National Certificate of Educational Achievement
TAUMATA MĀTAURANGA Ā-MOTU KUA TAEA

Exemplar for Internal Achievement Standard

Earth and Space Science Level 2

This exemplar supports assessment against:

Achievement Standard 91190

Investigate how organisms survive in an extreme environment

An annotated exemplar is an extract of student evidence, with a commentary, to explain key aspects of the standard. It assiststeachers to make assessment judgements at the grade boundaries.

New Zealand Qualifications Authority

To support internal assessment

<table>
<tr><td></td><td>Grade Boundary: Low Excellence</td></tr>
<tr><td>1.</td><td>For Excellence the student needs to investigate comprehensively how organisms survive in an extreme environment.

The student needs to:
provide integrated links between conditions of the extreme environment and biological adaptations or technological modifications
justify, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the conditions of the extreme environment.
This student has explained, in depth, the extreme environmental conditions that exist in hot pools (1), and has linked biological adaptations to the extreme environment that makes high temperature cyanobacterial survival possible (2).

For a more secure Excellence, the student could discuss how the ability to photosynthesise in the far red range of the visible spectrum contributes to the survival of cyanobacteria. For example, the role of bilins (cyanobacteria plant pigments) and the ability to use Far-Red Light Photoacclimation (FaRLiP) could be explained and linked to survival in the extreme environment.</td></tr>
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Thermophiles their extreme environment and biological adaptations

The boiling point for water is 100°C. As with humans, the highest temperature at which most animals and plants can live is about 40°C. Above 50°C the only organisms that can survive the heat are some groups of bacteria and archaea.

A **thermophile** is an organism that thrives at relatively high temperatures, between 45 and 80 °C. Many thermophiles are archaea. It has been suggested that thermophilic eubacteria are among the earliest bacteria on the planet Earth.

As a prerequisite for their survival, thermophiles contain enzymes that can function at high temperature. Some of these enzymes are used in molecular biology (for example, heat-stable DNA polymerases for PCR), and in washing agents. (1)

The environment for thermophiles

Thermophiles are found in various geothermally heated regions of the Earth such as hot springs like those in Rotorua and deep sea hydrothermal vents.

Volcanic areas in many places of the world are associated with hot springs. The temperature of these hot springs can go up to 100^{0}C. Hydrothermal vents are exceptionally hot as the water is under pressure and can be heated above 100oC. They are generally acidic and corrosive as well as being very hot. The cause of the hot spring areas is magma being close to the surface of the Earth and open to rain water which seeps into the ground. Under the Taupo Volcanic Zone the magma chamber lies about 8km below the surface so is in easy reach of rain and other ground water. The temperature of many of the hot pools is over 50^{0}C yet supports life. One group of organism is the cyanobacteria which live and thrive in these hot pools. The water coming out of these volcanic areas is high in sulfur.

Adaptations of Cyanobacteria and microbial mats:

One group common in hot springs are cyanobacteria. They derive energy from the sun through photosynthesis, and produce oxygen much like plants. They will not grow in highly acidic waters. Their upper temperature limit is about 70°C; above this, photosynthesis cannot occur.

Cyanobacteria are usually green, and are found in most thermal areas throughout the world. Some cyanobacteria can be other colours because of pigments that mask the green chlorophyll. These pigments protect the bacteria from the sun's ultraviolet radiation.

Cyanobacteria growing in near darkness use a previously unknown process for harvesting energy and producing oxygen from sunlight, a research team led by a Penn State University scientist has discovered. The discovery lays the foundation for further research aimed at improving plant growth, harvesting energy from the Sun.

We now have clearly established that photosynthesis can occur in far-red light, in a wavelength range where people previously did not think that oxygenic photosynthesis could take place. (2)

Thermophiles, meaning heat-loving organisms, are organisms with an optimum growth temperature of 50 °C or more, a maximum of up to 70 °C or more, and a minimum of about 40 degrees C, but these are only approximate. Some extreme thermophiles (hyperthermophiles) require a very high temperature (80 °C to 105 °C) for growth. Their membranes and proteins are unusually stable at these extremely high temperatures. Thus many important biotechnological processes utilize thermophilic enzymes because of their ability to withstand intense heat.

Many of the hyperthermophiles Archea require elemental sulfur for growth. Some are anaerobes that use the sulfur instead of oxygen as an electron acceptor during cellular respiration. Some are lithotrophs that oxidise sulfur to sulfuric acid as an energy source, thus requiring the microorganism to be adapted to very low pH (i.e., it is an acidophile as well as thermophile). These organisms are inhabitants of hot, sulfur-rich environments usually associated with volcanism, such as hot springs, geysers, and fumaroles. In these places, especially in the Taupo Volcanic Zone, we find a zonation of microorganisms according to their temperature optima. Often these organisms are coloured, due to the presence of photosynthetic pigments. (1)

	Grade Boundary: High Merit
2.	For Merit the student needs to investigate in depth how organisms survive in an extreme environment. The student needs to: • explain links between conditions of the extreme environment and biological adaptations or technological modifications • explain, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the conditions of the extreme environment. This student has explained the extreme environmental conditions that exist in hot pools (1) and has explained biological adaptations to the extreme environment that makes high temperature cyanobacterial survival possible (2). To reach Excellence, the student could discuss how the ability to photosynthesise in the far red range of the visible spectrum contributes to the survival of cyanobacteria, and how this ability allows the high temperature cyanobacteria to live in an extreme environment without competition.

Thermophiles their extreme environment and biological adaptations

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A **thermophile** is an organism that thrives at relatively high temperatures, between 45 and 80 °C. Many thermophiles are archaea. It has been suggested that thermophilic eubacteria are among the earliest bacteria on the planet Earth.

As a prerequisite for their survival, thermophiles contain enzymes that can function at high temperature. Some of these enzymes are used in molecular biology (for example, heat-stable DNA polymerases for PCR), and in washing agents.

The environment for thermophiles

Thermophiles are found in various geothermally heated regions of the Earth such as hot springs like those in Rotorua and deep sea hydrothermal vents.

Volcanic areas in many places of the world are associated with hot springs. The temperature of these hot springs can go up to 100^0C. Hydrothermal vents are exceptionally hot as the water is under pressure and can be heated above 100oC. They are generally acidic and corrosive as well as being very hot. The cause of the hot spring areas is magma being close to the surface of the Earth and open to rain water which seeps into the ground. Under the Taupo Volcanic Zone the magma chamber lies about 8km below the surface so is in easy reach of rain and other ground water. The temperature of many of the hot pools is over 50^0C yet supports life. One group of organism is the cyanobacteria which live and thrive in these hot pools. The water coming out of these volcanic areas is high in sulfur. (1)

Adaptations of Cyanobacteria and microbial mats:

One group common in hot springs are cyanobacteria. They derive energy from the sun through photosynthesis, and produce oxygen much like plants. They will not grow in highly acidic waters. Their upper temperature limit is about 70°C; above this, photosynthesis cannot occur.

Cyanobacteria are usually green, and are found in most thermal areas throughout the world. Some cyanobacteria can be other colours because of pigments that mask the green chlorophyll. These pigments protect the bacteria from the sun's ultraviolet radiation.

Cyanobacteria growing in near darkness use a previously unknown process for harvesting energy and producing oxygen from sunlight, a research team led by a Penn State University scientist has discovered. The discovery lays the foundation for further research aimed at improving plant growth, harvesting energy from the Sun. We now have clearly established that photosynthesis can occur in far-red light.

Thermophiles, meaning heat-loving organisms, are organisms with an optimum growth temperature of 50 °C or more, a maximum of up to 70 °C or more, and a minimum of about 40 degrees C, but these are only approximate. Some extreme thermophiles (hyperthermophiles) require a very high temperature (80 °C to 105 °C) for growth. Their membranes and proteins are unusually stable at these extremely high temperatures. Thus many important biotechnological processes utilize thermophilic enzymes because of their ability to withstand intense heat.

Many of the hyperthermophiles Archea require elemental sulfur for growth. Some are anaerobes that use the sulfur instead of oxygen as an electron acceptor during cellular respiration. In these places, especially in the Taupo Volcanic Zone, we find a zonation of microorganisms according to their temperature optima. Often these organisms are coloured, due to the presence of photosynthetic pigments. (2)

	Grade Boundary: Low Merit
3.	For Merit the student needs to investigate in depth how organisms survive in an extreme environment. The student needs to: • explain links between conditions of the extreme environment and biological adaptations or technological modifications • explain, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the conditions of the extreme environment. This student has explained the extreme environmental conditions that exist in hot pools (1), and has given a simple explanation of how a biological adaptation to the extreme environment that makes high temperature cyanobacterial survival possible. (2). High temperature enzymes have been mentioned. For a more secure Merit, the student could develop the explanation of how the biology of the cyanobacteria links to its survival. For example, the student could explain how the enzyme high temperature polymerase allows DNA replication to occur at high temperatures and not denature.

Student 3: Low Merit

NZQA Intended for teacher use only

Thermophiles their extreme environment and biological adaptations

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As a prerequisite for their survival, thermophiles contain enzymes that can function at high temperatures and so they can live in a harsh environment and photosynthesise.

The environment for thermophiles

Thermophiles are found in various geothermally heated regions of the Earth such as hot springs like those in Rotorua and deep sea hydrothermal vents.

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Cyanobacteria growing in near darkness use a previously unknown process for harvesting energy and producing oxygen from sunlight, a research team led by a Penn State University scientist has discovered. The discovery lays the foundation for further research aimed at improving plant growth, harvesting energy from the Sun.

We now have clearly established that photosynthesis can occur in far-red light, in a wavelength range where people previously did not think that oxygenic photosynthesis could take place. Cyanobacteria also reproduce asexually.

Thermophiles, meaning heat-loving organisms, are organisms with an optimum growth temperature of 50 °C or more, a maximum of up to 70 °C or more, and a minimum of about 40 degrees C, but these are only approximate. Some extreme thermophiles (hyperthermophiles) require a very high temperature (80 °C to 105 °C) for growth.

Many of the hyperthermophiles Archea require elemental sulfur for growth. Some are anaerobes that use the sulfur instead of oxygen as an electron acceptor during cellular respiration. In these places, especially in the Taupo Volcanic Zone, we find a zonation of microorganisms according to their temperature optima. Often these organisms are coloured, due to the presence of photosynthetic pigments. (2)

	Grade Boundary: High Achieved
4.	For Achieved the student needs to investigate how organisms survive in an extreme environment. The student needs to: • describe why the conditions of the extreme environment require special biological adaptations or technological modifications for survival • describe, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the extreme environment. This student has explained the extreme environmental conditions that exist in hot pools (1), and has described biological adaptations to the extreme environment that make high temperature cyanobacterial survival possible (2). To reach Merit, the student could explain how the biology of the cyanobacteria links to its survival. For example, the student could explain how high temperature enzymes link to the survival of the cyanobacteria in hot pools.

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Thermophiles can live in an environment where other organisms would not survive. They do this by having different enzymes to other life. These enzymes are unique and allow thermophiles to live in the harsh environment. (2)

The environment for thermophiles

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Photosynthesis can occur with red light. Something scientists did not think was possible before. (2)

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	Grade Boundary: Low Achieved
5.	For Achieved the student needs to investigate how organisms survive in an extreme environment. The student needs to: • describe why the conditions of the extreme environment require special biological adaptations or technological modifications for survival • describe, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the extreme environment. This student has described the extreme environmental conditions that exist in hot pools (1) and has described two biological adaptations to the extreme environment that makes high temperature cyanobacterial survival possible (2). For a more secure Achieved, the student could describe how the specific enzymes produced by cyanobacteria are used to survive in the hot pool conditions.

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Cyanobacteria in New Zealand

Floating mats of cyanobacteria are present in hot pools in most of New Zealand's geothermal areas. An exception is the Rotokawa region near Taupō, where most springs are highly acid, with very few cyanobacteria. The cyanobacteria can carry out photosynthesis in hot weather and not worry about the heat. Cyanobacteria can survive in hot springs because they have enzymes and these enzymes let them survive. These enzymes allow other life processes to continue. Respiration for example would be carried out so as the cyanobacteria can reproduce. All life processes are fitted to hot water conditions. (2)

	Grade Boundary: High Not Achieved
6.	For Achieved the student needs to investigate how organisms survive in an extreme environment. The student needs to: • describe why the conditions of the extreme environment require special biological adaptations or technological modifications for survival • describe, using processed information, how the biological adaptations or technological modifications allow the organism(s) to survive the extreme environment. This student has provided some description of the extreme environmental conditions that exist in hot pools (1), and has described one biological adaptation to the extreme environment that makes high temperature cyanobacterial life possible (2). To reach Achieved, the student could further describe a second adaptation such as describe how the heat resistant enzymes allow cyanobacteria to carry out photosynthesis in a hot pool of water.

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