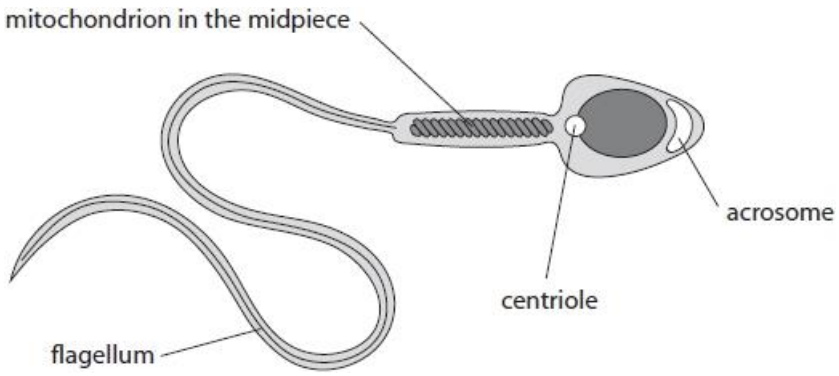
Questions

Q1.

Spermatogenesis is the process that results in the production of sperm cells.

The diagram shows a mature human sperm cell.



Human sperm cells contain centrioles but human egg cells do not.

Explain the role of the centrioles in sperm cells following fertilisation.

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(Total for question = 3 marks)

Q2.

A zygote is formed when gametes fuse at fertilisation.

Describe how the process of fertilisation results in the formation of a zygote from the gametes in humans.

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(Total for question = 3 marks)

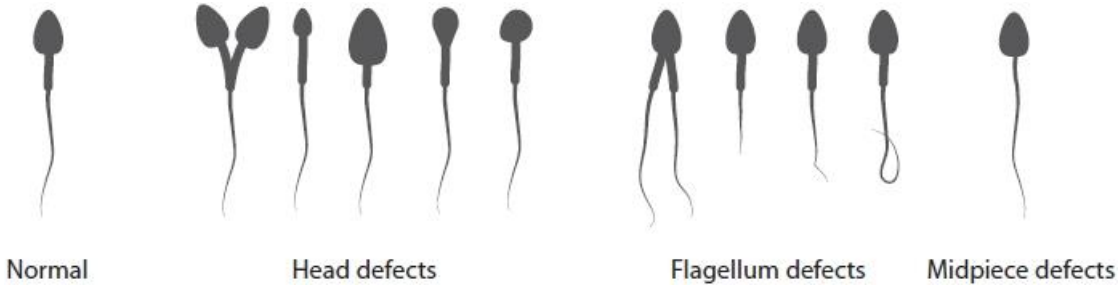
Q3.

Spermatogenesis is the process that results in the production of sperm cells.

*Male infertility can be caused by a number of factors related to sperm cells:

- low sperm count
- structural defects of sperm cells
- absence of an acrosome
- mutations in the mitochondrial DNA
- chromosome mutations.

The diagrams show a normal sperm cell and some sperm cells with structural defects.



Comment on how each of these five factors could result in male infertility.

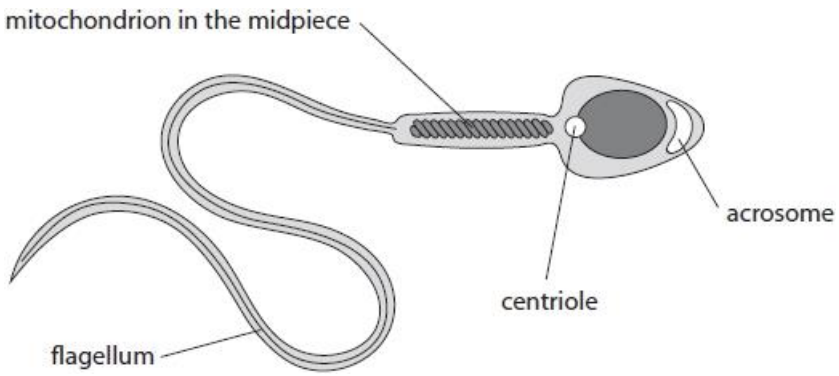
(6)

(Total for question = 6 marks)

Q4.

Spermatogenesis is the process that results in the production of sperm cells.

The diagram shows a mature human sperm cell.



(i) Which row of the table shows the type of nuclear division that takes place in spermatogonia and in primary spermatocytes?

(1)

	Spermatogonia	Primary spermatocytes
☒ **A**	meiosis I	meiosis II
☒ **B**	meiosis I	mitosis
☒ **C**	mitosis	mitosis
☒ **D**	mitosis	meiosis I

(ii) Which of the following pairs of cells are haploid?

(1)

☒ **A** primary spermatocytes and secondary spermatocytes

☒ **B** primary spermatocytes and spermatids

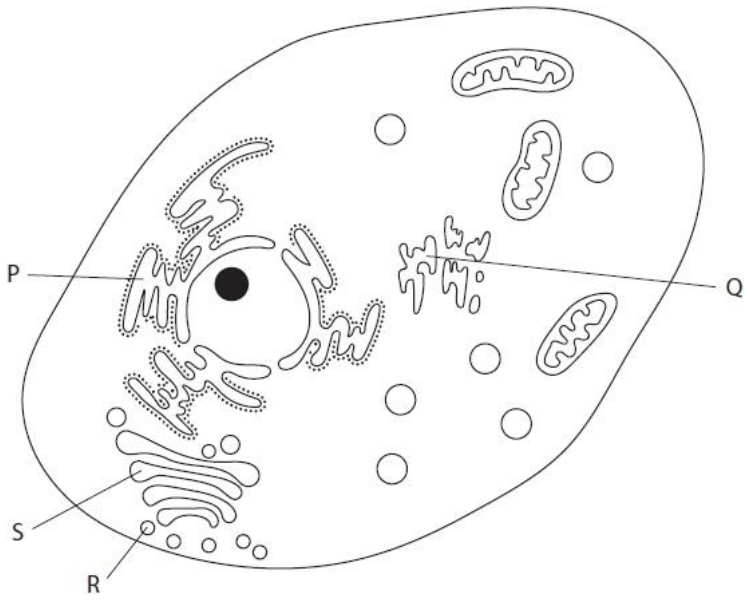
☒ **C** secondary spermatocytes and spermatids

☒ **D** spermatogonia and primary spermatocytes

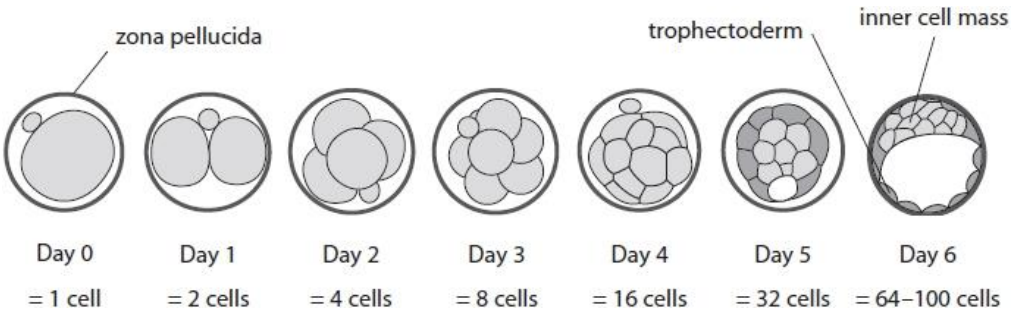
(Total for question = 2 marks)

Q5.

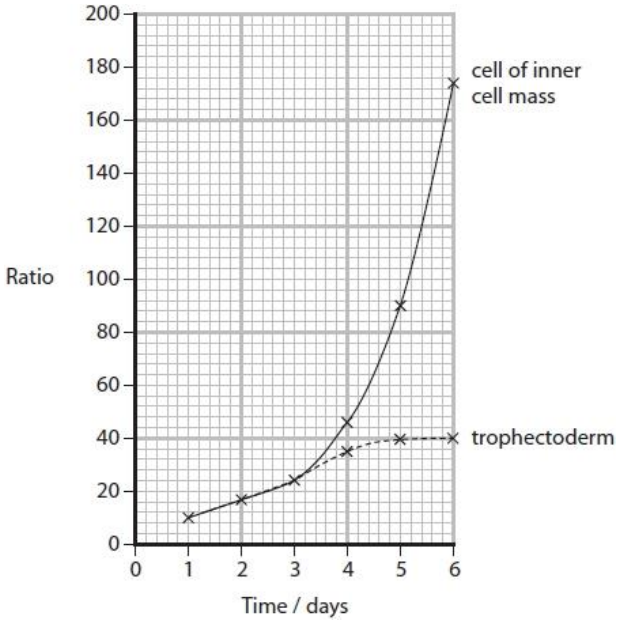
The diagram shows the structure of an animal cell.



The diagram shows the development of a zygote into a blastocyst.



The graph shows how the ratio of the volume of the nucleus to the volume of the cytoplasm of each embryonic cell changes as the blastocyst develops.



(i) The ratio shown in the graph can be calculated using the formula

$$\text{ratio} = \frac{\text{volume of nucleus}}{\text{total volume of cell} - \text{volume of nucleus}}$$

On day 2, the volume of the cell nucleus was 900 μm^3.

Calculate the total volume of this cell on day 2.

Give your answer to two significant figures.

(3)

Answer ..... μm^3

(ii) Comment on the changes in the ratios as the zygote develops into a blastocyst.

(3)

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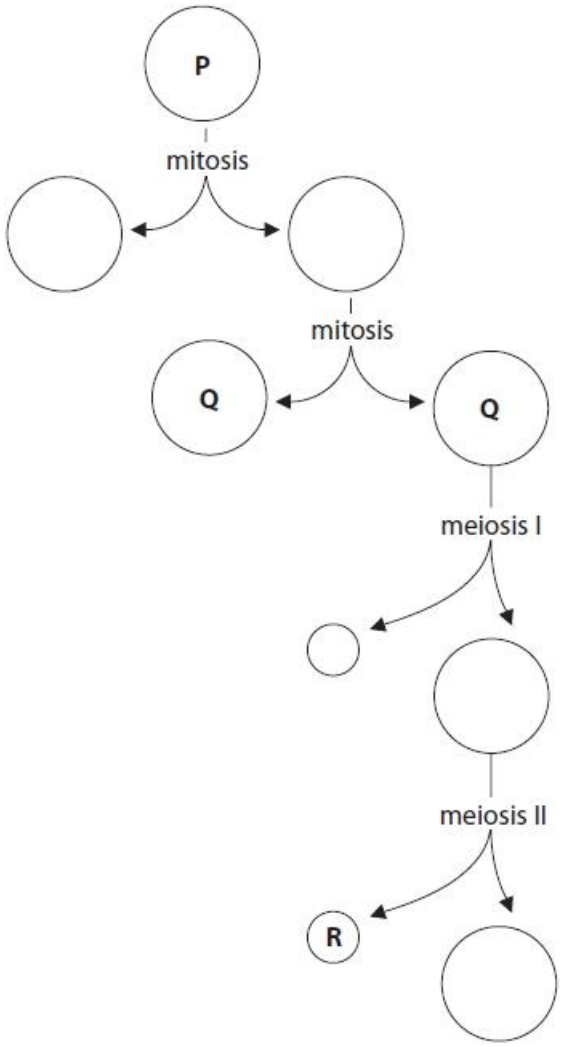
(Total for question = 6 marks)

Q6.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒

The diagram summarises the process of oogenesis in humans.



Which row contains the names for cells **P**, **Q** and **R**?

(1)

	P	Q	R
☒ **A**	germ cell	oocyte	polar body
☒ **B**	germ cell	polar body	ovum
☒ **C**	oocyte	polar body	ovum
☒ **D**	ovum	germ cell	oocyte

(Total for question = 1 mark)

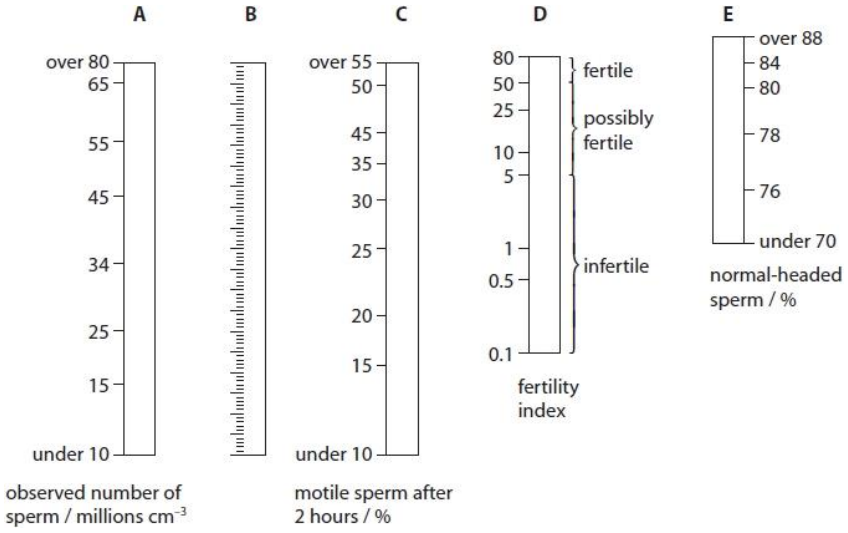
Q7.

Male fertility can be determined by a number of different factors.

Male fertility can be estimated using scales that take into account the number of sperm, their mobility and the percentage with a normal 'head'.

To calculate male fertility using these scales:

- draw a straight line between the observed number of sperm (scale A) and the percentage of sperm motile after 2 hours (scale C)
- from the intersection of this line with scale B, draw another straight line to scale E (the percentage of normal-headed sperm)
- the point where this second line crosses scale D (the fertility index), provides a relative assessment of fertility.



(i) Estimate the fertility of a man who produces a semen sample with:

- 25 million sperm per cm^3
- 35% of which are motile after 2 hours and
- 84% of which have normal heads.

(2)

Answer .....

(ii) Deduce why fertilisation is unlikely to occur if there are 5 million spermatozoa per cm^3.

(1)

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(Total for question = 3 marks)

Q8.

A study determined the number of oocytes in human females of different ages.

The table shows the results of this study.

Age / years	Mean number of oocytes per female
at birth	733 000
4 to 10	499 200
11 to 17	389 300
18 to 24	161 800
25 to 31	80 200
32 to 38	32 500
39 to 45	10 900

(i) Calculate the percentage change in the mean oocyte numbers between birth and 11 to 17 years.

(2)

Answer .....

(ii) Deduce when oocytes are produced in a female human.

(1)

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(Total for question = 3 marks)

Q9.

Male fertility can be determined by a number of different factors.

The mean volume of the semen produced by a male ejaculation is 3.4 cm^3.

This contains a mean concentration of 17 000 sperm mm^{-3}.

Calculate the mean total number of sperm in a single ejaculation.

Give your answer in standard form.

(2)

Answer .....

(Total for question = 2 marks)

Q10.

Male fertility can be determined by a number of different factors.

The distance from the point of ejaculation in the vagina to the upper end of the fallopian tube (where fertilisation takes place) is 19 cm.

Some sperm travel this distance in three hours.

Calculate the mean speed of these sperm in cm min^{-1}.

(1)

Answer .....

(Total for question = 1 mark)

Q11.

Some men are infertile due to a condition called azoospermia.

Men with this condition produce semen that contains spermatids instead of mature spermatozoa.

(i) State one structural difference between a spermatid and a mature spermatozoon.

(1)

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(ii) Explain why men with azoospermia are infertile.

(2)

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(iii) Infertility caused by azoospermia can be treated by using intracytoplasmic sperm injection (ICSI).

This procedure injects a single spermatid directly into an ooctye.
One concern about this procedure is that it uses selected spermatids. This eliminates the normal competition between sperm that precedes fertilisation.
Explain the advantage of competition between sperm.

(2)

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(iv) Describe two ethical implications of the use of ICSI.

(2)

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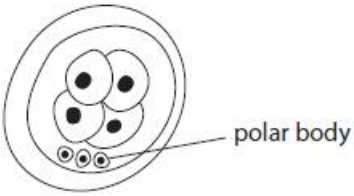
(Total for question = 7 marks)

Q12.

In vitro fertilisation (IVF) is a technique in which eggs are taken from the ovaries and fertilised with sperm in a laboratory.

The resulting embryos are cultured until the four-cell stage, as shown in the diagram.



Two screening techniques used to identify embryos with chromosomal abnormalities are:

- polar body biopsy in which the polar bodies are removed and the chromosomes analysed
- pre-implantation genetic diagnosis (PGD) in which one cell from the four-cell stage embryo is removed and the chromosomes analysed.

Embryos without chromosome abnormalities are placed into the mother's uterus.

The success rates of both techniques are shown in the table.

Technique	Percentage of embryos that survive screening (%)	Percentage of embryos transferred to the uterus that lead to the birth of baby (%)
Polar body biopsy	87	21
PGD	74	29
Control	IVF with no screening	16

Analyse the data to comment on the effectiveness of the two techniques.

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(Total for question = 4 marks)

Q13.

Leigh syndrome is a genetic disorder inherited from the mother. The mother carries genes for the disorder in her mitochondrial DNA.

Scientists have developed a technique for producing 'three-parent' babies.

This ensures that a mother with Leigh syndrome will not pass on the genes for this disorder to her baby.

The technique involves:

- removing the nucleus from the ovum of the mother
- removing the nucleus from the ovum of a donor female to produce an enucleated ovum
- inserting the nucleus from the ovum of the mother into the enucleated donor ovum
- fertilising this ovum with the sperm of the father to produce a zygote
- implanting the resulting embryo into the uterus of the mother.

(i) The 'three-parent' baby produced by this technique will inherit mitochondrial DNA from the

(1)

- ☒ **A** donor female
- ☒ **B** donor female and father
- ☒ **C** mother
- ☒ **D** mother and father

(ii) Explain the importance of DNA replication during the development of this zygote into a blastocyst.

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(Total for question = 4 marks)

Q14.

Mitochondrial disorders may be caused by mutations in the genes coding for mitochondrial components. Some of these genes are found in mitochondrial DNA (mtDNA) and some are found in nuclear DNA.

Leigh syndrome is an example of a mitochondrial disorder. In this syndrome, a number of different proteins involved in respiration are affected.

These mutations may be inherited or may occur when DNA replicates.

Explain why mutations in nuclear DNA can be inherited from either the mother or the father whereas mutations in mtDNA are only inherited from the mother.

(2)

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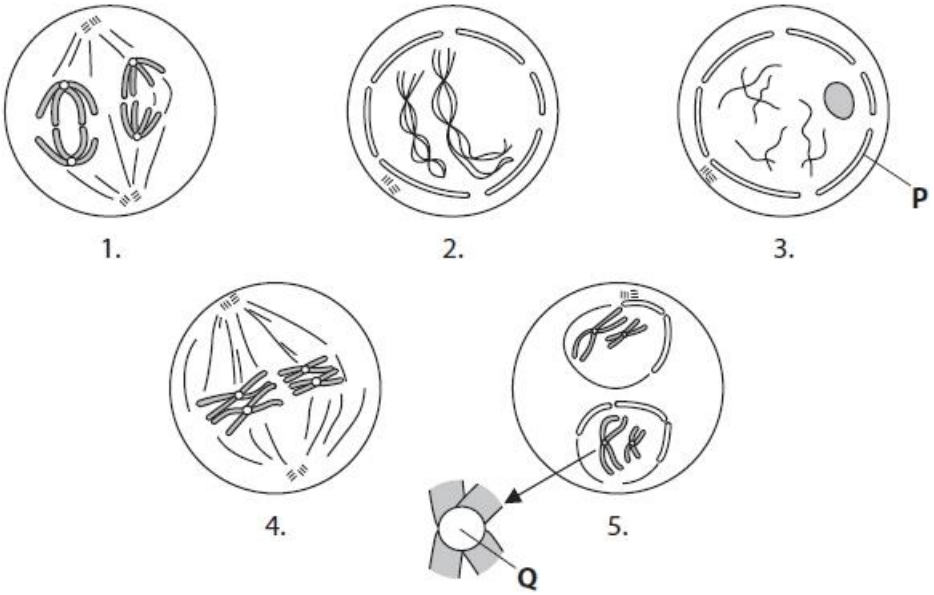
(Total for question = 2 marks)

Q15.

In some diploid organisms, haploid cells are produced by meiosis.

The diagram shows an animal cell at various stages during the first division of meiosis.



In mammals, meiosis occurs during oogenesis and spermatogenesis.

Describe how the products of oogenesis differ from the products of spermatogenesis in mammals.

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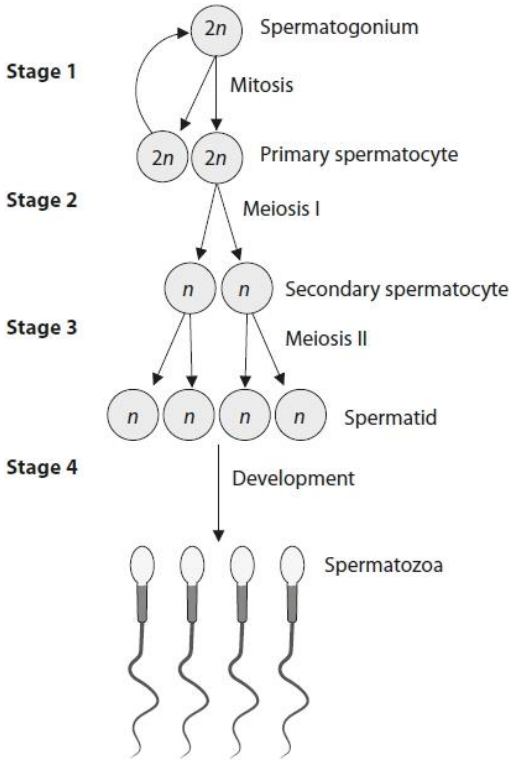
(Total for question = 4 marks)

Q16.

In mammals, gametes are produced by spermatogenesis and oogenesis.

The diagram shows some of the stages in spermatogenesis.



(i) Explain the significance of mitosis in stage 1 of spermatogenesis.

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(ii) Explain the events that take place in stage 2, that result in genetic variation.

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(iii) Compare and contrast the products of stage 2 and stage 3 in spermatogenesis with the products from these stages in oogenesis.

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(iv) Explain the importance of the acrosome that develops during stage 4.

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(Total for question = 11 marks)

Q17.

In mammals, gametes are produced by spermatogenesis and oogenesis.

The effect of storage time on sperm was investigated.

The table shows some results of this investigation.

Storage time /hours	Percentage of sperm with structural defects (%)	Percentage of sperm that could swim (%)
0	8.2 ± 3.9	85.0 ± 5.7
6	9.5 ± 3.1	67.5 ± 11.0
12	18.0 ± 3.9	66.3 ± 7.5
18	21.3 ± 6.1	67.5 ± 2.8
24	19.5 ± 3.1	58.8 ± 8.5
30	26.5 ± 3.1	41.3 ± 7.5

Analyse the data to comment on conclusions that can be made from this investigation.

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(Total for question = 4 marks)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

(i) The table shows the chromosome number and chromatid number of some of the cells formed during oogenesis in humans.

Cell type	Chromosome number	Chromatid number
ovum	23	23
primary oocyte	46	92
secondary oocyte	23	46

Which of the cells are haploid?

(1)

- ☒ **A** ovum and primary oocyte
- ☒ **B** ovum and secondary oocyte
- ☒ **C** primary oocyte and secondary oocyte
- ☒ **D** ovum alone

(ii) Explain how meiosis produces new combinations of alleles in gametes.

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(Total for question = 5 marks)

Q19.

Male fertility can be determined by a number of different factors.

Describe the process of spermatogenesis.

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(Total for question = 4 marks)

Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • to be the source of centrioles in the zygote (1) • so that the spindle (fibres) can be synthesised (in the zygote / embryo) (1) • so that the (fertilised egg cell /zygote) can divide by mitosis (to form the embryo) (1)	**ACCEPT** fertilised egg cell / cell resulting from fertilisation **IGNORE** egg **DO NOT ACCEPT** meiosis	(3) EXP

Q2.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to three of the following: • (contact between sperm and secondary oocyte results in) <u>acrosome</u> reaction (1) • meiosis is completed (1) • <u>cortical</u> reaction takes place (1) • fusion of sperm {nucleus / genetic material} with {nucleus genetic material} of ovum (1)	**PENALISE** 'egg' once **ACCEPT** ovum / egg cell / female gamete description e.g. enzymes are released from the <u>acrosome</u> **DO NOT ACCEPT** if described after cortical reaction or fusion of two cells **ACCEPT** description e.g. <u>cortical</u> granules are released that {hardens the membrane / forms a fertilisation membrane} **ACCEPT** egg cell / nuclei of the gametes	(3) EXP

Q3.

Question Number	Indicative content	
*	Low sperm counts: • fewer sperm arriving at the egg cell, reducing the likelihood of fertilisation • not enough enzymes released for fertilisation Absence of an acrosome: • sperm will not be able to digest through (the outer membrane of egg cell) • therefore {nucleus / genetic material} will not be released inside the egg cell Mutations in the mitochondrial DNA: • less energy available for flagellum • without energy sperm will not be able to swim (through female) Chromosomal mutations: • could result in {lack of / too much} genetic material • cell division maybe affected • embryo maybe defective and not develop Structural defects: • defect in head may prevent penetration of sperm into egg cell • defects in flagellum could prevent motility • two heads might prevent entry into egg cell* • small head may not contain {an acrosome / a nucleus}* • misshapen head may {not be able to penetrate egg cell / impair motility}* • two flagella may {get tangled up together / not receive sufficient energy for swimming}* • short flagella may not provide enough motility* • no mid piece would mean no energy for swimming*	**Level 1:** 1 mark = effect of one factor commented on 2 marks = effects of two factors commented on **Level 2:** 3 marks = effects of three factors commented on 4 marks = effects of four factors commented on **Level 3:** 5 marks = effects of all five factors commented on 6 marks = effects of all five factors commented on but includes **one** specific types of structural defects*

Q4.

Question Number	Answer	Mark
(i)	**The only correct answer is D** ***A*** *is incorrect because spermatogonia divide by mitosis and primary spermatocytes divide in meiosis I to form secondary spermatocytes* ***B*** *is incorrect because spermatogonia divide by mitosis and primary spermatocytes divide in meiosis I to form secondary spermatocytes* ***C*** *is incorrect because spermatogonia divide by mitosis and primary spermatocytes divide in meiosis I to form secondary spermatocytes*	(1) COMP
(ii)	**The only correct answer is C** ***A*** *is incorrect because primary spermatocytes are diploid* ***B*** *is incorrect because primary spermatocytes are diploid* ***D*** *is incorrect because primary spermatocytes are diploid*	(1) COMP

Q5.

Question Number	Answer	Additional Guidance	Mark
(i)	• correct reading from graph (1) • correct calculation of mean total cell volume (1) • correct conversion into two significant figures (1)	Example: 17 or 16 952.94 or 956.25 (ignore dps) **950** or **960** (952.94 or 956.25 gains **two marks)** (950 or 960 gains **three marks**) Correct answer with no working gains full marks	**3 exp**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to three of the following points: • (ratio) ICM increases up to 3/4 days (at a steady rate) / trophectoderm cells increase up to 3/4/5 days (1) • (after 3/4 days) ratios increases more steeply for ICM cells / (after 3/4/5 days) levels off for trophectoderm cells (1) • (as ratio increases) {volume of cytoplasm / volume of cells} decreases (over time) (for ICM cells) (1) • cells are differentiating (1)	**Accept** ratio increases up to 3 days **Accept** faster increase for ICM cells **Accept** ICM divide faster than trophectoderm cells	**3 exp**

Q6.

Question Number	Answer	Mark
	The only correct answer is A ***B*** *is not correct because Q is not a polar body* ***C*** *is not correct because P is a germ cell not an oocyte* ***D*** *is not correct because P is a germ cell not an ovum*	**(1)**

Q7.

Question Number	Answer	Additional Guidance	Mark
(i)	• two correct straight lines drawn (1) • possibly fertile (1)	**Allow** 11 - 13	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• off the bottom of the scale therefore person is infertile	**Allow** infertile (on the scale)	(1)

Q8.

Question Number	Answer	Additional Guidance	Mark
(i)	A calculation that shows: • data read from table and subtracted (1) • percentage change calculated (1)	Example of calculation • 733000 – 389300 = 343700 • 343700 / 733000 X 100/1 = 46.9% ACCEPT both positive and negative answers correct answer gets both marks ACCEPT 47% and 46.89%	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	produced before birth (1)	ACCEPT during gestation, pregnancy	(1)

Q9.

Question Number	Answer	Additional Guidance	Mark
	A calculation that shows: • total number of spermatozoa calculated (1) • answer given in standard form (1)	Example of calculation • 3400 × 17000 • = 5.8×10^7 **Allow** 5.78×10^7	(2)

Q10.

Question Number	Answer	Additional Guidance	Mark
	A calculation that shows: • speed of sperm travel = 0.11 cm min^{-1}	Example of calculation 3 × 60 = 180 19 ÷ 180 = 0.11 / 0.106	(1)

Q11.

Question Number	Answer	Additional Guidance	Mark
(i)	spermatids have no {tail / flagellum / acrosome} (1)	ACCEPT converse / spermatids have fewer {enzymes / mitochondria }	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following: • spermatids are non–motile / cannot swim to the egg (1) • therefore spermatids are unable to penetrate the egg (1)	ACCEPT stationary ACCEPT so no fusion with the oocyte occurs / no acrosome reaction / unable to fertilise the egg	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following: • {fittest / fastest / most developed / healthiest } will fertilise the oocyte (1) • therefore pass on advantageous alleles (1)	ACCEPT converse ACCEPT natural selection can take place	(2)

Question Number	Answer	Additional Guidance	Mark
(iv)	A description that makes reference to two of the following: • interference with natural process e.g. fertilising male gamete chosen by doctor rather than natural competition (1) • embryo may be abnormal because of {lack of competition from other sperm/ lack of natural selection / damage due to technique / chromosome abnormality / gene mutation passed on} (1) • provides possibility of {eugenics / artificial selection / designer babies} (1)		**(2)**

Q12.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to four of the following: • {screening / both techniques} are {more effective / produce more births} than control (1) • more embryos survive screening with polar body biopsy than PGD / polar body biopsy is less damaging than PGD (1) • PGD more effective (than polar body biopsy) / PGD produces more births (than polar body biopsy) (1) • (because) PGD produces 21% births compared to 18% with polar body (1) • PGD detects abnormalities in both paternal and maternal chromosomes / polar body biopsy only checks for maternal chromosome abnormalities (1)	**ACCEPT** converse **ACCEPT** converse **ACCEPT** converse **ACCEPT** 21.46 / 21.5 / 18.27 /18.3 **ACCEPT** 0.21 /0.215 / 0.18 / 0.183 / 0.1827 **DO NOT ACCEPT** just 21% alone **ACCEPT** ideas that polar body biopsy only screens for abnormalities from mother / PGD screens both parents	**(4)**

Q13.

Question Number	Answer	Mark
(i)	**The only correct answer is A** ***B*** *is not correct because the father's mitochondria do not enter the ovum on fertilisation* ***C*** *is not correct because only the nucleus was used from the mother* ***D*** *is not correct because only the nucleus was used from the mother and the father's mitochondria do not enter the ovum on fertilisation*	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to three of the following: • zygote divides by mitosis (several times to form blastocyst) (1) • to make identical copies of the {DNA (molecules) / chromatids} (1) • so that all cells (in the blastocyst) {will be diploid / have two copies of each chromosome} (1) • so that when the mitochondria divide they will have a copy of the DNA (1)	**ACCEPT** genetically-identical (daughter) cells / same genetic information **ACCEPT** correct number of chromosome / 46 chromosomes / 23 pairs **ACCEPT** mitochondrial DNA divides	**(3)**

Q14.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following: • because nuclear DNA is present in both the male and female {gametes / sex cells } **(1)** • because mitochondria are present in the { female gamete / ovum / secondary oocyte / egg cell} and not the sperm head **(1)**	**Accept** in male and female nuclei in the context of fertilisation **Accept** mitochondria are present in sperm {neck / mid piece} / mitochondria (DNA) not released by the sperm	**(2)**

Q15.

Question Number	Answer	Additional Guidance	Mark
	A description that makes reference to four of the following: • ova { are larger cells / contain more food stores / contain more cytoplasm } (1) • spermatozoa contain an acrosome, ova do not (1) • spermatozoa has a {tail / flagellum / microtubules}, ova do not (1) • ova are surrounded by the {zona pellucida / other cells}, spermatozoa are not (1) • oogenesis produces polar bodies, spermatogenesis does not (1)	accept references to egg and sperm accept sperm are motile while ova are not accept each spermatid may produce a spermatozoa / the number of spermatozoa produced are much higher than the number of ova	**(4)**

Q16.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to two of the following: • to produce several diploid primary spermatocytes (1) • so that lots of sperm can be produced from a single spermatogonium (1) • to replace the spermatogonia (1)		**(2)** **EXP**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following: • crossing over (in prophase I) (1) • to produce new combinations of alleles on a chromatid (1) • independent assortment (in metaphase I) (1) • to increase the combination of chromosomes in eachdaughter cell (1)	increase variety of combinations of maternal and paternal chromatids / alleles	(4) EXP

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to one similarity and twodifferences : **Similarities** • haploid cells produced from diploid cells in both (1) **Differences** • {stage 2 / meiosis I} results in two secondary spermatocytesbut only one secondary oocyte (1) • {stage 3 / meiosis II} results in four spermatids but one {ovum / egg cell} (1) • polar bodies are produced in oogenesis but not in spermatogenesis (1)		(3) EXP

Question Number	Answer	Additional Guidance	Mark
(iv)	An explanation that makes reference to the following: • Contains enzymes (1) • to enable the sperm to digest through the membrane of the(secondary oocyte) (1)		(2) EXP

Q17.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to four of the following: • storage time increases the percentage of sperm with structural defects (1) • storage time decreases the percentage of sperm that canswim (1) • because the error bars for no storage and 30 hours ofstorage do not overlap (1) • increase in storage time may not correlate with an increase inthe number of defects and / or decrease in the number of sperm that can swim (1) • as a number of the error bars {overlap / are large} (in bothsets of data) (1)	**ACCEPT** clear use of data to illustratepoint **ACCEPT** clear use of data to illustratepoint	**(4)** **EXP**

Q18.

Question Number	Answer	Additional Guidance	Mark
(i)	B ovum and secondary oocyte A is incorrect because secondary oocyte is diploid C is incorrect because the secondary oocyte is diploidD is incorrect because the primary oocyte is diploid		1
(ii)	*An explanation that makes reference to:* • crossing over (1) • which swaps {alleles / DNA / genes} between {homologous chromosomes} (1) • independent / random assortment (1) • because it is random movement of homologous chromosomes to poles (1)	**Allow** random movement of paternaland maternal chromosomes / random combinations of paternal and maternal chromosomes	4

Q19.

Question Number	Answer	Additional Guidance	Mark
	An description that makes reference to four of the following: • germ cells divide by mitosis / form {spermatogonia / primary spermatocytes} (1) • which divide by meiosis to form secondary spermatocytes (1) • which divide to form spermatids / 2nd meiotic division forms haploid spermatids (1) • which develop into {(mature) spermatozoa / sperm} (1) • which includes {an acrosome / flagellum} (1)	**Allow** differentiate	(4)