12.2D: Alternatives to Dominance and Recessiveness

With the inclusion of incomplete dominance, codominance, multiple alleles, and mutant alleles, the inheritance of traits is a complex process.

Learning Objectives

• Discuss incomplete dominance, codominance, and multiple alleles as alternatives to dominance and recessiveness

Key Points

• Incomplete dominance is the expression of two contrasting alleles such that the individual displays an intermediate phenotype.
• Codominance is a variation on incomplete dominance in which both alleles for the same characteristic are simultaneously expressed in the heterozygote.
• Diploid organisms can only have two alleles for a given gene; however, multiple alleles may exist at the population level such that many combinations of two alleles are observed.
• The complete dominance of a wild-type phenotype over all other mutants often occurs as an effect of “dosage” of a specific gene product: the wild-type allele supplies the correct amount of gene product whereas the mutant alleles cannot.
• One mutant allele can also be dominant over all other phenotypes, including the wild type.

Key Terms

• allele: one of a number of alternative forms of the same gene occupying a given position on a chromosome
• **incomplete dominance**: a condition in which the phenotype of the heterozygous genotype is distinct from and often intermediate to the phenotypes of the homozygous genotypes

• **codominance**: a condition in which both alleles of a gene pair in a heterozygote are fully expressed, with neither one being dominant or recessive to the other

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### Alternatives to Dominance and Recessiveness

Mendel’s experiments with pea plants suggested that: (1) two “units” or alleles exist for every gene; (2) alleles maintain their integrity in each generation (no blending); and (3) in the presence of the dominant allele, the recessive allele is hidden and makes no contribution to the phenotype. Therefore, recessive alleles can be “carried” and not expressed by individuals. Such heterozygous individuals are sometimes referred to as “carriers.” Further genetic studies in other plants and animals have shown that much more complexity exists, but that the fundamental principles of Mendelian genetics still hold true.

Mendel’s results, that traits are inherited as dominant and recessive pairs, contradicted the view at that time that offspring exhibited a blend of their parents' traits. However, the heterozygote phenotype occasionally does appear to be intermediate between the two parents. For example, in the snapdragon, *Antirrhinum majus*, a cross between a homozygous parent with white flowers (C<sup>W</sup>C<sup>W</sup>) and a homozygous parent with red flowers (C<sup>R</sup>C<sup>R</sup>) will produce offspring with pink flowers (C<sup>R</sup>C<sup>W</sup>). This pattern of inheritance is described as incomplete dominance, denoting the expression of two contrasting alleles such that the individual displays an intermediate phenotype. The allele for red flowers is incompletely dominant over the allele for white flowers. However, the results of a heterozygote self-cross can still be predicted, just as with Mendelian dominant and recessive crosses. In this case, the genotypic ratio would be 1 C<sup>R</sup>C<sup>R</sup>:2 C<sup>R</sup>C<sup>W</sup>:1 C<sup>W</sup>C<sup>W</sup>, and the phenotypic ratio would be 1:2:1 for red:pink:white.
A variation on incomplete dominance is codominance, in which both alleles for the same characteristic are simultaneously expressed in the heterozygote. An example of codominance is the MN blood groups of humans. The M and N alleles are expressed in the form of an M or N antigen present on the surface of red blood cells. Homozygotes ($L^M L^M$ and $L^N L^N$) express either the M or the N allele, and heterozygotes ($L^M L^N$) express both alleles equally. In a self-cross between heterozygotes expressing a codominant trait, the three possible offspring genotypes are phenotypically distinct. However, the 1:2:1 genotypic ratio characteristic of a Mendelian monohybrid cross still applies.

Mendel implied that only two alleles, one dominant and one recessive, could exist for a given gene. We now know that this is an oversimplification. Although individual humans (and all diploid organisms) can only have two alleles for a given gene, multiple alleles may exist at the population level such that many combinations of two alleles are observed. Note that when many alleles exist for the same gene, the convention is to denote the most common phenotype or genotype among wild animals as the wild type (often abbreviated "+"); this is considered the standard or norm. All other phenotypes or genotypes are considered variants of this standard, meaning that they deviate from the wild type. The variant may be recessive or dominant to the wild-type allele. An example of multiple alleles is coat color in rabbits. Here, four alleles exist for the $c$ gene. The wild-type version, $C^+ C^+$, is expressed as brown fur. The chinchilla phenotype, $c^{ch} c^{ch}$, is expressed as black-tipped white fur. The Himalayan phenotype, $c^h c^h$, has black fur on the extremities and white fur elsewhere. Finally, the albino, or "colorless" phenotype, $cc$, is expressed as white fur. In cases of multiple alleles, dominance hierarchies can exist. In this case, the wild-type allele is dominant over all the others, chinchilla is
incompletely dominant over Himalayan and albino, and Himalayan is dominant over albino. This hierarchy, or allelic series, was revealed by observing the phenotypes of each possible heterozygote offspring.

Figure: Example of multiple alleles for rabbit coat color: Four different alleles exist for the rabbit coat color (C) gene.

The complete dominance of a wild-type phenotype over all other mutants often occurs as an effect of “dosage” of a specific gene product, such that the wild-type allele supplies the correct amount of gene product whereas the mutant alleles cannot. For the allelic series in rabbits, the wild-type allele may supply a given dosage of fur pigment, whereas the mutants supply a lesser dosage or none at all. Alternatively, one mutant allele can be dominant over all other phenotypes, including the wild type. This may occur when the mutant allele somehow interferes with the genetic message so that even a heterozygote with one wild-type allele copy expresses the mutant phenotype. One way in which the mutant allele can interfere is by enhancing the function of the wild-type gene product or changing its distribution in the body. One example of this is the Antennapedia mutation in *Drosophila*. In this case, the mutant allele expands the distribution of the gene product; as a result, the Antennapedia heterozygote develops legs on its head where its antennae should be.
Figure 1: **Example of a mutant allele interfering with the function of a wild-type gene:** As seen in comparing the wild-type *Drosophila* (left) and the Antennapedia mutant (right), the Antennapedia mutant has legs on its head in place of antennae.