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Eukaryotic Cellular Reproduction: Mitosis & Meiosis

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Vocabulary

Click on each word below to go to the definition.

allele
anaphase (I) (II)
aneuploidy
autosome
benign
bone marrow transplant
cancer
carcinoma
cell cycle
cell plate
centromere
centrosome
chemotherapy
chiasma
cleavage furrow
contact inhibition
contractile ring
crossing over
cytokinesis
diploid
gamete
gap 1 (G_1)
gap 2 (G_2)
G_0 phase
haploid
homologous chromosomes
independent assortment
interkinesis
interphase
karyotype

Vocabulary

Click on each word below to go to the definition.

kinetochore
leukemia
lymphoma
malignant
meiosis (I) (II)
metaphase (I) (II)
metastasize
mitosis
mitotic phase (M phase)
monosomy
multiple myeloma
nondisjunction
polyploidy
prometaphase
prophase (I) (II)
radiation
sarcoma
sex chromosome
sister chromatid
spindle
somatic cell
stem cell transplant
synthesis (S phase)
telophase (I) (II)
tetrad
trisomy
tumor

Eukaryotic Cellular Reproduction Unit Topics

Click on the topic to go to that section

Mitosis

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The big idea...

Mitosis is a type of cellular reproduction where a cell will produce an identical copy of itself with the same number and patterns of genes and chromosomes.

Meiosis, on the other hand, is a special process used to make **gametes** (sex cells like sperm and eggs). These cells have half the number of chromosomes of the original cell, and each is unique.

Why Undergo Mitosis?

Cells undergo mitosis for a number of reasons.

Organisms use mitosis to:

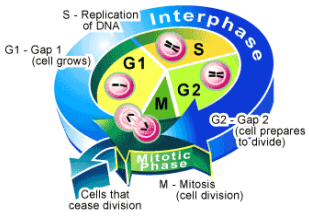
- repair damage (as in scars)
- regenerate lost parts (as in the lizard who loses its tail)
- grow in size
- reproduce asexually

Eukaryotic Cell Cycle

The eukaryotic cell cycle has two major divisions: **Interphase** and the **Mitotic phase**.

During interphase the cell metabolic activity is very high. It is busy growing and copying it DNA and organelles so it can divide.

The mitotic phase is the actual dividing of the cell. It involves a series of steps (or subphases).



1Which one of the following is NOT a function of mitosis?

- A growth
- B generation of lost parts
- C asexual reproduction
- D tissue repair
- E all are correct

2Which of the following occurs during interphase?

- A division of the cell
- B cell growth and duplication of the chromosomes
- C reduction in size of cell membrane
- D reduction in number of organelles

Interphase

Most cells spend more than 90% of the total time of the cycle is spent in interphase.

There are 3 distinct sub-phases to interphase:

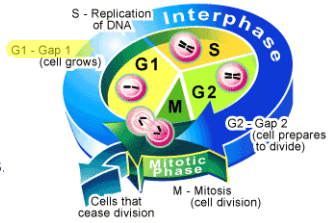
- Gap 1 (G_1)
- Synthesis (S Phase)
- Gap 2 (G_2)

Gap 1 (G_1 phase)

The cell increases in size.

The cell increases its supply of proteins, particularly those used in the duplication process.

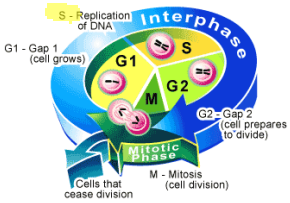
Duplication of organelles occurs.

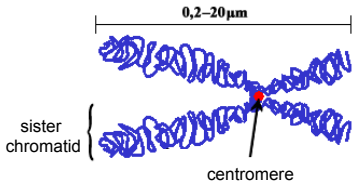


Synthesis (S-phase)

DNA replication occurs.

At the end of this sub-phase, each chromosome in the cell has doubled. The two copies of a chromosome remain attached at a central point called a **centromere**. Each copy is then know as a **sister chromatid.**

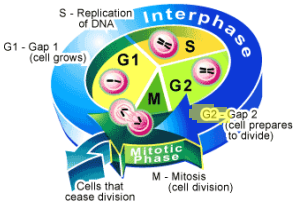




Gap 2 (G_2 phase)

The cell completes its growth in preparation for division.

Increases its supply with even more proteins.



3 Thinking back to prokaryotes, eukaryotic chromosomes differ from prokaryotic chromosomes in that they:

- A are circular in structure
- B are simpler
- C are housed in a membrane-enclosed nucleus
- D are copied after cell division

4 Eukaryotic cells spend most of their time in the cell cycle in which phase?

- A interphase
- B metaphase
- C anaphase
- D telophase

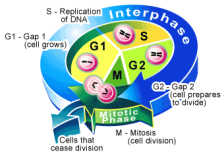
5 If the synthesis phase was eliminated from the cell cycle, the daughter cells would

- A have half the genetic material found in the parental cell
- B be genetically identical
- C synthesize the missing genetic material on their own
- D none of these answers are correct

Mitotic Phase

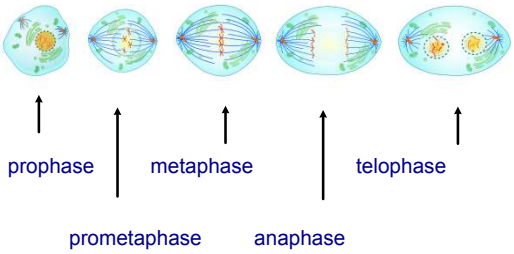
After a cell completes its preparation for division, it enters the mitotic phase.

There are 2 sub-phases to this phase - **Mitosis** (the division of the nucleus) and **Cytokinesis** (the division of the cytoplasm).



Sub-phases of Mitosis

Mitosis is further broken down into 5 sub-phases.



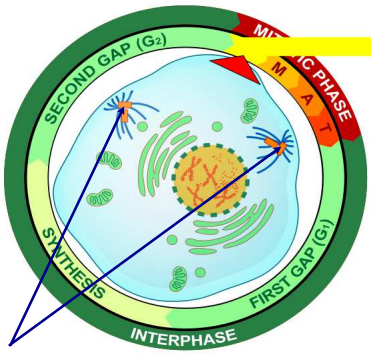
prophase

prometaphase

metaphase

anaphase

telophase



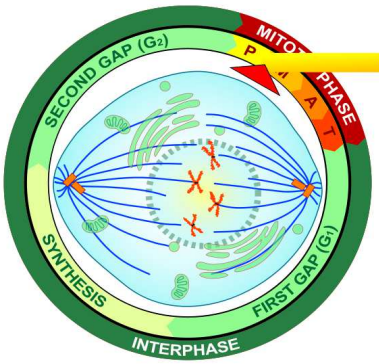
centrosomes

Prophase

· Arrays of microtubles called **spindles** start to form from 2 **centrosomes** (microtubule organizing centers in the cell)

· Centrosomes start to travel to the opposite ends (poles) of the cell

· Nuclear envelope starts to break apart



Prometaphase

· Nucleoli and nuclear membrane disappear

· Spindle is nearly completed and ready to provide a scaffold for chromosomes to travel

· Chromosomes attach to the spindle at their **kinetochores** - a protein structure at the centromere region of the sister chromatids

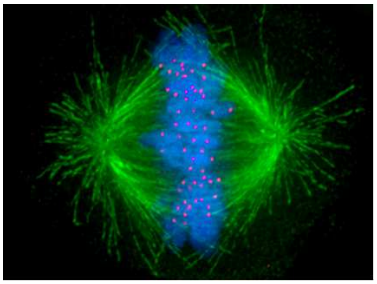
Centrosomes vs. Kinetochores

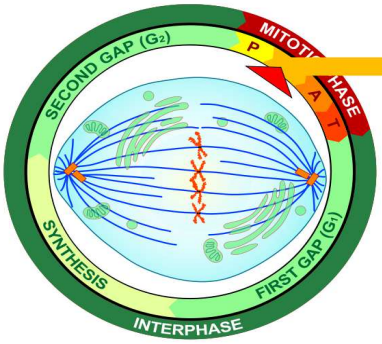
Image of a human cell during division showing:

spindles from the centrosome in **green**

chromosomes in **blue**

kinetochores in **pink**





Metaphase

· Spindle is completely formed

· Chromosomes align on the Metaphase plate (the equator of the cell)

6 The phase of mitosis during which the nuclear envelope breaks apart is called

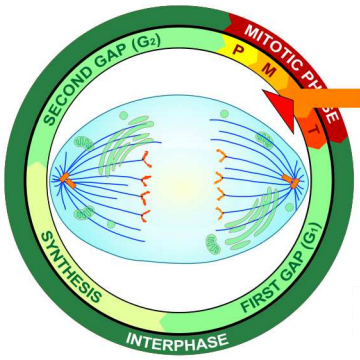
- A interphase
- B prophase
- C metaphase
- D anaphase

7 Which of the following pairs is correct?

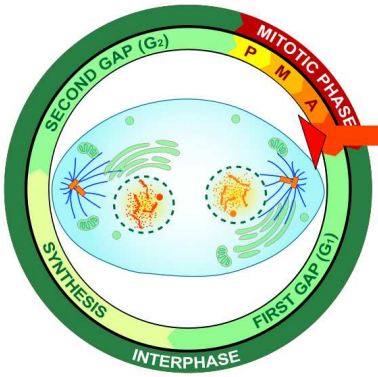
- A kinetochore:makes spindle; centromere:holds chromatids together
- B kinetochore:attaches to spindle; centrosome:holds chromatids together
- C centrosome:makes spindle; centromere:holds chromatids together
- D centrosome:holds chromatids together; kinetochore:attaches to spindle

8 During which phase do chromosomes line up on a plane located along the equator of the cell?

- A interphase
- B prophase
- C metaphase
- D anaphase



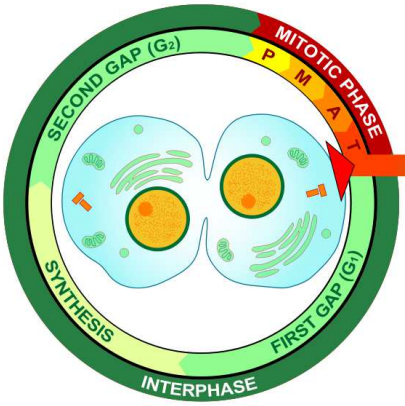
· Sister chromatids separate from each other at the centromere and are pulled to the 2 poles by the spindle fibers



· Cell elongation continues

· Nuclear envelope reappears around the chromosomes

· Nucleoli reappear



· Following telophase, the cytoplasm divides.

· Cytokinesis differs for plant and animal cells

9 During which phase does the nuclear envelope re-form?

- A interphase
- B metaphase
- C anaphase
- D telophase

10 The process by which the cytoplasm of a eukaryotic cell divides is called

- A mitosis
- B cytokinesis
- C teloplase
- D spindle formation

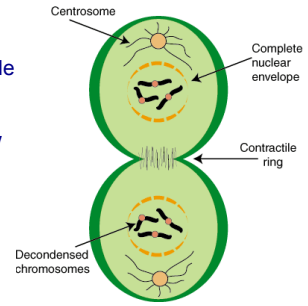
11 Which of these is not like the others?

- A Cytokinesis
- B Telophase
- C Anaphase
- D Metaphase
- E Prometaphase
- F Prophase

Cytokinesis - Animal Cells

A ring of microfilaments forms a **contractile ring** around the outside of the cell.

The ring forms a **cleavage furrow** which splits the cytoplasm in two.

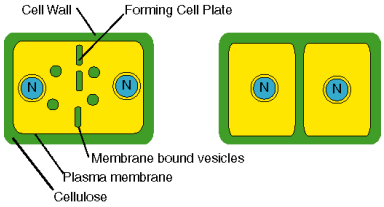


Cytokinesis - Plant Cells

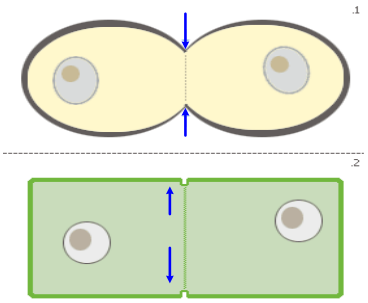
Vesicles containing cell wall material collect in the center of the cell and then fuse together.

The **cell plate** forms from the inside out and turns into a wall between the 2 new cells.

The membranes surrounding the vesicles fuse to form new parts of the plasma membrane.



Comparison of Cytokinesis



animal cell

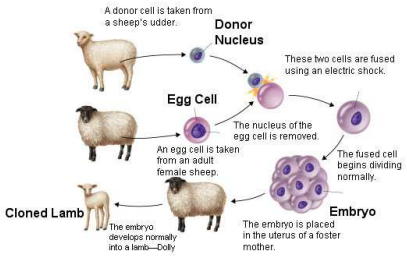
plant cell

12Cytokinesis in a plant cell is a result of the cell:

- A spontaneously dividing
- B forming a cleavage furrow in the middle
- C splitting from the outside in
- D a cell wall being created

Biotech: Nuclear Transfer Cloning

Cloning is the process by which the nucleus of a gamete is replaced with the nucleus of a somatic (body) cell, and the embryo develops through normal mitotic divisions.



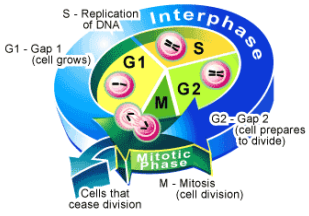
In sexually reproducing species, this process allows for the production of offspring which are genetically identical to the parent.

Click here to watch a video showing somatic cell nuclear transfer.

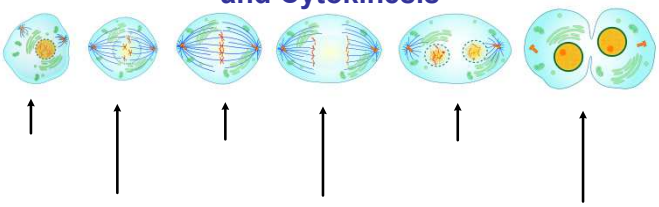
Summary of Phases of the Cell Cycle

Interphase
- Gap 1 (G_1)
- Synthesis (S Phase)
- Gap 2 (G_2)

Mitotic Phase (M phase)
- Mitosis
  - Prophase
  - Prometaphase
  - Metaphase
  - Anaphase
  - Telophase
- Cytokinesis



Review: Label The Sub-Phases of Mitosis and Cytokinesis



Anaphase Metaphase Cytokinesis
Prophase Telophase Prometaphase

Cell Cycle Control System

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Cell Cycle Control System

Three major checkpoints exist to regulate the cycle: at Gap1, Gap 2, and before Mitosis.

At each point, a signal that says "ok, you can proceed" is released.

If no signal is released, the whole cycle stops - this prevents problems in reproduction of the cell

13 Mature human nerve cells

- A remain undifferentiated unless injury occurs
- B divide more easily than other cells
- C are permanently in a state of nondivision
- D cease dividing after a number of cell generations

14 Cells can reproduce only if they receive the appropriate chemical signal at:

- A Gap 1
- B Gap 2
- C Before Mitosis
- D All of the above

Cancer

Cancer is a general term for many diseases in multi-cellular organisms which is caused by uncontrolled cell division. Cancer cells and normal cells are identical, with the exception that cancer cells divide uncontrollably.

Cancer cells are non-responsive to the cell cycle control system.

Cancer cells divide unchecked and can **metastasize** (spread) to other sites in the body.

Contact Inhibition

Cells typically will only grow and reproduce until they touch each other and then the cell cycle control system will stop signaling the cell to proceed. This is called **contact inhibition.**

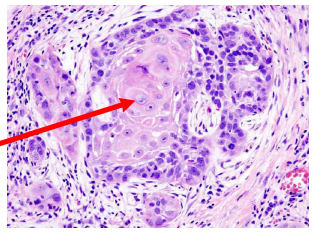
Cancer cells do not exhibit contact inhibition, instead they grow into masses called **tumors**. Some cancer cells continually synthesize factors which keep them dividing.

Video on contact inhibition

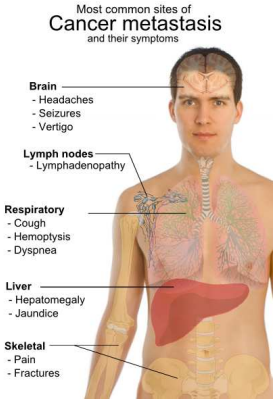
Cancerous Tumors

Tumors that cause damage to surrounding tissues are called **malignant** tumors. They are also said to **metastasize**, systemically spread the cancer to other areas of the body.

Tumors that are not life threatening or otherwise damaging are called **benign** tumors.



oral carcinoma cells



Typically when someone dies from cancer, it is not the result of the primary tumor, but instead the metastases kill them.

15 A benign tumor differs from a malignant tumor in that it

- A is cancerous
- B does not metastasize
- C spreads from its original place
- D never causes health problems

16 Which of the following cell types most likely spends less than 90% of its time in interphase?

- A nerve cell
- B muscle cell
- C cancer cell
- D blood cell

17 Lack of contact inhibition can lead to tumors.

- ❍ True
- ❍ False

General Types of Cancers

Carcinomas: epithelial tissue cancers

Sarcomas: connective tissue cancers

Leukemias, Lymphomas, Multiple Myeloma: cancers of blood-forming tissues

One Specific Cancer: Melanoma

ABCDE method for recognizing a potential melanoma (the most dangerous skin cancer)

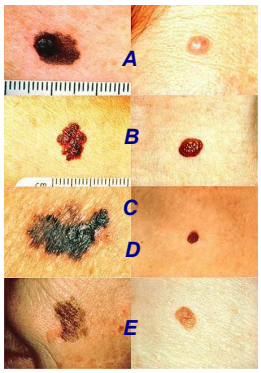
Asymmetrical skin lesion.

Border of the lesion is irregular.

Color: melanomas usually have multiple colors.

Diameter: moles greater than a pencil eraser

Enlarging



Treatment of Cancers

Chemotherapy and **Radiation** are the two most prescribed treatments for cancers.

Chemotherapy and Radiation

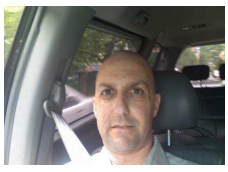
Chemotherapy disrupts the cell cycle, typically targeting the mitotic spindle formation. Chemotherapy is typically systemic, affecting the whole body.

Radiation is location specific - directed at the area affected by the tumor. It d isrupts the cell cycle by damaging the DNA in the area, and the cancer cells cannot repair themselves and continue dividing when that happens.

Side Effects of Cancer Treatment

The typical side effects from chemotherapy are from the damage also occurring to the normal cells which are affected by the chemicals.

This is seen easily in the fast-reproducing cells, like hair follicles, causing hair to fall out and of the digestive tract, causing nausea.



18 Which of the following is true about radiation treatment for cancer?

- A It is systemic, affecting the whole body
- B It damages the cells' DNA, disrupting its ability to divide
- C It disrupts the cell cycle by targeting the formation of mitotic spindles
- D It involves a surgical procedure

19 When receiving chemotherapy treatment, the patient's hair typically falls out because:

- A the hair follicles are producing cancerous cells
- B the chemicals injected during treatment attack the disulfide bonds common in hair cells
- C the chemicals injected during treatment affect the fastest growing cells
- D the chemicals are injected near the hairline, reaching these cells before others

Bone Marrow Transplants

Most blood cancers are also treated with bone marrow transplants. This involves a surgical procedure where bone marrow is removed usually from the pelvic bone and transplanted into the cancer patient. A patient may serve as his/her own donor in some cases.

This treatment is used for blood cancers because bone marrow produces **stem cells,** unspecialized cells that can divide through mitosis and differentiate into diverse specialized cell types. These cells can produce new, non-cancerous blood cells.

Stem Cells

In mammals, there are two types of stem cells.

Type of Stem Cell	Definition	Potency
Embryonic	Found in the blastocysts of developing embryos, embryonic stem cells can differentiate into any type of cell.	**Pluripotent** – Can differentiate into any cell type present in the organism
Adult	Adult stem cells act as a repair system by maintaining the turnover of regenerative organs, such as blood, skin or intestinal tissue.	**Multipotent** – Can differentiate into some, but not all, cell types present in the adult organism

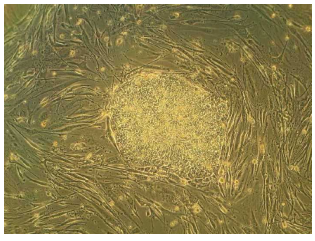
Stem Cell Technology

In addition to cancer treatment, scientists are developing methods for using stem cells to treat other ailments.

A trachea (windpipe) that was "grown" from harvested adult stem cells. It was used to replace a woman's damaged windpipe. Because the stem cells were her own, there was no chance for rejection by her immune system.

Embryonic Stem Cell Technology

Presently, embryonic stem cells have been used primarily for research. Potential for technologies exist, but currently no product has been produced.



Promising research using embryonic stem cells:

- Tissue engineering for organ transplants
- In vitro models to test drug response and predict toxicity
- Creation of neurons for the treatment of Parkinson's disease
- Alternative treatment for diabetes

20 Which of the following is pluripotent?

- A embryonic stem cells
- B adult stem cells

21 Which of the following is found in a blastocyst?

- A embryonic stem cells
- B adult stem cells

Meiosis

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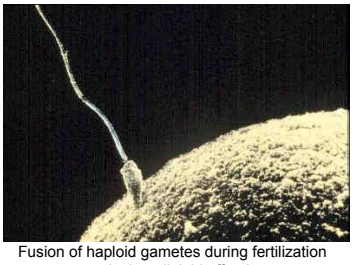
Gametes

The sex cells of organisms are called **gametes.** Eggs in females, sperm in males. In many eukaryotic organisms, the **somatic cells** (those that are not sex cells) have two sets of chromosomes (**diploid**).



Fusion of haploid gametes during fertilization results in a diploid offspring.

Gametes have one set of chromosomes (**haploid**) and they are produced by **meiosis**.

Sexual life cycles alternate between haploid and diploid phases.

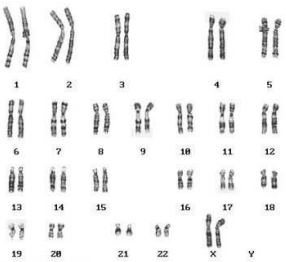
Homologous Chromosomes

The pairs of matching chromosomes in the somatic cells of diploid organisms are called **homologous chromosomes**. In humans, each somatic cell contains 46 chromosomes, which make up 23 homologous pairs.

Homologous chromosomes share shape and genetic loci, each pair controlling the same inherited characteristics. Each pair is inherited from the parents, one from mother, one from father (the sets are combined in the first cell following fertilization and then passed down by mitosis)

Karyotype

A **Karyotype** is a photographic inventory of chromosomes - the chromosomes are digitally separated and ordered.



A karyotype of a human female, showing 23 sets of homologous chromosomes

Alleles

Homologous chromosomes can carry different versions of the same gene. These "versions" are called **alleles**

2 examples: coat color and eye color in mice

Coat Color: Brown and White are different versions of the same gene for coat color.

Eye Color: Black eyes and Pink eyes are different alleles of the gene coding for eye color.

22 Two chromosomes in a nucleus that carry loci for the same traits in the same positions on the chromosome but can specify different versions of the same traits constitute a pair of:

- A homologous chromosomes
- B complimentary chromosomes
- C heterozygous chromosomes
- D none of these are correct

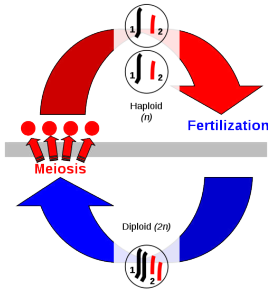
23 A karyotype is analogous to which of the following examples?

- A a map of hidden treasure
- B a movie showing the reproductive cycle of a beetle
- C a photograph of every couple at the prom
- D the answer key for a test

Meiosis

Meiosis reduces chromosome numbers in diploid organisms to create sex cells.

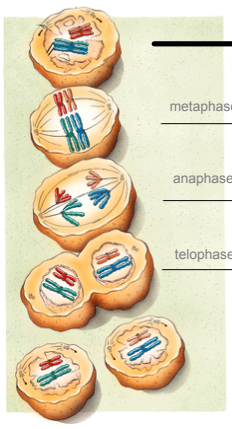
Like mitosis, meiosis is begun by a single duplication of chromosomes.Unlike mitosis, the overall result of meiosis is 4 daughter cells, each with half the number of chromosomes (haploid).



The Two Divisions of Meiosis

The process involves 2 consecutive divisions, simply called **Meiosis I** and **Meiosis II**.

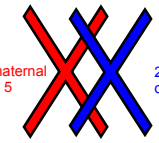
Halving the actual chromosome number occurs in Meiosis I. Then, the sister chromatids separate in Meiosis II, resulting in 4 cells.



prophase I

The nuclear envelope disappears and the spindle begins to form.

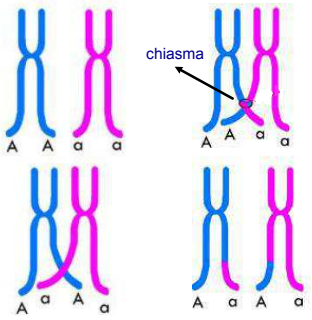
Homologous chromosomes (replicated during interphase) pair to form a **tetrad.**



2 copies of maternal chromosome 5

2 copies of paternal chromosome 5

Crossing Over

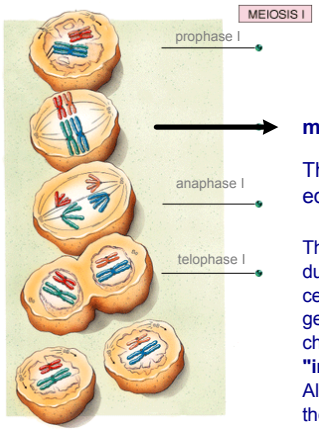


Crossing over occurs during prophase I. This is a genetic rearrangement between 2 homologous chromosomes that happens at a site called a **chiasma.**

Crossing over increase the genetic variation of the offspring. Since this can occur several times at variable location in each tetrad, the variation which can occur between 2 parents is extremely large.

This is one of the reasons that, with the exception of identical twins, everyone is a unique genetic entity.

Video on crossing over



Video on independent assortment

metaphase I

The tetrads line up at the equator of the cell.

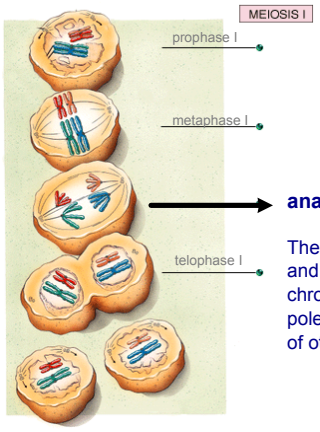
The way chromosomes line up during metaphase I gives each cell a unique combination of genes from each parent's chromosomes (an **"independent assortment"**). Along with crossing over, these methods account for most of the genetic variation in populations.

Independent Assortment

Given *n* pairs of chromosomes, there are 2^n ways in which chromosomes can line up during metaphase I.

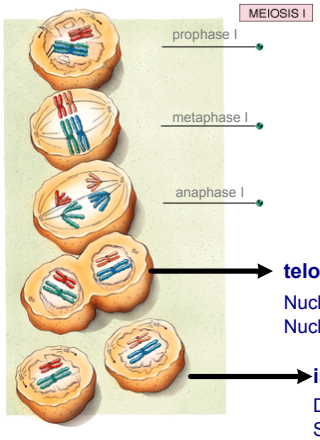
In humans there are 2^{23} *(8 million)* ways of combining homologues.

This means combining human gametes can produce 64 trillion combinations in the zygote!



anaphase I

The tetrad splits, maternally and paternally inherited chromosomes moving to one pole or the other, independent of other chromosomes.

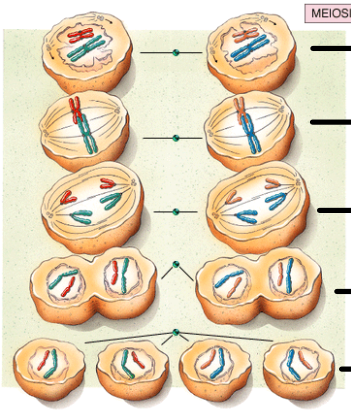


telophase I

Nuclear envelope reforms. Nucleus is now haploid.

interkinesis

Division of the cytoplasm. Similar to cytokinesis. The cells are now haploid.



prophase II: nuclear envelope disappears; spindle forms

metaphase II:chromosomes with 2 sister chromatids line up at the equator

anaphase II: chromosomes split apart, one chromatid moving to each pole

telophase II: nuclear envelope reappears

cytokinesis: cytoplasm divides

4 haploid daughter cells

24 A genetic rearrangement between 2 homologous chromosomes is called:

- A chiasma
- B homologous rearrangement
- C crossing over
- D haploid reduction
- E meiotic division

25 Crossing over can occur many times on each homologous pair.

- True
- False

26 Independent assortment states that

- A each pair of gametes separate independently of each other during meiosis
- B genes sort independently in animals but not in plants
- C independent sorting produces polyploid individuals
- D individual chromosomes from each parent sort independently of each other during meiosis

27 Which of the following statements is ***false***?

- A meiosis occurs in the ovaries and the testes of animals
- B sexual life cycles involve an alternation of diploid and haploid stages
- C mitosis produces daughter cells with half the number of chromosomes as the parent cell
- D a normal human has 46 chromosomes
- E a haploid cell has half the chromosomes that a diploid cell does

28 Which of these is NOT a component of meiosis?

- A crossing over
- B pairing of homologous chromosomes
- C random fertilization
- D production of gametes

29 With the exception of identical twins, siblings with the same parents will likely look similar but not identical to each other because

- A they have identical chromosomes
- B they have identical genes but not chromosomes
- C they have a similar but not identical combination of genes
- D they have a small chance of having identical genes

Accidents in Meiosis

Nondisjunction is the failure of chromosome pairs to separate either during meiosis I or meiosis II.

Fertilization of an egg resulting from nondisjunction with a normal sperm results in a zygote with an abnormal chromosome number.

Alterations in Chromosome Number

In most cases, human offspring which develop from zygotes with incorrect numbers of chromosomes abort spontaneously. This is one reason for the large number of miscarriages which happen during the first trimester of pregnancy.

There are two main types of alterations: **aneuploidy and polyploidy.**

Aneuploidy

Aneuploidy occurs when a gamete which has undergone a faulty meiosis and has an abnormal number of chromosomes unites with a normal egg or sperm. The zygote formed will have an abnormal number of chromosomes.

In a **trisomy**, the zygote has an extra copy of a chromosome.

If the zygote is missing a chromosome, it is called a **monosomy.**

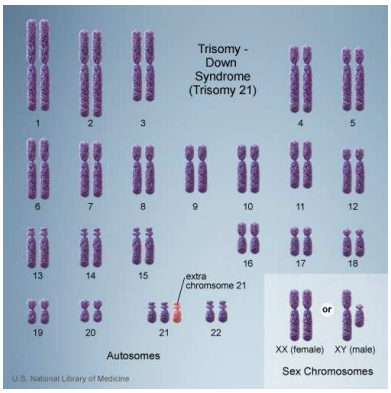
Trisomy 21 - Down Syndrome

Trisomy 21 is the most common chromosome-number abnormality with 3 copies of chromosome 21. It occurs in 1 out of 700 births.

Incidence of Down Syndrome increases with age of the mother.

Down Syndrome (common name for Trisomy 21) includes a wide variety of physical, mental, and disease-susceptibility features.

(little known fact: the incidence rate also increases with the age of the father)



30 Nondisjunction occurs when

- A a portion of a chromosome breaks off
- B chromosomes replicate too many times
- C two chromosomes fuse into one
- D members of a chromosome pair fail to separate
- E entire chromosomes are lost in Meiosis I

31 Aneuploidy occurs when a gamete which has had a problem during _____ ends up with _____chromosomes.

- A mitosis, extra
- B mitosis, less or extra
- C meiosis, extra
- D meiosis, less or extra

32 An individual with a trisomy has _____ extra copy/copies of a chromosome

- A one
- B two
- C three
- D four

Aneuploidy in Sex Chromosomes

Unusual numbers of **sex chromosomes** (those that determine sex, such as X,Y) do not upset the genetic balance as much as unusual numbers of **autosomes** (all other chromosomes) - perhaps due to the fact the Y chromosome carries fewer genes.

Abnormalities in sex chromosomes result in individuals with a variety of characteristics, the most seriously affecting fertility and intelligence.

The greater the number of X chromosomes, the greater likelihood of developmental and/or intellectual disabilities.

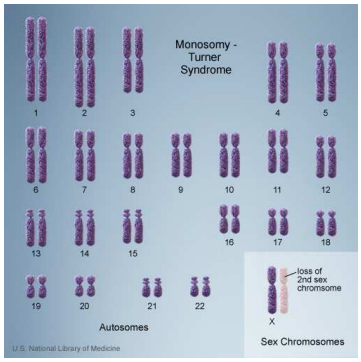
The Role of the Human Y Chromosome

Sex chromosome abnormalities illustrate the role of the Y chromosomes in determining a person's sex

A single Y chromosome is enough to produce "maleness" even in combination with a number of X chromosomes.
Example: XXY - Klinefelter's syndrome

The lack of a second X or Y chromosome will still result in "femaleness" due to the presence of one X chromosome.
Example: Xo - Turner's Syndrome

Turner Syndrome - Monosomy



33 Aneuploidy in sex chromosomes has no major consequences for the individual.

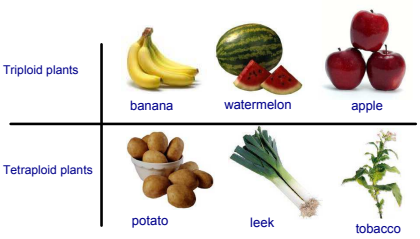
- ❍ True
- ❍ False

Polyploidy

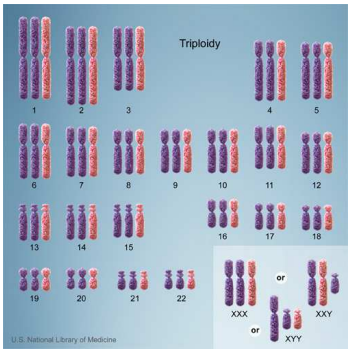
Polyploidy is lethal in humans. Polypoidy occurs when an organism has extra full sets of chromosomes.

Polyploidy is normal in plants and is sometimes necessary for completion of certain stages in the plant life cycle!

Polyploid plants tend to be larger and better at succeeding in farm fields.



Polyploidy in Humans



34 Having a full extra set of chromosomes is known as

- A aneuploidy
- B Turner's Syndrome
- C polyploidy
- D Crossing Over

35 A human with polyploidy can still reproduce normally.

- True
- False