Why Skaters and Pucks Slide on the Ice.

Professor Somorjai explains his latest findings about the nature of ice.

Somorjai’s recent discoveries have explained why skaters and pucks slide on the ice. These new findings challenge long-held theories about why ice is slippery. In the past, scientists believed that either pressure or friction melted the ice, creating a water lubricant that allows skates and pucks to slide.

Berkeley chemist Michel van Hove, a colleague of Somorjai’s, has done calculations which show that skates and pucks do not generate enough pressure to instantly liquefy ice. Somorjai has discovered that ice has a “quasi-fluid layer” that coats the surface of ice and makes it slippery. Even ice that is 200 degrees below zero Fahrenheit (-129 Celcius) or more still has this layer.

External Forces?

External forces, such as pressure and friction, can melt the ice. But Professor Somorjai’s findings indicate that ice itself is slippery. You don’t need to melt the ice to skate on it, or need a layer of water as a lubricant to help slide along the ice.

Slippery Layers

According to Professor Somorjai, the “quasi-fluid” or “water-like” layer exists on the surface of the ice and may be thicker or thinner depending on temperature. At about 250 degrees below zero Fahrenheit (-157 centigrade), the ice has a slippery layer one molecule thick. As the ice is warmed, the number of these slippery layers increases. This may help explain in part the difference between “fast ice” and “slow ice."

As the number of layers increases, the players’ skates need to "slosh" through more of these "water-like" layers; more friction occurs in these conditions, slowing the players down. These extra layers would also "soften" a landing for a figure skater—who skates on warmer ice than a hockey player. There is more on the structure of this "quasi-fluid" layer at the beginning of the "Skating" section. But before we get too technical, let’s examine how ice is made.

Making ice

So how do you make ice? Ice makers were hard at work long before Professor Somorjai’s research was published. Most of their knowledge about ice comes from trial and error, not from scientific journals and textbooks. In our conversation with San Jose Arena ice maker Bruce Tharaldson, we learned a great deal about ice. In addition, we got a chance to see and better understand the legendary ice resurfacer—the Zamboni.
Bruce Tharaldson talks about the process involved in making ice at the beginning of the season.

Bruce Tharaldson has been involved in the "ice business" for over 20 seasons, starting out making ice for the Minnesota North Stars (now the Dallas Stars). Bruce is responsible for constructing and maintaining the Sharks' playing surface throughout the 82-game season. The season begins in early October and ends in April. The playoffs can extend the season into May or even June.

At the beginning of the hockey season, the arena uses an advanced refrigeration system that pumps freezing "brine water" (salt water) through a system of pipes that run through a large piece of concrete known as the "ice slab." When the "ice slab" gets cold enough, layers of water are applied to it.

The first few layers are painted with the hockey markings and the advertisements that you see on (or more correctly "in") the ice. These layers are then covered with 8 to 10 more thin layers of ice. When complete, the ice is only one inch thick!

The ice stays in place from September to May. The NBA's Golden State Warriors played on a basketball court that sits on top of the ice. When world famous tenor Luciano Pavarotti visits the San Jose Arena, he sings on a stage above 10,211 gallons (38,652 litres) of frozen water.

The Zamboni Legend

Once the ice is made, the ongoing task of maintaining the quality of the ice becomes Bruce Tharaldson's primary focus. One of the essential tools for helping maintain the ice is the Zamboni. This mechanical marvel was first built in the early 1940s in southern California (of all places). Frank Zamboni and his brother Lawrence needed a more efficient way to resurface their large ice rink, "Iceland."

Up to that time, one would have to drag a scraper behind a tractor to smooth the surface and then go back and coat the ice with a thin layer of water to even things out and rebuild the thickness of the ice. This process could take over one hour! Frank Zamboni, an inexhaustible inventor, made the process much quicker with his newly invented "Zamboni ice resurfacer."

The Zamboni is a mechanical ice resurfacer. It works by scraping the ice surface and collecting the snow (which is later discarded). Next, it "cleans" the ice, by putting down water which flushes the grooves deep in the ice, loosening any dirt or debris.

The excess water and dirt is then collected. Finally, the Zamboni puts down a thin layer of heated water—which freezes and creates a smooth surface. The heated water, according to Tharaldson, is about 140 to 145 degrees Fahrenheit (60-63 centigrade); "the hotter the water," he says, "the more even a surface you'll get-it melts that top layer when you cut across [the ice]."

To be in the NHL you need to be, among other things, an exceptional skater. The players and coaches seem to agree that to be an effective skater, you need a combination of good technique and physical strength (although individual
responses differed as far as which was the more important quality).

The scientists in this section help break down the mechanics and physics of skating. Our exploration starts with the interaction between the blade and ice surface. In this section there are RealAudio and video clips from chemist Gabor Somorjai of Lawrence Berkeley National Laboratory, Sharks’ strength and conditioning coach Steve Millard, and Exploratorium scientist Thomas Humphrey.

Slippery when not wet?

The nature of ice was examined in “The Ice” section—by the latest findings of chemist Gabor Somorjai. This new information about ice changes the way we look at skating.

For years before Somorjai’s research, there was a debate as to whether pressure or friction created the water lubricant that was believed to be required for skating. Most scientists seemed to think that it was pressure. According to Somorjai’s findings this is not the case. So what do you skate on? Well, actually you skate on vibrating molecules.

Professor Somorjai and his team used new methods developed in the last 10 or 15 years to examine the surface structure and composition of the atoms and molecules that make up the ice. These techniques were developed for high-tech applications—like studying the surface of materials that can be used for magnetic disk drives, for example. Somorjai used these same methods to examine ice.

What he found was rather surprising. Somorjai told us, “the structure we determined was an almost impossible structure, indicating that every second water molecule on the surface was missing. Since that was not possible, we decided to go back and understand why [this was the case],”

After further study, Somorjai’s team found that the "missing" water [or ice] molecule was indeed there—but it was vibrating so rapidly that it was invisible to the technique they were using. Once Somorjai and his team found this out, they could change the conditions to further study these molecules.

Professor Somorjai uses this vacuum chamber to study the surface of ice and other materials. The vacuum chamber provides a controlled environment for his research.

Up and down

After further study, Somorjai found that these molecules behave like a liquid, but they only move up and down; they do not move from side to side on the surface of the ice. This is an important distinction. If the atoms moved side to side, the "liquid-like" layer would literally become liquid (which happens when the temperature rises above 32 degrees Fahrenheit). This "liquid-like" layer is thought to be what makes the ice slippery.

Starting and Stopping on a Slippery Surface

Accelerating and decelerating on a slippery surface requires a player to dig into the ice and push off from the surface. The sharp edges on hockey skate blades can dig deeply into the ice, allowing a player to accelerate quickly or stop on a dime using the "hockey stop." The friction between the blade and the ice is minimized because the surface of the ice is so slippery, and because only a small portion of the skate’s blade is actually in contact.
The Mechanics of Skating

NHL players can reach speeds in excess of 20 miles (32 km) per hour on the ice. Some speed skaters have been clocked at over 30 miles (48 km) per hour! What makes one player faster than another? A combination of strength and mechanics help a skater move efficiently and quickly on the ice.

When accelerating, players dig their skates into the ice and lean forward. They are exerting a strong force on the lower part of their bodies by leaning forward. Gravity pulls down on a hockey player's center of mass which "torques" him forward. It is important to note that skaters can only lean forward when they are accelerating. If they leaned forward when traveling at a constant speed or decelerating, they would fall over.