Name:

Understandings, Applications and Skills (This is what you maybe assessed on)

	Statement	Guidance
10.2.U1	Gene loci are said to be linked if on the same chromosome.	
10.2.U2	Unlinked genes segregate independently as a result of meiosis.	
10.2.U3	Variation can be discrete or continuous.	
10.2.U4	The phenotypes of polygenic characteristics tend to show continuous variation.	
10.2.U5	Chi-squared tests are used to determine whether the difference between an observed and expected frequency distribution is statistically significant.	
10.2.A1	Morgan's discovery of non-Mendelian ratios in Drosophila.	
10.2.A2	Completion and analysis of Punnett squares for dihybrid traits.	Alleles are usually shown side by side in dihybrid crosses, for example, TtBb.
10.2.A3	Polygenic traits such as human height may also be influenced by environmental factors.	
10.2.S1	Calculation of the predicted genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes.	
10.2.S2	Identification of recombinants in crosses involving two linked genes.	In representing crosses involving linkage, show genotypes as vertical pairs seperated by horizontal lines repesenting the chromosomes.
10.2.S3	Use of a chi-squared test on data from dihybrid crosses.	

Recommended resources:

http://bioknowledgy.weebly.com/102-inheritance.html

Allott, Andrew. *Biology: Course Companion.* S.l.: Oxford UP, 2014. Print.

<u>10.2.U2 Unlinked genes segregate independently as a result of meiosis.</u>

1. Mendel's Law of Independent Assortment

2. Describe the situation in which two or more genes will sort and therefore segregate independently of each other.

<u>10.2.A2 Completion and analysis of Punnett squares for dihybrid traits. AND 10.2.S1 Calculation of the predicted genotypic and phenotypic ratio of offspring of dihybrid crosses involving unlinked autosomal genes.</u>

3. Distinguish between dihybrid and monohybrid crosses.

4. When Mendel came upon his law of independent assortment, he was studying sweet-pea colour and shape. These traits are carried on separate chromosomes. The colour yellow (Y) is dominant over green (y). Smooth peas (S) are dominant over rough (s).
   a. State the possible genotypes for the following phenotypes:

Yellow, Smooth		*Green, Smooth*	
Green, rough	yyss only	*Yellow, rough*	

b. Use the Punnett grid to predict the ratio of phenotypes of offspring in a cross between two peas which are heterozygous for both genes (SsYy x SsYy).

genotype: ♀ SsYy
possible gametes: SY Sy sY sy

genotype: ♂ SsYy
possible gametes: SY Sy sY sy

	SY	Sy	sY	sy
SY				
Sy				
sY				
sy				

Phenotype	Smooth Yellow	Smooth green	Rough Yellow	Rough Green
Ratio				

5. A researcher has some smooth yellow peas. He wants to find out if they are homozygous or heterozygous for these dominant characteristics, so he performs a test cross.
   a. State the genotype and phenotype of the plant that must be used as the test cross.

   Genotype: Phenotype:

   b. Complete a series of Punnett grids for this cross. Deduce the phenotype ratios expected in the following crosses.
      i. Heterozygous for both colour and shape?

Phenotype				
Ratio				

ii.   Homozygous for both colour and shape.

Phenotype				
Ratio				

iii.   Heterozygous for colour, homozygous for shape.

Phenotype				
Ratio				

iv. Homozygous for colour, heterozygous for shape.

Phenotype				
Ratio				

c. In the cross, the student found 120 yellow-smooth and 124 green-smooth. Deduce the most likely genotype for the unknown pea. Explain your answer.

6. Morgan's experiments (1909 - 1914) with fruit flies produced results that could not be explained by Mendel's work on heredity as it stood. Morgan's key insight came after breeding a white-eyed male mutant with red eyed female flies. Complete the table to outline his observations and where the explain the conclusion:

Observation	Deduction – consistent or inconsistent with Mendelian theory?
The 1st generation offspring all had red eyes	
The 2nd generation contained a small number (roughly 25% of flies) with white eyes	
However all the white-eyed flies were male	

10.2.U1 Gene loci are said to be linked if on the same chromosome. AND 10.2.S2 Identification of recombinants in crosses involving two linked genes.

7. Mendel's law of independent assortment makes the assumption that genes for a pair or group of traits are being carried on separate chromosomes, and therefore the presence of one allele in a gamete is not connected to the presence of another. However, with hundreds of genes per chromosome, it is likely that some genes will be physically linked and therefore alleles will be inherited together.
   a. Define linkage groups.

   b. State the consequence of gene linkage in terms of the movement of alleles in anaphase I.

      Linkage groups will not …

   c. The term linkage is used in various ways in genetics. Distinguish between autosomes and sex chromomes.

   d. Distinguish between gene linkage and sex linkage.

e. The notation shows genes of Zea mays (corn). It is described as "heterozygous at both loci". These are both traits related to the corn kernels.

$$\frac{C \qquad W}{c \qquad w}$$

locus 1   locus 2
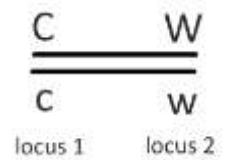
Key: C = colour, c = no colour;   W = waxy, w = no wax.

f. Draw some other possible combinations of these linked genes:

Homozygous dominant at both loci	
Homozygous recessive at locus 1.	
your choice	

g. Complete a punnet grid to show the possible phenotypes produced by a cross between the corn that is heterozygous at both loci. Use correct notations and show your working.

Phenotype				
Ratio				

h. List the combinations of alleles which are not possible in the cross above (unless recombination takes place at Prophase I).

i. A small number of kernels which are coloured but not waxy appear in the offspring. Explain the process that must have occurred for this to be the case.

j. State the stage of meiosis during which crossing over and exchange of alleles can occur.

k. Complete the punnet grid below:

What are the possible genotypes of this cross (including recombinants)?

$$\frac{P \quad\quad L}{p \quad\quad l}$$ crossed with $$\frac{p \quad\quad l}{p \quad\quad l}$$ (test)

	P L	p l		
p l	PpLl			
p l				
	no recombination		with crossing over (recombinants)	

10.2.U5 Chi-squared tests are used to determine whether the difference between an observed and expected frequency distribution is statistically significant. AND 10.2.S3 Use of a chi-squared test on data from dihybrid crosses.

8. In corn ears there are four main phenotypes: purple and smooth, purple and shrunken, yellow and smooth, yellow and shrunken. You will examine an ear of corn and determine the type of cross and genes responsible for the coloration and texture of the corn kernels and also whether the corn kernel colour and texture follows the expected pattern of dihybrid inheritance. Use the image below to take the sample for your investigation.
(activity based on: http://www.biologycorner.com/worksheets/corn_chi.html)

a. Select five rows on the corn ear to sample for colouration (purple or yellow) and texture (smooth or shrunken) and record your findings in the tables below. The sample used must be the same for both characteristics.

Kernel Colouration		
	Number of Kernels	Kernel Percentage (%)
Purple		
Yellow		
Total		

Kernel Texture		
	Number of Kernels	Kernel Percentage (%)
Smooth		
Shrunken		
Total		

b. Deduce the probable colouration phenotypes of the parents.

c. Deduce the probable texture phenotypes of the parents.

d. Assuming that purple (P) is dominant to yellow (p) and smooth (S) is dominant to shrunken (s) complete a dihybrid cross between two heterozygous parents and calculate the expected phenotype ratio.

Phenotype				
Ratio				

e. Using the same five rows as earlier count the phenotypes present and calculate the percentage frequency of each.

	Observed phenotype frequency	
	Number of Kernels	Kernel Percentage (%)
Purple and Smooth		
Purple and shrunken		
yellow and Smooth		
yellow and shrunken		
Total		

Did you obtain a 9:3:3:1 ratio? To determine if the deviations between expected frequencies and the observed data are due to natural variation or whether the difference is statistically significant use a chi-squared test.

f. Calculate the chi-squared value using the table below:

	Chi-squared calculations		
	Expected (number of kernels)	Observed (number of kernels)	$\frac{(Observed - Expected)^2}{Expected}$
Purple and Smooth	total x 9/16 =		
Purple and shrunken	total x 3/16 =		
yellow and Smooth	total x 3/16 =		
yellow and shrunken	total x 1/16 =		
Total			Chi-squared = sum of $(O-E)^2/E$

g. Calculate the degrees of freedom.

df = Number of classes (phenotypes) – 1   =

h.   Is the (expected) theory of dihybrid corn kernel colouration and texture inheritance supported by the (observed) data?
(is Chi-square value < critical value)

df	critical values at 5%
1	3.84
2	5.99
3	7.82
4	9.49
5	11.07

10.2.U3 Variation can be discrete or continuous. AND 10.2.U4 The phenotypes of polygenic characteristics tend to show continuous variation.

9. Polygenic inheritance gives rise to continuous variation.
    a. Define polygenic inheritance.

    b. Distinguish between polygenic inheritance and multiple alleles.

c. List one human and one plant example of polygenic inheritance.

d. Define contributing allele.

e. Explain how polygenic inheritance gives rise to continuous variation within a population using skin colour as an example.

10. Assume that two genes (A and B) are responsible for inheritance of skin colour, with two alleles each and that they are unlinked. The dominant alleles code for melanin production.
    a. Calculate the number of possible genotypes.
    b. Apply the possible genotypes to the range of phenotypes below:
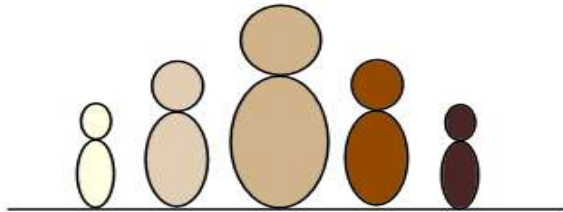
aabb	Aabb			

c. Using a punnet grid, explain why it is possible for children to have skin which is darker or lighter than both parents.

Mother genotype: *Father genotype:*

Outcome and explanation:

11. A characteristic is controlled by two unlinked genes with two alleles. Deduce the number of possible genotypes and phenotypes.

12. A characteristic is controlled by three genes with two alleles each. Calculate the number of genotypes possible in a cross between a homozygous recessive father and a homozygous dominant mother.

10.2.A3 Polygenic traits such as human height may also be influenced by environmental factors.

13. Most traits, including polygenetic traits such as height, maybe influenced by the environment of the organism. Complete the table to give examples of the ways in which this can happen.

Human Trait	Influencing Environment factors
Height	
Skin colour	

Data analysis

14. Gibberellin promotes both seed germination and plant growth. Researchers hypothesize that the gene GID1 in rice (*Oryza sativa*) codes for the production of a cell receptor for gibberellin. The mutant variety *gid1-1* for that gene leads to rice plants with a severe dwarf phenotype and infertile flowers when homozygous recessive. It is suspected that homozygous recessive *gid1-1* plants fail to degrade the protein SLR1 which, when present, inhibits the action of gibberellin. The graphs show the action of gibberellin on the leaves and α-amylase activity of wild-type rice plants (WT) and their *gid1-1* mutants.
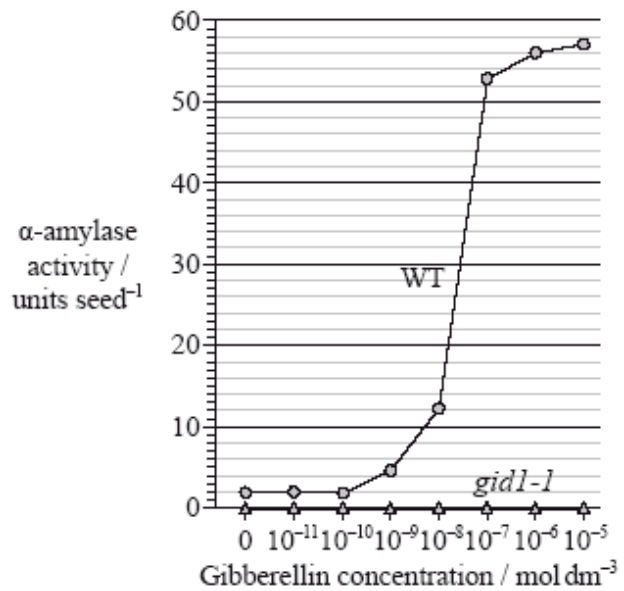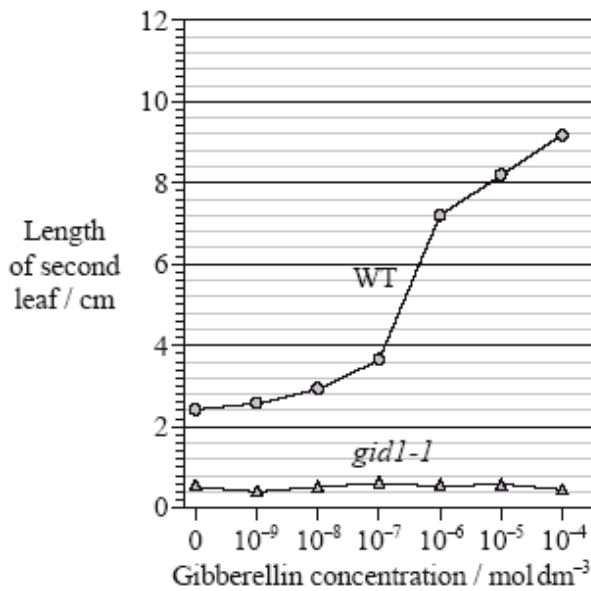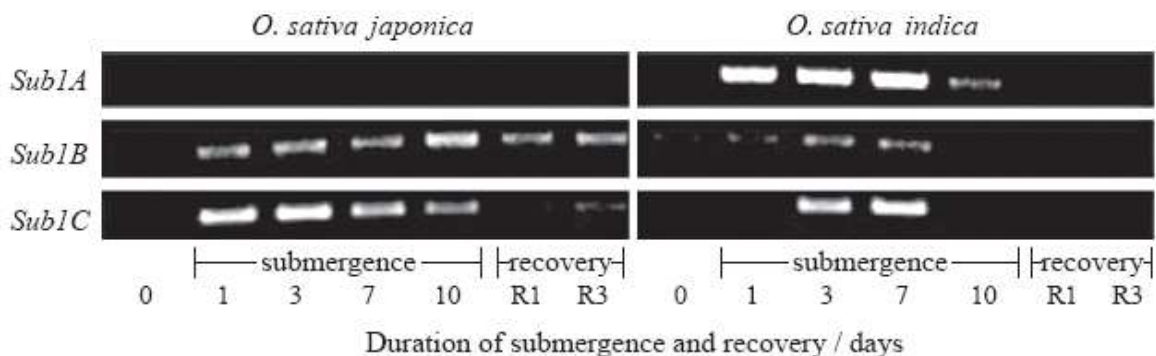

[Adapted by permission from Macmillan Ltd, Ueguchi-Tanaka, M et al. 2005. "Gibberellin-insensitive dwarf1 encodes a soluble receptor for gibberellins". *Nature*. Vol 437. Pp 693–698. Copyright (2005).]

a.

  i. State which variety of rice fails to respond to gibberellin treatment. (1)

  ii. The activity of α-amylase was tested at successive concentrations of gibberellin. Determine the increment in gibberellin concentration that produces the greatest change in α-amylase activity in wild-type rice plants (WT). (1)

  iii. Outline the role of α-amylase during the germination of seeds. (1) [linked to 9.4.S3]

b. Discuss the consequence of crossing gid1-1 heterozygous rice plants amongst themselves for food production. (3)

Most rice varieties are intolerant to sustained submergence under water and will usually die within a week. Researchers have hypothesized that the capacity to survive when submerged is related to the presence of three genes very close to each other on rice chromosome number 9; these genes were named *Sub1A*, *Sub1B* and *Sub1C*. The photograph below of part of a gel shows relative amounts of messenger RNA produced from these three genes by the submergence-intolerant variety, *O. sativa japonica*, and by the submergence-tolerant variety, *O. sativa indica*, at different times of a submergence period, followed by a recovery period out of water.

[Adapted by permission from Macmillan Publishers Ltd, Xu et al. 2006. *Nature*. Vol 442. Pp 705–708. Copyright 2006. http://www.nature.com/]

c.
    i. Determine which gene produced the most mRNA on the first day of the submergence period for variety O. sativa japonica. (1)

    ii. Outline the difference in mRNA production for the three genes during the submergence period for variety O. sativa indica. (2)

d. Using only this data, deduce which gene confers submersion resistance to rice plants. (2)
   Sub1A;

e. Evaluate, using all the data, how modified varieties of rice could be used to overcome food shortages in some countries. (2)

Citations:

Allott, Andrew. *Biology: Course Companion.* S.l.: Oxford UP, 2014. Print.

Taylor, Stephen. "Essential Biology 10.2 Dihybrid Crosses and Gene Linkage .docx." Web. 18 Sep. 2015. <http://www.slideshare.net/gurustip/essential-biology-102-dihybrid-crosses-gene-linkage-ahl>.

Taylor, Stephen. "Essential Biology 10.3 Polygenic Inheritance AHL.docx." Web. 18 Sep. 2015. <http://www.slideshare.net/gurustip/essential-biology-103-polygenic-inhertance-ahl>.