CHAPTER 8

LIFE SCIENCES

The following report should be read in conjunction with the Life Sciences question papers of the November 2020 NSC examination.

8.1 PERFORMANCE TRENDS (2016–2020)

The number of candidates who wrote the Life Sciences examination in 2020 increased by 18 191 in comparison to that of 2019. The performance of the candidates in 2020 reflects a slight decline at the 30% level from 72,3% in 2019 to 71,0%, as well as at the 40% level from 49,0% in 2019 to 47,9%.

Table 8.1.1 Overall achievement rates in Life Sciences

Year	No. wrote	No. achieved at 30% and above	% achieved at 30% and above	No. achieved at 40% and above	% achieved at 40% and above
2016	347 813	245 157	70,5	157 224	45,2
2017	318 474	236 809	74,4	166 071	52,1
2018	310 041	236 584	76,3	160 208	51,7
2019	301 037	217 729	72,3	147 436	49,0
2020	319 228	226 700	71,0	153 028	47,9

Over the years there has been an improvement in the drawing of graphs. There has also been a considerable improvement in the layout and application of genetic cross diagrams.

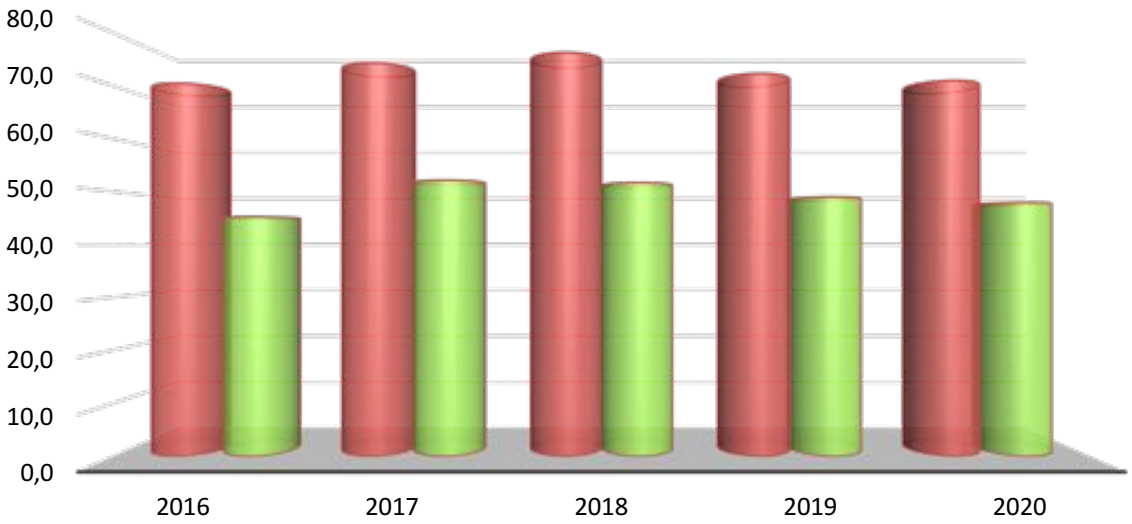
Another challenging area that has seen some improvement is the understanding and application of a dihybrid cross in genetics. The topic on evolution is the last item on the ATP and may therefore not enjoy the attention it deserves. This is evident in the lower performance in this topic, more especially human evolution.

The scientific investigation and the calculation activities still seem to challenge most candidates. This form of assessment is found in papers 1 and 2 and it would serve the learners well if they could master it. Scientific investigations and calculations are introduced in grade 10 and should be thoroughly reinforced before Grade 12. Training and teacher support on these concepts must be given from Grade 10.

With the implementation of the amended section 4 of the *CAPS* (NSC November 2021), there is a change in the weighting of topics across the two Life Sciences papers. The topics on Reproduction and Responding to the Environment in paper 1 both have a greater weighting than before. Therefore, teaching strategies should cater more time and resources towards these sections.

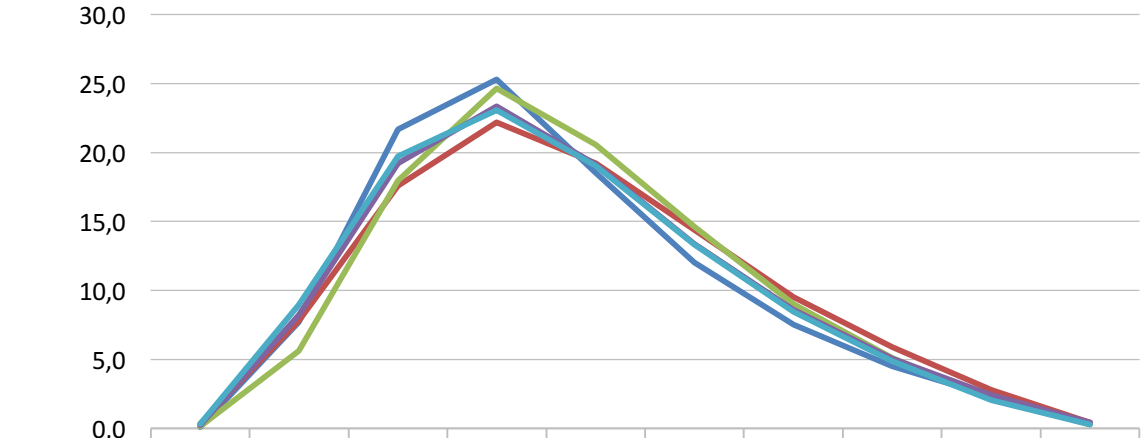
In paper 2, the topic on meiosis will be assessed for 21 marks. This topic was tested in both papers before, but exclusive assessment in paper 2 will allow for more in-depth testing. Teacher workshops should therefore focus strongly on the teaching of Reproduction, Human Response to the Environment, Genetics and Evolution.

Graph 8.1.1 Overall achievement rates in Life Sciences (percentage)



	2016	2017	2018	2019	2020
% achieved at 30% and above	70,5	74,4	76,3	72,3	71,0
% achieved at 40% and above	45,2	52,1	51,7	49,0	47,9

Graph 8.1.2 Performance distribution curves in Life Sciences (percentage)



	0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-100
2016	0,1	7,7	21,7	25,3	18,5	12,0	7,5	4,5	2,3	0,4
2017	0,3	7,8	17,6	22,2	19,2	14,4	9,5	5,9	2,8	0,4
2018	0,1	5,6	18,0	24,6	20,6	14,6	9,0	5,1	2,1	0,3
2019	0,2	8,2	19,2	23,3	19,1	13,4	8,6	5,1	2,4	0,4
2020	0,3	8,9	19,7	23,1	19,0	13,3	8,4	4,9	2,0	0,3

8.2 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 1

General comments

(a) Some candidates were not familiar with basic terminology in the different topics. This resulted in poor performance, even in the lower-order questions.

(b) Many candidates ignored the instruction to start each question on a new page.

(c) Some candidates gave more answers than what were required. If only TWO answers were required, only the first two answers will be marked according to Marking Principle 2 of Life Sciences.

(d) Poor performance is still being recorded in questions based on scientific investigations despite the support provided in the diagnostic reports of previous years.

(e) There was also poor performance in the Endocrine System, Homeostasis and Plant Hormones.

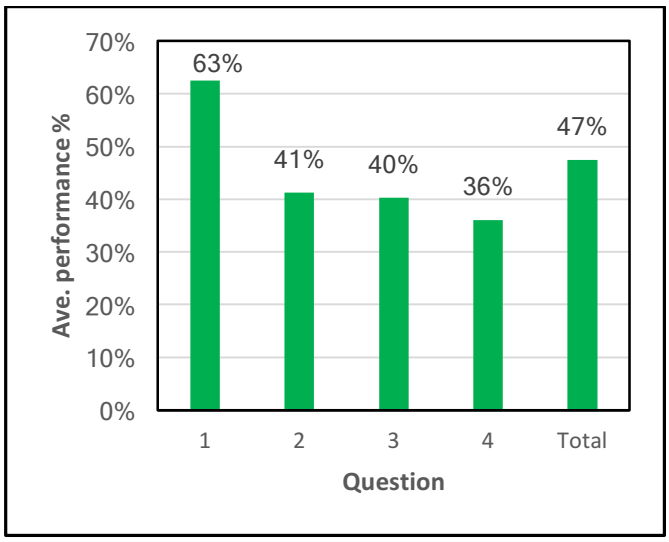
(f) The candidates' performance indicates that the work on Human Impact on the Environment, which was taught in Grade 11, was not properly revised or revisited in Grade 12.

(g) Since textbooks do not always carry accurate information, teachers should always be guided by the *CAPS* and *Examination Guideline* for Life Sciences.

8.3 DIAGNOSTIC QUESTION ANALYSIS FOR PAPER 1

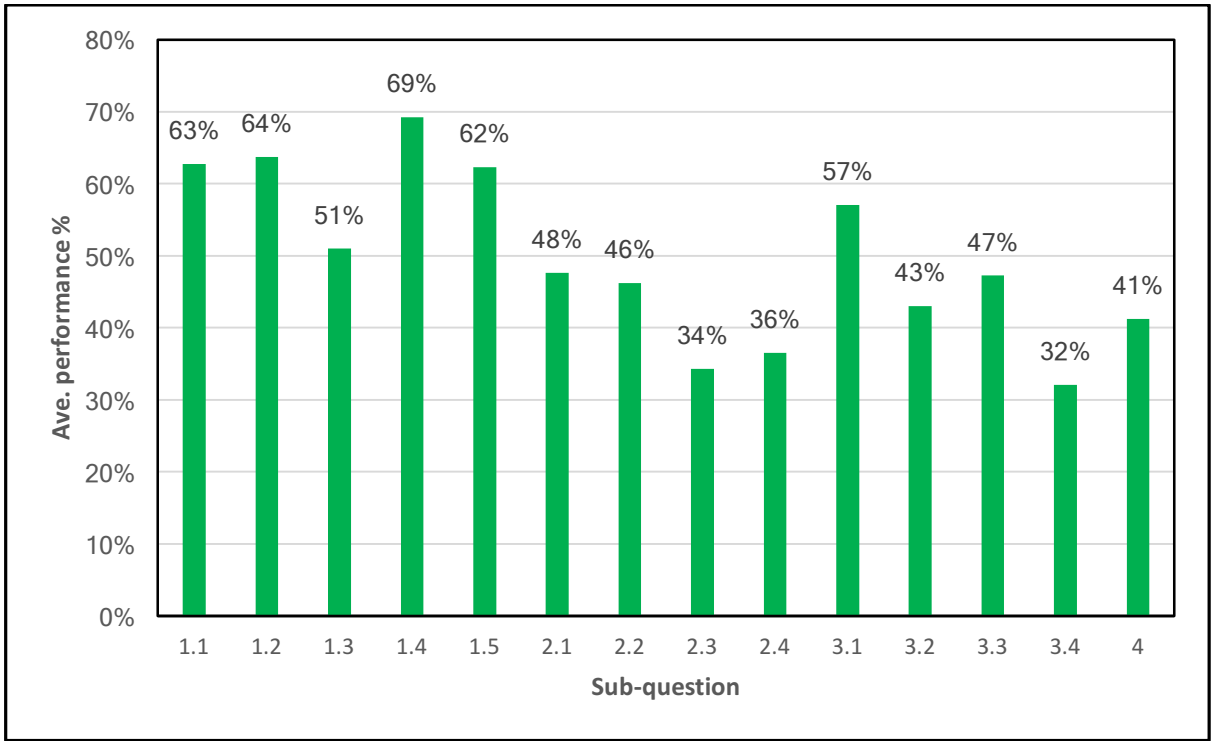
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 8.3.1 Average performance per question in Paper 1



Q	Topic/s
1	Multiple Choice, Terminology, Matching Items, Human Reproduction and Neurons
2	Brain and Sense Organs, Thyroxin and TSH and Plant hormones
3	Meiosis, Human Reproduction and Human Impact
4	Homeostasis and Human Impact

Graph 8.3.2 Average performance per sub-question in Paper 1



Sub-question	Topic/s
1.1	Multiple-Choice Questions
1.2	Terminology
1.3	AB matching
1.4	Human Reproduction – Sperm and development of the zygote
1.5	Human Response to the Environment - Neurons
2.1	Human Response to the Environment - Brain and ear
2.2	Human Response to the Environment - Accommodation
2.3	Endocrine System - Thyroxin and TSH
2.4	Plant hormones - Scientific investigation (auxin)
3.1	Meiosis
3.2	Human reproduction - Female
3.3	Human reproduction - Scientific investigation (male fertility)
3.4	Human impact - Fertilisers and nitrogen pollution
4	Homeostasis - Temperature and carbon dioxide Human Impact - Importance of carbon dioxide and global warming

The worst performance by candidates was recorded in the sub-questions on Thyroxin and TSH, Plant Hormones (based on an investigation), Human Reproduction, Homeostasis and Human Impact.

8.4 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 1

QUESTION 1: MULTIPLE-CHOICE, TERMINOLOGY, MATCHING ITEMS, HUMAN REPRODUCTION AND NEURONS

Common errors and misconceptions

(a) In Q1.1 candidates performed in well except for Q1.1.7 where they could not apply their knowledge on the methods to control alien invasive plants.

(b) In Q1.2 biological terms remain problematic for many candidates. In this regard candidates:

- Gave the term *monosomy* in Q1.2.3 instead of *haploid* for a cell that only has one set of chromosomes. 'Monosomy' was not accepted as an answer since it refers to the absence of a chromosome, e.g., 45 chromosomes instead of 46.
- Provided the term *tropism* in Q1.2.4 when the required term was *phototropism*; *umbilical cord* instead of *umbilical artery* in Q1.2.7 and could not differentiate between the *parasympathetic* and *sympathetic* nervous system in Q1.2.9.
- Confused the term *corpus callosum* with *corpus luteum* in Q1.2.6 and *choroid* with *chorion* in Q1.2.10.

(c) In Q1.3.3 many candidates did not know that internal fertilisation takes place in both altricial and precocial development.

(d) Many candidates lost marks in Q1.4 due to a lack of knowledge of the structure of the sperm and the developing zygote, despite this being stipulated as a requirement in the *Examination Guideline*.

(e) Marks were lost in Q1.5 due to candidates' inability to follow the instructions to give numbers of TWO neurons and not only one.

Suggestions for improvement

(a) There needs to be a greater emphasis on the teaching and learning of appropriate terminology related to the various topics, together with the correct spelling of these terms. Teachers should use various strategies to improve the teaching of terminology, many of which have been outlined in the Diagnostic Reports of the previous years.

(b) Learners should be encouraged to read questions with proper understanding.

(c) Certain sections of work, especially those that involve structure and function (such as the reproductive system in Q1.4, the sperm and the development of the zygote and the neurons in Q1.5) are best taught using diagrams.

Teachers should give learners multiple opportunities to label drawings and write in the functions next to the labels. The blank diagrams found in the *Mind the Gap* study guide will prove useful in this regard.

(d) Teachers should use the information provided by the *Examination Guideline* and not teach unnecessary content (given by some textbooks).

QUESTION 2: BRAIN, SENSE ORGANS, THYROXIN AND TSH AND AUXINS

Common errors and misconceptions

(a) Poor performance in Q2.1 was due to a lack of knowledge of basic terminology which was evident when candidates provided the answer:

- *Cerebellum* instead of *cerebrum* in Q2.1.1(a)
- *Oval window* instead of *round window* in Q2.1.2
- *Cochlea* instead of *Organ of Corti* where the receptors are found in Q2.1.3
- On *pupillary mechanism* instead of *accommodation* in Q2.2

(b) In Q2.1.4 candidates mentioned the functions of the medulla oblongata instead of explaining the consequence of it being damaged.

(c) Many candidates were unable to state the relationship between the cerebellum and the semi-circular canals in Q2.1.5. They described the whole process of balance, instead of how the cerebellum responds to the impulses. They also referred generally to effectors instead of specifically to skeletal muscles.

(d) In Q2.1.6 candidates described the normal process of hearing, instead of explaining how the hardening of the oval window will lead to hearing loss in older people. Many candidates used the word 'message' instead of 'impulse'. They used the terminology sound waves, pressure waves, vibrations and impulses incorrectly in their descriptions.

(e) Poor performance is Q2.3 can be attributed to the fact that candidates:

- Lacked the skill to interpret and use the graph to do the calculation correctly.
- Were unable to make the link that a high thyroxin concentration will increase the metabolic rate by using more glucose during cell respiration. Therefore, less glucose will be stored and fat will also be broken down to supply glucose, leading to weight loss.
- Had insufficient scientific knowledge, e.g. instead of glucose that is used they just wrote that energy is used up. The concept that glucose is broken down during cell respiration to release energy (as ATP) in a cell, is not well understood.
- Lacked the insight to explain the negative feedback between thyroxin and TSH when there is a high thyroxin concentration in the blood.

(f) In Q2.4 interpreting the investigation from the diagrams provided challenges to many candidates who showed a lack of knowledge of the prescribed practical work.

Candidates were not familiar with what 'agar' is. They could not state in a *cause-effect* way why the apical bud was placed on the block of agar jelly.

They explained the effect of light on auxins or apical dominance instead of the functions of auxins in cell elongation.

(g) Candidates were still not able to differentiate between the action verbs *state*, *describe* and *explain* in questions. Those who simply stated an answer correctly obtained 1 out of the 2 marks. An explanation consists of two parts, a statement and a substantiation of the statement and is thus credited with the full 2 marks. This is applicable to Q2.1.5 and Q2.1.6, Q2.2, Q2.3.3 and Q2.4.1.

Suggestions for improvement

(a) Teachers must use the correct biological terminology and not the common names, e.g. *impulse* instead of *message*. Learners should be taught to distinguish amongst vibrations, pressure waves, sound waves and impulses.

(b) The section on disorders or defects, together with their corrective mechanisms related to the nervous system, must not be neglected by teachers.

(c) Teachers should guide learners on how to answer questions based on predicting the effect of a part, such as the oval window when it fails to function. A successful answer depends in the first instance, on the learners' knowledge of the function of the structure. It is then easy to deduce what would happen if that function was not performed.

(d) Teachers should use diagrams or a table like the one below to show learners the difference between accommodation and pupillary mechanism, to avoid confusion between the two concepts. The first step is to ensure that learners can name the parts of the eye that are responsible for each process whilst they also identify these structures in a diagram of the eye.

	Accommodation	**Pupillary mechanism**
Stimulus	- Change in distance of object from the eye	- Change in light intensity
Parts involved	- Lens - Suspensory ligaments - Ciliary muscles	- Pupil - Radial muscles of iris - Circular muscles of iris
Main change that must take place	- Shape of lens	- Diameter of pupil
What brings about the change above	- Suspensory ligaments - Ciliary muscles	- Radial muscles of iris - Circular muscles of iris

(e) The formula to calculate percentage increase must be taught in schools.

(f) Teachers must expose learners to extracts like the one on thyrotoxicosis. This question had a high cognitive demand requiring an application of knowledge. Learners must be exposed to such questions and teachers must assist learners in reading with understanding.

(g) Learners should know the functions of thyroxin and other hormones. Teachers should emphasise the effects of too much or too little of a hormone on the body, and allow learners to explain the effects.

(h) The endocrine system must be taught with homeostasis to ensure that learners can understand the link between the feedback mechanisms of the different hormones.

(i) Teachers must integrate scientific investigations into the teaching and learning process. Prescribed practical work in plant responses must be done. Previous examination papers are useful in exposing learners to the different types of investigations of this topic. Teachers must emphasise cause-effect relationships and teach learners the skill of formulating answers in a logical way.

QUESTION 3: MEIOSIS, HUMAN REPRODUCTION AND HUMAN IMPACT

Common errors and misconceptions

(a) In Q3.1.2 some candidates were not able to correctly identify the phases of meiosis represented in the diagram. This is evident that they are not able to recognise the events of each phase. In some cases, for example, they identified the phase in diagram 2 as anaphase II rather than telophase II.

(b) Most candidates could not answer Q3.1.7. They could not apply their knowledge to explain the structural differences between the replicated chromosomes (due to DNA replication) and unreplicated chromosomes (due to splitting during anaphase II).

(c) The following common errors were observed in Q3.2:

- Some candidates lost a mark in Q3.2.1 by not correctly identifying part D.
- In Q3.2.3 candidates lost marks because they described ovulation instead of oogenesis. A description of oogenesis is provided in the *Examination Guideline*.
- Many candidates could not state how the uterus is suited for its function in Q 3.2.4.
- In Q3.2.5 many candidates could not explain in a cause-effect way why a person would not menstruate if the ovaries on both sides were removed.

(d) Some candidates failed to identify the dependent variable in the investigation in Q3.3.2 and the way in which it was measured.

(e) In Q3.4.2 many candidates could not explain why the farmer will not benefit economically by using more fertiliser than the recommended amount.

(f) In Q3.4.4 many candidates did not read the question properly and as a result they missed the 'effect that an increase in nitrogen pollution' will have on 'the number of bacteria'. They answered the question as to what the effect would be on water quality ignoring the effect on bacteria. Most included oxygen in their answer. Oxygen was the secondary effect. They answered the question as it was asked in previous question papers. Because they did not answer the question correctly, they lost the compulsory mark.

Suggestions for improvement

(a) Teachers should use strategies that will familiarise learners with the sequence of phases in meiosis as well as the defining events of each phase. The defining events must be observed in the form of diagrams.

(b) Blank diagrams from the *Mind the Gap* study guide could be used. The diagrams in the first column should first be labelled by the learners. Thereafter, the defining characteristics of each phase should be written alongside the diagram for each phase. This is a more active form of learning rather than giving learners a sheet where all this information already appears.

(c) Questions on the drawing of diagrams representing different phases of meiosis have appeared in many past examination question papers. Teachers should collate 4 or 5

such questions from past examination papers to provide practice for learners. In this way learners can master this skill in different contexts.

(d) Teachers should assist learners to differentiate amongst terminology e.g., replicated chromosome, unreplicated chromosome, chromatid and daughter chromosome as follows:

Term	Description
Unreplicated chromosome	This refers to a chromosome as it appears before DNA replication takes place.
Replicated chromosome	This refers to a chromosome as it appears after DNA replication takes place. Because of DNA replication all chromosome material is doubled. Hence, each replicated chromosome is made up of two chromatids, joined by a centromere.
Chromatid	This refers to each of the two threads of a replicated chromosome.
Daughter chromosome	This refers to each chromatid after it splits from its sister chromatid during anaphase II and is moving towards the poles.

(e) Teachers must place more emphasis on scientific investigations such as was assessed in Q3.3. They must teach learners how to identify variables using the aim of the investigation and not the results. Every formal assessment should assess Specific Aim 2, to familiarise learners with the scientific skills.

(f) There seems to be confusion between the terms *leaching* and *eutrophication* as was evident in answers to Q3.4. Leaching is the process when fertilisers are washed off the land by rain-water into rivers and lakes. Eutrophication is the process whereby the fertilisers accumulate in a water body, encouraging algal bloom.

QUESTION 4: ESSAY ON THERMOREGULATION, CO_2 CONTROL AND CO_2 & GLOBAL WARMING

Common errors and misconceptions

(a) In the essay in Q4, many candidates did not present their answers clearly under the following expected headings:

- How the body maintains the temperature when it arises above normal limits
- Maintaining the carbon dioxide level when it rises above normal levels
- Importance of carbon dioxide to maintain atmospheric temperature and the effect of increased levels of carbon dioxide on global warming

(b) Many candidates did not write the paragraphs in a cause-effect way to provide a logical flow of the processes.

(c) For the account on 'how the body maintains the temperature when it arises above normal limits', candidates lost marks in the following ways:

- Few candidates mentioned that the receptors are stimulated. Most candidates stated that the hypothalamus and medulla oblongata will detect the change.

- Many candidates used the word 'messages' instead of 'impulses' that were sent to the blood vessels in the skin causing it to dilate.

- Candidates lost marks for not stating that 'blood vessels in skin are stimulated', they just refer to 'blood vessels'.

- They did not write '**more** blood flows to the skin/sweat glands'. Candidates did not understand the 'more' concept. Sweat glands release sweat continuously but with a higher than normal temperature, more sweat will be lost.

(d) For the account on 'maintaining the carbon dioxide level when it rises above normal levels' candidates lost marks in the following ways:

- Many candidates mentioned the cardiovascular centre and respiratory centre but did not mention the medulla oblongata.

- Candidates had the idea that an increase in temperature causes an increase in the level of carbon dioxide.

- Some candidates discussed the action of adrenalin instead of carbon dioxide regulation.

(e) For the account on 'importance of carbon dioxide to maintain atmospheric temperature and the effect of increased levels of carbon dioxide on global warming' candidates lost marks in the following ways:

- Candidates did not know the functions of CO_2 and the fact that CO_2 is needed to keep the earth warm to make life on Earth possible.

- They described CO_2 as causing global warming rather than the *increase* in CO_2 which increases the average global temperature that leads to global warming.

- Candidates did not know the difference between the greenhouse effect and the enhanced greenhouse effect.

(f) From the 3 marks awarded to the synthesis of the essay, candidates lost 1 mark for:

- Relevance, when they gave answers for both a hot and a cold day or when they described the effect of ozone and deforestation on global warming.

- Logical sequence, when they failed to present information in a logical fashion.

- Comprehensiveness, when they answered only one aspect of the essay in detail or answer all three aspects but not in sufficient detail.

Suggestions for improvement

(a) From 2021, according to the Amendments to Section 4 of *CAPS* for the Life Sciences, there will be no essay in the examination paper.

(b) Learners do not understand the homeostatic control of temperature. The *Mind the Gap* study guide provides clear, detailed diagrams that describe the process of thermoregulation and CO_2 regulation.

(c) Some aspects of thermoregulation are not examinable. Teachers must consult the *Examination Guidelines* to note which aspects are required for assessment.

(d) When teaching the section on homeostasis, learners must be taught to identify, for each negative feedback mechanism, the stimulus, the control centre that receives the stimulus and formulates a response, the target organ that will respond, and how balance is then restored. The *Mind the Gap* study guide provides a framework of 6 principles against which all negative feedback mechanisms can be learnt.

8.5 OVERVIEW OF LEARNER PERFORMANCE IN PAPER 2

General comments

(a) In general, candidates did not perform as well as expected in recall type questions. This is an indication that they are not learning basic terms, laws, principles and definitions.

(b) Candidates performed well in questions requiring short answers, but performance was poor in questions requiring extended responses in the form of paragraphs and essays or in questions where answers had to be substantiated.

(c) Many candidates had difficulties in the interpretation of tables, graphs, case studies and diagrams. They also found it challenging to correctly phrase their responses.

(d) Many candidates still lack the skill of constructing a good essay.

(e) Certain problem areas mentioned in previous reports, for example investigations which form part of the work throughout the year, remain a challenge to some candidates.

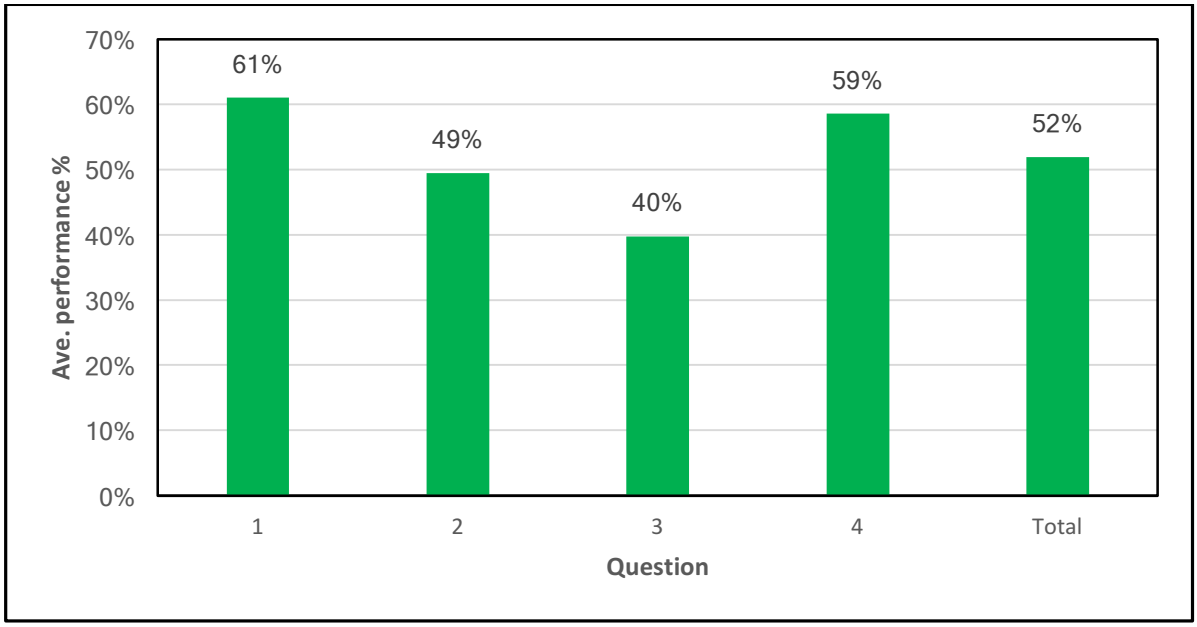
(f) Candidates' performance indicates that they are still having trouble in certain aspects of meiosis, genetics and evolution.

(g) Since textbooks do not always carry accurate information, teachers should always be guided by the *CAPS* and *Examination Guidelines* documents for Life Sciences, e.g., many textbooks refer to DNA fingerprinting instead of DNA profiling.

8.6 DIAGNOSTIC QUESTION ANALYSIS FOR PAPER 2

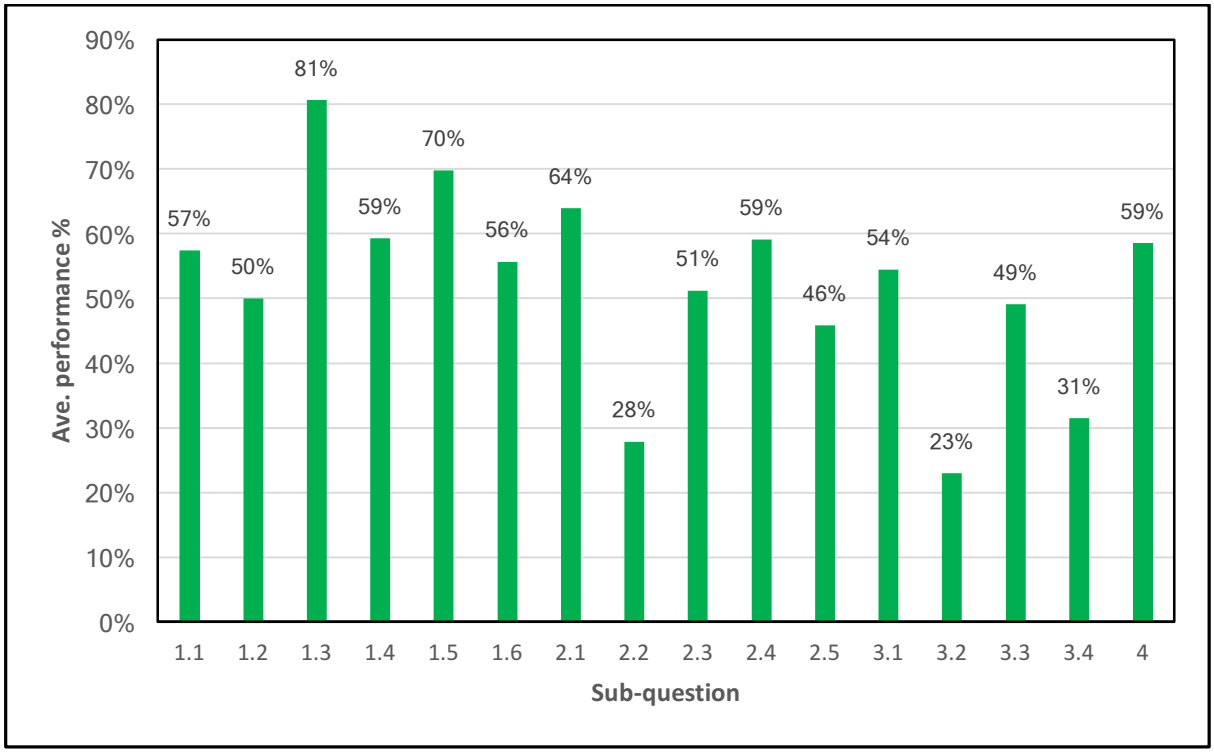
The following graph is based on data from a random sample of candidates. While this graph might not accurately reflect national averages, it is useful in assessing the relative degrees of challenge of each question as experienced by candidates.

Graph 8.6.1 Average performance per question in Paper 2



Q	Topic/s
1	Multiple Choice, Terminology, Matching Items, Meiosis, Dihybrid cross and Phylogenetic tree
2	DNA profiling, Cloning, Genetics (Pedigree diagram and sex-linked inheritance)
3	Evolution
4	DNA, DNA replication and Mitosis

Graph 8.6.2 Average performance per sub-question in Paper 2



Sub-question	Topic/s
1.1	Multiple-Choice Questions
1.2	Terminology
1.3	AB matching
1.4	Meiosis
1.5	Genetics - Dihybrid cross
1.6	Evolution - Evidence for evolution
2.1	DNA profiling
2.2	Genetics - Cloning
2.3	Genetics - Blood groups and genetic cross
2.4	Genetics - Mutations
2.5	Genetics - Pedigree diagram
3.1	Evolution - Natural selection
3.2	Evolution - Human evolution
3.3	Evolution - Scientific investigation (reproductive isolating mechanisms)
3.4	Evolution - Biogeography and Speciation
4	DNA - Location, structure, replication and significance of replication

The worst performance by candidates was recorded in the sub-questions on human evolution, cloning as well as biogeography and speciation.

8.7 ANALYSIS OF LEARNER PERFORMANCE IN EACH QUESTION IN PAPER 2

QUESTION 1: MULTIPLE-CHOICE, TERMINOLOGY, MATCHING ITEMS, MEIOSIS, A DIHYBRID CROSS AND A PHYLOGENETIC TREE

Common errors and misconceptions

(a) Incorrect understanding of the stem of Q1.1.6 led many candidates to give the phenotypic ratio of the F1 generation, rather than that of the F2 generation.

(b) In Q1.1.7 candidates were unfamiliar with the scientist who discovered the fossils of *Homo sapiens* and *Ardipithecus*. Candidates are required to know the names of the scientists who discovered the three hominid genera.

(c) Some candidates could not analyse the graphical representation of artificial selection in Q 1.1.8.

(d) Q1.1.10 required an application of the scientific method to a new scenario. The poor performance in this question indicates that candidates are unfamiliar with the terminology associated with the scientific process (further evidenced in Q3.3).

(e) Providing the correct biological terms in Q1.2 was problematic for many candidates. In this regard candidates:

- Confused similar sounding terms e.g., *homologous* and *homozygous in* Q1.2.1 as well as *chromatin* and *chromatid in* Q1.2.5.
- Could not provide the term *karyotype* for the shape and arrangement of chromosomes in a somatic cell in Q1.2.6.
- Named an organism that has a protruding jaw rather than giving the biological term for ‘having a protruding jaw’.

(f) In Q1.3 candidates were not able to differentiate between *continuous* and *discontinuous* variation.

(g) Marks were lost in Q1.4 because candidates were unable to identify the phase during which crossing over occurred and the number of chromosomes that would occur in a daughter cell. This type of question is often asked and candidates are meant to apply their response to the chromosome number given in the example and not assume that it is for a human cell. Once again learners confused similar sounding terms, viz. *centromere* and *centrosome.*

(h) It is encouraging to note that candidates are performing better in applying knowledge to a dihybrid cross, as in Q1.5, although the following challenges still occur:

- Phenotypes are written as a cross, e.g., *white x rough* instead of *White fur and rough texture.*
- Double letters are used for the genotype of gametes for a single characteristic.

(i) Q1.6 and Q3.2 were poorly answered and this was due to candidates' inability to read off a *phylogenetic tree* and to construct relatedness between species.

Suggestions for improvement

(a) Subject advisors must ensure that all teachers have copies of the most recent *Examination Guidelines (2021)*. Learners must also have access to the *Examination Guidelines* and use it as a 'tick list' as they study and master each topic.

(b) Teachers must use the *CAPS* document and the *Examination Guidelines* to establish what content is examinable.

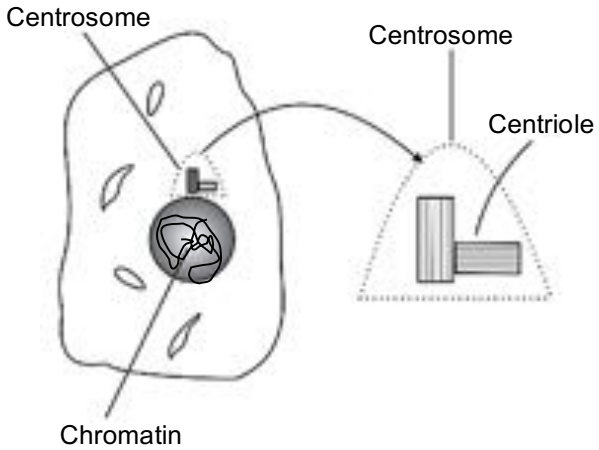
(c) The scientific process is a crucial component of assessment in Life Sciences and is often tested at a higher cognitive level. Teachers must use relevant and contextual examples to reinforce an understanding of the scientific process (see the section under Q3 for an elaboration on the scientific process).

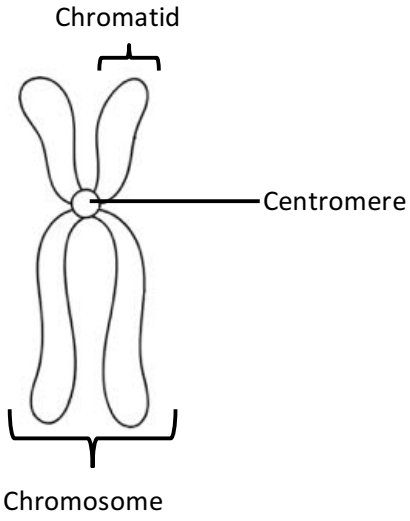
(d) There needs to be a greater emphasis on the teaching and learning of appropriate terminology related to the various topics, together with the correct spelling of these terms. Learners should be given activities where they have to distinguish between similar sounding words. This could take the form of a 'match-the-column' type of exercise.

The following table lists some terms that often cause confusion:

Term	Description
Chromosome	The DNA-containing structure that is made up of genes (found in cells that are undergoing cell division)
Centrosome	Structure that is responsible for the formation of spindle fibres during cell division in animal cells and is made up of two centrioles
Centromere	Structure that holds two chromatids together in a replicated chromosome and which also attaches the chromosome to the spindle fibres during cell division
Centriole	Two structures arranged at right angles to each other and together make up the centrosome.
Chromatin	The DNA-containing network found in cells in interphase (non-dividing)
Chromatid	A chromosome is made up of two chromatids held together by a centromere

The diagrams below can help to clarify some of the often-confused terms.

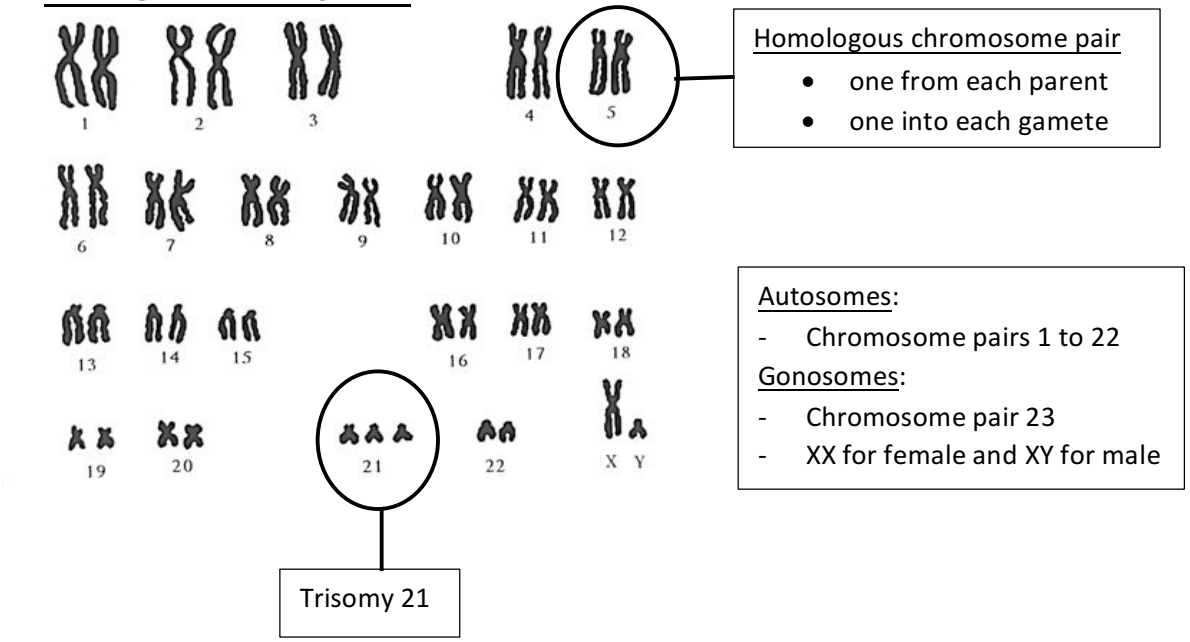




(e) Pictures of *karyotypes* can be used to reinforce the following concepts:

- Homologous chromosome pairs
- Autosomes and gonosomes
- Non-disjunction and Down syndrome (Trisomy 21)
- Introduction to meiosis
- Introduction to genetics
- Random assortment

THE HUMAN KARYOTYPE

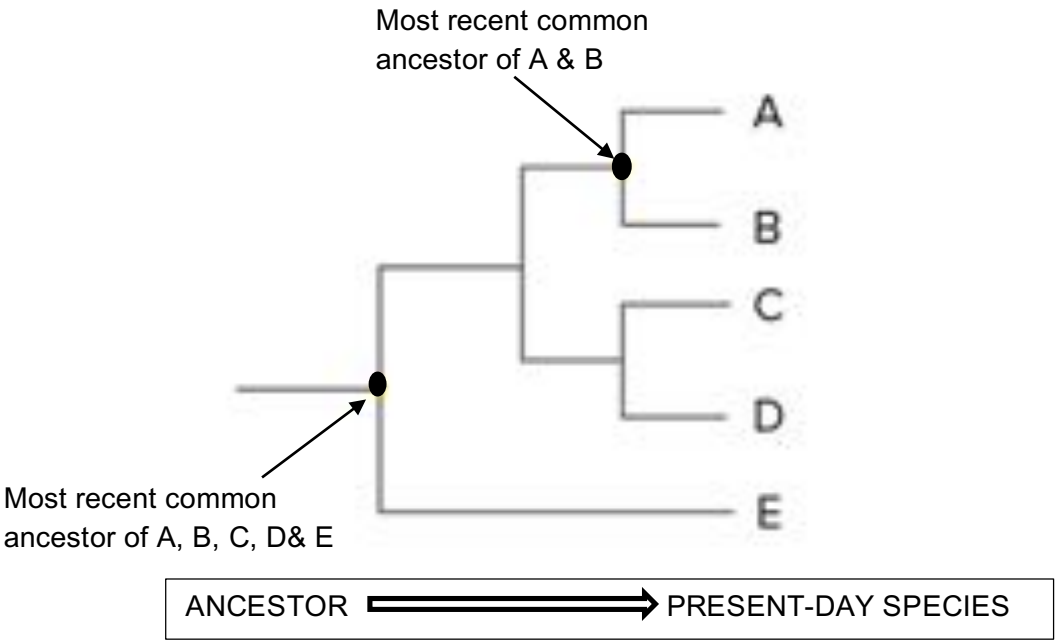


(f) Meiosis is best taught using diagrams from past question papers. Learners must be able to identify:

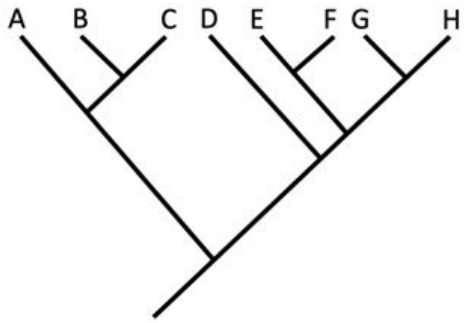
- The phase represented in the diagram, with reasons. When a phase is asked for, candidates will only be credited if they indicate whether it is from stage I or II e.g., *Metaphase I.*
- The correct sequence of phases
- The structures represented
- Functions of each structure
- Site of meiosis in plants and humans
- Chromosome number in parent and daughter cells

(g) Teachers must emphasise the difference between the genotype of an *individual* (BBhh) and the genotype of a *gamete* (Bh) in a dihybrid cross.

(h) Too many candidates refer to *phylogenic trees* instead of *phylogenetic trees*. Reinforce the mechanics of how phylogenetic trees work by using the following diagrams.



Phylogenetic trees may also be represented as follows:



Teachers must provide as many examples as possible of the different forms of phylogenetic trees. Almost every question paper has a different version and learners also need to familiarise themselves with those that are plotted on a timeline (as in Q3.2) and identify points of extinction and species that exist during the same period.

QUESTION 2: DNA, CLONING, GENE MUTATIONS AND GENETICS

Common errors and misconceptions

(a) In Q2.1.1 it is encouraging to note that fewer candidates referred to a *DNA fingerprint* but used the correct term, *DNA profile.*

(b) Candidates knew how to identify an individual from a DNA profile in Q2.1.2, but were unable to adequately explain how they did it in Q2.1.3. Many candidates wrote that the DNA matched, when it was required that they refer to the bands of the DNA profile. Many candidates confused the interpretation of a DNA profile for paternity testing with

that for forensics, mentioning that 50% of the bands match or that they were similar. it was required that they identify the bands that match exactly.

(c) Q2.2 recorded the lowest performance in the entire question paper. It is very evident that candidates are not familiar with the steps involved in cloning and the rationale behind each step. This question further tested the candidate's understanding of chromosome complement in gametes and somatic cells.

(d) Possible reasons for poor performance in Q2.3 may be because:

- Candidates used incorrect notation to represent blood group alleles.
- Candidates did not understand that the inheritance of blood group AB displays co-dominance, whereas the inheritance of blood groups A and B displays complete dominance.
- Although learners could conduct a genetic cross, they were unable to describe the process involved.
- Reference was not made to 'alleles' being *dominant* or *recessive*, but rather that a particular blood group is dominant over another.

(e) In Q2.4.1 most candidates provided a description of a *mutation* rather than that of a *gene mutation*.

(f) In Q2.4.3, although candidates could show the first steps of the calculation, they lost the last mark as they may not have used a calculator to compute the final answer.

(g) Candidates indicated the alleles in their answer to Q2.4.4 as superscripts on sex chromosomes (X^DX^d), even though this was not an example of a sex-linked inheritance.

(h) Confusion still exists between *pedigree diagrams* and *phylogenetic trees* which caused some candidates to lose a mark in Q2.5.1.

(i) In Q2.5.2 candidates lost the single mark as they only used the symbolic representation to identify the females and did not look to the third generation where words were used.

(j) Candidates probably lost marks in Q 2.5.3 because:

- This question was based on a sex-linked allele that is dominant, whereas they generally encounter sex-linked alleles that are recessive in most examples.
- The pedigree diagram had a combination of symbols and words.
- They used the incorrect genetic notation for a sex-linked allele.

(k) Many candidates lost marks in Q2.5.4 because they used the term *normal* instead of *unaffected.* They must use the terms that are provided in the key or in the description provided.

(l) The poor performance in Q2.5.5 confirms that candidates can represent a genetic cross, but are unable to explain the dynamics of the type of inheritance represented. Candidates did not refer to the inheritance of the Y chromosome from the father and the recessive allele on the X chromosome from the mother.

Suggestions for improvement

(a) The different application of DNA profiles needs to be clarified for learners as follows:

Use of DNA profile	What to look for
Forensics (Identification of a criminal, family member or a deceased person)	All the bands of the DNA sample must match exactly with that of the individual in question.
Paternity testing	Each band of the child must match either that of the mother or of the potential father. If the child has a band that does not match that of either parent, then that excludes that male as the father (see diagram below).

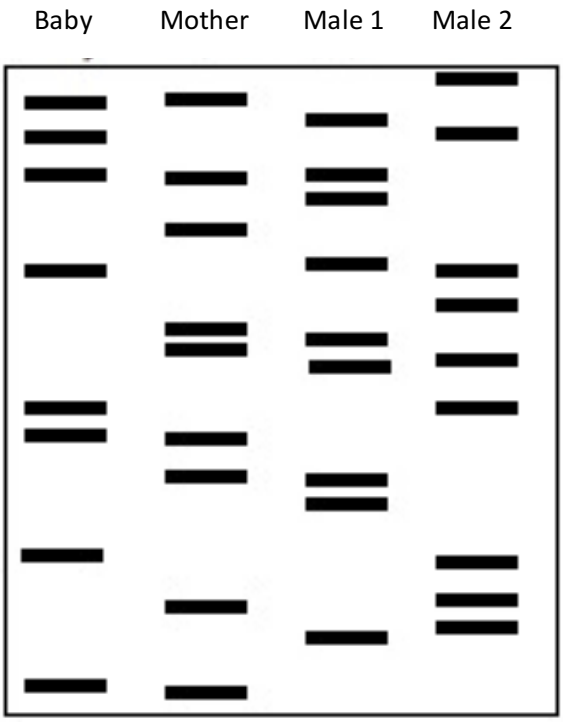
Q2.1 from this question paper must be used in the classroom as an example of the use of DNA profiles in forensics.

The following example may be used by teachers to explain how a DNA profile is used to confirm paternity. If there is a contest for paternity between male 1 and male 2, then the DNA profiles of the baby, mother and the two males will be compared as follows:

1) Look at the DNA bands of the baby

2) Identify all DNA bands that are common with that of the mother.

3) If all the remaining DNA bands of the baby correspond with that of one of the males, then that male is the father.



(b) Subject advisors and teachers should use Q2.2 in this question paper as a teaching tool. The stem of this question explains, in a very concise way, the steps involved in cloning. As the questions are answered, it becomes very clear as to the rationale behind every step. Previous question papers have diagrammatic descriptions of the process of cloning and these could all be compiled into a worksheet for the learners.

(c) Since the inheritance of blood groups display both co-dominance and complete dominance, it is important that learners understand the difference. The only accepted notations for the blood group alleles are as follows:

Phenotype (Blood group)	Genotype	Type of dominance
A	Homozygous - (I^AI^A) Heterozygous - (I^Ai)	Complete dominance of I^A over i
B	Homozygous - (I^BI^B) Heterozygous - (I^Bi)	Complete dominance of I^B over i
AB	Heterozygous - (I^AI^B)	Co-dominance between I^A and I^B
O	Homozygous - (ii)	Complete dominance of I^A and I^B over i

(d) Learners must be able to distinguish amongst the following terms:

- Mutation – a sudden change in the genetic composition of an organism
- Gene mutation – a change in the sequence of nitrogenous bases or nucleotides in DNA
- Chromosomal mutation – a change in the normal structure or number of chromosomes

Subject advisors must inform teachers that a description of *point* and *frameshift* mutations are not required.

(e) In Q2.5.3 and Q2.5.5 candidates lost marks for using the incorrect notations to represent alleles. The following table clarifies for learners the correct notations used for each of the different types of inheritance:

Type of inheritance	Brief description of the mode of inheritance
Complete dominance	One allele masks the expression of the other allele; e.g. B is dominant over b
Incomplete dominance	Neither of the alleles are dominant over each other. An intermediate phenotype is obtained when both alleles are present.
Co-dominance	Both alleles are equally dominant and both are expressed in the phenotype e.g. I^A and I^B
Sex-linked	The allele causing the disorder is found on the X-chromosome, e.g. X^HX^h & X^HY
Dihybrid cross	Two characteristics are investigated and therefore there will be four letters in the individual's genotype, e.g. RRYy (two for each characteristic) Gametes will have two different letters e.g. Ry

Pedigree diagrams are used by examiners to test higher order thinking. The mode and format may differ from one question paper to the next. Some aspects of the diagram may be omitted to test the candidate's ability to synthesise information. Candidates must use the descriptions given in the stem and/or key of a pedigree diagram when asked to provide a phenotype.

When asked to explain inheritance of alleles in an individual/s, learners must apply the following steps:

- Give the phenotype of the individual/s
- State the genotype of the individual/s
- State which allele is inherited from each parent or which each allele is passed on from each parent to the offspring

QUESTION 3: NATURAL SELECTION, HUMAN EVOLUTION, REPRODUCTIVE ISOLATION, BIOGEOGRAPHY AND SPECIATION

Common errors and misconceptions

(a) Q3.1 was well answered as it required a generic description of natural selection that required simple recall.

(b) Q3.2 on human evolution was one of the most poorly answered questions in this paper. Some provinces indicated that this topic was not assessed in their preparatory examinations.

(c) Many candidates, in Q3.2.1, referred to the family as *hominids* or *hominins* instead of *Hominidae* even though it is mentioned in the *Examination Guideline*.

(d) Candidates were unable, in Q3.2.2, to describe how cultural evidence is used to support the theory of human evolution.

(e) Interpretation of a phylogenetic tree in Q3.2.3 is still problematic.

(f) In response to Q3.2.4, candidates were unable to identify *H.ergaster* as a transitional species. This indicates that they are not familiar with the characteristics of a transitional species.

(g) Many candidates lacked the knowledge and understanding needed to explain how certain fossils are used to support the *Out of Africa hypothesis* in Q 3.2.5 even though it is clearly elaborated in the *Examination Guideline.*

(h) Candidates were unable to identify the independent variable in Q3.3.1.

(i) Many candidates referred to sample space instead of sample size in response to Q3.3.2. Also, the term accuracy was used incorrectly.

(j) In Q3.3.3 candidates incorrectly referred to baseline, fair testing and controlled variables, instead of to the *control.*

(k) When responding to Q3.3.4 and Q3.3.5 candidates were unable to identify the variables that had to be included in the graph caption and in the conclusion.

(l) Q3.4.1 was based on past and present distribution of a species and required candidates to have a good understanding of the concept of biogeography and to apply it to the given scenario. Due to the higher cognitive demand of this question, most candidates failed to score maximum marks.

(m) Candidates incorrectly use the words *species* and *population* interchangeably in Q3.4.2. Up to 4 marks were lost when they started with the species (rather than the population) being separated by a geographical barrier with no further mention of two groups/populations being formed. Furthermore, candidates provided a generic account of speciation, without relating it to the scenario provided.

Suggestions for improvement

(a) The preparatory examinations set by provinces must mimic the NSC examinations as closely as possible in format, content and scope.

(b) Scientific classification must be revisited in Grade 12 under the topic of human evolution even though it was originally taught in Grade 10. In this regard, learners must know the following:

Family of humans: *Hominidae*

Genera studied in human evolution:

- *Ardipithecus*
- *Australopithecus*
- *Homo*

Species studied in human evolution*:*

- *Australopithecus africanus*
- *Homo habilis*
- *Homo erectus*
- *Homo sapiens*
  (Other species may be mentioned in phylogenetic trees, graphs and extracts)

(c) Teachers must explain to learners how each line of evidence is used to support the theory of human evolution. The following table may be used and elaborated on:

Type of evidence	Explanation for evolution
Fossil record	Anatomical features of fossils are examined, compared and placed in sequence from most simple to more complex. Transitional species are those that display characteristics in-between those that it follows and those that it precedes. Transitional species may also share some characteristics with each of these two groups.
Biogeography	The current location of closely related species is an indication of how they may have evolved from a common ancestor. Biogeography may be linked to continental drift and speciation.
Genetic evidence	Similarities and differences between the genetic composition (DNA) of species shows relatedness between species and their possible evolution from a common ancestor.
Cultural evidence	The increasing complexity of items such as artefacts and tools are an indication of the advances (evolution) of the human intellect.

(d) Teachers need to explain to learners how fossil and genetic evidence support the *Out of Africa* hypothesis. This is clearly elaborated in the *Examination Guidelines*.

(e) The scientific process is frequently assessed in the Life Sciences. Questions on the scientific investigation will always be text and data-rich and learners must be sensitised to not be intimidated by this. Careful and repetitive reading of the stem and investigative process is required. Also, multiple exposure in a classroom situation can acclimatise learners to the style and format of these questions. The list below provides some terms associated with investigations and their meanings:

Term	Meaning
Observation	What the scientists saw, heard or encountered that encouraged them to investigate further.
Hypothesis	A possible prediction and/or explanation of the relationship between the two variables.
Aim	Usually starts with the words 'to investigate …' and includes both variables. It describes what the investigation is trying to find out.
The independent (manipulated) variable	This is the variable that the scientists will control.
The dependent (responding) variable	This variable is what reacts or responds to the independent variable.
The controlled variables	All other variables that must be kept constant to ensure the validity of the investigation so that any effect is ONLY due to the change in the independent variable.
The control	A second set up in the investigation that allows a comparison with the results of the experiment. The control is identical to the experiment except that it excludes the variable that is being tested.
Accuracy	Refers to the care taken when making measurements.
Validity	This refers to the experimental method and how appropriate it is in addressing the aim of the investigation. For example, keeping all other factors constant/identifying the controlled variables helps in making an investigation valid.
Results	The evidence produced during the investigation that will either support or refute the hypothesis. These may be presented in the form of an extract, a table, a graph or a diagram.
Improving the reliability of results	Results can be made more reliable if: • The investigation is repeated • A bigger sample size is used • The samples are taken randomly • Many readings are taken to obtain an average reading (these depend on the nature of the investigation),
Conclusion	This is directly linked to the aim of the investigation and confirms or refutes the hypothesis

(f) When formulating a caption for the graph, learners must include the variables that they have plotted. Variables used in the conclusion are drawn from the hypothesis or from the aim of the investigation.

(g) When teaching speciation by geographical isolation, teachers should use the description given in the *Examination Guidelines*, but must emphasise the concept that a population of the common ancestor becomes separated by a geographical barrier and forms two different populations. This is the starting point of speciation. Also, the geographical barrier must be correctly identified when a scenario is given.

(h) Teachers should consult all past diagnostic reports when they prepare their lessons to address misconceptions identified in previous years.

QUESTION 4: ESSAY ON DNA LOCATION & STRUCTURE, PROCESS OF DNA REPLICATION AND ITS SIGNIFICANCE FOR MITOSIS

Common errors and misconceptions

(a) In the essay in Q4, many candidates did not present their answers clearly under the following expected headings:

- Location and structure of DNA
- Process of DNA replication
- Significance of DNA replication in mitosis

(b) Candidates often lost the mark for:

- Relevance, by including irrelevant information such as on transcription, a description of the structure and location of RNA and the significance of DNA replication to meiosis rather than mitosis.

- Logical sequence, when they did not present information in a logical fashion. The events in the description of DNA replication were not given in the correct sequence. The significance of DNA replication was not provided in a cause-effect sequence.

- Comprehensiveness, when they answered only one aspect of the essay in detail or when they answered both aspects, but not in sufficient detail.

(c) Candidates did not receive credit on the actual content of the essay when they incorrectly:

- Mentioned components of RNA while discussing DNA
- Described transcription instead of DNA replication.
- Identified the location of DNA
- Stated that replication results in two identical strands instead of two identical DNA molecules with one original and one new strand
- Provided examples of complementary base pairs

(d) Many candidates neglected to identify the monomers of DNA as nucleotides and the complementary base pairs that are held together by weak hydrogen bonds.

Suggestions for improvement

(a) The 2021 NSC supplementary examination will be the last question paper to feature an essay in Q4. As from November 2021, the format of the question paper will be according to the amended section 4 of the *CAPS*. Subject advisors must facilitate and implement the amended *Examination Guidelines* (2021). This document outlines the new format of the question paper. There will still be paragraph-type questions and teachers will need to continue developing skills in learners that help them formulate extended writing responses. It is envisaged that an essay-type question of a different nature may be introduced into the question papers in a few years' time.

(b) The confusion between *DNA replication* and *transcription* is common. Both processes involve the same early steps, but that is where the similarity ends. Teachers must emphasise the differences between these two processes.

The following similarities exist between the processes of DNA replication and transcription:

- Occurs in the nucleus
- The DNA double helix unwinds
- The hydrogen bonds between the N-bases break/the DNA molecule unzips.

The table below outlines differences in the processes of DNA replication and transcription.

DNA replication	Transcription
Both strands act as templates	Only one strand acts as a template
Free DNA nucleotides from the nucleoplasm attach to each strand	Free RNA nucleotides from the nucleoplasm attach to the template strand
Complementary base pairing occurs (A-T) and (G-C)	Complementary base pairing occurs (A-U) and (G-C)
Two Identical DNA molecules are formed	An mRNA molecule is formed