2009 'A' Level
H2 Biology
Mark Scheme

PAPER 1 (MCQ)

1	**A**
2	**C**
3	**A**
4	**D**
5	**D**

6	**A**
7	**B**
8	**D**
9	**B**
10	**D**

11	**C**
12	**D**
13	**D**
14	**D**
15	**C**

16	**B**
17	**B**
18	**C**
19	**C**
20	**A**

21	**B**
22	**C**
23	**D**
24	**A**
25	**C**

26	**B**
27	**B**
28	**B**
29	**B**
30	**C**

31	**B**
32	**B**
33	**C**
34	**A**
35	**B**

36	**B**
37	**B**
38	**C**
39	**B**
40	**C**

PAPER 2 (CORE)

QUESTION 1

(a)
A – mRNA
B – polypeptide
C – cisterna/lumen of rough endoplasmic reticulum (reject RER/cristae)

(b)

Location	Ribosome present	Ribosome absent
Nucleus		√
Chloroplast	√	
Vacuole		√
Mitochondria	√	

4 correct = 2
3 correct = 1

(c)
1 allows the movement of synthesized polypeptide across the membrane;
2 functions as a receptor to bind the signal recognition particle/signal peptide of the polypeptide;
3 functions to hold the ribosome so that the polypeptide can be inserted into the ER lumen.

(d)
1 **transport** vesicle carrying the protein buds off the rough endoplasmic reticulum and transported to and fuse at the cis face of the Golgi body;
2 **secretory** vesicle buds off the trans face of the Golgi body and transports the protein to the cell surface membrane;
3 Membrane of the vesicle fuses with the plasma membrane and releases the protein via <u>exocytosis</u>;
4 **microtubules** aid in the transport of the vesicles from the ER to the Golgi body and to the plasma membrane

Examiner's comments: Many candidates <u>unnecessarily</u> wrote about the roles of the RER and Golgi in relation to the proteins.

(e)
1 through protein pore/protein channels on cell surface membrane

QUESTION 2

(a)

Bacterial chromosome	Plasmid
1 larger, with more genes	smaller, with fewer genes
2 has genes coding for production of enzymes for cell metabolism	has genes coding for genetic markers such antibiotic resistance

Examiner's comments: Need to mention exactly what the genes are coding for.

(b)
(i)
1 Sex pilus of the F^+ donor cell makes contact with the F^- recipient cell
2 Replication **and** transfer of F plasmid from F^+ into F^- cell

(ii)
1 Foreign DNA taken up by bacteria through its cell wall **and** plasma membrane
2 and is incorporated into bacterium's DNA via genetic recombination (homologous recombination or site-specific insertion)

(c)
1 Acquire antibiotic resistant genes
2 Acquire genes that confer ability to use a new metabolite
3 Acquire genes for other xenobiotic resistance (A xenobiotic is a chemical which is found in an organism but which is not normally produced or expected to be present in it)

Examiner's comments: Avoid making vague statements about helping bacteria to survive, increase variation or having same characteristics as donor.

(d)
1 phage attaches to specific receptors on bacterial cell wall and injects **viral** DNA into bacterial cell
2 expression of viral genes produces viral proteins like enzymes that breakdown host **bacteria** DNA into smaller pieces
3 Packaging of host **bacteria** DNA, together with **viral** DNA into the capsid of newly assembled phages
4 Upon lysis, resultant phages infect other bacteria which acquire the original bacterial DNA

Examiner's comments:
- Be specific in terms used: refer to **bacterial** DNA and **viral** DNA (not chromosomes or genomes) during description.
- There is no need to describe generalized and specialized transduction separately as the potential marking points in both are the same for the overall process of transduction.

QUESTION 3

(a)

1 DNA polymerase unable to replicate to the end of the chromosome without a free 3'OH end of a **pre-existing** nucleotide
2 Prevents loss of genetic information by acting as a disposable buffer blocking ends of chromosome
3 Prevents chromosomal DNA ends from being recognized as double-stranded breaks and initiating apoptosis/unintentional cell death
4 Prevents chromosomal end-to-end fusions with its binding to proteins to form a protective nucleoprotein cap

(b)

(i)

1 Binds to 3' end of DNA template at the enzyme's active site
2 Elongation of DNA via complementary base pairing using RNA as a template , catalyzing formation of phosphodiester bonds between nucleotides
3 The process is **repeated** as the telomerase moves in the 5' to 3' direction of the growing chain

Examiner's comments: Before describing the process of reverse transcription, need to mention about the binding of DNA template to enzyme's active site.

(ii)

1 Forms complementary base pairs with the end of the DNA / allows extension of DNA from its 3' end
2 Serves as a template for the complementary base pairing of new **deox**yribonucleotides
3 5'TTAGGG3' sequence is repeated

(c)

(i)

Circle RNA template sequence 3'-CAAUCCCAAUC-5'. This will code for the telomeric sequence TTAGGG.

(ii)

1 Stablilises telomerase RNA molecule by complementary base pairing
2 Contributes to specific shape to fit stably into telomerase enzyme

(iii)

1 DNA contains gene coding for transcription of telomerase RNA
2 RNA polymerase binds to and unzips double-stranded DNA
3 One of the two strands acts as a template for transcription of a complementary RNA strand

QUESTION 4

(a)

1 refers to the position of a **gene** on a chromosome
2 different alleles of a gene occupy the same gene locus

(b)

1 expected numbers if no linkage for all phenotypes : 660
2 total : 2640

(c)

1 genes found on the same chromosome

(d)

F_1 phenotypes:	Red eye, Normal wings				x	Purple eye, Vestigial wing			
F_1 genotypes:	RN/rn					rn/rn			
F_1 gametes:	RN	rn	Rn	rN		rn	rn	rn	rn

F_2 genotypes shown in Punnett square

F_1 gametes	RN	rn	Rn	rN
rn	RN/rn	rn/rn	Rn/rn	rN/rn

F_2 genotypes	RN/rn	rn/rn	Rn/rn	rN/rn
F_2 phenotypes	Red eye, Normal wing	Purple eye, Vestigial wing	Red eye, Vestigial wing	Purple eye, Normal wing
F_2 phenotypic ratio	1139 :	1195 :	151 :	155
	(Parental Phenotypes)		(Recombinant phenotypes)	

Examiner's comments:
Phenotypic ratio is not 1:1:1:1 as there is linkage of genes.
Many candidates did not use a convention to indicate linkage e.g. sticks or loops.
Some candidates annotated the recombinants.

(e)

1 calculation of recombination frequency (no. of recombinants / total no. of offsprings x 100%) where low recombinant frequency suggests close proximity of genes;
2 distance between genes represented as map units i.e. 1 map unit = 1% recombinant frequency;
3 if expected phenotypic ratio is obtained, it indicates no linkage between genes;

Examiner's comments: **Low recombinant frequency implies genes close proximity; BUT high recombinant frequency does not mean genes far apart.

QUESTION 5

(a)
1 gene was present in all of the species, so making it a good basis for comparison
2 slow mutation rate in gene / gene is highly conserved / restriction on change / silent mutations
3 found in mitochondria, therefore it is passed down the maternal line

(b)
1 Gene mutation base substitution
2 Due to errors in DNA replication

(c)
1 Neutral mutations do not confer any selective advantage or disadvantage
2 Rate of mutation is steady / plot of the line is straight
3 Silent mutations, no effect on the phenotype

(d)
1 **Genetic variations** exist among the Hawaiian honey creepers.
2 **Different selection pressures** on the different islands as each island was colonised by honey creepers, an example of adaptive radiation
3 Honey creepers with a selective advantage in the particular environment survived till reproductive age and pass on their genes to offsprings

QUESTION 6

(a)
(i)
A sister chromatids;
B centromere;
C kinetochore microtubules.

(ii)
1 during interphase (S phase of cell cycle), semi conservative replication of DNA occurs;
2 each chromosome is replicated to form two **identical** sister chromatids

(b)
(i)
1 anaphase

(ii)
1 centromeres divide;
2 sister chromatids separate to form chromosomes;
3 chromosomes pulled to opposite poles of the cell by the shortening of the kinetochore microtubules attached to the centromere

QUESTION 7

(a)

1 light saturation has occurred - an increase in light intensity will not cause further increase in the rate of photosynthesis.
2 Photosynthesis is at a maximum rate;
3 light is no longer a limiting factor, but some other factors are limiting. Eg. temperature

Examiner's comments: Even when carbon dioxide assimilation leveled off, photosynthesis and carbon dioxide assimilation still takes place.

(b)

1 at the lowest light intensity, there would be a low rate or no photosynthesis;
2 but **respiration** would still occur and carbon dioxide would be given off;
3 this occurs below the compensation point where carbon dioxide take in by photosynthesis is less than the carbon dioxide given off by respiration

Examiner's comments: A common error was to state that although there was no light reaction, there is still dark reaction which uses up carbon dioxide to give a negative value.

(c)

1 Point A is the compensation point when the rate of respiration equals the rate of photosynthesis;
2 There is no net gain in dry mass and no growth;
3 as any products of photosynthesis are used up in respiration;

QUESTION 8

(a) Describe the mode of action of enzymes. [8]

Active site

1 Active site contains catalytic residues involved in catalysis, and
2 contact residues involved in complementary binding of substrate to enzyme to form enzyme-substrate complex

Enzyme specificity

3 lock and key mechanism where substrate referred to as key while enzyme is referred to a lock
4 induced fit mechanism where binding of substrate induces conformational change in shape of enzyme enabling better fit/more effective binding of substrate

Lowering of activation energy

5 Enzymes lower activation energy of the reaction through formation of enzyme-substrate complex
6 Serves as a template to position substrate molecules in the correct orientation for catalysis ;
7 Induces stress in bonds of substrate ;
8 Increases substrate reactivity.

(b) Explain how pH affects the rate of an enzyme catalysed reaction. [8]

1 Optimum pH = pH at which the rate of an enzyme catalysed reaction is at its maximum
2 Ionic **and** hydrogen bonds maintaining the specific 3D conformation of enzyme are intact, hence 3D conformation of active site ideal ;
3 High frequency of **effective** collisions between enzyme and substrates results in high concentration of enzyme-substrate complexes formed hence products formed per unit time ;

4 Changes in pH affect concentration of H+ (and OH-) in the medium ;
5 Alters ionic charges of **acidic and basic** R groups of amino acid residues
6 Disrupts **ionic and hydrogen bonds** maintaining the specific 3D conformation of enzyme intact, hence 3D conformation of active site disrupted
7 Prevents enzyme-substrate complex formation ;
8 Enzyme denatured when pH is altered by a large extent ;

(c) Explain the effect of non-competitive inhibitors on enzyme activity [4]

1 Binds to an allosteric site on the enzyme, altering the 3D conformation of the active site
2 Substrate cannot bind to the active site, hence rate of reaction decreases
3 A non-competitive inhibitor renders a proportion of the enzyme molecules out of action where effective enzyme concentration is decreased.
4 Increasing the concentration of the substrate will not decrease the effect of inhibition

QUESTION 9

(a) Describe the transmission of an action potential along a myelinated neurone. [8]

1 resting potential in axon at -70 mV,

2 arrival of stimulus cause the opening of **some** voltage-gated Na^+ ion channels hence diffusion of Na^+ ions into the neurone results in depolarization;

3 when depolarization exceeds threshold potential , **all** voltage-gated Na^+ ion channels open causing further diffusion of Na^+ ions in results in an action potential when potential difference changes to +40 mV;

4 at the peak of the action potential, voltage-gated Na+ ion channels close while voltage-gated K+ ion channels open

5 diffusion of K+ ions out of axon results in membrane repolarisation (membrane potential decreases from +40 mV to resting level of -70 mV);

6 hyperpolarization due to voltage-gated K+ ion channels which remain open after the repolarisation phase

7 Na^+-K^+ pumps pump 3 Na^+ ions out for every 2 K^+ ions taken in restores the unequal distribution of Na+ ions and K+ ions in the intracellular and extracellular fluids at resting potential; **REJECT** "restores resting potential"

8 depolarization spreads to the node of Ranvier just ahead of the action potential due to the lateral diffusion of Na^+ ions to neighbouring node of Ranvier, resulting in the opening of Na^+ voltage-gated ion channels leading to diffusion of Na+ ions into axon at neighbouring node of Ranviers

**Examiner's comments: ****To describe the setting up of resting potential first, before describing depolarization. This is because depolarization cannot take place unless there is resting potential.

(b) Explain how a nerve impulse is passed across a synapse. [8]

1 Ca^{2+} concentration in synaptic knob is low
2 arrival of nerve impulse/action potential at the synaptic knob causes depolarisation of pre-synaptic membrane;

3 Voltage-gated Ca^{2+} channels open/increased permeability to Ca^{2+} ions causing diffusion of Ca^{2+} ions through pre-synaptic membrane into neurone;

4 synaptic vesicles containing neurotransmitter (eg. acetylcholine) migrate towards pre-synaptic membrane and fuse with it
5 release of neurotransmitter into synaptic cleft via exocytosis

6 neurotransmitter diffuses across synaptic cleft and bind to receptors on post-synaptic membrane;

7 ligand-gated sodium channels open, causing Na^{+} ions to diffuse in (in the case of EPSPs)
8 which results in depolarisation of post-synaptic membrane leading to an action potential

(c) Suggest the reasons why nerve impulses only travel in one direction across the synapse. [4]

1 Ca^{2+} ion channels open found only in pre-synaptic neurone;
2 vesicles containing the neurotransmitter found only in pre-synaptic neurone;
3 receptor proteins found only in post-synaptic neurone;
4 so neurotransmitter diffuses down concentration gradient;

Examiner's comments: Reject refractory period as question is on synapse.

PAPER 3 (APPLICATIONS)

QUESTION 1

(a)

(i)

TA CG
AT GC

(R) sequence not palindromic

(ii)

1 It is to cleave any **foreign** DNA that enters the bacterial cell
2 They protect bacteria from attack by viruses.

Examiner's comments: Reject cut at restriction site as the question is not about the use of the enzymes in genetic engineering.

(iii)

1 DNA from two or more <u>different sources</u> being incorporated in vitro into a <u>single</u> DNA molecule
2 Example, cDNA of human growth hormone and plasmid from E.coli cut with same restriction enzyme like BamHI, forming sticky ends
3 Complementary sticky ends anneal via hydrogen bonds ; DNA ligase join cDNA to plasmid, forming recombinant DNA

Examiner's comments: Unable to gain full marks if there is no example given, and no name of gene.

(iv)

1 HindII cuts across both strands of DNA create <u>blunt</u> ends that can join to any other blunt end fragment resulting in <u>non-specific annealing</u> because no sticky ends as recognition sites
2 Require use of <u>linkers</u> for hydrogen bonds to form
3 Particular restriction enzyme could cut at **more than one** restriction site so was less specific / could cut at the wrong place and therefore insert the gene in the incorrect location.

(b)

1 PCR **repeating** cycles of denaturation and elongation stages involves heating to high temperatures of 95˚C and 72˚C respectively
2 PCR requires high temperature of 95˚C to break the hydrogen bonds between the double-stranded DNA
3 Taq DNA polymerase able to withstand this high temperature without being denatured
4 Can remain stable without denaturation, allowing PCR process to take place

Examiner's comments: Responses are expected to focus on the ability of Taq polymerase to withstand high temperatures and not the description of the process.

QUESTION 2

(a)

(i)

[any 2 points]

1 Stem cells are unspecialized, can differentiate to specialized cells

2 Capable of long-term self-renewal, able to replicate/proliferate many times

3 Unlimited potency, which is the indefinite potential to differentiate

(ii)

1 Ability to differentiate into any cell type to become all the tissues of the body
2 Ability to continue to divide to produce more cells
3 Formation of fetus

Examiner's comments:
Reject description of how the 8-cell embryo had been derived from the zygote.
Reject explanation of the features of stem cells in relation to their potential use instead of their use in the formation of fetus.

(b)

(i)

1 Group A dogs 1 & 2 showed more expression of normal allele of 'G' than those in group B and dog 3 in group A, with an improvement in health
2 **No** dogs in group B showed an improvement in health

(ii)

1 Stem cells given to group A contain normal 'G' allele that was successfully expressed, producing normal protein

2 Stem cells given to group B had not taken up normal allele
3 Immune response to viral vector

Examiner's comments:
Many candidates merely restated the difference in expression between the two groups, or comments relating to group A also just restated the information given in the question rather than providing an explanation.

(iii)

1 Receptors on viruses allows virus to enter the host stem cell via receptor-mediated endocytosis

(iv)

1 Most transgenes insert ectopically and disrupts other useful genes

2 Difficulties in controlling the activity level of the transgene to make appropriate amounts of the gene product at the right time and in the right place

3 Short-lived nature of gene therapy as the rapidly dividing nature of many cells prevent gene therapy from achieving any long-term benefits

4 Immune response against common viruses since patients would have acquired antibodies during previous infection

5 Difficulty in treating multigene or multifactorial disorders

6 Limitations posed by current delivery methods e.g. safety of retroviral vectors, low efficiency of transfer

Examiner's comments:
Some candidates did not read the question carefully and included references to cost and ethics, which did not properly address the question of why the treatment is not effective.

QUESTION 3

(a)

1 Expression of allele in presence of bacteria causes infected leaf cells to die before infection spreads to entire leaf, causing plant to die
2 When there is no bacteria infection, the allele should not be expressed to prevent unnecessary damage to other healthy, non-infected leaf cells

Examiner's comments:
Some candidates simply restated the information given in the question, while others referred only to a waste of resources rather than the more critical effect of the expression of the allele.

(b)

1 Inability of transcription factors and RNA polymerase to bind to transcriptional control element
2 No formation of transcription initiation complex, hence transcription prevented

Examiner's comments:
Answers referring to formation of different or non-functional proteins are not appropriate as both alleles code for the same protein.

(c)

1 Gel electrophoresis separates DNA fragments based on size
2 Since Xa2 allele is 25bp larger than Xa1 allele, there will be 2 different sized DNA fragments
3 Xa2 DNA fragment will migrate slower than Xa1 DNA fragment
4 Xa2 band will be nearer the wells on the gel than Xa1 at the end of gel electrophoresis

(d)(i)

1 Increase mean number of bacteria colonies per leaf for first 3 days for all 3 groups as bacteria begins to multiply immediately after infection
2 After day 3, number of bacteria colonies per leaf decreases to 8 for P, 5 for R as time is needed for plant to recognize and subsequently trigger expression of alleles to produce the protein
3 After day 3, number of bacteria colonies per leaf start to drop for Q as the protein causes the death of the infected leaf cells so that the bacteria are unable to infect other healthy leaves

(d)(ii)

1 High crop yield through reduction of spoilage due to bacteria infection
2 Resistance to bacteria reduces need for employment of pesticides (cost-saving and health benefits)

(d)(iii)

1 Imprecise science / elementary stages – inserted genes might show undesirable effects on long term;
2 Lack of mandatory food labeling in some countries, not allowing consumers to make an informed choice based on religious, medical (allergies), personal backgrounds (vegetarians)

Examiner's comments: In this question, the specific example involves transferring a gene from one type of rice to another. Therefore, comments relating to religious objections to animal genes in the rice were irrelevant.

QUESTION 4

(a) Distinguish between a genomic DNA library and a cDNA library. [6]

Genomic DNA library	cDNA library
1 collection of all the cloned DNA fragments from the entire genome	represents the subset of genes / obtained from reverse transcription of mature mRNA in the starting cell
2 consists of large amount of DNA	consists of much smaller amount of DNA
3 presence of introns	absence of introns
4 No difference in the amounts of different DNA molecules.	Some proteins are produced in very large quantities by specialized cells. cDNA library prepared from these cells is highly enriched for the cDNA molecules encoding the protein.
5 useful if unsure as to what cell type the gene is expressed / useful if unable to obtain the particular cell type	useful for the study of genes responsible for the specialized functions of a particular cell type
6 not useful for tracing changes in patterns of gene expression	useful for tracing changes in patterns of gene expression during development / make cDNA from cells of the same type at different times in the life of an organism.
7 useful for if analysis of regulatory sequences or the introns associated with the gene is needed	useful if coding sequences of the gene were to be known / to deduce the amino acid sequence of the protein from the DNA sequence

Examiner's comments:

- When asked to 'distinguish' or 'compare', candidates should give adequate detail of both.
- One common problem was that the point about the different content in terms of coding and non-coding regions was made in a number of different ways, but the mark was only awarded once.
- It is not relevant to the question to describe how DNA in these libraries is used.

(b) Describe the properties of plasmids that allow them to be used a cloning vectors. [6]

1 The entire DNA sequence is known
2 Determine specific site where cloned gene inserts / easy to manipulate plasmid

3 Multiple cloning site with unique restriction enzyme sites
4 Segment of DNA containing many restriction sites, allowing insertion of one or several pieces of DNA into region of multiple cloning sites without fragmenting the plasmid

5 Contains one origin of replication (ori)
6 Enables independent replication of the plasmid and foreign gene inside the host cell. This results in multiple copies of the plasmid and foreign gene within one bacterium to be formed.

7 Contains suitable regulatory sequences, eg. prokaryotic promoter if bacteria host is used
8 Allows recognition by host cell's RNA polymerase for expression of inserted gene

9 Contains readily genetic / selectable markers such as antibiotic genes and LacZ gene which confer well-defined phenotypes on host cell
10 This allows easy identification of host cells containing the gene or recombinant vector

11 Minimal amount of DNA
12 Able to accept more inserts of larger size.

13 Relaxed mode of replication (high copy number for plasmid)
14 Large amount of cloned DNA can be produced.

Examiner's comments:
It is not relevant to the question to describe how plasmid was used.

(c) Outline the large-scale production of a named important protein by genetic engineering. [8]

1 Based on known amino acid sequences, DNA constructs of A chain and B chain of human insulin were synthesised;

2 Each gene was placed under the control of a lac promoter and part of the β-galactosidase structural gene;

3 Both recombinant plasmids were transformed separately into *E.coli*;

4 Transcription of lac promoter switched on when *E. coli* were grown in the presence of lactose;
5 The 2 artificial genes were expressed independently as fusion proteins;

6 The correct signal for initiation of translation is provided by the region immediately upstream of the β-galactosidase gene;

7 Cyanogen bromide is used to cleave the methionine residue, separating insulin polypeptides from the β-galactosidase fragments;

8 Purified A and B chains are attached to each other via disulfide bonds to form functional insulin;