Basics in Biology
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Life

Tree of Life

Building Blocks of Life

The History of Cell

Cell
Chemistry of the Cell
- Water
- Ions
- Nucleic acids
- Carbohydrates
- Lipids
- Proteins

Prokaryotic and Eucaryotic Cells
Animals, plants, fungi, and protists
Bacteria

Prokaryotic
- Cell wall
- Nucleoid
- Capsule
- Flagella

Eucaryotic
- Mitochondrion
- Vacuole
- Nucleus
- Chloroplast
- Ribosomes
- DNA

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 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

- Interphase: The nucleus replicates its DNA and the cell grows.
- Interphase-prometaphase transition: The chromosomes condense and become visible, the nuclear envelope breaks down, and the mitotic spindle begins to form.
- Prophase: Chromatids replicate and form sister chromatids. The nuclear envelope breaks down, the centrosomes nucleate the spindle fibers.
- Prometaphase: The chromosomes align at the metaphase plate, and the chromosomes are oriented for division.
- Metaphase: The chromosomes align at the metaphase plate, and the chromosomes are oriented for division.
- Anaphase: The sister chromatids separate and move to opposite poles of the cell.
- Telophase: The nuclear envelope re-forms, chromosomes decondense, and the cell returns to interphase.

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

- 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.

Human Chromosome

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- 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 replication** → **transcription** → **translation** → **protein** → **physiology**

DNA

- 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 discovers the basic rules of heredity of garden pea.
- **1869**: Johann Friedrich Miescher discovers DNA and names 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

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

### 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

### DNA Replication
- DNA Replication Prior to Cell Division
- Parent Strands
  - Adenine (A)
  - Thymine (T)
  - Guanine (G)
  - Cytosine (C)
- Complementary New Strand
- The Central Dogma of Molecular Biology
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
ribonucleotides deoxyribonucleotides
uridine (U) thymidine (T)

Transcription

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Transcription Initiation

Transcription

Promoter for regulatory gene
Regulatory gene
Promoter for lac operon
Operator
Structural gene for \( \beta \)-galactosidase
Structural gene for \( \beta \)-galactosidase permease
Structural gene for \( \beta \)-galactosidase transacetylase
lac Operon

Transcription

RNA polymerase
Trp absent
Transcription proceeds
Inactive repressor
mRNA transcript

Trp present
Active repressor
Active repressor bound to operator; transcription blocked
Co-repressor (tryptophan)
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

References

- Molecular Biology of the Cell by Alberts et al.
- Genes VII by Lewin
- Online Biology Book: http://www.emc.maricopa.edu/faculty/farabee/BIOBK/BioBookTOC.html