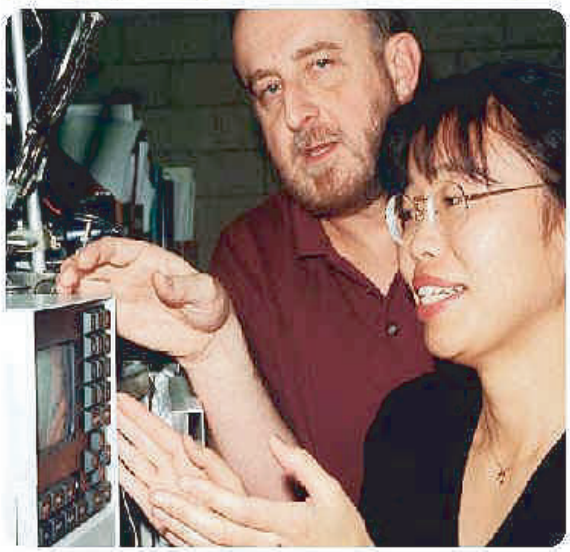
Canadians in Biology

The Mystery of the Frozen Frogs



Dr. Kenneth Storey with a graduate student

Humans die if they are frozen. Ice crystals form inside our cells, irreparably damaging the cell membrane. But some species of frogs freeze solid every winter in Canada. Frozen frogs have no heartbeat. They stop breathing. They appear to be dead, but come spring, they thaw out and hop away. Award-winning cryobiologist Kenneth Storey has spent much of his career trying to understand this survival mechanism. At his lab at Carleton University in Ottawa, he began freezing thumbnail-sized wood frogs and spring peepers in cozy moss-filled boxes, carrying out experiments to try to discover the molecular secrets that allow them to survive being frozen.

A Natural Cryoprotectant

Dr. Storey suspected that the frogs have a mystery molecule that allows their cells to withstand the rigours of freezing. He soon discovered that the molecule was glucose, the same blood sugar that your cells use for fuel. As soon as ice starts forming on their smooth, green skin, frogs start packing their cells with glucose (released from glycogen stored in the liver). This prevents ice crystals from forming within the cells. If humans had the same glucose levels in their blood as freezing frogs, they would be diabetic and extremely sick. So Dr. Storey's next challenge is to find out what makes frog cells pull the glucose out of the blood.

But Would It Work for Individual Human Organs?

From the beginning of his frog research, Dr. Storey believed that the secret of the icy frogs might one day help save human lives by allowing organs that have been donated for transplant to be frozen. Doctors now have to race against time once a heart or a liver has been taken from a donor. Human livers taken from donors for transplant generally last only six to eight hours after death, a heart and lung only four to five. Freezing would give doctors time to wait for the perfect match. During the Second World War, scientists did experiments to learn how to freeze blood. After the war, they tried to same approach with organs, but failed to freeze them without destroying them. That is when they began looking for a model in the natural world. When a scientist in Minnesota accidentally left frogs in his car trunk overnight and found they survived freezing, Dr. Storey was intrigued.

One Mystery at a Time

Dr. Storey was recognized in 1984 with a Steacie Award as one of Canada's most promising young scientists. Discovering that glucose was the cryoprotectant in frogs was only the first step. He has found more than 20 genes (out of the 2 000 that make up a frog's chromosomes) that are turned on when the animal starts to freeze. It appears that these genes shut down the frog's metabolism and then pack its cells with sugar. Dr. Storey explains that once he and other scientists have identified all the genes that are involved in cryoprotection, they then have to discover how to turn the genes on and off.

Not Only Frogs Are Cool

Researchers in his lab now study ground squirrels, bats, snails, and turtles. Some turtles can hibernate for three or four months under water without breathing. A hibernating ground squirrel does not freeze solid, but it does turn off its metabolism and lives in a state of suspended animation. Are the same genes involved in freeze-tolerant frogs, turtles, and squirrels? No, says Dr. Storey, but the processes and mechanisms seem to be similar. For example, in both squirrels and frogs, enzymes known as "stress-activated kinases" are turned on when an animal starts to freeze, and these act to shut its metabolism down. Dr. Storey says it will take years to figure out exactly how it all works. If he cannot get organs to freeze without damage (like those of a frog), the next best thing would be to get them to stay in a squirrel-like state of hibernation.

"These animals are living in a state of suspended animation. If you think about suspended animation, that is exactly what you want for organs for transplant. Squirrels aren't dead at five degrees. We want mammalian organs to act like that in fridges everywhere."