Breeding dragons: investigating Mendelian inheritance

Mendelian inheritance can be a tricky topic to teach, but **Pat Tellinghuisen**, **Jennifer Sexton** and **Rachael Shevin's** memorable dragon-breeding game makes it easier to understand and remember.

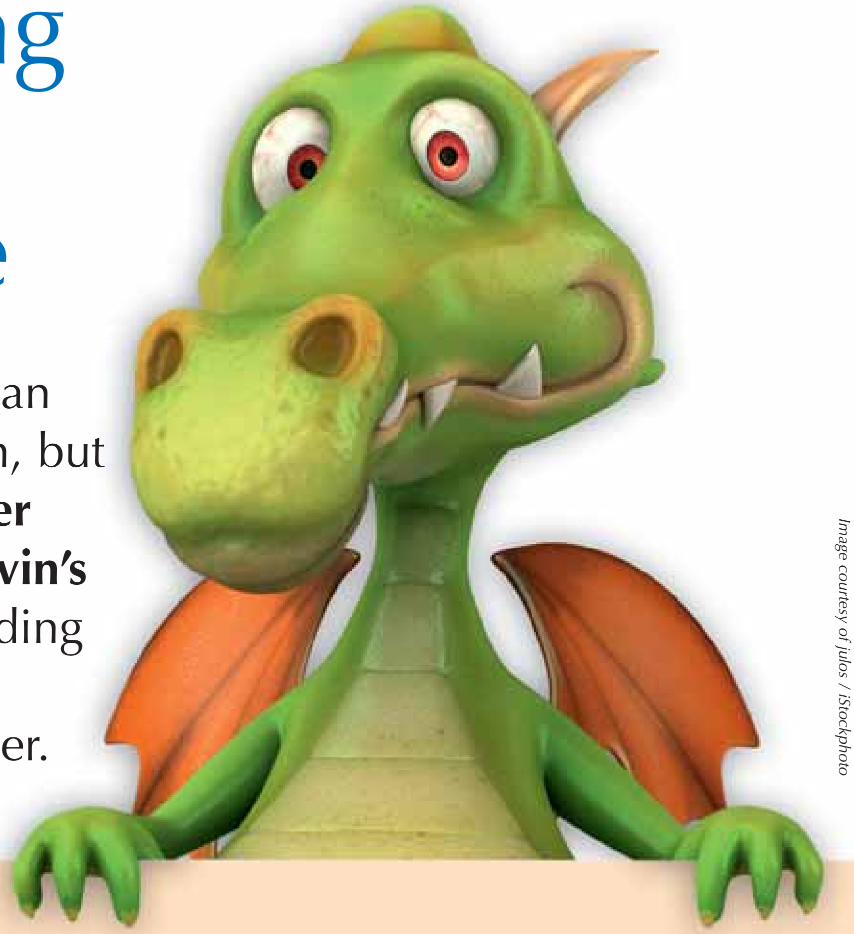


Image courtesy of julos / iStockphoto

REVIEW

- **Biology**
- **Ages 10-15**

As a secondary-school biology teacher I had never come across the idea of teaching genetics using mythical creatures, but after my initial surprise, I realised that using the genetics of dragons was perfectly coherent with the scientific facts... and really good fun! The idea of randomly choosing genes and looking for the resulting traits of baby dragons is ingenious and effective at the same time.

Even if they aren't real, dragons can help to raise interest in a topic generally considered boring (at least by students) and can convey scientific concepts as well as real organisms like Mendel's peas do.

I recommend this article to primary- and lower-secondary school biology teachers willing to address the basics of Mendelian genetics (genes, alleles, genotype and phenotype, dominance, meiosis and breeding) in a novel and playful way. The activity could be carried out very easily in the classroom with practically no equipment.

Suitable comprehension questions include:

1) Dragons have:
   a) seven chromosomes
   b) seven genes
   c) seven pair of chromosomes
   d) seven alleles.
2) When you breed dragons, the number of chromosomes of their offspring:
   a) is divided into half
   b) remains the same
   c) is doubled
   d) depends on their sex.

Giulia Realdon, Italy

Image courtesy of Alexsey / iStockphoto

Dragons may be mythical animals, but they can still be good tools for investigating Mendelian inheritance. In the following activity, students will 'breed' baby dragons, using paper chromosomes to determine the genotype and phenotype.

The activity has been tested with students aged 12-13, and generally takes one lesson – about 45 to 60 minutes.

Materials

For the whole class

- A DNA model
- A picture of a chromosome

For each student

- A set of chromosome strips in two colours (14 pink strips for the mother and 14 blue strips for the father)
- A student worksheet
- Crayons (at least four colours)

The chromosome strips, Tables 1-3 from the worksheet and the basic dragon drawing can be found on pages 42/43 or downloaded from the *Science in School* website[w1].

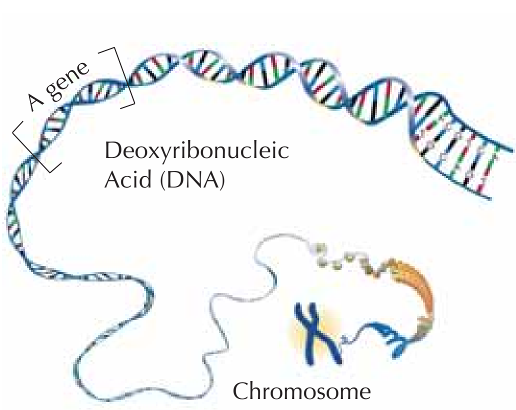
Procedure

Using the information below, introduce the dragon story and the required background for the activity to the students. Then hand out the materials and let the students follow the instructions on the student worksheet. Tables 1–3 can also be downloaded from the *Science in School* website[w1].

The story

Dragons are a curious type of creature. Amazingly, though, their genetics is very similar to that of humans – or even guinea pigs. Many schools keep pet guinea pigs, but wouldn't it be much more exciting to keep a herd of dragons? Unfortunately, dragons are very expensive, so your school can only afford two – one of each sex. The purpose of this activity is to determine what kinds of dragon you could have in your herd when (or if) your two dragons decide to mate.

Image courtesy of Darryl Leja, NHGRI / NIH



How DNA is packaged into chromosomes (not to scale)

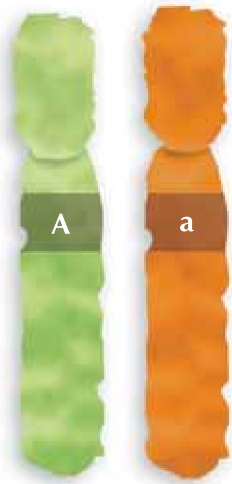


Image courtesy of Nicola Graf

Different alleles of the same gene (not to scale)

Background for the students

Each cell in all living organisms contains hereditary information that is encoded by a molecule called deoxyribonucleic acid (DNA): show students the DNA model. DNA is an extremely long and skinny molecule, which when all coiled up and bunched together, is called a chromosome: show students the picture of a chromosome. Each chromosome is a separate piece of DNA, so a cell with eight chromosomes has eight long pieces of DNA.

A gene is a segment of the long DNA molecule. Different genes may be different lengths and each gene is a code for how a certain polypeptide should be made. One or more polypeptides form a protein, which can generally be sorted into two different types: those that run the chemical reactions in your body (enzymes), and those that are the structural components of your body (structural proteins). How an organism looks and functions is a result of the cumulative effect of both these types of protein.

Any organism that has 'parents' has an even number of chromosomes, because half of the chromosomes come from the 'father' and the other half from the 'mother'. For example, in plants, a pollen grain is the paternal contribution and an ovule is the maternal contribution. These two cells combine to make a single cell, which will grow into a seed (the offspring).

Humans have 46 chromosomes, sorted into 23 pairs. One chromosome in each of the 23 pairs is from the person's father, the other from his or her mother. Since chromosomes come in pairs, genes do too. One gene is located on one member of the chromosome pair; the other gene is in the same location on the other chromosome. The gene 'pair' is technically referred to as a 'gene', as both members of the pair encode the same trait. For any gene, a variety of different forms – known as *alleles* – may exist, but each person can have a maximum of only two alleles (one from the mother, and one from the father). The two copies of the gene that a person has may be the same or different alleles.

Our dragons have 14 chromosomes in seven pairs, and we will look at only one gene on each of the pairs. We will be investigating seven different traits (e.g. the ability to breathe fire), each of which is controlled by a single gene – we say that such a trait is *monogenic*. Each of the seven genes has two alleles.

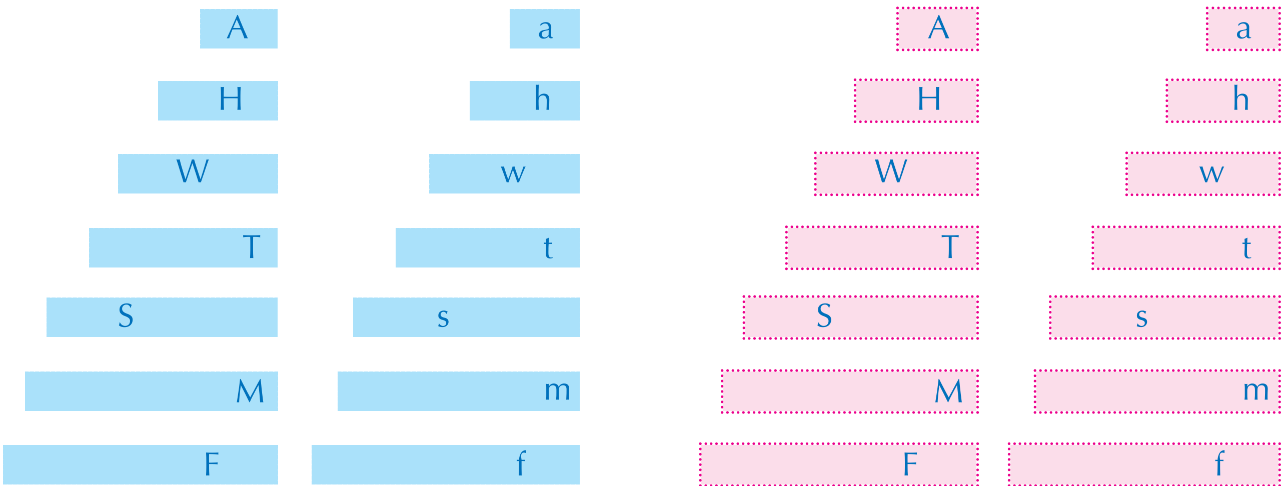
Student worksheet

One set of 14 strips represents the chromosomes from the mother (female) dragon. The other, differently coloured set, represents the chromosomes from the father (male) dragon.

Each chromosome strip has a letter, which may be either upper or lower case. The upper-case letters represent dominant alleles, and the lower-case letters represent recessive alleles. Each pair of letters codes for a trait. If at least one dominant allele (upper-case letter) is present, the dominant trait will occur (e.g. the dragon can breathe fire); the recessive trait (e.g. inability to breathe fire) will only occur if the dragon has two copies of the recessive allele.

1. Sort the chromosomes so that they are matched into pairs of the same length and letter of the alphabet. You should have seven chromosome pairs for each colour (blue for male, pink for female).

   The traits encoded by the letters are as follows:
   - F and f represent whether or not the dragon breathes fire
   - M and m represent the number of toes
   - S and s represent the number of tail spikes
   - T and t represent the colour of the tail
   - A and a represent the colour of the body
   - W and w represent the colour of the wings
   - H and h represent whether or not the dragon has a horn.
2. Take the longest pair of male chromosomes (blue) and the longest pair of female chromosomes (pink) and place them face down on your desk so that you cannot see the letters.
3. Without turning the chromosomes over, pick one of each colour and put them together to form the chromosome pair for the baby dragon. Discard the remaining pair of chromosomes.
4. Repeat steps 2 and 3, moving from the longest to the shortest chromosomes, until you have seven new chromosome pairs, each consisting of one pink and one blue strip.
5. Turn over the seven pairs of chromosomes of the new baby dragon. For each pair, record the letter on the blue chromosome in the 'Male gene' column in Table 1 and the letter of the pink chromosome in the 'Female gene' column. Be sure you copy the letters exactly, noting whether they are upper or lower case.
6. Return all the chromosomes to their proper bags.
7. Record which alleles (letters) your dragon has for each trait, and enter them in the second column of Table 2. We refer to the two alleles inherited for a particular gene as the *genotype* (e.g. TT). The observable traits of an individual (e.g. a red tail) are known as the *phenotype*.
8. Refer to Table 3 to determine which alleles are dominant or recessive for each trait, then enter the phenotype of your dragon in Table 2.
9. Now you are ready to draw your baby dragon: colour and add the relevant body parts to the basic dragon picture (which can also be downloaded from the *Science in School* website[w1]). See Table 3 for suggestions as to how the additional body parts can be drawn.

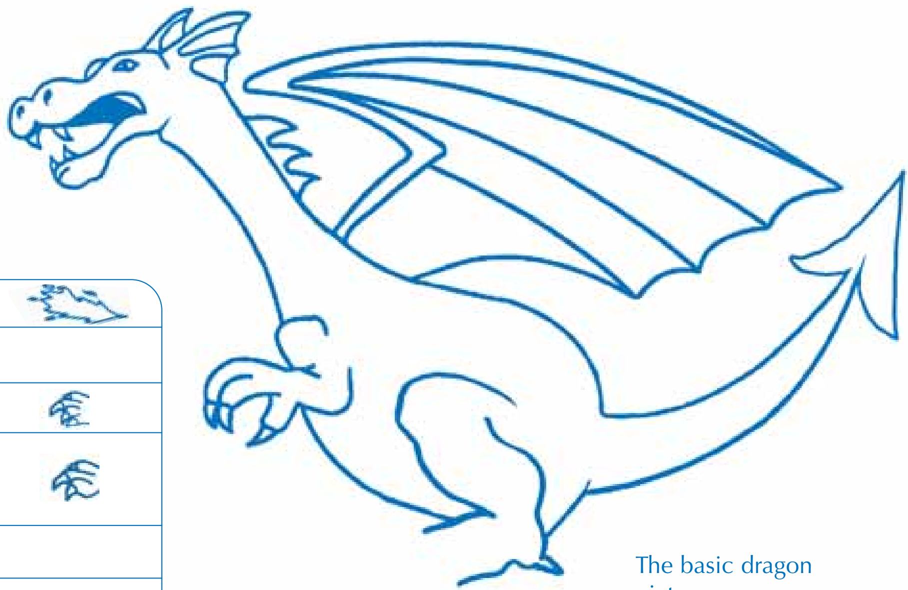


Male gene (blue)	Female gene (pink)

Table 1: The genes your dragon has inherited from its parents

Trait	Genotype	Phenotype
Fire/No fire (F/f)		
Toes (M/m)		
Spikes on tail (S/s)		
Tail colour (T/t)		
Wing colour (W/w)		
Horn/no horn (H/h)		
Body colour (A/a)		

Table 2: Genotype and phenotype of your baby dragon



The basic dragon picture

Genotype	Phenotype	
FF or Ff	Breathes fire	
ff	Does not breathe fire	
MM or Mm	Four toes	
mm	Three toes (all dragons have at least three toes)	
SS or Ss	Five spikes on tail	
ss	Four spikes on tail (all dragons have at least four tail spikes)	
TT or Tt	Red tail	
tt	Yellow tail	
WW or Ww	Red wings	
ww	Yellow wings	
HH or Hh	Horn	
hh	No horn	
AA or Aa	Blue body and head	
aa	Green body and head	

Table 3: Translating the dragon genotype into the phenotype

Variations

Codominance

To introduce the concept of codominance, you can extend the activity by swapping the relevant materials concerning the body colour trait (genotype Aa) for the following ones with the genotypes A/Ä/a, where A and Ä are codominant and a is recessive:

Genotype	Phenotype
AA or Aa	Blue body and head
ÄÄ or Äa	Black body and head
AÄ	Stripy blue and black body and head
aa	White body and head

Table 1a: Translating the dragon genotype into the phenotype (extension for codominance example)

Trait	Genotype	Phenotype
Body colour (A/Ä/a)		

Table 2a: Genotype and phenotype of your baby dragon (extension for codominance example)

Chromosome set 1

For the father	A	Ä
For the mother	A	Ä

Chromosome set 2

For the father	a	Ä
For the mother	A	A

Other variations

Instead of drawing dragon parts, you could have your students draw other mythical creatures, or even build them, for example from marsh

Acknowledgements

This activity is based on an idea by Patti Soderberg, adapted with permission from *The Science Teacher* (see Soderberg, 1992). Her reebops lesson was then adapted by the authors. Credit for the chromosome strips goes to Nancy Clark[w2], and Marlene Rau, editor of *Science in School*, included the codominance example.

References

Soderberg P (1992) Marshmallow meiosis. *The Science Teacher* **59(8)**: 28-31. The article can be freely downloaded from the *Science in School* website, with kind permission from *The Science Teacher*. See: www.scienceinschool.org/2011/issue18/dragons#resources

Web references

w1 – The chromosome strips, tables and the basic picture for this activity can be downloaded from the *Science in School* website. See: www.scienceinschool.org/2011/issue18/dragons#resources

w2 – Retired US science teacher Nancy Clark's collection of classroom resources can be found online: www.nclark.net

w3 – Find out more about the Vanderbilt Student Volunteers for Science here: http://studentorgs.vanderbilt.edu/vsvs

Resources

The Scottish 'Gene jury' project proposes a 'make a baby' game, focusing on pre-implantation diagnostics and genetics. See the Gene jury website (www.biology.ed.ac.uk/projects/GeneJury) or use the direct link: http://tinyurl.com/6edlhnq

To learn more about genetic diseases, and the research into them, see:

Patterson L (2009) Getting a grip on genetic diseases. *Science in School* **13**: 53-58. www.scienceinschool.org/2009/issue13/insight

For our two-part article on molecular evolution and the genetics behind positive selection of certain alleles, see:

Bryk J (2010) Natural selection at the molecular level. *Science in School* **14**: 58-62. www.scienceinschool.org/2010/issue14/evolution

Bryk J (2010) Human evolution: testing the molecular basis. *Science in School* **17**: 11-16.www.scienceinschool.org/2010/issue17/evolution

Staying with the subject of genetics and evolution, a simple way to teach the Hardy-Weinberg principle in class is described here:

Pongsophon P et al. (2007) Counting Buttons: demonstrating the Hardy-Weinberg principle. *Science in School* **6**: 30-35. www.scienceinschool.org/2007/issue6/hardyweinberg

Try the UK Science museum's online game 'Thingdom' to learn about genetics while creating your own fictional organism. See: www.sciencemuseum.org.uk/WhoAmI/Thingdom.aspx

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To learn how to use this code, see page 1.