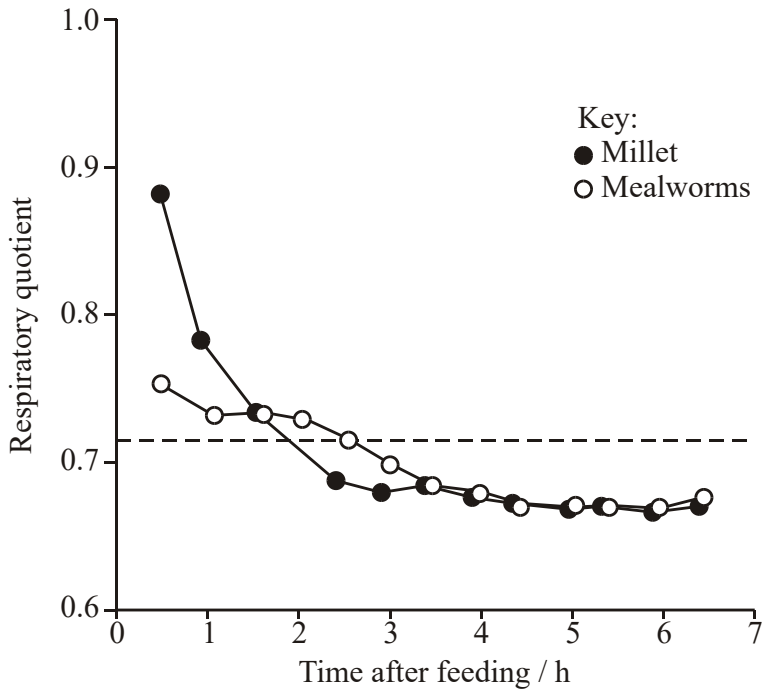
TOPIC 1 – BIOMOLECULES

Respiratory Quotient (6 marks)

The respiratory quotient (RQ) is a measure of the metabolic activity of an animal. It is a ratio of CO_2 produced to O2 consumed. In general, the lower the RQ value the higher the energy yield. The RQ is dependent on the diet consumed by the animal. The following table lists the typical RQ values for specified diets.

Diet	**RQ**
Lipid	0.71
Carbohydrate	1.00
Protein	0.74

In an experiment to assess RQ values for house sparrows, the birds were fed a diet of pure mealworms (beetle larvae) or millet (a type of grain). The graph below shows the RQ values of a house sparrow fed on a high carbohydrate diet (millet) and a high lipid diet (mealworms).



a. Compare the RQ values for millet and mealworms between 1 hour and 6 hours after feeding. *(2 marks)*

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The expected RQ value for house sparrows metabolizing millet is 0.93. The expected value when metabolizing mealworms is 0.75.

b. Explain why the expected RQ values for millet and mealworms are different. *(2 marks)*

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c. Suggest reasons for:

i. the high initial RQ values for house sparrows fed on millet. *(1 mark)*

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ii. the rapid fall in RQ values for house sparrows fed on millet. *(1 mark)*

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Diet and Disease (9 marks)

A study was conducted to look at the short-term effects of a change in diet on the risk of disease in adults. The table shows data on the habitual diet of the participants as well as the study diet followed for two weeks.

	Mean daily intake ± standard deviation	
	Habitual diet	**Study diet**
Energy / kJ	10 143±949	9992±479
Fat / g	100±6	99±5
Saturated fat / % total fat	37±2	60±1
Unsaturated fat / % total fat	63±2	40±1
Monounsaturated fat / % total fat	46±1	32±1
Polyunsaturated fat / % total fat	17±1	8±1
Carbohydrate / g	248±23	232±16
Protein / g	119±12	120±9

a. Comment on the total energy content of the two diets. *(1 mark)*

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b. Distinguish between the two diets. *(2 marks)*

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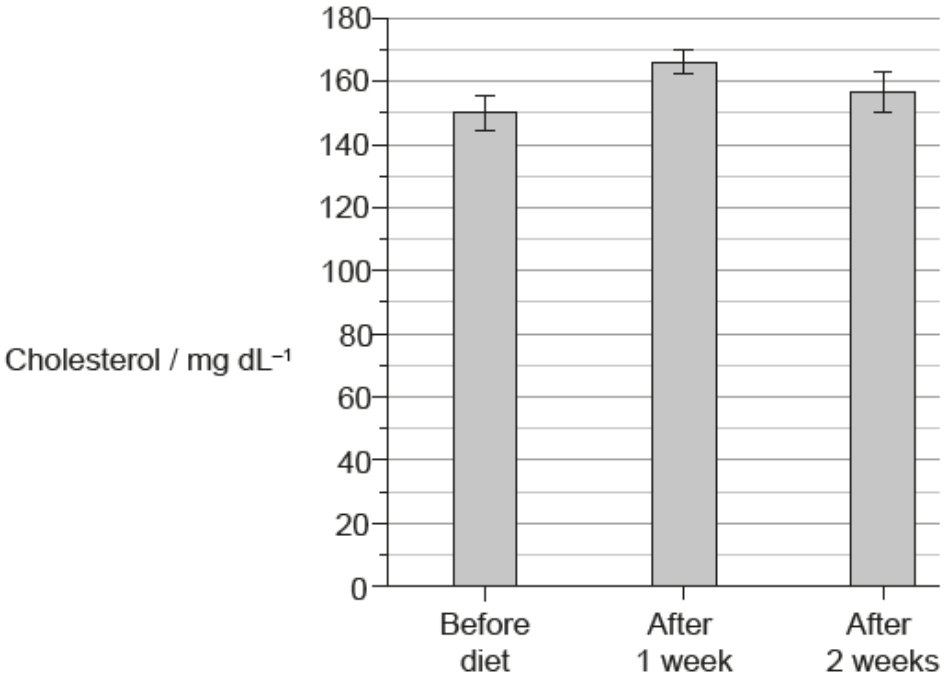
Total blood plasma cholesterol levels were measured before the study began and once a week after starting the study diet. Mean results are shown in the bar chart, including the standard deviation.



c. Calculate, showing your working, the percentage change in mean cholesterol level after **one week** on the study diet. *(2 marks)*

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Control of blood glucose concentration was investigated using an oral glucose tolerance test. For this test, the person was given a concentrated glucose drink (at time zero) and then blood samples were taken every 15 minutes to determine the plasma insulin level. This test was done before the study diet and after two weeks on the study diet. Mean results are shown in the graph, including the standard deviation.

d. Compare the data for plasma insulin levels before and after the study diet. *(2 marks)*

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Saturated fatty acids can increase levels of cholesterol in the body, while high insulin levels are a sign of diabetes. The hypothesis made before the study was that saturated fats in the diet affected the risk of coronary artery blockage and diabetes.

e. Using all the data in this question, evaluate whether this hypothesis is supported by the study. *(2 marks)*

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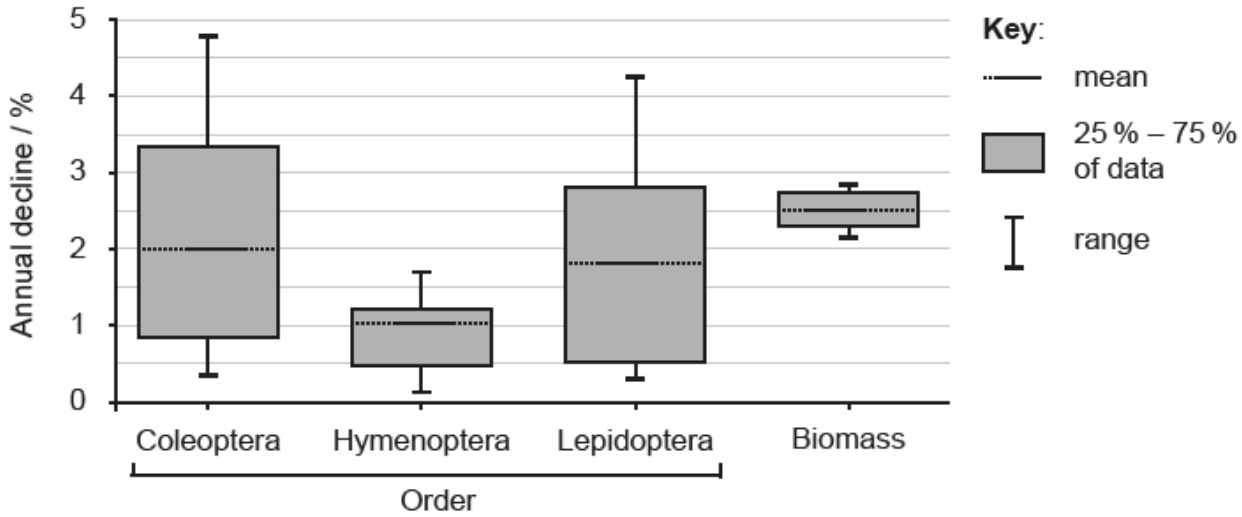
Bumblebee Biomass (13 marks)

The biodiversity of insects worldwide is in decline. Destruction of habitats, pollution and climate change have contributed to the decline in global populations and to the extinction of insect species. A comprehensive literature review was carried out to determine the annual global rate of decline in insect species. The graph shows the results for three major orders of terrestrial insects and total decline in insect biomass worldwide.



a. State the mean annual decline in insect biomass. *(1 mark)*

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b. Compare and contrast the results for Hymenoptera and Lepidoptera. *(2 marks)*

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c. Calculate the number of Coleoptera species that would be expected to exist after one year from a starting number of 400000 species, assuming the mean rate of decline. *(1 mark)*

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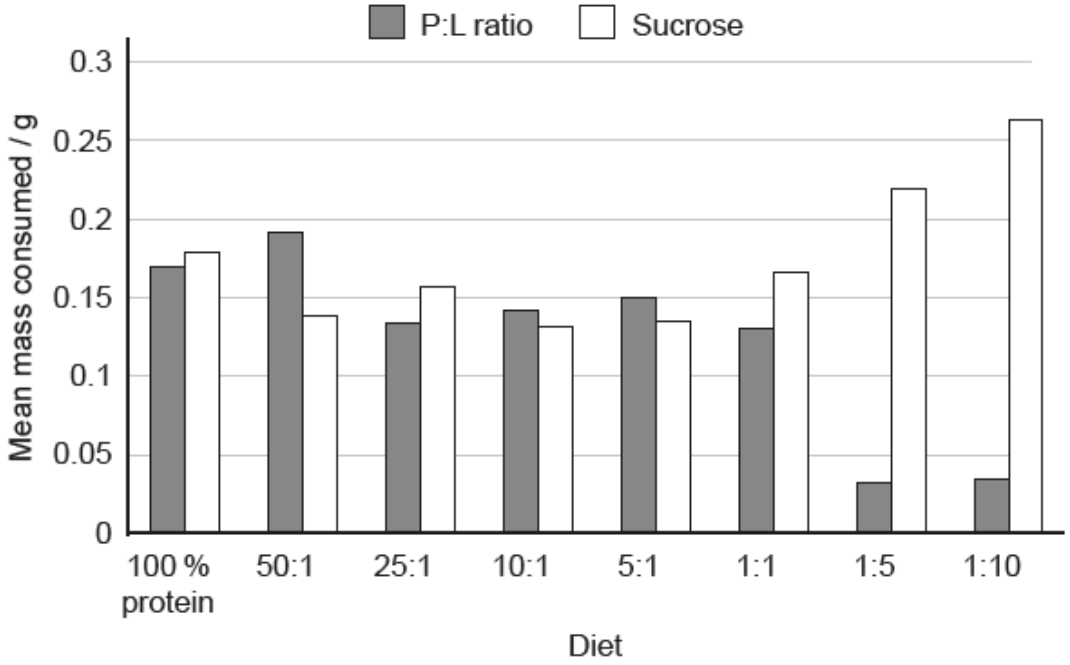
One species of the order Hymenoptera is the buff-tailed bumblebee (*Bombus terrestris*), which feeds on pollen and nectar obtained from specific plants. Destruction of preferred habitats has affected the size of bumblebee populations and for survival, bumblebees have to feed on pollen from other available plant habitats. To simulate different pollens, researchers fed bumblebees on eight diets consisting of a mixture of proteins and lipids in different ratios (P:L). The bumblebees also had access to sucrose. There was no restriction on the amount of each food the bumblebees could consume. The chart shows the mean daily mass of food eaten for eight diets with different P:L ratios.



d. Identify in how many of the diets sucrose was the greatest mass of food consumed. *(1 mark)*

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e. Calculate the mass of lipid eaten when the bumblebees were presented with the 5:1 diet. *(1 mark)*

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f. Compare and contrast the results for the 1:1 and the 1:10 P:L diets. *(2 marks)*

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g. Suggest a reason that the mass of protein and lipid mixture eaten at 25:1 is lower than at 50:1. *(1 mark)*

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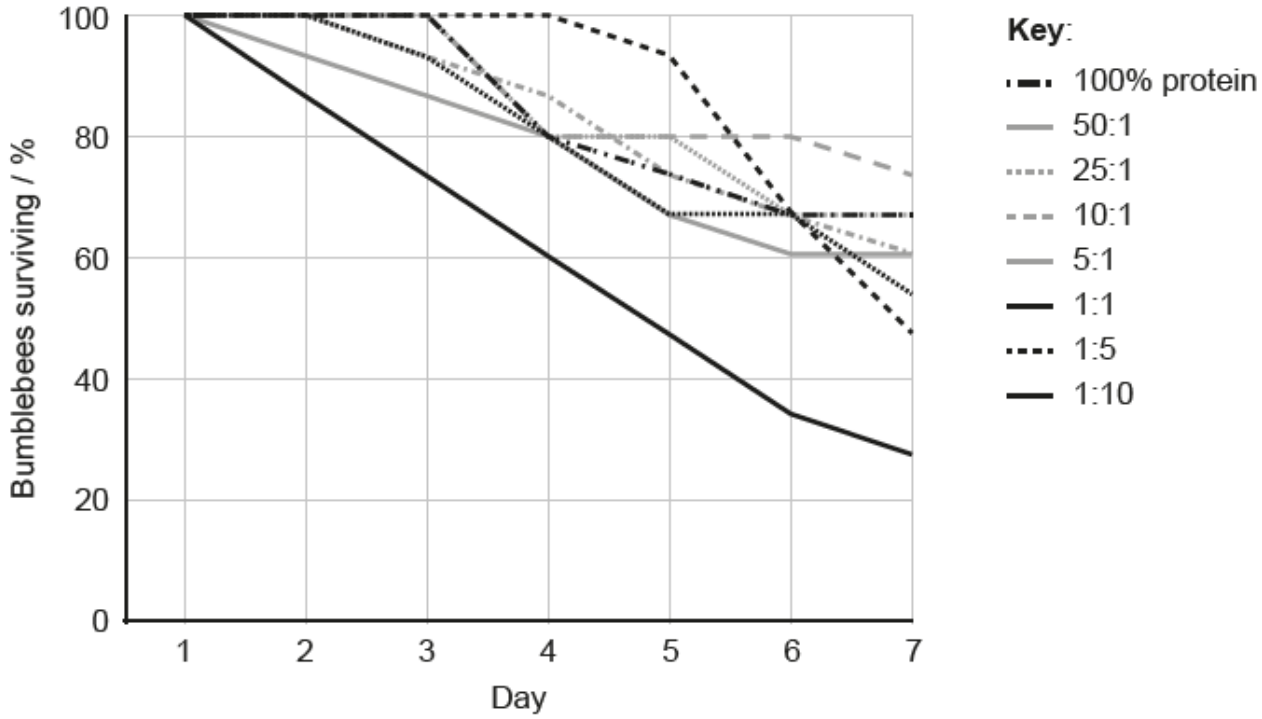
The graph shows the percentage of bumblebees that survived each day while being fed on different P:L diets. For each trial, n = 15.



h. State the relationship between high lipid content and survivability on day 7. *(1 mark)*

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i. Suggest with a reason which P:L diet is closest to the normal diet of these bumblebees. *(1 mark)*

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j. Discuss whether these studies show that habitat destruction can affect global bee numbers. *(2 marks)*

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Answers

1a *(2 marks)*

a. between 1.5 and 3.5 hours (or number between these figures) after feeding mealworm RQ values are higher than for millet
b. no difference in RQ values between 3.5 hours and 6 hours
c. between 0.5 and 1.5 hours (or number between these figures) millet RQ values much higher than for mealworm
d. between 2 and 3 hours mealworm RQ values are slightly higher than for millet

1b *(2 marks)*

a. millet is not composed entirely of carbohydrates
b. millet contains more carbohydrates
c. mealworms contain more lipids / proteins

1ci *(1 mark)*

using carbohydrate (from millet as a respiratory substrate)

1cii *(1 mark)*

reverting to other substrates / carbohydrates (from millet) used up

2a *(1 mark)*

a. energy is not changed (between the two diets)
b. study diet slightly lower in energy than habitual diet (but means/SD overlap)
c. spread of values show more variation for habitual diet / higher SD in habitual

2b *(2 marks)*

a. they differ in percent of saturated and unsaturated fats (but not total fat)
b. percent of saturated fats is higher in study diet / lower in habitual diet
c. (mono/poly) unsaturated fats decreased in study diet compared to habitual diet/more in habitual diet
   OR polyunsaturated fats in study diet only half of what they were in habitual diet
d. (slightly) less carbohydrate in study

Allow numerical points if they are a valid comparison using distinguishing terms.

2c *(2 marks)*

a. [(165–150) ÷ 150] × 100
b. (=) 10 (%)

Allow up to 167 = 11.3 %. 1 mark for correct working if above 167.

2d *(2 marks)*

a. both show same pattern of rise, level and then decrease / show same trend
b. both show same/similar levels of insulin (at all times) due to overlapping error bars
c. both rise for 30/45 minutes

Do not give credit for contrasts.

2e *(2 marks)*

Hypothesis is partially supported

a. Increased saturated fats in study diet resulted in increase in cholesterol levels
b. cholesterol level is risk for blockage of coronary arteries

Hypothesis is not supported

c. high insulin levels are sign of (Type II) diabetes
d. insulin levels were the same in both diets so no increased risk
e. study only 2 weeks long

3a *(1 mark)*

2.5% (*% required)*

3b *(2 marks)*

a. both show a decline in number
b. the mean decline for Hymenoptera is less than the mean for Lepidoptera ***OR*** there is a wider range of decline among the species of Lepidoptera

3c *(1 mark)*

392000 (species)

3d *(1 mark)*

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3e *(1 mark)*

0.025g *(Unit needed)*

3f *(2 marks)*

a. in both a greater mass of sucrose was eaten (than of the P:L mixture) ***OR*** the total mass eaten by both groups is the same/very similar
b. the mass of sucrose eaten in the 1:10 mixture diet is greater than in the 1:1 diet ***OR*** the mass of the P:L mixture eaten in the 1:10 is less than in the 1:1

Accept vice versa for all answers.

3g *(1 mark)*

a. the mixture was closer to what the bees ate naturally
b. the bees like the taste better/prefer sucrose
c. there was more lipid in the 25:1 mixture so they achieved their daily lipid/energy requirement with less mass of food
d. the bees eating 50:1 diet ate more to reach their daily lipid requirement
e. prefer the higher proportion of protein (in the 50:1)

3h *(1 mark)*

the higher the lipid content, the fewer bees survived/negative correlation

3i *(1 mark)*

10:1 diet as this has the highest survival rate (after 7 days) *(Reason must be given)*.

3j *(2 marks)*

a. habitat destruction removes the plants/flowers/natural food source of the bees
b. bees have to look for other food sources
c. many of these alternative sources of food are not suitable for bee survival ***OR*** pollen with a different proportion of protein to lipid would reduce survival
d. no control where bees are fed their normal diet is included
e. simulation is not using natural pollen / habitat ***OR*** sample size is too small to make conclusions

Accept other reasonable discussion using the data.