# Biology Keystone Review Packet Part II

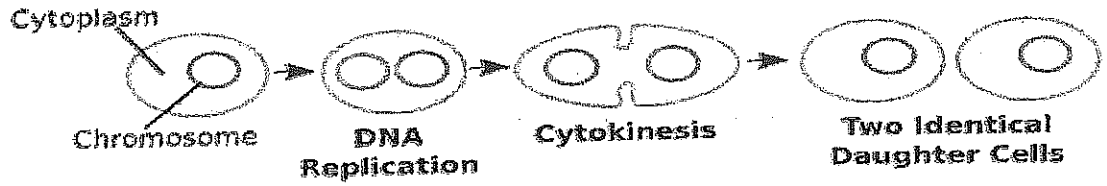
*Module B Review Materials*

# Everything you really, really need to know about...

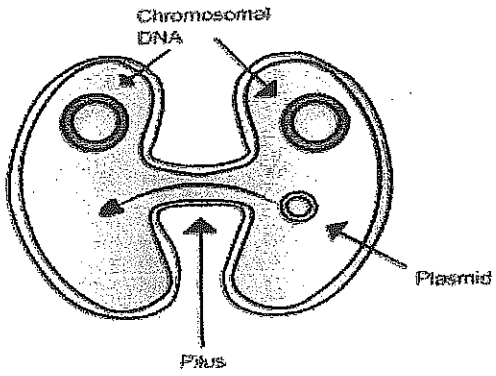
# Cell Growth and Reproduction

## Prokaryotic Cell Division....a.k.a. binary fission

In binary fission, prokaryotic organisms make a copy of their DNA and then split in two, with each new organism containing a complete set of DNA. This is a form of asexual reproduction. Each daughter cell is exactly the same as the parent cell from which it came.




Prokaryotic organisms can obtain DNA segments (plasmids) from other organisms via a process called conjugation.




## Eukaryotic Cell Division

We are eukaryotes and frequently we need to make more cells. We need to have our cells divide and make more for a number of reasons such as...

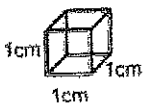
1. Growth and development. In order to become a larger, multicellular organism, we need to make more cells.

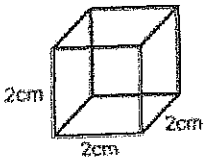
2. Replacing dead cells. Our cells have a life span. We're constantly losing dead skin cells and red blood cells. These need to be replaced.

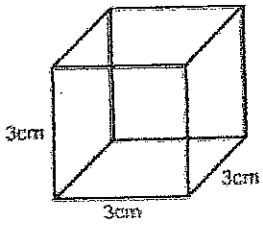
3. Repairing damaged tissue. If you fall and skin your knee, the healing process is largely comprised of cells dividing to repair the damaged area.

4. DNA overload. Cells grow. They become larger, but they can become too large. If they're allowed to continually grow, they become too large to be controlled by the DNA within the nucleus. By dividing, the size of the cells is continually being cut down to a manageable size.

5. Surface area to volume ratio. The problem again is cell growth. As cells get larger, they're demands increase. Raw materials need to be brought into the cell through the cell membrane. The problem is that the cell membrane's growth doesn't keep pace with the growth of the cell in volume and the cell can't keep pace with providing itself with all the raw materials that are necessary.



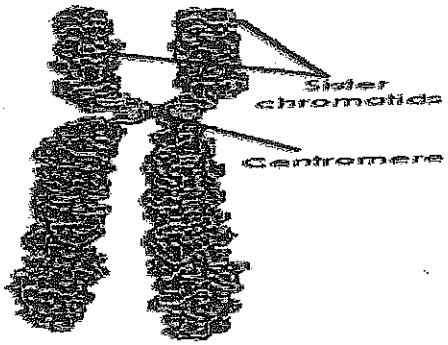

| | | | |
|---|---|---|---|
| surface area | (1cm x 1cm) x 6 = 6cm² | (2cm x 2cm) x 6 = 24cm² | (3cm x 3cm) x 6 = 54cm² |
| volume | 1cm x 1cm x 1cm = 1cm³ | 2cm x 2cm x 2cm = 8cm³ | 3cm x 3cm x 3cm = 27cm³ |
| surface area:volume | 6:1 | 24:8 | 54:74 |



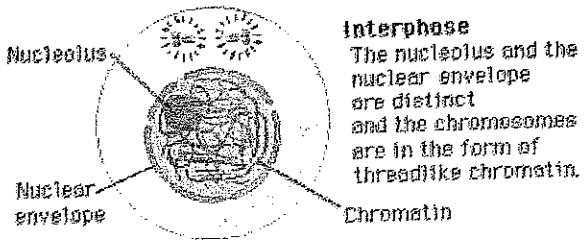
Now that you know why cells divide, the question becomes, "How do cells divide?".

There are stages to a cell's life and each plays a role in continuing the cellular division process.

Interphase: This stage is a non-dividing portion of the cell's life. Interphase can be broken up into three smaller stages; $G_1$, S and $G_2$. During $G_1$, the cell grows and makes more organelles for itself. During S, the chromosomes within the nucleus are replicated. For humans, that means that our 46 monad chromosomes become 46 dyad chromosomes, with each chromosomes' sister chromatids being held together at the centromere.




In replicating all the chromosomes, the cell is preparing an entire extra set of chromosomes so that it can eventually divide itself in half, thus providing each new cell with a complete set of genetic material. S is followed by $G_2$, in which the cell gets ready to divide.

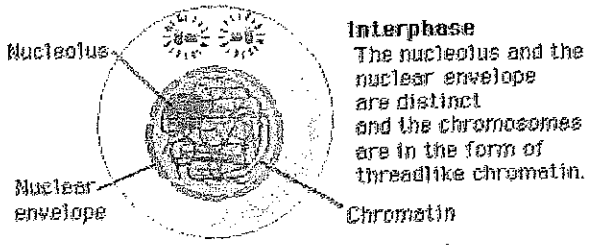



Cell division (or the M phase) is now set to start and the first part of cell division is known as Mitosis. Mitosis deals with the

HALF, TO PRODUCE HAPLOID CELLS. THESE WILL THEN BECOME EITHER SPERM CELLS OR EGG CELLS.

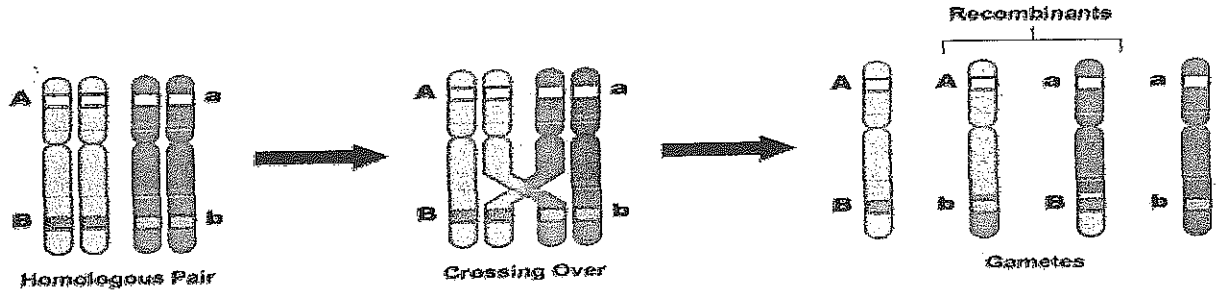
THE PROCESS OF MEIOSIS IS VERY SIMILAR TO MITOSIS, BUT WITH A FEW IMPORTANT DIFFERENCES. FIRST OF ALL, THERE ARE TWO CELL DIVISIONS THAT TAKE PLACE IN MEIOSIS, MEIOSIS I AND MEIOSIS II. THUS, YOU END MEIOSIS WITH FOUR CELLS INSTEAD OF JUST TWO.

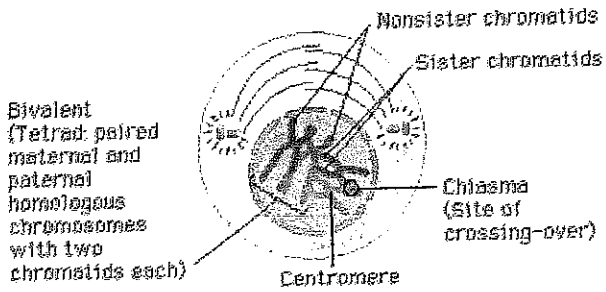
INTERPHASE: THIS IS THE SAME AS IN MITOSIS.



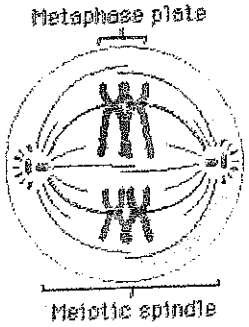

MEIOSIS I:

PROPHASE I: THIS IS ALSO THE SAME AS IN MITOSIS EXCEPT THAT SOMETIMES, HOMOLOGOUS CHROMOSOMES WILL BECOME INTERTWINED AND SWAP PIECES OF GENETIC MATERIAL, THUS LEADING TO GREATER GENETIC VARIETY WITHIN A POPULATION. THIS IS CALLED CROSSING OVER.

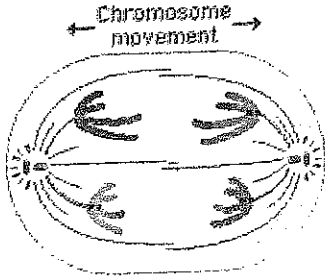





**Metaphase I: Once in metaphase I, the cell does something very different than in metaphase of mitosis. The chromosomes line up on the equator, but they do so with their homologous partner. Each dyad chromosome is attached to only one spindle fiber.**

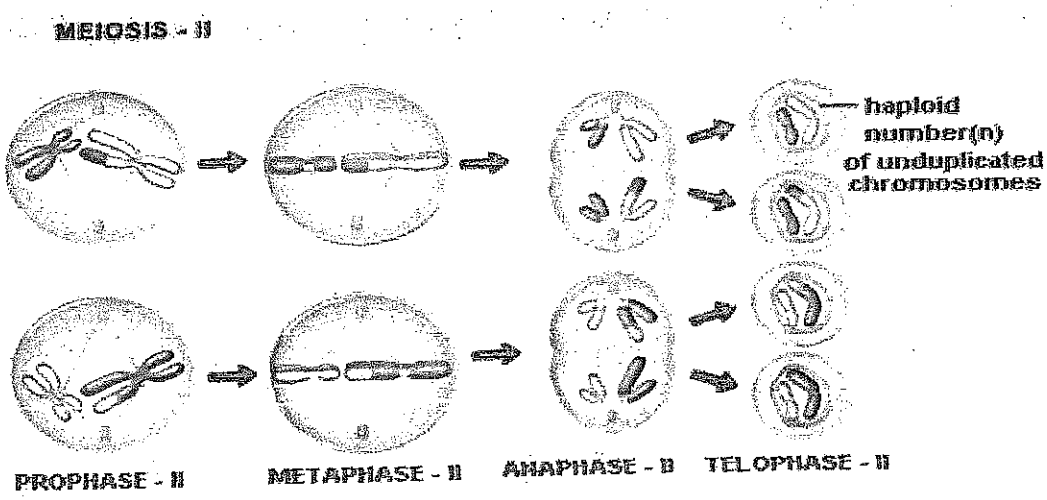



**Anaphase I: As the spindle fibers shorten, they don't rip the dyad chromosomes in half, but instead, they separate the homologous pairs.**



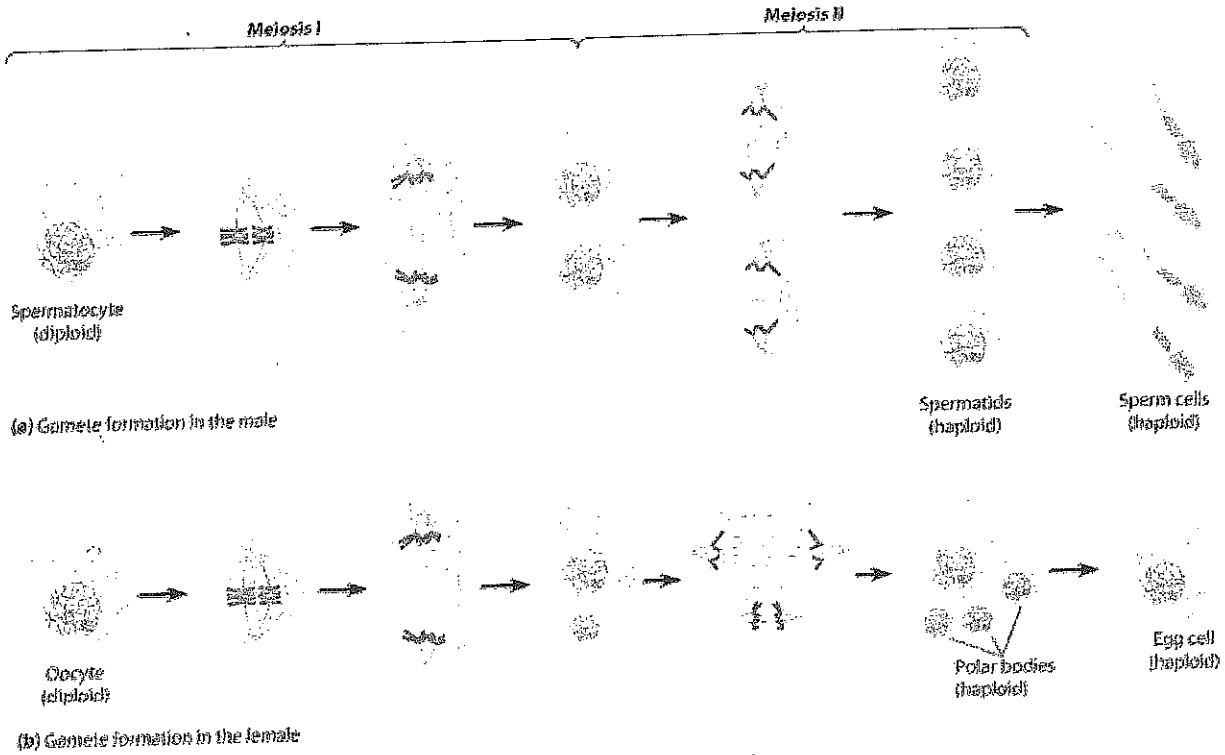
Telophase I: The cell can now start to reform its nuclei and begin cytokinesis. The most important thing to note is that the number of chromosomes that will end up in the two daughter cells has now been cut in half. The cells have gone from being diploid, to being haploid.

After cytokinesis, the cells will advance into meiosis II. The reason for meiosis II is that, although the chromosome number has been divided in half, the chromosomes themselves are still dyad instead of monad. This needs to change and meiosis II will take care of that because all the steps are exactly the same as mitosis.




There are a few differences in the way that males go through meiosis vs. females. The male version of meiosis is called spermatogenesis and the female version is called oogenesis. The main difference is that while males ultimately make four sperm cells, females only make one egg. The other three cells produced by the female are called <u>polar bodies</u> and they are destroyed. The reason for this is that the egg needs to supply all the nutrients for the resulting zygote prior to the embryo

FORMING A PHYSICAL CONNECTION (UMBILICAL CORD) WITH THE MOTHER. BY DIVIDING UNEQUALLY, THE CYTOPLASM THAT NORMALLY WOULD HAVE GONE INTO FOUR SEPARATE CELLS IS INSTEAD ALL PACKED INTO ONE, GIANT EGG CELL.



# Cell Growth and Reproduction

Module B, Anchor 1

**Key Concepts:**

- The larger a cell becomes, the more demands the cell places on its DNA. In addition, a larger cell is less efficient in moving nutrients and waste materials across the cell membrane.
- Asexual reproduction is the production of genetically identical offspring from a single parent.
- Offspring produced by sexual reproduction inherit some of their genetic information from each parent.
- Chromosomes make it possible to separate DNA precisely during cell division.
- During the cell cycle, a cell grows, prepares for division, and divides to form two daughter cells.
- During prophase, the genetic material inside the nucleus condenses. During metaphase, the chromosomes line up across the center of the cell. During anaphase, the chromosomes separate and move along spindle fibers to opposite ends of the cell. During telophase, the chromosomes, which were distinct and condensed, begin to spread out into tangle of chromatin.
- The cell cycle is controlled by regulatory proteins both inside and outside the cell.
- Cancer cells do not respond to the signals that regulate the growth of most cells. As a result, the cells divide uncontrollably.
- The diploid cells of most adult organisms contain two complete sets of inherited chromosomes and two complete sets of genes.
- In prophase I, replicated chromosomes pair with corresponding homologous chromosomes. At metaphase I, paired chromosomes line up across the center of the cell. In anaphase I, chromosome pairs move toward opposite ends of the cell. In telophase I, a nuclear membrane forms around each cluster of chromosomes. Cytokinesis forms two new cells. As the cells enter prophase II, their chromosomes become visible. The final four phases of meiosis II result in four haploid daughter cells.

Meiosis

- In mitosis, when the two sets of genetic material separate, each daughter cell receives one complete set of chromosomes. In meiosis, homologous chromosomes line up and then move to separate daughter cells. Mitosis does not normally change the chromosome number of the original cell. Meiosis reduces the chromosome number by half. Mitosis results in the production of two genetically identical diploid cells, whereas meiosis produces four genetically different haploid cells.
- Alleles of different genes tend to be inherited together from one generation to the next when those genes are located on the same chromosome.

**Vocabulary:**

Cell division
Chromosome
Interphase
Prophase
Centriole
Telophase
asexual reproduction
chromatin
mitosis
centromere
metaphase
cyclin
sexual reproduction
cell cycle
cytokinesis
chromatid
anaphase
growth factor

Key

# Cell Growth and Reproduction

Module B, Anchor 1

**Cell Growth, Division, and Reproduction:**

1. What are the reasons why cells divide? How does division address these issues?

*Materials Exchange – As cells grown, their volume increases faster than their surface area. This prevents them from effectively exchanging materials with their environments. Dividing brings the SA:V ratio back into alignment, allowing for more effective exchange of materials.*

*DNA overload – As the cell grows, the demand on the DNA increases. Dividing decreases the demands on the DNA.*

2. Describe what is meant by each of the following: cell volume, cell surface area, ratio of surface area to volume. Why is the ratio of surface area to volume important to cell survival?

*Cell volume – amount on space inside the cell membrane*
*Cell surface area – amount of space taken up by cell membrane*
*SA:V ratio – relationship between the amount of surface area and the amount of volume.*
*SA:V ratio is related to materials exchange within the cell.*

3. In order for cells to divide successfully, the cell must first

*A. duplicate its genetic information*

4. Compare and contrast sexual and asexual reproduction.

*Both types of reproduction create new organisms. Sexual reproduction involves the genetic material of two organisms. It creates new combinations of alleles not seen in previous organisms. Therefore, it produces offspring with different physical structures than their parents. Asexual reproduction requires only one organism. It produces offspring identical, both physically and genetically, to their parents.*

5. Which type of reproduction is best suited to a changing environment? Why?

*Sexual. Sexual reproduction produces offspring with a variety of phenotypes. This allows a greater chance of survival in a changing environment. If the organisms were produced via asexual reproduction, they would all be identical. If the environment changed in a way unfavorable to these organisms, they would all die.*

**Cell Cycle/mitosis:**

1. List and describe the stages of interphase. Illustrate each description.

*G1 phase – normal growth and cell activities*
*S phase – DNA replication*
*G2 phase – cell synthesizes organelles and chemicals needed for division*

2. List and describe the stages of M phase. Illustrate each stage.

*Prophase – Genetic material condenses and becomes visible, nuclear envelope disintegrates, centrioles begin to move to opposite sides of the cell.*
*Metaphase – chromosomes line up in the center of the cell, spindles attach*
*Anaphase – spindles pull sister chromatids to opposite sides of the cell*

*Telophase – nuclear envelop reforms around two new nuclei*
*Cytokinesis – cytoplasm divides into two identical cells*

3. If a cell has 12 chromosomes before division, how many chromosomes will be in each of its daughter cells after mitosis and cytokinesis? Why is this important?
*12 – so that no DNA is missing from any cell*

4. Describe how a eukaryotic cell's chromosomes change as a cell prepares to divide. Why is it advantageous to package DNA into chromosomes for cell division?
*Chromosomes duplicate and condense. Packaging DNA into chromosomes makes it easier to separate evenly.*

5. What is the relationship between interphase and cell division? Why must the DNA be duplicated before cell division can occur?
*Interphase prepares the cell for division. If the DNA was not replicated before division, each daughter cell would only receive half the appropriate amount of DNA.*

6. How is the process of cell division different in prokaryotes and eukaryotes?
*In prokaryotes, genetic material is not package in a nucleus. Like in eukaryotes, the DNA duplicates. In then attached to two different places on the cell membrane. A network of proteins forms between the areas, pinching in the membrane to divide.*

7. Compare and contrast cell division in plant and animal cells.
*Plants – cell wall cannot pinch in, therefore the cell builds a cell plate between the two nuclei*

*Animal cell – the cell membrane pinches in to form two new cells.*

8. What type of cells are produced by mitosis?
*Somatic/body cells*

**Meiosis:**
1. List and describe the stages of meiosis I.
*Prophase I – nuclear envelope disintegrates, chromosomes line up in tetrads, crossing-over occurs.*
*Metaphase I – chromosomes line up in tetrads across center of cell, spindles attach*
*Anaphase I – spindles pull chromosomes to opposite sides of the cell*
*Telophase I – nuclear envelopes reform around chromosome sets, producing two haploid neclei*
*Cytokinesis – cell splits into two haploid cells*

2. List and describe the phases of meiosis II.
*Prophase II – nuclear envelope disintegrates, centrioles move to opposite sides of the cell*
*Metaphase II – Chromosomes line up end to end, spindles attach*
*Anaphase II – sister chromatids are split and pulled to opposite ends of the cell*
*Telophase II – cytoplasm begins to divide, nuclear envelopes form around each nuclei*
*Cytokinesis – cell divides into four haploid gametes*

3. Compare and contrast meiosis I and meiosis II.
*Meiosis I – tetrads form, crossing-over occurs, cell begins diploid but ends haploid*
*Meiosis II – cells begin and end haploid, no tetrads or crossing-over*

4. What type of cells are produced by meiosis? How do the end products of meiosis differ in males and females?
*Gametes*
*Males produce four haploid gametes. Females produce one large haploid egg cell and three polar bodies.*

5. Compare and contrast meiosis and mitosis.
*Meiosis produces four haploid cells. The cells are not genetically identical to each other or to the parent cell.*
*Mitosis produces two diploid cells. The cells are identical to the parent cell and to each other.*

6. What events ensure that the cells produced by mitosis are genetically identical diploids, while the cells produced by meiosis are genetically different haploids?
*In mitosis, the chromosomes duplicate once and divide once. The chromosomes line up end to end, so that when they are pulled apart each cell receives a full set of genetic material.*
*In meiosis, the chromosomes duplicate once but divide twice. This reduces the amount of genetic material in each cell by half. When the cells divide the first time, chromosomes line up in pairs instead of end to end. This ensures that each cell receives half the genetic material.*

8. Why does mitosis produce diploid cells, while meiosis produces haploid cells?
*Mitosis is producing replacement body cells, so the cells need a full complement of DNA to function correctly. Meiosis is producing gametes. One gamete is fertilized by another to form offspring, therefore each must have only half the genetic material needed.*

**Regulating the Cell Cycle:**
1. The timing in the cell cycle in eukaryotic cells is believed to be controlled by a group of closely related proteins known as:
*B. cyclins*

2. Compare and contrast internal and external regulators. Give examples of each.
*Internal regulators respond to events inside the cell, such as the duplication of the DNA.*
*External regulators respond to events outside the cell, such as contact with other cells.*

3. How do cancer cells differ from noncancerous cells? How are they similar?
*Cancer cells no longer respond to growth regulators, therefore never stop dividing. Otherwise, they are like normal body cells.*

4. What is apoptosis? What is the role of apoptosis in regulating the cell cycle?
*Programmed cell death. Apoptosis plays a key role in removing damaged cells.*

# Everything you really, really need to know about...

# Heredity I

## Gregor Mendel's Principles

1. Principle of Dominance - One of Gregor Mendel's great discoveries was the principle of dominance. He noted that when he bred two parents with different versions of a particular trait, one of those versions apparently disappeared in the hybrid (heterozygous) offspring. If he then mated those offspring to each other, the vanished trait reappeared in the third generation, apparently completely unchanged despite being invisible in generation 2. He named the version of the trait which was visible in the hybrids the dominant and the one that was invisible in the hybrids the recessive.

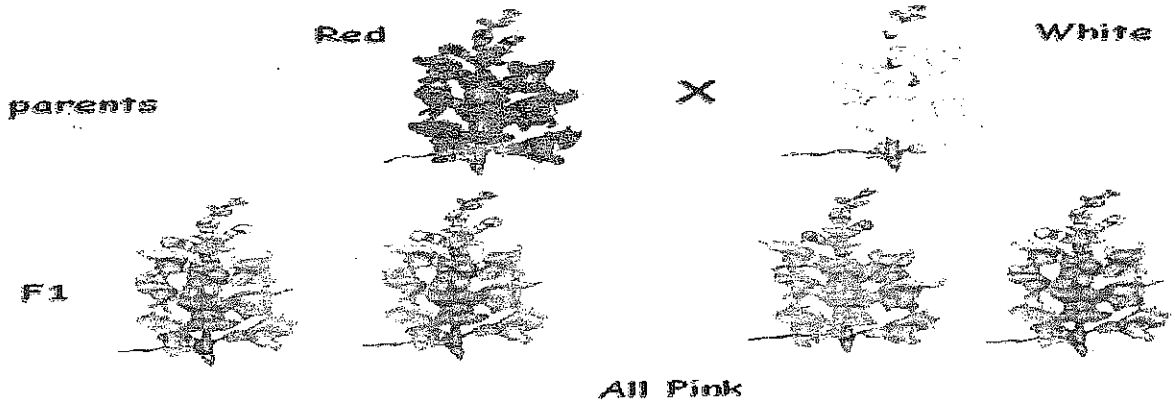
2. Principle of Segregation - According to the principle of segregation, for any particular trait, the pair of alleles of each parent separate and only one allele passes from each parent on to an offspring. Which allele in a parent's pair of alleles is inherited is a matter of chance. We now know that this segregation of alleles occurs during the process of sex cell formation (i.e., meiosis).

3. Principle of Independent Assortment - According to the principle of independent assortment, different pairs of alleles are passed to offspring independently of each other. The result is that new combinations of genes present in neither parent are possible. For example, a pea plant's inheritance of the ability to produce purple flowers instead of white ones does not make it more likely that it will also inherit the ability to produce yellow pea seeds in contrast to green ones. Likewise, the principle of independent assortment explains why the human inheritance of a particular eye color does not increase or decrease the likelihood of having 6 fingers on each hand. Today, we know this is due to the fact that the genes for independently assorted traits are located on different chromosomes.

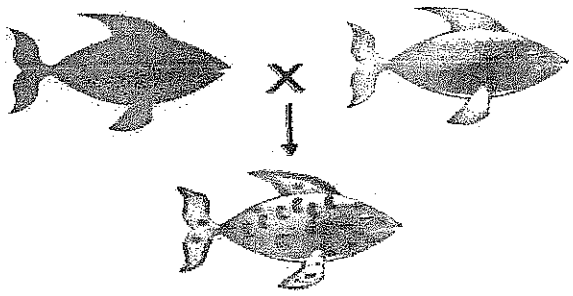
Mendel's three principles provide the foundation for studying genetics but there are many exceptions to his rule on dominance. His principle of dominance describes traits that today, we refer to as complete dominance, but not all traits show complete dominance.

## Mendelian Exceptions

Incomplete Dominance – Instead of one allele being dominant and another being recessive, the heterozygous condition results in a blending of the two traits.

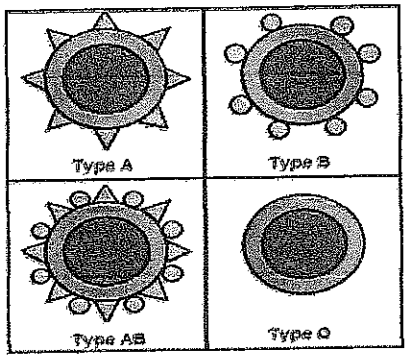



Codominance – In this case, both alleles are dominant, but instead of blending, both traits are expressed in a heterozygote.



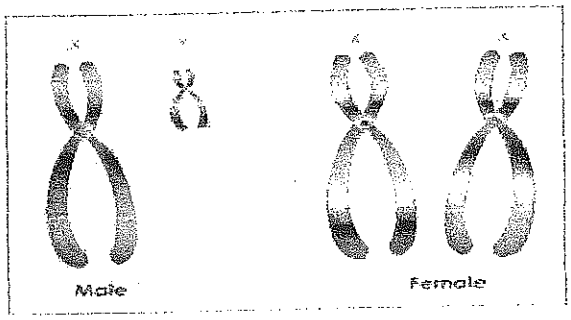

Multiple Alleles – Generally, the word multiple means "more than one". But in genetics, that's not the case. It's "normal" for there to be two different alleles for a trait, but some traits have more than two alleles, such as blood type. Each

INDIVIDUAL HAS TWO GENES FOR BLOOD TYPE, BUT WITHIN THE HUMAN POPULATION THERE ARE MORE THAN TWO OPTIONS ($I^A$, $I^B$ AND $I^O$) FOR WHAT THOSE TWO ALLELES WILL BE.




| Blood Type | Genotype | | Can Receive Blood From |
|---|---|---|---|
| A | $I^A i$<br>$I^A I^A$ | AA<br>AO | A or O |
| B | $I^B i$<br>$I^B I^B$ | BB<br>BO | B or O |
| AB | $I^A I^B$ | AB | A, B, AB, O |
| O | $ii$ | oo | O |

SEX-LINKED TRAITS – HUMANS HAVE TWENTY-THREE PAIRS OF CHROMOSOMES. THE FIRST TWENTY-TWO PAIRS ARE CALLED AUTOSOMES. THEY ARE HOMOLOGOUS TO EACH OTHER. THE TWENTY-THIRD PAIR IS THE PAIR WE CALL OUR SEX CHROMOSOMES BECAUSE THEY DETERMINE OUR GENDER. FOR FEMALES, WITH TWO X CHROMOSOMES, THEY ARE ALSO HOMOLOGOUS, BUT FOR MALES WITH ONE X AND ONE Y CHROMOSOME, THEY ARE NON-HOMOLOGOUS. THERE ARE VERY FEW GENES ON THE Y CHROMOSOME, BUT THE X HAS QUITE A FEW.



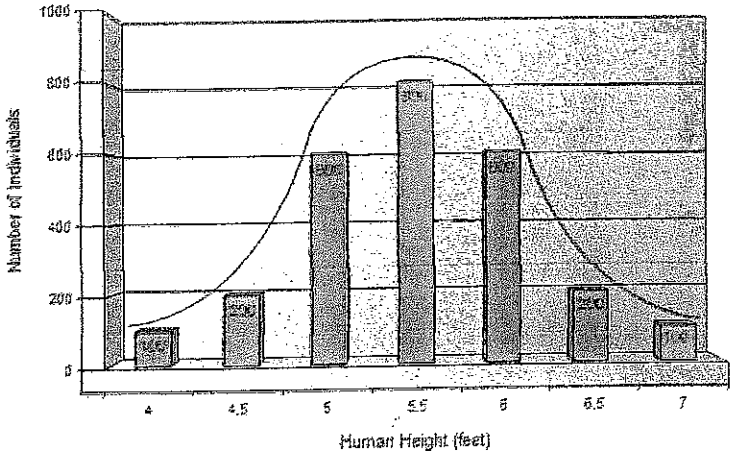

THE REASON FOR THE FOCUS ON THESE TRAITS IS THAT FEMALES INHERIT A PAIR OF GENES FOR ANY TRAIT ON THE X CHROMOSOME BUT MALES ONLY INHERIT ONE. AN EXAMPLE FOR THIS TYPE OF TRAIT WOULD BE COLORBLINDNESS. IT IS A SEX-LINKED RECESSIVE TRAIT AND OBSERVING THE PUNNETT SQUARE BELOW SHOWS WHY MORE MALES THAN FEMALES ARE COLORBLIND.

Punnett Square for Color Blindness

| | $X^B$ | $X^b$ |
|---|---|---|
| $X^B$ | $X^BX^B$ | $X^BX^b$ |
| $Y$ | $X^BY$ | $X^bY$ |

B = Normal
b = Color Blind

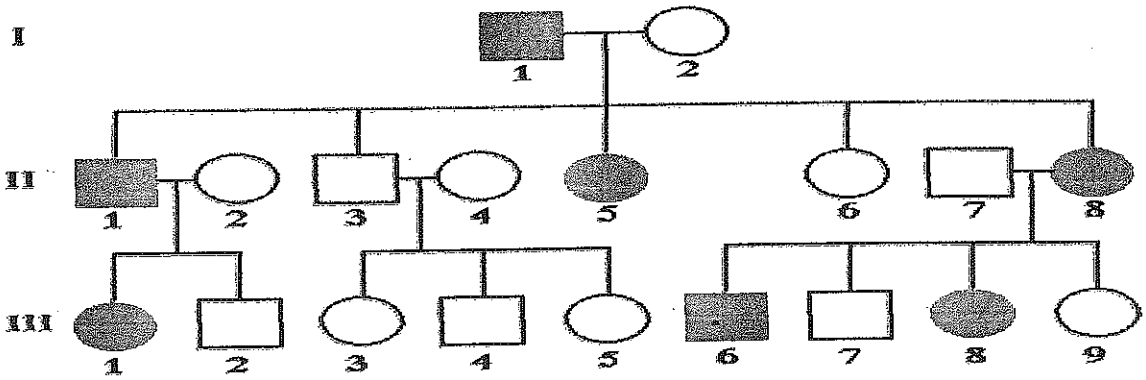
Polygenic Traits – These are traits in which many genes blend together to produce the trait. For most traits, we inherit one gene from our mother and one gene from our father. The resulting combination of two genes then determines the phenotype of the trait. With polygenic traits, we inherit multiple genes from each parent for just one trait. An example of a polygenic trait is human height. There aren't just two or three human heights. We have a broad range from very short to very tall. That's because our height results from many genes inherited from both mother and father all blending together to comprise this one trait.



## Human Genetics

Studying human genetics is not easy for several reasons. We can't tell two people that they need to have a child together simply because they possess the traits that are being studied. When we do have children, we tend to have very few and we have a long period of time between generations. One method of studying the movement of human genes through generations is with pedigree charts.

Pedigree charts uses circles (females) and squares (males) to depict a trait moving through generations of a family. This can sometimes be used to determine the type of trait it is and often the genotypes of the people within the family.




Pedigree 1. An idealized pedigree of a family with hypercholesterolemia, an autosomal dominant disease where the heterozygote has a reduced number of functional low density lipoprotein receptors.

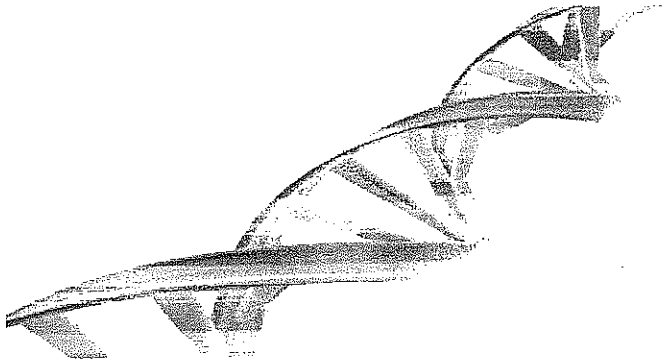
Twin Studies are another tool used by researchers. In studying the issue of nature vs. nurture, scientists will try to find identical twins that have been separated at birth. These twins have the same genetics (nature) but, having been raised by different families, they've had different environmental experiences (nurture). Similarities between the twins can then be attributed to genes and differences to the environment.

# Everything you really, really need to know about...

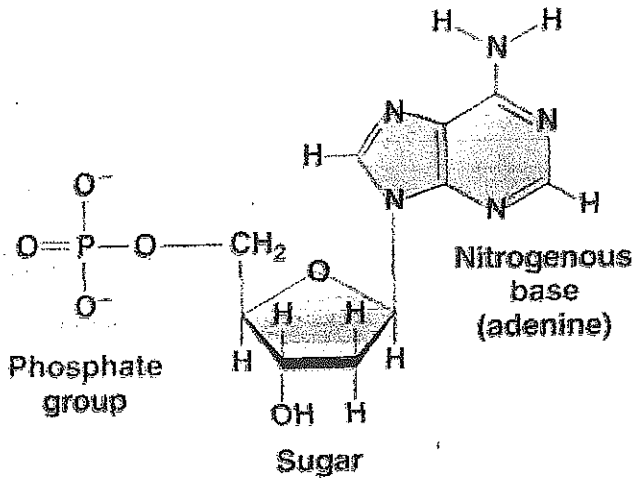
# Heredity II

## DNA Structure

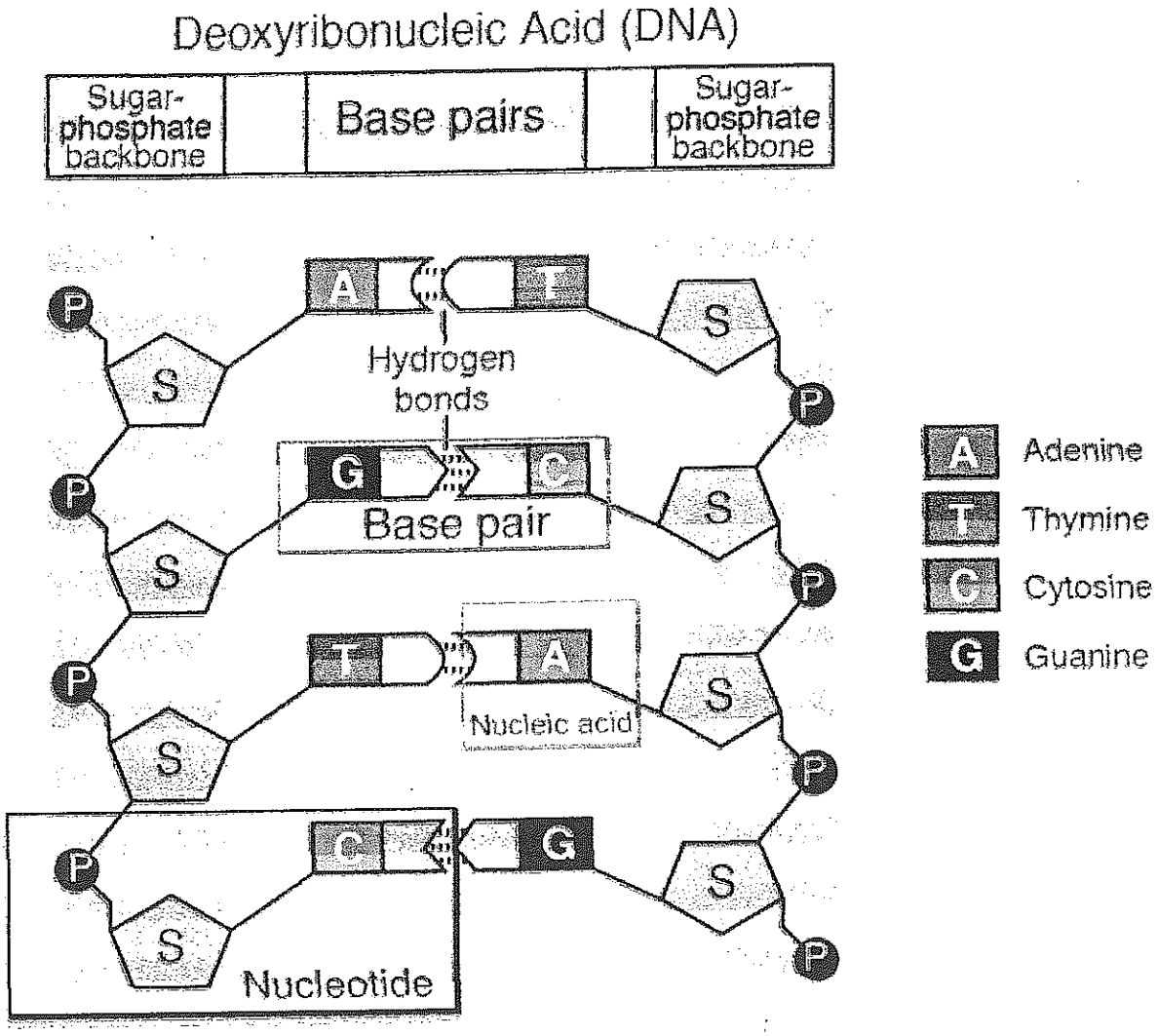
In 1953, the world of genetics changed as the structure of DNA (Deoxyribonucleic Acid), which comprises the genetic material within our chromosomes, was discovered by James Watson and Francis Crick. They determined that the general shape of DNA was in the form of a double helix.



The monomers that compose the double helical strand are called nucleotides and each nucleotide is composed of a molecule of deoxyribose (sugar), a molecule of phosphate and one of four different nitrogenous bases, either adenine, guanine, thymine or cytosine.



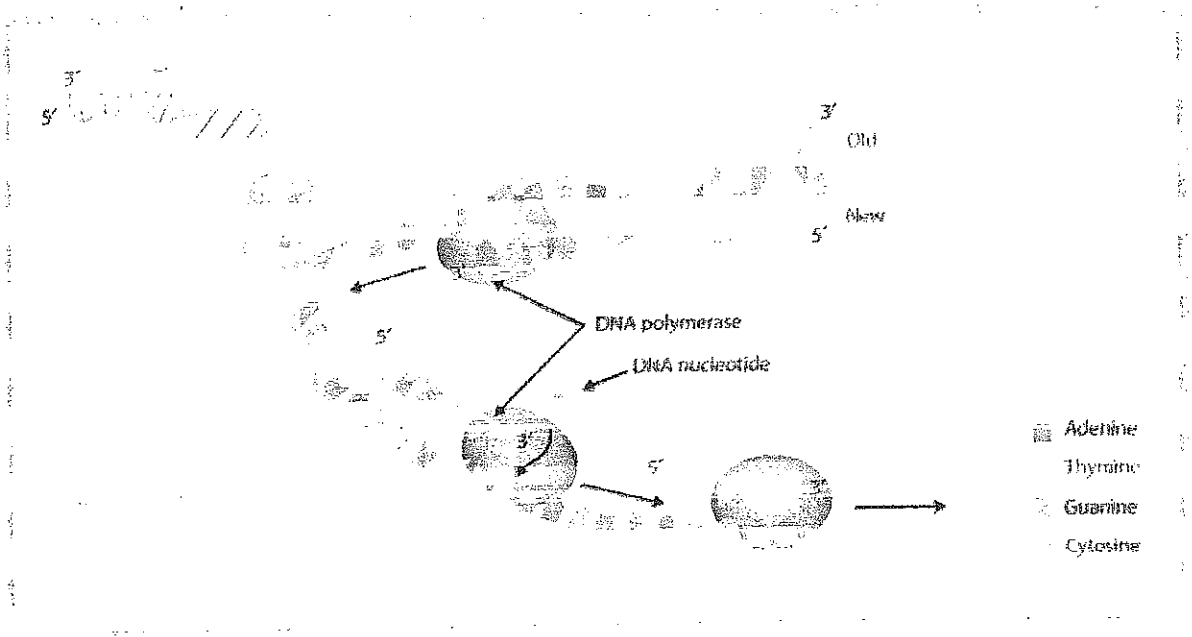

THE NUCLEOTIDES ARE THEN BONDED TOGETHER SO AS TO FORM THE SHAPE OF A "TWISTED LADDER". THE SIDES OF THE LADDER ARE ALTERNATING SUGARS AND PHOSPHATES AND THE RUNGS OF THE LADDER ARE COMPOSED OF THE NITROGENOUS BASES. THE NITROGENOUS BASES LINK TOGETHER VIA HYDROGEN BONDS INTO WHAT ARE CALLED <u>BASE PAIRS</u>. BASE PAIRS ARE IMPORTANT IN THAT ONLY ADENINE WILL BOND TO THYMINE AND ONLY CYTOSINE WILL BOND TO GUANINE.




## DNA Replication

As was learned in our studying of the cell cycle, during the S portion of interphase, all chromosomes must be replicated. Since chromosomes are composed of DNA, this means that all of the DNA must be copied exactly in preparation for a cell to divide into two cells. This is accomplished through what is called semi-conservative replication. In semi-conservative replication, an enzyme (DNA Helicase) will break the hydrogen bonds between the base pairs, separating the DNA strand into

two templates. Then, another enzyme, DNA Polymerase, will add free-floating DNA nucleotides to each of the templates, following the base pairing rules ( A-T, C-G). When complete, there are two strands of DNA, each with an "old" section and each with a "new" section.

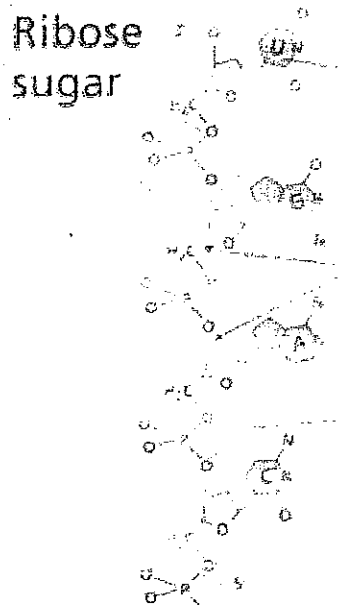



## RNA Structure

In addition to DNA, there is a second type of nucleic acid called RNA (Ribonucleic Acid). It is different than DNA in several important ways.

DIFF WITH DNA

1. It's single-stranded instead of double stranded.
2. Although it's still composed of nucleotides, the nucleotides contain the sugar ribose instead of the sugar deoxyribose.
3. Although RNA has the nitrogenous bases of adenine, cytosine and guanine, it does n't have the base thymine. Instead, it has the base uracil, which will bond to adenine.
4. There are specific types of RNA.....mRNA (messenger), tRNA (transfer) and rRNA (ribosomal).




**Components of Nucleic Acids**

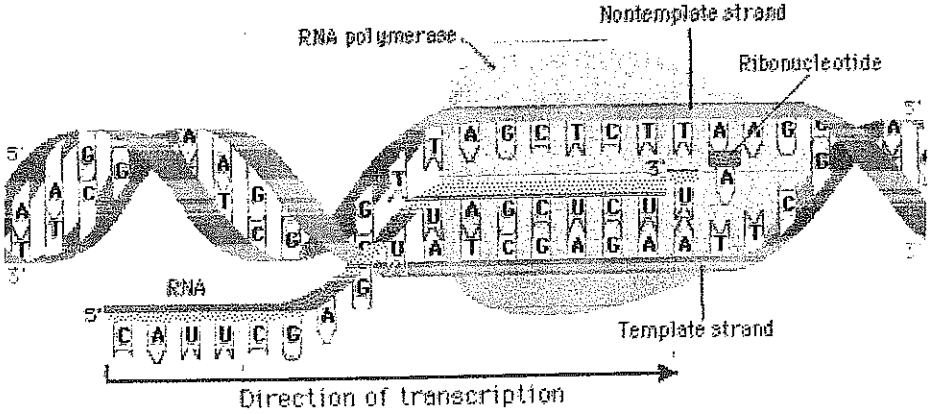
| | DNA only | DNA & RNA | | RNA only |
|---|---|---|---|---|
| Nitrogen Bases | Thymine | Adenine | Guanine | Cytosine | Uracil |
| Sugars & Phosphate | 2-Deoxyribose | Phosphate | | Ribose |

**Both DNA and RNA are necessary in order for your cells to go through what is called protein synthesis.**

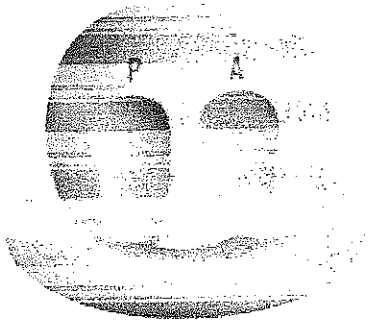
**Protein Synthesis**

PROTEIN SYNTHESIS IS THE "CENTRAL DOGMA" OF MOLECULAR BIOLOGY. YOUR DNA IS A CODE, VERY SIMILAR TO A TELEPHONE NUMBER. IF YOU PUSH THE CORRECT SEQUENCE OF NUMBERS, YOU END UP WITH THE CORRECT PERSON ANSWERING THE PHONE. IF YOU PUSH THE WRONG NUMBERS OR YOU PUSH THE NUMBERS IN THE WRONG ORDER, THE WRONG PERSON ANSWERS. TELEPHONES USE A CODE WITH TEN DIFFERENT DIGITS (0 – 9). YOUR BODY'S CELLS USE DNA AS THEIR CODE TO MAKE THE CORRECT PROTEINS FOR YOUR BODY TO FUNCTION, BUT INSTEAD OF A TEN DIGIT CODE, YOUR CELLS USE A FOUR LETTER CODE (A, T, C, G). IF IT READS THE CORRECT LETTERS, IN THE CORRECT ORDER, THE CORRECT PROTEIN IS PRODUCED. THIS PROCESS HAS TWO STEPS....TRANSCRIPTION AND TRANSLATION.

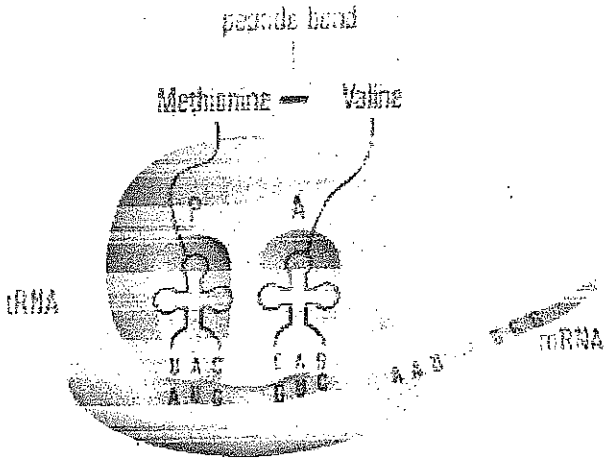
1. TRANSCRIPTION – IN TRANSCRIPTION, THE ENZYME, RNA POLYMERASE UNWINDS THE DNA WITHIN A GENE AND ADDS FREE-FLOATING RNA NUCLEOTIDES TO THE DNA SENSE STRAND (OR TEMPLATE STRAND). IN DOING SO, IT CREATES MRNA (MESSENGER).




THE MRNA THEN LEAVES THE NUCLEUS, WHERE TRANSCRIPTION TOOK PLACE, AND HEADS TO A RIBOSOME, WHICH IS THE SITE OF PROTEIN PRODUCTION. THE RIBOSOME IS COMPOSED OF BOTH PROTEIN AND RRNA (RIBOSOMAL). A RIBOSOME HAS TWO PARTS, THE LARGE AND SMALL SUBUNITS, AND THE MRNA ENTERS THE SMALL SUBUNIT. THE LARGE SUBUNIT THEN ATTACHES ON, IN WHICH THERE ARE TWO SPACES FOR TRNA (TRANSFER) MOLECULES. PICTURED BELOW ARE THE LARGE AND SMALL SUBUNITS OF A RIBOSOME, WITH ITS TWO SITES (P AND A) FOR TRNA MOLECULES.




2. TRANSLATION – WITH THE MRNA EMBEDDED WITHIN THE SMALL SUBUNIT, TRNA MOLECULES ENTER THE TWO SITES WITHIN THE LARGE SUBUNIT OF THE RIBOSOME. THE THREE BASES AT THE BOTTOM END OF THE TRNA (CALLED THE ANTICODON) MUST MATCH UP VIA THE BASE PAIRING RULES WITH EACH SET OF THREE BASES ON THE MRNA (CALLED THE CODON). ON THE OPPOSITE END OF THE TRNA IS AN AMINO ACID, THE MONOMER OF PROTEINS. AS TWO TRNA'S LINE UP NEXT TO EACH OTHER WITHIN THE LARGE SUBUNIT, A PEPTIDE BOND FORMS BETWEEN THE AMINO ACIDS, LINKING THEM TOGETHER. THE RIBOSOME THEN MOVES ALONG THE MRNA CHAIN, BRINGING IN MORE AND MORE TRNA MOLECULES AND THUS ADDING MORE AND MORE AMINO ACIDS TO THE EVER-GROWING CHAIN. ULTIMATELY, A PROTEIN IS FORMED.




IN ORDER TO DETERMINE THE CORRECT SEQUENCE OF AMINO ACIDS, A CHART CAN BE USED TO READ THE MRNA CODONS. THE SAME CHART CAN BE USED FOR ALL LIVING THINGS AS DNA PROVIDES THE GENETIC CODE FOR ALL LIFE.

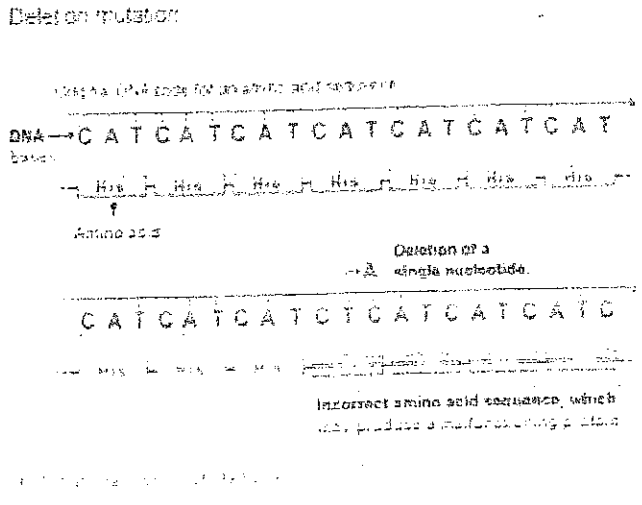
## Codons Found in Messenger RNA

NOT DNA

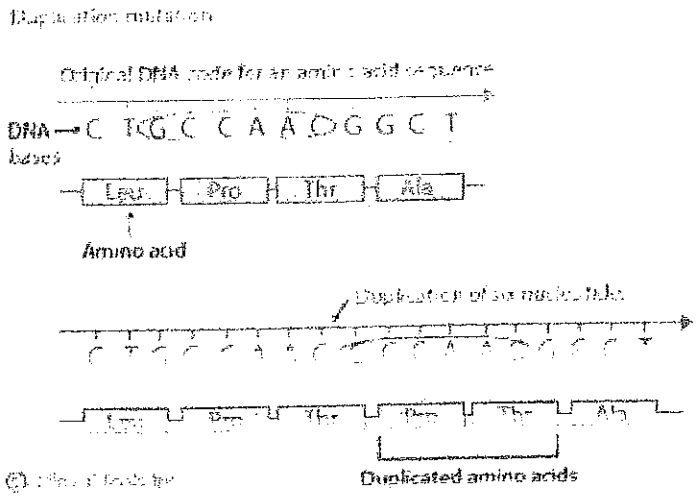
| First Base | Second Base: U | Second Base: C | Second Base: A | Second Base: G | Third Base |
|---|---|---|---|---|---|
| U | Phe | Ser | Tyr | Cys | U |
| | Phe | Ser | Tyr | Cys | C |
| | Leu | Ser | Stop | Stop | A |
| | Leu | Ser | Stop | Trp | G |
| C | Leu | Pro | His | Arg | U |
| | Leu | Pro | His | Arg | C |
| | Leu | Pro | Gln | Arg | A |
| | Leu | Pro | Gln | Arg | G |
| A | Ile | Thr | Asn | Ser | U |
| | Ile | Thr | Asn | Ser | C |
| | Ile | Thr | Lys | Arg | A |
| | Met | Thr | Lys | Arg | G |
| G | Val | Ala | Asp | Gly | U |
| | Val | Ala | Asp | Gly | C |
| | Val | Ala | Glu | Gly | A |
| | Val | Ala | Glu | Gly | G |

**MUTATIONS – NOW THAT YOU UNDERSTAND PROTEIN SYNTHESIS, YOU CAN SEE THAT IT ALL TRACES BACK TO THE ORIGINAL CODE WITHIN THE DNA. THEREFORE, MOST CHANGES TO THAT CODE, LEAD TO THE WRONG PROTEIN BEING PRODUCED. SOME OF THOSE POSSIBLE CHANGES INCLUDE...**

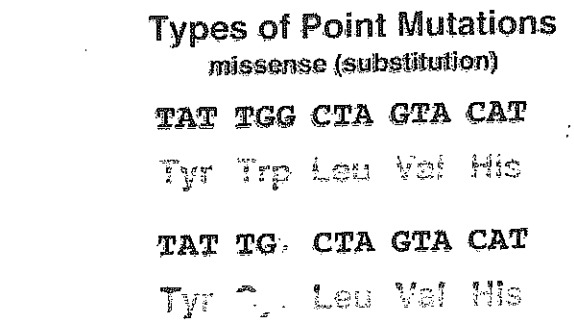
1. **DELETION – ONE OR MORE BASES IS DELETED. (FRAMESHIFT MUTATION)**



2. DUPLICATION – ONE OR MORE BASES IS REPEATED. (FRAMESHIFT MUTATION)




3. REPLACEMENT – ONE BASE IS REPLACED BY ANOTHER. (POINT MUTATION)




4. INVERSION – A SERIES OF BASES IS TURNED AROUND.

Biotechnology in conjunction with genetics is an ever-expanding field of study. We touch on just a few aspects in this review.

1. The Human Genome Project - The Human Genome Project (HGP) was one of the great feats of exploration in history — an inward voyage of discovery rather than an outward exploration of the planet or the cosmos; an international research effort to sequence and map all of the genes - together known as the genome - of members of our species, *Homo sapiens*. Completed in April 2003, the HGP gave us the ability, for the first time, to read nature's complete genetic blueprint for building a human being.

2. Genetic Engineering - Genetic engineering refers to a set of technologies that are being used to change the genetic makeup of cells and move genes across species boundaries to produce novel organisms. The techniques involve highly sophisticated manipulations of genetic material and other biologically important chemicals.

3. Stem Cells – Stem cells are undifferentiated cells that still have the ability to become almost any specific cell type. Due to this undifferentiated potential, stem cells have the possibility of being used in many types of therapies.

4. Cloning - DNA information from the nucleus of a donor adult cell is copied into a cell whose nucleus (thus also its genetic material) has been removed. Chemicals or electric current are used to stimulate cell division. Once the cells start dividing and the embryo reaches a suitable stage, it is planted into the uterus of a female host where it develops until birth.

The common theme among all these types of biotechnology is that of ethics. Should we pursue such technologies or should we not?

# Genetics

Module B, Anchor 2

**Key Concepts:**

- An individual's characteristics are determines by factors that are passed from one parental generation to the next.
- During gamete formation, the alleles for each gene segregate from each other so that each gamete carries only one allele for each gene.
- Punnett squares use mathematical probability to help predict the genotype and phenotype combinations in genetic crosses.
- The principle of independent assortment states that genes for different traits can segregate independently during the formation of gametes.
- Mendel's principles of heredity, observed through patterns of inheritance, form the basis of modern genetics.
- Some alleles are neither dominant nor recessive. Many genes exist in several different forms and are therefore said to have multiple alleles. Many traits are produced by the interaction of several genes.
- Environmental conditions can affect gene expression and influence genetically determined traits.
- The DNA that makes up genes must be capable of storing, copying, and transmitting the genetic information in a cell.
- DNA is a nucleic acid made up of nucleotides joined into long strands or chains by covalent bonds.
- DNA polymerase is an enzyme that joins individual nucleotides to produce a new strand of DNA.
- Replication in most prokaryotic cells starts from a single point and proceeds in both directions until the entire chromosome is copied.
- In eukaryotic cells, replication may begin at dozens or even hundreds of places on the DNA molecule, proceeding in both directions until each chromosome is completely copied.
- The main differences between DNA and RNA are that (1) the sugar in RNA is ribose instead of deoxyribose; (2) RNA is generally single-stranded, not double-stranded; and (3) RNA contains uracil in place of thymine.
- In transcription, segments of DNA serve as templates to produce complementary RNA molecules.
- The genetic code is read three "letters" at a time, so that each "word" is three bases long and corresponds to a single amino acid.
- Ribosomes use the sequences of RNA codons to assemble amino acids into polypeptide chains.
- The central dogma of molecular biology is that information is transferred from DNA to RNA to protein.
- Mutations are heritable changes in genetic information.
- The effects of mutations on genes vary widely. Some have little or no effect; some produce beneficial variations. Some negatively disrupt gene function.
- Mutations often produce proteins with new or altered functions that can be useful to organisms in different or changing environments.

- Human genes follow the same Mendelian patterns of inheritance as the genes of other organisms. Many human traits follow a pattern of simple dominance. The alleles of other human genes display codominant inheritance. Because the X and Y chromosomes determine sex, the genes located on them show a pattern of inheritance called sex-linkage.
- Changes in a gene's DNA sequence can change proteins by altering their amino acid sequences, which may directly affect one's phenotype.
- If nondisjunction occurs during meiosis, gametes with an abnormal number of chromosomes may result, leading to a disorder of chromosome numbers.
- Recombinant DNA technology – joining together DNA from 2 or more sources – makes it possible to change the genetic composition of living organisms.
- Transgenic organisms can be produced by the insertion of recombinant DNA into the genome of a host organism.
- Ideally, genetic modification could lead to better, less expensive, and more nutrition food as well as less harmful manufacturing processes.
- Recombinant DNA technology is advancing the prevention and treatment of disease.
- DNA fingerprinting analyzes sections of DNA that vary widely from one individual to another.

**Vocabulary:**

| | | | |
|---|---|---|---|
| Genetics | fertilization | allele | principle of dominance |
| Trait | segregation | hybrid | gene |
| Gamete | probability | genotype | phenotype |
| Homozygous | heterozygous | codominance | independent assortment |
| Multiple allele | polygenic trait | base pairing | Incomplete dominance |
| Replication | DNA polymerase | nucleotides | nucleic acid |
| RNA | messenger RNA | ribosomal RNA | RNA polymerase |
| Transfer RNA | transcription | polypeptide | genetic code |
| Codon | anticodon | translation | gene expression |
| Biotechnology | PCR | genetic marker | transgenic |
| Recombinant DNA | clone | plasmid | gene therapy |
| DNA fingerprinting | genome | autosome | sex-linked gene |
| Sex chromosome | nondisjunction | | |

Key

# Genetics

Module B, Anchor 2

**Basic Mendelian Genetics:**

1. Different forms of a gene are called:
   *C. alleles*

2. Organisms that have two identical alleles for a particular trait are said to be:
   *C. homozygous*

3. What is the difference between a dominant and recessive allele?
*A dominant allele shows whenever it is present. A recessive allele shows only if no dominant alleles are present.*

4. State the principle of dominance. How does this explain the phenotype of heterozygous organisms?
*Some alleles are dominant, others are recessive. Heterozygous organisms have one dominant and one recessive allele. The dominant allele takes over and shows over the recessive allele.*

According to this principle, under what conditions will an organism show a recessive phenotype?
*When no dominant alleles are present, as in tt.*

5. State the principle of segregation. How does this explain how two heterozygous organisms can produce homozygous offspring?
*Alleles segregate during the formation of gametes. Each organism contains two alleles for each trait. These alleles go into different gametes during meiosis. The heterozygous parent has Tt as the genotype. The T separates from the t when gametes are formed. This allows the T or t to pair up with another letter, giving homozygous phenotypes.*

6. State the principle of independent assortment.
*Alleles segregate independently during the formation of gametes.*

7. What is a punnett square? How are punnett squares used in genetics?
*Punnett squares show the possible offspring of a cross. They are used to predict outcomes of crosses.*

8. Show the cross between two guinea pigs. One is heterozygous for black color, the other is white. Record the genotypic and phenotypic ratios of the offspring.

| *Black – Tt* | | *T* | *t* |
|---|---|---|---|
| *White tt* | *t* | *Tt* | *tt* |
| | *t* | *Tt* | *tt* |

*genotype ratio: 1:1 ratio of Tt, tt*
*phenotype ratio:1:1 ratios or black to white*

**Other Patterns of Inheritance:**

1. Compare and contrast codominance, incomplete dominance, and complete dominance.

*Codominance – both alleles are equally dominant, both show up in the heterozygous offspring*
*Incomplete dominance – one allele is dominant, but not completely; heterozygous offspring show a blend of parental traits*
*Complete dominance – one allele is completely dominant over the other, heterozygotes show Dominant trait*

2. Compare and contrast multiple alleles and polygenic traits.

*Multiple alleles – one gene controls the trait, more than two alleles exist for the trait*
*Polygenic traits – multiple genes control the trait*

*In both instances, more phenotypes are present than with a more simple inheritance pattern*

3. Why do multiple alleles and polygenic traits produce many different phenotypes for a trait?

*Multiple alleles have more options for alleles, producing more phenotypes. Polygenic traits show a continuum of traits as they are controlled by multiple genes. Any alteration of any allele for any gene results in a slight change in phenotype.*

4. Can a trait show more than one inheritance pattern?

*Yes. For example, blood type in humans shows multiple alleles, codominance, and complete dominance.*

5. You would like to determine if a plant shows codominance or incomplete dominance. What type of cross would you perform and why? Explain how you would know whether the gene involved showed co- or incomplete dominance.

*Breed the two homozygous plants to get a hybrid plant. If both traits show up, the plant shows codominance. If a blend shows the plants show incomplete dominance. For example, you breed a red plant and a white plant. If the hybrid offspring are red with white spots, they show codominance. If the offspring are pink, they show incomplete dominance.*

6. What is the relationship between genes and the environment?

*Gene expression is affected by the environment. For example, a set of identical twins may be predisposed genetically to heart disease. One twin exercises and eats well. They do not develop heart disease due to their lifestyle. The other twin smokes and eats poorly. They do develop heart disease.*

**DNA Structure:**

1. Thoroughly describe the structure of a DNA molecule.

*DNA is composed of nucleotides; nucleotides are composed of sugar, phosphate, and nitrogenous base. DNA has a double helix shape. The sides of the helix are sugar-phosphate backbone. They are composed of deoxyribose and phosphate. The "rungs" of the helix are composed of base pairs. Adenine bonds with thymine and cytosine with guanine. The two sides of the molecule run antiparallel. The sides are held together with covalent bonds. The base pairs are held together with hydrogen bonds.*

2. What are the base pairing rules? If the percentage of adenine in a sample goes up 5 %, what will happen to the percentage of thymine? What will happen to the percentage of guanine?
*Adenine – thymine*
*Cytosine – guanine*
*Thymine will also go up 5%. Guanine will go down 5%.*

3. What are the three roles of DNA? Explain how the structure of DNA aids in each role.
*Store information – stores information in the sequence of the base pairs*
*Copy and transmit information – the hydrogen bonds between bases break easily, exposing the bases to be copied. The covalent bonds hold the two sides together during replication. This allows the molecule to be copied and passed on to offspring.*

4. What happens when a piece of DNA is missing?
*C. Genetic information is lost*

**DNA Replication:**
1. Thoroughly describe the process of DNA replication.
*The DNA molecule is unwound. The hydrogen bonds between the bases are broken. Enzymes match up bases according to the base-pairing rules. The leading and lagging strands are assembled in opposite directions. Once the strands are fully replicated, the new DNA molecules are proof-read.*

2. Compare and contrast DNA replication in prokaryotes and eukaryotes.
*In prokaryotes, DNA replication starts at a single point and proceeds in both directions. In eukaryotes, replication starts in multiple locations.*

3. What is base pairing and how is it involved in DNA replication?
*A=T C=G This ensures that the two DNA strands are identical, as A must bond with T and C must bond with G.*

4. When a DNA molecule is replicated, how do the new molecules compare to the original molecule? How does replication ensure that this occurs?
*Each new molecule is comprised of one new strand and one original strand. The two molecules are identical to each other and to the template strand. Since the old molecule is used as a template and the base-pairing rules must be followed, the strands are identical.*

**Transcription:**
1. Thoroughly describe the process of transcription.
*The DNA strand is unwound starting at the promoter region. RNA polymerase binds to the promoter region on one DNA strand and begins matching base pairs. This continues until the termination sequence is reached. The RNA strand breaks off the DNA and the DNA reforms. The RNA is then edited.*

2. What is made during transcription?
*RNA*

3. Why is transcription necessary for protein synthesis?
*Each DNA molecule contains many genes, each coding for a different protein. RNA contains only the gene for one protein. Also, DNA does not leave the nucleus. Protein synthesis occurs in the cytoplasm. RNA is capable of traveling to the cytoplasm for protein synthesis.*

4. Suppose you start with a DNA strand ACCGTCACG. Use the rules of base pairing to determine the complementary RNA strand.
*UGGCAGUGC*

5. Compare and contrast DNA and RNA structure. How does the different structure of RNA relate to its different function in cells?
*Both –made of nucleotides; contain phosphate, adenine, cytosine, guanine*
*RNA – contains ribose and uracil; single-stranded; only one gene*
*DNA – contains deoxyribose and thymine; double stranded, many genes*

6. Compare and contrast DNA replication and transcription.
*Both – DNA is unwound and bases are added*
*Replication – entire molecule is copied; template strand becomes part of new molecules*
*Transcription – only part of one strand is copied; template strand rejoins and is left as it was*

7. Describe the process of RNA editing.
*RNA is cut into introns and exons. Exons are used to create final RNA molecule. The same RNA strand can be cut and rejoined in multiple ways, producing different final RNA from the same original molecule.*

**Protein Synthesis:**
1. List the three types of RNA. Describe the role of each in protein synthesis.
*Messenger RNA – carries the message from DNA to be used to create proteins*
*Ribosomal RNA – makes up ribosomes, the site of protein synthesis*
*Transfer RNA – reads the mRNA and matches up complementary amino acids*

2. What is made during protein synthesis?
*protein*

3. What are codons and anticodons? How do they work together during protein synthesis?
*Codons – sequences of three bases on mRNA*
*Anticodon – sequence of three bases on tRNA complementary to mRNA codon*

*The anticodons and codons are complementary to each other. The tRNA matches up with the mRNA. On the opposite end of the tRNA is an amino acid. This is how the tRNA translates the mRNA into an amino acid sequence.*

4. Thoroughly describe the process of protein synthesis.
*The mRNA is transcribed in the nucleus. It travels to the cytoplasm, where it binds to the ribosome. The mRNA moves through the A and P sites of the ribosome. The tRNA molecules*

*match up with the exposed codons on the mRNA. The amino acids on the other end of each tRNA bind together to form a polypeptide. When the stop codon is reached, the polypeptide is released.*

5. Explain why controlling the proteins in an organism controls the organism's characteristics.
*Proteins determine all of our traits. The order of amino acids in a protein determine how it functions. Any alteration in a protein will result in a change of loss of function for the characteristic it controls in the organism.*

6. What is the correct sequence of transfer of genetic information in most organisms?
*B. DNA, RNA protein*

7. What are the roles of endoplasmic reticulum and ribosomes in protein synthesis?
*Rough ER houses ribosomes. Ribosomes are the site of protein synthesis. The rough ER also modifies proteins after translation.*

8. Does protein synthesis occur in all organisms?
*Yes.*

**Mutation:**
1. What is a mutation?
*A heritable change in the genetic material of an organism.*

2. What are some causes of mutation?
*Carcinogens, mistakes in replication, etc.*

3. List and describe the types of gene mutations.
*Substitution – one base is switched for another*
*Insertion – one base is added to the sequence*
*Deletion – one base is removed from the sequence*
*Insertion and deletion mutations fall into the category of frameshift mutations.*

4. What types of gene mutations are most severe? Why?
*Frameshift mutations alter more codons, and thus have a more severe effect on the function of the protein. If substitution mutations result in a stop codon they are also severe.*

5. List and describe the types of chromosome mutations.
*Deletion – gene deleted*
*Duplication – extra copy of gene included*
*Inversion – gene order is reversed*
*Translocation – genes from nonhomologous chromosomes are switched*

6. How does the repetitive nature of the genetic code help to reduce the damage done by mutations?

*Multple codons code for the same amino acid. Therefore, a mutation may change a base without changing the amino acid for which that codon codes. This would result in no change in the protein function.*

7. One difference between a gene mutation and a chromosomal mutation is
   *C. A chromosomal mutation can affect the number of chromosomes in a cell*

8. Most mutations
   *A. have no effect on the organism*

**Human Heredity:**

1. A normal human zygote contains
   *B. 46 chromosomes*

2. What is a nondisjunction? How does a nondisjunction cause chromosome disorders?
*Nondisjunction occurs when the chromosomes fail to separate properly during meiosis. This results in a gamete having too many or too few of a particular chromosome. If this gamete is fertilized, the resulting organism will have a chromosome disorder.*

3. What is the difference between autosomes and sex chromosomes?
*Sex chromosomes determine gender. Autosomes are all the remaining chromosomes.*

4. What are sex-linked traits? How are they inherited differently between males and females?
*Traits on the x chromosome. Males have one x chromosome, while females have two. This means that a male will show any trait on its X, even a recessive one. Females still require two copies of the recessive X to show such a trait. Therefore, x-linked traits are more common in males than in females.*

5. Which of the following forms a Barr body:
   *C. one of the X chromosomes in a female cell*

**Genetic Engineering:**

1. Organisms that contain genes from other organisms are called
   *A. transgenic*

2. Describe what happens during a polymerase chain reaction. What is the use of PCR?
*The first step in using the polymerase chain reaction method to copy a gene is to heat a piece of DNA, which separates its two strands. Then, as the DNA cools, primers bind to the single strands. Next, DNA polymerase starts copying the region between the primers. These copied can serve as templates to make still more copies.*

3. Explain what genetic markers are and describe how scientists use them.
*A gene that makes it possible to distinguish bacteria that carry a plasmid from those that don't carry it. Scientists use genetic markers to determine if a transgenic attempt was successful.*

4. What are transgenic organisms? What are the potential benefits of transgenic organisms? Concerns?
*Organisms that contain genetic material from other species. Transgenic organisms may improve agricultural yields, reduce pesticide use, manufacture human proteins, etc. There is some fear over unintended side-effects. For example, crops may spread pesticide resistance to weed species. Allergic reactions or other illnesses may occur, transgenic organisms are patented which reduces the free nature of food supplies, etc.*

5. How can genetic engineering impact human health?
*Genetic engineering could help produce human proteins for use in medicine. There is also some concern over an increase in disease or allergies.*

6. Describe the uses of DNA fingerprinting.
*Establishing family relationships, crime scenes, etc.*

7. A gene that makes it possible to distinguish a bacterium that has been transformed from one that has not is:
*C. a genetic marker*

8. Explain what a DNA probe is and describe how it could be used to identify a person who has an allele for a genetic disorder.
*Small segments of DNA that help locate a particular gene in a long DNA sequence. They could be used to analyze the individual's DNA to determine the presence, or lack therof, of a gene.*

# Everything you really, really need to know about...

# Evolution

Biological evolution, simply put, is descent with modification. This definition encompasses small-scale evolution (changes in gene frequency in a population from one generation to the next) and large-scale evolution (the descent of different species from a common ancestor over many generations). Evolution helps us to understand the history of life.

Biological evolution is not simply a matter of change over time. Lots of things change over time: trees lose their leaves, mountain ranges rise and erode, but they aren't examples of biological evolution because they don't involve descent through genetic inheritance.

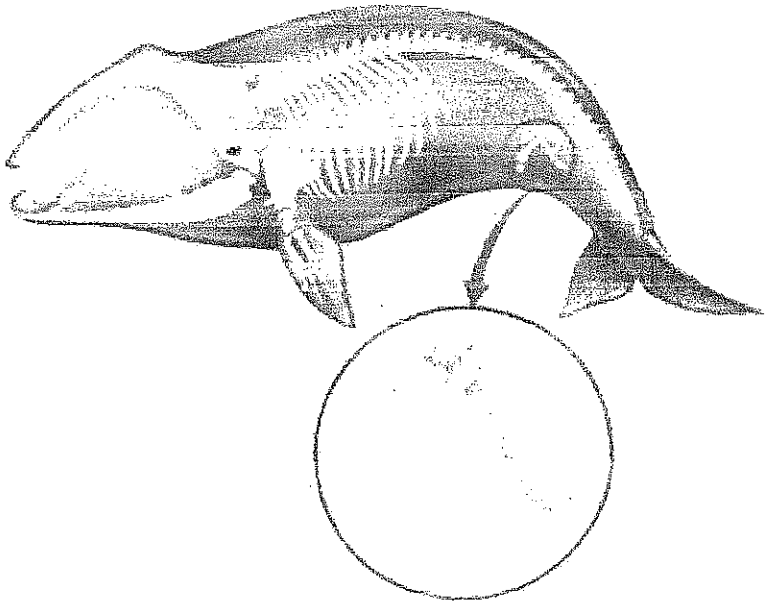
The central idea of biological evolution is that all life on Earth shares a common ancestor, just as you and your cousins share a common grandmother.

Through the process of descent with modification, the common ancestor of life on Earth gave rise to the fantastic diversity that we see documented in the fossil record and around us today. Evolution means that we're all distant cousins: humans and oak trees, hummingbirds and whales.

## Evidence

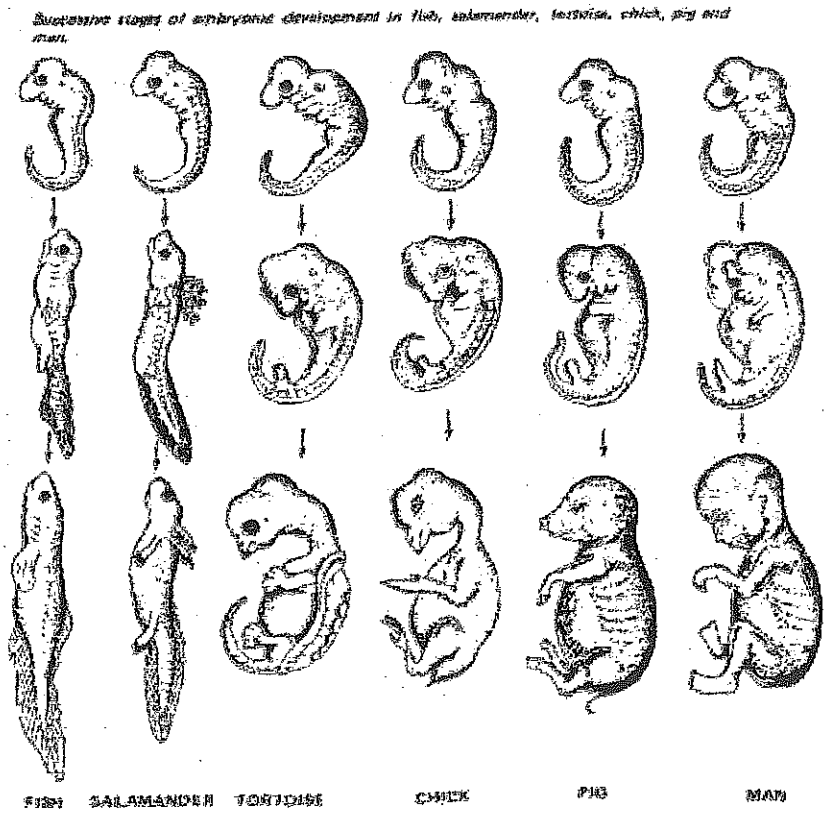
Fossils – Fossils can be used as a record of the physical features that comprised living things in the past. They can therefore document the physical changes that living things have gone through over time. In order to do this, it's usually necessary to know the age of a fossil. Radioactive isotope dating, which uses the half-life of radioactive isotopes such as carbon-14, is a common way to accomplish this.

Vestigial Organs - These are body parts that are still present today, but seem to have no function. The classic example in humans would be the appendix. If it was a functional body part at one time, but is not anymore, this supports the idea of change. The picture below shows leg bones in a whale. This would be another example.



Homologous Structures - To get back to the idea that we're all related, we look at the concept of homologous structures. These are body parts in different organisms that have enough similarities to support the idea of a genetic relationship. Think, for instance, about the skeletons of most mammals. Although there are some differences in size and shape, the general design and function is still the same.


EMBRYOLOGY – STICKING WITH THE IDEA THAT WE'RE ALL RELATED, WE CAN LOOK AT THE PROCESS OF EMBRYOLOGICAL DEVELOPMENT. IN COMPARING DIFFERENT SPECIES, IT SEEMS THERE ARE A LOT OF COMMONALITIES ABOUT THE WAY WE DEVELOP.




DNA – THE MOST COMMON AND CURRENT METHOD OF SUPPORTING THE IDEA THAT LIFE HAS CHANGED OVER TIME AND THAT WE'RE ALL RELATED

is in the analysis of DNA. Similarities in DNA segments which lead to similar proteins, which lead to similar functions, support the fact that different species have diverged from common ancestors

## Darwin's Theory of Natural Selection

Although individuals prior to Darwin had attempted to explain the means by which life changed, it was Darwin's explanation in his book, "The Origin of Species" that has thus far stood the test of time. His explanation of the process can be simplified into four basic ideas.

1. Variety exists within species via sexual reproduction and mutations.

2. There is a limited amount of natural resources available to living things.

3. There are more individuals reproduced each year than can be sustained by this limited amount of natural resources.

4. As individuals struggle to live, they compete for these natural resources. Those individuals born with advantageous traits (due to their genes), will survive more often and therefore reproduce more, thus passing on those genes.

Therefore, it is the interaction between living things and their environment that causes changes to occur. As those changes add up, one species could give rise to two. The formation of a new species is called <u>speciation</u>. The most common type of speciation would be <u>divergent</u>. When members of the same species begin adapting to different environmental pressures, they diverge from each other. On the other hand, when two different species begin adapting to similar environmental pressures, they will sometimes become more alike. This is <u>convergent</u> evolution. Think about dolphins and fish. They both adapted to an aquatic environment where a tail and a dorsal fin were advantageous.

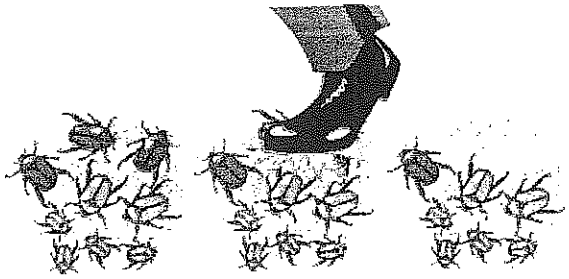
## Hardy-Weinberg Equilibrium

Hardy-Weinberg equilibrium is a principle stating that the genetic variation in a population will remain constant from one generation to the next in the absence of disturbing factors. When mating is random in a large population with no disruptive circumstances, the law predicts that both genotype and allele frequencies will remain constant because they are in equilibrium. In other words, no evolution will occur. This equilibrium can be disturbed in a number of different ways...

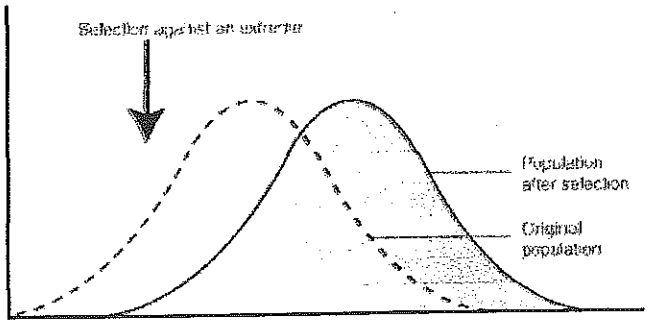
1. mutations – Mutations will disrupt equilibrium by adding new genes into a population.

2. migration – Migration will disrupt equilibrium because when individuals leave (emigrate) or enter (immigrate) a population, they bring their genes with them.

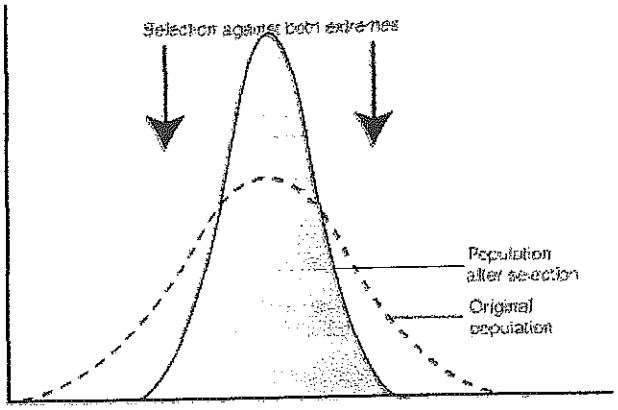
3. genetic drift – Genetic drift is the change in a small population due simply to chance.



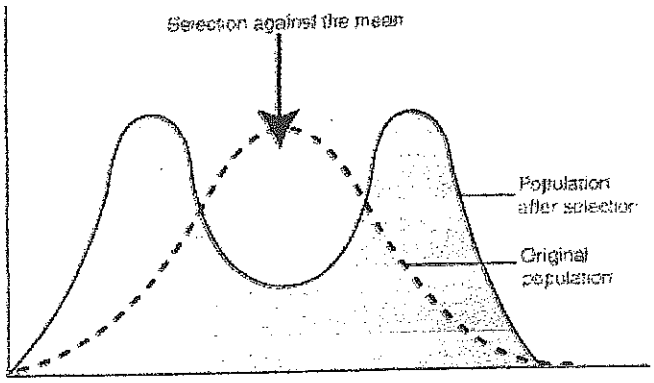
4. directional selection – This is the change in a population toward one extreme form of a trait.




5. stabilizing selection – This is the change in a population in which the average form of a trait becomes even more beneficial.

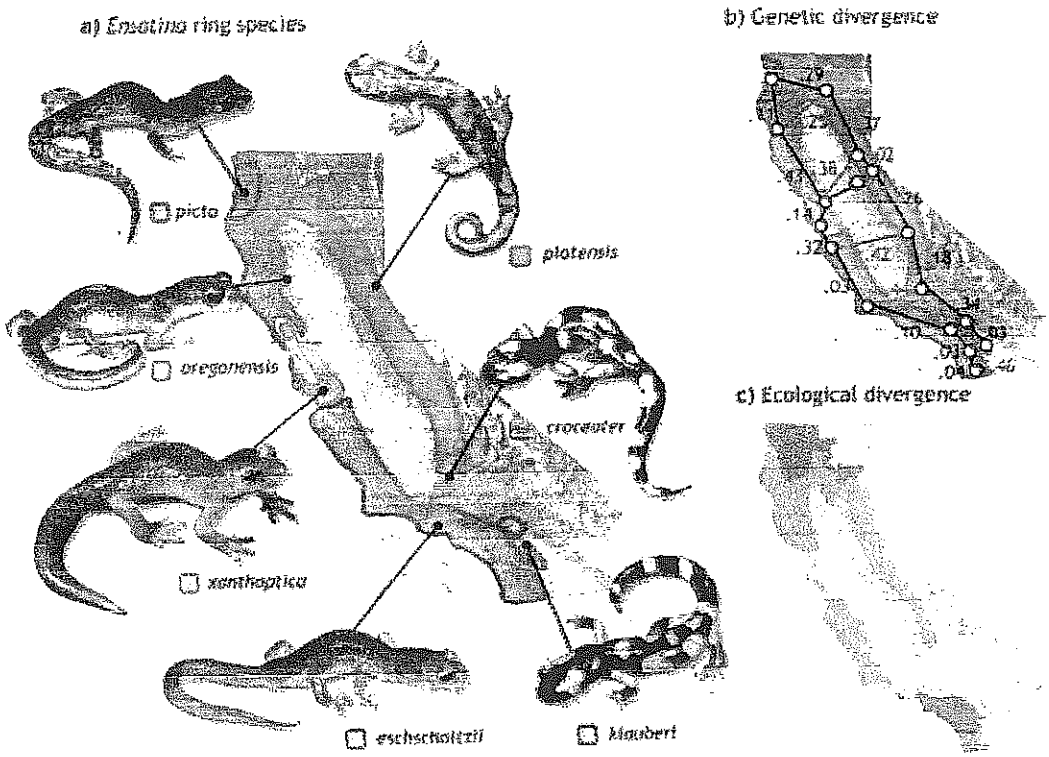



6. DISRUPTIVE SELECTION – THIS IS THE CHANGE IN A POPULATION WHEN BOTH EXTREME FORMS OF A TRAIT ARE BENEFICIAL.




7. SEXUAL SELECTION – SEXUAL SELECTION OCCURS WHEN INDIVIDUALS CHOOSE MATES BASED ON SPECIFIC CHARACTERISTICS. THOSE TRAITS THEN BECOME MORE PREVALENT WITH EACH PASSING GENERATION.

8. GEOGRAPHIC ISOLATION – THIS OCCURS WHEN ONE SEGMENT OF A POPULATION BECOMES PHYSICALLY ISOLATED FROM THE REST OF THE GROUP AND THEN ADAPTS TO ITS OWN ENVIRONMENT.




9. REPRODUCTIVE ISOLATION – REPRODUCTIVE ISOLATION TAKES ONE GENE POOL AND DIVIDES IT INTO MULTIPLE GENE POOLS. THIS DIVISION COULD BE BASED ON GEOGRAPHY, REPRODUCTIVE TIMING OR ANATOMICAL DIFFERENCES BETWEEN INDIVIDUALS. WHATEVER THE REASON, WHAT WAS ONCE ONE GENE POOL BECOMES MULTIPLE GENE POOLS, WHICH THEN ADAPT DIFFERENTLY.

Key

# Theory of Evolution

Module B, Anchor 3

**Basic Evolutionary Theory:**

1. Explain what the term "evolution" means. Provide an example.

*Evolution – change in species over time. Example – whales evolved from a land mammal into a marine mammal.*

2. What is natural selection? How does natural selection relate to evolution?

*The process by which some organisms survive and reproduce and others do not. Natural selection is the mechanism by which evolution occurs.*

3. Describe the conditions necessary for natural selection to occur.

*Struggle for existence – some organisms live, others die*
*Variation and adaptation – organisms are not all alike, organisms that are well-suited to survive in their environment possess adaptations*
*Survival of the fittest – those organisms best adapted will survive and reproduce at higher rates than those who are not.*

4. How does natural variation affect evolution? What are the sources of genetic variation within populations? Explain how each increases genetic variation.

*Without natural variation, all organisms would be identical. Therefore, no organism would have an advantage over another. If a change occurred in the ecosystem the entire species would be wiped out. Genetic variation arises from:*
*Recombination during sexual reproduction – genes are put into new combinations during Meiosis, producing new phenotypes*
*Mutation – mistakes are made in the copying of DNA*
*Lateral gene transfer – genes are passed between prokaryotic organisms*

5. How does natural selection account for the great diversity of organisms on the Earth today?

*Organisms adapted to their environments, creating a wide variety of organisms suited to various niches within various environments.*

6. An inherited characteristic that increases an organism's ability to survive and reproduce in its specific environment is called a(n)

*B. adaptation*

7. How well an organism survives and reproduces in its environment can be described as its

*A. fitness*

8. How are fitness and adaptation related?

*Fitness is the ability to survive and reproduce. This is made possible through the use of adaptations which make an organism better suited to its environment.*

9. Why is reproduction, as opposed to simply survival, needed for fitness?

*An organism cannot affect the species as a whole without producing offspring*

10. What is the role of the environment in determining fitness?
*The environment determines what traits make an organism more fit. For example, a trait allowing organisms to store water would increase fitness in a desert environment. In a rainforest, this trait would not be advantageous.*

11. Why does natural selection work only on heritable characteristics, as opposed to acquired characteristics?
*Acquired characteristics cannot be passed on to offspring, therefore they cannot affect the genetic make-up of the population. For example, dying your hair purple does not give you genes for purple hair. Therefore, your children will not have purple hair.*

12. What is the principle of common descent?
*All life is descended from one common ancestor.*

13. Use the theory of natural selection to explain how two unrelated organisms, such as sharks and dolphins, come to possess very similar physical adaptations.
*The organisms occupy similar niches in similar environments. Therefore, the same types of adaptations are advantageous to them. This would lead to the possession of very similar physical traits.*

**Natural Selection and Genetics:**
1. The combined genetic information of all members of a particular population forms a:
*A. gene pool*

2. How is evolution defined, genetically speaking?
*Change in allele frequency.*

3. Explain what the term relative frequency means, include an example illustrating your answer.
*The frequency of an allele in relation to the other alleles in the gene pool. For example, fur color in rabbits comes in grey and white. There are 65 grey alleles and 35 white alleles. The frequency of the grey allele is .65; the frequency of the white allele is .35.*

How does evolution change the relative frequency of alleles in a gene pool? Why does this happen?
*Natural selection selects against particular phenotypes. The frequency of the alleles controlling those phenotypes is decreased. The frequency of other alleles in the gene pool goes up in response.*

4. The frequency of a particular allele changes from 30% to 10%. Is this population evolving? Why or why not?
*Yes. The allele frequency has changed significantly.*

5. Does natural selection work directly or indirectly on genotype? Explain your answer.
*Phenotype. An albino rabbit dies because it is white and stands out to predators more than a brown rabbit. It does not die because it has a white allele.*

6. Compare and contrast evolution in single-gene vs. polygenic traits.
*Single gene traits – measured by change in allele frequency*
*Polygenic – measured by shift in phenotypes, as the genetics behind various phenotypes are extremely complicated.*

7. List and describe the three types of selection which occur when polygenic traits are evolving.
*Directional – organisms on either end of the bell curve become more fit, shifting the average to one side or the other*

*Stabilizing – organisms at either end of the curve become less fit, exaggerating the already existing norm.*

*Disruptive – organisms at both ends of the curve become more fit, creating two distinct phenotypes.*

8. What is genetic drift? List and describe the two types of genetic drift.
*Allele frequencies change by chance, as opposed to natural selection.*

*Founder effect – a small group of organisms colonizes a new habitat. By chance, there genetic make-up is different than the original population as a whole*

*Bottleneck effect – the population is quickly and dramatically reduced. The surviving organisms have a different allele frequency than the original population.*

9. Compare and contrast genetic drift and natural selection.
*Both result in changes to allele frequencies, but natural selection is not due to chance.*

10. What is genetic equilibrium?
*The allele frequencies within a population remain stable.*

11. What are the conditions required in order to maintain genetic equilibrium? Explain each.
*Large population – reduces effect of genetic drift*
*No mutation – does not introduce new alleles into the population*
*Random mating – no particular group is leaving more offspring*
*No movement in or out of the population – individuals arriving may bring new alleles, individuals leaving may remove alleles*
*No natural selection – natural selection changes allele frequencies do to variations in fitness.*

12. Which of the following conditions is MOST likely to result in changes in allele frequencies in a population?
*B. small population size*

**Speciation:**
1. What constitutes a species?
*Individuals who can mate and create fertile offspring.*

2. What is necessary for speciation to occur? Why is this necessary?
*Reproductive isolation – allows differences in the genetics of a population to build up until they can no longer produce fertile offspring.*

3. List and describe the types of reproductive isolation.
Geographic – populations are separated by a physical barrier
Behavioral – populations are physically able to mate, but do not due to behavioral issues (ex – different courtship rituals)
Temporal – populations mate at different times (one in April, one in June)
Mechanical – reproductive organs do not fit correctly

4. Can two populations be separated by more than one isolating mechanism?
*Yes*

5. Describe the genetic changes which occur between populations after reproductive isolation has occurred.
*As the individuals mate, changes occur to their genetic material. Since they are not reproducing together, these differences do not become shared in their offspring. This makes them less and less similar.*

**Evidence for Evolution:**
1. Explain how each of the following provide evidence for evolution:

Vestigial structures – *Structures which once had a function, but no longer do. They would not be present unless they were once used.*

Homologous structures – *same structure, different function. Ex – wing of bat, flipper of whale, arm of human. Would not be structurally similar if they didn't have a common ancestor.*

Analogous structures – *Unrelated organisms with similar physical structures. Show how organisms adapt to their environment.*

Biogeography – *Organisms that are unrelated but live in similar environments have similar adaptations due to their similar needs*

Fossils – *Provide a visual record of how organisms change over time*

Embryology – *Vertebrate embryos look very similar in the womb, possessing traits their adult counterparts lack. They would not have these parts if they did not once use them.*

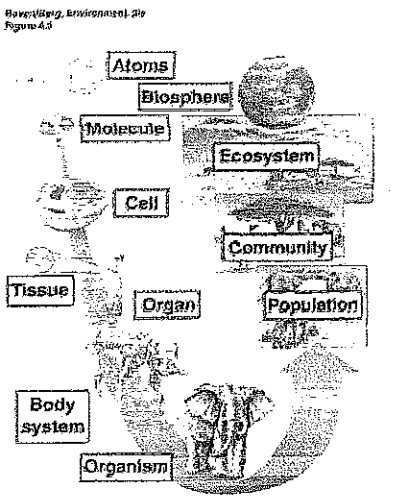
Molecular biology – *The number of differences in an amino acid sequence can be calculated to determine how long ago the organism shared a common ancestor.*

2. If species A and B have very similar genes and proteins, what is probably true?
*A. Species A and B share a relatively recent common ancestor*

# Everything you really, really need to know about...

# Ecosystems and their Interactions

Ecology is the study of how living things interact with each other and their environment. Ecology is a major branch of biology because it involves living organisms. Ecology also overlaps with geography, geology, climatology and other sciences. Ecology focuses on ecosystems and their organisms.




## Levels of ecological organization

Organism- individual living things

Population- a group of organisms of the same species that live in an area

Community- the various populations of organisms that live in an area

Ecosystem—collection of all the organisms that live in a particular place, together with non-living environment

Biosphere- the regions of the surface and atmosphere of Earth where living organisms exist

## Abiotic and biotic factors

The environment includes two types of factors:

Abiotic factors – the non-living aspects of the environment. They include factors like sunlight, soil, temperature, and water

Biotic factors- the living aspects of the environment. They consist of other organisms including members of the same and different species.

An ecosystem consists of all the biotic and abiotic factors in an area and their interactions. Ecosystems can vary in size.

Ecosystems are considered "open systems" because they need constant inputs of energy.

A niche refers to the role of a species in its ecosystem

A habitat is the physical environment in which a species lives and to which it is adapted.

## Energy Flow through an ecosystem

To survive, ecosystems need a constant influx of energy. Different organisms have different roles.

Producers- produce food for themselves and other organisms. Most producers are called autotrophs because they make their own food. Two types are:

Photoautotrophs- use energy from sunlight to make food by photosynthesis

Chemoautotrophs – use energy from chemical compounds to make food by chemosynthesis.

Consumers- organisms that depend on other organisms for food. Consumers are heterotrophs and are classified by what they eat:

Herbivores- consume producers such as plants or algae. Examples include: deer, rabbits, and mice

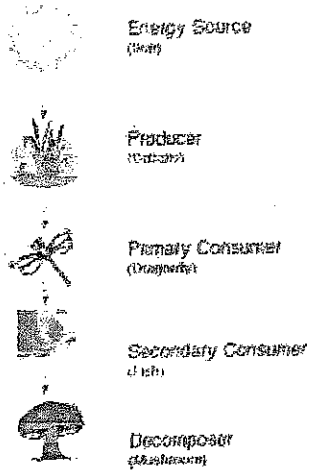
Carnivores- consume animals. Examples include: lions, polar bears, hawks

Omnivores- consume both plants and animals. Examples include: humans, pigs, brown bears, crows

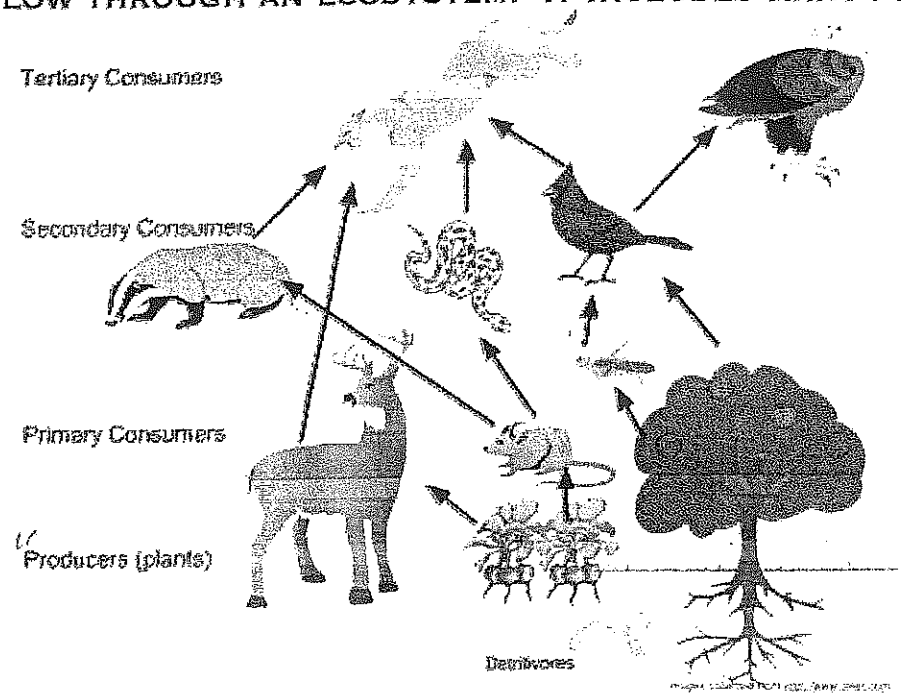
Decomposers- break down the remains and other wastes and release simple inorganic molecules back into the environment. Producers can then use the molecules to make new organic compounds.

## Food Chains & Food Webs

Food Chain- represents a single pathway by which energy and matter flow through an ecosystem.



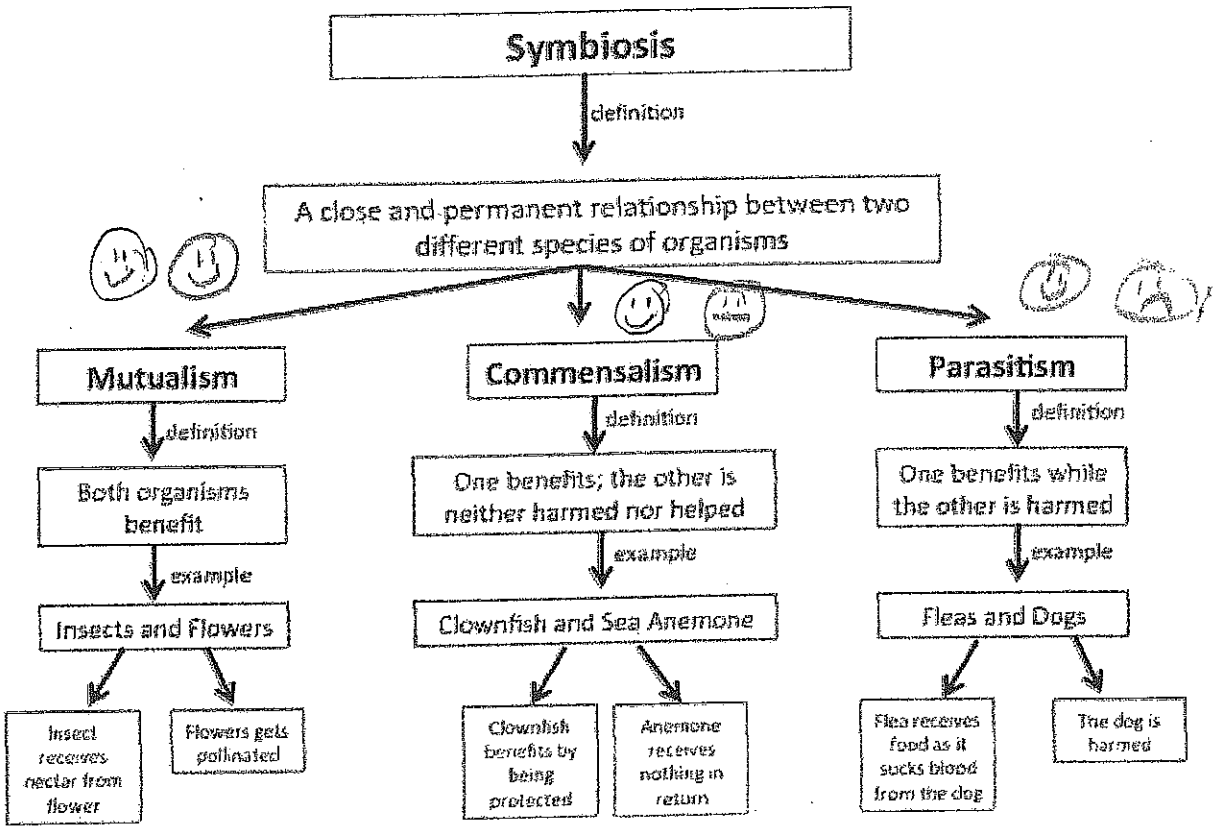

Food Webs- represent multiple pathways through which energy and matter flow through an ecosystem. It includes many food




chains.

Ecological Pyramid- represents the energy that is passed up a food chain or web from lower to higher trophic levels.

Trophic levels are feeding positions in a food chain or web. Only about 10% of energy available at one level is available to the next level. Why? Because it is used for




## Population Dynamics

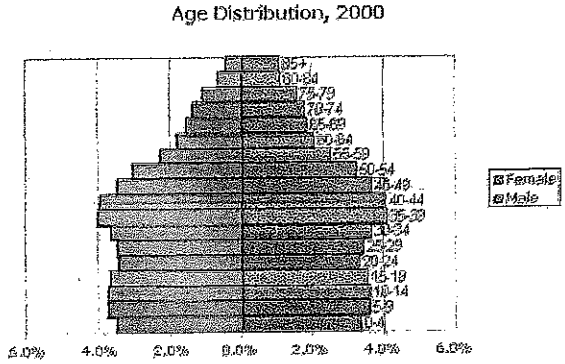
Population- a group of organisms of the same species that live in the same area. The population is the unit of natural selection and evolution. We measure a population's health on how large it is and how fast it is growing.

Population size- the number of individuals in a population

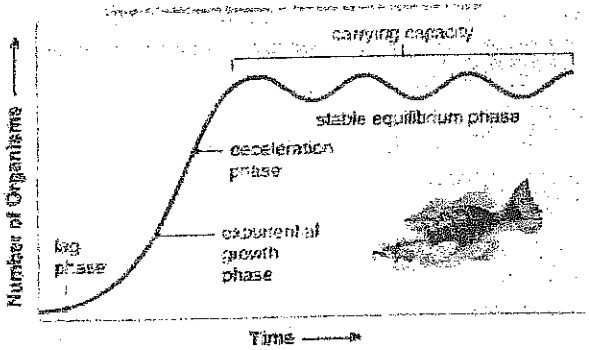
Population density- the average number of individuals in a population per unit of area or volume. Crowding may affect the health of a population.

Population Structure and Growth can be demonstrated in graphs:

## Population Structure Graph:




## Population Growth Graph:




Exponential Growth- under ideal conditions (food, shelter, light, etc.) most species can grow at exponential rate.

Logistic Growth – most populations do not live under ideal conditions therefore they do not grow exponentially. Factors that limit growth are known as density dependent factors (food, space, etc.)

Carrying Capacity- the largest population that can be supported in an area without harming the environment. It is the "ceiling"

Population Growth rate is calculated by:

Population Growth Rate = (birth rate + immigration rate) – (death rate+emigration rate)

## Biomes

Climate (temperature, humidity, atmospheric pressure, wind, rainfall, and other meteorological measurements in a given region over long periods of time) help determine the nature of a Biome. Climate refers to the average weather in an area over a long period of time. Weather refers to the conditions of the atmosphere from day to day.

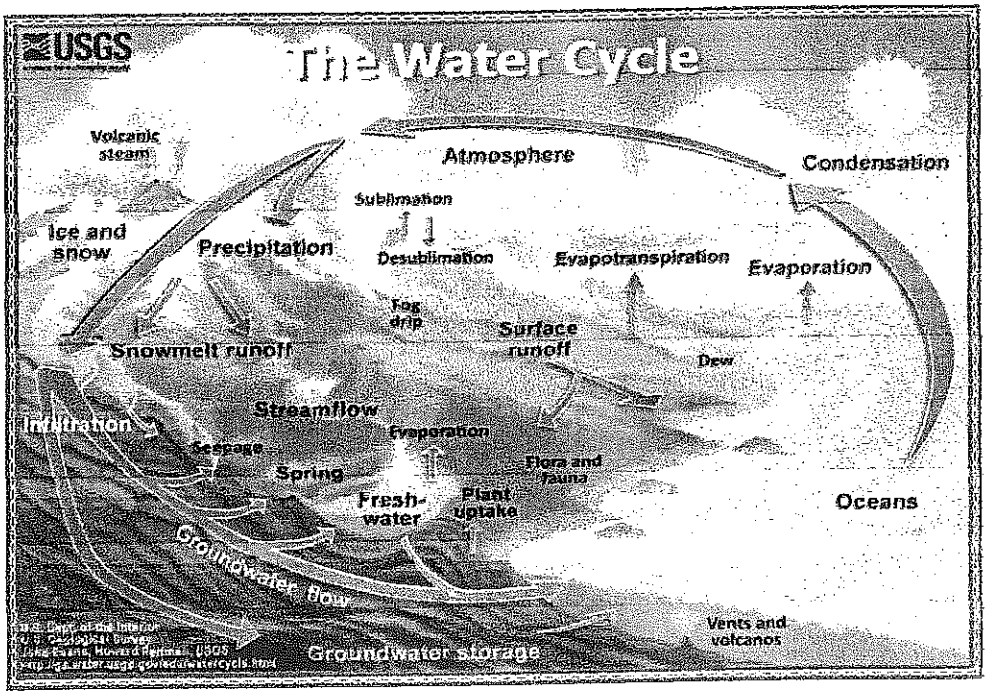
Biomes are classified into:

- Terrestrial Biomes
- Aquatic Biomes
- Freshwater & Wetlands Biomes

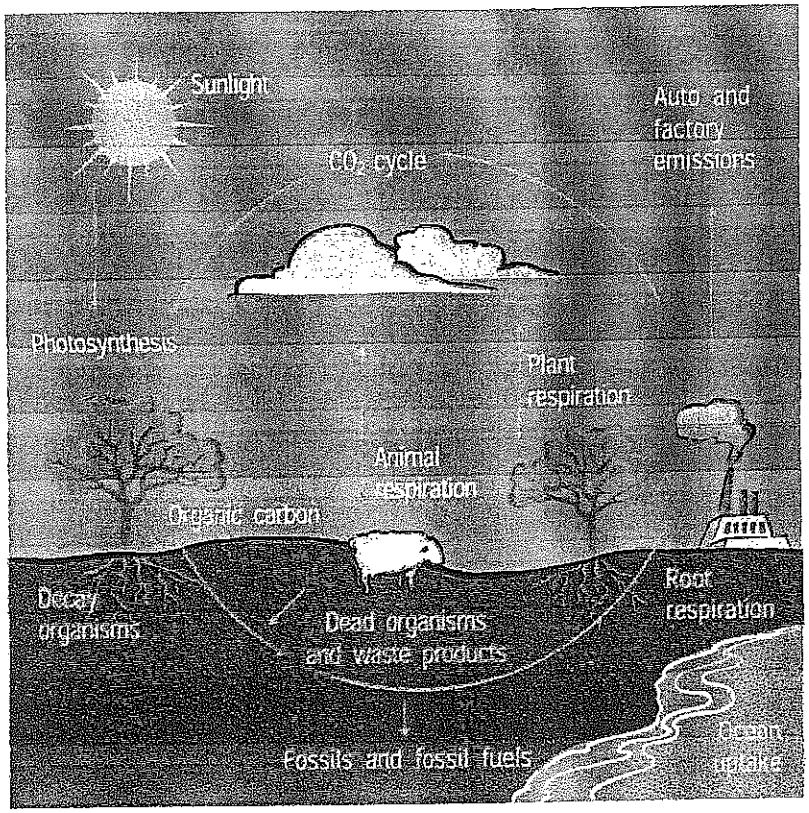
## Biogeochemical Cycles-

Biogeochemical Cycle are the chemical elements and water that are needed by organisms that are continuously recycled in an ecosystem.

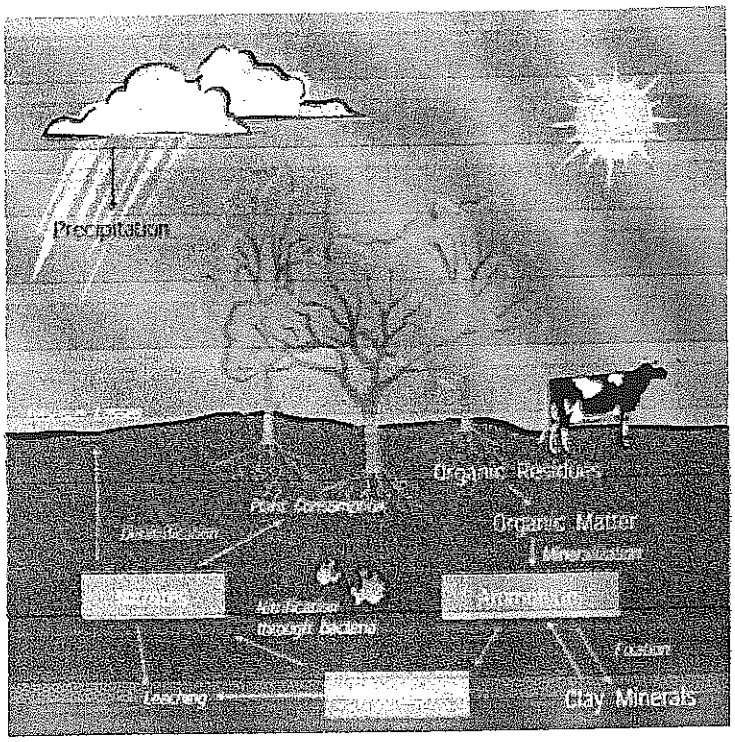
***Water Cycle*** – a global cycle that involves water molecules moving through the water cycle.

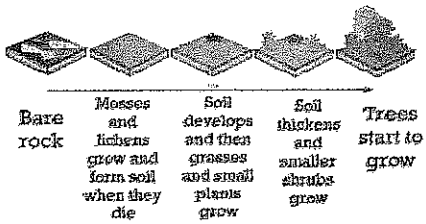


## CARBON CYCLE




## NITROGEN CYCLE



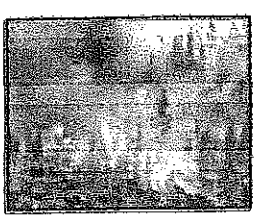




## Ecological Succession

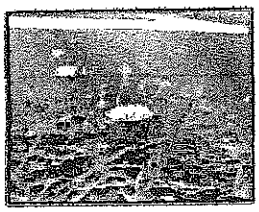
Communities, the organisms that live in an ecosystem, are not usually static. This means that the population or number of species change over time. This is called ecological succession. There are two cases of succession;

Primary succession – occurs in an area that has never been colonized. This type of environment may occur when a landslide uncovers an area of bare rock, lava flows from a volcano and hardens into rock.

Secondary Succession – Occurs when formerly inhabited area is now disturbed.

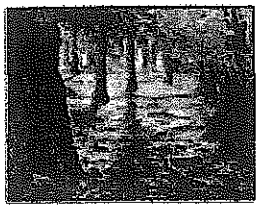


Organisms are driven away or killed by some type of **disturbance**, like a forest fire, leaving behind only the soil.



**Pioneer species**, like grasses and weeds, begin to grow from the soil. Roots and seeds left over may also begin to grow again

Some pioneers species die and are replace or outcompeted by other species like shrubs and small trees.



Small and Large trees begin to grow, and the community reaches an **equilibrium** or balance. This results in a **climax community**.

Secondary Succession: The *reestablishment* of community following disturbance. – This could be because of a fire, flood, human activities (farming, development, etc.)

## Biodiversity

Biodiversity refers to the variety of life and its processes, including the variety of living organisms, the genetic difference among them and where they occur.

### Factors that affect or threaten biodiversity

- Non-native species
- Development
- Extinction
- Pollution
- Overuse of resources
- Deforestation