

FEED THE WORLD

WITH BIOCHEMISTRY



DESIGNING YOUR GOLD CREST PROJECT

This pack includes background information and examples of using biochemistry to feed the world. It also provides examples of lab-based practicals and computer-based research projects to help you design your own Gold CREST Award project.

To achieve your Gold CREST Award you are required to meet a set of criteria. This resource sheet is designed to help you work towards achieving your award.

You are expected to design, plan and carry out an investigation with a clear set of aims involving a **minimum of 70 hours of work**.

Your final report will include background information, progress of your investigation, results/findings, conclusions and reflection. You need to present your findings in an understandable manner using an appropriate medium.

This project should be self-directed and contribute something unique to the scientific community. You are expected to organise your time effectively and demonstrate a high level of understanding of the topic and a clear strategy to solve the problem you are addressing.

Look at the **CREST Awards site** for more information about the required criteria.



DESIGNING YOUR GOLD CREST PROJECT

If you plan to design and implement a lab-based experiment, look at **'Understanding the need for GMOs'**.

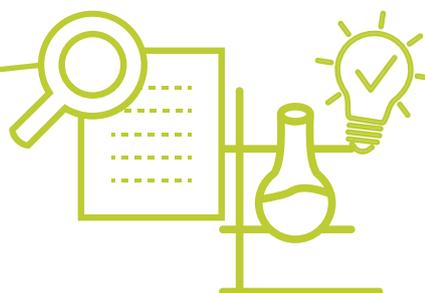


If you want to design an investigative research project, have a look at project example **'Are GMOs safe to use?'** and project example **'The latest GM technologies and the future of GMOs'**

You can use any of these examples as starting points for your own projects or just as ideas for designing your own.



You can combine any of these examples to create a project that involves different areas of biochemistry using physical experiments as well as web-based research projects to make your own unique project.



WORLD HUNGER: THE FACTS



WORLD POPULATION

7.6 BILLION



PEOPLE WITHOUT
ENOUGH FOOD =

815 MILLION



BIGGEST FOOD
SHORTAGE =

ASIA

(519.6 MILLION HUNGRY PEOPLE)



THE POPULATION IS
PREDICTED TO REACH

9 BILLION

IN 2045.

MORE THAN 1/3 OF
FOOD PRODUCED
AROUND THE WORLD
IS NEVER CONSUMED
AND ENDS UP WASTED.



75%

OF THE WORLD'S
POOREST PEOPLE LIVE IN
RURAL AREAS AND DEPEND ON
AGRICULTURE FOR THEIR LIVELIHOOD.



50%

OF THE WORLD'S POOREST FAMILIES
DON'T BUY FOOD, THEY GROW IT.
CULTIVATING ENOUGH FOOD IS MADE
WORSE BY DROUGHT AS A RESULT OF
CLIMATE CHANGE AND INCREASINGLY
UNPREDICTABLE RAINFALL.



489 MILLION OF THE WORLD'S HUNGRY PEOPLE LIVE IN
COUNTRIES EXPERIENCING ONGOING CONFLICT AND VIOLENCE.

WORLD HUNGER: THE FACTS



9000

PEOPLE IN SOUTH
SUDAN LOSE ACCESS TO
FOOD EVERY DAY



50%

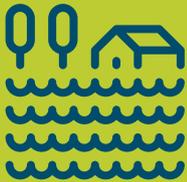
OF HUNGRY
PEOPLE ARE IN
FARMING FAMILIES



60%

OF THE
WORLD'S HUNGRY
ARE WOMEN

EVERY YEAR, AN ESTIMATED **25%** OF FOOD
CROPS ARE DESTROYED BY INSECT PESTS.



LACK OF INFRASTRUCTURE, INCLUDING ROADS AND STORAGE FACILITIES, FREQUENT WAR AND DISPLACEMENT, AS WELL AS NATURAL DISASTER (EARTHQUAKE, TSUNAMI, HURRICANES), CLIMATE CHANGE AND CHRONIC POVERTY PREVENT THE AVAILABILITY OF FOOD.



THE SCIENTISTS' MISSION:

NOT ALL ASPECTS THAT LEAD TO LACK OF FOOD CAN BE CONTROLLED, ESPECIALLY CONFLICT, BUT RESEARCH IS BEING DONE TO TACKLE OTHER ISSUES. WE CAN HELP TO PRODUCE FOOD THAT IS SUSTAINABLE AND RESILIENT TO GROW AND THRIVE IN THESE MORE CHALLENGING ENVIRONMENTS. CLIMATE CHANGE IS CAUSING PROBLEMS IN AGRICULTURE DUE TO THE UNPREDICTABILITY IT CREATES. RESEARCH INTO MAKING CROPS RESISTANT TO CHANGING CONDITIONS, MAKING THEM EASIER TO GROW, AND MORE NUTRITIOUS IS HELPING TO SOLVE THESE PROBLEMS.

WORLD HUNGER: THE SOLUTIONS

GENETICALLY MODIFIED CROPS

Genetic modification (GM) is the direct manipulation of an organism's genes using biotechnology. The first genetically modified crop (a tomato) went on commercial sale in 1994. A second copy of the gene polygalacturonase was inserted into the genome of the tomato. This gene encodes an enzyme that degrades pectin, a component of the tomato cell wall that results in the fruit softening. The second copy of the protein interferes with the production of the normal protein, resulting in the delay of the softening process, so the fruit lasts longer.

Why genetically modify food?

1. Herbicide Tolerance - Ensuring that crops can survive treatment of surrounding unwanted weeds. Modern herbicides are often synthetic mimics of natural plant hormones which interfere with the weed's growth. The 'carryover' effects to other plants and crops make them less desirable to use. This means that the herbicides don't only impact the weeds, but may also impact the crop for the worse.

2. Insect/Virus Resistance - Used to make the crops less 'appealing' to insects, allowing the crops to survive. One example is the spider mite that lives on the underside of leaves: they lay their eggs and punch holes in the leaf to feed. Common modification involves the insertion of genes from the bacteria *Bacillus thuringiensis* into the crop. This means the crop can produce Cry toxins which are toxic to certain insects. In the US, 40% of the maize is GM using methods like this.

3. Stacking Traits - To broaden crop enhancements that allow the farmers to meet their needs under complex farming conditions. This increases survival of crops and ensures maximum crop yield. For example, resistance to insect pests and resistance to weeds in a single crop. This is achieved by crossing two single modified traits together. One example is maize which is resistant to pests and tolerant to herbicides.



WORLD HUNGER: THE SOLUTIONS

GENETICALLY MODIFIED CROPS



4. Drought Tolerance - This enables plants to be able to withstand the harsh dry land and lack of rainfall in some countries and also to cope with the unpredictability of the weather. Changing the expression of regulatory genes is a common method for this. This results in the accumulation of osmolytes (compounds that affect water uptake, and carry water in and out of the cells in times of need) and proteins involved in the transport of water and ions.

5. Delayed Browning - These modifications ensure the fruit and vegetables stay fresh for longer and less is wasted due to damage during transit - Tesco estimates that 40% of apples are wasted. One example, the 'arctic apple', which doesn't brown even when cut, allows it to retain flavour and nutritional value. This occurs by blocking the enzyme polyphenol oxidase (PPO) which is responsible for allowing polyphenols and oxygen to react which causes the browning.



WORLD HUNGER: THE SOLUTIONS

CASE STUDY: GOLDEN RICE

Golden Rice has been genetically modified to be grown and consumed in areas with a shortage of dietary vitamin A. Vitamin A is important for growth and development, is essential to maintain the immune system and also important for good vision. It is needed by the retina of the eye to produce retinal, which together with other proteins (opsin) forms rhodopsin. This is the light absorbing protein necessary for low light vision.

A deficiency of vitamin A is estimated to kill 670,000 children under the age of 5 each year as well as more than 500,000 cases of irreversible blindness in children. The goal of The Golden Rice project was to genetically engineer rice to biosynthesize beta-carotene, a precursor of vitamin A. In normal rice, the edible part of the rice plant doesn't produce this protein. This was achieved in 2005 when scientists genetically engineered the rice to 'switch on' the three beta-carotene biosynthesis genes. The rice produces 23 times more beta-carotene than original rice. In 2018, the first approvals for the cultivation of Golden Rice were accepted in Australia, New Zealand, Canada and the USA.





A LAB-BASED PRACTICAL EXPERIMENT EXAMPLE - UNDERSTANDING THE NEED FOR GMOS.

Specific conditions and tight control are needed for crop farming with small changes in the environment having the potential to kill off a farmer's year of hard work and impact their livelihood. Determine what changes in the environment impact plant growth.

1. Start by growing your own crop. You could try growing plants from seeds; perhaps choose a fast growing herb seed such as lemongrass or chives, or use already established plants.



2. If you start with the seeds, grow the seeds in normal conditions (soil, sun, water) to get growth before you start the experiment. You will need quite a few pots of the crop to test each variable.



3. When your plants have established, grow the plants in varying conditions to mimic the external factors that may affect a farmer's field. For example, change the temperature, pick three temperatures (room temperature, a higher temperature and a colder temperature) but keep everything else the same (water, pH and sunlight). To keep these constant, give the exact volume of water at the same time each day to each plant, keep the pH the same by using the same soil source. Sunlight may be harder to control but you could put them in the same place on a windowsill.



4. Change other variables too (examples include pH, amount of sunlight, volume of water, humidity). Think about how you would change these variables.



5. You could try adding things to the soil you wouldn't expect to find, for example rubbish or herbicides/ weed killers. Take care with using weed killers, make sure to read the instructions and assess the risk. Farmers cannot always control the environment around their farms! Make sure you always have a control where all variables remain constant and 'normal'.



6. From your observations, propose genetic modifications you would make to help the crops survive in these harsh conditions. What are the weak points in crop production?



7. If you want to take this experiment to the next level, you could compare the robustness of different herbs. Test these varying conditions on a range of herbs. Can some herbs survive the harsher conditions better than others?

AN INTERACTIVE WEB-BASED RESEARCH PROJECT EXAMPLE - ARE GMOS SAFE TO USE?

There is a lot of debate around the use of genetically modified organisms. Many people are worried about the long term effects and ethics of eating genetically modified crops. Organise and hold a debate addressing the ethical dilemmas behind this topic. Consider the pressures of world hunger - lack of food, environment, weather, natural disaster, plant disease, pests - and look at where GM is, or can be, used to tackle these.



Ensure you present both sides of the argument, both reasons to support GM and reasons against it - collect 'quotes' or 'expert advice' to support your key arguments. Don't forget to include your evidence. Evidence may involve real world examples of where in the world GMOs have impacted people, where they have been a success, where it has failed and where it might benefit people in the future. This will require some in depth research; use internet searches to find facts and figures to support your statements. Start by using search engines which may direct you to research centres that specialise in this area. You could look at this paper as a good starting point of topics to do further research into <http://giecdn.blob.core.windows.net/fileuploads/file/2017/10/gmo%20ethical%20analysis%20thoma%20shaw.pdf>.



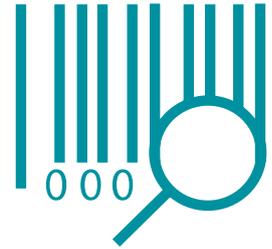
Make sure you consider the source of the facts and data: do they come from a reliable person or research group? Is it published data and how did they calculate their findings? Does the source of the evidence affect its reliability? When presenting your arguments, it is important to ensure the data is reliable and trustworthy. Any quotes you do get, make sure the person is happy to go on the record. Again, consider your source; are they an expert in the field or someone from the general population? Will this affect the argument?

You could look at fruit and vegetables that are genetically modified - look at why they were modified and the benefits to society. Other evidence may be physical evidence - can you find GMOs in your local supermarket? Use these to support your arguments.

Investigate where in the world specific GMOs are important and look for evidence where they have made a difference and where they haven't. You could even look beyond crops - where else do you see genetic modification? Weigh up the advantages and disadvantages of these. Ensure you give a balanced argument before you make your decision - evidence is key.

A WEB-BASED RESEARCH PROJECT EXAMPLE - THE LATEST GM TECHNOLOGIES AND THE FUTURE OF GMOS.

There are many examples of where genetic modification has been used. One example is there are crops that can fix their own nitrogen meaning farmers can reduce the need for artificial fertilizers. Another is a detrimental strip rust disease that destroys wheat crops worldwide; earlier this year scientists isolated the first major resistance gene to this disease. With 1/3 of the world's population relying on wheat as a food source, is it not our responsibility to change this?



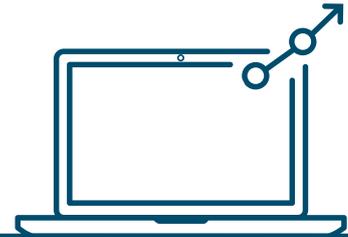
However, finding out which of the foods we eat have undergone genetic modification is difficult. GM in crops is not a new technology, so foods you don't expect to be GM may in fact be; they may not always be clearly identifiable. Carry out a study to identify how GMOs are labelled by looking at the foods sold at your local supermarkets. Do some research into the guidelines surrounding GMOs and the rules in place for the correct labelling and advertising. Find out what companies are out there that market GMOs. What food products can you find that are marked? Are there any products you are surprised that undergo genetic modification?



Explore the different types of GM technology, what types of industries use it and where. Look beyond crop growth in harsh environments. One example that is currently being explored is improving nutritional content of foods for consumers in developing countries. You could also look at how scientists hope to use GM in the production of vaccines. What is the future of GM? Where else are we likely to see GM as new technologies expand? What are the advantages and disadvantages of these techniques? What are the impacts on different people and different countries?

Look outside of genetic modification. These techniques have been put in place to help solve the problem of over population and harsh environments. There are other techniques that are available to help solve these problems that don't use GM. One example is hydroponics. This is a subset of hydroculture, that grow plants without soil using mineral solutions in water. Other resources can be recycled to make up the mineral systems, for example using duck manure. This technique is used in the UK which allows us to get tomatoes all year-round. What are the advantages and disadvantages of these and how do they compare to the methods that require GM?

USEFUL LINKS



LOOK AT THE FACTS ASSOCIATED WITH THE HUNGER PROBLEM

www.thehungerproject.org

www.mercycorps.org.uk

LEARN MORE ABOUT WHAT GMOS ARE AND WHERE YOU FIND THEM

www.gmoanswers.com/current-gmo-crops

CHECK OUT MORE ABOUT THE SCIENCE BEHIND GOLDEN RICE

www.goldenrice.org

CHECK OUT SOME GAMES

<https://monsanto.com/company/outreach/education-outreach/research-resources/farmer-choices-game/>

WHY IS GM REQUIRED

www.saps.org.uk/secondary/teaching-resources

Author: Tabitha Jenkins, March 2019

