

Cell Division

- Mitosis
- Meiosis

2 categories of Cells

- Germ Cells: the reproductive cells that will create the offspring of the animal. Sperm and egg (and the cells that produce the sperm and egg). Produce offspring. Meiosis
- Somatic Cells: all other cells, such as skin, muscle, and nerves. Reproduce for growth, repair, replacement. Mitosis.

2 types of reproduction

- **Asexual:** produces offspring that are genetically identical to parent. ([mitosis](#)).
 - Budding:** offspring grows out of parent
 - Fragmentation:** parent breaks into distinct pieces, each of which can produce an offspring.
 - Regeneration:** a piece of a parent is detached, it grows and develops into a completely new individual. Sea star

•Sexual Reproduction

- 2 parents
- Genetic material from each contributed
- Genetic diversity
- NO CLONES
- Daughter cells are individual
- Meiosis produces the cells used for sexual reproduction

Cells divide in 2 stages

- 1st copy the DNA (this process is called **replication**)
- Then split the cell in two to form daughter cells (this process is called **binary fission**)

Prokaryotes Have a Simple Cell Cycle

- The hereditary info is stored in DNA
- prokaryotic chromosome is a **single circle** of DNA
- 1st DNA unzips at a point called the **origin of replication**
- a new double helix forms by adding complementary nucleotides to the exposed DNA strands that have been unzipped
- Goes on until the cell has 2 complete copies of the hereditary information
- After replication, cells GROWS
 - When big enough, the cell splits into 2 equal halves
 - new plasma membrane and cell wall form
 - eventually the cell constricts in two to form two daughter cells
 - each daughter cell is a complete, living cell with its own DNA

Eukaryotic cells

- have a complex cell cycle
- contain more DNA than prokaryotic cells
 - Not circular
 - DNA in eukaryotic cells is linear and packaged into a compact chromosome
 - there is more than one chromosome in a eukaryotic cell
- Somatic & Germ Cells have different Cell Cycles
- **Mitosis:** occurs in non reproductive cells (**somatic cells**)
- **Meiosis:** is a cell division mechanism that occurs in cells that participate in sexual reproduction
- **germ cells**

•The eukaryotic cell cycle is divided into distinct phases

–Interphase (G_1 , S , and G_2 phases)

–Mitosis (M phase)

–Cytokinesis (C phase)

•Interphase

–first phase of the cycle & sometimes considered a resting phase but is actually a period of activity

–comprised of three phases

• G_1 phase

–primary growth phase of the cell following division

–most cells spend majority of lifespan in this phase

•S phase

–DNA replication occurs in prep for cell division

• G_2 phase

–further preparation for cell division, including replication of mitochondria and synthesis of microtubules

•Mitosis (M phase)

–a microtubular apparatus binds to the chromosomes and moves them apart

•Cytokinesis (C phase)

–the cytoplasm divides, creating two daughter cells

Chromosomes

- Chromosome number varies among organisms
 - most eukaryotes have between 10 and 50 chromosomes in their somatic cells
 - Chromosomes are paired in somatic cells
 - these pairs are called **homologous chromosomes**, or **homologues**
 - homologues contain information about the same traits but the information may vary
 - cells that have two of each type of chromosome are called **diploid cells**
 - one chromosome of each pair is inherited from the mother and the other is inherited from the father
 - Prior to cell division, each of the homologous chromosomes replicates, forming two identical copies called **sister chromatids**
 - the sister chromatids are joined together by a structure called a **centromere**
 - humans have 23 pairs of homologous chromosomes
 - when each chromosome in the pair is replicated, this makes for a total of 92 chromatids

karyotype: an arrangement of chromosomes

- Chromosomes can be compared based on size, shape, and centromere location
- The karyotype at right shows the 23 pairs of human chromosomes
- Chromosomes are comprised of **chromatin**, a complex of DNA and protein
- there is also some RNA associated with chromosomes
- the DNA in a chromosome is one very long double-stranded fiber that extends unbroken for the length of the chromosome
- the DNA is coiled in order to allow it to fit into a small space despite being very long

DNA STRUCTURE

- DNA is coiled around proteins called **histones**
- the histones have positive charges to counteract the negative charges associated with the phosphate groups of the DNA
- The DNA coils around a core of eight histone proteins to form a complex called a **nucleosome**
- the nucleosomes in turn can be coiled together further to form ultimately a compact chromosome

MITOSIS

Interphase sets the stage for cell division

- chromosomes are first duplicated
- chromosomes begin to wind up tightly in a process called **condensation**
- sister chromatids are held together by a protein complex called **cohesin**

Following interphase, division of the nuclear contents occurs, known as **mitosis**. There are Four distinct stages of mitosis

1. Prophase
2. Metaphase
3. Anaphase
4. telophase

PROPHASE (beginning of mitosis)

- the condensed chromosomes first become visible
- the nuclear envelope begins to disintegrate and the nucleolus disappears
- centrioles separate in the center of the cell and migrate to opposite ends ("poles") of the cell
- the centrioles start to form a network of protein cables called the **spindle** (spindle is made of microtubules)
- some of the microtubules extend toward the centromere of the chromosomes
- these microtubules will grow from each pole until attached to a centromere at a disc of protein called a **kinetochore**

Metaphase

- chromosomes (attached to microtubules of the spindle) align in the center of the cell
- the centromeres are aligned along an imaginary plane that divides the cell in half, known as the **equatorial plane**

•Anaphase

- sister chromatids separate
- enzymes break the cohesin and the kinetochores
- the microtubules of the spindle are dismantled starting at the poles
- this pulls the chromatids toward the poles

•Telophase

- the spindle is dismantled
- nuclear envelope forms around the set of chromosomes at each pole
- the chromosomes begin to uncondensed
- the nucleolus reappears

• **Cytokinesis**

- occurs at end of mitosis
- Cytoplasmic division (into roughly equal halves)
 - **in animals:**
 - cytokinesis occurs by actin filaments contracting and pinching the cell in two
 - this action is evident as a **cleavage furrow** that appears between the daughter cells
 - **in plants:**
 - new cell wall laid down to divide the 2 daughter cells
 - cell wall grows at right angles to the mitotic spindle and is called the **cell plate**

Controlling the Cell Cycle

The cell cycle is controlled by checkpoints to ensure that a previous phase is fully completed before advancing to the next phase

- feedback from the cell determines whether the cycle switches to the next stage
- three principal checkpoints control the cycle in eukaryotes
- G₁, G₂, and M checkpoints

G₁ checkpoint	•G₂ checkpoint	M checkpoint
this checkpoint makes the decision about whether the cell should divide and enter S some cells never pass this point and are said to be in G ₀	this checkpoint leads to mitosis Is cell truly ready for its nuclear material to divide?	this checkpoint occurs during metaphase and triggers the exit process of the M phase and entry to the G ₁ phase

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What Is Cancer?

- **Cancer** is a growth disorder of cells
- apparently normal cells grow uncontrollably and spread to other parts of the body
- Result: a growing cluster of cells (**tumor**)
 - **benign tumors:** surrounded by a healthy layer of cells (aka encapsulated) & do not spread to other areas
 - **malignant tumors:** not encapsulated and are invasive
 - spread to different areas of the body to form new tumors (**metastases**)

•Lung Cancer

- Cancer is caused by a gene disorder in somatic tissue in which damaged genes fail to control properly the cell cycle
 - **mutations** causes damage to genes
 - may result from chemical or environmental exposure, such as UV rays
 - viral exposure may also alter DNA

2 classes of genes involved in Cancer

proto-oncogenes

- these genes encode proteins that stimulate cell division
- mutations to these genes can cause cell to divide excessively
- when mutated, these genes become **oncogenes**

tumor-suppressor genes

- these genes normally turn off cell division in healthy cells
- when mutated, these genes allow uncontrolled cell division

- Cancer: when damaged genes fail to control cell division
 - one such gene, *p53*, affects the G₁ checkpoint
 - its normal action is to detect abnormal DNA
 - Halts cell division of a cell with damaged DNA until the DNA is repaired or directs the cell to be destroyed if the damage cannot be fixed
 - if this gene itself becomes damaged, it will allow damaged cells to divide unchecked

Discovery of Meiosis

Gametes

- reproductive cells (eggs and sperm)
- contain half the complement of chromosomes found in somatic cells
- the gametes fuse to form a new cell called a **zygote**, which contains two complete copies of each chromosome
- the fusion of gametes is called **fertilization**, or **syngamy**

Meiosis: gamete formation

- involves some mechanism to halve the # of chromosomes found in somatic cells
- if not the number of chromosomes would double with each fertilization

Meiosis: process of reduction division in forming gametes
this ensures a consistent chromosome number across generations

Meiosis and fertilization constitute a cycle of sexual reproduction

Somatic cells have two sets of chromosomes making them **diploid**

Gametes have only one set of chromosomes, making them **haploid**

Asexual Reproduction

- Some organisms reproduce by mitotic division and do not involve gametes
- an example is binary fission in prokaryotes
- Other organisms are able to reproduce both sexually and asexually
- for example, strawberry plants flower (sexual reproduction) and send out runners (asexual reproduction)

Germ Line Cells: 2n

In animals, the cells that will eventually undergo meiosis are reserved early on for the purpose of reproduction

- these cells are referred to as **germ-line** cells and are diploid like somatic cells
- **Only germ-line cells will undergo meiosis to produce haploid gametes**

Meiosis involves 2 divisions (M1 and M2)

- DNA is replicated **only** before meiosis I

meiosis I: separates pairs of homologues

meiosis II : separates the replicate sister chromatids

when meiosis is complete, the result is that one diploid cell has become four haploid cells

Meiosis I divided into 4 events

1. Prophase I	Homologues pair up and exchange segments
2. Metaphase	The paired homologous chromosomes align on a central plane
3. Anaphase I	Homologues separate from the pairing and move to opposite poles
4. Telophase I	Individual chromosomes gather at each of the two poles

Prophase

- Homologous chromosomes line up as pairs
- **crossing over** occurs between two non-sister chromatids of homologous chromosomes
- the chromatids break in the same place and section of chromosomes are swapped
- the result is a hybrid chromosome
- the pairing is held together by the cohesion between sister chromatids and the crossovers

During metaphase I

- the orientation of the homologous chromosome pairing is a matter of chance
- each possible orientation of which homologue faces which pole results in gametes with different combinations of parental chromosomes
- this process is called **independent assortment**

In anaphase I and telophase I

- the chromosome pairs separate and individual homologues move to each pole
- In telophase I, the chromosomes gather at their respective poles to form two chromosome clusters

After Meiosis I.....

- a brief interphase occurs where there is no replication of DNA
- Meiosis II follows and is basically a mitotic division of the products of meiosis I except that the sister chromatids are non-identical because of crossing over in meiosis I

•Meiosis II also divided into 4 stages

1. **Prophase II:** new spindle forms to attach to chromosome clusters
2. **Metaphase II:** spindle fibers bind to both sides of the centromere and individual chromosomes align along a central plane
3. **Anaphase II:** sister chromatids move to opposite poles
4. **Telophase II:** the nuclear envelope is reformed around each of the four sets of daughter chromosomes

How Meiosis Differs from Mitosis

Meiosis has 2 unique features not found in mitosis

- **Synapsis**
 - process of drawing together homologous chromosomes down their entire lengths so that crossing over can occur
- **reduction division**
 - because meiosis involves two nuclear divisions but only one replication of DNA, the final amount of genetic material passed to the gametes is halved

Evolutionary Consequences of Sex

Sexual reproduction has an enormous impact on how species evolve because it generates rapidly new genetic combinations

3 mechanisms help produce this variety

1. Independent assortment
2. Crossing over
3. Random fertilization

Name _____

PART I: CELL CYCLE AND MITOSIS

Define and describe the difference between a germ cell and a somatic cell. Make at least 4 comments in each column.

Germ:	Somatic

Draw the Cell Cycle:

- Identify phases, subphases & what cell activities characterize each.
- Label 3 gap phases;
- Define apoptosis:

Do all cells have a cell cycle that is equal in duration?

Mitosis: How a somatic cell divides.

Why is it important to create new cells? List 3 reasons why mitosis is important.

- a) _____
- b) _____
- c) _____

Complete the chart by noting what occurs in each phase of the cell cycle.

Interphase	Gap 0 (G0)	
	Gap 1 (G1):	
	S Phase:	
	Gap 2 (G2):	
Mitosis or M Phase	Prophase:	
	Metaphase:	
	Anaphase:	
	Telophase:	
Cytokinesis	C	

What is the final product of Mitosis?

Define:

a) Haploid:

b) Diploid:

c) sister chromatids:

d) homologous pairs:

.

e) crossing over

f) Independent Assortment

How is cancer a disease of the cell cycle?

What is the difference between asexual and sexual reproduction? What are the benefits of each?

What is the difference between the centriole and the centromere?

At what phase is the DNA most difficult to see under a microscope? Explain.

What phase involves the separation of sister chromatids towards opposite poles of the cell?

Are the newly formed daughter cells equal and identical in all ways?
Same size?

PART II MEIOSIS

MEIOSIS: combining genetic material through fertilization
What is the purpose of meiosis?

Use words or pictures to identify the events at each stage below.

Interphase:

Prophase I

Metaphase I

Anaphase I

Telophase I

Prophase II

Metaphase II

Anaphase II

Telophase II

Interphase

What is the final product of Meiosis?

Use the table below to differentiate between Meiosis and Mitosis

Mitosis	Meiosis