DNA, RNA and Protein Synthesis

Protein synthesis isn't easy, but imagine the warm, glowing feeling you'll get once you've worked your way through all these questions on it. Can't imagine it? Never mind, give the questions a go and you'll soon feel it.

1 The average human cell contains around 2 m of DNA.
The average human cell nucleus is only 10 μm in diameter.

1.1 Describe how the DNA in a eukaryotic cell is arranged so that it can fit into the nucleus.

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(2 marks)

1.2 Prokaryotic DNA is not stored in a nucleus.
Give **one** other difference between the way that DNA is arranged in eukaryotic cells and prokaryotic cells.

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(1 mark)

It is estimated that the DNA in a human cell contains around 20 000 protein-encoding genes.
These genes correspond to only 1.5% of the DNA sequence.

1.3 Using the information provided above, calculate the average length of a human gene in metres.

Length of gene = ... m

(2 marks)

1.4 What name is given to the complete set of genes present in a cell?

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(1 mark)

1.5 What name is given to the complete set of proteins that a cell is able to produce?

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(1 mark)

In prokaryotes, around 90% of the DNA is protein-encoding.

1.6 Suggest **two** reasons why prokaryotes have a much greater percentage of protein-encoding DNA than humans.

1. .....

2. .....

(2 marks)

1.7 Protein-encoding DNA leads to the production of mRNA.
Other parts of the DNA encode functional RNA. Give **two** examples of functional RNA.

1. .....

2. .....

(2 marks)

2 Leigh syndrome is a metabolic disorder that affects the central nervous system. It can be caused by a mutation in the MT-ATP6 gene, which is located in the mitochondrial DNA.

2.1 Give **two** differences between the structure of DNA found in the mitochondria and the structure of DNA found in the nucleus.

1. .....

2. .....

(2 marks)

2.2 What name is given to the location that a gene occupies on a particular DNA molecule?

A Intron ☐

B Exon ☐

C Allele ☐

D Locus ☐

(1 mark)

Table 1 contains some of the DNA codons that code for particular amino acids.

Table 1

Amino acid	DNA codon
Isoleucine	ATT, ATC, ATA
Glutamic acid	GAA, GAG
Leucine	CTG, TTA, TTG
Methionine	ATG
Valine	GTT, GTC, GTA, GTG
Arginine	CGG, AGA
Alanine	GCT, GCC, GCA, GCG

2.3 Give **one** piece of evidence from **Table 1** that shows the genetic code is degenerate.

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(1 mark)

Figure 1 shows **one** of the mutations in the MT-ATP6 gene that can cause Leigh syndrome.

Figure 1

Original gene: CAA CCA ATA GCC CTG GCC GTA

Mutated gene: CAA CCA ATA GCC CGG GCC GTA

Codon position: 152 153 154 155 156 157 158

2.4 Describe the effect that the mutation shown in **Figure 1** will have on the mRNA sequence produced from the MT-ATP6 gene.

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(1 mark)

2.5 Using **Table 1** for reference, describe the effect that the mutation shown in **Figure 1** will have on the amino acid sequence produced from the MT-ATP6 gene.

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(1 mark)

2.6 MT-ATP6 codes for a subunit of ATP synthase, an enzyme involved in respiration.
Explain how a change in its amino acid sequence could affect the function of ATP synthase.

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(3 marks)

2.7 Describe how the mRNA produced from the MT-ATP6 gene is translated into a protein.

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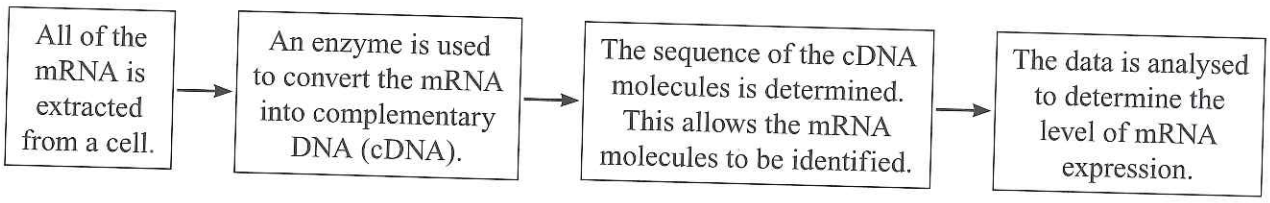
(5 marks)

3 Transcriptomics involves studying the RNA present in a cell.
One technique involved in transcriptomics is described in **Figure 2**.

Figure 2



3.1 Describe how mRNA is produced from DNA by RNA polymerase.

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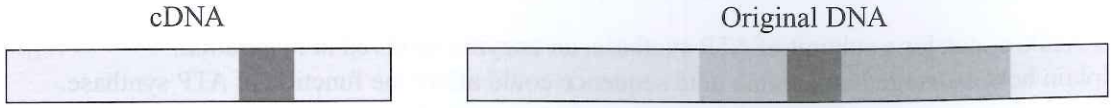
(4 marks)

A team of scientists have developed a new drug. The team used the method in **Figure 2** to investigate how the levels of three different mRNA molecules changed when eukaryotic cells were treated with the drug.

Figure 3 shows two images. One represents the cDNA for one of the mRNA molecules. The other represents the original DNA strand from which the mRNA was produced in the nucleus.

Figure 3



3.2 Explain why the cDNA and the original DNA shown in **Figure 3** are different.

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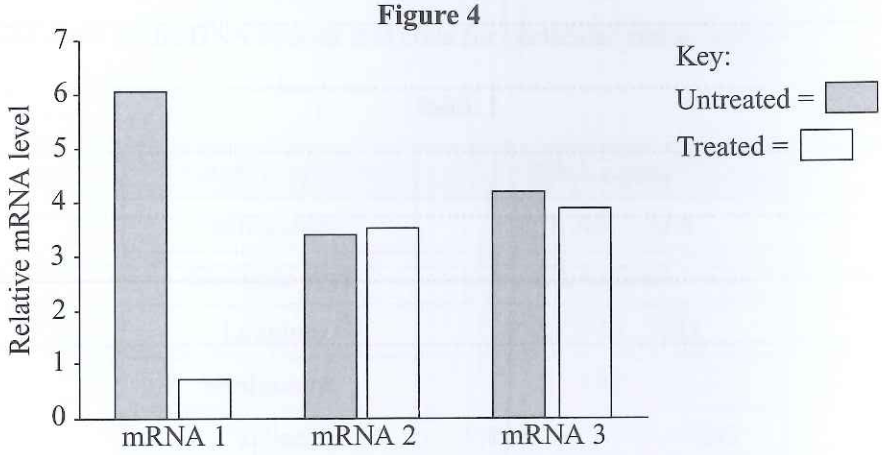
(2 marks)

The results of the scientists' experiment are shown in **Figure 4**.

Figure 4



The scientists hypothesised that the new drug had two possible methods of action:
Method 1: By preventing RNA polymerase from working.
Method 2: By destroying particular mRNA sequences.

3.3 With reference to **Figure 4**, explain why the drug cannot be acting via Method 1.

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(2 marks)

3.4 Explain how the results shown in **Figure 4** can be explained if the drug acts via Method 2.

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(2 marks)

EXAM TIP

Make sure you know the basics of DNA and RNA structure, as well as the relationship between the base sequence in DNA, mRNA and tRNA. If you do, questions like 2.4 will be easy marks in the exam. It's important to remember that U replaces T in RNA too.

Score

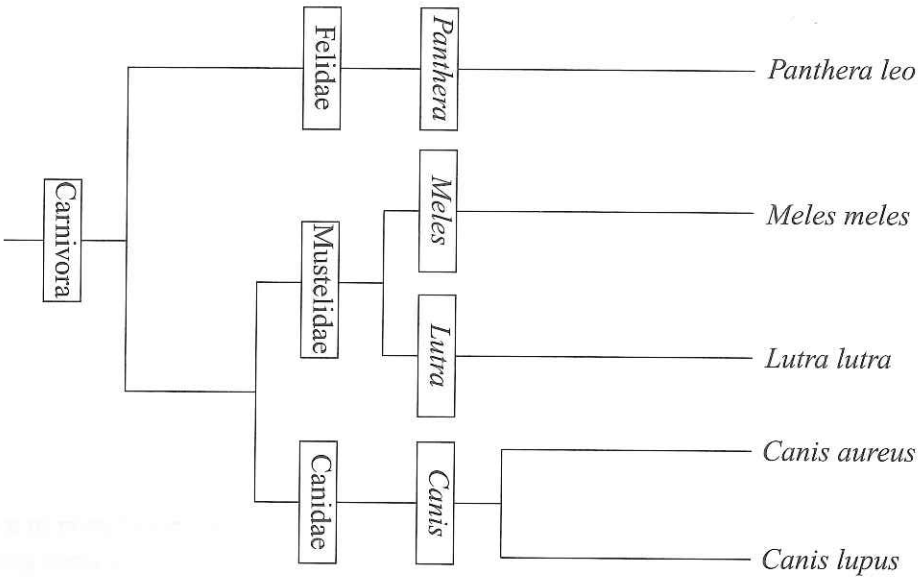
35

Diversity, Classification and Variation — 1

It is due to variations in the genetic code that there is such a great diversity of life on Earth. And because there's so much diversity, scientists find it easier to classify organisms into groups. There's a lot to remember for this section, but don't worry — these questions are here to help you make sure you're all set for your exams.

1 **Figure 1** is a phylogenetic tree. It shows how different species from the order Carnivora are related.

Figure 1



1.1 What is the definition of a species?

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(1 mark)

1.2 The plural of genus is genera.
How many different genera are represented in **Figure 1**?

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(1 mark)

1.3 Which **two** species in **Figure 1** are most closely related? Give a reason for your answer.

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(1 mark)

1.4 What taxon is represented by the groups Felidae, Mustelidae and Canidae in **Figure 1**?

A Kingdom ☐

B Phylum ☐

C Class ☐

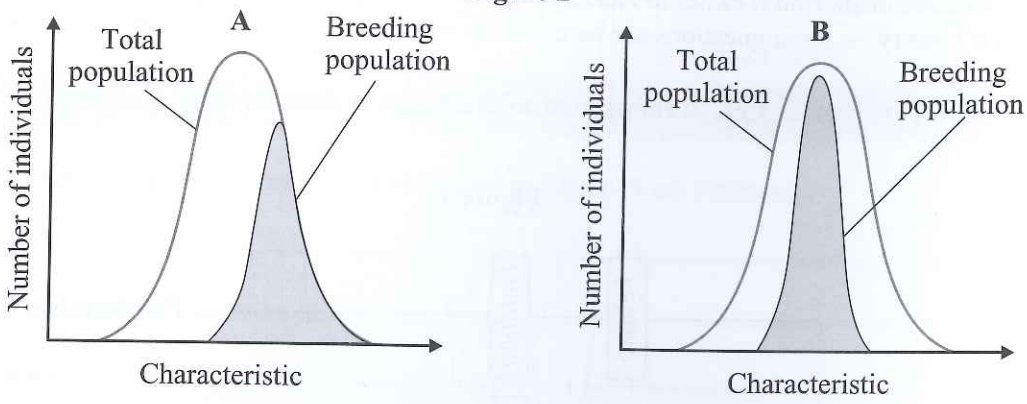
D Family ☐

(1 mark)

2 Species become better adapted to their environment via the process of natural selection.

Figure 2 shows two populations (**A** and **B**) experiencing natural selection.

Figure 2



2.1 Compare and contrast the **two** types of natural selection shown in **Figure 2**.

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(3 marks)

In **Figure 2**, one graph represents the selection on height faced by a plant population in a dense forest. The other graph represents the selection on height faced by a plant population in open grassland.

2.2 Using this information, state which population (**A** or **B**) is from the forest. Explain your answer.

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(2 marks)

2.3 Suggest why the plant population in open grassland is undergoing a different type of selection to the one in the dense forest.

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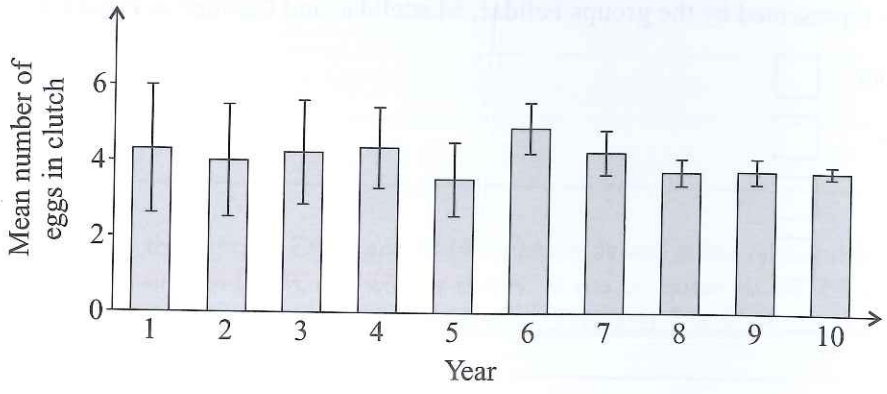
(1 mark)

Clutch size is the number of eggs laid by a female bird during one breeding season.
Figure 3 shows the mean number of eggs in a clutch over several years for a bird population.
The error bars indicate standard deviation.

Figure 3



2.4 Suggest an explanation for the changes shown in **Figure 3**.

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(3 marks)

3 When classifying organisms, scientists often look at the proteins found within the organisms.

3.1 Explain why proteins can be analysed to help classify organisms.

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(3 marks)

Scientists compared the amino acid sequence of a protein in four species, to that in humans. They counted the differences in each amino acid sequence, compared to the sequence in humans. The data obtained is presented in **Table 1**.

Table 1

Species	Number of differences in amino acid sequence compared to human protein
A	25
B	7
C	1
D	7

3.2 Using the information in **Table 1**, discuss the scientists' results.

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(2 marks)

3.3 It was concluded that species **B** and **D** were more closely related to each other than they were to humans. Explain why this is not a valid conclusion for this data.

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(1 mark)

EXAM TIP

Standard deviation is a measure of the variation around the mean. Error bars can be used to show standard deviation in graphs. Put simply — the shorter the bar, the smaller the standard deviation and the less spread out the data is. Not all error bars represent standard deviation though, so make sure you read the question carefully to figure out what they mean.

Score

19

Diversity, Classification and Variation — 2

1 Scientists investigated the diversity of plants in an ungrazed field. The data obtained is shown in **Table 1**.

Table 1

Species	Number of individual plants counted in different quadrats					Mean number counted
Rapeseed	24	46	32	28	32	
Common sunflower	1	0	2	1	1	
Common poppy	8	12	6	10	8	
Creeping thistle	13	14	7	15	13	

1.1 Complete **Table 1** to show the mean number of each species counted.

(1 mark)

1.2 Using the mean values you added to **Table 1** and the formula provided below, calculate the index of diversity for plants in this field. Show your working.

$$d = \frac{N(N-1)}{\Sigma n(n-1)}$$

where N = total number of organisms of all species
and n = total number of organisms of one species

$d =$ .....

(2 marks)

The scientists then gathered data in a second field on which farm animals were allowed to graze. The mean number of creeping thistle was much lower in the second field than in the first.

1.3 The scientists wanted to determine if the difference in means between the two fields was significant. State which statistical test they could have used to determine this. Explain your choice.

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(2 marks)

1.4 Further investigations in both fields showed the overall biodiversity of the grazed field to be lower than that of the ungrazed field. Suggest an explanation for this.

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(2 marks)

2 Scientists wanted to investigate the impact of different farming practices on ladybird biodiversity. To do so, they counted the number of different ladybird species on organic and conventional farms. This allowed them to compare the species richness of the ladybirds in the different types of farm.

2.1 Explain why it may have been more useful for the scientists to compare indexes of diversity for their investigation.

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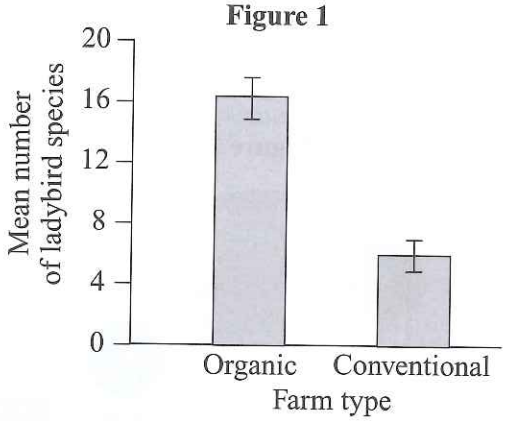
(2 marks)

The scientists' data can be seen in **Figure 1**. The error bars indicate standard deviation.

Figure 1



2.2 The scientists concluded that conventional farming had a much greater impact on the number of ladybird species than organic farming. Use the data in **Figure 1** to evaluate this claim.

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(3 marks)

2.3 Describe and explain **two** ways in which the scientists could have ensured that the results they obtained were representative of the farms sampled.

1. .....

2. .....

(2 marks)

3 A student wanted to investigate the effectiveness of different types of antibacterial hand sanitiser against a type of bacteria found on the surface of the skin. She was provided with paper discs, three different types of hand sanitiser, a bottle of bacterial broth culture and an agar plate.

3.1 The agar plate that the student used would have first been autoclaved. Explain why.

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(2 marks)

3.2 Describe a method that the student could use for her investigation.
Include details of the aseptic techniques she should carry out.

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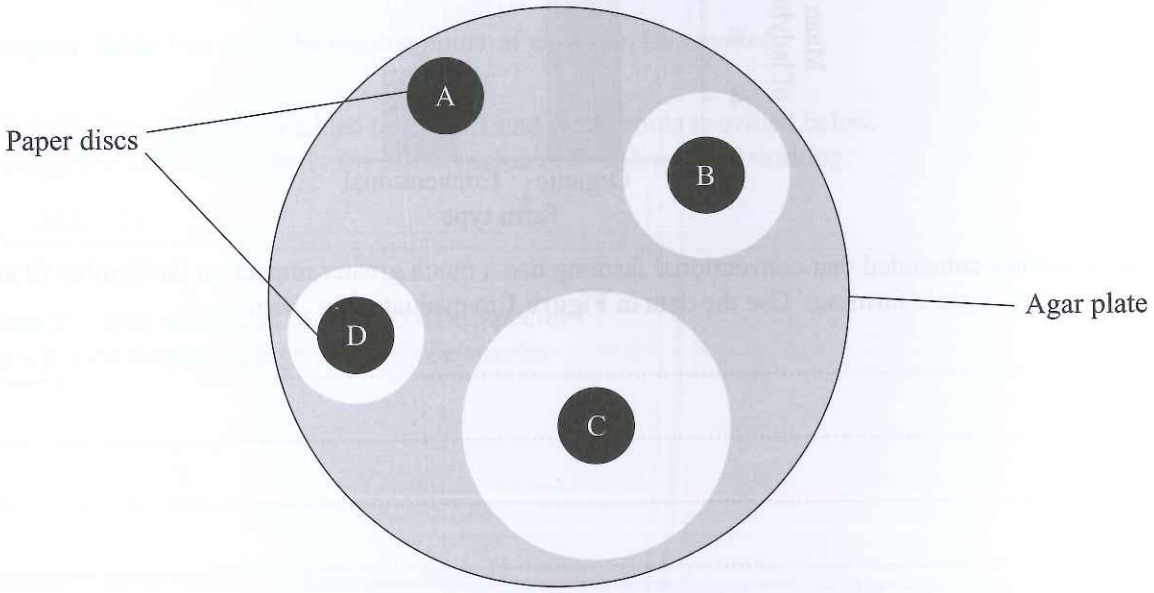
(5 marks)

Figure 2 shows the student's results.

Figure 2



3.3 Disc **A** did not contain any antibacterial hand sanitiser. Explain why it was used.

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(2 marks)

The area of the inhibition zone surrounding each paper disc indicates the effectiveness of the antibacterial hand sanitiser.

3.4 Complete **Table 2** by calculating the areas of the inhibition zones in **Figure 2**.

The area of a circle can be calculated using the formula πr^2, where r = radius of the circle.

Table 2

Disc	Area of Inhibition Zone / mm^2
B	
C	
D	

(1 mark)

4 Gametes are produced by meiosis. Errors occurring in meiosis can lead to significant health problems.

4.1 Explain how meiosis gives rise to genetic variation.

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(4 marks)

4.2 The diploid number for human cells is 46. Using the formula provided below, calculate the possible number of different combinations of chromosomes following meiosis in humans.

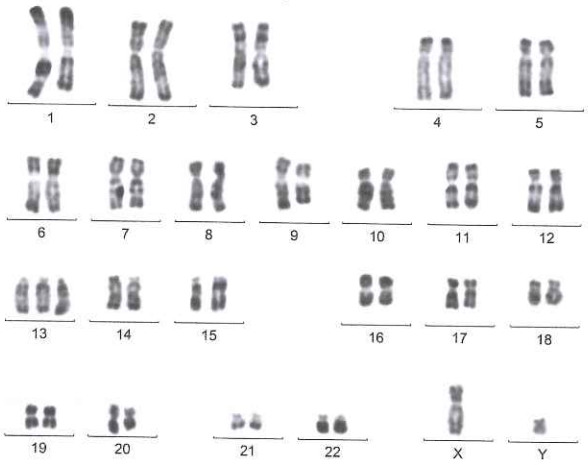
number of combinations = 2^n
where n = the number of homologous chromosome pairs

number of different combinations of chromosomes = ...

(1 mark)

Patau syndrome is a rare chromosomal disorder.
Figure 3 shows the chromosomes of a male with Patau syndrome.

Figure 3



Pr Philippe VAGO, ISM/SCIENCE PHOTO LIBRARY

4.3 Using **Figure 3**, suggest and explain how events in meiosis can cause Patau syndrome.

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(4 marks)

EXAM TIP

Phew. There's a lot of maths on these pages. The question might seem simple if you're given the formula, but it's still easy to make mistakes. You need to make sure that you're substituting the correct numbers into the formula. For example, with the index of diversity formula, make sure you don't get 'N' (number of all organisms) and 'n' (number of one species) mixed up.

Score

33