Lamarck's Ladder

Overview

Darwinism is a theory of biological evolution developed by the English naturalist Charles Darwin (1809–1882) and others. It states that all species of organisms arise and develop through the natural selection of small, inherited variations that increase the individual's ability to compete, survive, and reproduce. The environment plays a critical role in the natural selection process of Darwinian evolution through the phenotypic variation produced over time by small genetic changes to the DNA sequence, such as beneficial random mutations. However, the vast majority of environmental factors cannot directly alter DNA sequence.

Jean-Baptiste Pierre Antoine de Monet, chevalier de Lamarck (1744 – 1829), often known simply as Lamarck, was a French naturalist. Before Darwin, Lamarck was one of the first scientists to support the Theory of Evolution. His theory was that species evolved based on the behavior of their parents. His hypothesis stated that an organism can pass on phenotypes acquired because of environmental pressures within their lifetime and pass them to its offspring. One of his most famous examples is his explanation of a giraffe's long neck. He proposed that the continuous stretching of the neck by the giraffe to reach higher and higher leaves caused the muscles in the neck to strengthen and gradually lengthen over a period of time, which gave rise to longer necks in giraffes. Lamarck's hypothesis was rejected and later became associated with flawed science concepts. However, scientists today debate whether advances in the field of transgenerational epigenetics indicate that Lamarck was correct, at least to some extent.

Modern genetics has revealed that epigenetic mechanisms directly regulate genetic processes and can be dramatically altered by environmental factors. Therefore, environmental epigenetics provides a molecular mechanism to directly alter phenotypic variation in an individual and can be passed on to their offspring. While these changes may not be as visually dramatic as Lamarck's giraffes, the epigenetic influences discovered during recent genetic studies are extraordinary examples of how the environment can directly alter phenotype in a heritable manner.

Source: Jablonka, E., & Lamb, M. J. (1999). Epigenetic inheritance and evolution: the Lamarckian dimension. Oxford University Press on Demand.

Vocabulary

Phenotype is the genetic term for an individual's expressed traits (their observable characteristics). An example would be brown hair. Phenotypes vary from individual to individual and this is called **phenotypic variation.**

Genotype is the genetic term for the sequence of genes that make up an individual's strand of DNA. An example would be the gene for brown hair. Since individuals inherit genes from both parents, an individual's DNA sequence may include a gene for brown and blonde hair but the individual would only express the brown hair phenotype.

Environmental pressures are changes in an individual's environment that can influence genes to switch on or off (active or inactive), thereby changing how the individual's body develops or functions.

Molecular mechanisms are what scientists call the series of interacting molecular (molecules) parts and processes that produce an individual's physical functions.

Epigenetics is the study of molecular mechanisms that change phenotype by switching genes on and off (active vs inactive gene expression) but do not change genotype (DNA sequence).

DNA methylation (methylate) is an epigenetic molecular mechanism that occurs as a result of the addition of a methyl (CH_3) group to DNA which inhibits gene expression (inactive).

DNA histone acetylation (acetylate) is an epigenetic molecular mechanism that occurs as a result of the addition of an acetyl ($C(O)CH_3$) group to DNA which allows gene expression (active).

Transgenerational epigenetics, also called genetic imprinting, is when parents transfer the genes to their offspring with the epigenetic changes (methylation or acetylation). If an offspring received a gene with DNA methylation, the gene would be inactive and would not express the phenotype and vice versa for a gene with DNA acetylation.

Learning Goals

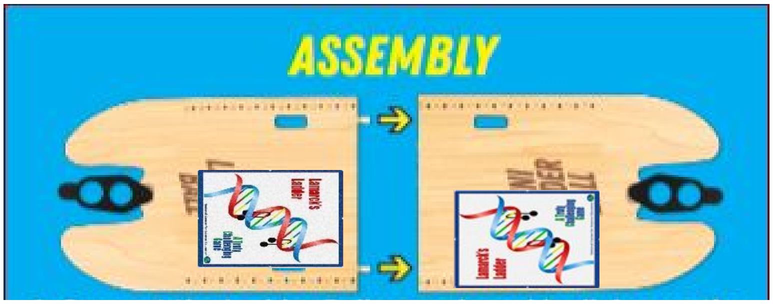
1. To enhance the general public's understanding of and appreciation for epigenetic mechanisms role in the variability and evolutionary inheritance of human health genetic traits.
2. To use a model to demonstrate an abstract cause and effect relationship to describe and predict an evolutionary phenomena in a natural system.

Materials

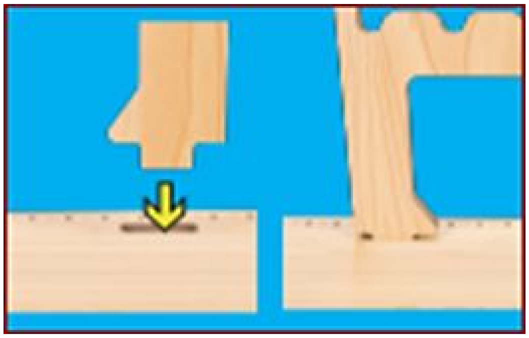
- Two Game Platforms
- Two Ladder Ball Towers
- Five Gene Rungs (colored dowels)
- Five Bolas (one white and four blue)
- Five Epigenetic Game Cards

Set-up

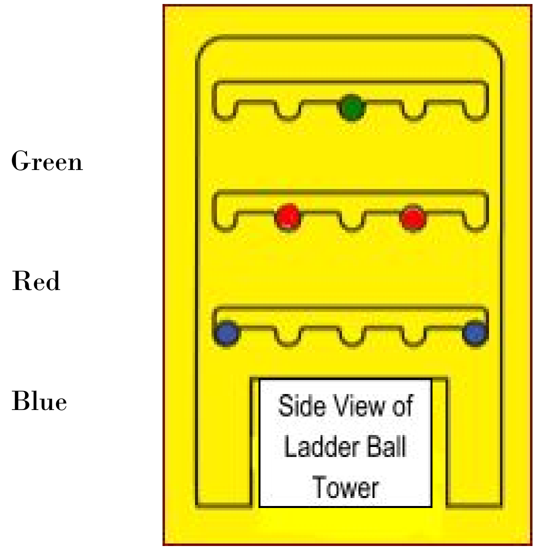
1. Join the two sides of the game platform together by inserting the dowels into the pre-drilled holes.



2. Insert both sides of the two Ladder Ball Tower feet into the game platform.



3. Insert the colored dowels (genes) into the notches of the Ladder Ball Tower as indicated below. You may begin with either side.



Note: The opposite side will show **Yellow** along the top row, **Blue** along the second row, and **Red** along the bottom row.

Procedure

The aim of Lamarck's Ladder is to model the epigenetic mechanisms resulting in inheritable health related genetic traits. By adding a methyl group (blue bola) or acetyl group (white bola) to the gene (colored dowel) described on each game card, the player will demonstrate how genes are switched on and off during environmental stresses.

The game may be played alone (one player shooting from both sides), two players (one player shooting from each side) or by multiple players (groups) taking turns from each side. The game cards should be randomly chosen. Each player or group should be allowed three attempts to methylate or acetylate the proper gene for each card before the next player makes their attempt. After a player succeeds or if neither player succeeds, the players should move to the next game card.

Definition of Success: The player who improves the least healthy epigenetic modifications wins.

Modifications and Guiding Questions

1. Discuss epigenetic mechanisms of gene control that can promote or repress the expression of genes without altering the genetic coding of an organism.
2. Discuss how epigenetics has helped and/ or hindered species development via changes to the epigenome.

- [The Role of Epigenetics in Human Evolution]

3. The role of epigenetics in cellular differentiation, tissue development, environmental induced disease etiology, epigenetic transgenerational inheritance, and the general systems biology of organisms and evolution.

- Role of Epigenetics in Developmental Biology and Transgenerational Inheritance

NGSS Standards

HS.Inheritance and Variation of Traits

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

- HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.
    - HS-LS3.B. Variation of Traits. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.