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Wheat breeding and evolution

Wheat is a staple crop for a significant proportion of the world's population. Wheat cultivation began about 12,000 years ago and now occupies more land than any other commercial crop. Varieties of wheat have been developed that produce flours used in a range of foods, including bread, pasta, breakfast cereals and biscuits. Wheat consists of the carbohydrate starch, and gluten – the leading source of vegetable protein in human food. The development of wheat from wild grasses demonstrates the dramatic effect of both evolution and selective breeding on the structure of a crop plant and the chemical makeup of the product harvested from it.

Suitable for Key Stage:

1 2 3 4 5

CLEAPSS

Safety checked but not trialled by CLEAPSS

20 YEARS OF PIONEERING GREAT BRITISH BIOSCIENCE BBSRC 1994 - 2014

Contents

Key Information

Teacher

View online

Scan the QR Code.

Science topics

Age
11–16 years old
Duration
60-120 minutes

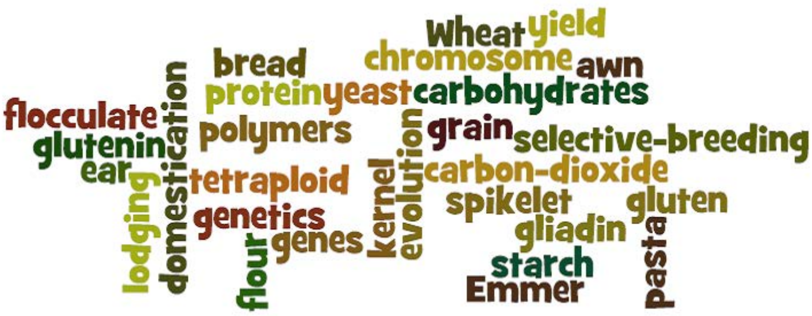
Evolution, properties of materials, selective breeding, genetics, plant science.

Resources

- The history of wheat domestication
- Recent research on wheat
- Practical activities
- Quiz
- Crossword
- Wordsearch
- PowerPoint presentation

Keywords

Wheat, evolution, selective breeding, domestication, Emmer, lodging, grain, spikelet, awn, kernel, ear, yield, genetics, tetraploid, chromosome, genes, carbohydrates, protein, starch, flour, bread, pasta, yeast, carbon dioxide, gluten, gliadin, glutenin, polymers, flocculate.



Key Information

Learning outcomes

Students will be able to:

- Identify the part of a wheat plant used to make flour
- Describe the differences between wild grasses and domesticated wheat
- Explain the role of genetics in producing different varieties of wheat
- Select appropriate flours to use for different foods
- Compare the properties of different flours.

What you will need

- Ears of wheat
- Ears of wild goatgrass (a wild ancestor of wheat)
- Flour (strong flour, plain flour, spelt flour, Alimonti 00 flour, rice flour)
- Salt
- Sugar
- Yeast
- Water
- Cling film
- Bowls
- Sieve
- Balance
- Timer
- Measuring cylinders (10 ml and 50 ml)
- Measuring jug
- Baking parchment
- Rulers
- Food processor
- Microwave
- Tubes (preferably boiling tubes with stoppers, or screw-cap plastic tubes)
- Washing-up liquid
- Vinegar

Optional

- Diluted lactic acid
- Sodium dodecyl sulphate (SDS) aka sodium lauryl sulfate solution <1%.

Key Information

Prior learning

Students should be familiar with the different parts of plants. A basic understanding of evolution, inheritance, genetics and gene expression will help students understand selective breeding and domestication. Students should also know the difference between monomers and polymers and have encountered carbohydrates and proteins. Knowledge of fermentation will enable students to understand the role of yeast in producing bread with the desired characteristics.

Teacher preparation

Halve the ears of wheat and grass for the starter activity to provide enough material for the whole class. Split the class up into groups of four and provide each group with half an ear of grass and half an ear of wheat.

For the flour activities you may want to prepare dough for the students in advance to save time. Solutions of washing-up liquid and vinegar or SDS and dilute lactic acid should be made up prior to the sedimentation test.

Print out the student instruction sheets for the practicals and provide the quiz, crossword or wordsearch to students before or after the lesson as homework.

Introducing the lesson

These activities illustrate the changes to both the structure and the chemistry of the wheat plant and can be delivered as either a chemistry or a biology lesson. Depending on the time available you may want to provide the students with a very brief outline of the lesson and get them started on making dough and setting up some of the experiments.

You can then cover the background and provide more information about wheat and recent research while the dough rises. The threshing, sedimentation test and dough washing, if you have prepared dough, can also be carried out while the students are waiting for their dough to rise.

Health and safety

These instructions are for guidance only. Observe Good Laboratory Practice when carrying out these activities. Check whether any students have asthma or allergies to wheat or grass before starting the practicals. You may want students to wear eye protection and lab coats or disposable aprons to protect clothes.

Flour presents a low-level hazard in small-scale use. Handling flour is unlikely to produce anything worse than skin irritation in those who are allergic to gluten. The fine dust may be a nuisance and some children may be allergic to certain types, possibly only on ingestion. Take care to prevent clouds of dust from dry flour. There is a risk of inhalation and flour can give rise to short term respiratory, nasal and eye symptoms. It may provoke an asthmatic attack in individuals with pre-existing disease. Any dough prepared in the laboratory should not be consumed.

Vinegar and sodium dodecyl sulfate (SDS) solutions <1% present a low-level hazard. Ensure that only diluted solutions of SDS or lactic acid are provided to students. Solid SDS is harmful if swallowed, causes skin irritation and serious eye damage. Students should wear suitable eye protection and avoid splashing vinegar or other acids on skin or in the eyes. Students with sensitive skins should take particular care handling vinegar or soap solutions. Ensure students thoroughly wash their hands after the activity. You may also want to make certain there is good ventilation if using vinegar. Used reagents and any excess vinegar can be disposed of down a sink.

For all chemicals used in practicals, schools should refer to suppliers' safety advice. Consult CLEAPSS or the Scottish Schools Education Research Centre (SSERC) for further guidance.

Suppliers

Ears of wheat and wild grass can be obtained from Mike Ambrose, Germplasm Resources Unit, John Innes Centre, Norwich Research Park, Norwich, NR4 7UH – **Mike.Ambrose@jic.ac.uk**. At certain times of year it may be possible to obtain ears of wheat from local farmers.

Flour and other consumables are available in most supermarkets and the equipment required should be available in most schools. Sodium dodecyl sulfate (SDS) aka sodium lauryl sulfate and lactic acid can be obtained from Timstar **www.timstar.co.uk**

All about wheat

Wheat is a staple crop for a significant proportion of the world's population. Wheat cultivation occupies more land (240 million hectares) than any other commercial crop.

History – Wheat throughout history

Wheat has always formed one of the main constituents of the human diet, and can be traced back to 10,000 BC. Wheat has been found in pits where human settlements flourished over 8,000 years ago. The Egyptians were the first to produce risen loaves using yeast, probably by accident when beer was used to mix dough instead of water. In the British Museum, you can see actual loaves that were made and baked in Egypt over 5,000 years ago.

From rocks to millstones, man has refined the method of grinding grains of wheat to make flour and produce risen bread loaves over the ages. In the Middle Ages, windmills and watermills were built closer to where the grain was grown. Crop rotation was also introduced at this time. The first rotations only alternated grassland and crops, but the big breakthrough in the 18th century was the 'Norfolk four-course' which introduced the sequence of wheat/root crop/fallow/beans.

In 1701 Jethro Tull invented the mechanical seed drill. This resulted in farming becoming less labour-intensive and allowed farmers to grow crops on a much larger scale.

The period from 1900 onwards has resulted in crop-breeding advances that have increased the quality and yield of wheat, and made production more efficient by improving management and mechanisation.

Illustration of common wheat, Triticum aestivum, from Prof. Dr Otto Wilhelm Thomé, 'Flora von Deutschland, Österreich und der Schweiz', 1885, Gera, Germany

Public domain

Background

The national small grain cereal collection held at the John Innes Centre is the largest collection of wheat seeds in Britain. Some varieties date back to the late 18th century while others have been collected from all over the world. It is a 'living museum' of seeds that provides a vital bank of genetic material widely used by plant scientists and breeders. Recent advances in DNA technology have made it possible to examine many of the older and more exotic varieties of wheat in order to try to isolate characteristics that can benefit modern farmers. Some of the older varieties that could tolerate poor soil need less fertiliser so may be useful to organic farmers.

Production

In 2000, enough wheat to cover an area nine times the size of the UK was produced worldwide. Wheat is sown on 40% of Britain's arable land, resulting in a total harvest of 12–17 million tonnes. In the middle of the 19th century, wheat yields were 1 tonne per hectare and by 1940 they were up to 2.5 tonnes per hectare. The average yield in the UK is currently 8 tonnes per hectare but this increase has been slowing since 1980.

One hundred kilos of wheat contain 2 million grains – enough to make 100 loaves of bread! And only wheat contains enough gluten to make raised or leavened bread.

Food uses of wheat

Wheat is rich in carbohydrates, protein and essential vitamins and minerals such as vitamins B and E, calcium and iron, as well as fibre, and can be used for both food and non-food purposes. More foods – such as flour, cakes, pastries, biscuits, crackers, bread, pasta, egg noodles and animal feed – are made from wheat than from any other grain.

The harder the wheat, the higher the amount of protein in the flour. Soft, low-protein wheats are used in cakes, pastries, biscuits and crackers. Hard, high-protein wheats are used in breads. Durum wheat, a hard wheat with high-protein content, is used in pasta and egg noodles.

Wheat ear

Non-food uses of wheat

Gluten, which is a protein constituent of wheat, is also used in the pharmaceutical and papermaking industries. Wheatgerm is a concentrated source of vitamin E, used in skincare production, and bioethanol is a liquid biofuel made from the carbohydrate content of crops, including wheat.

The future – Meeting the world's food challenges

Interesting fact

Wheat makes up 20% of the calories consumed by people globally.

Since 1901, the world's population has increased fourfold. By 2050, it is likely to increase to 9 billion. This presents the enormous challenge of feeding an additional 2 billion people using the same amount of land and water that is available today.

Better quality crops with higher yields will provide the potential to enhance the nutritional benefits of food and increase the amount of food produced. This, coupled with a reduction in the use of chemicals and an increase in profitability, is the reason the world's farmers plant more and more each year.

The earth's resources are under severe strain, but sustaining and protecting the environment can help to meet our growing demand for food. Inorganic and organic fertilisers have boosted quality and yield, and crop protection has improved so farmers are losing less of their yield to pests, disease and weeds.

In addition, the increase in global trade in wheat has meant that farmers now face competition from many other markets. The modern wheat trade is strictly regulated, with farming currently requiring technological and administrative – as well as agricultural – skills.

Wheat breeding and evolution

Wheat was one of the first crops brought into cultivation. Its domestication began about 12,000 years ago.

Wheat originates from the Fertile Crescent in the Middle East (northern Israel, Lebanon and parts of Iraq and Syria). There is evidence that the wild grasses, which are the ancestors of modern wheat, were collected by hunter-gatherers for thousands of years before they were cultivated.

Wild Emmer wheat (Triticum dicoccoides) and, to a lesser extent, a relative of wild einkorn wheat (Triticum urartu) were the first cultivated wheat species. Both are wild grasses with seven chromosomes ($n = 7$).

Wild Emmer is a natural hybrid between T. urartu and an unidentified goatgrass. In the hybrid, the seven chromosomes from each parent spontaneously doubled ($2n = 28$) to give a natural, fertile, interspecies hybrid that is tetraploid.

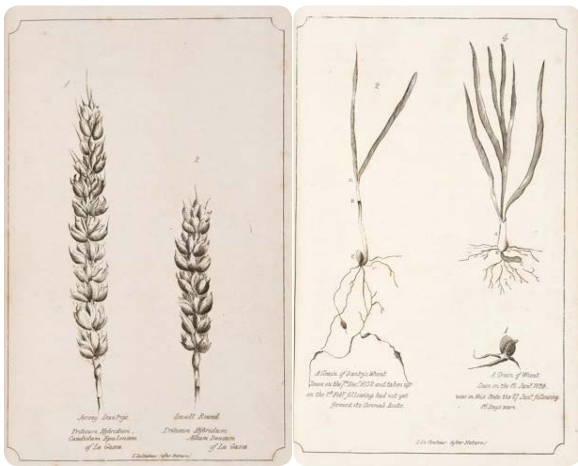
Emmer was widely grown in the Neolithic period and spread throughout Europe, eventually reaching the UK in about 4,000 BC. Domesticated Emmer wheat (T. dicoccum) continued to diversify over the centuries, and a major development from Emmer was the tetraploid ‘durum’ wheat (Triticum durum).

Meanwhile, in the Middle East, Emmer wheat became the ancestor of bread wheat (Triticum aestivum) when it hybridised with a goatgrass (Aegilops squarrosa) to gain another set of seven chromosomes. Natural chromosome doubling made the hybrid fertile ($2n = 42$). A. squarrosa contributed the genes that produce the glutenin proteins, which account for the elasticity of dough made from T. aestivum flour. Bread wheat reached the UK, and replaced Emmer wheat, during the Iron Age (800–100 BC).

Wild wheats typically have ears that are fragile and shatter once ripe, and glumes that are tightly stuck to the grains. These characteristics make them difficult to harvest and thresh. Domesticated wheats have non-shattering ears and grains that are easier to thresh.

Distinctively, bread wheats produce glutenins in their flour, which, when the flour is kneaded with water, produce an elastic dough that rises well and gives a light loaf with an open structure.

T. aestivum was produced by natural and semi-natural interspecific hybridisations that generated new gene combinations and characteristics that made wheat suitable for cultivation and processing. Subsequently, ongoing selection and, recently, directed breeding, has continued to change the wheat plant.



Triticum hybridum in John Le Couteur’s ‘On the varieties, classification and properties of wheat’, 1837, John Innes Historical Collections

Wheat breeding and evolution

Interesting fact

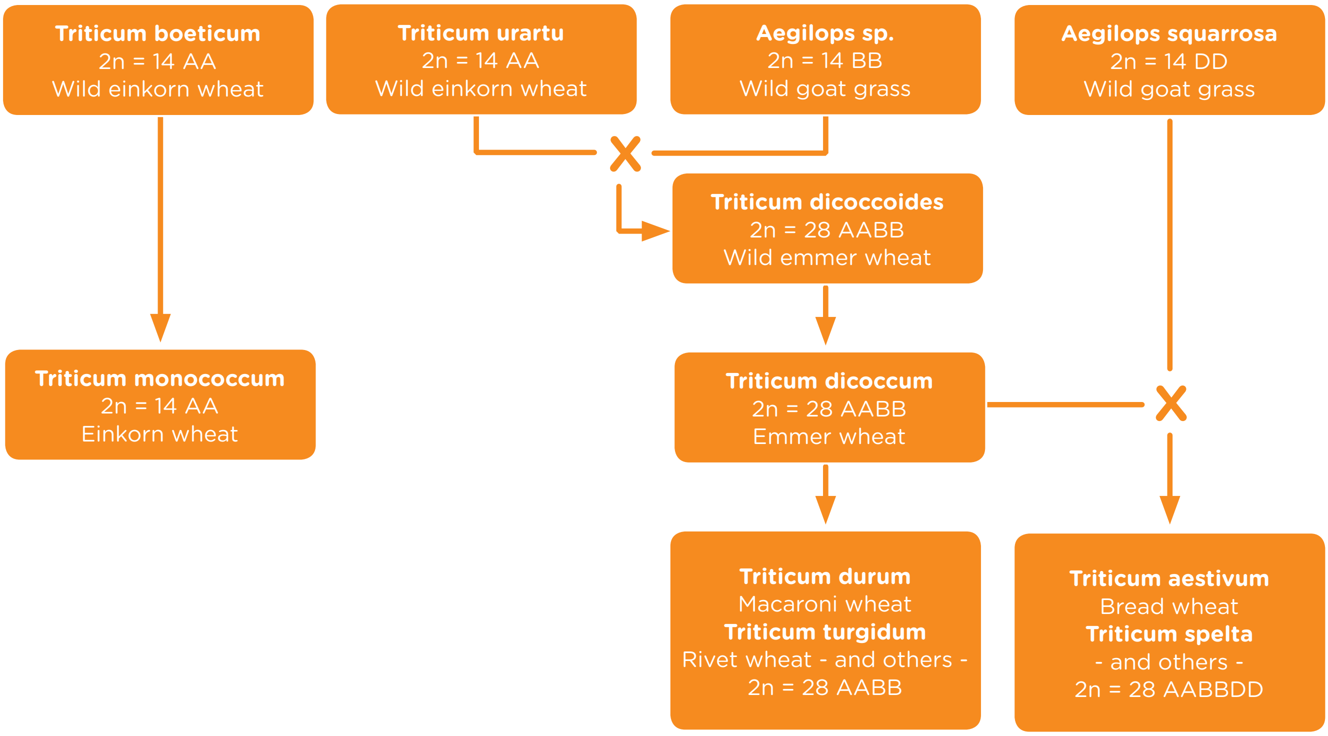
Wheat is the most important UK crop with an annual value of about £1.6 billion.

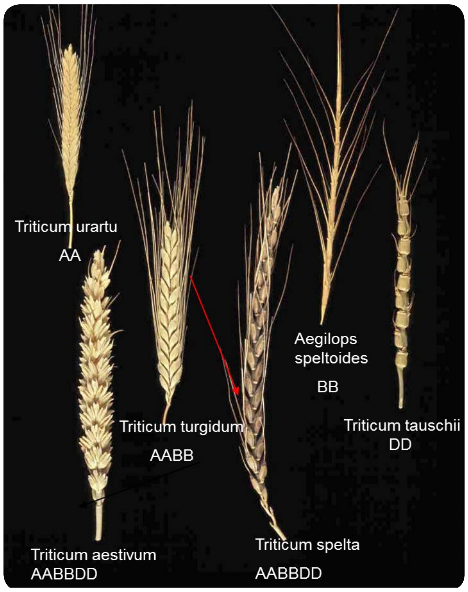
The most obvious change in cultivated wheat has been the dramatic reduction in height since the beginning of the 20th century, and especially since the 1960s. By the deliberate introduction of a single gene (various alleles of a single gene) referred to as Reduced height (Rht) genes, it has been possible to produce semi-dwarf wheats. These new shorter varieties of wheat are more resistant to lodging (the falling over of wheat stalks) and produce more grain than older varieties. The increase in grain yield is because a greater proportion of the products of photosynthesis accumulate in the grains rather than in the leaves. The shorter and more uniform height of the wheat also makes it possible for farmers to manage large fields and mechanise harvesting using combine harvesters. This dwarfing gene was the basis of the green revolution and helped to double wheat yields, worldwide, in the 1960s and 1970s.

The wheat genome was published in 2012 by a consortium of researchers from the UK, Germany and the USA. They identified around 96,000 genes – four times as many as in the human genome.

Wheat varieties, 19th century to present

Wheat breeding and evolution





Variety among wild, ancient and modern wheat ears

© John Innes Centre

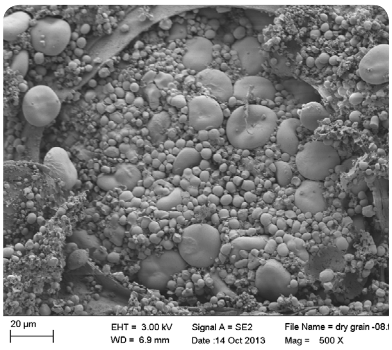
Wheat varieties growing in greenhouse

© John Innes Centre

Flour properties and bread-making quality

Interesting fact

Before the Second World War, most of the UK's bread-making wheat was imported from the USA and Canada, where varieties were rich in gluten proteins.



Scanning Electron Micrograph

One of the major concerns for breeders of modern bread wheats is that the wheat flour produces a loaf with the desired physical characteristics. Differences in the nutritional quality of a loaf are almost entirely determined by the processing of the flour into wholemeal or white flour.

The bread-making quality of flour is affected by its total protein content, but mainly by the amount of gluten. The most important physical property of the loaf is its crumb structure. This should be open with plenty of air spaces, otherwise the loaf will have a very dense and chewy texture. For the loaf to have plenty of air spaces the bread dough must be elastic, so that it expands as the fermenting yeast in the dough mix produces carbon dioxide. Crucial to this are the glutenin proteins. These are long flexible protein molecules. During the kneading process these proteins become physically entangled with one another and create an elastic network of protein that helps retain, and is stretched by, the carbon dioxide produced by the yeast.

Gluten is composed of the two proteins gliadin and glutenin. Together these may make up 80% of the protein in wheat grains. Gluten forms when wheat dough is kneaded and glutenin and gliadin molecules associate to create an elastic network. Glutenin gives dough its elasticity. Gliadin is alcohol-soluble and has primarily monomeric proteins, whereas glutenin is only soluble in dilute acids or alkalis and is primarily made up of polymers.

Different types of wheat, and other, flours have different amounts of, or no, glutenins. These differences can be crudely demonstrated by looking at the kind of dough produced with these flours, how much (if at all) these doughs expand when proved and the structure of the loaves baked from them.

It is possible to wash out the starch and low molecular weight proteins from dough and retain only (mainly) the glutenins – as a gooey lump. The amount of glutenin left, from different flours, indicates the relative 'strengths' of the flours.

There is a physico-chemical test (used by breeders and the flour industry) to estimate the bread-making quality of flour. It uses a weakly acidified, dilute solution of sodium dodecyl sulfate (SDS) to make the glutenins (and other high molecular weight proteins) in the flour swell and form into small clumps or masses (flocculate). The more sediment there is after a 5–10 minute sedimentation period, the more proteins there are in the flour and the better the flour will be for bread-making.

Types of flour

Interesting fact

Gluten is also important as a food additive and animal protein substitute. It is commonly found in Asia, as seitan, and is used much like tofu, as a replacement for meat and fish protein.

'Strong bread-making flour' from the local supermarket will contain a lot of proteins, mainly glutens, and should produce a good elastic dough, a reasonably open crumb structure in a loaf, a lot of gluten in a dough-washing experiment and plenty of flocculant in an SDS test. Other types of flour will vary in their gluten content compared to 'strong' flour.

Rye, maize and rice flours contain negligible amounts, if any, of these proteins and do not 'rise' significantly.

'00 flour' or 'Italian flour' is durum flour used for making pasta (and bread). This has less protein than strong flour, but still has significant amounts.

Spelt flour should be low in glutens – but does contain other proteins. Spelt flour is typically fortified with bread-making flour to improve its bread-making qualities.

Soya flour contains no glutenins. It is high in protein and produces a lot of flocculant in an SDS test.

Synthetic wheat

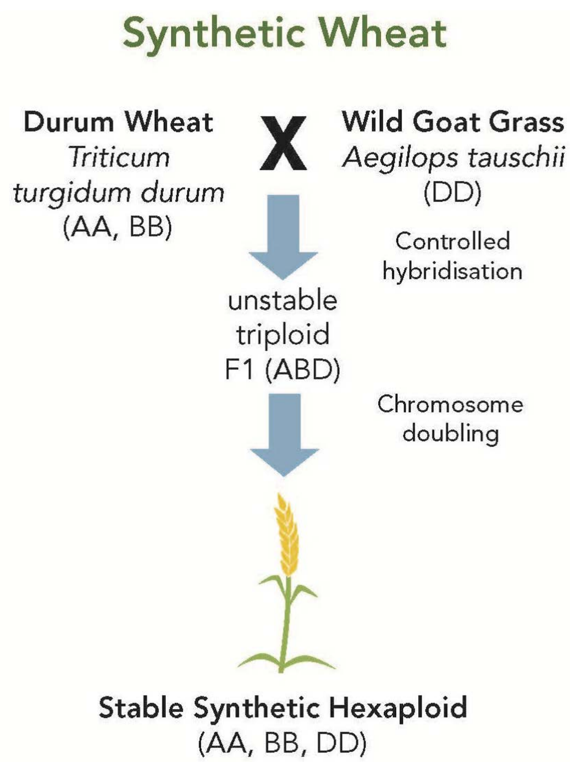
Scientists in Cambridge have recreated the original rare cross between an ancient wheat and wild grass species that happened in the Middle East 10,000 years ago. If this new wheat is crossed with modern UK varieties it could increase the yield of wheat grown in the UK. It could also provide a new genetic variety that would make future wheat crops more drought tolerant, disease resistant and requiring less fertiliser.

The original ancient cross has provided the genetic basis for all of today's modern wheat varieties. Over the years domestication of the wheat plant has increased yields, but recently those increases have slowed. Domestication of wheat has involved repeated inbreeding, which has reduced the genetic diversity of wheat grown by farmers. The possibilities for improvement from within the existing modern wheat genomes are reaching their limit.

Breeding new wheats from ancient wild relatives recaptures some of the variation lost as agriculture developed. The synthetic wheat programme involves crossing durum pasta wheat with wild goatgrass using traditional crossing techniques in a glasshouse, combined with a tissue culture technique carried out in the laboratory. This novel technique guarantees seed germination. The resulting hybrid plants produce 'synthetic' seed which is then crossed with current varieties

Crossing synthetic wheats with modern wheats provides an excellent way of transferring novel sources of genetic diversity from wild relatives into varieties already grown by farmers across the UK.

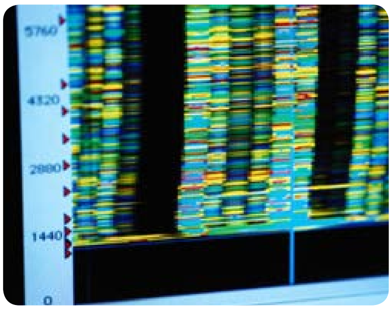
Bagged wheat ear



Major breakthrough in deciphering bread wheat's genetic code

Interesting fact

The bread wheat genome is five times larger than the human genome and there are three genomes in each plant.



DNA sequencing data

In 2010, UK scientists published a draft sequence of the wheat genome. Now, they have unlocked key components of the genetic code in the first analysis of the complex and exceptionally large bread wheat genome.

The first task was for researchers to produce genome sequences from a commonly used laboratory variety of wheat. This is one of the largest genome projects ever undertaken. Completing this sequence represents a major achievement because wheat has a very large and complex genome, five times larger than that of humans. Bread wheat (Triticum aestivum) is a complex hybrid, composed of the complete genomes of three closely related grasses. Until now the very large size and complexity of the genome have been significant barriers to crop improvement.

The data will help scientists understand the function of specific genes and to identify genetic variations between different wheat types. Both of these are valuable to wheat breeders in combination with new genetic technologies as they will speed up the development of new varieties. The genetic information was released as raw data in the form of letters representing the genetic 'code'. The sequences of DNA were fragments of the complete genome, like the pieces of a jigsaw that haven't been pieced together. Professor Neil Hall described the raw data of the wheat genome as 'like having tens of billions of Scrabble letters; you know which letters are present, and their quantities, but they need to be assembled on the board in the right sequence before you can spell out their order into genes'.

In 2012, the scientists announced that they had identified about 96,000 genes and placed them in an approximate order. The researchers made this rapid progress by developing a new strategy that compared wheat's genetic sequences to known grass genes (for example from rice and barley), and also by comparing these to the simpler genomes of wheat's ancestors. This revealed a highly dynamic genome that has undergone genetic loss as a consequence of domestication. The research will accelerate wheat improvement by allowing wheat breeders and researchers to identify useful genetic variation and to select plants with desirable combinations of genes and specific traits. The scientists have made a major breakthrough in understanding how to breed wheat varieties that are more productive and better able to cope with disease, drought and other stresses that cause crop losses. The achievement is expected to speed up development of wheat varieties with enhanced nutritional value.

Historic grain collections help preserve future biodiversity

One key to maintaining world food security is to preserve biodiversity in food crop species. The John Innes Centre Germplasm Resources Unit is the largest collection of cereals and plant seeds in the UK and includes important wheat, oat and barley varieties. Seeds are sent out for use in both research and plant-breeding programmes, as well as for educational purposes in the UK and across the world.

In the mid-1970s, collections of seeds from research institutes across the UK and expeditions mounted by UK universities and the British Army through Europe, Asia and Africa were brought together into a single seed storage facility in Cambridge.

In 1990, this 'seed museum' and historical varieties were moved to a new facility at the John Innes Centre (JIC) where they could also be used more readily in plant research by scientists. The collections include 9,533 wheat varieties from all the wheat-growing regions of the world.

Over the years the cereal collections have been successfully screened for many traits leading to the identification of new sources of resistance to a range of diseases, as well as tolerance to drought, salinity and aluminium.

The Watkins collection of bread wheats was assembled in 1928, and features 1,200 wheats collected from 32 countries around the world. But, in the 1960s, there was a real risk that the collection would be discarded for higher-yielding varieties. Recently this historic collection has proven invaluable and researchers have identified novel variations in genes that respond to day length and control vernalisation (when seeds break from dormancy in the spring, following a period of cold).

Developments in biotechnology are helping scientists understand and unlock the diversity in the wheat collections, which researchers hope will translate into improving the crops of tomorrow.

The seed collections of the Germplasm Resources Unit

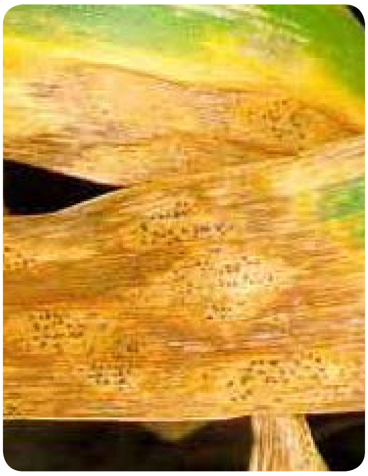
Wheat defence against Septoria: two genes in the front line

Scientists at Rothamsted Research have identified two genes in wheat which are crucial to resisting infection by a fungal disease. Septoria leaf blotch is one of the most economically damaging diseases of wheat. The disease is caused by the fungus Mycosphaerella graminicola (Mg) and it is a major threat to crop yields in the UK and worldwide.

Researchers had previously identified a gene in the fungus that enabled the disease to evade the immune responses of wheat during the early stages of infection. Now, using modern biotechnology methods, two wheat genes have been identified that activate the wheat defence response. This finding will help scientists combat the disease in the future.

When pathogens attack wheat plant leaves, the leaves release signals that the plants have evolved to recognise and subsequently initiate a response within the leaf cells to protect themselves against the pathogen. However, pathogens are successful in evading the immune response of the host plant because they have also evolved other signals that are able to suppress the first layer of plant defence, often making them 'invisible'. There is a long symptomless infection phase of between 7 to 14 days, which is followed by rapid deterioration of the leaf tissue. This life cycle of the disease makes it difficult to spot and stop the disease before it is too late for the crop.

The most commonly known and studied fungal signal that both plants and animals can recognise is chitin, which is a major component of fungal cell walls. Very little was known about the mechanism that wheat may have evolved to recognise the invading fungus, but research has discovered that wheat is more like rice, having two genes for recognition of fungal chitin and elicitation of the immune response. The fungus contains a single gene that prevents the two wheat genes from functioning. Having identified the molecules that are involved in this interaction in wheat, scientists can now think of ways to detect the presence of the pathogen and to stop symptoms before they affect the crop. Septoria leaf blotch is closely related to the fungus that causes Black Sigatoka disease, which can devastate banana plantations in just a few months. The discovery of how Septoria leaf blotch evades detection in wheat could also help in the protection of banana crops.



Septoria

Rothamsted Wheat Trial: Second generation GM technology to emulate natural plant defence mechanisms

Grain Aphid

© Rothamsted Research

How GM wheat works

© Rothamsted Research

Scientists from Rothamsted Research have conducted a controlled experiment, combining modern genetic engineering with their knowledge of natural plant defences to test whether wheat can repel aphid attack in the field.

Aphids (also known as greenfly and blackfly) are unwelcome visitors that suck sap from plants. They cause significant damage to agriculture and reduce farmers' yields by damaging crops and spreading plant diseases such as barley yellow dwarf virus.

Currently a large proportion of UK wheat is treated with broad spectrum chemical insecticides to control cereal aphids. Unfortunately, repeated use of insecticides often leads to resistant aphids and kills other non-target insect species including the natural enemies of aphids, which could have a further impact on biodiversity.

Scientists have been seeking novel ecological solutions to overcome this problem in wheat. One approach has been to use an odour, or alarm pheromone, which aphids produce to alert one another to danger. This odour, (E)-ß-farnesene, is also produced by some plants as a natural defence mechanism and not only repels aphids but also attracts the natural enemies of aphids, e.g. ladybirds. Scientists are using biotechnological tools to genetically engineer a wheat plant which produces high levels of this aphid-repelling odour, which could help promote sustainable and environmentally friendly agriculture.

The work is the product of years of studying how insects naturally interact with one another and with the plants that surround them in the ecosystem through their natural chemistry. The decision to use genetic modification as a tool came after trying other approaches (synthetic dispensers and essential oils with high levels of (E)-ß-farnesene) that did not effectively deliver the repellent odour. Release of the repellent from the plant will improve the performance of the repellent, as demonstrated by the wild potato. Use of insect repellents and attractants delivered by crops has been used successfully in East Africa where non-GM plants that release a repellent are grown alongside crops.

Starter Activity:
On Your Marks, Get Set, Thresh!

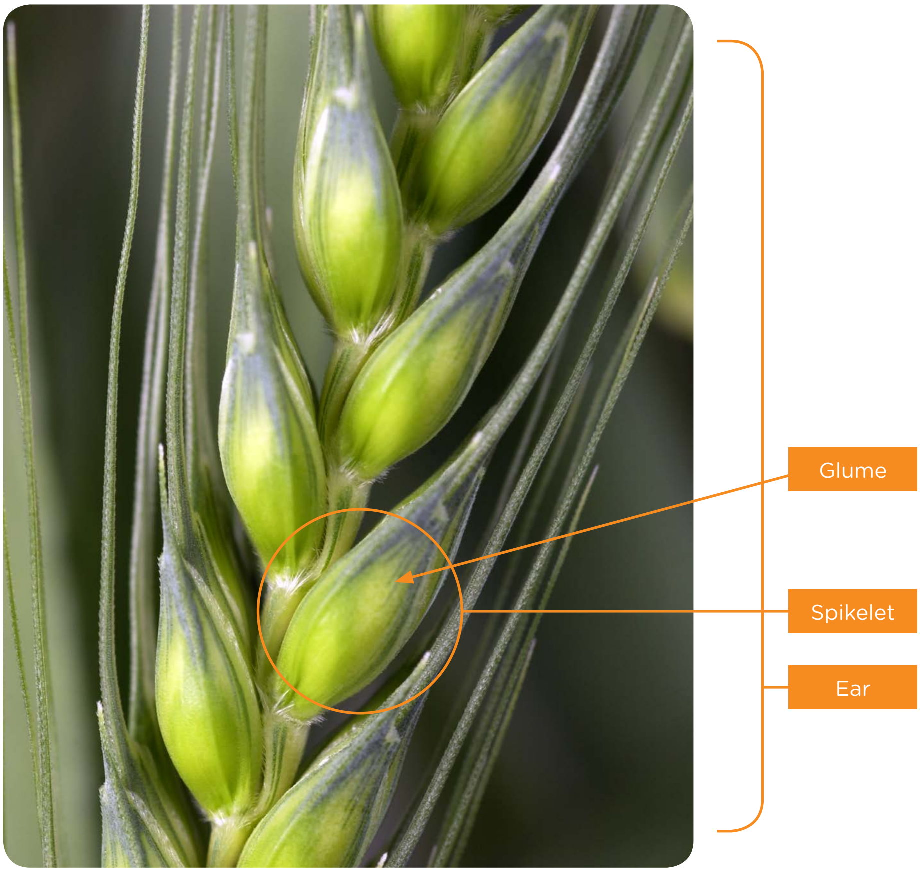
Teacher

Duration

10 minutes

What you will need

- Ears of wheat
- Ears of wild goatgrass
- Timer



Wheat ear

The ears of a domesticated wheat plant are dramatically different to those of their wild relatives. This activity compares the differences in anatomical structure and the difference in threshing time.

- The wild relative has evolved thick outer glumes to protect the small grains from predation and early germination
- Domestication has bred out the thick glumes and selected for much larger grains

Health and safety

Make sure you source wheat that has not had any hazardous chemicals such as pesticides applied to it. Students should avoid raising dust that could contain allergens or fungal spores and should wash their hands after the activity.

Starter Activity:
On Your Marks, Get Set, Thresh!

Process

1. Form into groups of four
2. Time one person to extract a single grain from an ear of a modern free threshing wheat
3. Record the time
4. Separate the individual spikelets from the stem of each ear of wild goatgrass
5. Now time one person to extract a single grain from a wild goatgrass
6. Record the time
7. The other members of your group should now repeat the experiment with the wild goatgrass
8. Record the time
9. Clear up the threshed grains and remaining wheat and place in the bin
10. Wash your hands
11. Think about your answers to the following questions

Discussion questions

1. Which was harder to extract and why?
2. How would you describe the differences in the size and shape of the grains?
3. How could you speed this up to extract the grain from a field of wheat?
4. How do you think hunter-gatherers began the process of selection and domestication of wheat?
5. What were the extra efforts and rewards of farming versus foraging?
6. What makes one wheat good for growing on a farm and the other good for growing in the wild?

Practical Activity: Dough Washing

What you will need

- Timer
- Flour
- Salt
- Balance
- Sieve
- Measuring cylinder (250ml) or measuring jug
- Food processor
- Cling film
- Water
- Large bowl

Dough washing removes the starch and water-soluble materials from the dough, leaving (mainly) glutenin. The whole process (making dough, resting it and dough washing) is rather long, but can be dramatically shortened by using pre-prepared dough for dough washing.

The appearance of the glutenin from the dough is fascinating and its texture an interesting talking point. Markedly different amounts of glutenin are obtained from different flours.

Students should not consume any dough prepared in a laboratory. Check whether any students have asthma or allergies to wheat or flour prior to the experiment and take care to prevent clouds of dust from dry flour.

Timings

This activity requires a few minutes to make the dough. There is then a rest period of up to an hour. Washing starch from the dough takes about 5 minutes.

To reduce the time required:

- Pre-prepared dough could be used for dough washing
- Pupils can make dough and come back after 30–60 minutes.

Process

1. Mix 250–300g of flour with 150–175ml of water and a teaspoon of salt in a food processor until a soft dough is formed
2. Wrap in cling film and record its weight
3. Rest the dough for 60 minutes
4. Wash over a sieve in several changes of clean water in a large bowl – squeeze the dough as you wash it until the water runs clear
5. Remove excess water with a final squeeze of the dough and reweigh the dough.

Prepared glutenin will keep for a few days in a refrigerator.

Practical Activity: Dough Washing

Table 1 - Typical amounts of glutenin obtained from different types of flour

Flour	Dough weight (g)	Washed weight (g)
Strong flour	410	100
Plain flour	410	90
Spelt flour	410	80
Alimonti 00 flour	450	80
Rice flour	420	0

Flour	Dough pre-washing	Glutenin post-washing
Strong bread-making flour		
00 flour		
Spelt flour		
Rye flour		Nothing left post-washing.

Practical Activity: Dough Washing

Maize flour		Nothing left post-washing.
Rice flour		Nothing left post-washing.

Picture 1 - Doughs made from different types of flour, and the remaining glutenin.

Practical Activity: Dough Rising and Baking

What you will need

- Timer
- Flour
- Salt
- Sugar
- Balance
- Measuring cylinders (100ml)
- Measuring jug
- Baking parchment
- Ruler
- Food processor
- Cling film
- Water
- Large bowl
- Yeast
- Microwavable plate
- Microwave

The amounts, and quality, of proteins in flour determine the extent to which dough will rise. This determines the crumb structure and density of the loaf baked from the dough.

Differences in the rising of dough from different flours can be quite marked and can be accentuated and recorded by 'proving' plugs of dough in measuring cylinders, or baking parchment cut into strips and formed into tubes.

Students should not consume any dough prepared in a laboratory. Check whether any students have asthma or allergies to wheat or flour prior to the experiment and take care to prevent clouds of dust from dry flour.

Timings

Dough can be made in a food processor in less than 5 minutes. Quick start yeast will raise dough (approximately doubling its size) in 30–60 minutes and dough can be 'baked' in a microwave in 5–8 minutes. (Place the dough on a microwavable plate not in a baking tin).

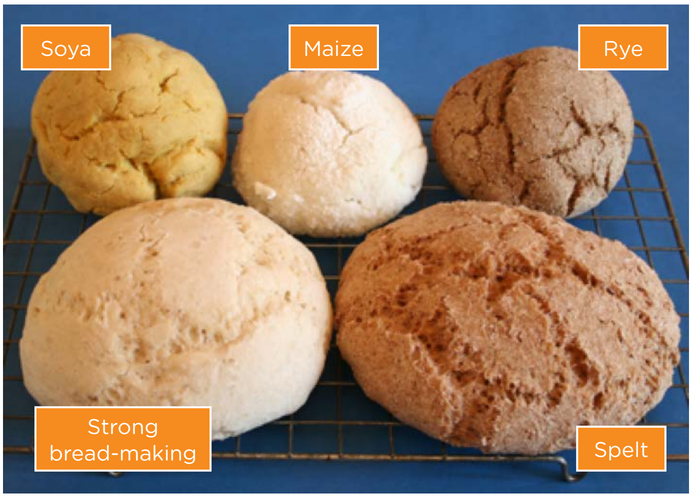
The complete process is rather long, but can theoretically be fitted into a 60-minute lesson or double lesson. Students can set up the experiment for subsequent lessons or classes and/or return to see how 'their' dough is progressing. Alternatively it can be set up as a pre-prepared demonstration with students taking guesses as to which flour produced which bread.

Practical Activity: Dough Rising and Baking

Process

1. Mix 250g flour, ½ teaspoon salt, ½ teaspoon sugar, ½ teaspoon of 'quick start' yeast and 150–160ml of water (at approx. 30°C) in a food processor, to make soft dough
2. Add more water if necessary
3. Place the dough in a 100ml measuring cylinder, or baking parchment formed into a tube
4. Record the height of the dough
5. Prove the dough in a warm place for 30–60 minutes. Dough from strong bread-making flour will double in size (approximately) in 60 minutes. This process is very temperature dependent. If you have a cold classroom consider rising dough in a warmer location, ideally at 25°C
6. 'Bake' the dough for 5–8 minutes in a microwave on a microwavable plate (6 minutes in a 650W microwave)
7. Record the height of the 'baked' dough.

Starting dough, risen dough, 'baked' loaves and loaf crumb structures, from different flours, are pictured below:



Picture 2 - Loaves baked from dough made with different flours. The same weights of flour and water were used and the dough was allowed to rise for the same period of time.

Picture 3 - Dough plugs. Plugs of similar starting weights, allowed to rise for the same period of time, in baking parchment tubes of similar diameter.

Practical Activity: Dough Rising and Baking

Teacher

Strong bread-making flour	Dough 	Risen dough 
	Baked loaf 	Crumb structure 
00 flour	Dough 	Risen dough 
	Baked loaf 	Crumb structure 

Practical Activity: Dough Rising and Baking

Spelt flour	**Dough** 	**Risen dough** 
	Baked loaf	**Crumb structure** 
Rye Flour	**Dough** 	**Risen dough** 
	Baked loaf 	**Crumb structure** 

Maize flour	Dough	Risen dough
		
	Baked loaf	Crumb structure
		
Soya Flour	Dough	Risen dough
		
	Baked loaf	Crumb structure
		

Practical Activity: Sedimentation Test for Protein Quality

What you will need

- Washing-up liquid
- Vinegar
- Water
- Variety of flours
- Tubes (preferably boiling tubes with stoppers, or screw-cap plastic tubes)
- Timer
- Balance
- Measuring cylinders (10ml and 50ml)

Optional

- Sodium dodecyl sulfate (SDS)
- Lactic acid

The sodium dodecyl sulfate (SDS) sedimentation test is used commercially to predict the bread-making quality of flours. Protein content as well as quality affects sedimentation rates. In simple tests both protein content and quality are measured.

The method depends on differences in glutenin swelling, viscosity and sedimentation rates when glutenins interact with water at acidic pH. Addition of the ionic detergent SDS increases the electrostatic repulsion, swelling and flocculation of electrically charged glutenins. Most sedimentation occurs within 5–10 minutes of mixing the reagents. The more sedimentation (flocculant) there is, the more protein there is in the flour and the better its bread-making quality.

Soya flour contains a lot of protein, but no glutenin. It produces a lot of flocculant in an SDS test, but does not make good bread.

In this practical you will carry out a simplified version of the test using washing-up liquid in place of SDS and vinegar in place of lactic acid. Soap and SDS are both ionic detergents (termed anionic as they have a negatively charged head). Lactic acid and acetic acid, the acid present in vinegar, are classified as weak acids. Despite this the two are quite different in their acidity – lactic acid has a lower pKa and deprotonates ten times more easily than acetic acid.

Students should wear suitable eye protection and avoid splashing vinegar or other acids on skin or in the eyes. Students with sensitive skins should take particular care handling vinegar or soap solutions.

If you are carrying out the practical with older students and want to compare the simplified version of the sedimentation test with the commercial test it is recommended that you use an SDS solution just <1%.

Timings

It requires about 5 minutes to set up 3 or 4 tubes of flour/water ready for the washing-up liquid and vinegar reagent. Flocculant begins to form almost immediately the reagent is added, but tubes need to stand undisturbed for 5–10 minutes for a proper comparison to be made.

In order to save time and ensure more reliable results make the washing-up liquid/vinegar solution in advance. More able pupils can be instructed how to make their own dilutions of the washing-up liquid and vinegar.

Practical Activity: Sedimentation Test for Protein Quality

Process

Simplified version of the sedimentation test using washing-up liquid and vinegar:

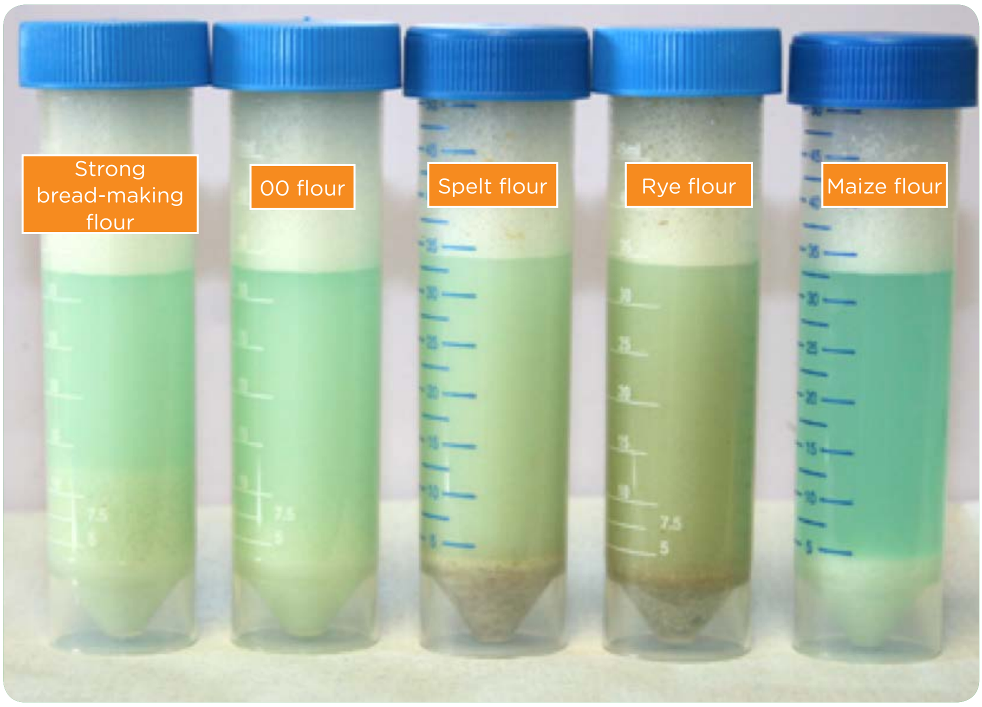
1. Add 8ml of water to 2g of flour in a tube with a secure stopper
2. Shake well for 10–20 seconds
3. Now dilute washing-up liquid (any cheap brand should work) 1:3 v/v with water e.g. 100ml washing-up liquid added to 300ml water
4. Acidify this with vinegar (distilled malt or white vinegar is 5–8% acidity – any brand should work) 1:25 v/v e.g. add 16ml of vinegar to 400ml of the diluted washing-up liquid
5. Shake all the tubes of flour/water again
6. Add 24ml of washing-up liquid/vinegar to each tube and shake
7. When all the tubes have been filled, shake them again
8. Stand tubes for 5–10 minutes and then check sedimentation levels (picture 5).

The following method is a crude version of the SDS/lactic acid commercial test that eliminates some of the mixing and resting steps of laboratory protocols.

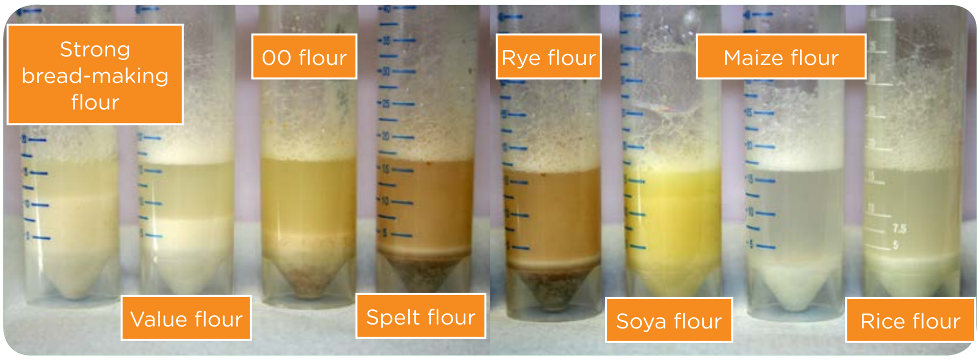
SDS/lactic acid should be prepared fresh each day. Lactic acid is supplied as a laboratory grade solution of 85% lactic acid. This stock solution of lactic acid should be diluted in water 1:8 v/v e.g. 3 ml lactic acid and 24ml water. An aqueous solution of just <1% w/v SDS should be made e.g. 10g SDS added to 1 litre of water. The diluted lactic acid should be added to the SDS solution in a 1:50 v/v ratio e.g. 20ml diluted lactic acid added to 1 litre of SDS solution.

1. Place 1g of flour in a tube (preferably a boiling tube or if possible a 50ml plastic tube with a screw cap)
2. Add 4 ml of water, secure stopper and mix by shaking vigorously for 10–20 seconds
3. Allow to rest while preparing the other sample tubes
4. Shake all the tubes again
5. Add 12ml of SDS/lactic acid solution to each tube of flour/water
6. Shake for 10–20 seconds
7. Allow to rest for 2 minutes
8. Shake for 10–20 seconds
9. Allow the tube contents to settle and then examine the rate and amount of flocculant. 5–10 minutes will be enough for most flocculant to settle (picture 6).

Practical Activity: Sedimentation Test for Protein Quality



Picture 5 - Sedimentation test results using washing-up liquid/ vinegar.



Picture 6 - Sedimentation test results – using SDS/lactic acid.

Plenary

Recap the properties of flour and ask students to share the results of their experiments.

Remind students of the key developments in the evolution and breeding of wheat and discuss the pros and cons of repeated inbreeding. You may want to discuss the potential approaches that could be used in the future to improve wheat crops.

Key Stage 3 Biology

Structure and function of living organisms

Nutrition and digestion

- Content of a healthy human diet: carbohydrates, lipids (fats and oils), proteins, vitamins, minerals, dietary fibre and water, and why each is needed
- The consequences of imbalances in the diet, including obesity, starvation and deficiency diseases
- Plants making carbohydrates in their leaves by photosynthesis and gaining mineral nutrients and water from the soil via their roots.

Material cycles and energy

Photosynthesis

- The dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere

Interactions and interdependencies

Relationships in an ecosystem

- The importance of plant reproduction through insect pollination in human food security

Genetics and evolution

Inheritance, chromosomes, DNA and genes

- Heredity as the process by which genetic information is transmitted from one generation to the next
- A simple model of chromosomes, genes and DNA in heredity, including the part played by Watson, Crick, Wilkins and Franklin in the development of the DNA model
- The importance of maintaining biodiversity and the use of gene banks to preserve hereditary material.

Key Stage 4 Science

How science works

1. Data, evidence, theories and explanations

Pupils should be taught:

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

d) that there are some questions that science cannot currently answer, and some that science cannot address

2. Practical and enquiry skills

Pupils should be taught to:

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

b) work accurately and safely, individually and with others, when collecting first-hand data

3. Communication skills

Pupils should be taught to:

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

b) use both qualitative and quantitative approaches

4. Applications and implications of science

Pupils should be taught:

a) about the use of contemporary scientific and technological developments and their benefits, drawbacks and risks

b) to consider how and why decisions about science and technology are made, including those that raise ethical issues, and about the social, economic and environmental effects of such decisions

c) how uncertainties in scientific knowledge and scientific ideas change over time and about the role of the scientific community in validating these changes

5. Organisms of health

In their study of science, the following should be covered:

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

Key Stage 4 Science

6. Chemical and material behaviour

In their study of science, the following should be covered:

a) new materials are made from natural resources by chemical reactions

b) the properties of a material determine its uses.

Research Links

Wheat defence against Septoria:two genes in the front line [Reference/webpage no longer available – January 2017]

On your Marks, Get Set, Thresh!

Duration

10 minutes

What you will need

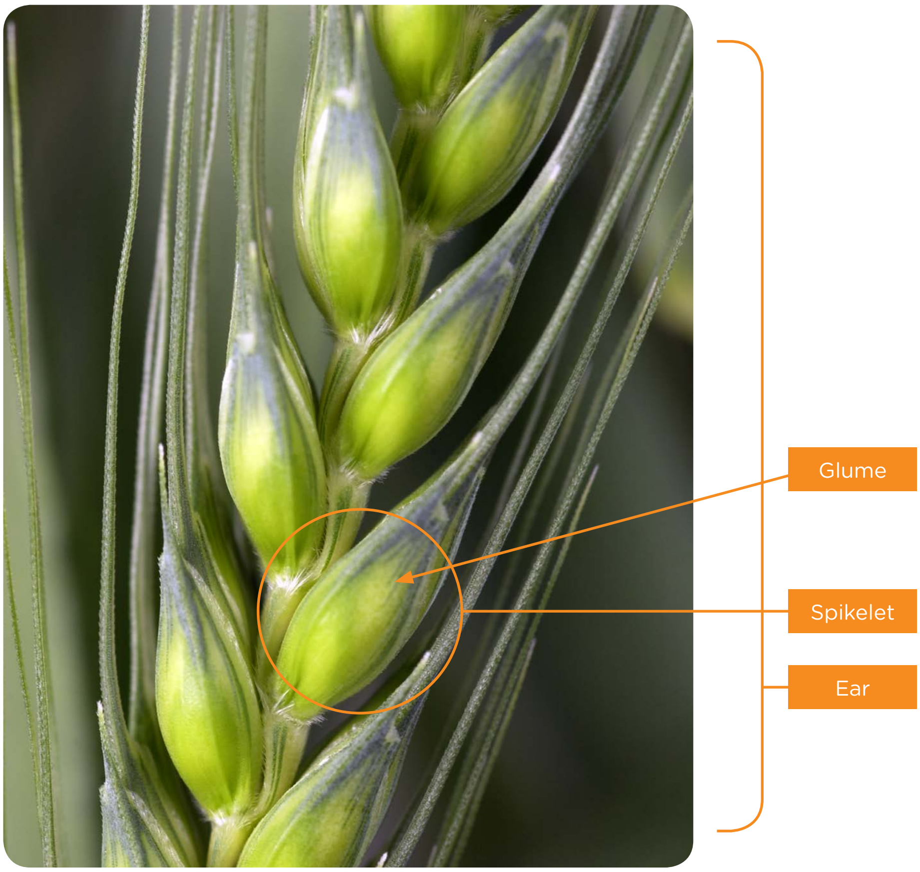
- Ears of wheat
- Ears of wild goatgrass
- Timer

The ears of a domesticated wheat plant are dramatically different to those of their wild relatives.

What is the difference between the structure of wild and domesticated wheat?

How does this affect the threshing time?

- The wild relative has evolved thick outer glumes to protect the small grains from predation and early germination
- Domestication has bred out the thick glumes and selected for much larger grains.



Wheat ear

On your Marks, Get Set, Thresh!

What you should do

1. Form into groups of four
2. Time one person to extract a single grain from an ear of a modern free threshing wheat
3. Record the time
4. Separate the individual spikelets from the stem of each ear of wild goat grass
5. Now time one person to extract a single grain from a wild goatgrass
6. Record the time
7. The other members of your group should now repeat the experiment with the wild goatgrass
8. Record the time
9. Clear up the threshed grains and remaining wheat and place in the bin
10. Wash your hands
11. Think about your answers to the following questions

Discussion questions

1. Which was harder to extract and why?
2. How would you describe the differences in the size and shape of the grains?
3. How could you speed this up to extract the grain from a field of wheat?
4. How do you think hunter-gatherers began the process of selection and domestication of wheat?
5. What were the extra efforts and rewards of farming versus foraging?
6. What makes one wheat good for growing on a farm and the other good for growing in the wild?

Dough Washing

Student

What you will need

- Flour
- Salt
- Water OR pre-prepared dough
- Measuring cylinder (250 ml) or measuring jug
- Cling film
- Access to a balance
- Sieve
- Large bowl
- Timer

Dough washing removes the starch and water-soluble materials from the dough, leaving (mainly) glutenin.

You will notice the appearance of glutenin from the dough. How would you describe the texture?

Do not consume any dough prepared in a laboratory. Inform the teacher or responsible adult if you have asthma or allergies to wheat or flour before starting and take care not to create clouds of dust from dry flour.

How long you have

This activity requires a few minutes to make dough and then up to an hour for the dough to ‘rest’. Alternatively you may be provided with pre-prepared dough. Washing starch from the dough takes about 5 minutes.

What you should do

If you have flour:

1. Mix 250–300g of flour with 150–175ml of water and a teaspoon of salt until a soft dough is formed
2. Wrap in cling film and record its weight
3. Rest the dough for 60 minutes then continue on to step 4

If you have ready-made flour:

4. Record its weight
5. Wash over a sieve in several changes of clean water in a large bowl – squeeze the dough as you wash it until the water runs clear
6. Remove excess water with a final squeeze of the dough and reweigh the dough

Prepared glutenin will keep for a few days in a refrigerator.

Dough Washing

Table 1 - Typical amounts of glutenin obtained from different types of flour

Flour	Dough weight (g)	Washed weight (g)
Strong flour	410	100
Plain flour	410	90
Spelt flour	410	80
Alimonti 00 flour	450	80
Rice flour	420	0

Dough Rising and Baking

Student

Summary

What you will need

- Timer
- Flour
- Salt
- Sugar
- Access to a balance
- Measuring cylinders (100 ml)
- Measuring jug
- Baking parchment
- Ruler
- Cling film
- Water
- Large bowl
- Yeast
- Microwavable plate
- Microwave

The amounts, and quality, of proteins in flour determine the extent to which dough will rise. This determines the crumb structure and density of the loaf baked from the dough.

Differences in the rising of dough from different flours can be quite marked and can be accentuated and recorded by ‘proving’ plugs of dough in measuring cylinders, or baking parchment cut into strips and formed into tubes.

Do not consume any dough prepared in a laboratory. Inform the teacher or responsible adult if you have asthma or allergies to wheat or flour before starting and take care not to create clouds of dust from dry flour.

Timings

Dough can be made in 5–10 minutes.

Quick start yeast will raise dough (approximately doubling its size) in 30–60 minutes.
Dough from strong bread-making flour will double in size (approximately) in 60 minutes.

Dough can be ‘baked’ in a microwave in 5–8 minutes.

Process

1. Mix 250g flour, ½ teaspoon salt, ½ teaspoon sugar, ½ teaspoon of 'quick start' yeast and 150–160ml of water (at approx. 30°C) in a food processor, to make soft dough
2. Add more water if necessary
3. Place the dough in a 100ml measuring cylinder, or baking parchment formed into a tube
4. Record the height of the dough
5. Prove the dough in a warm place for 30–60 minutes. This process is very temperature dependent and you should keep the dough warm, ideally at 25°C
6. 'Bake' the dough for 5–8 minutes in a microwave on a microwavable plate (6 minutes in a 650W microwave)
7. Record the height of the 'baked' dough.

The microwave allows the dough to be cooked quickly. Dough is not normally baked in a microwave and this method will not give the bread a crispy crust.

Sedimentation Test for Protein Quality

Student

What you will need

- Safety glasses
- Washing-up liquid/ vinegar solution
- Tubes (preferably boiling tubes with stoppers, or screw-cap plastic tubes)
- Variety of flours
- Timer
- Access to a balance
- Water
- Measuring cylinders (10ml and 50ml)

A sedimentation test is used commercially to predict the bread-making quality of flours. Protein content as well as quality affects sedimentation rates. In simple tests both protein content and quality are measured.

The method depends on differences in glutenin swelling, viscosity and sedimentation rates when glutenins interact with water at acid pH. Addition of the ionic detergent SDS increases the electrostatic repulsion, swelling and flocculation of electrically charged glutenins.

The more sedimentation (flocculant) there is, the more protein there is in the flour and the better its bread-making quality.

Soya flour contains a lot of protein, but no glutenin. It produces a lot of flocculant in an SDS test, but does not make good bread.

In this practical you will carry out a simplified version of the test using washing-up liquid or soap flakes in place of SDS and vinegar in place of lactic acid.

Wear safety glasses or goggles. Take care with vinegar or any other acids and wash off immediately if you get them on skin or in the eyes. Thoroughly wash your hands after the activity.

Timings

It requires about 5 minutes to set up 3 or 4 tubes of flour/water ready for the washing-up liquid and vinegar reagent.

Flocculant begins to form as sediment almost immediately the reagent is added, but tubes need to stand undisturbed for 5–10 minutes for a proper comparison to be made.

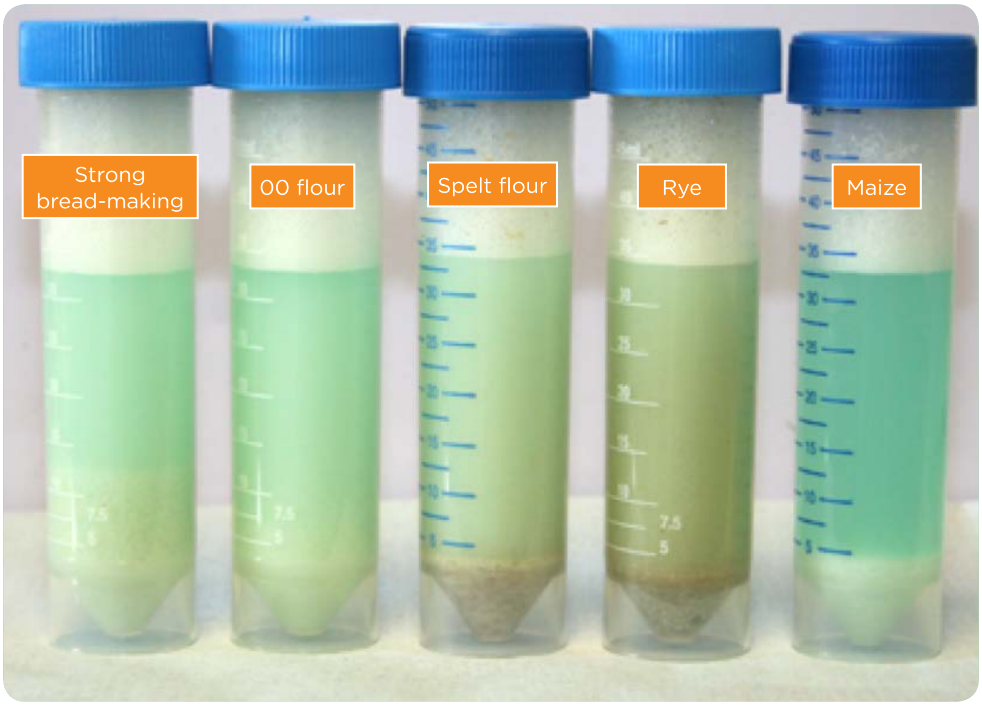
Sedimentation Test for Protein Quality

What you should do

This is a simplified version of the commercial method using washing-up liquid and vinegar:

1. Place 2g of flour in a tube (preferably a boiling tube or if possible a 50ml plastic tube with a screw cap)
2. Add 8ml of water
3. Mix by shaking vigorously for 10–20 seconds
4. Add 24ml of washing-up liquid/vinegar solution to each tube and shake
5. When all the tubes have been filled, shake them again for 10–20 seconds
6. Stand tubes for 5–10 minutes and then check sedimentation levels

The results of a sedimentation test can be seen in the picture below. The strong bread-making flour has a lot of sediment (flocculant) indicating it has a lot of protein and would make good bread.



Sedimentation test results using washing-up liquid/vinegar.

Quiz

Student

The wheat quiz can be carried out in class using the background information sheet 'All about wheat'.

1. Who were the first people to make bread using yeast?
2. How far back can we trace wheat?
3. What is the Norfolk four-course?
4. Who invented the mechanical seed drill?
5. Where is the national small grain cereals collection?
6. What is gluten?
7. Which vitamin is found in wheatgerm?
8. How many grains are there in 100 kilos of wheat?
9. Which country produces the most wheat?
10. What is durum wheat used for?

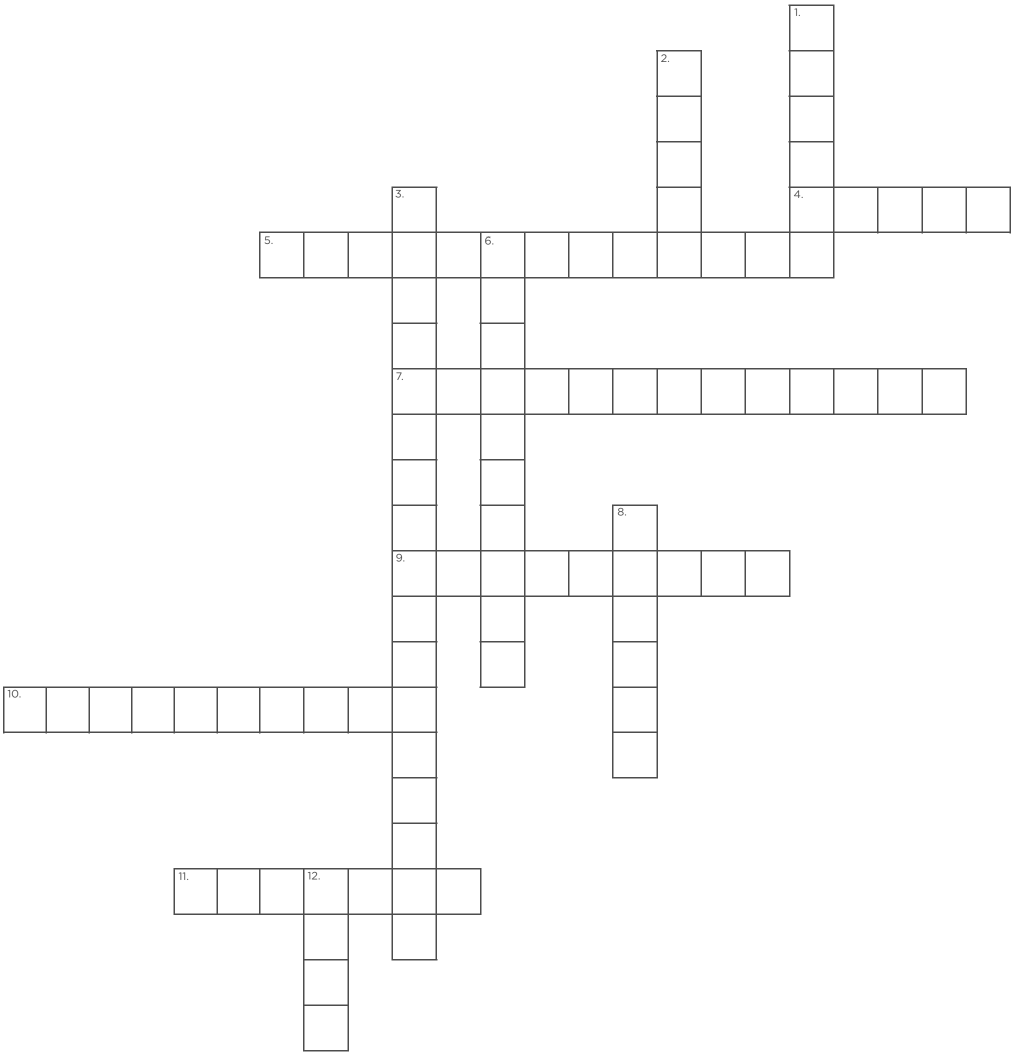
Quiz Answers

The wheat quiz can be carried out in class using the background information sheet ‘All about wheat’.

1. Who were the first people to make bread using yeast? **Egyptians**
2. How far back can we trace wheat? **10,000 years**
3. What is the Norfolk four-course? **A crop rotation method**
4. Who invented the mechanical seed drill? **Jethro Tull**
5. Where is the national small grain cereals collection? **John Innes Centre**
6. What is gluten? **Protein**
7. Which vitamin is found in wheatgerm? **Vitamin E**
8. How many grains are there in 100 kilos of wheat? **2,000,000**
9. Which country produces the most wheat? **China**
10. What is durum wheat used for? **Pasta**

Crossword

Student



Down

1. Made up of gliadin and glutenin
2. Carries out fermentation making bread rise
3. Breeding animals and plants for particular traits
6. Four sets of chromosomes
8. The main carbohydrate in flour
12. Wild type of grass

Across

4. Ancestor of bread wheat
5. The adaptation of an organism to be of use to humans
7. Gas produced in fermentation
9. The change in genetic composition of a population over successive generations
10. To make something form into clumps
11. The term for wheat that falls over before being harvested

Wordsearch

Student

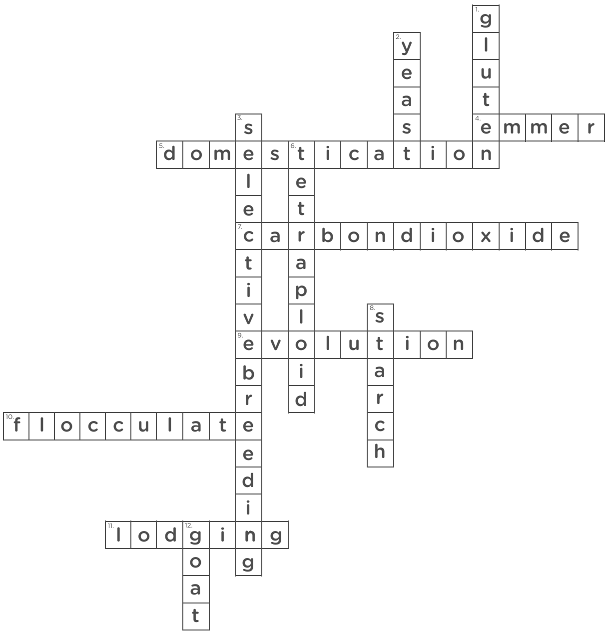
C	F	I	N	I	F	Y	O	D	Z	D	L	P	G	Y	Z	E	D	W	H	M
J	Y	F	I	G	R	W	E	X	O	E	B	S	V	F	Q	K	A	E	F	O
Q	Q	C	D	T	H	B	D	A	N	M	R	G	U	F	P	Z	T	W	M	F
H	E	A	A	E	C	C	K	R	S	E	E	P	R	A	L	A	G	M	G	S
U	F	R	I	L	Q	A	E	Q	M	T	D	S	N	A	L	O	Q	J	E	K
E	C	B	L	E	J	K	R	Y	T	A	X	O	T	U	I	S	U	L	R	D
Y	E	O	G	K	H	Q	L	B	A	E	I	V	C	I	L	N	E	R	J	Y
C	A	H	Z	I	N	O	U	T	O	T	T	C	E	U	C	C	K	Q	E	I
T	R	Y	R	P	P	K	S	W	U	N	O	R	A	K	T	A	Q	N	E	E
S	F	D	Z	S	R	A	R	L	G	L	D	W	A	I	L	B	T	L	O	L
T	C	R	R	P	P	K	O	D	F	W	N	I	V	P	S	S	R	I	F	D
A	P	A	C	A	G	V	R	U	X	W	N	E	O	K	L	W	Z	E	O	Q
R	L	T	H	M	E	E	N	Q	H	U	B	P	C	X	B	O	Y	G	A	N
C	N	E	R	W	M	F	N	E	P	R	R	Q	G	G	I	M	I	I	K	D
H	L	S	O	D	E	M	A	E	E	O	C	V	L	K	N	D	E	D	E	D
C	M	P	M	S	D	T	A	E	T	D	H	S	U	E	A	I	E	G	R	S
F	T	M	O	Z	T	W	D	E	S	I	E	O	T	J	M	W	G	L	D	B
K	J	F	S	S	X	I	I	A	H	N	C	R	E	L	O	M	H	D	F	J
P	Q	T	O	F	N	N	K	E	E	I	K	S	N	N	T	Y	E	S	O	B
Q	Y	F	M	G	K	C	X	G	W	Q	T	B	I	I	V	M	Z	R	P	L
R	U	H	E	O	D	R	I	T	E	W	D	L	N	E	T	U	L	G	J	J

Awn
Bread
Carbohydrates
Carbon dioxide
Chromosome
Domestication
Ear
Emmer
Evolution
Flocculate
Flour
Genetics
Genes
Gliadin
Gluten
Glutenin
Grain
Kernel
Lodging
Pasta
Polymers
Protein
Selective breeding
Spikelet
Starch
Tetraploid
Wheat
Yeast
Yield

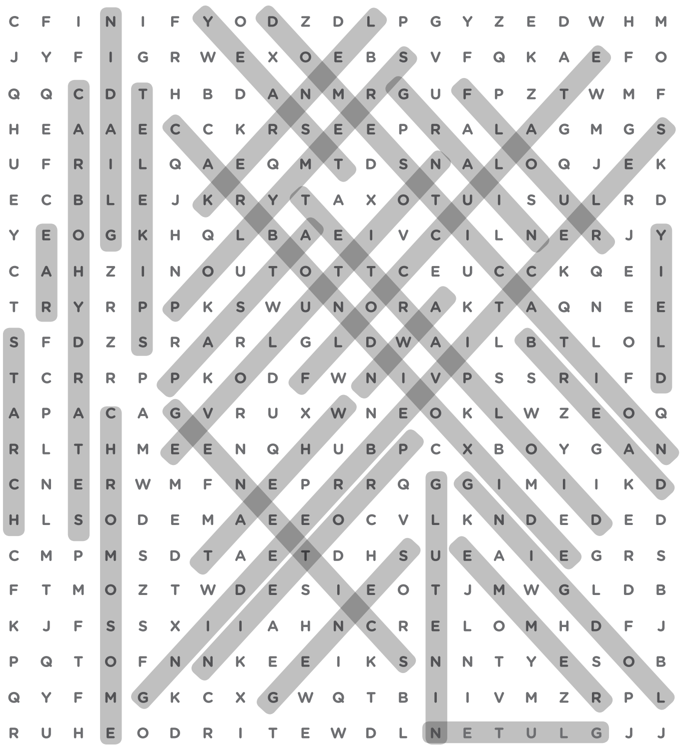
Answers

Teacher

Crossword | page 47



Wordsearch | page 48



Glossary

Awn
A hair - or bristle-like appendage on a wheat spikelet (awned wheats were also termed bearded wheats).

Carbohydrate
An essential food group found in our diet (includes sugar, starch and fibre).

Carbon dioxide
A gas produced by cell respiration and fermentation. Used by plants for photosynthesis.

Chromosome
A structure within the cell that bears the genetic material as a thread-like linear strand of DNA bonded to various proteins in the nucleus of eukaryotic cells, or as a circular strand of DNA (or RNA in some viruses) in the cytoplasm of prokaryotes and in the mitochondrion and chloroplast of certain eukaryotes.

Domestication
To tame or reclaim from a wild state; as, to domesticate a plant.

Ear
Also known as the spike. This is the part of the wheat plant that holds the kernels of grain. The ear is the flower of the wheat plant.

Emmer
One of the first cultivated wheat species and the ancestor of bread wheat. Emmer is a natural hybrid between T. urartu and an unidentified goatgrass.

Evolution
The change in genetic composition of a population over successive generations, which may be caused by natural selection, inbreeding, hybridisation, or mutation.

Flocculate
Form or cause to form into small clumps or masses.

Genes
Part of a chromosome. One gene contains the ‘instructions’ for a particular characteristic such as flower colour. The fundamental, physical, and functional unit of heredity.

Genetics
The study of the patterns of inheritance of specific traits. Also known as heredity.

Gliadin
A monomeric protein which is present in wheat flour. It is a component of gluten.

Glume
Also known as husks. This is the hard outer covering that protects the wheat grains.

Gluten
The protein of wheat and other grains which gives the dough its tough elastic character.

Glossary

Glutenin
The main protein in wheat flour (also called glutelin). It is polymeric.

Grain
The seed of the wheat plant that comprises the embryo, the endosperm – a nutritional energy store primarily in the form of starch – and the bran.

Husk
See Glume.

Lodging
The term used to describe the falling over of wheat stalks prior to harvesting.

Polymers
A compound made up of several repeating units (monomers) linked by chemical bonds.

Protein
A molecule composed of polymers of amino acids joined together by peptide bonds.

Selective breeding
The intentional breeding of organisms with a desirable trait or traits, in an attempt to produce offspring with similar desirable characteristics or with improved traits.

Spike
See ear.

Spikelet
The individual units of the ear, comprising the kernels of grain and outer glumes and, in some varieties of wheat, an awn.

Starch
A polysaccharide carbohydrate consisting of a large number of glucose monosaccharide units joined together by glycosidic bonds.

Tetraploid
Organisms that possess four times more chromosomes than a haploid cell.

Yeast
Colloquial name for the fungus that is characteristically single-celled most of its life – eukaryotic, reproduces asexually by budding or binary fission, and capable of fermenting carbohydrates.

Yield
A measure of the amount of grain produced.

Wheat Breeding and Evolution

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