Chemical Institute of Canada | For Our Future

CIC Fun Facts Handbook

The following facts are taken from the high school publication Discover Canadian Chemistry*, which was published by the Chemical Institute of Canada from 1991 to 2001 and the middle school publication* Exploring Chemistry*, which was published in 1996 and 1997.*

Electronics Industry

Copper Conducts Computers

Smaller, faster and cheaper.

These words could be the slogan for a new car, but they are also the three driving forces behind computer chip technology. If there is something that makes one chip better than another, it is always size, speed, or lower cost.

What does chemistry have to do with micro electronics? Every computer chip in the world is designed using a photolithographic process and includes complex layers of tungsten connectors and silicon interconnected with polysilicon films. Without chemical knowledge, we would not have computers at all! The original chips were designed using chemical processes, including oxidation, photolithography, etching and implantation. Chemical technicians are constantly working towards developing newer and better chips.

Today, the new hero of chip technology is a famous old conductor that is highly efficient and not too expensive...copper. Traditionally, aluminum wiring, which is cheap, plentiful, and also pliable, has been used in computer chips to transmit information. But in 1997, IBM announced a breakthrough in their research that made the use of copper transistors possible.

Copper is a better conductor than aluminum, which means that electrons can pass through it at a greater speed, making the chip work FASTER. Copper wires pass electronic information with close to 40 percent less resistance than aluminum. This means that copper microprocessors conduct electricity up to 15 percent faster than aluminum. Talk about cutting down your download time! This higher efficiency level means that not as many chips are needed to do the *same amount of work. Also, thinner pieces of copper wiring can be used than the more cumbersome aluminum wiring, as copper is not as delicate and will not break as easily. Aluminum wires are more breakable due to electromigration, or voids made when individual electrons move erratically due to high currents.*

Aluminum wires are about 0.35 microns thick and copper wires are about 0.20 microns thick. To put that in more familiar terms, one micron is over 100 times thinner than a human hair! Since up to a quarter mile of wiring is used on a single computer chip, the thinner wires and lower number of chips can help manufacturers make SMALLER chips and SMALLER computers.

All this, and CHEAPER too! The new copper chips are 10-15 per cent cheaper to make than the old ones. It makes you wonder why nobody thought of copper before! Actually, they did think of it before. Researchers have been working steadily since the late 1960s on developing a practical and manufacturable copper chip.

All that work with such minuscule results!

GIVING YOUR DIGITAL TV A BRAIN

There are many sectors of computer companies that will be taking advantage of the better conductive power of copper. One place computer companies are planning on developing is a place where you have never had a functional computer before...your television.

Zarlink (formerly known as Mitel) is teaming up with IBM to create integrated digital television sets, or iDTVs. Small chips inserted into a "set-top box" mechanism in your television will, in effect, give your TV a brain.

The set-top box in a digital television contains a tuner and a demodulator. A tuner receives a signal and a demodulator decodes it and changes it into a picture. Until recently, each component had its own chip. With new technology, the tuner, demodulator, and proposed interactive elements in the digital TVs will share a single chip.

"Less space makes new technology possible," says Michael Salter, Communications Manager at Ottawa's Zarlink. "And you will always get a better signal with less devices."

Some features of the new TVs will be digital text, Internet access, e-commerce capabilities, incorporation of personal video recorders, and digital versatile disks.

In contrast, Mr. Salter says that one factor alone will bring iDTV technology into North America. "Acceptance of digital TV depends on bringing down the cost," he says.

Again, it seems that smaller, faster and cheaper is the order of the day.

Flying Gold Molecules

Organometallic chemists are finding new ways to make gold molecules that "fly," and to control where they land. The result is a new way to make thin gold films for the electronics industry.

Gold is very important in microelectronics, especially for connecting individual components and forming switches. it is preferred over other materials like copper and aluminum because gold conducts electricity very well, and is not corroded by the oxygen and water in the atmosphere. But gold is expensive, so making a thin film of it saves money as well as space.

Thin films can now be made through a process called "Chemical Vapour Deposition," or CVD, as Iona as the coating material is part of a compound that can be easily vaporized. For instance, a thin silicon coating-the kind used in some *solar cells-can be obtained when silane, $SiH_4(g)$, is passed over a hot object. It decomposes into two molecules of hydrogen that are carried off in the gas stream, and one atom of silicon, which stays on the surface.*

There are two special problems involved in making gold films by CVD, but recent research has solved them both. First, for a heavy element like gold, it is hard to find a molecule that is volatile enough to "fly."

Now Richard Puddephatt at the University of Western Ontario in London, Ont. has found one-the alkylgold compound CF_3-Au-Cº N-CH_3 works especially well. It is a solid but it vaporizes easily and, on contact with hot objects, it decomposes into a very pure gold coating.

The second problem is that microelectronics often requires the gold to be deposited as very thin lines that connect individual components on a silicon wafer. Obviously, the CVD process will coat more than just those lines if the whole wafer is heated.

The solution is to focus a laser beam to create intense heat only where the coating is desired. Then, as the alkylgold compound flies over the wafer, the gold film forms only where the laser beam is focused. The resulting lines can be made just a few manometers thick.

The entire gold circuit is traced out with 'laser writing' — moving the laser beam around on the wafer. That kind of writing makes a valuable point!

Food Industry

The Chemical Detective

Is apple juice made just from apples? It sounds like a simple question that has an easy answer. However, Nick Low of the Department of Applied Microbiology and Food Science at the University of Saskatchewan has found that it isn't always the answer to this question. In 1990, Low developed a technique involving High Performance *Liquid* Chromatography (HPLC) to detect trace oligosaccharides (carbohydrates) which are present when fruit beverages have been adulterated with less expensive materials. This test is now called the Low-1 Test.

Chromatography is essentially the separation of components from a mixture and often uses two phases, mobile and stationary. In HPLC, the stationary phase is a packed column and the mobile phase is a liquid; hence High Performance Liquid Chromatography. The separation occurs when the mixture is placed on the stationary phase and the mobile phase is allowed to pass over it. As the mobile phase moves, the components of the mixture that are more soluble in it move and elute off of the column. Thus, the components that have a higher affinity for the mobile phase will elute first. As a result, the components will be separated in a certain order. The order of the elution is characteristic for each mobile phase.

Fruit juices are made up of 95% carbohydrates. The major carbohydrates naturally present in these foods are glucose, fructose, and sucrose. Fruit juice adulteration occurs when less expensive carbohydrates such as those from sugar beet or sugar cane are used by unscrupulous manufacturers to supplement the natural fruit juice. In most cases the adulterant used resembles the major carbohydrate profile of the juice. For example, beet sugar is an ideal adulterant for orange juice while inulin (a fructose polymer) or high-fructose syrup from corn are better suited for apple juice.

Agriculture and Agri-Food Canada, the Food and Drug Administration (USA) and many other regulatory agencies worldwide now use the Low Test(s) for fruit juice authenticity determination. The first major impact of the Low-1 Test occurred in the United Kingdom in 1990 when Dr. Low revealed that there was a high level (~70)% of adulteration of commercial juices. Most of the adulteration was traced back to a company in Israel which had been producing 30% more orange juice than it had oranges!

A modified test (Low-2 Test) was used five years later when Low was on leave at the University of Reading, U.K., in 1995. This time the fruit juice shown to be adulterated was apple. It was found that hydrolyzed inulin was the *adulterant which looks and tastes like apple juice. The adulteration was traced back two companies, one in Belgium and one in Holland. The two companies had been selling the adulterated product worldwide and significant quantities were sole to Europe and North America. As a result, every major apple juice seller including Coca-Cola (distributors of the Minute Maid brand) was found with adulterated product.*

Since the development of Low-1 and Low-2 Tests, Dr. Low has become world-renowned as a chemical detective in cases of fruit beverage adulteration. Dr. Low is currently working with state-of-the-art equipment to develop authenticity tests that are more sophisticated and sensitive so as to make it more difficult for people to produce fraudulent foods.

The Chemistry of Chocolate

"Chocoholics" everywhere will tell you that eating chocolate makes them feel good, but why? Chocolate contains more than 300 known chemicals, some of which react within the human brain to alter mood. One of these chemical reactions is the release of endorphins, proteins which occur naturally in the brain to reduce pain, which in large amounts can make you feel more relaxed or energetic.

Chocolate also contains caffeine in very small amounts, but has a lot of the weaker related stimulant theobromine. Like caffeine, theobromine has been linked to causing migraine headaches, but its positive properties have not been ignored. In the 1940s and '50s, the Hershey company extracted the stimulant from cocoa beans and sold it to Coca Cola, which used the chemical in its soda.

Phenylethylamine is related to amphetamines, and both are stimulants of the nervous system which raise blood pressure and blood glucose levels. Practically speaking, phenylethylamine has been shown to make people feel more alert and gives them a sense of well-being.

In 1992, a new chemical was discovered, which was later found in chocolate. Anandamide is a messenger molecule that plays a role in depression, memory, and pain. The name comes from the Sanskrit word "ananda", which means "bliss". Researchers think the presence of anandamide in chocolate may explain why it is by far the most-craved food.

Anandamide is found naturally in the human body, and acts as a molecular key to receptors on nerve cells. The anandamide key attaches to a receptor and allows ions to flow into the nerve cell, equalizing charges both inside and outside the cell. These molecular keys help alleviate pain and aid in relaxation. Pain-killing drugs like morphine and codeine mimic naturally-occurring key molecules. But scientists hope the mood-enhancing qualities of anandamine will have more benefits than just a chocolate craving. They are hoping it may contribute to finding the cure for mental diseases.

Now you know some of the reasons why chocolate makes you feel so good. It only takes a little bit of chocolate to curtail a craving and get that cheerful chocolatey feeling!

GANONG - A CANADIAN SUCCESS STORY

Next time you bite into your favourite chocolate bar or give your sweetheart a heart-shaped box of treats, remember that Canadian innovation helped make chocolate what it is today.

Ganong Brothers Ltd. was founded in 1873 in St. Stephen, NB, when James and Gilbert Ganong realized their retail grocery business was failing. They decided to specialize in confectionery products, and later moved on to chocolates.

In fact, it is a proud Canadian fact that the Ganong invented the chocolate bar. Arthur Ganong and his manufacturer George Ensor needed to find a way to keep chocolate from melting in their pockets on their frequent fishing trips. They came up with a peanut and chocolate mixture which they wrapped in cellophane. In 1910, several years after their invention, the 5-cent chocolate bar was introduced to the North American market.

Throughout their history, Ganong has brought many innovations to the confectionery business. They installed the first lozenge machine in 1887 (which is still in use), and they were the first manufacturer in Canada to use cellophane packaging.

Today, Ganong Brothers Ltd. is still a family company, headed by fourth-generation president David A. Ganong. Their continued success has led them to be regarded as one of the best-managed private companies in Canada.

At its St. Stephen, N.B. location, Ganong employs two food science graduates and a "chocolatier", or confectionery technologist. In this dream job, they are primarily responsible for ensuring product quality through testing of raw ingredients such as glucose, sugar, and nut meats, finished product starch cook tests, and evaluations of product weight and packaging material. Chocolatier Phil Whiteside did not mention anything about product taste-testing, but it seems that would be a great fringe benefit of the job!

Friendly Fertilizers

Softgels are also used in the fertilizer industry. The perfect fertilizer is one that will provide that plant with the right nutrients at the precise times and in the exact quantities that the plant requires for maximum growth.

The Imperial Oil Company in Edmonton, Alta. recently took a huge step forward in agrochemistry by producing a controlled-release fertilizer. The controlled-release is achieved by coating fertilizer granules with a gelatin capsule similar to the capsule that surrounds a paintball. This coating is water-soluble and allows the fertilizer to be released at a controlled rate. These capsular coating in no way harm or pollute the soil, making the product environmentally sound.

Green Chemistry

Ecologically Friendly Inventions

A company called Spilkleen in North York, Ont. is making great strides in the chemistry of absorbent materials. This company was founded in 1976 as a family effort to promote the scientific thinking of their youngest son, Ragui Ghali. The company was originally in Concord, Ont. and called Uthane Research.

Ragui Ghali's inventions have been very significant and they involve using materials that are filling our landfills, to actually clean up the environment. Absorbent materials have many applications, such as absorbing oil spills and, believe it or not, dehydrating chicken manure.

The first significant product developed by Ghali while working in his new lab for insulating and packaging foam called Icynene. Icynene is based on the technology of chemically cross-linking isocyanurate, urea, and urethane molecules together in a three-dimensional polymeric matrix. The isocyanurate molecules allow for high-temperature stability. Urea leads to fire resistance. Flexibility is achieved with urethane. It is cheaper than other insulating materials, will not burn in normal air, has no odour and will not release toxic substances.

The next product that this inventor developed was called Spilkleen. Believe it or not, it is made from mainly old phone books. The key ingredient is the cellulose in the phone books. The phone books are finely shredded and mixed with binders to stop them from swelling when they absorb liquids. The absence of swelling enables Spilkleen to absorb liquids, through wicking action, and to hold onto the liquid without it leaking out again. This product is 1/3 the volume and mass of clay absorbents. Spilkleen is also easier to handle and more efficient to transport and store, and it is biodegradable, environmentally friendly and non-toxic - not to mention, it helped find a purpose for old phone books!

After further refining Spilkleen, it was discovered that this product could clean up environmentally disastrous oil spills. The sawdust-like material absorbs all of the oil and no water, after which it can be removed from the water surface.

This is not all, however, Ragui Ghali is now working on developing a material called Ultra-Absorbent, also made from waste cellulose that will absorb 2000 times its own mass in water turning it to a gel. His hope is that oil tankers could someday transport oil in gel form preventing any leakage if the ship's contents were to spill. If there was leakage the oil would float in this gel form until it could be towed away like an iceberg. To date Ultra-Absorbent has been used to dehydrate chicken manure allowing for easier transport, thus increasing its demand by the fertilizer industry. What farmers were once paying people to remove to landfill sites in now being used very efficiently thanks to this invention.

This is one story of a scientist in Canada using waste to develop materials that benefit the environment.

Health

Antimatter and Positron Emission Tomography

What do Star Trek and Positron Emission Tomography (PET) have in common? ..... ANTIMATTER!

PET is a non-invasive diagnostic technique that takes 3-dimensional images of the body. Measurements and observations are done in vivo via an injection of radioactive isotopes into a patient and subsequent detection of the isotope's decay. So where does antimatter come into this? It's in the decay of the isotope.

The radioisotopes that are most often used are carbon-11, nitrogen-13, oxygen-15 and fluorine-18. These isotopes are neutron deficient and decay when a proton spontaneously converts to a neutron causing a positron to be emitted. These isotopes are mainly used because they decay only by positron emission. A positron, one type of antimatter, is a positively charged electron.

When a positron is emitted it collides with an electron and undergoes an antimatter-matter annihilation process. In this process the two equivalent masses of the positron and electron are converted into electromagnetic radiation in the form of two equal ray photons (511 keV) that are emitted at 180 to each other. The emission of the rays is what is detected.

The reason these isotopes are used is that carbon, nitrogen, and oxygen are already present in molecules in our body. Thus, the addition of these isotopes would not significantly alter the chemical properties associated with these molecules. Although fluorine is not present in biological molecules, it can still be used because it is considered to be "isosteric" with the hydrogen atom which is present in the body. The half-lives of the isotopes are less than two hours, minimizing the exposure to radiation but still long enough to make observations. The isotopes are readily produced in their pure form in a cyclotron which adds protons to stable isotopes by high-energy bombardment of the stable nuclei with protons or deuterons. Since the half-lives are so short (oxygen-15: 2.03 minutes, carbon-11: 20.4 minutes, nitrogen-13: 9.96 minutes, and fluorine-18: 109.8 minutes) the isotopes must be made immediately prior to use. Thus, a cyclotron must be nearby.

In 1980, TRIUMF (Tri-University Meson Facility) started western Canada's only PET project in conjunction with the teaching hospital of The University of British Columbia. TRIUMF makes carbon-11, oxygen-15, fluorine-18, and bromine-75 which has a half-life of 98.0 minutes, and radiopharmaceuticals that are used in the imaging process. Once the radiopharmaceuticals are made by chemists they are sent underground in a 2.4 km pneumatic pipeline to the hospital. Travelling time is only 2 minutes! The radiopharmaceuticals are used by the Neurodegenerative Disorders Clinic where movement disorders such as Parkinson's Disease and Amyotrophic Lateral Sclerosis (ALS) are studied.

In a similar joint venture the Faculty of Pharmacy at the University of Toronto and the Regional Radiopharmacy at Chedoke-McMaster Hospitals are working together to synthesize new radiopharmaceuticals. The radiopharmaceuticals will be used for research and clinical purposes such as radioisotope synovectomy in rheumatoid arthritis, myocardial imaging, and neurophysiological measurements. Research is also being done to try and develop a tumour specific therapeutic and diagnostic radiopharmaceutical.

Canadian Chemists Make Molecular Bracelet

Roland Pomeroy and Weng Kee Leong of Simon Fraser University (Burnaby, BC) have made a new compound with an unprecedented ring of twelve metal atoms. The almost planar ring looks like a bracelet with charms dangling from it. The ring contains six osmium (Os) atoms alternating with six tin (Sn) atoms. Coordinated to each tin atom are two phenyl groups while the osmium atoms are each bonded to four carbonyl groups. A phenyl group is a planar ring of six carbon atoms (C_6H_5) that has alternating single and double carbon-carbon bonds. Five of the carbons are bonded to hydrogens while the remaining carbon is attached to the tin atom. A carbonyl group (CO) is better known as carbon monoxide that contains a carbon-oxygen triple bond. The group is coordinated to the osmium atom through the carbon. The structure of the compound was determined by crystallographers at Simon Fraser University and Siemens Analytical X-Ray Systems in Madison, Wisconsin.

Pomeroy is a chemistry professor who studies organometallic chemistry. More specifically, he is interested in the preparation of new metal cluster compounds and the study of their physical and chemical properties. An organometallic chemist studies metal compounds containing organic components bonded to metal atoms. The discovery of this molecule is important because it raises the possibility of creating other rings or polymers with osmium-tin chains.

Cobalt Radiation Therapy

In 1951 at the Chalk River Nuclear Plant, in Chalk River, Ontario a group of Canadian scientists isolated a source of radiation even stronger than X-rays. It was, and still is, widely used to treat cancer patients. The source of this radiation was the radioactive isotope cobalt-60. The production of this radioactive isotope at the required nuclear activity was carried out in Canada four years before it was repeated in any other country.

During cancer radiation therapy the beam of radiation produced by cobalt-60 is pointed at the targeted position on the patient. The radiation ionizes the cancerous cells, which slow their growth. This allows the healthy cells a chance to repair both themselves and the damage that has been done around them. Canada continues to lead the world in this type of cancer treatment.

The Technology Behind Drug Patches

A company called Pharma Patch plc in Toronto, Ont. is involved in the study and development of through the skin (transdermal) delivery of difficult-to-deliver drugs. The company was created in 1993 as the result of a merger of two Canadian companies, Medipro and Synorex.

The key transdermal drug delivery system is the "patch" in which medication is delivered through the skin for distribution in the body by the circulatory system. There are five core technologies at Pharma Patch plc: patch designs for use with liquid drug solutions; chemicals that enhance the ability of the skin to absorb the drug; patches that are designed to deliver creams; polymer systems that are designed primarily for wound care; evolving technologies for light-activated delivery of drugs.

Difficult-to-deliver drugs are usually ionic and polar with high molecular weights. This makes oral use of the drug ineffective. What actually happens with the "patch" is that the drug seeps out of the "patch" and sits against the skin. Continuous contact between drug and skin is maintained by the adhesive on the patch. The drug is usually combined with chemicals that allow for better skin penetration.

The drugs that are commonly found in "patches" today include the very well known nicotine "patch" that has helped many people stop smoking, heart medications, and hormones like estradiol and progesterone.

A main advantage of this type of drug delivery is that people do not have to remember to take their medications at certain times, for the drug is released from the "patch". All they have to remember is to put it on. Also the levels of the drug is the body are very even, compared with the fluctuations that can happen with oral dosage.

The chemicals that we call drugs are all different in how they act in your body andn they all differ in their best route of entry. The "patch" is opening up many doors for drugs that may have once been ineffective just because it was not possible to continously deliver them directly to the circulatory system.

Finding Cures In Our Trees

It is no joke to say that everything in our world is chemical. Even trees have chemistry!

Trees have been and always will be one of the greatest renewable chemical resources available. Different species of trees contain many different chemicals and each chemical found may have important properties that can be used in medicine and industry.

There have been many spectacular finds in this field. One of the most exciting is the discovery of taxol which can be extracted from the bark of the Pacific Yew. This product shows promise in the treatment of advanced ovarian and breast cancer. Taxol is only available from these trees, and it takes about three of these trees to treat one cancer patient.

Important natural products extracted from Canadian trees include perfume oils, analgesics and sugar derivatives. The use for a new discovery can be something as simple as ski wax or as complex as pharmaceuticals. There are many trees in Canada that have not yet been chemically evaluated. This means that there are many chemicals out there that no one know about yet.

There are many methods to extract these compounds from bark and from foliage. The most commonly used methods are stream distillation and solvent extraction. Many new chemicals are found this way. They are analyzed to determine what they are, and then they are tested for potential uses.

The forests give us clear air to breathe and can give us shelter from the sun. However, there are many things in trees themselves that are there for us to discover. This is why it is so important to maintain our forests.

New Canadian Studies on Cystic Fibrosis

Cystic Fibrosis ("CF") is an inherited disease that affects the epithelial ("surface" or "lining") tissue throughout the body. A defect in the protein molecules that conduct chloride ions across cell membranes causes a wide array of symptoms: extra salty sweat that can be itchy in hot weather; acid in the small intestine that makes it hard for enzymes to digest food; and most seriously, a lack of lubrication on the cell surfaces that leads to a build up of sticky mucus clogging the lungs and sinuses and various ducts. This build up leads to infection, inflammation, allergic reaction (e.g. asthma), and the release of toxins and even stickier DNA from all kinds of ruptured cells. Once, people with CF usually died in infancy. Now, with pills to help their digestion, antibiotics to fight infection, and regular physiotherapy to clear the lungs of mucus, they can expect to survive to about 30 years of age.

In the Department of Chemistry at McGill University, the laboratories of Graham Darling and Jik Chin are investigating several areas relevant to understanding CF. One project is the preparation and calibration of new fluorescent chemical indicators to "probe", by means of fluorescent microscopy (see picture), the reactions of individual cells to various stimuli. This helps them to understand the mechanisms of inflammation and spasm within specific tissues in infected lungs, and to identify which drugs could best help in various situations. Another project is the preparation of new artificial enzymes that could specifically digest and loosen mucus in CF-afflicted lungs, or deactivate toxins there, or aid in the digestion of food. Finally, work is also being done on an artificial "chloride channel" molecule that, inhaled as a mist, would enter the membranes of lung cells and allow the re-establishment of the natural mechanisms for clearing out mucus as it is formed.

This research combines the specialties of synthetic organic chemistry, polymer chemistry, coordination chemistry, biochemistry and analytical spectroscopy. Though currently targeted towards CF, results may also be relevant to helping people with other diseases, and even to applications outside the field of medicine.

New Cancer Drug Given the Green Light for a Red Light Solution

A Canadian scientific team led by Julia Levy and David Dolphin from the University of British Columbia has developed a new technique that fights the war against cancer tumours. The technique is called photodynamic therapy and is being developed by the company Quadra Logic Technologies (QLT) that was founded by Levy and Dolphin.

Photodynamic therapy has been shown to eliminate small tumours as well as tumours that are present in hard-to-reach places. The cancer is attacked by microscopic strangulation of the tumour cells so that the supply of oxygen is severed and the cells can no longer survive. This is accomplished with the use of a weapon, the laser gun, and its ammunition, a chemical called photofrin. The effective wavelength used for the laser corresponds to the red light region of the spectrum. A laser (light a mplification by stimulated emission of radiation) is a concentrated, sharply focused, intense beam of light that has only one single wavelength (monochromatic). Photofrin is a light-sensitive chemical that, when treated with laser light, acts as a catalyst (a catalyst is a substance that increases the rate of a reaction without being used up in the reaction) to activate oxygen. Triplet oxygen is the normal form of oxygen present in the air. Photofrin complexes the oxygen and, when activated by the laser, allows an excited state of oxygen, called singlet oxygen, to be formed. The singlet oxygen is a non-discriminating oxidizing agent that takes oxygen from everything in its path and this results in suffocation of the cells.

The chemical warfare begins by intravenous injection of photofrin into the patient. The photofrin selectively accumulates inside the tumour and waits for the laser gun to be strategically placed so that it has a clear shot at the tumour. The selective accumulation occurs because the light-activated molecule is carried to cells via a lipoprotein component of the blood that normally carries cholesterol to dividing cells. Cancer cells differ from normal cells in that they divide at a greater rate and so the newly formed blood vessels in the tumour region have a higher concentration of the receptors for recruiting the lipoproteins. This property of cancer cells causes the photofrin to be selectively delivered to the rapidly dividing tumour cells. When the laser is affixed on the photofrin-filled tumour, the photofrin becomes 'armed' and catalyzes the production of a highly reactive singlet oxygen. The singlet oxygen has a half life of only 5 ms (milliseconds) so that once the laser is turned off; its effects are felt for only a short time. Disintegration of the tumour cells and the tiny blood vessels that nourish the tumour are ultimately responsible for the annihilation of the tumour.

During the development of photofrin, another light activated molecule was discovered by Dr. Dolphin and Dr. Levy that is currently being developed by QLT. This molecule is a Benzoporphyrin derivative (BPD) and works chemically in a similar way to photofrin. However, BPD has certain advantages over photofrin. For example, BPD is taken up by cells more readily and therefore, the waiting period between injection of the molecules and laser treatment is only 2-3 hours for BPD (48 hours for photofrin). In addition, BPD is cleared out of cells more rapidly, resulting in lower toxicity. Lastly, BPD requires a longer wavelength (less energy) to be activated. These benefits show greater potential for this light-activated molecule and BPD is now being clinically tested for the treatment of psoriasis, skin cancer, and ocular (eye) diseases.

Photodynamic therapy is an extremely important development in cancer treatment because it allows the cancer cells to be selectively attacked, leaving the healthy cells unharmed. The treatment is most successful if the cancer is identified in its initial stages. Early detection is very important because, given time, cancer cells will spread throughout the body (metastasis) and will no longer be manageable by simple therapies such as the one described.

No Simple Rx for Developing a Medication

Scientists Look for Ways to Control Asthma

A new medication is seldom really new-the search for a new drug usually starts 10 or 15 years before it is ready for patients to use.

For example, scientists at the Merck Frosst Centre for Therapeutic Research in Montreal have been working for 13 years on a new way to control asthma. This chronic disease is caused by inflammation and constriction of bronchial tubes in the lung, which make it difficult to breathe. Asthma affects 5 to 10 percent of the Canadian population.

Some existing asthma medications have serious side effects, and others work only after an asthma attack. It would be far better to stop the asthma reaction from occurring at all, and that may finally be possible.

In 1979 a group of Swedish scientists identified the compounds — called leukotrienes (LT's) —that are responsible for constricting bronchial tubes. Everyone has LT's, but an asthma attack involves an unusually high production of them.

Scientists at Merck Frosst realized that this discovery could lead to a safe way to prevent asthma attacks,. and they began exploring two possible approaches.

One involves making compounds to inhibit the enzymes that produce too many LT's.. That would prevent the LT excess that can trigger an asthma reaction.

The other approach has been to make compounds (called LT receptor antagonists) that attach themselves to the tissue sites that LT's are looking for. By getting there first, they prevent the LT's from settling in and constricting the tissues.

Both approaches-as in any search for a new medication-start with organic chemists who find or create compounds that might work. They start either with natural sources, such as plant extracts, or with synthetic chemical compounds.

Testing and refining the compounds can be a long process-only I in 10,000 will have the properties needed.

When a compound has passed a variety of tests for activity, non- toxicity, solubility, and so on, then pharmacy researchers take over. These researchers include analytical chemists to study the compound's purity and how well it is absorbed by the body, and physical chemists to study the compound's physical properties and stability.

Eventually they decide on the best form for the new medication-pill, capsule, aerosol, etc. Finally, the drug is ready for testing on human patients which may take months or years.

The Merck Frosst scientists have developed compounds both to prevent an excess production of LTs, and to stop excess LTs from causing an attack.

It is a long process, but a new asthma -therapy is within sight.

Solution for Blood Shortages

Have you ever wondered what is done to blood after it has been donated? Donated blood is screened, tested, and stored for up to 6 weeks. If it is kept longer than 6 weeks it is considered outdated and can't be used for transfusions. Hemosol Inc. of Etobicoke, Ont. uses this outdated blood to make a product called Hemolink which is a red blood cell substitute that can be used for transfusions.

Blood consists of red and white blood cells, plasma, and platelets. The red blood cells contain hemoglobin which can bind and subsequently release oxygen. Hemoglobin, a protein, is a tetramer consisting of four parts each of which binds an oxygen molecule. In order to produce the Hemolink the red blood cells are first separated from the other components in the blood.

Secondly, the hemoglobin is extracted from the red blood cells and heated. The heat treatment ensures that no viruses remain that may have been overlooked in the screening process. Finally, all of the remaining proteins are removed including those which determine blood type (O, A, B, and AB). Therefore, Hemolink can be used for any person no matter what their blood type is.

The purified hemoglobin is treated with a chemical that can form permanent connections between different parts of the protein. These permanent connections are called cross-links. The process involves oxidizing the sugar raffinose to *create many reaction sites in the molecule. The oxidized raffinose is then added to the hemoglobin and the product is reduced to make the connections permanent. The cross-links help stabilize the hemoglobin molecule which in turn, improves the ability of hemoglobin to bind and deliver the oxygen. When cross-linked, the hemoglobin structure is stabilized and more than one hemoglobin molecule can join together. The larger hemoglobin complex can then circulate in the blood for a longer period. Hemolink circulates in the blood stream for a couple of days before it is excreted. This is shorter than transfused red blood cells (~ 1 month) but still enough to counteract oxygen shortages that occur during blood loss.*

Hemosol is currently trying to make two types of Hemolink. One is frozen while the other is refrigerated as a fluid. Another version that they are trying to make is freeze dried! This would be useful for shipping because it is light weight. In order to use the freeze dried version sterile water would only need to be added!

Hemosol is currently conducting clinical trials of Hemolink in humans. Hopefully it will be available in the year 2000. Hemosol has hopes that Hemolink will avoid many of the problems of blood transfusions as well as blood supply shortages.

At the University of Toronto, Dr. Ronald Kluger and Dr. Andrew Grant (now at the University of Winnipeg) have developed a new patent called "Acyl Phosphate Esters and Modification of Proteins Therewith" which is licensed to Hemosol by the University of Toronto. With this patent, hemoglobin can be modified to produce cross-linked hemoglobin which will be used by Hemosol in hemoglobin-based oxygen carriers (HBOC's). Kluger has developed two other patents related to HBOC technology which are also licensed to Hemosol. It is hoped that cross-linking technologies developed by Kluger will be used to chemically modify hemoglobin to deliver therapeutic drugs and enhance treatment of cancer and infectious diseases.

Life’s Little Mysteries

Amber: Prehistoric Preservations

Did you know that amber isn’t a fossil but cross-linked polymerized terpenes? Amber is the result of sticky plant secretions (resins) that harden when exposed to air and then undergo the slow process of cross-linking and polymerization. Consequently, these resins are extremely resistant to environmental influences. Resin isn’t sap but rather a mixture that consists mainly of terpenoid compounds which are both volatile and nonvolatile.

Terpenoids are molecules that have structures based on the linkage of isoprene units (C_5H_8). Amber containing small animals such as insects, small lizards (geckos), and small frogs has been found. In these cases the animal became stuck in the resin which has then continued to flow over it. As the resin hardens, the volatile terpenes and other vapours in the resin penetrate the animal’s tissue and gradually replace the water and kill bacteria. Air, light and heat from the sun induce chemical reactions in the resin resulting in cross-linking of the terpenes.

Thus, the animal is embalmed and preserved. The animal is so well preserved that in some cases the DNA is preserved has been removed and studied (made famous by the movie "Jurassic Park"). These studies have shown how prehistoric animals are related to their modern day descendants.

The Bermuda Triangle Mystery Solved?

"The mysterious loss of a ship and all of its crew." "The disappearance of aircraft and the pilots as well." These mysterious phenomena have been reported over a certain area of the Atlantic Ocean near Bermuda. While studying gas hydrates, the late Dr. Donald Davidson, a Canadian physical chemist, proposed a theory that may explain these mysteries.

Dr. Davidson received his BSc and his MSc degrees in chemistry from the University of New Brunswick, and his PhD from Brown University. He was a staff chemist at the National Research Council in Ottawa for many years, until his death in 1986. He had a great interest in gas hydrates and it was his knowledge in this field that led to his proposed Bermuda Triangle theory in 1984.

At enormous pressures and low temperatures (as at the bottom of the sea), water and gas molecules form gas hydrates. These compounds resemble ice but, unlike ordinary ice, the water molecules form cages that trap gas molecules such as methane. The solid hydrates retain their stability until conditions, such as higher temperatures or lower pressures, cause them to decompose. This decomposition releases enormous amounts of trapped gas.

The disappearance of ships and aircraft may be the result of these natural gas blowouts. This could turn the sea, very briefly and without notice, into a mass of froth that could sink any ship in the area. As the methane gas rises, an airplane flying through the gas would experience engine failure, or worse: a spark from the engine could turn the aircraft into a flying fire ball.

When Davidson proposed his Bermuda Triangle theory in 1984, the scientific community did not take much notice. However, new information concerning blowouts of naturally occurring gas hydrates (presented at a meeting of the American Association for the Advancement of Science in 1990), and aircraft pilot reports of waterspouts on the ocean's surface that might be the result of these blowouts, lend support to Dr. Davidson's theory.

New Products to Improve Your Life

Big Accomplishments for a Small Particle

In 1990, Atomic Energy of Canada Ltd. (AECL) received an award for developing one of the 100 most-significant technical products of the year. This product is a family of electron accelerators that are called IMPELA (Industrial Materials Processing Electron Linear Accelerator), developed by J. McKeown at AECL's Chalk River Laboratory in Ontario. McKeown's initial project was to research and develop a proton accelerator to create a new source of fuel for generation of nuclear power. In order to make things easier, a smaller and less complicated electron accelerator was designed to create high energy electron beams that could model the behaviour of high energy proton beams. These efforts led to the development of IMPELA.

The source of the electrons for the electron beam is simple. It comes from plugging the instrument (IMPELA) into the socket in the wall. This supplies the power to heat the wires within the electron gun (just like the one in your T.V.) from which the electrons are generated and then extracted. The electrons are then directed from the heated wire to the accelerator and the accelerator does its job by speeding up the electrons and concentrating them into a single beam that generates from 5 to 18 MeV (million electron volts) of energy and supplies a range of 20 to 250 kilowatts of power (energy/second). This newly developed electron accelerator is appreciated because no other accelerator can provide both a high energy and a high powered electron beam. The more energy the electron beam has, the deeper the electrons can penetrate the target material and therefore, the more applications the beam can provide.

Now that we have this concentrated, fast moving electron beam, what can we do with it? Well, we can affix this electron beam on different materials to modify their chemistry by inducing such processes as polymerization, cross-linking and free radical activation. How does it work? You've probably heard of X-rays. IMPELA generates X-rays which are high energy light particles (or photons). The beam of electrons does this by bombarding the target atoms and displacing an electron in the inner shell. The vacancy created is then filled by an electron from a higher energy level and therefore, an X-ray is emitted during the transition to the lower energy level. Also, the electron beam can remove *valence (outer) electrons from the target atoms and cause them to be very unstable and reactive. As a result of these high energy intermediates, chemical reactions and chemical changes take place within the target material.*

One valuable use of this process is in the cellulose industry. Cellulose is a polymer found in the cell wall of plants and is the most abundant natural polymer in the world (a polymer is made up of repeating units that are strung together like beads to make a very large molecule). This polymer is extracted from wood chips in a process known as pulping. Cellulose is the starting material for paper and viscose, and pre-treatment with the electron beam makes the cellulose much more accessible to the chemicals used in the pulping process (carbon disulfide, alkali, and acid). Therefore, electron processing greatly reduces the volume of chemical use. The viscose obtained from cellulose is used in products such as clothing, tapes, textiles, cellophane and reinforced hose and belts.

The electron beam can also be used to reduce the use of hazardous chemicals in the plastics industry to cure (polymerize), cross-link (join adjacent polymer chains together), and graft (attach new molecules to the surface of the polymer) polymer materials. This decrease in chemical use and the replacement of gamma rays, emitted from radioactive sources such as cobalt-60, by electron beams in certain applications renders the electron beam environmentally friendly. The electron beam also kills bacteria, viruses, and fungi and can be used in the sterilization of medical supplies, in the disinfestation of agricultural products, as well as in the treatment of waste water (sewage).

Butyl Rubber and Bubble Gum

Butyl rubber has unique properties. The most important property of butyl rubber is that it is the best sealant of all the known rubbers.

The major application of butyl rubber is in the lining of tires. It formerly was used to make the inner tube of the tire, but now that there are tubeless tires butyl rubber is incorporated into the tire on the inside. It is a good thing that a rubber such as this was discovered or we would be forced to put air into our tires every day!

Another important property of this rubber is that it is blood compatible. This feature allows this substance to be used in biomedical applications such as artificial joint materials.

You may have been chewing gum earlier or you may be chewing it right now. Well, GET THIS: Butyl rubber is used in all chewing gum. Rest assured that this chemical has been approved as edible.

One of the two companies responsible for the production of butyl rubber in North America is the Polysar Rubber Corporation in Sarnia, Ont.. (The other is Exxon in the United Stated.) Judith E. Puskas is employed by Polysar Rubber Corporation as an Associate Research Scientist in Research and Development and Lab Services, and she is involved in the work of the Butyl Technology Group.

The production of butyl rubber is very complex and the polymerisation process occurs at -100^{o}C. Puskas has made many contributions to the production of butyl rubber. She has seven U.S. patents relating to the synthesis of butyl rubber. Puskas' group at Polysar also involves the contributions of Co-Op students whose work does not go unnoticed. Puskas has published many journal articles with students as co-authors.

Chemical Breakthrough

A young researcher discovers a way of assembling inorganic molecules

Quesnel, British Columbia, for those who don't know, lies in the centre of the province, about 600 km northeast of Vancouver. This town of 8,300 people is known for its logging, not as a breeding ground for new materials chemists. Not until this year, anyway. That was before Quesnel (pronounced Quen-nel) native Mark MacLachlan, a doctoral student in the University of Toronto's Department of Chemistry, published a paper in the prestigious journal *Nature* unveiling a new, metal-like substance that someday might be used on everything from removing pollution to sniffing out dangerous gases in mine shafts. He shared credit for the paper with Geoffrey Ozin and microscopist Neil Coombs but according to Ozin the promising new kind of microporous material they have created -- known as a germanium sulphide mesostructure -- would not have been possible without MacLachlan's insight.

Ozin is well known for his work on using chemical methods to assemble molecules into more complex structures. He says materials chemistry is a burgeoning field right now: chemists are expanding beyond their traditional field of assembling molecules into using those molecules as building blocks in multimolecular structures of greater and greater complexity. Using molecules as building blocks is nothing new to organic chemists: it's how everything up to the bones in our own bodies is "assembled."

But materials chemists like Ozin are still learning how to use chemistry to "assemble the inorganic." "We are just beginning to approach the complexity of hard materials in the natural world with these new supramolecular materials," he explains. To better understand what the team has created, think of a honeycomb, with its hexagonal spaces constructed of beeswax walls. Now imagine that same kind of highly organized structure but with walls of germanium sulphide one molecule thick and hexagonal spaces up to 500 angstroms across (an angstrom is one ten-thousandth of a millimetre). Instead of a solid wall of sulphide molecules you have something that could be a sieve or a net. Because the metal sulphide clusters are electrically conductive, the new structure could be modified to detect other molecules passing through the holes in the net, making it a chemical sensor, of sorts."We thought it might be useful for detecting odours because it can respond electrically. Or it could be used to trap heavy metal molecules, to remove pollution from a river, for instance," says MacLachlan. Other uses, if any, will become apparent over time. What the scientists are celebrating right now is finding out how to construct such a material. Their difficulty was that sulphide clusters have to be dissolved to assemble and these sulphide clusters do not dissolve in water. The chemists had to find a different solvent to make the structure work.

It was MacLachlan who hit upon using formamide, a relatively obscure liquid. "When we used formamide, the clusters just snapped together," says MacLachlan. The assembly process uses formamide and a surfactant, something like dish soap. Instead of spherical soap bubbles (or micelles, in chemistry terms), this surfactant forms cylindrical micelles: the sulphide clusters assemble in the spaces in between. Remove the surfactant and you are left with a germanium sulphide honeycomb. MacLachlan, now finishing his PhD after doing his undergraduate studies at The University of British Columbia, is trying not to let the excitement of his first Nature paper at the age of 25 go to his head. "I came to the University of Toronto because I find this whole field fascinating." The young scientist is actually the first in his family to earn a university degree -his family works in the logging industry in Quesnel. Now, besieged by reporters from across Canada, he is also proving remarkably good at explaining his work in terms the general public can understand. One favourite analogy involves comparing his process to casting logs in concrete, then burning out the logs to leave a concrete structure behind. Sounds like something a guy from Quesnel would say, doesn't it?

Chemistry in Cosmetics

It is often the search for excellence which leads us on to bigger and better things. Just ask John and Lotte Davis, who founded Advance Group Hair Products Ltd. (AG) in Burnaby, B.C. in 1989.

John had previously been with a hair product company from Britain. One day, while perusing the company plant, he noticed a young man dumping a large quantity of a white, granular substance into a tank full of hair product. The substance was salt, used to preserve and thicken products, but which can also be damaging to hair. John realized that he did not even know what was going into his own products.

At AG, salt is not used and products are highly concentrated so as to offer more value than the competition. They have a research and development chemist, Zdravka Stoyeff, who is always working on new products. But the most important component of their R & D system is feedback from the salons and customers themselves.

A new product goes through rigorous stability testing, including freezing and thawing, and is used on mannequin heads before it is tested in a small network of salons. It takes about a year to develop a new product.

AG is now a multi-million dollar enterprise with 30 products and over 100 employees. Products are available as far east as Ontario and shipments have recently begun to the USA. A vision of high-quality products with no unnecessary ingredients is now a Canadian success story.

Chemist, Nam Fong Han went into the cosmetics business for similar reasons. He noticed a rising demand from consumers for natural, plant-based products with no synthetic chemicals. His Ottawa-based company Natunola manufactures canola-based ingredients for cosmetics rather than traditional petroleum-based ingredients. The result is a product family that is less greasy and also has a very high temperature resistance, which means finished products will have a longer shelf life.

Vegelatum ™ is a gel-strucured botanical emollient that is used as a base in creams and moisturizers, eye shadows, hair products and other cosmetic applications. When applied to the skin it has a protective and smoothing effect. Although you will not see the trade name Vegelatum ™ on the back of your makeup bottle, Natunola ingredients are used in product lines from Estee Lauder (and MAC), the Body Shop, Clairol (Herbal Essences), and other familiar brands.

There are six chemists working at Natunola. They are responsible for quality control and research and development. A new cosmetic ingredient will take at least 6 months to develop, as it is put through rigorous testing that includes tests for bacteria growth and temperature resistance.

Han has prototypes of some cosmetic products, used to try out Natunola ingredients. Here is a formula you can try at home. You can also experiment with different types of oil essences. Vegelatum ™ is not generally available for consumer use, but you can get a free sample from the company, at: www.natunola.com

Natunola Vegelatum TM Massage Gel (1)

Ingredient	*%Wt*
Vegelatum ™ Clear	*q.s.*
Natunola ™ Canola Oil	*10.70*
Isopropyl Myristrate	*15.00*
Grapeseed Oil	*0.50*
Jojoba Oil, Golden	*0.20*
Eucalyptus Oil	*0.05*
Spearmint Oil	*0.05*
Grapefruit Oil, Pink	*0.10*
Australian Myrtle Oil	*0.10*
Tocopherol q.s.	*q.s.*

Procedure: Mix all ingredients at room temperature. Add colour if desired.

Specifications are based on information available at the time of printing. This information is provided in good faith and is subject to the following conditions:

1. Natunola makes no warranty of any kind concerning any product, formulation or procedure or other matter contained in the information including, without limitation, any warranty that the sale or use of any product, formulation or procedure will not infringe any patent or other third party right.

2. The user of the information will not provide it to third parties and will indemnify Natunola harmless from any liability arising of the recipient's use of the information. (August 2001),

Cleaning Up with Crystal Engineering

Crystal engineering, a relatively new field of chemistry, has been rapidly expanding since it was first introduced in 1971. Crystal engineering is a cross-disciplinary field that uses aspects of supramolecular chemistry (the study of how molecules interact with each other) and X-ray crystallography (a technique for determining the position of atoms in crystals) to develop the protocols for predicting and controlling the structure and functional properties of solids. This field encompasses all aspects of design in the solid state and has no boundaries in terms of the chemical type of moieties involved or which intermolecular/ionic forces can be exploited. Mike Zaworotko of Saint Mary's University, Halifax, N.S. is a crystal engineer involved in developing two types of new compounds that are functionally and structurally similar to well-known minerals such as clays and zeolites but are chemically very different. Zaworotko has focused primarily on using organic molecules or metal cations for the assembly of 2-dimensional networks. The organic molecules are multifunctional carboxylic acids such as trimesic acid and pyromellitic acid and they can form either salts or cocrystals.

Zeolites are naturally occurring or synthetic aluminosilicate compounds with a framework structure enclosing cavities occupied by large ions and water molecules. Natural zeolites are used in kitty litter to absorb ammonia and control odours, and in the "cracking" of crude oil. In this case the large molecules of crude oil are "cracked" into smaller ones thereby altering the petroleum product. The new clays and zeolites that Zaworotko is developing are mainly organic in nature and can have many possible applications. Some of these new applications involve the clean-up of pollutants, drug delivery (matrix for oral delivery of otherwise unstable drugs), crop remediation (slow release of pheromones), and new industrial catalysts. One of the compounds that Zaworotko's research group has created is a sponge-like zeolite compound that is capable of "soaking up" PCB's and polyaromatics which makes it ideal for hazardous waste clean-up. The tiny zeolite crystals form a molecular mesh that has a hydrophobic interior surface that preferentially adsorb organic molecules. This characteristic makes it ideal for cleaning polluted water as the sponge-like zeolite can be used as a filter. The research has been supported over the past few years by NSERC (National Science and Engineering Research Council) and the Environmental Science and Technology Alliance of Canada.

Separation of Compounds by Chromatography

Suppose you had a mixture of compounds. Would it be possible to separate them from one another? Can you think of a way? You certainly could not sort them by hand! The method that scientists use to group the different components of a mixture is known as chromatography. Would you believe that you can separate some mixtures within minutes just with paper and water? When paper is used to achieve the separation of a mixture, the technique is known as paper chromatography.

Chromatography works due to the fact that molecules which have a property called polarity in common tend to be attracted to each other. A polar molecule is simply a molecule that has a region which is electron rich and a region which is electron poor. These regions are sometimes represented as being negatively charged and positively charged. Polar molecules are held together by forces of attraction between opposite charges on different molecules. Water molecules have electron rich regions on the oxygen atoms and electron poor regions on the hydrogen atoms. Thus, *water molecules are polar and consequently they stick together because the positive region of one water molecule is attracted to the negative region of another. These interactions provide an explanation for the high boiling point of water.*

Paper is made up of extremely long molecules called cellulose. Cellulose is a polymer which means that it is made up of thousands of smaller molecules strung together like beads. These bead-like molecules that make up the cellulose chains are polar and, as a result, cellulose has many regions of high and low electron density. The "charged" regions on one cellulose chain are attracted to the oppositely charged regions on an adjacent cellulose chains and this helps to hold the fibres together in paper. The fact that the long cellulose chains are aligned in one direction can be demonstrated by tearing a piece of newspaper. You will find that newspaper tears easily and along a fairly straight line if torn in one direction, but when torn at a 90o angle the paper will not tear along a straight line. From what has been said so far, you might be thinking that only identical polar molecules are attracted to each other. But what happens when you dip the end of a strip of paper such as a coffee filter into a cup of water? The water actually climbs the paper! This process occurs because the polar water molecules that are in contact with the strip of coffee filter begin to move up the paper as they find new charged regions on the cellulose to stick to and are replaced from below by other water molecules in the cup. Mixtures of dyes are used to make inks of different colours. Each individual dye is composed of a different compound. Suppose you dabbed the end of a strip of paper with a black felt pen. What do you think would happen if you then dipped this end into the cup of water making sure that the pen mark is above the water level? The water would climb the paper as before, but the ink would also be carried up the paper by the water. In fact, the different dyes in the ink would be carried up the paper to different extents depending on whether they were more attracted to the cellulose in the paper or the water rising up the paper. Eventually all of the different dyes used to make the ink would be separated from one another.

Check out the experiment Radial Paper Chromatography on the Fun Science.page.

Protection

Anti-Chemical Warfare

Chemical warfare agents, as defined by the United National Chemical Weapons Convention, are "any chemical which, through its chemical effect on living processes, may cause death, temporary loss of performance, or permanent injury to people and animals". Chemical warfare agents can belong to many different groups such as vesicants, blood agents, and nerve gases. Vesicants include mustard gases, which cause blistering of skin, eyes, and lungs. Hydrogen cyanide is an example of a blood agent, which when inhaled causes death by preventing normal utilization of oxygen. Nerve gases such as sarin eventually cause loss of motor control and death due to the inhibition of the enzyme that prevents the build up of acetylcholine, and acetyl cholinesterase. Due to the variety of chemical warfare agents and their modes of dispersal different types of detectors have been developed.

Chemical agent detectors made of paper were created about 20 years ago. These detectors are useful because they allow the detection and identification of airborne chemical warfare agents. The paper is impregnated with different dyes sensitive to specific families of liquid chemical warfare agents. It is then attached to clothing or equipment for rapid and easy detection of contamination. When airborne droplets from the chemical agent contact the paper a colour change takes place which identifies the agent.

The dyes used enable the detection of three types of chemical agents; H-type (mustard gas), V-type (nerve gas toxic when inhaled), and G-type (nerve gas toxic when absorbed by the skin). Each dye turns a different colour (red, yellow, or green) and is not masked by the colour of the paper.

Unfortunately, the dyes used for the detection of the two types of nerve gases (yellow and green) have been found to be mutagenic. As a result, the Canadian Department of National Defense has developed three new dyes to detect the chemical agents. Before the dyes can be used they must fit the following criteria: insolubility in water, solubility in the chemical agent and must be a solid during the paper drying process. Other chemical agents may be present on the battlefield; therefore, it is desirable that the dye used is also insoluble in liquids such as petroleum products, antifreeze solutions, and alcohol solutions. Most importantly, the dyes must be non-mutagenic and give the correct strong colour upon reaction with the chemical agent droplets.

Another type of chemical agent detector is a CAM (chemical agent monitor) which was used by the Canadian Forces during the Persian Gulf War. CAMs are hand held detectors that are used for real-time monitoring of mustard and nerve vapours in chemically contaminated environments. The CAMs detects the chemical agent by drawing air across a heated silicon membrane which preferentially allows chemical warfare agents to pass through into the analysis area. However, these detectors can not give advance warning to an off-site chemical incident. Consequently, the Defense Research Establishment Suffield (DRES), in Medicine Hat, Alberta, developed the

CADS (chemical agent detection systems). The CADS are CAMs linked by cable over distances to a central computer. This system allows for early detection of chemical warfare agents and consequently, sounds an alarm to warn the people. This system was also developed for the Canadian Forces in the Persian Gulf War.

Paper detectors, CAMs, and CADS help with the detection of chemical agents but fast and efficient methods for decontamination are needed if the agents come into contact with the skin as nerve agents can cause death in five minutes if sufficient quantities are absorbed by the skin. Consequently, DRES has developed a lotion which is fast acting, easy to apply and remove but effective in destroying chemical warfare agents.

Canadians At The Top Of Explosive Detection

The first Explosives Vapour Detector (EVD) was recently invented by Lorne Elias of the National Aeronautic Division of Canada's National Research Council in Ottawa, Ont.. Explosives Vapour Detectors are now in use in ten international airports in Canada, making them among the most secure airports in the world. The device is so sensitive that it can detect one part of explosive material in one trillion (10^{12}) parts of air.

To use the detector, suitcases are placed in an area in which an air pump collects air samples in small glass cartridges. These are removed and connected to an analyzer unit the size of a suitcase. This analyzer unit is a gas chromatograph. The device takes around two minutes to analyze the sample. If the sample is safe (no volatile explosives detected) the digital display will read "O.K."; if not, the display reads "ALARM". The concentration of the explosive detected also shows up on the display screen. If explosives are detected, dogs are brought in to pinpoint the location of the material. Dr. Elias is now working on reducing the EVD's analysis time to five seconds.

Chemistry Defending Plants

According to Soledade C. Pedras, her greatest success and pride is in being able to apply her passion for and knowledge of chemistry in the field of plant biology (known as bio-organic chemistry). It is, in fact, an unusual combination, but the spin-offs can be extremely beneficial for the field of agriculture and in helping to solve the problem of famine in some parts of the world.

After obtaining a doctorate from the University of Alberta, Pedras pursued a career at the NRC's Plant Biotechnology Institute of Saskatoon. In 1994, she was offered a position as Assistant Professor of Chemistry at the University of Saskatchewan where she directs a research team of approximately 10 graduate students, research associates, and technician assistants. Pedras and her team are studying the molecular and enzymatic defence reactions of plants to *attacks by pathogens. Her goal is to discover the chemical and biological strategies that plants use to resist various toxins (often transmitted by microbes, insects or other creatures) found in their natural environment. Once they are well known and analysed, these particular defence strategies can be transmitted to other plant species through traditional plant breeding or modern genetic engineering.*

The following is a very concrete example of what is keeping Pedras busy at present. Western Canada is known for the numerous agricultural species under cultivation, including canola and mustard plants. Unfortunately, these plants are subject to attacks from disease-causing micro-organisms that release phytotoxins. Destruxin B is a phytotoxin produced in plants attacked by the Alternaria blackspot microbe. However, a certain type of white mustard, also attacked by micro-organisms, will not develop Alternaria blackspot because it has developed a very effective defence mechanism. And what Pedras has succeeded in discovering is this very special defence mechanism.

To discover the mechanism, she had to use modern chemical techniques. First, HPLC (high-performance liquid chromatography) was used to analyse the disappearance of destruxin B concentrations in white mustard plants. Pedras then isolated the transformed destruxin B product, by separation methods such as FCC (flash column chromatography). The crucial phase was to determine the chemical structure and composition of the extracted product, which was done through the application of NMR and HRMS techniques (nuclear magnetic resonance and high-resolution mass spectroscopy). This was how Pedras discovered that enzymatic protein was transforming the destruxin B into an inoffensive HO-destruxin-B molecule. Using the same chemical techniques, Pedras' team succeeded in isolating and characterising this enzyme.

In the not too distant future, it will be possible to sequence this protein and determine the gene that contains the code responsible for synthesizing the enzyme. Through Pedras' work and the collaboration with molecular biologists, this coding gene can be used and introduced into the gene pool of other species of plants (such as canola) to make them resistant to Alternaria blackspot. Thus, through her research and relentless work, Pedras will soon find the key to defending plants through, environmentally friendly solution (eliminating insecticides and fungicides) while increasing farmers' harvest yields.

Other

Environmental Analysis Through Chemistry

Since the industrial revolution in the 19th century and the numerous technological breakthroughs that have occurred up to the present day, a large number of companies have emerged in Canada and in all parts of the world. Although these companies generally produce articles intended to improve the human condition, the wastes and gases escaping from factories have had, and continue to have, a harmful effect on the health of the environment. In this country, Environment Canada is the department that is largely responsible for sampling and analysing air and water pollution. To carry out this task, Environment Canada uses the services of chemists and chemical technologists in analytical chemistry to assess the rates of pollution and contamination in nature. Environment Canada is one of the departments with many government laboratories hiring chemistry specialists.

One of these specialists is Stephen Beauchamps, a chemist assessing air quality at the Environment Canada facilities in Dartmouth, N.S.. His work consists of identifying and measuring the various air pollutants. To perform his duties, he uses devices such as the "gas phase mercury detector" or the "brewer" spectrophotometer," both of which was designed and is manufactured exclusively in Canada. The latter instrument is used among other things to determine the ground-level ozone rate, (not to be confused with the ozone layer), a prime indicator of urban air quality. The combustion of hydrocarbons (oil, natural gas, petroleum, coal, etc.) discharges pollutant molecules (NO_2, NO, volatile organic matter) into the air. These react with sunlight to produce ozone molecules, and thereby become a direct indicator of the level of pollution.

Other instruments such as gas analysers, designed by multidisciplinary teams that include chemists and chemical engineers, are used more specifically to identify pollutant gases and their concentration (SO2, SO_4, CO_2, etc.). The analyser collects air samples that are then exposed to a special light. The gas molecules receive this light energy in the form of wavelengths that they first absorb. They subsequently re-transmit this energy in the form of another specific wavelength that is picked up by a light sensitive sensor.

Since each re-emitted wavelength is specific and characteristic of each pollutant molecule, the integrated computer can therefore deduce the nature of the pollutant as well as its atmospheric concentration.

Water quality analysis is equally as important as air quality analysis in determining the rate of regional pollution, especially in the Maritimes where acid rain is frequent. Water samples taken from lakes and waterways are analysed by chemists in laboratories through a battery of tests. The initial tests are used to assess the characteristics of the water such as pH, conductance and turbidity (detection of suspended particles). Another series of tests is conducted to determine the presence of fecal coliform (bacteria) and other micro-organisms. The samples are next analysed for contaminating pollutants. This category includes fertilizers, pesticides and herbicides from agricultural regions, heavy metals such as mercury, cadmium, zinc and copper, as well as acid rain fallout in the form of nitrogen oxides and sulphur dioxides. All these chemical products can be identified and measured using a range of tests and chemical reactions developed by researchers in laboratories.

The colorimetric analysis system for measuring nitrate concentration (NO_3) is a good example. The procedure consists of pouring a part of the sample into a coiled glass rod containing cadmium. This catalyst transforms the nitrate into nitrite (NO_2). This recovered product will next react with a reactant known as sulphanilamide to form a diazotized compound. The latter will react with a certain quantity of N(1-naphtyl) ethylene diaminedihydrochloride to be transformed into a reddish, nitrogenated dye. The intensity of the colour is directly proportional to the initial quantity of nitrate and can be determined by a colorimeter.

Although Canada has new laws to control pollution, thousands of new chemical products are nevertheless developed each year. The manufacturing processes for these products, or the products themselves, pollute our air and water. From this perspective, the future of chemistry increasingly lies in developing non-toxic, non-polluting products, as well as in designing new pollution management techniques.

Fun Facts

A noble gas

For many years it was thought that the noble gases where chemically inactive. In 1962 Dr. Neil Bartlett treated xenon gas with the powerful fluorinating agent, PtF_6. A yellowish- orange solid compound formed. This compound contained platinum, fluorine and.... YES xenon. This was the first inert gas compound ever formed! This discovery was made while Dr. Bartlett was a chemistry professor at the University of British Columbia between the years 1958 and 1966.

Why sugar rots your teeth

The truth is that it is not actually the sugar that rots your teeth. It is the plaque and sugar combination that does the dirty deed. Plaque is a collection of bacteria that adheres to your teeth and gets its energy by breaking down the sugars you eat. During sugar breakdown, many products are formed, one of which is lactic acid which decreases the pH in your mouth. In an acidic environment, the hard enamel that protects your teeth dissolves, which leaves your teeth vulnerable to decay and cavities. The saliva (average pH 6.8) in your mouth counteracts this decrease in pH by using *buffers such as bicarbonate ion (HCO) and the COOH and NH groups of proteins. However, the time it takes for the saliva to neutralize the acid depends on the amount of sugar that has been ingested. Therefore, the more sugar that is available, the more the bacteria multiply, the lower the pH in your mouth becomes, and the longer your teeth are susceptible to decay.*

Why the leaves change colour in the different seasons

Within all leaves there are molecules called pigments that are responsible for their colours. These molecules are present at all times; however, whether or not a particular colour dominates is dependent on the amount of pigment present. The relative amounts of pigments are governed by conditions such as temperature, rainfall, and length of day. In the spring and summer, when the temperature is warm and the days are long, the green pigment called chlorophyll is present in the largest quantity; hence the leaves are green. On the other hand, in the autumn, when the temperature gets cooler and the days get shorter, the chlorophyll diminishes, allowing the carotenoids to show their true colours, their yellow pigment. In addition, there are pigments called anthocyanins that are responsible for the red and purple hues in the autumn leaves.

How the morning glory flower changes its colour from purplish red buds to give flowers with blue petals

Remarkably, it is the change in pH that is responsible for the changing colours in the morning glory flower. The colours we see are due to pigments, just like in leaf colour. However, in this case, one pigment called heavenly blue anthocyanin (HBA) portrays two different colours when the pH shifts from a slightly acidic to a slightly basic environment. In a laboratory experiment, when flowers are exposed to CO gas, HBA finds itself in an acidic (pH 6.6) medium which causes the protonated pigment to reflect a purplish red hue. On the other hand, when the flower petals are returned to an atmosphere containing O, the medium becomes basic (pH 7.7) and this same pigment becomes deprotonated and reflects a blue tone. Hence, acid-base chemistry is responsible for the purplish red buds and the blue flowers.

Making paper from Ground Wood Fibre

Did you know that a process for making paper that is used today was discovered by a Canadian? Charles Fenerty, from Nova Scotia, developed the idea of making paper from ground wood fibre after he watched wasps build nests out of finely chewed wood fibre. In 1838 Fenerty produced the first usable newsprint made from ground wood fibre. At this time, most of the paper was made with rags which were decreasing in availability as the demand for paper was increasing. Thus, alternative paper making methods were needed. Fenerty's method for making paper was very important because it used the abundant supply of trees. It also helped start the pulp and paper industry which is Canada's largest source of manufacturing, employment, export, and international trade.

A career in chemistry

The time taken to earn a BSc in chemistry or chemical engineering is 4 years. A Diploma in Chemical Technology takes 2 years. A shortage of professionals in these fields is predicted within a few years. The National Research Council - the principal science and engineering organization of the government of Canada - employs more than 400 chemists, chemical engineers and chemical technologists in laboratories across the country. They study everything from high temperature superconductors, to ways to make plants more stress tolerant, to new processes to reduce discharge of harmful substances into the environment.

Acknowledgements

Discover Canadian Chemistry was originally published annually in hard copy under the auspices of The Canadian Society for Chemistry in celebration of National Chemistry Week (since October 1991). It was produced at many different locations. The writers have been predominantly university students or future high school teachers.

Issue 1
Written and devised by Josef Takats, FCIC, University of Alberta with the assistance of . Michael Falk, FCIC, Harry Ainlay Composite High School. Edited by Anne Le Rongetel and designed by Debra Bachman. Illustrations by Dwight Ailott.

Funding from the Canadian Society for Chemistry, the Chemical Education Trust Fund (of the CIC) and the Royal Society of Canada

Issue 2
Written by Susan Sharpe. Production by Josef Takats, FCIC, University of Alberta with the assistance of Dr. Michael Falk, FCIC, Harry Ainlay Composite High School. Designers Doug Madill, Laird Saikeld (Madillustration Design Inc.).

Major funding for this issue came from Science Culture Canada with additional generous support from the Chemical Education Trust Fund (of the CIC) and from the Royal Society of Canada.

Issue 3
Produced at Dalhousie University, in Halifax, NS. The researcher/writer was Nada Haidar, BSc. and the coordinator/editor was Mary Anne White, FCIC, BSc, PhD. The design work was by Jungle Drums, Halifax, NS. Translation to French was by François Gauthier, Qualigram, Montréal, QC.

Funding for this project came from Science Culture Canada.

Issue 4
Produced at Dalhousie University, in Halifax, NS. The researcher/writer was Nada Haidar, BSc. and the coordinator/editor was Mary Anne White, FCIC, BSc, PhD. The design work was by Mark McGowan and illustrations were by Jennifer Strong, Halifax, NS. Translation to French was by François Gauthier, Qualigram, Montréal, QC.

Funding for this project came from Science Culture Canada.

Issue 5

Produced at Simon Fraser University in Burnaby, British Columbia. The researcher/writer was Kelly L. Jordan, BSc, and the coordinator/editor was B. Mario Pinto, FCIC, BSc, PhD. The design work and illustrations were by Bill Schuss, Burnaby, BC. Translation to French was by François Gauthier, Qualigram, Montreal, QC.

Funding for this project came from Industry Canada.

Issue 6
Produced at the University of Victoria in Victoria, British Columbia. The researcher/writer was Sarah Baker and the coordinator/editor was Peter Wan, FCIC. The design work and illustrations were by Ari Niemi of Motion Illustration & Design, Ottawa, Ont.. Translation to French was by François Gauthier of Qualigram, Montreal, QC.

Issue 7
Produced at the University of Victoria in Victoria, British Columbia. The researcher/writer was Sarah Baker and the

coordinator/editor was Dr. Peter Wan, FCIC. The design work and illustrations were by Ari Niemi of Motion Illustration & Design, Ottawa, Ontario. Translation to French was by François Gauthier of Qualigram, Montreal, QC.

Partial sponsorship for this project was received from the Chemical Education Trust Fund of the CIC and Industry Canada.

Issue 8
Produced at the University of Manitoba, Winnipeg, Man. The researcher/writer was Brigitte Yvon, a senior honours chemistry student in the Department of Chemistry at the University of Manitoba. Norm Hunter, FCIC was the coordinator/editor. The design work and illustrations were by Ari Niemi of Motion Illustration & Design, Ottawa and the translation to French was by François Gauthier, trad. a., Qualigram, Beloeil, QC

Issue 9
Produced at the University of Manitoba, Winnipeg, Man. The researcher/writer was Brigitte Yvon, a graduate student in the Department of Chemistry, the University of Manitoba, contributed "Shedding the Light on Diseases" and "It's All Elemental" as well as to the general articles. Bruce Rolston, University of Toronto, contributed "Chemical Breakthrough" and "1998 Nobel Prize Canadian Connection". Mario Leclerc contributed "Virus Detecting Plastics". Norman Hunter, FCIC was the coordinator/editor. The layout and design by Ari Niemi of North Wind Design, and the translations were done by François Gauthier, trad. a., Qualigram,

Dow Chemical Canada Inc. has provided sponsorship for this project.

Issue 10
Published under the auspices of The Chemical Institute of Canada, in celebration of National Chemistry Week. Charles-André Vinette, a high school teacher from Ottawa, Ont., just beginning his career, who has a MSc in biology was the principal author and researcher. Gale Thirlwall-Wilbee was responsible for the coordination/editorial work. The layout and design were by Ari Niemi of North Wind Design and French to English translations by Ursula Desmarteau.

Dow Chemical Canada Inc. has provided sponsorship for this project.

Issue 11
Holly LeBlanc, a new journalism graduate and future teacher from Ottawa, Ont. is the principal author and researcher. Gale Thirlwall-Wilbee was responsible for the coordination/editorial work. "Smoke and Mirrors" was written by Joe Schwarcz, MCIC, director, McGill University, Office for Chemistry and Society and the National Coordinator for National Chemistry Week, 2001. The article appeared in Canadian Chemical News, March 2001, page 11. The layout and design were by Ari Niemi of North Wind Design and the translations were done by François Gauthier, trad. a., Qualigram, in collaboration with Normand Voyer, MCIC, Université Laval.

Dow Chemical Canada Inc. has provided sponsorship for this project.

Issue 12
Published under the auspices of The Chemical Institute of Canada, in celebration of National Chemistry Week. Holly LeBlanc (ottawa, ON), a recent journalism graduate and future teacher is the principal author and researcher. Gale Thirlwall-Wilbee was reponsible for the coordination/editorial work with help from Penny McLeod. The layout and design were by Ari Niemi of North Wind Design and the translations were done by François Gauthier, trad. a., Qualigram.

Dow Chemical Canada Inc. has provided sponsorship for this project.

Exploring Chemistry *was first published under the auspices of the Canadian Society for Chemistry in celebration of NCW 1996. It was revised in 1997 based on feedback from the middle school teachers across the country. It was produced at the University of Victoria in Victoria, BC. The researcher/writer was Sarah Baker and the*

coordinator/editor was Peter Wan, FCIC. The design work and illustrations were by Ari Niemi of Motion Illustration & Design, Ottawa.

Funding for this project came from Shell Canada Limited, the Chemical Education Trust Fund of The Chemical Institute of Canada and Rohm and Haas Canada Inc.