05 5 Population genetics

Preservation and extinction of genetic traits from generation to generation

> "And God made the beast of the earth after his kind, and cattle after their kind, and every thing that creepeth upon the earth after his kind: and God saw that it was good." — Genesis 1:25

Frequency of change in alleles

1. Previous lessons on genetics dealt with inheritance of a single trait controlled by one or more genes. Genotype expressed as a phenotype.
2. Population genetics studies the change in the frequency of alleles already in existence in a population by comparing the change in genotype frequency with its change in phenotype frequency from generation to generation.
3. Phenotype selection is a selection for a trait's genotype.
4. To study frequency changes in alleles, we analyze populations rather than individuals.
5. Population genetics is studied by both creationists and evolutionists. Their models and interpretations differ.

Vocabulary

1. Population – any group of organisms coexisting at the same time and place that are capable of interbreeding with one another. It is the smallest unit that can change beyond one generation.
2. Kind – The group identity of organisms that define the boundary confines of allele change. A kind is often a species, but can include groupings in a genus, order, or family.
3. Gene – DNA code in a population for a trait such as eye color.
4. Allele – DNA code (gene) alternatives in a population for a trait such as blue eyes or brown eyes. Diploid organisms have two alleles for each gene—one from each parent. A population can have many alleles for one trait.
5. Gene Pool – is the sum total of all of the alleles (genes) at all loci in the population.
6. Loci- are locations on the chromosome where alleles for each type of gene can be found.
7. Polymorphism- is the occurrence of different traits in the same species.
8. Variation– refers to changes in population allele frequencies, already existing, over time. The population is the smallest unit that can change beyond one generation.
9. Genetic diversity – refers to the number of alleles in a population for a gene. Large gene pools often have greater genetic diversity.
10. Genetic homeostasis- Organisms manifest genetic stability by resisting change. Variation is limited to a population kind.
11. Adaptation – the adjustment of a population's phenotype/genotype in response to change in its environment. Changes in the environment may require adaptation in order for a population to survive.
12. Natural Selection – naturally occurring forces that cause survival and reproduction advantage or disadvantage for individuals in a population according to phenotype differences. This contributes to the frequency change, preservation, or loss of alleles. Selective pressures include food shortage, disease, natural disasters, etc.
13. Mass selection- The practice of intentionally selecting and controlling breeding of individual organisms for a desirable trait.
14. Hybridization- The crossing of two varieties of the same species.

15. Heterosis- also called hybrid vigor resulting from the benefit of hybridization.
16. Pure strains- are the result of inbreeding, which can result in higher frequency of defects.
17. Genetic engineering- is the intentional altering of the genetic code by changing the DNA code, adding or deleting genes.
18. Recombinant DNA- the combination of DNA from two sources such as the human insulin gene in bacteria.
19. DNA probes- are pieces of DNA with a nucleotide sequence that match known genes.
20. Eugenics- the practice of breeding humans for desired traits.
21. Genetic Drift –naturally occurring changes in the gene (allele) frequency in a population without selection influences often within a parameter of deviation from the 'norm.' However, allele frequency can drift away the norm resulting in a random drifting of increase or decrease allele frequency.
22. Bottleneck Effect – drastic change in the gene pool (allele frequencies) when a population undergoes a severe reduction in size for at least one generation due to a selective event. Some alleles may be eliminated from the population.
23. Allele fixation – when a gene has only one allele. Sometimes, one allele of a gene becomes the only allele, and the alternative alleles are eliminated from the population.
24. Founder Effect – change allele frequency when a small group of individuals establishes its own population.
25. Gene flow – genes migrate between populations. Gain or loss of alleles from a population due to migration of fertile individuals, or from the transfer of alleles when organisms from one population mate with organisms from another.
26. Evolution – a theory that proposes populations can experience unlimited change in genotype-phenotype expression over time resulting in new populations of species and kinds of organisms.
27. Creation – proposes that populations experience limited change in genotype-phenotype expression over time and can result in new phenotypes in populations of organisms but as variations of the same kind of organism.

Hardy-Weinberg equilibrium theorem

The Hardy-Weinberg Theorem states that allele frequencies of a gene in a population will remain constant, as long as selective forces are not favoring one phenotype over another. For a population to be in Hardy-Weinberg equilibrium, the following conditions or assumptions must be true:

1. The population is very large.
2. The population is genetically stable.
3. All organisms in the population are involved in breeding.
4. All litters are the same size.
5. No mutations occur.
6. No selection pressures occur.
7. There is no migration in or out of the population.

If one of these conditions is not true, then the allele frequencies are changing. They are not at equilibrium. Natural populations are subjected to many selective forces, and thus, are not at equilibrium.

Hardy-Weinberg calculations are used to determine allele frequencies at a moment in time, and is useful to compare and evaluate allele changes and the rate of change in allele frequencies.

Equilibrium theorem for populations serves as a control number. Such populations do not exist. But a population can be studied by comparing it to its theoretical equilibrium.

Hardy Weinberg equation

1. The Hardy-Weinberg equation provides a way of calculating allele frequencies and genotypes at a moment in time.
2. The total frequency of two alleles in a population is the percent of one allele (p) + the percent of another allele (q) = 100%.
   a. Percents are often expressed as decimals: $p + q = 1$ (e.g. 70%=30% = .7 + .3 = 100% = 1)
   b. Allele frequencies indicate the number of times a gene is present in a population and the probability of inheriting that gene.
3. Total frequency of genotypes in a population with two alleles: $p^2 + 2pq + q^2 = 1$
   a. p^2 is homozygous dominant genotype (2 dominant alleles).
   b. q^2 is homozygous recessive genotype (2 recessive alleles).
   c. 2pq is heterozygous genotype (1 of each allele).
   d. $(p^2 + 2pq)$ is the dominant phenotype frequency.
   e. $(p^2 + 2pq)$ also equals = $1 — q^2$

Applying the Hardy-Weinberg equation for a population trait having only two alleles.

1. First, count the number of phenotypes: recessive _________ and dominant ________.
2. Calculate the frequency of homozygous recessive phenotypes.
   a. (Recessive phenotypes/Total population) = _____% homozygous recessives = q^2
   b. q^2 = _______ % of recessive phenotypes, which are homozygous genotypes (dd) not alleles. Some recessive alleles are in the heterozygous individuals.
3. Calculate the frequency of the recessive allele (d).
   a. $q = \sqrt{q^2}$
   b. q is the recessive allele frequency, and is expressed only in homozygous genotype.
   c. There are more recessive alleles in the population than are expressed in the phenotype because of the heterozygous occurrence.
4. Calculate frequency of the dominant allele (D).
   a. $p = 1 - q$ = ______ (the percentage is usually expressed as decimal number.)
   b. $p + q$ = 100% or 1 = the total (100%) number alleles in the population.
5. Calculate the frequency of homozygous dominant genotype (DD).
   a. p^2 = _______ % are homozygous dominant.
6. Calculate the percentage of heterozygous alleles.
   a. 2pq = _______ % are heterozygous.
7. If you know one variable, you can solve for the following questions.
   a. What is the allele frequency of the recessive allele (d)?
   b. What is the allele frequency of the dominant allele (D)?
   c. What is the frequency of the homozygous recessive genotype (dd)?
   d. What is the frequency of the homozygous dominant genotype (DD)?
   e. What is the frequency of the heterozygous genotype (Dd)?
   f. What is the frequency of the recessive phenotype (dd)?
   g. What is the frequency of the dominant phenotype when Dd x dd?
   h. How long would it take for a given allele to be fixed given a certain selective force for it?
      1) Calculate allele frequencies over time, then calculate the rate of change.

i. How strong would migration of the alternative allele into the population have to be to counteract the effects of selection and maintain the alternative allele at the original frequency?

1) Calculate the rate of change in allele frequency to determine the rate of migration needed to maintain an unchanged allele frequency in the population.

Determining allele frequencies in a population at equilibrium.

1. A population having only two alleles: $(p + q)^2 = p^2 + 2pq + q^2 = 1$

- There are three possible genotype combinations: 1 + 2 = 3
- (n (n+1)/2 = number of genotypes. n = the number of alleles. This formula calculates how many are possible at a locus (location on the chromosome). n is also the number of homozygous genotypes possible.
- Example 1: (2 (2 + 1))/2 = 3; Example 2: (9 (9 + 1))/2 = 45
- n[(n — 1)/2] is used to calculate how many heterozygous genotypes are possible.

2. A population having three alleles: $(p + q + r)^2 = 1$

- There are six possible genotype combinations: 1 + 2 + 3 = 6
- (3 (3 + 1))/2 = 6

3. A population having four alleles: $(p + q + r + s)^2 = 1$

- There are ten possible genotype combinations: 1 + 2 + 3 + 4 = 10
- (4 (4 + 1))/2 = 10

4. How many genotype combinations are there for five alleles?

- (n (n+1)/2 =_______

5. How many genotype combinations are there for ten alleles?

- (n (n+1)/2 =_______

Examples of population genetics

Demonstrations of how the natural or artificial selection of phenotypes selects for inheritable genotypes.

The peppered moth (*Biston betularia*)

1. Prior to industrial revolution in London, light colored moths were more common than darker colored moths.
2. During the industrial revolution, the darker moths became more common than the lighter colored moths.
3. After the peak of the industrial revolution, the lighter moths once again became more abundant.
4. The allele frequency change between light and dark alleles may have been selected by predators as the environment changed.
5. In 1954, Kettlewell attempted to explain that the dark soot accumulation on trees from the factories caused the change in frequency of colored moths. However, a year after his report, another scientist showed that Kettlewell's experiment was flawed.

6. In 1998, Michael E. N. Majerus of the Department of Genetics at the University of Cambridge showed that Kettlewell's experiments were incomplete and failed to answer key questions.

Mosquito resistance to pesticide

1. Pesticides are used to control insect borne diseases and agricultural damage.
2. Mosquito populations have become resistant to pesticides used to control their populations.
3. Mosquitoes with a genotype to resist the effect of pesticide survive and pass on their genotype for resistance to the next generation. As a result subsequent generations produce populations of mosquitoes that are resistant to pesticides.

Bacterial resistance to drugs

1. Antibiotics are proteins produced by microorganisms that kill other microorganisms.
2. Microorganisms with genes that produce agents that prevent harm caused by the antibiotics survive and others die.
3. New generations of surviving organisms inherit the resistant genes and result in populations of antibiotic resistance populations.
4. Drugs should always be taken as prescribed in order to prevent antibiotic resistance from occurring.

Pseudomonas metabolism of nylon

1. Scientists discovered that bacteria in genus Pseudomonas were able to produce a new enzyme, nylonase, to metabolize nylon.
2. Because nylon was invented in 1935, the production of a gene capable of metabolizing nylon is new.
3. Subsequent generations of Pseudomonas inherit the modified gene.
4. Modified genes allow for new traits within a species population.

Lizards and fire ants

1. Scientists discovered that lizards in the presence of ants will typically remain motionless.
2. However, such behavior in the presence of fire ants results in death.
3. Lizards in areas where fire ants live twitch and run. Lizards lacking the twitch and run gene died.

Jacob's goats

1. Genesis 30:32-43 describes Jacob bargaining with his uncle Laban to raise cattle for thee two of them distinguished by their color and spots.
2. Jacob applied selection influence on the cattle to increase the number of cattle for himself.

Darwin's finches

1. Charles Darwin observed thirteen species of finches on the Galápagos islands in the 1830s.
2. The finches have a variety of bill shapes and sizes, all suited to their varying diets and lifestyles.
3. The different traits in the finch population show design capacity for genetic variation in a species.
4. The finches are still finches.
5. Princeton zoology professor Peter Grant observed the rate of beak size/shape change during droughts on the islands. He calculated that such change could take place in 1,200 years, which is plenty of time since Noah's flood in 2,348 BC.
6. Darwin formulated a theory for change capacity in populations over time from generation to generation. He proposed that there was no limit to the amount of variations possible. In an article

that he wrote in 1844, he stated: "I can see no difficulty in a race of bears being rendered, by natural selection, more and more aquatic in their structure and habits, with larger and larger mouths, till a creature was produced as monstrous as a whale." (Charles Darwin, *The Origin of Species: A Facsimile of the First Edition*, Harvard University Press, 1964, p. 184). Other scientists do have difficulty envisioning such a transformation in the absence of evidence for unlimited change.

Adam and Eve and the human population

1. The human race began with Adam.
2. Eve was created from Adam.
3. The human population is the result of procreation.
4. All the varieties of traits in the human population are possible by design of the DNA molecule and the shuffling of alleles that occurs in meiosis and procreation.
5. Variations occur: Wilt Chamberlain (7 feet, 1 inch tall, and weighed 275 pounds) and Willie Shoemaker 4 feet, 11 inches tall and weighed barely 100 pounds.
6. Population studies of humans show that all humans come from a pair of humans.
7. Noah's flood introduced a bottle neck in the genetics of the human race with eight survivors. The entire human population is descended from Adam and Eve through Noah.
8. Studies of the y chromosome reveal the migration of human populations by male ancestry.
9. Studies of mitochondrial DNA reveal the migration of human populations by female ancestry.
10. Human migration studies show that the human population was scattered geographically according to their association to the three sons of Noah (male ancestry). The diverse languages at the tower of Babel were used to separate lineages based on their relatedness to the sons of Noah.

Explanation and careful interpretation

Explanations for the change in frequencies must be evaluated carefully. A common error is to attribute intentional change by organisms as a result of a change in the environment. For example, frogs with genes producing anti-freeze agents in their blood are able to survive cold climates and thus be selected by cold temperatures. It is incorrect to say that frogs produced antifreeze in their blood so that they could survive cold temperatures. A correct explanation is to say that frogs with antifreeze in their blood are able to survive freezing temperatures, reproduce, and pass on their antifreeze genes to their offspring.