From Field to Food

This lesson explains the energy inputs into beef cattle and how energy is lost as we go up the food chain. It explores the agricultural processes used to produce beef in the UK, and the impacts on the environment. These notes accompany the PowerPoint 'From Field to Food', alongside:

A quiz (separate document)
A carbon cycle worksheet (separate document)
A carbon footprint numeracy worksheet (separate document)

These resources were developed for use during Biology Week 2013, but you are free to use them at any point. The PowerPoint and the worksheets are available for you to modify, and you may wish to use parts of them in other lessons. We value your feedback, and a short survey can be found along with more resources at www.societyofbiology.org/biology-week-schools. Here you will also be able to share your pupils' views, which we may then use in blogs and articles.

The British beef industry has high standards of safety, hygiene, animal welfare and the environmental stewardship, and the environmental problems of beef production can be far worse in many other parts of the world.

Background information

What is food security?

Food security is a state in which every member of the population has access to food that is safe to eat, nutritious, meets all dietary needs and allows for an active and healthy life.

This lesson ties food security with the idea that meat is source of food with a high energy input compared to the energy output, and it takes a multitude of processes to make the food that we can buy so easily at the supermarket.

Lesson plan: Introduction

Slide 2: Learning outcomes

- Describe what cattle eat.
- Illustrate energy transfer by cows in a graph or pie chart.
- Create a flow chart showing the process of digestion in a cow.
- Explain what carbon and water footprints are.
- Prioritise approaches that can be taken by consumers, scientists and farmers to reduce the environmental impact of producing beef.

ACTIVITY You may wish to use questions from the quiz at the start and end of the lesson

Slide 3 and 4: What goes into making a beef sandwich?

Ask the class what they think goes into a beef sandwich.

Consider the flour that makes up the bread, and therefore the water, sunlight, land and nutrients needed to grow the wheat.

Beef production

Slide 5 – 11: Interactive quiz

Guess the cattle breed and what it is used for (one is a trick – meat and dairy).

Slide 12: What do cattle eat?

This is very much dependant on the way in which the cattle are reared and will vary considerably. Generally, beef cattle are fed on two types of food: grass (which can be fed as silage) and concentrate.

Silage is grass or another crop which is left to ferment, producing a moist and palatable food source. The large black bales seen on fields contain silage. The other part of the diet is pellets (concentrate).

You may wish to ask students to guess some of the ingredients in animal pellets:

- Wheat, barley and maize
- Oilseed rape
- Molasses (by-product of refining sugar cane)
- Additional minerals, proteins, oils and fats
- Food production by-products come from the wastage from confectionary, distilleries, and cereal manufacture

Grains in the concentrate have environmental footprints, for example a high carbon footprint from fertiliser production, and the environmental footprint of the cow must take these into account. Pellet production and transport also contributes to the water and carbon footprints.

Many of the ingredients may have been imported from overseas.

However, the pellets do contain some recycled waste from human food production.

Pellets help ensure cattle have a complete and nutritious diet.

Slide 16: What do beef cattle eat in the UK?

It is important to highlight that there are different ways of rearing beef cows in the UK, and different rearing techniques have varying energy input from different foods. They also vary greatly in their carbon footprint. The diet also varies depending on the age of the cattle.

Intensive beef production, 18 month beef production and grass beef production are three common methods of rearing for beef, each with different diets.

Intensive beef production cows are fed a high proportion of concentrate. Silage or straw is added to aid digestive function. They reach a suitable weight the earliest.

Grass-fed beef production has the longest production time and cattle are slaughtered towards the end of the summer, when the grass begins to decline. These cows are fed primarily on grass (including silage), and have concentrate supplements.

In the UK, much of the beef from intensive farms is used in products such as lasagne. Grass-fed cattle are more likely to be used as roast beef. Much of beef quality, however, is determined by the way the meat is treated post-slaughter.

Each of these methods has different pros and cons, such as the resources they need, the time it takes to prepare cattle for slaughter, and also possible welfare issues. The different systems are used for particular breeds, and will vary depending on the resources the farmer has available (such as what pasture they have).

Grass is lower in energy so more is required, but unlike grain it can't be used for human consumption.

Slide 13, 14 and 15: How do cattle digest food?

Cattle are ruminants; they regurgitate food and 'chew the cud', and digestion is aided by symbiotic microbes in their stomach.

Technically, cattle have one stomach with four separate compartments. These are the rumen, the reticulum, the omasum and the abomasum. This anatomical definition of a stomach is a compartment that secretes digestive enzymes, and only one compartment actually does this.

Cellulose is trapped within a plant cell wall, and this prevents most species from digesting it. The microbes in the stomach break it down and allow energy release from the fibre.

Although other animals, such as chickens, produce more meat from the same amount of feed, rumination allows cattle to digest plant material which is inaccessible to other animals.

ACTIVITY You may wish to ask students to make a flow diagram of this process

Slide 16: What happens to the energy?

This relates to energy conservation in trophic levels, and how most is not converted into meat for use higher up the food chain (in this case by humans) but dissipated in various ways. Only 5% of all energy input into a cow is converted into their biomass, but another 1% of this is lost in the form of inedible slaughtering products, such as hair. For more information

on presenting trophic levels, please see http://ow.ly/psrGX. If you wish to talk in more detail about types of energy, it might be worth explaining that some becomes kinetic energy as the animal moves around, but this is included in respiration.

Despite this, even the energy that manages to be converted into a product that we can eat may still be wasted due to poor handling, poor preservation or poor storage capacities.

ACTIVITY You may wish to ask students to draw this information as a pie chart

Slide 17: Cattle need food, but what else?

Pupils can be tested on what else cattle need, and they may be able to think of more than we have listed here. Beef herds often have less medication than dairy herds, and herds for grass-fed require more land, whereas intensively reared cattle will spend more time in buildings.

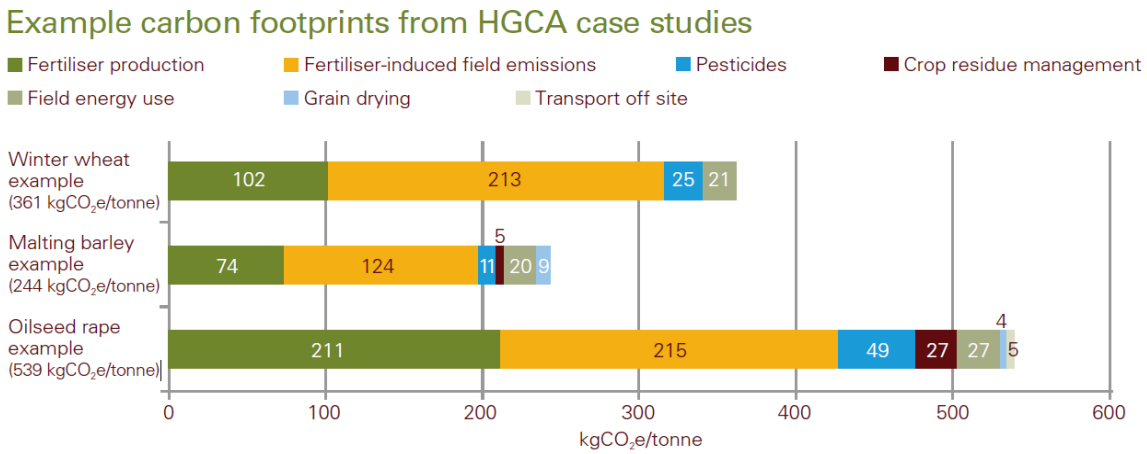
Slide 18: What is a carbon footprint?

The Department for the Environment, Food and Rural Affairs considers carbon footprint to be the total of the six main greenhouse gases, including carbon dioxide, methane, nitrous oxide and other fluorinated compounds.

In beef, gases other than CO_2 feature prominently in the carbon footprint, particularly methane in cow burps and N_2O from manure.

Slide 19: What contributes to the carbon footprint of beef?

Some of the carbon footprint comes from the inputs used to grow crops for feed. Fertiliser production and the emissions it produces when applied to the field contribute highly to the carbon footprints of the wheat, barley and oilseed rape in concentrate feed. Pesticide application and transport also contribute to crop carbon footprint.



The carbon footprint of a kg of beef is approximately 12.65 CO_2e, but this figure varies greatly between the upbringing of cattle, variations in their lifecycle, the breed and exactly what they eat. Upland beef cattle, for example, eat mainly grass and are kept on marginal

land which cannot be used for other purposes. They have a smaller carbon footprint than cattle fed a high proportion of concentrate feed.

ACTIVITY You may wish to use the carbon cycle worksheet

Slide 20 and 21: What is the water footprint of beef?

The water footprint is the total water volume used to make a product.

The total water footprint of a kg of beef is around 13,000 litres, and much of this is contained within the grass or silage which the cow eats (although this does vary considerably with farming practices).

The water footprint described here includes water taken from the 'available' water supply, such as rivers, lakes and groundwater. They also include the rainfall that waters crops directly. It is important to note that the water trapped in grass came from rain water and would not be available for other uses, whereas there are potential environmental impacts of the water used to irrigate crops for feed, for example.

This is a greater problem in other parts of the world and beef is an extensive component of global water use.

Cattle require free access to a plentiful supply of drinking water.

Plenary

If you would like to have a class discussion, here are some ideas. These 'solutions' come with new issues of their own, so discussion about why these may not be the best solutions or may not stop problems in total is a good way for pupils to recap on what they have been taught. It is important to remember that farmers need to make a profit. When discussing the problems and solutions, you may wish to divide students into groups and ask them to pretend they are scientists, farmers, supermarkets and consumers.

Slide 22: How can these figures be reduced by farmers?

Plant more trees on their farm to offset the livestock carbon footprint:

This is called carbon sequestration- when biological compounds accumulate carbon via the capturing of carbon dioxide. Although planting a multitude of trees will inevitably increase the total carbon sequestration, there can also be issues with this. Planting trees can disturb soil and release more carbon dioxide, so it is not efficient enough to be a solution in itself.

Farmland can also be carefully managed with wildlife in mind.

Adopting more productive cattle breeds to produce beef:

Some breeds can make more efficient use of food, or are more resistant to particular diseases. There are around 40 breeds native to the UK.

Identifying desirable genes in cattle and selectively breeding for these:

Selecting for specific genotypes that increase yield will can increase beef output relative to the food input, leading to more efficient beef production. Genes that contribute to a greater disease resistance could also be targeted.

Desirable genetics can also be targeted that influence body size and structure to reduce wastage of biomass during slaughter.

Optimise animal feed further so cows only eat what they need, with the best nutritional value:

Pollution from excess nutrients is an issue when the animals are overfed. Animals will often eat more than they need for growth and wellbeing, so measuring this more carefully will allow for less wastage as a cow converts the feed into its own biomass. Improving the nutrient balance of food may also aid efficient biomass conversion, and a lower cost of production. Reducing fibre in particular will reduce methane emissions, so will cut down on the carbon footprint of the animal.

Use manure more effectively as a fertiliser:

Developing and buying equipment that applies manure much more quickly back into the ground as fertiliser reduces nitrous oxide emissions into the atmosphere.

Slide 23: How can these figures be reduced by scientists?

Designing new animal concentrate feed that reduce methane emissions:

Increasing the digestibility of feed will make energy transfer more efficient. Less fibre content can lead to reduced methane emissions because less fermentation is required.

Livestock are considered to be responsible for around 37% of the total methane production on a global scale, which is due to the microbial breakdown of food within the stomach.

Developing plant breeding programmes to improve crops for cows to eat:

Selectively breeding crops for feed could lead to yield increase, so less land use could be used to make the same amount of feed for a cow. Crops can also be developed which reduce the need for pesticides and fertiliser, again reducing the total carbon footprint of the beef.

Slide 24: How can these figures be reduced by us, the consumer?

The NHS reccomends consuming 70g of red and processed meat a day, which is equal to around three, thinly sliced cuts of meat. With two rashers of bacon and two sausages coming in at 130g, it is easy to see how we could be eating more than is necessary. The full NHS health guidelines are here: www.nhs.uk/Livewell/Goodfood/Pages/meat.aspx#red

Health issues associated with overeating meat include bowel cancer, alongside usual overeating issues such as obesity. So eating less meat in general may be beneficial for both our health and the environment.

Other meats can use less resources than their equivalent weight in beef, so eating meats such as chicken in place of beef could reduce resource use too.

Slide 25 and 26: Is this the future of beef production?

This synthetic burger was unveiled at the beginning of August 2013 as an idea to combat the need for animal rearing. It was developed by Dr Mark Post and his team as Maastricht University, and Dr Post stated that this lab meat reduces land and water use by 90% and cut overall energy use by 70%.

You may wish to show your students a video: http://ow.ly/pswkA

Although this was completely legal in the production of the beef fibres, is it completely ethical? This is a good debate to have with students as issues can include:

- Were the fibres alive? Did the scientists 'kill' something?
- What is the difference between eating these fibres and eating beef from a cow?
- Are there any better solutions than this to reduce the environmental impact of meat production?
- Who will decide whether we adopt this technology? Government, consumers, scientists and retailers?

Slide 27: Learning outcomes

- Understand the environmental resources that go into making beef.
- Understand what is needed to feed cattle.
- Know what carbon and water footprints are.
- How environmental impact may be reduced by consumers, scientists and farmers.

ACTIVITY You may wish to use questions from the quiz

Discussion points

Further questions to ask could include:

In the UK, the proportion of food which is imported is increasing. Is this a problem?

In many developing countries people aspire to have diets more like ours, inclduing more meat and dairy products. If this means that fewer people can be fed on the same amount of land, is it a problem? How should we deal with this?

Links

Food Security

Silage Making

Beef Management Guide

Future carbon dioxide removal *via* biomass energy constrained by agricultural efficiency and dietary trends

UK's Carbon Footprint 1993 - 2010

The Carbon Footprint of the Beef, Cattle and Sheep Sector

Understanding Carbon Footprinting for Cereals and Oilseeds

Testing the Water

How UK Farmers Could Reduce Greenhouse Gas (GHG) Emissions

Reducing Emissions from Livestock

Synthetic meat: How the world's costliest burger made it on to the plate

Curriculum links for GCSE biology

Exam Board	Specification outline
AQA	**Unit 1: Biology 1** **B1.5.Energy and biomass in food chains** The amounts of material and energy contained in the biomass of organisms is reduced at each successive stage in a food chain because: -some materials and energy are always lost in the organisms' waste materials -respiration supplies all the energy needs for living processes, including movement. Much of this energy is eventually transferred to the surroundings **B1.6 Waste materials from plants and animals** Candidates should use their skills, knowledge and understanding to: - evaluate the necessity and effectiveness of schemes for recycling organic kitchen or garden waste. **Unit 3: Biology 3** **B3.4 Humans and their environment** Candidates should use their skills, knowledge and understanding to: -analyse and interpret scientific data concerning environmental issues -evaluate methods used to collect environmental data and consider their validity and reliability as evidence for environmental change -evaluate the methods being used to feed and provide water to an increasing human population, both in terms of short term and long term effects -evaluate the positive and negative effects of managing food production and distribution, and be able to recognise that practical solutions for human needs may require compromise between competing priorities. **B3.4.2 Deforestation and the destruction of areas of peat** - crops can be grown from which biofuels, based on ethanol, can be produced -there can be increases in cows and in rice fields to provide more food. These organisms produce methane and this has led to increases in methane in the atmosphere. **B3.4.4 Food production** a) At each stage in a food chain, less material and less energy are contained in the biomass of the organisms. This means that the efficiency of food production can be improved by reducing the number of stages in food chains. b) The efficiency of food production can also be improved by restricting energy loss from food animals by limiting their movement and by controlling the temperature of their surroundings.
Edexcel	**Unit B1: Influences on Life** **Topic 3: Problems of, and solutions to a changing environment** **3.17** Demonstrate an understanding of how some energy is transferred to less useful forms at each trophic level and this limits the length of a food chain **3.18** Demonstrate an understanding that the shape of a pyramid of biomass is determined by energy transferred at each trophic level **3.19** Explain how the survival of some organisms may depend on the presence of another species **3.20** Analyse, interpret and evaluate data on global population change **3.21** Explain how the increase in human population contributes to aincrease in the production of pollutants, including phosphates, nitrates and sulphur dioxide **Unit B2: The Components of life** **Topic 1: The building blocks of cells** 1.12 Discuss an understanding of the advantages and disadvantages of genetic engineering to produce GM organisms, including: the production of herbicide-resistant crop

	plants
OCR: Applied Science Double Award:	**Unit 2: Science for the needs of society** **2.1 Living Organisms** **2.1.5 Farming Methods (for both tiers**) explain why intensive farming produces more food but: • excessive use of artificial fertilisers can cause damage to the environment (eutrophication) and be hazardous to health (nitrates in drinking water); • herbicides, pesticides and fungicides may enter and accumulate in the food chain; • intensive farming of animals raises ethical dilemmas. explain how organic farming uses alternative methods but that productivity may be lower **2.1.6 Ecology (for both tiers)** • be able to interpret food webs.
OCR Biology A: Twenty First Century Science Suite	**Module B3: Life on Earth** **B3.1 Systems in balance – how do different species depend on each other?** 12. understand that energy is transferred between organisms in an ecosystem: a. when organisms are eaten b. when dead organisms and waste materials are fed on by decay organisms (decomposers and detritivores) 13. explain how energy passes out of a food chain at each stage via heat, waste products and uneaten parts, limiting the length of food chains
OCR Biology B: Gateway suite	**Module B2: Understanding Our Environment** **Item B2b: Energy flow** Understand how pyramids of biomass show the dry mass of living material at each stage of a food chain. Explain how some energy is transferred to less useful forms at each stage (trophic level) in the food chain, to include: • heat from respiration • excretion • egestion. Describe how excretory products, faeces and uneaten parts can be used as the starting point for other food chains. Explain how carbon is recycled in nature, limited to: • plants removing carbon dioxide from the air by photosynthesis • feeding passes carbon compounds along a food chain or web • plants and animals releasing carbon dioxide into the air, as a product of respiration • burning of fossil fuels (combustion) releasing carbon dioxide • soil bacteria and fungi, acting as decomposers, releasing carbon dioxide into the air. **Item B2g: Population and pollution** Explain the term 'carbon footprint' in terms of the amount of greenhouse gases given off in a certain period of time. **Module B4: It's A Green World** **Item B4h: Farming** Recall that intensive farming means trying to produce as much food as possible from the land, plants and animals available.