

**BIOLOGY**

**DATE :** 3 June 2016

**DURATION OF EXAMINATION:**

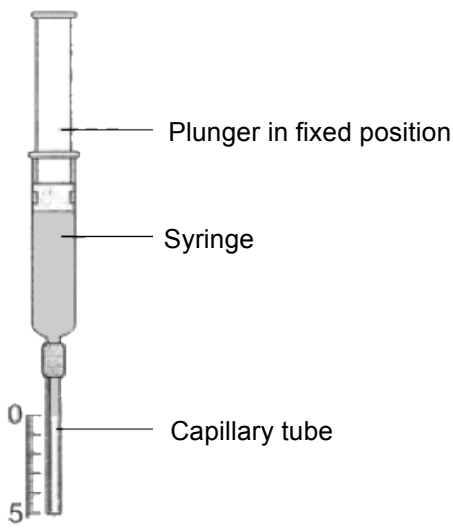
3 hours (180 minutes)

**PERMITTED EQUIPMENT:**

- Calculator TI-Nspire™, in 'Press-to-Test' mode
- Pencils for diagrams and graphs

**INSTRUCTIONS:**

- Begin the answer to each question on a separate double sheet.

<b>Question P</b>		
	<b>Page 1/3</b>	<b>Marks</b>
<p><b>a)</b> Research on the structure of the plasma membrane reveals that lipid-soluble compounds can pass rapidly into cells. Other research shows that the plasma membrane is selectively permeable to amino acids, ions, and some carbohydrates. It has been demonstrated that all membranes have the same basic structure but that they can vary in the type of protein and lipid that they contain. Many of these proteins provide a means of communication between cells and molecules in the environment.</p> <p>i. Name four components of the plasma membrane and briefly describe their structure.</p> <p>ii. Apart from lipid solubility, give any two other factors that can influence the movement of molecules across a membrane.</p> <p>iii. Explain how the structure of the plasma membrane permits selective permeability and communication with molecules in the environment. Give one example for each.</p> <p><b>b)</b> <b>Figure 1</b> shows an apparatus used to investigate a metabolic process in yeast. A suspension containing both yeast and glucose is drawn into the syringe. The syringe is then attached to a capillary tube and held in a vertical position. Finally, pressure is applied to the plunger until the level of the suspension is in line with the top of the scale; the plunger is then fixed in place.</p> <p><b>Figure 1</b></p>  <p>i. Explain why the level of the suspension travelled down the capillary tube during the course of this experiment.</p> <p>ii. You want to compare the rate of this metabolic process using different kinds of sugars. Describe how you would do this experiment using the apparatus of <b>figure 1</b>.</p>		
		<b>4</b>
		<b>2</b>
		<b>4</b>
		<b>2</b>
		<b>3</b>

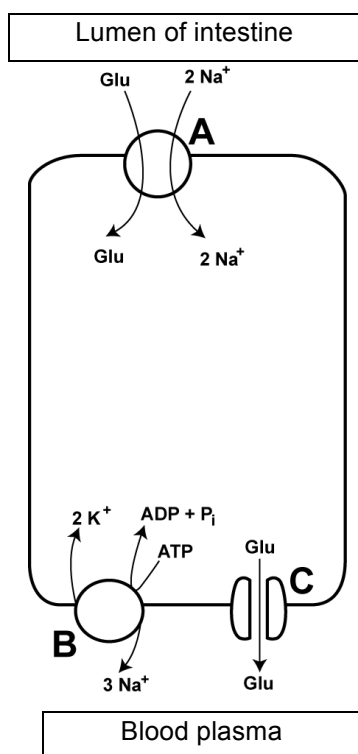
Question P

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Marks

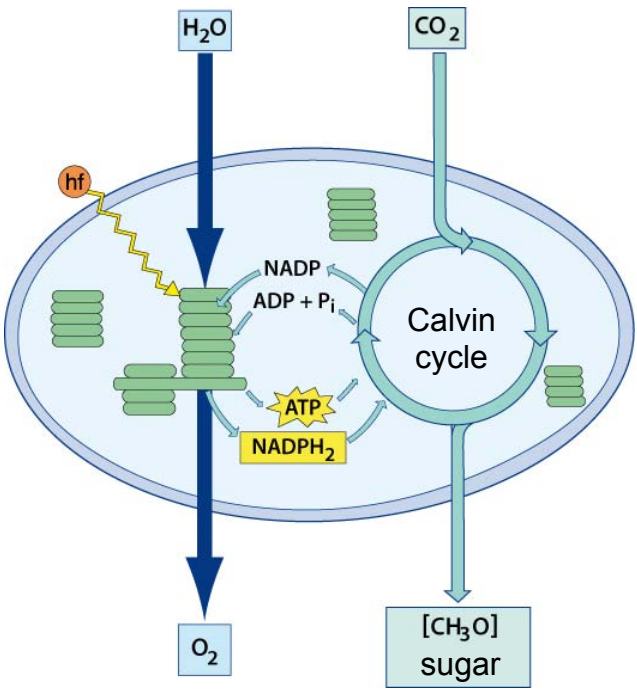
- c) Nutrients from digestion reach the blood plasma through the mucosa cells lining the intestines. Glucose passes through mucosa cells to reach the blood plasma as shown in the diagram of **figure 2**. The table of **figure 2** shows the respective concentrations of  $\text{Na}^+$ ,  $\text{K}^+$  and glucose in the mucosa cells and in the blood plasma. All the glucose in the intestine will be absorbed, even if the concentration in the lumen of the intestine is low.

**Figure 2**



	Concentration in the mucosa cells lining the intestines ( $\text{mmol L}^{-1}$ )	Concentration in the blood plasma ( $\text{mmol L}^{-1}$ )
$\text{Na}^+$	10	145
$\text{K}^+$	140	5
Glucose	5	0.005

- Identify the types of transport occurring at A, B and C. Give the type of biological molecule that makes up these transporters. **2**
- Describe the transport mechanisms that allow glucose to move from the lumen of the intestine to the blood plasma, even when the concentration in the intestine is very low. **4**
- Justify the use of ATP at B using data from the table shown in **figure 2**. **2**
- If structure A were replaced by a structure like C what would happen with respect to glucose absorption? **2**

Question P		
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<p>A toxic substance, phlorizin is tested on an intestinal segment kept alive in a physiological solution. The addition of phlorizin does not decrease the consumption of oxygen by the mucosa cells but causes the inhibition of the absorption of glucose into the blood plasma.</p>		
v. Identify which of the processes occurring at A, B or C in <b>figure 2</b> is not affected by phlorizin. Justify your answer.		1
vi. Make a hypothesis to explain how phlorizin works.		2
<p><b>d) Figure 3</b> shows a diagram of a chloroplast and an overview of photosynthesis.</p>		
<p><b>Figure 3</b></p>  <p>The diagram illustrates the two main stages of photosynthesis within a chloroplast. On the left, the light-dependent reactions occur in the thylakoid membranes. Light energy (represented by a yellow arrow labeled 'hf') is absorbed by photosynthetic pigments, leading to the photolysis of water (<math>\text{H}_2\text{O}</math>) into oxygen (<math>\text{O}_2</math>) and protons. Electrons from this process are transferred through a series of carriers, which drives the synthesis of ATP from ADP and inorganic phosphate (<math>\text{P}_i</math>). Additionally, NADP<sup>+</sup> is reduced to NADPH<sub>2</sub>. On the right, the Calvin cycle takes place in the stroma. It uses carbon dioxide (<math>\text{CO}_2</math>) as a carbon source, along with the ATP and NADPH<sub>2</sub> produced in the light reactions. The cycle results in the production of sugar (<math>[\text{CH}_2\text{O}]</math> sugar) and the regeneration of NADP<sup>+</sup> and ADP + <math>\text{P}_i</math> to be reused in the light reactions.</p>		
i. Give the main steps in the production of ATP and NADPH <sub>2</sub> (NADPH + H <sup>+</sup> ) during the light phase of photosynthesis.		4
ii. What is the role of NADPH <sub>2</sub> in the Calvin cycle?		2
<p>During a series of experiments the following factors affecting the rate of photosynthesis are changed:</p> <ul style="list-style-type: none"> <li>- light intensity is decreased.</li> <li>- only green light is used.</li> <li>- the concentration of <math>\text{CO}_2</math> in the environment is increased.</li> </ul>		
iii. How can each of these factors change the rate of photosynthesis? Justify your answers.		6

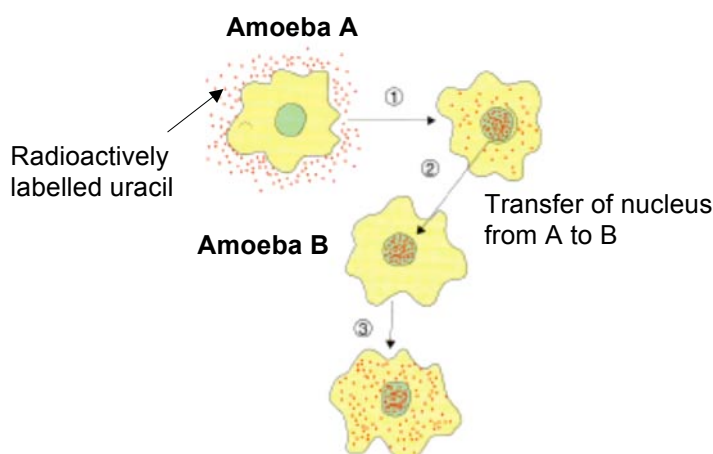
Question G

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Marks

- a) An amoeba (A) was placed in a nutrient medium containing radioactively labelled uracil. After two hours the whole cell was found to be radioactive. The nucleus from amoeba A was then removed and transferred to amoeba B where the nucleus had been previously removed. Two hours later radioactivity could be measured in the cytoplasm of amoeba B. The experiment is shown in **figure 1** below.

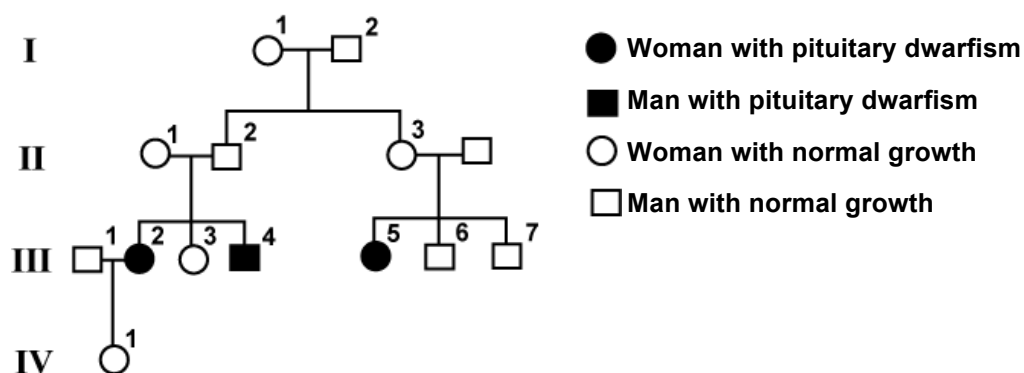
**Figure 1**



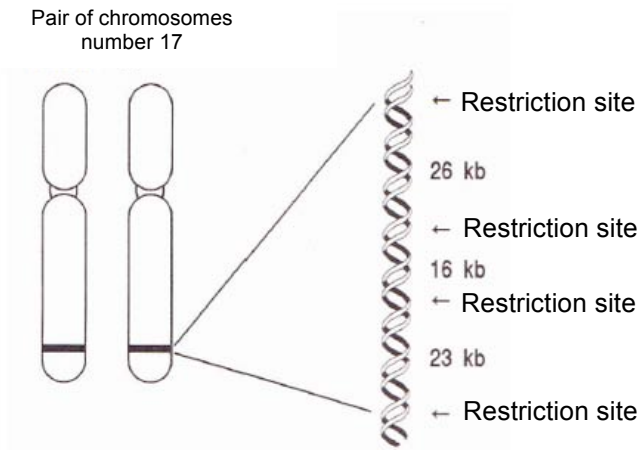
- What is uracil and what is it used for in the cell? 2
- Explain the results for each stage in the experiment of **figure 1**. 4
- What would be the result of the experiment if radioactively labelled thymine were present in the nutrition medium of amoeba A, instead of radioactively labelled uracil? Justify your answer. 2

- b) **Figure 2** shows a family tree for pituitary dwarfism, an inherited form of dwarfism, which is caused by a non-functional growth hormone.

**Figure 2**



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Question G		
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<p>i. With the help of <b>figure 2</b>, demonstrate that the allele responsible for pituitary dwarfism is recessive and autosomal.</p> <p>ii. State the possible genotypes for: I-1, II-1, III-2 and IV-1. Justify your answers.</p> <p>iii. Using a Punnett square, calculate the probability of pituitary dwarfism for a fourth child born to the parents II-3 and II-4.</p> <p>c) <b>Figure 3</b> shows a section of chromosome 17 containing the growth hormone gene GH1, which consists of 1660 base pairs. This section of the chromosome has four recognition sites for a specific restriction enzyme.</p> <p><b>Figure 3</b></p>  <p>The chromosome section is analysed. People with pituitary dwarfism have a DNA fragment of 18.5 kb when their DNA is cut with the specific restriction enzyme.</p> <p>i. Explain how restriction enzymes work.</p>	<p><b>3</b></p> <p><b>4</b></p> <p><b>2</b></p>	
		<b>2</b>

Question G

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Marks

**Figure 4** shows a part of the sequence of gene GH1.

**Figure 4**

	Non transcribed strand
Position of nucleotides	...520 ↓ <span style="float: right;">555... ↓</span>
Normal sequence	... GAG GGT GGC ACC AGG GAT CCC CAA TCC TGG GGC CCC ...
Mutant sequence	... GAG GGT GGC GCC AGG GAT CCC CAA TCC TGG GGC CCC ...

ii. Identify and name the type of mutation that causes this pituitary dwarfism.

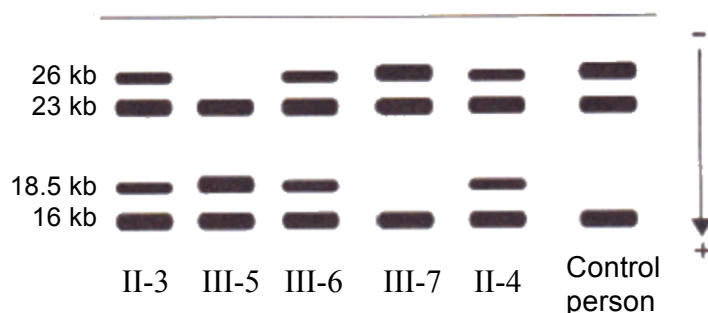
2

iii. Describe the consequences of this mutation at the molecular level.

2

**Figure 5** shows the results of DNA analysis from five persons of the family tree in **figure 2** and from a control person without the allele responsible for pituitary dwarfism.

**Figure 5**



Fragments under 10 kb are not visible in this electrophoresis

iv. Explain the principal of DNA electrophoresis.

3

v. Identify the DNA fragment that contains this mutation for pituitary dwarfism. Justify your answer.

3

vi. The growth hormone is a protein of 191 amino acids. Calculate how many base pairs are needed for the production of this protein.

1

vii. Explain, using a labelled diagram, why this number deviates from the 1660 base pairs that make up the gene for growth hormone.

4

Children suffering from this type of dwarfism have been treated with growth hormone, but in 80% of the cases the treatment was ineffective.

viii. How can this information together with the result in **figure 5** be used in a genetic counselling of each of the persons III-6 and III-7, if they want to have children?

6

Question E

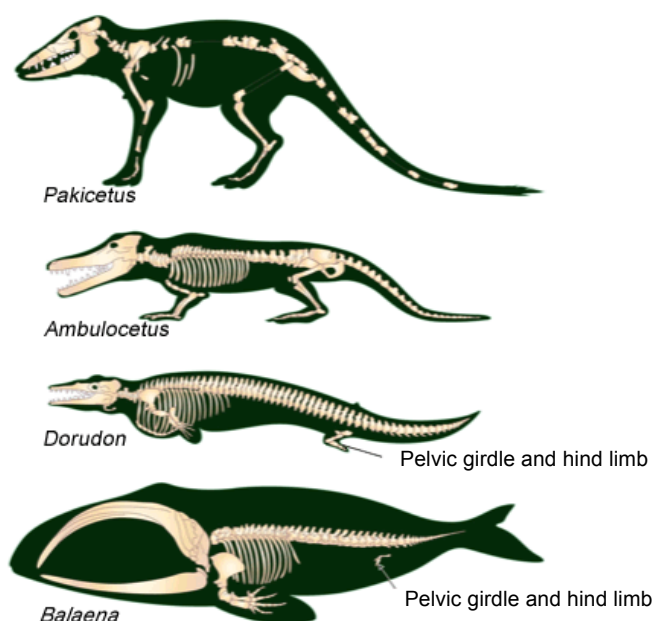
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Marks

In the past, biologists were not certain whether cetaceans (a group with whales, dolphins and porpoises) were the ancestors of terrestrial mammals or the descendents of terrestrial mammals that have returned to an aquatic life.

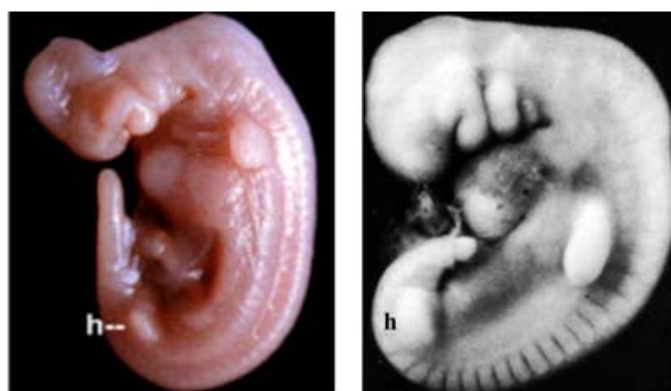
- a) **Figure 1** shows a chronological series of fossils from the Eocene (~50 million years ago - mya) *Pakicetus* (top) to a skeleton of the modern whale (*Balaena*, bottom). All these animals belong to the cetaceans' lineage.

**Figure 1**


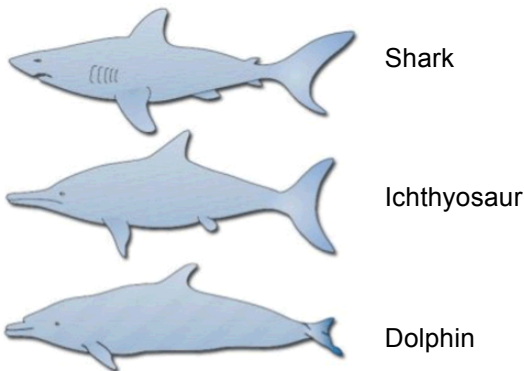


**Figure 2** shows a 24 days old dolphin embryo (left) and a 30 days old human embryo (right). Modern adult cetaceans have no hind legs. Even so, precursors of hind legs (h in **figure 2**), with various developing bones, nerves, and blood vessels, temporarily appear in the cetacean embryos. They subsequently degenerate before birth.

**Figure 2**





Question E		
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<p><b>Figure 3</b> shows atavistic external hind limbs found in cetaceans (see arrows). Atavistic traits are ancestral forms that can reappear.</p> <p><b>Figure 3</b></p>  <p>i. Using <b>figures 1 to 3</b>, give and explain three pieces of evidences in favour of the cetaceans having evolved from terrestrial mammals.</p> <p><b>b)</b> The shape of modern cetaceans is quite similar to the shapes of sharks and ichthyosaurs (an extinct group of marine reptiles).</p> <p><b>Figure 4</b></p>  <p>Shark</p> <p>Ichthyosaur</p> <p>Dolphin</p> <p>i. Explain the terms <u>analogous structures</u> and <u>convergent evolution</u>, using two examples from <b>figure 4</b>.</p>		
		6
		4

Question E

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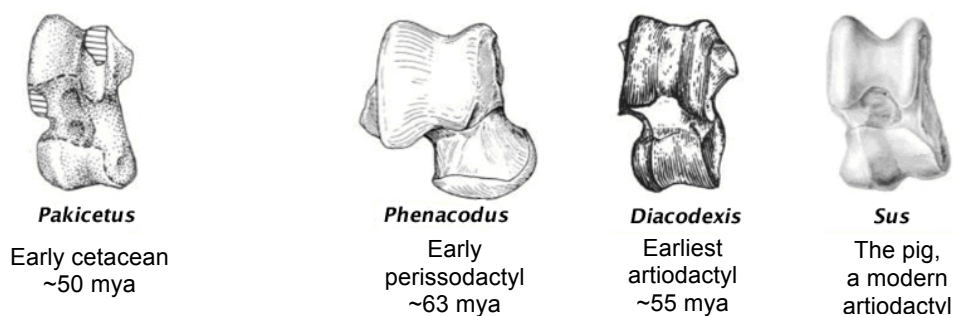
Marks

c) Modern ungulates are divided into two sub-groups:

- Perissodactyls are ungulates with an odd number of toes on each foot, for example horses, zebras, rhinos and tapirs.
- Artiodactyls are ungulates with an even number of toes on each foot, for example cows, camels, pigs and hippopotami.

As shown in **figure 1** early ancestors of modern cetaceans had legs. **Figure 5** shows one of the anklebones from *Pakicetus* and the corresponding bone of some other mammals thought to be related.

**Figure 5**



- i. Using **figure 5** determine, with justification, to which sub-group of ungulates *Pakicetus* belongs.

2

d) In order to further understand the relationship between cetaceans and other mammals, the sequences of the same DNA segment were determined and compared. The study is based on a part of the gene for beta casein, a milk protein, found in 2 cetaceans (sperm whale and porpoise) and 5 other mammals. The table of **figure 6** shows the results of this comparison.

**Figure 6**

Species	DNA sequence (bases 141-200 of the beta casein gene)																			
Sperm Whale	AGT	CCC	CAA	AGC	TAA	GGA	GAC	TCT	CCT	TCC	TAA	GCA	TAA	AGA	AAT	GCC	CTT	CCC	TAA	ATC
Camel	T--	---	---	-A-	---	---	---	CA-	-A-	---	---	--G	C--	---	---	---	---	G-T	-C-	G--
Cow	---	---	---	--T	G--	---	---	-A-	GG-	---	---	---	C--	G--	---	---	---	---	---	--A
Hippopotamus	---	---	---	---	A--	---	---	-A-	---	---	---	---	---	---	---	---	---	-T-	---	---
Pig	--A	TT-	---	---	---	---	---	CA-	TG-	---	C--	--G	---	--G	---	---	---	---	---	---
Porpoise	---	---	---	---	---	---	---	-A-	---	---	---	---	---	---	---	--G	---	---	---	---
Rhinoceros	---	--T	-C-	-A-	---	---	---	CA-	-T-	---	---	--T	C--	--T	T--	---	--C	--T	---	---

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Question E																																																																	
Page 4/4	Marks																																																																
<p>i. Copy and complete the table below showing the number of differences between the DNA sequences of these 7 species.</p> <table><tr><td>Sperm whale</td><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Camel</td><td>11</td><td>0</td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>Cow</td><td>8</td><td></td><td>0</td><td></td><td></td><td></td><td></td></tr><tr><td>Hippopotamus</td><td>3</td><td></td><td></td><td>0</td><td></td><td></td><td></td></tr><tr><td>Pig</td><td>10</td><td>14</td><td>13</td><td></td><td>0</td><td></td><td></td></tr><tr><td>Porpoise</td><td>2</td><td></td><td></td><td></td><td></td><td>0</td><td></td></tr><tr><td>Rhinoceros</td><td>12</td><td>11</td><td>15</td><td>13</td><td>15</td><td>12</td><td>0</td></tr><tr><td></td><td>Sperm whale</td><td>Camel</td><td>Cow</td><td>Hippopotamus</td><td>Pig</td><td>Porpoise</td><td>Rhinoceros</td></tr></table>	Sperm whale	0							Camel	11	0						Cow	8		0					Hippopotamus	3			0				Pig	10	14	13		0			Porpoise	2					0		Rhinoceros	12	11	15	13	15	12	0		Sperm whale	Camel	Cow	Hippopotamus	Pig	Porpoise	Rhinoceros	2
Sperm whale	0																																																																
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Rhinoceros	12	11	15	13	15	12	0																																																										
	Sperm whale	Camel	Cow	Hippopotamus	Pig	Porpoise	Rhinoceros																																																										
<p>ii. Determine the evolutionary relationship between the sperm whale and the other six species by representing this relationship in a phylogenetic tree.</p>	3																																																																
<p>iii. Explain why it is better to compare DNA sequences rather than amino acid sequences to establish evolutionary relationships of different species.</p>	3																																																																