Chocolate

At a glance

	Content summary	National Curriculum links	Activities
Lesson 1	The properties and chemistry of chocolate Why do we enjoy chocolate?	Particle theory; pure / impure substances; working scientifically to investigate an unknown, making and recording observations; interpreting data	**Activity A:** Chocolate detectives - What is chocolate? **Activity B:** Chocolate detectives – investigating chocolate
Lesson 2	How is chocolate produced? The history of chocolate and buying 'Fairtrade'	Working scientifically; understanding the implications of science in society and how our choices impact others	**Activity C:** Chocolate detectives – where does chocolate come from?

Background, National Curriculum links

These activities are intended for one or two lessons for Year 7-9 students about chocolate. The students are 'chocolate detectives' investigating the properties and chemistry of chocolate, developing understanding of what chocolate is and where it comes from. There is an opportunity to discuss why chocolate is enjoyed in multiple forms. The second lesson examines how the chocolate we enjoy is produced and the meaning of 'Fairtrade'.

Lesson 1

In lesson 1 students use labels on chocolate bars to gain understanding of the ingredients that make up chocolate. They compare different types of chocolate. They measure the melting points of control and 'test' samples (melted and re-set) to investigate the molecules present in chocolate.

National Curriculum

- Reinforcement of particle theory of matter;
- Understanding of the properties of a mixture; notion of a 'pure' substance;
- Using a technique to determine melting point; collecting data; presenting data graphically;
- Drawing conclusions from experimental evidence.

Lesson 2

In lesson 2 students consider the impact of the chocolate industry in society, and where cocoa comes from. They calculate the price per gram of the chocolate in various chocolate bars. They discuss if this could be 'fair' for the cocoa farmer. They learn about Fairtrade.

National Curriculum

- Chocolate provides an engaging context to maximise pupils' engagement and motivation for science.
- Students can connect the chocolate they eat to scientific processes involved in manufacture and the societal impacts these have.

Teacher subject knowledge

The lessons can be taught by science teachers of any subject background.

Cross-curricular links: a brief history of chocolate

Chocolate is one of our favourite foods. In 2021, the value of the chocolate confectionery industry to the UK economy is estimated to be worth £1.15 billion. This large industry developed in Europe from the sixteenth century, using cocoa imported from the American continent. The cocoa plant was grown in Central and South Americas for centuries before chocolate was ever known in Europe or Asia. Local people such as the Aztecs prepared cocoa as a drink, flavouring it with chilli, maize (corn) and fruit. In 1516 the Spanish explorer Hernan Cortes reached the American continent. There he tasted a dark, bitter drink, finding it tasted better when sweetened. Cortes brought cocoa beans back to Europe, sparking a craze in chocolate, which was for a time more expensive than coffee or tea. The history of chocolate can be investigated by inviting students to prepare a 'chocolate timeline' showing key dates. The multiple ways that chocolate is used and prepared can also be discussed. Discussing the principles of 'Fairtrade' in relation to chocolate will help students understand the origins and social responsibilities associated with this highly processed, delicious and popular product.

Student background knowledge

The vast majority of students will have eaten and drunk chocolate in one or more forms. Find out what they know.

Resources and timing

Two 50 or 60 minute lessons are required.

Technical requirements

Lesson 1

Activity A: Chocolate detectives: What is chocolate?

To share amongst the students:

- Chocolate packaging with ingredients labels – students can bring in their own items. These can be kept for Activity C. Students can bring their favourite chocolates – not just bar chocolate.
- Samples of different types of bar (unfilled) chocolate, e.g. dark, milk, white; with varying percentages of cocoa solids
- A table of possible results is provided. A blank table is provided in 'Activities' below. The Twix bar is 35% milk chocolate, but the amount of cocoa solids in the chocolate is not stated. Students may see glucose syrup in the ingredients, but this is most likely to be in the caramel layer in the bar.

Type of chocolate	% Cocoa solids	Ranking in ingredients list			
		Cocoa butter	Cocoa mass	Sugar	Milk/milk powder/milk fat
Twix	Not stated	6	7	1	Powder 5 Fat 8
White	0	3	0	1	Powder 2
Milk	33	2	4	1	Powder 3 Fat 5
Dark	54	3	2	1	None
Extra dark	72	0	1	2	None

Activity B: Chocolate detectives – investigating the structure of chocolate

The experiment is based on:
http://www.rsc.org/learn-chemistry/resource/res00000688/chocolate-and-structure-experiment?cmpid=CMP00004977.

Each pair or group of students will need:

- Two boiling tubes
- 250 cm^3 beaker
- Thermometer (0 - 100˚C)
- Timer
- Access to kettle – for boiling water

Each pair or group of students will need samples of chocolate:

- 'Control' milk chocolate, 1 square per student to taste and 1 square per pair or group, sized to fit into the boiling tube.
- 'Test' milk chocolate melted and re-hardened (same chocolate as above), 1 square per student to taste and 1 square per pair or group.

The simplest way to prepare the 'test' sample is to place a wrapped chocolate bar in a warm place, such as on a radiator. As soon as the chocolate has melted, place it in a refrigerator (not one used to store chemicals) to re-harden. Remove the chocolate once it has reset. Use at room temperature in the lesson.

Table 1 gives information about different forms of chocolate. If possible, to extend the activity student groups could be given test samples of chocolate that are prepared (melted and reset) according to the conditions listed in Table 1; or different brands of chocolate that have been melted and reset in the same way.

Table 1 figures are averages. Melting point graphs are unlikely to give clear melting points. This will help students realise that substances can melt over a temperature range.

Table 1: Forms of chocolate and conditions for preparing them.

Cocoa butter polymorph form	Conditions for making each polymorph	Melting point °C
I	Rapidly cooling molten chocolate	17.3
II	Cooling the molten chocolate at 2°C	23.3
III	Solidifying the molten chocolate at 5-10°C (or storing 'Form II' at 5-10°C)	25.5
IV	Solidifying the molten chocolate at 16-21°C (or storing 'Form III at 16-21°C)	27.3
V	Solidifying the molten chocolate whilst stirring Needs a special process called 'tempering'	33.8
VI	Storing 'Form V' at room temperature for four months	36.3

Lesson 2

Activity C: Chocolate detectives – where does chocolate come from?

Students will require access to:

- The chocolate bar wrappers from Activity A.
- The 12-minute video 'The Story of Chocolate' available from: Cocoa farmers - Fairtrade Foundation (scroll down to the video, which is also on YouTube).
- The Universal Declaration of Human Rights, available in pdf format at: eng.pdf (ohchr.org).
- The Fairtrade Foundation: Home - Fairtrade Foundation.
- The London Commodities Market data available at: Latest commodity and futures prices - FT.com – enter 'Cocoa' in the browse box.

Activities

Lesson 1

Activity A: What is chocolate?

Compare the type of chocolate and ingredients lists of different chocolate confectionery items using the information on the wrappers. The packaging lists ingredients in order from highest to lowest percentage mass, but does not give figures. The only ingredient that may have a figure is 'cocoa solids'. The ingredients to look for are:

- cocoa solids, cocoa butter, cocoa mass – these are obtained from cocoa beans and form the basis of the chocolate;
- sugar – added to sweeten the cocoa;
- milk/skimmed milk powder/milk fat – to lighten the colour and sweeten the flavour.

Complete the table using information from chocolate bar wrappers. An example is provided in the table. Compare different types of chocolate.

Type of chocolate	% Cocoa solids	Ranking in ingredients list			
		Cocoa butter	Cocoa mass	Sugar	Milk/milk powder/milk fat
Milk 	33	2	4	1	Powder 3 Fat 5
Dark 					
White 					

1. What is chocolate made from? What do you notice about the chocolates listed in the table? Is this surprising?
    - Sugar is the highest ranked ingredient in most chocolate, especially milk and filled bars.
    - All chocolate contains cocoa butter and sugar.
    - Cocoa butter / solids / mass is usually low ranked in milk chocolate.
    - Cocoa solids is higher than sugar in dark and extra dark chocolate only.
    - Students may be surprised that chocolate doesn't contain much cocoa; 'milk' chocolate contains powdered not liquid milk; sugar is highest ranked ingredient in most bars.

2. Which ingredients give chocolate its dark colour?
    - Cocoa mass and cocoa solids – white chocolate does not contain either of these.

3. Which type of chocolate is healthiest to eat?
    - Extra dark chocolate is healthiest – this contains most cocoa mass, less sugar and no fat from milk.
    - Dark chocolate is high in a chemical called theobromine, which has health benefits (see Extension).
    - Chocolate contains a small amount of caffeine (see Extension).

4. Is chocolate a natural food? How do you know?
    - Chocolate is not a natural food, but is a heavily processed food.
    - Cocoa is a natural food. Chocolate is cocoa mixed with other ingredients.
    - Cocoa solids are a mixture of about 400 different substances.

5. Why do we enjoy eating these chocolate bars?
    - We like the sugar, the way chocolate melts, and the flavour of the cocoa.
    - Some people prefer plain or dark chocolate, which contains less sugar and a higher percentage of cocoa solids.
    - Aztecs enjoyed chocolate with chilli, which has a very warming taste. It is possible to buy chilli-flavoured chocolate.

Activity B: Chocolate detectives: Investigating the chemical structure of chocolate

This activity involves tasting and then measuring the melting point of 'control' and 'test' samples of chocolate to investigate their structure.

Chocolate terminology

- Percentage of cocoa solids – this gives chocolate dark or light qualities and affects its taste. Dark chocolate contains around 35%, Milk about 25% and White 0%.
- Cocoa butter – is the most important ingredient in chocolate. It is a fat. Molecules of cocoa butter form crystals. The crystals can be different sizes and shapes.
- Snap – how the chocolate snaps relies on the texture and glossiness of chocolate. These depend on how the ingredients are prepared and mixed, as well as their proportions.

- Conching – chocolate is a complex mixture of substances. Conching means removing the most volatile (lowest boiling point) compounds and controlling for moisture content and viscosity, which determines how liquid/solid the bar is.
- Tempering – carefully melting, stirring and cooling a chocolate mixture. If this is not done correctly, the chocolate will be crumbly, brittle and change taste.
- Polymorphic - Cocoa butter is 'polymorphic', which means it can form many shapes. The polymorphs are known as 'forms' of chocolate. The forms have varied chemical properties and affect the structure and eating quality of chocolate. Table 1 gives information about forms of chocolate and their melting points.

Table 1: Forms of chocolate and conditions for preparing them.

Cocoa butter polymorph form	Conditions for making each polymorph	Melting point °C
I	Rapidly cooling molten chocolate	17.3
II	Cooling the molten chocolate at 2°C	23.3
III	Solidifying the molten chocolate at 5-10°C (or storing 'Form II' at 5-10°C)	25.5
IV	Solidifying the molten chocolate at 16-21°C (or storing 'Form III at 16-21°C)	27.3
V	Solidifying the molten chocolate whilst stirring Needs a special process called 'tempering'	33.8
VI	Storing 'Form V' at room temperature for four months	36.3

Investigating the chemical structure of chocolate

This is genuine research as the structure of chocolate is variable, so outcomes are unknown. Take careful notes at each stage and draw conclusions from evidence.

Outside a science laboratory

Snap and then eat a square of 'control' milk chocolate and, separately, a 'test' square of melted and reset milk chocolate of the same brand. Make notes about:

- The snap of both squares, noting any differences between them.
- Any differences in texture, mouth feel (graininess) and taste.

In a science laboratory

- Put about 125 cm^3 hot water at about 50˚C in the beaker.
- Place a few small pieces of chocolate in a boiling tube. There should be enough to cover the bulb of a thermometer.

- Place the boiling tube in the beaker.
- Start the timer.
- Stir the chocolate continuously with the thermometer.
- Take temperature recordings every 30 seconds until the chocolate has completely melted. This should take about 5 minutes.
- Repeat the steps above with chocolate that has been melted and reset.
- Plot the melting point data of both chocolates on the same axes (x – time, y – temperature).
- Use the graphs to determine the melting points of each sample.

Questions to discuss

What happened when the chocolate was eaten?

- Chocolate melts on the tongue, creating a cooling sensation. This is because melting is endothermic (heat is absorbed from the environment). The melting of chocolate is usually regarded as pleasant.
- The melted and reset chocolate may taste bitter and be more crumbly than the 'pure' chocolate.

What do you notice about the melting points of the two samples of chocolate?

- Most forms of chocolate melt at about 25 – 30°C, which is similar to mouth temperature.
- The melting points spread over a range of temperatures.
- The 'test' chocolate may have a lower melting point than the control sample.

Why do the test and control samples have different melting points? Use Table 1 and the snap test to decide which forms of chocolate are present in the two samples.

- The outcome will depend on the chocolate used in the test.
- The most desirable form of cocoa butter is 'form V'. This form is associated with the best eating qualities.
- A sharp snap indicates presence of form V.

How was the melted and reset sample prepared?

- This may be possible to determine from the information in the table, the melting point data and the snap test.

Extensions

Arrange a visit to a chocolate factory to find out how chocolate is prepared.

The book '*The Science of Chocolate*' provides detail on chocolate chemistry that could be used to extend this activity. Chapters, which can be purchased separately, include: the History of Chocolate, Ingredients, Cocoa bean processing and Experiments with chocolate and chocolate products. The Science of Chocolate (RSC Publishing) Stephen Beckett

The health benefits chocolate are discussed in this article. Note that detailed chemical terminology is used. The Chemistry of Chocolate (reagent.co.uk)

Lesson 2

Activity C: Chocolate detectives: Where does our chocolate come from?

This activity investigates the origins of the chocolate in our favourite bars.
Also, watch the video 'The Story of Chocolate: Unwrapping the Bar' available on YouTube and at: http://www.fairtrade.org.uk/en/farmers-and-workers/cocoa

Questions to answer from the video

- Where does cocoa come from?
- How much does a cocoa farmer in the Ivory Coast earn each day?
- In what ways does Fairtrade help cocoa farmers?
- How much cocoa trades on a Fairtrade basis?
- What sum of money would pay one cocoa farmer to have a reasonable standard of living for a year?
- How can Fairtrade help achieve this figure?
- What contribution can students make?

Thinking about a favourite bar of chocolate…

- How much does it cost? Calculate the cost per gram.
- Check the wrapper to see if the cocoa in the chocolate is 'Fairtrade'.
- Compare the prices per gram of different chocolate bars – is Fairtrade chocolate more expensive?
- Would you change to buying only Fairtrade chocolate? Why / why not?

How can we help cocoa farmers get a fair price for their cocoa?

- Examine the Universal Declaration of Human Rights Article 23 – available at: eng.pdf (ohchr.org). Discuss how buying chocolate could make a difference to people's life quality.

What could be done in school to promote Fairtrade?

The website http://www.fairtrade.org.uk has resource material available to develop further ideas. Examples (if these are not already done in school) include:

- A Fairtrade breaktime, focusing on healthy and Fairtrade food and drink for breaktimes.
- Run a school assembly focusing on Fairtrade.
- Organise a School Fairtrade Fortnight.

Extensions

Further information about the process of making chocolate is available at: Step-By-Step Guide to How Chocolate Is Made (thespruceeats.com)

Investigate the trading price of cocoa. This can be done via the London Commodities Market at: Latest commodity and futures prices - FT.com – enter 'Cocoa' in the browse box. Cocoa is traded daily. Data are available showing spot and trend prices in US dollars per metric tonne.

Use the cocoa spot price to calculate the value of the cocoa in a typical chocolate bar. Compare this with the cost of the bar. Is this is reasonable? How much of the price of the bar might be paid to the cocoa farmer?

Visit a chocolate factory - ask questions about the types of chocolate, where thery come from, the price paid for cocoa and if the trade is 'fair'.

Consider the history of chocolate (see curriculum links). How has chocolate developed over time? What has helped this development? Make a timeline of the history of chocolate. As a starting poing see: A brief history of chocolate - BBC Bitesize