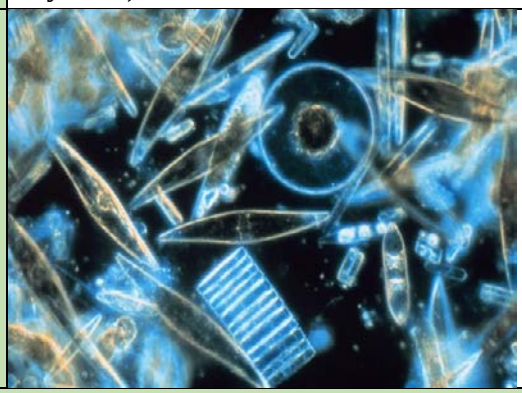
生物策略表

類別	生物策略 (Strategy)
生物策略 STRATEGY	蛋白質能在冰凍環境下生長 (Protein enables growth in freezing temperatures)
生物系統 LIVING SYSTEM	等片藻科 (Diatomaceae)
功能類別 FUNCTIONS	#分配液體 #排出固體 #應付撞擊 #改變相性 #改變溶解度（溶解、乳化、沉澱、結晶） #防止變形 #防止破裂/斷裂 #保護免受冰危害 #保護免受溫度危害 #Distribute liquid #Excel solids #Manage impact #Modify phase #Modify solubility (dissolving, emulsifying, precipitating, crystallizing) #Prevent deformation #Prevent fracture/rupture #Protect from ice #Protect from temperature
作用機制標題	海冰矽藻分泌的蛋白質能藉由抑制周圍冰晶的再結晶，而使其能在冰凍溫度下生長 (The protein secretion of the sea ice diatom enables growth in freezing temperatures by inhibiting the recrystallization of the surrounding ice crystals.)
生物系統/作用機制示意圖	

作用機制摘要說明 (SUMMARY OF FUNCTIONING MECHANISMS)

海冰矽藻是單細胞藻類，生活在極冷的水中環境，包括北極和南極海冰。在這些惡劣的環境中，他們發展出保護自己免受極端溫度、鹽度和光照影響的機制。這樣的一項機制就是細胞外冰結合蛋白 (extracellular ice-binding protein)。

由海冰矽藻分泌的細胞外冰結合蛋白，與位於此藻保護性外層外部微小而生長中的冰晶對齊並結合。儘管確切的結合機制尚不清楚，但一般相信冰結合蛋白在三維拼圖結構中，作用為冰晶的互補片段。冰結合蛋白能將小冰晶鎖定在適當的位置，從而防止它們重新排列成更大的冰晶。小冰晶重新排列成較大的冰晶（稱為冰的再結晶），是冰晶生長會自然發生的過程。

冰的再結晶是在冷凍溫度下細胞死亡的基本機制之一。小冰晶可以存在於細胞表面而不會導致細胞死亡，但大冰晶則不能。當相鄰的小冰晶結合在一起，並沿著同方向排列時，會形成大冰晶，它的作用有如細胞的利刃。巨大的冰晶強大到足以迫使它們進入

細胞之間，並刺穿細胞的保護性外層。當細胞內部曝露於冰凍溫度下時，就會死亡。細胞外冰結合蛋白阻止大冰晶的形成，因此對於嵌入冰中的海冰矽藻之生長和生存至關重要。

Sea ice diatoms are single-celled algae that live in extremely cold, aquatic environments, including Arctic and Antarctic sea ice. In these harsh environments, they have developed mechanisms to protect themselves against the extremes of temperature, salinity, and light. One such mechanism is extracellular ice-binding protein.

Extracellular ice-binding proteins, excreted by sea ice diatoms, align themselves with and bind to the small, growing ice crystals just outside of the sea ice diatom's protective outer layer. While the exact binding mechanism is unknown, it is believed that the ice-binding proteins act as complementary pieces to ice crystals in a three-dimensional jigsaw puzzle. The ice-binding proteins lock the small ice crystals in place, thereby preventing them from rearranging into a larger ice crystal. This rearrangement of small ice crystals into a larger one (known as ice recrystallization) occurs spontaneously and is a natural part of ice crystal growth.

Ice recrystallization is one of the primary mechanisms of cell death in freezing temperatures. While the small ice crystals can exist at the surface of cells without causing cell death, large ice crystals cannot. Large ice crystals, formed when the adjacent small ice crystals join together and align themselves in the same direction, act as knives to the cells. The large ice crystals are powerful enough to force their way in between cells and puncture the cells' protective outer layer. The insides of the cells, when exposed to freezing temperatures, die. The extracellular ice-binding proteins prevent the large ice crystals from forming, and are thus essential for the growth and survival of sea ice diatoms embedded in ice.

文獻引用 (REFERENCES)

「可能有助於海冰矽藻生存的一個因素是矽藻釋放的外聚合物質，它在海冰凍結時可幫助保持在液態環境。我們一直在研究另一種潛在的生存機制，該機制與對冰晶具有親和力蛋白質的產生有關。與矽藻群落相關的是可以和冰晶強烈相互作用的細胞外蛋白（以前稱為冰活性物質）。這些蛋白質最明顯的作用是在生長中的冰晶表面引凹陷小點 (pitting) 和其他變形，這是雜質吸附到晶體表面的跡象。」(Janech et al. 2006: 410)

「我們呈現了 IBPs 對抑制冰的再結晶和保留冰中的鹽水具有強大的作用。這兩種特性都有助於保持在冰中的液態環境，對於嵌入冰中的微生物生存至關重要。」(Raymond et al. 2009: 130)

「矽藻 IBP 類似於植物防凍劑，因為它們不會明顯降低冰點，這表明它們主要作為生物體中的防凍劑。」(Janech et al. 2006: 410)

「冰的再結晶 (IR) 是一個大的冰晶以較小的冰晶為代價生長的過程。它在自然界中不斷發生…在部分冷凍環境的適度冷卻條件下，或由於冷凍物質的溫度波動而以加速的速率…再結晶…由於膜破裂和細胞脫水而損害細胞和組織，降低了細胞存活率。生活在寒冷環境中並容易受到冰再結晶傷害的生物，例如海冰矽藻，已經發展出…冰結合蛋白，可與冰相互作用，用於各種生物學目的。冰結合蛋白吸附到冰的表面，並將冰的生長限制在結合的蛋白分子之間的區域。這類蛋白質已顯示出有效阻斷 IR 的作用...並可能在冰再結晶成為障礙的許多應用中充當添加劑。儘管有多種［冰結合蛋白］的冰再結晶抑制的活性已被研究…但［冰結合蛋白］抑制 IR 的機制尚不清楚。」(Zalis 2013)

"One factor that may contribute to survival is the release by the diatoms of exopolymeric substances that can help to preserve a liquid environment as sea ice freezes. We have been investigating another potential survival mechanism that involves the production of proteins that have an affinity for ice crystals. Associated with the diatom community are extracellular proteins (formerly called ice-active substances) that strongly interact with ice. The most conspicuous effect of these proteins is to cause pitting and other deformities on the surface of growing ice crystals, which is a sign of adsorption of an impurity to a crystal surface." (Janech et al. 2006: 410)

"We show that the IBPs have strong effects on inhibiting the recrystallization of ice and on retaining brine in ice. Both these properties help preserve a liquid environment in ice, which is considered essential for survival for microbes embedded in ice." (Raymond et al. 2009: 130)

"Diatom IBPs resemble plant antifreezes in that they do not appreciably lower the freezing point, which suggests that they mainly function as cryoprotectants." (Janech et al. 2006: 410)

"Ice recrystallization (IR) is a process in which large ice crystals grow at the expense of smaller ones. It occurs constantly in nature...in conditions of moderate cooling of a partially frozen environment or at accelerated rate due to temperature fluctuations of frozen substances...Recrystallization...damages the cells and tissues due to membrane rupture and cell dehydration, reducing the survival rates. Organisms inhabiting cold environments and prone to IR injuries, such as... [sea ice diatoms], have developed...ice binding proteins which interact with ice for various biological purposes. The [ice binding proteins] adsorb to ice surfaces and restrict the growth of ice to the areas between bound protein molecules. Such proteins were shown to block IR effectively...and may serve as additives in many applications in which ice recrystallization is an obstacle. Although ice recrystallization inhibition (IRI) activity of a variety of [ice binding proteins] was studied...the mechanisms by which [ice binding proteins] inhibit IR is unknown." (Zalis 2013)

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生物系統延伸資訊連結 (LEARN MORE ABOUT THE LIVING SYSTEM/S)

https://en.wikipedia.org/wiki/Diatom
https://www.onezoom.org/life/@biota=93302?img=best_any&anim=flight#x536,y641,w0.8094
https://eol.org/pages/3735

撰寫/翻譯/編修者與日期

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