10 Genetics and evolution

Introduction

- genes may be linked or unlinked
- meiosis leads to independent assortment of chromosomes and unique composition of alleles
- gene pools change over time

10.1 Meiosis

Chromosome replication

- meiosis follows a period of interphase with cell cycle phases G_1, S and G_2
- DNA is replicated in S phase so each chromosome consists of two chromatids
- synapsis occurs where homologous chromosomes align beside each other: tetrad/bivalent
- synaptonemal complex: protein-based structure forming between homologous chromosomes

Exchange of genetic material

- during prophase I breaks in DNA occur: non-sister chromatids exchange homologous sequence: after crossing over they continue to adhere at connection points called chiasmata

Chiasmata formation

- consequences of chiasmata are increased stability of bivalents and increased genetic variability
- exchanges DNA between maternal and paternal chromosomes: decouples linked combinations
- crossing over can occur multiple times and between different chromatids within same homologous pair

New combinations of alleles

- crossing over produces new combinations of alleles on chromosomes of haploid cells

Meiosis I

- first meiotic division is unique, second round resembles mitosis
- differences between meiosis I and II: sister chromatids remain associated with each other, homologous chromosomes exchange DNA (genetic recombination), reduction division
- creation of genetic variety of gametes; segregation of homologous chromosomes (anaphase I)

Independent assortment

- homologous chromosomes pair up and then separate to poles; pole to which it moves depends on which pole the pair is facing; is random; irrespective of other pairs: independent orientation

Meiosis II

- daughter cells enter meiosis II after meiosis I without passing through interphase
- meiosis II is similar to mitosis
- sister chromatids are separated, but likely to be non-identical sister chromatids (crossing over)

10.2 Inheritance

Segregation and independent assortment

- segregation: separation of two alleles of every gene that occurs in meiosis
- genes found on different chromosomes are unliked; genes on the same are linked: do not segregate independently
- crossing over between genes occurs more frequently the further the separation of the genes

Linked genes

- Morgan shows that genes are arranged in linear sequence along X chromosome
- each particular gene is found in a specific position on one chromosome type: locus of a gene
- chromosomes with same sequence of genes are homologous; alleles will be different
- all genes on a chromosome are part of one DNA molecule
- diploid have two of each type of autosome

- two types of linkage: autosomal gene linkage and sex linkage

Types of variation
- variation: differences between individual organisms
- variation is discrete or discontinuous when individuals fall into number of distinct categories
- blood types are an example of discrete variation; there are no in-between categories

Continuous variation
- when two or more genes affect the same character they have an additive effect
- Mendel's expected 3:1 ratio did not occur and he had variety of flower colors: two unlinked genes with co-dominant alleles
- number of frequency variants can be predicted with alternate rows of Pascal's triangle
- as number of genes increases, distribution becomes increasingly close to normal distribution
- closeness to normal distribution suggests more than one gene involved: polygenic inheritance

Chi-squared tests are used to determine whether the difference between observed and expected frequency distribution is statistically significant
- are differences between observed and expected due to sampling error or are differences statistically significant
- method: table of observed frequencies, calculate expected frequencies (assuming independent assortment), determine degrees of freedom (one less than total number of classes), find critical region from chi-squared values, calculate X^2 = sum of $(obs-exp)^2/exp$, if calculated value is equal to or below the chi-squared value H_0 is not rejected

10.3 Gene pools and speciation
Gene pools
- gene pool: all genes and their different alleles present in an interbreeding population
- species is a group of potentially interbreeding populations with common gene pool that is reproductively isolated from other species
- some populations are geographically isolated: multiple gene pools for same species
- genetic equilibrium exists when all members of population have equal chance of contributing to the future gene pool

Allele frequency and evolution
- evolution: cumulative change in heritable characteristics of a population over time
- evolution occurs because: mutations introducing new alleles, selection pressures favoring reproduction of some varieties, barriers to gene flow emerging between different populations
- if a population is small, random events can also have a significant effect on allele frequency

There are different categories of reproductive isolation
- speciation is the formation of a new species by the splitting of an existing population
- allopatric speciation: isolation occurs because of geographic separation
- sympatric speciation: isolation of gene pools within same geographic area, e.g. behavioral
- temporal isolation: populations may mate/flower at different seasons or different times of day

Gradualism in speciation
- gradualism: species slowly change through a series of intermediate forms
- gradualism is dominant framework in paleontology but there are gaps in the fossil record

Punctuated equilibrium
- long periods of relative stability in a species are punctuated by periods of rapid evolution
- gaps in fossil record might not be gaps at all
- geographic isolation and opening of new niches within shared geographic range can lead to rapid speciation
- rapid change is much more common in organisms with short generations (prokaryotes, insects)