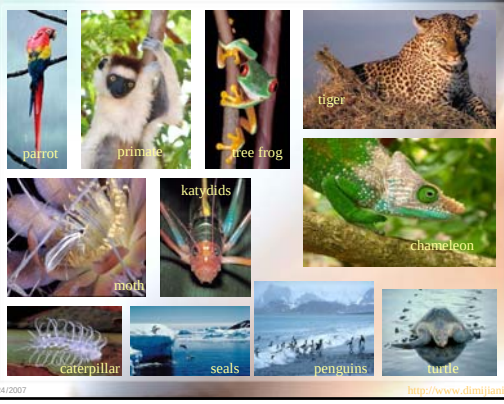
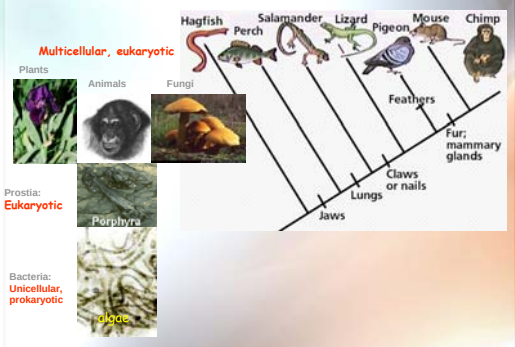
Basics in Biology

Heping Zhang

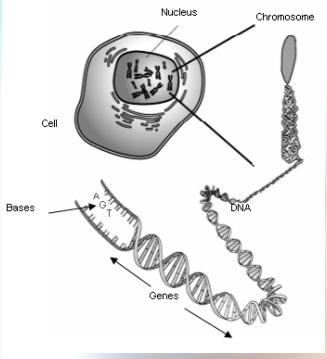
Life



Tree of Life



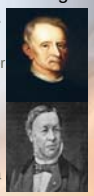
Building Blocks of Life



- Cell
- Chromosome
- DNA
- Genome and Genes
- RNA and Protein

The History of Cell

Cell is the structural and functional unit of all living organisms (a human has 100 trillion cells).



Robert Hooke (1635-1703), one of the first scientists to use a microscope to examine pond water, cork and other things, referred to the cavities he saw in cork as "cells", Latin for chambers.

Mattias Schleiden (in 1838) concluded all plant tissues consisted of cells.

In 1839, Theodore Schwann came to a similar conclusion for animal tissues.

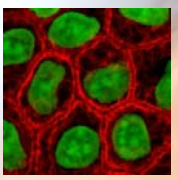
Rudolf Virchow, in 1858, combined the two ideas and added that all cells come from pre-existing cells, formulating the Cell Theory.

http://upload.wikimedia.org/wikipedia/commons/8/80/Rudolf_Virchow.jpg

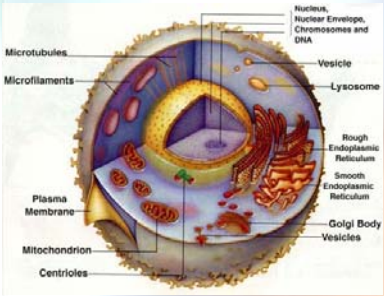
Cell

The largest known cell is Ostrich Egg

Cells in culture, stained for keratin (red) and DNA (green).

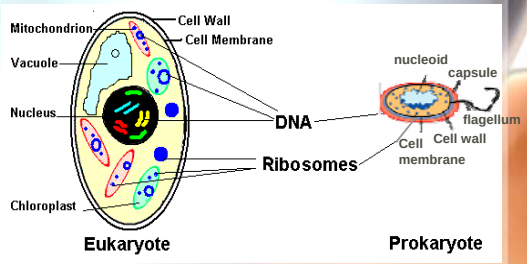


Chemistry of the Cell



- Water
- Ions
- Nucleic acids
- Carbohydrates
- Lipids
- Proteins

Prokaryotic and Eucaryotic Cells



With or without nucleus

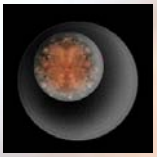
Animals, plants, fungi, and protists

Bacteria

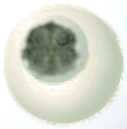
Cell Cycle

Cells can differentiate, migrate,Interact and assemble into complex tissues and organs.

It goes through a cell replication, called mitosis, in five major steps.



Interphase



The cell is engaged in metabolic activity and performing its duty as part of a tissue. The DNA duplicates during interphase to prepare for mitosis. Chromosomes are not clearly discerned in the nucleus, although a dark spot called the nucleolus may be visible.

Prophase

Chromatin in the nucleus begins to condense and becomes visible in the light microscope as chromosomes. The nuclear membrane dissolves, marking the beginning of prometaphase. Proteins attach to the centromeres creating the kinetochores. Microtubules attach at the kinetochores and the chromosomes begin moving.

Metaphase

Spindle fibers align the chromosomes along the middle of the cell nucleus. This line is referred to as the metaphase plate. This organization helps to ensure that in the next phase, when the chromosomes are separated, each new nucleus will receive one copy of each chromosome.

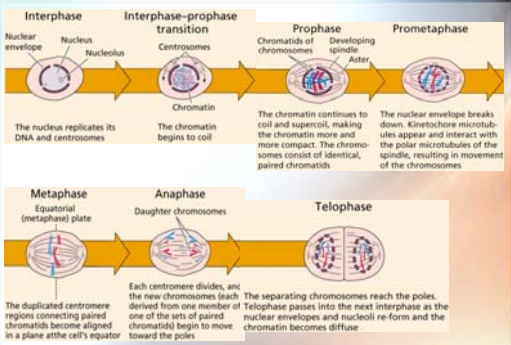
Anaphase

The paired chromosomes separate at the kinetochores and move to opposite sides of the cell. Motion results from a combination of kinetochore movement along the spindle microtubules and through the physical interaction of polar microtubules.

Telophase

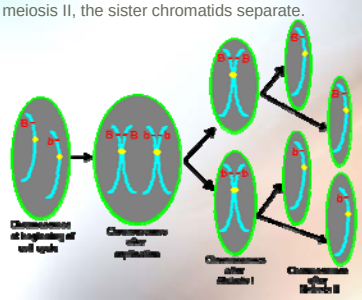
New membranes form around the daughter nuclei while the chromosomes disperse and are no longer visible under the light microscope. Cytokinesis or the partitioning of the cell may also begin during this stage.

Mitosis

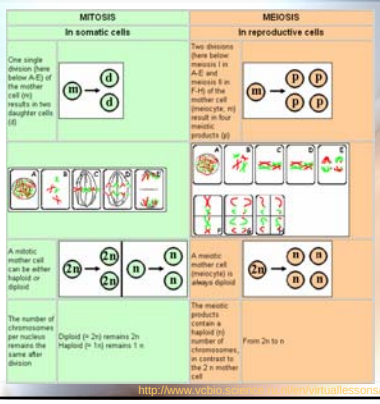


Meiosis

- Meiosis creates gametes (egg and sperm cells).
- In meiosis I (reduction division), each chromosome is replicated to yield duplicated sister chromatids.
- In meiosis II, the sister chromatids separate.

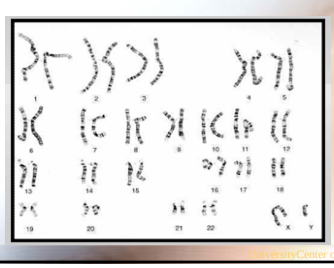


Meiosis vs. Mitosis



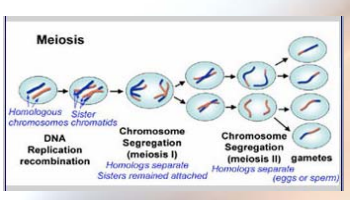
Human Chromosome

- Humans have 23 pairs of chromosomes.
- The first 22 pairs of chromosomes are ***autosomes***;
  The 23rd pair determines ***sex***, XX and XY.
- One of each pair normally comes from each parent.

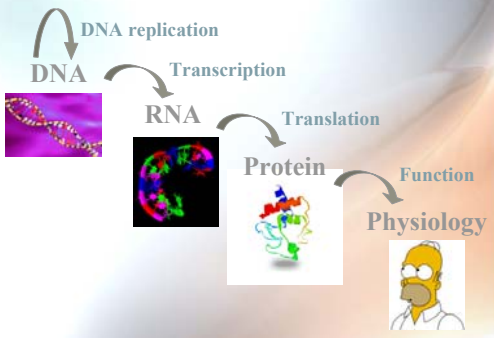


Crossover and Recombination

- Physical contact between chromatids may occur, resulting in the formation of ***chiasmata*** ("Cross" in Greek).
- ***Genetic recombination*:** genetic information (DNA) is exchanged between two of the four chromatids.
- A new combination of the maternal and paternal haplotypes



Central Dogma of Molecular Biology



DNA

- Deoxyribonucleic acid
- Nucleotides comprises of:
  - A phosphate group
  - A deoxyribose sugar
  - One of four nitrogen bases:
    - Purines: adenine (A), guanine (G)
    - Pyrimidines: cytosine (C), thymine (T)
- Hydrogen bond base pairing: A = T, C ≡ G

What is a Genome?

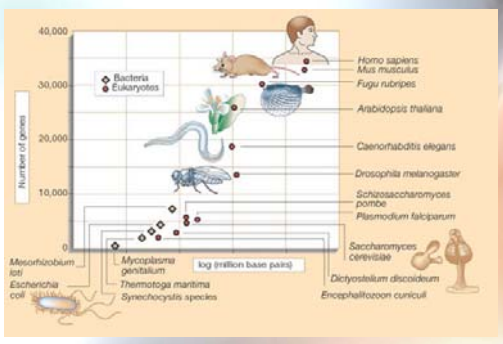
It is the total genetic information carried by a cell or an organism.

1865 Gregor Mendel discover the basic rules of heredity of garden pea.

1869 Johann Friedrich Miescher discovered DNA and named it nuclein.

1911 – Thomas Hunt Morgan discovers genes on chromosomes are the discrete units of heredity

Sequenced and In-Progress Genomes



Human Genome

- International 13-year effort formally begun in 1990
- Aims
  - Sequence the entire 3 billion DNA bases
  - Dissect the code of estimated 25,000 genes that determine the physical characters of the human body
  - Store this information in databases
  - Improve tools for data analysis,
  - Transfer related technologies to the private sector
  - Address the ethical, legal, and social issues (ELSI) that may arise from the project
- Cost = $3 billions

Comparative Genomes

Organism	Genome Size(Bases)	Estimated Genes
Human (*Homo sapiens*)	3 billion	20,000-30,000
Laboratory mouse (*M. musculus*)	2.6 billion	30,000
Mustard weed (*A. thaliana*)	100 million	25,000
Fruit fly (*D. melanogaster)*	137 million	13,000
Roundworm (*C. elegans*)	97 million	19,000
Yeast (*S. cerevisiae*)	12.1 million	6,000
Bacterium (*E. coli*)	4.6 million	3,200
Human immunodeficiency virus (HIV)	9700	9

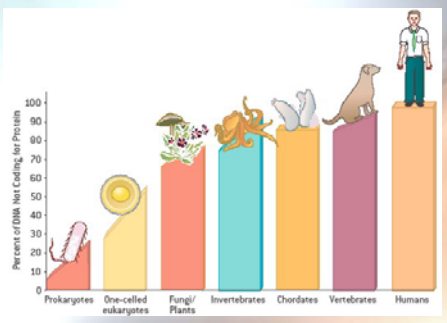
The Units of Heredity - Genes

- Genes are made of strands of DNA.
- The physical location of a gene is its ***locus***. Different versions of genes are called ***alleles***.
- Genetic disorders are caused by mutations, in the instruction code of a particular gene(s), preventing the gene(s) from functioning properly.

Regions in the Genome

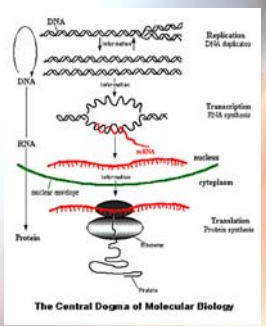
- Genes: coding for proteins or RNAs
- Intergenic: between genes, do not comprise of genes, "junk DNA", may have regulatory functions

Coding vs Noncoding



From DNA to Protein

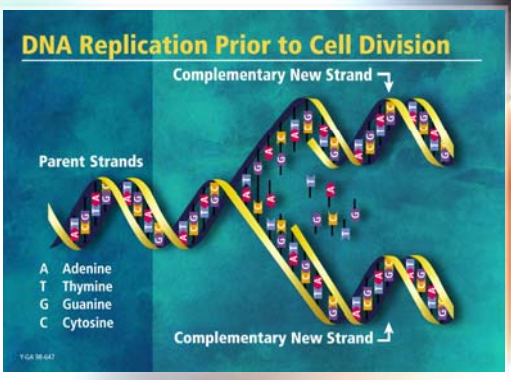
- Replication of DNA
- Transcription of DNA to messenger RNA (mRNA)
- Translation of mRNA into proteins
- Folding proteins into 3D forms



The Central Dogma of Molecular Biology

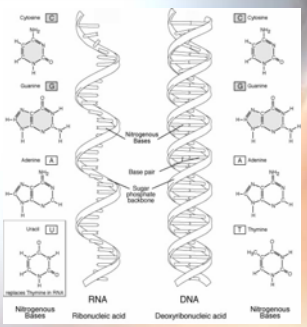
http://www.accessexcellence.org/AB/GG/central.html

DNA Replication



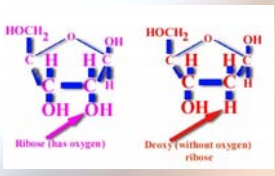
RNA (Ribonucleic Acid)

RNA is composed of a four-letter alphabet. However, the thymine (T) in DNA is replaced by a uracil (U) in RNA.



RNA vs. DNA

RNA polymerase	DNA polymerase
one strand	double strands
ribonuclotides	deoxyribonucleotides
uridine (U)	thymidine (T)



Transcription

Transcription Detail

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Developed by: Patty Hain and Nathan Wambaugh

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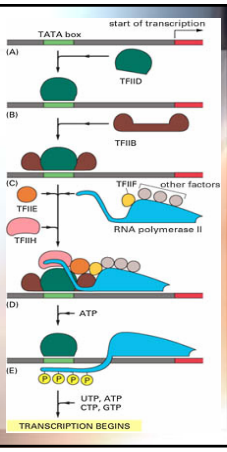
Transcription Initiation



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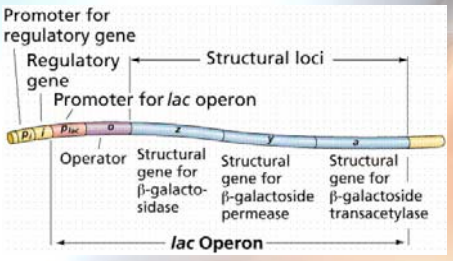

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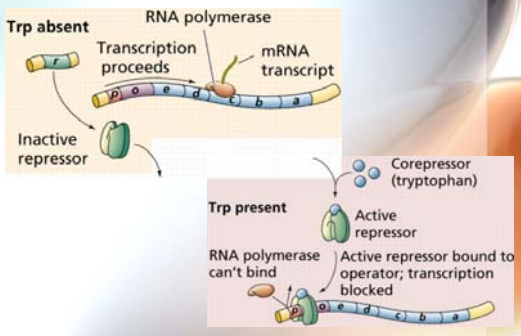
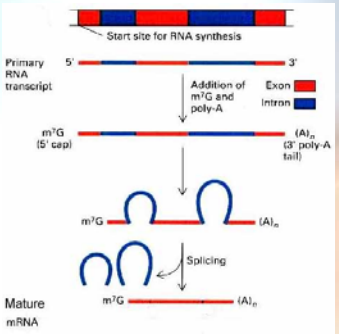
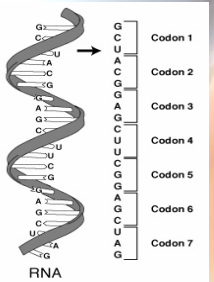


Splicing

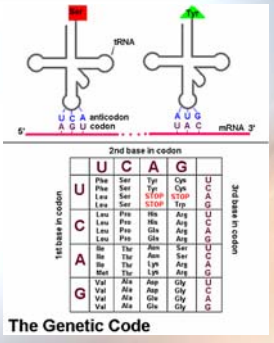


Codons and Building Proteins

- The message encoded in RNA is read in three-letter words ***codons***.
  - Code for specific amino acids, which are the building blocks of proteins.
  - The beginning of a coding sequence: ***start codon***; the end of the amino acid sequence: ***stop codon***.

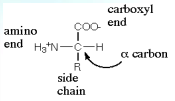


Genetic Code

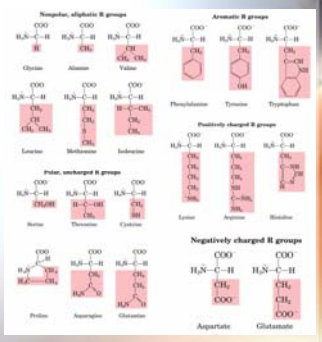


Amino Acids - Building Blocks of Proteins

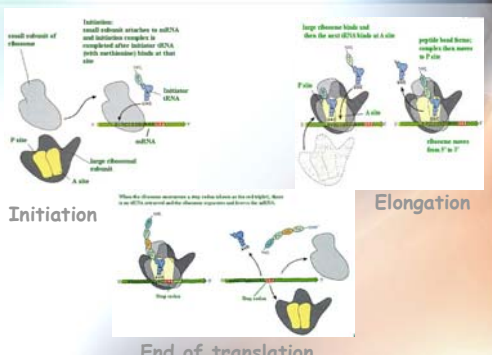
20 amino acids



- **Abbreviation with 1 or 3 letters**
- **Protein: chain of amino acids**

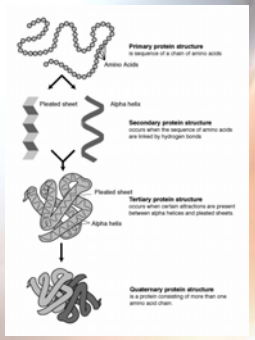


Translation

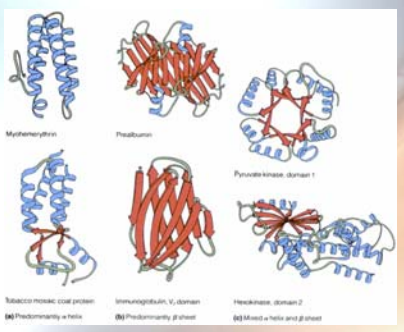


Protein Structure

- Primary structure: the amino acid sequence
- Secondary: local in sequence
- Tertiary: 3D fold of one polypeptide chain
- Quaternary: Chains packing together



Globular Protein Structures



http://www.aw-bc.com/mathews/ch06/fi6p16.htm

References

- Molecular Biology of the Cell by Alberts et al.
- Genes VII by Lewin
- MIT Biology Hypertextbook: http://web.mit.edu/esgbio/www/
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