BIOLOGY REVISION NOTES

FOR AQA GCSE (9-1)
SIMPLE, CLEAR & MEMORABLE

PAPER 2

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USING THIS BOOK

This is **Higher Tier** only material – this means you will only need to revise this if you are sitting the higher tier Biology paper.

This is **Biology (separate science)** only material – this means you will only need to revise this if you are sitting the triple award separate science Biology paper (**8462**).

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THIS IS A SPECIFICATION CHAPTER

1.1 THIS IS A SPECIFICATION TOPIC

1.1.1 This is a specification subtopic

5 HOMEOSTASIS AND RESPONSE

5.1 HOMEOSTASIS

- Homeostasis is the regulation of the internal conditions of a cell or organism to maintain optimum conditions for function in response to internal and external changes.

- Homeostasis controls:
  - blood glucose concentration
  - body temperature
  - water levels

- Homeostatic automatic control mechanisms may involve nervous or chemical responses.
- A stimulus (plural stimuli) is a change in the environment.
- The Central Nervous System (CNS) consists of the brain and spinal cord.

- All control mechanisms include:
  - **receptors:** cells which detect stimuli and send information to coordination centres
  - **coordination centres:** organs which receive and process information from receptors
  - **effectors:** muscles or glands which bring about responses which restore optimum levels

5.2 THE HUMAN NERVOUS SYSTEM

5.2.1 Structure and function

- The nervous system enables humans to react to their surroundings and to coordinate their behaviour.

  stimulus → receptor → coordinator → effector → response

- From stimulus to response:
  - stimulus detected by receptor
  - receptor sends information along neurones as electrical impulses to the CNS
  - CNS receives and processes information, coordinates response of effectors, and sends electrical impulses to effectors
  - effectors receive information and respond

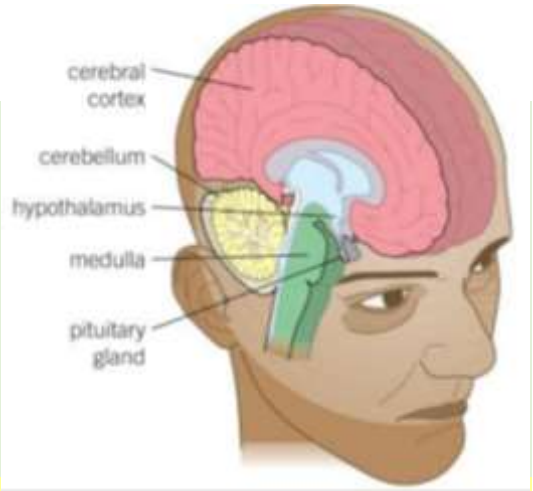
- In the reflex arc:
  - receptor produces electrical impulse
  - impulse received - moves along sensory neurone
  - sensory neurone releases neurotransmitter chemicals across synapse (empty space) between itself and the relay neurone in the spinal cord
  - impulse received - moves along relay neurone
  - relay neurone releases neurotransmitter chemicals across synapse between itself and the motor neurone in the spinal cord
  - impulse received - moves along motor neurone
  - effector receives impulse and produces a response

stimulus → receptor → sensory neurone → relay neurone (in CNS) → motor neurone → effector → response

- Importance of reflex actions:
  - automatic and rapid (do not involve thought process from brain)
  - protect from danger

5.2.2 The brain

- The brain controls complex behaviour.
- It is made of billions of interconnected neurones and has different regions that carry out different functions.



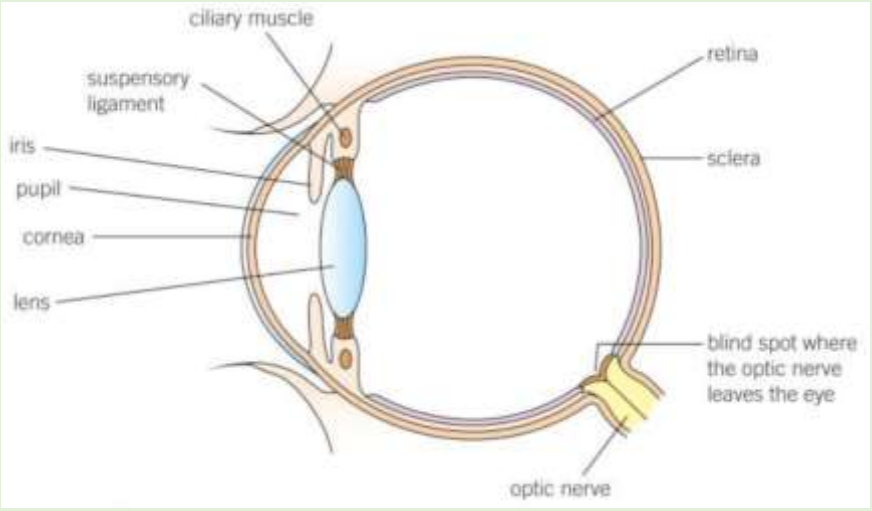
- Parts of the brain:
  - **cerebral cortex:** consciousness, memory, intelligence and language
  - **cerebellum:** muscular activity and balance
  - **medulla:** unconscious activities, e.g. breathing

- Difficulties of investigating brain function and treating brain damage and disease:
  - complexity of brain
  - delicacy of brain
  - drugs often cannot reach brain due to thick surrounding membranes
  - surgery is difficult as not all functions are understood

- Neuroscientists have been able to map the regions of the brain to particular functions by:
  - studying patients with brain damage
  - electrically stimulating different parts of the brain
  - using MRI scanning techniques

5.2.3 The eye

- The eye is a sense organ containing receptors sensitive to light intensity and colour.



- Parts of the eye:
  - **retina:** contains receptor cells which detect light intensity and colour
  - **optic nerve:** transmits impulses (of image) from eye to brain
  - **sclera:** tough white outer layer that protects eyeball
  - **cornea:** transparent section of sclera at front which is curved to slightly refract light
  - **iris:** controls size of pupil and thereby how much light enters the eye
  - **ciliary muscles:** control suspensory ligaments
  - **suspensory ligaments:** control thickness of lens

- Accommodation is the process of changing the shape of the lens to focus on near or distant objects.

- To focus on a near object:
  - ciliary muscles contract
  - suspensory ligaments loosen
  - lens is thicker and refracts light rays strongly

- To focus on a distant object:
  - ciliary muscles relax
  - suspensory ligaments pulled tight
  - lens is thinner and only slightly refracts light rays

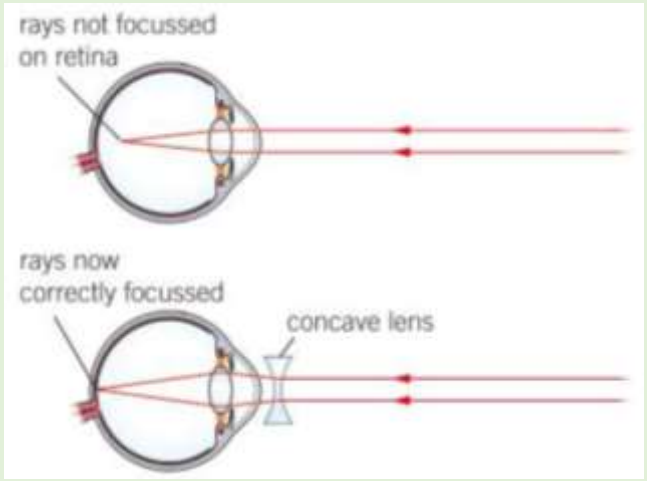
- To adapt to dim light:
  - muscular iris makes pupil larger
  - more light enters eye as light-sensitive receptor cells are not detecting enough light

- To adapt to bright light:
  - muscular iris makes pupil smaller
  - less light enters eye so light-sensitive receptor cells are not damaged

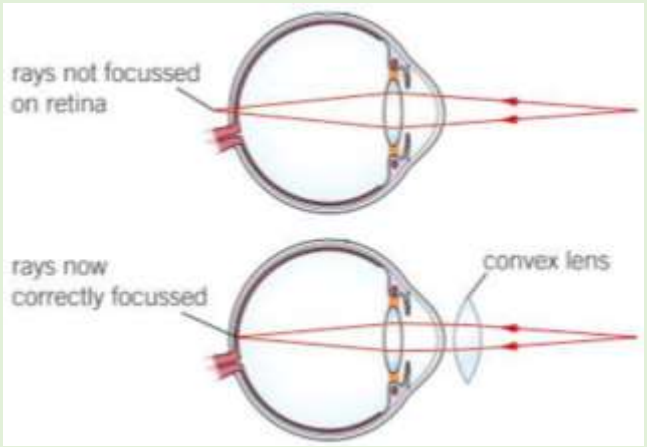
- Two common defects of the eye in which rays of light do not focus on the retina:
  - **myopia (short sightedness):** light rays focused in front of retina
  - **hyperopia (long sightedness):** light rays focused behind retina

  - generally these defects are treated with spectacle lenses which refract the light rays so that they focus on the retina
  - new technologies now include:
    - hard and soft contact lenses
    - laser eye surgery to change the shape of the cornea
    - replacement lens in the eye

- Myopia (short sightedness):
  - lens too thick or eyeball too long
  - light focused in front of retina
  - concave lens spreads light rays from distant objects



- Hyperopia:
  - lens too thin or eyeball too short
  - light focused behind retina
  - convex lens brings together light rays from nearby objects



5.2.4 Control of body temperature

- Body temperature is monitored and controlled by the thermoregulatory centre in the brain.

- Receptors are found in the:
  - **thermoregulatory centre:** contains receptors sensitive to blood temperature
  - **skin:** contains temperature receptors and sends nervous impulses to the thermoregulatory centre

- If the body temperature is too high:
  - **blood vessels dilate (vasodilation):** more blood flows near the skin, which turns red and emits radiation to the surroundings
  - **sweat produced from sweat glands:** as sweat evaporates it transfers energy from the skin to the surroundings

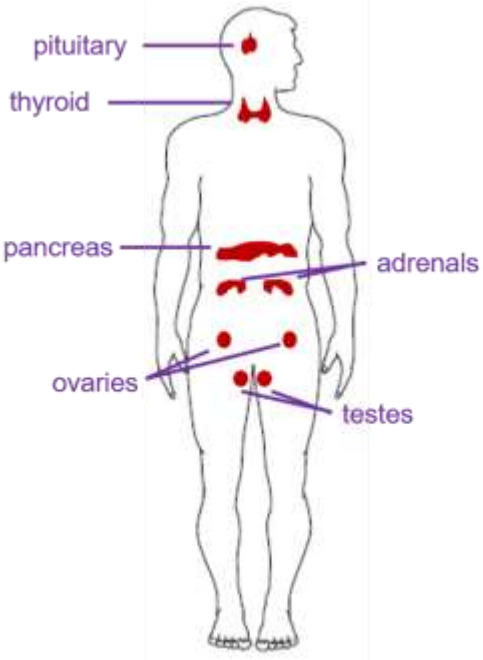
- If the body temperature is too low:
  - **blood vessels constrict (vasoconstriction):** less blood flows near the skin so less radiation is emitted
  - **sweating stops:** less evaporation of sweat
  - **skeletal muscles contract (shiver):** contractions require energy from respiration, an exothermic reaction which transfers energy to the body

5.3 HORMONAL COORDINATION IN HUMANS

5.3.1 Human endocrine system

- A hormone is a large chemical molecule produced in an endocrine gland that coordinates a specific organ's functioning.
- The endocrine system is made up of glands which secrete hormones directly into the bloodstream to its target organ where it produces an effect.

- The pituitary gland in the brain is a 'master gland' which secretes several hormones into the blood in response to body conditions.
- Pituitary hormones stimulate the secretion of other hormones by other glands to bring about effects.



5.3.2 Control of blood glucose concentration

- Blood glucose concentration is monitored and controlled by the pancreas.

- If blood glucose concentration is too high:
  - the pancreas secretes insulin
  - in liver and muscle cells excess glucose is converted into glycogen for storage
  - this causes glucose to move from the blood into the cells

- If blood glucose concentration is too low:
  - the pancreas secretes glucagon
  - in liver and muscle cells glycogen is converted into glucose
  - amino acids/lipids are broken down into glucose

- Glucagon interacts with insulin in a negative feedback cycle to control blood glucose levels in the body:
  - if the blood glucose is too high, insulin is released
  - if the blood glucose is too low, glucagon is released
  - this continues to keep the blood glucose level constant

- Type 1 diabetes:
  - a disorder in which the pancreas fails to produce sufficient insulin
  - treated with insulin injections
  - it is a genetically inherited disorder

- Type 2 diabetes:
  - a disorder where body cells no longer respond to insulin produced by the pancreas
  - treated by a carbohydrate-controlled diet and an exercise regime
  - obesity is a risk factor

5.2.4 Maintaining water and nitrogen balance in the body

- Uncontrolled loss of water, ions and urea:
  - **exhalation:** water leaves body via lungs
  - **sweat:** water, ions and urea lost from skin

- Controlled loss of water, ions and urea:
  - **kidney function:** excess water, ions and urea removed in urine

- If body cells lose or gain too much water by osmosis they do not function effectively.

- The digestion of proteins from the diet results in excess amino acids which need to be excreted safely.
- In the liver these amino acids are deaminated to form ammonia, which is toxic.
- Ammonia is immediately converted to urea for safe excretion.

- The kidneys produce urine by filtration of the blood and selective reabsorption of useful substances such as glucose, some ions and water.

- Antidiuretic hormone (ADH) and negative feedback:
  - controls water level in body by acting on kidney tubules
  - released by pituitary gland when blood concentration is too high
  - this causes more water reabsorption in the kidney tubules

- **Kidney dialysis** is the process of artificially performing the function of the kidney by connecting a patient to a dialysis machine:
  - tube connected to vein via arm
  - blood flows along tube into machine
  - semi-permeable membrane separates patient's blood and dialysing fluid (fluid containing same concentrations of components as healthy blood plasma)
  - harmful/excess substances diffuse through the membrane into the dialysing fluid

Advantages	Disadvantages
- cleans blood to ensure functioning - treatment is not every day - reduced risk of death	- light-headedness - lifestyle affected (up to 4hrs twice a week) - risk of infection

- **Kidney transplants** involve the replacement of a damaged kidney with that of a donor.

Advantages	Disadvantages
- **improved quality of life** (no more dialysis) - **reduced risk of death**	- major surgical procedure with risks of **infection and damage** to other organs - **immunosuppressant drugs must be taken** for the rest of patient's life - patient more **prone to infection** due to immunosuppressant drugs

5.3.4 Hormones in human reproduction

- During puberty reproductive hormones cause secondary sex characteristics to develop.

- Testosterone, in males:
  - produced in the testes
  - stimulates sperm production
  - stimulates the development of secondary sex characteristics

- Oestrogen, in females:
  - produced in the ovary
  - involved in ovulation and the menstrual cycle

- Hormones in the menstrual cycle:
  - follicle stimulating hormone (FSH) causes the maturation of eggs in the ovary
  - luteinising hormone (LH) stimulates ovulation
  - oestrogen stimulates the development of the lining of the uterus
  - progesterone maintains the lining of the uterus

- Interaction of hormones in the menstrual cycle: *inhibits means stops
  - FSH secreted by the pituitary gland:
    - stimulates the maturation of eggs
    - stimulates the production of oestrogen
  - oestrogen secreted by the ovaries:
    - stimulates the development of the lining of the uterus
    - inhibits the release of FSH
    - stimulates the production of LH
  - LH secreted by the pituitary gland:
    - stimulates the release of a mature egg from the ovary
    - thereby stimulates the release of progesterone after ovulation
  - progesterone secreted by the empty egg follicle:
    - maintains the lining of the uterus if the egg is fertilised so that the embryo can be implanted there
    - otherwise progesterone does **not** maintain the lining of the uterus so the menstrual cycle restarts
    - inhibits the release of FSH and LH

5.3.5 Contraception

- Fertility can be controlled by hormonal and non-hormonal methods of contraception.

- Hormonal methods:
  - **oral contraceptives:**
    - contain small amounts of oestrogen and progesterone
    - these hormones inhibit the production of FSH and LH
    - these hormones stop the lining of the uterus developing
    - these hormones keep the cervix's mucus thick to stop sperm getting through
    - easy to use as it does not require a doctor
    - relatively effective at preventing egg maturation and ovulation
    - must be taken regularly
    - risk factor for raised blood pressure, thrombosis, breast cancer
  - **injection, implant or skin patch**:
    - slowly release progesterone
    - progesterone inhibits the production of FSH and LH, and therefore the maturation and release of eggs for a specified period of time
    - contraceptive injection prevents egg release
    - contraceptive implant is 99.95% effective at preventing ovulation
    - contraceptive patch can be used without a doctor
    - contraceptive injection only lasts 12 weeks
    - contraceptive implant must be performed by a doctor
    - contraceptive patch only lasts a week

- Non-hormonal methods:
  - **barrier methods** such as condoms/diaphragms:
    - prevent the sperm reaching the egg
    - no side effects
    - condoms do not need medical advice
    - protect against STDs
    - condoms may get damaged and let sperm through
    - diaphragms must be fitted by a doctor
  - **intrauterine devices**:
    - contain copper to prevent implantation
    - some contain progesterone to thicken the mucus of the cervix to stop sperm getting through
    - extremely effective at preventing implantation
    - may cause period problems
    - may cause infections
  - **spermicidal agents:**
    - kill or disable sperm
    - readily available
    - not very effective; some sperm survive
  - **abstaining from intercourse during maturation**
    - sperm cannot fertilise egg when it is in the oviduct
    - does not use artificial methods of contraception (ethical)
    - very unreliable in terms of knowing when to stop abstaining

- **surgical methods** for sterilisation:
  - vasectomy in males (sperm ducts are cut and tied)
  - tubal ligation in females (oviducts cut or tied)
  - permanent contraception with no risk of human error
  - women require general anaesthetic for the surgery

5.3.6 The use of hormones to treat infertility

- In Vitro Fertilisation (IVF) treatment is a modern reproductive technology used to treat infertility.

- In IVF:
  - a mother is given FSH and LH to stimulate the maturation of several eggs (she may be able to then become pregnant normally)
  - the eggs are collected from the mother and fertilised by sperm from the father in the laboratory
  - the fertilised eggs develop into embryos
  - one or two embryos are inserted into the mother's uterus

- Disadvantages of IVF:
  - very emotionally and physically stressful
  - low success rates
  - can lead to multiple births, which are a risk to both the babies and the mother

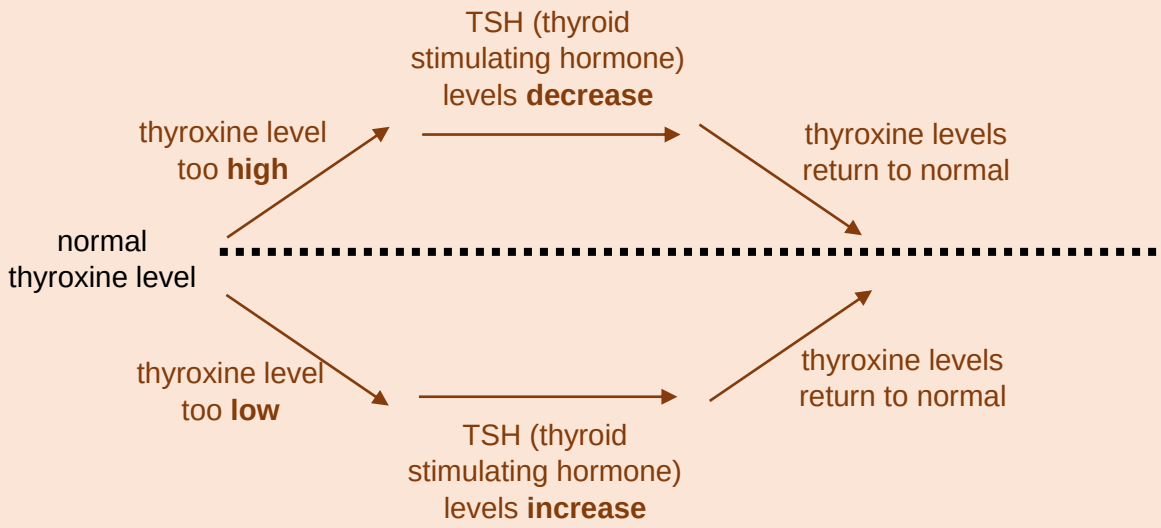
5.3.7 Negative feedback

- Thyroxine: *(**is** controlled by negative feedback)*
  - produced in the thyroid gland
  - stimulates basic metabolic rate
  - plays an important role in growth and development

- Adrenaline: *(is **not** controlled by negative feedback)*
  - produced in the adrenal glands in times of fear or stress
  - increases heart rate
  - boosts delivery of oxygen and glucose to brain and muscles
  - prepares body for 'flight or fight' situations

Negative feedback diagram for thyroxine:

TSH (thyroid stimulating hormone) is produced in the pituitary gland:



5.4 PLANT HORMONES

5.4.1 Control and coordination

- Plants produce hormones to coordinate and control growth and responses to:
  - **light** (phototropism)
  - **gravity** (gravitropism/geotropism)

- Unequal distributions of auxin cause unequal growth rates in plant roots and shoots.

- Gibberellins are important in initiating seed germination.
- Ethene controls cell division and ripening of fruits.

5.4.2 Use of plant hormones

- Plant growth hormones are used in agriculture and horticulture.

- Auxins are used:
  - as weed killers
  - as rooting powders
  - for promoting growth in tissue culture

- Ethene is used in the food industry to control ripening of fruit during storage and transport.

- Gibberellins can be used to:
  - end seed dormancy
  - promote flowering
  - increase fruit size

6 INHERITANCE, VARIATION AND EVOLUTION

6.1 REPRODUCTION

6.1.1 Sexual and asexual reproduction

- Gametes are sex cells:
  - in animals: sperm and egg
  - in plants: pollen and egg

- Asexual reproduction:
  - offspring produced by mitosis
  - involves only one parent
  - does **not** involve fusion of gametes
  - **no** mixing of genetic information leads to genetically identical offspring

- Sexual reproduction:
  - gametes produced by meiosis
  - involves two parents
  - involves the fusion of male and female gametes
  - mixing of genetic information leads to variety in offspring

6.1.2 Meiosis

- Meiosis is the division of cells in reproductive organs to form gametes.

- In meiosis:
  - genetic information is copied
  - cell divides twice to form four gametes, each with a single set of chromosomes (23 – haploid)
  - all gametes are genetically different from each other

- The male and female gametes fuse together at fertilisation to restore the normal number of chromosomes (46 - diploid).
- New cells divide by mitosis, increase in number and differentiate.

6.1.3 Advantages of sexual and asexual reproduction

Advantages of **sexual** reproduction	Advantages of **asexual** reproduction
- produces **variation** in offspring - if environment changes variation gives a **survival advantage** by natural selection - natural selection can be speeded up by humans in **selective breeding** to increase food production	- only **one parent needed** - more **time and energy efficient** as do not need to find a mate - **faster** than sexual reproduction - **many identical offspring** can be produced when conditions are favourable

- Some organisms reproduce by both methods depending on the circumstances:
  - **malarial parasites:** asexually in the human host / sexually in the mosquito
  - **fungi:** asexually in the spores / sexually to give variation in unfavourable conditions
  - **plants:** asexually by runners (e.g. strawberry plants) or bulb division (e.g. daffodils) / sexually to produce seeds

6.1.4 DNA and the genome

- The nucleus of a cell contains genetic material, composed of 23 pairs of chromosomes, therefore 46 in total.

- Each chromosome is composed of a chemical called DNA.
- DNA is a polymer made of two strands in a double helix.

- A gene is a small section of DNA which codes for a particular sequence of amino acids to make a specific protein.

- The genome for an organism is the entire genetic material of that organism.

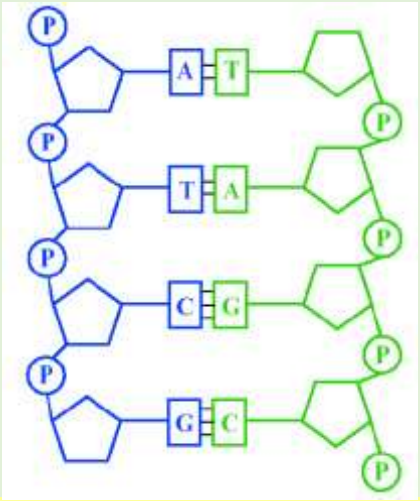
- Importance of the human genome:
  - searching for genes linked to different diseases
  - understanding and treating inherited disorders
  - tracing human migration patterns from the past

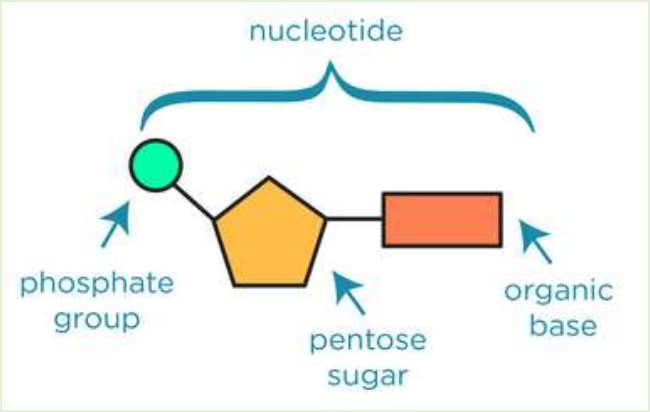
6.1.5 DNA structure

- DNA is a polymer made from four different nucleotides.
- Each nucleotide consists of a common sugar and phosphate group with one of four different bases attached to the sugar.

- DNA contains four bases: A, C, G and T
- A sequence of three bases is the code for a particular amino acid.
- The order of bases controls the order in which amino acids are assembled to produce a particular protein.

- The long strands of DNA consist of alternating sugar and phosphate sections.
- Attached to each sugar is one of the four bases.





- In the complementary strands:
  - a C is always linked to a G on the opposite strand and
  - a T is always linked to an A on the opposite strand.

- Protein synthesis:
  - a template is produced by the DNA
  - proteins are synthesised on ribosomes according to the template
  - carrier molecules bring specific amino acids to add to the growing protein chain in the correct order
  - when the protein chain is complete it folds up to form a unique shape
  - this unique shape enables the proteins to do their job as enzymes, hormones or forming structures in the body such as collagen

- Mutations occur continuously.
- Most do not alter the protein, or only alter it slightly so that its appearance or function is not changed.

- A few mutations code for an altered protein with a different shape.
- An enzyme may no longer fit the substrate binding site or a structural protein may lose its strength, so the mutation has altered its activity.
- Non-coding parts of the DNA can switch genes on and off, so variations in these areas of DNA may affect how genes are expressed.

6.1.6 Genetic inheritance

- Definitions:
  - **gamete:** sex cell
  - **chromosome:** strand of DNA
  - **gene:** small section of DNA coding for a specific characteristic
  - **allele:** a (different) form of a gene
  - **dominant allele:** always expressed, even if only one copy is present
  - **recessive allele:** only expressed if two copies are present
  - **homozygous:** an organism with identical alleles for a characteristic
  - **heterozygous:** an organism with different alleles for a characteristic
  - **genotype:** genetic makeup of an organism for a characteristic
  - **phenotype:** expression of genotype of an organism for a characteristic

- Dominant alleles are shown in capitals, e.g. B or P
- Recessive alleles are shown in lowercase, e.g. b or p

- Where there are two dominant alleles, e.g. BB, B is expressed.
- Where there is one dominant alleles, e.g. Bb, B is expressed.
- Where there are two recessive alleles, e.g. bb, b is expressed

- Most characteristics are a result of the interaction of multiple genes rather than a single gene, so a genetic cross does not always determine an organism's characteristic.

Punnett Square B – black hair b – brown hair		Homo-zygous	
		b	b
Hetero-zygous	B	Bb	bb
	b	Bb	bb
Genotype ratio	Bb : bb 2 : 2 (so 1 : 1)		
Phenotype ratio	black : brown 2 : 2 (so 1 : 1)		
Probability of black hair	$\frac{2}{4}$ = 50%		
Probability of brown hair	$\frac{2}{4}$ = 50%		

Punnett Square H – long hair h – short hair		Hetero-zygous	
		H	h
Hetero-zygous	H	HH	Hh
	h	Hh	hh
Genotype ratio	HH : Hh : hh 1 : 2 : 1		
Phenotype ratio	long : short 3 : 1		
Probability of long hair	$\frac{3}{4}$ = 75%		
Probability of short hair	$\frac{1}{4}$ = 25%		

6.1.7 Inherited disorders

- Inherited disorders are caused by the inheritance of certain alleles:
  - **polydactyly**: having extra fingers or toes, caused by a dominant allele
  - **cystic fibrosis**: cell membrane disorder, caused by a recessive allele

Punnett Square P – polydactyly p – no polydactyly		Homo-zygous	
		p	p
Hetero-zygous	P	Pp	pp
	p	pp	pp
Genotype ratio	Pp : pp 3 : 1		
Phenotype ratio	polydactyly : no polydactyly 3 : 1		
Probability of polydactyly	$\frac{3}{4}$ = 75%		
Probability of no polydactyly	$\frac{1}{4}$ = 25%		

Punnett Square C – no cystic fibrosis c – cystic fibrosis		Homo-zygous	
		C	C
Hetero-zygous	c	Cc	Cc
	c	Cc	Cc
Genotype ratio	Cc : other 4 : 0		
Phenotype ratio	no c.f. : c.f. 0 : 4		
Probability of c.f.	$\frac{0}{4}$ = 0%		
Probability of no c.f.	$\frac{4}{4}$ = 100%		

- Arguments for embryo scanning:
  - could reduce healthcare costs for foetus once born
  - could avoid life of pain and suffering

- Arguments against embryo scanning:
  - expensive
  - risk of miscarriage
  - can five false positive or negative result
  - no cures for genetic disorders
  - prompts decisions on termination

6.2 VARIATION AND EVOLUTION

6.2.1 Variation

- Variation describes the differences in the characteristics of individuals in a population.

- Variation is caused by:
  - inherited genes (genetic)
  - conditions of development (environmental)
  - a combination of genes and the environment

- The genome can interact with the environment to influence the development of the phenotype of an organism:
- E.g. skin colour may darken in sunny climates
- E.g. a genetic tendency to be underweight may be overcome by too much junk food

- There is usually extensive genetic variation within a population of species.

- Mutations are changes in the DNA code in which:
  - most have no effect on the phenotype
  - some influence phenotype
  - very few determine phenotype

- In organisms, mutations:
  - occur continuously
  - rarely lead to a new phenotype
  - if one is suited to an environmental change it can lead to a relatively rapid change in the species by survival of the fittest

6.2.2 Evolution

- Evolution is a change in the inherited characteristics of a population over time through a process of natural selection which may lead to the formation of a new species.
- The theory of evolution states that all species evolved from simple life forms that first developed three billion years ago.

- Survival of the fittest:
  - species show wide range of phenotype
  - individuals with characteristics most suited to the environment survive and breed
  - individuals with less suited characteristics become extinct
  - the ‘useful’ alleles are passed on to the next generation

- If two populations of one species become so different in phenotype that they can no longer interbreed to produce fertile offspring they have formed two new species.

6.2.3 Selective breeding

- Selective breeding is the process by which humans breed plants and animals for particular genetic characteristics.
- Also known as artificial selection, it has been done for thousands of years.

- Selective breeding in detail:
  - parents with desired characteristic chosen from mixed population
  - they are bred together
  - offspring with the desired characteristic are bred together
  - this continues over many generations until all offspring show the desired characteristic(s)

- Characteristics include:
  - disease resistance in food crops
  - animals which produce more meat or milk
  - domestic dogs with a gentle nature
  - large or unusual flowers

- However, selective breeding can lead to inbreeding:
  - closely related animals are bred
  - they have similar genetic characteristics
  - a specific disease could wipe out the whole population
  - an undiscovered defect could be in all the population

6.2.4 Genetic engineering

- Genetic engineering is the process which involves modifying the genome of an organism by introducing a gene from another organism to give a desired characteristic.

- Uses of genetic engineering:
  - plant crops have been genetically engineered to be resistant to diseases or to produce bigger better fruits
  - bacterial cells have been genetically engineered to produce useful substances such as human insulin to treat diabetes

Benefits	Risks
- improved growth rate of organisms - increased food value of GM crops - crops well-suited to different climates - GM crops can release pesticides - possibility of overcoming inherited disorders	- effects of eating GM crops not fully explored - effects on populations of wild flowers and insects - GM crops are infertile - fears of human engineering

- In genetic engineering:
  - enzymes are used to isolate the required gene
  - gene is inserted into a vector, such as a bacterial plasmid or virus
  - vector is used to insert gene into required cells
  - gene is replicated and transferred to cells of organism at an early stage in their development
  - organism develops with desired characteristics

6.2.5 Cloning

<u>Tissue culture</u>
- using small groups of cells from part of a plant to grow identical new plants
- important for preserving rare plant species or commercially in nurseries

<u>Cuttings</u>
- an older, but simple, method
- used by gardeners to produce many identical plants from a parent plant

<u>Embryo transplant</u>
- splitting apart cells from a developing animal embryo before they become specialised
- then transplanting the identical embryos into host mothers

<u>Adult cell cloning</u>
- nucleus removed from unfertilised egg cell
- nucleus from adult body cell inserted into egg cell
- electric shock stimulates egg cell to divide to form an embryo
- these embryo cells contain the same genetic information as the adult cell
- when the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development

6.3 THE DEVEVELOPMENT OF UNDERSTANDING OF GENETICS AND EVOLUTION

6.3.1 Theory of evolution

- Charles Darwin, as a result of observations on a round the world expedition, backed by years of experimentation and discussion linked to developing knowledge of geology and fossils, proposed the theory of evolution by natural selection:
  - individual organisms within a particular species show a **wide range of variation** for a characteristic
  - individuals with characteristics **most suited to the environment** are more likely to **survive to breed successfully**
  - the **characteristics** that have enabled these individuals to survive are then **passed on to the next generation**

- Darwin published his ideas in *On the Origin of Species* (1859).
- There was much controversy surrounding these new ideas.
- The theory of evolution by natural selection was only gradually accepted because:
  - the theory **challenged the idea that God made all** the animals and plants that live on Earth
  - there was **insufficient evidence** at the time the theory was published to convince many scientists
  - the **mechanism of inheritance and variation was not known** until 50 years after the theory was published

- Jean-Baptiste Lamarck's theory was:
  - changes occur in an organism during its lifetime
  - these can be inherited (although now we know that this cannot occur)

6.3.2 Speciation

- Alfred Russel Wallace independently proposed the theory of evolution by natural selection.
- He published joint writings with Darwin in 1858 which prompted Darwin to publish *On the Origin of Species* (1859) the following year.

- Wallace worked worldwide gathering evidence for evolutionary theory.
- He is best known for his work on warning colouration in animals and his theory of speciation.
- Alfred Wallace did much pioneering work on speciation but more evidence over time has led to our current understanding of the theory of speciation.

- Speciation occurs by the following steps:
  - **isolation:** where two populations of a species become separated
  - **genetic variation** between the two populations
  - **natural selection** operates differently on the two populations
  - **speciation:** the two populations become so different that they can no longer successfully interbreed (to produce fertile offspring)

6.3.3 The understanding of genetics

- In the **mid-19th century** Gregor Mendel carried out breeding experiments on plants.
- One of his observations was that the inheritance of each characteristic is determined by 'units' that are passed on to descendants unchanged.
- In the **late 19th century** behaviour of chromosomes during cell division was observed.

- In the **early 20th century** it was observed that chromosomes and Mendel's 'units' behaved in similar ways.
- This led to the idea that the 'units', now called genes, were located on chromosomes.
- In the **mid-20th century** the structure of DNA was determined and the mechanism of gene function worked out.

6.3.4 Evidence for evolution

- The theory of evolution by natural selection is now widely accepted.

- Evidence for Darwin's theory of evolution:
  - **characteristics are passed on** to offspring in genes
  - **fossil record** shows evolution
  - **antibiotic resistance** in bacteria

6.3.5 Fossils

- Fossils are the 'remains' of organisms from millions of years ago, which are found in rocks.

- Ways of fossilization:
  - parts of organisms have not decayed due to absence of required conditions
  - parts of organism replaced by minerals during decay
  - preserved traces of organism, such as footprints, burrows and rootlet traces

- The fossil record is incomplete (and scientists speculate) because:
  - early forms of life were soft-bodied, leaving few traces behind
  - traces were destroyed by geological activity

- We can learn from fossils how much or how little different organisms have changed as life developed on Earth.
- More recent fossils are nearer to the surface and will look more like modern organisms' skeletons.

6.3.6 Extinction

- Extinctions occur when there are no remaining individuals of a species still alive.

- Factors which may contribute to extinction:
    - new predators
    - new diseases
    - successful competition
    - climate change
    - loss of habitat
    - catastrophic events, e.g. asteroid impact (cause mass extinctions)

6.3.7 Resistant bacteria

- Bacteria can evolve rapidly because they reproduce at a fast rate.
- Constant mitosis provides more opportunities for random mutation.

- How antibiotic resistant bacteria evolve:
    - mutations produce new strains
    - some strains are resistant to antibiotics, so are not killed
    - resistant strains survive and reproduce, increasing the population
    - resistant strain spreads because people are not immune to it
    - there is no effective treatment

- MRSA (Methicillin-resistant Staphylococcus aureus) is a type of bacteria that is resistant to antibiotics, and can be deadly due to no effective treatment.
- The development of new antibiotics is expensive and slow, so it is unlikely to keep up with the emergence of new antibiotic resistant strains.

- To reduce the rate of development of antibiotic resistant strains:
    - doctors should **not provide antibiotics inappropriately** (e.g. for virus)
    - patients should **complete their course of antibiotics** so all bacteria are killed (and none survive and mutate)
    - antibiotics are **not used for agricultural purposes**

6.4 CLASSIFICATION OF LIVING ORGANISMS

- Carl Linnaeus classified living things into groups depending on their structure and characteristics.
- Linnaeus classified things into:
    - kingdom
    - phylum
    - class
    - order
    - family
    - genus
    - species

- He named organisms by the binomial system of genus and species.
- E.g. in *Homo sapien:* *Homo* is the genus and *sapien* is the species.

- New models of classification were proposed due to the development of evidence of internal structures, enabled by:
    - improvements in microscopes
    - better understanding of biochemical processes

- Carl Woese developed a three-domain system due to evidence available from chemical analysis, the domains being:
    - **archaea:** primitive bacteria in extreme environments
    - **bacteria:** true bacteria
    - **eukaryota:** protists, fungi, plants, animals (cells having nuclei)

- Evolutionary trees are a method used by scientists to show the relation between organisms, using:
    - **classification data** for living organisms
    - **fossil data** for extinct organisms

7 ECOLOGY

7.1 ADAPTATIONS, INTERDEPENDENCE AND COMPETITION

7.1.1 Communities

- Levels of organisation in an ecosystem:
  - **organism** (individual)
  - **population** (of one species)
  - **community** (all organisms of habitat)
  - **ecosystem** (interaction between community and environment)

- An **ecosystem** is the interaction of a community of living organisms (biotic) with the non-living (abiotic) parts of their environment.
- Organisms require a supply of materials from their surroundings and other organisms to survive and reproduce.

- **Interdependence** describes how a species depends on other species for food, shelter, pollination, and seed dispersal.
- If one species is removed it can affect the whole community.
- A **stable community** is one where all the species and environmental factors are in balance so that population sizes remain fairly constant.

- **Competition** means obtaining resources when there are not enough for all:
  - animals compete for food, mates and territory
  - plants compete for light, space, water and mineral ions

7.1.2 Abiotic factors

- Abiotic factors are non-living factors, including:
  - **light intensity:** affects photosynthesis (plant growth) and distribution
  - **temperature:** affects photosynthesis and distribution
  - **moisture levels:** affects the ability for plants to grow at all
  - **soil pH / mineral content:** distribution + low pH inhibits decay
  - **wind intensity and direction:** tree shape, transpiration rates
  - **carbon dioxide levels:** affects photosynthesis
  - **oxygen levels for aquatic animals:** affects distribution (fish need O_2)

7.1.3 Biotic factors

- Biotic factors are living factors, including:
  - **availability of food:** affect survival and reproduction
  - **new predators:** defenceless species can be wiped out
  - **new pathogens:** non-resistant species can be wiped out
  - **outcompetition:** population gets low enough to disallow reproduction

7.1.4 Adaptations

- **Adaptations** are features that enable an organism to survive in the conditions in which they normally live.

- Types of adaptations:
  - **structural:** physical features, e.g. sharp teeth, or vibrant petals
  - **behavioural:** active features, e.g. dancing to attract mates
  - **functional:** processual, e.g. producing venom

- Typical animal adaptations:
  - **thick fur** for insulation
  - **camouflaged** skin
  - **large feet** as not to sink into snow/sand
  - **long eyelashes** to protect from sand (camels)
  - **low SA:V ratio** to reduce heat loss
  - **high SA:V ratio** to increase heat loss

- Typical plant adaptations:
  - **thick stem** to hold water
  - **widespread roots** to absorb as much water as possible
  - **wax cuticle** to prevent water loss
  - **tightly curled leaves** to prevent water loss
  - **few/many stomata** to decrease/increase water loss

- **Extremophiles** are organisms that live in environments that are very extreme, such as at high temperature, pressure, or salt concentration.
- Bacteria living in deep sea vents are extremophiles, living in little light and high pressure.

7.2 ORGANISATION OF AN ECOSYSTEM

7.2.1 Levels of organisation

- A food chain is a representation of feeding relationships within a community.

- All food chains begin with a **producer** which synthesises molecules, usually a green plant or alga which makes glucose by photosynthesis.
- **Producers** are eaten by **primary consumers**.
- **Primary consumers** are eaten by **secondary** and **tertiary consumers**.

- How to determine the distribution and abundance of a species in an ecosystem:
    - **transect:** a measured line by which species are counted at intervals
    - **quadrat:** a square frame outlining a sample area in which species are counted

- Predators are consumers that kill and eat other animals.
- Prey are those that are killed and eaten.
- In a stable community the number of predators and prey rise and fall in cycles, called cyclic fluctuation:
    - prey population increases
    - lots of food is available for predators, so predator population increases
    - eventually there will be a shortage of prey for predators
    - some predators will die of starvation, so predator population decreases
    - prey are not at so much risk any more, so the cycle restarts

7.2.2 How materials are cycled

- All materials in the living world are recycled to provide the building blocks for future organisms.

- The carbon cycle returns carbon from organisms to the atmosphere as carbon dioxide to be used by plants by photosynthesis.

- The water cycle provides fresh water for plants and animals on land before draining into the seas. Water is continuously evaporated and precipitated.

- The role of microorganisms in cycling materials:
    - **detritivores** are organisms that eat dead plant/animal material and produce waste
    - bacteria and fungi decompose the detritivores and their waste
    - this returns carbon dioxide from the carbon sink to the atmosphere
    - nutrients, including mineral ions, are returned to the soil for plants to absorb

7.2.3 Decomposition

- Factors affecting the rate of decay of biological material:
  - **temperature:** enzymes in decomposers have a warm optimum temperature
  - **water:** moisture makes it easier for microorganisms to digest their food
  - **availability of oxygen:** most decomposers respire aerobically so oxygen is needed
- Gardeners and farmers try to provide optimum conditions for rapid decay of waste biological material.
- The compost produced is used as a natural fertiliser for growing garden plants or crops.
- Anaerobic decay produces methane gas.
- Biogas generators can be used to produce methane gas as a fuel.

7.2.4 Impact of environmental change

- Environmental changes affect the distribution of species in an ecosystem, including:
  - **temperature**
  - **availability of water**
  - **composition of atmospheric gases**
- The changes may be:
  - **seasonal:** temperate regions experience significant seasonal changes every year
  - **geographic:** changes in soil structure, pH, altitude in a region
  - **caused by human interaction:** deforestation, water pollution, air pollution

7.3 BIODIVERSITY AND THE EFFECT OF HUMAN INTERACTION ON ECOSYSTEMS

7.3.1 Biodiversity

- Biodiversity is the variety of all the different species of organisms on earth, or within an ecosystem.

- A great biodiversity ensures the stability of ecosystems by reducing the dependence of one species on another for food, shelter and the maintenance of the physical environment.
- The future of the human species on Earth relies on us maintaining a good level of biodiversity.

- How human activity affects biodiversity:
    - **waste:** plastic in the oceans kills species / digging for landfill destroys habitats
    - **deforestation:** destroys habitats / endangers certain tree species
    - **global warming:** polar animals cannot hunt without ice / seas could flood habitats

7.3.2 Waste management

- Increasingly more resources are being used due to:
    - rapid growth in the human population
    - an increase in the standard of living mean

- Pollution kills plants and animals, which can reduce biodiversity.
- Unless waste and chemical materials are properly handled, more pollution will be caused.

- Pollution can occur:
    - **in water:** from sewage, fertiliser or toxic chemicals
    - **in air:** from smoke and acidic gases
    - **on land:** from landfill and toxic chemicals

7.3.3 Land use

- Humans reduce the amount of land available for other animals and plants by building, quarrying, farming and dumping waste.

- Peat bog destruction:
    - peat is used to produce garden compost
    - destructing peat bogs reduces the area of the habitat and the biodiversity
    - the decay or combustion of peat releases CO_2 into the atmosphere

7.3.4 Deforestation

- Large-scale deforestation in tropical areas is aimed to:
  - provide land for cattle and rice fields
  - grow crops for biofuels

- Negative implications of deforestation:
  - habitats destroyed
  - loss of biodiversity
  - release of CO_2 in the atmosphere (global warming)
  - loss of rural scenery

7.3.5 Global warming

- Levels of carbon dioxide and methane in the atmosphere are increasing, which contributes to global warming.

- Biological consequences of global warming:
  - **loss of habitat:** rising sea levels flood low-lying areas
  - **changes in distribution:** animals permanently migrate north/south
  - **changes in migration patterns:** seasons change, so organisms' migration changes
  - **reduced biodiversity:** species cannot cope with temperatures so become extinct

- The scientific consensus of global warming is based on systematic reviews of thousands of peer reviewed publications.
- Evidence is uncertain/incomplete because:
  - little data is available for over a century ago
  - some data is irrelevant

7.3.6 Maintaining biodiversity

- Scientists and concerned citizens have put in place programmes to reduce the negative effects of humans on ecosystems and biodiversity.

- Programmes include:
  - **breeding programmes** for endangered species
  - **protection** and **regeneration** of **rare habitats**
  - **reintroduction of field margins and hedgerows** in agricultural areas where farmers grow only one type of crop
  - **reduction of deforestation and carbon dioxide emissions** by some governments
  - **recycling resources** rather than dumping waste in landfill

- Negative human interactions in an ecosystem:
  - dumping **waste** in **landfill**
  - dumping **plastic** in the **oceans**
  - **deforestation**
  - **releasing toxic chemicals** into oceans/soil

7.4 TROPHIC LEVELS IN AN ECOSYSTEM

7.4.1 Trophic levels

- Trophic levels can be represented by numbers, starting at level 1 with plants and algae.
- Further trophic levels are numbered subsequently according to how far the organism is along the food chain.

- Trophic levels:
  - **Level 1 (producers):** plants and algae make their own food
  - **Level 2 (primary consumers):** herbivores eat plants/algae
  - **Level 3 (secondary consumers):** carnivores that eat herbivores
  - **Level 4 (tertiary consumers):** carnivores that eat other carnivores
  - Apex predators are carnivores with no predators.

- Decomposers break down dead plant and animal matter by secreting enzymes into the environment.
- Small soluble food molecules then diffuse into the microorganism.

7.4.2 Pyramids of biomass

- Pyramids of biomass can be constructed to represent the relative amount of biomass in each level of a food chain.

7.4.3 Transfer of biomass

- Producers are mostly plants and algae which transfer about 1% of the incident energy from light for photosynthesis.
- Only approximately 10% of the total biomass from each trophic level is transferred to the level above it.

- Reasons for losses of biomass:
  - not all ingested material is absorbed, **some is egested as faeces**
  - **some absorbed material is lost as waste**, such as carbon dioxide and water in respiration and water and urea in urine
    (large amounts of glucose used in respiration)

7.5 FOOD PRODUCTION

7.5.1 Factors affecting food security

- Food security is having enough food to feed a population.
- Suitable methods must be found to feed all people on Earth.

- Biological factors which are threatening food security include:
  - the **increasing birth rate** has threatened food security
  - **changing diets** in developed countries mean scarce food resources are transported around the world
  - **new pests and pathogens** that affect farming
  - **environmental changes** that affect food production, such as widespread famine occurring in some countries **if rains fail**
  - the **cost of agricultural inputs**
  - **conflicts that have arisen in some parts of the world** which affect the availability of water or food

7.5.2 Farming techniques

- The efficiency of food production can be improved by restricting energy transfer from food animals to the environment, by:
  - limiting their movement
  - controlling the temperature of their surroundings
- Some animals are fed high protein foods to increase growth.

7.5.3 Sustainable fisheries

- Fish stocks in the oceans are declining.
- It is important to maintain fish stocks at a level where breeding continues or certain species may disappear altogether in some areas.

7.5.4 Role of biotechnology

- Modern biotechnology techniques enable large quantities of microorganisms to be cultured for food.

- The fungus *Fusarium* is useful for producing mycoprotein, a protein-rich food suitable for vegetarians:
  - the fungus is grown on glucose syrup
  - in aerobic conditions
  - biomass is harvested and purified

- A genetically modified bacterium produces human insulin.
- When harvested and purified this is used to treat people with diabetes.

- GM crops could provide more food or food with an improved nutritional value such as golden rice.

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