Modes of Sexual Reproduction

Most species produce two types of gametes

- E.g. In animals, testes produce sperm and ovaries produce egg cells.

Plants (inc. mosses and ferns) also produce gametes.

- in higher plants, eggs are produced in cones and flowers (sex organs) and sperm is spread as pollen grains

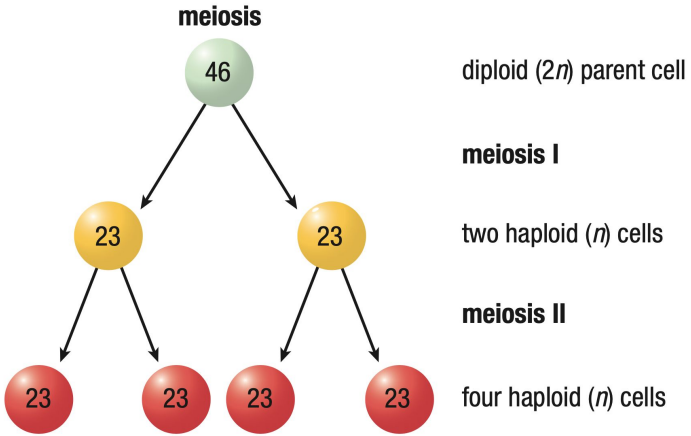
Many species have male and female individuals while others are hermaphroditic.

Diversity in sexual reproduction

Organism	**Types of individuals and gametes**	**Method of Fertilization**
bread mould fungus	“+” and “-” individuals produce similar-looking gametes where they come in contact	Gametes fuse forming a zygote
willow tree	Separate male and female trees. Males pollen grains and female eggs.	Insects pollinate flowers
giant clams	Young clams are males and change into females as they mature	External fertilization - all individuals in an area simultaneously release their sex cells in the open water
earthworm	Hermaphrodites with both sperm and eggs	Internal fertilizations - two worms exchange sperm, fertilizing each other’s eggs
parrot fish	Separate males and females Fish can change sexes Sperm and egg cells	External fertilization - sperms are released over eggs in water
Canada goose	Separate sexes Sperm and egg cells	Internal fertilization

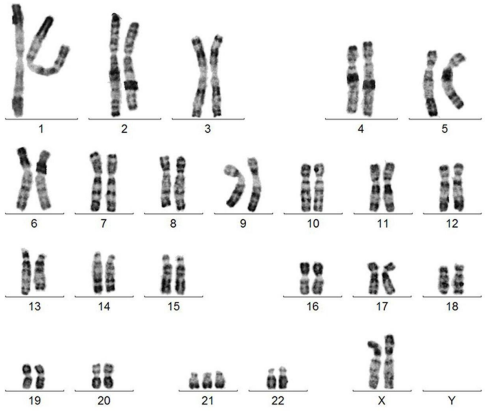
Sexual Reproduction - Meiosis

- The production of gametes (sex-cells) depends on the process of **meiosis**
- Meiosis occurs in **two stages** (Meiosis I & Meiosis II)
- Results in **4 daughter cells** that have half the number of chromosomes (**haploid**) as the diploid parent cell
- Offspring are genetically distinct!

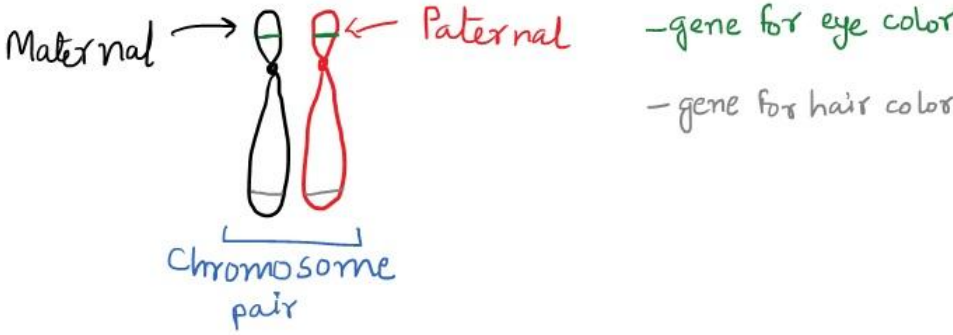


Homologous pairs

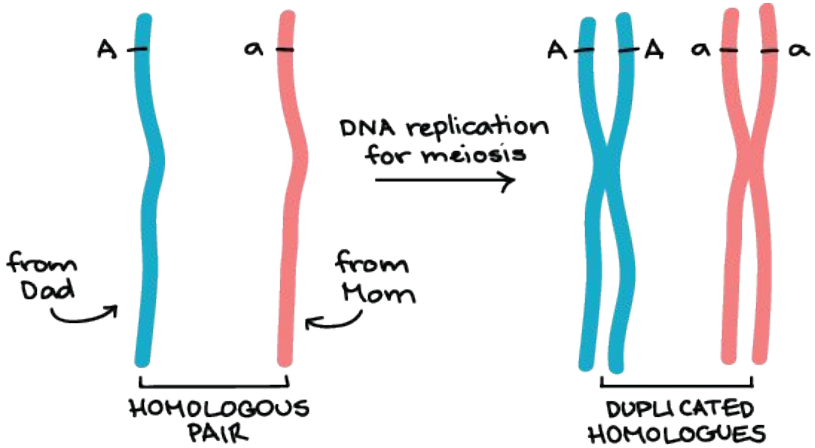
- Humans receive one set of DNA from an egg cell, and one set of DNA from a sperm cell.
- As a result, all our somatic cells have 23 PAIRS of chromosomes (46 chromosomes in total)
- We call these pairs HOMOLOGOUS PAIRS.



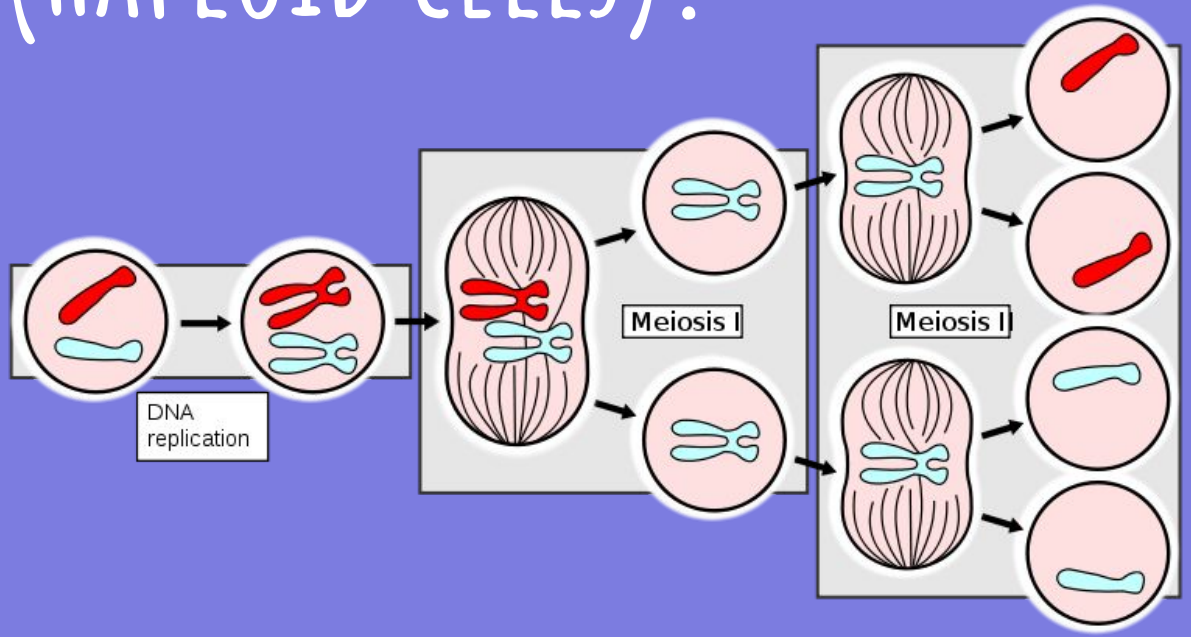
Homologous Chromosomes



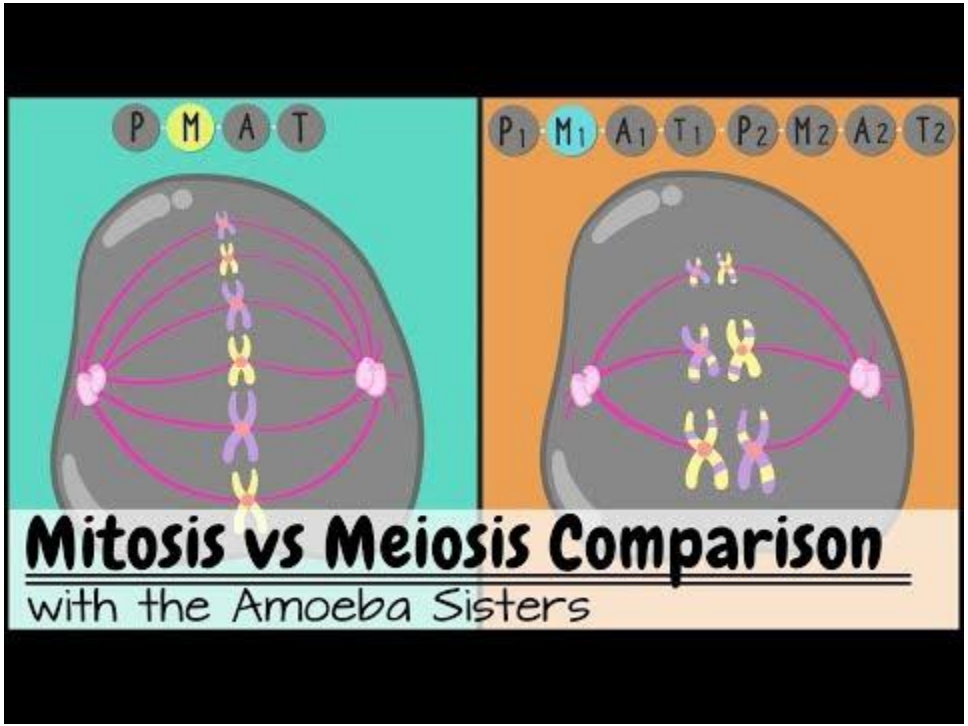
- Have similar structural features (e.g. size, banding patterns, centromere positions)
- Have the same genes at the same loci position - while the genes are the same, alleles, a form of a gene, may be different
- Alleles help account for different traits, e.g. blue, brown, green eye colour
- Pair up with each other during meiosis



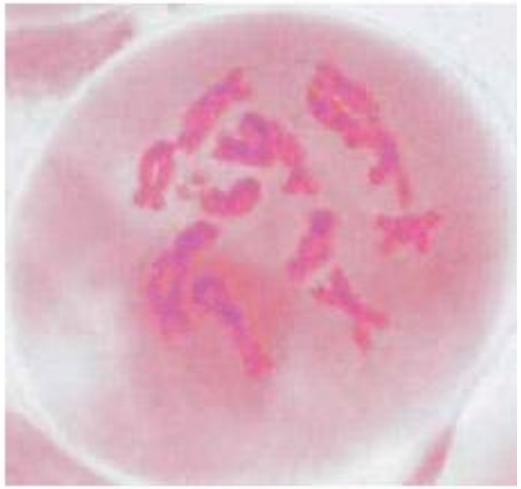
Meiosis - For the production of gametes (haploid cells)!

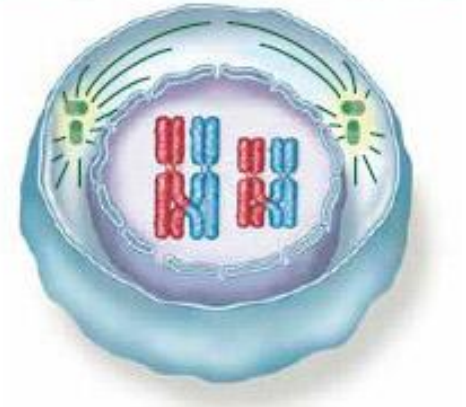


Mitosis VS Meiosis



Late prophase I–prometaphase

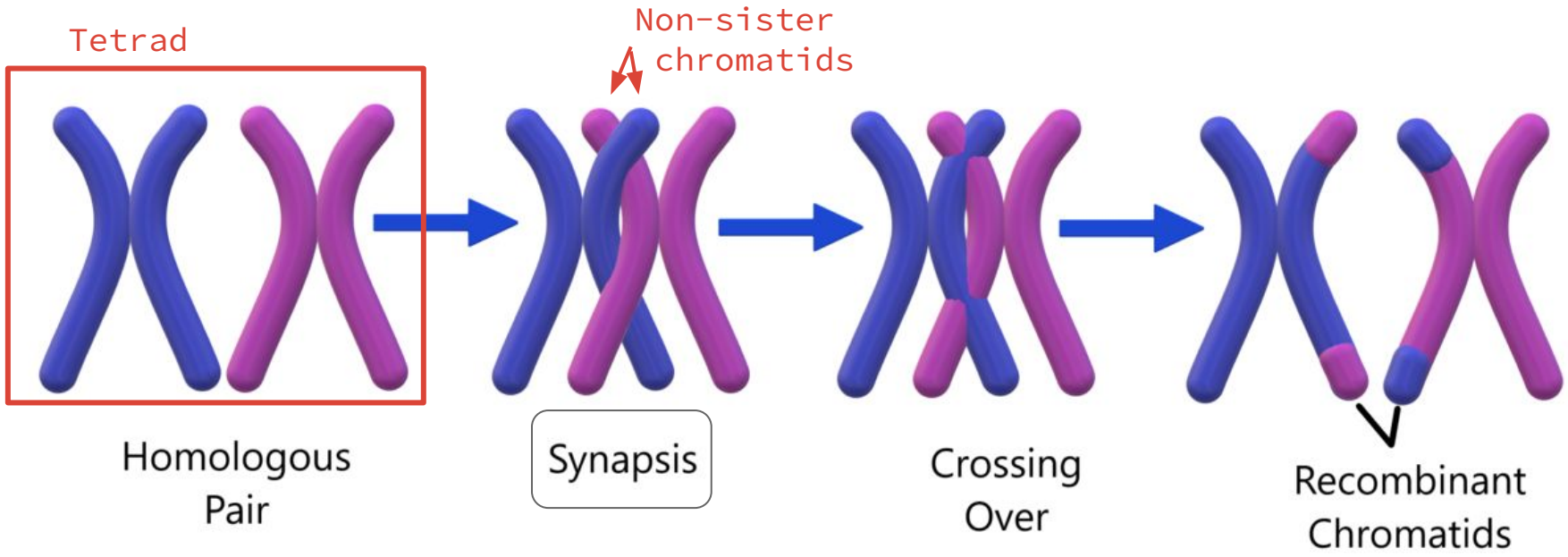




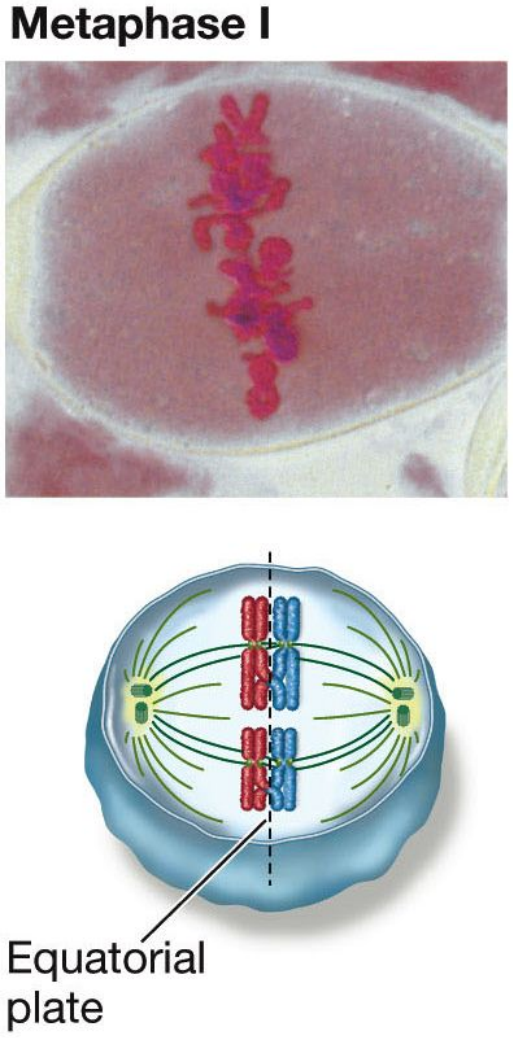
*** Note chromosomes have already duplicated creating sister chromatids*

Prophase 1

- Chromosomes condense
- Chromosomes come together in forming homologous pairs (tetrad)
- Crossing over occurs (synapsis)



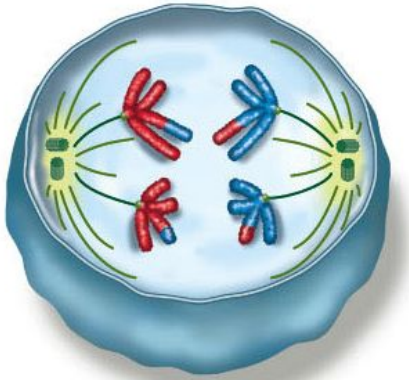
During **synapsis**, **crossing over** occurs between **non-sister** chromatids - they exchange segments.
This results in **variation**!



Metaphase 1

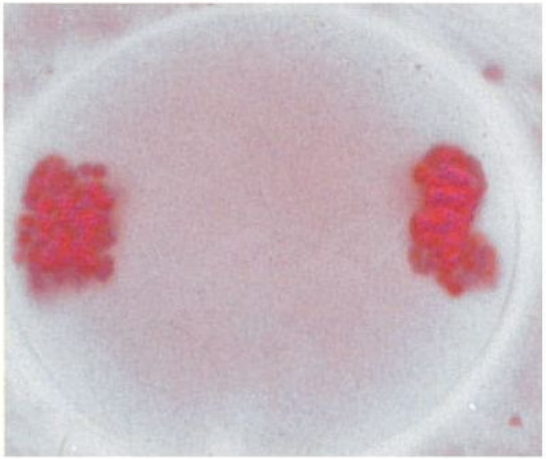
- Homologous pairs (tetrads)line up at equatorial plate

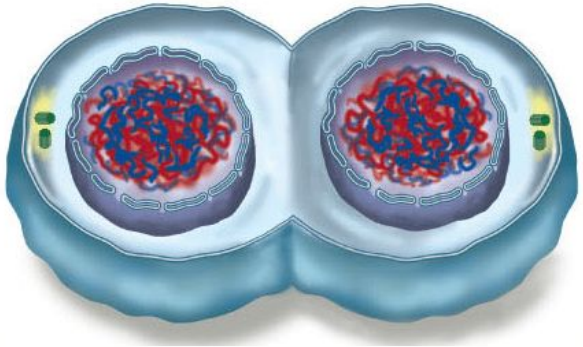
Anaphase I



Anaphase 1

- Homologous pairs separate
- Move to opposite ends of cell



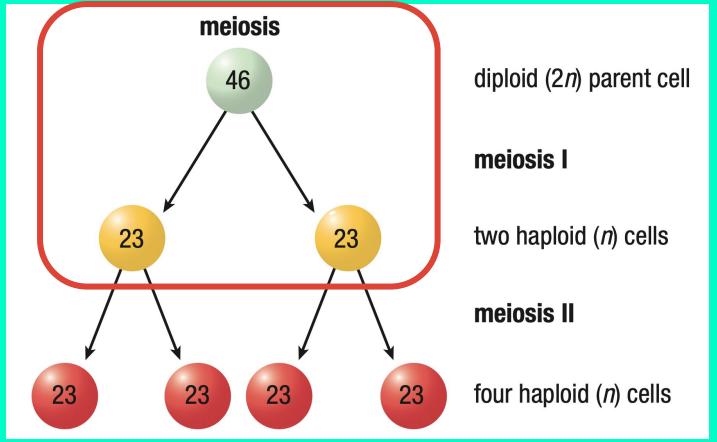


Telophase 1

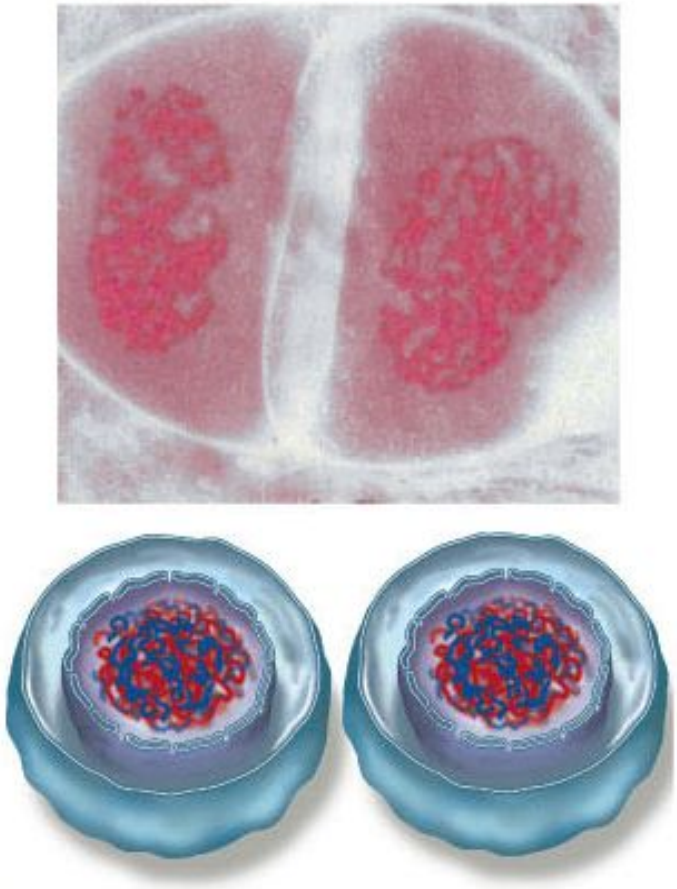
- Nucleus completes division
- Nuclear membrane reforms
- Cleavage furrow

End of Meiosis 1

Two haploid daughter cells are formed.



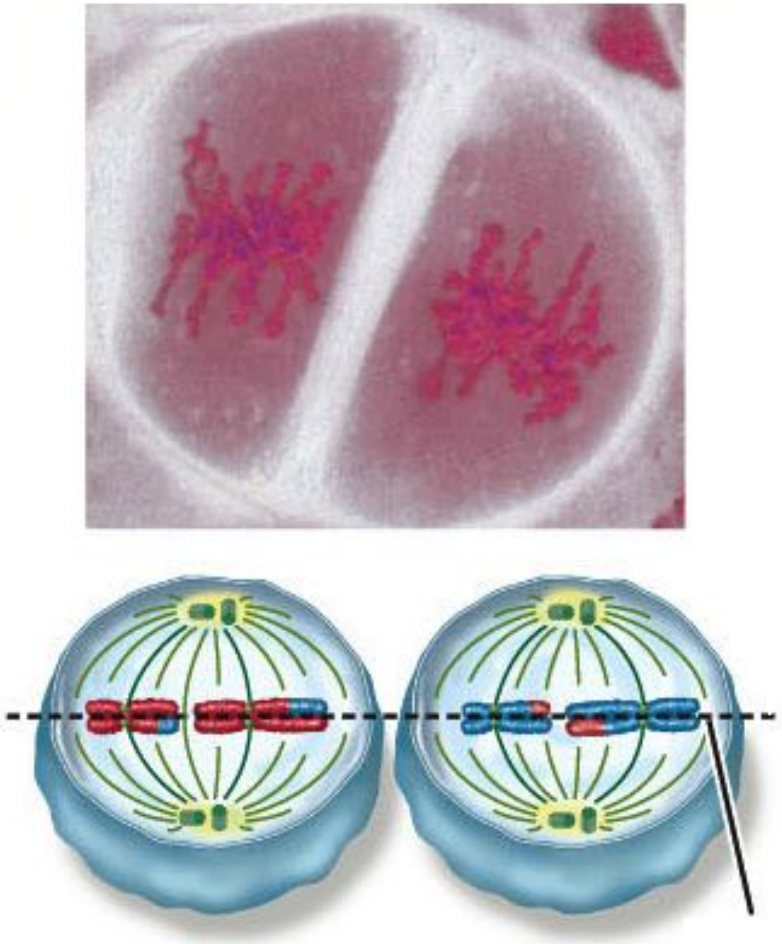
Note: Meiosis 1 is where the reduction division occurs (2n → n)



Note: crossing over does not occur during prophase of meiosis 2

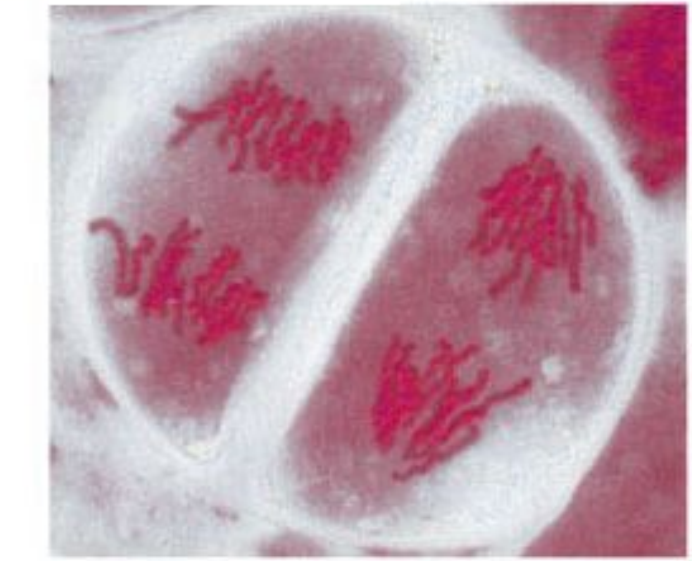
Prophase 2

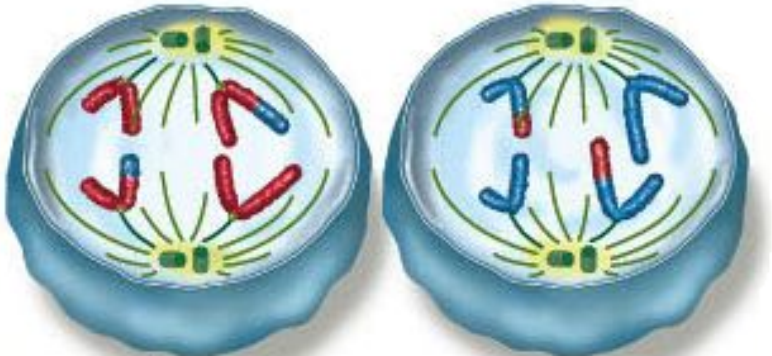
- New spindle fibers form
- Chromosomes condense
- Nuclear membrane disintegrates



Metaphase 2

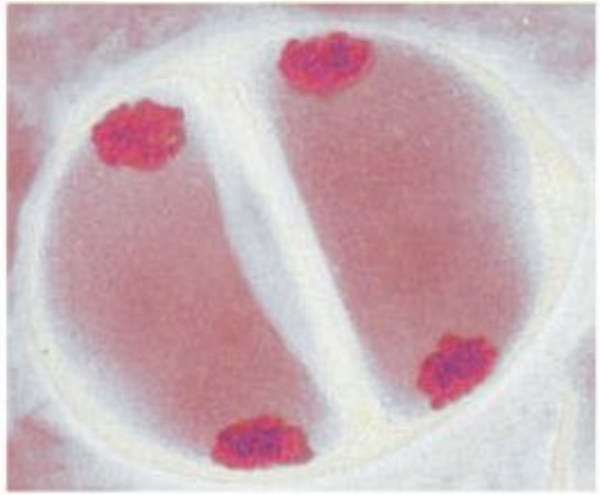
- Chromosomes (made up of two sister chromatids) line up at the equatorial plate

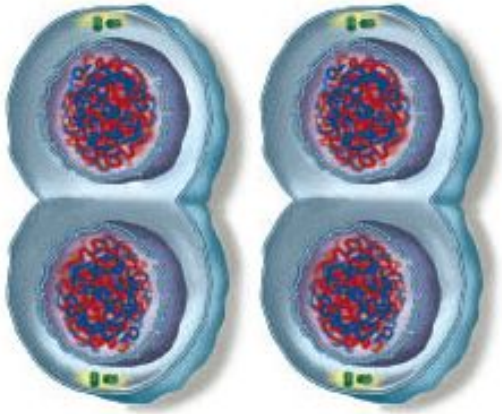




Anaphase 2

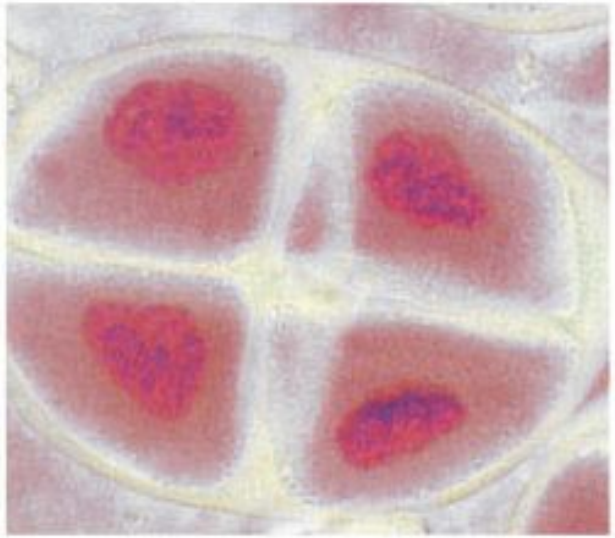
- Chromatids separate
- Move to opposite poles

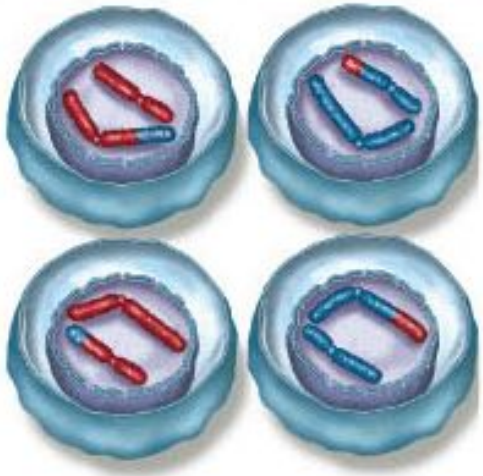




Telophase 2

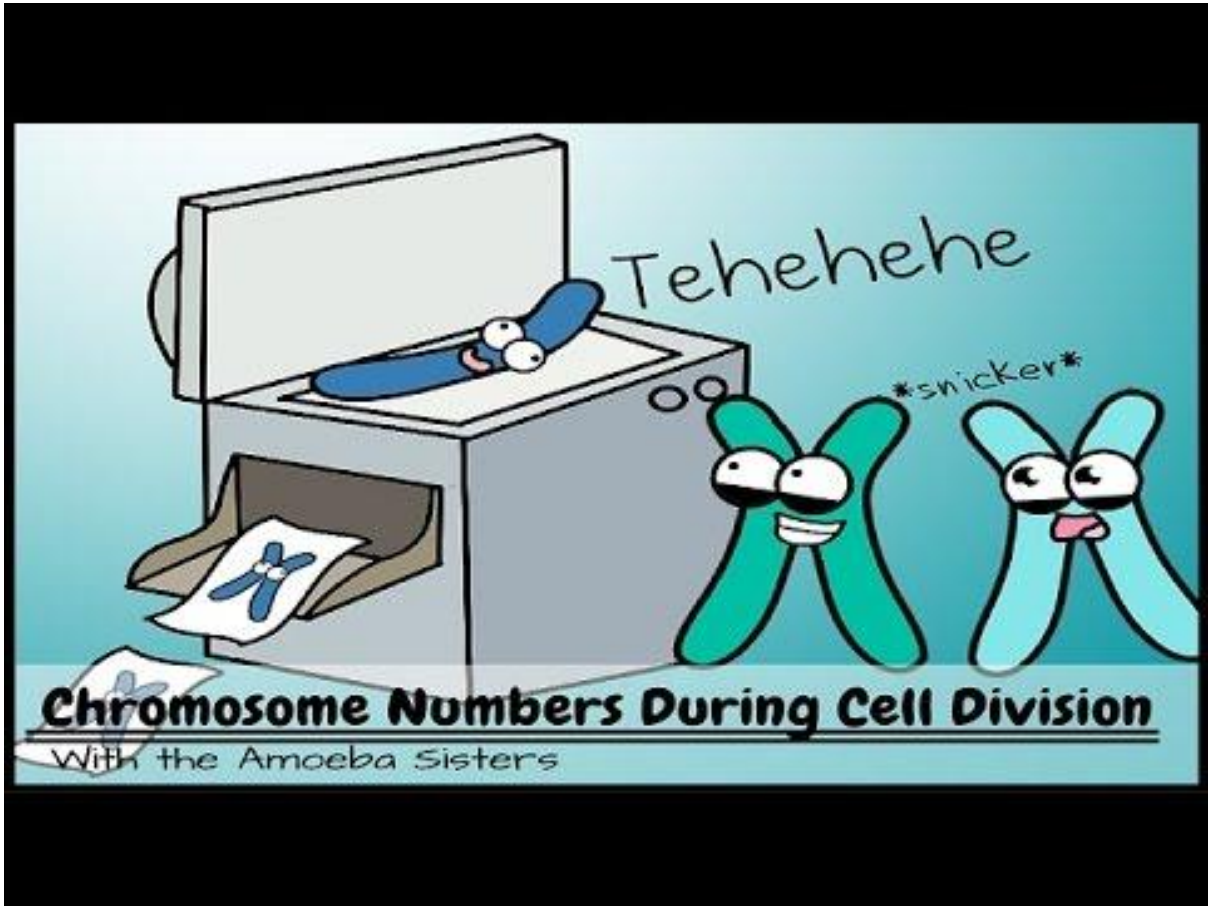
- Cytoplasm separates

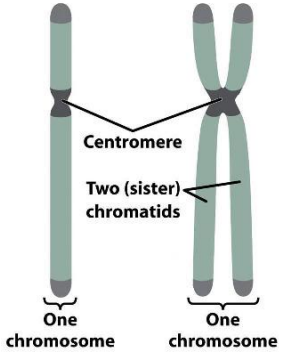




Product

- Result is 4 haploid cells
  - half the number of chromosomes as parent cell


Tehehehe
snicker
Chromosome Numbers During Cell Division
With the Amoeba Sisters



Phase (Mitosis)	# Chromosomes	# Chromatids
Prophase	46	92
Metaphase	46	92
Anaphase	92	92
Telophase	92	92
End of Mitosis (separated cells)	46	46

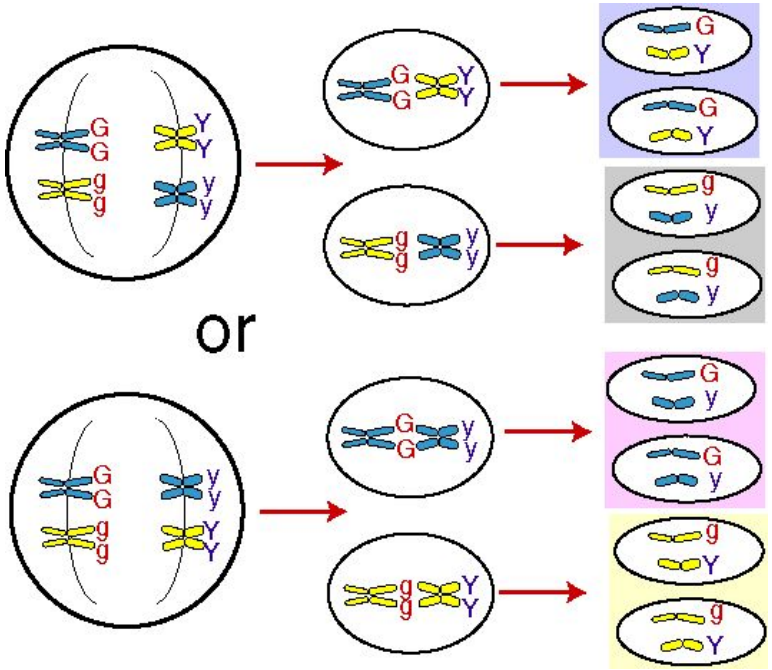
Phase (Meiosis I)	# Chromosomes	# Chromatids
Prophase I	46	92
Metaphase I	46	92
Anaphase I	46	92
Telophase I	46	92
End of Meiosis I (separated cells)	23	46

Phase (Meiosis II)	# Chromosomes	# Chromatids
Prophase II	23	46
Metaphase II	23	46
Anaphase II	46	46
Telophase II	46	46
End of Meiosis II (separated cells)	23	23

Random Assortment of Homologous Chromosomes

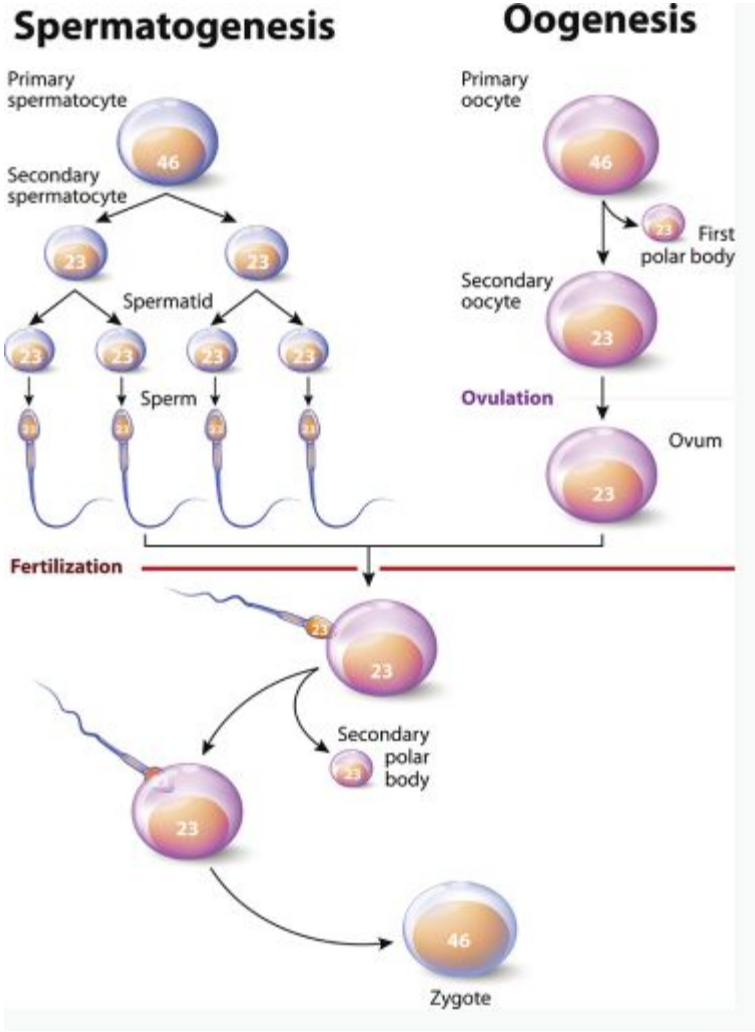
Random Assortment (metaphase 1)

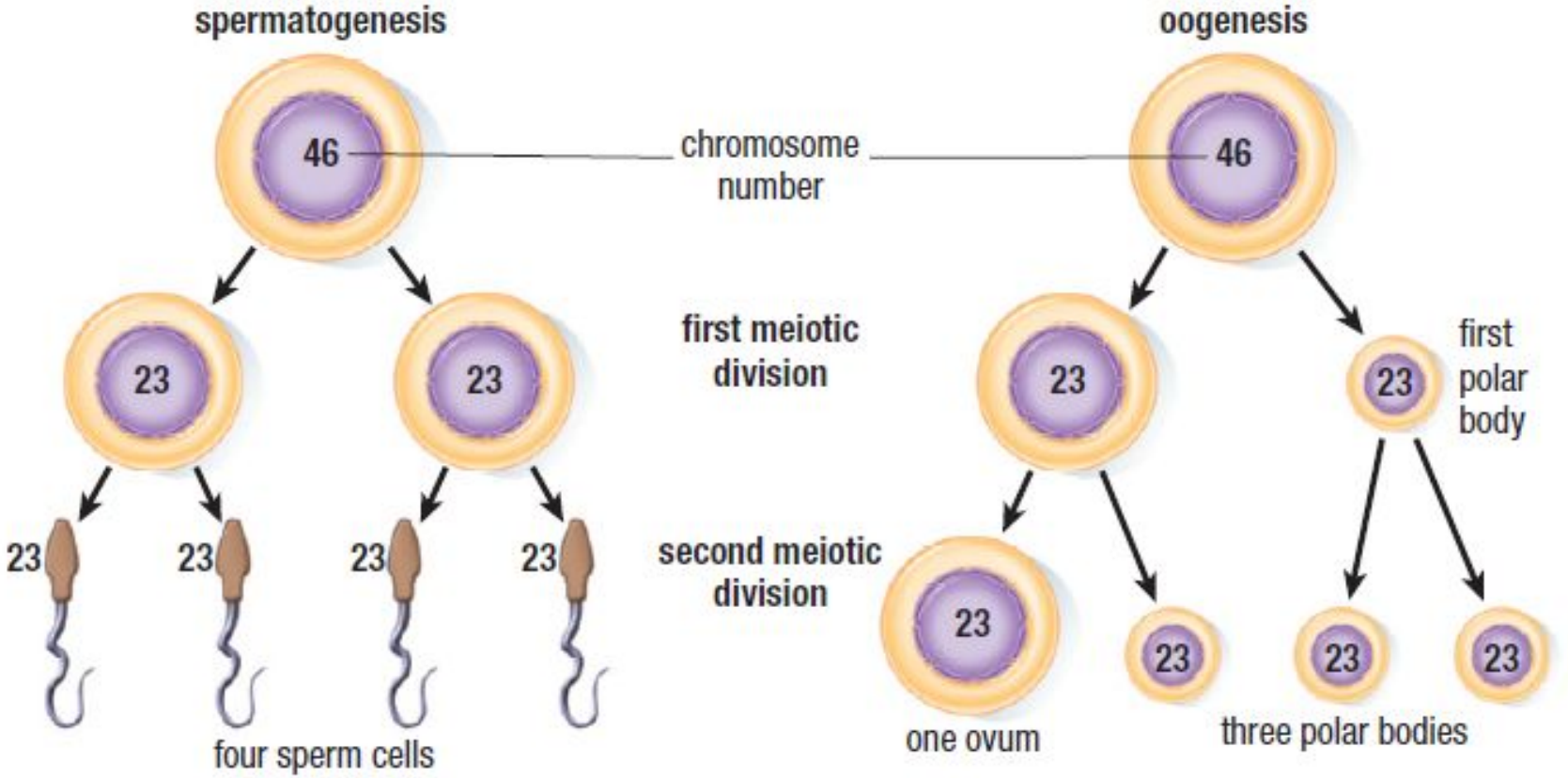
- Random line up of homologous chromosome pairs at the cell's equator helps to ensure **variation.**
- The number of possible combinations of chromosomes depends on the # of chromosome pairs. For diploid (2n) organisms the number of possible combinations is 2^n
- For humans, the number of possible combinations is 2^{23} = 8 388 608!



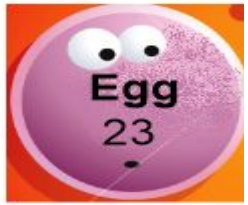
Gametogenesis (Meiosis)

- **Gametogenesis:** the production of gametes (sex cells) in animals
- **Spermatogenesis:** production of mature sperm cells
- **Oogenesis:** the production of mature egg cells
- In oogenesis, cytoplasm **does not** divide evenly
  - Cells that do not receive enough cytoplasm are called polar bodies
  - One cell (ovum) is produced

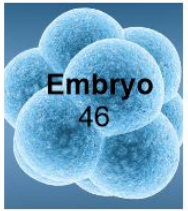



spermatogenesis
oogenesis
46
chromosome number
46
first meiotic division
23
23
23
first polar body
second meiotic division
23
23
23
23
23
23
23
23
23
four sperm cells
one ovum
three polar bodies

The Haploid-Diploid Cycle of Sexual Reproduction in Humans



Zygote
46



Skin 46

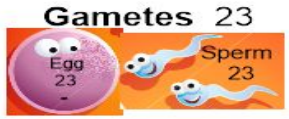
Muscle 46

Heart 46

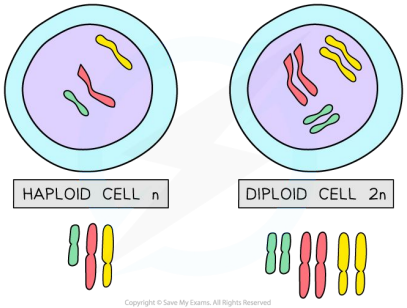
Germinal Cells 46
(Oocytes,
Spermatocytes)

MITOSIS

MEIOSIS



Types of Cells



Somatic Cells

- Human somatic cells have 46 chromosomes (23 pairs) - said to be **diploid**
- The **n** value of a cell tells you how many **PAIRS** of chromosomes that cell has. **2n** = how many chromosomes there are total. So for humans, 2n for our somatic cells = 46
- Most reproduce by mitosis.

Gametes

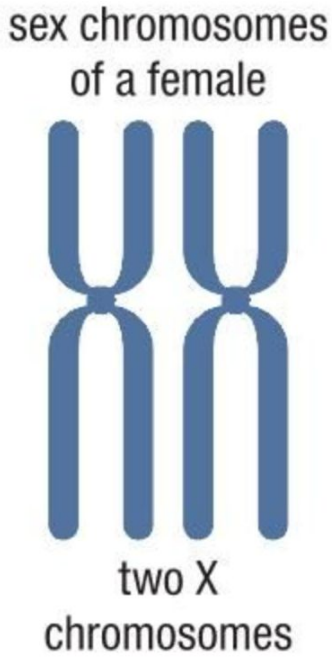
- Human gametes have 23 chromosomes - said to be **haploid**
- n= the haploid number of chromosomes in a species; for humans, n=23
- Must be made by special cells in the ovaries/testes by a process called **meiosis.**

Sex chromosomes

In females, sex chromosomes consist of a matching pair of homologous chromosomes (XX)

In males, sex chromosomes consist of a partially matching pair (XY)

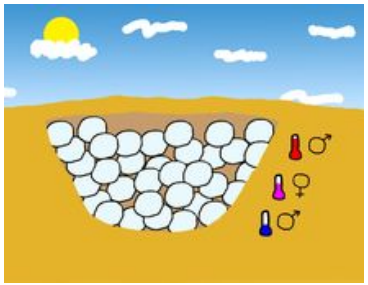
- One is much smaller than the other
- The larger of the two is a homologue to the sex chromosome in the female (X)



Sex Determination Methods

Some species have different systems to determine sex (other than the XX/XY system)of offspring:

- Some reptiles - sex of offspring is temperature dependent
- Some fish are born female then become male or vice-versa



Other Sex-Determination Methods

You do not need to memorize this!

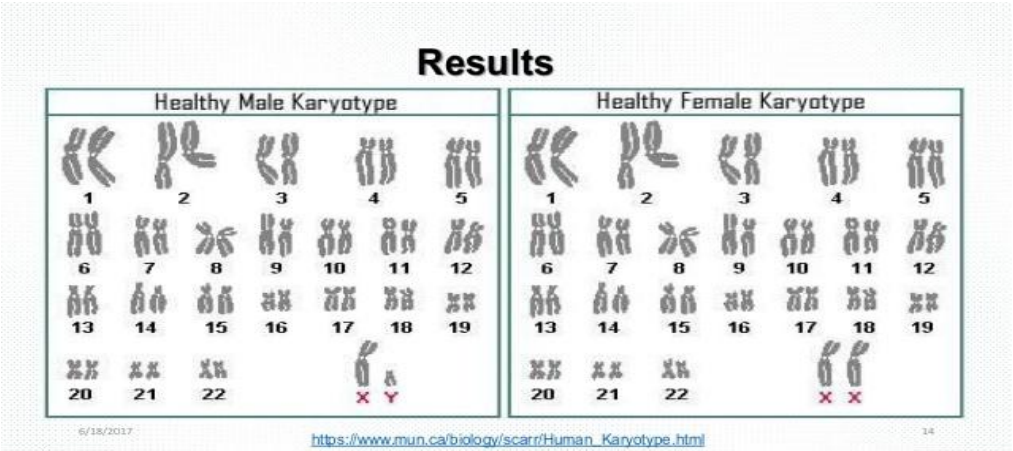
Table 2 Common Sex-Determination Mechanisms in the Animal Kingdom

Sex determination	Examples	Description
XX/XY	mammals, some insects	XX females, XY males
ZW/ZZ	birds	ZW females, ZZ males
temperature	turtles, crocodiles	If the eggs are kept relatively warm, most or all eggs hatch as females. If the eggs are kept relatively cool, most or all eggs hatch as males.
age	some fish, some mollusks	All young are born male. As they become older and larger, they change into females.
social structure	some fish	All young fish are females. When the dominant male fish dies, a large female changes into a male.
fertilization—haploid/diploid	bees, ants, wasps	Fertilized eggs ($2n$) become females. Unfertilized eggs (n) become males.
infection	some insects	Variable. In one form, infected individuals develop into females.
none	earthworms and other hermaphroditic organisms	All individuals have both male and female reproductive organs.

Karyotype

A karyotype is a picture of an individual's chromosomes that have been sorted and arranged according to size and type

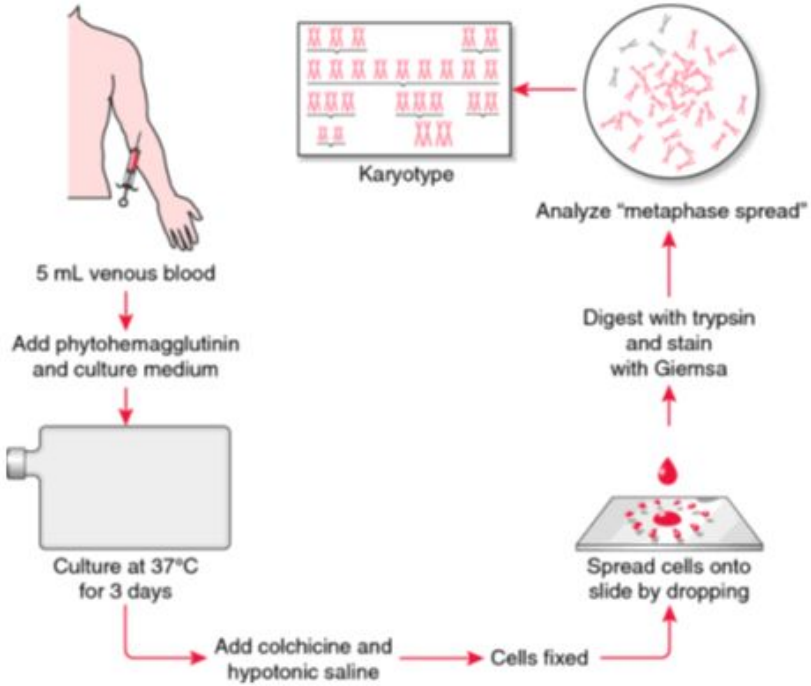
- Note there are 1 pair of **sex chromosomes**, the other 22 pairs are **autosomal chromosomes**.



Karyotypes can be used to look for abnormal numbers or structures of chromosomes.

How are karyotypes Made?

1. Technicians remove a small sample of tissue (i.e. blood or amniotic fluid)
2. Mix it with a solution that stimulates mitosis
3. **Colchicine** is added to stop the cells in **metaphase** and the sample is placed on a slide
4. A stain is added to make light and dark bands appear on the chromosomes and a photograph is taken
5. The chromosomes are cut out and arranged in homologous pairs



4.3 Textbook Review

4.3 Summary

- Sexual reproduction produces genetically variable offspring by combining the genetic information from two parents.
- During meiosis I, chromosomes exchange genetic information, known as crossing over, during prophase I.
- Homologous chromosomes are assorted independently of other pairs.
- The formation of genetically variable sex cells in meiosis II is called gametogenesis.
- There are many different sex-determination systems in living things.
- Mammals have X and Y sex chromosomes and use an XX/XY system for female/male sex determination.

Homework:
Pg. 160 #3-9, 11