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WORLD'S #1 ACADEMIC OUTLINE

Quick Study® ACADEMIC

BIOLOGY

THE BASIC PRINCIPLES OF BIOLOGY

Basic Concepts

Biological Science: The Study of Life

A. The Scientific Method: How scientists study biology
1. Observe phenomena and formulate testable and falsifiable (in case they are wrong) hypotheses
2. Test hypotheses, collect data, and analyze statistically (if necessary)

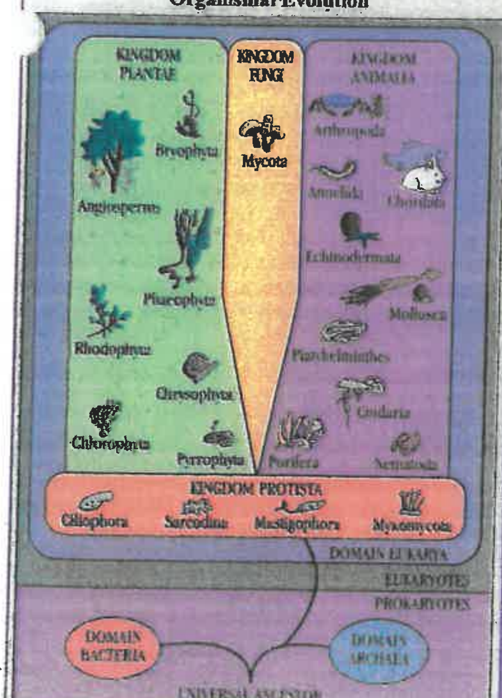
B. What is life?
1. **Characteristics:** Metabolism, reproduction, growth, movement, responsiveness, complex organization

Evolution

Concept that all organisms are related to each other by common ancestry: The unifying theme in biology

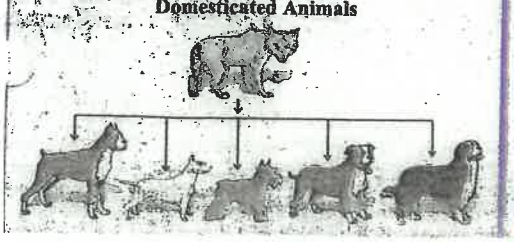
A. Natural Selection: A mechanism for the occurrence of evolution
1. Survival of those offspring best adapted to the conditions in which they live:
   a. Individuals produce sexually many more offspring than could possibly survive
   b. These offspring are not identical (in most situations), but show variations based on genetic differences
   c. Essentially, those individuals with variations that allow them to survive (i.e., adaptations) to the age of reproduction can pass their genes on to the next generation
   d. Thus, nature is selecting offspring and shaping the evolution of species
2. Charles Darwin and Alfred Wallace, 19th century biologists, formulated the concept of natural selection

Organismal Evolution



B. Artificial Selection: Human selects traits in offspring (ex: pets, farm crops)

Domesticated Animals



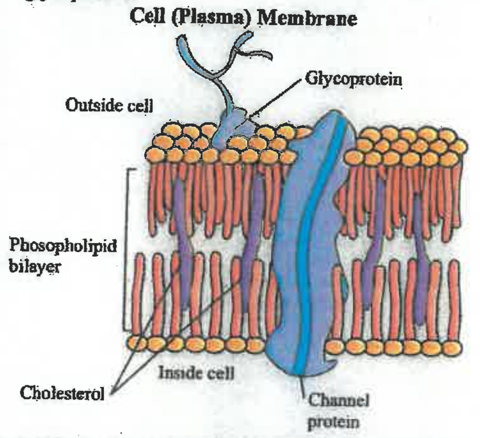
Cytology: The Study of Cells

Cell Theory:
All living things are composed of cells and come from cells

A. Cell Size: Small to maximize surface area to volume ratio for regulating internal cell environment

B. Cell (Plasma) Membrane: Composed of fluid-like phospholipid bilayer, proteins, cholesterol and glycoproteins

Cell (Plasma) Membrane

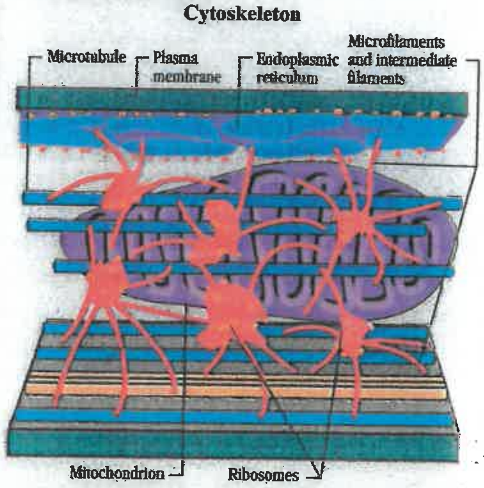


C. Cell Wall: Outside of cell membrane in some organisms; composed of carbohydrate (e.g., cellulose or chitin) or carbohydrate derivative (e.g., peptidoglycan)

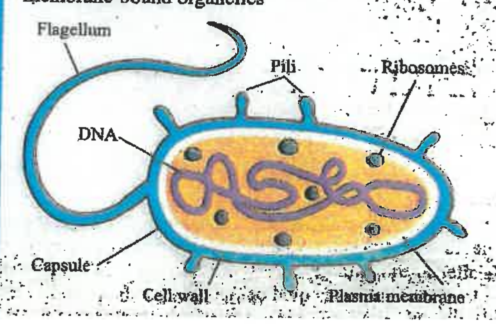
D. Cytoplasm: Material outside nucleus
1. Site for metabolic activity
2. **Cytosol:** Solutions with dissolved substances such as glucose, CO_2, O_2, etc.
3. **Organelles:** Membrane-bound subunits of cells with specialized functions

E. Cytoskeleton: Supportive and metabolic structure composed of microtubules, microfilaments, and intermediate filaments

Cytoskeleton



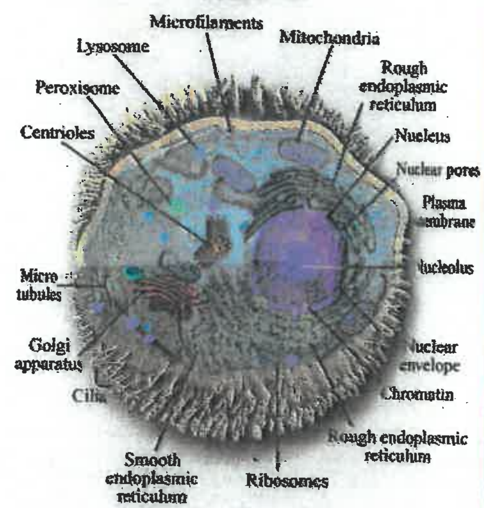
Prokaryotic Cells:
Simpler cellular organization with no nucleus or other membrane-bound organelles



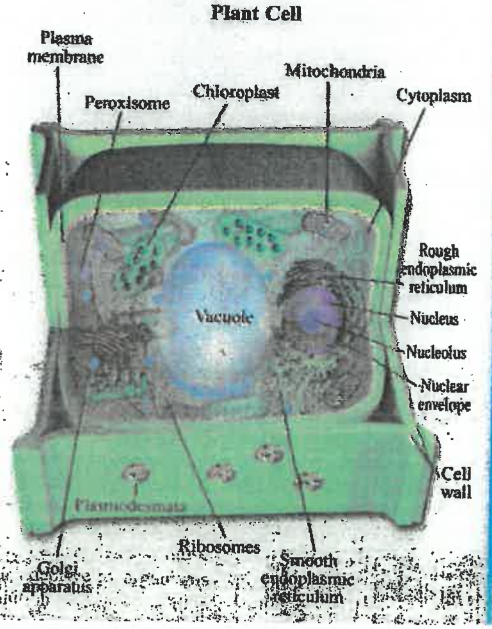
Eukaryotic Cells:
Complex cellular organization

A. Membrane: Bound organelles including the following:
1. **Nucleus:** DNA/chromosomes, control cellular activities via genes
2. **Nucleolus:** Located within nucleus, site for ribosome synthesis
3. **Rough endoplasmic reticulum:** With ribosomes, involved in protein synthesis
4. **Smooth endoplasmic reticulum:** Without ribosomes, involved primarily in lipid synthesis
5. **Golgi apparatus:** Packaging center for molecules; carbohydrate synthesis
6. **Lysosome:** Contains hydrolytic enzymes for intracellular digestion
7. **Peroxisome:** Involved in hydrogen peroxide synthesis and degradation
8. **Chloroplast:** Site of photosynthesis
9. **Chromoplast:** Non-green pigments
10. **Leukoplast:** Stores starch
11. **Mitochondrion:** ATP production
12. **Vacuole:** General storage and space-filling structure

Animal Cell



Plant Cell



Energy & Life

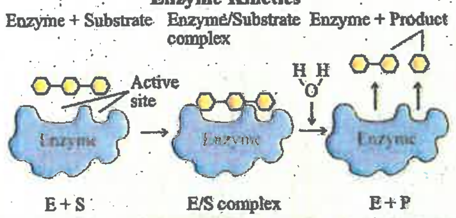
Our Sun

Organisms must use the sun's energy (directly or indirectly) to become and remain in an organized state

A. **Metabolism**: Series of chemical reactions involved in storing (anabolism) or releasing (catabolism) energy

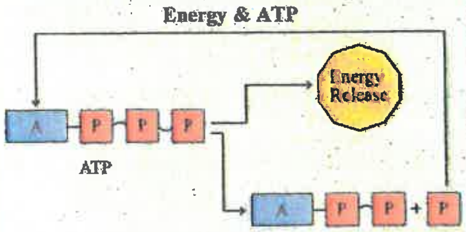
B. **Enzymes**: Biological catalyst; facilitate metabolic chemical reactions by speeding up rates and lowering heat requirements

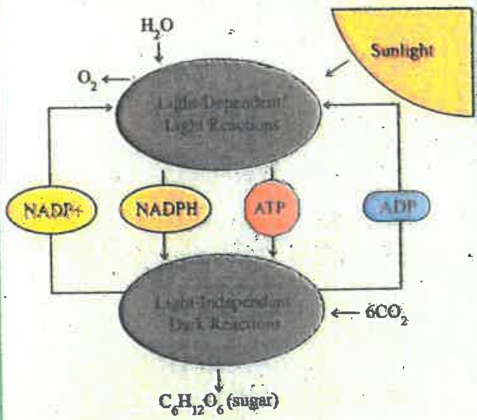
Enzyme Kinetics



C. **Adenosine triphosphate (ATP)**: A high-energy molecule; energy stored in ATP is released by breaking phosphate-to-phosphate bonds and creating adenosine diphosphate (ADP) or adenosine monophosphate (AMP); ATP is recycled by adding back phosphate groups using energy from the sun

Energy & ATP





Photosynthesis

Sunlight or radiant energy is captured by chlorophyll and carotenoid photopigments (found in cytoplasm in prokaryotes and chloroplasts in eukaryotes) in two main steps:

A. **Light-dependent reactions (Light Reactions)**: The captured light energy is transferred to electrons that come from H_2O; O_2 is a by-product

B. **Light-independent reactions (Dark Reactions)**: Energized electrons are transferred to CO_2 (reduction reactions) to form glucose (in the Calvin-Benson cycle)

Cell Respiration

Highly energized electrons stored temporarily in glucose are removed (oxidation reactions) in a step-wise fashion to maximize energy capture at each step:

A. **Glycolysis**: Anaerobic process in cytoplasm in which glucose, a six-carbon compound, is oxidized to two pyruvates, which are both three-carbon chains

B. **Krebs cycle**: Aerobic process that oxidizes pyruvates to CO_2

C. **Chemiosmotic phosphorylation**: The energized electrons released during the previous steps are used to concentrate hydrogen ions in one area (of the cell membrane in prokaryotes; of the mitochondrion in eukaryotes) to create a chemical gradient between positively and negatively charged ions (i.e., a battery); the potential energy resulting from this osmotic gradient is used to resynthesize ATP from ADP and AMP; after electrons have been used, they must be transferred to O_2

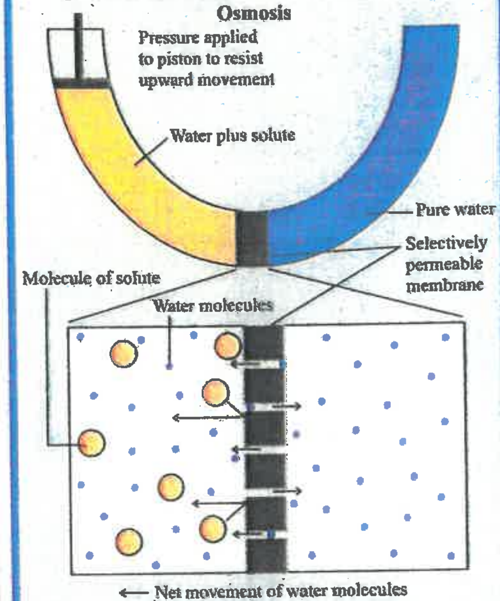
Cell Transport

Passive Transport

A. Relies on thermal energy of matter; the cell does not do work; there are four categories:

1. **Diffusion**: Movement from an area of high to low concentration
2. **Facilitated diffusion**: A permease, or membrane enzyme, carries substance
3. **Osmosis**: Diffusion across a semi-permeable membrane
4. **Bulk flow**: Mass movements of fluids affected by pressure and solutes

Osmosis

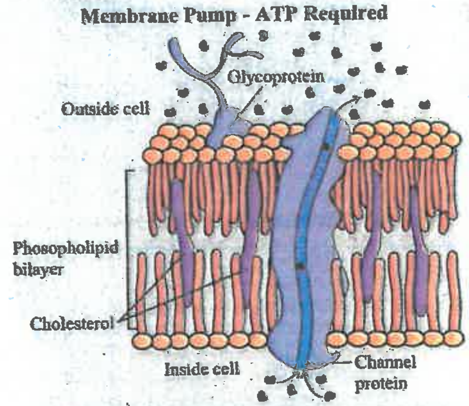


Active Transport

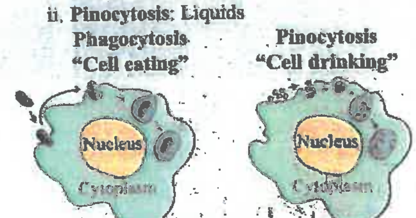
A. Relies on the cell providing energy supply; there are three categories:

1. **Membrane pumps**: Permease used to move substance, usually in the opposite direction of diffusion

Membrane Pump - ATP Required

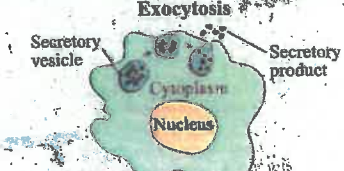


2. **Endocytosis**: Materials are brought into cell via:
   i. **Phagocytosis**: Solids
   ii. **Pinocytosis**: Liquids



3. **Exocytosis**: Expel materials from cell

Exocytosis



Cell Reproduction

Cells reproduce in two steps:

A. **Mitosis**: Division of nuclear material

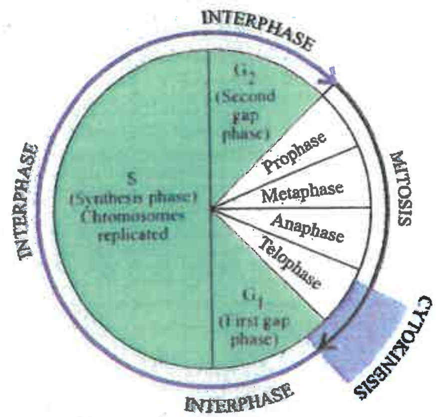
B. **Cytokinesis**: Division of remaining cellular contents of the cytoplasm

Cell Cycle

A. Cells go through 4 stages:

1. G_1 : Active growth and metabolism
2. S : DNA synthesis and duplication
3. G_2 : Synthesis of molecules in preparation for cell division
   a. Stages G_1, S, & G_2 above are collectively referred to as **Interphase**; Interphase chromosomes are referred to as chromatin, a diffuse, loosely scattered arrangement of chromosomes
4. **Mitosis & Cytokinesis**:
   a. Mitotic chromosomes in the Mitosis/Cytokinesis stage are highly condensed and coiled, and thus distinct

Cell Cycle



Mitosis - Four Mitotic Stages:

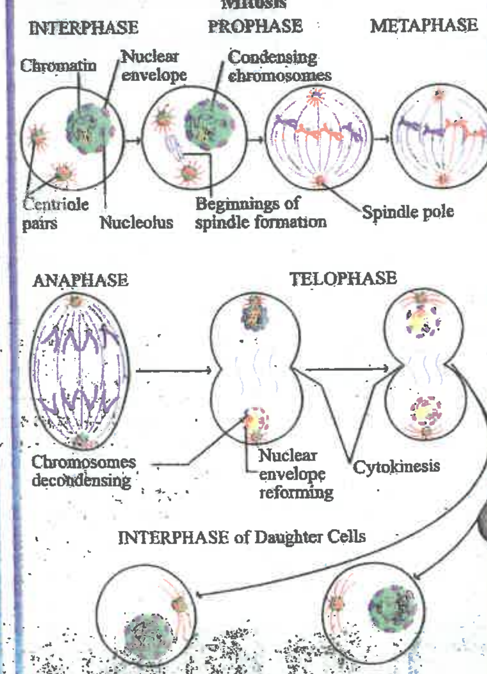
A. **Prophase**: Chromosomes condense and organize, nuclear membrane and nucleoli disappear, spindle apparatus assembled and attached to centromeres of duplicated chromosomes

B. **Metaphase**: Spindles line up duplicated chromosomes along equator of cell, one spindle to each half or chromatid of duplicated chromosome

C. **Anaphase**: Centromere of each duplicated chromosome is separated and paired chromatids are pulled apart

D. **Telophase**: Chromosomes uncoil; nucleoli reappear; cytokinesis occurs and two genetically identical daughter cells are produced

Mitosis



Two new cells are genetically identical (i.e., clones)

Organismal Reproduction & Meiosis

Sexual Processes

A. **Sexual Reproduction:** Involves the fusion of genetic material (gametes) from two parental organisms

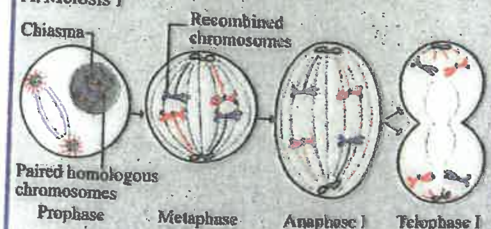
B. To ensure the proper chromosomal numbers in the zygote (fertilized egg), each gamete must have half or haploid (N) of the original diploid (2N) amount of DNA

C. **Meiosis:** Reduces the chromosome number by half and results in new genetic combinations in the gametes

Meiosis - 2 distinct stages

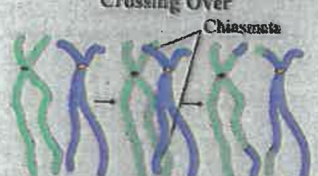
Preceded by interphase; many meiotic events similar to mitosis; differences are noted below

A. Meiosis I



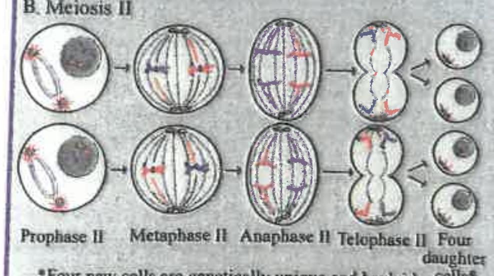
1. **Prophase I:** Chromosomes condense and organize and matched or homologous chromosomes (one maternal and one paternal in each pair) are physically paired; segments of chromatids can cross over within each chromosome pair

Crossing Over



2. **Metaphase I:** Homologues line up at equator
3. **Anaphase I:** Homologues separated into two groups, with each group having a mixture of maternal and paternal chromosomes
4. **Telophase I:** New haploid nuclei forming for two new daughter cells
5. **Interkinesis:** No replication of DNA occurs because each chromosome is still duplicated and consists of two chromatids (although crossing over results in some chromatids with maternal and paternal segments)

B. Meiosis II



*Four new cells are genetically unique and haploid

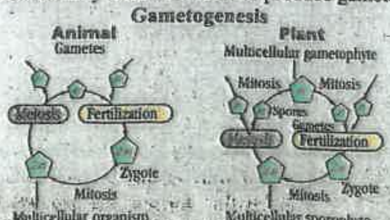
1. **Prophase II:** Chromosomes condense
2. **Metaphase II:** Chromosomes line up at equator
3. **Anaphase II:** Chromatids of each chromosome are separated
4. **Telophase II:** Each daughter cell from Meiosis I will form two more cells for a total of four cells

Faunal/Floral Gametogenesis

A. In animals, meiosis occurs in germinal tissues and is called spermatogenesis in males and oogenesis in females; each results in a gamete

B. In plants the process is similar except that mitotic divisions may follow meiosis to produce gametes

Gametogenesis



Genetics & Mendel

Introduction

A. **Genetics:** The study of traits and their inheritance

B. 19th century biologists believed that traits blended; if blending occurred, things would become more similar, not different; Darwin and Wallace stated that variations or differences in offspring were necessary for natural selection to occur

C. Gregor Mendel provided the most plausible hypothesis for genetics: **Mendelian genetics:** Two laws were developed by using statistics to analyze results of crosses involving distinguishing traits of garden peas

I - Law of Segregation of Alternate Factors

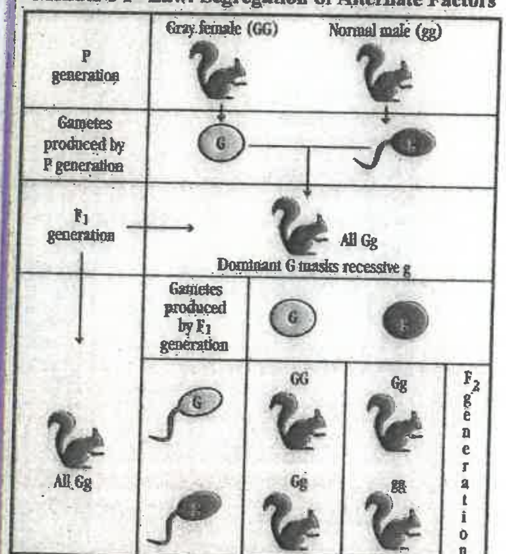
Developed by Mendel using single-trait crosses

A. **Single-trait crossbreeding:**

1. Two true-breeding (those that consistently yield the same form when crossed with each other) parents (P_1) but different strains were crossed (e.g., round versus wrinkled seed)
2. The offspring (F_1) from this cross all showed only one trait (e.g., round seed) and this was called the dominant trait; the traits from the parents did not blend
3. The F_1 individuals were crossed with each other to produce F_2 individuals
4. 3/4 of the F_2 expressed the dominant trait; 1/4 expressed the trait of the other P_1 parent (e.g., wrinkled seed) which had not been expressed in the F_1 generation and was thus recessive

B. Mendel's crosses for single traits can be summarized as follows:

Mendel's 1st Law: Segregation of Alternate Factors



C. **Mendel's first conclusions:** Discrete factors (now known as genes) were responsible for the traits and these factors were paired, separated (which occurs during meiosis) and recombined (during fertilization); alternate forms of factors or genes exist called alleles; the F_1 individuals had two alleles, their genotype consisted of a dominant and recessive allele (e.g., Rr with R for round and r for wrinkled seed); thus, the F_1's were hybrids; their phenotype was similar to only one of original parents (e.g., round seed)

Mendel Updated

A. Genes are found on chromosomes, and thus multiple traits assort independently as long as they are located on different chromosomes; Mendel studied traits in peas that were each on separate chromosomes; genes on the same chromosome are linked and thus will not normally assort independently

B. Interactions between alleles:

1. **Complete dominance:** One allele dominates another allele
2. **Incomplete dominance:** Neither allele is expressed fully
3. **Codominance:** Both alleles are expressed fully
4. **Multiple alleles:** More than two alleles for a gene are found within a population
5. **Epistasis:** One gene alters the affect of another gene
6. **Polygenic inheritance:** Many genes contribute to a phenotype
7. **Pleiotropy:** One gene can effect several phenotypes
8. **Environmental influences:** Where the genotype and environment interact to form a phenotype

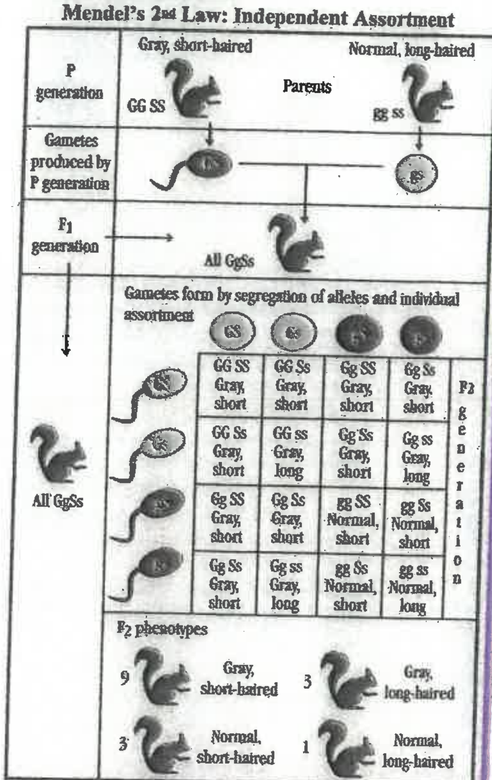
II - Law of Independent Assortment

Developed by Mendel using multiple-trait crosses

A. Two true-breeding parents of different strains for two traits were crossed; the F_1's were then crossed, producing F_2 individuals

B. The results of crosses involving two traits can be summarized as follows:

Mendel's 2nd Law: Independent Assortment



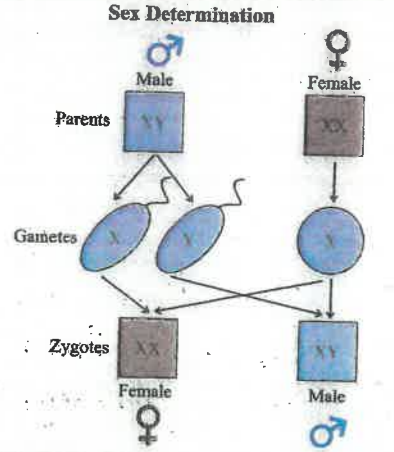
C. Mendel concluded statistically that these results occurred because alleles for one trait or gene did not affect the inheritance of alleles for another trait

Chromosomes & Sex Determination

A. In many animals, special chromosomes determine sex; the remaining chromosomes are autosomes

B. In humans, there are 44 autosomes and two sex chromosomes: X and Y in males, X and X in females

Sex Determination



Sex-Linked Traits

In humans, the Y chromosome contains the determinant for maleness; the X contains many genes; if a male gets a recessive (or dominant) allele on the X chromosome from his mother, he will express the trait; therefore, males are frequently afflicted with X-linked disorders

Molecular Genetics

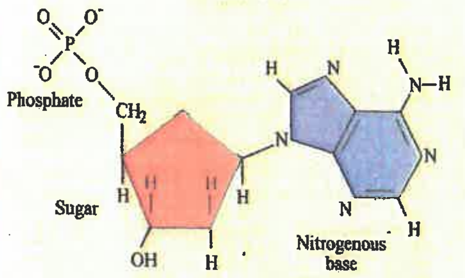
Genes, DNA & Nucleic Acid

A. Gene functions:
1. To be preserved and transmitted
2. To control various biological functions through the production of proteins (i.e., large, complex sequences of amino acids) and RNA

B. Gene structure; two types of nucleic acids:
1. Deoxyribonucleic acid (DNA)
2. Ribonucleic acid (RNA)

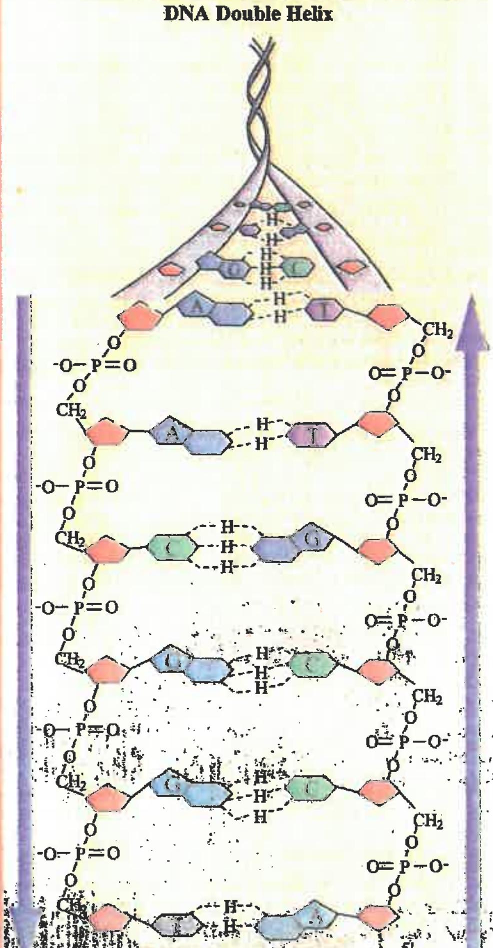
C. Nucleotides: The components of nucleic acids; three subunits:

Nucleotides



1. Sugar (deoxyribose in DNA; ribose in RNA)
2. Phosphate
3. Nitrogenous base (five possible bases)
   a. In DNA, the nucleic acid of chromosomes, four nitrogenous bases are found: Adenine (A), guanine (G), cytosine (C), and thymine (T)
   b. RNA consists of similar bases, except uracil (U) replaces thymine (T)
   c. DNA is a double helix molecule: Similar to a spiral staircase or twisted ladder, with the sides formed by repeating sugar-phosphate groups from each nucleotide, and the horizontal portions (i.e., steps) formed by hydrogen bonds involving A with T or C with G
   d. **Hereditary information**: Genes found along the linear sequence of nucleotides in the DNA molecule

DNA Double Helix



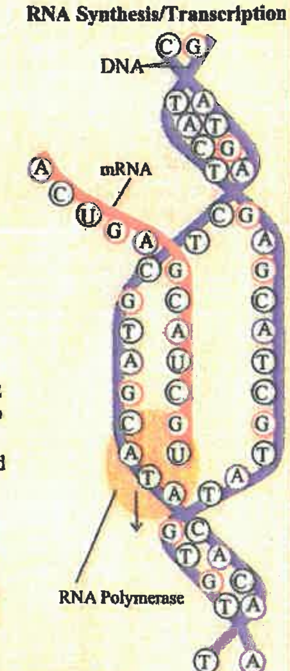
The Central Dogma

A. **Replication**:
1. DNA is copied from other DNA by unzipping the helix and pairing new nucleotides with the proper bases (i.e., A with T and C with G) on each separated side of the original DNA

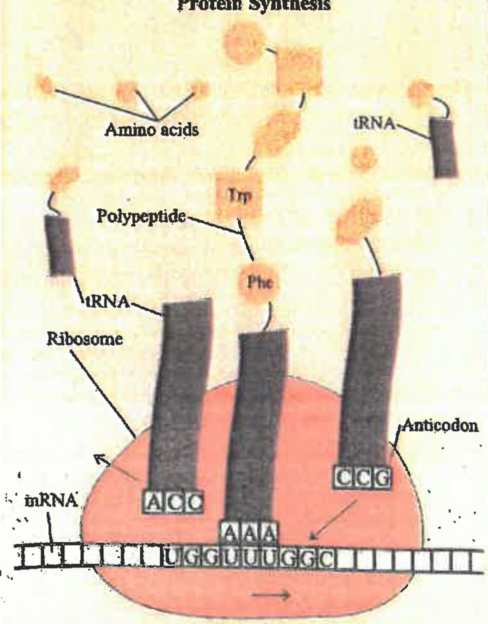
B. **Transcription**:
1. Messenger (m)RNA is copied from DNA by unzipping a portion of the DNA helix that corresponds to a gene
2. Only one side of the DNA will be transcribed and nucleotides with the proper bases (A with U and C with G) will be sequenced to build pre-mRNA
3. Sequences of nucleotides called introns are removed and the remaining segments called exons are spliced together
4. The mature mRNA leaves the nucleus to be transcribed by the ribosomes

C. **Translation**:
1. Proteins are synthesized from (m)RNA by ribosomes (which are composed of ribosomal (r)RNA and proteins) which read from a triplet code (i.e., codons) that is universal
2. The ribosomes instruct transfer (t)RNAs to bring in specific amino acids in the sequence dictated by the mRNA, which in turn was built based on the sequence of nucleotides in the original gene portion of the DNA

RNA Synthesis/Transcription



Protein Synthesis



Mutations

Any random, permanent change in the DNA molecule; many are harmful, some have no effect, and a few actually benefit the organism; nature selects those mutations that are beneficial or adaptive in organisms to help shape the course of evolution

Population Genetics

Genes in populations versus individuals

A. Populations evolve just as do species

B. **Genotype**: Genetic composition of an individual

C. **Gene Pool**: Genetic composition of a population of individuals; that is, all alleles for all genes in a population

D. Evolution involves changes in gene pools over time; to understand changes in gene pools as populations evolve, an understanding of non-evolving populations is necessary

The Hardy-Weinberg Law

A. Both allelic frequencies and genotypic ratios (i.e. gene pools) remain constant from generation to generation in sexually producing populations, if the following conditions of equilibrium exist:
1. Mutations do not occur
2. No net movement of individuals out of or into a population occurs
3. All offspring produced have the same chances for survival, and mating is random; that is, no natural selection occurs
4. The population is large so that chance would not alter frequencies of alleles

B. **Algebraic equivalent of the Hardy-Weinberg Law**:
1. $p^2 + 2pq + q^2 = 1$ where
   a. p = frequency of dominant allele
   b. q = frequency of recessive allele
   c. p^2 = AA genotype
   d. 2pq = Aa genotype
   e. q^2 = aa genotype

C. **Example**:
1. If in a group of six individuals there are nine dominant (A) alleles and three recessive (a) alleles, then p = 9/12 or 0.75 and q = 3/12 or 0.25; a total of 12 gametes will be produced, nine of which will have the dominant allele and three with the recessive allele
2. The algebraic equation above can be used to predict the ratios of the three possible genotypes as a result of fertilizations
   a. Frequency of AA genotypes is p^2 or $(0.75)^2 = 0.56$
   b. Frequency of Aa genotypes is 2pq or $2(0.75)(0.25) = 0.38$
   c. Frequency of aa genotypes is q^2 or $(0.25)^2 = 0.06$
3. The frequencies of dominant and recessive alleles are still the same—the specific alleles have been redistributed

Hardy-Weinberg & Natural Populations

A. Few (if any) populations are in equilibrium; therefore, changes in allele frequencies and thus gene pools do occur in natural populations

B. The Hardy-Weinberg Law helps to identify the mechanisms of these evolutionary changes by predicting that one or more of the four conditions required are not met; that is:
1. Mutations occur
2. Individuals leave and enter populations
3. Nonrandom mating and natural selection occur
4. Small populations exist

Allele Frequency Changes

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