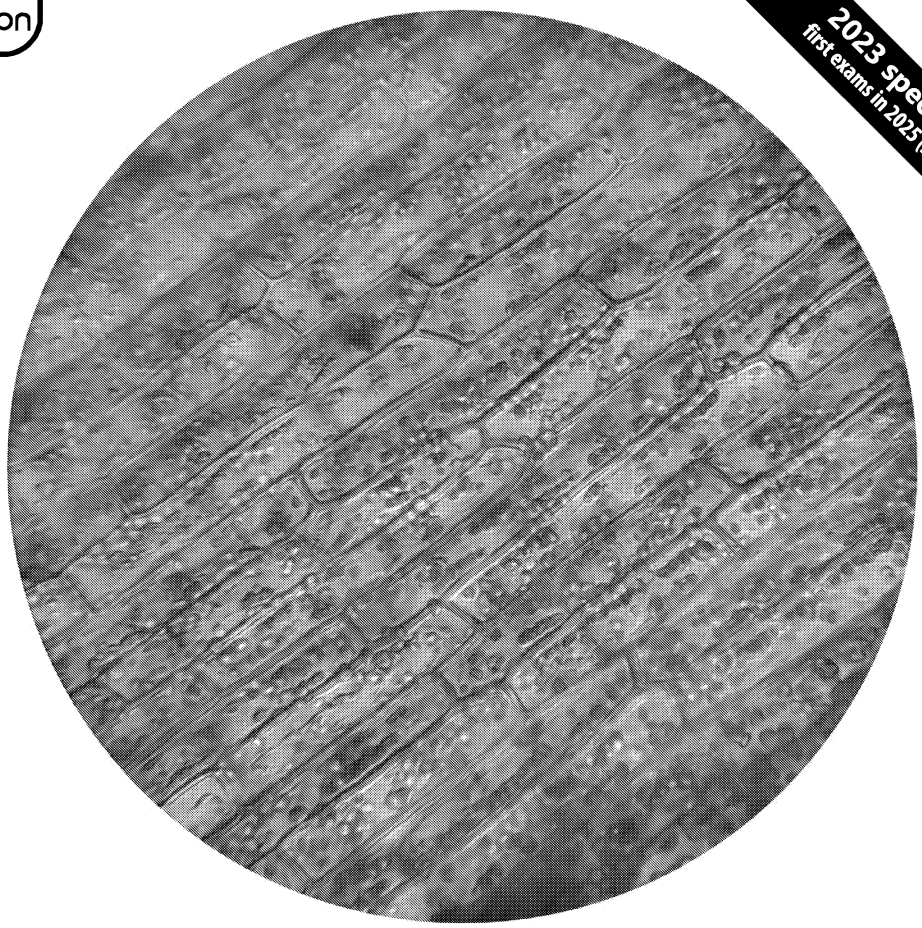
Zig Zag Education

Biology

A Level | OCR A | H020/H420

2023 specification
first exams in 2025 (2024 for AS)



Debates in Biology

for A Level OCR Biology A

Update v1.1, May 2024

zigzageducation.co.uk

POD 11743

Contents

Teacher's Introduction

This resource contains a series of articles designed to relate to the A Level OCR Biology A course. The articles are 2–3 pages long each and provide the opportunity to read about areas of disagreement and controversy within the world of biological sciences, from historical developments to issues thrown up by modern scientific breakthroughs. Each article is followed by a set of activities which allow students to assess their understanding of the article, consider the debates contained in the article, and develop skills relevant to the specification.

The articles are written to be accessible to all A Level students, though they are likely to be more suitable for students working at a higher level, with good A Level content knowledge being assumed. The articles could be set as a classroom activity for students who have finished classwork, as a homework activity for the whole class (perhaps with a focus on different activities for students working at different levels), or as extra reading for students looking to broaden their knowledge and/or apply to study Biology at university.

Each article is preceded by a summary of the skills that students can develop by reading the article and completing the activities, allowing the resource to also be set as a way of practising skills that require development or gaining competency in common practical assessment criteria (CPAC).

The sections included in the activities are described below:

COMPREHENSION	These questions are designed to be reasonably straightforward and should be accessible to students working at all levels. They could be set as a homework or class activity for everyone, and they are useful for ensuring that everyone has followed the arguments in the article before moving on to a higher-level activity.
DISCUSSION	A series of questions that should help students to consider the different arguments contained within each article. Useful for developing skills of evaluation as well as the ability to consider how changes in biology can affect our everyday lives. Discussion questions could be set either as homework ahead of a class discussion or as a classroom activity for immediate feedback within a lesson.
TASK	This section varies between articles, with the following types of task being provided: - MEET THE SPEC – a series of questions that allow the students to check that their knowledge of the relevant section of the specification is up to scratch. - EXAM PRACTICE – an exam-style question that relates to the content of the article and allows students to practise exam skills such as dealing with data and answering application questions. - RESEARCH – a task that allows students to practise and demonstrate practical competency 5 (researches, references and reports). Students are asked to find out more about an aspect of the science covered within the article and produce a resource – such as an information leaflet or a PowerPoint presentation – to feed back their findings. They must consider the selection of good-quality sources of information and produce a list of references.
EXTENDED ANSWER QUESTION	This activity is designed to give students practice at answering different types of level-marked question, with a maximum of 6 marks available. Some of the questions reflect the 'debate' theme of the pack while others are more general ways of assessing student knowledge of the specification. Level indicators have been included to allow exam-style marking of this activity.
EXTENDED READING	An optional extra activity. This section provides a list of popular science books that relate to the article content so that students can continue reading about the topic if they want to. This could be especially helpful for students looking to apply for a Biology degree, or could be used for a higher-ability group to perhaps read a book together and discuss it.

It is intended that the articles and activities will be made available to students either on paper or electronically, and that students will write their responses to the activities on separate paper; no spaces for writing answers have been left within the resource.

A full mark scheme is provided for each activity, allowing for teacher marking or for students to self- or peer-mark work. Some sections do not have allocated marks per question, simply providing suggested answers or content that can be marked as correct or corrected/added to as necessary. Exam practice and extended answer questions are marked in the same way as exam questions, with allocated marks per question and level descriptors allowing students to see how marks are gained or missed in an exam.

October 2022

Update v1.1, May 2024:

Changes have been made to reflect the 2023 accessibility and clarity amendments to the specification.

- Chi-squared formula provided on page 19 and notation updated in answer on page 61
- Parkinson's disease removed from Task: Meet the Spec question 6 on page 36 and answers on page 75

A web page containing all the links listed in the Activities sections in this resource is conveniently provided on ZigZag Education's website at ***zzed.uk/11743***

You may find this helpful for accessing the websites rather than typing in each URL.

1. PROGRESS IN SCIENCE: THE STO

KEY SKILLS
- Evaluating the use of the scientific method to move scientific theory forward.
- Drawing conclusions from experimental evidence.

That DNA contains the code for life is common knowledge today, and scientists a
clone organisms from it. This was not always the case, however, and the story o
understanding of its function and structure is filled with examples of observation
scientific opinion, as well as the odd dose of controversy.

THE DISCOVERY OF DNA

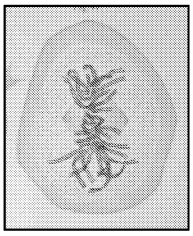


FIGURE 1: ONE OF FLEMMING'S DRAWINGS OF CHROMOSOMES DURING MITOSIS

1865 – Mendel presents the results of his pea experiments and is largely ignored by the scientific community.

1869 – Fr
he calls 'n
white blo
which co
protease
nuclein co
inheritan
show enc

1870

1879 – Walther Flemming discovers chromosomes and describes their behaviour during mitosis.

1880

1881 – Albrecht Kossel renames nuclein as DNA and identifies five bases.

1890

1900 – Th
Mendel is

1900

1909 – W
first uses
describe a

1902 – Walter Sutton and Theodor Boveri independently discover that chromatin contains the heritable material that determines characteristics, and match the results of meiosis to Mendel's ratios.

1910

1920s – P
sugar bas
an incorr

1920

1937 – Florence Bell takes first X-ray image of DNA, showing that it has a regular structure and allowing her to calculate its dimensions.

1930

1944 – O
evidence
contains

1940

1950 – Erwin Chargaff notices that the quantities of adenine and thymine in DNA are equal, as are the quantities of cytosine and guanine, and so discovers A–T and C–G pairing.

1950

1952 – Ro
crystallog
Chase pro
genetic m

1960

1958 – Meselson and Stahl demonstrate that DNA replication is semi-conservative.

1970

1953 – W
propose

1980

1983 – PCR is invented.

1966 – M
bases co

1990

1990 – The Human Genome Project is launched.

1975 – Fr
Sanger de
techniqu
sequenci

2000

1998 – The first multicellular organism, the roundworm *C. elegans*, has its genome sequenced.

2010

2003 – Th
Genome P
complete

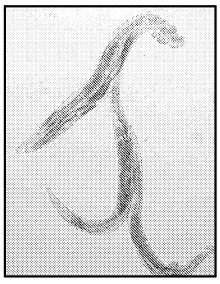


FIGURE 3: *C. ELEGANS*

DNA vs Proteins

When Miescher first discovered DNA, he dismissed the idea that it could play a role in inheritance, and this view continued to be the scientific consensus for many years. When, in 1902, Sutton and Boveri found that chromatin was responsible for inheritance patterns, the protein content of chromosomes was thought to be more significant than the DNA component. Proteins were known to be highly complex, specific molecules, and so were considered much more likely to be responsible for the huge variety of life than simple DNA with its four different bases. It was not until the mid 1900s that this view began to shift as the result of observations from two different experiments, outlined below.

Oswald Avery, Colin MacLeod and Maclyn McCarty, 1944

It was known that of two strains of pneumonia bacteria (*Streptococcus pneumoniae*), a strain called S strain was fatal when given to mice, while another strain, R strain, was non-fatal. This was due to the smooth sugar capsule of the S strain which allowed it to avoid the immune systems of the mice.

Research into pneumonia was common at this time, and another researcher, Frederick Griffith, had discovered that when he injected mice with heat-killed S bacteria as well as live R bacteria, the mice died. Analysis showed that the dead mice had become infected with S strain bacteria, despite having only been given dead S cells; the living R strain bacteria had somehow been transformed by the c
Griffith decided that the bacteria contained a 'transforming principle' that allowe
properties of S bacteria.

Avery wanted to find out which element of the bacterial cells this 'transforming p
designed an experiment in which he treated the contents of S bacteria in several
assessed their ability to transform R bacteria. The findings are shown below:

Treatment	Cell element destroyed	Tra
Carbohydrase enzyme	Sugar coat	
Protease enzyme	Protein	
RNase enzyme	RNA	
DNase enzyme	DNA	

They concluded from these results that DNA must be the transforming principle o
protein as was thought by so many scientists of the time. Despite Avery's results
before DNA was accepted as the molecule of inheritance.

Alfred Hershey and Martha Chase, 1952

Bacteriophages (viruses that infect bacteria) were known to be simple viruses, consisting of a protein capsule and DNA. Hershey and Chase inserted radioactive phosphorus into the viral DNA, and radioactive sulfur into the protein coat, and then allowed the bacteriophages to infect *E. coli* bacteria. After separating the bacteria from the 'used' viruses with a centrifuge, they found that most of the radioactive phosphorus was now inside the bacteria, while most of the radioactive sulfur remained part of the virus structure. This added to the evidence provided by Avery that DNA is the molecule that contains hereditary information and helped this theory to gain wider acceptance.

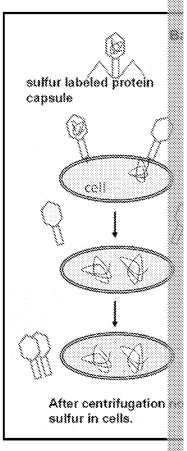


FIGURE 6

ACTIVITIES (ARTICLE 1)

COMPREHENSION

1. How did Frederick Miescher know that he had discovered a new molecule, a
   when he found nuclein?
2. Describe the significance of Sutton and Boveri's discoveries in 1902.
3. Why were so many scientists convinced that it was proteins rather than DNA
4. Describe Rosalind Franklin's role in the discovery of the double helix.
5. Explain Avery's experiment and how the results provide evidence that DNA, no
6. Suggest why Hershey and Chase added radioactive phosphorus to DNA and
7. How did Hershey and Chase's results add to the evidence produced by Avery

DISCUSSION

1. Discuss the significance of the rediscovery of Mendel's work in the search fo
2. Discuss how observation and experimentation by successive researchers ca
   disputes in science and progress in a particular field.

TASK: MEET THE SPEC

1. Draw a simple diagram that shows:
   a. How nucleotides are joined by a phosphodiester bond. Label the main c
   b. How hydrogen bonds would join bases to the complementary strand.
2. Describe the following:
   a. The structure of ATP and ADP
   b. The role of ATP
3. Use a Punnett square to explain how chromosome division during meiosis c
   3 : 1 offspring phenotype ratio. (NB Mendel achieved this ratio in the F2 ge
   homozygous dominant parent with a homozygous recessive parent in the F1
4. Explain the connection between Chargaff's discovery in 1950 and the propos
   replication method for DNA.
5. Explain what Nirenberg discovered in 1966.
6. Use bullet-point stages to describe the process of PCR.

EXTENDED ANSWER QUESTION

Describe how a gene, or series of genes, can be used to synthesise a protein.

EXTENDED READING

The following book goes into more depth on topics addressed in this article:

- *Unravelling the Double Helix* by Gareth Williams

2. PARADIGMS IN SCIENCE: CLASS

KEY SKILLS
- Understanding the process of change in science.
- Application of knowledge to a new context and interpretation of phylogenetic tre

WHAT IS A PARADIGM?

In science, the term 'paradigm' is used to mean a set of ideas that explain a concept, such as the Darwinian understanding of evolution, and DNA determining protein function. Scientists make observations of the world, consensus is reached between researchers, and a paradigm is established that provides a framework for further scientific questions and study. Often paradigms can remain in place for many years; however, if new observations arise that do not fit with the assumptions of an existing paradigm, then a scientific revolution can take place and the paradigm changes – or 'shifts' – to contain a new set of ideas and assumptions. One example of a revolution in scientific thinking over recent years is the basis on which we classify organisms. The system of naming organisms in biology has until relatively recently had 'kingdom' as its largest taxonomic group, but this has since been replaced by 'domain', while some of the groupings within the kingdom system have been questioned. The change from the 'five kingdoms' to the 'three domains' method of classification reflects new understanding of the relationships between different groups of organisms and could be considered a paradigm shift in action.

THE FIVE KINGDOMS

This system was proposed in 1969 by Robert Whittaker; after much deliberation a scientists, he proposed the following groups with their distinctive features:

Kingdom	Features
Animalia	Multicellular, motile, heterotrophic, eukaryotic
Plantae	Multicellular, non-motile, autotrophic, eukaryotic
Fungi	Multicellular/unicellular, heterotrophic (saprotrophic), eukaryotic but with c walls made from chitin
Protista	Unicellular, heterotrophic/autotrophic, eukaryotic
Monera	Unicellular, heterotrophic/autotrophic/chemotrophic, prokaryotic

Whittaker's system moved from the then common plant/animal two-kingdom division to a system that included far more diversity. He classified primarily on the basis of ecological role, with attention also given to cellular structure in the latter years of his work. He was less interested in evolutionary relationship, feeling that this provided more confusing groups of organisms with fewer visible, functional similarities. On this basis he categorised the seaweeds alongside plants, separating them from the rest of the algae, which he placed in the protista group, and he placed all the prokaryotes together in one group on the basis that they lacked a nucleus.

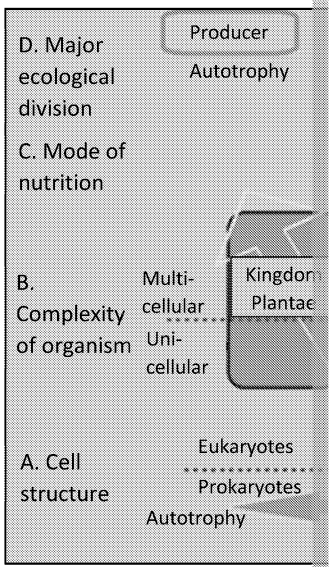


FIGURE 7: THE FIVE KINGDOMS AS

THE THREE DOMAINS

At the time of Whittaker's work there was a widely held opinion among scientists classification of single-celled organisms was not possible as their differences were however, improvements in molecular biology (DNA sequencing) changed this, and under criticism. A scientist called Carl Woese carried out analysis of ribosomal RN that is similar across all living organisms) and found that the rRNA of prokaryotes bacteria and a group that he named the archaea. Scientists are now aware of mu differences between these two groups of prokaryotes, such as differences in their cell wall structure, respiration reactions and RNA polymerase structure. Along with these fundamental differences between the two groups of prokaryotes, more recent research has since demonstrated that the prokaryotes as defined by Whittaker are not a monophyletic group (see below). Archaea have been found to share a more recent ancestor with eukaryotes than they do with the bacteria, rewriting the tree of life as shown in Figure 8.

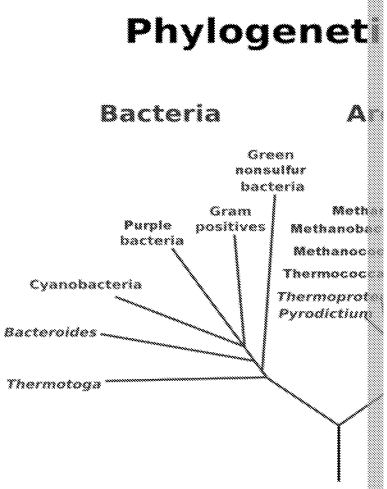


FIGURE 8: CARL WO

A **monophyletic** group includes all the descendants of a common ancestor. So, the archa monophyletic, but the prokaryotes are not.

A PARADIGM SHIFT?

A scientific revolution takes place when the assumptions underpinning a concept used previously. The assumptions underpinning the five kingdoms system are tha cellular structure are valid ways to classify organisms, with evolutionary relationsh overriding factor. On the other hand, the assumption underpinning the three-do systematics stands alone, making evolutionary relationship the only valid criterio from multiple, observable criteria to the use of an entirely new technology, and th the tree of life, could be said to be a 'paradigm shift' in this area of biology, but it some areas of the scientific community the shift is perhaps incomplete or still in p

Carl Woese was especially critical of Whittaker's classification of the prokaryotes nucleus, feeling that the lack of a feature was not a valid criterion. Woese actuall distinction between prokaryotes and eukar reclassification of the prokaryotes, but this biology textbooks still use prokaryote and e distinction. In addition to this, some biolo 'synoptic' classification (which doesn't dep especially for teaching, and the five kingdo textbooks today, even alongside the three domains. While the importance of understanding the evolutionary relationships between organisms is not disputed and the three-domain system is universally accepted, the simplicity and functional usefulness of the five kingdoms mean that the shift away from this system has not fully taken place.

Three domains, or two?

Woese's three domains are not the end of the classification story, and molecular biology has not yet answered all of the questions surrounding the relationship between archaea and eukaryotes. Woese strongly believed that archaea and eukaryotes shared a common ancestor that was itself neither archaeon nor eukaryote, but new ideas about the emergence of the eukaryotes (see Article 3) have led some to believe that the eukaryotes may have emerged from within the archaea, leading to the possibility of a new, two-domain tree of life, referred to as the Eocyte tree (see Figure 9).

COMPREHENSION

1. What is meant by the term 'paradigm' in science?
2. List some of the ideas behind:
   a. the Darwinian theory of evolution
   b. DNA determining protein function
3. How do scientific paradigms change?
4. Suggest why the discovery of prions did not lead to a paradigm shift.
5. What was wrong with Whittaker's classification of the seaweeds?
6. Explain why it is contradictory for textbooks to include both Whittaker's and
7. Explain why the prokaryotes are not a monophyletic group.

DISCUSSION

1. Evaluate the different criteria for classification mentioned in the article.
2. Discuss why scientists are so concerned with the classification of organisms.

TASK: EXAM PRACTICE

1. Figure 10 below shows an example of a phylogenetic tree containing mamm

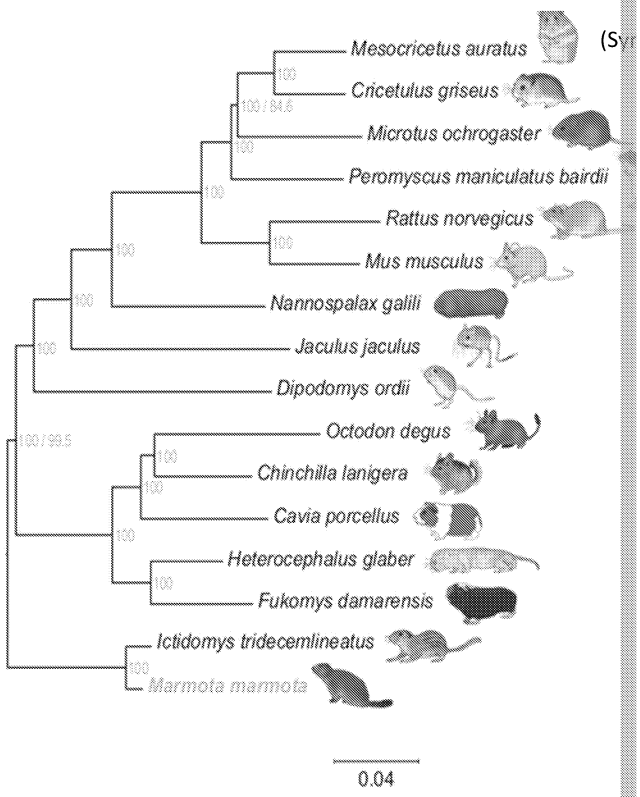


FIGURE 10

   a. Explain what is shown by a phylogenetic tree.
   b. Explain what this tree tells us about the relationships between *Octodon* and *Cavia porcellus*.

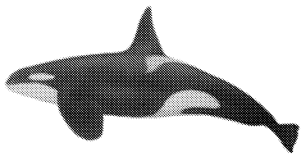
c. Fill in the gaps (labelled a–i) in the table below to give the complete tax
Syrian hamster.

Domain	(f)
(a)	Anima
(b)	Chorda
(c)	Mamma
(d)	(g)
(e)	Cricetid
Genus	(h)
Species	(i)

d. Explain how molecular analysis could have been used to produce this p
e. Give one **other** example of a molecule that could be analysed to provid
f. The scale bar below the phylogenetic tree provides a numerical value f
has taken place on the horizontal axis of the tree, measured in number
site. Use the scale bar to calculate the number of substitutions that ha
the root of the tree and *Marmota marmota*.

Extended Answer Question

The orca, or killer whale, is a species of marine mammal. While orcas are curren
they are also classified into separate groups known as ecotypes. The table belo
some different orca ecotypes.

Antarctic ecotype	Appearance	Distribution	Feeding habits	Numb base d from
A		Open waters of Southern Ocean	Feed mainly on minke whales	
B		Gerlache Strait off the coast of western Antarctica	Cooperative hunting of penguins	
C		Waters off the coast of eastern Antarctica	Not certain, but known to feed on fish	

Use information in the table provided to evaluate the current classification of or

Extended reading

The following books go into more depth on topics addressed in this article:

- *The Naming of the Shrew* by John Wright
- *The Variety of Life* by Colin Tudge
- *The Tangled Tree* by David Quammen

3. ENDOSYMBIOSIS: CELLS INSIDE

KEY SKILLS
- Understanding what is required for the scientific community to accept new idea
- Selecting and citing references.

Endosymbiotic theory states that mitochondria and chloroplasts (and possibly some
living prokaryotes that were taken up by other cells, possibly in a process such as ph
a symbiotic relationship in which the internal cells carried out respiration or photosy
and protection from their host; these groups of cells are thought to be the ancestor
is now widely accepted, but agreement took many years and the work of multiple sc

1870

1879 – Heinrich Anton de Bary first uses the term 'symbiosis', referring to it as 'a phenomenon in which dissimilar organisms live together'.

1867 – Simon Schwendener propo that lichens are a combination of two organisms, appeari to contradict Darwi new theory of survi of the fittest.

1880

FIGURE 12: KONSTANTIN MERESCHKOWSKI IS THOUGHT TO BE THE FIRST SCIENTIST TO PUT FORWARD A REASONED ARGUMENT FOR ENDOSYMBIOSIS

1882 – Franz Kamienski's work on mycorrhizal associations leads to wider acceptance of symbiosis as a biological strategy.

1890

1883 – Andreas Sch chloroplast replica symbiosis betwee

1900

1905 – Konstantin case for organelles once been free-livi unquestionably re evolution entered host'. He alludes t and photosynthet chloroplasts replica

1910

1918 – French biologist Paul Portier writes that mitochondria are symbiotic bacteria living inside host cells, and attempts to culture free-living mitochondria in the lab; his attempts are widely discredited.

1920

1920s – Ivan Wallin, an American biologist nicknamed 'Mitochondria Man', also puts forward the idea that mitochondria originated as aerobic bacteria, and attempts to repeat Portier's culturing experiment. He claims success, but his contemporaries believed that his cultures had been contaminated with bacteria.

1930

1961 – Hans Ris te contents of algal chloroplasts for the presence of DNA a positive result. He observes the struc similarity between inside chloroplasts bacterial chromos

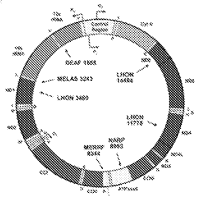


FIGURE 13: THE CIRCULAR MITOCHONDRIAL CHROMOSOME

1940

1963 – Margit and Sylvan Nass, while using their lab's newly acquired electron microscope, notice that the mitochondria contain fibrous structures. They go on to demonstrate that these structures are made of DNA.

1950

1967 – Lynn Marg Cells', in which sh chloroplasts origin formed an endo- (host cell in respon Her article is rejec

1960

1967 – Jostein Goksøyr writes in the journal *Nature*, proposing that an anaerobic and aerobic prokaryote might have formed a partnership, leading to the development of a new, aerobic, eukaryote.

1970

1970 – Peter Rave similarities betwe prokaryotic cells.

1972 – Rudolf Raff and Henry Mahler propose that organelles such as mitochondria may have formed within cells from infoldings of the cell surface membrane.

1980

1975 – Linda Bon ribosomal RNA (r more similarity b of prokaryotes th rRNA and cytopla

1975 – Lawrence Bogorad puts forward the idea that genetic material inside early cells split into small clusters within the cell and that membranes formed around these clusters to form the organelles.

1981 – Lynn Margulis (see 1967) publishes a book, this time presenting more evidence for her theory (see below).

THE CURRENT EVIDENCE

When endosymbiotic theory was first proposed it seemed to go against accepted scientific thinking around evolution, and the evidence gained from simple observation of organelles was limited. Advances in scientific techniques such as electromagnetic imaging and molecular analysis have allowed researchers to put together a more convincing set of evidence, and endosymbiotic theory has now been widely accepted in the scientific community. It has taken many years of determined evidence-gathering by advocates of the theory, however, and there are still unexplained observations and questions to be answered.

Some of the evidence in support and critique of the endosymbiotic origin of mitochondria and chloroplasts is listed below.

Supporting evidence:

- Mitochondria (Mt) and chloroplasts (Cps) have a double membrane surrounding them which could have resulted from a phagocytosis-like event
- The outer membranes of Mt and Cps have a similar composition to cell surfa
- The inner membranes of Mt and Cps are different from all other eukaryotic c membranes contain a lipid called cardiolipin, which is otherwise only found i membranes of Cps contain electron carriers that are also found in cyanobac
- Mt and Cps contain DNA.
- The DNA of Mt and Cps is different from nuclear DNA and similar to bacteria contains no histones or introns.
- Mt and Cps have their own enzymes for protein synthesis.
- Eukaryotic cells have larger 80S ribosomes while Mt, Cps and prokaryotes ha As a result of this, Mt are susceptible to the effects of some antibiotics.
- DNA sequence analysis can trace the bacterial groups from which Mt and Cp
- Mt DNA analysis has allowed their evolutionary history to be traced back to alpha-proteobacteria, and they share their shape and folded membrane wit
- Mt and Cps replicate independently of the host cell and pass their DNA dow
- Mt replicate in a process similar to binary fission.
- There is similarity in size between Mt/Cps and bacterial cells.

Observations that provide criticism:

- Some of the proteins needed by the Mt are coded for by genes located in the nucleus (though in some species these same genes are found in the Mt).
- The mechanism used by Mt to replicate is not identical to binary fission and involves some eukaryotic components.
- Some Mt have linear chromosomes.
- The mechanism by which bacteria were initially taken up by host cells has not been explained.

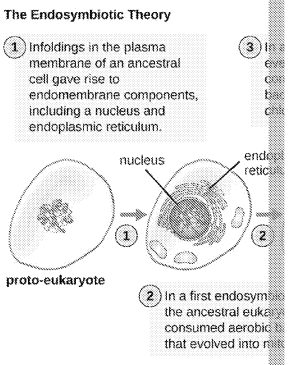


FIGURE 15: THIS DIAGRAM IS A COMM
BEEN CRITICISED FOR IGNORING QUE

In addition to these critical observations, several other questions remain that scientists have yet to fully answer. For example:

- How did other cell organelles such as the nucleus arise?
- Why did eukaryotes only evolve once?
- Given that Cp and Mt membranes cannot simply self-replicate but must be c did the DNA that codes for Cp and Mt membrane production originally com

ACTIVITIES (ARTICLE 3)

COMPREHENSION

1. What does endosymbiotic theory say about the origin of eukaryotic cells?
2. What is 'symbiosis', and how does it compare to endosymbiosis?
3. Suggest why Portier (1918) and Wallin (1920s) attempted to culture free-liv
4. Explain why endosymbiotic theory made so little progress between the wor of Margulis in 1967.
5. Describe some alternative theories that were put forward for the origin of c
6. Explain how the following pieces of evidence help to support Margulis's the
   a. Hans Ris's work in 1961.
   b. The discovery made by Margit and Sylvan Nass in 1963.
   c. Bonen and Doolittle's work in 1975.
   d. The presence and composition of the Mt/Cp double membranes.
   e. The sizes of ribosomes in eukaryotes and prokaryotes.
   f. Mt/Cp replication method.
7. Explain how the mechanism of membrane production inside cells presents a endosymbiotic theory.

DISCUSSION

1. Discuss how endosymbiotic theory has changed the scientific view of evolut

TASK: RESEARCH

Either on your own or with a friend, find out about current scientific thinking on t nucleus. You should produce an A4 summary page or a PowerPoint presentatio

Consider the following:

- What different lines of thought are there?
- Is there any evidence/critique for existing theories?

Some suggested reference sources are provided below, but you should aim to in own. You should choose your references with care, ensuring that you source inf books or websites. Keep a bibliography of all the pages that you use and include summary/presentation.

- **https://www.scientificamerican.com/article/the-nuclear-family/**
- **https://www.frontiersin.org/articles/10.3389/fmicb.2018.02604/full** (esp 'The Conundrum of the Eukaryote Nucleus')
- **https://www.quantamagazine.org/did-viruses-create-the-nucleus-the-ans** NB Can you spot a phrase that you should never use in the first paragraph o of this source after noticing this?

EXTENDED ANSWER QUESTION

Compare and contrast the structure of eukaryotic cells and prokaryotic cells.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *A Short History of Nearly Everything* by Bill Bryson
- *The Vital Question* by Nick Lane

4. FROM ASSUMPTION TO EVIDEN
THE STORY OF TROPISMS

KEY SKILLS
- Understanding the progression of ideas in the scientific community and the impor
- Dealing with data.

PLANT TROPISMS

From the days of the Greek philosophers there have been discussions on the res surroundings. Plato, who lived from 427–347 BCE, believed that plants were able environment, while Aristotle, 384–322 BCE, argued that plants were not responsiv features that separated them from animals. A contemporary of Aristotle, Theop not able to actively respond to environmental change, but instead suggested tha one side of the plant, explaining why plants bend towards the Sun. With no expe contrary, this explanation of plants bending towards the Sun persisted into the 1 plants that 'the part beateth by the sun waxeth more faint and flaccid in the stalk, and less able to support the flower' (Bacon et al., 1627). From this time onwards scientific experimentation increased, and various scientists, on experimenting with plant seedlings, suggested explanations for the light response such as the effects of the 'bad air' released by plants, and that of cool draughts coming from a window. Other types of plant response were explained by ideas such as 'plant irritability', the impact of gravity pulling roots downwards, and changing turgor levels inside plant cells. Even by the mid-1800s there remained a consensus among scientists that plants were not capable of active responses to stimuli, and it was not until later in this century that scientific thinking on plant sensitivity began to change. One scientist who played a role in this shift of opinion was the well-known naturalist Charles Darwin.

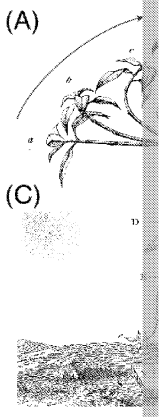


FIGURE 16: EARLY T
BONNET IN THE MI
KNOCKED OVER RIG
PHOTOTROPISM, (B)
GROWS AROUND AN O
SHOWS PHOTOTRO

DARWIN'S LESS WELL-KNOWN WORK

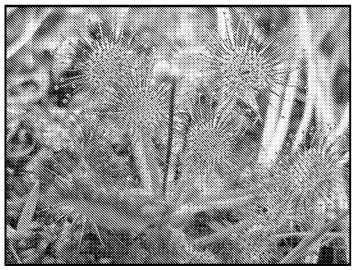


FIGURE 17: *DROSERA ROTUNDIFOLIA*, OR THE ROUND-LEAVED SUNDEW, IS FOUND IN BOGGY PARTS OF THE UK. IT TRAPS INSECTS IN STICKY LIQUID ON ITS LEAVES, WHICH THEN CURL AROUND THE INSECT BEFORE IT IS DIGESTED WITH ENZYMES.

Darwin observed insectivorous plants such as *Dro* amazed to note its sensitivity to touch, and its ap between different types of object, concluding tha 'nervous system' that allowed them to respond to the environment directly and actively. He becam interested in the responses of plants to objects (now known as thigmotropism) and investigated the circular movements of climbing plant shoots a they wrapped around supports, which he called 'circumnutation'. His work on climbing plants, together with the work of Albert Benhard Frank i the late 1800s (which suggested that shoot and r responses share a mechanism but with different tissue responses), led to his theory that the process of circumnutation formed th basis of all types of plant responses (a theory now known to be incorrect).
From here he moved onto investigating light sensitivity in plants. The prevailing theory among other scientists such as Julius Von Wiesner and the eminent plant physiologist Julius Sachs was that the light falling along the length of the shoot ca

Darwin's experiments suggested otherwise, demonstrating that the light-sensitiv
shoot and not the main part of the stem (see Figure 18).

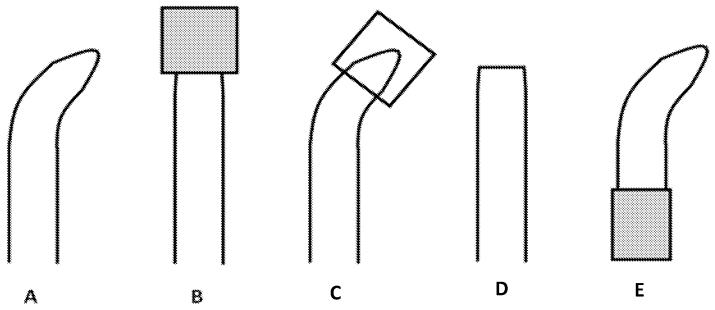


FIGURE 18: DARWIN'S EXPERIMENTS ON GRASS SEEDLINGS. A = UNMODIFIED SHOOT, B = SHOOT W
TIP, C = SHOOT WITH A CLEAR COVER OVER THE TIP, D = SHOOT WITH TIP REMOVED, E = SHOOT WITH

After his important work on shoot phototropism, Darwin decided to attempt to r
out by Theophil Ciesielski in which the tips of growing roots were removed, leadi
These results were viewed as controversial after Julius Sachs (mentioned above)
laboratory, but Darwin's attempts yielded the same results as Ciesielski. Sachs a
relationship, and Sachs was unconvinced by Darwin's amateur 'country-house' in
awareness of this meant that he worked hard to be as consistent as possible in h
blaming Sachs's outcome on a lack of precision in removing the root tips.

Darwin's conclusions in his book on plant movement included his theory of circu
conclusion that the growing tips of plants acted like an animal brain, receiving in
before sending an unidentified 'influence' to other parts of the plant. His theory
comparison of plant responses to animal behaviour were generally rejected, but
shoot and root apices was significant, and his 'influence' has been studied in mu

UNDERSTANDING AUXINS

Darwin's 'influence' was investigated further by Peter Boysen-Jensen in the early
out more experiments on plant shoots, looking at what happens when the move
interrupted. He found that when a permeable gelatin sheet is inserted across a shoot, bending towards light takes place as normal, but that when impermeable mica is used on the shady side of the stem, the bending is stopped. These results demonstrate the importance of the growth 'influence' and that it must travel downwards from the growing tip, specifically travelling down the shady side of the stem to cause the shoot to bend.

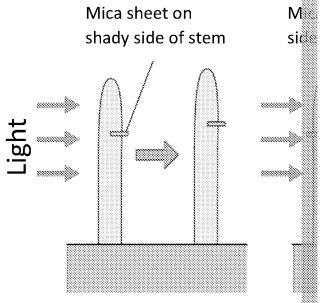


FIGURE 19: PETER BOYSEN-JEN

In 1926, Frits Went carried out similar experiments in which he allowed the growth substance to diffuse into agar blocks, which he t
shoots before observing their curvature. This work allowed the growth substanc
analysed and identified as indoleacetic acid (IAA). IAA was soon found to be par
growth substances, or hormones, now known as auxins, taken from the Greek w

At around the same time as Went's work described above, he and Nicolai Cholod
theory that the auxin forms a gradient across the stem or root in response to a s
affecting the rate of cell elongation, leads to bending. Although the Cholodny–W
accepted, it has faced its own share of questions, with concerns around the suffi
auxin gradient, the speed at which plant responses occur in comparison to the fo
and the relevance of other plant hormones. More recent research has suggested
auxin sensitivities between different plant tissues, as well as the potential involv
alongside auxin in root gravitropism.

ACTIVITIES (ARTICLE 4)

COMPREHENSION

1. Describe the prevailing explanation of plant shoots bending towards light be
   became commonplace.
2. Explain the significance of Darwin's observations of carnivorous plants to hi
3. What was Darwin's theory of circumnutation?
4. Explain how Albert Benhard Frank's results now appear to be correct.
5. Explain results A–E from Figure 18.
6. List as many different areas of conflict that have occurred throughout the histo
7. What evidence is there in the article of Darwin's commitment to the scienti

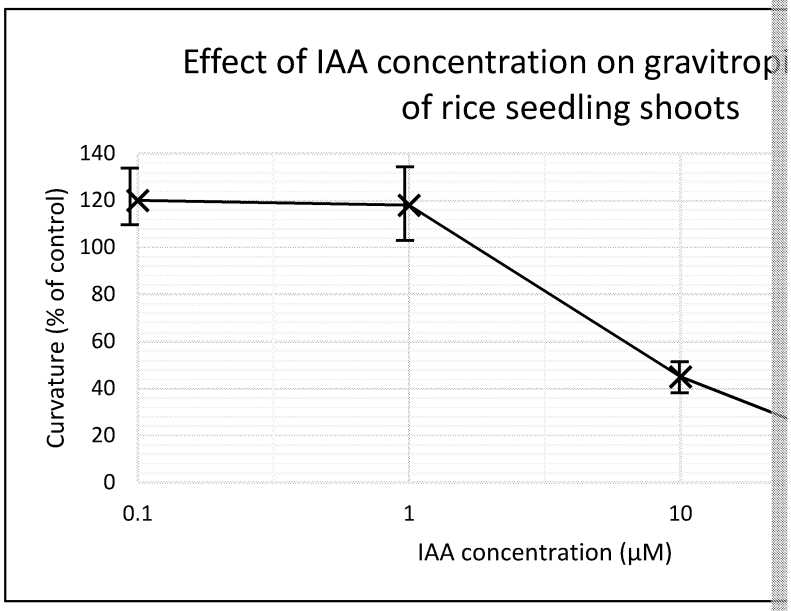
DISCUSSION

Discuss the importance of the scientific method in establishing understanding of
of Darwin and Sachs have tried to ensure that their results were valid?

TASK: EXAM PRACTICE

1. A group of researchers carried out an experiment looking at the effects of IA
   curvature in a plant tropic response to gravity. Rice seeds were fixed to glas
   immersed in solutions of different IAA concentration. The slides were tilted
   before the shoot curvature was measured using a protractor.
   a. What is a plant tropic response?
   b. Give three additional control measures that the scientists would need t

   The graph below shows the results of the experiment:



Rice seedling data taken from 'Cholodny–Went revisited: a role for jasmonate in gravitropism

   c. Suggest how the control experiment could have been carried out.
   d. Suggest why the curvature is expressed as a percentage of the control
   e. What conclusions could the scientists draw from these results?
   f. The x-axis above uses a logarithmic scale. What does this mean, and w
      this scale here?

g. Another investigation into plant tropisms looked at the response of pla
shown in Figure 20 was used.

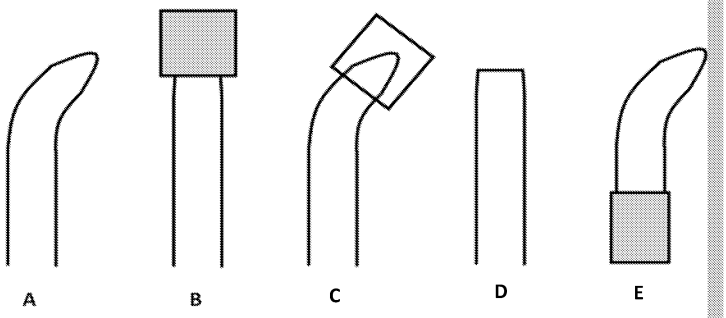


**FIGURE 20: A = UNMODIFIED SHOOT, B = SHOOT WITH A DARK COVER OVER THE TIP, C = SH
OVER THE TIP, D = SHOOT WITH TIP REMOVED, E = SHOOT WITH COVER AROUND LOWER STE**

Use your knowledge of shoot responses to light to describe and explain
i. Shoot B
ii. Shoot D
iii. Shoot E

EXTENDED ANSWER QUESTION

Describe the role of plant hormones in responding to low water availability, e.g. w
summer drought.

5. EVOLUTION AND GENETICS: FROM DARWIN AND MENDEL TO

KEY SKILLS
- Understanding the progression of ideas in the scientific community and the import
- Understanding and carrying out the chi-squared test.

DARWIN'S DIFFICULTIES

It is well-known that Darwin's work on evolution by natural selection faced oppos establishment, but what is perhaps less well-known is that he received oppositio There was general acceptance of his idea that all species descended from a comm Darwin's lack of understanding of inheritance, his process of natural selection fac

The problem of 'blending'

During Darwin's lifetime the prevailing theory of inheritance was known as 'blending theory', which stated that the offspring would display characteristics that were an average of their two parents; so, for example, a parent with long legs crossed with a short-legged parent would lead to medium-legged offspring. In 1867, scientist Fleeming (pronouncing 'Fleming') Jenkin wrote in a review of Darwin's book *On the Origin of Species* that under blending theory, any occurrence of variation would then be diluted over the course of subsequent generations as it was blend average mate; a problem known as 'swamping'. He believed that swamping con advantageous traits could become more common in a population, creating a pro show concerned him greatly. At one point he wrote to a colleague: '*I have lately crudely and indistinctly, that propagation by true fertilisation will turn out to be a fusion, of two distinct individuals*'. This suggests that Darwin was beginning to do the blending of characteristics, but he never developed this idea any further.

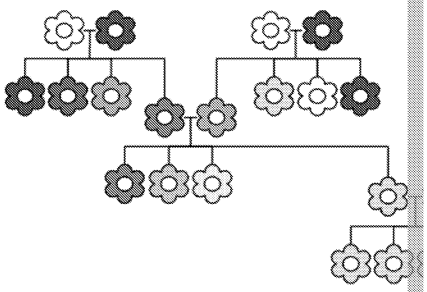


FIGURE 21: A REPRESENTATION OF THE OUTCOM POPULATION WOULD BECOM

The problem of variation

One of the principles of Darwin's theory of evolution by natural selection is that among a population before selection can occur, but when Darwin first put forwa a mechanism by which this variation migh could be passed on, writing that the cause *be useful to probe our ignorance*'. Darwin and in a later book proposed a theory of in 'pangenesis'. The theory of pangenesis st produces chemicals (which Darwin named transported in the blood to the sex organs the parent to be passed on to their offspri variation in gemmules was brought about affected the parent during their lifetime. research into other scientists' work combi he had no evidence to back up the existen a cousin of Darwin, in an attempt to prove (supposedly containing gemmules) from o

Are gemmules making a comeback?

Darwin's gemmules were heavily criticised during his lifetime, and pangenesis has been ignored for many years, but scientists are beginning to find evidence of nucleic acid transfer between cells. These take the form of specialised vesicles containing small RNAs as well as small and microRNAs in the blood. One piece of research has even suggested that the production of these RNAs changes in response to environmental stress, and that the results of these changes can be detected in subsequent generations.

male and female, before breeding them together. His results showed that no characteristics of the original rabbit were present in the offspring, disproving the theory of pangenesis.

Another problem with pangenesis is that it supports the Lamarckian theory of the inheritance of acquired characteristics, which states that changes affecting organisms during their lifetime can be passed on to their offspring. This idea is now widely refuted (though the emergence of epigenetics shows that the idea may have some merit) and was also highly controversial in Darwin's time.

Mendel and Darwin

As scientists living in the twenty-first century it is clear to us that an understandi solved Darwin's difficulties regarding the nature of inheritance, but although they same time, Mendel's ideas appear to have had no impact on Darwin. There is so was aware of Mendel's studies, with some claims that Mendel's paper was found his death, but many believe that even if Darwin had known about Mendel, it is li have made little difference to his conclusions given his dedication to his own theo read and annotated a copy of Darwin's *On the Origin of Species* and there is evid up of his work.

Unlike Darwin's book, Mendel's paper was largely ignored at the time of its publica after his death on its rediscovery in 1900. At this time, the feeling in the scientific c work contradicted Darwin's rather than complemented it, and those who supported Mendelian theories of inheritance were considered to be anti-Darwinian. It was thought that while Darwin wrote about the gradual accumulation of small changes, Mendel's work focused on larger differences between generations, and a false distinction was drawn between what Darwin referred to as 'individual differences' and the discrete differences such as seed colour and shape studied by Mendel.

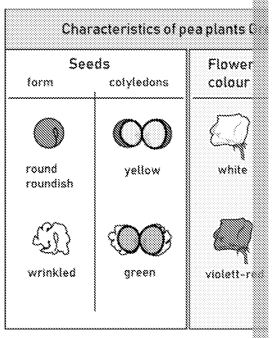


Figure 22: The discrete c fam

Reconciling ideas: the work of Fisher

Ronald Fisher was a mathematician who developed an interest in inheritance during his time as a student. He was convinced by Darwin ideas on the process of natural selection, also saw that Mendelian inheritance was to conserve variation in populations rath 'swamping' it by blending. Fisher set out show that Darwinian natural selection an Mendelian inheritance could work togeth and in 1918 published a paper called 'The Correlation between Relatives on the Supposition of Mendelian Inheritance'. In paper he suggested that large differences between related individuals could be exp by the presence of many Mendelian 'fact (now known as genes) acting together, a for reconciliation between the gradualism Darwin and the larger differences studied Mendel. Fisher's later work focused on demonstrating the effects of Mendelian i natural selection, and though he faced op Reginald Punnett, his mathematical mode acceptance through the 1920s and 1930s.

The Mendel–Fisher controversy

Fisher carried out the chi-squared test on Mendel's data and found that the probability of the results fitting Mendel's theory so perfectly was less than 0.0001 across all his pea experiments; Mendel's results were too good to be true. His great respect for Mendel meant that he stopped short of accusing him of removing results that did not fit with his theory, but his work led to a consensus that the data was likely to have been modified by someone. Although the altering of data is considered unacceptable in modern science, many today are willing to overlook this controversy regarding Mendel's work, with some suggesting that his own theories led to an unconscious bias toward his expected results.

ACTIVITIES (ARTICLE 5)

COMPREHENSION

1. Explain why blending theory was so problematic for Darwin's process of nat
2. Where did Darwin believe that variation originated, and how did he think it
3. What problems were there with Darwin's theory from question 2?
4. How has recent research potentially vindicated the inheritance theories of D
5. Why were Mendel's ideas thought to contradict Darwinism?
6. How did Fisher reconcile the theories of Mendel and Darwin?
7. Explain why Fisher chose to use the chi-squared test when analysing Mende worry him?

DISCUSSION

Discuss the importance of scientists communicating effectively with each other a

TASK: MEET THE SPEC

1. Write definitions for the following keywords:
   a. Natural selection
   b. Heritable
   c. Vesicle
   d. Gene
   e. Discrete
2. Explain Darwin's theory of evolution by natural selection. Use the following **variation**, **selection pressure**, **allele(s)**, **frequency**.
3. In addition to writing about the additive effects of genes on the features of about the effects of epistasis and autosomal linkage. Explain how these ge unexpected outcome of a genetic cross.
4. Many other statisticians during Fisher's time were also interested in the cha populations, including Godfrey Hardy and Wilhelm Weinberg.
   a. Explain the uses of the principle that Hardy and Weinberg established.
   b. List some of the assumptions that their principle makes.
5. In Mendel's research on the inheritance of height in pea plants, he crossed (Tt × Tt). He counted 787 tall offspring and 277 short offspring.

   Use your knowledge of the genetic ratios and the chi-squared test alongside the critical values table provided to analyse Mendel's results and write a full conclusion from the test.

Degrees of freedom	0.5	
1	0.455	2
2	1.368	4
3	2.366	6
4	3.357	7

$$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

EXTENDED ANSWER QUESTION

Describe how the process of natural selection can be harnessed by humans to br desirable characteristics. Use a named example throughout your answer.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *The Monk in the Garden* by Robin Marantz Henig
- *The Tangled Tree* by David Quammen

6. SCIENCE IN THE HEADLINES: THE USE OF DATA IN SCIENCE REP

KEY SKILLS
- Use of statistics such as correlations and risk percentage, as well as the visual dis
- Selecting and citing references.

Science can be complicated, and it is usually the job of the media to communicat discovery to the public in ways that non-specialists can understand. The process requires the following:

- Researchers publish good science.
- Research institution press offices release accurate information to the press.
- Journalists understand the research and write clear articles that communica
- The public choose to read science articles and take away the right message

Given that press officers and journalists covering scientific stories are not always and that it is usually the job of these individuals to sell their media, achieving eff always easy. World-changing events such as the COVID-19 pandemic have demo for science to be communicated well, but in addition to huge stories like this the about nutrition and health that can affect the small decisions that people make e need to sell clicks and copies, but they also have a duty to inform and not to mis

Data that backs up research findings is clearly crucial in the scientific community trained to understand statistics, and poorly explained numbers in science report unnecessary concern and confusion.
Headlines that make huge claims about the connection between lifestyle factors and frightening illness, and the use of confusing graphs, are just some of the ways in which science reporting can be problematic.

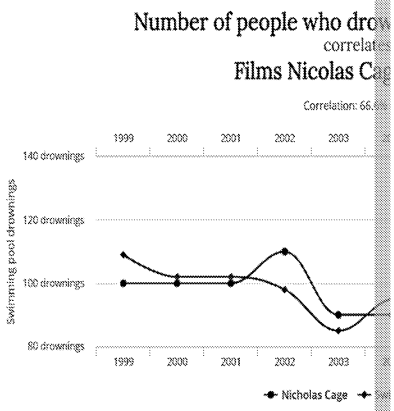


FIGURE 24: 'SPURIOUS CORRELATIONS' IS A WEBS SHOW HOW EASY IT IS TO SPOT CORRELATIONS

CORRELATION VS CAUSATION

Correlation describes the relationship between two factors; it can be strong or weak, and positive (as one factor increases, so does the other) or negative (as one factor increases, the other decreases). Correlations can be spotted simply by looking at and analysing data but causation, that is whether one factor has caused the change in the other, can be more difficult to establish. correlation may be obviously silly (see Figure 24), others may have the appearan long-lasting controversies in the scientific community.

One example of such a debate surrounds the connection between high fructose c HFCS is a sweetener derived from corn that is high in the fruit sugar fructose, and processed foods due to its low cost and high sweetness. In 2012 a study was pub between the availability of HFCS in a country and incidence of type 2 diabetes; re type 2 diabetes prevalence in countries where HFCS was widely available. The st such as 'Syrup Fuelling Diabetes on a Global Scale' and, unsurprisingly, corn syrup point out the potential problems with the study, claiming that there were multipl contributed to the diabetes prevalence in the countries studied; essentially pointi on a correlation to conclude that HFCS was dangerous to public health without pr In this instance the scientists do point out the limitations of their study, which is b rather than coming from measures of individuals, and which measures HFCS avail

The challenge of studying diet and disease

Studying the link between diet and disease presents challenges; it can be very difficult to carry out controlled experiments in this branch of science and researchers often rely on 'ecological studies' (such as the study on HFCS and diabetes) which make use of observations from existing data. While such studies yield large samples and much data, they suffer from weaknesses such as reliance on group rather than individual data and an inability to control confounding variables. Ecological studies can be useful in early research into a new topic, but results should always be interpreted with care.

such subtleties often do not mak
misunderstanding is a real risk. I
the dietary use of fructose is still i
showing that blood sugar spikes a
foods containing fructose, but oth
fructose may interfere with norm
that regulate appetite.

While the truth about the multipl
is still subject to ongoing researc
Coffee Daily Linked to Lower Dea
Dark Chocolate Less Likely to be D
science reporting still has work to
between correlation and causatio

Understanding risk

Science reports such as 'air pollution increases the risk of dementia by 40 %' and '
meat leads to a 9 % increased risk of breast cancer' can be very alarming, and are
make in our everyday lives, but they do not tell the whole story. Many non-scient
of risk percentages, and while some media articles do a good job of explaining the
the headline itself is sometimes all that is noticed. The percentages mentioned a
risk' of disease in individuals exposed to high levels of air pollution or processed m
are not, but the figures are not very useful unless the reader also knows the 'abso
disease in the absence of the environmental changes mentioned. So, if the absolu
cancer is 14 % (14 in 100 women will develop breast cancer in their lifetime), then
when eating processed meat applies only to the initial 14 %:

$$0.09 \times 14 = 1.26$$

$$14 + 1.26 = 15.26\ \%$$

So, eating large amounts of processed meat means that 15 women per 100 will d
than 14; a rather less dramatic increase than the initial story suggested, and one
that they can live with.

The use of graphs

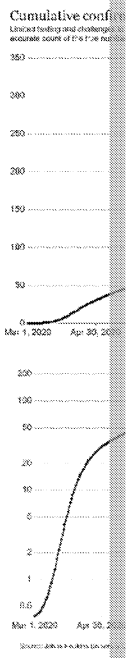


FIGURE 25
GRAPHS SH

Visual representations of data are common in science reporting and, done well, graphs can aid understanding and speed up delivery of information. However, graphs are extremely vulnerable to misinterpretation, error and even abuse (during the COVID-19 pandemic there were several examples of governments and media organisations knowingly presenting misleading graphs to the public in the attempt to manipulate opinion). During the 2020 pandemic, the main role of graphs was to clearly display trends in infection and death rates to aid public understanding and encourage support for safety measures. The difficulty for scientists producing these graphs was that the types of graph commonly used in the scientific community to understand exponential rates of increase are not necessarily the best for communicating with the public. It is common practice to represent large numbers with exponential increase using a logarithmic scale, but research has shown that non-scientists and even some scientists struggle to interpret such graphs. One study showed that when members of the public were shown linear and logarithmic representations of the same COVID-19 data (see Figure 25), those shown the logarithmic scale graph were more likely to answer data interpretation questions incorrectly. This finding has been corroborated by other researchers, although there has been one study suggesting that the scale used does not affect understanding of data, w
quality of other information in the media may account for this. In addition to und
the shape of a graph, other concerns around graph use in the media include the us
that the public understand how other factors might be influencing the numbers sh
of infection may not also include information about changing rates of testing for t

COMPREHENSION

1. Explain why effective science reporting can be so difficult.
2. What is the difference between correlation and causation?
3. Why is there controversy surrounding the link between fructose and diabet
4. Explain the importance of including absolute risk data in science news abou
5. Describe why good graph production can be difficult.
6. Suggest what different conclusions people might come to about the progress o reading a graph with a logarithmic rather than a linear scale, if understanding o this matter?

DISCUSSION

Discuss the importance of high-quality science reporting.

TASK: RESEARCH

Working individually or with a peer, use your existing knowledge together with a public information leaflet or web page to educate non-scientists on how to recog

You can use the reference sources below and should include at least two more o your references with care, ensuring that you source information only from reputa bibliography of all the pages that you use and include this at the end of your leaf

- **https://theconversation.com/how-to-spot-bogus-science-stories-and-read**
- **https://www.compoundchem.com/2014/04/02/a-rough-guide-to-spottin**

EXTENDED ANSWER QUESTION

A team of scientists investigated the effect of a high fructose corn syrup (HFCS) d They fed one group of mice a diet high in HFCS for 12 weeks while a control grou The scientists then fed the two groups of mice an identical meal and monitored t minutes. Some of their results are shown in Figure 26. Standard deviations are s

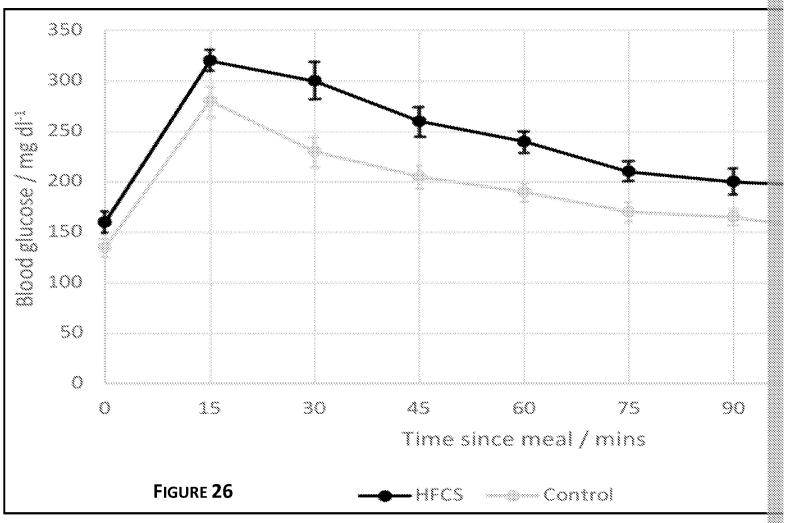


FIGURE 26

A student concluded from these results that HFCS could cause diabetes in human

Evaluate the student's conclusion.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *Bad Science* by Ben Goldacre
- *I Think You'll Find It's a Bit More Complicated Than That* by Ben Goldacre
- *How to Make the World Add Up* by Tim Harford

7. CONSERVATION: IS IT WORKIN

KEY SKILLS
- Evaluating the costs and benefits of different conservation methods.
- Reading graphs and interpreting data.

Humans have been attempting to conserve the world's ecosystems for hundreds o
from the economic to ethical and aesthetic, but conservation methods have not a
over the best ways to conserve biodiversity are ongoing. There are many challen
the world, and effective conservation involves the consideration of multiple facto

- **A growing human population** – there is a strong connection between huma
number of extinctions that take place, and studies have shown that more de
likely to have a greater number of endangered species due to land being us
wildlife for food. There has been conflict and controversy over conservatio
resident populations to move away from their homes in national parks and
indigenous people groups.
- **Poverty** – at a national level, poverty means that government funding for conservation is limited, but at a local level it can increase conflict between humans and the wildlife that they live alongside. Poorer communities are more likely to rely on the natural resources around them, so the risk of habitats being lost to farmland and over-hunting becomes greater.
- **War and disease** – since the 1950s, most of the conflicts that have occurred around the world have coincided with the most biodiverse regions, and though the impact of war on nature can vary, its effects are most often harmful, e.g. increased hunting and habitat damage. The recent COVID-19 pandemic has had similar consequences with reduced protection for wildlife from poaching and a lack of money coming from tourism.
- **Climate change** – this is a global issue, and reducing carbon emissions worldwide is crucial, but climate change also has local impacts on the survival and distribution of species. This can increase the urgency of conservation efforts but can also change the methods required; ensuring a p
when its conditions are rapidly changing is not an effective use of resources
instead need to focus on both helping populations build resilience to chang
species recolonise new habitats.
- **Lack of funding** – effective conservation projects are often long term, and m
periods can be difficult. Funding can also be poorly distributed among cons
groups and those whose work affects larger, more charismatic species ofte
smaller groups focusing on, for example, invertebrate conservation.

FIGU
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WORKING AROUND THESE PROBLEMS: DO THE STRATEGIES WORK?

Government payments to local people

One approach that has become popular in recent years is known as payment for
involves governments or corporations paying landowners to protect services suc
storage or clean water that their land might offer. There are convincing argume
simple way to provide protection for land while also improving the lives of comm
reducing human–wildlife conflicts. The reality is less simple, however. Most PES
depend on the willingness of landowners to take part, and assessing their effecti
is to say that a landowner wouldn't have left a piece of land wild anyway, or may
develop a different piece of land instead. Payments may need to be long term a
the payments offered by other, more damaging, practices, as well as needing to
different types of land. Some disagree in principle with the idea of giving nature
giving governments and corporations the option to pay smaller landowners simp
their own environmental damage.

A scheme in China known as 'Grain for Green' paid farmers to convert parts of their land back into forest, with evidence suggesting higher annual income for those taking part in the scheme as well as a return to forest or grassland of more than eight million hectares, but there have been some problems with the creation of tree monocultures and non-native trees being planted. In Costa Rica, a national PES scheme has allowed a country that had lost around half of its forest cover to begin a steady recovery. Landowners are paid different amounts based on the amount of reforestation that they commit to, and the scheme aims to focus on lower-income farmers. There is some evidence, however, that larger companies have been benefiting from a greater share of payments, and there are concerns that future funding may not be enough to maintain progress.

FIGURE 28: COVER HAS DO

Large studies looking at the efficacy of PES schemes have concluded that they provide a small overall benefit to conservation, but economic benefits f weaker, with problems such as a lack of proof of landownership among poor farm

Working with communities

Prior to the 1980s, conservationists frequently adopted a 'fortress conservation' m isolate biodiverse areas and prevent people from living within them, entering the This kind of conservation brought conflict between local people and governments, its ethics, and from the mid-1980s a different approach began to gain in popularity (CBC). This approach acknowledges t and indigenous people in conservatio social and economic benefits to com their surroundings. This would seem certainly avoids many of the issues a CBC is not straightforward, and there effectiveness. A study reviewing mul management in tropical forests found involved, but variation in forest healt buy-in meant that not all schemes w and some showed no benefit at all. A community-managed areas to more h found that wildlife populations were different schemes, but that the risk t because of disturbance from large m CBC was used. Areas of concern arou of buy-in even within communities that take part, differing levels of external gover community projects, which can affect outcomes, and doubts around whether com economically from the schemes.

FIGURE 29: *LIOCICHLA BUGUNORUM* IS A RARE BIRD SPECIES FOUND ONLY IN THE SINGCHUNG BUGUN VILLAGE COMMUNITY RESERVE IN INDIA. THE RESERVE IS RUN BY MEMBERS OF THE LOCAL BUGUN TRIBE, AND PROFITS FROM TOURISM ARE SHARED BY THE LOCAL COMMUNITY.

Protected areas

Protected areas such as national parks and nature reserves have been a conserva and their purpose is to restrict human access to preserve pristine habitat. The ar by protected areas has been steadily increasing and is now at around 15 %. This s conservation progress, but research into the value of protected areas is often we and experimental controls. Studies suggest that the level of protection offered va concerns about effectiveness. Some protected areas are selected by government and cost rather than ecological value, and lack of funding and inadequate staffing

comes to enforcing protections. Some protected areas are described as 'paper parks', meaning that they are protected in theory, but the protections offered are lacking and exploitation continues, either legally or illegally. Other kinds of problems involve the value of these areas to wildlife, with protected areas being too small or fragmented with a lack of connecting corridors. Marine Protected Areas (MPAs) are of especial concern, covering only 7 % of the world's oceans with poor enforcement of regulations and including a low diversity of habitat types. Improving the efficacy of protected areas will require governments to focus on the specifics of the types of protection provided rather than on meeting percentage targets, and the quality of research into the most effective protection mechanisms needs to improve.

FIGUR
SOME
STILL S
AS WE

ACTIVITIES (ARTICLE 7)

COMPREHENSION

1. Explain how each of the following conservation mechanisms helps to overc
   described in the first section of the article:
   a. PES
   b. CBC
   c. Protected areas
2. Why is climate change such a huge problem for conservation?
3. Describe some of the problems with PES schemes.
4. Evaluate community-based conservation.
5. What is the purpose of giving a habitat protected area status?
6. List the main challenges facing protected areas.

DISCUSSION

Is conservation working? Include consideration of the effects on local people in

TASK: EXAM QUESTION

1. A group of researchers wanted to find out about the effects of different typ
   on lion populations in Botswana and South Africa. They investigated densit
   in Venetia Limpopo, a fully fenced reserve in South Africa, and in Northern T
   Botswana. Some of their results are shown in figures 31 and 32 on the next
   the following questions:

   a. Describe the difference in lion population densities in the two reserves
   b. Calculate the percentage decrease in population density in Venetia Lim
   c. Suggest an explanation for the differences in population density betwe
   d. Suggest the advantage of using population density as a measure rather
   e. Use Figure 31 (overleaf) to suggest an explanation for the change in po
      both reserves in 2009.
   f. Evaluate the two nature reserves on the basis of the information provi

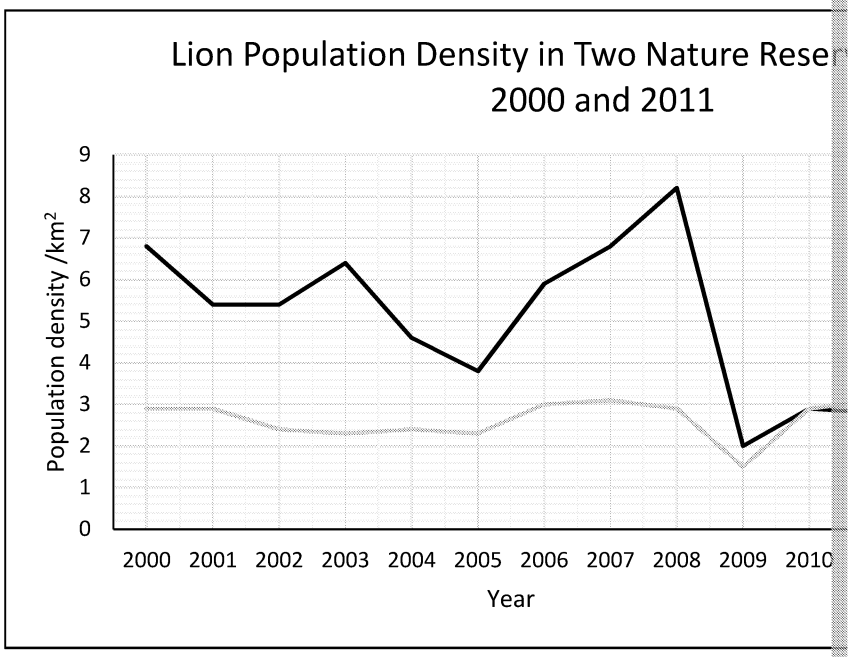

FIGURE 31

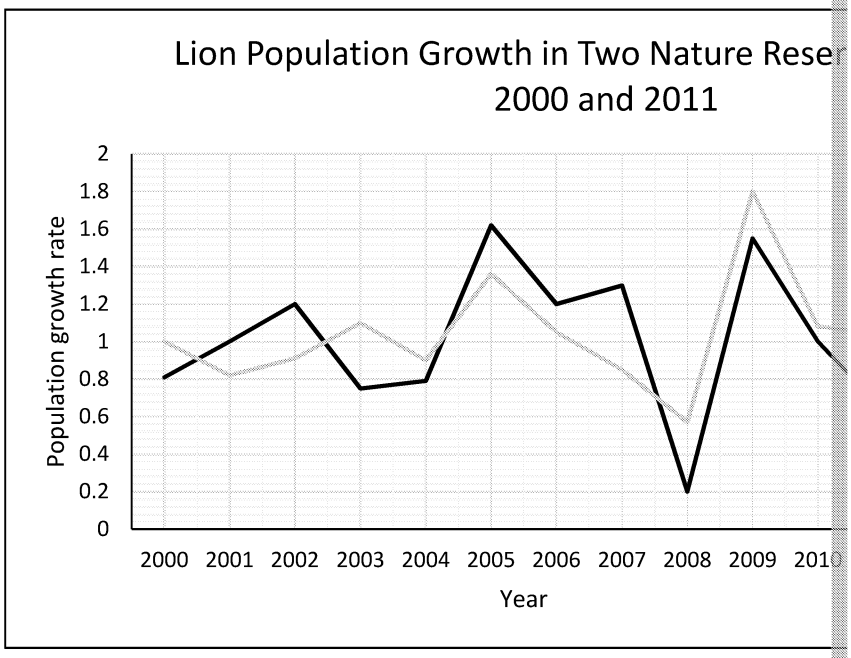

FIGURE 32

EXTENDED ANSWER QUESTION

Outline the ways in which human activities are putting species in sensitive ecosy

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *Working with Nature* by Jeremy Purseglove
- *Wild Hope* by Andrew Balmford
- *Future Sea* by Deborah Rowan Wright

8. GUESSING GAMES: HOW MAN

KEY SKILLS
- Understanding how estimates are developed in biology along with their uses and
- Investigation design.

Towards the end of the seventeenth century, naturalist John Ray wrote 'the species of insects in the whole earth (land and water) will amount to 10,000: and I do believe they rather exceed than fall short of this sum'. Though he later revised his estimate to 20,000, we now know that there are at least this many insect species in the UK alone, and new species are discovered around the world every year. Estimates of just how many insect species there are vary widely and are just part of an overall uncertainty around the total number of all species on Earth. Difficulty in defining the term 'species', especially where prokaryotes are concerned (most of the estimates discussed below apply to the eukaryotes alone) along with historical inaccuracies in classifying organisms, add to the problem and mean that the estimated numbers have changed frequently.

FIGURE 33: THIS NEW FUNGUS SPECIES, NAMED *CORTINARIUS HEATHERAE*, WAS DISCOVERED IN 2020 JUST OUTSIDE HEATHROW AIRPORT IN THE UK

CHANGING ESTIMATES

The number of species that have been currently identified and described a new species are discovered all the time, a even close to describing all of Earth's spe new species are found and described is re until every species has been discovered a estimating species numbers.

Ratio extrapolation

Until the mid-1980s, ratio extrapolation w of estimating species numbers. Research million species and were reasonably conf mammal and bird species had been foun were roughly two to three times as many of these large species found in the tropic species were far less well-documented, but the majority of the described million s and these from temperate regions. Assuming that the ratio of temperate to tropic larger animals, it could be estimated that there would be two to three undiscovere species, leading to an estimated **3–5 million** species in total. This estimate relies o different regions being consistent, and scientists think that it is likely that there are estimate suggests.

Body size

This method relies on the observation that as species increase in body mass they decrease in number. This can be represented numerically on a graph which shows that a body size decrease of 10× leads to a species number increase of 100×, giving an extrapolated estimate of around **10 million** species in total. Scientists are concerned that this method becomes problematic once species reach a body length of less than 2 mm, at which point the method of estimation comes up with numbers that are significantly larger than known numbers. While scientific understanding of the body size to species number relationship is not good enough to make firm estimates, the 10 million species estimate that this method provides is consistent with some other estimates described on the next page.

Host relationships

In 1982, researcher Terry Erwin caused controversy in the world of species numb
study based on the idea that if you know how many species live on any particula
host species there are, it is possible to extrapolate an estimate for the total num
rainforest trees in Panama as his host spec
into the canopy to cause insects high up in t
He then looked specifically at beetle specie
species and grouping them into 'guilds' of h
and scavengers. He then used a combinati
all arthropods are beetles, 20 % of beetles a
diversity is twice as rich as that on the fore
to certain tree species, there are 50,000 sp
an estimate of **3–100 million** species. His w
for the number of assumptions that it mad
host specificity and the proportion of arthro
been claimed that Erwin specifically wanted
community and encourage discussion and r

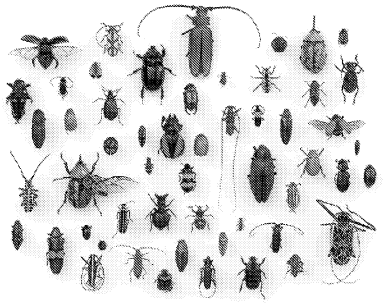

FIGURE 35: BEETLES (ORDER COLEOPTERA) ARE INCREDIBLY DIVERSE, THOUGHT TO MAKE UP MORE THAN 20 % OF THE WORLD'S SPECIES

Arthropods: Invertebrates with tough exoskeletons, paired legs and segmented bodies
arachnids, crustaceans and myriapods (millipedes and centipedes).

Taxonomy

The most recent species estimate, generally considered to be the most accurate,
8.7 million species, with an uncertainty of 1.3 million either way. This estimate i
patterns in numbers of well-known groups such as large mammals (i.e. number o
orders, etc.), and applying the same scaling patterns to groups that are less well-k
applied to the prokaryotes, but it has been generally praised by scientists as it av
other eukaryote estimates. This number would mean that scientists have identif
species, and another 480 years will be needed to find and describe the rest.

COUNTING PROKARYOTES

Classifying prokaryotes in order to count them has historically been very challenging due to the difficulty of culturing many strains in the lab, and to the resolution of microscopes and the identification of different morphologies. Since the advent of DNA sequencing, the possibilities have improved significantly (though the prokaryotic ability to transfer genes between individual adult cells continues to make the process very complex). Scientists often use a combination of the sequenced genome and sequenced RNA from bacterial ribosomes to increase certainty.

One study based on such data predicted that there could be up to a trillion prokaryotic species, but more recent studies, which do not rely on using the same scaling rules as shown in the eukaryotes, suggest that it is more likely to be in the millions.

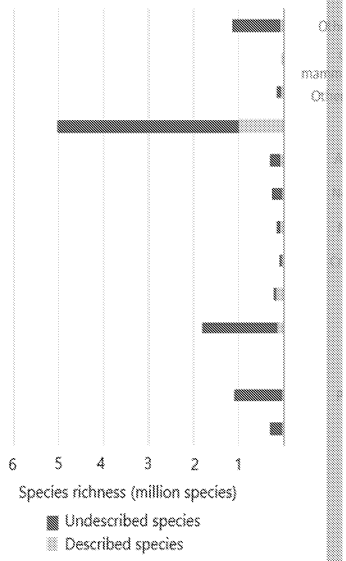

**FIGURE 36: THE SPECIES RICHNESS O
RESEARCH TH**

WHY DOES IT MATTER?

With current estimates suggesting that humans may have hundreds of years of t
important to understand why this work is necessary. Human curiosity is certainly
probes to Mars, then we should probably be keen to find out with whom we sha
though, having an accurate idea of how many species there are can help to infor
Many scientists believe that we are currently living through a mass extinction ev
of losing species before we even knew that they existed. With the natural world
new medicines, materials and services, it is essential that we know how best to c
habitats, and only by knowing where they are and what lives there, can we do th

ACTIVITIES (ARTICLE 8)

COMPREHENSION

1. Why is it so difficult to say how many species there are on Earth?
2. Suggest why uncertainty around the number of insect species has a large im
   species numbers.
3. For each of the following methods of estimating species numbers, state:
   i. the assumptions on which it is based
   ii. any potential disadvantages of the method
      a. Ratio extrapolation
      b. Body size
      c. Host relationships
4. Erwin's study on rainforest beetles was controversial, but he has been prais
   What positive outcomes might his research have provided despite its contro
5. Explain how taxonomy has been used to give the most recent species estim
   the most accurate estimate so far.
6. Explain why the prokaryotes are even more difficult to count than the eukar
7. Use Figure 36 to:
   a. list some of the most- and least-studied groups of organisms
   b. list some of the most- and least-rich taxa
   c. suggest what kinds of organisms might be found in 'other eukaryotes'

DISCUSSION

Discuss the importance of discovering and documenting Earth's species.

TASK: INVESTIGATION DESIGN

Plan an investigation into species diversity in a habitat or habitats of your choice
the following:

- Your habitat of choice and why it might be important to assess its diversity.
- A detailed method description.
- Measures that you will take to ensure that your results are valid.
- How you plan to record and represent your findings.
- Any mathematical analysis that you might be able to carry out, and why.

EXTENDED ANSWER QUESTION

Conservation efforts aim to maintain the world's biodiversity. Outline the advant
and *ex situ* conservation methods.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *The Variety of Life* by Colin Tudge
- *Innumerable Insects* by Michael S Engel

9. INTENSIVE FARMING: THE COSTS O

KEY SKILLS
- Identifying and using good research sources.
- Making connections between different areas of the specification.

WHAT IS INTENSIVE FARMING?

Earth currently supports over 7.8 billion people, and with that number predicted t the next 30 years, food production challenges are only going to increase. Farming early part of the twentieth century in response to growing populations, seeking to produce more food from the same amount of land with lower energy inputs. Intensive farming today involves extensive use of chemical fertilisers and pesticides, heavy machinery and crop monocultures, with larger fields which often require the clearing of other habitat such as hedgerows, forest and wetland. Intensively farmed livestock may be kept in large numbers inside buildings where the animals are fed on high-nutrient feed, often with antibiotics added to their food to keep them healthy and increase their growth rate.

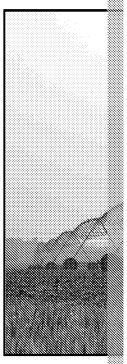

FIGURE 37: I

Every aspect of intensive farming is designed to improve energy efficiency, gaining maximum output from minimum energy input, and many argu ensure that enough food can be produced and made available at low cost to con environmental and ethical impacts are growing, however, and with the climate e urgent, many believe that it is time for a revolution in food production.

THE COSTS OF INTENSIVE FARMING

Chemical use

Although the energy inputs in relation to outputs are low due to improved efficie intensive system, the chemical inputs need to be high to achieve this. Crops mus themselves against pests or competing with weeds, and factors that might limit t eliminated. So farmers apply pesticides, herbicides, fungicides and fertilisers in e maximise yield in a minimal t environment are becoming m the complexity of soil structu concerns around the killing o the fungi that form crucial ne The growth of monocultures a the problem of soil degradati required to provide nutrients t These fertilisers can leach aw to problems such as eutrophi

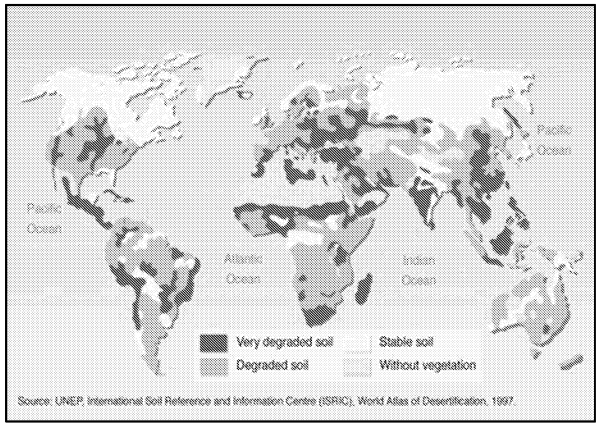

FIGURE 38: LEVELS OF SOIL DEGRADATION ARE THOUGHT TO BE INCREASING AROUND THE WORLD

Biodiversity

Chemical use (see above) is k declines in invertebrate diver lower trophic levels of food c pollinators such as bees. In a increasing, leading to larger fields and often specialisation in production of speci to the loss of valuable hedgerows in the UK and have been associated with a 54 % farmland. Monocultures such as rice, wheat and soy bring all the soil issues desc food variety for invertebrate species, and so for other consumers higher up the f farmland has become a well-known problem around the world, with deforestati spotlight as land is cleared to grow food to feed cattle or to make room for crops

Climate change

Although greenhouse gas emissions from farming are decreasing in Europe, glob
still increasing. Deforestation and changes in land use lead to the release of hug
and the soil, livestock such as cattle release methane during their digestive proce
feed and chemical fertilisers can be fossil fuel intensive. In addition to this, artifi
can release huge amounts of nitrous oxides, gases that have a strong greenhous

Antibiotics

Antibiotics are essential drugs in the fight against bacterial infection in human an
in intensive agriculture is that antibiotics are not only administered by vets to inf
routinely included in animal feed as a preventative measure against infection in c
increasing growth rates. In some countries this kind of antibiotic use is well regu
countries there is no regulation at all. The result of this is that antibiotic residue
from these farms, as well as in the surrounding soil and waterways, having been
along with the animal waste. This is a cause for concern for meat consumers, bu
development of antibiotic-resistant bacteria in animals and in the environment.

Ethics

There is a great deal of concern around the morality of intensively farming animals, with methods sometimes referred to as factory farming. In Europe these practices are highly regulated, but they are still common in many parts of the world. Animals are kept in small spaces to reduce the energy required for movement, increasing the risk of infection and of animals injuring each other. The animals are often kept indoors throughout their lives and can be fed concentrated feed containing antibiotics and growth hormones. There is concern about the potential for animal suffering in these situations, as well as around the quality of the meat produced and the amount of land needed elsewhere to grow the required feed.

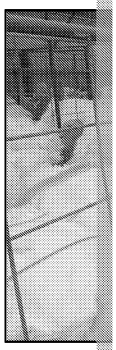

FIGURE 39

Equality

The main argument for intensive farming is that it is the best way to provide eno
prices that ordinary people can afford, but we all know that there are still many h
The current problem is not a lack of food, but a lack of equality; huge amounts o
world are used to feed livestock and make biofuels to supply the rich with what t
the world remain hungry.

THE FUTURE OF FARMING

Given all the problems with intensive farming, there is much discussion about th
comes to sustainable management of the world's resources. The climate crisis n
scientists worry that we are living through a mass extinction of the world's biodiv
needs enough food to eat. Not everyone agrees about the best way to solve all t

Organic farming and sustainable management

Studies show that the yield of organic farming is lower than that of intensive farm
despite this there are many scientists who argue that organic farming should not
about the future of food production. Recent research has shown that in times of
quality on organic farms actually leads to a higher yield than intensive farming, a
to reduce food waste and meat consumption, land use need not increase by all t
organic. Opponents argue that we cannot afford to give over more land to farmi
lack of animal farming would lead to a shortage of the necessary organic fertilise

It is also hoped that by introducing more methods of sustainable habitat manage
the world's resources more responsibly. Agroforestry, for example, combines th
woodland with the growth of agricultural crops and the raising of animals, while
marine habitats can enable fishing to be a form of sustainable food production.

Intensive farming

A more common argument is that intensive farming will need to continue if we a
without increasing our impact on the natural world. One study that uses modell
outcomes has shown that in Ghana and some parts of India, biodiversity is highe
intensive farming than it is when more land is used for wildlife-friendly farming.
can only be directly applied to Ghana and India, it suggests that wildlife does bet
undisturbed habitats, and that more efficient, smaller farms could be better for b

The reality is that the future of farming is unlikely to be entirely organic or entirely intensive, and that beneficial farming methods are likely to differ around the world. Many people in the developing world get their food from small, subsistence farms, so these are likely to remain organic while farmers improve their efficiency so that there is no need to expand into valuable habitat areas. Farming in temperate regions such as Europe, where biodiversity levels are generally lower and much land has already been given over to farming, could benefit from sharing this land with wildlife more effectively and from ways of reducing the damage caused by intensive farming. It is hoped that technologies such as robotics and satellite monitoring, alongside improved biological pest control and fertiliser-release systems, could help to reduce the impacts of intensive farming while simultaneously improving yields.

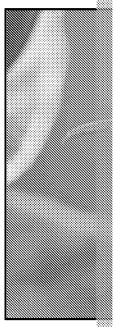

FIGURE 40
EGG
SPECIES-S

ACTIVITIES (ARTICLE 9)

COMPREHENSION

1. List the ways in which farming has intensified through the twentieth centur
2. What are the benefits of intensive farming?
3. What are the environmental concerns about the following?
   a. Pesticides b. Crop monocultures c
4. Explain why the use of antibiotics in animal feed could be damaging.
5. What are the ethical arguments against intensive farming?
6. What are the arguments for and against a future of organic farming and sus
   the world?
7. Suggest the benefits and risks of biological pest control.

DISCUSSION

What should the future of farming look like, and why?

TASK: RESEARCH

New and alternative farming and habitat management techniques are thought t
of food production. Working in a pair or individually, produce a design and the t
presentation, that explains these forms of agriculture and management and disc
problems. Choose your research sources with care and produce a references list

Some examples of relevant farming methods include:

- Aquaculture
- Hydroponics
- Regenerative agriculture
- Agroecology e.g., agroforest
- Sustainable fishing

EXTENDED ANSWER QUESTION

Discuss the conflict that exists between the needs of humans and those of anima

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *Cows Save The Planet* by Judith Schwartz
- *Call of the Reed Warbler* by Charles Massy
- *The Soil Will Save Us* by Kristin Ohlsson

10. STEM CELLS: SCIENTIFIC SENS
SLIPPERY SLOPE?

KEY SKILLS
- Consideration of the importance of ethics in science.
- Application of knowledge from one area of the specification to another.

Although the term 'stem cell' has been in use since the mid-1800s, and the idea
undifferentiated ancestor cells since 1909, it was not until the 1950s that stem
At around that time interest in blood stem cells was increasing, with successful
carried out between identical twins in 1956. Embryonic stem cells were discove
an improved understanding of diseases such as cancer and diabetes, and to mu
regenerative medicine. Stem cell treatments are now available for various cond
in the field of pluripotent stem cells mean that scientists continue to believe tha
Despite their potential, many are concerned about the ethics of stem cell use, a
remains uncertain.

THE STEM CELL SENSATION?

Current therapies

Current stem cell therapies are used to treat blood disorders, including blood ca
In blood cancers such as leukaemia and lymphoma, cancer cells in the bone marr
healthy blood cells, or lead to the production of harmful cells, and cancer treatments such as radiotherapy and chemotherapy are used to destroy the harmful cells in the bone marrow. A bone marrow transplant taken either from the patient's own cells or from a closely matched donor can then be given to replace these destroyed cells with healthy cells.

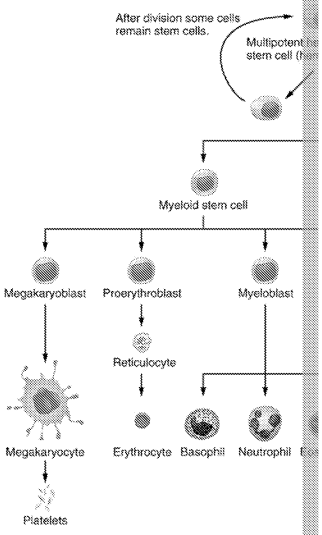

FIGURE 41: THE DIFFERENTIATION

Sickle cell disease is a genetic disorder in which the haemoglobin protein does not function correctly, leading to crescent-shaped red blood cells which can stick together in the blood vessels and prevent the delivery of oxygen to the tissues. Transplanting bone marrow cells from a healthy donor allows the production of healthy red blood cells (only a small proportion of healthy cells are needed to reverse the sickle-cell effect), effectively curing the sickle cell disease. Due to the accompanying immunosuppressant drugs and chemotherapy, this kind of treatment is often on suitable for everyone.

In all these kinds of therapies (unless a patient's own cells are used) it is importa
between the donor and the recipient, and it can sometimes be difficult or impos
good tissue match, a patient's immune system may still destroy the donor cells,

Future therapies

Although therapies for the treatment of blood disorders are the only current appl
medicine, there are other therapies that show promise and which are currently i
a few of the potential treatments at this point in their development.

- **Parkinson's disease** – Parkinson's disease is a neurodegenerative condition c
dopamine-producing neurones in a specific part of the brain, which leads to s
tremor and difficulty with movement. Animal trials injecting induced plurip
brain have so far been promising, and a clinical trial involving one human pa
therapy in humans is safe, with efficacy still to be assessed.
Another trial using embryonic stem cells to treat seven patients in a similar way began in Japan in early 2021.
- **Degenerative eye disease** – stem cell therapy for the treatment of eye diseases such as age-related macular degeneration has been progressing since the early 2000s, and studies involving the use of embryonic stem cells have shown promise so far. There have been a limited number of human studies using iPSCs, with some success at stabilising a patient's vision, but one set of research being halted after abnormal cell activity was detected.
- **Diabetes** – the use of pancreas and islet cell transplantation has been shown to decrease the need for injected insulin in type 1 diabetes patients over recent years, but the shortage of donor organs is a problem. Scientists have been working on generating insulin-producing cells fr
iPSCs, and it is hoped that these cells might be able to perform the same funct
To date, clinical trials involving the implantation of islet cells derived from emb
an 'encapsulation device' to protect them from the immune system) have sho

THE SLIPPERY SLOPE?

Despite the huge potential of stem cell therapies, many are concerned about the
These concerns range from worries about safety through to more complex issue
research and possible future applications.

Safety

Making progress towards effective stem cell therapy involves the completion of c
safety testing is carried out before any treatment reaches this stage, this will still
humans for the first time, which is by its nature a risky process. With stem cells s
results from the very property that makes pluripotent stem cells so valuable: the
differentiate. Once implanted into the body, it is intended that stem cells will di
type, but sometimes they do not behave in the way that is expected, instead dev
differentiated cells called teratomas. These growths are like tumours but can co
teeth, muscle and hair, while also having the ability to develop into a tumour and
Ensuring that cells are specialised before implanting them reduces the likelihood
risk has yet to be eliminated.

Ethics

Ethics is an important area of science that is frequently overlooked by students, b
scientific discovery is applied to a real-life situation, its impacts must be consider

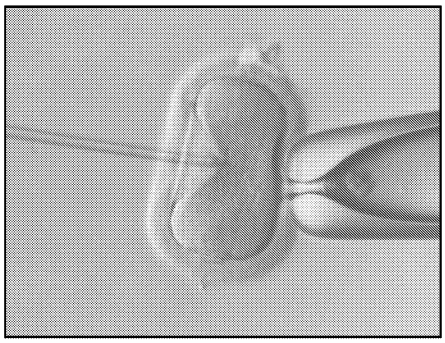

FIGURE 42: AN EGG BEING FERTILISED DURING IVF. OFTEN MORE EMBRYOS ARE PRODUCED THIS WAY THAN ARE NEEDED, LEAVING EMBRYOS WHICH COULD THEN BE USED IN RESEARCH.

The use of human embryos in stem cell res
to many, and, given that views on this topi
about when human life begins, it will rema
absolute conclusion will never be reached
research for saving and improving human li
favour of the use of embryonic stem cells, w
embryos left over from IVF which would ot
improving the ethics of this kind of researc
stem cell world has raised hopes that stem
free, but the reality is that iPSCs have not v
effective than embryonic stem cells, and so

Is there a slippery slope?

For stem cell research to be classed as a 'slippery slope', it not only needs to have
associated with it, but there must be potential for those ethical concerns to get w
that allowing research into embryos now could open the door to other research o
acceptable. The reality here is that embryo research has been going on for decad
around the world, though the level of regulation can shift depending on the views
Other areas of concern in this area include the production of stem cells using cloning technology such as somatic cell nuclear transfer (SCNT) and the production of chimera embryos.

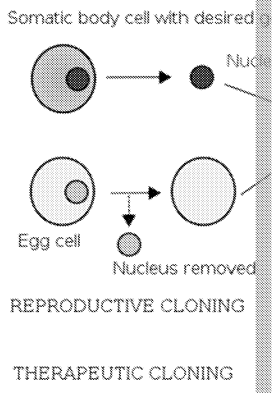

FIGURE 43: SCNT CAN BE USED I
THERAPEUTIC CLONING, WHICH IS
GENETICALLY IDENTICAL TO THOSE O
AND USED FO

- **SCNT** – this technology involves inserting a body cell nucleus into an empty egg cell before encouraging it to develop into an embryo. It has been used to create animal clones such as Dolly the sheep, but if a human cell nucleus is used then it can also be a source of pluripotent stem cells. Although this technically does not involve regular human embryos, and so could be said to avoid some of the usual ethical issues, it is only a step away from human cloning, and so could contribute to the fears of a slippery slope.
- **Chimera embryos** – chimeras are organisms that contain cells from more than one individual. Chimeras can occur naturally if zygotes fuse early in development, but they made the news in early 2021 after scientists create
containing cells from humans and monkeys that survived for longer than 14 d
involved injecting pluripotent stem cells from humans into animal embryos, a
allow scientists to monitor and study the stem cell activity during developme
that by producing a mouse–rat chimera with mice that have lost the ability to
animals made up of mouse and rat cells, but a pancreas made up almost enti
shows that it is possible to use chimeras to grow whole organs and raises the
grow human organs for transplant. Concerns about work like this include wo
as well as questions about what is required for human status. Is a monkey w
is it part human, and, therefore, requiring higher legal status? Might such 'a
What would be the status of their offspring? The moral issues could become

ACTIVITIES (ARTICLE 10)

COMPREHENSION

1. Suggest why the first stem cell transplant was carried out between identical
2. Explain the role of stem cell therapy in treating blood disorders.
3. Evaluate the progress that has been made in trials of stem cell therapy in tre
4. Why are eye conditions such good candidates for stem cell therapy?
5. Suggest why a patient receiving stem cell treatment for type 1 diabetes that the patient's own cells would still need to take immunosuppressants.
6. Describe the risks associated with clinical trials of stem cell therapies.
7. Explain how SCNT provides an alternative method of pluripotent stem cell p

DISCUSSION

Discuss the future of stem cells in medicine along with the challenges faced by re

TASK: MEET THE SPEC

1. What is a stem cell?
2. Define the term **differentiation** in the context of stem cells.
3. Describe two examples of cell types that can arise from stem cells in human
4. What is a plant meristem?
5. Describe two examples of cell types that can arise from cambium stem cells
6. Explain how stem cells might be valuable in the following medical applicatio
   a. Replacing damaged tissues
   b. Treatment of Alzheimer's
   c. Studying development

EXTENDED ANSWER QUESTION

Outline the importance of cell differentiation in multicellular organisms.

EXTENDED READING

The following book goes into more depth on topics addressed in this article:

- *The Future of Brain Repair* by Jack Price

11. VACCINES: THE IMPORTANCE

KEY SKILLS
- Understanding the importance of effective scientific communication.
- Carrying out effective research and making use of reputable sources.

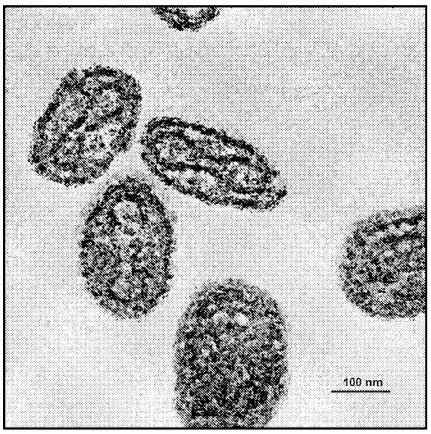

FIGURE 44: THE SMALLPOX VIRUS USED TO KILL 400,000 PEOPLE IN EUROPE EVERY YEAR DURING THE 1700S AND IS THOUGHT TO HAVE BEEN RESPONSIBLE FOR THE END OF THE AZTEC EMPIRE AFTER BEING CARRIED TO THE AMERICAS BY EUROPEANS. THANKS TO THE WORK OF JENNER AND, MUCH LATER, THE WORLD HEALTH ORGANIZATION, SMALLPOX WAS FINALLY ERADICATED IN 1980. THERE ARE NOW ONLY TWO LABS IN THE WORLD STILL HOLDING SMALLPOX STOCKS FOR RESEARCH PURPOSES.

THE STORY OF VACCINATION

The science of vaccination has its origins in E
practice known as inoculation, or variolatio
that caused smallpox), had been practised i
and Asia, for many years before this. Inocu
the skin lesions of an infected person and s
uninfected person. Although there was stil
after this process, death rates after inocula

Eight-year-old Edward Jenner underwent s
before going on to study medicine. During
across and considered the well-known idea
mild disease known as cowpox never went
until 1796 that he decided to test his theor
deliberately used to protect against smallp
lesion and used it to inoculate a local garde
Phipps. Phipps developed mild symptoms o
later inoculated with smallpox he did not b
healthy when exposed to smallpox again so
Jenner concluded that his theory was correct, and named the process vaccination, after the Latin name for cowpox, *vaccinia*.

**FIGURE 45: AN E
TO**

Following this success, Jenner travelled to London to find volunteers to test his new vaccine but struggled to find any willing to help him. It was not until some more well-known doctors began to show interest that vaccination became popular. Jenner spent so much time vaccinating local people for free that his medical business suffered, but he was recognised for his work and eventually vaccination replaced the risky variolation process practised before it.

THE IMPORTANCE OF EFFECTIVE VACCINATION COMMUNICATION

As can be seen from the story of Jenner, even when the process of variolation wa
hesitant to try his new vaccination procedure without additional endorsement. T
today, and the importance of effectively gaining the public's trust around vaccina
For example, in the UK the uptake of the COVID-19 vaccination was incredibly go
but this was not the case everywhere in the world, and this increased vaccine he
to incidences of poor communication and poor science involving vaccinations.

Perception of risk

When establishing trust in a vaccine, helping the public to correctly understand risk is crucial. Most people today are unfamiliar with the dangerous symptoms of many of the diseases we vaccinate for, so the risk of neurological damage, for example, can feel greater than the risk of a disease. Scientists often try to help people better understand vaccine risk by directly comparing the likelihood of harm from a vaccine with the likelihood of harm from the disease that it protects against (see Figure 46).

- **The DTP vaccine** – this was a combined vacc
pertussis (more commonly known as whoop
for controversy during the 1970s. Some doc
hospital wrote an article in which they sugge
between the DTP vaccine and neurological d
passing through their care. This was very qu
was shortly followed by television documen
and the formation of vocal groups of parent
some doctors were doubting its safety. Vacc
80 % to around 30 %, and the lack of data ar
that reassurances from the government ma
until an extensive study was carried out into
neurological complications in children that t
established and confidence slowly began to
and vaccination rates did not recover until t
several severe whooping cough epidemics o

- **The MMR vaccine** – the controversy during the late 1990s and early 2000s a
rubella (MMR) vaccine is one of the most famous vaccine scares and is frequ
science, scientific bias, and the importance of the role of politicians and the
communication. In 1998, Doctor Andrew Wakefield proposed a causal link b
and the presence of the measles virus in the intestines of 12 children follow
multiple large studies refuting any connection between these events, the m
Wakefield's conclusions, politicians refused to admit whether or not they ha
legal cases against the vaccine companies built up. It was not until 2004 tha
withdrew their support for his research, and it took until 2010 for the medic
published his research to remove his article. Soon after this it emerged that
legal team representing parents of autistic children against the pharmaceut
between the vaccination and autism.

- **The AZ vaccine (in Europe)** – developed in partnership with the pharmaceutical company AstraZeneca, this vaccine against COVID-19 was one of several, while being the cheapest and the easiest to store and distribute. It entered the research stages in early 2020, and by the end of the same year it had been approved for use in the UK, shortly followed by approval in the rest of Europe. Uptake in the UK was strong, but soon began to falter elsewhere, and it is thought that this was due to differences in communication about the vaccine in the different countries. Some government officials in the EU were reported to have made comments about the effectiveness of the AZ vaccine, while media stories around a smaller sample of older participants during the AZ trial stages were more widespread in Europe than in the UK. In addition to this, a possible connection made between the AZ vaccine and the occurrence of rare blood clots led to a temporary halt in vaccination in the EU, while in the UK vaccination continued, albeit with slightly altered age range advice.

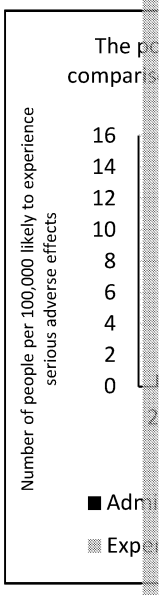

FIGURE 46: DA
RISKS AND BEN
CORONAVIRUS
FOR RI

Some common vaccine concerns:

- Vaccines might cause the disease that they are supposed to prevent.
- Unpleasant side effects, e.g. flu-like symptoms.
- The risk of serious side effects being greater than the risk of the disease, e.g. autis
- Vaccination being unnecessary if disease prevalence is low.
- Not knowing the purpose of additional chemicals inside a vaccine.

Vaccines that have done well

The examples given above show just how delicate public trust in vaccination can creep in, with potentially serious consequences. Vaccination, however, is said to stories of global health, and there have been many examples of highly successfu

- **Smallpox** – in the early stages of smallpox inoculation, Lady Mary Wortley M ambassador to Turkey, was instrumental in encouraging the people of Brita variolation, notably by having her own children inoculated during the 1700s soon after this, and though it was not always readily accepted (see above), i smallpox cases around the world. By the 1960s, smallpox was only present parts of Asia, and the World Health Organization (WHO) launched a campai these places too. By the end of the 1970s there were no more large outbre stages of the programme involved hunting for any final cases and vaccinating everyone in the local surroundings. The last local case of this type was found in 1977, and the final death from smallpox occurred in Birmingham in the UK in 1978, the sad result of accidental release of the virus from a hospital research lab. Smallpox was a good candidate for eradication, being an easily identifiable disease with a short period of contagion and no vectors other than humans.
- **Poliomyelitis** – most commonly known as polio, poliomyelitis is caused by the poliovirus. It is transmitted from human to human through faecal contamination of food and water and it affects the nervous system, sometimes leading to temporary or permanent paralysis. Death rates vary depending on the type of polio strain, but average figures fall between 5–15 %. Polio, like smallpox, has only human vectors, and it has been eradicated everywhere in the world except for Afghanistan and Pakistan. It is thought that the lack of complete eradication is due to factors such as the changing prevalence of different disease strains, political instability and poor sanitation in the regions where it still exists, and setbacks during the spread of the COVID-19 pandemic.

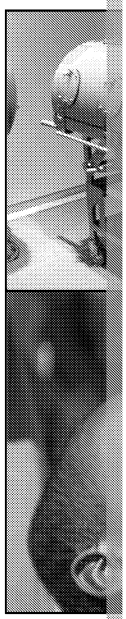

FIGURE 47: A
IN THE MID-1
POLIO PA
ADMIN

ACTIVITIES (ARTICLE 11)

COMPREHENSION

1. Suggest why inoculation is less harmful than being naturally infected with th
2. Evaluate Edward Jenner's vaccine research.
3. List as many reasons as you can for hesitancy and mistrust around vaccines.
4. What problems can be seen with Andrew Wakefield's MMR research?
5. What does Figure 46 show about the risks vs benefits of the AZ vaccine? Us changed its advice to the under 30s, suggesting that they be offered a differ
6. Explain why smallpox was a good candidate for eradication.
7. Suggest why smallpox is the only disease to be eradicated so far.

DISCUSSION

1. Discuss the importance of effective vaccine communication between scientis and the public.
2. Discuss whether or not some vaccines should be compulsory.

TASK: RESEARCH

Evidence suggests that the best way of dealing with vaccine hesitancy is to listen t their questions honestly. Use information in this article, your existing knowledge produce a newspaper column in which you, the scientist, answers multiple questi

Questions could include:

- How are vaccines tested?
- How was the COVID-19 vaccine developed so quickly?
- How do vaccines work?
- Why do vaccines cause flu-like side effects?

You may use these questions, but aim to come up with at least two additional qu article in the style of a Q&A and be sure to explain your answers in a way that is s

Keep a reference list of all of your research sources.

EXTENDED ANSWER QUESTION

Discuss the reasons why changes may need to be made to a global vaccination pr

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *Stuck: How Vaccine Rumors Start – and Why They Don't Go Away* by Heidi J Larson
- *The History of Vaccines* by Karie Youngdahl et al.

12. MONEY IN SCIENCE: THE MAR IDEAS

	KEY SKILLS - Evaluating scientific data. - Considering the importance of experimental design in gaining valid results.

WHO PAYS FOR SCIENCE?

Historically, science was primarily the work of private individuals with the interes their lives to study. Scientists might have had the backing of a wealthy family or v themselves and able to fund their own work. Galileo, for example, was funded b Charles Darwin came from a wealthy family and funded his own work for most o institutions were often also funded by wealthy individuals, and sometimes receiv they were very restrictive in their membership, never accepting women, or men

Although private individuals do still fund science research today, things are gene grants coming from governments, charities and private corporations. While this v provided scientific opportunities to far more people than the earlier systems, it h government funding is often dependent on the priorities of the elected politician that funding from private companies with a stake in the outcome of a study migh The scientific community does have safeguards against this kind of financial bias, interest, peer-review and good scientific journalism, but there are examples of c have been able to control the scientific narrative.

MONEY AND BIAS

The tobacco industry

When scientific research during the 1950s began to produce evidence of a link b tobacco industry became worried about its future and, in collaboration with a pu to launch the Tobacco Industry Research Committee (TIRC). The TIRC released a it said that the link between cancer and smoking was not proven and that it was contributory risk factors. At the same time, the statement reassured the public o concern, and its commitment to scientific research. In reality, the TIRC was desig the emerging evidence about the harms of tobacco; to stir up uncertainty aroun smoking and cancer, to fund contradictory research, and to control the flow of in

The TIRC provided funding to universities to carry out cancer research (though not research into the connection between smoking and cancer) and employed its own scientific advisory board (SAB) to review research and provide legitimacy. Many on the SAB were dismayed at the way their work was controlled by the TIRC, and the misleading messages that the TIRC released to the public, but their worries were drowned out by more vocal SAB members, often smokers themselves, who worked to offer funding to scientists who supported the arguments of the tobacco industry. The result of this campaign was that average cigarettes smoked per individual increased from 3344 per year in 1954 to 4025 per year by 1961, hugely increasing the profits of the tobacco industry.

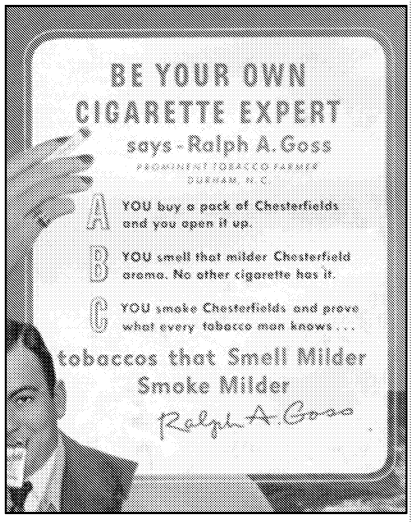

FIGURE 48: PARTS OF TWO 1950S CIGARETTE A CREATED SCIENTIFIC CONTROVERSY S

Today there is widespread acceptance of the causal link between cigarette smoke a
companies are more concerned about finding ways to reduce the dangers of smok
them, but there is still concern around tobacco industry funding behind organisati
giving up smoking, and scientific institutions can face severe criticism for accepting

The plastics industry

Bisphenol A, more commonly known as BPA, is a chemical found in many everyday
storage containers. Molecules of BPA can be released from these plastics when he
stored food and drink and make thei
currently classified as safe by food st
the UK, but many believe that this sh
of BPA have a structural similarity to
oestrogen receptors, meaning that B
and has been linked to development
prostate development in males, and
the diet in such small quantities, thos
does not cross a threshold at which i
argue that it is harmful even at extre

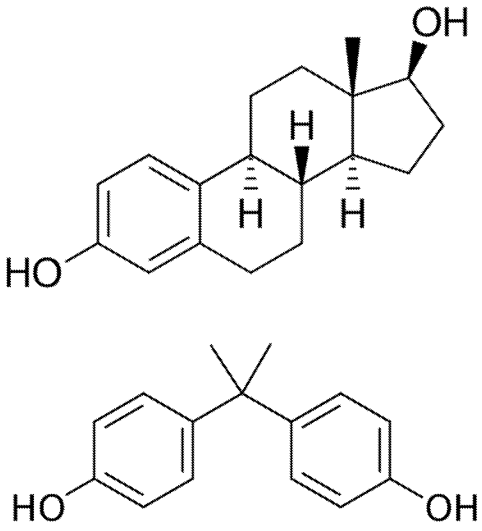

FIGURE 49: OESTROGEN (TOP) IS IMITATED BY BPA (BOTTOM)

Since potential harmful effects were
many studies have been carried out
human health; most studies were g
were privately funded by BPA and p
government-funded studies, more t
significant connection between BPA
none of the industry-funded studies
result. It has since come to light tha
involved a strain of mice referred to as CD-SD which are known to be resistant to the effects of synthetic oestrogens. In addition to this, these industry-funded studies did not include an experimental design feature called a positive control, which would have clearly demonstrated the resistance in the CD-SD mice.

In the attempt to clear up the controversy, the plastics industry went on to fund a review run by the Harvard Centre for Risk Analysis (HCRA) (which at this time had also run studies showing no connection between the risks of mobile phones and driving, funded by the communications industry, and between the risks of mercury poison in fish, funded by the Tuna Association) which concluded that BPA was safe in low concentrations. This review has been cast into doubt by some of the scientists involved, but its conclusion is still used by the plastics industry.

WHO OWNS SCIENTIFIC DATA?

While the effect of funding source on the validity of experiment data is one conc
another is the fate of data collected by scientific organisations. Data is collected
and by private companies, and there are various examples of controversy surrou
money that such information can make for its owners.

Crop seeds

Sixty per cent of the world's seed market is now controlled by four large corporations, and data from the USA shows that 80–90 % of corn, soy and wheat varieties planted there are owned by just one company. In the past, farmers would plant a crop and save a proportion of the seeds to sow the following year. Today, however, plant varieties are often developed by large companies who then own the patents and effectively 'rent' out the seeds, with farmers paying for the right to grow them for just one year. These seeds might be genetically modified or selectively bred to have desirable characteristics and are then sometimes made infertile to prevent seed collection and resowing. This kind of ownership means that poorer farmers often cannot afford to buy the most reliable seed varieties, and also encourages global monocultures that are bad for biodiversity.

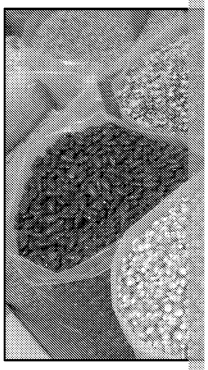

FIGURE 50: SOME SE
SEEDS, WHICH WILL T
SECOND YEAR IF SEED
FOR FARMERS WHO A

Vaccines

Vaccines, like other newly developed drugs, are patented during the early years a
ownership to the companies that developed them and allow these companies to
production. This is to promote competition between pharmaceutical companies
idea being that this will lead to better products. What this also means, though, i
cannot afford to pay the high prices for these patents cannot produce vaccines, a
richest parts of the world. During the COVID-19 pandemic in 2021, there was so
decided to temporarily waive the patents on COVID-19 vaccines, enabling anyon
vaccine to do so. While many praised this step, the UK and the EU were unconvi
effect on competition, as well as worry that it would not make any difference, as
world do not have the knowledge or facilities to produce vaccines even if they ar

Genetic information

Henrietta Lacks was an African American woman who was diagnosed with cervica
1951. Unbeknown to her, her doctor passed her cell sample on to other researche
her cells for scientific research. Her family did no
in use until many years after her death, by which
development of many important drugs and treat
compensation available to her family. Henrietta
today, though her descendants now have more s
This case highlighted the new ethical and philoso
human biological data, and with the publishing o
genetic data has been added to cellular data. The
companies such as 23andMe, that collect DNA sa
order to provide information about genetic disea
companies are amassing huge databases of huma
people must give their consent for their data to b
close family members can also be identified from
cannot give their consent. Medical understandin
databases for research, so such information is cr
of whether someone owns their own genetic info
by a company or a database is a complex one to a
companies are able to make money from selling t

FIGURE 51: HENRIETTA LACKS' CELLS GAVE RISE TO A LINE OF CELLS KNOWN AS HELA WHICH ARE STILL IN USE TODAY. HELA WERE INVOLVED WITH THE TESTING OF COVID-19 VACCINES, AND MORE THAN 17,000 PATENTS HAVE BEEN ISSUED ON PRODUCTS TESTED ON THIS CELL LINE.

COMPREHENSION

1. How was historical science funding different from today's funding models?
2. Describe the strategy of the tobacco industry in the 1950s and 1960s.
3. How has funding by the plastics industry affected perceptions of BPA safety?
4. What is the difference between a negative control and a positive control in s
5. How would the inclusion of a positive control in the industry-funded BPA stu misleading results?
6. What are the problems associated with large company monopolies on crop s
7. Explain why scientific developments are often patented.
8. Why was the COVID-19 vaccine patent waiver in 2021 controversial?

DISCUSSION

Discuss the following statement:

'Researchers should never accept funding from organisations with a financia

TASK: EXAM PRACTICE

1. A group of researchers were interested in the effect of a chemical called BP They treated pregnant mice with either BPA or no BPA (control) and measur offspring to glucose. Some of the results are shown in Figure 52.

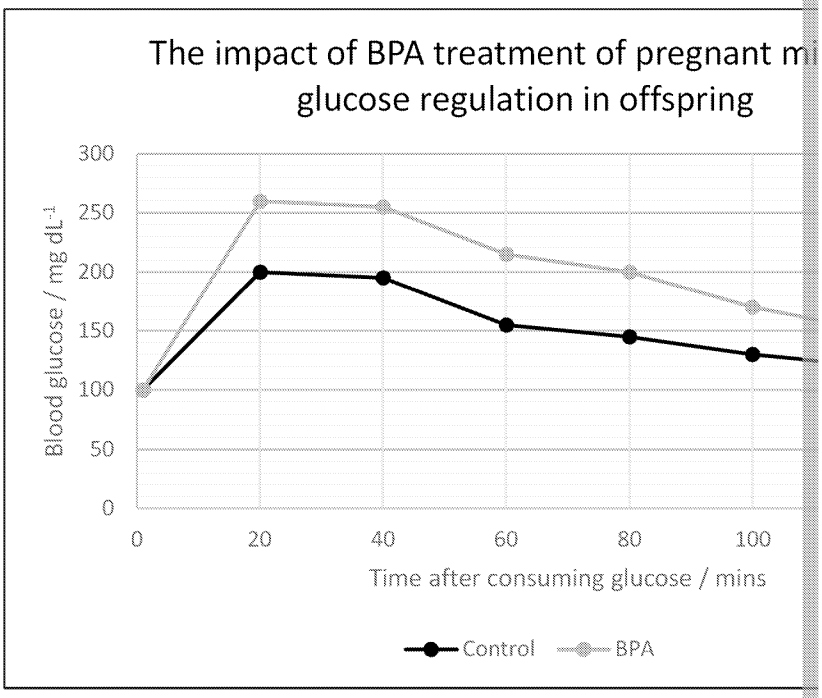

FIGURE 52

Data taken from 'Bisphenol A (BPA) Exposure In Utero Leads to Immunoregulatory Cytokine Dysreg Potential Mechanism Programming Breast Cancer Risk' by Catha Fischer and Ro

a. State the purpose of the control in this experiment.
b. A student read the results of this study and concluded that BPA was a h pregnant women. Evaluate this conclusion.

Figure 53 shows the effect of BPA on the membrane potential of the beta ce
offspring of the BPA-treated mice.

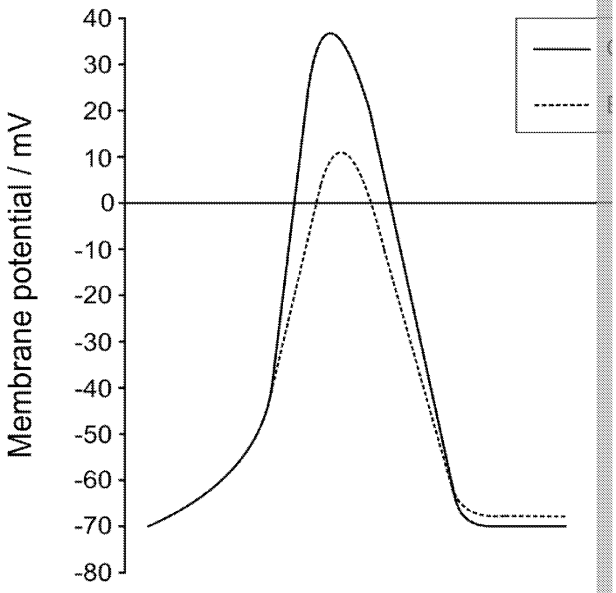

FIGURE 53

c. Describe the impact that BPA has on the membrane potential of the be
d. Use Figure 53 and your own knowledge to suggest an explanation for the re

EXTENDED ANSWER QUESTION

Discuss the ethical issues related to GM technology.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *The Immortal Life of Henrietta Lacks* by Rebecca Skloot
- *The Epigenetics Revolution* by Nessa Carey
- *Bad Pharma* by Ben Goldacre

13. GENE TECHNOLOGY: THE ULT
SOLUTION OR AN ALARMING FUT

	KEY SKILLS - Considering the importance of ethics for biologists. - Carrying out effective research and recognising valid research sources.

Gene technology is a broad term used to describe a range of techniques that involve working with DNA, but it most often refers to processes that involve gene alteration, such as genetic engineering, gene therapy and gene editing. These kinds of technologies are thought to have great potential to produce high-quality food to treat disease, but their use has been controversial from their inception, and many are concerned about their safety and the ethical questions that come with altering an organism's DNA.

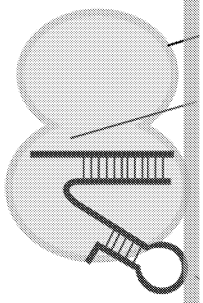

FIGURE 54: CRISPR

TYPES OF GENE TECHNOLOGY

Name of technology	Description	Applications
Genetic engineering	- DNA of both donor and vector is cut using restriction enzymes. - DNA fragment of interest is removed from donor and inserted into vector using DNA ligase. - Vector inserts DNA into new host organism so that it can express a new protein. - Marker genes such as antibiotic resistance genes and fluorescence genes can be used to identify transformed cells.	- Often used to transform bacterial or plant cells. - Bacterial cells can produce useful products such as human insulin. - Crops can be given desirable qualities such as pest and disease resistance to increase food production. - Crops can be given nutritional properties that they would not otherwise have.
Gene therapy	- As above, this involves the use of a vector such as a virus or a lipid envelope called a liposome to insert a DNA fragment into DNA. - Allows correction of mutations. - Carried out in humans for medical reasons. - Can be carried out on adult body cells (somatic cell therapy) or in gametes (germline therapy).	- Treatment of genetic disorders in humans. - Inserting a healthy version of the CFTR gene into the cells lining the airways of cystic fibrosis patients. - Treatment of blood disorders such as sickle cell disease. - Immunotherapy: the genetic alteration of T cells to enable them to target cancer cells more effectively.

Name of technology	Description	Applications
Gene editing	- Involves a technology known as CRISPR (pronounced 'crisper') / Cas9. - A CRISPR is a sequence of DNA which, when transcribed, produces CRISPR RNA, or crRNA. This crRNA then associates with an enzyme known as Cas9. - The crRNA binds to complementary target regions of DNA inside a host cell (the CRISPR can be specifically designed to target any region desired), which is then cut by the Cas9 enzyme. - The cell then repairs this damage to the DNA, and scientists can provide template sequences to control what the repaired DNA sequence will be.	- Clinical trials in the treatmen of blood disorders such as sickle cell disease and thalassemia have involved inserting a CRISPR that cause a mutation in a gene that codes for a fetal haemoglob repressor protein. This means that fetal haemoglob is produced and can take ov the function of faulty adult haemoglobin. - Animal studies involving the correction of a mutation in the dystrophin gene that causes muscular dystrophy have been promising so far. - There is potential to gene ed crop varieties in similar ways to recombinant DNA above.

SHOULD WE BE CONCERNED ABOUT THE FUTURE OF GENE TECHNOLOGY?

There are several gene technologies that have the potential to vastly improve h arrival of CRISPR/Cas9, scientists' ability to edit genomes has increased very qui it is essential that the ethical discussions and regulations keep up with what sci

Ethical questions

- **Safety** – as mentioned in the table above, there are various safety issues th where gene technology is concerned, ranging from the escape of undesira environment to harmful effects on human health. There was great alarm i when Chinese researcher He Jiankui announced that he had gene edited two embryos using CRISPR/Cas9 and that those embryos had developed to term and given rise to two supposedly HIV-resistant baby girls. He claimed that the process had been safely tested on animals, but many are concerned about the unknown level of accuracy of CRISPR/Cas9 and the possibility of unexpected effects from knocking out gene function, both of which might mean that the baby girls grow up with new health issues which they could then pass on to their own children.

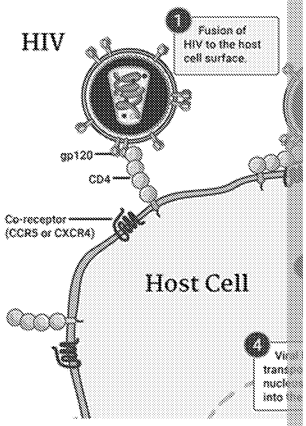

FIGURE 55: HE JIANKUI CLAIM SWITCH OFF THE GENE CODING FO OF CCR5 IN ALLOWING

- **Informed consent** – somatic cell therapy is carried out on fully developed in
give their consent to a medical procedure, and as the therapy only affects th
it affecting future generations. Germline therapy involves altering sex cells o
the future child has no opportunity to consent to the changes, and neither c
- **Equality** – it is likely that many gene technology treatments of the future wil
concern that this may lead to a divide between those who are able to afford g
who are not. When combined with fears over 'designer babies', it is possible
between a genetically healthy rich and a poorer population who still live with
- **Discrimination** – the question of who decides on the desirability of a human trait is difficult to answer. While there are some dangerous medical conditions that it is easy to say we should be aiming to cure, the potential elimination of other, non-life-threatening conditions raises questions of identity and value that are far more complex. Many who currently live with such genetic disorders see it as part of their identity, and the idea that certain genes could be edited out of humanity suggests that our society does not see such individuals as having value. It could be argued that diversity in society is to our benefit, and the eradication of certain conditions could be equated to controversial ideas such as eugenics.

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- **Animal rights** – gene technologies such as recombinant DNA technology and gene editing can be combined with cloning technology to produce, for example, a line of goats that secrete useful proteins in their milk. In such a scenario, genetic modification would be carried out on a goat embryo, which would then be i
female goat and allowed to grow and develop into an adult. This individual c
cell nuclear transfer to give rise to many more goats with the same ability. W
that the goat's offspring will have the desirable characteristic that is of use t
about the low success rate in animal cloning; many embryos and foetuses d
with birth defects, and it is thought that animals cloned in this way may hav

Regulation of gene technology

Chinese researcher He Jiankui was sentenced to three years in prison after effect
with an unproven technique, and following on from this an international group o
halt to all germline work in human embryos that would result in the birth of a ch
was to provide clear regulation and allow time for safe procedures and clear eth
In reality, the regulations around gene technology vary around the world, and w
altered crops is mainly limited to Europe, germline editing other than for researc
almost everywhere, and is prohibited in many places, including the UK and Europ
the UK government carried out a public enquiry to learn about public opinion reg
technologies in food production, with the understanding that regulation needs t
technology while allowing gene technology to be used to improve crop yields an

ACTIVITIES (ARTICLE 13)

COMPREHENSION

1. Describe the process of producing transformed cells using recombinant DNA
2. Give examples of the current/potential applications of the following:
   a. Recombinant DNA technology
   b. Gene cloning
   c. Gene therapy
3. How is the new gene editing technology different from recombinant DNA te
4. How can gene technologies be combined with cloning technology?
5. What kinds of regulations exist to control the use of gene technologies? Ho regulations need to change to remain up to date?

DISCUSSION

Discuss the use of gene technology in human medicine.

TASK: RESEARCH

Working either individually or with a peer, write an article or produce a presenta babies controversy surrounding Chinese researcher He Jiankui. You could find ou

- the CRISPR gene editing process
- the changes that he claims to have made to the DNA of the twin girls, and w
- the reactions of the scientific community
- why the scientific community is so concerned
- the consequences of the scandal for gene editing research going forward

You should produce a references list to include at the end of your article/present sources are reputable.

EXTENDED ANSWER QUESTION

Evaluate the use of cloning technologies.

EXTENDED READING

The following books go into more depth on topics addressed in this article:

- *Frankenstein's Cat* by Emily Anthes
- *Faster Stronger Smarter* by Adam Rutherford
- *The Code Breaker* by Walter Isaacson

ANSWERS

1. Progress in science: the story of D

COMPREHENSION

1. The molecule that he found contained phosphorus and was not digested by protease not be a protein.
2. Their work showed that chromosomes contained the heritable material, and so redu the molecule responsible for heredity. They also made the link between Mendel's w support for his findings.
3. Proteins are far more complex molecules than DNA; they have 20 amino acids rather many more combinations of amino acids are possible in comparison to bases. Scient simple as DNA could not store enough information to give the variety of life that we chromosomes were known to contain proteins as well as DNA, so they were a possib
4. Franklin took Photo 51, an X-ray crystallography image that showed the double helic Maurice Wilkins found the photograph and showed it to his friends Watson and Crick about the double helix and so would not have had this starting point for their DNA st She was not credited for her role until many years afterwards.
5. Avery separated out the components of the bacterial cells and destroyed each comp If the cells were still able to transform the R strain, then the destroyed component co factor'. His results showed that when either the sugar coat, protein or RNA was dest transformed, eliminating these molecules; however, when DNA was destroyed, the f demonstrating that DNA is the transforming factor.
6. Phosphorus occurs in DNA molecules but never in proteins, and sulfur is found in on DNA, so by using these two molecules the researchers can be sure of being able to cl movements of the different molecules.
7. After infection by bacteriophages, the labelled DNA was found to have been transfer the bacterial cells, while the labelled protein remained with the empty phage shells. material on to their host cells, it can be concluded from this that the DNA is the herita

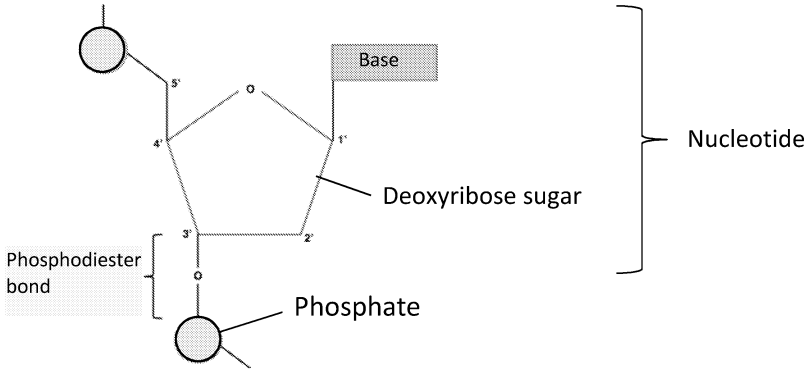
DISCUSSION

Possible points might include:

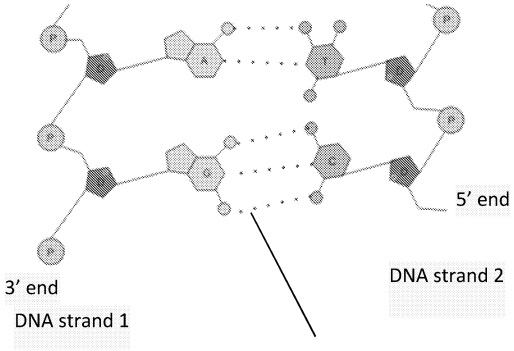
1. - Mendel's work was discredited/ignored at the time that he presented it becaus there was no proposed mechanism for the passing on of his heritable factors.
   - Rediscovery of his work may have given impetus to the search for his heritable
   - Mendel worked with precise numbers and ratios, so his work would have provi factors might function / be distributed among offspring.
   - Mendel's numbers allowed researchers to check their work against existing dat
   - The fact that Mendel's numbers matched those found by Sutton and Boveri pro three scientists.
   - Mendel's work provided a framework for Darwin's theory of natural selection, could have occurred.
2. - The discovery of chromosomes gave support to Mendel's work, leading to its eventu
   - Mendel's work allowed for wider understanding and acceptance of Darwin's wo
   - Work of subsequent scientists adds information to the 'bare bones' of what has understanding progresses in steps rather than leaps, e.g. Miescher discovered t came after him discovered its chemical composition, its involvement with inher
   - Early work on DNA led many to believe that proteins were the heritable elemen
   - It can sometimes take the work of more than one set of researchers for an idea evidence has to be replicated on more than one occasion for old ideas to be re e.g. Avery followed by Hershey and Chase.
   - Improvement in scientific techniques allows for progress; Florence Bell's image double helix, but Rosalind Franklin's did.
   - Putting together the work of several scientists can allow pieces to fall into place of Franklin as well as that of Chargaff to provide them with their model.
   - There are often many wrong proposals before a correct theory is reached, e.g. structure, and actually Watson and Crick themselves worked on alternative stru idea. New discoveries can serve to disprove theories as well as support them.
   - The early work of the scientists on DNA paved the way for modern advanced te fingerprinting and sequencing.

TASK: MEET THE SPEC

1. Something along the lines of:
   a.



   b.



2. a. Both ATP and ADP are phosphorylated nucleotides. ATP consists of a ribose su
   groups, while ADP consists of a ribose sugar, adenine and two phosphate grou
   b. ATP is an energy storage molecule, storing energy for cells in small, usable amo
   when it is broken down into ADP + inorganic phosphate (P_i).
3. F1 generation: BB × bb = all offspring are Bb
   F2 generation = Bb × Bb
   During meiosis the following gametes are produced by each parent: B and b
   This leads to the following cross:

	B	b
B	BB	Bb
b	Bb	bb

   Phenotype ratios: B phenotype × 3 : b phenotype × 1 (3 : 1)
4. Chargaff's base pairing rule meant that one DNA strand would always be compleme
   for the use of one strand as a template for the other. This means that by keeping o
   new strand of DNA could be made that would be identical to the original; a semi-co
5. He discovered the triplet code, which is the way in which four bases can provide a co
   each combination of three bases codes for a particular amino acid. With four differe
   are 4^3 (64) different combinations of bases available, more than enough to encode 2
   one base per amino acid would allow for 4^1, or 4, combinations, and a 'doublet' code
   amino acid would still only give 4^2, or 16, possible combinations. 64 combinations s
   required, but it does allow for code degeneracy, reducing the potential impact of mu
6. - Add the following to the PCR machine: DNA to be amplified, free nucleotides, D
   - Heat to 95 °C to break the hydrogen bonds in the DNA sequence and reveal te
   - Cool again to around 55 °C so that primers can bind.
   - Reheat to around 70 °C so that DNA polymerase can bind and join free nucleot
   complementary to the template strands.
   - This forms two new copies of the original DNA sequence and is one PCR cycle.
   doubling the amount of DNA each time.

Extended Answer Question

Indicative content:

Transcription
- The hydrogen bonds between the two strands of the double helix break.
- RNA polymerase attaches to the DNA strand at the beginning of a gene.
- RNA polymerase catalyses the joining of free RNA nucleotides.
- Complementary RNA nucleotides line up opposite the template strand.
- Thymine is replaced with uracil.
- The free RNA nucleotides are joined to each other, forming a single-stranded mRNA

Translation
- mRNA leaves the nucleus and enters the cell cytoplasm.
- mRNA attaches to a ribosome.
- tRNA nucleotides carry amino acids.
- tRNA nucleotides with anticodons complementary to the mRNA codons attach to th
- Peptide bonds form between neighbouring amino acids.
- tRNA molecules detach from the amino acids and leave the ribosome.
- Process continues until a stop codon is reached.

Protein formation
- Polypeptide folds to form a 3D/tertiary structure.
- Polypeptides can join with other polypeptides to form a quaternary structure.

Level descriptors

Level 3 (5–6 marks)	An accurate and detailed description of the process of protein s present, and the sequence of events is presented clearly and lo
Level 2 (3–4 marks)	A mostly accurate description of the process of protein synthes More than half of the keywords are present, and the events of p sequence and clearly identifiable.
Level 1 (1–2 marks)	Some accurate description of the process of protein synthesis, b are present, and the information is presented in a disordered w are difficult to identify.
0 marks	No response is provided, or there is an absence of creditworth y

2. Paradigms in science: classificat

Comprehension

1. A set of ideas and/or assumptions that underpin a scientific concept.
2. a.
   - Not all organisms survive for long enough to reproduce.
   - There is competition for resources.
   - Naturally occurring variation exists.
   - Variation in parents can be passed on to offspring.
   - Those organisms with advantageous features are more likely to survive a

   b.
   - DNA contains bases which pair in a complementary fashion.
   - The order of bases determines the amino acid in a protein.
   - The order of bases makes up the triplet code.
   - If the order of bases changes this can lead to a change in the amino acid s
   - The sequence of amino acids determines the tertiary/3D structure of a p
   - The structure of a protein determines its function.
3. Observations are made that do not fit with an existing paradigm. Scientists will loo resolution is possible then the assumptions beneath a paradigm must be changed. paradigm shift.
4. Prions were shown to be able to contain heritable information about protein struct that did not fit with the existing assumption that nucleic acids contained heritable i existing assumptions rather than replacing them.
5. He separated the single-celled algae from the multicellular seaweeds when they sh and he classified seaweeds with plants when they are in fact protista.
6. They are based on two quite different methods of classification (one molecular, the system splits the prokaryotes into two fundamentally different groups that are not system puts them together.
7. A monophyletic group contains all the descendants of a common ancestor, but the A monophyletic group that included all the prokaryotes would also have to include

Discussion

Ideas for discussion could include:

1.
   - Cell structure, such as eukaryote and prokaryote. This is a useful method beca features and does provide some information about evolutionary relationships and bacteria together, which is phylogenetically incorrect, and it does not allo such as wall structure and cellular reactions. It can also become confusing wh transition from prokaryote to eukaryote.
   - Mode of nutrition, such as heterotrophic, autotrophic, etc. An easily observab divided plants and animals from each other. It becomes more problematic wh included in the system, as some of these are heterotrophs and some are autot
   - Motility. Again, useful for dividing plants from animals but less so when single many of these are also motile but clearly not animals. This also risks grouping
   - Ecological function. Provides easily observable differences that can be very us about biodiversity and conservation, but leads to overlapping groups. It woul together, as well as grouping algae together with plants.
   - Molecular biology, such as DNA, RNA and protein sequences. This has only be allows previously unobservable differences to be seen clearly. It provides a cl difference and shows evolutionary relationships between different groups wit drawn due to convergent evolution. Could be considered to be far more obje students of biology to understand, and not of value to ecologists. Is also incon prokaryote to eukaryote.
2.
   - Global agreement on the identification of organisms is useful for scientists co sharing knowledge.
   - Allows for identification of new species.
   - Helpful to ensure that species at risk are identified and conserved.
   - Allows development of medicines from relatives of species already known to b
   - Identification of invasive species.
   - Avoiding dangerous species of plant and animal.
   - Allows us to learn more about our relationships with the world around us and
   - Naming both organisms and groups of organisms means that we can often kn that we have never come across before just by being told its scientific name.
   - Classifying microorganisms and viruses is crucial for learning about disease an

TASK: EXAM PRACTICE

1. a. - The evolutionary relationships between organisms. (1)
   - The organisms which share the most recent common ancestors. (1)

   b. *Octodon degus* and *Chinchilla lanigera* are more closely related to each other / ancestor than either does with *Cavia porcellus*.

   c.

Domain	**(f) Eukaryote/Eukarya**
(a) Kingdom	Animalia
(b) Phylum	Chordata
(c) Class	Mammalia
(d) Order	**(g) Rodentia**
(e) Family	Cricetidae
Genus	**(h) Mesocricetus**
Species	**(i) auratus**

(1) (1)

   d. - Sequence the DNA / RNA / protein amino acids of the different species. (1
   - Sequences that are most similar to each other / have the fewest differences shar
   - These organisms will be placed next to each other / closest to a node on t

   (Accept converse statements)

   e. DNA, RNA, or protein amino acid sequence. (1)
   NB Must be a different answer to that given in point 1 of part d.

   f. 0.064 OR 0.06 (2)
   (Scale bar measures 11 mm and distance between root and *M. marmota* is 18 m
   1.8 / 1.1 = 1.6 (1)
   1.6 × 0.04 = 0.064

EXTENDED ANSWER QUESTION

Indicative content:

Arguments for current classification as same species

- Whales all have similar colouring/markings.
- Body shape of all whales is very similar.
- Body size/mass differences could be environmental rather than genetic.
- Ranges of whales are similar / could overlap, allowing interbreeding.
- No statistical analysis to show whether differences in DNA bases are statistically sign other species to show whether differences in DNA bases constitute different species
- Very few DNA differences between ecotypes B and C, suggesting that they could be t

Arguments against current classification as same species

- There are visible differences in whale markings.
- The shape of the dorsal fin of ecotype A is slightly different from that of ecotypes B a
- There are visible differences in body size/mass.
- The ecotype distributions are different / may not overlap, preventing interbreeding
- There are many DNA differences between ecotype A and ecotypes B and C, suggesti

Level descriptors

Level 3 (5–6 marks)	Evaluation refers to all information in the table, is clear and is lo understanding of the criteria for separating/grouping species is DNA differences and interbreeding.
Level 2 (3–4 marks)	Evaluation refers to most information in the table, is reasonably organised. Understanding of the criteria for separating/groupin references to DNA differences and interbreeding.
Level 1 (1–2 marks)	Evaluation refers to some information in the table, but lacks cla understanding of the criteria for separating/grouping species is
0 marks	No response is provided, or there is an absence of creditworth

3. Endosymbiosis: cells inside cells

Comprehension

1. The ancestors of eukaryotic cells developed an endosymbiotic relationship with aer
prokaryotes. These internal symbionts then evolved into modern mitochondria and
2. Symbiosis is a permanent relationship between two species. It is often advantageou
evolutionary advantage. Endosymbiosis is a form of symbiosis which involves one o
body of its partner, or host.
3. Successful cultures of mitochondria would have demonstrated their ability to live in
their bacterial origins.
4. There was no way to provide the necessary evidence to back up the theory, so it re
it was possible to look at intracellular structures with an electron microscope and to
present evidence for this older idea.
5. Raff and Mahler proposed that intracellular organelles could have developed from in
membrane, and Bogorad suggested that cellular DNA could have split within the cel
membrane compartments around each DNA cluster. These theories are both examp
form within existing cells rather than with the involvement of other cells.
6. a. We would expect DNA to be present inside chloroplasts if chloroplasts originate
The similarities between chloroplast and bacterial DNA provide further support
   b. This is like (a) but fits with the hypothesis that mitochondria originated as free-
   c. This discovery does not fit with the internal development theories of Raff and M
suggesting that the rRNA inside chloroplasts had an external origin, specifically
with cyanobacteria than with algae.
   d. This is consistent with the organelles having been taken into the cell by some fo
membrane could have formed from the host cell surface membrane, while the
original endosymbiont.
   e. This suggests that the ribosomes of Mt and Cps originated in prokaryotic cells ra
host cell.
   f. This is like the replication method of bacterial cells, and the ability to replicate i
their time as free-living cells.
7. The use of membranes as evidence in the endosymbiont theory requires that those r
those organelles were free-living bacteria, but membranes are not replicated from o
synthesised anew from molecules coded for by a cell's DNA. If the genes required to
only present in the host cell then this could be considered counterevidence, while th
organelle's DNA could help to support the theory.

Discussion

Possible points for discussion:

- Darwin's theory was based on the idea that competition exists between organisms.
successfully will survive and pass on their successful alleles. (Darwin famously wrote
of the structure of any one species had been formed for the exclusive good of anothe
theory, for such could not have been produced through natural selection.')
- Competition acts as the selection pressure.
- Early scientists struggled to reconcile this need for competition with the idea that in
together and effectively help each other; this seemed to go against 'survival of the fi
and each organism being in a constant fight for its own survival against every other o
- Darwin's theory also contains the idea of gradual change, not large changes taking pl
- Endosymbiosis involves not only interspecies cooperation but also the emergence of
of a single phagocytic event.
- Scientists had to accept symbiosis as a successful strategy, and, not only that, but as
co-evolution of two species, and as a strategy that could lead to speciation in a singl
- Understanding that cooperation is an important evolutionary strategy is essential to
could have evolved, as well as explaining other examples of symbiosis.

TASK: RESEARCH

Suggested answers to the research questions from the links provided:

- **What different lines of thought are there?**
  - Autogenous (changes happening within the cell itself) vs endosymbiotic develo
  - The eukaryotic nucleus only evolved once, but there are various examples of n bacteria which suggest that multiple mechanisms of evolution might have bee
  - Compartmentation of the nucleus is thought to provide evolutionary advantag cytoplasmic enzymes or viral interference and prevention of the translation of
  - Mitochondria endosymbiosis could have introduced the genes for internal me allowing the cell to construct its own nucleus.
  - The cell could have engulfed an archaea cell known as an eocyte.
  - The original host cell could have been a simple cell that used RNA instead of D This archaeon then provided the majority of the genes found from the nucleus.
  - Could have been fusion of a bacterial cell and an archaeon.
  - Could have been an endosymbiotic relationship with a virus.
  - A virus could have contributed its 'nucleus-building' genes to the existing geno
- **Is there any evidence/critique for existing theories?**
  - Nucleus has some similarities to mitochondria and chloroplasts, e.g. double m ability to replicate.
  - The eukaryote genome seems to contain information from both the archaea a
  - Nuclear membrane with its nuclear pores is different from bacterial membran
  - Some archaea have histones, a feature that they share with eukaryotes.
  - Some viruses build their own compartment inside a cell to separate transcript known as nucleocytoplasmic large DNA viruses (NCLDVs).
  - NCLDV compartments have inner and outer membranes, and are also a simila
  - Poxviruses have similar DNA polymerase enzymes to eukaryotes.
  - Lots of differences between bacterial genomes and eukaryotic ones, appearing nucleus being a bacterial endosymbiont.
  - A few scientists have all been working on the virus theory independently of ea promising evidence.
  - Coronaviruses construct double-membrane compartments which contain pore
  - Viruses frequently take genes from cells, so it is hard to be sure whether the s genes to eukaryotes or taking them.
- **Note**: the third article provided in the question contains the phrase 'energy-produc be aware that they should never refer to energy as being 'produced'; this phrase wi They can refer to ATP being produced, or to energy being released.

Extended Answer Question

Indicative content:

Compare (similarities)

- Both contain genetic material / DNA.
- Both have ribosomes for protein synthesis.
- Both have cell surface/plasma membranes.
- Some eukaryotes have cell walls, as do prokaryotes.
- Some eukaryotes and some prokaryotes have flagella.

Contrast (differences)

- Eukaryotic cells are larger than prokaryotic cells (10–100 µm contrasted with < 2 µm
- Prokaryotic cells have a single, circular chromosome, while eukaryotes have multiple
- Prokaryotes have no internal membrane-bound organelles; eukaryotes have nuclei/mitochondria/chloroplasts/vacuoles, etc.
- The ribosomes of prokaryotes are smaller (70S) than those of eukaryotes (80S).
- The cell walls of prokaryotes are made of the polysaccharide murein whereas those cellulose (both of which are also polysaccharides).
- The flagella of eukaryotes and prokaryotes are made of different substances.
- Prokaryotes have plasmids while eukaryotes do not.
- Some prokaryotes have a surrounding capsule outside their cell walls while eukaryot

Level descriptors

Level 3 (5–6 marks)	Response shows a detailed knowledge of the structure of both and is clear and logically structured. Many key terms are used 'compare' and 'contrast' are covered equally.
Level 2 (3–4 marks)	Response shows a good knowledge of the structure of both eu reasonably clear and well structured. Several key terms are us both 'compare' and 'contrast' are covered to some extent.
Level 1 (1–2 marks)	Response shows limited knowledge of the structure of both eu lacks clarity and structure. Few key terms are used in their cor or 'contrast' is missing or lacking creditworthy material.
0 marks	No response is provided, or there is an absence of creditworth

4. From assumption to evidence: the story

Comprehension

1. Theophrastus's theory that the side of the plant nearest to the Sun dries out faster a direction. This suggests that the plant is sensitive to the sunlight but does not activ
2. He observed that the sundew plant responded to specific types of touch and conclu system' of some sort. This led to his later investigations on other types of plant res
3. Circumnutation is the word that Darwin used to describe the circular motions of the grow along a support. He concluded from his research that all plant tropisms are ba motion, and that the motion leads to the different growing directions seen in respo
4. Frank's results suggested that one mechanism acting differently in different plant tis tropisms. We now know that IAA forms a gradient across both roots and shoots bu to it; in shoots it causes cell elongation, but in roots it inhibits cell growth.
5. a. Auxin redistributes itself along the shaded side of the stem, causing increased c shoot to bend towards the light.
   b. The cap on the top of the shoot prevents the light from reaching it, and so aux stem. The shoot grows straight upwards.
   c. The cap is clear, so light reaches the top of the shoot and the process describe
   d. The growing tip is removed, so auxin cannot move from the tip into the stem, a
   e. The light is prevented from reaching the main part of the stem, but this has no auxin, and the process described in (a) takes place as normal. This demonstrat as opposed to the main stem.
6. - Whether or not plants can actively respond to stimuli.
   - The stimuli that cause plant responses, e.g. 'bad air' or low temperatures.
   - The process that leads to stimulus response, e.g. cell turgor, 'irritability' or gra
   - Whether or not plant responses should be compared to animal responses.
   - The theory of circumnutation.
   - The location of the light-sensitive tissue (shoot tip or main stem).
   - The work of Ciesielski on root gravitropism.
   - Darwin's 'amateur' methods vs laboratory work.
   - The Cholodny–Went theory.
7. Darwin repeats his experiments many times on many different plant species, record them in his 'boring' book. He is also very concerned that his experiments are carried compensate for his amateur status and lack of laboratory setting.

Discussion

Ideas for discussion could include:

- Without experimentation and evidence, incorrect explanations can be considered co without challenge.
- Experimentation is essential to move towards true explanations of the world.
- Experiment questions should be based on observations of the world, e.g. Darwin obs carnivorous plants and from this developed his experiments on plant responses to o
- Experiments need to be replicable by other scientists for their results to be accepte
- Experiments must include repeats, e.g. testing many plant shoots/roots, testing mo
- Variables must be controlled, e.g. angle of shoot/root tip removal, amount of shoot/ amount of light received, angle of light received, soil moisture and nutrient levels, te
- Experiments must be recorded with care to allow other scientists to check methodolo
- Conclusions should not go beyond what the evidence shows, e.g. Darwin concluding system just like animals.
- The quality of the science does not always relate directly to the eminence of the sci
- Good science does not always have to be carried out in a fully equipped laboratory.
- New experiments can either build on or lead to questioning of existing theories.
- Questioning theories does not always mean that they are wrong but may mean tha the Cholodny–Went theory.

TASK: EXAM PRACTICE

1. a. A directional response to a stimulus.
   b. Three from:
      - Species/genotype of rice seed. (1)
      - Seeds kept in identical conditions prior to germination. (1)
      - Light intensity / keeping seedlings in the dark. (1)
      - Temperature. (1)
      - Depth of immersion / volume of solution. (1)
      - Use of distilled water to make up solutions. (1)
   c. Immersing seeds on a glass slide into distilled water/solution without IAA adde
   d. So that a fair comparison can be made between the seedlings / to cancel out a of growth.
   e. - Increasing IAA concentration from 0.1 µM to 1 µM has little effect on sho
      - The standard deviations of the curvature for 0.1 µM and 1 µM overlap, sh difference between these two sets of results. (1)
      - Increasing the concentration of IAA above 1 µM causes a decrease in sho
      - At a concentration of 100 µM no shoot curvature occurs at all. (1)
   f. - Each increase on the scale goes up by an order of magnitude (rather thar each time). (1)
      - Useful for showing data with a large range. (1)
   g. i. 1. The shoot grows straight up.
         2. The auxin/IAA does not redistribute to the shady side of the stem in shoot tip being covered).
      ii. 1. There is a lack of / reduced shoot growth.
          2. No/reduced auxin/IAA is present in the shoot (due to the tip being r
      iii. 1. The shoot grows towards the light.
           2. The auxin is produced in the tip of the shoot, so covering the stem h and redistribution (to the shady side of the stem).

EXTENDED ANSWER QUESTION

Indicative content:

Leaf loss occurs when water is frozen / during the winter

- During the spring and summer, high auxin levels inhibit ethene production.
- In response to shorter days, auxin levels decrease, leading to leaf ageing/senescenc
- Ageing leaves produce more ethene.
- Ethene stimulates expansion in breakdown of cells of the abscission layer (as a resu breakdown), causing it to break and resulting in the leaf falling.

Stomatal closure occurs during drought

- Abscisic acid (ABA) binds to receptors on the cell surface membranes of guard cells.
- Calcium ion channels in the cell surface membrane open, and calcium ions move int
- Increased calcium ion concentration causes other channel proteins in the cell surfac
- This series of channels opening eventually leads to a loss of ions such as potassium i
- Ion loss raises the water potential of the cells, causing water to leave the guard cell
- Water loss causes a drop in pressure / flaccidity in the guard cells, and they close.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the processes of both l clear and logically structured. Many key terms are used in thei processes are covered equally.
Level 2 (3–4 marks)	Response shows good knowledge of the processes of both leaf reasonably clear and well structured. Several key terms are us both processes are covered to some extent.
Level 1 (1–2 marks)	Response shows limited knowledge of the processes of leaf los clarity and structure. Few key terms are used in their correct c stomatal closure is missing or lacking creditworthy material.
0 marks	No response is provided, or there is an absence of creditworth

5. Evolution and genetics: from Darwin and Me

Comprehension

1. Darwin's theory relied on variation being passed down through the generations and blending theory meant that any new variation would be diluted or 'swamped' in ea
2. Darwin thought that cells produced heritable chemicals called gemmules which migr and could be passed on to offspring. The environment could cause changes in gemm
3. He had no evidence for his theory, and the idea that environmental factors lead to v an organism during its lifetime could be passed on to its offspring – a controversial i now know to be (mostly) incorrect.
4. The emergence of epigenetics has shown that the Lamarckian ideas of inheritance o entirely incorrect: environmental factors can lead to epigenetic changes which are k organisms. It is also now known that nucleic acids can travel around the body outsi gemmules, and there is some evidence that these extracellular nucleic acids can aff
5. Mendel's work was carried out on discrete factors such as colour and shape, while D through small differences. The two ideas were considered to be incompatible with e
6. Fisher was convinced that large, apparently discrete changes could be brought abou many heritable factors which acting alone might cause only very small changes. Thi Darwin's and Mendel's changes could be caused by the same mechanism.
7. The purpose of a chi-squared test is to establish whether or not the difference betwe significant; in this case, Mendel had a theory about what he expected the ratios to b Fisher to see whether Mendel's results matched his theories, and how closely. He w Mendel's results matched his theories more exactly than could be reasonably expect

Discussion

Possible points for discussion could include:

- Darwin clearly wrote to his colleagues often, and this would have helped him to ho
- Darwin's work would have been effectively 'checked' by many other scientists work problems with his theory could be spotted and discussed.
- Other scientists could work on the same problems as Darwin, increasing the chance solution / disprove incorrect ideas, e.g. Dalton.
- Darwin's work was read by Mendel, affecting his ideas and giving him a context for t
- Had Darwin read Mendel's work he could have avoided many of his later worries.
- If more people had heard Mendel's work than just the scientists in the room when h would not have been forgotten until many years later.
- Scientists from across different disciplines need to be aware of each other's work, in problems, e.g. Fisher was a statistician, but he had a lot to offer the field of genetics
- Scientists can scrutinise each other's work to check for inaccuracies or biases that th aware of, e.g. Fisher and Mendel.

Task: Meet the spec

1. a. The process by which evolutionary change takes place. Naturally occurring vari survival rates of organisms, and so affects their chances of reproducing and pas
   b. Used to describe traits that are passed from one generation to the next / from p trait to be heritable it must be determined by the genes rather than by enviro
   c. A membrane-bound sac containing chemicals which can be transported around endocytosis or exocytosis.
   d. A section of a chromosome / of DNA that contains the code for building a sing e
   e. Data that is not continuous but that can only be assigned certain values, e.g. ta graduations in between.
2. - Naturally occurring genetic variation exists in a population as the result of gene or genetic mutation.
   - Selection pressures such as predators or food shortages mean that some of thi
   - This advantage increases the likelihood that these individuals will survive and r advantageous alleles.
   - If the selection pressures remain the same then the frequency of these alleles w

3. Epistatic genes or allele combinations can mask the expression of other genes, while two genes being inherited together, reducing variety among offspring. Both events relation to expected outcomes.
4. a. Calculating the number of individuals in a population that are either homozygo when it is impossible to do this from looking at phenotype alone. It can also b dominant and recessive alleles.
   b. - No selection is acting on a population.
   - No organisms are entering or leaving a population.
   - Mating is random.
   - Population is large.
5.

Degrees of freedom	Probability level			
	0.5	0.1	0.05	0.01
1	0.455	2.706	**3.841**	6.635
2	1.368	4.605	5.991	9.210
3	2.366	6.251	7.815	11.345
4	3.357	7.779	9.558	13.277

	f_o	f_e	$f_o - f_e$	$(f_o - f_e)^2$	$(f_o - f_e)^2/E$
Tall	787	798	-11	121	0.152
Short	277	266	11	121	0.455

0.152 + 0.455 = 0.607 (chi-squared value)
1 df
P = 0.05
Critical value = 3.841

The chi-squared value of 0.607 is smaller than the critical value of 3.841 at 1 df and we accept the null hypothesis and there is no significant difference between observe Any difference observed is due to chance.

Extended Answer Question

Indicative content:

- Humans can replicate natural selection using the process of artificial selection.
- Rather than allowing the environment to supply a selection pressure, humans apply which characteristics they want to be present in the next generation.
- Use of a named example, e.g. disease/pest/drought resistance / high yield in crops, horses, high milk yield in dairy cows, soft wool in sheep.

The following example uses high yield in crops, but marker should substitute the student's

- Breeders select parent crop with high yield, e.g. individuals that produce many seed
- Parent crops are bred together to produce offspring.
- Offspring are allowed to develop and grow.
- Individuals with high yield are chosen from among the offspring.
- High-yield offspring are bred together.
- The process is repeated over many generations.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the process of selective natural selection and is clear and logically structured. Many ke context, and an appropriate example is used throughout.
Level 2 (3–4 marks)	Response shows good knowledge of the process of selective br natural selection and is reasonably clear and well structured. Se correct context, and an appropriate example is referred to mor
Level 1 (1–2 marks)	Response shows limited knowledge of the process of selective b natural selection and lacks clarity and structure. Few key term and an appropriate example is referred to only once or is entir
0 marks	No response is provided, or there is an absence of creditworth

6. Science in the headlines: the use of data in s

Comprehension

1. It relies on multiple factors, including good science, a strong chain of communicatio journalists who are competent scientists and who prioritise public understanding ra
2. Correlation is a connection between two variables, while causation means that one in the other.
3. - Studies linking HFCS to increased diabetes risk provide correlation data and no
   - Studies are often 'ecological', meaning that they are based on observation dat Such studies are lacking in data from individuals and are often unable to contro in the case of diabetes as there are so many different risk factors).
   - Companies with a commercial interest in HFCS are keen to deny the health ris
   - The science on fructose is inconclusive so far; it seems to be good for blood su risks to do with how it is metabolised and its impacts on appetite regulation ho
3. Knowing a relative risk increase without knowing the absolute risk is not useful. On and the increase in risk is it possible to calculate what the new risk level is.
4. - Choices of scale such as logarithmic scales can be confusing.
   - Representations that require the use of error bars can be confusing because gene
   - Relying solely on a graph for information can be misleading when there may be
   - Data can be used selectively to put across a pattern that is misleading.
5. The log curve is flatter than the linear curve, making it appear to those not used to su slowing down and reaching their peak, while the linear curve shows an infection rate t to a misunderstanding of what stage in a breakout a country has reached and could a

Discussion

Ideas for discussion could include:

- Sharing important scientific breakthroughs with people who may be able to benefit treatments (doctors).
- Sharing discoveries with other areas of the scientific community to allow further re
- Securing enhanced financial support from government or charities.
- Improving public understanding of and interest in science.
- Encouraging future scientists to study science.
- Engaging school students who maybe aren't naturally drawn to science.
- Helping the public to make informed choices about things that affect their lives, suc
  - diet
  - whether or not to take up medical treatments / vaccines
  - forms of exercise
  - use of new technologies resulting from advances in computing and engineering
  - behaviours that affect the environment, such as reducing waste production an
- Informing public support / opposition for government policies connected to science
  - funding
  - environment
  - food supply
  - medicine
  - education
- Encouraging appreciation for the natural world.
- Reducing the risk from harmful movements such as anti-vax, climate-change denial, fo
- Teaching those working in potentially damaging industries such as farming, building trade to improve their methods and be environmentally responsible.

Task: Research

Ideas that students may come up with after reading the sources provided:

- Be cautious when studies involve non-human models such as mice and rats; they m
- Beware of bold or unlikely claims, especially in headlines designed to be eye-catchi
- Ensure that you understand any scientific language used.
- Check whether the article links back to an original source of research.

- If something sounds unlikely, check whether it has been covered by other news out
  those outlets are.
- Take note of whether claims have been made by the scientists or are speculation b
- Be aware of language such as 'proven', 'linked' or 'suggests', as these words indicat
  idea being put forward, i.e. something that is 'linked' implies correlation where the
  causation.
- Note situations in which a researcher or media source may have links with a compa
  the outcome of a study.
- Check whether any samples in a study are large enough, and whether they are representa
- Science studies should be peer-reviewed and replicable by other researchers.
- Medical trials should involve a control group, and the gold-standard style of trial is
  the researchers nor the participants know who is receiving a treatment and who is

Extended Answer Question

Indicative content:

Arguments in support of the student's conclusion

- An HFCS diet causes a larger increase in blood glucose after a meal than a control d
- The larger increase in blood glucose that results from an HFCS diet is statistically sig
  for HFCS and control diets do not overlap.
- The blood glucose remains higher after 120 minutes for mice on an HFCS diet than
- Raised/elevated blood glucose can be a sign of diabetes.
- Elevated blood sugar over time can reduce the response of target cells to insulin, le

Arguments against the student's conclusion

- The study is carried out in mice so cannot be directly applied to humans.
- 12 weeks on an HFCS diet may not be long enough to accurately determine its effec
  response may return to normal after a longer period).
- These are the results of one study; more repeats would be needed before drawing
- The findings show a correlation between an HFCS diet and elevated blood glucose,
  increased blood glucose.
- Slightly elevated blood glucose may not be enough to cause diabetes.
- We would need to compare these results with the blood glucose response of diabet
  whether or not the increase in blood glucose is comparable.

Level descriptors

Level 3 (5–6 marks)	Response includes a range of points that both support and ref The answer is clear, logically structured and shows a good und and the connection between blood glucose and diabetes.
Level 2 (3–4 marks)	Response includes points that both support and refute the stu reasonably clear and logically structured and shows some und and the connection between blood glucose and diabetes.
Level 1 (1–2 marks)	Response is unbalanced, only providing points that either supp conclusion. The answer is lacking in clarity and structure and s data interpretation and the connection between blood glucos
0 marks	No response is provided, or there is an absence of creditworth

7. Conservation: is it working?

Comprehension

1. a. Payments help to reduce poverty, meaning that locals need to rely less on the
   A growing population is also more likely to exploit its surroundings, and a finan
   reduce this problem. Ecosystem services bring financial benefits, so may increa
   b. Involving the community should help give local people ownership of conservat
   of growing populations damaging wildlife. A well-managed project should also
   will reduce poverty. During times of war/disease, external agencies will often
   presence may help to manage and protect delicate areas without outside inpu
   to fund projects with community benefits as well as conservation benefits.
   c. May help to prevent hunting of animals for food by large/poor local populatio
   keep wildlife away from crops and reduce conflict with local people.
2. Cannot be dealt with by local-scale action such as establishing a protected area or i
   around the world need to work together and provide necessary funding to allow ch
   Conserving species in their habitats may no longer be possible, and new population
   areas to ensure survival.
3. - They may not have the intended benefit, enabling landowners to develop land
   - They may not be a good use of money; landowners may be receiving money to
   would not have carried out anyway.
   - Distribution of money may not be equitable between large and small landowne
   - Ethical objections to monetising nature.
   - Allows governments/corporations to continue exploiting natural resources while giv
   - Funding needs to be long-term and competitive.
   - Landowners need to be willing to participate.
   - Land management strategies need to be effective (e.g. not reforesting by plantin
4. CBC schemes appear to be extremely attractive, offering benefits to the environme
   rather than excluding local people. They avoid the controversy of asking local peop
   from using resources that they need while allowing benefits gained from the impro
   improve the lives of communities. Many communities may also want to help becau
   may not expect a financial incentive. However, not all communities, or individual m
   to take part in or support these schemes, the benefits may not funnel down to local
   individual households. Governments / conservation agencies may struggle to cede
   others to run their schemes. Conflicts between humans and conservation requirem
5. To prevent/control human access and exploitation of an area to preserve its wildlife
6. - Lack of government support/funding.
   - Lack of staff / poor management.
   - Being unable to enforce regulations around, for example, hunting.
   - Conflict with local people living within/near protected areas.
   - Poor choices of areas to designate.
   - Difficult to design research that establishes the effectiveness of protected area
   - Too small/fragmented / poorly connected.
   - MPAs do not cover enough of the oceans.
   - MPAs are not diverse enough.
   - Protected areas cannot protect against climate change.
   - Too many visitors causing damage to protected areas.

Discussion

Ideas for discussion could include:

Yes

- Large mammal populations in Gorongosa National Park that were decimated by war
- PES schemes in China and Costa Rica have increased forest cover while improving th
- CBC in East Africa has been shown to be just as effective at preserving forest as less
- Singchung Bugun Village Community Reserve has enabled protection of rare bird sp
  from increased tourism.

- Global protected area coverage has been steadily increasing.
- The Great Barrier Reef is protected by a well-managed MPA.
- Attitudes towards conservation methods have changed, meaning that there is a bet
  involve local people and governments in conservation.

No

- The scale of the climate crisis is greater than all small conservation efforts.
- Human population is still growing.
- Monoculture reforestation in China.
- Future funding concerns in Costa Rica.
- PES money going to large corporations rather than to locals.
- Not enough evidence of benefits to local people.
- Some CBC schemes have shown no benefit to the habitats concerned.
- Living alongside wildlife can lead to crop damage for local communities, reducing th
- 'Paper park' protected areas.
- Lack of enforcement in protected areas.
- Protected areas are too small and distant from each other.
- Not enough MPAs / lack of diversity of MPAs.

TASK: EXAM QUESTION

1. a. Any three from:
   - Venetia Limpopo (VL) has a higher population density for most of the tim
   - VL shows an overall downward trend while Northern Tuli (NT) remains fa
   - Both populations dip in 2009. (1)
   - VL has a greater decrease in 2009. (1)
   - NT population density recovers more quickly. (1)
   - NT population density is higher than VL in 2011. (1)

   b. 59 % (2)
   OR
   (6.8 – 2.8 = 4)
   4/6.8 (1)

   c.
   - VL is fully fenced, meaning that all lions remain within the reserve, while N
     lions to roam beyond the protected area. (1)
   - Lions leaving NT reserve will be more vulnerable to poaching / more likel
     communities and be killed (leading to a generally lower population densi

   d.
   - It takes into account / cancels out any differences in area between the tw
   - Allowing for direct comparison. (1)

   e.
   - 2008 shows a decrease in population growth for both reserves, leading to
     following year. (1)
   - VL shows a greater drop in growth than NT, explaining the more dramati
     this reserve. (1)

   f. Two from:
   - VL has a generally larger population density, suggesting that full fencing le
     for lions. (1)
   - NT has a very stable lion population, suggesting that conditions are consis
   - VL's downward population trend suggests that conditions in VL reserve co
   - Both populations show a decrease in 2009, so the reserves are not able to
     environmental factors. (1)
   - VL showed a slow recovery from the decrease in 2009, suggesting that co
     growing lion population. (1)
   - VL population is lower than NT population in 2011, suggesting that the fe
     influencing reserve effectiveness. (1)

Extended Answer Question

Indicative content:

- Hunting/fishing local species for food/fur/sport.
- Introduction of non-native/invasive species of plants and animals (either on purpose
  on or outcompete local species.
- Introduction of new diseases which kill local species.
- Development of important habitat for human habitation.
- Pollution from human activities, e.g. burning fuels / oil spills / sewage discharge / lit
- Erosion of land by walking / because of tree loss from deforestation leads to habita
- Soil run-off (resulting from soil erosion) into waterways can lead to nutrient imbala
  pH change, killing aquatic organisms.
- Farming of land can lead to habitat loss (through, for example, deforestation), biod
  pesticides, and fertiliser run-off into waterways, killing local organisms.
- Fertiliser run-off (from farming) can lead to algal blooms / deoxygenated waterways / eu
- On a larger scale, greenhouse gas emissions are changing average global temperatu
  extreme weather events. Species that cannot relocate to new habitats if an existing
  risk of dying out.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the impacts of human a and is clear and logically structured. Many key terms are used i
Level 2 (3–4 marks)	Response shows good knowledge of the impacts of human act is reasonably clear and well structured. Several key terms are u
Level 1 (1–2 marks)	Response shows limited knowledge of the impacts of human a and lacks clarity and structure. Few key terms are used in thei
0 marks	No response is provided, or there is an absence of creditworth

8. Guessing games: how many spec

Comprehension

1. Answers could include:
   - Historical classification errors.
   - Difficulty in defining a species.
   - Poor scientist communication in the past meant that species were described m
   - There are a lot of species to find!
   - Many organisms are very small.
   - Prokaryotes are especially difficult to classify.
2. Insects are the largest of the taxa, and most species are yet to be described (shown
   discovered all the time. These things mean that there is a high level of uncertainty a
   world's species.
3. a. Ratio extrapolation
      i. Most large species have been found, and the ratio of tropical to tempera
      is in larger species.
      ii. Relies on the assumptions above, and scientists think that there are prob
      estimate states.
   b. Body size
      i. Body size to species number rule applies in the same way across all sizes a
      ii. Rule appears to apply differently in very small organisms, and scientists a
      understanding of the size–species relationship.
   c. Host relationship
      i. 40 % of all arthropods are beetles, a certain percentage of beetles are in e
      is always twice as rich as that on the forest floor, beetles are host-specifi
      50,000 species of tropical tree.
      ii. Assumptions above are not proven, range of estimates provided is very la
      previous estimates.
4. - A much larger estimate, making the scale of the unknown obvious and increasing
   - Showing how many unproven assumptions had to be relied on provided many
   estimate could not be improved until more of these assumptions had been stu
5. Patterns of numbers seen among the main taxonomic groups in larger, more-well-s
   less-well-studied taxa. This avoids the ecological assumptions made in the other es
6. Their size makes it difficult to identify morphological features that could help to cla
   sexually, so the biological species concept cannot be used, and horizontal gene tran
   difficult, and it is not possible to culture all species in a laboratory setting.
7. a. Most studied – chordates, plants, molluscs
      Least studied – viruses, prokaryotes, fungi, 'other eukaryotes'
   b. Most diverse – insects, fungi, prokaryotes, 'other eukaryotes'
      Least diverse – chordates, crustaceans, molluscs
   c. Single-celled eukaryotes such as amoeba and Euglena, the protists (seaweed, a

Discussion

Points for discussion could include:

- Fulfilling our curiosity.
- It is right that we should know what species there are.
- Learning about evolutionary processes.
- Rates of extinction are increasing and we could lose species before we know about t
- Knowing which species live where could help to focus conservation where it is need
- Interest in new species discoveries could improve funding for conservation.
- Potential for finding new medicinal compounds in, for example, plants and fungi.
- New building materials and fibres, e.g. building with mycoprotein, sustainable cloth
- Species which may aid the management of ecosystems, e.g. plants/algae that remo
- New species may have genes for desirable traits that could be discovered, sequence
  e.g. crop varieties that are resistant to disease, pests, etc.
- Better understanding of prokaryotes could bring potential for new antibiotics, new v
  bioremediation opportunities, etc.

TASK: INVESTIGATION DESIGN

Suggested ideas for each section are given below. This list is not exhaustive.

- **Your habitat of choice and why it might be important to assess its diversity**
  - Named habitat example, e.g. woodland, arable field, wetland, domestic garde
  - Could be investigating the effect of certain management techniques on an are conservation measures, or of the use of a new pesticide, etc.
  - Could be looking to compare two different areas with a different named facto
  - Could be making an initial assessment of an area to inform future land use/ma
  - Could be interested to find out what lives in an area.
- **A detailed method description**
  - Randomly placed quadrats.
  - Randomness ensured by laying out a grid system over the investigation area a to generate coordinates.
  - Recording species presence/absence in each quadrat for a species richness me abundance in frequency to calculate an index of diversity later.
  - For measuring insect abundance could use a sweep net or pitfall traps.
  - In an aquatic environment a net could be used.
  - A mark–release–recapture technique could be described to estimate the size o
  - May want to take some measurements to give some extra detail on the habita soil, moisture levels, aspect, wind exposure, salinity.
  - Consideration given to ethical issues to prevent habitat damage.
  - Any safety measures required.
  - Use of a key or an ID guide to any species likely to be found.
- **Measures that you will take to ensure that your results are valid**
  - Description of how randomness will be ensured (see above).
  - A method for deciding how many quadrats to complete, e.g. continuing to pla species are discovered / keeping a running mean.
  - Sampling always done at a specified time of day/year.
  - If comparing habitats, take the same number of samples in each.
  - Ensure that all researchers can identify species accurately.
- **How you plan to record and represent your findings**
  - Raw data table: could give an example of what the table would look like.
  - Bar chart to show number of each species recorded.
  - If comparing two habitats then need to use different bar colours to distinguish
- **Any mathematical analysis that you might be able to carry out, and why**
  - Index of diversity calculation that takes species evenness into account alongsi
  - Chi-squared test could be used to find out whether the species richness in two

EXTENDED ANSWER QUESTION

In situ

Advantages

- Enables species' habitats to be conserved along with the species themselves, mean be conserved.
- Possible to protect larger populations, which are likely to be more genetically diverse
- Possible to carry out research into biotic and abiotic factors affecting a species' surv
- Directing resources at natural habitats increases the likelihood of recovery.
- Communities can gain a sense of ownership of their local environment and can be i
- Provides the potential for learning about sustainable management or development
- Ecotourism can bring important income to local communities.

Disadvantages

- Difficult or impossible to control some factors that may be affecting a species' surv
- Species may die out if their natural habitat changes or becomes unsuitable for their
- Remaining habitat may be fragmented or broken up, not leaving enough habitat for

Ex situ

Advantages

- Individuals can be protected and their health monitored. Any diseases can be treat
- Environment can be controlled, and any harmful factors removed, e.g. hunting, pred
- Breeding can be assisted, e.g. with IVF techniques, and genetics of a small populatio international breeding programmes.
- Easy to carry out research in a controlled environment, and findings can be applied t
- Establishments such as zoos enable public education around the importance of con

Disadvantages

- A finite number of individuals can be protected, leading to small captive population
- Disease can spread more easily.
- It can be difficult to replicate a species' natural habitat.
- Many species are not easy to breed in captivity.
- Research carried out in captive animals may not be easy to apply to wild population
- Ethical arguments around keeping animals in captivity.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the advantages and dis *ex situ* conservation and is clear and logically structured. Many correct context.
Level 2 (3–4 marks)	Response shows good knowledge of the advantages and disad conservation and is mostly clear and logically structured. Sever correct context.
Level 1 (1–2 marks)	Response shows limited knowledge of the advantages and disa *ex situ* conservation, and clarity and structure are lacking. Few correct context.
0 marks	No response is provided, or there is an absence of creditworth

9. Intensive farming: the costs of effic

COMPREHENSION

1. - Increased use of chemicals such as fertilisers, pesticides and herbicides.
   - Increased mechanisation / use of machinery.
   - Indoor rearing of animals.
   - Larger fields/farms.
   - Monoculture crops.
   - Reduced human labour.
   - Concentrated animal feed.
   - Genetically modified crop varieties.
   - Antibiotics in animal feed.
   - Improved energy efficiency.
2. Increased energy efficiency means that more food can be produced in a smaller spa
   Food costs can be kept low, and enough food can be produced to feed everyone in t
3. a. Pesticides – kill non-target species such as pollinators and dung beetles, reduc
      Killing lots of invertebrates interrupts the food chain, reducing food sources fo
   b. Monocultures – reduce variety of food available to invertebrates, so reducing b
      specific, and huge quantities of the same crop may allow those populations to g
      require the same soil nutrients year after year, allowing the soil to become dep
      degradation / high levels of fertiliser use.
   c. Chemical fertilisers – can leach into surrounding water and cause eutrophicatio
      into the atmosphere, increasing the greenhouse effect.
4. Antibiotics can be found in the meat of the animals, causing a potential health haza
   resistant bacteria will be selected for in both the animals and the surrounding enviro
   infections harder to treat in both animals and in humans who encounter bacteria in t
   antibiotics means that it is easier to keep animals in overcrowded conditions.
5. Poor quality of life for animals that live their whole lives inside, increased risk of illne
   close contact with each other, poor-quality food or food that contains antibiotics an
6. **For**
   - Yield difference can be as little as 8 % below intensive farming.
   - More efficient than intensive farming during drought.
   - Improved soil quality.
   - If food waste problems are improved then not much more land will be needed.
   - Might be a good method in more temperate parts of the world.
   - Many people around the world already gain their food from organic farms.
   - Not everyone can afford to farm intensively.

   Against
   - Yield difference can be up to 25 % – not enough food for everyone.
   - More land would be needed, and in tropical regions with high-value habitat thi
   - Some studies suggest that wildlife does better in larger areas of undisturbed la
     an organic farm.
   - Future technologies may help to make intensive farming more sustainable.
7. **Benefits**
   - Reduction in pesticide use and, therefore, all the problems that they bring.
   - Pest specificity means that only the pests will be killed while other invertebrate

   Problems
   - Pest controllers will only have been studied in their native habitats, so their im
   - Controllers may themselves turn into pests.
   - Controllers may become an invasive species and cause damage to native popul

Discussion

Students are likely to have different opinions on this question but should be able to back
Possible opinions with arguments include:

A combination of farming methods

- Neither method is without problems, so it is likely that we will need a combination
- Different methods may work better / may be more appropriate in different parts of
- Areas rich in biodiversity may need to keep farmland to a minimum, so more intens
- Areas with lower biodiversity and lots of habitat loss already might benefit from im existing farmland.
- Areas with existing soil degradation may have a more urgent need to switch to orga
- Many farmers in developing countries work small subsistence farms and would not intensive farming methods.
- Using both methods could keep food production efficiency high while improving su
- Adding in other, newer farming methods such as agroforestry to complement existi broaden the options / reduce impacts on the natural world.
- Consumers need a choice in what kind of food they want to buy.

Organic only

- Yield not so far below intensive.
- Could work if other problems such as inequality and food waste were addressed.
- Need to protect the world's soils.
- Higher-quality food.
- Happier animals.
- Stopping chemical use would be better for biodiversity.
- Many farmers around the world already farm this way.
- Essential to reduce risk of antibiotic resistance developing.
- Animal exploitation appears to have had a role in the development of a global pand
- Intensive farming of animals requires lots of land just to grow food for animals.

Intensive only

- More energy efficient, so requires less land overall.
- Food is more affordable; not everyone can afford to buy organic produce.
- Making more efficient use of existing farmland allows other land to be set aside for
- Studies showing that biodiversity requires space to thrive.
- Important that owners of small, organic farms in the developing world do not feel t increase their yield.
- Integrated pest control that incorporates biological control will reduce pesticide use.
- GM crops in the future could further reduce the chemical inputs.
- Improvements in technology should mean that the impacts of intensive farming car

Task: Research

A summary of each of the suggested farming methods is given below.

Aquaculture

- The farming of aquatic animals for food, e.g. fish, prawns, mussels.
- Already a large farming sector.
- Can be carried out in freshwater or marine environments and can also be done in s
- Avoids the problems of overexploitation of natural fish stocks.
- More energy efficient than other kinds of livestock farming.
- Produces healthy sources of protein for consumers.
- Concerns over fish welfare.
- Aquaculture within the natural environment can cause pollution if not managed car in the water and can lead to eutrophication.
- Infection in fish pens.
- Destruction of coastal habitat such as seagrass beds and mangroves.
- Using tanks or reservoirs on land can prevent habitat problems.
- Many popular fish are carnivores, so must be fed fish themselves to grow.
- New technologies are allowing the development of fish feed that does not need to c
- It is also possible to farm seaweed.

Hydroponics

- Growing crops directly into water rather than in soil.
- Correct balance of nutrients can be added to the water.
- Waste water from fish farms can be used as it is high in nitrogenous waste.
- Allows crops to be grown on a large scale, often in racks stacked on top of each othe
- Not dependent on soil type or affected by degradation.
- Water medium needs to be oxygenated.
- Artificial lights can provide perfect growing conditions.
- Roots need a support, such as a mesh made from recycled plastic.
- Evaporation rates are lower so less water is needed than in traditional systems.
- Lower risk from pests and infection.
- Provides opportunities for city communities to get involved in growing crops.
- Crops cannot be certified as organic because they are fed using artificial nutrients, t could solve this debate.
- Good for growing leafy vegetables, such as lettuce, but not for growing high-calorie c and potatoes.
- Financial costs of running farms can be high.

Regenerative agriculture

- Makes use of farming methods that prioritise soil health.
- Soil health should improve over time and not degrade.
- Techniques include low- or no-till methods (that do not require regular digging and t chemical use, regular crop rotation, the growing of a variety of crops at any one time crop fields.
- Over time this allows the soil microbiome to regenerate, and the soil becomes more to degradation.
- Undisturbed soil is a better carbon store.
- Healthy soils are more stable so the effects of soil run-off after rain will be reduced.
- Farmers can grow legumes (e.g. clover) between crops to fix nitrogen in the soil.
- Allows farming on soil that is difficult to plough, e.g. heavy clay soils.
- Studies so far show improved yield on regeneratively farmed land.

Agroecology

- A method of farming that treats farmland as an ecosystem, making use of our unde e.g. naturally existing pollinators and pest controllers, nutrient cycling, and compet t
- Aims to enhance the health of ecosystems while reducing the impacts of farming on
- Focus on improving sustainability of farming by improving soil health and reducing c
- Aims to improve the resilience of farms to a changing climate by, for example, growi multiple varieties of the same crop.
- Both traditional farming with chemicals and organic farming can make use of agroec
- An example of agroecology is agroforestry, whereby trees are planted on land perha Animals can graze under the trees, fertilising the soil and having a good quality of li source of wood, nuts, fruits, etc.

Sustainable fishing

- Enables communities that depend on fish as a food source to continue fishing in a way th
- Quotas can be set to limit the number of fish that can be caught and, therefore, prevent
- Quotas will differ between species and ecosystems depending on which fish popula
- Quotas need to take the life cycles of different species into account to avoid the rem breeding females.
- Regulating the types of fishing that can be carried out can help to protect certain ha be especially harmful, and the types of nets used can affect whether or not other sp by mistake.

Extended Answer Question

Indicative content

- Deforestation is often carried out to make way for agricultural land or housing; this l
  fragmentation and huge biodiversity losses.
- Removal of hedgerows to create larger fields leads to the loss of wildlife corridors a
  small animals.
- Animals may eat or trample crops, leading to problems such as illegal hunting and k
  pesticides which can reduce the numbers of ecologically important insect species a
- Grazing animals can change habitats, in some cases for the worse, e.g. grazing on tr
  of trees and lead to their loss from the landscape; this can lead to habitat and biodi
- Grazing animals can remove important grassland or marshland species from an eco
  removing any services such as water retention and soil stabilising that these specie
- Chemical fertilisers are often needed to produce a high crop yield, but these can be
  problems with algal growth and the death of aquatic organisms.
- Certain crop varieties may be preferred for their high yield, but the growth of large
  diversity, reducing potential habitat and food sources for small animals.
- Humans frequently burn fossil fuels to power homes and industry, leading to the re
  global warming / climate change; species that cannot adapt to changing temperatu
- Human meat and animal product production sometimes leads to the intensive farm
  about whether the needs of these animals are being met.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the conflicts between t animal and plant populations and is clear and logically structur their correct context.
Level 2 (3–4 marks)	Response shows good knowledge of the conflicts between the animal and plant populations and is mostly clear and logically s used in their correct context.
Level 1 (1–2 marks)	Response shows limited knowledge of the conflicts between th animal and plant populations, and clarity and structure are lack in their correct context.
0 marks	No response is provided, or there is an absence of creditworth

10. Stem cells: scientific sensation or slipp

Comprehension

1. Identical twins have the same DNA, so the immune system would not reject a transp
2. It can be used to treat blood cancers and sickle cell disease.
   - Blood cancers – the cancerous cells in the bone marrow are destroyed using ra then a healthy bone marrow transplant is used to replace these cells. This tra patient themselves before the cancer treatment, or can be from a tissue-matc
   - Sickle cell disease – healthy bone marrow cells from a tissue-matched donor a where they can produce normal, functioning haemoglobin. This leads to the p which alleviate the symptoms of the disease. This treatment is usually followe immune rejection.
3. - Animal trials are promising, but results should be treated with caution as they m
   - The existing trial in humans involves only one person, so is not representative.
   - The above trial shows that the therapy is safe in humans but not how effective
   - The new trial involves only seven people, which is still a very small sample size
4. The eye is 'immune privileged', meaning that the immune system does not attack fo same way that it does in the rest of the body. This means that any stem cell therapy immune suppressants will not be needed.
5. The patient's immune system destroys the islet cells in the pancreas of type 1 diabe generated from the patient's own body would still contain whichever genes caused t place. This means that there would still be a risk of rejection of those islet cells with
6. - Risks that come with any early clinical trials that involve the progression of a tr animals to being tested in humans.
   - The risk of teratoma formation if the stem cells get out of control, differentiati
   - Teratomas can develop into cancerous tumours.
7. SCNT involves the transfer of an adult cell nucleus into an empty egg cell, which is th embryo. The cells in the embryo will behave in the same way as regular embryonic s alternative source of pluripotent stem cells that perfectly match a patient.

Discussion

Potential points for discussion include:

- Huge potential for regenerative treatments involving replacement of damaged cells in the brain or spinal cord, new heart cells, replacement windpipes, replacement of
- This would mean potential cures for many currently life-limiting conditions such as p lung disease, heart disease and diabetes. Such conditions often have treatments bu causes of death in developed countries.
- A reduction in the need for immunosuppressant medication if iPSCs can be produce
- Making existing therapies – such as that for sickle cell disease – more accessible to a
- Combining gene therapy and stem cell therapy could repair genetic mutations in a pa them, e.g. in type 1 diabetes.
- Embryonic stem cells are still the main source of pluripotent stem cells, and researc controversial for many.
- iPSCs could solve these problems, but they are still unreliable and only a few studies hav
- Stem cells do not always behave predictably, leading to the formation of teratomas a
- Other potential future stem cell uses bring new controversies, e.g. SCNT and the hu chimera embryos and concern around the status of animals in relation to humans.
- Some of these future technologies bring worries about a 'slippery slope' where ethical st

TASK: MEET THE SPEC

1. An undifferentiated cell that has the potential to differentiate into other cell types.
2. The process by which cells become specialised.
3. Erythrocytes, also known as red blood cells, and neutrophils, a type of white blood c
   Red blood cells do not have a nucleus so cannot replace themselves without a sour
4. Regions of a plant where growth takes place; many stem cells are found here.
5. Xylem vessels and phloem sieve tubes. Both cell types arise from a type of meristem t
   are specialised for the transport of water and minerals, and phloem sieve tubes for th
6. a. Stem cells could be encouraged to grow into a specific cell type to form new ti
      damaged tissues, e.g. heart muscle damaged in heart disease, islets of Langerh
      autoimmune attack, or spinal cord that has been damaged due to injury. In th
      these tissues could come from a patient's own body, reducing the risk of immu
   b. Using stem cells to grow healthy neurones could enable the replacement of br
      of Alzheimer's.
   c. Stem cells can be studied during different stages in development, e.g. encoura
      allow the study of developmental disorders, or encouraged to divide under dif
      the development of cancers.

EXTENDED ANSWER QUESTION

Indicative content

- Multicellular organisms are large, active and have bodies that consist of many cell la
- Multicellular organisms need different cell types to carry out different functions.
- Examples of different functions include:
  - Carrying out effective exchange with the environment, e.g. gas exchange, abso
  - Producing important molecules, e.g. hormones or enzymes
  - Transporting substances around the organism's body, e.g. red blood cells, xyle
  - Transporting specific substances across their cell surfaces, e.g. absorption in th
    nerve signals
  - Providing structure and support, e.g. xylem vessels, epidermal cells
  - Providing the ability to move, e.g. muscle cells
  - Attacking invading pathogens, e.g. white blood cells
- Cells need to be able to specialise, or differentiate, to carry out these different funct
- Differentiation involves the development of different cell shapes and combinations o
  - Red blood cells have no nucleus
  - White blood cells have a large nucleus and are very mobile
  - Nerve cells are long and thin and have many transport proteins in their surface
  - Xylem vessels have no cell contents and walls strengthened with lignin
  - Secretory cells have many mitochondria to generate ATP
- Once cells have differentiated, similar cells can work together in tissues to carry out
  tissue in plants, photosynthetic tissue in plants, muscle tissue in animals.
- Tissues can work together to form organs that carry out a particular function, e.g. m
  forms the heart, photosynthetic tissue and vascular tissue forms leaves.
- Organs work together to form organ systems that carry out a particular function, e.g
  out circulation; the lungs, airways and diaphragm carry out ventilation.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the connection betwee cells and is clear and logically structured. Many key terms are u many examples of cell function and specialism are given.
Level 2 (3–4 marks)	Response shows good knowledge of the connection between m cells and is mostly clear and logically structured. Several key te context and several examples of cell function and specialism ar
Level 1 (1–2 marks)	Response shows limited knowledge of the connection betwee cells, and clarity and structure are lacking. Few or no key terms and few or no examples of cell function and specialism are give
0 marks	No response is provided, or there is an absence of creditworth

11. Vaccines: the importance of tru

COMPREHENSION

1. Inoculation involves infecting someone with pus from someone who is already suffe
to contain dead and digested viruses that have been killed by phagocytes, and so wi
without giving the full infection. Some people may still become infected if there are
2. Positive: his research was based on real-life observation; he knew that Phipps had e
infected because he administered it deliberately. Variolation was commonplace at t
been concerned about testing the process on a child. He attempted to test the vacc
a successful vaccine!
Negative: he used only one test subject. He went straight into human testing. He te
may not have fully understood what he was doing. He did not have a control subject
attempted to infect Phipps with smallpox. He was unable to recruit additional partic
3. - Not trusting the person offering the vaccine.
   - The use of animal products inside the vaccine (see cartoon of cowpox turning p
   - Uncertainty from medical professionals.
   - Dangers reported extensively in the media.
   - Hearing about bad experiences of others.
   - Lack of public data on safety and effectiveness.
   - Not being aware of the seriousness of the original disease.
   - Lack of confident endorsement from politicians.
   - Vaccine being cheap (e.g. in the EU, AZ is sometimes referred to as the 'Aldi va
   - Not being confident in the testing procedures.
   - Fear of dangerous side effects.
   - Fear of unpleasant side effects.
   - Worry that the vaccine will cause the disease.
   - The vaccine being ineffective.
   - Not thinking that they need the vaccine.
   - Not understanding how group/herd immunity works.
   - Not understanding the contents of a vaccine.
   - Not knowing how vaccines work.
   - Conspiracy theories / disinformation being spread online.
   - Ethical concerns around the research procedure, e.g. use of embryonic stem ce
4. He carried out his research on only 12 children (a small sample size), his theory was ba
evidence of causation, and he was known to be biased because he was being paid to f
and autism.
5. In the 20–29 age group, the risk of blood clotting appears to be higher than the risk o
hence the government advice that under 30s should be offered a different vaccine. A
from COVID-19 effects becomes greater while the risk from the vaccine becomes les
vaccine outweighs any risk from age 30 and above. Note that these risk levels apply
exposure is low (e.g. during lockdown), and the benefit of the vaccine in comparison
increase if exposure increased (e.g. working in an office, going to the cinema).
6. - It has distinctive symptoms, so can be easily identified and tracked by those me
   for locations where vaccines are needed.
   - It is contagious for only short periods of time, so is less likely to be passed on by
   have a lower rate of transmission. This means that vaccination rates do not nee
   contagious so a high level of vaccination is needed.
   - It only travels through human populations and has no animal vectors, so cannot
   spreading back to humans after being eliminated.
7. There are many factors that influence the success of a vaccination programme:
   - Not all diseases are as easily identifiable so they may be misdiagnosed and con
   - Not all vaccines are equally effective.
   - Some diseases require extremely high vaccination levels to achieve herd immun
   - Some vaccines are difficult to store and distribute.
   - Some diseases spread from animal to human so animals would need to be vacc
   - Political unrest / war / disease means that vaccinators cannot get to places whe
   - Many people live with poor medical care and sanitation.
   - Vaccine hesitancy.
   - Government support.

Discussion

Possible points for discussion could include:

1. - Good understanding of how vaccines work increases public confidence.
   - Scientists are often trusted figures.
   - Scientists can present data from testing and demonstrate safety.
   - Scientists can explain the contents of a vaccine.
   - Scientists agreeing with each other can improve confidence.
   - Government support can increase confidence among those who trust the gove
   - The media response often depends on the government, and this will be how n
   - Remarks made by powerful politicians can have a large impact on public feelin comments on the AZ vaccine, Tony Blair not disclosing that his son had been g
   - The media can focus on a certain side of the story, which can either increase o
   - News stories focusing on a small number of negative events can be quickly ampli
   - The public will always question why governments have made certain decisions use of a vaccine will always erode confidence, even if the reason is to check sa
2. **Arguments for**
   - Vaccines are highly effective.
   - Vaccines are very safe.
   - Herd immunity requires large numbers of people to be vaccinated.
   - Only herd immunity can protect people who cannot be vaccinated (e.g. people
   - Vaccination is not just an individual act but something that protects others.
   - Diseases that we vaccinate against are dangerous.
   - Everyone being vaccinated gives the possibility that a disease might be eradica
   - Improving quality of life.
   - Enabling life to return to normal after an epidemic / a pandemic.

   Arguments against
   - Ethical arguments around the right of people to make their own decisions.
   - Some vaccines can have rare serious side effects.
   - Can encourage mistrust and conspiracy theories.
   - Decreases trust in government/science/medics.
   - Could reduce vaccination rates due to reduced trust.

Task: Research

Possible questions and answers could include:

- **How are vaccines tested?**
  - Identification of potential drug candidates, e.g. selection of antigen; decisions a weakened pathogen, mRNA.
  - Preclinical trials to check safety of vaccine when administered to humans and a
  - Clinical trials in several phases:
    - Phase 1 – a small group of fewer than 100 volunteers to test safety and c
    - Phase 2 – a larger group of several hundred volunteers to assess dose size will have a control group.
    - Phase 3 – if phase 2 is safe and successful, a much larger control trial with carried out to assess safety and efficacy on a larger scale.
  - Approval and licensing – researchers submit their findings to be assessed for a
  - Phase 4 – continued safety assessments are made once the vaccine is in use.
- **How was the COVID-19 vaccine developed so quickly?**
  - Rather than starting with phase 1 and only moving on to the next phase when it w place simultaneously and was assessed for approval and licensing as it went along than usual, and volunteers were keen to help. Scientists from all around the world
- **How do vaccines work?**
  - A small amount of dead or weakened pathogen, or a part of a pathogen (such a so that body cells can build the antigens), is injected into a patient.
  - This initiates the immune response: T-lymphocytes with complementary cell su and are activated, initiating the activity of killer T cells and T helper cells.
  - T helper cells release chemical signals that increase phagocyte activity and assist w
  - Activated B cells differentiate into plasma cells, which begin to produce antibo
  - After this set of responses, memory T cells and memory B cells are left in the bl immune response if the body comes into contact with the actual pathogen in th

- **Why do vaccines cause flu-like side effects?**
  - Because they initiate the immune response, which includes fever (a raised body te pathogen activity) and inflammation (leaking of fluid and white blood cells from th
- **What about dangerous side effects?**
  - Some vaccines do come with a small risk of dangerous side effects such as alle and blood clotting. Allergic reactions will happen very quickly after a vaccinat very quickly at the immunisation centre. Other types of adverse reaction are v vaccine would not have passed safety tests), and these are taken as an accept the vaccination. All medical treatments involve an analysis of risk vs benefit, a considered that the risk from the disease outweighs the risk from the vaccine.
  - Use of a graph or numbers to express/compare risk can be very helpful here.
- **Weren't there some cases of vaccines causing harm to children?**
  - You might be thinking of the whooping cough and MMR vaccines. Both have s to be very safe. The whooping cough vaccine that we now use is actually diffe and has an even lower risk of harm than that one did, while the doctor behind be biased, his data has been found to be invalid, and he has been struck off th

Extended Answer Question

Indicative content

- Some pathogens show antigenic variability / mutate / change their surface antigens less effective.
- New vaccines and boosters need to be introduced to increase effectiveness against
- Scientists need to predict which strain is likely to be the most prevalent in the comi development efforts on this strain, e.g. the influenza virus changes frequently, so th the disease is never eliminated.
- New risks / negative side effects associated with a particular vaccine may come to l younger recipients of the AstraZeneca COVID-19 vaccine), leading to changing advic vaccination programme.
- Public trust may decrease, causing governments to change their approach, e.g. intr education, introducing restrictions for the unvaccinated.
- Global circumstances may change, e.g. conflicts and political instability, leading to v or abandoned.
- New disease vectors may emerge, e.g. domestic animals, leading to the need to vac closely with specific species.
- Immunity that results from a vaccine may decrease more quickly than expected, leadin
- A vaccine may turn out to be more effective than expected, reducing the urgency o
- A vaccine may turn out to be less effective than expected, leading to the need to de

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the challenges facing g and is clear and logically structured.
Level 2 (3–4 marks)	Response shows good knowledge of the challenges facing glob mostly clear and logically structured.
Level 1 (1–2 marks)	Response shows limited knowledge of the challenges facing gl clarity and structure are lacking.
0 marks	No response is provided, or there is an absence of creditworth

12. Money in science: the marketplace

Comprehension

1. Historically, scientists were funded either by rich patrons or by means of their own w
scientific institutions funded either by wealthy donors or by government, but only a
Today science can still be funded by wealthy individuals but is more likely to be fun
or government.
2. They set up the TIRC, promising to continue with important research and telling the p
about the connection between smoking and cancer. The TIRC employed its own scie
science that they agreed with and gave funding to scientists to carry out research tha
3. Research funded by the plastics industry appears to be designed specifically so that i
between BPA and harmful health consequences. The rats used were resistant to BP
the experiments meant that it was not possible to see that this was the case. The in
HCRA which concluded that there were no health risks. This conclusion has been qu
the review team but is still used by the industry to prove BPA safety.
4. A negative control is a repeat in an experiment where a researcher expects to see a
the variable of interest (e.g. a group of people in a medical trial that take a placebo
is to show that any positive result gained in an experiment is the result of the variab
factor. A positive control is a repeat where a variable that researchers know will giv
experiment (e.g. a group in a medical trial that takes a previously proven medicatio
is to show what result would be expected if the variable under investigation yields a
5. If the researchers had tested an oestrogen disruptor known to have a harmful impac
this impact in the CD-SD rats, they would have known that this strain of rats was no
This would mean that we would know that the lack of harmful effects was not due to
to the resistance of the rats.
6. Seeds are expensive and need to be bought every year due to infertile/hybrid seed v
manufacturers. This means that only farmers who can afford these prices on a yearl
bred / genetically modified crop varieties developed by seed companies. The monop
around the world grow the same varieties of crop, which risks a loss of biodiversity a
make food crops vulnerable to disease, pests or climate change.
7. Patents allow the developers to make more money from their products because no o
without paying for the right to do so. This gives a financial incentive to develop the
people will want to pay for it.
8. Waiving the COVID-19 patent has concerned some people because it may reduce com
to work to produce better vaccines in the future. There are also concerns that waiving
as many of those who might gain from the lack of patent may not have the facilities to

Discussion

Possible points for discussion include:

Support of statement

- Evidence shows that it is possible for the outcome of a study to be affected by the so
- Tobacco company funding led to a focus on less relevant research, as well as poor co
with the public.
- BPA research funded by the plastics industry showed a different outcome to governm
- Famously, the MMR vaccine research that initiated the controversy was funded by a
- Scientists may not want their funding to be cut, so they may embark on non-controv
to publish results that go against the interests of their funder.
- Some science outcomes are too important to allow those with a financial interest to
tobacco and BPA on health, and the risks of vaccine hesitancy.
- Misinformation and disinformation are becoming more widespread on social media,
damaging shifts in public opinion on important issues, e.g. vaccine uptake.

Against statement

- Gaining government funding can be complicated and difficult.
- Some research would not happen were it not for the investment of private individua
- Companies are only likely to fund research that could affect their profits.
- There is enough scientific scrutiny from peer reviews and journalists to avoid the fu
- Most scientists are scrupulous and dedicated to their research, and examples of their b
- Governments and public bodies may be just as likely to have an interest in the outco
development of a new vaccine or drug may make a government or university look go

TASK: EXAM PRACTICE

1. a. - To provide a comparison with the effects of BPA. (1)
   - To show that any change in glucose regulation was the result of BPA treatm

   b. Any three from:
   - BPA treatment of mothers does lead to raised blood glucose after a meal
   - The study involved a pregnant mammal, so is likely to be representative o
   - The study was carried out in pregnant mice, so cannot be directly applied
   - No statistical analysis has been carried out, so cannot be sure that the di significant. (1)

   c. - The membrane potential (of the beta cells) in BPA-treated mice reaches a does not increase / become as positive as in control mice. (1)
   - The membrane potential (of the beta cells) in BPA-treated mice reaches a comparison to (around) +40 in control mice. (1)

   d. Any six from:
   - Potassium ion channels do not close / not enough potassium ion channels
   - Potassium ions do not accumulate inside the beta cells. (1)
   - The beta cell membranes of BPA-treated mice do not depolarise / the ne become much less negative. (1)
   - Voltage gated calcium ion channels (in the cell surface membranes of the
   - Calcium ions cannot diffuse into the beta cells. (1)
   - The vesicles containing insulin do not move to cell surface membrane (of
   - Insulin is not secreted/released from the beta cells by exocytosis. (1)
   - Insulin does not reduce blood sugar levels by causing cells to take up mo increasing rate of glucose respiration. (1)

EXTENDED ANSWER QUESTION

Indicative content

Positive ethical outcomes

- Fewer harmful chemicals can be used on crops, e.g. pest-resistant crops won't need
- GM crops increase the chance of being able to feed a growing world population, e.g. resistant and have improved nutritional qualities.
- Drugs can be made in large quantities by genetically modifying farm animals, e.g. pr milk of goats, reducing the price of drugs and making them more widely available.
- Scientists often share knowledge, making advances in genetic technology available t
- Patents can be waived to allow scientists in poorer countries to make use of new te
- The motivation of 'owning' a technology can encourage scientists to work faster and technologies being developed.

Ethical concerns

- Growing GM crops in monocultures can be a risk to biodiversity that needs to be co
- Altering the genes of animals may have negative impacts on the health of animals.
- Concerns around the exploitation of animals.
- Patents can mean that only the group of scientists that developed a technology are a
- Farmers in poor countries may not be able to afford the seeds for the drought- and p
- Farmers may be unable to collect seeds if crops are created to be sterile, forcing the every year.
- Farmers may need to pay each year for permission to regrow GM crops that are own

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the ethical issues arou and logically structured.
Level 2 (3–4 marks)	Response shows good knowledge of the ethical issues around G clear and logically structured.
Level 1 (1–2 marks)	Response shows limited knowledge of the ethical issues aroun and structure are lacking.
0 marks	No response is provided, or there is an absence of creditworth

13. Gene technology: the ultimate solution or an

Comprehension

1. - The gene of interest is located and a suitable vector is selected, e.g. virus, plas
   - Restriction endonuclease enzymes are used to cut the gene of interest out of t vector DNA. This produces complementary sticky ends.
   - DNA ligase enzymes are used to insert the DNA fragment into the vector.
   - Host cells such as bacteria are transformed. This can be achieved by putting th the modified plasmid vectors and then using an electric shock or heat shock to plasmids. Cells that do take up the vectors are described as transformed. If the another type of transformation method must be used, e.g. a virus or a gene gu
   - Transformed cells are identified using the presence of either a fluorescence ge
2. a. - Transformed bacteria can produce useful proteins such as human insulin
      - Transformed crops can be resistant to common pests or disease, as well a
      - Transformed crops can be nutritionally enhanced, e.g. Golden Rice conta
      - Transformed crops can be given a higher yield or a longer shelf life.
   b. - Production of copies of genes for transforming cells.
      - Gene copies for research purposes.
      - Expression of useful products, such as human insulin.
   c. - Treating patients suffering from some genetic conditions, e.g. cystic fibro
      - Helping a cancer patient's T cells to target cancer cells more effectively.
3. Recombinant DNA relies on the use of restriction endonucleases to locate a rest editing uses CRISPR sequences associated with a Cas9 enzyme. Restriction endo enzymes found in different cell types, and they have a limited number of restric cut, while CRISPR sequences can be designed to be specific to any section of DN technology can be used in any kind of cell to target any gene, while recombinan restriction endonucleases available. Recombinant DNA is useful for inserting ne simply to silence genes, with this kind of use being less controversial than gene
4. Animals can be genetically modified or gene edited at the embryo stage before bei mother. Modifications could include the ability to secrete useful proteins such as b goats. Animals with these desirable characteristics could then be cloned using som that the next generation also has the desired characteristics.
5. - Genetic modification of food crops is heavily regulated in Europe but less so in m
   - Germline gene alteration is strictly regulated in most parts of the world and pro for research), while somatic cell alteration is less regulated.
   - In China the use of germline gene editing is considered to be human experiment
   - Gene technology is changing, and the urgency of food production and fighting c Public opinion may also be shifting as these technologies become more familiar important that regulations take the technology's potential into account as well a country's population.

Discussion

Discuss the use of gene-technology in human medicine.

Possible points for discussion include:

- Somatic gene therapy is already used to treat some conditions, and, due to it affect especially controversial.
- Somatic gene therapy can repair mutations in, for example, cells in the airways with blood with the sickle-cell mutation.
- Somatic gene therapy (CAR T-cell therapy) can be used to assist the body in destroy
- Somatic gene therapy is limited by the need to be able to access the relevant cells (blood), so may be limited in its applications by this.
- Germline therapy is potentially more powerful (but is also more controversial becau body before a baby is born, and these changes can be passed on).
- Germline therapy could be used to eradicate many harmful and life-limiting conditi administration of vaccines for the same purpose.

- Germline therapy raises the issue of consent for the treated individual and for futur
- Germline therapy could have unexpected side effects, so safety is not yet assured.
- Germline therapy, especially when combined with CRISPR technology, can correct ma
  cells, so raises questions around discrimination against individuals with non-life-threa
- Choosing to correct certain mutations could be equated to theories of eugenics, wh
  individuals should be removed from the gene pool for the purpose of 'improvemen
- Germline therapy could allow parents to alter the genes in an embryo to select for a
  known as a 'designer baby' and is very controversial.
- Gene therapy could be expensive and could widen the divide between health of ric
- In an extreme example, gene alteration could lead to 'classes' of people separated b
  their genes.
- Germline therapy applied in animals could be used to produce important human pr
  or hormones in the milk of animals, allowing cheaper and more reliable production c
  brings with it concerns about the welfare and exploitation of animals.

TASK: RESEARCH

Information that students may find for each of the following sections:

- The CRISPR gene-editing process
  - Clusters of regularly interspaced short palindromic repeats (CRISPRs) are secti
    repeating nucleotide sequences alternating with regions of DNA called 'spacer
  - In nature, CRISPRs are found in bacterial cells, where they function as a sort of
    The spacer sequences found within the CRISPR are derived from viruses that h
    cell, and if the cell is infected with one of these viruses again the spacer is tran
  - The crRNA then combines with a Cas9 enzyme and another piece of RNA called
    complex can locate, bind to and cut the double-stranded section of DNA that is
  - Cas9 enzymes only cut DNA that is adjacent to regions known as PAMs (protos
    that the CRISPR DNA itself is protected from being cut by the crRNA.
  - Scientists have shown that it is possible to make use of this bacterial system to
    The crRNA can be designed to target any section of DNA (unlike restriction end
    specific restriction sites), and scientists can then incorporate an RNA template t
    repairing the cut DNA. This template can also be specially designed so that the
    way, e.g. switching the gene on or off, or altering the gene so that it produces a

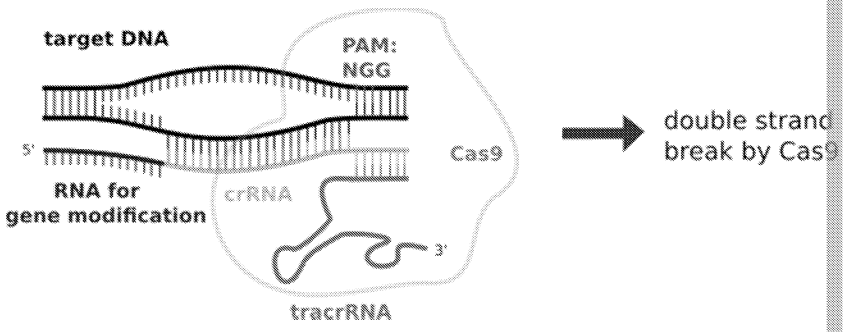


FIGURE 54: ILLUSTRATION OF CRISPR/CAS9 EDITING A SECTION OF TAR

- The changes that He Jiankui claims to have made to the DNA of the twin girls, and w
  - To infect body cells, HIV binds to a series of receptors on the cell surface mem
    the CCR5 gene.
  - He claims to have knocked out the function of the CCR5 gene using a combina
    technology, meaning that HIV cannot bind to and infect the cells of the baby g
- The reactions of the scientific community
  - Unsure whether He had actually done what he claimed, although the process H
    sounded plausible.
  - Concern over ethics of what had supposedly been done.
  - Unhappy with lack of transparency of whole process.
  - Wanted a full investigation of the work to verify the truth of He's claims.
  - Disappointment that the scientific community had not regulated itself better; t
    who had known what He was doing and had not raised an alarm.

- Why the scientific community is so concerned
  - Safety:
    - The CCR5 gene is thought to have other roles in the immune system; rese
      a mutated version of CCR5 are more likely to die from a flu infection.
    - HIV is now a treatable disease, so the risk to the babies from the use of CR
      greater than the risk from HIV would have been.
    - Risk from off-target effects of CRISPR technology.
    - If gene editing is carried out after the first embryonic cell division and is o
      embryonic stem cells, it is possible that the developing embryo will becom
      of these cells will be gene edited, while others are not – a condition know
  - Effectiveness:
    - Evidence suggests that while one of the twins has two edited copies of the
      edited copy, so the second twin is still vulnerable to HIV.
    - The first twin does have two faulty copies of the mutated gene, but it is th
      mosaicism, so many of her cells may in fact still be vulnerable.
  - Other concerns:
    - One study has suggested that the twins may have improved memory and in
      that could be considered 'designer baby' features. There is little evidence to
- The consequences of the scandal for gene-editing research going forward
  - Scientists worry that He's work may have reduced the public appetite for the re
    therapies in the future, and for research involving editing of somatic cells.
  - Many scientists have called for a moratorium on all similar research until safety
  - Some think that He's work could, by encouraging global conversations on the is
    into gene editing embryos.
  - It could become more difficult to gain approval or funding for similar research in
  - He's prison sentence could put other scientists off attempting similar gene edits

Good articles for reference:

What is CRISPR? **https://www.livescience.com/58790-crispr-explained.html**

He Jiankui: Baby gene experiment 'foolish and dangerous' **https://www.bbc.co.uk/news/**

CRISPR babies: more details on the experiment that shocked the world **https://www.new**
crispr-babies-more-details-on-the-experiment-that-shocked-the-world/

Did CRISPR help – or harm – the first-ever gene-edited babies? **https://www.sciencemag**
help-or-harm-first-ever-gene-edited-babies

CRISPR-baby scientist fails to satisfy critics **https://www.nature.com/articles/d41586-01**

The CRISPR-baby scandal: what's next for human gene-editing **https://www.nature.com/**

What CRISPR-baby prison sentences mean for research **https://www.nature.com/article**

Extended Answer Question

Indicative content:

Arguments that support the use of cloning in animals

- Cloning can be useful to farmers for increasing the number of animals with desirable
  desirable traits are passed on (in sexual reproduction it is down to chance whether c
- Cloning can be used to increase the numbers of an endangered species with a small
  members are unable to breed.
- Cloning allows the reliable production of certain medicines via 'pharming'.
- New drugs can be tested on animals produced by cloning; this ensures that all test su
  their responses to a drug will not be affected by differences in their genes.

Arguments that support the use of cloning in plants

- Identical plants can be produced in large numbers and in a relatively small space usi
- Tissue culture produces plants more quickly than growing them from seed.
- Cloning a plant ensures that it will have the same desirable characteristics as the par
- Plants that are difficult to grow from seed can be propagated using cloning techniqu
- Plants that have been genetically modified can be replicated using cloning.

Arguments against the use of cloning in animals

- Animal cloning by somatic cell nuclear transfer is expensive and has a low success ra
- Cloned animals will be genetically identical, limiting cloning's usefulness in helping to
  endangered species.
- Animal welfare concerns around low embryo viability and reduced lifespan / illness s
- Ethical concerns around the exploitation of animals.
- Concerns that animal cloning could pave the way towards human cloning.

Arguments against the use of cloning in plants

- Cloning in plants produces monocultures with low genetic variation; such populations
  such as by the emergence of a new disease.
- Tissue culture production of plants can be more expensive than growing from seed, a
- The cells in a tissue culture are susceptible to infection.

Level descriptors

Level 3 (5–6 marks)	Response shows detailed knowledge of the arguments for and a clear and logically structured.
Level 2 (3–4 marks)	Response shows good knowledge of the arguments for and aga mostly clear and logically structured.
Level 1 (1–2 marks)	Response shows limited knowledge of the arguments for and ag clarity and structure are lacking.
0 marks	No response is provided, or there is an absence of creditworthy