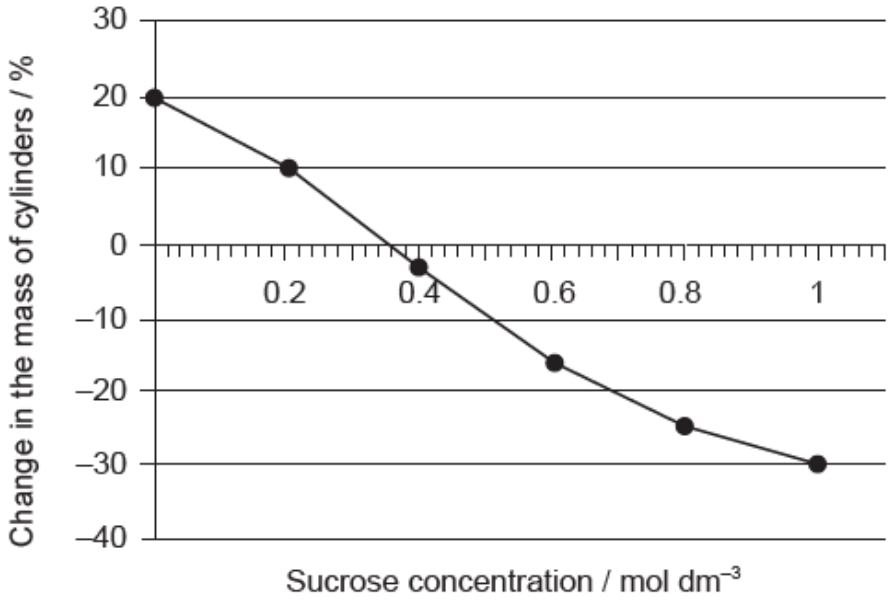
TOPIC 2 – CELLS

Osmosis (5 marks)

An experiment was carried out to study osmosis in plant cells. Small cylinders of zucchini (*Cucurbita pepo*) were cut and placed in different sucrose solutions at 25 °C. The figure shows the percentage changes in mass after 24 hours.



a. Estimate the solute concentration of the zucchini cells. *(1 mark)*

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b. If a zucchini is allowed to dry in the open air, predict how the osmolarity of the zucchini cells would change. *(1 mark)*

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c. Explain **one** reason for calculating the percentage changes in mass. *(2 marks)*

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d. Predict what would happen to a red blood cell placed in distilled water. *(1 mark)*

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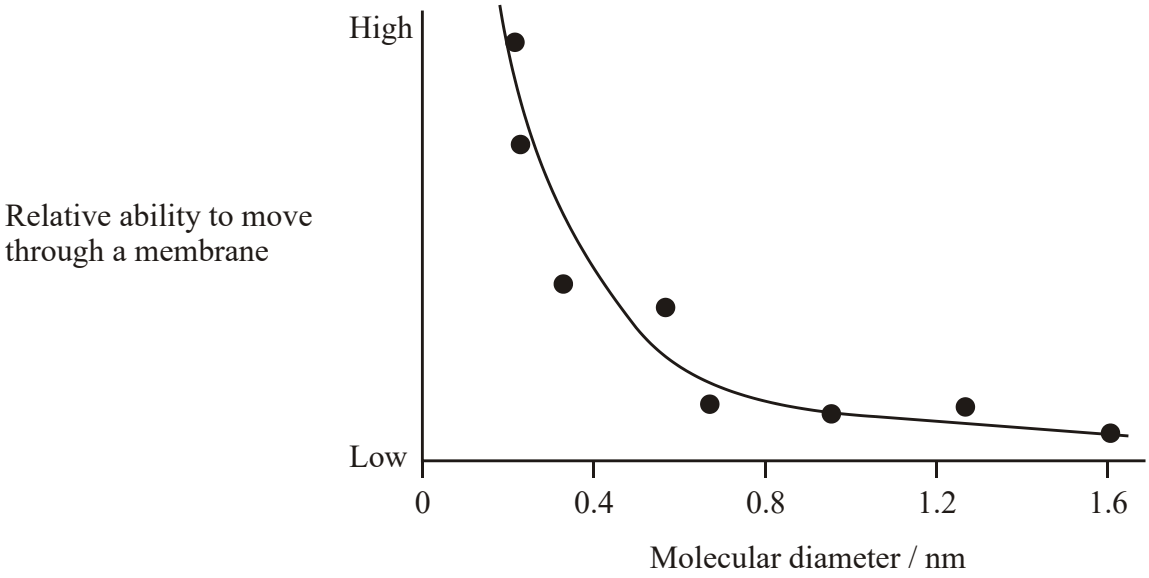
Membrane Transport (7 marks)

A study was carried out to determine the relationship between the diameter of a molecule and its movement through a membrane. The graph below shows the results of the study.



a. From the information in the graph alone, describe the relationship between the diameter of a molecule and its movement through a membrane. *(2 marks)*

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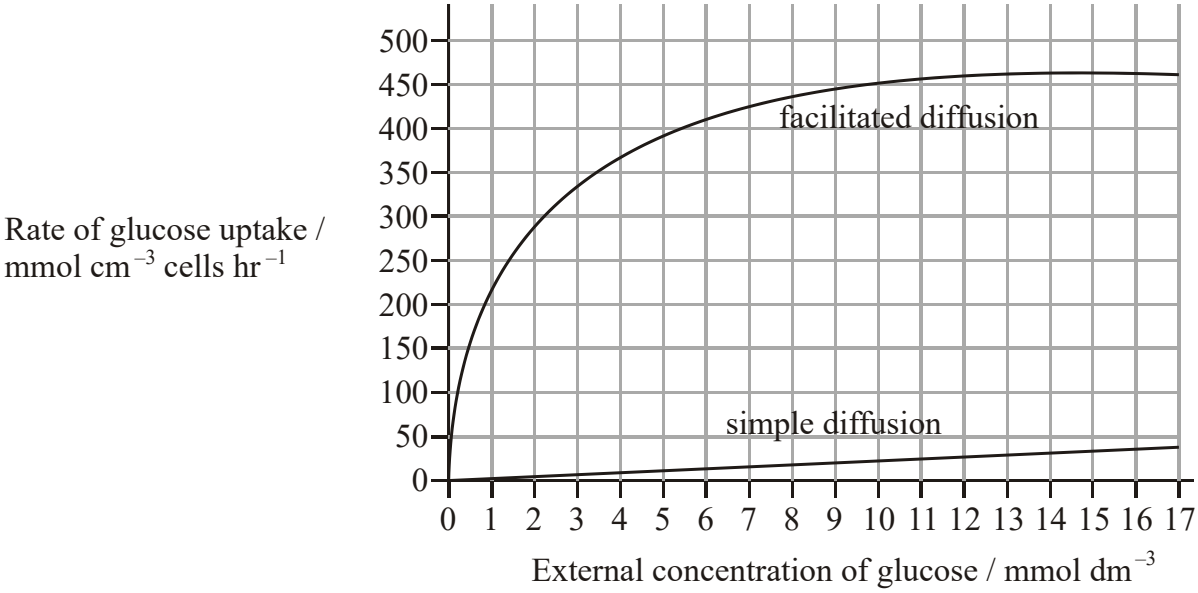
A second study was carried out to investigate the effect of passive protein channels on the movement of glucose into cells. The graph below shows the rate of uptake of glucose into erythrocytes by simple diffusion and facilitated diffusion.



b. Identify the rate of glucose uptake at an external glucose concentration of 4 mmol dm^{-3}. *(2 marks)*

i. simple diffusion .....

ii. facilitated diffusion .....

c. Compare the effect of increasing the external glucose concentration on glucose uptake by facilitated diffusion and by simple diffusion. *(3 marks)*

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d. Predict, with a reason, the effect on glucose uptake by facilitated diffusion of increasing the external concentration of glucose to 30 mmol dm^{-3}. *(2 marks)*

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e. The pH was maintained at 7.5 throughout the experiment. Explain why this was necessary. *(2 marks)*

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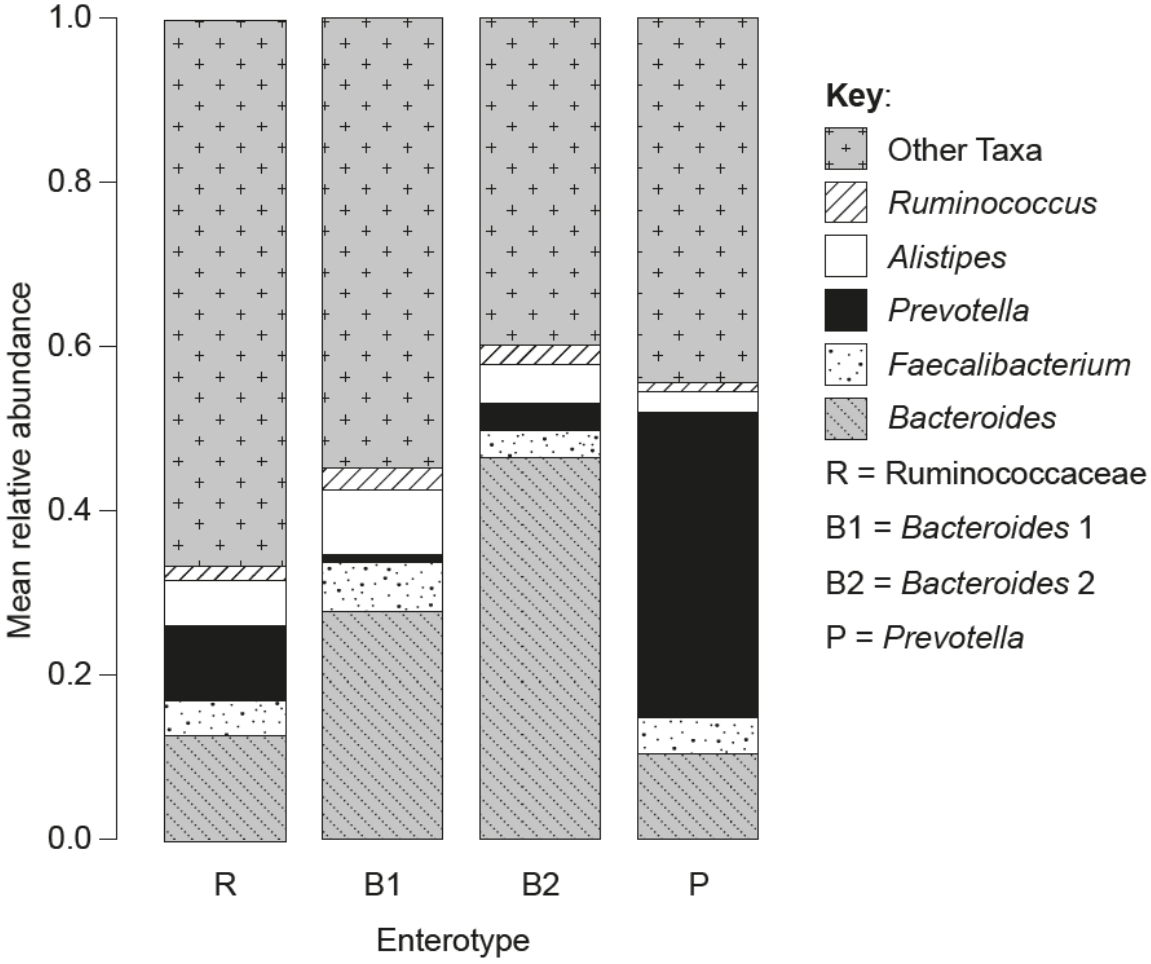
Bacteria Enterotypes (12 marks)

There is increasing interest in the bacteria that live in the human gut, known as the gut microbiota. Evidence is accumulating of widespread effects on human health, with some species of bacteria increasing the prevalence of specific diseases and others giving protection.

Long-term diet appears to influence the numbers and types of bacteria that are present in an individual's gut. Several different characteristic combinations of bacteria (called enterotypes) have been discovered. The stacked column graph shows relative amounts of different genera of bacteria in the gut of people with four of these enterotypes. The *Bacteroides 2*(B2) enterotype is associated with an increased prevalence of inflammatory bowel disease.



a. Using the data in the graph, describe the features that characterize the B2 enterotype. *(2 marks)*

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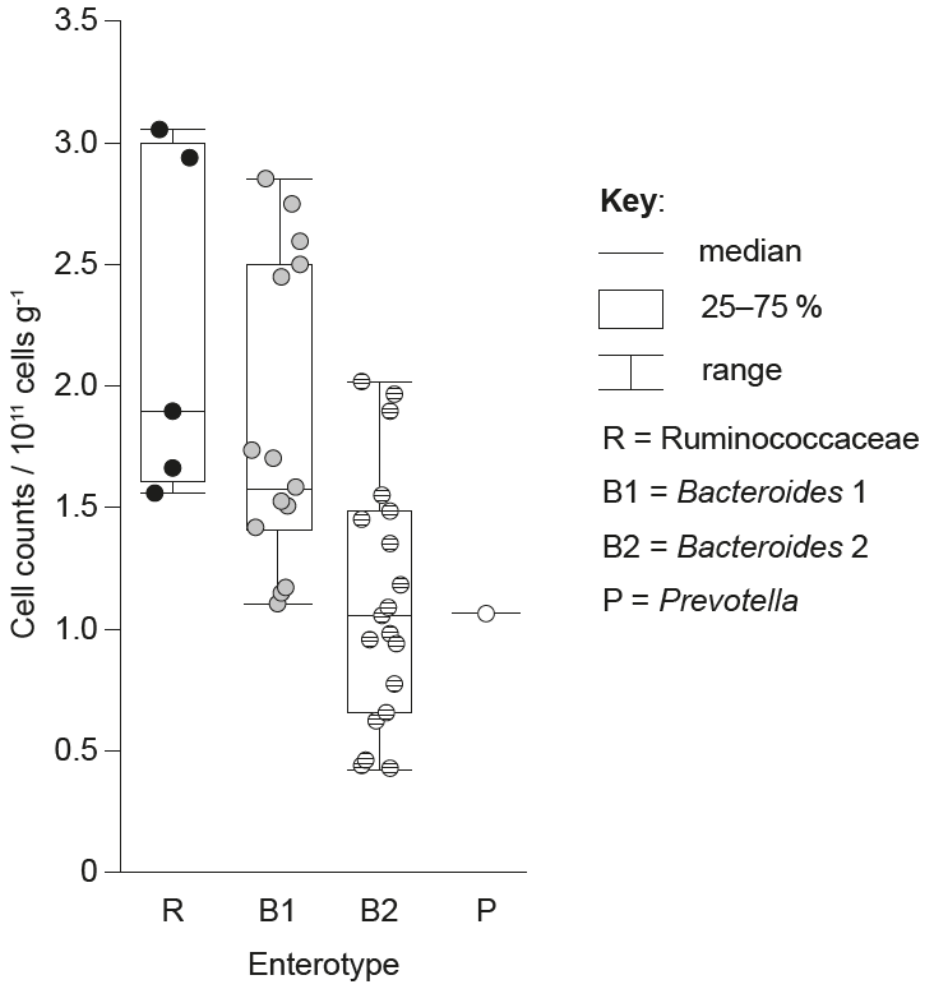
Samples of feces were collected from 40 individuals and were immediately frozen to preserve them. The numbers of bacteria in the feces (cell counts / 1011 cells g-1) were later measured and the enterotype was determined. The box plot shows this data. Each data point shows the cell count from one fecal sample.



b. Estimate the median number of bacterial cells per gram of feces in the R enterotype. *(1 mark)*

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c. Distinguish between the cell counts in the R and B2 enterotypes. *(2 marks)*

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d. Comment on the data for the P enterotype. *(1 mark)*

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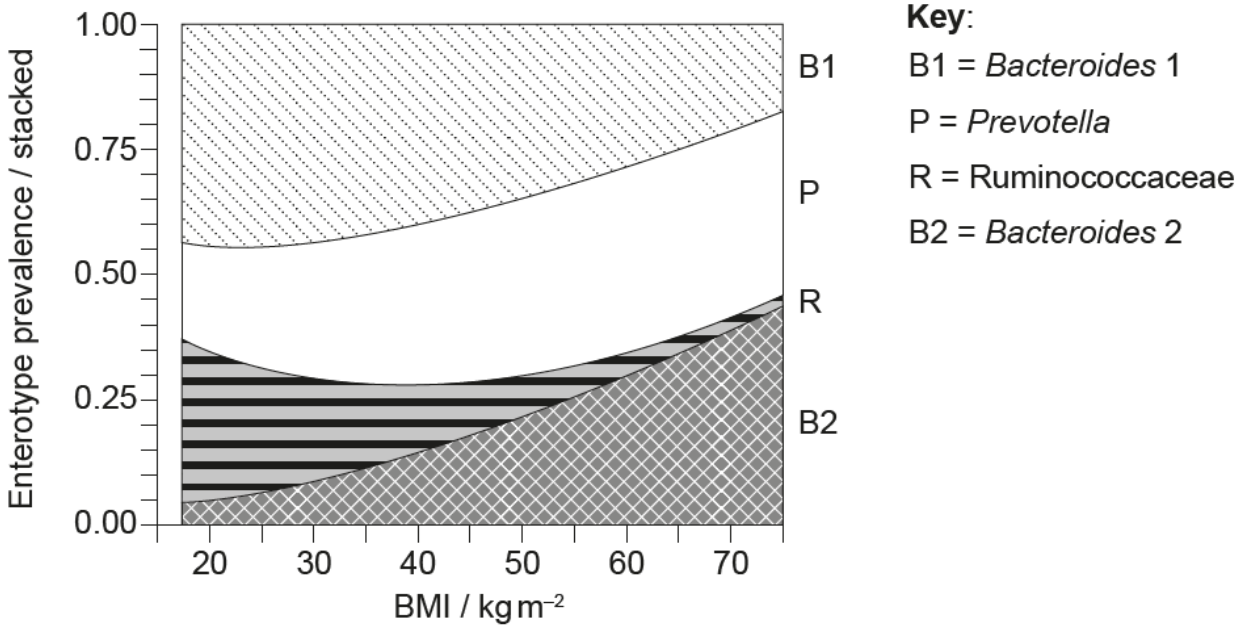
Statins are drugs that are commonly prescribed to reduce cholesterol concentrations in the blood. As part of research into the effects of statins, the enterotype and body mass index (BMI) of 782 individuals were determined. The results are shown in the stacked graph.



e. Estimate the prevalence of the P enterotype at a BMI of 50. *(1 mark)*

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f. State the relationship between BMI and the prevalence of the B2 enterotype. *(1 mark)*

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g. Evaluate the evidence provided by the data in the graph for the hypothesis that the R enterotype causes low BMI. *(2 marks)*

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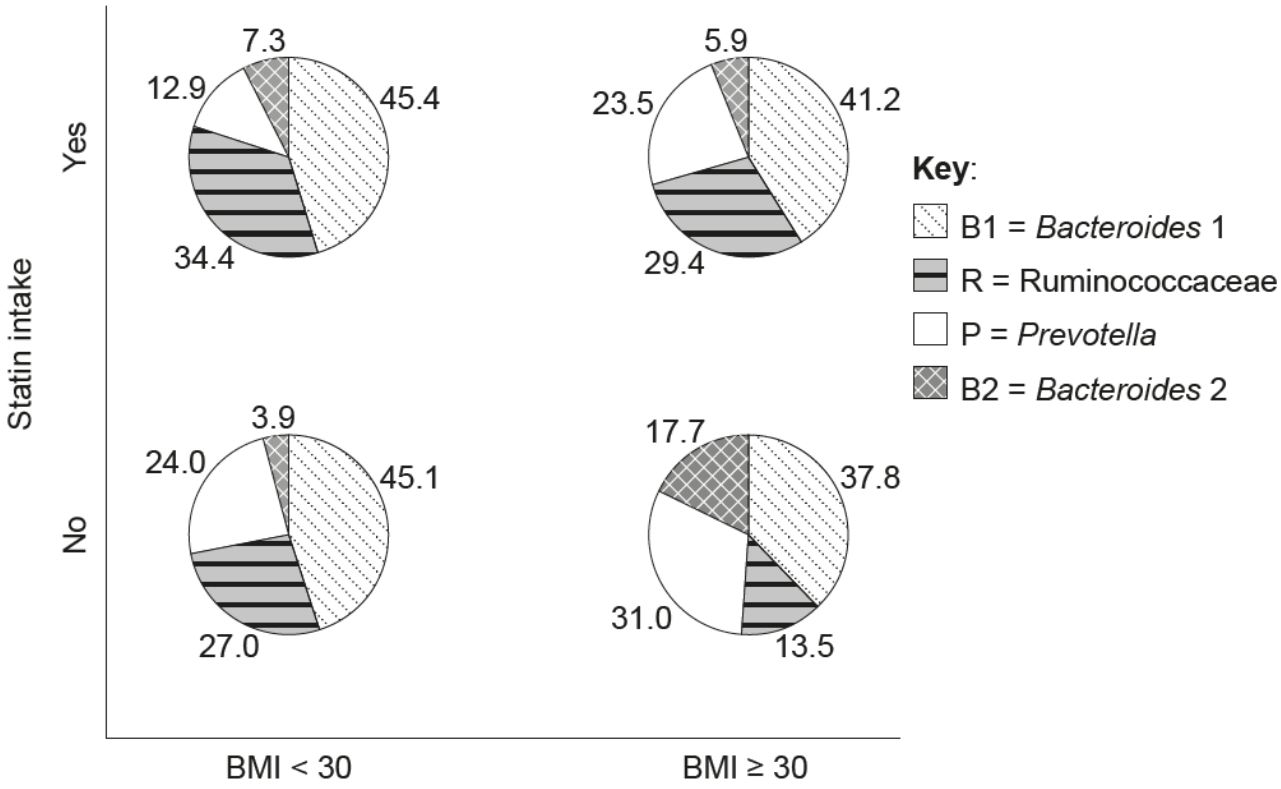
The 782 individuals for whom BMI and enterotype had been determined were divided into four groups, according to whether or not they were taking statins and their BMI category. The prevalence of the four enterotypes in each of these groups is shown as a percentage in the pie charts.



The prevalence of inflammatory bowel disease rises with increases in BMI. At any BMI level, individuals with the B2 enterotype have a higher prevalence of inflammatory bowel disease than with other enterotypes.

h. Using the data in the graph, discuss whether statins could reduce the incidence of inflammatory bowel disease. *(2 marks)*

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Answers

1a *(1 mark)*
0.36 mol dm^{-3}/M. (*Units required. Allow a range of 0.35–0.37 mol dm^{-3}/M)*

1b *(1 mark)*
osmolarity will increase «because the cells become dehydrated» ***OR*** the cells become hypertonic
Accept water potential of the tissue decreases. Do not accept "change" instead of "increase".

1c *(2 marks)*
a. the change in mass indicates whether the tissue has gained/lost water
b. the pieces of tissue will not all be the same mass «at the beginning of the experiment»
c. to compare the relative changes in mass

1d *(1 mark)*
a. water would move into the red blood cells
b. it would lyse ***OR*** swell ***OR*** burst

2a *(2 marks)*
a. as the diameter of the molecule increases the permeability / relative ability to move decreases (*accept converse*)
b. the relationship is logarithmic / non-linear / negative
c. for molecules above 0.6 (± 0.1) nm relative ability to move changes little / for molecules below 0.6 (± 0.1) nm relative ability to move changes rapidly

2b *(2 marks)*
a. 10 mmol cm–3 cells hr–1 (*accept values within ±5*)
b. 370 mmol cm–3 cells hr–1 (*accept values within ± 10*)

2c *(3 marks)*
a. glucose uptake in facilitated diffusion levels out whereas uptake in simple diffusion does not level out / continues to rise
b. glucose uptake increases in both
c. glucose uptake is higher in facilitated diffusion (than in simple diffusion)
d. uptake in simple diffusion is constant / linear whereas in facilitated diffusion uptake increases rapidly at start / not constant

2d *(2 marks)*
a. little / no change in glucose uptake
b. most / all (protein) channels in use

2e *(2 marks)*
a. pH changes could change the permeability of the membrane
b. pH values away from optimum pH affect membrane proteins ***OR*** so channels can function properly
c. change in pH affects 3D structure of protein ***OR*** change in pH denatures the protein
d. the interaction of glucose and the membrane protein is affected

3a *(2 marks)*
a. nearly half is *Bacteroides* / more *Bacteroides* (than other enterotypes)
b. few *Prevotella*/fewer *Prevotella* than in P and R ***OR*** less *Faecalibacterium* than other enterotypes ***OR*** *Ruminococcus* is the lowest in B2
c. only 40 % other taxa / fewer other taxa (than other enterotypes) / less overall diversity (of taxa)

3b *(1 mark)*
1.9×10^{11} / 190000 million / 190 billion (cells per gram)
Cells per gram not needed as in stem. Accept 1.80×10^{11} to 1.95×10^{11}.

3c *(2 marks)*

a. lower values for cell counts in B2 (than in R) / converse ***OR*** median is higher in R (than in B2) / R median is 1.9 versus B2 median is 1.1 ***OR*** lower number of cell counts in R
b. all counts in R higher than third/75th/upper quartile in B2 ***OR*** 25-75 % range (box) in B2 is smaller than in R
c. R maximum 3.1 versus B2 maximum is 2.1 ***OR*** R maximum is higher than B2 max
d. B2 minimum is lower than R minimum

The ranges are basically the same.

3d *(1 mark)*

a. only one sample/count/data point
b. only analysed feces from one person (with this enterotype)
c. not a big enough sample

3e *(1 mark)*

0.35. *(Accept any values between 0.33 and 0.37. Accept 35%)*

3f *(1 mark)*

B2 is associated/commoner/more prevalent in people with higher BMI ***OR*** (prevalence of) B2 increases as BMI increases

*Accept positive correlation/**OWTTE**.*

3g *(2 marks)*

a. R is more common/prevalent in people with low BMI
b. statement about it being far more common
c. but this correlation does not prove that R causes low BMI
d. low BMI could(actually) be the cause of higher prevalence of R

So 'R is far more common in people with low BMI', would gain both a and b.

3h *(2 marks)*

a. high/highest % of B2 enterotype in people with BMI greater than (or equal to) 30 with no statins ***OR*** taking statins could reduce the percentage of B2 enterotype in people with BMI ≥ 30 ***OR*** reducing BMI to below 30 could lower % of people with B2 enterotype without taking statins
b. but statins may not cause a person to change from B2 to another enterotype ***OR*** lower B2 in those taking statins if BMI is > 30 so might reduce IBD/inflammatory bowel disease ***OR*** but when BMI < 30, there is almost double the prevalence of B2 in those taking statins so might not have an effect / increase (prevalence of) inflammatory bowel disease

One for correct data and one for discussion