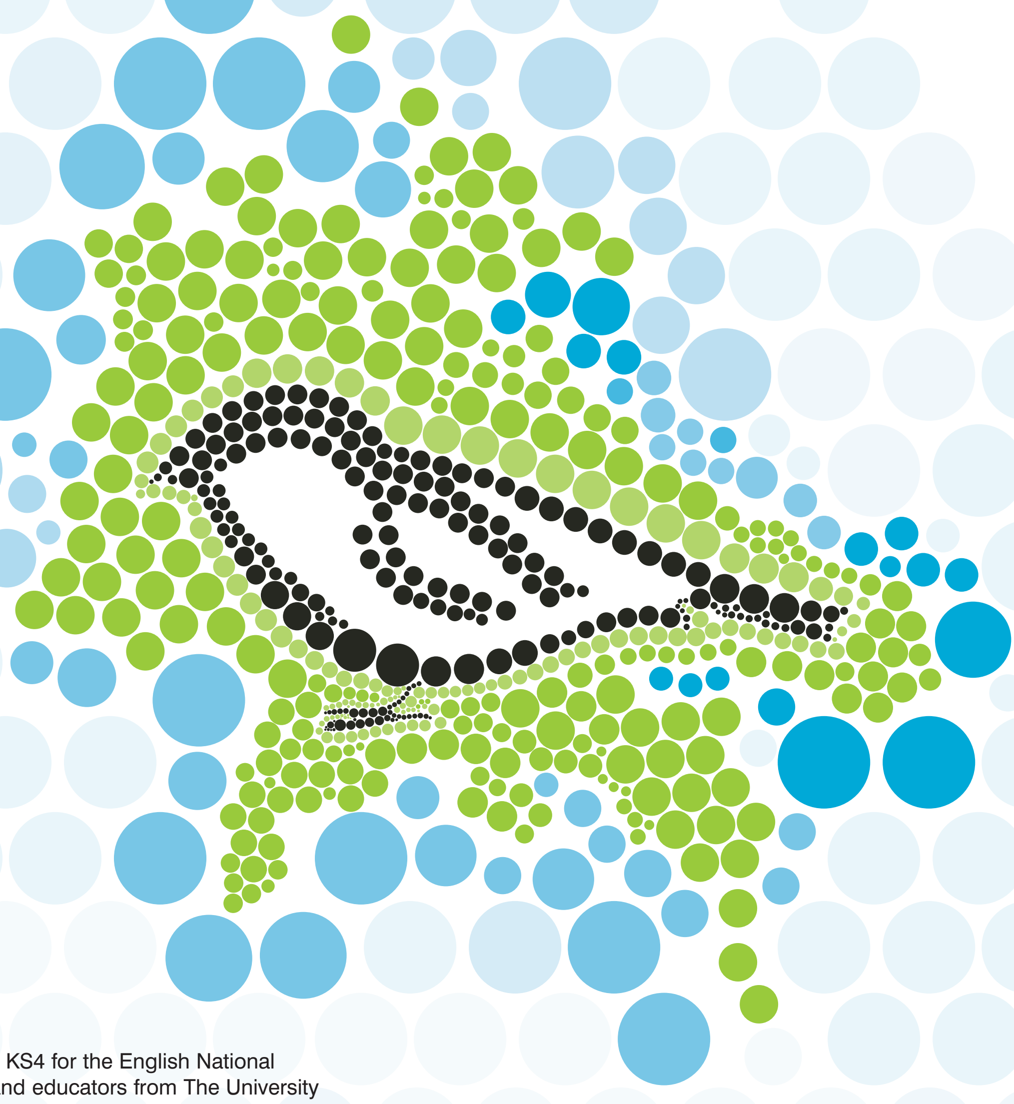
Clippy Island:

An Investigation into Natural Selection



Contributors:

This pack has been developed for teaching at KS4 for the English National Curriculum by at team of scientists, curators and educators from The University of Manchester and The Manchester Museum: Lauren Furness, Louise Sutherland, Hannah Chalk, Dr. Susan Bulleid, Dr. Amanda Bamford and Henry McGhie.

This session was trialled and tested by Lauren Furness and Abigail Jones, working with Year 10 students at Sandbach High School with support from the MLA Learning Links Project.

This project was supported by the Biotechnology and Biological Sciences Research Council as part of the Research Councils UK Darwin Today programme

Concept adapted from: Understanding Evolution. 2008. University of California Museum of Paleontology. 12 December 2008 http://evolution.berkeley.edu/

Design and illustration by Sarah Crossland

MANCHESTER 1824 The University of Manchester The Manchester Museum

BBSRC bioscience for the future

Darwin Today

Supported by MLA Museums, Libraries and Archives Council

Real World Science

Session Overview 1

Session Length: one hour
Number of pupils: 30 (but can be adjusted for different class sizes)

Session Overview:

- In this exercise, students will observe the process of natural selection on a population of birds called 'Springbeaks' over four seasons of breeding on an isolated environment called 'Clippy Island.'
- Students will simulate feeding in a timed exercise to illustrate how a limited food supply and the introduction of genetic variants can lead to natural selection and adaptation
- Students will examine whether or not beak size affects the ability of a Springbeak to gather food and how this variation can affect successive generations in the population
- Students will calculate the population ratios in successive generations on the island.

Objectives of the Session

Students will:
- Understand that organisms show natural variation within a population
- Understand that species characteristics can change over periods of time
- Understand that natural selection is the main mechanism which drives evolution
- Know that natural selection acts on individuals and that populations evolve
- Understand that adaptations are controlled by genes, and that these genes are passed from parent to offspring.

Key Vocabulary

- species
- evolution
- natural selection
- adaptation
- genes
- variation
- mutation
- offspring
- selection pressures
- environmental conditions
- survival of the fittest
- phenotype
- homogenous
- alleles

Links to GCSE Specifications 2006 (Science)

Knowledge, Skills and Understanding

1. Data, evidence, theories and explanations

a) how scientific data can be collected and analysed

b) how interpretation of data, using creative thought, provides evidence to test ideas and develop theories

c) how explanations of many phenomena can be developed using scientific theories, models and ideas

2. Practical and enquiry skills

a) plan to test a scientific idea, answer a scientific question, or solve a scientific problem

3. Communication skills

a) recall, analyse, interpret, apply and question scientific information or ideas

b) use both qualitative and quantitative approaches

c) present information, develop an argument and draw a conclusion, using scientific, technical and mathematical language,conventions and symbols and ICT tools.

Breadth of Study

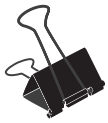
5. Organisms and health

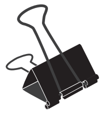
a) organisms are interdependent and adapted to their environments

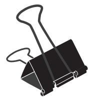
b) variation within species can lead to evolutionary changes and similarities and differences between species can be measured and classified

c) the ways in which organisms function are related to the genes in their cells

Equipment 2

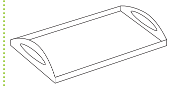

(51mm)
20 large binder clips (the big beaks)

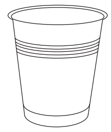

(41mm)
20 medium binder clips (the medium beaks)

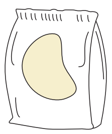

(32mm)
20 small binder clips (the small beaks)

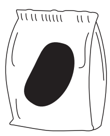

(25mm)
20 tiny binder clips (the tiny beaks)

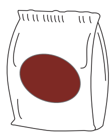

1 large paper clip (the gaping beak)

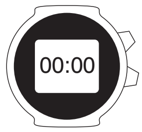

4 plastic trays


30 plastic cups (for the stomachs)

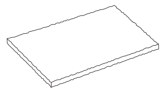

2 bags of dried butter beans white beans

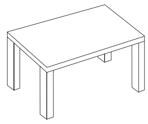

1 bag of dried black beans black beans

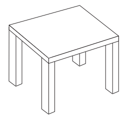

1 bag of dried mung beans red beans



1 stop watch


2 large foam sheets (table-sized)


2 large tables

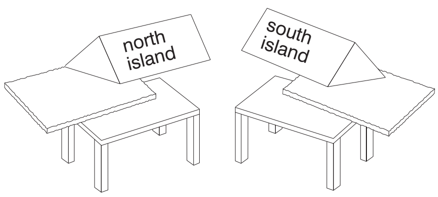

1 small table

The Set Up

step 1

Lay out 2 tables on opposite sides of the room.

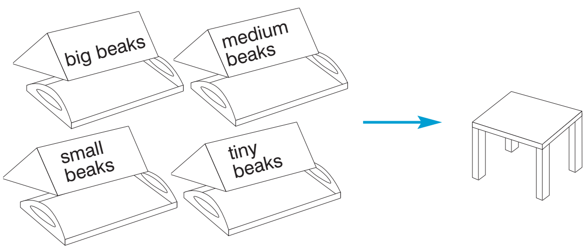
step 2



Place one foam mat on each table. Attach "North /South Island" signs and a copy of "Calorie values of food on Clippy Island" (Table 3.1). These can be found in the accompanying resource pack.

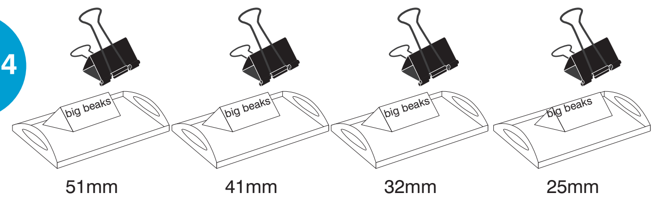
plus 2x TABLE **3.1**

step 3



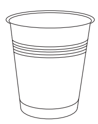
Place the four plastic trays on a separate table and mark each one as "big beaks" / "medium beaks" / "small beaks"/ "tiny beaks." Place these on the small table.

step 4



Place the different beaks (tiny, small, medium, large clips) in the appropriate tray. Place the gaping beak to one side.

step 5



Have the plastic cups ready to one side for the feeding.

step 6

TABLE **3.4**

Copy the Population Record Chart (**Table 3.4** in the resource pack) on to a flip chart.

step 7

W

Have 30 Student Worksheets printed off and ready.

You are now ready to start!

Introduction 3

- Tell the students that they are going to become members of a bird population in an imaginary place called Clippy Island to undertake an investigation into natural selection. Ask the students to define **natural selection.**
- Clippy Island is populated by one species called Springbeaks. Springbeaks are simple creatures; they can't fly and live on the three species of bean that grow on the island. Springbeaks are all exactly the same except they have variations in food requirements and beak size. In this activity, students will investigate whether beak size affects survival rates over four breeding seasons.
- Explain that Springbeaks can have five different beak sizes. Showing the students the different clip sizes, tell them that there are three wild types (small beaks, medium beaks, big beaks) and two mutants (tiny beaks and gaping beaks). Discuss the term **mutant.**
- Explain that the object of the game is to collect as much food as possible using the beaks during a 30 second feeding period.
- The food on Clippy Island is represented by three types of bean. Showing the students the three types of bean, explain that the beans have different calorie values. **See Table 3.1 for the specific values.**
- Explain to the students that there are feeding rules. These rules must be followed and are detailed in **Table 3.2**

  Birds have different food requirements based on their beak size. Each beak type has a **threshold for survival.** Larger beaked birds need more food to survive than birds with smaller beaks. The **threshold for survival** is listed in **Table 3.3.**

  Using the information in **Table 3.1** and student worksheets provided, the students can determine the number of calories they earned in a feeding season.

  Using **Table 3.3** as a guide the students can calculate if their bird **died, survived, or survived and reproduced.**
- If the Springbeak **died**, the student must return their beak and sit down
- If the Springbeak **survived**, the student can feed on the same island in the next season
- If the Springbeak **survived/reproduced**, the student can feed on the same island in the next season and must also give another student an identical sized clip and invite them to feed on the same island during the next season.

  You should then record the population after the feeding season on **Table 3.4 Population Record Chart**

  Once the students understand the concept of the game you are ready to move on to the Pre Season Scenario discussed in Section Four.

Notes

Information Tables

Calorie values of food on Clippy Island

TABLE 3.1

Calorie values of food on Clippy Island		
FOOD TYPE	FOOD DESCRIPTION	CALORIES (SCORE)
RED BEANS	Small red mung bean	10
WHITE BEANS	Large white butter bean	5
BLACK BEANS	Round black bean	2

The Feeding Rules

TABLE 3.2

The Feeding Rules
Springbeaks have 30 seconds to feed per season
Springbeaks must pick up beans one at a time with their beaks like tweezers and place them in their stomachs (the plastic cups)
Springbeaks do NOT scoop up beans or shovel them into the clip. Cheating results in automatic extinction!
Springbeaks count the number of beans they picked up during the feeding season.
Whether the Springbeak dies, survives or survives and reproduces is dependent on the number of calories it can eat in one season.

The Threshold for Survival: Food Requirements

TABLE 3.3

The Threshold for Survival: Food Requirements			
BEAK SIZE	DIE	SURVIVE	SURVIVE AND REPRODUCE
BIG BEAK	Less than 75 calories	75 calories	150 calories
MEDIUM BEAK	Less than 50 calories	50 calories	100 calories
SMALL BEAK	Less than 25 calories	25 calories	50 calories
GAPING BEAK	Less than 100 calories	100 calories	200 calories
TINY BEAK	Less than 10 calories	10 calories	20 calories

Population Record Chart

TABLE 3.4

Population Record Chart	North Island					South Island				
	Tiny Beak	Small Beak	Medium Beak	Large Beak	Gaping Beak	Tiny Beak	Small Beak	Medium Beak	Large Beak	Gaping Beak
Season One	0	2	2	2	0	0	2	2	2	0
Season Two										
Season Three										
Season Four										
Final population										

See accompanying resource pack for full size tables

Procedure 4

Set up the season as detailed in the tables below and after each season the students should carry out Steps 1-5:

1. Tally the number of beans and calories they earned by the end using **Table 3.1** and record their scores on their Student Worksheets.

2. Calculate whether their bird died, survived or reproduced using the information in **Table 3.3: The Threshold for Survival**. They should record this information on their worksheets.

3. Count how many birds survived and/or reproduced on each island and record it on **Table 3.4: Population Record Chart** at the front of the room.

4. Discuss what happened during the season.

5. Collect all the beans both consumed and left over from the season.

Pre Season Practice

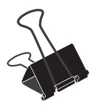
Pre season Practice

The Scenario: The students are one large population of Springbeaks with three different beak sizes. They will practise feeding and scoring to help them understand the activity.

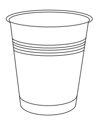
Instructions: All students should receive a beak (clip) and a cup (stomach). These can be assigned randomly. Following the feeding rules **(Table 3.2)**, allow all students to practise feeding for thirty seconds. Once they have had a practice round have them return their clips and prepare for Season One of feeding.

Pre Season Set Up:

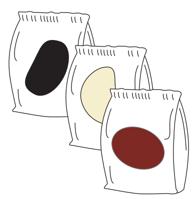
NORTH ISLAND	SOUTH ISLAND
4 x Handful Black Beans	4 x Handful Black Beans
4 x Handful Butter Beans	4 x Handful Butter Beans
4 x Handful Mung Beans	4 x Handful Mung Beans



x 30 any sizes



x 30



x 4 handfuls of each

1 Season One: Clippy Island splits into two

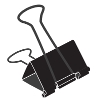
The Scenario: Clippy Island undergoes a significant change. A rise in water level divides the island in half creating the South Island and North Island. For this season there are identical numbers of Springbeaks on both sides and they have the same amount of food.

Instructions: Place the North Island sign in the middle of one foam mat and the South Island sign on the other foam mat. For Season One choose six students for each island. Each island begins with two small beaks, two medium beaks and two large beaks.

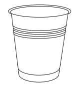
Expected Outcomes: Small beaked birds should have been able to feed most effectively because they could pick up beans more easily and needed fewer beans to survive and reproduce.

Season One Set Up:

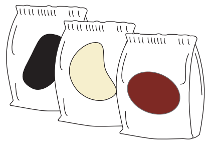
NORTH ISLAND	SOUTH ISLAND
50 x Black Beans	50 x Black Beans
50 x Mung Beans	50 x Mung Beans
50 x Butter Beans	50 x Butter Beans



x 6 per island
2 small / 2 medium / 2 large



x 6 per island



x 100 of each

2 Season Two: New variations through mutation

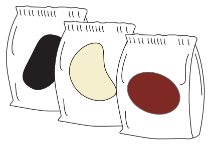
The Scenario: A new variant appears in the population due to random mutation. Introduce one tiny beak to North Island and one gaping beak to South Island by giving out the mutations to two students (tip: don't give the gaping beak to a very competitive student as it should be the one that does not survive).

Instructions: Begin with the number of students on each island after Season One. This will include any survivors from Season One as well as their offspring.
Repeat the activity and calculate populations.

Expected Outcomes: The tiny beak should have reproduced the most in this Season Two. They needed very little food to survive and reproduce. The gaping beak should have died out.

Season Two Set Up:

NORTH ISLAND	SOUTH ISLAND
50 x Black Beans	50 x Black Beans
50 x Mung Beans	50 x Mung Beans
50 x Butter Beans	50 x Butter Beans



x 100 of each

3 Season Three: A Famine on North Island

The Scenario: The North Island experiences a drought causing a shortage of food.

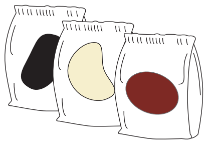
Instructions: Begin with the number of students on each island after Season Two. This will include any survivors from Season Two as well as their offspring.

Expected Outcomes: The North Island population should decline in numbers owing to lack of food. Tiny beaks are most apt to survive, followed by the small beaks.

Season Three Set Up:

NORTH ISLAND	SOUTH ISLAND
20 x Black Beans	50 x Black Beans
20 x Butter Beans	50 x Butter Beans
10 x Mung Beans	50 x Mung Beans

x 70 Black beans
x 70 Butter beans
x 50 Black beans



4 Season Four: Stability

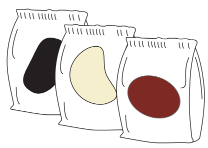
The Scenario: Conditions are equal on both sides of the island

Instructions: Begin with the number of students on each island after Season Three. This will include any survivors from Season Three as well as their offspring.

Expected Outcomes: The population of the North Island should have stabilised with the introduction of increased amounts of food. The populations of both the North Island and the South Island should now look very different after four feeding seasons.

Season Four Set Up:

NORTH ISLAND	SOUTH ISLAND
50 x Black Beans	50 x Black Beans
50 x Butter Beans	50 x Butter Beans
50 x Mung Beans	50 x Mung Beans



x 100 of each

Discussion Notes 5

Evolution by natural selection is the theory which accounts for the changes in a population over time. In this scientific sense, the word 'theory' means a well supported generalisation that explains all of the available facts. It is not a guess or a hypothesis. Evolution is driven by natural selection. Natural selection occurs because of slight variations between individual organisms in a population that are associated with differences in survival and breeding success.

All species and populations show natural variation like the beak size in Springbeaks. This type of variation occurs within a species. But there is also variation between species such as the calorie value of the different species of bean that grow on Clippy Island.

A species is a group of animals or plants that interbreed to produce fertile young. Species are made up of populations, and populations are composed of individuals. In this session Springbeaks are a breeding population that inhabit one large island. When the island splits in two, the original population of Springbeaks divides into two populations because the birds on North Island could no longer breed with the birds on South Island.

In Season One it was apparent that the Springbeaks with small beaks were better adapted to the environment than those with big beaks. The Springbeaks with the smaller beaks could feed more effectively and also needed fewer calories to survive. This variation should have resulted in a higher survival rate because those that survived with the beneficial trait or adaptation (in this case the small beak) were more likely to reproduce. This phenomenon is called 'survival of the fittest.'

Variation in beak size is determined by genes, which are the genetic information passed from parent to offspring. Organisms with forms of genes that produce advantageous phenotypes will pass their traits on to the next generation. Those that carry forms of genes that produce disadvantageous phenotypes will not pass on their traits and will be less represented in successive generations.

Mutations occur because of random errors in the DNA copying process. When mutations occur, new alleles (forms of a gene) are integrated into the population. If these alleles result in an advantageous phenotype then they will remain or expand in successive populations through reproduction. If new alleles cause a detrimental phenotype then the organism will die out. In Season Two, mutations were introduced on the North and South Islands which manifested themselves as a tiny beak and a gaping beak. The tiny beak was the advantageous phenotype because it required very little food to survive and could reproduce on a minimal amount of food. The gaping beak was the detrimental phenotype as its beak was poorly adapted to the environment and it could not sustain itself to reproduce.

The results of Season Two should illustrate that evolution is not 'progress,' but rather is the result of a population adapting to its environment by the elimination of unsuccessful genetic variants and the domination of successful genetic variants.

The term 'survival of the fittest' refers to how well 'fitted' an organism is to the environment in which it lives. In Season Three there was a drastic food reduction due to the environmental conditions on North Island. Whilst the population of South Island should have remained stable, the principle of survival of the fittest is demonstrated by the probable death of medium beaks and large beaks on the North Island. Overall the population of North Island will have declined. This is because environmental pressures determine how beneficial a trait is to an organism.

Natural selection only allows organisms to adapt to their current environment. In Season Four the population of North Island should have stabilised with the introduction of increased amounts of food. The populations of both North Island and South Island should look very different after four feeding seasons. Overall it should be evident that natural selection acts on individuals and that this causes the population to change. The changes that occur in this experiment do not lead to the generation of new characteristics in individuals; they merely change the proportions of the existing traits in the population.

Key Questions

Use the Key Questions as prompts to elicit ideas from students. The Key Questions could be set as homework and then followed up next lesson.

- Which Springbeak type was the most successful overall?
- Which population was larger in the end?
- How did the populations compare in terms of numbers and varieties?
- If the populations started out with the same number of each beak type, why do you think they didn't all develop in the same way?

Research Profiles

Why are animals different shapes?

My name is Tokiharu Takahashi and I am a researcher in the Faculty of Life Sciences at The University of Manchester. My primary area of research is in evolutionary developmental biology. I study how and why different animals have different shapes. I am particularly interested in how vertebrates (animals with back bones) evolved from invertebrate (animals without backbones).

From worms to whales, we are surrounded by animals of different shapes and forms. Remarkably all of them are related and descended from a common ancestor. The body shape of each animal is formed throughout its gestational development. Research on gestational development is essential to understanding evolutionary relationships. In my research we are examining and comparing embryos of various animal species working to understand mechanisms underlying this process.

Why are there so many species in the tropical rainforests?

My name is Sharon Zytynska and I am a researcher in Evolutionary Biology in the Faculty of Life Sciences at The University of Manchester. My primary area of research is in Community Genetics. I am interested in how genetic variation within a species affects other species it interacts with in an ecological community. My research takes me as far as the rainforests of Belize in Central America.

I carry out investigations into how variation within a tree species affects the other species of plants that grow on it. By collecting samples from trees, I can extract DNA and analyse how similar the specimens are at the genetic level. My results show that the genetically similar trees have the most similar plants growing on them. We still do not fully understand why there are so many species in the tropics, but genetic diversity of plants may explain why overall diversity is maintained. My work has implications in conservation, since conserving genetic diversity in trees will enhance the preservation of other species including mammals and birds.

Whatever happened to our gills?

My name is Donald Ward and I am a researcher in Physiology at The University of Manchester. I am interested in how blood calcium levels are regulated. The primary focus of my work is trying to understand how the CaR works in controlling blood calcium levels and how its function has adapted to meet various evolutionary challenges. Using this research we hope to improve upon our current treatments for the bone disease osteoporosis and the cardiovascular problems of people on kidney dialysis.

Calcium is important as it gives our bones strength, allows our muscles to contract and our nerves to fire. Fish breathe under water using their gills for oxygen exchange, but the gills also regulate their calcium levels. We use our lungs to breathe on dry land, but the job of regulating blood calcium levels remains with glands in the neck known as the parathyroids. Amazingly, gills and parathyroid glands are related since the same gene, Gcm-2, leads to the development of both. So, gills are an ancestor to human parathyroid glands which means a remnant of our gills is still present in our necks! Both tissues express a protein called the calcium-sensing receptor (CaR). The part of the CaR that binds calcium is actually derived from an ancient bacterial protein secreted to supply the bacterium with nutrients. Therefore evolution has adapted already existing calcium-regulating genes and tissues for new uses in higher organisms.

Why do we have bones and some animals don't?

My name is Julie Huxley-Jones and I was a researcher at The University of Manchester. I was interested in why vertebrates, such as fish, mammals and birds, have tissues such as bone, cartilage and skin and why invertebrates (animals without backbones) do not. I looked at the genes responsible for the proteins that function to surround and support cells in the same way the mortar glues together bricks in a building. These genes characterise the properties of the different tissues I was investigating; they make bone strong, cartilage bouncy and skin elastic. (continued on next page)

Research Profiles (cont.)

Why do we have bones and some animals don't? (cont)

Using Darwin's theory of evolution I was able to show how these genes have evolved. By investigating this process researchers can learn about changes in animal development from simple organisms to complex humans. From here we can begin to understand how and why changes in their activity can cause diseases such as osteoarthritis and eczema. If mutations in genes are linked to certain diseases, how can we treat them? I am now working in the pharmaceutical industry to help discover and generate new treatments to help patients with these diseases to help attain this goal.

Where did our crop plants come from?

My name is Sarah Ayling and I am a researcher in Bioinformatics at The University of Manchester. I came to The University of Manchester to study Biological Sciences and completed a Ph D in developing new methods to explore the evolutionary relationships between different members of the same species. This involved developing software to show how different plant populations are related to one another using genetic data. The project I am currently working on uses this idea to explore the origins of farming.

Archaeological evidence shows that farming of wheat, barley, peas and a number of animals first began about 10,000 years ago. Modern crops evolved from wild types through selection by these early farmers. In wheat, for instance, there is a gene which retains the grain on the ear once it is ripe rather than falling to the ground; the early farmers would most likely have preferred these mutant plants as it is easier to gather grain from the ear than the ground. Through selective breeding all domestic wheat now keeps its grain on the ear. By comparing modern wild and domesticated wheat we are able to construct family trees to determine which wild population that domesticated wheat is most closely related to. This will give us insight into where and how agriculture first began. Studying evolutionary histories of crops can help lead to improved crops and food production in the future.

For more information visit:
http://www.ls.manchester.ac.uk/