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Brer Rabbit, Rare Rabbit

Directional Selection, Allele Frequencies and Evolution

INTRODUCTION

Key concepts:
Monohybrid; Mendelian cross; genotype; homozygous; heterozygous; dominant; recessive; phenotype; directional selection; evolution; gene pool; allele frequency; Hardy-Weinberg Principle; carrying capacity.

This simulation activity is aimed at students aged 16 – 18 years studying Advanced Level Biology. It is designed to help them understand the following core principles related to the study of allele frequency in a gene pool:

- Inheritance of dominant and recessive alleles in monohybrid Mendelian crosses.
- The reason why allele frequencies remain more-or-less constant in an environment where there is no selection pressure for particular phenotypes.
- How the Hardy-Weinberg Principle can be applied to calculate the allele frequency for dominant and recessive alleles of a phenotype controlled by two alleles of a single gene, and amongst a population of individuals in which there is no selective advantage for any given phenotype.
- Evolution is a change in allele frequencies in a population over a period of time.
- The reason why allele frequencies change in an environment where there is directional selection, the latter of which favours the survival of individuals with a particular phenotype.
- The reason why retention of disadvantageous alleles in a gene pool is desirable in terms of a species' ability to adapt to potential changes in the environment.

The simulation adapts and develops some of the principles reported in the article "Counting Buttons: demonstrating the Hardy-Weinberg principle" *(Pongsophon, Roadrangka and Campbell; Science in School; Issue 6: Autumn 2007)*.

RESOURCES

The activity can be accessed online on the EMBLog teachers' portal hosted by the European Learning Laboratory for the Life Sciences at the EMBL. The program to carry out the activity has been developed using Flash-based SAP Xcelsius software.

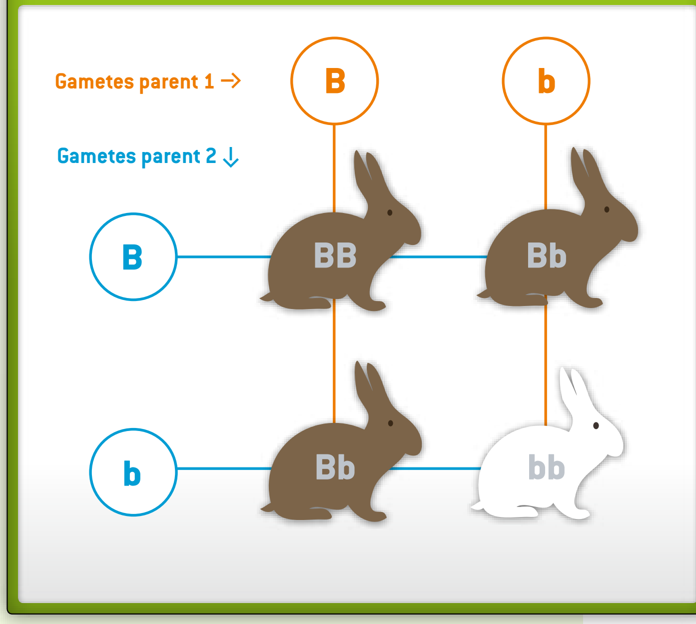
Via www.science-on-stage.de you will get to the EMBLog teachers' portal (you have to register to access the content).

CORE

Allele Frequency: No Selection
Students are presented with background information about a model population of 64 rabbits in which there are two alleles for coat colour, brown *(B)* and white *(b)*. The allele for brown coat colour is dominant over the allele for white coat colour, so that rabbits of genotype *BB* and *Bb* have brown fur whereas those of genotype bb have white fur. The allele for fur colour is inherited in a straightforward monohybrid Mendelian fashion, and given the dominance of the allele for brown fur, brown rabbits outnumber white rabbits at a ratio of 3:1. Therefore, the initial population of 64 rabbits has 16 rabbits of homozygous genotype *BB*, 32 rabbits of heterozygous genotype *Bb* and 16 rabbits of homozygous genotype bb.

The rabbits live in a habitat, which is covered by vegetation for some of the year and covered by snow for the rest of the year. Rabbits with brown fur are better camouflaged in vegetation, whereas rabbits with white fur are better camouflaged in snow. On balance, there is no advantage or disadvantage to having either brown or white fur.

Punnet square



To remind students how a Mendelian monohybrid cross works, students use an interactive Punnett square to simulate a genetic cross between two heterozygous *(Bb)* rabbits.

Students then use the program to find out the genotypes of all the offspring of the starting population. The program factors in four assumptions: firstly, there is random mating between the parent rabbits of different genotypes; secondly, the carrying capacity of the habitat is 64 rabbits; thirdly, an equal proportion (50 %) of offspring of all three genotypes will survive to reproduce; finally, the offspring of the first generation that survive to maturity become the parents of the next generation.

The program guides students so they are able to discover the numbers of offspring of each genotype over ten generations. This information is used to calculate the frequencies of alleles *B* and *b* in each generation. To make sure that students understand how allele frequencies are derived, they are required to make a sample calculation by entering data and checking whether it yields the correct answer.

Students discover that the frequencies of alleles *B* and *b* remain more or less constant. The program is designed to display the output data (allele frequency against generation number) in a graph.

Allele Frequency: Hardy-Weinberg Principle

In the rabbit population, rabbits of genotype *BB* and *Bb* look the same (brown fur), so it is not possible to work out the number of individuals of each genotype. However, the numbers of rabbits of genotype bb can be recognised and counted (they all have white fur). The activity leads students through the theory underpinning the Hardy-Weinberg Principle, to show how the number of rabbits of genotype *bb* can be used to estimate the numbers of rabbits of genotypes *BB* and *Bb* respectively.

Students are required to apply the Hardy-Weinberg Principle to a given problem. By inputting the relevant data selected from the information provided, they are able to analyse the information to calculate the estimated number of rabbits of genotypes *BB* and *Bb* in a given population in which the number of rabbits of genotype *bb* is known. Hints are provided to lead the students through the calculations, and there is also a provision to check that the calculations have been done correctly.

Allele Frequency: Selection

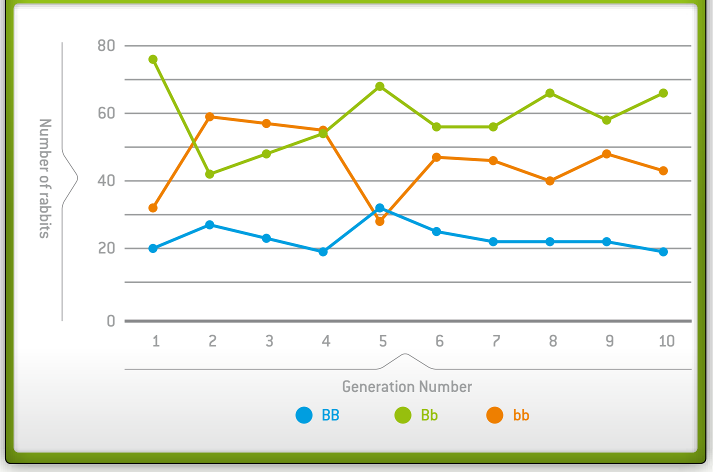
As a result of climate change, the habitat is no longer covered by snow for any part of the year. This puts white rabbits (genotype *bb*) at a disadvantage. They are no longer camouflaged in a habitat, which is covered by vegetation all-year-round, and are much more prone to predation. White fur is a disadvantage now: All rabbits of white fur are predated before they reach maturity. The environment selects against them.

As for "No Selection", students use the program to find out the genotypes of all the offspring of the starting population and subsequent generations. However, this time the parameters have changed. The program factors in three of the previous four assumptions (random mating between the parent rabbits of different genotypes; carrying capacity of the habitat is 64 rabbits; offspring of one generation, which survive to maturity, become the parents of the next generation). But note, there is one key difference: the proportion of offspring of all three genotypes, which survive to reproduce, is no longer equal, because none of the white rabbits reach maturity. The program takes this into account, and applies adjustment equations to calculate how many of the rabbits of genotypes *BB* and *Bb* reach maturity to become parents of the next generation. This will be above 50 %, but the actual percentage depends on the numbers of rabbits of genotype *bb* born into each generation.

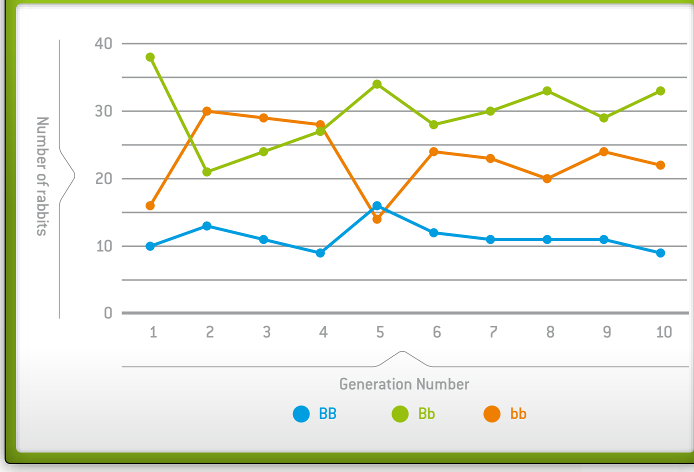
As for the "No Selection" scenario, the program guides students so they are able to discover the numbers of offspring of each genotype over ten generations. This information is used to calculate the frequencies of alleles *B* and *b* in each generation.

Students discover that the frequencies of alleles *B* and *b* change from one generation to the next (frequency of allele *B* increases, whereas frequency of allele b decreases). The program is designed to visualise the output data (allele frequency against generation number) in a graph.

Number of rabbits per generation



Number of rabbits reaching maturity



Questions to Summarise Key Concepts

The final part of the activity is a set of questions. Completion of these questions provides evidence that students have completed the activity and helps the teacher to check students' understanding of the key concepts, which underpin it. Students enter their answers to the questions and also their name and date. They print out their responses and return them to their teacher for marking.

CONCLUSION

This simulation activity can be accessed online. It could be completed within lesson time, or it could be given as homework or as a self-study assignment. Students check their own learning by completing a multiple-choice quiz at the end of the activity, which is marked by the program. In addition, a set of questions is supplied for students to complete and print out. Should teachers want to assess how well students understand the key concepts covered by this simulation, they can use these traditional exam-style questions.

We would appreciate your feedback on this activity, including any suggestions for improvement. A mark scheme to the exam-style questions can be supplied on request. Contact: richard.spencer@stockton.ac.uk