UNIVERSITY OF SWAZILAND

MAIN EXAMINATION PAPER: DECEMBER 2013

TITLE OF PAPER: GENETICS

COURSE CODE: B303

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:
1. THIS PAPER IS DIVIDED INTO TWO SECTIONS
2. ANSWER QUESTION 1 (COMPULSORY) IN SECTION A AND ANY THREE OTHER QUESTIONS IN SECTION B
3. EACH QUESTION CARRIES TWENTY FIVE (25) MARKS
4. ILLUSTRATE YOUR ANSWER WITH LARGE AND CLEARLY LABELLED DIAGRAMS WHERE APPROPRIATE

SPECIAL REQUIREMENTS: CANDIDATES MAY BRING CALCULATORS

THIS PAPER SHOULD NOT BE OPENED UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATORS

SECTION A (COMPULSORY)

Question 1

(a) Describe the molecular organisation of eukaryotic chromosomes. (2 marks)

(b) Explain the relation between the terms allele, locus, genotype and phenotype. (2 marks)

(c) Explain the chromosome theory of inheritance, indicating how it is related to the principle of independent assortment and meiosis. (3 marks)

(c) Explain two processes unique to meiosis which are responsible for genetic variation. (3 marks)

(d) Explain what is meant by dosage compensation, highlighting how this is achieved in mammals and drosophila. Hence, describe one piece of evidence that suggests that the process that causes dosage compensation in female mammals occurs at random. (6 marks)

(e) Explain how interrupted conjugation, transformation, and transduction can be used to map bacterial genes, illustrating how these methods are similar and different. (9 marks)

[Total = 25 marks]

SECTION B (ANSWER ANY THREE QUESTIONS FROM THIS SECTION)

Question 2

(a) Assuming that genes assort independently, state the phenotypic ratios produced by the following crosses:
(i) a selfed monohybrid, (1 mark)
(ii) a selfed dihybrid. (1 mark)

(b) A population of pure breeding black goats was crossed with that of pure breeding white goats. All F_1 progeny were white. Selfing F_1 produced 13 white and 4 black F_2 goats.
(i) Explain the term pure breeding. (1 mark)
(ii) Explain the observed results. (1 mark)
(iii) The F_2 white goats have two genotypes. Predict the phenotypic distributions obtained when these goats are test-crossed. (1 mark)
(iv) Calculate the probability that if the F_2 white goat is chosen at random, test-crossing it gives all white progeny in F_3. (1 mark)

(c) In sailfin mollies (fish), gold color is due to an allele (*g*) that is recessive to the allele for normal color (*G*). A gold fish is crossed with a normal fish. Among the offspring, 88 are normal and 82 are gold.
(i) Predict the most likely genotypes of the parents in this cross. (2 marks)
(ii) Assess the plausibility of your prediction by performing a chi-square test. (4 marks)

(d) A young woman is worried about having a child because her mother's only sister had a son with Ducheme Muscular Dystrophy (DMD), a rare X-linked recessive disorder. The young woman has no brothers or sisters.
(i) Draw the relevant parts of the pedigree of the family described above. (Be sure to include the grandmother, the three women mentioned, and all their spouses. Label the individuals) (4 marks)
(ii) On the pedigree in **(d)(i)** above, indicate the most likely genotypes of all the individuals in the pedigree. (4 marks)
(iii) Calculate the probability that the young woman's first child will have DMD. (5 marks)

[Total = 25 marks]

Chi square Distribution Table

	Probability Values								
df	0.995	0.990	0.975	0.950	0.500	0.050	0.025	0.010	0.005
1	0.00 +	0.00 +	0.00 +	0.00 +	0.45	3.84	5.02	6.63	7.88
2	0.01	0.02	0.05	0.10	1.39	5.99	7.38	9.21	10.60
3	0.07	0.11	0.22	0.35	2.37	7.81	9.35	11.34	12.84
4	0.21	0.30	0.48	0.71	3.36	9.49	11.14	13.28	14.86
5	0.41	0.55	0.83	1.15	4.35	11.07	12.38	15.09	16.75
6	0.68	0.87	1.24	1.64	5.35	12.59	14.45	16.81	18.55
7	0.99	1.24	1.69	2.17	6.35	14.07	16.01	18.48	20.28
8	1.34	1.65	2.18	2.73	7.34	15.51	17.53	20.09	21.96
9	1.73	2.09	2.70	3.33	8.34	16.92	19.02	21.67	23.59
10	2.16	2.56	3.25	3.94	9.34	18.31	20.48	23.21	25.19

Question 3

(a) The mold *Neurospora crassa* has ordered tetrads. The following tetrads were obtained when a wild type (***leu*$^+$ *ad*$^+$***)** strain of *Neurospora* was crossed to a mutant strain that requires leucine and adenine supplements to grow (***leu*$^-$ *ad*$^-$**). Only one member of each spore-pair produced by the final mitosis is shown, since the two spores in the pair have the same genotype.

Tetrad Types

	I	II	III	IV	V
	ad+leu+ ad+leu+ ad-leu- ad-leu-	ad+leu- ad+leu- ad-leu+ ad-leu+	ad+leu+ ad+leu- ad-leu+ ad-leu-	ad+leu- ad-leu+ ad-leu- ad+leu+	ad-leu+ ad+leu+ ad-leu- ad+leu-
Σ =	30	30	40	2	18

(i) Indicate in a table the tetrad types which are PD, NPD, TT. (4 marks)
(ii) Label each tetrad type as a M_I or M_{II} segregant. (4 marks)
(iii) Use information in **(a)(i)** and **(a)(ii)** to determine the best possible map for the two genes relative to each other and to their centromere(s). (6 marks)

(b) Three mutations in yeast were studied. Yeasts with ***Ser*$^-$** genotype are unable to grow without serine in the medium. The ***His*$^-$** mutation confers inability to grow without histidine in the medium. The third mutation causes a small colony phenotype. Wild-type yeast are ***Ser*$^+$, *His*$^+$** and ***big***. When ***Ser*$^-$** haploid mutant yeast was mated to a ***His*$^-$ *small*** haploid mutant yeast, sporulation of the resulting diploid was induced and the following tetrad types were obtained.

	Tetrad Type A	Tetrad Type B	Tetrad Type C
	Ser$^-$ His$^+$ big Ser$^-$ His$^+$ small Ser$^+$ His$^-$ big Ser$^+$ His$^-$ small	Ser$^-$ His$^+$ big Ser$^-$ His$^+$ big Ser$^+$ His$^-$ small Ser$^+$ His$^-$ small	Ser$^+$ His$^-$ big Ser$^-$ His$^+$ small Ser$^-$ His$^-$ big Ser$^+$ His$^+$ small
Σ =	**9**	**90**	**1**

(i) State the genotypes of parentals used in the cross. (1 mark)
(ii) Determine the linkage relationship amongst the three loci, hence calculate the genetic distances between the gene pairs and draw the genetic map showing the correct relative order of the ***Ser***, ***His***, and ***size*** loci. (10 marks)

[Total = 25 marks]

Question 4

(a) About 70% of all Caucasians can taste the chemical phenylthiocarbamide, and the remainder cannot. The ability to test this chemical is determined by the dominant allele ***T***, and the inability to taste is determined by the recessive allele ***t***. If the population is in Hardy-Weinberg equilibrium, determine the genotypic and allelic frequencies in this population. (3 marks)

(b) In an experimental population of *Tribolium confusum* (flour beetles), body length shows a continuous distribution with a mean of 6mm. A group of males and females with a mean body length of 9mm are artificially selected and interbred. The body lengths of their offspring averaged 7.2 mm. Determine the narrow sense heritability in this population. (3 marks)

(c) In a large herd of cattle, three different characters showing continuous distribution are measured, and the variances in the following table are calculated:

	Quantitative traits		
Variance	Shank length	Neck length	Fat content
Phenotypic	320.2	730.4	106.0
Environmental	248.1	292.2	53.0
Additive genetic	46.5	73.0	42.4
Dominance genetic	15.6	365.2	10.6

(i) Calculate the broad- and narrow-sense heritabilities for each trait. (6 marks)
(ii) In the population of animals studied, which character would respond best to artificial selection? Justify your answer. (2 marks)
(iii) A project is undertaken to decrease mean fat content in the herd. The mean fat content is currently 10.5 %. Animals with a mean of 6.5% fat content are interbred as parents of the next generation. What mean fat content can be expected in the descendants of these animals? (3 marks)

(d) You have isolated four strains of *E. coli*. By interrupted mating experiments you have determined the markers that are transferred at high frequency and their times (in minutes) of entry into the F^- recipient. The table below gives the results. Note that ***lac***, ***mal***, ***man*** are markers for inability to ferment lactose, maltose and mannitol; ***arg***, ***his***, ***lys***, ***met***, ***pur***, ***trp*** are markers for requirement for arginine, histidine, lysine, methionine, purines and tryptophan and ***uvr*** is a marker for sensitivity to UV irradiation.

	Hfr1	**Hfr2**	**Hfr3**	**Hfr4**
Markers and times of entry	***man*** -13	***mal*** - 29	***lys*** - 16	***pur*** - 6
	trp - 6	***met*** - 14	***arg*** - 9	***trp*** - 3
	his - 23	***thr*** - 4	***mal*** - 2	***thr*** - 31
	pur - 3	***uvr*** - 20	***his*** - 32	***lac*** - 23

Assume that the entire *E. coli* chromosome takes 100 minutes to be transferred and that ***thr*** locus is arbitrarily assigned the values 0 min and 100 min. Construct a linkage map of the *E. coli* chromosome with map distances expressed in minutes. (8 marks)

[Total = 25 marks]

Question 5

(a) A snapdragon plant that bred true for white petals was crossed with a plant that bred true for purple petals, and all the F_1 had white petals. The F_1 was selfed. Among the F_2, three phenotypes were observed in the following numbers: 240 white; 61 solid purple; 19 spotted purple.

(i) Propose an explanation for these results, showing genotypes of all generations (make up and explain your symbols). (8 marks)

(ii) A white F_2 plant was crossed with a solid purple F_2 plant, and the progeny were 50% white, 25%solid purple and 25% spotted purple. Determine the genotypes of the F_2 plants crossed. (4 marks)

(b) Explain the following (use examples where applicable):

(i) point mutation, (1 mark)
(ii) frameshift mutation, (1 mark)
(iii) aneuploidy, (1 mark)
(iv) trisomy, (1 mark)
(v) Robertsonian translocation. (1 mark)

(c) Describe how potentially carcinogenic chemicals can be detected by their mutagenic activity in bacteria. (8 marks)

[Total = 25 marks]

Question 6

(a) You are given a 300 nucleotide long sequence believed to be that of an mRNA molecule. How could you

(i) confirm that this RNA is mRNA and not either tRNA or rRNA? (3 marks)
(ii) decide whether it is a prokaryotic or eukaryotic mRNA? (3 marks)

(b) What characteristics possessed by an expression vector are not found in an ordinary cloning vector when the host is a bacterial cell? (4 marks)

(c) Outline how you could isolate a hypothetical gene from an organism X and clone it in *E. coli* using plasmid pBR322 as a vector. (15 marks)

[Total 25 marks]

END OF QUESTION PAPER