Principles of Inheritance

How Traits are Transmitted within Families

Chromosomes

- Chromosomes are the complex DNA and protein units that carry the genetic code in all cells with nuclei.
- In sexually-reproducing organisms, chromosomes come in homologous pairs:
  - Each member of the pair contains information on how to build the same protein products.
  - One member of each pair comes from the mother and one comes from the father.

Karyotype

- A Karyotype is a photomicrograph of the chromosomal complement of an individual.
- The chromosomes are arranged according to size, and numbered, with the first pair being the largest chromosomes and the twenty-second pair being the smallest in humans, except for the Y (male-determining) chromosome.

Human Karyotype

Human Genome

- Humans have 23 pairs of chromosomes:
  - 22 pairs of **autosomal chromosomes** affecting almost all aspects of the individual other than sex.
  - 1 set of **sex chromosomes**:
    - A pair of X chromosomes for Females
    - One X and one Y chromosome for Males
  - Approximately 100,000 genetic loci on the 23 pairs of chromosomes.

Locus

- The position of a gene on an homologous chromosome pair is known as a **Locus**:
  - The locus of the beta gene for the Hemoglobin molecule is near the tip of the short arm of chromosome number 11.
  - The locus of the alpha gene is near the tip of the short arm of chromosome number 16.
**Alleses**
- Many genes have different forms
- We discussed two forms of the gene for Hemoglobin, the normal form called type A, and the mutant variety that results in sickle cell, type S
- These variants of a particular gene are called Alleles

**Genotype vs. Phenotype**
- **Genotype** is the genetic makeup of an individual
  - This usually refers to what alleles an individual has at a specific locus
    - e.g., at the ABO locus, one A allele, one O allele
- **Phenotype** is the observable expression of the genotype
  - The phenotype for the above genotype would be Blood Type A.

**Homozygous**
- If an individual has two of the same alleles at a particular locus, he is said to be **homozygous (or is a homozygote)**
  - A person is homozygous if he inherits a Hemoglobin S allele from both his mother and father
  - Genotype: Hb$^S$/Hb$^S$
  - Phenotype: Sickle Cell Anemia

**Heterozygous**
- If an individual has two different alleles at a particular locus, he is said to be **heterozygous (or is a heterozygote)**
  - A person is heterozygous if he inherits a Hemoglobin S allele from his mother and a Hemoglobin A allele from his father
  - Genotype: Hb$^S$/Hb$^A$
  - Phenotype: Sickle Cell Trait (Carrier)

**Dominant and Recessive**
- Alleles are said to be dominant or recessive depending upon whether they are expressed (dominant) or hidden (recessive) in heterozygotes
  - In the ABO system, A and B alleles are dominant over O, and co-dominant with each other (Blood type AB)
  - O is recessive to both A and B

**Gregor Mendel**
- Augustinian Monk
- Determined that the nature of inheritance was particulate (genes)
- Published findings in 1865
- Was unknown until 1900
Mendelian Genetics

- An individual can have two different types of genes for a particular characteristic and only express one type
  - Example: ABO blood type system, if you have both an A type gene and an O type gene, your blood type is A, and your blood functions as blood type A

Mendelian Genetics

- Law of Segregation
  - Genes occur in pairs (because chromosomes occur in pairs, one from the mother and one from the father)
  - During meiosis, chromosome pairs separate so that each gamete contains one member of each pair
  - Each gamete has an equal (50-50) chance of containing a particular maternal or paternal chromosome (randomness)

Mendelian Genetics

- Law of Independent Assortment
  - Alleles that govern one trait sort into gametes independently of the alleles for other traits--providing they are on separate chromosomes
  - Chance governs which pairs of alleles from loci on separate chromosomes are found in any given gamete

MEIOSIS

The process of Meiosis accounts for the Law of Segregation

- Homologous pairs separate at the end of metaphase I of meiosis. The homologous pairs separate at the end of metaphase I of meiosis.
- Each homologous pair exchanges segments of DNA during meiosis.
- Crossing over occurs when homologous chromosomes exchange pieces of DNA.
- The result of crossing over is that the gametes have a mixture of maternal and paternal chromosomes.
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SO HOW DOES IT WORK?

<table>
<thead>
<tr>
<th>GAMETES</th>
<th>Father A</th>
<th>Father O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mother A</td>
<td>Blood Type A</td>
<td>Blood Type O</td>
</tr>
<tr>
<td></td>
<td>3 out of 4 = 75%</td>
<td>1 out of 4 = 25%</td>
</tr>
</tbody>
</table>

Independent Assortment

- The ABO locus is on chromosome 9, the Rhesus (Rh) locus is on chromosome 1
- These two factors are transmitted independent of one another
  - Phenotype (Blood type): A+
  - Genotype: A/O +/
  - Gametes: A+/ A− O+/ O− in equal numbers
Genetic Linkage

- If two different genes have loci on the same homologous chromosome pair, they are said to be **Linked**
  - The locus for insulin and the locus for tissue compatibility (affects transplant rejections) are both found on the sixth chromosome pair in man
  - These two genes are linked

Autosomal Dominant: Huntington’s Disease

Autosomal Recessive: Phenylketonuria

Sex-Linked Recessive: Hemophilia A

Fig. 7-6  Sibling females (IV-3 and IV-4) with hemophilia. Note that IV-3 and IV-4 are children of double first cousins. This would not influence the occurrence of the disease in males but can be a factor increasing its likelihood in females, as will be discussed further in Chapter 10. (From Pola and Svorak, 1968. Courtesy of V. Pola and Folia Hematologica, Leipzig.)