Version 1.0: 0107

ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

General Studies 6761

Specification A

GSA5 Science, Mathematics and Technology

Mark Scheme

2007 examination - January series

Mark schemes are prepared by the Principal Examiner and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation meeting attended by all examiners and is the scheme which was used by them in this examination. The standardisation meeting ensures that the mark scheme covers the candidates' responses to questions and that every examiner understands and applies it in the same correct way. As preparation for the standardisation meeting each examiner analyses a number of candidates' scripts: alternative answers not already covered by the mark scheme are discussed at the meeting and legislated for. If, after this meeting, examiners encounter unusual answers which have not been discussed at the meeting they are required to refer these to the Principal Examiner.

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Unit 5 Question 1
(GSA5 Science, Mathematics and Technology)

This component is an objective test for which the following list indicates the correct answers used in marking the candidates' responses.

1.1	**B**	**1.11**	**B**
1.2	**A**	**1.12**	**D**
1.3	**D**	**1.13**	**D**
1.4	**B**	**1.14**	**A**
1.5	**A**	**1.15**	**C**
1.6	**D**	**1.16**	**A**
1.7	**B**	**1.17**	**C**
1.8	**C**	**1.18**	**C**
1.9	**A**	**1.19**	**B**
1.10	**A**	**1.20**	**D**

Unit 5 Question 2
(GSA5/2 Science, Mathematics and Technology)

The nationally agreed assessment objectives in the QCA Subject Criteria for General Studies are:

AO1 Demonstrate relevant knowledge and understanding applied to a range of issues, using skills from different disciplines.

AO2 Communicate clearly and accurately in a concise, logical and relevant way.

AO3 Marshal evidence and draw conclusions; select, interpret, evaluate and integrate information, data, concepts and opinions.

AO4 Demonstrate understanding of different types of knowledge and of the relationship between them, appreciating their limitations.

All mark schemes will allocate a number or distribution of marks for some or all of these objectives for each question according to the nature of the question and what it is intended to test.

Note on AO2

In all instances where quality of written communication is being assessed this must take into account the following criteria:

- select and use a form and style of writing appropriate to purpose and complex subject matter;
- organise relevant information clearly and coherently, using specialist vocabulary when appropriate; and
- ensure text is legible and spelling, grammar and punctuation are accurate, so that meaning is clear.

Note on AO4

In previous General Studies syllabuses, there has been a focus on the knowledge and understanding of facts (AO1), and the marshalling and evaluation of evidence (AO3) – on what might be called 'first-order' knowledge. AO4 is about understanding what counts as knowledge; about how far knowledge is based upon facts and values; and about standards of proof – what might be called 'second-order' knowledge.

By 'different types of knowledge' we mean *different ways of getting knowledge*. We might obtain knowledge by fine measurement, and calculation. This gives us a degree of certainty. We might obtain it by observation, and by experiment. This gives us a degree of probability. Or we might acquire it by examination of documents and material remains, or by introspection – that is, by canvassing our own experiences and feelings. This gives us a degree of possibility. In this sense, knowledge is a matter of degree.

Questions, or aspects of them, which are designed to test AO4 will therefore focus on such matters as:

- analysis and evaluation of the nature of the knowledge, evidence or arguments, for example, used in a text, set of data or other form of stimulus material;
- understanding of the crucial differences between such things as knowledge, belief or opinion, and objectivity and subjectivity in arguments;
- appreciation of what constitutes proof, cause and effect, truth, validity, justification, and the limits to these;
- recognition of the existence of personal values, value judgements, partiality and bias in given circumstances;
- awareness of the effects upon ourselves and others of different phenomena, such as the nature of physical, emotional and spiritual experiences, and the ability to draw upon and analyse first-hand knowledge and understanding of these.

GENERAL MARK SCHEME FOR A2 ESSAYS

The essay questions in General Studies A are designed to test the four assessment objectives (see INTRODUCTION above) as follows:

AO1 – 6 marks AO2 – 5 marks AO3 – 7 marks AO4 – 7 marks **Total – 25 marks**

Each answer should be awarded two separate marks, comprising a mark out of 20 for content (Assessment Objectives 1, 3 and 4) and a mark out of 5 for communication (Assessment Objective 2).

The mark for content should be awarded on the basis of the overall level of the candidate's response in relation to the following general criteria and descriptors for each level.

Level of response	**Mark range**	**Criteria and descriptors for Assessment Objectives 1, 3 and 4:** knowledge, understanding, argument and illustration, evaluation.
LEVEL 4	16 – 20 (5)	**Good response to the demands of the question:** sound knowledge of material (AO1); clear understanding and appreciation of topic, nature of knowledge involved and related issues (AO4); valid arguments and appropriate illustrations, coherent conclusion (AO3).
LEVEL 3	11 – 15 (5)	**Competent attempt at answering the question:** relevant knowledge (AO1); reasonable understanding and appreciation of topic, nature of knowledge involved and related issues (AO4); some fair arguments and illustrations, attempt at a conclusion (AO3).
LEVEL 2	6 – 10 (5)	**Limited response to the demands of the question:** only basic knowledge (AO1); modest understanding and appreciation of topic, nature of knowledge involved and related issues (AO4); limited argument and illustration, weak conclusion (AO3).
LEVEL 1	1 – 5 (5)	**Inadequate attempt to deal with the question:** very limited knowledge (AO1); little understanding and appreciation of topic, nature of knowledge involved and related issues (AO4); little or no justification or illustration, inadequate overall grasp (AO3).
LEVEL 0	0	**No response or relevance to the question**

The mark for communication (AO2) should be awarded using the following scale and criteria.

5 marks	Clear and effective organisation and structure, fluent and accurate expression, spelling, punctuation and grammar.
4 marks	Clear attempt at organisation and structure, generally fluent and accurate expression, spelling, punctuation and grammar.
3 marks	Some organisation and structure evident, variable fluency, occasional errors in expression, punctuation and grammar.
2 marks	Limited organisation and structure, little fluency, a number of errors in expression, spelling, punctuation and grammar.
1 mark	Lacking organisation, structure and fluency, frequent errors in expression, spelling, punctuation and grammar.
0 marks	No response

Note: A totally irrelevant response (Level 0) should also receive 0 marks for communication. A brief and inadequate response (Level 1) should be awarded not more than 2 marks and a limited response (Level 2) normally not more than 3 marks for communication. Responses at Level 3 and 4 for content may be awarded up to 5 marks for communication.

1 Some problems which science and technology are trying to address are international in scale, e.g. global warming, flu pandemics, computer crime, national disasters emergency planning.

Discuss the causes and effects of one such problem. To what extent is international scientific and technological co-operation needed to solve this problem? How realistic is such co-operation?

Global warming is an increase in the average temperature of the Earth's atmosphere and oceans. There is a scientific theory which states that much of the recently observed and projected global warming is human-induced. The theory states that this is a result of a strengthened greenhouse effect caused by man-made increases in carbon dioxide and other greenhouse gases, through the burning of fossil fuels and deforestation.

This is expected to result in climate changes including rises in sea level and changes in the amount and pattern of precipitation. Such changes may increase extreme weather events such as floods, droughts, heat waves, and hurricanes, change agricultural yields, or contribute to biological extinctions. Although warming is expected to affect the frequency and magnitude of these events, it is very difficult to connect any particular event to global warming. A small minority of qualified scientists contest the view that humanity's actions have played a significant role in increasing recent temperatures.

The problem is (by definition) global in scale, and there is significant effort to deal with it by international scientific cooperation. The Kyoto Protocol (1997) is an international treaty on climate change, and is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases.

In terms of the realism of such cooperation, a key weakness of this process has been the refusal of the US, the largest single producer of greenhouse gases, to participate in the reduction targets, along with a small number of other nations including Australia. It also excludes many developing countries, which are increasing their emissions as their economies take off. The Montreal conference in 2005 agreed to further discussions on the extension of targets for reductions after 2012 by Kyoto signatories. The US agreed only to non-binding discussions.

A **flu pandemic** is a large scale epidemic of the influenza virus. The World Health Organization (WHO) warns that there is a substantial risk of an influenza pandemic within the next few years. One of the strongest candidates is the A(H5N1) subtype of avian influenza. This is a type of influenza virus that is hosted by birds, but may infect several species of mammals, including humans. A strain of the H5N1-type of avian influenza virus that emerged in 1997 has been identified as the most likely source of a future influenza pandemic

In September 2005, a leading UN health official warned that a bird flu outbreak could happen anytime and had the potential to kill 5-150 million people. In addition to the obvious human loss, this would have significant social and economic consequences for those areas most badly affected.

International cooperation is extensive through organisations such as the World Health Organisation (WHO), the Food and Agriculture Organization of the United Nations (FAO), and the World Organisation for Animal Health (OIE). The EU Commission has adopted a new proposal for a Directive on avian influenza.

Measures to deal with a 'bird flu' pandemic include the development of antiviral drugs, which are sometimes effective in both preventing and treating the infection, and vaccines which, however,

take at least four months to produce and must be prepared for each subtype. At a more local level in areas where the disease is endemic, some degree of prevention may be possible by changing local farming and commercial practices. This is limited by widespread poverty in some areas, a reliance on subsistence farming methods, and cultural practices such as cock-fighting.

Computer crime can take many forms: hacking - deliberately gaining unauthorised access to an information system, for example, political, military, financial or industrial systems; the development of computer viruses such as the "love bug", worms, trojans, etc; fraud - manipulating banking systems to make unauthorised electronic funds transfers and the unauthorised use of credit card numbers and other data collected as part of identity theft; confidence tricks and scams - e.g. the Nigerian banking scam; piracy - making unauthorised copies of games, music, films, etc, and downloading files illegally; pornography - both hardcore and soft pornography, including material designed to appeal to paedophiles; offensive content - racist, blasphemous, politically subversive, seditious or inflammatory material that tends to incite hate crimes; harassment - cyber bullying, harassment by computer, stalking, and cyberstalking.

Regulation of the internet has been discussed at the UN-sponsored World Summit on the Information Society (WSIS), most recently in November 2005. Through it, the US government maintains overall control of the foundations upon which the internet is built, overseeing the California-based Internet Corporation for Assigned Names and Numbers (ICANN), which is responsible for the net's root servers and naming system.

Otherwise, dealing with computer crime is the responsibility of individual national legal systems. Courts in different countries have taken various views on whether they have jurisdiction over items published on the internet, or business agreements entered into over the internet. Some commercial organisations have used the courts to protect their intellectual property - most notably, the record companies which have pursued individuals who have illegally downloaded music tracks. There have been some *ad hoc* examples of international cooperation - for example, Operation Ore was a large-scale international police operation, commencing in 1999, which gained details of thousands of users of child pornography websites from their credit card details, the best-known of whom was Pete Townshend.

A **natural disaster** is a catastrophe that occurs when a hazardous physical event precipitates extensive damage to property, a large number of casualties, or both. Common natural phenomena that can result in natural disasters include - blizzards and snowstorms, drought, earthquakes, epidemics, famine, flood, forest fires, hailstorms, heat waves, hurricanes, landslides and mudslides, tornadoes, tsunamis, volcanic eruptions etc. It is likely that relatively recent specific disasters will be referred to by candidates - the 2004 tsunami, hurricane Katrina, the Kashmir earthquake 2005 etc.

Descriptions of causes by candidates will vary according to the type of disaster discussed. Their effects, however, will almost certainly include the death of significant numbers of people, major injuries that need to be treated over a long period, destruction and damage to homes and other property, disruption of local industry and agriculture leading to social and economic dislocation.

Science and technology can contribute to disaster management in a number of stages: mitigation - for example, flood prevention schemes; preparation - for example, mobile emergency communication systems; response - for example, the rapid deployment of medical staff, earthmoving equipment, etc; recovery - the replacement of essential infrastructure, such as bridges, roads, power, water and sewage systems.

International cooperation exists through networks of non-governmental organisations (Oxfam, Médecins Sans Frontières, etc.) and through the United Nations. The UN's Humanitarian Early Warning Service (www.hewsweb.org) provides up-to-date information on droughts, floods,

seismic activity, locust swarms, storms, volcanic activity and tsunami warnings. Regional groups of nations cooperate, for example on tsunami warnings; but international rivalry and conflict can often prevent effective cooperation - c.f. India and Pakistan, or Greece and Turkey.

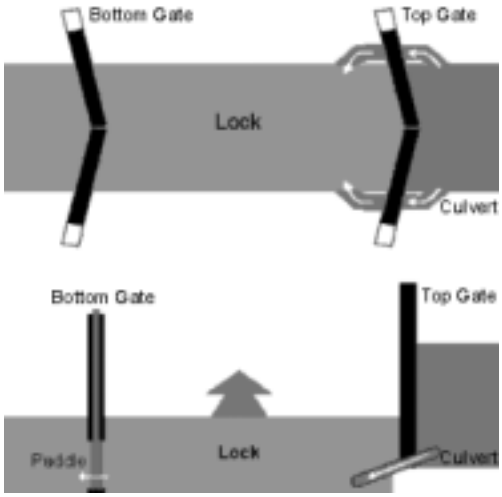
Candidates can legitimately tackle problems other than those identified in the question, but should deal with all aspects of the question to gain a higher level mark. Strong answers are likely to be aware that many scientific and technological problems are outside the control of any single government; but that national self-interest can often act as a barrier to effective action.

2 Explain how canals have been engineered to deal with the practical problems presented by the landscape.

How realistic is the suggestion that our canals and waterways could be used more extensively for freight traffic to relieve pressure on roads and motorways?

Engineering solutions:

- An **aqueduct** is an artificial (man-made) channel that is constructed to convey water from one location to another. Many aqueducts are raised above the landscape, resembling bridges rather than rivers. Sufficiently large aqueducts may also be usable by ships.
- A **canal lock** or **navigation lock** is a device that lifts or lowers boats, barges or other vessels from one water level to another. Locks used on canals allow the negotiation of hills without recourse to lengthy detours, or the use of tunnels or aqueducts. The same kind of locks are used on rivers, often in connection with dams since there is generally a difference in water level between the upstream side of a dam and the downstream side.



- An **inclined plane** is a system used on some canals for raising boats between different water levels. An inclined plane can be considered a specialist type of funicular railway. An inclined plane is a quicker and more efficient (in terms of water loss), alternative to a flight of canal locks, but is more costly to install and run.
- A **boat lift** or **lift lock** is a machine for transporting boats between two different water heights, and is an alternative to the canal lock and the canal inclined plane. It may be either vertically moving, like the Anderton Boat Lift, or rotational, like the Falkirk Wheel.
- **Contouring –** canal which closely follows the contour line of the land it traverses in order to avoid costly engineering works.
- **Tunnels** can be cut through higher ground (e.g. Dudley tunnel – 3100 yards long).
- Cuts **– open channels cut through higher ground.**
- Embankments **– raised channels over lower ground.**

Increased use of canals for freight?

Advantages:

- widespread existing network – most canals are linked to other canals, navigable rivers or the sea.
- they could take traffic away from overcrowded roads.
- less carbon emissions than road vehicles.
- suitable for non-time-sensitive traffic – e.g. waste disposal.

Disadvantages:

- very limited access to specific industrial locations.
- much slower than other methods of transport.
- not suitable for time-sensitive freight – e.g. deliveries to supermarkets, etc.
- might restrict recreational & leisure use of canals.

Conclusion:

There is limited scope for extended use, but could be useful for particular types of freight.

3 Using suitable examples, explain the contributions to knowledge of classical physics and quantum physics.

Physics is the science of the natural world dealing with the fundamental constituents of the universe, the forces they exert on one another, and the results produced by these forces.

Classical physics is based on principles developed before the rise of quantum theory, including the special theory of relativity. The scale of classical physics is the level of isolated atoms and molecules on upwards, including the macroscopic and astronomical realm.

Among the branches of theory included in classical physics are:

- Classical mechanics - is concerned with the set of physical laws governing and mathematically describing the motions of bodies and aggregates of bodies.
- Classical electrodynamics - provides a description of electromagnetic phenomena whenever the relevant length scales and field strengths are large enough that quantum mechanical effects are negligible.
- Classical thermodynamics - studies the effects of temperature, pressure, and volume changes on physical systems at the macroscopic scale.
- Special theory of relativity and General theory of relativity - the insight that gravitation is not viewed as being due to a force (in the traditional sense) but rather a manifestation of curved space and time, this curvature being produced by the mass-energy content of the spacetime.
- Classical chaos theory and nonlinear dynamics - deals with the behaviour of certain nonlinear dynamical systems that (under certain conditions) exhibit the phenomenon known as chaos, most famously characterised by sensitivity to initial conditions.

Quantum physics is the physics of the incredibly small. It is a fundamental physical theory that replaces Newtonian mechanics and classical electromagnetism at the atomic and subatomic levels and is the underlying framework of many fields of physics and chemistry, including condensed matter physics, quantum chemistry, and particle physics.

Quantum mechanics has had enormous success in explaining many of the features of our world. The individual behaviour of the microscopic particles that make up all forms of matter - electrons, protons, neutrons, and so forth - can often only be satisfactorily described using quantum mechanics. Most physicists believe that quantum mechanics provides a correct description for the physical world under *almost* all circumstances. The only known exceptions, where quantum mechanics *may* fail, are situations where the effects of general relativity, the dominant theory of gravity, are important: this happens in the vicinity of black holes, or when considering the observable Universe as a whole.

Much of modern technology operates at a scale where quantum effects are significant. Examples include the laser, the transistor, the electron microscope, and magnetic resonance imaging. The study of semiconductors led to the invention of the diode and the transistor, which are indispensable for modern electronics.

Some more general points on the importance of physics might include:

- it is the most fundamental of all the natural sciences - its principles affect our daily lives; it includes such areas as light, sound, the atom, mechanics, magnetism
- each of the other natural sciences (biology, chemistry, geology, etc) deals with particular types of material systems that obey the laws of physics
- progress in many areas of the economy and business – aerodynamics, communications, medicine, nanotechnology, energy – depend on advances in physics.

4 Trips into space for the exceptionally wealthy are now a reality, and holidays in space may become more widely available later in the 21st century.

Explain the scientific principles involved in space travel.

Discuss the attractions and risks involved in recreational space journeys.

Orbiting and reaching space

For a flight from Earth to be a spaceflight, the spacecraft has to ascend from Earth and at the very least go past the edge of space. The edge of space is, for the purpose of space flight, often accepted to lie at a height of 100 km (62 miles) above mean sea level. Any flight that goes higher than that is by definition a spaceflight. Where the Earth's atmosphere ends space begins but the atmosphere fades out gradually so the precise boundary is difficult to ascertain - hence the need for an arbitrary altitude for the edge of space.

One can distinguish the sub-orbital spaceflight and the orbital spaceflight. There sometimes appears to be confusion among the general public about the difference between sub-orbital and orbital spaceflights. In common usage the term *orbit* refers to a closed trajectory around the Earth (or another central body). The term *sub-orbital* refers to a trajectory which intersects the central body before a complete orbit is achieved. An *orbital spaceflight* is one which completes an orbit fully around the central body. Achieving orbit is essential for going anywhere else, such as to the Moon or Mars.

A low Earth orbit (LEO) is an orbit around Earth typically around 200 - 1200 km (124 - 726 miles) above the Earth's surface. This is generally below intermediate circular orbit (ICO) and far below geostationary orbit. Orbits lower than this are not stable and will decay rapidly because of atmospheric drag. Most manned spaceflights have been in LEO, including all Space Shuttle and various space station missions. Although gravity in LEO is not much less than on the surface of the Earth (it reduces 1% every 30 km), people and objects in orbit experience weightlessness.

Because of the speed difference, atmospheric re-entry is much more difficult for orbital flights than it is for sub-orbital flights. Sub-orbital space flights, being at a much lower speed, do not generate anywhere near as much heat upon re-entry.

Sub-orbital flights are spaceflights just as orbital flights are. Both go beyond the atmosphere and past the edge of space. A sub-orbital flight may reach a higher height than an orbital one. The most important requirement for an orbital flight over a sub-orbital one is speed. The shock wave produced by high speed atmospheric re-entry generates lots of heat from which the spacecraft must be protected.

Space tourism is the recent phenomenon of space travel by individuals for the purpose of personal pleasure. Currently, space tourism can only be contemplated by exceptionally wealthy individuals and corporations, with the Russian space programme providing transport.

Among the primary **attractions** of space tourism are the uniqueness of the experience, the awesome and thrilling feelings of looking at Earth from space (described by astronauts as extremely intense and mind-boggling), status symbol, and various advantages of weightlessness.

The greatest **dangers** are likely to be malfunctions of the craft at take-off (e.g. Space Shuttle Challenger, 1986), or during re-entry (e.g. Space Shuttle Columbia, 2003). The landing of an orbital capsule by parachute may also be a significant risk. Less drastic, but no doubt unpleasant, is the likelihood of "space sickness" (or space adaptation syndrome), a form of motion sickness. The most important factor affecting human physical well being in space is weightlessness (more precisely, a microgravity environment). Living in this type of environment impacts on three types of human tissue: gravity receptors (affecting balance); fluids (loss of

plasma in the blood stream); weight bearing structures (muscle atrophy and loss of bone tissue). The effects of these problems are not likely to be long-lasting for a tourist in space for a relatively short time, but may be more dangerous for those who stay in space for a protracted period of time - if, for example, trips to Mars became feasible. Radiation exposure is a further risk. Protective shielding and protective drugs may lower the risks to an acceptable level, but longer-term exposure will inevitably result in greater risks.

5 Explain the science of how embryonic stem cell lines are established.

Indicate their potential medical benefits and discuss the ethical concerns about their production and use.

Stem cells are primal undifferentiated cells which retain the ability to differentiate into other cell types. This ability allows them to act as a repair system for the body, replenishing other cells as long as the organism is alive. Stem cells could be described as cells which have not yet chosen a "career path"; and have the potential to become many different types of cell. There are several types of stem cells: some, found in the bone marrow, are already committed to the "career path" of immune cells but have not differentiated into specific types of immune cell. Others have the potential to become almost any cell in the body (such as cells in early embryonic tissue).

Embryonic stem cells (ESCs) are stem cells derived from the undifferentiated inner mass cells of a blastocyst, an early stage embryo (approximately 1 week old in humans) consisting of 50-150 cells. Embryonic stem cells are technically immortal, which means they can divide (i.e. replicate) indefinitely. Moreover, they are pluripotent, meaning they are able to grow (i.e. differentiate) into all derivatives of the three primary germ layers: ectoderm, endoderm and mesoderm.

A **stem cell line** is a family of constantly dividing cells, the product of a single embryo. It is obtained from cells found in human or animal tissues and can replicate for long periods of time in vitro. Stem cell lines are stem cells that have been isolated from tissue or blood and held in liquid culture medium under conditions designed to support their growth and proliferation. Under the correct conditions this proliferation enables substantial expansion of the cell numbers. Following expansion, the stem cell cultures can be harvested, divided into vials and preserved at ultra-low temperatures. This stock of frozen cells is called a cell bank and the freezing process is a crucial stage which enables the cell bank to be stored in a viable and stable state until required. The cells can be thawed and re-cultured for research or therapy. In some cases, such as embryonic stem cells, the cultures appear to have the capacity to expand indefinitely, without changing. Such cell cultures are called stem cell lines.

Some stem cells have already been used in **medicine** for many years. Bone marrow transplants are a long-standing and safe treatment for children with leukaemia and deficient immune systems. They work by seeding the body of the recipient with stem cells which multiply and become the immune cells that the child needs to fight infectious disease.

Because of their unique combined abilities of unlimited expansion and pluripotency, embryonic stem cells potentially are the ultimate source for regenerative medicine and tissue replacement after injury or disease. They offer the hope of a cure for many types of disease, such as insulin-dependent diabetes, Parkinson's disease, Alzheimer's disease, and tissue damage such as that suffered by spinal trauma victims. They could potentially replace heart tissue damaged by a heart attack. It has even been suggested that they could be used to re-grow missing teeth and be a cure for baldness!

The **ethical debate** over stem cell research arises from how they are created. Some are the by-product of in-vitro fertilisation attempts by couples trying to have children. Unused ones, rather than being discarded, are harvested. Others are deliberately created specifically for this research. From the biological point of view, the blastocyst is not yet an individual. Blastocysts are an early developmental stage far from possessing a nervous system (or any other organs), and thus biologically speaking do not have feelings. To some, this does not address the concern that using blastocysts in embryonic stem cell research is instrumentalising a developing human being. Some Christian organisations (such as Catholics, Eastern Orthodox and Fundamentalists) believe that a human blastocyst is a human being, with human rights, and therefore oppose embryonic stem cell research because the start of each cell line involves the

destruction of a blastocyst. Others do not view a blastocyst as a human being, and may instead see opposition to stem cell research as unfounded due to the suffering that new medical technologies could prevent.

In the US, President G W Bush withdrew (2001) federal funding from new ESC lines, but the administration's decision does not prohibit private embryonic stem cell research. In the UK, ESC research is licensed under strict conditions by the Human Fertilisation and Embryology Authority.

The exposure of the claims of the South Korean researcher Hwang Koo-suk to have produced patient-specific stem cell lines as incorrect (2005) has undermined confidence in the rate of progress in stem cell research.

6 Discuss, in scientific and technological terms, threats to the human food chain.

A **food chain** describes a single pathway that energy and nutrients may follow in an ecosystem. A **food web** or **food network** extends the food chain concept from a simple linear pathway to a complex network of interactions. The **human food web** includes domesticated crop and 'wild' plants, domestic and wild animals, fish and other aquatic animals.

The **human population** expanded rapidly in the 20th century - it doubled to 6 billion people in the 40 years from 1960 and there are currently 75 million people born annually. Food production has grown also - world cereal consumption has more than doubled since 1970, and meat consumption has tripled since 1961. The global fish catch grew more than six times from 1950 to 1997. The World Resources Institute said in 1999 that half of all the commercial fertilizer ever produced had been applied since 1984.

However, there are questions about the **sustainability** of this growth - farmers are having to turn to increasingly marginal land; soil degradation has already reduced global agricultural productivity; many of the pesticides on which the crop increases have depended are losing their effectiveness, as the pests acquire more resistance; in many countries there will be progressively less water available for agriculture.

The most immediate examples of threats to the food chain are in areas of **famine**. Famine is associated with naturally-occurring crop failure and pestilence and artificially with war and genocide. Where there is a reliance on subsistence agriculture, famine can result from harvest failure or drought. War has often been associated with famine, most recently in the Sudan. Famine is often a problem of food distribution and poverty, rather than an absolute lack of food (Ireland in the 1840s). In many cases, such as the Great Leap Forward in China (late-1950s), North Korea in the mid-1990s, or Zimbabwe in the early-2000s, famine can be caused as an unintentional result of government policy.

For some time it was hoped that a positive effect of **climate change** would be increased agricultural yields, because of the role of carbon dioxide in photosynthesis, especially in preventing photorespiration, which is responsible for significant destruction of several crops. Whilst local benefits may be felt in some regions (such as Siberia), recent evidence is that global yields will be negatively affected. Moreover, the region likely to be worst affected is Africa, both because its geography makes it particularly vulnerable, and because seventy per cent of the population rely on rain-fed agriculture for their livelihoods.

Another threat is **overfishing**. Since 1950, technological advances in fishing have resulted in annual catches increasing from 18m tonnes in that year to 95m tonnes in 2000. During the 1990s, this rapid growth tapered off as fish populations declined dramatically. The latest figures from the UN Food and Agriculture Organisation say 52% of commercial fish species are fully exploited, 17% overexploited and 8% depleted. Many species are in desperate trouble, including tuna, plaice, monkfish and cod.

Threats to the human food chain might also include **infectious diseases**. BSE (bovine spongiform encephalopathy) is transmitted when prion proteins carry the disease between individuals and cause deterioration of the brain. Transmission can occur when healthy animals consume tainted tissues from others with the disease. Foot-and-mouth disease is a highly contagious and sometimes fatal viral disease of cattle and pigs. There was an outbreak of foot-and-mouth disease in Britain in 2001 which resulted in the slaughter of many animals.

Some would argue that **genetically modified food** is a potential threat to the human food chain (though others could argue that GM food is a means of coping with threats to the food chain). A genetically modified food is derived in whole or part from a genetically modified organism (GMO) such as a crop plant, animal or microbe such as yeast. Genetically modified foods have been available since the 1990s. The principal GM ingredients of GM foods currently available

(mainly from the US) are derived from genetically modified soya beans, maize and oil seed rape. It is claimed that there may be dangers to human health, as well as damage to the environment and biodiversity, from the development of GM crops.

It might also be argued that some **production methods** are threats to the human food chain – for example, the use of pesticides which can leave residual traces in raw food; and food additives such as sudan-1, which was recently withdrawn from use in the EU because of its potentially carcinogenic properties.