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Study Skills

Here are some handy hints and tips to get you through the stressful examination time, and to help you ace your exams!

BEFORE THE EXAMINATION

Manage your time carefully
Draw up a revision schedule so that you have enough time to revise. Sit down with your exam timetable, and make sure that you allocate enough time for revision to each subject, paying particular attention to those subjects you might be struggling with. Give yourself two hours each day to cover a certain subject or area of the curriculum.

Break down the work into manageable sections or topics that you can cover in the time allocated. Reward yourself if you complete a section successfully and have done well in the revision questions.

Don't be distracted by the radio, television or your cell phone or computer. Switch these devices off, and make sure that you are able to focus without interruption.

When managing your time, remember to also make sure that you have some leisure time to spend with friends and family. Spending time relaxing with your friends can help reduce stress, but you must make sure that you keep on top of your studies!

Ask for help
If you are struggling with a particular subject or topic, don't be afraid to ask for help. Remember that your teacher is there to help you understand your subject. Alternatively, you may want to have a look for video tutorials on the Internet. Also ask your friends or fellow learners for help. They may have a way of explaining the problem that will help you understand it better.

Practice makes perfect
Your Ace It Study Guide will be a great help in preparing for your examinations by giving you practical examples, revision questions and hints and tips for exam success.

Try to access copies of past examination papers so that you can practise your skills. Your school library may have copies of past papers, but alternatively you could have a look at the Department of Basic Education's website: www.thutong.doe.gov.za, which has copies of past papers, together with marking memoranda.

Get enough exercise
Getting plenty of regular exercise not only helps you to keep healthy, it also has been proven to lower stress levels and leads to better sleep. Even if you are not a sportsman or sportswoman, a quick walk around the block during a study break will help you to destress, and clear your head.

Eat a healthy diet and drink plenty of water
It is extremely tempting to keep snacking on chips, sweets and chocolates while studying, but these snacks won't help your body in the long term. Try to eat foods that will keep you fuller for longer. Aim for a balanced diet, with lots of fruit and vegetables, and wholewheat or wholegrain bread.

Drink plenty of water. Your brain and your body need water to function properly. Make sure that you drink plenty of water while you are studying. Research suggests that drinking water can help improve exam results and lower stress levels.
Above all, DON’T PANIC!!

Try to keep a clear head. Getting into a panic is a recipe for disaster when you are preparing for an exam. Try meditating for 10 minutes every morning and evening to help you relax and think clearly. If you are struggling with a particular topic, put it aside for a while, and revise another subject before going back to the problem area. You may very well find that if you approach it after a break, it doesn’t seem quite so frightening after all.

Remember

If you are feeling deeply depressed and anxious at this stressful time, make an effort to seek help from a parent, teacher or counsellor. There are plenty of people out there who are willing and able to help!

ON THE DAY

☐ Pack your bag with all your stationery, calculator, ruler and any other items you may need the day before. Make sure that you have extra pens and pencils, and double-check them before you leave for the examination venue.
☐ Pack your Identity Document.
☐ Have a good night’s sleep. Cramming the night before will just make you tired and unable to think clearly during the exams.
☐ Get up in good time. Ask your family to wake you earlier than usual, or ask a friend to give you a wake-up call.
☐ Leave plenty of extra time when travelling to the venue, in case there are traffic or other hold-ups.

WRITING THE EXAMINATION

☐ Keep calm and relaxed, and have confidence in what you have learned and revised.
☐ When you receive the paper, you are given time to read through the paper. Make use of this time by identifying all the questions you know you can easily finish.
☐ Read all of the questions carefully, making sure you know what is being asked. Underline the key words that will tell you what type of answer is required.
☐ Don’t write a long paragraph when only a brief list is required. Conversely, don’t write a bulleted list when a detailed description or explanation is required. Use the number of marks as a guideline.
☐ Start with the questions you know best, but keep the numbers in the correct order. If you can’t answer a question, don’t waste time. Move on and come back to it later. Sometimes a later question will remind you about something to help answer an earlier one.
☐ Keep an eye on the time. Each question has a mark allocation. Work out how much time you need for each question or section, and stick to it, or else you won’t get to the other questions.
☐ Always leave your weakest topic for last so that you don’t waste valuable time struggling with the answers.
☐ Make sure that you have attempted all questions.

Ace it!
How do you learn Life Sciences?

Each of us is an individual, and we all have different ways of learning. Some people like to write everything down when revising, others draw huge colourful mind maps, still others recite lists and facts. Some learners need to walk up and down or be physically active when learning.

It can be very useful for you to find out what kind of a learning style you have. You can then learn techniques to help you when revising the large amount of content in Life Sciences Grade 12.

Take the quiz below to see what type of learning style you have:

<table>
<thead>
<tr>
<th>Question</th>
<th>Description</th>
</tr>
</thead>
</table>
| Question 1 | When you read a book for relaxation, which do you prefer?  
| a) | A travel book which has a lot of photographs.  
| b) | A crime mystery which has a lot of dialogue.  
| c) | A book where you need to solve problems or answer questions. |
| Question 2 | What do you do when you listen to music?  
| a) | Daydream or create pictures in your mind that go with the music?  
| b) | Sing or hum along with the music?  
| c) | Dance, move to the music, or tap your feet? |
| Question 3 | As an out-of-school activity, which of these would you prefer?  
| a) | An art class.  
| b) | A music class.  
| c) | An exercise class. |
| Question 4 | When you see the word 'c – a – t' what is the first thing you do?  
| a) | Get a mental image or picture of a specific cat.  
| b) | Say the word 'cat' to yourself.  
| c) | Get the feeling of being with a cat, for example feeling its fluffy fur or playing with it. |
| Question 5 | You are struggling to spell a word. What are you most likely to do?  
| a) | Write it out to see if it looks right.  
| b) | Sound it out phonetically.  
| c) | Write it out to see if it feels right. |
| Question 6 | You are waiting in a long queue at the movies. What are you most likely to do?  
| a) | Look at the posters up on the walls advertising other films.  
| b) | Talk to the person next to you.  
| c) | Move around, fidget or tap your foot. |
| Question 7 | You have a new smartphone. To figure out how it works, which would you rather do?  
| a) | Watch a YouTube video on the features of the phone.  
| b) | Listen to someone explain it to you.  
| c) | Fiddle with the phone yourself to figure out how it works. |
Question 8
If you are really angry, what are you most likely to do?
  a) Frown or have a thunderous expression on your face.
  b) Shout and lose your temper.
  c) Slam doors, punch a pillow and stomp around.

Question 9
You are visiting a history museum for the first time. What do you do first?
  a) Look around for a map or guide book showing the location of the various exhibits.
  b) Talk to a museum guide and ask them about the different exhibits.
  c) Go into the first exhibit that looks interesting and worry about directions later.

Question 10
You are trying to concentrate on doing your homework. What is most distracting for you?
  a) Visual distractions.
  b) Noise.
  c) Sensations like feeling hungry, having an itch, or feeling your shoes are too tight.

Question 11
You have been to a party. What are you most likely to remember the next day?
  a) The faces of the people you met, but not their names.
  b) The names of the people you met, but not their faces.
  c) The things you did and said while you were there.

Question 12
When learning for a history test, what would you rather do?
  a) Read notes, read headings in a book, look at photos and illustrations.
  b) Ask a friend to ask you questions, or repeat facts silently to yourself.
  c) Write things out on index cards, or make diagrams or models.

Number of a's: _____  Number of b's: _____  Number of c's: _____

Results:
A If you answered mostly a's you may be a visual learner. You tend to learn by seeing and looking.

B If you answered mostly b's you may be an auditory learner. You tend to learn by hearing and listening.

C If you answered mostly c's you are probably a kinaesthetic learner. You tend to learn best by touching and doing.

Remember that nobody is all visual, all auditory or all kinaesthetic. You may find that you are a combination of the three, or you might find that you will use different learning styles for different tasks.
Throughout this study guide you will see tips to help you learn the content, based on your learning style. Look out for the icons above to help you as you work through Grade 12 Life Sciences.
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**STRAND 1 Life at molecular, cellular and tissue level**

**UNIT 1 The code of life**

**DNA in the cell**

**What is DNA?**

Deoxyribonucleic acid (DNA) is a molecule that carries the genetic information or instructions that control the synthesis (making) of specific proteins needed for life.

**Location of DNA**

- DNA is largely found in the nucleus.
- On the chromosomes the DNA is arranged into specific sections that code for particular traits. These sections of the DNA are known as genes. Each gene has its own locus (position) on the DNA strands.
- Extranuclear DNA is DNA found in the mitochondria (mtDNA) and in the chloroplasts.

![Diagram of DNA and chromosomes]

**Structure of chromosomes**

- DNA winds around a histone core to make a 'bead'.
- The string of DNA and histones form a cord.
- ‘Beads on a string’ – when extended a chromatin thread looks like beads on a string.

As the cell prepares to divide, the cord forms loops attached to a protein scaffold.

The loops attached to the protein scaffold condense to form a chromosome that is visible during cell division.

**MY OWN NOTES**
The structure of DNA

- DNA is made up of building blocks or monomers (single units) known as nucleotides, which join to complementary base pairs to form a double strand.
- The double strand is twisted to form a **double helix** structure.

![DNA double helix showing complementary base pairing](image)

- A DNA nucleotide consists of a phosphate group, a deoxyribose sugar (a pentose 5-C sugar) molecule and a nitrogenous base.

There are four possible nitrogenous bases in DNA:

- Adenine (A)
- Guanine (G)
- Cytosine (C)
- Thymine (T)

- Complementary base-pairing: A purine base, which is larger, always bonds with a pyrimidine base which is smaller.

**PURINES:** A and G  
**PYRIMIDINES:** T and C

Adenine and thymine bond with a double hydrogen bond \((A = T)\).

Guanine and cytosine bond with a triple hydrogen bond \((G = C)\).

### The discovery of DNA

Rosalind Franklin and Maurice Wilkins used X-ray crystallography in producing the first images to suggest the shape of DNA.

In 1953, James Watson and Francis Crick used the unpublished photographs and measurements of Franklin and Wilkins to work out the correct structure of DNA. Watson and Crick were awarded the Nobel Prize in 1962 for their work.

### The role of DNA – genes and non-coding DNA

- DNA stores all hereditary information in the form of a code of nitrogenous bases.
- The length and sequence of bases in DNA determine the gene. The gene contains the instructions to make the proteins needed for all metabolic functions.
- A full set of all the genetic codes that is found in a species is called its genome.
- Replication of DNA ensures that the genetic information is passed from one generation to another.

![Generalised diagram of coding and non-coding DNA](image)
### Summary of coding and non-coding DNA

<table>
<thead>
<tr>
<th>Genes (Coding DNA)</th>
<th>Codons</th>
<th>Non-coding DNA (was referred to as 'junk DNA')</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition</td>
<td>Some codons act as a full stop.</td>
<td>Sections of short repeated sequences (STRs) of DNA that does not code for a protein. STR – Short Tandem Repeats.</td>
</tr>
<tr>
<td>Function(s)</td>
<td>Shows the end of the information about a protein.</td>
<td>Indicates the start of a gene. Regulates when and where genes are expressed. Useful in determining an individual’s identity as the STRs are highly variable.</td>
</tr>
</tbody>
</table>

### DNA replication

- DNA replication is the process of making new, identical DNA from existing DNA.
- DNA must be replicated correctly to avoid errors in the genes (mutations).

#### Step 1: Double helix starts to unwind and enzymes (DNA polymerase) break the weak hydrogen bonds between complementary bases, separating the two strands of DNA.

#### Step 2: Nitrogenous bases on DNA strands are exposed. Each strand acts as a template.

#### Step 3: Free-floating DNA nucleotides will pair up with complementary bases (A = T and G = C). Hydrogen bonds re-form between complementary bases.

#### Step 4: Two new DNA molecules are formed that are identical to the original strand and are made up of one old strand and one new strand. DNA rewinds into a double helix and winds itself around histones.

### Cell cycle

Each cell has its own cycle. (Note that this is Grade 10 work.)

- **Interphase** – Stage in the life cycle when the cell grows, chromosomes duplicate (DNA replication) and the duplication of some organelles takes place. This is the longest stage of the cycle.
- **Mitosis** is the division of the nucleus.
- **Cytokinesis** is the division of the cytoplasm between the two new cells.
QUICK QUIZ

Give the correct term for the following:

1. An example of extranuclear DNA. ________________________________

2. The proteins around which the DNA molecules wind themselves. ____________________________

3. The sugar found in DNA. ____________________________

4. In RNA thymine is replaced by ____________________________

5. The full set of chromosomes found in an organism. ____________________________

6. The monomers of DNA. ____________________________

7. The process of making an identical copy of DNA. ____________________________

8. The division of the nucleus. ____________________________

ANSWERS:

RNA

Basic structure of RNA

- Ribonucleic acid (RNA) is a single-stranded molecule made up of nucleotides.
- However, in RNA, the nucleotides consist of a phosphate group, a ribose sugar and a nitrogenous base. The nitrogenous base, uracil (U), replaces thymine (T).

There are four possible nitrogenous bases in DNA:
- Adenine (A)
- Guanine (G)
- Cytosine (C)
- Uracil (U)

MY OWN NOTES

ACE IT! Life Sciences Grade 12
## Types of RNA and location in cells

<table>
<thead>
<tr>
<th>RNA Type</th>
<th>Location</th>
<th>Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messenger RNA (mRNA)</td>
<td>Nucleus</td>
<td>Single-stranded and long. Every three bases = codon.</td>
<td>Copies the genetic code from DNA and carries genetic information to ribosomes in the cytoplasm. mRNA determines the order of amino acids in the protein.</td>
</tr>
<tr>
<td>Transfer RNA (tRNA)</td>
<td>Cytoplasm</td>
<td>Small molecule shaped like a three-leafed clover. Has an anti-codon on one end and amino acid on the other end.</td>
<td>Has an anti-codon, which determines the amino acid it must transport during protein synthesis.</td>
</tr>
<tr>
<td>Ribosomal RNA (rRNA)</td>
<td>Ribosome</td>
<td>Single-stranded and makes up most of the structure of ribosomes but has no definite shape.</td>
<td>Makes up the structure of the ribosome, which is the site for protein synthesis.</td>
</tr>
</tbody>
</table>

RNA types, location, structure and function

## Comparison of DNA and RNA

<table>
<thead>
<tr>
<th></th>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nucleotide strands</td>
<td>Two (double-stranded)</td>
<td>One (single-stranded)</td>
</tr>
<tr>
<td>Type of sugar in molecule</td>
<td>Deoxyribose</td>
<td>Ribose</td>
</tr>
<tr>
<td>Nitrogenous bases present</td>
<td>Adenine, guanine, cytosine, thymine</td>
<td>Adenine, guanine, cytosine, uracil</td>
</tr>
</tbody>
</table>

Comparison of DNA and RNA molecules
Comparison of DNA and RNA

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Nitrogenous bases present</td>
<td>Adenine, guanine, cytosine, thymine</td>
</tr>
</tbody>
</table>

UNIT 1 The code of life
Protein synthesis

What are proteins?
Proteins are very large, organic molecules that are made up of building blocks (monomers) called amino acids:
- There are 20 different amino acids.
- Amino acids are joined together by peptide bonds to form polypeptide chains (fewer than 50 amino acids) or proteins (more than 50 amino acids).
- Proteins are synthesised (made) according to the genetic code of DNA, and this takes place in two stages: transcription and translation.

Protein synthesis: transcription and translation
Refer to the diagram on page 7 when you read the following information.

<table>
<thead>
<tr>
<th>What</th>
<th>Process in which genetic code from DNA is copied into mRNA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where</td>
<td>Nucleus</td>
</tr>
<tr>
<td>How</td>
<td>The gene (section of DNA) coding for the protein unwinds.</td>
</tr>
<tr>
<td></td>
<td>Two DNA strands separate as hydrogen bonds break. Exposed DNA strand acts as a template for the formation of mRNA strand. Controlled by the enzyme RNA polymerase.</td>
</tr>
<tr>
<td></td>
<td>RNA nucleotides in nucleoplasm pair with exposed nucleotides on DNA strand. Remember: uracil replaces thymine. There are no thymine nucleotides in the mRNA molecule.</td>
</tr>
<tr>
<td></td>
<td>mRNA strand is formed. Every three bases on mRNA is a codon, which codes for a particular amino acid.</td>
</tr>
<tr>
<td></td>
<td>mRNA strands separates from DNA and exits nucleus through nuclear pores. DNA returns to double helix shape.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transcription</th>
<th>Translation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process in which genetic code carried by mRNA directs the sequence (order) of amino acids using tRNA.</td>
<td></td>
</tr>
<tr>
<td>Newly formed mRNA attaches to ribosome and bases of mRNA are exposed.</td>
<td></td>
</tr>
<tr>
<td>tRNA molecules, carrying specific amino acids determined by anti-codons, travel to ribosome to deposit amino acids according to codons on mRNA (codons match with complementary anti-codon).</td>
<td></td>
</tr>
<tr>
<td>Codon/anti-codon pairing occurs and amino acid is released from tRNA and will form peptide bond with subsequent amino acids. tRNA molecule moves back into cytoplasm to pick up more amino acids.</td>
<td></td>
</tr>
<tr>
<td>Ribosome moves along entire mRNA strand to read the codons. Enzymes link the amino acids together to form a polypeptide chain or protein. The protein, once made, will detach from the ribosome and move to the site where it is needed.</td>
<td></td>
</tr>
</tbody>
</table>

Summary of stages of protein synthesis
The genetic code

- The genetic code is a code that a cell uses to translate the information stored in DNA into proteins, which the cell uses.
- The code is made of four nucleotides arranged in sets of three on the mRNA strand (codon).
- The genetic code is universal, with 64 different codons identified that code for 20 amino acids.
Questions

This unit is examined in Paper 2 for about 27 marks (19%).

**Question 1**
Provide the correct term for the following: (5)

1.1 The base that pairs with thymine. __________________________________________

1.2 The sugar that forms part of DNA. __________________________________________

1.3 The shape of the DNA molecule. ___________________________________________

1.4 Repeating units (monomers) that form a nucleic acid. ________________________

1.5 The bonds that hold two DNA strands together. ______________________________

**Question 2**
In the space below draw a labelled diagram of a monomer found in DNA with adenine as a nitrogenous base. (4)

**Question 3**
When a sample of DNA was analysed, 34% of the bases were found to be guanine.

3.1 What percentage of cytosine would you expect to find in the sample? __________

3.2 What percentage of adenine would you expect to find in the sample? __________

**Question 4**
Study the diagrammatic representation of part of two nucleic acid molecules found in the cells of organisms. Figure A is found as such in cells, while Figure B is formed with A as the template. Use Figures A and B to help you to answer the following questions:

4.1 Give the full name of the nucleic acid represented in Figure B. Motivate your answer. ____________________________________________________________ (2)

4.2 Identify parts numbered 1 to 6. __________

   1 - _________________________________

   2 - _________________________________

   3 - _________________________________

   4 - _________________________________

   5 - _________________________________  6 - _________________________________

   $\frac{1}{2} \times 6 = (3)$
4.3 Tabulate three differences between DNA and RNA.

Question 5

DBE NSC Life Sciences February 2014 Paper 1

Study the diagram below, which shows a stage in protein synthesis.

![Diagram of protein synthesis](image)

5.1 Identify the stage in protein synthesis shown in the above diagram. ____________________________________________ (1)

5.2 Write down the DNA base triplets that correspond to the codons numbered 6 and 10. ____________________________ (2)

   6: ____________________________  10: ____________________________

5.3 Name the bond represented by X. ____________________________________________ (1)

5.4 Name the organelle in which the process represented in the diagram above takes place. ________________________ (1)

5.5 Use the table below, that shows the amino acids coded for by various tRNA anticodons, to answer the following questions.

<table>
<thead>
<tr>
<th>Anticodons on tRNA</th>
<th>Amino acid coded for</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCU</td>
<td>Proline</td>
</tr>
<tr>
<td>GAA</td>
<td>Glutamate</td>
</tr>
<tr>
<td>GGA</td>
<td>Glycine</td>
</tr>
<tr>
<td>CUU</td>
<td>Leucine</td>
</tr>
<tr>
<td>GUG</td>
<td>Histidine</td>
</tr>
<tr>
<td>ACC</td>
<td>Threonine</td>
</tr>
<tr>
<td>CAC</td>
<td>Valine</td>
</tr>
<tr>
<td>UGG</td>
<td>Tryptophan</td>
</tr>
</tbody>
</table>

5.5.1 Write down the names of the amino acids coded for by the codons numbered 7 and 9. ______________________ (2)

   7: ____________________________________________

   9: ____________________________________________

5.5.2 Identify amino acid 5. ____________________________________________ (1)
Question 6
DBE NSC Life Sciences February 2013 Paper 1

The result of profiling various DNA samples in a criminal investigation is shown below.

Circle the letter of your answer.

Which conclusion about the crime could the DNA analyst draw?

A Only suspect X was involved.
B Only suspect Y was involved.
C Suspects X and Y were both involved.
D Neither suspect X nor Y was involved.

Question 7
DBE NSC Life Sciences February 2016 Paper 2

The diagram below represents two stages of protein synthesis:

7.1 Provide labels for:
   (a) Molecule 1 _________________________(1)   (b) Organelle 6 _________________________(1)

7.2 Give only the NUMBER of the part which represents:
   (a) DNA template strand _____ (1)   (b) Monomer of proteins _____ (1)   (c) Codon _____ (1)

7.3 Describe translation as it occurs at organelle 6.  

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
7.4 Provide the:
(a) DNA sequence that codes for glycine. ____________________________________________ (2)
(b) Codon for proline. __________________________________________________________ (2)

7.5 State TWO differences between a DNA nucleotide and an RNA nucleotide. (4)

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double-stranded</td>
<td>Single-stranded</td>
</tr>
<tr>
<td>Large molecule</td>
<td>Smaller molecule</td>
</tr>
<tr>
<td>Contains thymine</td>
<td>Contains uracil</td>
</tr>
<tr>
<td>Deoxyribose sugar</td>
<td>Ribose sugar</td>
</tr>
</tbody>
</table>

**Answers**

**Question 1**
1.1 Adenine ✓
1.2 Deoxyribose ✓
1.3 Double helix ✓
1.4 Nucleotides ✓
1.5 Hydrogen bonds ✓

**Question 2**
2. [Diagram of DNA structure]

**Question 3**
3.1 34% cytosine ✓ (guanine pairs with cytosine) ✓
3.2 16% adenine ✓
(100% DNA sample – 68% C and G = 32% A and T)
32% + 2 = 16% adenine ✓

**Question 4**
4.1 Ribonucleic acid ✓ – contains uracil ✓
4.2 1 – phosphate group ✓
2 – ribose sugar ✓
3 – cytosine ✓
4 – adenine ✓
5 – uracil ✓
6 – guanine ✓
(½ × 6)

**Question 5**
5.1 Translation ✓
5.2 6: GGA ✓
10: GTG ✓
5.3 Peptide bond ✓
5.4 Ribosome ✓
5.5.1 7: Glutamate ✓ and 9: Proline ✓
5.5.2 Histidine ✓

**Question 6**
Answer: D

**Question 7**
7.1 (a) DNA ✓ (1) (b) Ribosome ✓ (1)
7.2 (a) 2 ✓ (1) (b) 5 ✓ (1) (c) 7 ✓ (1)
7.3 – The mRNA attaches to the ribosome ✓
– When each codon ✓ of the mRNA
– Matches with the anticodon ✓ on the tRNA
– The tRNA brings the required amino acid to the ribosome ✓
– When the different amino acids are brought in sequence ✓
– Adjacent amino acids are linked by peptide bonds ✓
– To form the required protein ✓/polypeptide
Any 4 (4)
7.4 (a) CCT ✓ (2) (b) CCU ✓ (2)
7.5 DNA
– Has deoxyribose ✓ sugar
– Has nitrogen base thymine (T) ✓/ A, C, G and T
RNA
– Has ribose ✓ sugar
– Has nitrogen base uracil (U) ✓/ A, C, G and U
(Mark first TWO only)
TABLE NOT REQUIRED (2 × 2) (4)

UNIT 1 The code of life
UNIT 2 Meiosis and reduction division

Chromosomes

All organisms have a specific number of chromosomes called the chromosome number, represented by \( n \).
- Humans have 23 paired chromosomes (one set from the maternal line and one set from the paternal line), therefore the total number of chromosomes in a normal somatic cell is 46. The cell with 46 chromosomes is said to be diploid.
- In a human somatic cell: \( 2n = 46 \), therefore \( n = 23 \), which is haploid.
- A haploid chromosome number is found in gametes.
- There are two types of chromosomes in humans: 22 pairs of autosomes and 1 pair of gonosomes.
- These paired chromosomes are homologous chromosomes – they are the same length, size and shape and carry genes that code for the same characteristic, e.g. seed colour.

Terminology to learn

**Diploid**: Having two sets of chromosomes in each cell.
**Haploid**: Having one set of chromosomes in each cell.
**Somatic cells**: All body cells except sex cells.
**Gamete**: Sex cell (sperm or egg/ovum).
**Autosome**: Chromosome that does not determine sex of an individual.
**Gonosome**: Sex chromosomes, X and Y.

The process of meiosis

Meiosis is a type of cell division that is needed to ensure that the gametes that are formed have half the number of chromosomes.

Replication of DNA occurs before the two divisions: meiosis I and meiosis II.

Centrioles (2 centrosomes) are found only in animal cells and are responsible for making the spindle fibres.

Spindle fibres occur in plant cells even though they do not have centrioles.
Meiosis I – The reduction division: the separation of the duplicated homologous chromosomes

<table>
<thead>
<tr>
<th>Prophase I</th>
<th>Metaphase I</th>
<th>Anaphase I</th>
<th>Telophase I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homologous chromosome (bivalent)</td>
<td>Bivalents line up randomly at the equator</td>
<td>Spindle fibres shorten and pull homologous pairs apart</td>
<td>One complete set of chromosomes reaches each pole</td>
</tr>
</tbody>
</table>

pair of centrioles

- Chromosomes become visible.
- Nuclear membrane disappears.
- Spindle fibres form from centrosome.
- Homologous chromosomes pair up and exchange segments of chromosomes during crossing over, seen as chiasmata.

- Independent assortment occurs as homologous chromosomes (bivalents) line up randomly at the equator.
- Spindle fibres attach to centromeres.
- Spindle fibres contract and pull one chromosome of each pair towards opposite poles.
- Chromosomes reach the poles and nuclear membrane re-forms.
- Cytokinesis occurs.
- Two new cells, that are genetically different with half the chromosome number, are formed.

Stages of meiosis I

Meiosis II – The mitotic division

Each chromosome consists of two chromatids. These need to be separated.

<table>
<thead>
<tr>
<th>Prophase II</th>
<th>Metaphase II</th>
<th>Anaphase II</th>
<th>Telophase II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromatids visible</td>
<td>Spindle fibres shorten</td>
<td>Each centromere divides as chromatids are pulled to opposite poles</td>
<td>Nuclear membrane re-forms once chromosomes reach the poles</td>
</tr>
<tr>
<td>Spindle fibres form and attach to centromeres</td>
<td>Chromatids (now called chromosomes) pulled towards each pole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Nuclear membrane breaks down and spindle fibres form.
- Chromosomes (with two chromatids) are visible.
- Chromosomes line up at the equator.
- Spindle fibres attach to the centromeres.
- The separation of the chromatids occurs in this phase.
- Daughter chromosomes are at poles and nuclear membrane re-forms.
- Cytokinesis occurs.

Stages of meiosis II

UNIT 2 Meiosis and reduction division
The purpose of reduction division in meiosis

Reduce the chromosome number for gametogenesis

Gametogenesis is the production of gametes (sex cells), which are haploid.

Exceptions to the rule: mosses and ferns

- Reduction division does not take place in all organisms in order to produce haploid gametes, as seen in mosses and ferns.
- In mosses: the dominant generation is the leafy gametophyte plant (which is haploid) that produces haploid gametes through mitosis (sperm cells are made in the antheridia and egg cells are made in the archegonia). Meiosis occurs only in the sporangium, to produce haploid spores in the sporophyte generation.

The life cycle of a moss

- In ferns: the dominant sporophyte generation is diploid and meiosis takes place in the sporangia of the sori, producing haploid spores that grow into the gametophyte generation. The gametes are produced by mitosis in the haploid gametophyte generation.
- In mosses and ferns the gametes are produced by mitosis and are identical within each species. The spores are produced by meiosis and are therefore genetically different.
Importance of reduction division in meiosis

Reduce the chromosome number from diploid to haploid

- The reduction division of meiosis ensures that the chromosome number of a species is halved in the production of a gamete. Therefore in humans, which are diploid (2n), the number of chromosomes in the gametes will be haploid (n).
- This ensures that the chromosome number of a species remains constant in order to counteract the doubling effect of fertilisation.
- Production of gametes that are haploid.

Introduction of genetic variation

- The exchange and recombination of genes is ensured through crossing over that takes place at the chiasmata.
- Independent assortment or random segregation further ensures variation by the random arrangement of homologous chromosomes at the equator, which will then segregate or separate between the two poles.

Consequences of abnormal meiosis

Aneuploidy - abnormality caused by the addition or loss of one or more chromosomes, e.g. Down's syndrome. This is caused by non-disjunction. This happens when two homologous chromosomes do not separate from each other during meiosis. One daughter cell will have 2n + 1, i.e. 47, and the other will have 2n - 1, i.e. 45 chromosomes.

Down's syndrome – Trisomy 21

<table>
<thead>
<tr>
<th>Name of disorder</th>
<th>Down's syndrome or Trisomy 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromosome number</td>
<td>2n + 1 = 47 (extra chromosome 21)</td>
</tr>
<tr>
<td>Karyotype</td>
<td><img src="image" alt="Karyotype of a Down's syndrome individual" /></td>
</tr>
</tbody>
</table>

What causes it? Non-disjunction (failure of chromosomes to separate correctly) of the homologous chromosome 21 pair during the reduction division. This occurs more often when older women give birth. The risk of having a Down's syndrome child increases as the maternal age increases.

Symptoms Short stature; small, round head; skin folds at corners of eyes; heart defects; vision and hearing; sometimes mental disabilities.

Summary of Down's syndrome
Comparison of mitosis and meiosis

<table>
<thead>
<tr>
<th>Differences</th>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>• One division producing two cells.</td>
<td>• Two divisions producing four cells.</td>
<td></td>
</tr>
<tr>
<td>• Chromosome number remains diploid.</td>
<td>• Chromosome number is halved.</td>
<td></td>
</tr>
<tr>
<td>• Genetically identical cells are produced.</td>
<td>• Genetically different cells produced.</td>
<td></td>
</tr>
<tr>
<td>• Used in production of somatic cells.</td>
<td>• Used in production of gametes.</td>
<td></td>
</tr>
<tr>
<td>• Two daughter cells produced.</td>
<td>• Four daughter cells produced.</td>
<td></td>
</tr>
</tbody>
</table>

Similarities

• Replication occurs prior to cell division.
• Cell division begins with diploid cells, with exceptions to the rule, gametophyte of moss and fern.

Differences and similarities between mitosis and meiosis

Questions

This unit is examined in Paper 1 for about 11 marks (7%) and in Paper 2 for about 12 marks (7%).

Question 1

Match the statement in Column A with the correct terms in Column B. Write only the correct letter in the column provided on the left in the table below.

<table>
<thead>
<tr>
<th>Answer</th>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>The chromosome complement/condition of a body cell, which contains two sets of chromosomes.</td>
<td>A Karyotype</td>
</tr>
<tr>
<td>1.2</td>
<td>A visual representation of an organism's chromosomes.</td>
<td>B Chiasmata</td>
</tr>
<tr>
<td>1.3</td>
<td>The point at which chromatids of homologous chromosomes cross over during meiosis.</td>
<td>C Centromere</td>
</tr>
<tr>
<td>1.4</td>
<td>Cells such as gametes, which only contain one set of chromosomes.</td>
<td>D Diploid</td>
</tr>
<tr>
<td>1.5</td>
<td>Region on the chromosome where the spindle fibres attach during cell division.</td>
<td>E Haploid</td>
</tr>
</tbody>
</table>

Question 2

Study the diagrams below and answer the questions.

2.1 Which diagram (A, B or C) represents meiosis I? ____________________________(1)

2.2 Suggest why the chromosomes in diagram B will be genetically different from those of the parent cell at the beginning of meiosis. ____________________________(1)

2.3 How many chromosomes will each daughter cell have at the end of this cell division? ____________________________(1)

2.4 Give TWO reasons why this type of cell division is important. ____________________________(2)
**Question 3**  
*DBE NSC Life Sciences February-March 2012 Paper 1*

The karyotype below is that of a male person with a genetic disorder called Klinefelter syndrome.

3.1 State ONE visible difference between the karyotype shown and the normal karyotype of a male. (2)

3.2 Use your knowledge of meiosis to explain how Klinefelter syndrome could have resulted. (4)

---

**A karotype of a male with Klinefelter syndrome**

---

**Question 4**  
*DBE NSC Life Sciences February-March 2016 Paper 1*

The graph below shows changes in the amount of DNA present in a cell over a period of 36 hours.

Which ONE of the following parts of the graph represents interphase?
A. T to V  
B. W to X  
C. V to Y  
D. X to Z

---

**Question 5**  
*DBE NSC Life Sciences February-March 2016 Paper 2*

The diagram alongside shows crossing over.

Which ONE of the following combinations of alleles would be present in chromatid C after crossing over occurred at point P?  
A. Aart  
B. abrT  
C. ABRt  
D. ABRT
**Question 6**
*DBE NSC Life Sciences February-March 2013 Paper 2*

The diagrams below show different phases in meiosis:

3.1 Label structures W and X. (2)

3.2 How many chromosomes are present in each cell in:
   (a) Phase A ____________________________ (1)
   (b) Phase C ____________________________ (1)

3.3 Give only the LETTER of the diagram that represents anaphase II. ______ (1)

3.4 State the function of structure Y and structure Z. (2)

__________

3.5 Identify phase C. _______________________________ (1)

**Question 7**
*DBE NSC Life Sciences November 2015 Paper 2*

The diagram alongside shows a cell undergoing meiosis.

The diagram above shows …
A. non-disjunction in metaphase II.
B. a chromosomal aberration that results in haemophilia.
C. a chromosomal aberration involving chromosome pair number 23, leading to Down's syndrome.
D. non-disjunction in anaphase I.

**Question 8**
*DBE NSC Life Sciences November 2015 Paper 1*

The diagram alongside illustrates a phase in meiosis.

5.1 Identify part A_________________________ (1)
    B_________________________ (1)
    C_________________________ (1)

5.2 Identify the phase shown alongside __________________________ (1)

5.3 Give a reason for your answer to 5.2. __________________________ (2)
5.4 In the space below, draw a diagram of the cell on the previous page as it would appear during anaphase I. (4)

Answers

Question 1
1.1 D ✓
1.2 A ✓
1.3 B ✓
1.4 E ✓
1.5 C ✓

Question 2
2.1 A ✓
2.2 Crossing over has taken place. ✓OR Random assortment of homologous chromosomes has occurred. ✓ (1)
2.3 Two chromosomes. ✓ (1)
2.4 Introduces variation through crossing over and independent/random assortment. ✓ Reduces the chromosome number by half. ✓ (2) [5]

Question 3
3.1 A normal male karyotype will have only one X and one Y chromosome while Klinefelter syndrome shows two X chromosomes and one Y chromosome. ✓ ✓ (2)
3.2 During meiosis I ✓ the homologous chromosome pair 23 ✓ of the female parent ✓ does not separate / there is non-disjunction. ✓ OR During meiosis II ✓ the chromosome 23 ✓ of the female parent ✓ does not separate / non-disjunction of chromosomes and both chromatids move to the same pole. ✓ OR An ovum with 2 X chromosomes ✓ is produced during fertilisation. ✓ This ovum is fused with a sperm cell with a Y chromosome ✓ to form a zygote with XXY chromosomes. ✓ (any 4) (4) [6]

Question 4
A

Question 5
D

Question 6
3.1 W Cell membrane ✓ / Plasmalemma ✓ X Homologous chromosomes ✓ / Bivalent (1)
3.2 (a) 4 ✓ (1) (b) 2 ✓ (1)
3.3 D ✓ (1)
3.4 Y Holds the sister chromatids together ✓ Z Pulls chromosomes/chromatids to the poles ✓ (2)
3.5 Telophase II ✓ (1) [8]

Question 7
A

Question 8
5.1 (a) Chromosome ✓ (1)
(b) Spindle fibre ✓ (1)
(c) Centromere ✓ (1)
5.2 Metaphase II ✓ (1)
5.3 - Chromosomes lying independently ✓ / singly - at the equator ✓ (2)

Mark allocation:
C - Shows 4 chromosomes ✓ ✓ (not chromatids)
S - Shows separation ✓ of genetic material
D - Correct variation shown in the chromosomes ✓ (shading on the chromosomes must be complementary!)
(Use the letters for marking process) (4) [10]
Strand 2: Life processes in plants and animals

Unit 3 Diversity of reproductive strategies in vertebrates

**Reproduction**: The production of a new generation of organisms from an existing organism.

**Sexual reproduction**: Reproduction that involves the fusion of gametes to form a zygote.

**Reproductive strategies**: The way in which organisms ensure that reproduction is successful.

---

### Types of fertilisation

The type of fertilisation used by an animal is dependent on whether an animal reproduces in water or on land.

- **Fertilisation**: Fusion of an egg cell with a sperm cell.

#### External fertilisation
- Fertilisation occurring outside an animal's body.
- This type of fertilisation is common in many aquatic animals and only possible for animals that breed in water.
- The chance of external fertilisation is increased by:
  - Animals producing large numbers of sperm and eggs
  - Some animals ensuring that the release of sperm and eggs occurs at the same time, e.g. male frogs call to attract a mate. The male then holds onto the female in an embrace so that the position is perfect to deposit sperm over the eggs in order to maximise fertilisation.

#### Internal fertilisation
- Fertilisation occurring inside a female's body.
- Sperm is transferred from the male into the female's reproductive tract.
- This type of fertilisation is common in most terrestrial animals. Fewer sperm and eggs are produced.
- Sperm need water to swim therefore, in terrestrial animals, sperm is in a watery fluid when transferred from the male to the female. Internal fertilisation increases the probability of successful fertilisation.

---

### Development of the embryo

<table>
<thead>
<tr>
<th>Type of development</th>
<th>Explanation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ovipary</td>
<td>Form of sexual reproduction where the mother lays eggs that hatch outside her body.</td>
<td>Fish, amphibians, reptiles, birds</td>
</tr>
<tr>
<td>Ovovivipary</td>
<td>Form of sexual reproduction whereby the eggs are kept inside the female's body until the eggs hatch internally but there is no connection between the mother and developing embryo. Ovovivipary protects the developing embryo from predators and drying out.</td>
<td>Some shark and snake species</td>
</tr>
<tr>
<td>Vivipary</td>
<td>Form of sexual reproduction in which the embryo develops inside the mother's body and is nourished through the placenta until birth.</td>
<td>Mammals</td>
</tr>
</tbody>
</table>

Various types of embryo development

---
AMNIOTIC EGG

- Reptiles and birds lay eggs that have a hard shell. This shelled egg can survive and develop on land and is known as the amniotic egg.

An amniotic egg

- embryo
- amnion - grows around embryo - contains amniotic fluid to protect embryo
- allantois - stores wastes produced by the embryo - exchanges gases with the environment
- chorion - works with allantois to allow for gaseous exchange
- yolk sac
- yolk - provides food for developing embryo
- shell - protects the egg - prevents egg from drying out - exchanges gases with the environment

Altricial and precocial development

These are terms that are used to describe how much an animal has developed at the time of birth and hatching.

<table>
<thead>
<tr>
<th>Altricial development</th>
<th>Precocial development</th>
</tr>
</thead>
</table>
| - Young are born in a helpless condition and need parental care:  
  - Young are not able to move around.  
  - Young are vulnerable to predators.  
  - Young are dependent on parents for shelter, nutrition and defence.  
  E.g. Eagles, dogs, cats, humans | - Young are born relatively independent and require little or no parental care:  
  - Young are able to move independently.  
  - Young are able to avoid predators.  
  - Young are not as dependent on parents for shelter, nutrition and defence as altricial animals.  
  E.g. Turtles, chickens, horses |

Altricial and precocial development strategies

Altricial chicks in their nest are helpless.

A muscovy duckling is an example of precocial development, and can leave its nest soon after hatching.

MY OWN NOTES
PARENTAL CARE

- Parental care occurs when the parents look after the young once they are born.
- Common in birds and mammals, in particular altricial animals.
- Increases the chances of offspring surviving and reaching reproductive age.

There are a number of levels at which parental care can occur. These are listed below in order from the most to the least parental care.

- The eggs develop in the body of the female. When young are produced, the female gives them long-term protection, and feeds them. Examples include most mammals. Humans have the longest time period of parental care!
- The eggs develop in the body of the female, but she takes very little interest in her offspring. Examples include some types of lizard.
- The female lays eggs, looks after the eggs, and feeds the hatchlings. Both parents usually take it in turn to tend to the young, and keep them fed and warm. Birds are a good example of this.
- The female lays eggs, and looks after the eggs and the young. Crocodiles exhibit this level of parental care.
- The female lays eggs and protects them, but does not protect the young. Some fish species behave in this way.
- The female finds a suitable safe place in the environment to lay her eggs, and then pays no further attention to the eggs or the young. Turtles exhibit this level of parental care.
- The female lays eggs and then moves on, taking no interest in the eggs or the young. Some fish species behave in this way.

QUICK QUIZ

Give the correct term for each of the following:

1. The type of fertilisation that takes place outside of the male and female bodies. ______
2. The embryo develops inside the body of the female. ______
3. The type of development where the young are dependent on their parents for shelter and food. ______
4. The type of development in which the young are relatively independent. ______
5. The type of egg in which the embryo develops. ______
6. The structure which protects the egg. ______

| 1. external fertilisation | 2. internal fertilisation | 3. oviparous | 4. viviparous | 5. amniotic egg | 6. shell |

Questions

This unit is examined in Paper 1 for about 6 marks (4%).

Question 1

Indicate whether each statement in column A refers to A only, B only, both A and B or neither in column B. (6)

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>A. reptiles</td>
<td></td>
</tr>
<tr>
<td>1.2</td>
<td>A. mammals</td>
<td>B. amphibians</td>
</tr>
<tr>
<td>1.3</td>
<td>A. fish</td>
<td>B. birds</td>
</tr>
<tr>
<td>1.4</td>
<td>A. mammals</td>
<td>B. reptiles</td>
</tr>
<tr>
<td>Column A</td>
<td>Column B</td>
<td>Answer</td>
</tr>
<tr>
<td>-------------------------------------------------------------------------</td>
<td>-------------------------------</td>
<td>------------</td>
</tr>
<tr>
<td>1.5 An eagle feeding newly hatched offspring.</td>
<td>A. altricial development</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. precocial development</td>
<td></td>
</tr>
<tr>
<td>1.6 Animals are born live.</td>
<td>A. ovoviviparous</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. viviparous</td>
<td></td>
</tr>
</tbody>
</table>

**Question 2**
For each reproductive strategy mentioned below, describe how the strategy maximises the reproductive success of the animal.

2.1 Female leopards feed and protect their cubs for many months.  

______________________________________________________________________  (2)

______________________________________________________________________

______________________________________________________________________

2.2 Fish lay about 4 million eggs a year.                                    (2)

______________________________________________________________________

______________________________________________________________________

For questions 3 to 5 circle the letter of your choice.

**Question 3**
Department of Eastern Cape Education NSC June Examination 2016
Which one of the following descriptions correctly represents the reproductive strategy shown in the diagram alongside?

<table>
<thead>
<tr>
<th>A</th>
<th>Precocial development</th>
<th>Able to feed themselves</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Altricial development</td>
<td>Unable to feed themselves</td>
</tr>
<tr>
<td>C</td>
<td>Precocial development</td>
<td>Bodies covered with soft feathers</td>
</tr>
<tr>
<td>D</td>
<td>Altricial development</td>
<td>Independent of their parents</td>
</tr>
</tbody>
</table>

**Question 4**
DBE NSC November 2015 Paper 1
In seahorses the female deposits the eggs into a pouch in the male’s body. The male then secretes sperm into the pouch. Fertilisation takes place in the pouch. The fertilised eggs develop in the pouch.
What type of fertilisation and reproductive strategy does this represent?

<table>
<thead>
<tr>
<th>A</th>
<th>External fertilisation and vivipary</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Internal fertilisation and vivipary</td>
</tr>
<tr>
<td>C</td>
<td>External fertilisation and ovipary</td>
</tr>
<tr>
<td>D</td>
<td>Internal fertilisation and ovipary</td>
</tr>
</tbody>
</table>
Question 5

A Vivipary
B Ovipary
C Ovovivipary
D Altricial

Question 6

Write the correct term for each of the following:
6.1 A method of reproduction in which eggs are laid and development of these eggs takes place outside the mother’s body.
6.2 Stores waste produced by the embryo.
6.3 A type of reproduction where the foetus develops inside the uterus.
6.4 Requires the production of a large number of gametes to ensure survival of the species.
6.5 A type of development in birds where the young are capable of moving and feeding themselves.
6.6 The type of fertilisation associated with viviparous reproduction.

Answers

Question 1
1.1 A only ✓
1.2 A only ✓
1.3 B only ✓
1.4 Neither ✓
1.5 A only ✓
1.6 Both ✓

Question 2
2.1 Female leopards show parental care by feeding and nourishing their young and providing protection from predators. ✓ This increases the chances of survival and the offspring reaching sexual maturity. ✓
2.2 Many eggs are eaten by predators or are washed away ✓, so the great numbers that are laid ensures that some will be fertilised and develop into fish. ✓

Question 3
B

Question 4
C

Question 5
C

Question 6
6.1 Ovipary
6.2 Allantois
6.3 Vivipary
6.4 External fertilisation
6.5 Precocial development
6.6 Internal fertilisation
Structure of male reproductive system

- **prostate gland**: secretes fluid that helps sperm move faster. It has an alkaline pH to neutralise acidic vaginal secretions.
- **ureter**: transports urine to the bladder.
- **vas deferens/sperm duct**: carries sperm from the epididymis to the penis.
- **epididymis**: stores sperm until maturity.
- **rectum**: receives sperm from the epididymis.
- **scrotum**: skin sac that protects the testes and ensures they are kept at a lower temperature than body temperature for sperm production.
- **testes**: contains seminiferous tubules where sperm are produced by spermatogenesis.

**HOW ARE SPERM PRODUCED?**

Sperm are produced by spermatogenesis (meiosis), which takes place in the seminiferous tubules that make up the testes.

**Diagram of a sperm cell**

- **head**: nucleus contains male's haploid genetic material.
- **middle piece**: mitochondria supply energy for moving.
- **tail**: used to swim.
**Female reproductive system**

**Structure of female reproductive system**

- fallopian tube (oviduct): muscular tube linking ovary to the uterus; moves egg to the uterus by muscular contractions and the beating of cilia
- ovary: organ that produces egg and sex hormones - oestrogen and progesterone; oogenesis takes place here.
- uterus: hollow organ with a thick muscular wall that houses and protects developing foetus until birth
- endometrium: lining of the uterus wall that fills with blood and is shed during menstruation
- cervix: entrance to the uterus; contains glands that supply mucus to the vagina
- vagina: passage between uterus and outside of the body, birth canal

**Diagram of female reproductive system**

---

**Tip for visual learners:**
Diagrams on pages 25 and 26: Highlight a label and then colour the structure in using the same colour.
Puberty

- This is the period of growth when sex organs develop and begin to produce gametes. This process is controlled by hormones.
- **Secondary sexual characteristics** become more pronounced during puberty.

**Secondary sexual characteristics:**

**MALES** – testes produce testosterone, which trigger the following changes:
- Rapid growth in height.
- Hair growth in pubic region, armpits and face.
- Voice gets deeper.
- Shoulders and chest get broader.
- Penis and testes increase in size.
- Sperm production.

**FEMALES** – ovaries produce oestrogen, which triggers the following changes:
- Rapid growth in height.
- Hair growth in pubic region and armpits.
- Breasts begin to develop.
- Hips widen.
- Vagina grows in size.
- Ovulation (egg release) and menstruation (periods) occur.

**Hypothalamus** secretes gonadotropins → stimulates pituitary gland

**Pituitary gland** secretes:
- FSH (follicle-stimulating hormone) → stimulates ovaries to develop egg and secrete oestrogen
- LH (luteinising hormone) → triggers ovulation

**Testes produce:**
- **testosterone** → secondary sexual characteristics → sperm production

**Ovaries produce:**
- oestrogen → secondary sexual characteristics
- progesterone → maintains endometrium lining → suppresses LH secretion and FSH secretion

Body changes controlled by hormones in males and females during puberty

**QUICK QUIZ**

The diagram below represents a part of the male reproductive system.

*DBE NSC Grade 12 February/March 2016 Paper 1*

1. Give the LETTER and the NAME of the part that:
   (a) Is used in copulation. ______________________
   (b) Produces testosterone. ______________________

2. Give ONLY the LETTERS of the TWO parts in the diagram that:
   (a) Contribute to the formation of semen ______________________
   (b) Provide a passage for the sperm cells ______________________
Menstrual cycle

- The **menstrual cycle** is the series of events controlled by hormones that causes changes in the ovaries and the endometrium.
- **Menstruation** is the passing out of the endometrium tissue through the vagina.
- The menstrual cycle lasts on average for 28 days. Day 1 begins with menstruation.
  - Day 14 results in ovulation (release of an egg).

**Diagram of Menstrual cycle**

- **FSH**: stimulates development of Graafian follicle.
- **Oestrogen**: promotes thickening of the endometrium and increased oestrogen causes increase in LH.
- **LH**: rapid increase of LH brings on ovulation.
- **Progesterone**: inhibits FSH and LH and promotes further thickening of the uterus.

Day 1 to 14: development of Graafian follicle containing the egg which secretes oestrogen
Day 14: ovulation occurs (release of the egg from the Graafian follicle into fallopian tube).
Day 15 to 28: corpus luteum secretes progesterone.

Day 1 to 5: menstruation takes places.
Day 6 to 13: endometrium thickens due to oestrogen.
Day 14: ovulation due to LH.
Day 15 to 23: further thickening of endometrium due to progesterone.
Day 24 to 28: endometrium will begin to deteriorate leading to menstruation.

A flow diagram showing hormonal control of the menstrual cycle
Fertilisation → Process of a sperm cell fusing with an egg cell to form a zygote
- Acrosome of the sperm cell releases an enzyme that breaks down the cell membrane of the egg, allowing the nucleus of the sperm to enter and join with the egg nucleus. As soon as this happens the membrane of the egg changes so as not to allow any other sperm to enter.
- Zygote divides by mitosis to form a blastocyst (hollow ball of cells) and is moved along the fallopian tubes/oviducts by the cilia towards the uterus for implantation.

Implantation → Process of the attachment of the blastocyst into the lining of the endometrium in the uterus
- Once the blastocyst is implanted into the endometrium lining, finger-like outgrowths called villi absorb nutrients and anchor the embryo. The cervix secretes a mucus plug, which seals the uterus and prevents entry of bacteria.
- Corpus luteum secretes progesterone to ensure no ovulation takes place and to maintain uterus lining.

Gestation
Gestation (period for which the young develop in the womb) in humans is 40 weeks. (See diagram on page 30.)

Development of foetus and the role of the placenta

BIRTH
- Happens 280 days after last menstruation.
- A hormone oxytocin causes the uterus to contract.
- The contractions increase in number and strength during labour.
- These contractions push the baby towards the birth canal (vagina).
- The head appears first followed by the rest of the baby.
- The umbilical cord is cut and the baby is now on its own.
- The placenta is expelled.
deoxygenated blood in uterus wall filled with mother’s blood

space in uterus wall filled with mother’s blood

oxygenated blood (from mother)

umbilical cord - Connects foetus to the placenta
- Has two arteries that carry deoxygenated blood and one vein that carries oxygenated blood

amniotic fluid - Support foetus and allows it to move
- Acts as a shock absorber and prevents injuries
- Maintains temperature to keep foetus warm
- Lubricates vagina during birth

Diagram of a foetus and its placenta

amnion - membrane that surrounds the foetus and secretes amniotic fluid
**Contraception (birth control)**

Contraceptives are used to prevent a pregnancy. There are a number of different methods used by the male or female.

<table>
<thead>
<tr>
<th>Contraceptive device</th>
<th>Used by</th>
<th>Method</th>
<th>Effectiveness (reliability) Approximate %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Withdrawal</td>
<td>Both</td>
<td>The penis is removed from the vagina before semen is ejaculated.</td>
<td>78% (Not reliable as sperm may be released before ejaculation.)</td>
</tr>
<tr>
<td>Rhythm</td>
<td>Female</td>
<td>The female keeps a record of her temperature. Her temperature rises around ovulation. Sexual intercourse is avoided from about day 10 to 20 of her menstrual cycle.</td>
<td>76% (Not reliable as body temperatures can change due to illness. Ovulation may not happen exactly at day 14 due to physiological changes in the woman.)</td>
</tr>
<tr>
<td>Spermicide</td>
<td>Female</td>
<td>A spermicide is inserted into the vagina before sexual intercourse. The spermicide kills the sperm and acts as a barrier preventing sperm from entering through the cervix.</td>
<td>72%</td>
</tr>
<tr>
<td>Female condom</td>
<td>Female</td>
<td>Placed inside the vagina. It acts as a barrier which sperm cannot pass through. Also prevents the spread of STIs.</td>
<td>80% If used correctly 95%</td>
</tr>
<tr>
<td>Diaphragm or cap</td>
<td>Female</td>
<td>This is inserted into the vagina to cover the cervical opening. It acts as a barrier to prevent sperm swimming into the uterus.</td>
<td>85%</td>
</tr>
<tr>
<td>Loop/IUD (intra-uterine device)</td>
<td>Female</td>
<td>This needs to be inserted by a doctor/ sister. It prevents an ovum or embryo from becoming attached to the uterine wall.</td>
<td>99%</td>
</tr>
<tr>
<td>The contraceptive patch</td>
<td>Female</td>
<td>The patch is stuck onto the skin of the female. It releases hormones, which prevent the formation of a follicle in the ovary.</td>
<td>99%</td>
</tr>
<tr>
<td>Contraceptive injection</td>
<td>Female</td>
<td>Contains progesterone or a combination of progesterone and oestrogen. This is required every 2 to 3 months. It prevents ovulation.</td>
<td>99%</td>
</tr>
<tr>
<td>Contraceptive pill</td>
<td>Female</td>
<td>Taken each day. It contains hormones which prevent the production of ova and therefore ovulation does not take place.</td>
<td>99%</td>
</tr>
<tr>
<td>Tubal ligation Female sterilisation</td>
<td>Female</td>
<td>The oviducts are cut and tied. This prevents an ovum from moving down the tube and sperm from swimming up the tube.</td>
<td>More than 99%</td>
</tr>
<tr>
<td>Condom</td>
<td>Male</td>
<td>Is placed over the erect penis. It acts as a barrier preventing the sperm from entering the vagina. It also prevents the spread of HIV and STIs.</td>
<td>82% If used correctly 98%</td>
</tr>
<tr>
<td>Male sterilisation vasectomy</td>
<td>Male</td>
<td>The sperm ducts are cut and tied. Sperm cannot travel down into the urethra. Semen is still produced.</td>
<td>More than 99%</td>
</tr>
</tbody>
</table>

If no contraception is used there is an 85% chance of falling pregnant.
Questions

This unit is examined in Paper 1 for about 31 marks (21%).

Question 1

Study the diagrams below and answer the questions that follow.

1.1 On the diagram above, label parts A, B, C, D and F.

1.2 State one function of the following:
   (a) Part C: ________________________________ (1)
   (b) Part F: ________________________________ (1)

1.3 Write down the letter of the part where sperm is produced. ________________________________ (1)

1.4 Explain why it is necessary for part D to “hang outside” the body of the male. ________________________________ (1)

1.5 Name the following:
   (a) the cells in the testes that secrete a male sex hormone. ________________________________ (1)
   (b) the hormone that stimulates the development of the secondary sexual characteristics in males. ________________________________ (1)

1.6 During a vasectomy, part B is surgically cut.
   (a) Will it be possible for a man who is HIV positive to infect another person after he undergoes a vasectomy? ________________________________ (1)
   (b) Explain your answer to question 1.6 (a). ________________________________
Question 2

The two graphs below show the changes in temperature in a woman's body and the levels of the hormones oestrogen and progesterone during the menstrual cycle. The release of the ovum takes place when there is a rise in body temperature.

2.1 What was the temperature of the woman on day 15?  

2.2 By how many degrees Celsius did her temperature vary between days 13 and 15? Show ALL working.

2.3 From the graph, state two factors that indicate that ovulation occurred.

2.4 Explain the importance of the higher level of progesterone from day 15 to day 20.

2.5 Name the structure in the ovary that secretes:
(a) Oestrogen:  
(b) Progesterone:  

2.6 Name the hormone secreted by the pituitary gland that triggers ovulation.
Question 3
Provide the correct term for the following statements in the space provided.

3.1 The lining of the uterus. 

3.2 The outermost embryonic membrane that contributes to the formation of the uterus. 

3.3 The shedding of the endometrium. 

3.4 The tube in the female reproductive system where fertilisation usually takes place. 

3.5 The male organ that deposits sperm into the vagina. 

Question 4
DBE NSC Life Sciences November 2013 Paper 2
Study the diagram alongside and answer the questions.
Match the structures (A to F) with the descriptions (4.1 to 4.5) below. Write only the letter. A letter may be used more than once, or not at all. 

4.1 Where gaseous exchange occurs between the mother and the foetus. 

4.2 Removes excretory products from the foetus. 

4.3 Contains strong muscles which will push the foetus out during birth. 

4.4 Structure that is clamped and cut after birth. 

4.5 Acts as a shock absorber for the developing foetus. 

Question 5
DBE NSC February-March 2016 Paper 1
Read the extract below.

Anele found out that she had scar tissue blocking both her Fallopian tubes and therefore could not have a baby. She decided to try in vitro fertilisation (IVF).

The IVF procedure was performed as follows:
• Anele was given hormone supplements to stimulate the production of ova in the ovaries.
• The mature ova were then collected and placed in a test tube.
• Her partner was then asked to release his semen into a special container.
• The ova and the semen were then mixed in a test tube.
• The morulas that developed after a few days were then inserted into Anele’s uterus.

The diagram below is a representation of how the procedure was done:
5.1 Explain why Anele's condition had prevented her from falling pregnant. (2)

5.2 Name ONE hormone that was:
   (a) Given to Anele to ensure that ova were produced in the ovaries. (1)
   (b) Produced by the developing follicles in the ovaries, as the ova were maturing. (1)

5.3 Describe the events that take place in the test tube after fertilisation, until a blastocyst is formed. (4)

5.4 Explain ONE possible consequence for the developing embryo if the corpus luteum disintegrates immediately after implantation. (3)

Question 6
Essay DBE NSC Paper 1 November 2015
Explain the structural suitability of the sperm cell for its function and describe its involvement in the formation of a zygote and the development of this zygote until implantation. (17)

Note: NO marks will be awarded for answers in the form of flow charts, tables or diagrams.

Question 7
DBE NSC February-March 2015 Paper 1
Study the diagram below, which shows a process occurring in a human male:

7.1 Name the process by which male gametes in humans are formed through meiosis. (1)

7.2 Name the organ in males where the process mentioned in Question 7.1 takes place. (1)

7.3 Write how many chromosomes will be found in each cell at:
   A ____________________________
   B ____________________________
7.4 Name TWO processes occurring during the 1st meiotic division that contribute to the genetic variation of cells.

A ____________________________ B ____________________________ (2)

7.5 How many cells at B will carry the Y-chromosome? ____________________________ (1)

7.6 What are the mature cells at B called? ____________________________ (1)

Answers

Question 1

1.1 A - Prostate gland ✓
   B - Vas deferens/sperm duct ✓
   C - Epididymis ✓
   D - Testes ✓
   F - Acrosome ✓
   (5)

1.2 (a) To store sperm. ✓ (1)
     (b) To digest/break down the wall of the ovum. ✓ (1)

1.3 D ✓ (1)

1.4 To regulate the temperature so that it is below body temperature for sperm production. ✓ (1)

1.5 (a) Interstitial cells/cells of Leydig. ✓ (1)
     (b) Testosterone. ✓ (1)

1.6 (a) Yes. ✓ (1)
     (b) The semen will not contain sperm cells but will still have the fluid from the various glands ✓ and the virus will still be present in the secretions of the various glands. ✓ (2)

Question 2

2.1 37.1°C ✓ (1)

2.2 37.1°C - 36.5°C ✓ = 0.9°C ✓ (2)

2.3 An increase in temperature on day 14 ✓ and a rise in the level of progesterone after day 14. ✓ (2)

2.4 The progesterone will thicken the endometrium ✓ further and maintain its thickness. ✓ (2)

2.5 (a) Graafian follicle. ✓ (1)
     (b) Corpus luteum. ✓ (1)

2.6 LH/luteinising hormone. ✓ (1)

Question 3

3.1 Endometrium ✓

3.2 Chorion ✓

3.3 Menstruation ✓

3.4 Fallopian tube/oviduct ✓

3.5 Penis ✓

Question 4

4.1 A ✓

4.2 A or B ✓

4.3 E ✓

4.4 B ✓

4.5 D ✓

(5)

Question 5

5.1 - As a result of the blocked Fallopian tube ✓
   - the sperm cannot reach the ovum ✓
   - therefore fertilisation cannot take place ✓
   (any 2) (2)

5.2 (a) FSH ✓/follicle stimulating hormone (Mark first ONE only) (1)
     (b) Oestrogen ✓ (Mark first ONE only) (1)

5.3 - A zygote ✓ is formed
   - which divides by mitosis ✓
   - forming a ball of cells ✓
   - called the morula ✓
   - which further divides to form a hollow ball of cells ✓ (any 4) (4)

5.4 - Progesterone levels would fall ✓
   - The endometrium would no longer be maintained ✓
   - A miscarriage would occur ✓ (3)

(11)
### Question 6

**ASSESSING THE PRESENTATION OF THE ESSAY**

<table>
<thead>
<tr>
<th>Relevance</th>
<th>Logical sequence</th>
<th>Comprehensive</th>
</tr>
</thead>
<tbody>
<tr>
<td>All information provided is relevant to the question</td>
<td>Ideas arranged in a logical/cause-effect sequence</td>
<td>Answered all aspects required by the essay in sufficient detail</td>
</tr>
<tr>
<td>Only information regarding: • The structural suitability of the sperm cell • Events during fertilisation • Events after fertilisation until implantation</td>
<td>All structures are related to the respective functions of the sperm cell. The sequence of events in fertilisation and post-fertilisation until implantation is in the correct order.</td>
<td>At least the following points should be included: • The structural suitability of the sperm cell (4/6) • Events during fertilisation (3/5) • Events after fertilisation until implantation (4/6)</td>
</tr>
</tbody>
</table>

| 1 mark | 1 mark | 1 mark |

#### Structural suitability of the sperm cell for internal fertilisation
- The front of the head of the sperm cell contains an acrosome vesicle which carries enzymes to dissolve a path into the ovum
- Nucleus of the sperm carries genetic material of the male haploid number of chromosomes
- The middle piece contains mitochondria which release energy so that sperm cells could swim
- The presence of a long tail enables sperm cells to swim towards the ovum
- The contents of the sperm cell such as the cytoplasm is reduced condensed making the sperm light for efficient movement

#### Fertilisation
- In the Fallopian tubes
- one sperm cell makes contact with the ovum’s membrane
- The nucleus of the sperm enters the ovum
- Then the ovum membrane becomes impenetrable to other sperms
- The nucleus of the sperm fuses with the nucleus of the ovum
- to form a diploid zygote
- This is called fertilisation

#### Events after fertilisation until implantation
- The zygote divides by mitosis many times
- to form an embryo
- It first consists of a ball of cells called the morula
- which then develops into a hollow ball of cells called the blastula/blastocyst
- It embeds itself into the uterus lining/ endometrium
- using chorionic villi

### Question 7

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>7.1 Spermatogenesis</td>
<td>7.2 Testis</td>
<td>7.3 (a) 23</td>
</tr>
<tr>
<td>7.4 - Crossing over</td>
<td>- Random assortment/segregation of chromosomes</td>
<td>7.5 2</td>
</tr>
<tr>
<td>7.6 Sperm cells/spermatozoa/male gametes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Content: (17)

#### Synthesis: (3)

[20]
STRAND 1 Life at molecular, cellular and tissue level
STRAND 4 Diversity, change and continuity
UNIT 5 Genetics and inheritance

Genetic concepts

**What is genetics?**
- The study of heredity – the inheritance of traits from one generation to the next.
  A trait is a genetic characteristic e.g. eye colour, height, a condition. Traits are determined by genes.

**The ‘father of genetics’**
- An Austrian monk named Gregor Mendel (1822 – 1884) is said to be the 'father of genetics'. He was the first person to identify and document some of the basic principles of heredity through numerous experiments with pea plants.
- He hypothesised that inherited traits are controlled by 'factors' (now known as genes) that exist in pairs and are passed from parents to offspring as complete characteristics.
- Mendel’s First Law of Inheritance or Law of Segregation: An organism’s characteristics are determined by factors (genes) which occur in pairs (homologous pairs). Only one gene of the pair can occur in a gamete.

**TERMINOLOGY**

<table>
<thead>
<tr>
<th>Term</th>
<th>Explanation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gene</td>
<td>Section of DNA coding for a particular trait.</td>
<td>Eye colour</td>
</tr>
<tr>
<td>Allele</td>
<td>Alternative form of a gene.</td>
<td>Blue eye colour, Brown eye colour</td>
</tr>
<tr>
<td>Dominant allele</td>
<td>Allele that is always expressed in the phenotype. Represented by a capital letter, usually of the first letter of the trait.</td>
<td>B = brown eye colour</td>
</tr>
<tr>
<td>Recessive allele</td>
<td>Allele that is only expressed in the phenotype when a dominant allele is not present. Represented by the lower case letter, the first letter of the corresponding dominant allele.</td>
<td>b = blue eye colour</td>
</tr>
<tr>
<td>Locus</td>
<td>Position or location of a gene on a chromosome.</td>
<td></td>
</tr>
<tr>
<td>Genotype</td>
<td>The genetic make-up of an individual, showing the alleles that determine the trait.</td>
<td>BB or Bb or bb</td>
</tr>
<tr>
<td>Phenotype</td>
<td>Outward expression of the genetic make-up of the individual (genotype).</td>
<td>Brown or blue eye colour</td>
</tr>
<tr>
<td>Homozygous (purebreeding)</td>
<td>Both alleles for a trait are the same.</td>
<td>BB or bb</td>
</tr>
<tr>
<td>Heterozygous (hybrid)</td>
<td>Two alleles for the trait are different.</td>
<td>Bb</td>
</tr>
</tbody>
</table>

Explanation of genetic terms with examples
Inheritance and variation

Organisms are different from one another; even within species there is variation. This is due to:
- Variation within the genes, brought about by the events in meiosis (crossing over and independent assortment).
- Variation in environments, which can influence the expression of genes or cause mutations.

Inheritance of characteristics can be shown through crosses, represented by Punnett diagrams.

Monohybrid Inheritance and crosses

- A monohybrid cross is the mating or cross between two parents, involving a single characteristic/trait with two alleles.

Example

A homozygous tall plant is crossed with a homozygous short plant. The dominant trait is tall.

The inheritance pattern can be shown as follows:

\[
\begin{array}{c|c|c|c|c}
 & T - Tall & t - short \\
\hline
P_1 & TT & \times & tt \\
\hline
\text{Gametes} & T & t & T & t \\
\hline
F_1 & & Tt & Tt & & \\
\hline
\end{array}
\]

- P_1 represents the parents of the first generation
- Gametes are represented in a circle and only list the gametes with different alleles from each parent
- F_1 represents the first filial generation → first generation of offspring
- Gametes of first parent are placed in the first row and gametes of second parent placed in the first column
- Arrows indicate the gamete combination of each parent
- Genotypes and phenotypes of offspring are analysed and expressed as a percentage or ratio.

F_1 Genotypes 100% TT (homozygous) F_1 Phenotypes 100% tall

If the F_1 generation were to self-pollinate the F_2 would be as follows:

\[
\begin{array}{c|c|c|c|c}
 & T - Tall & t - short \\
\hline
P_2 & Tt & \times & Tt \\
\hline
\text{Gametes} & T & T & t & t \\
\hline
F_1 & & TT & Tt & & \\
\hline
\end{array}
\]

- F_2 Genotypes 1 TT : 2 Tt : 1 tt
- F_2 Phenotypes 3 tall : 1 short

Monohybrid cross with Punnett diagram between a tall plant and a short plant
### Incomplete/Partial Dominance

**Definition**
Both types of alleles influence the phenotype and a mixing/blending effect is seen.

**Example**
Can be seen in snapdragon plant flowers: Homozygous for red (R) flowers crossed with homozygous for white (r) flowers

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR x rr</td>
<td>100% Pink flowers</td>
</tr>
</tbody>
</table>

Genotypes: 100% Rr
Phenotypes: 100% Pink flowers

### Co-dominance

**Definition**
Both alleles are expressed equally in the heterozygote individual.

**Example**
Can be seen in some cattle regarding coat colour: Homozygous red coat (R) crossed homozygous white coat (W)

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Phenotypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>RR x WW</td>
<td>100% Roan coats</td>
</tr>
</tbody>
</table>

Genotypes: 100% RW
Phenotypes: 100% Roan coats

### The inheritance of blood groups is an example of co-dominance.

Blood group A and blood group B are co-dominant. Blood group O is recessive to both group A and B.

- Gene for blood group A = \( I^A \)
- Gene for blood group B = \( I^B \)
- Gene for blood group O = \( I^O \)

### Dihybrid cross

This is a cross between two homozygous parents that differ in their alleles for two genes, resulting in a dihybrid offspring.

#### Example
Pea plant homozygous for yellow and round seeds crossed with a pea plant homozygous for green and wrinkled seeds. Yellow and round seeds are dominant.

- **P₁**
  - Gametes: \( YR \times yr \)
  - Cross: \( YYRR \times yyrr \)

- **F₁**
  - Genotypes: 100% YyRr (heterozygous)
  - Phenotypes: 100% Yellow and round seeds

#### Test Cross

- **What is it?** Cross between an organism of unknown genotype with the homozygous recessive organism.
- **Why is it done?** To determine the genotype of an organism that shows the dominant phenotype. Therefore, to determine if an organism is homozygous dominant or heterozygous.
- **Interpretation of cross results** Unknown organism is homozygous dominant if offspring phenotypic ratio is 3:1.
- Unknown organism is heterozygous if offspring phenotypic ratio is 1:1.
Sex chromosomes

Sex determination
- Sex is determined by the gonosomes or sex chromosomes.
- In humans, there are two sex chromosomes:
  A long chromosome → X chromosome
  A short chromosome → Y chromosome
- Female chromosomes → XX and Male chromosomes → XY
- The chance of a child being a male or female is always 50%.

Sex-linked disorders
Genetic disorders that are determined by genes on the sex chromosomes – usually the X chromosome.
When a gene on the X chromosome mutates to form a recessive allele, the following can be seen:
- In males: the effect of the allele is seen as they have only one X chromosome.
- In females: the effect of the allele is only seen if both X chromosomes have that allele. If the female is heterozygous for the allele she is a carrier of the disorder but does not suffer from the disorder.

Examples of X-linked disorders:  
- Colour blindness – inability to distinguish red from green.
- Haemophilia – blood clotting does not occur.

Mutations
- A mutation is a sudden unexpected change in the genetic structure (DNA or chromosome) of a cell.
- If a mutation occurs in a gamete it may be passed onto the next generation.

<table>
<thead>
<tr>
<th>Term</th>
<th>Gene mutation (point mutations)</th>
<th>Chromosomal mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is it?</td>
<td>Sudden change in the DNA sequence that usually occurs during replication.</td>
<td>Sudden change in the structure or number of chromosomes, that usually occurs in meiosis.</td>
</tr>
<tr>
<td>Types</td>
<td>Deletion – when one base is removed from DNA.</td>
<td>Deletion – removal of a portion of a chromosome.</td>
</tr>
<tr>
<td></td>
<td>Addition – when one base is added to DNA.</td>
<td>Duplication – extra copies of a section of a chromosome.</td>
</tr>
<tr>
<td></td>
<td>Substitution – when one base is replaced with another one.</td>
<td>Translocation – section of a chromosome that is moved to another locus.</td>
</tr>
<tr>
<td></td>
<td>Inversion – when two bases are swapped.</td>
<td></td>
</tr>
<tr>
<td>Example</td>
<td>Albinism</td>
<td>Cri-du-chat syndrome</td>
</tr>
<tr>
<td></td>
<td>Sickle cell anaemia</td>
<td>Down Syndrome</td>
</tr>
</tbody>
</table>

Various types of mutations

What causes mutations?
- Factors that cause mutations are known as mutagens.
- Known mutagens are: UV light, X-ray radiation, radioactive elements, some chemicals, such as tar in tobacco smoke.

Useful mutations
Some mutations are useful if not for the individual then for the population. A useful mutation will be found more often in a population because of natural selection.
Some examples: Sickle cell anaemia – red blood cells are not the correct shape. The malaria parasite does not enter these cells therefore people with this condition do not get malaria.
## Genetic engineering and DNA technology

### Summary of genetic engineering technology

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DNA fingerprinting</strong></td>
<td><strong>What is it?</strong> DNA is analysed for unique sequences (usually non-coding DNA) to identify individuals and trace genetic relationships.</td>
</tr>
<tr>
<td><strong>How is it done?</strong></td>
<td><strong>Step 1:</strong> Sample DNA is cut into fragments, using restriction enzymes.</td>
</tr>
<tr>
<td></td>
<td>DNA fragments are of differing sizes.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 2:</strong> Fragments are separated according to size through gel electrophoresis.</td>
</tr>
<tr>
<td></td>
<td>• DNA is placed into a gel plate at the negatively charged end.</td>
</tr>
<tr>
<td></td>
<td>• Fragments move towards the positively charged end of the gel plate.</td>
</tr>
<tr>
<td></td>
<td>• Larger fragments move more slowly through the gel.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 3:</strong> DNA fragments are transferred from the gel to a filter sheet and radioactive probes are added, which bind to specific DNA fragments.</td>
</tr>
<tr>
<td></td>
<td><strong>Step 4:</strong> Radioactive DNA shows up as dark bands (similar to a barcode) on X-ray film.</td>
</tr>
<tr>
<td><strong>Uses of DNA fingerprinting</strong></td>
<td><strong>Forensics</strong> – help in solving crimes.</td>
</tr>
<tr>
<td></td>
<td><strong>Paternity testing</strong> – determining the father of a child.</td>
</tr>
<tr>
<td></td>
<td><strong>Ancestry lineage</strong> – mitochondrial DNA is passed from mother to offspring and is useful for tracing genetic linkages and, therefore, evolutionary relationships.</td>
</tr>
<tr>
<td><strong>Cloning</strong></td>
<td><strong>What is it?</strong> Process of making one or more genetically identical copies of individual cells or organisms.</td>
</tr>
<tr>
<td></td>
<td><strong>How is it done?</strong> 1. Nucleus from donor egg cell is removed and nucleus with selected DNA is inserted into donor egg cell, (known as somatic cell nuclear transfer (SCNT)).</td>
</tr>
<tr>
<td></td>
<td>2. Recombinant egg cell is stimulated, using electric current to start dividing to form an embryo.</td>
</tr>
<tr>
<td></td>
<td>3. Embryo is placed into uterus of surrogate mother and develops into cloned individual.</td>
</tr>
</tbody>
</table>

Continued on page 43
<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stem cell technology</td>
<td>grew is therapeutic cloning whereby embryonic or adult stem cells are used to produce tissues to treat diseases. Potential diseases that could be treated with gene therapy: Parkinson’s disease, Cystic Fibrosis.</td>
</tr>
<tr>
<td>Gene therapy</td>
<td></td>
</tr>
</tbody>
</table>
| Genetic Engineering       | What is it? Genetic engineering is the process whereby the genes in an organism are changed or manipulated with the intent of making the organism better. How is it done? An example:  
Step 1: Human insulin gene isolated with restriction enzymes.  
Step 2: Gene is inserted into plasmid genome of bacterium.  
Step 3: Plasmid with recombinant DNA is placed into bacterium.  
Step 4: Transgenic bacteria multiply, producing human insulin. |

![Diagram of genetic engineering process](image)

Uses of genetic engineering
- Improvement of crops – enhancing nutrition content, drought/herbicide/insect resistance
- Medical field – gene therapy to treat diseases, production of insulin for diabetics.

Disadvantages of genetic engineering
- Expensive
- interfere with nature
- Loss of biodiversity
- Unsure of long term effects
- Violation of natural organism’s intrinsic value (right to independent existence)
- May be difficult for poor people to access
- Immoral/ we cannot play God
- Potential health impact
- Domination of the world food products by only a few companies
- Genes from transgenic organisms could escape and be transferred to wild organisms

Advantages of genetic engineering
- Production of medication
- Control pests with specific genes inserted into the crop
- Using specific genes to increase crop yields / food security
- Selecting genes that may increase maturation times to meet the demand
- Using specific genes to improve nutritional value of food for better health
- DNA and proteins of transgenic organisms unlikely to cause problems / transgenic organisms do not survive easily in wild
- Endangered species can be saved
- Production of resources cheaply
- Selecting the best genes to produce better resistant crops
- Selecting genes to increase shelf life of plant products
- Selecting genes that may decrease maturation times to meet the demand
- Improve the taste of food
- Produce organisms that can clean up pollution
- Increases genetic variation
Questions

This unit is examined in Paper 2 for about 45 marks (30%).

Question 1
Match the statement in Column A with the correct term in Column B. Write only the correct letter in the column provided on the right in the table below.

<table>
<thead>
<tr>
<th>ANSWER</th>
<th>COLUMN A</th>
<th>COLUMN B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Different forms of a gene located at the same position on a chromosome.</td>
<td>A Locus</td>
</tr>
<tr>
<td>1.2</td>
<td>The appearance of an organism due to its genetic make-up.</td>
<td>B Genetics</td>
</tr>
<tr>
<td>1.3</td>
<td>The location of a gene on a chromosome.</td>
<td>C Homozygous</td>
</tr>
<tr>
<td>1.4</td>
<td>This type of gene is not expressed in a heterozygote individual.</td>
<td>D Allele</td>
</tr>
<tr>
<td>1.5</td>
<td>Genetic make-up of an organism.</td>
<td>E Phenotype</td>
</tr>
<tr>
<td>1.6</td>
<td>The science of heredity.</td>
<td>F Heterozygous</td>
</tr>
<tr>
<td>1.7</td>
<td>Complete set of chromosomes for an organism.</td>
<td>G Recessive</td>
</tr>
<tr>
<td>1.8</td>
<td>This type of gene is expressed in an organism.</td>
<td>H Genotype</td>
</tr>
<tr>
<td>1.9</td>
<td>An organism with identical alleles for a particular trait.</td>
<td>I Genome</td>
</tr>
<tr>
<td>1.10</td>
<td>An organism with different alleles for a particular trait.</td>
<td>J Dominant</td>
</tr>
</tbody>
</table>

Question 2

DBE NSC Life Sciences February-March 2013 Paper 1

A rare form of rickets in humans is caused by a sex-linked dominant allele (R) which is carried on the X chromosome. An affected female, whose father was unaffected, married an unaffected male.

2.1 Determine the possible genotypes and phenotypes of their offspring by using a genetic cross in the space below. (6)

2.2 What is the percentage chance that they will have a child who is an unaffected male? (2)

2.3 Explain why this disorder, although it is sex-linked, does NOT affect males only. (2)

2.4 This genetic disorder is caused by a gene mutation in which the DNA triplet CAG is altered to TAG.
   (a) Name this mutation. (1)
   (b) Describe how the type of mutation mentioned in (a) will affect the structure of the protein for which it codes. (2)
   (c) Give two reasons why this couple should undergo genetic counselling before having children. (3)
**Question 3**

*DBE NSC Life Sciences February-March 2013 Paper 1*

The pedigree diagram given traces the inheritance of vestigial (reduced in size) and normal wing characteristics in fruit flies. Study the diagram and answer the questions.

3.1 State the dominant wing characteristic of the flies used in these crosses.

__________________________________________ (1)

3.2 Use the letters G and g and write down the genotype of the following:

(a) A ____________________ (1)

(b) J ____________________ (1)

3.3 If fruit fly C was crossed with a male having vestigial wings, what would be the possible genotype(s) of the offspring?

__________________________________________

(4)

**Question 4**

DNA fingerprinting may be used in forensic science to solve crimes. Study the image below, which shows the DNA fingerprints of the victim of a rape case, the evidence collected from the crime scene and three possible suspects. Answer the questions that follow.

4.1 Explain how a forensic scientist could use a DNA fingerprint to solve a crime.

[Image taken from: http://www.berkeley.edu/news/berkeleyan/2001/05/02_dna.html]
4.2 Based on the evidence above, state which suspect most likely committed the crime. Justify your answer.

4.3 The evidence collected at the crime scene used to generate the DNA fingerprint was blood. Of the type of blood cells provided in bold, which could be used to generate the DNA fingerprint? Underline your choice.

(white blood cells/ red blood cells)

4.4 If a forensic sample was too small for DNA analysis, name and explain the procedure used to generate a larger sample for analysis.

---

Monohybrid inheritance and crosses

**Question 5**

*DBE NSC February-March 2016 Paper 2*

In dogs rough hair (H) is dominant to smooth hair (h). A heterozygous rough-haired dog is mated with a smooth-haired dog.

Represent a genetic cross to show the phenotypic ratio of the puppies.

---

**Question 6**

In guinea pigs, black hair is dominant over white hair. If a heterozygous black male was crossed with a pure breeding white female, what would the offspring of the first filial generation be? Illustrate your answer with diagrams.

---

**Question 7**

7.1 Sheep homozygous for white wool are crossed with sheep homozygous for black wool. All the offspring are white. Explain this diagrammatically and show the expected results of mating the F₁ males and F₁ females.

7.2 If homozygous white sheep are mated with heterozygous white sheep, what will be the expected result (diagrams required).
Incomplete dominance

Question 8
In minks (a small animal with a long body and short legs), long silky fur and short silky fur are equally dominant, with a heterozygote having medium length fur. You are given eight male minks with medium length hair and eight female minks, two of which have long silky fur, three have short fur and three have medium length fur. Long silky fur is the most valuable sort. Explain in terms of genetics, the quickest way of breeding a pure strain of long silky-furred animals.

Co-dominance

Question 9
A roan coat bull (RW) mates with a white coat cow (WW). What will the genotype and phenotype of the offspring be?

Question 10

DBE NSC November 2015 Paper 2

The father of a child can be determined by analysing blood groups.

10.1 Explain how an analysis of blood groups can be used to determine paternity.

10.2 A man and a woman both have blood group B.

Use a genetic cross to show how it is possible for them to have a child with blood group O.
In rabbits, grey hair is dominant to white hair and black eyes are dominant to red eyes. These letters below represent the genotypes of some rabbits:

| GG – Grey hair | BB – Black eyes |
| Gg – Grey hair  | Bb – Black eyes |
| gg – White hair | bb – Red eyes  |

11.1 What are the phenotypes of the rabbits that have the following genotypes?

(a) Ggbb ____________________________

(b) ggBB ____________________________

(c) ggbB ____________________________

(d) GgBb ____________________________

11.2 A male rabbit with the genotype GGbb is crossed with a female rabbit with the genotype ggBb. The punnet square is set out below:

<table>
<thead>
<tr>
<th>Gb</th>
<th>Gb</th>
<th>Gb</th>
<th>Gb</th>
</tr>
</thead>
<tbody>
<tr>
<td>gB</td>
<td>GgBb</td>
<td>GgBb</td>
<td>GgBb</td>
</tr>
<tr>
<td>gb</td>
<td>Ggbb</td>
<td>Ggbb</td>
<td>Ggbb</td>
</tr>
<tr>
<td>gB</td>
<td>GgBb</td>
<td>GgBb</td>
<td>GgBb</td>
</tr>
<tr>
<td>gb</td>
<td>Ggbb</td>
<td>Ggbb</td>
<td>Ggbb</td>
</tr>
</tbody>
</table>

How many out of the 16 offspring have:

(a) Grey fur and black eyes ____________________________

(b) Grey fur and red eyes ____________________________

(c) White fur and black eyes ____________________________

(d) White fur and red eyes ____________________________

[8]
Sex-linked disorders
Question 12
Adapted from DBE NSC November 2015 Paper 2
A lack of immunity to infections (agammaglobulinemia) is a sex-linked recessive genetic disorder in humans. The dominant allele is represented by \(X^A\) and the recessive allele is represented by \(X^a\).

An individual with the disorder is described as affected, and an individual without it is described as unaffected. The pedigree diagram below illustrates inheritance of this disorder.

12.1 Name the genotypes of individuals:

(a) 1 ___________________________________________________________________________ (2)

(b) 2 ___________________________________________________________________________ (2)

12.2 What percentage of the males in this pedigree diagram is affected? Show ALL working. ___________________________________________________________________________ (2)

12.3 Explain why any son of an affected female will always have this disorder. ___________________________________________________________________________ (3)

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
**Answers**

**Question 1**

1.1 D ✓ 1.6 B ✓
1.2 E ✓ 1.7 I ✓
1.3 A ✓ 1.8 J ✓
1.4 G ✓ 1.9 C ✓
1.5 H ✓ 1.10 F ✓

**Question 2**

2.1 X<sup>Y</sup> = rickets X<sup>−</sup> = no rickets

P<sub>f</sub>: Fathers genotype = X<sup>Y</sup>Y

Mothers genotype = X<sup>Y</sup>X<sup>−</sup> ✓

Gametes: X<sup>−</sup> or Y X<sup>Y</sup> or X<sup>−</sup>

F<sub>i</sub>: X<sup>−</sup>X<sup>−</sup>: 1 X<sup>−</sup>Y: 1 X<sup>Y</sup>Y: 1 X<sup>Y</sup>X<sup>−</sup> ✓

F<sub>i</sub> genotypes: 1 affected female (heterozygous): 1 unaffected female: 1 affected male: 1 unaffected male ✓ ✓

2.2 25% ✓

2.3 It is a dominant trait ✓ so, if it is present in the genotype, it will be evident in the phenotype. ✓

2.4 (a) Point mutation/substitution. ✓

(b) It could change the mRNA codon, ✓ which could change the amino acid that should be present in the protein. ✓

(c) To determine the chances of having a child with the disorder. ✓

Help them evaluate whether they could cope with such a child. ✓

Help them make an informed decision on whether to have children. ✓

Any 2 (2)

**Question 3**

3.1 Normal wings ✓

3.2.1 Gg ✓

3.2.2 gg ✓

3.3 Gg ✓ and gg ✓

**Question 4**

4.1 Used as a comparison with the DNA fingerprints of the crime scene evidence to place a suspect at a crime scene. ✓

4.2 Suspect 1. ✓

4.3 White blood cells. ✓

4.4 Polymerase chain reaction (PCR). ✓

Small amount of DNA is heated, ✓ the enzyme DNA polymerase and DNA nucleotides are added, which replicates the DNA. ✓

**Question 5**

P<sub>i</sub> Phenotype Rough hair × Smooth hair ✓

Genotype Hh × hh ✓

Meiosis

Gametes H h h h

Fertilisation

Phenotypic 1 rough hair : 1 smooth hair ✓ ratio

P<sub>i</sub> and F<sub>i</sub> ✓

Meiosis and fertilisation ✓

Any 6

**Question 6**

B = Black hair b = white hair

heterozygous × pure breeding white male

black male

P<sub>i</sub> Bb × bb ✓

Gametes B b b b ✓

F<sub>i</sub> B b b b ✓

F<sub>i</sub> genotypes 50% Bb 50% bb ✓

Any 6 (2)

F<sub>i</sub> phenotype 50% black 50% white ✓

Any 6 (2)
**Question 7**

\[ W = \text{white wool} \quad w = \text{black wool} \]

a) \( P_1 \) WW \( \times \) WW

\[
\begin{array}{c|c|c}
\text{gametes} & W & w \\
\hline
F_1 & W & W \\
W & wW & Ww \\
wW & wW & Ww \\
\end{array}
\]

\( F_1 \) genotypes 100% (all) \( Ww \)

\( F_1 \) phenotypes: all have white hair

b) \( F_1 \) male WW \( \times \) \( F_1 \) female WW

\[
\begin{array}{c|c|c|c}
\text{gametes} & W & w & Ww \\
\hline
F_2 & W & w & Ww \\
W & WW & Ww \\
wW & Ww & Ww \\
\end{array}
\]

\( F_2 \) genotypes 25% WW 50% Ww 25% ww

\( F_2 \) phenotypes: 75% white 25% black

c) WW \( \times \) Ww

\[
\begin{array}{c|c|c|c}
\text{genotypes} & 50% WW & 50% Ww & 50% Ww & 50% Ww \\
\hline
\text{phenotypes} & \text{all white wool sheep} & \text{medium} & \text{medium} & \text{medium} \\
\end{array}
\]

**Question 8**

L = long silky fur  S = short silky hair

LS medium length silky fur

8 males LS medium length

8 females 3 LL 3 LS 3 SS

Breed a male LS with a LL (long fur) female

\[
\begin{array}{c|c|c|c}
\text{F1} & L & S & L \\
\hline
\text{LL} & \text{LS} & \text{LS} \\
\end{array}
\]

Then \( F_1 \) inbreed LL \( \times \) LL

All offspring will have long silky fur

**Question 9**

roan coat bull  white coat cow

\[
\begin{array}{c|c|c}
\text{P1} & RW & WW \\
\hline
\text{gametes} & R & W & W \\
\hline
\text{F1} & W & RW & WW \\
W & RW & WW \\
\end{array}
\]

\( F_1 \) genotypes 50% RW 50% WW

\( F_1 \) phenotype 50% roan 50% white

**Question 10**

10.1 - The blood groups of the mother, possible father and the child must be compared.

- If this shows that it is not possible that these parents can produce a child with his/her blood group, then this man is not the father.
- If this shows that it is possible that these parents can produce a child with his/her blood group, then he may/may not be the father.
- because other males have the same blood group.

Any 5

10.2

\( P_1 \) Phenotype Blood group B \( \times \) Blood group B

\( \text{Genotype} \ P_1^{B1O} \times P_1^{B1O} \)

\( \text{Meiosis} \)

\( \text{Gametes} \ P_1^B, P_1^O \times P_1^B, P_1^O \)

\( \text{Fertilisation} \)

\( \text{F1} \) Genotype \( \{P_1^{B1B}, P_1^{B1O}, P_1^{B1B}, P_1^{B1O}, P_1^{B1O}, P_1^{O1O}\} \)

\( \text{Phenotype} \)

3 blood group B : 1 blood group O

\( P_1 \) and \( F_1 \)

\( \text{Meiosis and fertilisation} \)

Any 6

11.1 (a) Grey hair with red eyes
(b) White hair with black eyes
(c) White hair with red eyes
(d) Grey hair with black eyes

11.2 (a) 8 \( \checkmark \)  (b) 8 \( \checkmark \)  (c) 0 \( \checkmark \)  (d) 0 \( \checkmark \)

**Question 12**

12.1 (a) \( X^A Y^B \)
(b) \( X^A X^B \)

12.2 \( \frac{3}{8} \times 100 = 42.86\%  / \ 42.9 / 43\% \)

12.3 - An affected female carries two/recessive alleles \( X^A X^B \)

- Sons/male inherit one X chromosome from their mothers
- Sons/male need only one recessive allele to show affected
- And therefore must inherit \( X^A \) from their mothers

Any 6
Humans have two systems in which to respond to the environment: the nervous system and the endocrine system.

**Human Nervous System**

**NERVOUS SYSTEM**

- **Central nervous system (CNS)**
  - Brain and spinal cord
  - Receive and interpret information.
  - Control centres.

- **Peripheral nervous system (PNS)**
  - Cranial nerves and spinal nerves
  - Communicates between CNS and the rest of the body.

**Sensory division**
- **Sensory nerve fibres**
- Conduct impulses from receptors to CNS.

**Motor division**
- **Motor nerve fibres**
- Conducts impulses from CNS to effectors (muscles and glands).

**Autonomic nervous system (ANS)**
- **Involuntary**
  - Conducts impulses from CNS to cardiac muscle, smooth muscle and glands.

**Somatic nervous system**
- **Voluntary**
  - Conducts impulses to skeletal muscles.

A diagram showing the levels of organisation in the human nervous system

**Central nervous system (CNS)**
- Composed of the brain and the spinal cord, which together work as the control centre that receives information from all parts of the body.
- The brain and spinal cord are protected by the skull and three membranes known as the meninges:
  - **Dura mater** (outer membrane): Tough and found just below the skull.
  - **Arachnoid membrane**: Thin.
  - **Pia mater** (inner membrane): Rests on the brain and spinal cord and is well supplied with blood vessels.
- **Cerebrospinal fluid** (CSF) fills the spaces between the membranes and has the following functions:
  - Acts as a shock absorber.
  - Provides chemical environment for proper functioning of the brain and spinal cord.
  - Supplies nutrients and removes wastes for CNS.
  - Maintains even pressure around CNS.
The brain

- corpus callosum: largest white matter region of brain.
  - Connects left and right hemispheres of the brain.
  - Co-ordinates the activities of the two cerebral hemispheres.
- hypothalamus: largest white matter region of brain.
  - Houses centre for vision, hearing, taste, smell and touch.
  - Higher mental functions such as intelligence, memory, judgement and reasoning are controlled here.
- pituitary gland: made of grey matter with white matter.
  - Controls involuntary muscles.
  - Controls vital reflexes like breathing, heart rate, blood pressure, peristalsis, swallowing and coughing.
- cerebrum: largest part of brain.
  - Initiates voluntary movement of limbs and speech.
  - Houses centre for vision, hearing, taste, smell and touch.
- cerebellum: made of grey matter.
  - Co-ordinates and controls complex muscular movements such as cycling and walking; inner ear actions.
  - Centre of balance, posture and smooth movements take place.

The spinal cord

- Gives rise to peripheral nerves.
- Connects receptors (not in the head) to the brain.
- Connects the brain to effector organs such as glands and muscles.
- Centre for the reflex action.

Peripheral and autonomic nervous system (PNS)

- The PNS is composed of nervous tissue outside the CNS: The sensory neurons carrying information to the CNS from receptors and motor neurons carrying information from the CNS to the effector organs.
- The function of the PNS is to carry impulses to and from the CNS.

**Autonomic nervous system**
- Controls involuntary muscles and regulates activity of certain glands.
  - Sympathetic nervous system
    - Controls activities that increase amount of energy we use.
    - Active when the body is in a stressful situation.
  - Parasympathetic nervous system
    - Controls activities that decrease amount of energy we use.
    - Active when the body is relaxed.

**Somatic nervous system**
- Controls voluntary skeletal muscle receptors.
Structure and functioning of nervous tissue

- Nerve tissue is made up of nerve cells called neurons.
- A neuron consists of:
  - A cell body – contains large nucleus to control cellular activities, granular cytoplasm, mitochondria and other organelles.
  - Dendrites – branching fibres responsible for making contact with other neurons.
  - Axon – fibre leading away from cell body that carries nervous impulses. It is insulated by the myelin sheath.

(Fibres are strands of cytoplasm.)

Types of neuron

Sensory neuron
Carries information from receptor to the central nervous system (CNS).

Motor neuron
Carries information from CNS to an effector organ (to bring about a response).

Interneuron / Connector neuron
Carries information within CNS. Connects the sensory neuron and the motor neuron.
Reflex Arc

- **Reflex action**: Rapid involuntary response to a stimulus received by a sense receptor organ.
- **Reflex arc**: The pathway along which an impulse travels during a reflex action.
- **Synapse**: Microscopic gap between neurons where an impulse moves across to adjacent neurons by chemicals called neurotransmitters.

![Diagram of a simple reflex arc](image)

**Pathway of a reflex action = reflex arc**

**Function of reflex action**

Protects the body from dangerous situations. For example:

1. Person pricks a finger, pain receptors in finger detect stimulus.
2. Impulse travels along sensory neuron to spinal cord via dorsal root.
3. Impulse moves across synapse to connector neuron and then to motor neuron, which travels along the ventral root.
4. Motor neuron carries impulse to the effector organ (muscle) to bring about response to move finger away.

**Significance of the reflex arc**

- Fast transmission of nerve impulses from the detector organ to the effector organ.
- The nervous impulse does not need to travel to the brain and then back to the CNS (waste of time).
- Connector neuron makes a short cut.
- Helps protect the body from harm by bringing about an unlearned reflex action.

**Significance of synapses**

- Ensures that a nervous impulse moves in one direction only.
- Neurotransmitters are only made and released at the end of a neuron.
- Neurotransmitter receptors are only found on the other side of a synapse at the beginning of the next neuron.
Disorders and Injuries of the Human Nervous System

### Disorders

<table>
<thead>
<tr>
<th>Name of disorder</th>
<th>Possible causes</th>
<th>Symptoms</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiple Sclerosis (MS) (disease whereby scarring on the myelin sheaths interrupt nerve impulses) Immune system attacks the myelin sheaths of the neurons causing disruption in impulse transmission.</td>
<td>Virus infection. Gene defect. Environmental factors.</td>
<td>Blurred or loss of vision. Loss of co-ordination and balance. Muscle spasms and dizziness. Decreased concentration and memory loss. Depression.</td>
<td>There is no cure but drugs can help treat symptoms, and there are therapies – physical, speech and occupational.</td>
</tr>
</tbody>
</table>

### Injuries to the Brain and Spinal Cord

- Injuries to the brain and spinal cord are serious and often the effects are permanent, such as brain damage, coma and paralysis.
- The use of stem cells is being investigated to treat spinal cord injuries.

### Effect of Drugs on the Nervous System

Addictive drugs affect the activity of two important neurotransmitters:
- Serotonin: Involved in sleep, aggression, eating, sexual behaviour, depression and body temperature.
- Dopamine: Involved in regulating behaviour, motor activity, motivations, mood and learning.

#### Dagga/Cannabis/Marijuana/Weed

Effect on neurotransmitters
Continuous dopamine release causes:
- Calm, relaxed feelings.
- Loss of short term memory.
- Slow movements.
- Feeling of pleasure.

Harmful effects on the user can include:
- Memory loss.
- Emotional problems.
- Sterility.
- Lung cancer.
- Depression.
- Personality disturbances.
- Anxiety.

#### Ecstasy/MDMA

Effect on neurotransmitters
Stimulates serotonin release which causes:
- Happy and ecstatic feelings.
- Increased confidence and energy.
- Damage to nerve-ending that changes the brain permanently.

Harmful effects on the user can include:
- Mental health problems.
- Depression.
- Dehydration.
- Poor sleep patterns.

#### Heroin

Effect on neurotransmitters
Surge in dopamine causes:
- Sedation.
- Dulls pain.
- Feeling of well-being, freedom from anxiety.
- Inhibits medulla oblongata activity.

Harmful effects on the user can include:
- Alteration of brain chemical balance.
- Respiratory failure.
- Death from overdose.

#### Tik/Crystal methamphetamine

Effect on neurotransmitters
Excess secretion of dopamine causes:
- Intense pleasure.
- Exhilaration.
- Addiction.

Harmful effects on the user can include:
- Anxiety and fear.
- Violent and self-destruction.
- Delusions.
- Depression.
- Death from overdose.

Summary of the effect of drugs on the CNS
**Receptor organs**

Receptor organs are able to detect a range of stimuli such as light (photoreceptors), temperature (thermoreceptors), sound, pressure and pain (mechanoreceptors), tastes and smell (chemoreceptors).

**Structure and function of the eye**

- **Suspensory ligaments**: holds the lens in position and attaches ciliary body to lens. 
- **Cornea**: transparent area of sclera that allows transmission of light. Refracts light rays. 
- **Aqueous humour**: protects the eyeball. 
- **Pupil**: opening of iris that allows light to enter. 
- **Iris**: coloured part of the eye that controls the size of the pupil. Has radial and circular muscles. 
- **Conjunctiva**: protects the eyeball. 
- **Lens**: transparent, flexible structure that focuses light onto retina to form image. 
- **Ciliary body**: muscles that can change the shape of the lens. 
- **Sclera**: protects the eyeball and gives it shape. 
- **Choroid**: rich blood supply provides nutrients and oxygen and reduces reflection of light. 
- **Retina**: contains photoreceptor cells (rods and cones) that generate impulses when stimulated by light. 
- **Yellow spot**: region of clearest vision - lots of cones present. 
- **Blind spot**: region of no vision (no rods or cones present). Optic nerve leaves the eye here. 
- **Optic nerve**: carries impulses from retina to the brain. 

There are two types of photoreceptors found in the retina: 
- Cones respond to bright light and colour. 
- Rods detect movement and respond in dim light.

**Summary**

- Light rays reflected from a tree 
- Image of tree upside down on retina 
- The part of tree which is most clearly seen is that which is focused on the yellow spot 
- Interpretation of tree is the right way up 
- Brain interprets information 
- ‘Seeing’ a tree

**Binocular vision**

Three dimensional vision that allows one to perceive depth and distance by focusing on an object, using two eyes to give a single image.

UNIT 6 Responding to the environment
Accommodation

The change in the shape of the lens to focus light from objects from different distances.

Near vision (closer than 6m)

When you look at an object closer than six metres, the following happens to your eye so that the cornea and lens can focus the image on the retina.

- Ciliary body contracts.
- Suspensory ligaments relax.
- Lens becomes convex (rounded).

Far vision (greater than 6m)

When you look at an object in the distance, the following happens to your eye so that the cornea can focus the image on the retina.

- Ciliary body relaxes.
- Suspensory ligaments contract.
- Lens becomes longer and flatter.
The pupil reflex

The adjustment of the size of the pupil in response to the amount of light entering the eye:

- **Bright light** – circular muscles in iris contract, radial muscles relax, pupil becomes smaller, therefore less light enters the eye.

- **Dim light** – radial muscles contract, circular muscles relax, pupil becomes larger, therefore more light enters the eye.

Eye Defects

- **Short-sightedness**: Ability to only focus on objects nearby and not distant objects.
  - A short-sighted person:
    - can focus on objects that are close by
    - cannot focus on objects at a distance.

  Short sightedness is corrected by wearing spectacles that have concave lenses to bend the light rays less.

  Diagrams showing how short sightedness can be corrected

- **Long-sightedness**: Ability to focus on objects at a distance but not nearby objects.
  - A long-sighted person:
    - can focus on objects at a distance
    - cannot focus on objects close by.

  Long sightedness is corrected by wearing spectacles that have convex lenses to bend the light rays more.

  Diagrams showing how long sightedness can be corrected

- **Astigmatism**: Blurry vision that results from curves in the cornea. These prevent the proper focussing of light on the retina.
  - cornea with normal curvature
  - cornea with unequal curvatures causes many focal points

  Diagrams showing the effects of astigmatism

- **Cataracts**: Forms when the lens becomes cloudy and therefore light is not transmitted through to the retina properly. Vision is blurred. Can be corrected by surgery, whereby a plastic lens replaces the cloudy lens.

  Short-sightedness, long-sightedness and astigmatism can be corrected by wearing prescribed glasses or contact lenses.
Structure and functions of the ear

**Structure**

- **Ossicles:** Three smallest bones in the middle ear that transfer mechanical waves to the oval window.
- **Pinna:** Directs sound waves towards the eardrum.
- **Eardrum/tympanic membrane:** Separates outer and middle ear. Sound waves vibrate against the eardrum, and are converted into mechanical waves.
- **Auditory canal:** Glands secrete waxy substance (cerumen) to trap dust particles and keep the canal clean.
- **Eustachian tube:** Connects the throat with the middle ear and ensures equal air pressure on either side of the eardrum.
- **Cochlea:** Coiled tube containing the organs of Corti that convert mechanical waves from the eardrum into nerve impulses to interpret sound.

**Functions**

**A. Hearing**

1. The pinna directs sound waves into and along the auditory canal to the tympanic membrane (eardrum). The membrane vibrates.
2. The vibrations are transferred to the ossicles of the middle ear. The vibrations travel through solid bone and are therefore amplified.
3. The foot plate of the stirrup transfers the vibrations on to the oval window.
4. The oval window transfers the vibrations as pressure waves to the perilymph (fluid) of the upper canal (vestibular canal).
5. The pressure waves are transferred through the membrane of the middle canal to the endolymph. They stimulate hair cells (mechanoreceptors) of the organs of Corti.
6. The hair cells send nervous impulses along the auditory nerve to the cerebrum of the brain where they are interpreted.
7. The pressure waves pass on to the tympanic canal where they are finally absorbed by the round window.
B. Balance

There are two senses concerned with balance.

Change of movement of the head:
- This is detected by the cupulae positioned in the ampulla. The cupula contains hair cells embedded in a cone of jelly. As the endolymph moves against the jelly the hair cells send impulses to the brain. The endolymph travels in the opposite direction to which the head is moving. The speed at which the endolymph moves is also detected.
- Each of the three semicircular canals are positioned in a different plane so that the endolymph will move through at least one of the canals in whichever direction the head moves.

Position of head:
- In the utricle and saccule there are maculae. These are made up of jelly containing little crystals called otoliths and at the base of the jelly are patches of hair cells. The otoliths react to gravitational pull. When the head is straight up the otoliths exert equal pressure on the hair cells.
- A change in the position/angle of the head exerts more pressure on certain hair cells than on others. The different pressures on the hair cells is sent as nervous impulses to the cerebellum of the brain to interpret the angle of the head in relation to the force of gravity.

Hearing defects
- Deafness: Loss of the ability to hear. This may be caused by injury, disease, aging or genetic defects and ranges from partial hearing loss to complete deafness. Hearing aids or cochlea implants can help treat deafness.
- Middle ear infections: Painful infections behind the eardrum that may cause the eardrum to burst. If these infections occur often scar tissue may result, causing loss of hearing.
- Grommets: Small tubes that connect the middle ear with the outer ear to drain fluid freely and prevent fluid in ear infections.
Questions

This unit is examined in Paper 1 for about 40 marks (27%).

Question 1
1. Provide the correct biological term for the following statements:

1.1 The scientific word that describes a nerve cell. ________________________________________________________________________

1.2 The chemicals found in vesicles that transmit an impulse across the synapse. ________________________________________________________________________

1.3 Liquid found in the CNS that circulates nutrients and oxygen. ________________________________________________________________________

1.4 Part of the brain that controls balance. ________________________________________________________________________

1.5 An eye defect which causes the lens to become cloudy. ________________________________________________________________________ [5]

Question 2
2. Study the diagram alongside and answer the questions.

2.1 Identify the neuron shown in the diagram. ________________________________________________________________________ (1)

2.2 Label A, B and C on the diagram. ________________________________________________________________________ (3)

2.3 What is the function of the myelin sheath that covers part C? ________________________________________________________________________ (1)

Question 3
3. Alongside is a section through the human brain. Study the diagram and answer the questions.

3.1 Label parts A and B on the diagram. ________________________________________________________________________ (2)

3.2 Identify the type of section in this diagram. ________________________________________________________________________ (1)

3.3 Which letter (X or Y) represents the front of the brain? _______(1)

3.4 Explain why damage to part labelled B might result in death, even if all other parts of the brain and body are working. ________________________________________________________________________ (4)

Question 4
4. The diagram shows a transverse section of the spinal cord.

4.1 Which letter represents the white matter? ________________________________________________________________________ (1)

4.2 Name the substance present in the central canal. ________________________________________________________________________ (1)
4.3 What is meant by a reflex action?

4.4 On the diagram, draw and label the neurons involved in a simple reflex arc.

Question 5

5. Study the diagram alongside and answer the questions.

*DBE NSC February-March 2012 Supplementary Exam (version 1)*

5.1 Label parts 2 to 5 on the diagram. 

5.2 Name and describe the process that causes part 1 to dilate.

5.3 State how the following defects can be treated to improve vision:

(a) Long-sightedness: 

(b) Astigmatism: 

(c) Cataract: 

(d) Short-sightedness: 

Question 6

6. The diagram alongside shows a cross section through the human ear.

*DBE NSC February-March 2013 Life Sciences Paper 2 (version 1)*

6.1 Identify part:

B: 

C: 

6.2 What does structure A consist of?

6.3 Explain what would happen if structure D had a hole in it.

UNIT 6 Responding to the environment
**Question 7**  
*DBE NSC February-March 2016 Paper 1*

Which ONE of the following represents the CORRECT combination of a visual defect, its nature and the corrective measure? Circle the letter of your answer. [1]

<table>
<thead>
<tr>
<th>VISUAL DEFECT</th>
<th>NATURE OF DEFECT</th>
<th>CORRECTIVE MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Cataracts</td>
<td>Curvature of lens is uneven</td>
<td>Biconcave lenses</td>
</tr>
<tr>
<td>B Short-sightedness</td>
<td>Lens cannot become less convex</td>
<td>Biconcave lenses</td>
</tr>
<tr>
<td>C Astigmatism</td>
<td>Lens cannot become more convex</td>
<td>Surgery</td>
</tr>
<tr>
<td>D Long-sightedness</td>
<td>Lens becomes cloudy and opaque</td>
<td>Biconvex lenses</td>
</tr>
</tbody>
</table>

**Question 8**  
*DBE NSC February-March 2016 Paper 1*

The diagram below shows a reflex arc.

8.1 Give ONLY the LETTER of the part that represents the:

(a) Effector ________ (1)
(b) Interneuron/Connector neuron ________ (1)
(c) Sensory neuron ________ (1)

8.2 Give the LETTER and NAME of the neuron in the diagram that is probably damaged if a person is able to detect the stimulus, but cannot respond. (2)

8.3 State if the nerve impulse travels from D to E or from E to D. ____________________________ (1)
Question 9

DBE NSC February-March 2016 Paper 1

The diagram alongside represents a part of a human ear.

9.1 Identify part:
   (a) A ______________________________ (1)
   (b) D ______________________________ (1)

9.2 Name the receptors that are found in part B.
   ____________________________________ (1)

9.3 Explain the consequence to the human body if:
   (a) Part C is damaged.
   ____________________________________ (2)
   (b) Part A becomes hardened.
   ____________________________________ (2)

9.4 Explain why people with middle-ear infections are usually advised not to travel by aeroplane.
   ____________________________________
   ____________________________________

Question 10

DBE NSC November 2015 Paper 1

Each diagram alongside represents parts of the human eye.

10.1 Give the LETTER and NAME of the part that:
   (a) Contracts to change the shape of the lens.
       ______________________________ (2)
   (b) Controls the amount of light that enters the eye.
       ______________________________ (2)
   (c) Is protected by the conjunctiva.
       ______________________________ (2)

10.2 Study diagram 1 and diagram 2. What process is responsible for the change in the shape of the part E? _____ (1)

10.3 Which diagram (1 or 2) represents the state of the eye when a person is reading a book? ___________ (1)
**Answers**

**Question 1**
1.1 Neuron ✓
1.2 Neurotransmitters ✓
1.3 Cerebrospinal fluid ✓
1.4 Cerebellum ✓
1.5 Cataract ✓

(b) Astigmatism: prescribed glasses or contact lenses that are specific to individual’s uneven curve on the retina. ✓
(c) Cataract: surgery to remove cloudy lens and replace it with a plastic lens. ✓
(d) Short-sightedness: glasses/contact lenses can be worn which have concave lenses; and/or surgery. ✓

**Question 2**
2.1 Motor neuron ✓
2.2 A – nucleus/cell body ✓
   B – dendrites ✓
   C – axon ✓
2.3 Insulates/protects the axon for efficient conduction of nerve impulse. ✓

**Question 3**
3.1 A – cerebrum ✓
   B – medulla oblongata ✓
3.2 Longitudinal section ✓
3.3 Y ✓
3.4 B is the medulla oblongata which controls vital reflexes ✓ like breathing ✓, heart rate ✓ and blood pressure. ✓

**Question 4**
4.1 X ✓
4.2 Cerebrospinal fluid ✓
4.3 A fast involuntary response ✓
4.4 ✓ Drawing the neurons:

interneuron ✓
sensory neuron ✓

motor neuron ✓

**Question 5**
5.1 2 – cornea ✓
   3 – lens ✓
   4 – suspensory ligaments ✓
   5 – ciliary body ✓
5.2 Pupil Reflex/Pupillary mechanism. ✓
   In dim light ✓ the radial muscles of the iris contract ✓ and circular muscles of the iris relax, ✓ which causes the pupil to dilate/get ✓ bigger, allowing more light to enter the eye. ✓
5.3 (a) Long-sightedness: glasses/contact lenses can be worn, which have convex lenses; and/or surgery. ✓

(b) Astigmatism: prescribed glasses or contact lenses that are specific to individual’s uneven curve on the retina. ✓
(c) Cataract: surgery to remove cloudy lens and replace it with a plastic lens. ✓
(d) Short-sightedness: glasses/contact lenses can be worn which have concave lenses; and/or surgery. ✓

**Question 6**
6.1 B: semi-circular canals ✓
   C: Eustachian tube ✓
6.2 Bone tissue ✓
6.3 D would not vibrate ✓ accurately to transmit sound waves to the ossicles ✓; loss of hearing can result. ✓

**Question 7**
B

**Question 8**
8.1 (a) E ✓
   (b) A ✓
   (c) C ✓
8.2 F ✓ motor neuron ✓
8.3 D to E ✓

**Question 9**
9.1 (a) Round window ✓
   (b) Cochlea ✓
9.2 Cristae ✓
9.3 (a) - Impulses from the cochlea cannot be transmitted to the brain ✓
   - and therefore hearing will not occur ✓
   (b) - Part A will not be able to vibrate ✓
   - The round window will not absorb the sound waves ✓ from the cochlea
   - and hearing will be affected ✓ (any 2) ✓
9.4 - Mucus in the middle ear ✓
   - will lead to the blockage of the Eustachian tube ✓
   - which will not be able to equalise the pressure ✓ in the middle ear
   - resulting in pressure on the tympanic membrane ✓
   - that may cause the tympanic membrane to burst ✓
   leading to hearing loss ✓ (any 4) ✓

**Question 10**
10.1 (a) A ✓ ciliary muscle ✓
    (b) C ✓ iris ✓
    (c) D ✓ cornea ✓
10.2 Accommodation ✓
10.3 Diagram 2 ✓
Unit 7 Human endocrine system: chemical co-ordination

The endocrine system is a communication system using chemical messengers called hormones. Hormones are protein molecules that bring about slow responses. The nervous system brings about rapid responses. The endocrine and nervous systems work together to bring about the smooth co-ordination of all the systems in the human body.

Endocrine glands

Endocrine glands do not have ducts (ductless glands). Hormones are secreted directly into the blood, which transports them throughout the body. Hormones affect certain target cells only, by changing the cells' activities.

Exocrine glands are glands that convey their secretions via ducts, e.g. salivary glands.

Differences between the endocrine and nervous systems

<table>
<thead>
<tr>
<th>Endocrine system</th>
<th>Nervous system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical messengers</td>
<td>Electro-chemical impulses</td>
</tr>
<tr>
<td>Chemical is transported in the blood stream around the body</td>
<td>Impulse is transmitted along a nerve fibre</td>
</tr>
<tr>
<td>Stimulates target organs</td>
<td>Stimulates a particular organ</td>
</tr>
<tr>
<td>The response is brought about by the target organ</td>
<td>The response is brought about by the effector organ</td>
</tr>
<tr>
<td>Slow and long term response</td>
<td>Rapid and short-term response</td>
</tr>
</tbody>
</table>

Differences between endocrine and nervous systems

Diagram that shows the location of the main endocrine organs in the body
<table>
<thead>
<tr>
<th>Endocrine gland</th>
<th>Location</th>
<th>Hormone</th>
<th>Target organ</th>
<th>Function of hormone</th>
<th>Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothalamus</td>
<td>Small region at the base of the brain</td>
<td>ADH</td>
<td>ADH travels to the posterior pituitary gland and then into the blood to the collecting ducts of the kidney.</td>
<td>ADH makes the walls of the collecting ducts more permeable, allowing water to be drawn back into the blood so that it does not pass out with the urine. The urine will be concentrated and dark in colour. This conserves water.</td>
<td>Not required</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td>At the base of the brain attached to the hypothalamus. It is controlled by the hypothalamus.</td>
<td>TSH</td>
<td>Thyroid gland at the base of the neck</td>
<td>Keeps the level of thyroxin in the blood constant.</td>
<td>Not required</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td>Master gland, as it controls the activities of a number of other endocrine glands.</td>
<td>FSH</td>
<td>Females: Ovaries</td>
<td>Stimulates the ovaries to produce eggs (ova) and to produce oestrogen. Stimulates the testes to make sperm.</td>
<td>Not required</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td></td>
<td>LH</td>
<td>Females: Ovaries</td>
<td>Stimulates the ovaries to produce progesterone. Causes the follicle to burst releasing the ovum (ovulation). Stimulates testes to produce testosterone.</td>
<td>Not required</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td></td>
<td>Progesterone</td>
<td>Males: Testes</td>
<td>Causes this tissue to produce milk in females only. Released after birth of a baby.</td>
<td>Not required</td>
</tr>
<tr>
<td>Pituitary gland</td>
<td></td>
<td>GH</td>
<td>Has an effect on many organs</td>
<td>Has a strong effect on the growth of liver, muscles, bone and cartilage. Overall growth.</td>
<td>Childhood: Dwarfism - too little GH Gigantism - too much GH Adult: Acromegaly - too much GH Large cheekbones and eyebrow ridges, enlarged hands</td>
</tr>
<tr>
<td>Endocrine gland</td>
<td>Location</td>
<td>Hormone</td>
<td>Target organ</td>
<td>Function of hormone</td>
<td>Disorders</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>At the base of the neck across the trachea and below the larynx.</td>
<td>Thyroxin</td>
<td>All cells in the body, except for brain cells and parts of the reproductive organs</td>
<td>Stimulates enzymes used in cellular respiration. Raises the speed of cellular respiration to release energy more rapidly. The metabolic rate is increased. Important in controlling: Body temperature - higher metabolic rate increases the amount of heat released. Blood pressure - raised metabolic rate in the heart and blood vessels affects the blood pressure. Normal development of skeleton, nerves, and reproductive organs.</td>
<td>Hypothyroidism - production of too little thyroxin. Hyperthyroidism - production of too much thyroxin.</td>
</tr>
<tr>
<td>Endocrine gland</td>
<td>Location</td>
<td>Hormone</td>
<td>Target organ</td>
<td>Function of hormone</td>
<td>Disorders</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>---------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------</td>
</tr>
</tbody>
</table>
| Pancreas        | Just below the stomach in the curve of the duodenum | **Insulin** secreted by beta cells | Glucose in the blood | Insulin reduces the amount of glucose in the blood by:  
  - Stimulating the membranes of cells to transport glucose into the cells  
  - Excess glucose to be changed into the storage glycogen that is stored in the liver and muscles  
  - Changes excess glucose into fat that is stored as adipose tissue if the body is unable to make more glycogen. | **Hypoglycaemia** – blood glucose drops below the normal level (60 – 110mg per 100ml of blood, about 1% of the blood). Movements become slow and the arms and legs feel weak; mental function is reduced and the person becomes pale and sweaty. **Hyperglycaemia** – blood glucose level rises above the normal level. Severe damage to the kidneys, eyes, nervous system and the heart. |
| Adrenal         | Above the kidneys | **Glucagon** secreted by alpha cells | Glycogen in cells | To raise the glucose level in the blood by:  
  - Stimulating the breakdown of glycogen into glucose in the liver  
  - Stimulating the liver cells to release glucose into the blood. | **Diabetes mellitus** – the Islets of Langerhans malfunction and are unable to control the glucose level in the blood. Symptoms are excessive thirst, fatigue, frequent urination, increased appetite, nausea, weight loss, vomiting and blurred vision. |
|                 |          | **Adrenalin** |              | Helps the nervous system prepare the body for an emergency.  
  'Fight or flight' response. (Either fight the enemy or run away from it). | Helps control blood circulation and carbohydrate metabolism.  
  - Increases the rate and depth of breathing  
  - Liver converts more glycogen into glucose  
  - Pupil in the eyes dilate  
  - The heart beat increases  
  - Digestion slows down  
  - Blood vessels to all non-vital organs constrict  
  - Blood vessels to vital organs dilate. | Not required |
<table>
<thead>
<tr>
<th>Endocrine gland</th>
<th>Location</th>
<th>Hormone</th>
<th>Target organ</th>
<th>Function of hormone</th>
<th>Disorders</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldosterone</td>
<td>Kidney distal tubules and collecting ducts</td>
<td>Controls the concentration of sodium ions in the body. Too much sodium in the blood - water moves too quickly by osmosis from the distal tubules and collecting ducts into the blood. This results in a higher volume of water in the blood and blood pressure increases.</td>
<td>Not required</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gonads</td>
<td>Lower abdomen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Female: Ovary   | Endometrium of uterus | Causes the secondary sexual characteristics to develop at puberty
Promotes repair and growth of endometrium
Causes the oocytes in the ovaries to mature
Affects calcium uptake and bone density
Lowers cholesterol in the blood | Not required                                                                                               |             |
| Corpus luteum in the ovary | Uterus Mammary glands | Maintains the endometrium during pregnancy
Together with prolactin prepares the breasts for the production of milk | Not required                                                                                               |             |
| Male: Testicles | Testosterone | Causes the male sex organs to mature
Causes the appearance of the secondary sex characteristics to appear at puberty
Keeps the male sex organs functioning correctly | Not required                                                                                               |             |
Negative feedback mechanism

A feedback mechanism is a system that controls the amount of hormone that is released. If there is too much, the amount needs to be reduced. If there is too little of the hormone, it needs to be increased. The feedback brings about the opposite effect, in other words, a negative feedback.

Flow diagram summarising a negative feedback mechanism

Two examples of negative feedback mechanisms

1. TSH and thyroxin

Thyroid stimulating hormone is secreted by the anterior lobe of the pituitary. TSH controls the amount of thyroxin produced by the thyroid gland. The amount of thyroxin in the blood is detected by the hypothalamus. If the level of the amount of thyroxin drops then there is an increase in the secretion of TSH:

- This stimulates the thyroid to secrete more thyroxin.
- The amount of thyroxin will increase.
- The hypothalamus detects this increase and will then secrete less TSH.
- This brings the level of thyroxin down.

Negative feedback involving TSH and thyroxin
2. **Insulin and glucagon**

These two hormones control the glucose concentration in the blood:

![Diagram showing a summary of the feedback mechanisms involving the anterior pituitary gland](image)

**Negative feedback involving insulin and glucagon**

Below is a diagram showing a summary of the feedback mechanisms involving the anterior pituitary gland:
Question 3

**DBE NSC 2014 Exemplar Paper 1**

The diagram alongside represents the interaction between two important endocrine glands. The gland labelled A is found at the base of the brain. The gland labelled C is present towards the front of the neck.

3.1 Give a label for gland A. ____________________________ (1)

3.2 Name hormone B. ____________________________ (1)

3.3 State TWO functions of hormone D. ____________ (2)

3.4 Describe the negative feedback mechanism that operates when the level of hormone D is higher than normal in the blood.  (5)

Question 4

**DBE NSC 2013 November Paper 2**

Diabetes mellitus is usually linked to the body mass index (BMI), which is calculated as follows: 

\[ \text{BMI} = \frac{\text{mass (kg)}}{\text{Height (m)}^2} \]

An investigation was done to determine the relative risk of developing diabetes mellitus in females for each BMI. The results are shown in the table alongside:

<table>
<thead>
<tr>
<th>Body mass index (BMI) (kg/m(^2))</th>
<th>Relative risk of developing diabetes mellitus in females (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20</td>
<td>7,5</td>
</tr>
<tr>
<td>20–25</td>
<td>18,0</td>
</tr>
<tr>
<td>26–30</td>
<td>37,5</td>
</tr>
<tr>
<td>31–35</td>
<td>57,0</td>
</tr>
<tr>
<td>&gt;35</td>
<td>74,5</td>
</tr>
</tbody>
</table>

[Adapted from American Diabetics Association, March 2007]

4.1 Draw a histogram using data in the table above. (6)
4.2 Name the hormone that results in diabetes mellitus when it is deficient. (1)

4.3 Name the organ that secretes the hormone mentioned in Question 4.2. (1)

4.4 State TWO other hormones (except the one mentioned in Question 4.2) that influence the glucose level of the blood. (2)

Question 5
DBE NSC 2012 November Paper 2
The nervous system and endocrine system help to protect the human body. Use suitable examples to describe how this is achieved through a reflex action and by the hormone adrenalin. Use your own paper to answer the question.

Note: NO marks will be awarded for answers in the form of flow charts or diagrams.

Question 6
DBE NSC February/March 2016 Paper 1
Some people with Type I Diabetes cannot produce insulin and therefore need to inject themselves regularly (insulin-dependent).

An investigation was done to determine the action of two types of insulin (A and B). The glucose uptake rate of cells, when using each type of insulin, was measured over time.

![Graph of Glucose uptake under the influence of Insulin A and Insulin B in 24 hours]

6.1 Name the human organ that produces insulin. _______________________________ (1)

6.2 Using the information in the graph, state TWO differences in the functioning of insulin A and B. (4)
Question 7

DBE NSC November 2015 Paper 1

7.1 Describe how the human body restores the carbon dioxide concentration in the blood when it rises above normal levels.

7.2 An investigation was conducted to compare the glucose concentration in the blood of two people, Mo and Thabiso, before and after ingesting glucose.

The following procedure was followed:

- The glucose concentration in their blood was measured at the start of the investigation and again 1 hour into the investigation.
- One hour into the investigation each of them was given 50 mL of a glucose solution to drink.
- For the next four hours after ingesting the glucose solution the glucose concentration in their blood was measured every 30 minutes.

The results are shown in the graph below. The arrows indicate when they drank the glucose solution.

NOTE: The normal glucose concentration in blood is between 80 and 120 mg/100 cm$^3$.

(a) Provide a suitable title for this graph.

(b) By how much did Thabiso's blood glucose concentration level increase (in mg/100 cm$^3$) after drinking the glucose solution? Show ALL working.
(c) How long did it take Mo’s blood glucose concentration level to return to its original level after ingesting the glucose solution? (1)

(d) (i) Who (Thabiso or Mo) has diabetes mellitus? (1)
(ii) Give ONE observable reason for your answer to Question 7.2(d)(i). (1)

(e) Explain the changes in Mo’s glucose level during period X. (4)

Answers

Question 1
For answers to this question, please see relevant pages in the Study Guide.

Question 2

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>c</td>
<td>2.5</td>
</tr>
<tr>
<td>2.2</td>
<td>d</td>
<td>2.6</td>
</tr>
<tr>
<td>2.3</td>
<td>a</td>
<td>2.7</td>
</tr>
<tr>
<td>2.4</td>
<td>b</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Question 3

**DBE NSC 2014 Exemplar Paper 1**

3.1 A - pituitary gland/hypophysis✓ (1)
3.2 B - TSH/thyroid-stimulating hormone✓ (1)
3.3 Controls metabolism✓
   - Influences heart rate✓
   - Influences functioning of central nervous system✓ (any 2) (2)
3.4 Higher levels of thyroxin is detected by the hypophysis✓
   - Which leads to decrease✓
   - In the secretion of TSH✓
   - Activity of thyroid is slowed down / less thyroxin produced✓
   - Thyroxin level drops to normal✓ (5)

**DBE NSC 2013 November Paper 2**

4.1

![Graph showing relative risk of developing diabetes mellitus in females of different BMI ranges]

Relative risk of developing diabetes mellitus in females of different Body Mass Index (BMI) ranges

- Relative risk increases with higher BMI.
- Highest risk is in the BMI range of 31-35.
- Lowest risk is in the BMI range of <20.

T ✓
(c) How long did it take Mo's blood glucose concentration level to return to its original level after ingesting the glucose solution? (1)

(d) (i) Who (Thabiso or Mo) has diabetes mellitus? (1)
(ii) Give ONE observable reason for your answer to Question 7.2(d)(i). (1)

(e) Explain the changes in Mo's glucose level during period X. (4)

Answers

Question 1
For answers to this question, please see relevant pages in the Study Guide.

Question 2

<table>
<thead>
<tr>
<th>2.1</th>
<th>c</th>
<th>2.5</th>
<th>d</th>
</tr>
</thead>
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<td>2.2</td>
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</tr>
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<td>a</td>
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<td>c</td>
</tr>
</tbody>
</table>

Question 3

DBE NSC 2014 Exemplar Paper 1
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3.2 B - TSH/thyroid-stimulating hormone✓ (1)
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   Which leads to decrease✓
   In the secretion of TSH✓
   Activity of thyroid is slowed down / less thyroxin produced✓
   Thyroxin level drops to normal✓ (5)

Question 4

DBE NSC 2013 November Paper 2
4.1

Relative risk of developing diabetes mellitus in females of different Body Mass Index (BMI) ranges

- Relative risk of developing diabetes mellitus in females
- Body mass index (kg/m²)
- T ✓
- Relative risk: 7.5, 18.0, 37.5, 57.0, 74.5

Relative risk of developing diabetes mellitus in females of different Body Mass Index (BMI) ranges

- Relative risk: 7.5, 18.0, 37.5, 57.0, 74.5

ACE IT! Life Sciences Grade 78
Checklist for the mark allocation of the graph

| Correct type of graph T Histogram therefore the bars are next to each other | 1 |
| Title of graph | 1 |
| Correct label, appropriate scale for X-axis and width of the bars for X-axis (including unit) | 1 |
| Correct label and appropriate scale for Y-axis (including unit) | 1 |
| Plotting of bars | 1 mark = 1 to 4 bars plotted correctly 2 marks = all 5 bars plotted correctly |

NOTE: If the wrong type of graph is drawn: Marks will be lost for 'correct type of graph'
If axes are transposed: Marks will be lost for labelling of X-axis and Y-axis
Marks will be lost for plotting bars

4.2 Insulin✓ (1) 4.3 Pancreas✓ (1) 4.4 Glucagon✓ adrenalin✓ thyroxin✓ (Mark the first two) (any 2) (2) [10]

**Question 5**

**Mechanism of reflex action**

*Example: withdrawal of hand after being pricked by a pin✓/from hot surface✓ (any other suitable example) (1)*
- Receptors in the skin✓
- receive the stimulus✓
- Stimulus is converted into a nerve impulse✓
- The impulse travels along the sensory neuron✓
- towards the spinal cord✓
- along the dorsal root✓ of the spinal nerve✓
- In the spinal cord, the sensory neuron makes synaptic contact✓
- with the connector✓/interneuron
- and then the impulses are transmitted along the motor neuron✓
- along the ventral root✓ of the spinal nerve
- to the effector organ✓/muscle
- which contracts✓ and pulls the hand away✓
- The reflex action provides a quick response to the stimulus so injury is minimised✓ (max 10)

**Action of adrenalin**

*Example: chased by a ferocious dog✓/ (any other suitable example) (1)*
- Adrenalin prepares the body to cope with the emergency, danger and stress in the following ways:
  - Brain becomes aware of danger✓/emergency situation
  - through impulses from the sense organs✓
  - Adrenal gland✓ is stimulated to secrete adrenalin
  - Messages are then sent to various parts of the body✓
    (blood vessels, heart✓)
  - Rate and depth of breathing increases✓
  - The conversion of glycogen to glucose is promoted✓ in the liver
  - Vital organs receive more blood✓/oxygen/glucose
  - to raise metabolic activities of cells✓ to release more energy
  - muscle tone increases✓
  - pupils dilate✓
  - to allow a rapid response✓ to ensure safety (max 5) [20]

**Question 6**

6.1 Pancreas✓ (1)

6.2

<table>
<thead>
<tr>
<th>Insulin A</th>
<th>Insulin B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glucose uptake peaks at a higher level✓/around 7 mg/kg/min ✓</td>
<td>Glucose uptake peaks at lower level✓/around 1 mg/kg/min</td>
</tr>
<tr>
<td>All glucose uptake occurs in a short period of time✓/the first 5 hours ✓</td>
<td>Glucose uptake is gradual✓/sustained over a period of 24 hours</td>
</tr>
<tr>
<td>The initial uptake of glucose rises rapidly to a maximum within the first few hours✓</td>
<td>The initial uptake of glucose rises slowly to the maximum over 5 hours✓</td>
</tr>
</tbody>
</table>

**TABULATION IS NOT REQUIRED**

(Mark first TWO only) [5]

UNIT 7 Human endocrine system – chemical co-ordination 79
Question 7

7.1 - Receptor cells /
in the carotid artery/aorta are stimulated
- to send impulses to the medulla oblongata in
the brain
- which then stimulates the heart /
- to beat faster /
- and the breathing muscles /example
- to contract more actively /
- This increases the rate/depth of
breathing /
- More CO₂ is taken to and exhaled from the
lungs/returning the CO₂ level in the blood to
normal

7.2 (a) Comparison of the blood glucose level of
two people over 5 hours before and after
ingesting glucose
(b) (145–125) / (Accept numbers in range 144–146
for the first value and 124–126 for the second
value) = 20 / mg/100 cm³
(2)
(Accept answer according to the values given by
learner)
(c) Accept any answer from 1.7 to 1.9 hours /102
- 114 minutes/1h42 min – 1h54 min
(d) (i) Thabiso /
(ii) - His glucose level is higher than the
normal range /
- It takes longer for his glucose level
to come down to its original level /
(1)
(MARK FIRST ONE ONLY)
(e) - When his glucose level is high /
99/98mg/100cm³
- insulin is secreted into the blood
- to convert excess glucose into glycogen in
the liver
- and to stimulate the cells to absorb more
glucose /
- thus decreasing the blood glucose level /
(1)
(1)
Unit 8  Homeostasis in humans

What is homeostasis?

Homeostasis is the process of maintaining a constant, optimal, internal environment for each cell, despite changes in the external and internal environment.

Negative feedback

To maintain a constant, optimal, internal environment there have to be regulatory processes; processes that can regulate the tissue fluid around each cell to keep the surrounding tissue fluid stable. This ensures that the environment of each cell is optimal for the organism to function at its best.

An example, using thyroxin, of a negative feedback mechanism is shown below:

Some of the factors that need to be kept constant are:
- Nutrients e.g. glucose
- Carbon dioxide
- Water
- Salts (minerals) e.g. sodium
- Temperature
- Others – hormones, excretory wastes and pH

Nutrients e.g. glucose

It is important to keep the level of glucose in and around the cell at a constant level. If there is too much glucose around the cell then water will be drawn out of the cell by osmosis and the cell will become dehydrated. It is therefore necessary to get rid of or store excess glucose. This is carried out by converting the excess glucose in a cell into glycogen. This balancing of the glucose level is carried out by means of two hormones, namely, insulin and glucagon.

<table>
<thead>
<tr>
<th>Hormone</th>
<th>Origin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulin</td>
<td>Beta cells of Islets of Langerhans in the pancreas</td>
<td>Reduces the level of blood glucose by converting it into glycogen (storage form).</td>
</tr>
<tr>
<td>Glucagon</td>
<td>Alpha cells of Islets of Langerhans in the pancreas</td>
<td>Increases the level of blood glucose by converting stored glycogen to soluble and usable glucose.</td>
</tr>
</tbody>
</table>

Summary of functions of insulin and glucagon
Complete the following flow diagram by writing in the missing word/s.

Flow diagram of the homeostasis of glucose

The homeostatic control of glucose is a negative feedback mechanism because:
- When the blood glucose level decreases there is a series of events that ensures that the level is increased
- When the blood glucose level increases there is a series of events that ensures that the level is decreased.

**Wastes e.g. carbon dioxide**

Too much carbon dioxide is poisonous to cells; therefore excess carbon dioxide needs to be removed. Carbon dioxide is carried as bicarbonate ions dissolved in the blood plasma, making it acidic. The breathing centre in the medulla oblongata is sensitive to the pH of the blood.
The homeostatic control of carbon dioxide is a negative feedback mechanism because:

- A decrease in carbon dioxide causes a series of events, such as shallower breathing, to increase the amount of carbon dioxide in the blood.
- An increase in the amount of carbon dioxide in the blood causes a series of events, such as deeper breathing, to decrease the carbon dioxide in the blood.

**Water**

**Osmoregulation** is the homeostatic control of water in the blood.

A hormone called ADH (anti-diuretic hormone) controls osmoregulation in kidneys.

If there is too much water in the blood, in other words the blood plasma is too dilute, the hypothalamus detects this change and secretes less ADH. The collecting ducts of the kidney tubules become less permeable to water and more water remains in the kidney filtrate, making the urine more dilute. The water content in the blood returns to normal.

If there is too little water in the blood, in other words the plasma is too concentrated, the hypothalamus detects this and secretes more ADH. This makes the collecting ducts of the kidney tubules more permeable and more water is drawn back into the blood from the kidney filtrate. The urine becomes less dilute, i.e. more concentrated. The amount of water in the blood plasma returns to normal.

![Flow diagram to show the homeostasis of water](image)

The homeostatic control of water is a negative feedback mechanism because:

- When there is an increase in the water in the blood, a process is put into place to reduce the amount of water in the blood.
- When there is a decrease in the water in the blood, a process is put into place to increase the amount of water in the blood.
The homeostatic control of carbon dioxide is a negative feedback mechanism because:

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- An increase in the amount of carbon dioxide in the blood causes a series of events, such as deeper breathing, to decrease the carbon dioxide in the blood.

Water

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If there is too little water in the blood, in other words the plasma is too concentrated, the hypothalamus detects this and secretes more ADH. This makes the collecting ducts of the kidney tubules more permeable and more water is drawn back into the blood from the kidney filtrate. The urine becomes less dilute, i.e. more concentrated. The amount of water in the blood plasma returns to normal.

The homeostatic control of water is a negative feedback mechanism because:

- When there is an increase in the water in the blood, a process is put into place to reduce the amount of water in the blood.
- When there is a decrease in the water in the blood, a process is put into place to increase the amount of water in the blood.
Salts (Minerals)

It is important for the body to maintain a constant level of salts as this affects the water content of the blood plasma and tissue fluid. The saltier a fluid is, the more water will be drawn into it. Aldosterone is the hormone used to maintain the level of salt in fluids in the body.

![Flow diagram showing the homeostatic control of sodium in the blood](image)

The homeostatic control of salts, e.g. sodium, is a negative feedback mechanism because:
- When there is too much sodium in the blood then a process is put into place to reduce the sodium content of the blood.
- When there is too little sodium in the blood then a process is put into place to increase the sodium content of the blood.

Temperature: Thermoregulation

The control of body temperature is called thermoregulation. It is important to maintain a constant internal body temperature, no matter what the external temperature is. The best body temperature for humans is 37°C. For example, enzymes work best at a temperature of 37°C.

Humans are endotherms:
- The body is able to make its own heat through metabolism, especially by the liver and brain.
- The body must balance the heat it generates with the heat lost to the surrounding air.
- Heat is lost to the air by the skin.
- The body produces heat all the time therefore the only aspect that can be controlled is the loss of heat by the skin.
The human skin

The structure of the human skin

dermis – contains and supports many structures: sweat glands, nerves, blood vessels. Mostly consists of connective tissue in two layers.

germinal epithelium – a row of cells that continually undergo mitosis, pushing older cells towards the outer surface.

fat cells – adipose tissue. Insulation keeps cold out and heat in. Also protection and padding.

blood capillary – vasoconstriction and vasodilation for thermoregulation.

epidermis – outer layer of the skin. Lower layers contain specialised melanocyte cells which contain melanin. This gives the skin colour. Melanin absorbs harmful UV rays.

sweat pore – through which sweat is released on the surface of the skin.

erector muscle of hair – contracts to pull hair upwards when cold. Relaxes to make hair lie flat when hot.

structures found in the epidermis:

- sebaceous gland – produces sebum which keeps skin and hair supple and waterproof.
- hair follicle – produce hairs for insulation against the loss of heat.
- sweat gland in dermis – produces sweat which is released on the surface of the skin through the sweat pores. Sweat cools the body.
- nails – protective coverings on tips of fingers and toes. Made of keratin. (not shown on diagram)

Annotated diagram to show the structure of a cross-section of skin

QUICK QUIZ
Below is a micrograph of a section of skin. Write labels next to each label line:

Micrograph showing a section of skin
Functions of the skin

- **Protection:**
  - The first line of defence to prevent infection – barrier to harmful organisms.
  - Reduces water loss.
  - Melanin absorbs harmful UV rays from the sun.

- **Sensitivity:**
  - Many tiny receptors respond to sensations of heat, cold, touch, pressure and pain.
  - Receptors send impulses to the brain and we interpret these and respond to the changes in our environment.

- **Thermoregulation:**
  - Maintains a constant internal temperature.

Adaptations of the human skin for thermoregulation

The human body temperature varies from 36.1 °C and 37.8 °C. A body temperature above 40 °C and below 34 °C can be harmful if it lasts for a long time. It is important for the body to keep a balance between heat loss and heat gain.

**Loss of heat from the body (cooling)**

Heat is lost from the body by evaporation, radiation, conduction and convection.

If the amount of heat that is lost from the body is greater than it is producing, then the body will cool down too much. The hypothalamus detects this decrease in the temperature of the blood and sets about conserving heat by doing the following:

- **Vasoconstriction:** The blood vessels in the dermis of the skin constrict, bringing less warm blood to the surface of the body. In this way less heat is lost to the surrounding air by conduction, convection and radiation.

- **Sweating is stopped:** There is no sweat to evaporate from the surface of the skin. This reduces the loss of heat.

- **Shivering:** If the above two measures do not conserve enough heat, then shivering occurs. Shivering occurs when cellular respiration takes place in the muscles involuntarily producing some heat to warm the body.

- **Hairs stand erect:** The hair erector muscles contract, causing the hairs to stand erect. This can cause goose bumps. Air is trapped between the erect hairs, forming a layer of insulation.
Heating of the body
Heat is gained by the body from cellular respiration and from the environment. If it is warmer than 37 °C. If the body produces more heat than it can lose then the body will get too hot. The hypothalamus detects this increase in the temperature of the blood and brings about processes to lose more heat by doing the following:

- **Vasodilation**: The blood vessels in the dermis of the skin dilate and bring more warm blood to the surface of the skin. The skin becomes warmer. The excess warmth is lost to the surrounding air by conduction, convection and radiation.
- **Sweating increases**: More sweat is released and this increases the rate of cooling of the skin by evaporation. As the sweat evaporates into a gas the surface of the skin cools. This will cool the warm blood flowing in the dermis of the skin.
- **Hairs lie flat**: The hair erector muscles relax causing the hairs to lie flat against the surface of the skin. There is no layer of air to insulate the body. This allows warmth to be lost to the surrounding air.
- **Shivering**: No shivering occurs.

The table below summarises thermoregulation by the skin. In each box write in more details from the information above.

<table>
<thead>
<tr>
<th></th>
<th>Heating of the body</th>
<th>Cooling of the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood vessels</td>
<td>Vasoconstriction</td>
<td>Vasodilation</td>
</tr>
<tr>
<td>Sweating</td>
<td>Stops</td>
<td>Increases</td>
</tr>
<tr>
<td>Hairs</td>
<td>Stand erect</td>
<td>Lie flat</td>
</tr>
<tr>
<td>Shivering</td>
<td>Starts</td>
<td>None</td>
</tr>
</tbody>
</table>

Summary of adaptations of the skin for thermoregulation

Below is a flow diagram summarising thermoregulation by the skin:

Flow diagram to show the homeostatic control of body temperature
Here is another summary of thermoregulation:

**My Own Notes**

---

ACE IT! Life Sciences Grade
Questions

This unit is examined in Paper 1 for about 11 marks (7%).

Question 1

DBE NSC 2014 Exemplar Paper 1

The following are effects of the secretion of different hormones:

1. An increase in the blood glucose level.
2. An increase in the heart rate.
3. An increase in the amount of digestive enzymes.
4. An increase in blood flow to the skeletal muscles.

Which ONE of the following combinations of the above effects is due to adrenalin? Circle the correct answer.

A 1, 3 and 4
B 2, 3 and 4
C 1, 2 and 4
D 1, 2, 3 and 4

Question 2

DBE NSC 2013 February/March Paper 2

2.1 Using the flow diagram above, explain the feedback mechanism in the interaction between the pituitary and thyroid gland.

2.2 If a person is not obtaining enough iodine in his/her diet, what changes would you expect in a person's metabolism?
Question 3

Below is an annotated diagram showing thermoregulation by the skin.

3.1 Use your own knowledge and information from the diagram above to explain how the skin assists in maintaining an average internal temperature of 37°C (normal temperature). Write no more than a page. (16)
3.2 Why is it so important to keep a constant internal temperature? In your answer include reasons in the explanation. (4)
Question 4

4.1 Label the following diagram and next to each label write down the function of the labelled structure. Use the following labels:
epidermis, dermis, adipose tissue, sweat pore, sweat duct, sweat gland, hair, hair follicle, sebaceous gland, erector muscle of hair, capillary loop

4.2 Name the layer in the epidermis that undergoes mitosis. _________________________________

4.3 Explain why the skin has so many nerve endings in it.

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
Name and state the functions of FOUR hormones secreted by the pituitary gland in humans. Describe how the pituitary gland controls the functioning of the thyroid gland using negative feedback.

Note: NO marks will be awarded for answers in the form of flow charts or diagrams.
Answers

Question 1
The answer is: C  [1]

Question 2
2.1 The pituitary✓ is sensitive to the concentration of the hormone, thyroxin✓ in the blood✓
When the thyroxin concentration in the blood decreases✓ below the normal level:
- The pituitary is stimulated to secrete more TSH✓
- TSH stimulates✓
- the thyroid gland
- to secrete more thyroxin✓
- Thus increasing the level of thyroxin✓
- in the blood to normal levels

When the thyroxin concentration in the blood increases✓ above the normal level:
- The pituitary is not stimulated to secrete TSH✓
- There is less stimulation of the thyroid gland to secrete thyroxin✓
- Thus decreasing the level of thyroxin✓ in the blood to normal levels  [max 8]  (8)

2.2 Hypothyroidism✓
Hypothyroidism causes a decrease in rate of metabolism✓ resulting in:
WF
- Weight gain✓
- Decrease in heart rate✓
- Slow growth of hair and fingernails✓  [4]  [12]

Question 3
3.1 See the notes on 'Cooling of the body and heating of the body'  [16]

3.2 Important to keep a constant internal temperature of 37°C as this temperature is the optimum temperature✓ for the functioning of enzymes✓
Enzymes catalyse, control and speed up chemical reactions✓
If enzymes are not able to function then many chemical reactions will not be able to take place✓  [4]  [20]

Question 4
4.1 See notenook for correct labels  [7]
4.2 germinal epithelium✓  [1]
4.3 The skin is the outermost covering of the body✓
Therefore it plays a protective role✓
The many nerve endings are present to pick up any stimuli/sensations on the skin✓
The stimulus will be relayed to the CNS✓ by the nerves
The central nervous system will bring about an appropriate response✓  [max 4]  [5]

Question 5
Possible answer

Hypothalamus
- The change in temperature is detected✓ by the thermo-receptors✓ in the skin
- Stimulus converted to nerve impulse✓
- Transmitted to the hypothalamus✓
- Hypothalamus sends impulses to the muscle layer in the arterioles✓ of the skin (Max 3)
- On a cold day the arterioles close to the surface constrict✓/vasoconstriction occurs
- Less blood✓ flows to capillaries close to the surface
- Sweat production decreases✓ / less sweat is lost
- less heat is radiated from the body✓/less heat is lost (4)
- On a hot day the arterioles close to the surface dilate✓/vasodilation occurs
- More blood✓ flows to the capillaries close to the surface
- Sweat production increases✓ / more sweat is lost
- More heat is radiated✓ from the body/more heat is lost (4)

Adrenal gland
-Secretes adrenalin✓
- Hormone that prepares the body to cope with emergency✓/danger/stress situations
- Adrenalin causes the blood vessels of the skin to constrict✓
- Less blood flows to the surface of the skin✓
- Because the skin is not an important organ during an emergency✓
- Re-directing more blood /more oxygen and food to vital organs✓
- To enable the body to respond during an emergency✓ (Max 6)

Presentation
Assessing the presentation of the essay - synthesis  [3]

<table>
<thead>
<tr>
<th>Description</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well structured – demonstrates insight and understanding of question</td>
<td>3</td>
</tr>
<tr>
<td>Minor gaps in the logic and flow of the answer</td>
<td>2</td>
</tr>
<tr>
<td>Attempted but with significant gaps in the logic and flow of the answer</td>
<td>1</td>
</tr>
<tr>
<td>Not attempted/ nothing written other than question number</td>
<td>0</td>
</tr>
</tbody>
</table>
Unit 9  Responding to the environment: Plants

It is important for plants to respond to their changing environment. Unlike most animals, plants cannot move their whole body to respond to differences in their environment but they can bring about a change by causing different parts of their structure to grow.

Plant hormones

A plant hormone is a chemical substance that causes many of the plant’s responses to the environment. Plant hormones affect growth and development in plants. They are needed in minute concentrations (sometimes below 1 part per 1 000 000).

These hormones may be produced in the tissue where they are required or produced in tissues at a distance from where they are required.

General functions of some plant hormones

<table>
<thead>
<tr>
<th>Name</th>
<th>Produced</th>
<th>Acts on</th>
<th>Function</th>
<th>Effect in plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxins</td>
<td>Meristems in shoot and root tips</td>
<td>Young cells in the tips of a plant</td>
<td>Cause young cells to elongate by taking in lots of water. This causes the vacuoles to fill up and elongate the cell while the cellulose cell walls are still elastic and can stretch.</td>
<td>Apical dominance High concentration in the apical bud stimulates growth. High concentration in the lateral (side) buds near the tip of a plant stops growth. Further away from the apical bud the lower concentration of auxin stimulates growth. See diagram on page 96.</td>
</tr>
<tr>
<td>Young leaves</td>
<td>Leaves</td>
<td></td>
<td></td>
<td>Leaf fall (fruit fall). As leaves age or when there is a decrease in temperature (autumn/winter). The cells of the abscission layer become waterproof like cork. The leaves no longer receive water and die. The leaves fall off the plant. This is called abscission.</td>
</tr>
<tr>
<td>Seeds in ovary</td>
<td>Ovary</td>
<td></td>
<td></td>
<td>Fruit development</td>
</tr>
<tr>
<td>Cells of a stem</td>
<td>Cells in the end of a stem e.g. a cutting</td>
<td></td>
<td></td>
<td>Root formation. Cuttings of stems are dipped into a powder containing a synthetic auxin. This stimulates the growth of adventitious roots.</td>
</tr>
</tbody>
</table>

UNIT 9 Responding to the environment: Plants
Abscisic acid

<table>
<thead>
<tr>
<th>Name</th>
<th>Produced</th>
<th>Acts on</th>
<th>Function</th>
<th>Effect in plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscisic acid ABA</td>
<td>Leaves, shoots</td>
<td>Growth-inhibiting hormone, which allows plants to respond to stress e.g. drought, frost</td>
<td>During autumn leaves of some plants produce abscisic acid which stops the growth of tips of shoots and lateral (side) branches. It also causes buds to become dormant.</td>
<td></td>
</tr>
<tr>
<td>Seeds</td>
<td>Dormancy of seeds. Prevents the germination of seeds in adverse conditions and while still in the fruit.</td>
<td>Gives the seeds time to mature and to only be dispersed when they are ready to germinate. Not all seeds will germinate at the same time. Germination can only happen when the amount of abscisic acid decreases. This will happen when the spring rains wash away the abscisic acid or as the seed passes through the gut of an animal.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roots</td>
<td>Under stress when there is too little water</td>
<td>Abscisic acid is carried to the leaves where it causes the stomata to close. This reduces water loss by the plant.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table summarising plant hormones**

**Pruning**

Gardeners and farmers cut off the tips (apical buds) to encourage lateral (side) growth of the plant. There is no longer any auxin being produced in the apical bud. Lateral growth takes place. See diagram below:

Pyramidal shape of a tree caused by the effects of auxin and apical dominance

Diagrams showing how auxin produced at shoot tips inhibits growth of lateral buds

---

**Weed control by using growth hormones**

Applying growth hormones encourages the plants to grow rapidly. This results in the plants using up their energy and stored food very quickly and the plant dies. Two examples of herbicides are 2,4-D and MCPA. These herbicides only have an effect on broad-leaved plants i.e. dicotyledons. The narrow-leaved plants (monocotyledons) such as mealie meal, rice canes and grasses are unaffected by these two herbicides. There are highly selective herbicides that are very specific, for example, a certain herbicide can be sprayed on sugar cane to kill other grass species. The sugar cane is unaffected.

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ACE IT! Life Sciences Grade
Plant tropisms

Auxins cause plant growth towards or away from external stimuli, e.g. light, water, gravity.
- If a plant grows towards a stimulus it is known as a positive response.
- If a plant grows away from a stimulus it is known as a negative response.

Geotropism – response of plants to the force of gravity
If a seedling is placed on its side, the shoot will grow away from the soil and the root will grow towards the soil. The shoot is growing away from the force of gravity and the radicle is growing towards the force of gravity.

Phototropism – response of plants to the stimulus of light
A pot plant growing near a window will grow towards the light coming through the window. Shoots are positively phototropic and roots are negatively phototropic. Shoots grow towards the light (positive phototropism) and roots grow away from light (negative phototropism).

Leaves and stems growing next to a window are arranged so that the leaves can get the most light.
Auxin made inactive by light

Auxin unaffected by light

Diagrams showing how one-sided light causes phototropism

Investigations to show tropisms

A clinostat is a special piece of laboratory apparatus that is used to study tropisms. Below are diagrams representing an experiment to show that the force of gravity has an influence on the growth of plants.

There is a motor in the base, which turns the disc around. It is difficult to eliminate the force of gravity, but rotating the seedlings on the clinostat, the force of gravity is neutralised. As the disc revolves, each side of a seedling is influenced by the force of gravity. In other words, no one side of a seedling experiences the force of gravity more than another side.

Plant defence mechanisms

Plants need to protect themselves from being eaten therefore they need defence mechanisms. The two main ways in which plants defend themselves are chemical and physical defences.

Chemical defences

Some ways in which plants defend themselves is by having an unpleasant taste or by being poisonous. Plants produce chemicals that are not directly used for growth. Some examples are shown in the table below.

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Plant</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethrins</td>
<td>Chrysanthemum</td>
<td>Toxic to insects; used in man-made insecticides.</td>
</tr>
<tr>
<td>Essential oils</td>
<td>Mint, lavender, oranges, lemons</td>
<td>Strong taste is unpleasant to herbivores.</td>
</tr>
<tr>
<td>Tannins</td>
<td>Acacias, tea</td>
<td>Help resist bacterial and fungal infections.</td>
</tr>
<tr>
<td>Ricin</td>
<td>Castor oil seed coats</td>
<td>Poisonous</td>
</tr>
<tr>
<td>Strychnine and atropine</td>
<td>Deadly nightshade</td>
<td>Poisonous</td>
</tr>
</tbody>
</table>

Table summarising chemical defences in some plants
### Physical defences

A physical defence is provided by having structural adaptations that are unpleasant to herbivores and insects. Some examples of physical defences are shown below:

<table>
<thead>
<tr>
<th>Structure</th>
<th>Plant</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorns or spikes</td>
<td>Acacias, cacti</td>
<td>Animal’s mouths will be harmed by eating thorns or spikes. Some animals like giraffe have adapted to eat thorns.</td>
</tr>
<tr>
<td>Dead bark</td>
<td>Trees</td>
<td>Strong taste is unpleasant to herbivores. They avoid eating them.</td>
</tr>
<tr>
<td>Thick waxy cuticles</td>
<td>Succulents</td>
<td>Protects the inner nutrient – rich sapwood from animals, e.g. beetles and ants.</td>
</tr>
<tr>
<td>Stinging hairs</td>
<td>Stinging nettle</td>
<td>Cause a burning sensation in the mouth.</td>
</tr>
</tbody>
</table>

Table summarising physical defences by some plants

In the space below, draw your own mind map to summarise this unit.
Questions

This unit is examined in Paper 1 for about 11 marks (7%).

Question 1

Study the graph below showing the effect of auxin on cell elongation in different parts of the plant. The y-axis above the 0 shows growth stimulation. The y-axis below the 0 shows the inhibition (prevents) of growth.

![Graph showing the effect of auxin on cell elongation in different parts of plants]

1.1 At what concentration does the shoot show the best % elongation? (1)

1.2 From the graph above describe how the cell elongation in the root differs from that in the shoot. (4)

1.3 What concentration of auxin has no effect on the elongation of lateral bud cells? (1)

[6]
Questions

This unit is examined in Paper 1 for about 11 marks (7%).

Question 1

Study the graph below showing the effect of auxin on cell elongation in different parts of the plant. The y-axis above the 0 shows growth stimulation. The y-axis below the 0 shows the inhibition (prevents) of growth.

Key:
- shoot
- lateral bud
- root

1.1 At what concentration does the shoot show the best % elongation? (1)

1.2 From the graph above describe how the cell elongation in the root differs from that in the shoot. (4)

1.3 What concentration of auxin has no effect on the elongation of lateral bud cells? (1)
Question 2

The diagram below shows two clinostat faces. Both faces are vertical and, on them are pinned pea seedlings with straight radicles (young roots) and plumules (young shoots). Both sets of apparatus were covered with black paper. Clinostat A was switched on, in other words, it rotated. Clinostat B was not switched on, in other words, it did not move.

A Rotating clinostat  
B Stationary clinostat

2.1 What would you expect the radicles to appear like on clinostat A after 5 days? (2)

2.2 Draw a labelled diagram of the seedling Z on clinostat B after 5 days. (4)

2.3 Explain using the effect of hormones why plant Z appears as you have drawn it. (4)

Question 3

DBE NSC 2014 February-March Paper 2

An investigation was carried out to determine the effect of two plant hormones (A and B) on the accumulation of starch in the cells of tobacco plants.

The investigation was set up as follows:
- 30 tobacco plants of the same species, size and age were used.
- They were divided into three groups, and each treated in a different way as follows:
  Group 1: 10 plants were treated with hormone A
  Group 2: 10 plants were treated with hormone B
  Group 3: 10 plants were given no hormone treatment
- All the plants were then left under the same conditions. The starch content in the cells was measured after every 6 hours for each group.

The graph below shows the results of the treatments for a period of 48 hours.

3.1 Explain the purpose of Group 3 in the investigation. (2)

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

3.2 Using the results, indicate the function of:

(a) Plant hormone A. (2)

________________________________________________________________________
________________________________________________________________________

(b) Plant hormone B. (2)

________________________________________________________________________

[6]
Question 4

2011 November Paper 2

Sipho did an investigation in his laboratory to look at the effect of different concentrations of auxin on cell elongation in coleoptiles (young stems). He used the following procedure:

- Fifteen (15) coleoptiles from one species of oat plants were used.
- All the coleoptiles used were of the same length.
- The tips of twelve (12) coleoptiles were cut.
- These coleoptiles were put into four groups (A, B, C and D). Each group of three coleoptiles was injected with a different concentration of auxin as shown in the table below.
- The last group E was used as a control in which the coleoptiles were not injected with auxin and tips were not cut. After four days the length of coleoptiles in each group were measured and an average was calculated:

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>Group</th>
<th>Tip (Present/Absent)</th>
<th>Concentration of auxin injected (arbitrary units)</th>
<th>Average length of coleoptile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>Absent</td>
<td>1</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>Absent</td>
<td>2</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>Absent</td>
<td>3</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>D</td>
<td>Absent</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>Present</td>
<td>0</td>
<td>30</td>
</tr>
</tbody>
</table>

4.1 Formulate a hypothesis for the investigation above. (3)

__________________________________________________________________________

4.2 Suggest why Sipho cut off the tips of each coleoptile before he injected them with auxin. (2)

__________________________________________________________________________

4.3 Apart from the factors that were kept constant, state ONE other factor that Sipho should have kept constant in all the groups. (1)

__________________________________________________________________________

4.4 What conclusion can be drawn from the results, about the effect of auxin concentration on cell elongation in the coleoptiles? (2)

__________________________________________________________________________
### Question 5

**DBE NSC February-March 2016 Paper 1**

The graph below shows the effect of different concentrations of gibberellins on the germination of seeds.

![Graph showing percentage of seed germination in different concentrations of gibberellins](Adapted from HortScience 44(3))

#### 5.1 One possible conclusion drawn from the results shown above, is that the ...

A. gibberellin concentration has no effect on the germination of the seeds.  
B. highest percentage of seed germination occurs at a gibberellin concentration of 1 500 mg/l. 
C. highest percentage of seed germination occurs at a gibberellin concentration of 1 000 mg/l.  
D. lowest percentage of seed germination occurs at a gibberellin concentration of 1 000 mg/l.  

#### 5.2 A gardener removes the apical buds from a rose bush in her garden regularly. As a result the rose bush will ...

A. produce more lateral branches.  
B. grow taller. 
C. remain the same size.  
D. produce fewer roses.

### Question 6

**DBE NSC November 2015 Paper 1**

The diagram alongside shows the growth movement of a part of a plant towards a stimulus.

#### 6.1 What growth movement is represented in the diagram? ____________________________  

#### 6.2 Identify the stimulus labelled A. ____________________________  

#### 6.3 Name the growth hormone that is responsible for the growth movement named in Question 6.1. ____________________________

#### 6.4 Will a high concentration of the growth hormone named in Question 6.3 stimulate or inhibit growth in the roots?  

#### 6.5 Name the phenomenon where the buds at the tip of the plant regulate the growth of the lateral branches.
Question 7

Thobeka investigated the effect of auxins on the growth of three plant shoots (A, B and C). The plant shoots were treated as follows:
- Shoot A – Not treated in any way
- Shoot B – Tip removed and agar plate with auxins placed on top
- Shoot C – Tip removed and agar plate without auxins placed on top

**NOTE:** Agar is a jelly-like substance that allows auxins to diffuse through it.

All shoots were exposed to the same light conditions.

The diagram below illustrates the set-up at the beginning of the investigation.

7.1 Identify the independent variable in this investigation. (1)

7.2 State TWO factors that must be kept constant in this investigation. (2)

7.3 Explain the results observed in:
(a) Shoot B after a few days (3)

(b) Shoot C after a few days (2)

7.4 Suggest TWO ways in which Thobeka could have improved the reliability of her investigation. (2)
Question 1
1.1 10–05 parts per million of auxin✓ (1)
1.2 The root growth is stimulated at a very low level✓ of auxin; from 10–6 to 10–45 parts per million✓. The shoot growth is stimulated by higher levels✓ of auxin; 10–3 to 1 parts per million✓ of auxin (4)
1.3 10–75 parts per million auxin✓ (where the graph line intersects the x-axis) (1)

Question 2
2.1 There would be no change in the pea seedlings✓ or the plumules and radicles would appear✓ as they are at the start of the experiment✓ (2)
2.2 The diagram needs to show: the plumules growing upwards✓
   The radicles would grow downwards✓ (4)
2.3 The plumules are negatively geotropic
   In the plumule the auxin will move to the lower side causing more growth and will elongate on this side✓ growing upwards✓. The lower level of auxin on the upper side inhibits growth✓.
   The radicle is positively geotropic – the auxin moves to the lower side of the radicle inhibiting growth✓ but the low auxin level causes more growth/elongation on the opposite side (upper side);✓ the radicle will bend and grow downwards✓.
   Four good points (4)

Question 3
3.1 To act as a control✓ allowing us to reason that any difference in starch content✓ was due to the action of the hormones✓ (any 2) (2)
3.2 (a) Stimulates✓ the accumulation of starch in cells✓ (2)
   (b) Does not promote✓ the accumulation of starch in cells✓ (2)

Question 4
4.1 The cell elongation in the coleoptile
   will increase✓/decrease/remain the same/differ as the auxin concentration✓ increases/decreases/differs✓ (3)
4.2 Removing the effect of auxin✓ produced at the tip
   as there can be varying concentrations✓ produced by each plant (2)
4.3 Type of soil✓/ amount of water✓ light intensity✓/ temperature✓/ size of the pot✓/ keep environmental conditions the same (1)
4.4 Increasing the concentration of auxin results in an increase in the cell elongation✓ up to an optimum concentration✓ then it starts inhibiting/decreasing the cell elongation✓ (any 2) (2)

Question 5
5.1 C✓ (1)
5.2 A✓ (1)

Question 6
6.1 Phototropism✓ (1)
6.2 Light✓/Sunlight/Radiant energy✓ (1)
6.3 Auxins✓/ IAA/ Indole acetic acid✓ (1)
6.4 Inhibit✓ (1)
6.5 Apical dominance✓ (1)

Question 7
7.1 Treatment✓ of plant shoot (1)
7.2 - Same type of plant✓
   - Placed in the same environment✓
   - Same amount of time✓
   - Tip removed at the same length✓
   - Same concentration of auxins✓
   - Same type of agar✓
   (Mark first TWO only) (any 2) (2)
7.3 (a) - Shoot B would show upward growth✓
   - Auxins in the agar gel diffused downwards✓ into the shoot
   - leading to cell elongation✓ (3)
   (b) - No growth in shoot C✓
   - Shoot tip contains NO auxins✓ (2)
7.4 - Repeat the investigation✓
   - Use more than 1 plant per investigation✓
   /increase sample size (Mark first TWO only) (any 2) (2)
STRAND 4 Diversity, change and continuity
Unit 10 Evolution by natural selection

Origin of ideas about origins

The origin of life on Earth is an ongoing curiosity. There are a number of different beliefs as to how life began on Earth. These beliefs are often grounded in traditional and cultural belief systems.

There are two main ideas about the origin of life on Earth:
Creation – These beliefs are not scientific, as they do not depend on observation and scientific investigation.

Evolution – These ideas are scientific, as observation and scientific investigations have taken place over many years. A change in the gene pool of a population over time is known as evolution. Change is very gradual from one generation to the next and takes place over millions of years.

Different kinds of evidence for evolution

Fossil record

Fossils are found in layers of rock. The rocks can be dated. A fossil is an organism that has been preserved by mineralisation in a number of different ways. The fossil also needs the correct temperature and pressure to form. (Fossils were studied in detail in Grade 10.)

- The depth at which a fossil is found is an indication of the order in which organisms arose. For example, fish fossils will be found in the deepest layers. Mammalian fossils are found in the layers closest to the Earth’s surface.
- Transitional fossils are found. These are the fossil remains of organisms that link one organism to another. For example, they can show the development of the modern horse.

Modification by descent – heredity

This is the passing of genetic characteristics from one generation to the next. Changes in a gene pool can happen because:

Two sets of genes (one from the mother and one from the father) combine during fertilisation in sexual reproduction. A gene or chromosome mutation occurs. (These concepts were studied in Grade 11.)

These variations lead to modified heredity material (chromosomes) being passed from the parents to the offspring. This is descent with modification. Genes found in a population are constantly changing and modified genes are inherited. An organism, which is well-suited to a particular habitat or niche will pass on these favourable genes to the next generation. The new generation will be modified from that of their parents.
Biogeography

This is the distribution of living organisms around the world. (This concept was covered in Grade 10.) Different plants and animals are to be found in similar habitats in different parts of the world.

- Hot grassy plains are found in Australia, southern Africa and South America. Each of these areas has its own large flightless bird: in Australia, the emu; in South Africa, the ostrich; and in South America the rhea. These birds have come from different ancestors because they are on separate continents. They look similar because they have evolved to adapt to the same habitats. Remember that all of these continents were once joined together before continental drift took place.

- Different species will adapt to the environment in which they live. If the environments on different continents are the same, then different species will be similar in appearance because they are each adapting to their specific environment.

- Darwin in his travels visited the Galapagos Islands. Here he noticed that each island had its own type of giant tortoise. The tortoises that lived in wet, grassy areas had domed shells. The tortoises living in drier conditions had saddleback shells. The saddleback shells allow the tortoises to stretch their necks upwards to eat cacti and leaves from bushes.

- Darwin proposed that one original type of tortoise had adapted to suit the different conditions on each island. The genetic material had adapted differently over time to suit the different habitats.

Genetics

Evolution works on the level of genes. In other words, mutations lead to adaptations to the genotypes (genetic makeup) and phenotypes (physical appearance) of a species from one generation to the next.

Genetics can explain:

- How variation leads to change.
- How variation is passed from one generation to another.
- That the genotype and therefore phenotype of a whole population changes with time.

Other forms of evidence

- Basic structure. An example is pentadactyl limbs (with five digits on each limb). Land-living vertebrates have the same basic structure for their limbs, even if they perform different functions or look different.
Biochemical structure. If you analyse the structure of the haemoglobin molecule of the cat, chimpanzee and humans, the haemoglobin of humans and the chimpanzee is almost identical and the cat’s haemoglobin is different. Closely related organisms have more similar biochemical structure.

**Difference between hypothesis and theory**

A hypothesis is a statement predicting an outcome for an experiment before the experiment has been carried out.

A theory is an explanation given after the experiment has taken place. A theory is the conclusion after testing the hypothesis.

A theory is put forward with the information available at a particular time. The theory may change when more sophisticated apparatus is invented, and a different conclusion may be reached.

The scientific method is used for experimentations.

![The scientific method of experimentation](image)

**Brief overview of the history of different theories about the development of the origins of life on Earth**

The development of the scientific method allowed scientists to explore ideas about the origins of life on Earth in a methodical manner, and to state with scientific confidence which mechanisms caused evolution.

**Lamarckism – evolution by acquired characteristics**

Lamarck was a French naturalist in 1801.

He was the first scientist to suggest that change in living organisms was as a result of natural processes and not the process of creation.

Lamarck explained evolution using the following two 'laws':

- **The law of use and disuse**: As an organism uses a structure or organ more regularly it will become better developed or enlarged in that organism. If an organism does not use a structure or organ frequently it will become less developed or reduced in size and may disappear altogether in that organism.

- **The inheritance of acquired characteristics**: The characteristics that are developed during the lifetime of an individual (acquired characteristics) can be passed on to their offspring/next generation.

Lamarck's suggestions were scientific in that they could be tested. However, after many investigations, acquired characteristics are not passed on to offspring.

**Darwinism – evolution by natural selection**

Darwin was an English naturalist who travelled on a ship, the HMS Beagle, that sailed to South America and Australia between 1831 and 1836.

Darwin studied the large variety of living organisms and fossils in the regions he visited.

He noticed similarities between the fossils that he found and the living plants and animals. He noticed the differences between similar organisms in different places.

He carried out two important studies on the Galapagos Islands:

- If there were Giant tortoises on each island.
- Different varieties of finch on each island and how each variety was specialised to eat a particular food, having different beaks, etc.
Darwin explained evolution using the concept of natural selection: Organisms produce a large number of offspring. In the offspring there is a great deal of variation. Some of the offspring have favourable characteristics and some do not. When there is a change in the environmental conditions or there is competition then the organisms, which have the favourable characteristics will survive and those which have the less favourable characteristics will die. The organisms with the favourable characteristics reproduce passing on the favourable characteristics to their offspring. The next generation will therefore have a higher proportion of individuals with the favourable characteristics.

## Differences between Lamarck and Darwin

An example: The webbed feet of duck

<table>
<thead>
<tr>
<th>Lamarck</th>
<th>Darwin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ducks walked on land looking for food. Food became scarce and they were forced to look for food in the water. The duck stretched their toes apart to swim. As a result a skin grew between their toes. This was the beginning of webbed feet. This characteristic was then inherited by the offspring.</td>
<td>There was a great variation in the appearance of the feet of duck in a population. Those duck who had webbed feet and entered the water to obtain food were the successful individuals. Their offspring would survive as they could obtain food. Those who could not obtain food from the water died.</td>
</tr>
</tbody>
</table>

Other examples: Giraffe or succulent feature of xerophytic (succulent) plants. Darwin worked with Wallace who had similar ideas after studying the plants and animals of Indonesia and together they presented a paper in 1858 on how evolution works. They explained evolution as a gradual change in a species over time. This is called gradualism.

## Punctuated equilibrium

In 1972 two scientists, Niles Eldridge and Stephen Jay Gould, suggested that evolution is not a slow gradual change over time but rather a punctuated equilibrium. This means that a sudden change will take place in a species (punctuated) and then this new change will last for a long period of time (equilibrium).

An example of punctuated equilibrium is the cichlid fish in a lake that was cut off 4 000 years ago from Lake Victoria in Uganda, Africa. This lake has five species of cichlid fish, similar to, but different from, one of the species in Lake Victoria.

![Graph: A graph to compare gradual Darwinian evolution with punctuated equilibrium](image)

### Gradualism compared to Punctuated Equilibrium

Darwin believed that evolution takes place through an accumulation of small gradual changes that occur over a long period of time. This concept is supported by transitional forms in fossil records.

Punctuated equilibrium suggested that evolution sometimes involves long periods of time where species do not change or very little change occurs this is equilibrium. This alternates with short periods of time where rapid changes occur. New species are formed in a short period of time, relative to the long period of no or little change. This concept is supported by the absence of transitional forms.
Artificial selection

This is selection carried out by people. People select a certain characteristic that is required and will deliberately breed this characteristic into the offspring.

<table>
<thead>
<tr>
<th>Artificial selection</th>
<th>Natural selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>The selective force is humans.</td>
<td>The selective force is the environment or nature.</td>
</tr>
<tr>
<td>Selection takes place in response to satisfy the needs of humans.</td>
<td>Selection takes place in response to the suitability to the environment.</td>
</tr>
<tr>
<td>May involve one or more species (as in cross breeding).</td>
<td>Occurs within a single species.</td>
</tr>
</tbody>
</table>

Table showing the differences between artificial and natural selection.

Examples

Domesticated animals

- Different varieties of dogs were bred by people long before Darwin and Wallace explained natural selection.
- Cattle were domesticated (humans used them for their benefit) about 10 000 years ago in the Middle East. They were used as a source of food (for their meat, milk); to carry heavy loads and to pull a plough; and their skins/hides could be used to make shoes and clothes.
- For many years farmers have used artificial selection to improve their herds. Special characteristics have been bred in certain types of cattle. Some examples:
  - Jersey cows have been selectively bred to produce high butterfat milk.
  - Nguni cattle have been bred to be very disease resistant.
  - Hereford cattle have been bred for their meat.

Nguni cattle have been bred to be very disease resistant; Hereford cattle are bred for their meat; Jersey cattle are bred for rich milk

Special breeds of cattle that have been artificially selected – you can see which of these breeds come from B. taurus or from B. indicus

Crop species

Over the centuries many plants have been selectively bred by man to be tastier, bigger, to be more productive, and so on.

Wheat is the most widely-grown cereal crop in the world. A cool climate is the ideal condition for wheat to grow. Mexico has a very large population to feed. The climatic conditions in Mexico include high temperatures and very dry conditions. Wheat does not grow well in this country.

In 1953 a scientist, Dr Norman Borlaug, started a breeding programme to produce wheat that would survive and produce well in Mexico. The results were plants that were rust (a disease) resistant; had short, thick stems that did not break easily; needed less water and that gave a high yield of grain. By 1963 the Mexicans were reaping a harvest that was six times greater than when he started his research. Dr Borlaug selected the plants with the desired characteristics that he needed and cross-bred them to get his final successful result. Mexico now has enough wheat for the country and is able to export some as well. This research was the start of the 'Green Revolution', which is the breeding and growing of crops to successfully feed the growing population of the world.
Darwin’s theory of evolution by natural selection

Charles Darwin proposed that in any environment the individuals that are best suited to it will reach adulthood. They will therefore be the individuals who reproduce and pass on their successful characteristics (genes) to their offspring. In other words the natural environment selects the individuals that are most suited to it as the parents of the next generation. These individuals will not survive and their genes will be removed from the gene pool and not passed on to the next generation. The phenotype of the population will change over time as unsuitable individuals die out before they can reproduce.

Evolution through natural selection can be explained with the knowledge we have of genetics. In his time Darwin did not have any of this detailed knowledge that we now have.

Factors on which evolution through natural selection depends

Variation in the gene pool of inherited characteristics

Variation in characteristics is possible by homologous chromosomes lining up randomly at the equator (independent assortment), the swapping of genetic information (crossing over) and mutations during meiosis. It is also affected by which sperm fertilises which egg.

Production of more offspring than is required

A population produces more offspring than is required to compensate for the offspring that are going to die because they are not well suited to the environment.

If the population were to remain constant, then each female would have to produce two individuals in her lifetime, one to replace her and one to replace the male. There is no guarantee that these two offspring would survive to adulthood and reproduce and there would not be much variation in the gene pool either. Therefore females produce more offspring than are needed to maintain the number of individuals in that population (geometric growth).

Most populations remain the same size over long periods of time

This happens because not all offspring reach adulthood to reproduce. A number of the offspring will not survive because of disease, being eaten by a predator or herbivore, by not being strong and healthy enough to compete with others. Darwin called this the struggle for existence.

The struggle for existence

There is competition within a species (intraspecific competition) and between different species (interspecific competition) for survival. Competition is for resources such as food, water, a mate, a shelter in the case of animals. In the case of plants competition is for water and nutrients from the soil, sunlight and carbon dioxide. The population does not exceed the carrying capacity of the habitat because of environmental resistance.

There is variation in all populations

No two individuals will be identical (except identical twins) even if they have the same parents. This is because during sexual reproduction and meiosis there is random segregation of chromosomes, crossing over between chromosomes, mutations of genes and which sperm fertilises an egg.

EXTRA INFORMATION

The Green Revolution has taken place over the last 30 years. Agriculturalists have artificially selected and bred crops, which show one or more of the following characteristics:

- Give a higher yield.
- Have shorter stems, resulting in varieties that are less likely to be damaged by wind and rain.
- Make better use of water and fertilisers.
- Are more resistant to pests and diseases.
- Are not very sensitive to temperature and/or day length, resulting in the possibility of growing two to three crops per year.
The most suitable variants/individuals in any environment are the ones that are most likely to survive and reproduce

The best suited individuals are those that are going to survive and win the struggle for existence. They fit into the environment the best. They are in the correct niche in the environment. Darwin called this the survival of the fittest. (Fit here, does not mean fit as in a sporting context but means most suitable or best adapted.)

Some of the selected characteristics are inherited so the offspring resemble their parents

Characteristics are carried by genes, therefore parents that have suitable characteristics for survival in a certain environment will reach reproductive age and pass these suitable genes on to their offspring. The offspring, because they inherit their genes from their parents, will resemble and look similar to their parents. Their phenotypes will be similar and their genes more suitable to adapt to and cope with the changing environment.

Factors that affect the process of natural selection

Changes in the environment

Environmental conditions are not constant. They change all the time, from year to year. Natural selection has made sure that a population is well suited to its environment. If the environment changes then only those individuals that are suited to the new situation will survive and be able to reproduce. The offspring will therefore inherit the genes that the successful adults have and that ensured their survival. Anything that causes a change in the gene frequency of a population is called a selection pressure.

Pressure by the environment leads to extinction or successful adaptation

A population cannot keep growing indefinitely (geometric growth), as the resources available remain more or less the same. As a population increases so the competition for the resources will increase. This leads to environmental resistance. Some individuals will succeed at obtaining the resources and survive, while others will not obtain the resources and will die out (logistic growth). The genes that allow certain individuals to survive will be passed on to the next generation of offspring.

When something changes in the environment the populations living in the environment can do one of two things:
- They can adapt successfully to the changed environment by the process of natural selection.
- They can become extinct because they do not have the necessary genetic variation for natural selection to work and for them to survive.

MY OWN NOTES
Continuous and discontinuous variation

<table>
<thead>
<tr>
<th>Feature</th>
<th>Continuous variation</th>
<th>Discontinuous variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genes and loci</td>
<td>Controlled by several different genes found at different loci on the homologous chromosomes.</td>
<td>Controlled by a gene at a certain locus on the homologous chromosomes.</td>
</tr>
<tr>
<td>Phenotypes</td>
<td>Dependent on genes and environment. Many variants.</td>
<td>Dependent on genes only. Only two variants.</td>
</tr>
<tr>
<td>Examples</td>
<td>Height. Foot size. Hair colour.</td>
<td>Mendel's pea experiments: tall or short; smooth or wrinkled seeds. Tongue roller or non-tongue roller in humans. Rhesus factor in blood either Rhesus positive or Rhesus negative.</td>
</tr>
<tr>
<td>Frequency graphs to show the two different types</td>
<td>Histogram graph is drawn as the independent variable is continuous – there are no gaps between the different categories. A normal distribution/bell-shaped curve is the result. The data is evenly spread on either side of the mean (average). See the graph below.</td>
<td>Bar graph is drawn as the independent variable is discontinuous – there are gaps between the different categories. See the graph below.</td>
</tr>
</tbody>
</table>

Table showing the differences between continuous and discontinuous variation

The formation or emergence of a new species – speciation

Speciation

Gradual change over time is called adaptation/evolution. Sometimes the change is so rapid that a new species is formed. This is called speciation.

The biological concept of a species

The word species comes from Latin and means 'a kind of organism'. Species were first identified by what they looked like (phenotype). There are organisms that look the same but they are different in some way. They may be different because:

- Their chemistry is different. For example some bacteria look identical but their DNA is different.
- Living in a similar environment, they may differ in various ways. For example dolphins, sharks and seals have a similar streamlined shape so that they can swim, but only their appearance is similar.

Dolphin  Seal  Shark

These unrelated animals have similar shapes and might be classified in the same group if we used their external appearance.
Continuous and discontinuous variation

<table>
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- Living in a similar environment, they may differ in various ways. For example dolphins, sharks and seals have a similar streamlined shape so that they can swim, but only their appearance is similar.

These unrelated animals have similar shapes and might be classified in the same group if we used their external appearance...
- Organisms can look very different from each other but still be the same species. Dimorphism means that there are two different forms and polymorphism means there are several different forms. For example, the peppered moth shows dimorphism. White moths survive in clean rural areas and the black moth survives in industrial areas which have high pollution levels. In each case the moth is camouflaged and its predators cannot see it to catch it.

- A species is a group of organisms that are able to reproduce fertile young.

**Interbreeding produces viable offspring in a species**

When members of a species interbreed they produce viable young.

**Speciation**

Genes cannot move from one species to another. This makes one species isolated (separate) from another species as they are not able to interbreed and reproduce. This is known as reproductive isolation. There is no movement of genes between the two species and, over time, each species adapts or evolves because of natural selection. The genotypes of the two groups become different from each other. The gene frequencies are different and they can no longer interbreed.

- Two new species have evolved.
- There are two types of speciation:

<table>
<thead>
<tr>
<th>Allopatric speciation</th>
<th>Sympatric speciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A population of a species is split by a geographical barrier e.g. river, landslide, mountains.</td>
<td>A population of a species may become split by differences in behaviour e.g. feeding time, roosting time; cichlid fish in lakes in Malawi.</td>
</tr>
</tbody>
</table>

As a result:
- The two separated groups of the population cannot interbreed.
- There is no longer a gene flow between the two new groups.
- Natural selection occurs independently in each new group.
- This happens because the environmental conditions will be different.
- As a result the two new populations become genotypically and phenotypically different over time.
- Even if the two populations were to meet at a later time, they will not be able to interbreed. i.e. each new population has become a new species. Speciation has taken place.

**Speciation due to geographic isolation – allotopic speciation**

New species can evolve if they are physically separated, for example, by a new river that develops during a flood. The two populations can no longer physically get together. Other physical barriers could be a mountain range or the sea.

**Examples of geographic isolation**

There are a number of examples of speciation due to geographic isolation. Choose only one of the following to study in detail.

<table>
<thead>
<tr>
<th>Galapagos finches</th>
<th>Galapagos tortoises</th>
</tr>
</thead>
<tbody>
<tr>
<td>Darwin identified thirteen different species of finches on the Galapagos Islands. The birds looked the same except that their beaks were structurally different as they had different diets. They were no longer able to interbreed and had become different due to natural selection.</td>
<td>There are eleven different populations of tortoises living on the Galapagos Islands. They can interbreed even though they look so different. Therefore they are considered as a subspecies. Darwin thought that the ancestors arrived five million years ago from the South American mainland when the islands first appeared as volcanoes in the Pacific Ocean. The main island has five different subspecies; there are six species are each isolated on a separate island.</td>
</tr>
</tbody>
</table>
Baobabs in Africa, Madagascar and Australia
There are eight different baobab species in the world today.
There are six species growing on Madagascar, one species in Africa and one species in north-western Australia.
The six species growing on Madagascar grow in very different environmental and climatic conditions and have therefore evolved to be different.
It is thought that 40 million years ago fruit, which floats easily, floated across the ocean to the eastern coast of Africa and the north-western coast of Australia and hence the result is different baobabs in the different continents.

Proteas in South Africa and Australia
Many different species are found in South America, Southern and Central Africa, Madagascar, Australia, New Zealand and many Pacific Islands.
Millions of years ago these southern continents were joined and known as Gondwanaland.
Some scientists suggest that the ancestor of the protea grew on Gondwana.
The continents moved apart 50 million years ago and each species of protea has adapted and evolved to the environmental conditions on each of the continents.
It is still possible to see that these plants are related to each other. They therefore must have had a common ancestor.

Other mechanisms for reproductive isolation

Breeding at different times of the year – seasonal isolation
This happens when two similar species produce their gametes at different times of the year. For example, the Rainbow Trout breeds in spring and the Brown Trout breeds in the autumn. Plants have short flowering seasons to prevent cross-pollination.

Species specific courtship behaviour – behavioural isolation
Courtship behaviours are specific to a species. A species may also have specific markings and/or colourings. These attract a partner of the same species or they stimulate the production of sperm or eggs. If the partner does not respond then mating will not be successful.
Recent studies have shown that the European Great Tits living in noisy cities have changed their normal song so that they can be heard by a partner. Birds sing to mark their breeding territory and to attract a mate. In the future the song of the city birds may be so different from that of the country birds that they will no longer respond to each other and reproduction between the two groups will no longer take place. They will be reproductively isolated and there will be two different species.

Adaptation to different pollinators
Some plants are cross-pollinated by a specific insect or bird. To prevent cross-pollination these flowers have their stigmas and anthers in different places to suit only their specific pollinator. So if a pollinator visits species A, collects pollen on its back and then visits species B, the stigmas will not be in a position to have the pollen brushed onto them. In other words, cross-pollination will not take place.

![Diagram of pollination](image)

**Young flower**
- Young stigma
- Ripe anthers put pollen on bee
- Ripe stigma collects pollen from bee
- Old anthers have shrunk
- Tongue of bee collecting nectar

**Old flower**

Successful pollination can only happen if the anthers and stigmas are in exactly the right place for the body shape of the pollinator.
Prevention of fertilisation – gametic isolation or mechanical isolation

Gametic isolation occurs when fertilisation between two different species does not happen. In plants the pollen grain needs a specific chemical to be present on the stigma for germination to take place and to grow a pollen tube to carry the male gamete to the ovum in the ovary. Only a flower of the same species will have the correct chemical.

Mechanical isolation refers to the fact that the shape of the female and male genital organs are not suited to one another and successful mating cannot take place between different species living in the same place.

Infertile offspring in cross-species hybrids

Sometimes breeding between different species does produce offspring. The offspring are cross-species hybrids. They are healthy individuals but they are not able to breed successfully and produce offspring.

- For example, a mule is the result of the breeding between a female horse (64 chromosomes) and a male donkey (62 chromosomes). The mule has 63 chromosomes (32 + 31). A mule cannot produce a successful gamete because 63 chromosomes is an odd number and when the chromosomes pair up during Prophase I during meiosis, there is one chromosome without a partner.
- A liger is the result of a male lion and a female tiger mating. The offspring are sterile cross-species hybrids.

Evolution in present times

Evolution takes place over many, many years and is therefore difficult to witness in a lifetime. However, there are examples of organisms adapting to their changed environment over a few generations. Organisms that can be observed changing and evolving are very small or micro-organisms, as they reproduce very quickly.

Examples of natural selection and evolution

Resistance to insecticides by insects

Insecticides are used to kill insects that eat crops and flowers. The insecticide kills most of the insects but some that are resistant to the poison will survive. They will remain and breed to produce offspring who will have the resistant gene. Therefore the insecticide is of no use, as the insects that are resistant to it survive and continue to harm the crop. The insect species has evolved because an environmental pressure has killed off some of the species and only those that are resistant to the poison survive.

- DDT is an insecticide that was introduced in 1945 to kill the mosquito that carries the malaria parasite. After a few years, malaria increased again. The mosquitoes had become resistant to DDT. The DDT also killed birds and fish that naturally prey on mosquitoes and therefore there were no longer any natural predators. This gave rise to an increase in the mosquito populations.
- The Colorado beetle feeds on potatoes. It is now resistant to about 50 of the most commonly used insecticides.

Bill and body size of Galapagos finches

- The most distinguishing characteristics of the finches on the Galapagos Islands are their body size and the shape and size of their beaks.

Two scientists, Peter and Rosemary Grant, have been studying these finches since 1973. Over these years they have studied the environmental pressures that have led to natural selection.
• In 1977 and the following years the Galapagos Islands experienced a severe drought. The seed supply was short, except for some large, tough seeds that the birds normally did not eat. There was great competition and a struggle for survival. Only the birds with the larger and stronger beaks managed to crack open and eat these seeds. These were the finches that managed to survive and were able to reproduce, whereas the population of the others decreased. The population had changed to suit the environment, an example of the survival of the fittest.

• In 1984 and 1985 there was more rain than usual. There was once again a good supply of the small, soft seeds. The finches with smaller beaks were the successful birds now. The larger birds with the larger and stronger beaks were without a good food source. They started to decrease in numbers and the birds with the smaller beaks flourished. The smaller finches with the smaller beaks had developed to suit the new environment by natural selection.

Resistance to antibiotics in various bacteria

An antibiotic is a drug produced by micro-organisms to kill other micro-organisms. For example, penicillin is produced by a fungus and it kills certain bacteria. The discovery of antibiotics has saved millions of lives. In some instances:

• The incorrect antibiotic is given.
• The patient does not complete a course of antibiotics.
• The patient may not need an antibiotic.

In these cases some of the bacteria that have a gene or genes that are resistant to the antibiotic can survive and continue to multiply. The particular antibiotic will no longer kill this species of bacteria. A new antibiotic needs to be developed.

A bacterium that evolves to become resistant to a number of drugs or antibiotics is said to be multi-drug resistant (MDR) and is referred to as a 'superbug'.

Tuberculosis (TB) is caused by the bacterium *Mycobacterium tuberculosis* and for the most part attacks the lungs. It is a serious disease that can spread quite easily. In recent years a number of antibiotic-resistant varieties have evolved. There are two antibiotics that are commonly used and the TB bacteria (MDR-TB) are now resistant to them.

Some of the TB bacteria are resistant to more than the two commonly-used antibiotics and this variety that has evolved is called XDR-TB or extremely drug-resistant. The first well-publicised cases of this bacterium occurred at Tugela Ferry, KwaZulu-Natal, in 2006. It takes up to two years of using very expensive antibiotics to treat these patients. The side effects are not pleasant.

It is very important to complete a course of antibiotics, even if you are feeling well.

Antibiotics are also used in agriculture to treat or prevent disease in cattle, chickens, pigs and fish, which are farmed in great numbers. Resistant forms of bacteria have evolved. Some of these bacteria are consumed in the meat by humans. The resistant genes can be passed on to bacteria species that infect humans.

HIV resistance to anti-retroviral drugs

Anti-retroviral drugs are used to treat HIV (Human Immunodeficiency Virus). HIV causes AIDS (Acquired Immune Deficiency Syndrome). The anti-retroviral drug stops the virus from multiplying and increasing in number. The reproduction of the virus is therefore slowed right down and the patient can lead a fairly normal life for many years.

There are five different classes of anti-retroviral drugs to treat HIV. Recently some forms of the virus have become resistant to the anti-retroviral drugs. A patient is given a combination of drugs, in other words drugs from two or more classes are given to ensure that all the viruses will be controlled. This is known as combination therapy. It is important to take these medicines correctly to prevent more and more forms of HIV from becoming resistant to the drugs.

MY OWN NOTES
Questions

This unit is examined in Paper 2 for about 23 marks (15%).

Question 1

2014 Exemplar Paper 2

Scientists investigated the resistance of mosquitos to DDT.

The following steps were followed:

• They captured a sample of mosquitos from the environment.
• The mosquitos were then exposed to a standard dose of DDT (4% DDT for 1 hour) in the laboratory.
• The number of mosquitoes that died was counted.
• Those that survived were left to reproduce.
• A sample was taken from this population every two months and the same procedure was followed for a period of 16 months.

The results are shown in the table below:

<table>
<thead>
<tr>
<th>Time (in months)</th>
<th>Mortality of mosquitoes (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>87</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
</tr>
<tr>
<td>6</td>
<td>69</td>
</tr>
<tr>
<td>8</td>
<td>60</td>
</tr>
<tr>
<td>10</td>
<td>54</td>
</tr>
<tr>
<td>12</td>
<td>35</td>
</tr>
<tr>
<td>14</td>
<td>27</td>
</tr>
<tr>
<td>16</td>
<td>22</td>
</tr>
</tbody>
</table>

1.1 Identify the:

(a) Independent variable ____________________________ (1)
(b) Dependent variable _____________________________ (1)

1.2 Formulate a hypothesis for this investigation. (3)

__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
__________________________________________________________________________
1.3 Draw a line graph to show how mortality of mosquitoes changed over the period of the investigation due to the application of DDT. (6)

1.4 State TWO factors, other than those mentioned, that should be controlled in this investigation. (2)

1.5 State TWO ways in which the scientists could improve the reliability of their results. (2)

1.6 Explain, in terms of natural selection, how mosquitoes may develop resistance to DDT. (8)
Question 2
2014 February/March Paper 1
Many species of cichlid fish are found in Lake Malawi. All these species have evolved from a single ancestral species. The diagrams below show the mouths of three different cichlid fish species formed through sympatric speciation in the same lake in Malawi. It also gives information about their feeding methods.

Species A
Eats insect larvae
Species B
Eats algae from stones
Species C
Eats floating plankton

2.1 State ONE advantage of the three cichlid species being specialised feeders, and eating different types of food. (2)

2.2 Describe the process that led to the formation of the three species of cichlid. (6)

Question 3
2013 February/March Paper 1
The diagram below shows five closely-related species of finches found on the mainland and on four nearby islands:

Closely-related species of finches found on the mainland and on four nearby islands
3.1 Describe how the different species on the four islands evolved over many generations from the original ancestor on the mainland.

---

**Question 4**

*2012 February/March Paper 1*

A group of learners from a school decided to do an investigation, using scientific literature, on the evidence presented by fossils to support the theory of evolution.

They formulated the following hypothesis:

'First appearance of fossils of single-cell/simple organisms are found in the oldest layers of rock'

A summary of their research from the scientific literature is shown in the table below:

<table>
<thead>
<tr>
<th>Era</th>
<th>Geological timescale (million years ago)</th>
<th>Major events in the history of life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic</td>
<td>65–present</td>
<td>Appearance of <em>Homo</em> species. Flowering plants, insects, birds and mammals became dominant.</td>
</tr>
<tr>
<td>Palaeozoic</td>
<td>570–240</td>
<td>Origin of reptiles, early fish, insects and spore bearing plants which became dominant. Origin of simple marine invertebrates and animals with hard parts.</td>
</tr>
</tbody>
</table>

4.1 According to the results in the table above, will the learners accept or reject their hypothesis? (1)

4.2 Explain your answer to Question 4.1. (2)

4.3 Explain the implications to the evolution theory if fossils of dinosaurs from the early Pre-Cambrian period were found. (2)

4.4 Explain why the invertebrates might have appeared earlier than our fossil record currently shows. (2)
Question 5
Study the diagram of a duck's foot alongside:

5.1 Ancestors of ducks did not have webbed feet. In terms of natural selection, explain how the webbed feet could have evolved. (7)

The following questions refer to Lamarck's explanation of evolution:

5.2 Describe the idea proposed by Lamarck to explain evolution. (4)

5.3 State why Lamarck's explanation is not accepted by most scientists today. (2)

Question 6
DBE NSC November 2015 Paper 2
The diagrams below represent the process of speciation in tortoises. Over a period of time species B and C evolved from species A.

UNIT 10 Evolution by natural selection
6.1 Explain why species A continued to exist on island 1. (2)

6.2 Describe how species B and C evolved from species A. (6)

---

**Question 7**

*DBE NSC November 2015 Paper*

The extract and the diagram below provide information about a type of antelope called a Bongo:

The Bongo is a large antelope species that is active at night and found in the dense jungles and forests of Africa. The dense forests have very little ground vegetation so the Bongo feeds in forest openings where new herbs and shrubs grow closer to the ground. They are preyed on by lions and leopards.

- Light brown coat and mane with white stripes
- Short, brown tail with black tip
- Dark brown belly
- Horns that can be laid flat along the back when running through dense vegetation
- Black and white markings on the face, chest and legs

7.1 State TWO characteristics that help the Bongo to camouflage themselves in the dense jungle. (2)

7.2 Use your knowledge of natural selection and explain how the Bongo's ability to lay its horns along its back could have developed over the years. (5)
**Question 8**

*DBE NSC November 2015 Paper*

The characteristics of organisms can be changed through selective breeding and the genetic engineering process.

8.1 State TWO similarities between the selective breeding process and the genetic engineering process. (2)

8.2 Explain TWO reasons why some people may be against the use of genetic engineering. (4)

**Question 9**

*DBE NSC November 2009 Paper 2*

9.1 The shell of the banded snail, *Cepaea nemoralis*, displays a wide variety of both colour and banding (rings). Birds, such as thrushes, eat these snails. The birds break open the shells by striking the snails against a stone.

It was found that there were equal numbers of light- and dark-banded snails in a specific grassland habitat where no thrushes were found. A population of thrushes was then introduced to this grassland.

An investigation was done to determine what colour snails (dark-banded or light-banded) were eaten most by the thrushes.

The results are shown below:

<table>
<thead>
<tr>
<th>Time (days)</th>
<th>Number of dark-banded shells found around stone</th>
<th>Number of light-banded shells found around stone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>1</td>
</tr>
</tbody>
</table>

9.1 Write a possible hypothesis for this investigation. (3)

9.2 What phenomenon does this investigation illustrate? (1)

9.3 Which snails were better adapted to prevent them from being eaten by the thrushes? (1)

9.4 Explain your answer to Question 9.3. (2)

9.5 Why can the number of snails at the start of the investigation be considered a controlled variable? (1)
**Answers**

**Question 1**

1.1 (a) time✓
(b) Mortality of mosquitoes✓

1.2 Mosquito Mortality due to DDT✓/Resistance of mosquitoes to DDT will decrease✓ over time✓
OR
Mosquito Mortality due to DDT✓/Resistance of mosquitoes to DDT will increase✓ over time✓
OR
Mosquito Mortality due to DDT✓/Resistance of mosquitoes to DDT will remain the same✓ over time✓

**Note:**
If the wrong type of graph is drawn:
- Marks will be lost for 'correct type of graph'
If axes are transposed:
- Marks will be lost for labelling of X-axis and Y-axis

1.3 Mark allocation for the graph:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Elaboration</th>
<th>Mark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of graph</td>
<td>Line graph drawn</td>
<td>1</td>
</tr>
<tr>
<td>Caption</td>
<td>Includes both variables: 'Percentage mortality of mosquitoes' and 'Time'</td>
<td>1</td>
</tr>
<tr>
<td>X-axis</td>
<td>Appropriate scale AND</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Correct label and units for X-axis: Time (months)</td>
<td></td>
</tr>
<tr>
<td>Y-axis</td>
<td>Appropriate scale AND</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Correct label and units for Y-axis: Mortality of mosquitoes (%)</td>
<td></td>
</tr>
<tr>
<td>Plotting of points</td>
<td>1-8 points plotted correctly - 1 mark</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All 9 points plotted correctly - 2 marks</td>
<td></td>
</tr>
</tbody>
</table>

Graph (6)

1.4 Same species of mosquito
- Identical laboratory conditions for the full period of the investigation ✓
- The same scientist must be used for the full period of the investigation ✓
- Mosquitos should not be hurt for the full period of the investigation ✓

(Mark first TWO only) (any 2) (2)

1.5 Use a larger sample of mosquitoes✓
- Repeat the investigation ✓
- Take many samples each time and calculate the average mortality ✓

(Mark first TWO only) (any 2) (2)

1.6 More mosquitoes are produced than can survive✓✓
- There is genetic variation ✓ amongst the mosquitoes.
- Some mosquitoes may be naturally resistant to DDT ✓✓
- When DDT is applied ✓
- those that are resistant survive ✓
- then reproduce ✓✓
- passing the allele for resistance to the offspring ✓✓

- Those that are not resistant, die ✓✓
- and their alleles are lost from the population ✓✓✓
- The number of DDT-resistant mosquitoes therefore increases over the generations ✓

(any 8) (8) (23)

**Question 2**

2.1 There is no interspecific competition ✓/there is no competition between the different species
This ensures the survival of each species ✓✓ as they are feeding within their own niche ✓

(any 2) (2)

2.2 Each species has a different diet and therefore different habitats/niches ✓
Each group underwent natural selection independently ✓
Each species becomes reproductively isolated/no longer reproduce with each other ✓
Gene flow between the groups no longer takes place ✓
And developed differently ✓
Genotypically and phenotypically ✓
They are isolated from each other ✓

(any 8) (2)
Question 3
3.1 Finch population had variation // different beak sizes
   *The population was separated by a geographical // physical barrier
   *Allopatric // speciation took place
As the separate islands had different environmental conditions // have different vegetation//different food for finches
Each group underwent natural selection independently
And developed differently
Genotypically and phenotypically
Gene flow // reproduction between the different populations did not occur
Resulting in new species being formed
(*Compulsory 2 marks and any other 6) (8) [8]

Question 4
4.1 Accepted // not rejected (1)
4.2 The bacteria//single-cell organisms appear in the oldest rock layers // strata // multi-celled // complex organisms appear later in Palaeozoic era // older era is equivalent to older rock strata (any 2) (2)
4.3 It would indicate that complex organisms did not evolve from simple organisms // therefore the theory will be rejected
OR
It would mean that first protists and dinosaurs co-existed // therefore dinosaurs did not evolve from protists (2) (2)
4.4 Invertebrates have soft bodies // which decay easily // do not fossilise
OR
Some invertebrates may have had an exoskeleton // which decays easily // does not fossilise
OR
Earlier fossils of invertebrates // might not yet have been discovered (2) (2)[7]

Question 5
5.1 There was variation // with regard to the feet within the ancestral duck populations
- Some ancestral ducks had skin // attached between the toes
- As food became scarce // environment changed
- Competition for food increased
- Those ducks which had skin attached between their toes // desired characteristic could swim better
- To secure food and survived
- Those ducks that did not have skin attached between their toes were unable to swim well
- Did not secure food and died
- Through natural selection entire populations // of ducks with webbed feet evolved (any 7) (7)
5.2 (a) If you use organs//structures repeatedly it develops // and organs and structures that are not used // disappear (4)

Acquired // characteristics are inherited
b) Acquired characteristics // are not inherited // only characteristics that are controlled by the genes are inherited
(2) (13)

Question 6
6.1 - Conditions//example on the island probably remained the same
- so they experienced the same selection pressure
- species A was already suited to those conditions (any 2) (2)
6.2 - The original species was separated // into three // different populations
- by the sea
- which acted as a geographical barrier
- There was no gene flow // between the populations
- Each population was exposed to different environmental conditions
- Natural selection occurred independently in each population
- and the individuals of each population became different // from each other over time
- genotypically // phenotypically
- Even if the three populations were to mix again
- they would not be able to reproduce with each other // interbreed
(1 *Compulsory mark + any 5) (6) [8]

Question 7
7.1 - Coat is light brown // on the upper side
- Dark brown belly
- White stripes on the back and mane
- Black and white patches on the rest of the body
- The tip of the tail is black (Mark first TWO only) (any 2) (2)
7.2 - There is variation // amongst the Bongo population
- Some have horns that can be laid on their backs
- while others do not have horns that can be laid on their backs
- The antelope must move through dense vegetation // without their horns getting entangled in the vegetation
- Those with horns that cannot be laid on their backs become entangled // die
- Those with horns that can be laid on their backs do not become entangled and escape predators // survive
- Those with horns that can be laid back will reproduce
- and pass the gene for horns that can be laid on their backs to the next generation
- Over many years the proportion of animals that are able to lay their horns on their backs increases

UNIT 10 Evolution by natural selection
Question 8
8.1 - Characteristics that are desirable/beneficial to humans are being selected
- The characteristics are chosen by humans. It is an artificial process
- It is not necessarily beneficial for the organism
(Mark first TWO only) (any 2) (2)
8.2 - The long-term effects on health are unknown which could lead to health problems in the future
- The long-term effects on the environment are unknown leading to environmental damage/ loss of biodiversity/damaging ecosystems/ nature
- People are morally opposed as humans are interfering with nature/ playing God/ interfering with the rights of every species
- Initially it is an expensive process and many people/countries may not be able to afford it
(Mark first TWO only) (any 2 x 2) (4) [6]

Question 9
9.1 Equal number of light and dark-banded snails will be eaten
OR
More light-banded snails will be eaten
OR
Less light-banded snails will be eaten
OR
More dark-banded snails will be eaten
OR
Less dark-banded snails will be eaten (3)
9.2 Natural selection/camouflage/predation/survival of the fittest/micro-evolution (1)
9.3 Light-banded OR Dark-banded (1)
9.4 Lower number of light-banded shells found, indicating that they are not easily detected by the birds
OR
Higher number of dark-banded shells found, indicating that they are not easily detected camouflaged by the birds (2)
9.5 Started with equal numbers of light and dark-banded snails in the environment (1) [8]
**Unit 11  Human evolution**

**Evidence of common ancestors for living hominids, including humans**

Anatomical differences and similarities between African apes and humans (hominins)

Both apes and humans are hominids.

**Fossil evidence**

<table>
<thead>
<tr>
<th>Key features</th>
<th>African apes (knuckle walkers)</th>
<th>Humans/Hominins (bipedal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td>Chimpanzees, gorillas, bonobo apes</td>
<td><em>Ardipithecus, Australopithecus, Homo</em></td>
</tr>
<tr>
<td>Bipedalism – to walk on two legs.</td>
<td>Longer arms. Use the knuckles on their front limbs for support.</td>
<td>Relatively shorter arms.</td>
</tr>
<tr>
<td>Pelvic girdle</td>
<td>Long narrow pelvis.</td>
<td>Cup-shaped pelvis with wider sacrum and hips.</td>
</tr>
<tr>
<td>Spinal curvature</td>
<td>Spine is not so curved.</td>
<td>Spine is curved.</td>
</tr>
<tr>
<td>Foramen magnum</td>
<td>The foramen magnum is near the back of the skull. When the ape walks the skull is in front of the spinal cord (and the rest of the body).</td>
<td>The foramen magnum is near the middle (underneath) of the skull. The skull is above the spinal cord when standing upright and walking.</td>
</tr>
<tr>
<td>Key features</td>
<td>African apes</td>
<td>Humans/Hominins</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Feet</td>
<td>The ape foot bones are more spread out with the toe like an opposable thumb.</td>
<td>Human foot is more compact to carry the full weight of the body. The big toe is in line with the other toes.</td>
</tr>
<tr>
<td></td>
<td><img src="image1.png" alt="Ape Foot" /></td>
<td><img src="image2.png" alt="Human Foot" /></td>
</tr>
<tr>
<td>Brain case size</td>
<td>Large – need a large brain for coordination.</td>
<td>Larger frontal area, which requires a large cranium and a higher forehead to house and protect it.</td>
</tr>
<tr>
<td></td>
<td><img src="image3.png" alt="Brain Case" /></td>
<td><img src="image4.png" alt="Brain Case" /></td>
</tr>
<tr>
<td>Teeth (dentition)</td>
<td>Larger teeth. Large canines. Gaps between incisors and canines.</td>
<td>Smaller teeth. Canine is smaller. No gaps between the incisors and canines.</td>
</tr>
<tr>
<td>Same dental formula.</td>
<td><img src="image5.png" alt="Ape Teeth" /></td>
<td><img src="image6.png" alt="Human Teeth" /></td>
</tr>
<tr>
<td>Prognathism = jaws that stick out beyond the brow. Palate shape</td>
<td>Longer jaw – stronger muscles required for their diet of tough (uncooked) foods. Face is large and protruding in the front i.e. prognathian face. Palate is long and rectangular in shape.</td>
<td>Shorter jaw – do not need strong muscles for their diet of softer (cooked) foods. Face is small and flatter in the front i.e. an orthognathian face. Palate is small and semi-circular in shape.</td>
</tr>
<tr>
<td></td>
<td><img src="image7.png" alt="Ape Jaw" /></td>
<td><img src="image8.png" alt="Human Jaw" /></td>
</tr>
<tr>
<td>Cranial ridge across the top of the cranium (for the attachment of jaw muscles)</td>
<td>There is a ridge for the attachment of the large jaw muscles.</td>
<td>No cranial ridge as humans have smaller jaws and do not need large jaw muscles.</td>
</tr>
<tr>
<td></td>
<td><img src="image9.png" alt="Ape Cranial Ridge" /></td>
<td><img src="image10.png" alt="Human Cranial Ridge" /></td>
</tr>
<tr>
<td>Brow ridge above eye sockets</td>
<td>Large brow ridge.</td>
<td>Small brow ridge. More upright brow, which holds a larger brain.</td>
</tr>
<tr>
<td></td>
<td><img src="image11.png" alt="Ape Brow" /></td>
<td><img src="image12.png" alt="Human Brow" /></td>
</tr>
</tbody>
</table>

Anatomical differences between apes and man
The number of fossils that have been found
- Evidence is based on many thousands of fossil fragments (pieces) found of hominins, as well as fossil remains of fires and bones of animals that were eaten.
- Fragments must be dated.
- Fragments and whole fossils carefully studied.
- Trace fossils of footprints found (1976) at Laetoli in Tanzania dated 3,6 mya.
- Information compiled from these studies.

Genetic evidence
- Modern technology, using DNA fingerprinting, has allowed genetic studies.
- 98% of human genome is identical to that of the chimpanzee.
- Shows that they must have a common ancestor.

Mitochondrial DNA
- Mitochondria contain their own DNA (mtDNA).
- mtDNA is different from that of nuclear DNA.
- It is circular like the plasmids found in bacteria.
- Only the nucleus of a sperm fertilises an ovum. The middle piece of the sperm that contains the mitochondria does not enter the ovum. Offspring have only the mtDNA from the mother.
- mtDNA is therefore only passed from one generation to another through the females.
- An individual’s mtDNA will be identical to its mother and grandmother and great grandmother and so on. (Female line of descent.)
- An individual’s mtDNA will be identical to that of their brothers and sisters.
- Used to determine:
  - If people are related to the same mother/grandmother.
  - How long ago the first modern people appeared – 6 mya – a date that matches fossil evidence.
  - If humans descended from one group of hominids or did they evolve in different places.
  - Where and when the original ancestors lived.

Cultural evidence: tool-making
- Culture is any form of learned behaviour e.g. making tools, socially accepted rules, rites of passage, body decoration.
- Cultural evolution happens much faster than biological evolution.
- Speed of cultural evolution is based on verbal or written language.
- In 5,000 years humans have progressed from using stone tools to cell phones and computers. Biologically there has been no change in humans in 5,000 years.
- Cultural evolution does not leave evidence such as fossils.
- Remains of tools, tool-making and fire are used to show changes in culture.
- Oldowan culture – name derived from Olduvai Gorge (Tanzania). The tools here were simple stone tools, which had had some pieces chipped off them. Before 2 mya. Made by Homo habilis.
- Acheulian culture – made by Homo erectus. Hand axes with a sharper cutting edge and more shape. 1.7 mya to 200,000 years ago.
- From 200,000 years ago tools became more complex, e.g. spears, choppers, a sharp tool to skin animals. This shows that hominins (Homo sapiens) were hunting their own food rather than eating from the leftover carcasses of a kill made by other predators.
- After 12,000 years ago (Stone Age) more sophisticated tools have been found, e.g. bows and arrows, spear throwers. Ornamental items have been discovered, e.g. ivory beads, necklaces made from animal teeth, small statues. Needles made from bone with thread made from animal sinews have been found. Paintings appear on the walls of caves.
- The Stone Age was followed by the Copper Age, then the Bronze Age and finally the Iron Age.
Out of Africa hypothesis

Evidence of African origins for all modern humans

The 'Out of Africa' hypothesis states that modern humans originated in Africa and then migrated out of Africa to the other continents.

The following have been used to support this hypothesis:

- Genetic links: Hominins split from the other hominids about 6 mya, and have developed alongside each other since then. This happened in Africa as the modern chimpanzee is purely an African species and humans have 98% of their genome that is common with that of the chimps.

- The oldest fossils of *australopithecines/Homo habilis/bipedal organisms* have been found only in Africa.

- The oldest fossils (2.4 mya) of *Homo erectus* have been found only in Africa.

- Analysis of mutations in mitochondrial DNA (mtDNA) shows that the oldest female ancestors of humans are from Africa.

- Analysis of mutations on the Y chromosome shows that the oldest male ancestors of humans are from Africa.

Key:

- Great Rift Valley
- 1 Afar Depression
- 2 Turkana
- 3 Olduvai Gorge
- 4 Cradle of Humankind

The Great Rift Valley runs from the Middle East to southern Africa
Scientists who discovered early hominins in East Africa

- Donald Johanson (1943 – ) In 1974, working in the Afar Depression, he and his colleagues discovered 'Lucy', scientific name *Australopithecus afarensis*. The skeleton was about 45% complete. Many bone fragments and teeth of other skeletons have since been found.

- Tim White (1950 – ) In 1992 and 1993 also working in the Afar Depression, he organised an expedition (1992 and 1993) that found and studied the earliest hominin fossils in the region.

- The Leakey family: Louis Leakey (1903 – 1972) and his wife Mary (1913 – 1996) worked from 1935, at Olduvai Gorge in the Serengeti Plains of northern Tanzania. After Louis’ death Mary continued to work there. They discovered many fossils and tools used by the different hominins.

- Their sons, Jonathan Leakey (1940 – ) and Richard Leakey (1944 – ), followed their parents in their careers and made important discoveries near Lake Turkana in northern Kenya on the border with Ethiopia. Richard’s wife, Maeva (1942 – ), and their daughter, Louise (1972 – ), are still actively discovering new fossils and new species near Lake Turkana.

Fossils discovered at/near the Rift valley sites in East Africa

- Chad in North Africa, nine skulls similar to modern apes were found and named *Sahelanthropus tchadensis*. They have a foramen magnum under their skull therefore were bipedal and not apes. Dated between 6 and 7 million years old, about the time when apes and hominins split.

- Tugen Hills area of Kenya: Thirteen bones of an ape-like animal with some hominin features named *Orrorin tugenensis* were found. The femur shows that it might have walked upright. Dated about 6 million years old.

Both of these show that hominins originated in Africa.

- Afar Depression: In 1992/1993 an expedition organised by Tim White discovered *Ardipithecus ramidus*, which lived here about 4.5 mya. More recent expeditions (2009) have found about nine other individuals.

<table>
<thead>
<tr>
<th>Feature</th>
<th><em>Ardipithecus ramidus</em></th>
<th><em>Australopithecus</em></th>
<th>Homo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Examples</td>
<td><em>Ardipithecus ramidus</em></td>
<td><em>Australopithecus afarensis</em> (Lucy)</td>
<td><em>Homo habilis</em> (handyman)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Australopithecus africanus</em> (Mrs Ples)</td>
<td><em>Homo erectus</em> (upright man)</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Australopithecus robustus</em></td>
<td><em>Homo heidelbergensis</em></td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Australopithecus sediba</em></td>
<td><em>Homo sapiens</em> (wise man)</td>
</tr>
<tr>
<td>Common name</td>
<td>Earliest Ape Man</td>
<td>Southern Ape Man</td>
<td>Humans</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two types: Gracile (slender) – lighter</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>but stockier than modern humans.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Robust (strong and powerfully built) –</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>larger skull with larger molar, cranial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ridge for muscle attachment, broader</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>than modern humans.</td>
<td></td>
</tr>
<tr>
<td>Found</td>
<td>Afar Depression, Africa</td>
<td>Fossils only found in Africa</td>
<td>Along Rift Valley and South Africa</td>
</tr>
<tr>
<td>Age</td>
<td>4,5mya.</td>
<td>3,9 to 2,5mya</td>
<td>2,4mya to present</td>
</tr>
<tr>
<td>Size</td>
<td>Small hominin.</td>
<td>Mostly small – about the size of a nine-year-old child</td>
<td>Mostly larger</td>
</tr>
<tr>
<td>Hind foot and limbs</td>
<td>Big toe able to grip like a thumb. Feet were rigid for walking</td>
<td>Big toe in line with the rest of the toes. Fully bipedal</td>
<td>Bipedal and longer legs</td>
</tr>
<tr>
<td>Arms</td>
<td>Long for climbing</td>
<td>Long for climbing</td>
<td>Shorter arms</td>
</tr>
<tr>
<td>Brain</td>
<td>Small brain: 350cm³</td>
<td>Small brain: 400 to 500cm³</td>
<td>Larger brain – increased frontal part (large forehead): 1 200 to 1 700cm³</td>
</tr>
<tr>
<td>Skull and face</td>
<td>Prognathous face</td>
<td>Prognathous face</td>
<td>Orthognathous face</td>
</tr>
<tr>
<td></td>
<td>Heavy brow ridges</td>
<td>Heavy brow ridges</td>
<td>No brow ridges</td>
</tr>
<tr>
<td>Teeth and diet</td>
<td>Teeth show diet of mainly plant material and fruit</td>
<td>Large-toothed</td>
<td>Smaller, less specialised</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thicker layers of enamel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Large jaws</td>
<td></td>
</tr>
</tbody>
</table>

Summary of information on the hominin fossils found along the Rift Valley and in South Africa
**Fossil sites in South Africa**

South Africa, especially The Cradle of Humankind (see more details later), is a site rich in fossil findings.

Fossils discovered at these sites: *Australopithecus and Homo*

### Australopithecus

*Australopithecus* (Australo’ means southern and ‘pithecus’ means man).

No fossils dated earlier than *Australopithecus* have been found in South Africa.

<table>
<thead>
<tr>
<th>Fossil</th>
<th><em>Australopithecus africanus</em></th>
<th><em>Australopithecus robustus</em></th>
<th><em>Australopithecus sediba</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dated  (mva)</td>
<td>3,3 to 2,1</td>
<td>1,8 to 1,2</td>
<td>1,95 to 1,78</td>
</tr>
<tr>
<td>Site where found</td>
<td>Taung and Sterkfontein</td>
<td>Kromdraai</td>
<td>Malapa</td>
</tr>
<tr>
<td>Features</td>
<td>Gracile</td>
<td>Robust</td>
<td>Gracile</td>
</tr>
<tr>
<td>Feet</td>
<td>Rigid</td>
<td>Rigid</td>
<td>Rigid</td>
</tr>
<tr>
<td>Arms</td>
<td>Long</td>
<td>Long</td>
<td>Long</td>
</tr>
<tr>
<td>Brain case size</td>
<td>500 cm³</td>
<td>530 cm³</td>
<td>420 cm³</td>
</tr>
<tr>
<td>Face</td>
<td>Prognathous</td>
<td>Less prognathous</td>
<td>Less prognathous</td>
</tr>
<tr>
<td>Brow ridges</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Cranial ridge</td>
<td>Absent</td>
<td>Present</td>
<td>Present</td>
</tr>
<tr>
<td>Teeth</td>
<td>Large, short canines</td>
<td>Molars- very large</td>
<td>_ Uncertain at present _</td>
</tr>
</tbody>
</table>

**Summary of information on Australopithecus**

**Homo**

- First developed in Africa, according to fossil records.
- Earliest Homo fossils are all African. This supports the ‘Out of Africa’ hypothesis.
- About 2,4 million years old.
- Lived alongside the later *Australopithecus* species for a long time.
- Likely that they evolved from gracile Southern Ape Men e.g. *A. africanus* or *A. afarensis*.
- Different to *Australopithecus* because they have:
  - Larger brain cases in relation to their size – the high forehead allows more space for the frontal lobe of the brain.
  - Orthognathous face.
  - Smaller teeth and less specialised.
  - Shorter arms.
  - Longer legs.

Four different species of *Homo* have been found in Africa. See the table below and on the next page:

<table>
<thead>
<tr>
<th>Features/ Fossil</th>
<th>Homo habilis</th>
<th>Homo erectus/ H. ergaster</th>
<th>Homo heidelbergensis</th>
<th>Homo sapien</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common name</td>
<td>Handy man – first tool makers</td>
<td>Upright man/ workman</td>
<td>Archaic Homo sapiens</td>
<td>Wise man</td>
</tr>
<tr>
<td>Discovered</td>
<td>Louis and Mary Leakey, 1963</td>
<td>In S. Africa, 1969. Swartkrans</td>
<td>First found in Heidelberg in Germany in 1908. Since found in Asia, Africa and other parts of Europe. In South Africa fossils have been found in Elandsfontein, near Saldhana.</td>
<td>Earliest – the Florisbad fossil skull. Others found at Makapansgat in Limpopo, Border Cave in KZ-Natal, Blombos Cave on the southern coast in W Cape and in Gaul. Also near Lake Tana and the Awash river in Ethiopia.</td>
</tr>
<tr>
<td>Discovered at</td>
<td>Olduvai Gorge, Tanzania</td>
<td>Wide area: North, East and South Africa. Also in Britain, Georgia, China. First one in Java, Indonesia in 1891.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Features/ Fossil</th>
<th>Homo habilis</th>
<th>Homo erectus/ H. ergaster</th>
<th>Homo heidelbergensis</th>
<th>Homo sapien</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dated mya</td>
<td>2.4 to 1.4</td>
<td>1.9mya to 143 000 yrs ago</td>
<td>700 000 yrs ago in</td>
<td>200 000 yrs ago</td>
</tr>
<tr>
<td>Features</td>
<td>About half the height of modern humans</td>
<td>Taller – about the size of humans</td>
<td>Wide, muscular body</td>
<td>Smaller body</td>
</tr>
<tr>
<td>Skull</td>
<td>Smaller eye sockets</td>
<td>Elongated skull. Brow bridge – prominent</td>
<td>Flatter face No distinct chin Large brow ridge Low forehead – no room for large frontal lobes</td>
<td>Rounded skull No brow ridge Distinct chin</td>
</tr>
<tr>
<td>Brain case</td>
<td>650cm³</td>
<td>900cm³</td>
<td>1 200cm³</td>
<td>1 700cm³</td>
</tr>
<tr>
<td>Jaw</td>
<td>Strongly built and rounded</td>
<td>Flatter</td>
<td>Small, less specialised</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Teeth</td>
<td>Smaller than Australopithecus</td>
<td>Flatter</td>
<td>Small, less specialised</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Face</td>
<td>Less prognathous</td>
<td>Flatter</td>
<td>Small, less specialised</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Arms</td>
<td>Long (tree dwelling)</td>
<td>Shorter</td>
<td>Orthognathus</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Legs</td>
<td>Shorter</td>
<td>Longer</td>
<td>Orthognathus</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Foot</td>
<td>Modern arch present</td>
<td>Orthognathus</td>
<td>Orthognathus</td>
<td>Orthognathus</td>
</tr>
<tr>
<td>Behaviour</td>
<td>Fossils found with stone tools. Tools for cutting, chopping and pounding food. Evidence of bones and meat being butchered, (Oldowan culture)</td>
<td>Fossils often found with tools (Acheulian culture) and early controlled use of fire (cooking). Carnivorous – hunted and therefore moved to find prey. Hunter-gatherers. Built shelters. First to migrate out of Africa (1.8mya). Lived in Africa alongside Homo habilis and Australopithecus robustus.</td>
<td>Had to cope with colder climates. Evidence of hunting with wooden spears – sharpened poles.</td>
<td>Probably evolved during the harsh climatic conditions of an ice age. 100 000 years ago migrated out of Africa. The final migration 'Out of Africa'</td>
</tr>
</tbody>
</table>

Summary of the evolution of hominins

A recent discovery by Lee Berger

_Homo naledi_ was discovered in Dinaledi chamber of the Rising Star cave system in the Cradle of Humankind. The discovery took place in September 2013 but the information was only announced to the world in September 2015. The new fossils were named _Homo naledi_. 'Naledi' means 'star'. Over 1 550 fossilised bone specimens of _H. naledi_ were found. The remains are of at least 15 individuals of different ages. The fossils are difficult to date because of the type of sediment that they are found in. The age is thought to be between 912 000 years to 2 million years old. The exact date is still to be confirmed once an accurate dating technique can be found. _Homo naledi_’s position on the phylogenetic tree is still uncertain. The face, skull, teeth and feet show enough similarity as to place it with _Homo sapiens_ but it also has characteristics of Australopithecines (the pelvis) and _H. habilis_ (curved bones of the hand) and _H. erectus_ (cranial characteristics – small brain; upright posture). It is thought that _H. naledi_ walked upright but also had features indicating that they climbed trees.

There are still many questions that need to be answered about _Homo naledi_. This is an example of the exciting nature of science.
The timelines below show the time line of the different hominin species and how they overlapped, in other words, living alongside each other:

Possible connections between some recent Homo species

Key:

Homo erectus evolved into several different species

Importance of the Cradle of Humankind

The Cradle of Humankind is in the Sterkfontein valley, north-west of Johannesburg. It is a World Heritage Site, which means it must be protected and conserved as it provides important historical knowledge for the whole of humankind. It has much value for the study of hominin (and other) fossils.

- More than one third of all African hominin fossils have been found here.
- More than 500 hominin fossils have been found at this site.
- More than 9 000 stone tools have been found here.
- Of a system of more than 200 caves, only 13 have been excavated.
- Caves are formed in limestone rocks and the organisms in the caves have been well preserved.
- This has been a stable landscape for millions of years.
Main fossil sites in South Africa

<table>
<thead>
<tr>
<th>Name of site</th>
<th>Where in South Africa</th>
<th>See the map page 132</th>
<th>Discovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taung</td>
<td>Southern North West Province</td>
<td></td>
<td>1924 Taung child skull. Found by Dart. Probably killed by a raptor. First hominin fossil found in Africa.</td>
</tr>
<tr>
<td>Sterkfontein Caves</td>
<td>Gauteng near Krugersdorp</td>
<td></td>
<td>1947 Ples. 1997 Little Foot. A. africanus 2,1 mya and more than 3 mya.</td>
</tr>
<tr>
<td>Kromdraai Wonder Cave</td>
<td>Near Sterkfontein (2km)</td>
<td></td>
<td>A. robustus 1,8 to 1,6 mya.</td>
</tr>
<tr>
<td>Swartkrans</td>
<td>Near Sterkfontein (1km)</td>
<td></td>
<td>A. robustus, H. habilis and H. habilis skulls and many small parts found. Evidence of tools as well as controlled use of fire.</td>
</tr>
<tr>
<td>Drimolen</td>
<td>7km from Sterkfontein</td>
<td></td>
<td>Many A. robustus and early Homo fossils. Also bone and horn tools.</td>
</tr>
<tr>
<td>Malapa</td>
<td>Near Muldersdrift 15km from Sterkfontein</td>
<td></td>
<td>Parts of four A. sediba (1,95 mya) fossils skeletons. Thought to be a link between A. africanus and H. habilis or H. erectus</td>
</tr>
<tr>
<td>Plovers Lake Cave</td>
<td>Near Sterkfontein (4km)</td>
<td></td>
<td>H. sapiens. Many bones, other fauna and spears and knives (70 000 years ago). Middle Stone Age remains.</td>
</tr>
<tr>
<td>Gladysvale</td>
<td>13km away from Sterkfontein</td>
<td></td>
<td>1991 A. africanus teeth. H. habilis, hand axe, fossil animals.</td>
</tr>
<tr>
<td>Florisbad</td>
<td>Near Bloemfontein, Free State</td>
<td></td>
<td>1932 archaic H. sapiens skull. Earliest fossil of 259 000 years ago.</td>
</tr>
<tr>
<td>Border Cave</td>
<td>KZN border with Swaziland</td>
<td></td>
<td>Five parts of fossil skulls. Early modern H. sapiens (70 000 years ago).</td>
</tr>
<tr>
<td>Blombos</td>
<td>Near Stilbaai, Cape coast</td>
<td></td>
<td>Modern H. sapiens teeth. Stone tools (60 000 yrs ago), beads (75 000 years ago), ochre artwork (80 000 years ago), signs of fishing (140 000 years ago).</td>
</tr>
</tbody>
</table>

Summary of the main fossil sites in South Africa

Scientists and the role they played in fossil discoveries in South Africa

<table>
<thead>
<tr>
<th>Scientists</th>
<th>Dates</th>
<th>Notes and discoveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robert Broom</td>
<td>1866 – 1951</td>
<td>A Scottish doctor, came to South Africa in 1897. World authority on mammal-like reptile fossils. While working at the Transvaal museum he discovered the importance of the Cradle of Humankind. Found the first skull at Sterkfontein, the first robust Australopithecus at Kromdraai and Homo habilis at Swartkrans. First scientist to prove that Australopithecus walked upright.</td>
</tr>
<tr>
<td>Raymond Dart</td>
<td>1893 – 1988</td>
<td>An Australian, came to South Africa in 1922 to take up a post as Professor of Anatomy at Wits University. In 1924 he received a box of rocks/fossils from a quarry at Taung in the NW province. These fossils turned out to be the Taung child, the first hominin skull ever identified in Africa. Described this find to be a species of early hominins and named it Australopithecus africanus.</td>
</tr>
<tr>
<td>Philip Tobias</td>
<td>1925 – 2012</td>
<td>Born in Durban. Took over from Dart as Professor in 1959. Worked with Louis Leakey. From 1966 he developed the Sterkfontein excavation site. South Africa's leading palaeontologist for many years.</td>
</tr>
<tr>
<td>Bob (CK) Brain</td>
<td>1931 -</td>
<td>Zimbabwean palaeontologist working on the deposits of debris in caves at the Cradle of Humankind. His fossil discoveries showed that many hominins evolved as a result of being preyed upon and that Australopithecus and early humans lived alongside each other.</td>
</tr>
</tbody>
</table>

(Continued on the following page)
<table>
<thead>
<tr>
<th>Scientists</th>
<th>Dates</th>
<th>Notes and discoveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Andre Keyser</td>
<td>1938-</td>
<td>A geologist and palaeontologist who originally studied mammal-like reptiles. Found more fossil humans than anybody else. Most of his early work was at Drimolen in the Cradle of Humankind.</td>
</tr>
<tr>
<td>Ron Clarke</td>
<td>1944-</td>
<td>Professor of Palaeontology at Wits University. Worked with Louis Leakey. He discovered and studied 'Little Foot', an Australopithecus fossil. He has also found H. ergaster and H. habilis fossils at Sterkfontein.</td>
</tr>
<tr>
<td>Lee Burger</td>
<td>1965-</td>
<td>Came to South Africa from America in 1989. Works at Wits University and discovered early hominins at Gladysvale cave. In 2008, at Malapa, his son found a fossil of Australopithecus sediba.</td>
</tr>
</tbody>
</table>

**Summary of the scientists who have found fossils in South Africa**

**Alternatives to evolution**

Different cultures and religious groups have different explanations for the origin and development of life on Earth.

**Different cultural and religious explanations for the origin of life on Earth**

**Creationism**
- A supernatural being created the universe and all living organisms as they appear now.
- The Bible is the word of God and therefore everything in it is true.
- These ideas are usually based within a culture and are traditional.
- This is not a scientific explanation.

**Intelligent Design**
- Special kind of Creationism.
- Features of living organisms are very complex therefore they come from an intelligent designer.
- The intelligent designer is God.
- Not based on experimental evidence.

**Biblical literalism**
- What the Bible says is taken literally word for word.
- God made the universe in six days and then rested on the seventh (the book of Genesis).
- Man was formed from the dust of the ground and life was breathed into him through his nostrils.
- Fundamentalists and evangelical Christian communities believe in the Bible completely and do not believe in evolution.

**Theistic evolution**
- Although it does have many scientific aspects, it is not scientific.
- Evolution is the tool that God uses to develop biodiversity, including humans.
- Classic religious ideas are not in disagreement with modern scientific ideas on evolution.

**Cultural ideas**
- Based on stories that describe the origin of a group of people. Stories passed down from generation to generation.
- There is often a god involved.
- Restricted to a certain group of people in a certain area.
Questions

This is examined in Paper 2 for about 43 marks (29%).

Question 1

2014 Exemplar Paper 2

The phylogenetic tree below shows one interpretation of the origin of humans. The dotted lines indicate the possible evolutionary relationships, and the vertical bars show the period during which the organisms are believed to have existed on Earth.

![Phylogenetic tree of human evolution]

1.1 Use the diagram to identify ONE organism that may have competed with *Homo heidelbergensis* for resources. (1)

1.2 Identify the common ancestor that gave rise to both *Paranthropus* and *Homo*. (1)

1.3 (a) For what period of time did *A. africanus* exist on Earth? Show all working. (3)

(b) Name ONE piece of evidence that could be used to prove that *A. africanus* existed during the time period calculated in Question 1.3 (a). (1)
1.4  (a) Which organism *H. ergaster* or *H. neandthalensis*, is more closely related to modern-day humans? (1)

(b) Explain your answer to Question 1.4 (a) using information in the diagram. (2)

---

**Question 2**

*2014 Exemplar Paper 2*

Study the table below, which indicates some of the hominid fossils found in different parts of the world:

<table>
<thead>
<tr>
<th>Species</th>
<th>Area where it was found</th>
<th>Period of existence</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Australopithecus afarensis</em></td>
<td>Eastern Africa</td>
<td>3.4–2.8mya</td>
</tr>
<tr>
<td><em>Australopithecus africanus</em></td>
<td>Southern Africa</td>
<td>2.1–2.8mya</td>
</tr>
<tr>
<td><em>Australopithecus sediba</em></td>
<td>Southern Africa</td>
<td>2.0–1.9mya</td>
</tr>
<tr>
<td><em>Homo habilis</em></td>
<td>Sub-Saharan (Africa)</td>
<td>2.3–1.4mya</td>
</tr>
<tr>
<td><em>Homo erectus</em></td>
<td>Africa, Europe, Asia</td>
<td>1.5–0.2mya</td>
</tr>
<tr>
<td><em>Homo heidelbergensis</em></td>
<td>Europe, China</td>
<td>0.6–0.35mya</td>
</tr>
<tr>
<td><em>Homo neanderthalensis</em></td>
<td>Europe, Western Asia</td>
<td>0.35–0.03mya</td>
</tr>
<tr>
<td><em>Homo sapiens</em></td>
<td>Worldwide</td>
<td>0.2mya–present</td>
</tr>
</tbody>
</table>

[Adapted from The Evolutionary Road, Jamie Shreeve, National Geographic, July 2010]

2.1 Explain why the information in the table supports the ‘Out of Africa’ hypothesis. (2)

2.2 Describe how the analysis of mitochondrial DNA is used to support the ‘Out of Africa’ hypothesis. (3)
DISCOVERY OF A NEW SPECIES IN SOUTH AFRICA

Professor Lee Berger, a paleoanthropologist at the University of the Witwatersrand, with the help of his 9-year-old son, found two fossils in South Africa on 15 August 2008.

Berger and about 60 of his colleagues from all over the world, studied the fossilised bone fragments before they announced their findings to the public on 8 April 2010. Their findings were published in a scientific journal.

They presented it as a new species called *Australopithecus sediba*, dated approximately 1.78 to 1.95 million years ago. It consists of many primitive features characteristic of other *Australopithecine* species and more advanced features typical of later *Homo species*.

The almost 2-million-year-old partial skeletons are thought to possibly be that of the transitional species between *Australopithecus africanus* (such as the famous Mrs Pies) and either *Homo habilis* or *Homo erectus*, the early ancestors of humans.

Berger said that the brain, hand and foot have characteristics of both modern and early pre-human forms. It represents a model that could have led to the human genus *Homo*.

It was noted that the brain of *A. sediba* is small, like that of a chimpanzee, but with a re-organisation more human-like, particularly with an expansion behind and above the eyes.

3.1 Explain why scientists took a long time to present their findings to the public.

3.2 Explain why it was important to publish their findings in a scientific journal.

3.3 Define the term 'transitional form'.

3.4 Use ONE characteristic from the passage to explain your answer to Question 3.3.

3.5 State SIX similarities not mentioned in the passage above, between *Homo sapiens* and other primates such as *Australopithecus sediba*.
**Question 4**
*2010 February/March Paper 2*

The diagram below shows a phylogenetic tree based on DNA similarities. The percentage next to each branch shows the amount of difference in the genome (DNA nucleotide sequence) of the two relevant groups:

![Phylogenetic Tree Diagram](image)

**A phylogenetic tree based on DNA similarities**

(Adapted from: Senior Biology 2)

4.1 From the diagram, determine how long ago chimpanzees split from the line of humans. 

__________________________________________________________

(2)

4.2 Which organism is most closely related to humans? ____________________________

(1)

4.3 Calculate the DNA similarity between the genome of the chimpanzee and the human. 

__________________________________________________________

(2)

**Question 5**
*2014 Exemplar Paper 2*

It is thought that modern humans evolved gradually from ape-like beings over millions of years through speciation. Describe how a single species can form new species, and explain how the differences in the skulls and other parts of the skeleton of primitive ape-like beings and modern humans support the idea that the general trend in human evolution has been towards bipedalism and a change in diet from raw food to cooked food.

Note: NO marks will be awarded for answers in the form of flow charts or diagrams.

Content: 17
Synthesis: 3
Total: [20]
The diagram below represents the possible evolution of humans, as well as the time period for the development of bipedalism, the use of fire and the use of tools.

6.1 According to the phylogenetic tree, which organism, Paranthropus boisei or Homo habilis, appeared first on Earth? (1)

6.2 Name TWO species whose existence on Earth overlapped with that of Homo erectus. (2)

6.3 Which organism was the direct ancestor of Homo habilis? (1)

6.4 List FIVE characteristics that are shared by all the organisms in the above phylogenetic tree. (5)

6.5 How long did Australopithecus africanus exist on Earth? (1)

UNIT 11 Human evolution
The diagram below shows a world map indicating four sites (1 to 4) where hominid fossils, representing two different genera, have been found. Genus A was found at three sites and genus B at one site. The age of each fossil was determined using radiometric dating.

Genus A
Site 2: 25 million years old
Site 3: 65 million years old
Site 4: 0.27 million years old

Genus B
Site 1: 3 million years old

Adapted from www.biologyreference.com

7.1 Which genus, A or B:
(a) represents Australopithecus? ________ (1)
(b) had a more prognathous skull? ________ (1)
(c) had smaller canines? ________ (1)
(d) is more closely related to Homo sapiens? ________ (1)

7.2 Name TWO examples of fossils of genus B found at site 1 in South Africa. (2)

7.3 At which site, 1 to 4, were the youngest fossils found? ________ (1)

7.4 Other than fossil evidence, what other evidence can be used to support the 'Out of Africa' hypothesis? (1)

Question 8

Scientists estimated the brain sizes of Australopithecus, Homo habilis, Homo erectus and Homo sapiens by using the cranial capacity of fossil specimens. They then compared their results to the time that each hominid existed on Earth.

The graph below represents the range of brain size and the time period that the hominid existed according to fossil evidence.

The results of the investigation are shown on the graph on page 145.
8.1 According to the graph:
(a) when did the first *Australopithecus* appear? ________________
(b) which of the species shows the greatest variation in brain size?

8.2 Give the size (in cm$^3$) of the:
(a) Largest brain of *Australopithecus* __________________________
(b) Smallest brain of *Homo sapiens* __________________________

8.3 State TWO types of evidence, other than fossils, that support the idea that all hominids evolved from a common ancestor.

---

**Question 9**

*NSC 2011 February/March Paper 2*

The diagrams below represent the skulls of two organisms, namely a modern human and a gorilla. Each arrow indicates the position of the foramen magnum. Study the diagrams and answer the questions that follow.
9.1 Identify each of the organisms that are represented by A and B. (2)

9.2 Tabulate FOUR observable differences between the skulls of organisms A and B. (9)

9.3 Which organism is bipedal for most of its adult life? (1)

9.4 Explain TWO possible advantages of bipedalism to the organism referred to in Question 9.3. (4)

9.5 Name any TWO similarities between organism A and B. (2)

Answers

Question 1

1.1 H. erectus✓
1.2 A. afarensis✓
1.3 (a) 3 mya - 2.4✓ mya = 0.6✓ my✓
   OR
   3 mya - 2.3✓ mya = 0.7✓ my✓
   (b) Fossils ✓
1.4 (a) H. neanderthalensis✓
   (b) H. neanderthalensis and H. sapiens share a common✓ ancestor✓
   OR
   Both evolved✓ from H. heidelbergensis✓

Question 2

2.1 The oldest fossils of human ancestors✓ were only found in Africa✓ (1)
2.2 Mitochondrial DNA is passed down from mother to child✓
   - mutations✓ on the mitochondrial DNA
   - were traced to an ancestral female that existed in Africa✓ (3)

[18]
Question 3

3.1 Carefully analyse ✓ and verify ✓ the evidence/findings before releasing the results (2)

3.2 To inform people of their findings ✓ so that they can critique ✓/verify their findings/use it for future research/acknowledge ownership of the findings (2)

3.3 A transitional form has characteristics ✓ of both ✓ the *Australopithecines* and humans (2)

3.4 The brain was small ✓ like other *Australopithecine* species but the re-organisation/ configuration of the brain ✓/an expansion behind and above the eyes was more like modern humans OR

Brain/hand/foot have characteristics ✓ of both ✓ modern and early pre-human (Mark first ONE only) (2)

3.5 Olfactory brain centres reduced ✓/reduced sense of smell

- Eyes in front ✓
- Binocular vision ✓/stereoscopic vision
- Eyes with cones ✓/colour vision
- Freely rotating arms ✓
- Elbow joints allowing rotation of forearm ✓
- Flat nails instead of claws ✓/bare, sensitive finger tips
- Opposable thumbs ✓/Upright posture ✓/bipedal Sexual dimorphism ✓/Long upper arms ✓
- Two teats ✓
- 5 Fingers ✓
- Fewer offspring ✓ (Mark first SIX only) (any 6) (6)

Question 4

4.1 5 ✓ mya ✓ (2)
4.2 Chimpanzee ✓ (1)
4.3 98.6% ✓ (2) [5]

Question 5

The development of a new species

- If a population splits into two populations ✓
- There is now no gene flow between the two populations ✓
- Since each population may be exposed to different environmental conditions ✓
- Natural selection occurs independently in each of the two populations ✓ such that the individuals of the two populations become very different from each other ✓
- Genotypically and phenotypically ✓
- Even if the two populations were to mix again ✓ they will not be able to reproduce with each other ✓, thus becoming different species (any 5)

The development of bipedalism

- The backward position of the foramen magnum on the skull ✓
- The narrow pelvis ✓
- The less-curved spine ✓
- Indicates that the ape-like beings were quadripedal ✓ (any 3)
- The forward position of the foramen magnum on the skull ✓
- The wider pelvis ✓
- The curved spine ✓
- Indicates that modern humans are bipedal ✓ (any 3) (6)

Change in the diet from raw food to cooked food

- The large teeth, especially the canines ✓
- As well as the large and long jaws ✓
- Which makes the skull prognathous ✓
- As well as cranial/brow ridges associated with large muscles that operate the jaws ✓
- Indicate that the ape-like beings ate raw food that required a great amount of processing ✓/tearing, biting and chewing ✓ (any 3)
- The smaller teeth, including the canines ✓
- As well as the smaller jaw size ✓
- Which makes the skull less prognathous ✓
- As well as the absence of cranial/brow ridges due to the presence of smaller muscles for chewing ✓
- Indicate that modern humans rely on a diet of cooked food that does not require the same amount of processing ✓/tearing, biting and chewing ✓ (any 3)

Content: 17
Synthesis: 3
Total: 20

ASSESSING THE PRESENTATION OF THE ESSAY

<table>
<thead>
<tr>
<th>Relevance</th>
<th>Logical sequence</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only information regarding development of a new species, the development of bipedalism and change in diet is given (no irrelevant information).</td>
<td>Generally, the development of a new species, the development of bipedalism and change in diet are explained logically.</td>
<td>All three aspects of the question are described correctly.</td>
</tr>
</tbody>
</table>
Question 6
6.1 Homo habilis ✓
6.2 Paranthropus robustus✓, Paranthropus boisei✓, Homo sapiens✓ and Homo habilis✓
(Mark first TWO only) Any 2 (2)
6.3 Australopithecus afarensis ✓
(1)
6.4 - Olfactory brain centres reduced✓/ reduced sense of smell
- Eyes in front✓/ Binocular vision / stereoscopic vision
- Eyes with cones✓ / colour vision
- Freely rotating arms✓
- Elbow joints allowing rotation of forearm✓
- Flat nails instead of claws✓/ bare, sensitive finger tips
- Opposable thumbs✓
- Bipedal✓/ upright posture / foramen magnum in a more forward position
- Sexual dimorphism✓/ distinct differences between males and females
- Parts of the brain that process information from the hands and eyes are enlarged✓
- Longer upper arms✓
- Large brains✓ / skulls compared to their body mass
- Five digits per limb✓
(Mark first FIVE only) Any 5 (5)
6.5 1-1,2 my✓/ 1 000 000 – 1 200 000 years
[10]

Question 7
7.1 (a) B✓
(b) B✓
(c) A✓
(d) A✓
(1)
7.2 Mrs Ples✓ Taung Child✓
{ A. africans
Little Foot✓ A. prometheus Karabo✓ A. sediba
(Mark first TWO only) Any 2 (2)
7.3 Site 4✓
(1)
7.4 Mitochondrial DNA✓/mtDNA/genetic evidence/
Y-chromosome/cultural evidence
(Mark first ONE only) (1)
[8]

Question 8
8.1 (a) 3,1✓ mya✓ (Accept 3,05 to 3,15 mya)
(b) Homo sapiens✓/H. sapiens
(2)
8.2 (a) 500✓ cm² (Accept 495 to 505 cm²)
(b) 850✓ cm² (Accept 845 to 855 cm²)
(1)
8.3 Genetic evidence✓/mitochondrial DNA/ tDNA✓
Cultural evidence✓/tool making
Comparative anatomy✓ between living hominids
(Mark first TWO only) Any 2 (2)
[7]

Question 9
9.1 A – Gorilla ✓ B – Modern human ✓
(2)
9.2

<table>
<thead>
<tr>
<th>GORILLA/A</th>
<th>MODERN HUMAN/B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Canines well developed ✓/form fangs</td>
<td>1. Canines not well developed ✓</td>
</tr>
<tr>
<td>2. Sloping face ✓</td>
<td>2. Flat face ✓</td>
</tr>
<tr>
<td>3. Brow-ridge well developed ✓</td>
<td>3. Brow-ridge less developed ✓</td>
</tr>
<tr>
<td>4. Proportionally smaller cranium ✓/brain</td>
<td>4. Proportionally large cranium ✓/brain</td>
</tr>
<tr>
<td>5. Proportionally wider cheek bone ✓</td>
<td>5. Proportionally narrower cheek bone ✓</td>
</tr>
<tr>
<td>6. Sagittal crest✓ on top of the skull</td>
<td>6. No sagittal crest ✓</td>
</tr>
<tr>
<td>7. Foramen magnum towards the back✓ of the skull</td>
<td>7. Foramen magnum towards the centre of the skull/more forward</td>
</tr>
<tr>
<td>8. Chin not well developed ✓</td>
<td>8. Chin well developed ✓</td>
</tr>
<tr>
<td>9. No pronounced forehead</td>
<td>9. pronounced forehead ✓</td>
</tr>
</tbody>
</table>
(Mark first FOUR only) (any 4 x 2)
(1) (1)
9.3 B ✓
9.4 - Allows total awareness✓ of the environment in sensing danger✓ /looking for food
- Enables hands to be free✓ to use implements✓ / carry objects or offspring/throw/protect
- Exposes a large surface area✓ for thermoregulation/lose body heat to surroundings in hot conditions/reduce overheating therefore reduce need for water
- Display of male/female sex organs✓ as part of courtship behaviour ✓
(Mark first TWO only) (any 2 x 2)
(4)
9.5 - Capable of upright posture✓
- Long upper arms✓
- Freely rotating arms✓
- Elbow joints allowing rotation of forearm✓
- Rotate hands at least 180°✓
- Flat nails instead of claws✓/bare finger tips
- Opposable thumbs✓/bare finger tips
- Eyes in front✓/binocular vision/stereoscopic vision
- Eyes with cones✓/colour vision
- Sexual dimorphism✓/distinct differences between male and female
- Olfactory brain centres reduced✓/reduced sense of smell
- Parts of the brain that process information from hands and eyes are enlarged✓
- Two mammary glands only ✓
(Mark first TWO only)
Humans depend on the environment for their survival. Our behaviour and the way in which we treat the environment have a direct relationship to our survival. Each problem does not exist on its own, so that the problems we have caused to the environment are interrelated.

The environment is in crisis because of the impact humans have had on it. We have used and are abusing Mother Nature to such an extent that the environment is now exerting a pressure (global warming) in response to our mismanagement of the resources. If we do not solve the problems that we cause in the environment the generations to follow will pay the price.

In summary, the causes and consequences of human impacts on the environment are:

- The atmosphere and climate change – greenhouse gases and global warming plus the depletion of the ozone layer.
- Water availability – including the uses of water.
- Water quality.
- Food security.
- Loss of biodiversity.
- Solid waste disposal.

These factors are interrelated and are interdependent.

Some examples:

- Through the planting of many exotic plantations water is dried up; biodiversity is lost; some species may become threatened or extinct; monoculture has its own problems; rapid run-off of water occurs, leading to soil erosion.
- Failing to recycle increases the amount of waste; this fills up the dumpsites more rapidly; more water and electricity are used to make more goods, e.g. glass and plastic bags; there is a waste of money and labour.
**Carbon dioxide emission**
- CO₂ is recycled in nature between cellular respiration, photosynthesis and decomposition.
- A **carbon sink** (oceans/plants/soil) stores carbon dioxide naturally.
- CO₂ is a **greenhouse gas** - affects the warmth of the air.
- Burning of fossil fuels releases CO₂.
- Cutting down forests means fewer plants to take in CO₂.

**Methane emissions** (a greenhouse gas) [CH₄]
- Has 20 times greater effect on global warming than does CO₂.
- Caused by:
  - Leakage while extracting natural gas from the Earth.
  - The decomposition of organic matter and sewerage.
  - Cattle - many are farmed to feed the increasing human population.
  - Permafrost, swamps and from under the sea. (In the cold the CH₄ is frozen. When temperature rises CH₄ escaped from below frost and ocean beds.)

**Concept of 'carbon footprint'**
- This is the CO₂ that an individual releases into the air as a result of his or her activities.
- **The need to reduce the carbon footprint**
  - In 2010, an average person in S. Africa had a carbon footprint of 9 200kg for the year.
  - To reduce the level of CO₂ emissions it has been calculated that each person should produce no more than 2 000kg CO₂ in a year.

**Deforestation** - the permanent removal of forests (carbon sinks).
- Mainly caused by need for:
  - Agricultural land to plant crops and/or to stock animals to feed the increasing world population.
  - Timber for building houses, furniture.
  - Wood as a fuel to burn for warmth, cooking, etc.
  - Wood to make charcoal.

**Consequences of deforestation:**
- Level of CO₂ rises as the carbon sink has been removed; burning of left-over branches adds CO₂ to atmosphere.
- Leads to global warming, changed rainfall patterns, increased flooding, loss of valuable topsoil.
- Extinction of species; reduced biodiversity.
- Loss of homes for indigenous people.

**Greenhouse effect and global warming; desertification, drought and floods. See page 151.**

**Ozone depletion**
- See page 152.
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THE ATMOSPHERE AND CLIMATE CHANGE

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Ozone depletion
See page 152.

Carbon footprints
CO₂ released into atmosphere

Cows produce methane
Melting icebergs
Aerosols deplete ozone
Greenhouse gases
- Methane \( \text{CH}_4 \)
- Carbon dioxide \( \text{CO}_2 \)
- Water vapour \( \text{H}_2\text{O} \)

What is global warming?
Humans through their activities are releasing more greenhouse gases. These extra gases add more warmth than is necessary to the atmosphere, leading to an increase in warming the globe.

What is the greenhouse effect?
- The natural warming of the atmosphere by greenhouse gases. (If there were no greenhouse gases the atmosphere would have a temperature of \(-18^\circ\text{C}\). Therefore natural quantities are required.)
- The greenhouse gases are warmed by radiant energy from the sun. These gases then warm the atmosphere.

The effects and consequences of global warming
Temperatures will increase causing:
- More water to evaporate, adding to the greenhouse gases.
- Snow and ice to melt, decreasing the reflection of the sun's rays back into the atmosphere.
- Sea levels will rise from the melting snow and ice.
- Volume of oceans will increase.
- Many islands and low-lying cities and areas will be flooded. A third of coastal wetlands will disappear. Climates will change.
- More extreme weather conditions will be experienced with winds, storms, floods, droughts, heat waves.
- More warm moisture in the air will cause heavy downpours and flooding.
- More dry periods will lead to heat waves, droughts. The soil will be made bare, leading to soil erosion, desertification.
- Farming methods will need to change and the production of food will be compromised.
- Many species of plants and animals will become extinct.
- Diseases will increase.
- Increase in the tropical (warm) environment allows for the breeding and spread of more diseases.
- Extreme temperatures will lead to the deaths of infants and the elderly.
What is ozone?
- Three molecules of oxygen O₃.
- The ozone layer is found between 15 and 40km above the Earth.
- It protects living organisms from dangerous UV radiation.

What causes the depletion of ozone?
Various chemicals/pollutants react with the O₃ making the layer of ozone thinner, or a hole (space) forms in the layer of O₃.
- CFCs (chlorofluorocarbons) and HCFCs (hydrochlorofluorocarbons) from aerosols, older fridges, air conditioners and foam expanders. These molecules are very stable compounds and can remain in the atmosphere for 100s of years. These release chlorine, which destroys ozone molecules.
- Methyl bromide from pesticides releases bromine, which is far more destructive to the ozone molecules than chlorine.
- Halon, which contains bromine from fire extinguisher use. As above.
- Solvents such as tetrachloroethane from cleaning solvents, paints and some medicines release chlorine into the atmosphere.
- Oxides of nitrogen from bacteria in the soil react with oxygen so that less ozone is made.

Prevention/remediation
Stop using and producing the gases that deplete ozone.
- 1987: Montreal Protocol was signed by 31 countries to stop the use of CFCs.
- 1990: South Africa signed the agreement.
- 2000: 80 countries had signed the agreement.

Consequences of the depletion of the ozone layer
- Allows more UV radiation to reach the Earth and therefore the UV rays:
  - Damage the nucleic acids in chromosomes, causing mutations.
  - Cause more skin cancer and eye cataracts.
  - Increase the water temperature, changing aquatic environments and the organisms that live in them.
  - Cause photosynthesis to slow down. Plants will grow more slowly affecting production of crops and food for animals. This will decrease food security.
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UNIT 12 Human impact on the environment

**Cost of water as a result of:**
- Building and maintenance of dams.
- Pipes to carry the water.
- Pumps and electricity.
- Machines that filter water to clean it.
- Chemicals to purify water.
- Maintenance of pipes, pumps, machines.
- Salaries of people working in the water industry.

**Wastage of water**
**Before use:**
- Evaporation from storage dams and reservoirs, while irrigating crops and gardens.
- Leaking pipes.
- Dripping taps from faulty valves.

**During use save water:**
- Toilets use a lot of water – place a brick in the cistern to save. Some toilets have a dual flush system.
- Shower rather than bath.
- Wash a car with a bucket of water rather than using a hose pipe.
- Do not leave a tap running while brushing teeth, washing vegetables.

**Destruction of wetlands**
- Wetlands important for:
  - Water purification.
  - Reducing risk of flooding.
  - Reducing seasonal changes in water levels.
  - Filling up underground stores of water – aquifers.
  - Controlling soil erosion.
  - Increasing biodiversity.

**Poor farming practices**
- Soil and land need to be in good condition so that rain can run off into dams and rivers without taking topsoil with it and eroding the land.
  - Overgrazing – animals eat the grass until there is none left. Soil is exposed and gets washed away in heavy rains. This soil is washed into the rivers and dams.
  - Deforestation.
  - Monoculture.
  - Burning vegetation.
  - Overuse of fertilisers.

**WATER AVAILABILITY**
Supply of water comes from rain. South Africa is one of the 30 driest countries in the world. Rainfall is seasonal.

**Construction of dams**
Dams store water for drinking, household use, agriculture, to make electricity.
**Impact on the environment:**
- Change the natural water flow.
- Loss of habitats below the dam.
- Water quality is reduced.
- Sediment flow is changed.
- Prevent natural migration of fish up and down streams.
- Prevent deposits of nutrient rich silt downstream.
- People have to move to a new area.

**Exotic plantations and depletion of water table**
It has been suggested that exotic or alien plantations take up more water than indigenous trees, drying up streams and the water table. Plantations should be grown in places of high rainfall. Movement of rainwater is quicker through plantations as there is not much vegetation holding the soil below the trees.

**Droughts and floods**
- Good storage facilities are required to trap and hold rain that falls during a flood, so that water is available during a time of drought.
- Wetlands help slow down and control flood waters.
- It is necessary to have vegetation covering and holding the soil so that it does not wash away.

**Boreholes and effects on aquifers**
The water from these is clean and safe to drink. They need to be monitored so that:
- More water is not pumped from them than enters them from rain.
- They do not become polluted or have toxic substances wash into them (e.g. mining in fracking in the Karoo).
**Water for domestic use**
This is the use of water in the home for cooking, cleaning, bathing/showering, getting rid of human waste, watering the garden, washing cars.
Important to have good, clean, safe water to drink.

**Water for mining**
- Used in the air conditioners deep in mines.
- Pressurised water is sprayed onto rocks to extract minerals.
- Used to cool down the machinery in mines.

**Water for industrial use**
- Used as a raw material, e.g. papermaking.
- Used for cooling machinery.
- Used to carry wastes away from the factories.
- This can cause pollution in water.

**Water for agricultural use**
- More than 70% of the water used, is used for agriculture.
- If crops don't get enough water from rain then farmers irrigate their crops, using water from rivers, streams or lakes.
- The increasing human population, along with higher living standards, needs more and more food from crops.

**The effect of mining on the quality of water**
- Groundwater seeps from the rock into the mine. This water, which is often polluted (effluent), needs to be pumped out. It is pumped into streams and dams.
- Many old mines no longer being worked have filled with acidic water. It is beginning to move out into the surface and underground water and is polluting it.

**A derelict mine causing contamination**

- Wet waste rock is piled near the mine. Contaminated water seeps from the rock and pollutes surface water.

The following have an impact on water quality:
- Processing chemicals, e.g. cyanide and sulphur, are toxic and can make their way into surface water.
- Acid drainage, e.g. metal sulphides from the ore, react with water to make sulphuric acid which can make its way into streams, etc.
- Heavy metal contamination, e.g. arsenic, lead and zinc found in the ore. These come into contact with acid water. They dissolve out of the ore and make their way into streams, etc. Heavy metals are toxic to humans and animals.
- Erosion occurs as much of the soil and rock is disturbed; roads are built; the powdery material is easily washed away.
- Sedimentation – the powdery material washes into local dams and streams, clogging them and polluting them.
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Irrigating crops
Thermal pollution
An increase in the temperature of water affecting its quality is caused by:
- Water used to cool machinery in power stations, pulp and paper mills and metal works.
- Run-off water from warmed surfaces, e.g. tarred roads.

The effects of the warm water:
- It holds less O₂ therefore aquatic animals will die or migrate to another part of the stream.
- It causes an increase in the metabolic rate of the aquatic organisms. (Enzymes work more efficiently at warmer temperatures.) This harms the organisms.

Heated water could be cooled before entering streams by:
- Warmed water standing in cooling ponds before being released.
- Cooling towers where heat is passed from the water to the air.
- Co-generation when the heat is recycled for domestic use or for industrial use.

Eutrophication
High nitrogen and phosphorous levels in bodies of water cause an increase in the growth of phytoplankton, algae and aquatic plants. This rapid growth is called an algal bloom, turning the water green. Aquatic plants below receive less sunlight and die, sink to the bottom and are decomposed by bacteria. This leads to a lack of O₂ in the water. Animals will die as there is no O₂. Habitat becomes a dead zone.

Water must be safe and clean
Water-borne diseases, e.g. cholera, dysentery, typhoid are spread by water, resulting in diarrhoea. Diarrhoea if not treated can lead to dehydration and death.

Invasive alien plants e.g. *Eichornia* - water hyacinth: originates from Argentina. It floats on the water and reproduces asexually and its population can double in two weeks. A dam can be covered in this weed in very little time. This makes fishing difficult; blocks channels taking water elsewhere, e.g. to be purified or to generate electricity. It can be controlled by:
- Removing it manually but if a few plants are left it will reproduce and cover the dam again.
- Spraying it with herbicides, but these chemicals will harm all other organisms.
- Biological control (using another organism to destroy the plant), e.g. a small insect from Argentina, which feeds on the sap of the plant and does not harm other plants.

The need for water purification and recycling
South Africa is a dry country and therefore needs to purify and recycle water.

**Purification of water**
Water stored in dams and reservoirs needs to be purified in water purification treatment plants. This costs money, hence in urban areas the user must pay for water.

**Recycling of water**
- Grey water (water from washing clothes or dishes and bath water) is used to water the garden.
- Sewage is purified in sewage treatment plants, to be pumped into streams or dams to be re-used.

**Pollution of the water supply**
- Organic matter - raw sewage; animal wastes, which can carry disease-causing organisms.
- Nutrients - nitrogen and phosphorus from organic matter and/or fertilisers, household cleaners. Causes eutrophication.
- Chemical sprays - pesticides and herbicides washed by rain into streams, etc. Harmful to aquatic organisms.
- Industrial wastes - suspended solids prevent sunlight from reaching the plants.
- Hot water reduces the O₂ content; heavy metals and other harmful chemicals from factories are toxic to aquatic organisms.
- Oil pollution from factory spillage and from vehicles leaving oil on tar roads then washes into streams, etc.
- Soil from eroded lands. Silts up dams and estuaries and can smother the underwater plants, as solids suspended in the water prevent sunlight from reaching aquatic plants.
Poor farming practices:
Monoculture – growing one crop each year. This does increase food security, although there are associated problems:
Pest control – monoculture can encourage the exponential growth of pests. Pesticides are required and these can kill other organisms and be passed along the food chain.
Loss of topsoil – when one type of crop is grown year after year the soil is depleted of nutrients. If expensive fertilisers are not added and it is no longer financially viable to plant another crop, the soil may be left empty, allowing the topsoil to be blown away or washed away by rain (soil erosion).
Need for fertilisers when the soil loses its fertility because of monoculture. Fertilisers are expensive, which makes the crop expensive and therefore leads to a reduction in food security.

Human exponential population growth
Human population (7 billion, and may double in the next 50 years) is on the increase, making it difficult for everybody to have adequate food security. Overpopulation could lead to malnutrition, starvation and death.

Droughts and floods
Climate change and extreme weather conditions are caused by global warming. Reduces food security. Threat to crop production – less food for people.

Invasive alien plants and reduction of agricultural land
The following reduce food security:
- When alien plants become invasive and take over suitable land for crops.
- More plantations being planted, as they are more economically productive than crops.

Wastage of food
Food security could be increased if food were not wasted. Food is wasted:
- At production on the farm.
- After harvesting the crop.
- During the processing of the crop into food products.
- During the selling of the food products (e.g. in the supermarkets).
- From eating (e.g. when more than we

Genetically engineered (GE)/genetically modified (GM) foods
These increase food security because:
- They may be resistant to pests (reduces use of expensive and poisonous pesticides).
- May be resistant to diseases caused by viruses/bacteria.
- Crops are able to tolerate:
  - Herbicides used to kill weeds.
  - Cold temperatures and not be harmed by frosts/grown in colder climates.
  - Droughts and salty soils, therefore crops can be grown in areas that were previously unsuitable.

The loss of wild varieties: impact on gene pools
With many people moving into urban areas there are fewer rural people growing wild varieties of crops. Wild varieties are often resistant to pests and disease and can be used to breed the pest/disease resistant gene/s into the domesticated crop. The loss of these varieties can cause reduction in food security.
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Food security
Means that all people have access to and can afford enough safe, healthy food for a healthy lifestyle.

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Habitat destruction
When natural vegetation is removed the animals living there will have to migrate to a new place or they may die. The habitat is destroyed.

Caused by:
Poor farming methods
- Overgrazing – animals graze on grass and its roots until the soil is no longer covered by vegetation. The grass is no longer present. Soil erosion can now occur.
- Monoculture – most economical and productive way to produce crops, but animals and indigenous plants are compromised.

Development
- Golf estates/housing estates – these have very little biodiversity. Indigenous bush/grasslands/forests are removed to establish these estates. The animals that usually live in these habitats migrate to other areas.
- Mining – destruction of plants to make way for mines and factories. The animals will have to migrate to other areas.
- Urbanisation – more people are moving to live in towns therefore towns need to be made larger. Habitats have to be destroyed to make way for this expansion.

The loss of the following for development:
Forests – the removal of indigenous forests for:
- Development of agricultural land.
- The establishment of housing estates/golfing estates/towns/factories.
- Selling the timber for building/furniture or to burn for energy.

Wetlands – these habitats are rich and if they are drained for development much biodiversity is lost.

Grasslands – for development or to plant crops.

Invasive aliens – these plants spread quickly as they thrive in the habitats in which they grow.

Alien plant invasions
Alien plants are not indigenous and spread very quickly and easily. They overcrowd and overtake natural habitats and destroy them. They can be controlled/eradicated by the following methods:
- Mechanical – dig/bulldoze/hoe/chop them out or kill them by ring-barking them.
- Chemical – use of herbicides to kill them. This is a quick but expensive method and the chemicals can harm other plants and animals.
- Biological – using a natural enemy, e.g. insect, to harm/eat the alien plant. Need to get the insect from the plant’s original habitat. The insect must also not eat/harm any of the indigenous plants/animals.

Loss of biodiversity (the sixth extinction)
Only extinction caused by a biotic factor (humans)

Poaching – killing of protected animals to eat or sell. This threatens the animal species, especially those that are becoming rare and are in danger of becoming extinct.
- Subsistence poaching involves killing animals to feed the poachers and their families.
- Commercial poaching is the selling of bush meat for financial gain. Also capturing animals to export and sell.
- Trophy poaching involves killing animals for a part of their body, e.g. rhino horn from rhinos, ivory from elephant, skins from leopard, lion, zebra, cheetah.

These animals are poached by using sophisticated means and many animals can be killed, reducing numbers greatly and in some cases endangering them or even making them extinct.

Indigenous knowledge systems and the sustainable use of the environment
Traditional health practitioners require plants to use as medicines to heal patients. These plants are indigenous and are harvested by people living in rural areas. Some of these plants are being overharvested, thus threatening them. They need to be harvested in a sustainable manner so that they do not become extinct. This may include planting more of the plants. The following are used in Western medicine and need to be conserved:
- Devil’s claw – treating fibrosis, osteoarthritis, small joint disease and rheumatism. This plant is now grown as a commercial crop.
- Rooibos – used as a tea. It does not contain any stimulants such as caffeine and is therefore a health drink. It is grown as a commercial crop.
- Fynbos – the flowers of these plants are used for floral art all over the world.
- African potato (Hypoxis) – the underground stem (corm) is used for the treatment of TB, HIV, some cancers, urinary tract infections, diabetes, rheumatoid arthritis.
- Hoodia – suppresses appetite – used in diet products, e.g. tablets, protein drinks, capsules, coffee, tea, syrups.
Managing dumpsites

Prevention of soil and water pollution
- Main pollutant is water/rain seeping through the layers of waste and collecting poisonous chemicals, which dissolve in it. These seep into the soil, groundwater and surface water poisoning them. Causes water pollution and soil pollution.

Prevention of pollution
- Thick plastic or clay lining at the base of the dump.
- Collection of underground wells and dams to collect seepage water and pump it out so that it does not reach the water sources and pollute them.

Good management
- Dumpsite needs to be far away enough from settlements so as not to cause harm to the residents but not so far as to make transport too expensive.
- Good system of underground wells and dams to collect seepage water and to pump it out.
- System of pipes to pipe off methane gas, to be used as a source of alternative energy.
- A base of clay or plastic to prevent the liquid from seeping into the soil and water.
- Waste should be flattened and buried with soil to form layers.

Rehabilitation
Once no more waste can be dumped on the site it needs to be rehabilitated for other purposes such as building houses, a school or factories; developing a park on it. Plants should be planted on it or between the buildings. If the site is left with nothing on it, vegetation will need to be planted to hold the soil in place and prevent it from eroding and washing away.

Methane gas could be pumped from the sealed

Dumpsite/rubbish dump/landfill site
This is where solid waste is dumped to decompose; levelled with bulldozers and covered with soil.

Disadvantages:
- Cannot be too close to settlements as dump sites are smelly and land is expensive.
- Transport costs increase, the further these sites are away from cities.
- Methane gas can build up and cause fires.
- Attract disease-carrying organisms, e.g. rats, mice, flies.

SOLID WASTE DISPOSAL.
With increasing numbers of people in urban areas, the disposal of waste becomes an environmental problem.

Safe disposal of nuclear waste (radioactive)
Nuclear waste is very toxic and dangerous as it can remain in the environment for millions of years. Radioactive waste can destroy nucleic acids in organisms, which can result in genetic defects, cancer and even death. It needs to be buried deep in the oceans or in the land (deserts) in thick concrete or lead containers.

Koeberg, 30 km north of Cape Town, is the only nuclear power station in South Africa and Africa. Waste is buried in Vaalplats in the Northern Cape. There is a research centre in Pelindaba in Gauteng.

The need for recycling
Recycling is very necessary to reduce the amount of solid waste and hence not put great pressure on making and managing more and more landfill sites.
Each person needs to:
- Reduce the amount of waste produced.
- Reuse products wherever possible.
- Recycle – take waste items (glass, plastic, paper, electrical goods) and place them in specially marked containers at schools, supermarkets, garages, etc. Use vegetable waste to make compost for the garden.

Using methane from dumpsites for domestic use, heating and lighting
Dumpsites produce a large amount of methane gas (greenhouse gas) from the decomposition of the waste. This gas can be piped off from dumpsites and used as a supply of alternate energy. This will reduce the greenhouse gas entering the atmosphere.
Questions

This unit is examined in Paper 1 for about 25 marks (17%).

Question 1

DBE NSC 2014 Exemplar Paper 1

1.1 The Human Sciences Research Council (HSRC) conducted a survey on food security across the provinces. The results showed the overall percentage of food-secure households in South Africa is 45.6% as opposed to 48% in 2008. The results, indicating the percentage of food-secure households in each province according to the latest survey, are shown in the table below.

<table>
<thead>
<tr>
<th>Province</th>
<th>Food-insecure households (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastern Cape</td>
<td>36</td>
</tr>
<tr>
<td>Limpopo</td>
<td>31</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>30</td>
</tr>
<tr>
<td>Free State</td>
<td>29</td>
</tr>
<tr>
<td>KwaZulu-Natal</td>
<td>28</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>21</td>
</tr>
<tr>
<td>Gauteng</td>
<td>19</td>
</tr>
<tr>
<td>Western Cape</td>
<td>16</td>
</tr>
</tbody>
</table>

(a) What is meant by 'food security'?  (2)

(b) State how the use of fertilisers by farmers can:

(i) Increase food security for a country.  (1)

(ii) Decrease food security for a country.  (1)

(c) State how the use of pesticides by farmers can:

(i) Increase food security for a country.  (1)

(ii) Decrease food security for a country.  (1)

(d) State TWO factors, other than the use of fertilisers and pesticides, which may have led to a decrease in the percentage of food-secure households in South Africa since 2008.  (2)
1.2 The carbon dioxide concentration in the atmosphere was recorded at 400 parts per million (ppm) in May 2013 compared to 316 parts per million (ppm) in 1958. This change is due to an increase in the use of fossil fuels as well as an increase in deforestation.

(a) Describe how deforestation contributes to the high carbon dioxide concentration in the atmosphere.

(b) State ONE other impact of deforestation on the environment.

(c) Explain why we should be concerned about the rising carbon dioxide level.

(d) Suggest ONE way in which the government can reduce carbon dioxide emissions caused by the generation of electricity.

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Question 2

*DBE NSC 2013 November Paper 1*

Genetic engineering involves a process where a gene is isolated from one organism and transferred into another organism. This gene can become part of the new host's genome. Usually the gene transfer takes place between organisms from different kingdoms.

For example, a gene from a certain bacterium codes for an enzyme that deactivates a herbicide (a weedkiller). This gene is isolated from the bacterium and inserted into the chromosome of a crop plant. The resulting plant will now be herbicide-resistant.

Before the products of genetic engineering can be sold, many tests must be done.

Some seed companies have exclusive rights to sell the seeds that they have genetically engineered. Farmers cannot use seeds harvested from the crops that they have grown. Farmers must buy the seeds from the seed companies every time they want to plant the crop.

[Adapted from Microbiology and Biotechnology, 1994]

2.1 What is meant by the term 'genome' referred to in the extract?

2.2 State ONE way in which the genetic engineering described in the extract differs from selective breeding.

2.3 Give ONE reason why the products of genetic engineering must undergo many tests before they can be sold.
2.4 Explain the value of growing herbicide-resistant crops. (3)

2.5 State THREE advantages of genetic engineering in crop production other than those mentioned in the extract above. (3)

2.6 Give a reason why seed companies insist that they must have the exclusive rights to selling of seeds. (2)

**Question 3**

*DBE NSC 2011 February-March Paper 2*

Study the passage below and answer the questions that follow.

**HOODIA**

*Hoodia gordonii* is a spiny succulent plant (cactus) indigenous to the semi-deserts of South Africa, Botswana, Namibia and Angola. It grows in extremely high temperatures and takes many years to reach maturity. *Hoodia* has been used by indigenous populations in southern Africa for centuries to treat indigestion and minor infections. However, the plant has become well known and is in big demand because of the discovery that indigenous people have always used the flesh of the plant to suppress their appetite while on long hunting trips in the desert. The South African Council for Scientific and Industrial Research has isolated the ingredient responsible for the plant's appetite-suppressant quality and it is now marketed as a slimming tablet.

3.1 What is the habitat of *Hoodia*? (1)

3.2 Name TWO medical conditions that can be treated with *Hoodia*? (2)

3.3 Explain why indigenous people must be compensated for the selling of the slimming tablets mentioned in the passage. (4)
Question 4

Invasive alien plants can cause environmental problems in an area.

4.1 Explain the impact of invasive alien plants on:

(a) Food security

(b) Water availability

4.2 Explain ONE DISADVANTAGE of controlling invasive alien plants using the following methods:

(a) Biological method

(b) Mechanical method

Question 5

Read the extract below.

FOOD SECURITY IN SOUTH AFRICA

One of the challenges in South Africa is access to food by the poor. In 2009 Statistics SA conducted a survey to determine the percentage of households in each province that had access to food. The results are shown in the table below:

<table>
<thead>
<tr>
<th>Province</th>
<th>Households that have access to food (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Cape</td>
<td>85</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>79</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>79</td>
</tr>
<tr>
<td>Free State</td>
<td>67</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>75</td>
</tr>
<tr>
<td>North West</td>
<td>79</td>
</tr>
<tr>
<td>KwaZulu-Natal</td>
<td>77</td>
</tr>
<tr>
<td>Limpopo</td>
<td>88</td>
</tr>
<tr>
<td>Gauteng</td>
<td>82</td>
</tr>
</tbody>
</table>

South Africa seems to have adequate food access in urban areas, but the same cannot be said of households in rural areas. In rural areas prices of staple foods (e.g. maize and rice) are usually higher than in urban areas.

Increasing agriculture is the key to food security and poverty alleviation. The majority of people living in rural areas have access to land, but more still needs to be done to make household farming (growing crops for family use) in these areas more efficient.

[Adapted from Food Security, Department of Agriculture, Forestry and Fisheries, March 2015]
5.1 What is meant by 'food security'?

5.2 Suggest ONE reason why food prices in rural areas are usually higher than food prices in urban areas.

5.3 State TWO ways in which household farming could reduce poverty.

5.4 Suggest TWO ways in which the Department of Agriculture can improve farming in the rural areas.

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**Answers**

**Question 1**

1.1 (a) Having access to enough food✓ on a daily basis, so as to ensure healthy living✓ (2)
(b) (i) Fertilisers provide nutrients that increase crop growth✓ (1)
(ii) Fertilisers are expensive – causes food prices to increase✓/ overuse of fertilisers can cause oxygen deprivation in soil which will eventually reduce crop production (1)
(c) (i) Pesticides ensure that pests do not cause large-scale damage to crops✓ Fertilisers provide nutrients that increase crop growth✓ (1)
(ii) Fertilisers are expensive – causes food prices to increase✓/ overuse of fertilisers can cause oxygen deprivation in soil which will eventually reduce crop production (1)
(d) Massive unemployment in the country✓
   - Increase in the size of the human population✓
   - Farms destroyed for development✓
   - Decrease in subsistence farming✓
   - Prolonged unfavourable environmental conditions✓
(Mark first TWO only) (any 2) (2) [8]

1.2 (a) There will be less trees✓
   - so less carbon dioxide will be used from the atmosphere for photosynthesis✓ (2)
(b) Can lead to the loss of biodiversity✓/habitat destruction/soil erosion (1)
(Mark first ONE only)
(c) Increased carbon dioxide levels lead to the enhanced greenhouse effect

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**Question 2**

2.1 An organism's complete set of genes✓ (1)
2.2 Genetic engineering: involves the transfer of genes✓ from one organism to another/(manipulation of DNA)
Selective breeding: Parents with desirable phenotypes are selected to produce offspring with desirable phenotypes✓

OR
Genetic engineering can involve gene transfer between organisms from different kingdoms✓
Selective breeding can occur using organisms from the same or different species within a kingdom✓ (2)
To assess the risks to human health✓/the environment
To determine if the presence of the transferred gene will affect the expression of other genes✓
To test the effectiveness✓ of the product
(Mark first ONE only) (any 1) (1)
The spraying of herbicide will kill the weeds - without killing the crops✓
- thus reducing the competition✓ and increasing the yield✓
2.5 Produce crops that are resistant to adverse conditions:
- drought/disease/pests
- Increase crop yield
- Change the time for the ripening of fruits
- Increase shelf life of plant products
- Improve nutritional value of food
- Improve the taste of food
- Developing fruit/plants with desirable characteristics
(Mark first THREE only) (any 3) (3)

2.6 The companies have invested a lot of time/money to make the GM seeds.
The companies want to control the seed market thus increasing their profit.
(Mark first ONE only) (any 1 x 2) (2)[12]

Question 3
3.1 Semi-desert✓ (1)
3.2 To treat
- indigestion✓
- minor infections✓
- obesity✓ (any 2) (2)
(Mark first TWO only)
3.3 Indigenous people were the first✓ to use the plant for suppressing appetite✓
Royalty must be paid✓ for their intellectual property✓ (4) [7]

Question 4
4.1 (a) - Invasive alien plants reduce food security✓
- since they grow rapidly and invade land✓
- that could be used to grow crops✓ (3)
(b) - Invasive alien plants reduce water availability✓
- since they use more water✓ (2)
4.2 (a) - The new organism may become a pest itself✓/it may feed on indigenous plants instead of the targeted alien plant
- since no natural enemy for it was brought into the area✓ (2)
(b) - Some parts that are left behind✓
- can regrow✓/will cost more money to remove them again (2) [9]

Question 5
5.1 - Food security refers to the access✓
- of adequate✓/safe/nutritious food
- to all people at all times✓ (Any 2) (2)
5.2 - Price is added to cover the cost of transportation✓ over long distances
- No competition✓ between dealers in rural areas
- Decrease demand✓ for goods in rural areas (Mark first ONE only) (any 1) (1)
5.3 - Decreased need to buy food✓
- Selling of excess produce to earn some money✓ (Mark first TWO only) (2)
5.4 - Making people aware of the benefits of farming✓
- Providing resources✓/example
- Developing skills for farming✓
- Providing incentives✓ to encourage farming (Mark first TWO only) (any 2) (2) [7]
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- Increase crop yield/
- Change the time for the ripening of fruits/
- Increase shelf life of plant products/
- Improve nutritional value of food/
- Improve the taste of food
- Developing fruit/plants with desirable characteristics/
(Mark first THREE only) (any 3) (3)

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- Developing skills for farming
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