CHIU
Conference of Heads of Irish Universities

Science & Technology Research in Irish Universities

University Research

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Introduction

Ireland's capacity to discover new knowledge through university research is critical to our long - term economic prosperity, social well - being and cultural vibrance. Knowledge is increasingly recognised as the central determining factor of the future prosperity and health of nations. The key to making the new concepts of the "knowledge economy" or " knowledge society" a reality for Ireland is research - the source of new knowledge, ideas and insights.

Irish universities have a strong record in undertaking research across the full range of subject disciplines from the sciences to the humanities and social sciences. Despite the historically very low level of state investment in university research by international standards, Irish universities have developed their capacity and talent by competing successfully for EU and private research funding.

The Government has increasingly recognised the value and importance of research and has begun to invest significant funds in university research facilities, equipment and programmes.

In view of the accelerating growth in the importance of research to creating a more progressive, humane and healthy world, C.H.I.U. felt that it would be appropriate to provide an insight for the public into research undertaken in Irish universities.

This booklet on Science and Technology research is the first in a series of booklets on university research and will be followed next year by a booklet on research in the Humanities and Social Sciences. C.H.I.U. hopes that this series of booklets, by giving snap shot examples, will give the public an informed appreciation of University research and its contribution to the advancement of knowledge to the benefit of the economy and society.

Dr Patrick F. Fottrell
Chairman

C·H·I·U
Conference of Heads of Irish Universities

C.H.I.U. represents the Heads of the seven Irish universities. It aims to promote the development of university education and research by formulating and pursuing collective policies and programmes.

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Tree Rings

Professor Dermot Diamond - Dublin City University

As any child knows, a tree declares its age through the rings that lie beneath its bark. But these rings can actually tell us much more: like how the climate changed during its life-span; and whether it witnessed a visit from outer space...

At DCU a team of researchers have been working in association with an international expert on tree rings based at Queen's University Belfast, to see what secrets ancient bog oak can reveal. They can already tell the level of growth a tree enjoyed from year to year. For periods of bad weather (and therefore poor growth) the tree will have narrow, dark rings, for periods of good weather the tree will have widely spaced, lighter rings. But there are periods in tree ring history when, for some unknown reason, trees haven't grown for periods of up to thirty years. The most likely explanation is that thick layers of dust were somehow expelled into the atmosphere, blocking out the sun and sending the trees into a long-term dormancy. This could only have been brought about by a climatic disaster: either a volcano or the impact of a meteor from space. But the question is, which was it?

To answer this question, the team are applying the latest in analytical chemistry to samples of bog oak that are thousands of years old. They're extracting some of the tree rings dating back to the time of the climatic disaster and searching for iridium - an element that could only come from outer space. If they find any, it will prove the impact of a meteor.

Antibiotics

Dr. Tony Pembroke, Dr. Tim Smyth - University of Limerick

When Alexander Flemming discovered penicillin in the 1920s, medicine took a huge leap forward. Simple diseases that had been killers became treatable and bacteria were no longer the threat to human life they had been. In the 70 years since Flemming's discovery antibiotics have saved millions of lives.

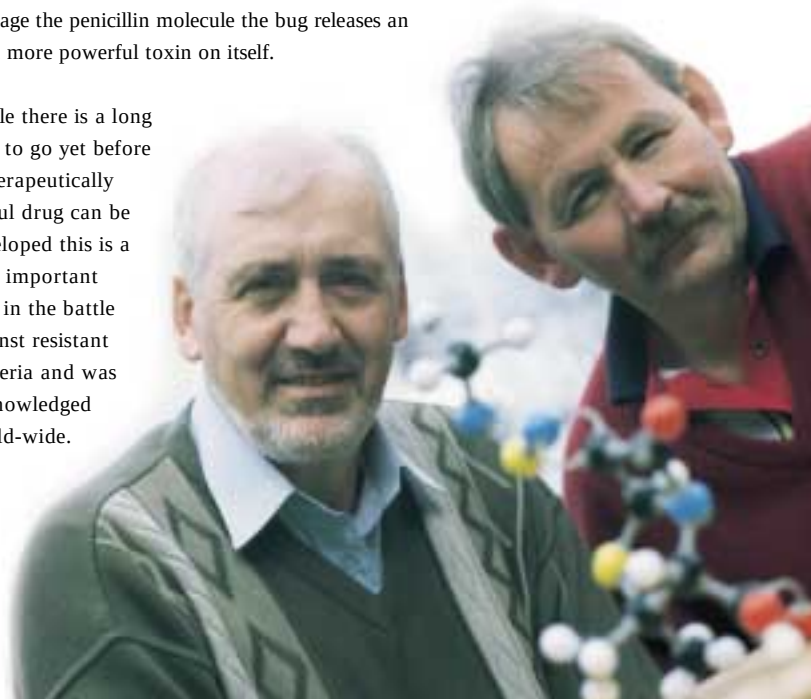
However, just as soon as antibiotics began to kill bacteria, bacteria began to evolve and change to disarm antibiotics. By now, bacteria have evolved so well that many scientists believe that we are reaching a post antibiotic age and that once again bacterial infections will become a major cause for concern. Vancomycin is the last stop antibiotic, an antibiotic so powerful that it was reserved for only the worst infections but already bacteria have emerged that are resistant to the drug. Now finding a way around antibiotic resistance has become a matter of urgency.

There are a few different approaches to dealing with the problem. The population can be encouraged to reduce the amount of antibiotics used both in medicine and in agriculture. However, something more needs to be done to cope with the bacteria that are already resistant. In the University of Limerick there are two teams of scientists working on the problem from different angles.

Dr. Tony Pembroke is trying to understand how bacteria have managed to evolve to deal with so many different antibiotics quite so quickly. It has been found that bacteria have mobile DNA. Parts of their genetic material can travel from bug to bug, giving each one the information necessary to disarm antibiotics. Dr. Pembroke's team is working on one particular mechanism for passing DNA around. It is a very ancient mechanism and could be the basis for many of the more evolved mechanisms of resistance. If scientists can understand how bacteria become resistant to antibiotics so quickly they can stop the process.

Dr. Timothy Smyth is taking an entirely different approach. He has 'booby trapped' penicillin so it works on resistant bacteria. Bacteria that are resistant to penicillin are capable of cutting the penicillin molecule into pieces. Dr. Smyth's team has used this to their advantage and has attached an extra piece to the penicillin molecule. This extra piece is lethal to the bacterium so by attempting to damage the penicillin molecule the bug releases an even more powerful toxin on itself.

While there is a long way to go yet before a therapeutically useful drug can be developed this is a very important step in the battle against resistant bacteria and was acknowledged world-wide.



Electrical Load Forecasting

Damien Fay - Dublin City University

When Ireland played Romania in the 1990 World Cup everyone stopped what they were doing and went home from work. They turned off their pc's, their office lights, their factory equipment and their ovens. The ESB had to reduce their energy production because nobody wanted their energy. That was a very particular day that nobody could have predicted but even over the course of a normal day electricity demand varies by up to 40%.

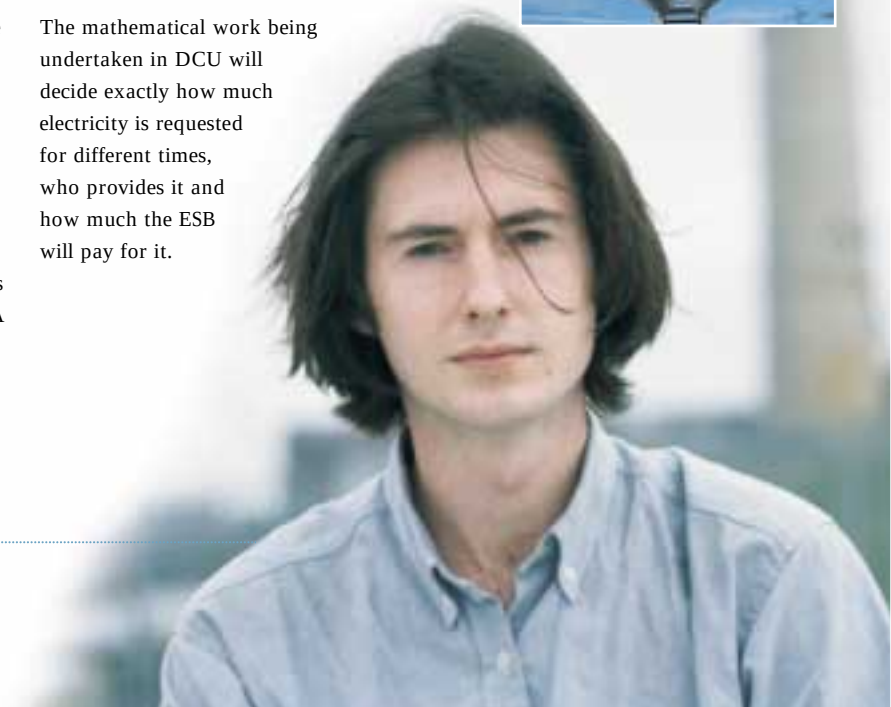
To produce electricity in the most effective and economical way possible a power production company would like to know how much power is going to be needed at any one time. They use a complicated mathematical process known as Load Forecasting to predict power demand years in advance.

If the power demand from the country goes up substantially a couple of things can happen. There is an on-going relationship with Northern Ireland whereby the ESB buys power from them rather than turning on extra stations. More commonly when demand goes up suddenly the ESB end up having to produce more expensive electricity.

There are 19 power stations in Ireland. They range from peat burning stations to hydro stations to Turlough Hill, the only pump storage station. A peat station will take about two hours to fire up which isn't much use when demand suddenly shoots up. Turlough Hill on the other hand supplies energy almost immediately but is much more expensive to run. So the more accurate the load forecast the cheaper the state's electricity will become. In fact a study conducted fifteen years ago in Britain estimated that an increase of just 1% in the accuracy of load forecasting could save £10 million a year.

In Dublin City University Damien Fay is trying to improve the mathematical models currently being used to predict electricity demand. This is of particular importance now as the government is planning to privatise 28% of the electricity market in the next few years. International companies will be bidding to supply electricity at the lowest prices. If the predicted requirements are wrong the state will end up paying hugely inflated prices for emergency supplies of power.

The mathematical work being undertaken in DCU will decide exactly how much electricity is requested for different times, who provides it and how much the ESB will pay for it.



Ecstasy

Dr. Gethin McBain, Dr. Alan Abaird, Dr. Alan Keenan, Dr. Patrick Guiry - University College Dublin

Although the amount written about Ecstasy in the media could be measured in acres rather than pages, surprisingly little is known about the long term effects of the drug. Will it be another healthcare timebomb like nicotine, which was judged to be harmless 40 years ago? Will it be too late when we find out?

A team of researchers at UCD are trying to find out. They have gathered together from three different disciplines to analyse the effects of MDMA -Ecstasy's active ingredient - on the brain, the gut and the cardiovascular system.

They have spent the past year developing an experimental model which will be used to establish the effects in some detail.

This research is part of a government initiative to use science and technology in the fight against drugs in our society.

Also in UCD, Dr. Patrick Guiry is looking at Ecstasy from a completely different angle. He and his team are working on technology which can be used in the fight against supply of the drug.

This technology allows them to analyse Ecstasy tablets for their specific constituents, or intermediates. The results of their analysis can help the Gardai link tablets seized on the streets with intermediates found in suspected Ecstasy laboratories - thus aiding prosecution of those involved.

Neutraceuticals

Dr. Dick Fitzgerald - University of Limerick

There is a whole new type of food product emerging. In America they're known as 'neutraceuticals', in Europe they're functional food ingredients and in Japan the products are already on the shelves. In Tokyo you can, for example, buy Calpis - a soft drink that not only refreshes you, it also lowers your blood pressure.

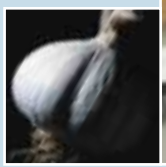
These new food products have functions that go far beyond nutrition. They are natural products that can prevent disease and they have become a huge area of research for multinationals.

In the University of Limerick Dr. Dick Fitzgerald is developing new active ingredients from milk proteins in a number of different health areas. Heart disease is the biggest killer in Ireland. Drugs that control blood pressure are vital in cardiovascular medicine yet these drugs have many serious side effects. Dr. Fitzgerald has discovered that particular segments of milk proteins can do exactly what these drugs do without the side effects. He has tested the proteins in the laboratory and is now planning to conduct clinical trials. These trials are a lot more straightforward and less costly than drug trials as the products are food ingredients not drugs. Once the trials have been completed the products are ready for marketing.

Osteoporosis is another major health issue in Ireland. This condition can be caused by poor calcium intake in early life that leads to porous bones in later life. The condition affects women in particular, yet teenage girls are eating fewer calcium rich dairy products for fear of gaining weight.

Dr. Fitzgerald has discovered novel proteins in milk that could be the answer. The proteins called caseinophosphpeptides carry calcium. These proteins could be concentrated into something like a chocolate bar that adolescents would be likely to eat and would go a long way towards preventing osteoporosis in later life.

This new science of 'neutraceuticals' doesn't just provide new ways of treating and preventing common illnesses it also adds extra value to simple products like milk. For a country like Ireland with strengths in farming and biotechnology this new area of science could turn out to be very rewarding.



Atmospheric Research Station

Professor S. Gerard Jennings - National University of Ireland, Galway

As we hear more and more about the consequences of global warming and the greenhouse effect, we realise the value of climatic research. But 40 years ago, when the Atmospheric Research Station was founded at Mace Head, near Carna in Galway, there was little known about such things.

Beginning within the modest confines of a refurbished coastal look-out post, it has grown to become one of the most important sites for atmospheric research in the northern hemisphere.

Operated by staff from the Department of Physics at NUI, Galway, the Atmospheric Research Station carries out research on trace elements in the atmosphere. Its findings are widely documented in international science literature.

This international dimension is vital, after all, pollution has no respect for political boundaries, so research depends on international collaboration. Another benefit of collaboration is that about 100 universities and institutions from 20 countries have had the opportunity to use the station's facilities.

As well as contributing to meeting Ireland's environmental commitments under international treaties, the station has also been part of the World Meteorological Organisation's Global Atmosphere Watch since 1994. Thus it has given Ireland and NUI, Galway a high profile in research on such important topics as global climate change, ozone depletion and environmental pollution.

Folic Acid

Professor John Scott - Trinity College Dublin

Folic acid is well known as a vitamin supplement for pregnant women, it reduces the chances of having a child with spina bifida or hydroencephaly, water on the brain. Some years ago Professor John Scott in Trinity College proved beyond doubt that natural sources of folate were not effective and that taking folic acid supplements was the only way to ensure that a pregnant woman got enough folic acid to protect her child.

Folic acid or folate in its natural form, is involved in cell division. This occurs at an accelerated rate during foetal development hence its importance during pregnancy. But this is a process that occurs all over the body, all through life and it seems inevitable that being deficient in a vitamin with such a basic role would have widely varied consequences. In fact studies indicate that folic acid deficiency is linked to colon cancer, breast cancer and Alzheimer's disease.

Folic acid also effects the level of chemical in the body called homocysteine. High levels of homocysteine are thought be as significant a risk factor in developing heart disease as cholesterol. However, to control cholesterol you need expensive artificial drugs whereas homocysteine can be controlled with a cheap vitamin supplement.

While the effects of folic acid on cancer, Alzheimer's disease and heart disease are still under investigation there is no dispute about its effect on developing foetuses. But this message is still not getting through to pregnant women and every year children are born with debilitating conditions that could have been prevented with a simple vitamin.

There are two basic problems. Nearly half of all pregnancies are unplanned, not necessarily unwanted but unplanned. Also, folic acid is most important in the first 28 days of pregnancy when the baby's spinal cord is being formed and many women are unaware of the pregnancy at that stage.

Just over a year ago the US government decided to take action. They passed a law making it compulsory to fortify flour with folic acid. The law came into effect in January 1998 so last year every American received an increased dose of folic acid.

Scientists, studying the effects of this fortification, found that the number of people suffering from low levels of folate has dropped from one in four Americans to about one in fifty. The measure has been effective in preventing spina bifida. They've also discovered that levels of homocysteine, the chemical thought to affect heart disease, have dropped substantially. In a country where heart disease is the number one killer it's estimated that as many as 50,000 new deaths due to heart disease were prevented.

In the UK and Ireland two committees have been formed to decide whether or not to proceed with folic acid fortification. Professor John Scott is on both committees.

Cancer Research

Dr. Rosemary O'Connor - University College Cork

Cancer is the second biggest killer in Ireland. Every year more than 20,000 people in Ireland develop cancer and over 7000 die from the disease. For many years scientists have been searching for an achilles heel in cancer, something they can use to target only cancer cells. A new direction in cancer research is trying to understand what makes cancer cells grow so well when they are damaged cells. If scientists can discover the factors that make cancers grow so effectively in the body they can use these factors to target the cell and kill or contain the cancer.

There are hundreds of thousands of cells in the human body. Each cell has a specific function and is finely tuned to play its role in the day-to-day workings of the body. Yet each day our body is bombarded with potential threats - threats that range from sunlight to bacterial infections to physical injuries like cuts or bruises. Some of these threats will kill cells outright and that usually is the safest possible result. Others, however, can result in genetic mutations that can in turn cause the cell to become cancerous.

When a cell suffers damage it will try and commit suicide so as to prevent any disruption to the overall workings of the body. Our cells have an in-built altruism preferring to die rather than cause illness. In fact, our cells are so eager to die for the common good that they have to be constantly told to stay alive by chemical messengers that circulate in the blood. If these are missing a cell will go for the default option and self-destruct.

When the cycle of cell suicide, or apoptosis as its known scientifically, goes wrong there can be catastrophic effects for the body. If the cells don't die when they are damaged they may grow to form an 'immortal' cancerous tumour. If they commit suicide before their time, their absence may result in degenerative diseases like Alzheimer's or Parkinson's disease.

In UCC Dr. Rosemary O'Connor is working on a number of projects concerned with cell suicide or apoptosis. In her research she is trying to understand the factors that keep cancer cells alive. She is working in particular on a factor called IGF1, a survival factor that is abundant in our bodies and particularly abundant in cancers. She is trying to find a way to retrigger apoptosis, to tell the cancerous cell to kill itself.

Most of the current anti-cancer drugs will kill cancer cells but will kill all kinds of other cells along the way, hence the loss of hair during chemotherapy. Dr. O'Connor is hoping that her research along with the work of research teams all over the world will result in a targeted drug for cancer. She believes that within a decade some drugs will be on the market.

Robotics and the Disabled

Dr. Gerard Lacey - Trinity College Dublin

Technology in Ireland is usually seen, in a business context, as a means of generating wealth in the country. But technology has tremendous potential for helping almost every sector of our society - none more so than the disabled.

In Trinity scientists have used cutting edge robotics to help the elderly blind. They've developed a device known as PAM-AID that can give a new lease of life to people who without it would be totally dependent on others. The mobility aid both supports the person using it and tells them where they're going. It operates like an intelligent walking frame on wheels. It detects the environment around it and communicates options to the person using it. It tells them when they pass an open doorway, when the corridor turns to the left or when an obstacle is approaching.

PAM-AID is replacing sight for its users, to do so it operates at a very sophisticated level of robotics. It has taken over five years and a unique combination of skills to develop PAM-AID to this level. Dr. Lacey has worked with computer programmers, robotic experts and with the blind to design the most efficient device possible.

PAM-AID is now ready to go onto the market and the team in Trinity have set their sights on a smart house - a house that uses technology to make it more user friendly. Again the ultimate aim is that this technology will be of particular use to the disabled. One of the team of scientists suffers from MS and has volunteered his own house as an experimental prototype for the team to work on. This next project is still in its infancy but the difference in lifestyle it could make to the disabled is immense.

Pine Weavil

Professor Martin Downes, Dr. Christine Griffin - National University of Ireland, Maynooth

How do you fight something you can barely see? Use something even smaller - and more deadly.

This is the breakthrough lesson learnt by scientists at Maynooth, in the war against the pine weavil. These tiny creatures have the potential to cause devastating damage to Coillte's ongoing cultivation of forestry, which has become more and more important in recent times.

The problem has been that many of the Sitka Spruce trees that were planted some decades ago are ready for harvest, leaving space behind for new young trees to be planted. However, the stumps left behind are heaven to the pine weavil. These little beetles normally live harmlessly in the forest canopy but once the trees are cut down they come down looking for a place to lay their eggs. And the smell of freshly felled pine brings them running to the stumps. The eggs hatch into larvae which proceed to eat away at the stumps until, as fully formed adults, they emerge and look for entire trees to live on. What they find are young, tender, fragile saplings which they devour - putting paid to any hope of developing a new forest.

Then NUI Maynooth got on the case. They began looking for natural pesticides in the Irish forest which would control the levels of pine weavils and give young saplings a chance to get a foothold before facing the onslaught. What they discovered was a number of species of nematodes - microscopic worm-like creatures which use insects as places to breed and eat. They burrow into their host's body - looking for food and somewhere to lay eggs - and devour the insect from the inside out, with the help of bacteria they carry in their gut. One nematode will enter and devour the insect; but that one nematode will lay hundreds of thousands of eggs, all of which will eventually hatch and go on the trail of yet more pine weavil larvae to devour.

One of the advantages of using natural methods of pest control is that they are self limiting, and don't leave toxic leftovers in the soil. Once the nematodes have eradicated the pine weavils (and thereby their own food supply), they will gradually disappear.

Ocean Research

Professor Michael Guiry - National University of Ireland, Galway

Most of Ireland is underwater, in fact 90% of our territory is under the sea. Yet just 10% of our GNP comes from the oceans. The Martin Ryan Research Institute in NUI Galway is trying to change those figures.

The Institute was set up to research new ways of developing the marine industry in Galway. It also hoped to have a long term effect on the economy of the West Coast. With an improved marine industry the indigenous population could stay in place and the area wouldn't be so reliant on what many see as becoming a theme park for tourists.

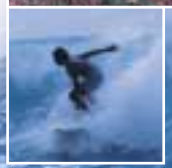
To fulfil the aims of the institute properly any project would have to be both sustainable and have low environmental impacts. In recent years problems such as BSE have arisen due to a cycle of animals being fed to animals and spreading infectious agents like BSE. Currently fish are being fed to fish and there are fears among some scientists that in time an equivalent disease could develop in farmed fish species. One project in Galway is trying to break the cycle.

They have developed a stronger, larger and faster growing variant of kelp seaweed. This new variant can be easily harvested from the sea two or three times a year, without causing environmental damage and it can be used for both human and fish consumption.

The native species of kelp that grows off the coast of Ireland does not grow sufficiently well to be an adequate food crop and harvesting the native species is environmentally disruptive. The new variant would be grown along ropes in the ocean from which the seaweed can be easily harvested.

Another project under way in the institute deals with the problem of nets dragging across the ocean floor. This is damaging to larval fish and reduces the size of the catch of years to come. As well as killing developing fish, the nets themselves get ripped and tangled which is expensive for fishermen. Researchers have simply put rollers on the nets which keep them off the bottom and protect the fish.

The director of the Martin Ryan Institute, Professor Michael Guiry, believes that the marine could in the future become as important as the biotechnology industry. Between £80 and £90 million worth of fish is landed in Ireland each year. In addition, £120 million worth of fish processing is carried out. Professor Guiry believes that in the long term fish processing must be developed as it is much more lucrative than selling whole fish. He believes that marine research is vital in finding new ways of exploiting the 90% of our territory that lies underwater.



Mathematics

Dr. Catherine Comiskey - National University of Ireland, Maynooth

Of all the areas of scientific exploration, mathematics is often seen as the most removed from the real world. However, in NUI Maynooth, Catherine Comiskey is applying this neglected science to some of the most real problems around us.

In her research she has focused on drug abuse. Opiates are one of the biggest health problems in poorer areas of Dublin. They are also the cause of most detected crime in the city. Over the last few years the Eastern Health Board and the Department of Health have been tackling the problem with methadone maintenance and drug treatment centres. The Gardai have been concentrating their anti-drug efforts on areas of the city with high levels of drug abuse.

However, to plan drug treatment strategies and long term management of the problem properly hard facts about addicts and their numbers are essential. Both the Judicial and the Health services need to know how many addicts there are, where they're located and whether or not their numbers are increasing.

While plenty of facts and figures about drug users were collected by the health services and by the judicial services, nobody was putting this information together to get a full picture of the scale of the problem. Dr. Comiskey's research has mathematically processed this raw data, creating a model that gives an estimate of the total number of opiate users living in the city. Her work has concluded that the problem is bigger than many had previously estimated, and she estimates that there could be as many as 13,460 opiate users living in Dublin.

Along with her team of researchers she is now embarking on a new study where she will mathematically evaluate the risk factors for developing an opiate addiction. It is hoped that her study will reveal which of the commonly accepted risk factors such as unemployment, lack of education and living in socially deprived areas, is the most important in encouraging drug abuse - so that health and education authorities can target their efforts at prevention.

Atmospheric chemistry

Professor John Sodeau, Dr. John Wenger - University College Cork

Ozone is essential to life on this planet, without this gas our planet would be a scorched wasteland. Ozone filters out the worst of the uv radiation and allows just enough through for life. The steady reduction of the ozone layer in the upper atmosphere has been well covered by the media over the last decade and is still a cause for concern. However, less well publicised is the increasing ozone levels in the lower atmosphere.

Ozone, while vital in the upper atmosphere, is poisonous to biological life forms and is dangerous in the lower atmosphere. There isn't enough ozone where we need it and there's too much where it can damage our health.

To know how best to approach the problem we need to understand what is causing the changes in ozone levels. In University College Cork a team of researchers led by Prof John Sodeau has been set up in the last year to tackle these problems. They aim to provide the scientific information necessary so that politicians can make informed decisions about how best to protect the environment.

They work by recreating atmospheric conditions in the laboratory. Prof Sodeau works on the upper atmosphere and recreates very low pressure conditions. He then adds tiny amounts of pollutants to see how they affect the gases and the ozone concentration.

Dr. John Wenger studies the lower atmosphere and sees how pollutants contribute to global warming. Again he recreates atmospheric conditions and injects small amounts of pollutants to see how they change normal atmospheric chemistry.

Nanotechnology

Dr. Donald Fitzmaurice - University College Dublin

Biotechnology was the new science of the 1980s. The boom in biotech made millions for Irish companies and their success continues today.

For the new millennium the buzzword is nanotechnology - a whole new area of science where systems operate at the molecular or atomic level. Nanotechnology can give control, accuracy and efficiency previously only dreamt of. Nanotechnology isn't going to change the way we do things but it is going to make existing technologies better.

In UCD Dr. Donald Fitzmaurice and his team have been conducting fundamental research in nanotechnology for the past five years and that research has lead to a marketable product. In fact, his campus company, Nanomat, will be one of the first companies in the world to go to the market with a nanotechnology based product. They have developed a car mirror that has an array of fused molecules that will change colour when an electrical current is passed through them giving a car mirror that can prevent glare.

It may not sound like ground breaking research but this automatically dimmable mirror has been taken on board by Donnelly Corporation, the company that produces 10% of everything that goes into cars around the world.

Dr. Fitzmaurice and his team are now raiding biology where individual molecules have long been communicating with each other, to find more and more efficient ways to deliver drugs to the sites where they are needed most in the body. They are trying to locate markers on cells, individual molecules that lie on the outside of particular types of cell. They will then try and develop a nano crystal that will seek out and bind to this cell marker. So, for example, if a drug is designed to work in the liver, they will find a molecule on a liver cell that identifies the cell as belonging to the liver, then find another molecule that will bind to the marker and then attach the drug to this binding molecule. This system will ensure that the drug only ends up where it's needed in the body.

Other projects the nanotechnology team are involved in range from supermarket pricing systems to camcorder technology

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