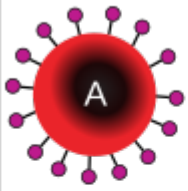
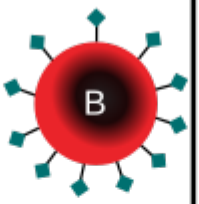
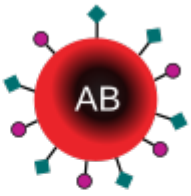
1. Explain what is meant by incomplete dominance, codominance, multiple alleles, epistasis, poly-genic inheritance, and pleiotropy; give an example of each.
2. Give two examples showing how the expression of genes is affected by the external environment.
3. Explain what is meant by a sex-linked trait, and define the term linkage group.
4. Discuss the meaning of recombination, and explain how recombinations are possible.
5. Discuss how chromosomes are mapped; explain how giant chromosomes can be used to study changes in hereditary patterns.
6. Describe the differences between X-linked inheritance and sex-linked inheritance

Contents

Non-Mendelian Genetics

Co-Dominance and multiple alleles

Co-dominance is said to occur when there is an expression of two dominant alleles. The prototypical case for this is the human ABO blood grouping.

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in red blood cell	 A antigen	 B antigen	 A and B antigens	None

Three alleles exist in the ABO system: A, B and O. This results in four blood types: A, B, O and the blended AB.

Incomplete Dominance

During Mendel's time, people believed in a concept of blending inheritance whereby offspring demonstrated intermediate phenotypes between those of the parental generation. This was refuted by Mendel's pea experiments that illustrated a Law of Dominance. Despite this, non-Mendelian inheritance can be observed in sex-linkage and co-dominance where the expected ratios of phenotypes are not observed clearly. **Incomplete dominance** superficially resembles the idea of blending inheritance, but can still be explained using Mendel's laws with modification. In this case, alleles do not exert full dominance and the offspring resemble a mixture of the two phenotypes.

Incomplete dominance in snapdragon flowers superficially appears like blending inheritance.Credit: Jeremy Seto (CC-BY-NC-SA)

The most obvious case of a two allele system that exhibits incomplete dominance is in the snapdragon flower. The alleles that give rise to flower coloration (Red or White) both express and the heterozygous genotype yields pink flowers. There are different ways to denote this. In this case, the superscripts of R or W refer to the red or white alleles, respectively. Since no clear dominance is in effect, using a shared letter to denote the common trait with the superscripts (or subscripts) permit for a clearer denotation of the ultimate genotype to phenotype translations.

Problem: Incomplete Dominance

If pink flowers arose from blending inheritance, then subsequent crosses of pink flowers with either parental strain would continue to dilute the phenotype. Using a Punnet Square, perform a test cross between a heterozygous plant and a parental to predict the phenotypes of the offspring.

Epistasis and Modifier Genes

Interplay of multiple enzymes in a biochemical pathway will alter the phenotype. Some genes will modify the actions of another gene. Credit: Jeremy Seto (CC0)

Genes do not exist in isolation and the gene products often interact in some way. **Epistasis** refers to the event where a gene at one locus is dependent on the expression of a gene at another genomic locus. Stated another way, one genetic locus acts as a modifier to another. This can be visualized easily in the case of labrador retriever coloration where three primary coat coloration schemes exist: black lab, chocolate lab and yellow lab.

Chocolate lab (top), Black lab (middle), Yellow lab (bottom) coat colorations arise from the interaction of 2 gene loci, each with 2 alleles.
Credit: Erikeltic [CC-BY-SA 3.0]

Two genes are involved in the coloration of labradors. The first is a gene for a protein called TYRP1, which is localized to the melanosomes (pigment storing organelles). Three mutant alleles of this gene have been identified that reduce the function of the protein and yield lighter coloration. These three alleles can be noted as "***b***" while the functioning allele is called "***B***". A heterozygous (Bb) or a homozygous dominant individual will be black coated while a homozygous recessive (bb) individual will be brown.

Black lab (BB or Bb) and Chocolate lab (bb) *Credit: dmealiffe[CC BY-SA 2.0]*

The second gene is tied to the gene for Melanocortin 1 Receptor (MC1R) and influences if the eumelanin pigment is expressed in the fur. This gene has the alleles denoted "***E***" or "***e***". A yellow labrador will have a genotype of either *Bbee* or *bbee*.

Black lab (EE or Ee) and Yellow lab (ee) [CC0]

The interplay between these genes can be described by the following diagram:

Black lab (B_E_, Chocolate lab (bbE_), Yellow lab with dark skin where exposed (B_ee) and Yellow lab with light skin where exposed. *Credit: Jeremy Seto (CC-BY-SA 3.0)*