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Eggheads: An Alternative Mendelian Genetics Model Organism

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Although numerous organisms can be used to teach basic Mendelian genetics, many of them pose problems. Eggheads, a teaching tool adapted from *Journal of College Science Teaching* (Beals, 1994), present an alternative to standard Mendelian organisms because they can be adapted to the conceptual understanding of students. To prepare Eggheads, various features are drawn onto plastic eggs to represent different patterns of inheritance. A set of 100 Eggheads constitutes the F_1 generation. The goal for students working with the Eggheads is to correctly explain the mode of inheritance shown by each feature, while demonstrating familiarity with standard genetics vocabulary.

Keywords: Introductory genetics, Mendelian genetics, model organism

Introduction

Eggheads are a teaching tool adapted from *Journal of College Science Teaching* (Beals, 1994) that are helpful in the study of basic Mendelian genetics because they have a limited set of features compared to the hundreds found in other organisms, such as fruit flies or garden peas. In addition, they can be specifically adjusted to the conceptual understanding of students. For these reasons, I use them in several general education courses and in a preparatory course for biology majors. The Egghead "creatures" are colored plastic Easter eggs on which numerous facial features have been drawn to represent various patterns of inheritance: complete dominance, incomplete dominance, codominance, sex-linked traits, and crossover, for example. In the exercise, students are presented with 100 offspring of a single pair of Egghead parents. They are informed that the genes for these Egghead characteristics are located on five pairs of chromosomes. The goal for students working with the Eggheads is to correctly explain the mode of inheritance shown by each feature, while demonstrating familiarity with vocabulary words that are frequently confused (character and trait, gene and allele, for example). Preparing a set of 100 Eggheads requires about 6 hours. A set, however, can be used repeatedly. The Egghead exercise can be completed by a class in about two 2-hour periods. Generally, the students are walked through this exercise and are only given directions about half-way through the activity.

Student Outline

In this activity, you will be working with a population of 100 Eggheads (*Ovocephalus knottei*), all offspring (F_1) of the same set of parents (P). Female Eggheads are purple, orange or green; male Eggheads are pink, blue or yellow. As a class you will determine the distribution of the various characteristics in the F_1. Then, in groups you will do the following:

1. Study each character in the F_1 and determine, wherever possible:
    - The genotypic ratio of the F_1
    - The phenotypic ratio of the F_1
    - The genotypes of the parents for this feature
    - The phenotypes of the parents for this feature
    - The 2 x 2 matrix that represents the cross of the parents
    - An explanation of which trait is dominant and which is recessive

2. Develop a glossary of terms that are listed below. Some entries will contain more than one term. Each glossary entry should have three parts: 1) the definition for each term; 2) an illustrative sentence in which you use the term(s) to describe inheritance specifically in Eggheads; 3) a diagram based on Eggheads.
    - Chromosome
    - Character / Trait
    - Gene / Allele / Locus
    - Dominant / Recessive
    - Phenotype / Genotype
    - Homozygous / Heterozygous
    - Genotypic ratio / Phenotypic ratio
    - Complete dominance / Incomplete dominance / Codominance
    - Linked genes / Crossing over / Genetic recombination
    - Autosome / Sex chromosome / Sex linked inheritance

3. Select any three of the Egghead features and carry out a chi-square analysis.

    This is a group assignment for which you will receive a group grade. Each person in the group must be present on each day in class that you work on this assignment to receive credit.

Materials

To prepare Eggheads for a class of 25 students, you will need the following materials:

- Plastic Easter eggs (100 per class set). These are available in craft stores from about February to April. They can also be purchased online from **www.orientaltrading.com**. The options for the eggs are extensive: three different sizes, vibrant and pastel shades, with and without speckles, colored on one half and clear on the other, spotted, and in variations of jungle prints.
- Superglue (to glue the two halves of the eggs together)
- Opaque paint markers (such as Elmer's® brand Painters)

To prepare a class set of Eggheads, count out 100 plastic eggs, about an even split between males (pink, blue, and yellow) and females (purple, green, and orange). If you are going to use three different sizes of eggs, select the eggs based on a combination of size and color. Glue the two halves of each egg together (superglue works well; Elmer's glue doesn't). Put all 100 eggs into a large container (a dishpan works well). Pull them out randomly, one at a time, draw one feature on each egg, and move them to a second large container. For the next feature, move them one at a time in the opposite direction.

- Draw up-triangle eyes ▲▲ on the first 3/4 of the eggs and down-triangle eyes ▼▼on the remaining 1/4. One possible distribution is shown in Table 1. Since the feature is not sex-linked, the color of the egg doesn't matter.
- Draw an upper mouth on the first 1/4 of the eggs, a complete mouth on the next 1/2, and a lower mouth on the remaining 1/4. Color doesn't matter here, either.
- If you want to include crossing over, first draw teardrop nose/ boxy ears on 5 eggs and round nose/round ears on 5 others. Then draw teardrop nose/ round ears on about 1/2 of the remaining eggs, round nose / boxy ears on about 1/2. Again, color doesn't matter.
- For sex-linked traits (eyelashes) draw eyelashes on all of the females (purple, orange, green) and only ½ of the males (pink, blue, yellow).
- A few Eggheads can be added to introduce mutations. For example, you could include only specked eggs that match either male or female colors. You could use a few half colored/half clear eggs. The possibilities are almost limitless.
- The table below shows an approximation of the distribution of traits in an Egghead generation. Actual values can be adjusted to make the assignment more or less challenging for students.

Table 1. Directions for preparing group of 100 Eggheads

BODY SIZE	**Small**	**Medium**	**Large**	**Total**
Males	10	26	13	49
Females	11	28	11	51
Total	21	54	24	100
Mendelian ratio	1	2	1	

EYES	**Up-triangle**	**Down-triangle**	**Total**
Males	40	9	49
Females	37	14	51
Total	77	23	100
Mendelian ratio	3	1	

NOSE	**Teardrop**	**Round**	**Total**
Males	27	22	49
Females	28	23	51
Total	55	45	100
Mendelian ratio	2	2	

EARS	**Round**	**Boxy**	**Total**
Males	27	22	49
Females	28	23	51
Total	55	45	100
Mendelian ratio	2	2	

Table 1, cont. Directions for preparing group of 100 Eggheads

EARS	**Round**	**Boxy**	**Total**
Males	27	22	49
Females	28	23	51
Total	55	45	100
Mendelian ratio	2	2	

MOUTH	**Upper**	**Complete**	**Lower**	**Total**
Males	12	28	9	49
Females	9	28	14	51
Total	21	56	23	100
Mendelian ratio	1	2	1	

FRECKLES	**Many**	**Few**	**None**	**Total**
Males	10	30	9	49
Females	17	22	12	51
Total	27	52	21	100
Mendelian ratio	1	2	1	

EYE BROWS	**Arched**	**Pointed**	**Total**
Males	23	26	49
Females	30	21	51
Total	53	47	100
Mendelian ratio	2	2	

HAIR	**Curly**	**Wavy**	**Straight**	**Bald**	**Total**
Males	25	13	9	2	49
Females	23	5	10	3	51
Total	58	18	19	5	100
Mendelian ratio	9	3	3	1	

EYE LASHES (sex linked)	**Lashes**	**None**	**Total**
Males	23	26	49
Females	51	0	51
Total	74	26	100
Mendelian ratio	3	1	

Table 2. Explanation of results of 100 Eggheads

Character	**Cross**	**Explanation**
Body size	Bb x Bb	Incomplete dominance of B allele (large body) over b allele (small body)
Eyes	Ee x ee	Complete dominance. The up-triangle allele is dominant to the down-triangle allele.
Nose	Nn x nn	Complete dominance. A test cross would have to be carried out to determine whether the tear-drop nose allele or the round nose allele were dominant. Linked to Ears.
Ears	Aa x aa	Complete dominance. A test cross would have to be carried out to determine whether the round ear allele or the boxy ear allele were dominant. Linked to Nose.
Mouth	UL x UL	Co-dominance. The U and L alleles are both completely expressed in the heterozygote.
Freckles	Ff x Ff	Incomplete dominance of F allele (freckles) over f allele (no freckles).
Eye brows	Bb x bb	Complete dominance. A test cross would have to be carried out to determine whether the arched brow allele or the pointed brow allele were dominant.
Hair	CcWw x CcWw	Interaction of two genes, producing 9:3:3:1 ratio of dihybrid cross.
Eye lashes	X^LX^l x X^lY	Sex-linked. The X^L allele (eyelashes) is completely dominant to the X^l allele (no lashes).
Color		Currently, there is no explanation of how color is inherited in Eggheads. Males are all primary colors (pink, yellow, blue) which suggests a single allele; females are all secondary colors (orange, purple, green) which suggests two alleles.

Notes for the Instructor

This exercise presents options for the instructor at the design, implementation, and assessment level. In the design of an Egghead generation, the instructor can make the Mendelian ratios more or less obvious; for example, out of 100 offspring the 3:1 ratio can be set up as 73:27 or 68:32. The instructor can restrict the model to include only patterns of inheritance that are more obvious (complete dominance, co-dominance and incomplete dominance) or can include more challenging patterns such as epistasis. More challenging patterns can be included with the expectation that not all students will be able to uncover all of them. At the implementation level, this exercise can be conducted in a variety of ways. It can be used as the mechanism by which students are introduced to the concepts of Mendelian genetics. It can also be used as a means by which students' knowledge of these concepts is applied. Students can be introduced to the model organism and asked to determine in small groups the pattern of inheritance shown by each character. Alternatively, students can be guided through the discovery process by questions that steer them toward the solution. Vocabulary can be introduced as the need for a term arises. At the assessment level, various forms of evaluation can be conducted, either of individuals or of groups. For example, students can be given the task of developing a Genetics Glossary that is illustrated by specific examples from the Eggheads. In addition, students can be required to conduct a Chi-squared analysis of the data they derived from their examination of the Eggheads. Instruction to carry out this analysis may or may not be necessary, depending on what has already transpired in the course. If a Chi-squared analysis is conducted, students should be shown how to determine the expected values.

One way in which the Eggheads can be used in a class of about 25 students is described here. Students work in pairs or in groups of three.

The 100 Egghead offspring are divided into enough containers to provide one container per group of students. About 8-12 Eggheads per container works best. The instructor introduces the Eggheads to the students. Initially, all they need to know is that all 100 Eggheads are offspring of the same set of parents and the colors of males and females. (I also include a binomial name, *Ovocephalus knottei*, because the science building at our institution is Knott Hall.) Each group of students examines the "organisms" and develops a list of their physical features. The instructor lists these physical features (with their alternate forms). The instructor then assigns each group of students the responsibility for determining the distribution of one feature in the Egghead generation. The instructor helps the students determine whether it would be necessary to divide the Eggheads into males and females when determining the distribution. (It is). Students tally the traits observed in a single container of Eggheads and then rotate through the containers of Eggheads until all 100 organisms have been examined by each group of students. The instructor checks the totals for errors and then lists the totals for each feature on chart paper that can be hung for future reference.

The instructor explains the goal of the exercise to the students: to correctly explain the mode of inheritance shown by each character, while demonstrating familiarity with pertinent vocabulary words.

The instructor suggests a feature for their first consideration: eye shape. Eyes can either be ▲▲or ▼▼. The instructor helps students to recognize that about ¾ of the Eggheads have ▲▲eyes and about ¼ have ▼▼eyes. Since students don't know at this point which allele is dominant and which is recessive, another form of representation will have to be agreed on to temporarily distinguish between the two alleles, for example U for ▲▲ and D for ▼▼. Groups of students work on dry-erase boards to diagram the genotypes of Egghead parents that would produce a 3:1 ratio. They develop a 2x2 matrix to represent the cross. (I avoid calling these Punnett squares because, although it appears that this is one of the few things students recall from their study of genetics in high school, they usually don't understand what it represents.) After students have decided which allele is dominant, they can be shown how to use the more traditional designation of the two alleles. As students progress, terms such as dominant and recessive, genotype and phenotype, homozygous and heterozygous, can be introduced into the discussion, but only as they are needed to streamline the conversation.

The instructor suggests a second feature for consideration: body size. About ¼ of the Eggheads are small, about ½ are medium, and about ¼ are large. Again, students work on dry-erase boards to diagram the genotypes of Egghead parents that would produce a 1:2:1 ratio.

The third feature introduces a wrinkle into the process. Ears can either be rounded ( ) or boxy [ ]. In the model, about ½ have ( ) ears and ½ have [ ] ears. When similar values are found for teardrop nose and round nose, the instructor asks whether the same Eggheads always have the same combinations. An examination of the entire group of organisms shows that all but a few Eggheads have either a combination of rounded ears/ round nose or boxy ears/ teardrop nose. Discussion of how the "oddballs" could have been produced leads to the concept of crossing over.

At this point, the instructor can direct the students to determine the inheritance pattern shown by the other features of the Eggheads on their own. Alternatively, the instructor can continue to lead the discovery process.

All of the students may not be able to "decode" all of the patterns in the Eggheads. For example, if hair is designed as an interaction of two genes to show a 9:3:3:1 ratio, not all students might be able to figure it out. The advantage to the model, however, is that the opportunity for more challenging discovery is available for students who are open to it.

Literature Cited

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