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NZQA
NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

# Scholarship 2008
# Biology

9.30 am Saturday 22 November 2008
Time allowed: Three hours
Total marks: 24

## QUESTION BOOKLET

There are THREE questions in this booklet. Answer ALL questions.

Write your answers in the Answer Booklet 93101A.

Show ALL working. Start your answer to each question on a new page. Carefully number each question.

Check that this booklet has pages 2–7 in the correct order and that none of these pages is blank.

**YOU MAY KEEP THIS BOOKLET AT THE END OF THE EXAMINATION.**

You have three hours to complete this examination.

## QUESTION ONE (8 marks)

**Sickle Cell Disease [SCD]** is a human genetic disorder resulting from a mutant form of the **Hb** gene, which is located on chromosome 11. The Hb gene codes for the protein **haemoglobin**, which is found in red blood cells and transports oxygen**.** The mutant allele **$Hb^s$** produces haemoglobin that differs in one amino acid from the normal haemoglobin. Red blood cells that contain the abnormal haemoglobin collapse into a jagged sickle shape in a low-oxygen environment. The $Hb^s$ allele produces **pleiotropic** effects in individuals who inherit it.

The sickled cells may clump and clog small blood vessels, often leading to other symptoms throughout the body. Individuals with sickle cell disease can suffer severe anaemia, pain, organ damage, and even paralysis. In Western countries, frequent blood transfusions can be used to treat individuals with SCD. This alleviates the symptoms and reduces the chances of organ damage.

Individuals can have the following genotypes / phenotypes:

- HbHb have normal red blood cells
- $HbHb^s$ have *sickle cell trait* with some of their red blood cells being sickled
- $Hb^sHb^s$ have *sickle cell disease* [SCD] with all of their red blood cells being sickled. The severe physiological effects that result often cause death before the individual reaches reproductive age. SCD kills about 100 000 people annually throughout the world.

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| **HbHb** | **$Hb^sHb$** | **$Hb^sHb^s$** |
|---|---|---|
| All red blood cells are normal | Mixture of normal and sickle red blood cells | All red blood cells are sickle-shaped |

Fig 1. The phenotype and genotype of haemoglobin in red blood cells.
Greenwood, Shepherd & Allan, *Year 13 Biology* (Hamilton, Biozone, 2006), p. 233.

**The frequency of the $Hb^s$ allele**

The frequency of the $Hb^s$ allele varies between populations around the world, with the highest frequencies of up to 20% being found in Africa. In comparison, New Zealand has a very low frequency of less than 1%. In the USA the frequency is similar to New Zealand in the general population, but can approach 10% amongst black Americans.

**Malaria** is a major global disease with most cases seen in Asia, Africa, and countries bordering the Mediterranean [Fig 2]. About half a billion people annually contract the disease with about one million dying from it. Most of the fatalities are children under the age of five, most of whom live in Africa. Malaria is caused by *Plasmodium,* a unicellular parasite, which is transmitted from person to person by *Anopheles* mosquitoes. The plasmodia enter the red blood cells where they repeatedly reproduce to release large numbers of new parasites.

The mutant $Hb^s$ allele provides some protection against malaria because the parasites are unable to reproduce inside the sickled blood cells.

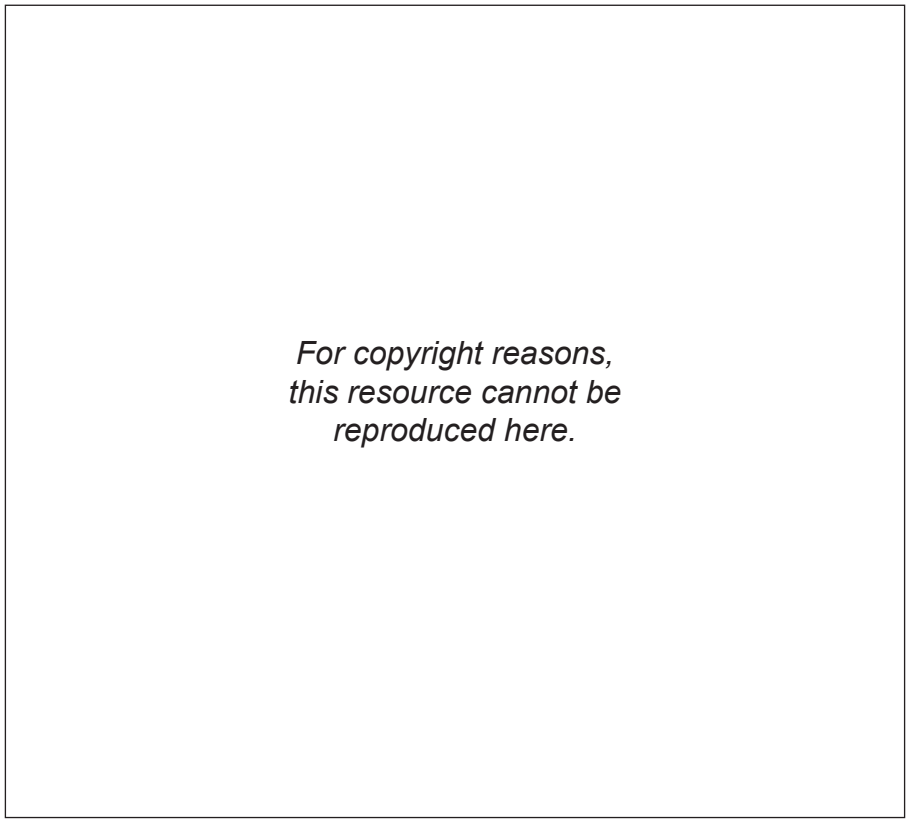


Fig 2. Distribution of malaria and the $Hb^s$ allele throughout Africa, Asia, Mediterranean.
Campbell and Reece, *Essential Biology* (2001), p 272.

**Discuss** the **genetics**, **inheritance** and **frequency** of the $Hb^s$ allele and **evaluate** whether modern biotechnological applications could, in the future, provide a **cure** for **sickle cell disease**.

**QUESTION TWO** (8 marks)

Antifreezes are specialised proteins that prevent the organisms that have them from freezing in the polar oceans of the Arctic and the Antarctic. One of these proteins is the antifreeze glycoprotein (AFGP), which is produced in some fish species. The AFGP proteins protect the fish by lowering their bodies' freezing point temperature so that it is lower than that of the surrounding seawater. This prevents ice crystals from forming within the fishes' body tissues when fish in icy waters drink and feed, which would be lethal.

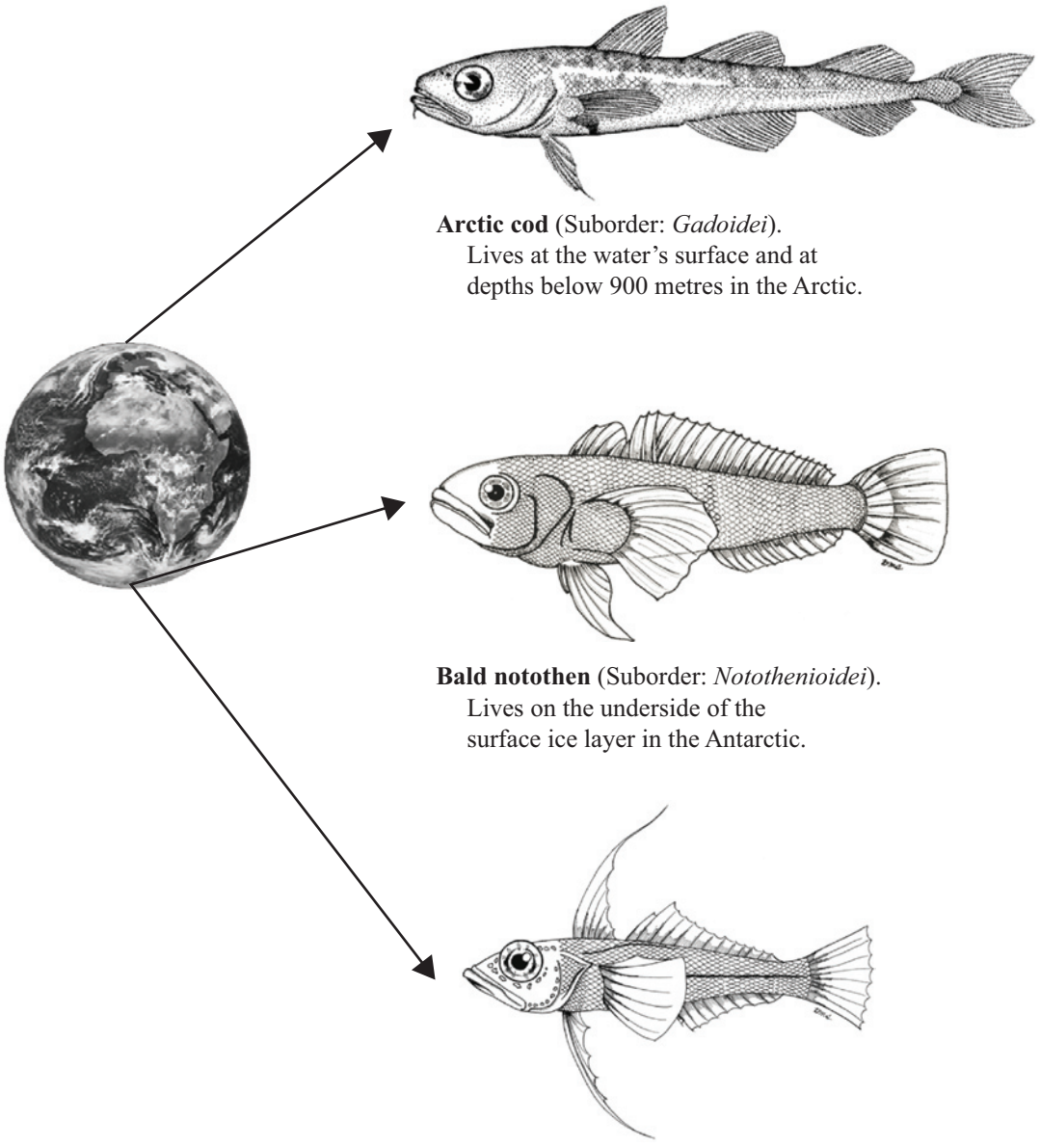


Fig 3: Three species of fish with antifreeze glycoproteins.
(Diagrams not to scale.)

A circumpolar current contributes to the thermal isolation and low temperatures of present-day Antarctica. This current formed about 30 million years ago when Antarctica separated from South America. Up until this time the waters around Antarctica had been relatively warm and a wide diversity of fish species flourished.

With the separation of Antarctica from South America, water temperatures began to drop, reaching freezing levels about 10–15 million years ago. At this time, it is thought that the modern day notothenioids were represented by a single species in which the gene for AFGP may have arisen.

Today the seawater temperature around Antarctica seldom varies more than a few degrees above freezing. These waters are now dominated by the notothenioids, of which there are more than 100 species. AFGP is also found in a species of arctic fish, the Arctic cod. This species is unrelated to the notothenioids, and its AFGP probably evolved about 4–5 million years ago during the glaciation of the Arctic seas. The Arctic cod and the notothenioids separated long before the antifreeze glycoproteins developed.

Researchers have found that the gene for AFGP in the Antarctic notothenioids is quite different in its origin and in its location within the genome from the gene expressing AFGP in the Arctic cod. However, their AFGPs are virtually identical and they both contain the **same repeating sequence** of three amino acids (threonine-alanine-alanine).

**Identify and discuss** the **patterns** and **processes** of antifreeze glycoprotein (AFGP) evolution in polar fishes.

**QUESTION THREE** (8 marks)

Some plants produce chemicals that inhibit the growth of other plants nearby; this relationship is known as **allelopathy.**

Black Walnut (*Juglans nigra*) is a common tree in North American **forests**. It is a large deciduous tree with roots that can extend up to 20 m from the tree. Mature Black Walnut trees (8–10 years) produce a toxic chemical called **juglone**, which has an allelopathic effect on some plant species.

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Fig 4. Large Black Walnut tree.
http://www.mitzenmacher.net/blog/wp-content/uploads/2006/09/Black%20Walnut_001.jpg

**Table 1: Tolerance to juglone by common trees**

| Tolerance to juglone | Trees |
|---|---|
| Juglone tolerant | Maple<br>Oak<br>Sycamore<br>Cedar |
| Juglone intolerant | Birch<br>Scotch Pine<br>Larch<br>Spruce |

Black Walnut trees produce juglone in all parts of the plant throughout the growing season, with large amounts being produced by:

- new leaves in spring
- roots in the summer
- maturing nuts in autumn.

For juglone intolerant plants, exposure to juglone may:

- cause severe wilting
- cause yellowing of leaves
- inhibit shoot and root growth
- inhibit nutrient uptake
- inhibit seed germination.

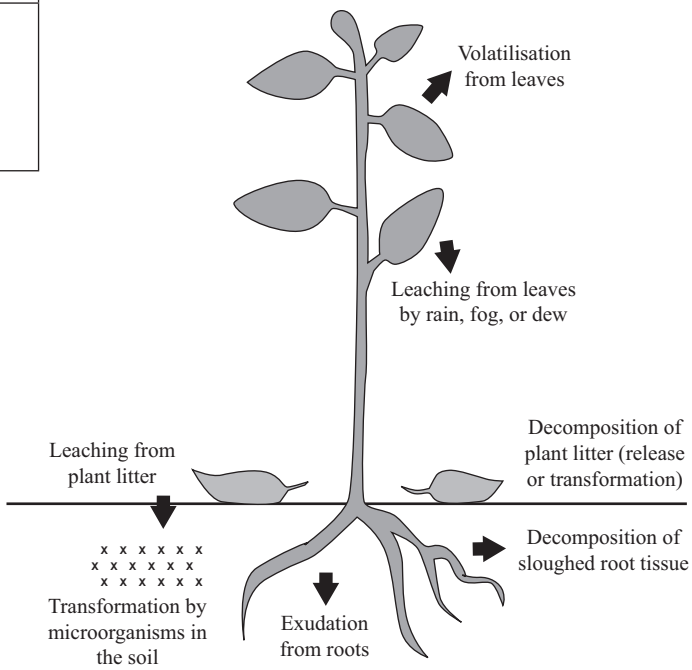


Fig 5. Diagram showing the various pathways for juglone to be released from a Black Walnut tree into the environment.

All soils become toxic where Black Walnut trees grow. Highest toxicity is closest to the tree, mainly because of greater root density and the accumulation of decaying leaves and nut shells. The level of toxicity in the soil is also affected by the type of soil and the amount of microbial activity.

Juglone is not very soluble in water so does not move very rapidly through the soil. In the decomposition of plant material, juglone can take up to six months to break down and become non-toxic.

**Discuss the statement "*Black Walnut plants control the environment in which they live*".**

Your discussion should include:

- **how the adaptations** of Black Walnut for allelopathy give it a **competitive advantage**
- the likely **impact over time** of Black Walnut trees on the **organisms** and the **biodiversity** of the community in which the tree lives
- an **evaluation** as to the **extent** to which the Black Walnut controls its environment.