Cell Division

Homologous Chromosomes	A pair of genetically different chromosomes, one of **paternal** and one of **maternal** origin, which have the **same genes** but may have **different alleles** at **corresponding loci**. They are similar in **size**, **shape**, **centromere position** and **staining pattern**.
Sister Chromatids	Genetically identical with the same alleles as they are the result of **semi-conservative DNA replication** during **S phase** of interphase.

Describe the process of mitosis.	
Stage	**Process**
Before Mitosis (Interphase)	There is **semi-conservative DNA replication** during **S phase** of interphase, producing **genetically identical sister chromatids**. At the end of interphase, the **chromatin** is **duplicated**, the **nuclear envelope** is **intact**, the **nucleolus** is **present**, and the **centrosome** is **replicated**.
Prophase	**Chromatin condenses** to form **chromosomes** with two genetically identical sister chromatids joined at the **centromere**. **Centrioles migrate** to opposite poles and **spindle fibers form**, extending from each pole to the kinetochores and metaphase plate. The **nuclear envelope disintegrates** and the **nucleolus disappears** as it is not needed as no rRNA is synthesized during mitosis.
Metaphase	**Kinetochore microtubules** from both poles, attached to the **centromere** of chromosomes with two genetically identical sister chromatids, **align** the chromosomes **singly** at the **metaphase plate**.
Anaphase	**Centromeres** of each chromosome **divide** and **sister chromatids**, now **chromosomes** are pulled to **opposite poles centromere first** as **kinetochore microtubules shorten**. Anaphase is very **short-lived stage** and quickly proceeds to telophase since **separation of sister chromatids** occurs very fast. **Non-kinetochore microtubules elongate**, causing the two poles to move further apart.

Describe the process of mitosis.	
Stage	**Process**
Telophase	The **chromosomes uncoil** into **long and thin chromatin**. The **spindle fibers disintegrate** and the **nuclear envelope reforms** around the chromosomes at each pole. The **nucleolus reappears**.
Cytokinesis	Animal cells: The cell membrane between the two nuclei **invaginates**, forming a **cleavage furrow** with the help of **microtubules**. The **cell membrane fuses** forming two daughter cells. Plant cells: **Vacuoles** appear in the middle of the cell, **coalescing** to form a **cell plate** and separating the two daughter cells.

Describe the process of meiosis.	
Stage	**Process**
Before Meiosis (Interphase)	There is **semi-conservative DNA replication** during **S phase** of interphase, producing **genetically identical sister chromatids**. At the end of interphase, the **chromatin** is **duplicated**, the **nuclear envelope** is **intact**, the **nucleolus** is **present**, and the **centrosome** is **replicated**.
Prophase I	**Chromatin condenses** to form **chromosomes** with two genetically identical sister chromatids joined at the **centromere**. **Synapsis** occurs and **homologous chromosomes** pair up to form **bivalents**. **Crossing over** occurs between **non-sister chromatids** of homologous chromosomes at chiasmata. **Corresponding portions** of the non-sister chromatids of homologous chromosomes **break** and **rejoin**, resulting in **exchange** of alleles. **Centrioles migrate** to opposite poles and **spindle fibers form**, extending from each pole to the kinetochores and metaphase plate. The **nuclear envelope disintegrates** and the **nucleolus disappears**.

Describe the process of meiosis.	
Stage	**Process**
Metaphase I	**Kinetochore microtubules** from both poles, attached to the **centromere** of chromosomes, **align** the **homologous pairs** of chromosomes in **two rows** at the **metaphase plate**. Each homologue is attached to the kinetochore microtubule from the pole it faces. **Independent assortment of homologous chromosomes** occurs as the orientation of a pair of homologous chromosomes is completely **independent** of other pairs.
Anaphase I	**Kinetochore microtubules shorten**, causing **homologous chromosomes** to **separate** to opposite poles, moving **centromeres first**. Centromeres do **not** separate and sister chromatids remain attached. **Non-kinetochore microtubules elongate**, causing the two poles to move further apart.
Telophase I	Each pole now has a **haploid set** of chromosomes, each consisting of **two sister chromatids**. The **chromosomes uncoil** into **long and thin chromatin**. The **spindle fibers disintegrate** and the **nuclear envelope reforms** around the chromosomes at each pole. The **nucleolus reappears**. Some cells skip telophase I and cytokinesis, **entering prophase II directly** after anaphase I.
Cytokinesis	Animal cells: The cell membrane between the two nuclei **invaginates**, forming a **cleavage furrow** with the help of **microtubules**. The **cell membrane fuses** forming two daughter cells. Plant cells: **Vacuoles** appear in the middle of the cell, **coalescing** to form a **cell plate** and separating the two daughter cells.
Prophase II	**Chromatin condenses** to form **chromosomes** with two sister chromatids joined at the **centromere**. **Centrioles duplicate** and **migrate** to opposite poles and **spindle fibers form**, extending from each pole to the kinetochores and metaphase plate. The **nuclear envelope disintegrates** and the **nucleolus disappears**.

Describe the process of meiosis.	
Stage	**Process**
Metaphase II	**Kinetochore microtubules** from both poles, attached to the **centromere** of chromosomes, **align** the chromosomes **singly** at the **metaphase plate**. The **orientation** of **sister chromatids** of each chromosome is completely **independent** of the orientation of the other chromosomes.
Anaphase II	**Centromeres** of each chromosome **divide** and **sister chromatids**, now **chromosomes** are pulled to **opposite poles centromere first** as **kinetochore microtubules shorten**. **Non-kinetochore microtubules elongate**, causing the two poles to move further apart.
Telophase II	The **chromosomes uncoil** into **long and thin chromatin**. The **spindle fibers disintegrate** and the **nuclear envelope reforms** around the chromosomes at each pole. The **nucleolus reappears**.
Cytokinesis	Animal cells: The cell membrane between the two nuclei **invaginates**, forming a **cleavage furrow** with the help of **microtubules**. The **cell membrane fuses** forming two daughter cells. Plant cells: **Vacuoles** appear in the middle of the cell, **coalescing** to form a **cell plate** and separating the two daughter cells.

State the differences between mitosis and meiosis.		
Point of Comparison	**Mitosis**	**Meiosis**
Location	Somatic cells in all parts of the body.	Reproductive organs, giving rise to gametes.
Nuclear Divisions	Once.	Twice.
Prophase	Homologous chromosomes do **not** pair up via synapsis and there is no formation of bivalents. **No** chiasma formation and crossing over and hence no exchange of equivalent portion of genetic material occurs between homologous chromosomes.	**Homologous chromosomes pair up** during **synapsis** to form **bivalents** at **prophase I**. There is **chiasma formation** and **crossing over** occurs such that **exchange** of **equivalent portions** of genetic material occurs between **non-sister chromatids of homologous chromosomes** during **prophase I**.
Metaphase	Chromosomes **align singly** at the **metaphase plate** during metaphase. Centromere of each chromosome attached to spindle fibers from **both poles**.	Homologous chromosomes aligned as **pairs** at **metaphase plate** during **metaphase I**. Centromere of each chromosome attached to spindle fibers from **one pole**.
Anaphase	**Centromeres separate**, causing **genetically identical sister chromatids** to separate to **opposite poles** during **anaphase**.	Centromeres do **not** separate and **homologous chromosomes** separate to opposite poles, and hence sister chromatids move to the **same poles** during **anaphase I.** I **Centromeres separate** causing **non-identical sister chromatids** to separate to opposite poles during **anaphase II**.
Telophase	**Two genetically identical** daughter cells formed and hence **no variation** occurs. Daughter cells have the **same number of chromosomes** as parental cells.	**Four genetically different** daughter cells formed and hence **variation** occurs. Daughter cells have **half** the **chromosome number** as parental cells.

Mitosis	Importance	<u>Explain the importance of mitosis.</u> Mitosis produces two **genetically identical daughter cells** so as to maintain **genetic stability**. Mitosis maintains **same type** and **number of chromosomes.** This allows for the **replacement** of **damaged cells** and thus the **repair of tissue**. An **increase in cell numbers** through mitosis allows for **growth** of the organism. Mitosis allows **asexual** reproduction which is advantageous in a stable environment.
	Genetic Stability	<u>Describe the role of mitosis in maintaining genetic stability.</u> During **S phase** of interphase, **semi-conservative DNA replication** where each strand of DNA acts as a **template** for the synthesis of the **complementary** strand via **complementary base pairing.** This results in the formation of chromosomes with **genetically identical sister chromatids**. During **metaphase**, chromosomes **align singly** on **metaphase plate**. During anaphase, **centromere divides** and the **kinetochore microtubules** from either pole attached to each sister chromatids, **shortens**, causing **genetically identical sister chromatids** to be separated and move to **opposite poles centromeres first**, ensuring equal distribution of chromosomes. The new daughter cells have **same number and type** of chromosomes with the **same alleles** as the parental cell, thus **maintaining genetic stability**.

Meiosis	Reduction Division	<u>Explain the need for reduction division in meiosis.</u> **Reduction division** is the production of **four haploid gametes** from a **diploid cell** during **meiosis**. Hence, when the sperm and egg fuse during **fertilization**, it gives rise to a **diploid zygote**, resulting in **restoration of chromosome number**. Thus, the **chromosome number** of the species **remains the same** after many generations. If meiosis did not occur, the fusion of gametes during **sexual reproduction** will result in the **doubling** in chromosome number with each generation. The haploid gametes formed by meiosis allows for **random fusion of gametes**, which combines genetic material from two individuals giving rise to **variation** in the offspring. In producing haploid gametes, there is **independent assortment of homologous chromosomes** during **metaphase I**, leading to a **variety** of gametes with different combinations of maternal and paternal chromosomes and hence **variation** in offspring. In addition, **crossing over** between **non-sister chromatids** of **homologous chromosomes** at **chiasmata** during **prophase I** results in **new combinations of alleles** in the chromosomes and gametes and hence **variation** in offspring
	Genetic Variation	<u>Explain how meiosis can lead to genetic variation.</u> **Crossing over** between **non-sister chromatids** of **homologous chromosomes** at **chiasmata** during **prophase I** leads to **exchange** of genetic material, forming **non-identical sister chromatids** with **new combinations of alleles** on chromosomes. **Independent assortment of homologous chromosomes** at the **metaphase plate** during **metaphase I**, where the arrangement of one pair of homologous chromosomes is **independent** of the arrangement of the other pairs, and the subsequent **separation** of homologous chromosomes during **anaphase I** results in gametes with **2^n** possible combinations of maternal and paternal chromosomes where n is number of chromosome pairs. In addition, **random orientation** of **sister chromatids** of each chromosome at the **metaphase plate** during **metaphase II** and their subsequent **separation** during **anaphase II** also contributes to the **new combination of alleles** in the gametes. Hence, meiosis produces **haploid** gametes that are **genetically different** from the parent, contributing to genetic variation. Chromosome **mutations** may during meiosis where the **chromosomes do not separate properly** in **nondisjunction**, resulting in **aneuploidy.** During **fertilization**, the **random fusion** of gametes results in offspring with a variety of genotypes and possibly phenotypes.

Cancer	Control of Cell Cycle	Explain the importance of control over the cell cycle. It allows for **coordination of growth** and helps to **minimize exposure to mutations** as increases in the number of DNA replication cycles increases the chance of alterations to DNA. This **prevents tumor formation** by preventing uncontrolled cell division, preventing **cancer**.
	Process	Explain how cancer results. **Uncontrolled cell division** occurs when cells **escape** the **control** mechanism that normally limits their growth, causing **mutations**. **Proto-oncogenes** are mutated to **oncogenes** which cause cells to divide excessively, causing a **gain-in-function** mutation. **Tumor suppressor genes** undergo a **loss-of-function** mutation, causing cells to lose their ability to stop dividing. The **upregulation of telomerase** removes the natural limit on the number of times the cell can divide which will lead to **increased cell division**. The lack of **apoptosis** and lack of **contact inhibition** result in **tumor formation**. **Metastasis** occurs and **secondary tumors** are formed. All these mutations are observed in a **single line of daughter cells**. Hence, the development of cancer is a **multi-step process** because for cancer to develop, **all** the **regulatory checkpoints** have to be disrupted and this requires an **accumulation of mutations**.
	Factors	**Chemical carcinogens** such as benzene and exposure to **uv light** as well as infection with certain **viruses** can cause **mutations** in the **nucleotide sequence** of DNA and result in cancer.