Evolution and Genetics

36-149 The Tree of Life

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Plan

1. De-briefing on Science Box
2. Evolution and Genetics
3. Book List Description
4. Feedback on First Writing Assignment

What is the Process of Biological Evolution?

Darwin's phrase is apt: "Descent with modification".

A Working Definition:

> Cross-generational change in a population of organisms that involves changes in gene frequency.

Key points:

1. Evolution is a *process*.
2. Evolution acts on populations; individuals do not evolve.
3. Evolution requires heritable variation in the population.
4. Evolution does not only occur over long periods of time.
5. Evolution does not always lead to "improvement."

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2. Theory of Common Descent
3. Theories of Evolutionary Mechanisms
4. Theories of Speciation

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1. The Fact of Evolution

   Evolution happens: Cross-generational change occurs in both gene frequencies and phenotypes.

   This is observed directly. Examples:

   - antibiotic resistant bacteria, influenza, HIV
   - Fish stocks

   The Fact of Evolution does not describe *how* evolution occurs or explain how it produces the diversity of life.

2. Theory of Common Descent
3. Theories of Evolutionary Mechanisms
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1. The Fact of Evolution
2. Theory of Common Descent

   All organisms alive on earth are descendants of one (or at most a few) common ancestor(s).

   As evolutionary changes accrue over time, new forms of life are generated as lineages split, a process called *speciation*.
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   Explain *how* evolutionary change occurs.

   - Natural Selection
   - Genetic Drift
   - Sexual Selection
   - Developmental Plasticity

   Current thinking: Most evolutionary change is driven by natural selection.

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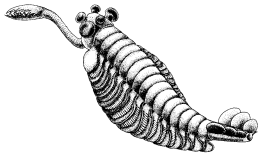
   Explain how population-level changes in gene and phenotype distributions produce new species.

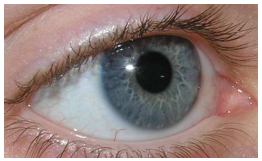
   Central Idea: Reproductive isolation.

   Modes of speciation: Allopatric, Parapatric, and Sympatric

What "The Theory" Must (And Does) Explain



The diversity of life.



The origins of complex adaptations.

Features that do not benefit individual organisms.

Cooperation and Social Behavior.

Coordination and Signalling

Extinction

What We Need First

To understand and study both the process of evolution and the theory of evolution (and its components), we need to touch on two prerequisite ideas:

- Genes and Genetics – the units and mechanisms of heredity for living things; just the basics, that's all.
- Populations – a statistical concept that helps us think about evolving groups of organisms.

Genetics today, populations thursday.

Genetics in Seven Easy Pieces

1. DNA (deoxyribonucleic acid) molecules are the principal unit of inheritance passed from parents to offspring.

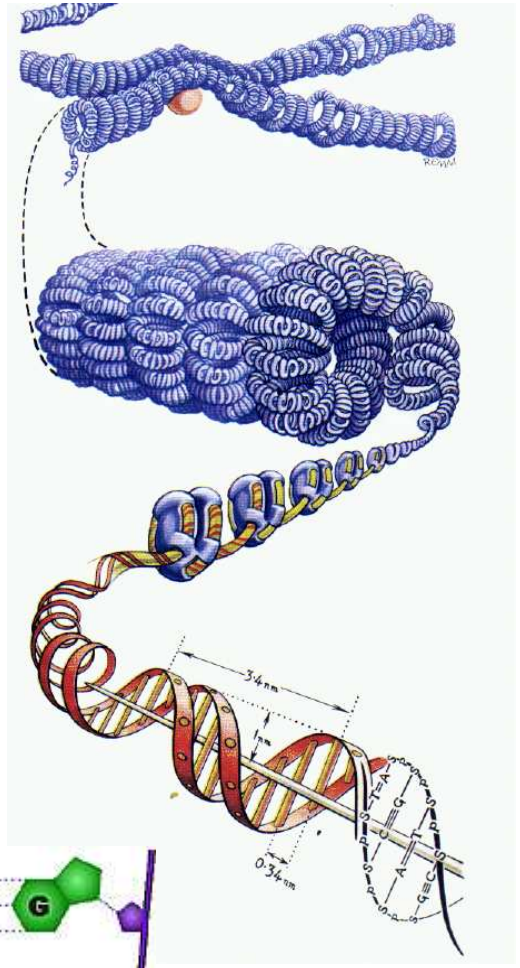
DNA consists of two complementary strands of *nucleotides* arranged in double helix.

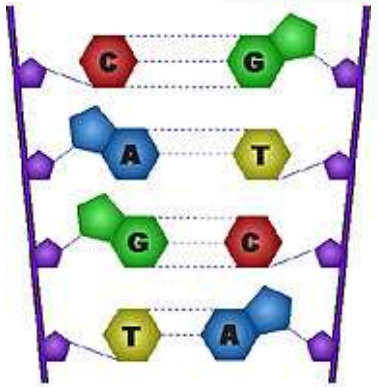
Four nucleotide bases: A (Adenine), T (Thymine), C (Cytosine), and G (Guanine).

These are the "letters" in the genetic code.

Only A & T and C & G bind together.

About 3 billion such "base pairs" in human genome.





Genetics in Seven Easy Pieces (cont'd)

2. DNA encodes recipes for the body's proteins.

Proteins are large molecules that perform many important functions in cells. Many important proteins are *enzymes*, which facilitate particular chemical reactions.

A protein is a chain of "amino acids" specified by a specific sequence of nucleotides on DNA, called codons.

Codons are the "words" in the DNA code

A *gene* is the basic unit of heredity.

It is a sequence of nucleotides on the DNA molecule. Most genes encode the information needed to produce a protein. Some genes regulate the expression of other genes.

Key Terms

- Nucleotide: A building block of nucleic acids; four basic types A, C, G, T, and U. Consists of a base, a phosphate, and a sugar.
- Gene: the basic unit of heredity, a sequence of nucleotides involved in producing a protein or part of one.
- Allele: One of the possible states of a gene
- Genome: the full complement of DNA present in a cell.
- Genotype: the genetic makeup of an individual, including alleles which have no external manifestation.
- Phenotype: all traits of an organism other than its genome

Genetics in Seven Easy Pieces (cont'd)

3. RNA (ribonucleaic acid) mediates the production of proteins.

$$\text{DNA} \xrightarrow{\text{transcription}} \text{RNA} \xrightarrow{\text{translation}} \text{protein}$$

transcription: the process by which a strand of DNA is copied to a complementary strand of RNA

translation: the process by which instructions from messenger RNA is converted, base by base, into the sequence of amino acids that form a protein

Genetics in Seven Easy Pieces (cont'd)

4. The genome is divided into genes, regulatory elements, and various non-coding DNA, arranged on chromosomes.

Less than 5% of human DNA codes for proteins, in about 30,000* genes. The function of the rest is not yet understood.

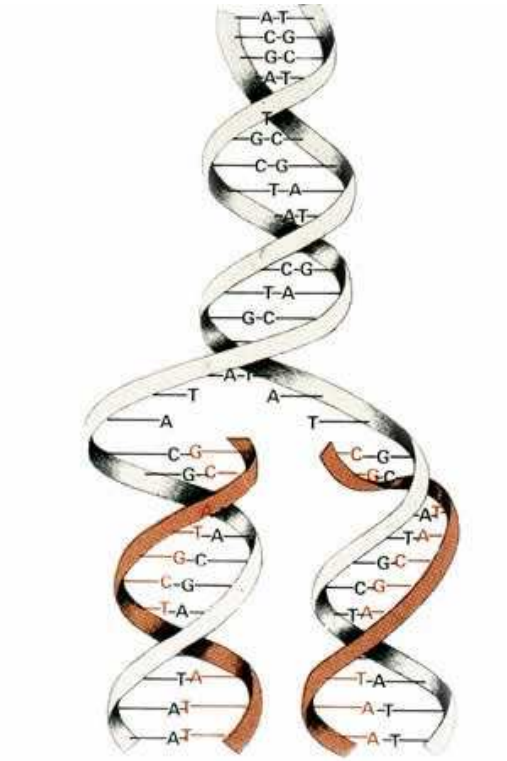
Chromosomes – bundled strands of DNA with many genes on them – are typically arranged in pairs. Humans have 23 pairs and get one of each pair from each parent.

Genetics in Seven Easy Pieces (cont'd)

5. DNA molecules replicate during cell division.

When the two strands of DNA separate, each has enough information to remake the whole because A-T and C-G pairs are complementary.

This is the key to DNA's ability to replicate.



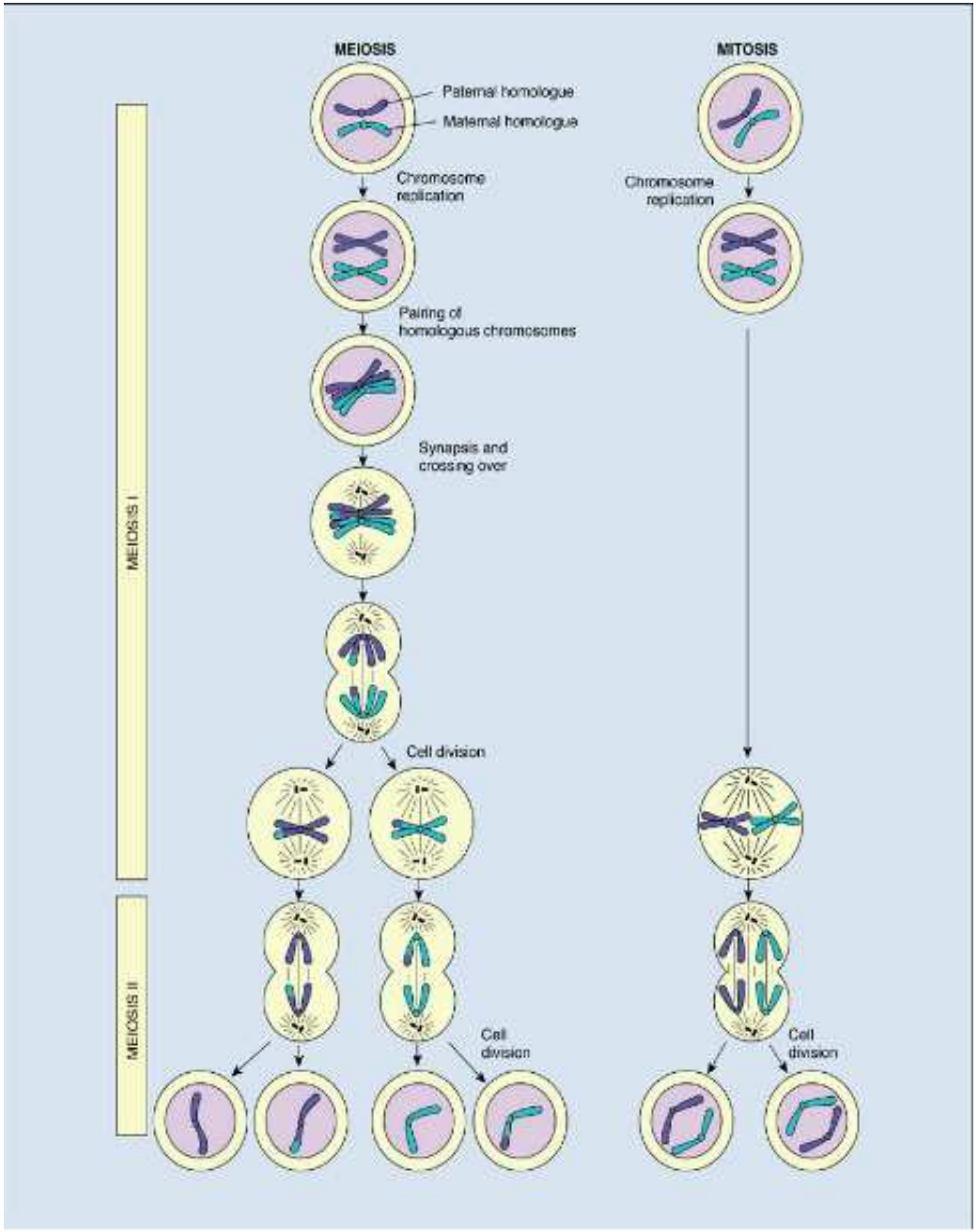
Genetics in Seven Easy Pieces (cont'd)

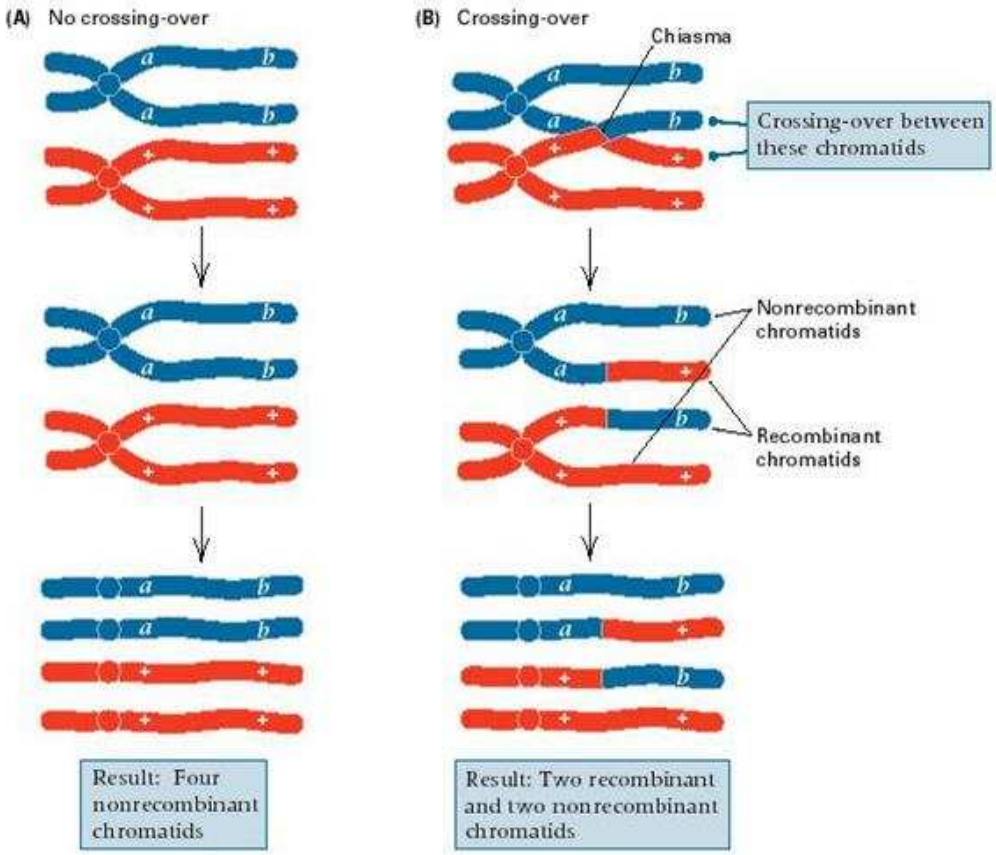
6. A variety of errors can occur during replication.

Mutations:

- substitution of a single base
- shift of the copying position
- transposition of sections of DNA
- duplication or deletion of sections of DNA

Recombination: a process in which DNA strands cross-over, break, and re-join, producing new genetic combinations not present in parents.


MEIOSIS
MITOSIS
Paternal homologue
Maternal homologue
Chromosome replication
Chromosome replication
Pairing of homologous chromosomes
Synapsis and crossing over
MEIOSIS I
Cell division
MEIOSIS II
Cell division
Cell division


(A) No crossing-over
(B) Crossing-over
Chiasma
Crossing-over between these chromatids
Nonrecombinant chromatids
Recombinant chromatids
Result: Four nonrecombinant chromatids
Result: Two recombinant and two nonrecombinant chromatids

Genetics in Seven Easy Pieces (cont'd)

7. Genes are (sometimes) inherited in characteristic Mendelian ratios.

In 1866, Gregor Mendel published a model for inheritance based on painstaking empirical work breeding pea plants.

Meanwhile, Darwin was struggling to find a workable theory of inheritance that would explain some key features of his theory of evolution.

Mendel's work was just what he needed, but alas, Mendel's work was little noted at the time. When recognized, early in the twentieth century, it would great advances in understanding evolution.

Mendel's Theory is a good approximation for some genes, such as eye color, hair color, and susceptibility to certain diseases. But the situation is now known to be much more complicated.

Genetics in Seven Easy Pieces (cont'd)

Mendel's Theory:

1. Alleles: "Alternative versions of genes account for variation in inherited characters"
2. Diploidy: An organism inherits two copies of each gene, one from each parent.
3. Dominance: If the two inherited alleles differ, one – which we call *dominant* – will be fully expressed; the other – which we call *recessive* – will have no noticeable effect.
4. Segregation: The two copies of each gene will be sorted into separate gametes during meiosis.
5. Independent Assortment: The copy passed to offspring is selected independently for each gene.

Mendelian Examples

Alleles are often labeled by a single letter, with the dominant allele uppercase (e.g., A) and the recessive allele lowercase (e.g., a).

The genotype at one site on the DNA (called a genetic locus) can be indicated by listing the alleles, dominant first (e.g., Aa).

Example: Eye color.

- B brown eyes, dominant allele
- b blue eyes, recessive allele

There are three possibile genotypes: BB (homozygous dominant), Bb (heterozygous), and bb (homozygous recessive).

What is the phenotype for each of the three genotypes?

Crosses:

$BB \times BB \longrightarrow ?$ $\qquad$ $bb \times Bb \longrightarrow ?$

$BB \times Bb \longrightarrow ?$ $\qquad$ $Bb \times Bb \longrightarrow ?$