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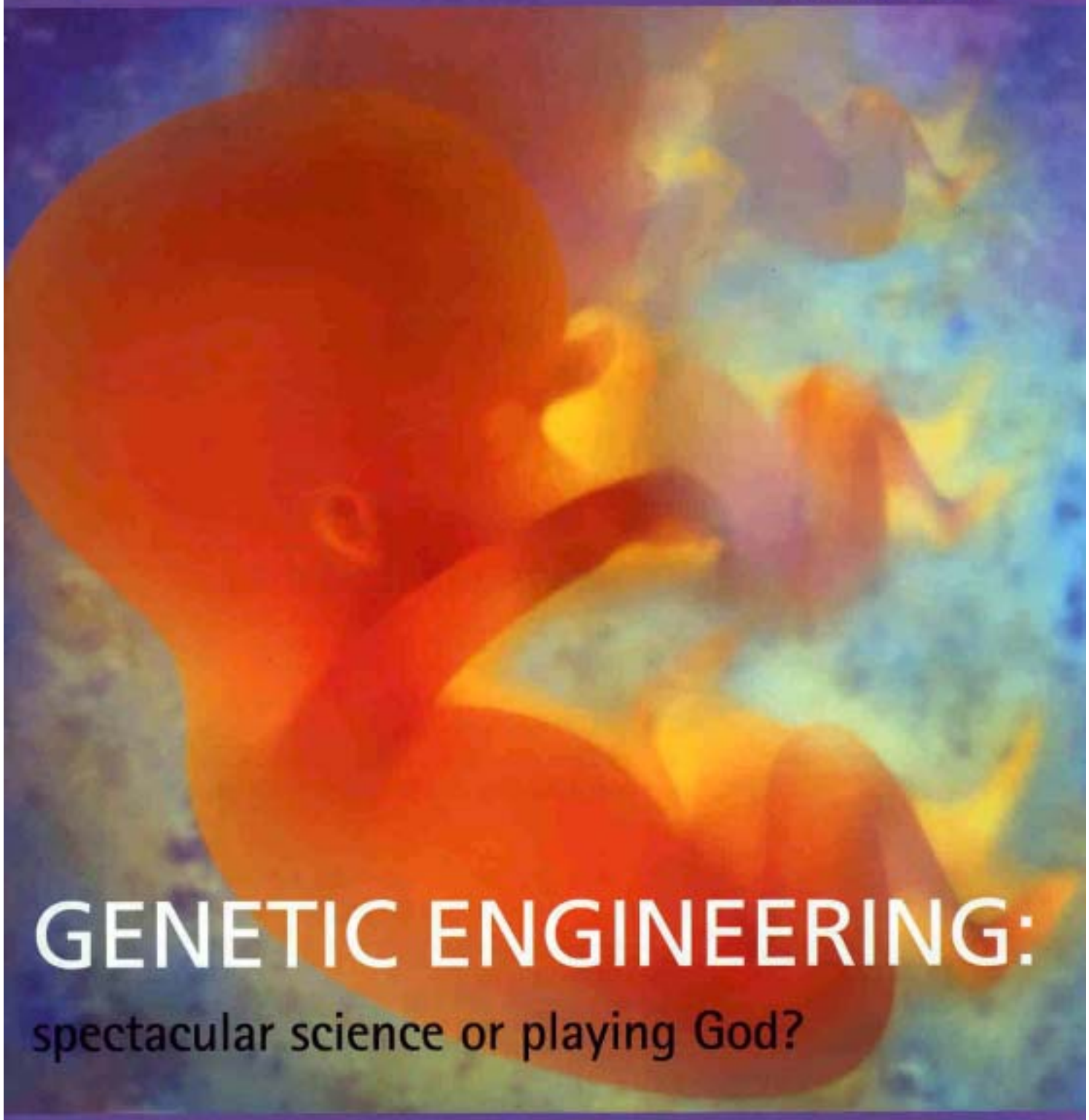

GENETIC ENGINEERING:

spectacular science or playing God?

Foundation for Education, Science and Technology

Department of Science and Technology

Archimedes magazine is a quarterly publication of the Foundation for Education, Science and Technology (FEST). It is published on a non-profit basis, to promote interest and knowledge about science and technology to the youth of South Africa, as well as their families and educators.

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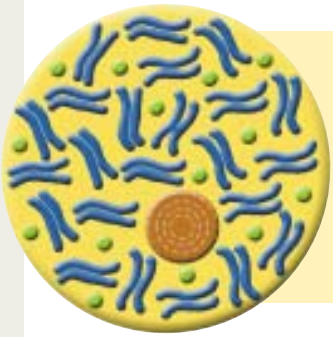
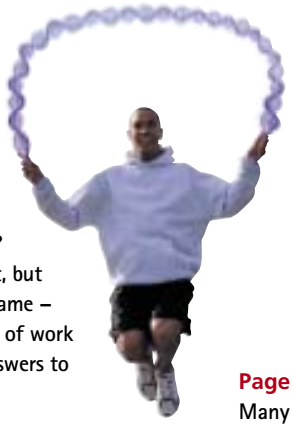
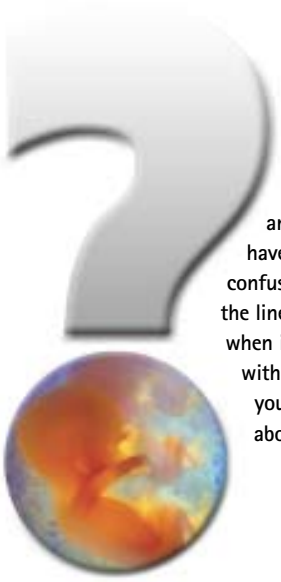
In the news



DNA





contents

Department of Science and Technology

Foundation for Education, Science and Technology

Some of you may have heard of molecular biology. But for Francis Crick and James Watson, the scientists who unearthed the existence of DNA as a double helix, this field of biology is basically one that they founded.

In this edition of *Archimedes* we are joining world-wide celebrations of the 50th anniversary of Crick and Watson's discovered DNA and will be uncovering why their efforts are worth celebrating so many years down the line.

The key to getting the most out of this issue will be to read "The story of DNA" on page 11. This article will help you to understand the basics of DNA and sets the scene for the rest of the articles in the magazine, which include an in-depth look at:

- the Human Genome Project (on page 17) which is a project that has captured the attention of the world for a number of years;
- a look at the debate on genetic engineering and cloning (on page 20);
- a discussion on the ethics of cloning (on page 26) which is a matter of serious and heated debate around the globe; and
- a short look at how our genes and lifestyle play a part in whether or not we are likely to develop diseases or not (on page 28).

So far, the advances in science, and particularly in the human sciences, that have resulted from the discovery of the double helix are astounding, but predictions are that this is just the tip of the iceberg and that there are much more exciting times ahead.

The last section of *Archimedes* is therefore devoted to telling you about the careers available in the field of molecular biology. We contacted a number of South African universities to find out what they have on offer and then asked some of their students what it was like to study towards a career in this field.

Not surprisingly, most them raved about their experiences. But, don't take my word for it. See what they had to say for yourself on page 36.

The Ed

Exciting times

Kelebogile Dilotsotlhe,
Manager PUSET

Almost 50 years ago to the day, two scientists by the name of Watson and Crick published a paper which described the structure of DNA as what they called a "double helix". While this was for them a great achievement, they surely could not have imagined the effect that their research would have in years to come.

Since pinpointing this structure, it could be argued that their work has changed the face of the living sciences into a much more exact science, which seems to become more and more exciting by the day. Studying DNA has not only allowed us to better understand the human body, but has also given us the power to change the characteristics of plants and animals to better suit our needs. DNA testing has also made the jobs of law enforcers easier since the introduction of DNA fingerprinting.

During the past few decades, we have seen interest in the science of genetics and DNA explode, and as technology becomes more advanced – making new things possible – genetics research has become a very fashionable career choice.

In South Africa, genetics is part of most universities' syllabi, which means that, as learners, you are assured of having access to the education you need to become a "Proudly South African" geneticist. The question, of course, is whether you have the willpower to work towards such a groundbreaking career. I strongly believe that if you have a passion for a subject, then hard work is all that is needed to complete the mix. So, if this is what you want to do, then go for it and don't look back.

I would also like to take this opportunity to wish you good luck for 2003. I trust that you will work hard and think carefully about the subjects you choose. Always remember that these choices play a part in deciding your future!

Best wishes,

Kelebogile Dilotsotlhe
Manager PUSET (Public Understanding of Science, Engineering and Technology):
Department of Science and Technology

In the news

howzat?

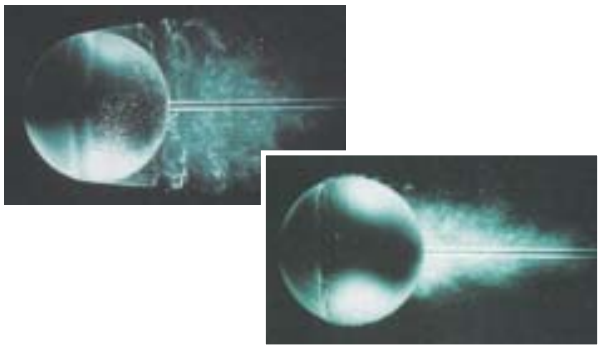
by Mike Bruton, Head: MTN ScienCentre, Cape Town

Cricket is full of science, maths and technology - batsman's wagon wheels, bowler's manhattans, consistency analyses, batting averages, trajectory, momentum, acceleration, stump cameras and ball speed measurers are all examples of the way in which maths, science and technology have crept into the ancient game, which has been played for over 400 years.

The most fascinating aspect of the science of cricket is the role played by the seam on the ball. The cricket ball consists of a cork/rubber core, wound with thread and covered by two hemispherical shapes of leather. The leather halves are sewn together to form the seam, which stands "proud" of the ball and interferes with the airflow over the ball. The airflow over the two halves of the ball on either side of the seam is determined by the state of the ball, whether it is new or old, smooth or rough. The flight characteristics of the ball therefore change during the course of a match as the ball becomes older.

Interestingly, rough balls travel through the air more easily than smooth balls! As the air flows over a smooth, new ball, it breaks away from the surface of the ball soon after passing the outer bulge, forming a pocket of swirling currents behind the ball, like the wake behind a boat. This wake creates drag and slows the ball down. The faster the ball moves, the larger the wake, and the more drag.

In the diagram, the ball on the left is smooth and the one on the right has a wire around it, simulating the seam on a cricket ball. The small amount of turbulence created by the wire causes the air to stick to the ball's surface for longer, thus making a smaller wake. If the ball is bowled with the seam at a steady angle, the air will break away sooner on one side than on the other, forming an asymmetrical wake,



which will cause the ball to swing in the air.

This swing will be accentuated if one side of the ball is smoother than the other, which is why you often see the bowler shining the ball on one side. The weather may also affect the flight of the ball as air flow patterns depend on the properties of air (density and viscosity) and the ball (roughness, speed and spin). Air is denser and more viscous in damp weather, and the ball may become rougher and easier to spin when it is moist. The effect of these variables is not, however, fully predictable, which is why cricket is always so full of surprises!

If you are stumped by the intricacies of cricket, don't miss the "Howzat? Science of Cricket" interactive exhibition at the MTN ScienCentre, Canal Walk from 8 February to 11 May 2003. To find out more call: (021) 529-8100 or visit www.mtnsciencentre.org.za

Test your knowledge

This year's World Knowledge Olympiad 2003 for both primary and secondary learners will take place on Tuesday 13 May 2003. Its main purpose is to enhance learners' general knowledge by encouraging them to read newspapers on a regular basis.

The Olympiad has been running for 12 years and has grown from strength to strength with regular sponsorship from Sanlam. This year, Sanlam's sponsorship is allowing the competition to offer a number of prizes – for both learners and schools – amounting to R112 000. All the prizes come in the form of unit trust investments in order to encourage a culture of saving among the learners.

Those schools wishing to take part in the competition and whose principals have not already received entry forms) should contact Prof Nico du Plessis before the closing date for entries, which is 25 March 2003. Prof du Plessis' contact details are: **Tel: (051) 436-4193; fax: (051) 436-1977; or email: nico@bigfivegame.co.za**

Coming Soon!

The National Science, Engineering and Technology Week

Are you still not sure whether a career in science, engineering and technology is what you want to do? Then a visit to this year's National Science, Engineering and Technology (SET) Week is what you need.

The event, which is hosted by the Department of Science and Technology, will take place from 5-10 May 2003.

Fascinating, informative and entertaining events will take place in all nine provinces as part of the celebrations. Events will include exhibitions, displays, interactive lectures and talks, demonstrations, workshops and science shows.

This year, National SET Week is positioned to be bigger, better and more imaginative than ever before.

To find out more about the events taking place in your province, contact the national project manager, Lesley di Santolo on: (012) 392-9335 or email: lesleyd@fest.org.za

Learners getting down to business at last years SET week.

How much will war cost?

The talk of war in Iraq has undoubtedly been the biggest news so far this year, and continues to dominate news bulletins around the world. However, while the idea of war in itself is a frightening concept, we don't often stop to think how much war will cost if it does happen.

When we speak of cost, we are not only talking about how much money it will cost, we also need to take into account:

- the number of lives that will be lost;
- the environmental costs; and
- the historical/archaeological costs.

In an online special edition of *NewScientist.com*, Fred Pearce approached MEDACT (a UK-based organisation of doctors set up to study the health consequences of conflict) to answer these questions.

According to MEDACT a war in Iraq could result in between 10 000 and 50 000 people losing their lives, half of which will be civilians (probably living in Baghdad).

If the weapons of mass destruction (ie, chemical, nuclear and biological that the United States believe are in Iraq, do come into the picture, this would add another 20 000 lives to the fatalities.

At worst, half a million people could lose their lives as a result of war in Iraq. This figure takes into account post-war famine, global recession due to soaring oil prices and an Iraqi military strike against Israel, which could result in nuclear retaliation on Baghdad.

Environmentally, the war could also have some devastating effects, including:

- if Saddam Hussein sets the Iraqi oil wells on fire, the smoke from the burning wells could have a negative effect on global climate and air pollution. Extinguishing the flames will also be difficult due to the wells containing gas;
- oil spills will damage the desert by creating a hard crust of sand and oil; and
- the digging of trenches and heavy war machinery in the desert could create sand dunes that will last for many years.

Iraq also has a lot of history and is home to ancient cities such as Ur, which was one of the earliest cities in the world. In southern Iraq, the highest ground is often on top of archaeological sites. These sites would probably be destroyed by bombs.

It would be hard to quantify, in monetary terms, the costs of the above losses, not only to the people living in the Middle East, but also to the rest of the world. However, it is important to remind ourselves that the costs of war are not just about money.

COMPETITION

Encouraging a culture of reading for all

While the reading of books does not strictly fall into the realm of science and technology, *Archimedes* believes that encouraging a culture of reading is essential to learners interested in all disciplines whether it be art or physics.

People claim that the culture of reading is significantly less vibrant than it used to be. Many think this is a result of the Internet, television, movies, parties and just simply too much other entertainment. But if that is the case, then why do we have this movement of hip, curious and creative young people writing poetry, drafting short stories, writing plays and crafting movie scripts? Why is there a sudden excitement about poetry readings and performances?

Bookeish is an organisation that aims to promote a new literary culture. And as one concrete way to do this, Bookeish has launched a competition for young writers and readers in high schools across the country.

A hundred township secondary schools have been chosen in the Western Cape, Gauteng and Limpopo provinces to participate. The competition, however, is not limited to these schools – any other school interested in participating will be warmly welcomed.

The aim of the competition is to take Africa's top 100 list of bestsellers into high schools. Publishers have donated copies of the available books on the list to these schools. Teachers will be be asked to establish reading groups of between four and six learners. These "book clubs" will then be encouraged to read from the list. The first groups to read 10 of the books will automatically be entered into the next round of the competition. Semi-finalists will then submit essays on five of their favourite books. They will also be entered into a quiz to test their knowledge on these books. The prize for the top teams and their teachers will be a weekend writing workshop in the Magaliesberg.

Bookeish has appointed a panel of eminent literary judges to judge the winning essays.

Well known (and lesser known) writers and poets will be visiting the schools to boost the book clubs' energy and enthusiasm.

Ultimately, Bookeish's aim is to use this competition to boost a reading culture in schools (and beyond) and to lay the groundwork for a new generation of African writers and poets to create works for the 21st Century!

For more information contact: Shireen Badat, programme manager: tel (011) 280 5017; or cell 082 377 4346.

Vaughan's future's in butterflies

Vaughan Jessnitz, a grade 11 learner from Postmasburg High School, recently proved that your passion can take you places. His interest in insects – particularly butterflies – has taken him from Postmasburg to Stöckholm, Sweden!

Vaughan represented his school at the Eskom Regional Expo for Young Scientists in Upington, where he won a gold certificate. On 4-5 October he represented the Northern Cape at the National Expo in Pretoria, where he was awarded the Derek Grey Award. From there, he was invited, as an honorary guest, to the Nobel Science Awards in Stöckholm, Sweden, in December. Over 28 countries were represented at this prestige event and Vaughan was the only South African.

Vaughan's interest in insects started when he was young. About four years ago two researchers came to Witsand Nature Reserve, where he lives with his parents, and Vaughan had to show them the different ecosystems. He took a serious interest in what these two people were doing – butterfly research. A new hobby started when he made a net for himself and started collecting butterflies.

About two years ago the hobby became more serious when he found that a few insects were very dependent on climate and would change their habits according to the rainfall, some species more than others. He stopped collecting butterflies for the sake of collecting and rather researched the insects and used them as bio-indicators. (Bio-indicators are those factors which collate the effect the environment has on insects.) There are about 12 species in his collection, which are semi-reliable, and four are 100% reliable. His research has allowed him to conclude and accurately prove that when the 100% reliable species are flying, rain can be expected within 24 hours.

A novel way to predict the weather, don't you think?

A website to help you make some serious choices

Do you want to choose a career? Do you want to further your education? Do you want to find somewhere to study? Do you want to be happy and successful? Visiting www.seriouschoices.co.za can help you do all this.

Educor, the holder of major brand names in private education (including the Damelin Education Group, the Graduate Institute of Management and Technology, Midrand University and Business School, Allenby Campus, Varsity College, Intec, Success College and Lyceum College) has launched this website with the aim of helping those who need sound career advice. And, the good news is that most of it is free of charge.

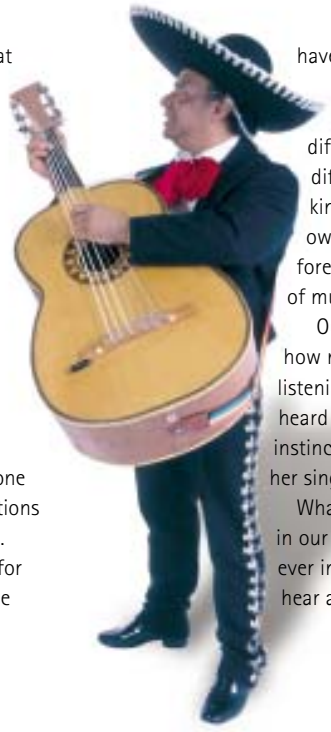
Serious Choices is a website that offers to:

- assess you as an individual and give you a career direction;
- help you to explore career and course options to make a more informed career decision;
- help you decide what studies you need to do;
- store your personal profile and test scores; and
- provide a printed report of your personal profile.

The website is comprehensive and has been designed for easy navigation. It is the only site in the country that provides courses offered by more than one educational institution. It covers all geographical areas in South Africa, all universities, technikons, technical colleges and the largest group of private colleges in South Africa.

The site provides the critical questions a person needs to ask about a specific career direction before embarking on it, so that career choices can be viewed objectively. The website is about self-discovery and self selection for the right career, and puts people in charge of their career decisions.

MUSIC – A LEGAL DRUG



The Journal of Science recently published an article that helps explain why the music industry is so lucrative ... because music grabs holds of brains and generates emotional responses, similar to the way drugs do.

The study, done by neuroscientist, Petr Janata, shows how the rostromedial prefrontal cortex – the region in the brain that tracks music – is also used during reasoning, memory retrieval, processing emotions and maintaining a sense of self.

This helps to explain why music is tied to our personal experiences, for instance, many of us will associate music with childhood memories such as our first slow dance with someone.

However, while Janata's discovery of this musical tracking centre is interesting, she says that it is only one piece of the musical puzzle. There are still many questions that need to be answered about our brains and music.

For instance, we know that music is not necessary for human survival, yet throughout human history, people have created music and integrated it into cultural and religious ceremonies.

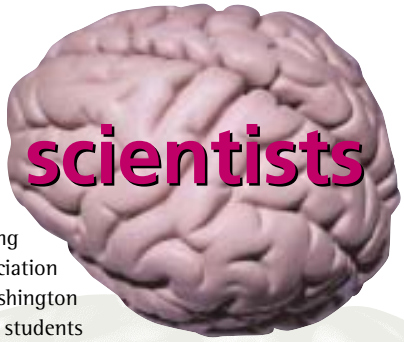
Scientists are also interested in finding out why different cultures like different music that is played in different tones. They believe that, depending on what kind of music we are exposed to, we will create our own "harmonic space" and therefore listening to foreign music tends to not fall into our expectations of music.

Our "harmonic space" would also help to explain how music can "hurt" our ears. In other words, if we are listening to someone singing a song that we have never heard before, and the person sings out of tune, we will instinctively know that the person is out of tune, as his/her singing does not follow the basic harmonic rules.

Whatever the reasons, music plays an important part in our lives from the moment we are born. Have you ever imagined what life would be like if you couldn't hear and, therefore, not listen to music?

International competition

Siemens awards young scientists



As one of its contributions to the advancement of science and technology world-wide, Siemens has announced the winners of the 2002-03 Siemens Westinghouse Competition in Maths, Science and Technology.

Steven J Byrnes, a senior at Roxbury Latin School in West Roxbury, Massachusetts, won the top prize in the individual category and a US$100 000 scholarship for his mathematics project, entitled "Poset-Game Periodicity".

Juliet R Girard and Roshan D Prabhu, seniors at William L Dickinson High School in Jersey City, New Jersey, won the top prize in the team category and will share a US$10 000 scholarship for their project, "Identification and High Resolution Mapping of Flowering Time Genes in Rice".

Albert Hoser, Chairman and CEO of the Siemens Foundation, which awards more than US$1-million annually in scholarships and grants through the Siemens Westinghouse Competition and other programmes, said: "It is inspiring to see these extraordinary highschool students working at the highest levels in science, mathematics and technology at such an early age."

The three received their awards during a ceremony held at the American Association for the Advancement of Science in Washington DC on December 9, 2002. Some 1 142 students which entered the 2002-03 competition, including 836 individual competitors and 306 teams. Prominent scientists and faculties from six leading research universities – which also host the regional competitions – judged entries at the regional and national levels.

Siemens awards South African schools

Closer to home, Siemens sponsored last year's floating trophy for the "Best Engineering Project" of the 20th Young Scientists Fair held in Windhoek, Namibia, and has also entered into an agreement with the National Department of Education in South African to run a nation-wide competition that recognises schools in previously disadvantaged communities that excel in the fields of maths and physical science.

Siemens donated 32 desktop personal computers to two Limpopo Province schools – Mbilwi High and Motse Maria Secondary – which were given the award for being the top performers in these subjects countrywide.

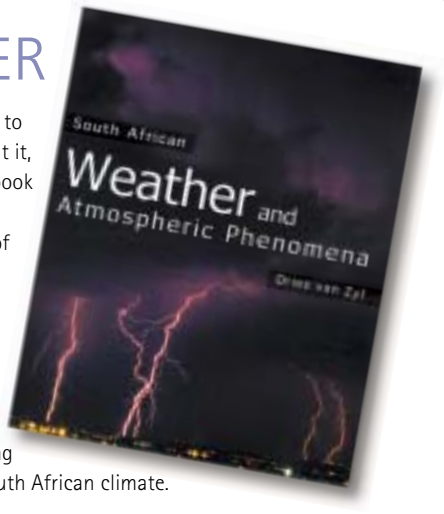
THE WONDERS OF SA WEATHER

After the recent heatwave that swept the country, many of us are left wondering what it was that caused it. The weather in South Africa is unique in the world and many foreigners have commented that our country the best place to be, weather-wise. Briza Publications recently published a book which looks specifically at South African weather and explains what makes it so special.

South African Weather and Atmospheric Phenomena by Dries van Zyl, is a stunning book for everyone who has ever wondered at the beauty and the dangers of the skies. It answers questions like:

- Why is the sky blue?
- What are the dynamics of a lightning flash?
- Where is the end of the rainbow?

The state of the weather colours every day of our lives, but although it is an inexhaustible subject, few people have more than a superficial understanding of its dynamics.



If you would like to find out more about it, this is the perfect book for you. Filled with beautiful pictures of clouds, lightning, rainbows, sunsets and other optical phenomena of the skies, you will thoroughly enjoy reading and learning more about our South African climate.

If you would like to buy this book, please visit your nearest good book store and ask for it by name and author, or give the following ISBN number: 1 875093 32 X.

The story of DNA

A step-by-step guide to understanding deoxyribonucleic acid and its functions in a cell

All this talk about genetic engineering and cloning sounds so impressive that most people are intimidated by the subject and would never consider themselves clever enough to seek a career in such a complex field. While there is no doubt that genetics and molecular biology are challenging career paths, they are certainly within your reach, even if you are not an A+ student. If you find genetic engineering interesting and exciting, then half the battle is won.

The next thing you will need to do, is find out more about it, and that's as easy as reading a magazine (like *Archimedes*), surfing the Net, or visiting a good bookstore/library. The first thing an aspiring genetic engineer will have to master, is a clear understanding of that wirey stuff called deoxyribonucleic acid (DNA) and why it is so important.

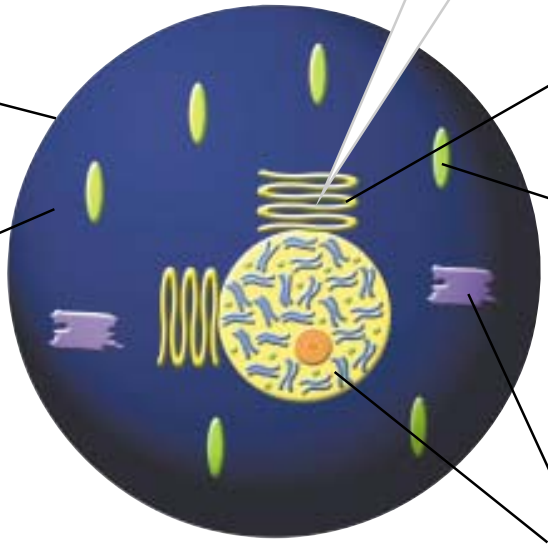
In the next few pages is a step-by-step guide to the basics of DNA. We will start by looking at its place in a cell and then gradually zoom in until we can see what it consists of and how it functions. To keep things simple, we will be looking at an animal heart cell, but it is important to remember that genetic engineering is not just about humans and animals. A lot of very important genetics work is being done in plants as well (for example, in the field of biotechnology, which was covered in the last issue of *Archimedes*).

Enjoy the trip!

THE (ANIMAL HEART) CELL

All the cells in an organism, such as a person, contain the same DNA, but the cells do not all look the same and will differ according to the functions that they have. Cells will take on different shapes and functions depending on which parts of the DNA in that particular cell are "switched on" or "switched off".

The heart cell consists of:



A plasma membrane

Cytoplasm (the cytoplasm is made up of inyosin fibres and actin fibres. The fibres slide up and down to cause the contraction and relaxing of the heart muscle. Heart muscle cells contract automatically, while others, such as your leg muscles only contract when you want them to. In order to do this, the cells use energy which is created by breaking down sugar and oxygen in the cytoplasm)

zooming in...

(a ribbon-like membrane dotted with ribosomes)

A few endoplasmic reticulum (a ribbon-like membrane dotted with ribosomes)

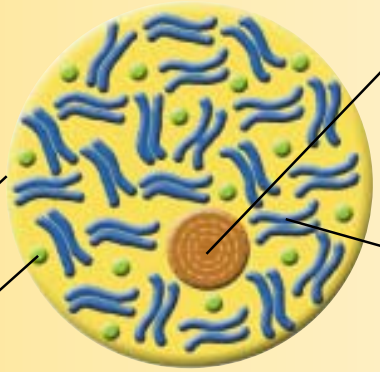
A number of mitochondria (the mitochondria are experts at breaking down sugar and oxygen into energy. The energy released from the mitochondria is used to do work like contract muscles, make DNA and proteins, and help us keep warm. They also contain their own DNA, called mitochondrial DNA)

A number of golgi

A nucleus

The cell nucleus

The nucleus of a cell is where most of the DNA is stored. DNA is the most significant part of the cell as it carries the genes that ensure that we have all the right body parts, as well as the genes that set each one of us apart as individuals. If our genes were the same, we would all look the same! The nucleus consists of:



The nuclear membrane; nucleoplasm

Nuclear pores (RNA, which serves as the messenger between the DNA and the rest of the cell, is born in the nucleus and leaves through the nuclear pores)

The nucleolus

DNA (a set of chromosomes pairs which consist of two strands: one from the mother and one from the father. DNA is also known as the chromatin network. Human DNA consists of 23 chromosome pairs)

DNA

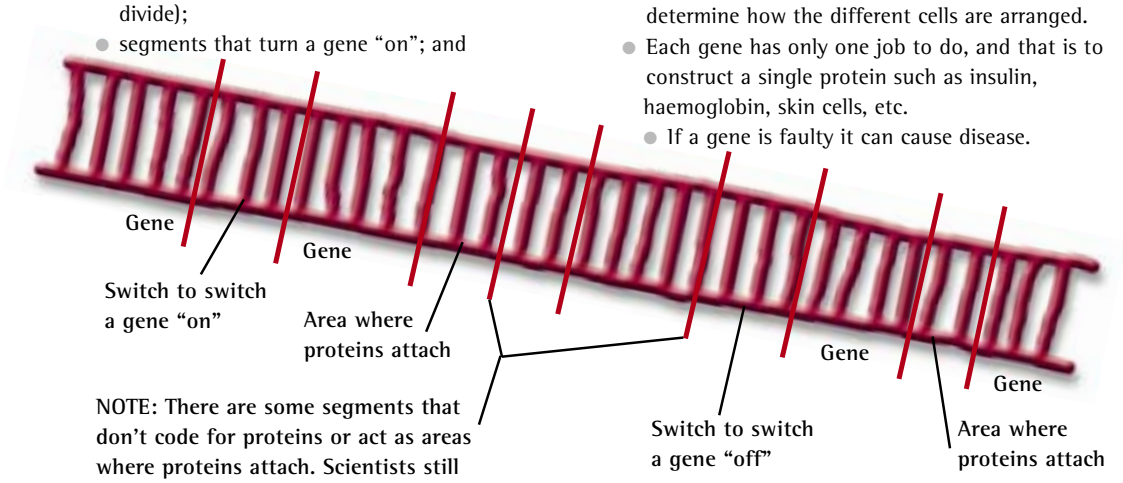
DNA is a long fibre, like a hair, that is made from two chromosome strands stuck together with a slight twist. DNA is organised into:

- segments of genes;
- segments where proteins attach to the DNA when it needs to coil into chromosomes (this usually happens when the cell is getting ready to divide);
- segments that turn a gene "on"; and
- segments that turn a gene "off".

NOTE: Only 80% of our DNA codes for proteins or regulate genes. Scientists don't know what the other does!

Genes and their functions

- Genes, which are segments of DNA scattered along the length of the strands, carry the instructions for making all the thousands of proteins that are found in a cell. They also determine how the different cells are arranged.
- Each gene has only one job to do, and that is to construct a single protein such as insulin, haemoglobin, skin cells, etc.
- If a gene is faulty it can cause disease.



NOTE: There are some segments that don't code for proteins or act as areas where proteins attach. Scientists still need to figure out what they are for

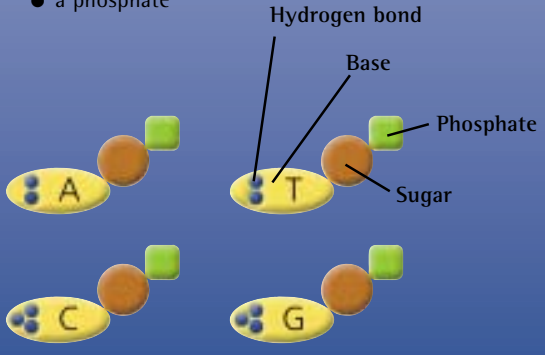
Above: DNA as a chromosome pair

AN EVEN CLOSER LOOK AT A CHROMOSOME PAIR

As was mentioned before, a chromosome pair is two strands of DNA which have coiled up together as a result of proteins that attach to them. These are made up of nucleotides.

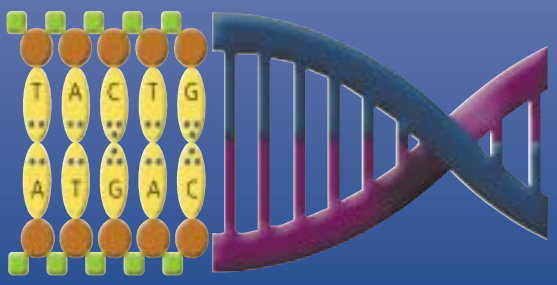
Nucleotides are made of:

- a base;
- a sugar; and
- a phosphate



There are four types of bases, namely:
C – Cytosine (three hydrogen bonds);
G – Guanine (three hydrogen bonds);
A – Adenine (two hydrogen bonds); and
T – Thymine (two hydrogen bonds).

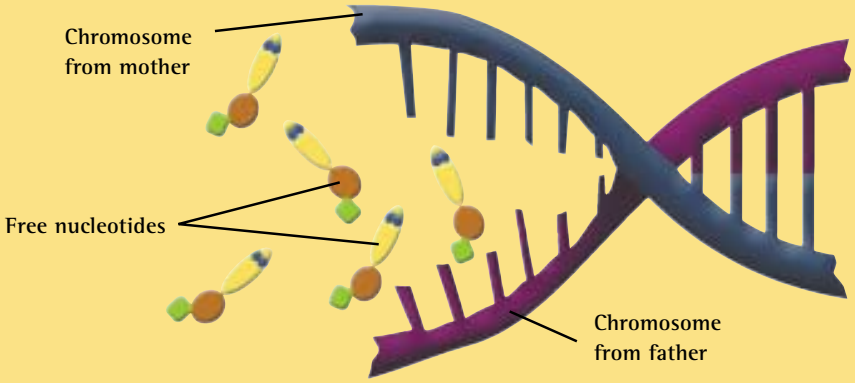
NOTE: The number of hydrogen bonds that each base has determines which bases will stick together when they come into contact with one another. Therefore, A and T go together and C and G go together.



DID YOU KNOW: All the DNA in one human nucleus contains 2,5 billion nucleotides, which would explain why the Human Genome Project has taken so long (see article on page 17)!

Demystifying DNA replication

Making a copy of a chromosome pair can be compared to making two zips out of one. In order to make a replica, an enzyme (which is a type of protein) called DNA Polymerase is needed.



Here's how it works:

1. A small section of the old chromosome pair unwinds and pulls apart by breaking the hydrogen bonds.
2. Free nucleotides float in and attach onto a partner with the same hydrogen bond (ie, A pairs with T and C pairs with G).
3. Once this pulled-apart section is filled with new partners, another section of the DNA gets pulled apart and the process continues.
4. When the process is complete, there are two brand-new chromosome pairs that are exact replicas of one another. Each has a strand from the original DNA and a new strand constructed by free nucleotides and DNA Polymerase.

WHAT IS RNA AND WHY IS IT IMPORTANT?

While our DNA contains our genetic coding and therefore is the most important part of a cell, it would be useless if there wasn't a way for it to transfer that information to the rest of the cell.

Luckily, RNA acts as DNA's "right-hand man" by making sure that instructions from the DNA are carried out in the cell. But how does it do this?

As we mentioned before, each gene (which is a stretch of DNA) is coded to make a particular protein. But, in order for a protein to be made the "switch" that controls when that particular protein should be made and when it shouldn't, needs to be "on".

For example, the cells in your pancreas are mainly there to make insulin. If you have just eaten something, your body needs to make insulin in order to properly digest the food. Once the DNA in the cells of the pancreas have registered that there is food that needs digesting, the switch which allows for insulin to be made, turns "on".

While RNA is smaller, it looks more or less the same as DNA, as it is also made up of nucleotides. However, one of the bases in the RNA is different. Instead of Thymine, RNA has Uracil.

What is the process?

1. RNA is made in the nucleus and its making is controlled by the enzyme, RNA Polymerase, which ensures that the right type of RNA is made for the protein it is going to make.
2. Once the RNA is made it moves through the nuclear membrane into the cytoplasm.
3. As soon as the RNA gets into the cytoplasm, ribosomes which are found in the endoplasmic reticulum (see original diagram of the heart cell), attach to the RNA. Ribosomes are able to translate the secret code of the RNA's nucleotide sequence to make a protein with the correct amino acid sequence.
4. The ribosome translates the RNA's secret code and works out which amino acid belongs where. Once the amino acids are in the right order, they are super-glued together. This chain of super-glued amino acids is called a protein.

Isolate DNA from wheatgerm!

Genetic engineering is a very simple process when we look at the basic activities involved. To understand this simple process we have to have a very basic understanding of DNA, proteins and enzymes. As is clearly explained in the previous article, DNA consists of genes, and the genes contain the "programmes" or "codes" that produce proteins.

Some proteins are enzymes and enzymes control cellular functions. All organisms consist of cells where each cell is performing certain biological functions. If we now change the genes within the DNA of the cells, different enzymes will be produced and therefore the cells will perform different biological functions.

The very basic objective of genetic engineering is to completely or slightly alter the genes within the DNA of an organism, to allow that organism to produce different proteins and enzymes and therefore perform different, more desirable biological functions. These different functions result in different behaviour, performance, or characteristics of the particular organism.

However, before this can be done, one first has to isolate the DNA of a particular organism.

Isolating DNA is not as difficult as you think. In fact, it was first done in 1869 by the Swiss scientist, Frederick Miescher. However, splitting the DNA and replacing genes is quite something else. Even more difficult, is to keep the new DNA in the cell. This is the major reason why it took more than 100 years to progress from isolating DNA, to the point where we are today.

To isolate DNA yourself, follow the instructions on the next page and end up with visible DNA. Although each DNA molecule is obviously too small to view individually, it is quite visible and amazing to see one of the basic elements of life – isolated DNA. This experiment will allow you to extract DNA from plant cells and takes about an hour to perform. Enjoy!

To isolate DNA in this experiment, you will need to find a few chemicals, basic equipment and raw wheatgerm. The items you need include:

1. A cup of wheatgerm (you can buy it at any health shop or even at some grocery stores)
2. Normal table salt (about 8 heaped teaspoons full)
3. Clear alcohol (something like Cane spirit or Gin would do just fine!)
4. Washing-up liquid (not the gel type)
5. Lemon juice (bottled lemon juice is fine)
6. Two glass bottles or large glasses
7. A sieve or even a tea strainer
8. Clean water
9. A teaspoon

Isolate DNA from wheatgerm!

STEP 1

BREAK DOWN THE CELL WALLS OF THE WHEATGERM.

Using a large glass, dissolve one level tablespoon of salt in 300ml of cold water. Add four squirts of lemon juice. Now add half a cup of wheatgerm to the solution and stir gently for 15 minutes. The lemon juice will break down the cell walls of the wheatgerm. Press this mixture through the sieve or strainer and discard the liquid. You will be left with a soggy pulp. Do this again for the other half a cup of wheatgerm. The soggy pulp you now have, contains the cell contents without the cell walls.

STEP 2

DISSOLVE THE DNA

Put one level tablespoon of salt in 300ml of water, stir the mixture until the salt is dissolved and add six teaspoons of alcohol. Add nine large drops of the washing-up liquid and stir gently. Add the soggy pulp from step one and stir it gently for about 20 minutes. During this period, the detergent in the washing-up liquid, will dissolve the DNA into the mixture. Now add about 10 level teaspoons of salt and stir gently for 10 minutes.

STEP 3

SEPARATE THE DNA SOLUTION FROM THE MIXTURE.

This step is quite easy – just let the mixture stand and allow the solids to settle out. After the solids have settled, gently pour the solution (liquid) into another glass, until it is about a quarter full, taking care that the solids do not mix with the solution. The solution in the new glass now contains the DNA in a dissolved form.

STEP 4

EXTRACT THE DISSOLVED DNA FROM THE SOLUTION.

Take the quarter-filled glass, fill it up with alcohol and stir very gently. As you stir, you will notice that the DNA precipitates out as very fine white threads. You can leave this mixture to further allow the DNA to settle. Gently pour the liquid off and *voilá* – there is your DNA!

The biggest microscopic riddle ever

Mapping the human genome

Imagine a riddle with over 2,5 billion parts ... can you see it? Now, add to this the extra challenge of not being able to see the parts – unless you look at them under a super-duper microscope – and that is the Human Genome Project (HGP). Doesn't sound like the kind of riddle that could ever be solved, but the sequencing of the human genome – which is all the DNA in our cells – is on the verge of completion, with an accuracy of 99,99% (fewer than one mistake for every 10 000 letters). Those who initiated the project believe that it is going to drastically change the face of medicine and the way that doctors go about treating their patients in the future.

The history of the HGP

The HGP began in the United States in 1990, when the National Institute of Health and the Department of Energy joined forces with international partners to decipher the massive amount of information contained in our genomes. Frequently ahead of schedule, HGP scientists have produced an increasingly detailed series of maps that help geneticists navigate through human DNA. They have mapped and sequenced the genomes of important experimental organisms. They completed a working draft covering 90% of the human genome in 2000 and, by the end of 2003, they will finish the sequence.

Why is the HGP such a big deal?

The HGP, the international quest to understand the genomes of humans and other organisms, will shed light on a wide variety of questions, like:

- How many genes do we have? (it is currently estimated that we have between 35 000 and 100 000 genes)
- How do cells work?
- How did living things evolve?
- How do single cells develop into complex creatures?
- What exactly happens when we become ill?

It is also believed that the HGP will give us insight into the fundamental mechanisms of life and lead to an era of molecular medicine, with precise new ways to prevent, diagnose and treat disease.

What is genomics?

Genomics is the study of all the DNA – or genome – of an organism. This includes mapping and sequencing the genome, as well as any variations or mutations or changes in DNA spelling that prevent proteins from functioning normally and result in health problems.

What are the main goals of the HGP?

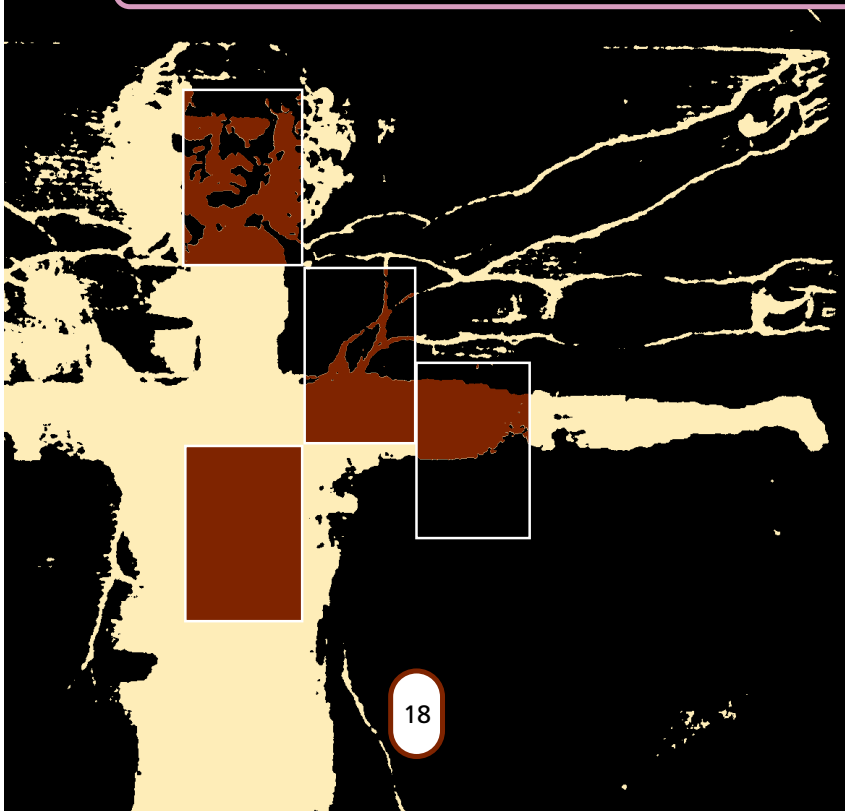
1. To map and sequence the human genome.
2. To map and sequence the genomes of important model organisms such as: e-coli, yeast, the roundworm, the fruit fly and the mouse.
3. To collect and distribute data. This includes the commitment to:
   - release within 24 hours all sequence data that spans more than 2 000 base pairs;
   - create and run databases;
   - develop software for large-scale DNA analysis; and
   - develop tools for comparing and interpreting genomic information.
4. To study the ethical, legal and social implications of genetic research.
5. To develop technologies that make large-scale sequencing faster and cheaper, and technologies for finding sequence variations.

What does "sequencing" and "mapping" involve?

In "The story of DNA" on page 11 it was explained that DNA is made up of nucleotides distinguished by their bases, which are Adenine, Thymine, Cytosine and Guanine. There are over 2,5 billion nucleotides in human DNA which occur in different sequences. Sequencing the DNA involves recording the order in which the nucleotides are arranged in their chromosome pairs. By doing this, the HGP scientists are able to build genetic and physical maps spanning the human genome.

The mapping of the human genome involves recording the sequence of nucleotides of all the human genes (which consist of segments of DNA which are typically several thousand base pairs long). It also includes the charting of variations in DNA spelling among human beings.

So, it is not only a matter of recording the order in which the nucleotides are found, but also involves deciphering what the sequence means and how it relates to the functioning of the human body.



Why do variations in the sequence of a gene sometimes cause disease?

As was detailed in "The story of DNA" on page 11, genes usually code for a particular protein. This means that when given the right stimuli the gene will initiate the production of a molecule of RNA which will carry the "recipe" for a particular protein out of the nucleus into the cytoplasm where the protein will be made up of 20 different amino acids.

Proteins make up essential parts of tissues and guide chemical reactions in living things.

However, if there is a misspelling in the DNA sequence of the gene, this could prevent the protein from functioning normally and result in disease.

Alterations in our genes are responsible for an estimated 5 000 clearly hereditary diseases, like Huntington's disease, cystic fibrosis and sickle cell anaemia. The spellings of many other genes influence the development of common illnesses that arise through the interaction of genes with the environment.

The HGP has helped scientists better understand what makes each and every one of us different...

During the sequencing and mapping of the human genome, scientists discovered one-letter variations in the DNA sequence, which are known in scientific terms as single-nucleotide polymorphisms (or SNPs). SNPs (pronounced "snips") contribute to differences among individuals. The majority have no effect, others cause subtle differences in countless characteristics of our appearance, while some affect the risk for certain diseases.

Figuring out the human genome

How is the HGP expected to change the face of medicine in the future?

All areas of medicine will be affected from diagnosis to prognosis. It is also hoped that, as we gain a better understanding of genetics, it will become easier to prevent a disease before it can do any damage.

DIAGNOSIS: Genetic analysis can now classify some conditions, like colon cancer and skin cancer, into finer categories. This is important since classifying diseases more precisely can suggest more appropriate treatments.

Pharmacogenomics is a new word that scientists and drug developers use to describe the idea of tailoring drugs for patients. These drugs would be designed specifically for the patient based on genetic fingerprinting which would be carried out beforehand. For example, cancer patients facing chemotherapy may experience fewer side-effects and improve their prognosis, by first getting a genetic fingerprint of their tumour. This fingerprint can reveal which chemotherapy choices are most likely to be effective.

PROGNOSIS: Diagnosing ailments more precisely will lead to more reliable predictions about the course of the disease. For example, a genetic work-up can inform a patient with high cholesterol levels how damaging that condition is likely to be.

How will the HGP contribute towards the prevention of disease?

Once scientists figure out what DNA sequence changes in a gene can cause disease, healthy people can be tested or screened to see whether they risk developing conditions like heart disease, diabetes or prostate cancer later in life.

Unfortunately, our ability to predict a disease sometimes precedes our ability to prevent or treat it. For example, a genetic test has been available for Huntington's disease for years, but no treatment is yet available.

There are two types of screening that are already used, but that will become more commonplace in future:

NEWBORN SCREENING: A particular type of predictive testing, newborn screening can sometimes help a great deal. For example, babies in the United States and a few other countries are routinely screened for phenylketonuria (PKU), a metabolic disorder that prevents the breakdown of phenylalanine, one of the building blocks of proteins and a component of the artificial sweetener Aspartame. Excess phenylalanine in the body is toxic to the nervous system. Children with the condition become severely mentally retarded, but the screening programme identifies children with the enzyme deficiency, allowing them to grow normally on a diet that strictly avoids phenylalanine.

CARRIER SCREENING: For some genetic conditions, people who will never be ill themselves can pass a disease to their children. For example, carrier testing for Tay-Sachs disease, which kills young children and is particularly common in some Jewish and Canadian populations, has been available and widely used for years.

What is gene therapy?

Gene therapy involves replacing a misspelled gene with a functional gene. Small groups of patients have undergone gene therapy in clinical trials for more than a decade, but this remains an experimental treatment. Unfortunately, the procedure of gene therapy recently suffered a major setback when a second child in a pioneering French gene therapy trial, developed leukaemia as a result of the treatment.

The trial was testing a treatment for "bubble boy" disease, or X-SCID (X-chromosome-linked Severe Combined Immunodeficiency). Boys with X-SCID have no resistance to infection due to a faulty copy of an X-chromosome gene that makes an immune protein called interleukin-2. Using a virus, the therapy introduces the correct copy of the gene into the patient's cells. The treatment appears to have cured a number of boys, so the two cases of leukaemia have come as a great disappointment.

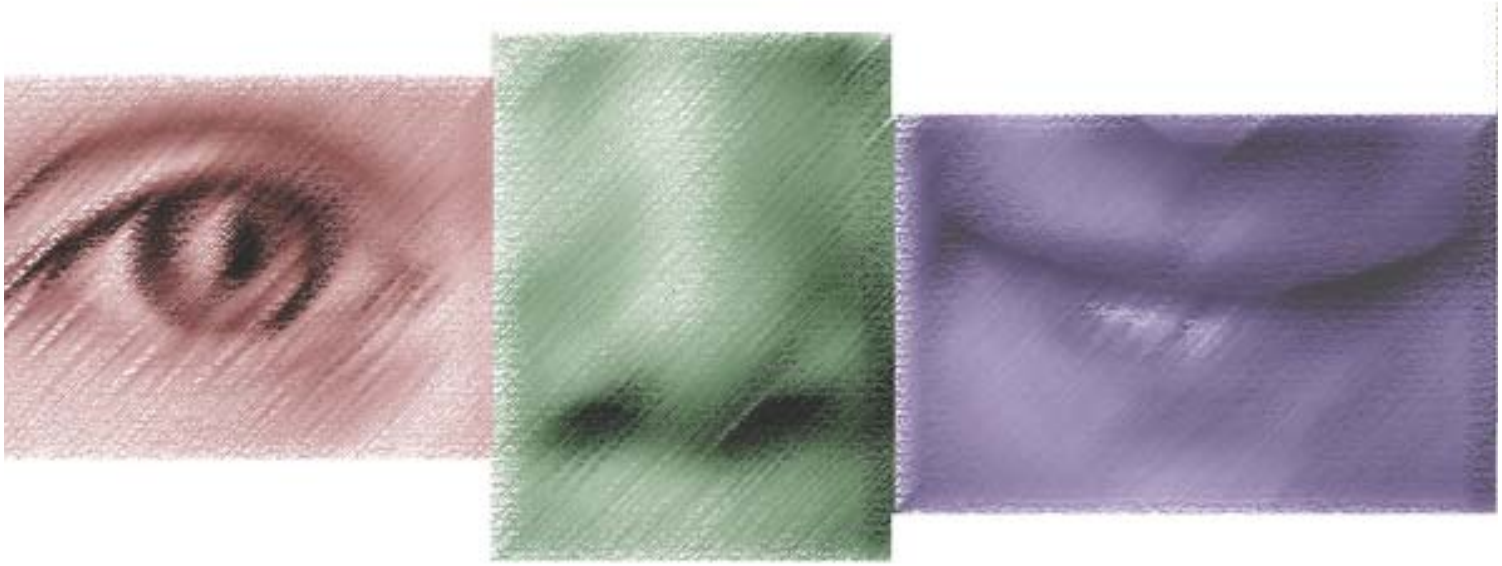
Scientists are now looking into the possibility of whether the technique used on the boys may have been the problem. In the meantime, a number of United States gene therapy trials have been put on hold as a result of the news.

What is gene-based therapy? How is it different to current methods of treatmet?

In many cases, instead of trying to replace a gene, it will be more effective and simpler to replace the protein the gene would give rise to. Alternatively, it may be possible to administer a small molecule that interacts with the protein - as many drugs do - and change its behaviour. Instead of having to rely on chance and screening thousands of molecules to find an effective drug, which is how most drugs we use today were originally found, scientists will begin the process of drug discovery with a clearer notion of what they are looking for. And because rationally designed drugs are more likely to act very specifically, they will be less likely to have damaging side-effects.

One of the first examples of gene-based therapy which targets a genetic flaw, was in the case of chronic myelogenous leukemia (which mostly affects adults). An unusual joining of chromosomes 9 and 22 produces an abnormal protein that spurs the uncontrolled growth of white blood cells. Scientists have designed a drug that specifically attaches to the abnormal protein and blocks its activity. In preliminary tests, blood counts returned to normal in all patients treated with the drug, and the patients only experienced very mild side-effects.

CLONING AND GENETIC ENGINEERING



Spectacular science or

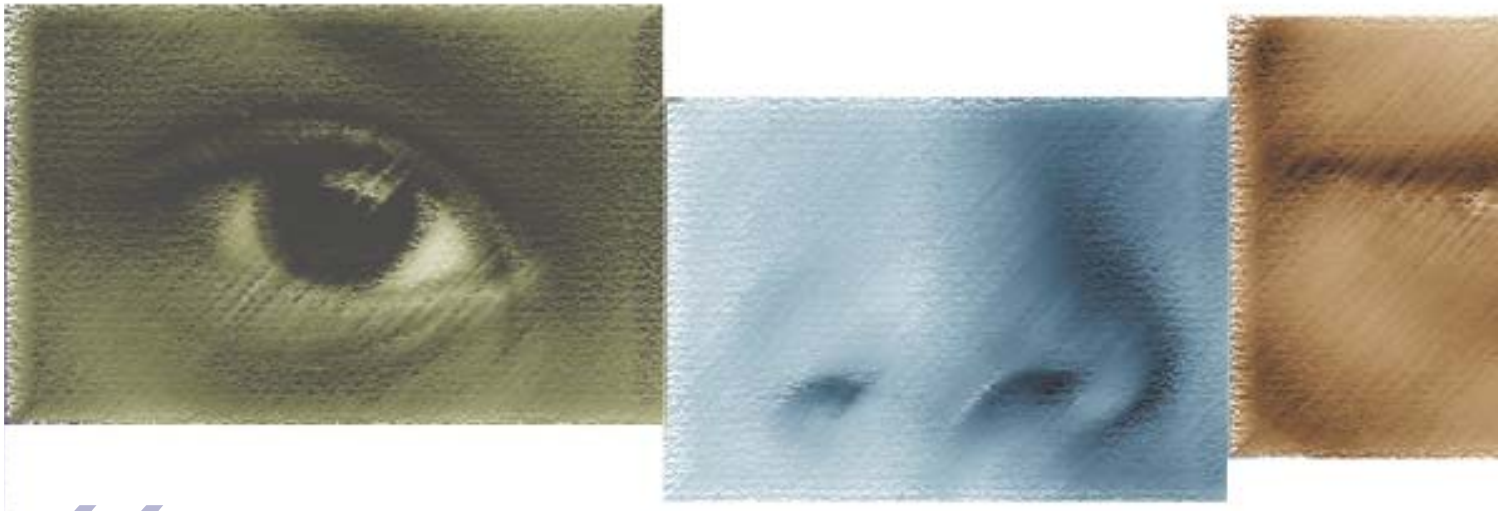
Dolly the sheep was evidence that cloning humans is a possibility

With the Human Genome Project nearing completion and the "successful" cloning of Dolly the sheep, global debates are raging about the ethics of human cloning and of genetic engineering in general. The United States (US) President, George Bush, backed by around 30 Catholic, Arab and Muslim countries, has come out against any kind of human cloning and has proposed a global ban on it.

Meanwhile, the first human clone (a baby girl called "Eve") was supposedly born on December 26 2002, followed by another two, one at the beginning and one at the end of January. Clonaid, the company claiming to have succeeded in cloning these babies, was founded by the Raelian sect which believes that humans were created by aliens. However, the world is very skeptical about whether Clonaid is telling the truth and no one has yet seen either the babies or proof that they are clones. The general feeling is that Clonaid's claims are just a publicity stunt.

Although, in theory, Dolly the sheep was evidence that cloning humans is a possibility, most scientists agree that there is still not enough known about human cloning and its implications, to even consider experimenting with it at this stage. However, that is not to say that it won't become a reality in years to come.

So why is there such a buzz around the whole subject of cloning and genetic engineering? Is it really such a big deal or is it just the next step in the name of scientific progress? Whatever the case, you need to decide for yourself. Read on to learn more about it and then ask yourself a few questions about the ethics of cloning.



“playing God”?

By Helen Malherbe

What is genetic engineering?

Genetic engineering (GE) is the manipulation of genetic material (ie, DNA or genes) in a cell or an organism in order to produce desired characteristics and to eliminate unwanted ones. GE includes a range of different techniques with many different uses, and can be applied to plants, animals and humans.

For example, the genetic modification of food is a form of GE that involves manipulating the cells of plants such as maize, to increase the yields, make it more nutritious and to make it drought- and disease-resistant.

However, the most contentious type of GE is definitely related to its applications in humans. GE in humans has opened up a Pandora's box of possibilities as it can be used for both the miraculous and the sinister.

The cloning of Dolly the sheep in 1996 was a very important event. Until then, the cloning of a human was only possible in theory. Recent films and TV programmes such as *Gattaca, Mutant X, Dark Angel* and books such as *Brave New World* all focus on possible consequences of this technology – but what is the real deal?

What is cloning?

If you were told that there was a clone of you sitting in the next room, what would you expect the clone to look and act like?

GE in humans has opened up a Pandora's box of possibilities

CONTINUED ON PAGE 22

Clones created in this way are not **100%** genetically identical

CONTINUED FROM PAGE 21

Probably, exactly the same as you. But, despite all the movies and TV programmes that have explored the possibility of exact clones, it is highly unlikely that a clone of you would look exactly the same and would certainly not act exactly the same.

A clone is not completely genetically identical, as there are small differences in the genetic make-up just as there are with identical twins. Despite the fact that identical twins come from the same egg, after a while one begins to notice the differences between them in order to tell them apart. It has been discovered – by doing a number of studies on identical twins brought up in the same environment – that genes mysteriously react differently to the same environment.

While cloning a whole human is certainly the ultimate challenge for genetic engineers, cloning is not limited to this goal. Cloning can be, and is, done on a much smaller scale and could involve no more than just the cloning of a single cell.

Therefore, cloning can be divided into two types:

1. reproductive cloning (which is the cloning of a whole organism); and
2. therapeutic cloning (which is the cloning of cells or even organs or other tissue for transplant purposes).

Due to the fact that genetic differences are likely to exist between a clone and its donor, this uncertainty has led to many countries banning the reproductive cloning of humans.

How are clones made?

Reproductive cloning:

In order to make a clone of someone, one needs a living cell and a human egg (ovum). The nucleus of the egg, which contains the DNA, is removed and replaced with the nucleus from the cell of the person/animal to be cloned.

A short electrical pulse then stimulates the egg to start dividing and the embryo is then implanted into the womb where it develops into a duplicate of the person that donated the cell nucleus. Clones created in this way are not 100% genetically identical, as there is some DNA from the original egg cell that is found outside the nucleus (mitochondrial DNA).

Therapeutic cloning and stem cells:

In therapeutic cloning an embryo is created in the same way as reproductive cloning, but it is not implanted into the womb of a woman. Instead, stem cells are extracted after the embryo starts dividing in the first 14 days after fertilisation, which kills the embryo. Stem cells are special cells with the ability to reproduce and become one of 300 types of cells, eg, skin, liver cell, hair or blood cells. These cells are then used to grow the specific type of tissue or organ that is needed and has the advantage of being genetically identical to the patient who donated it, eliminating the problem of organ or tissue rejection. Currently, if someone has an organ transplant, there is quite a high possibility that their body will reject the foreign organ and so they not necessary have to suppress the immune system to lessen the chances of this happening. Stem cells could potentially be used to repair damaged or defective tissues around the body, such as the cells in the pancreas that stop producing insulin in diabetics.

Adult stem cells versus embryonic stem cells

The problem with embryonic stem cells is that many people feel that by using a human embryo and then killing it, you are actually killing a potential person. It is for this reason that the United States and other countries are calling for a global ban on all human cloning, including the use of embryonic stem cells. As a result, there has been new research into the potential of what is known as “adult stem cells”.

More than 30 years ago it was discovered that, in addition to being found in embryos, stem cells are also found in adults. Adult stem cells can be removed from a person without causing any harm. Until very recently, it was thought that adult stem cells were only suitable for cloning a few types of cells and tissues. However, new studies have found adult stem cells with almost the same abilities as embryonic stem cells in various human tissues, including: the spinal cord, the brain, connective

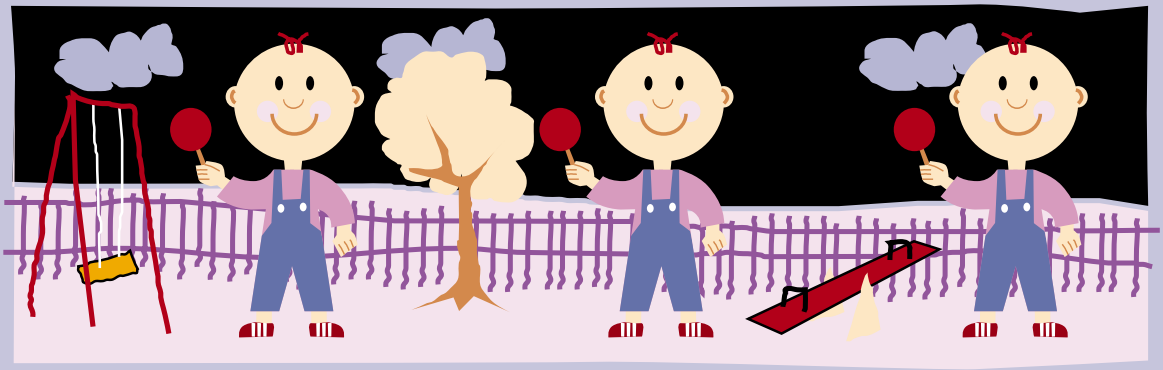
tissue and in the blood of the umbilical cord.

These studies have shown that it is possible for us to manipulate cells to take on new functions/start doing different jobs simply by placing them in different environments and "re-programming" them. For example, neural (brain) stem cells in mice have been transformed into the blood stem cells that produce the different types of blood cells. In other animals, bone marrow stem cells have become brain cells and liver cells. In humans, bone marrow stems cells of a patient have been transplanted into the areas of the heart damaged by a heart attack, triggering new growth of heart tissue.

Although adult stem cells are already being used successfully to treat a number of diseases, there are a number of problems to be overcome, such as finding and extracting the adult stem cells. Embryonic stem cells have not yet been used for therapy and research is still in the initial stages. Eventually, it may be that, rather than just one type, both types of stem cells will be used for different purposes – whichever proves to be the best for the situation. In the meantime, parallel research continues

Studies have shown that it is possible for us to manipulate cells to take on new functions

The "art" of eugenics?



The science of eugenics is the "improvement" of a race or breed by selecting inherited characteristics. The most well-known case of eugenic behaviour occurred during World War II when Hitler and the Nazis launched their programme to create the "perfect race". This led to the atrocity of the Holocaust and the elimination of six million Jews. Not only were millions of Jews killed, but many others were subjected to compulsory sterilisation.

This unforgettable event has helped to emphasise diversity among humans and the importance of the basic right to life that all the people of the world share.

However, the possibility of reproductive cloning has given rise to new concerns about how cloning could be used as a means of eugenics.

For instance, if reproductive cloning does become a reality, who decides who is chosen to be cloned? No doubt only the rich will be able to afford it and those with genetic disorders will almost certainly be excluded.

While some would say that cloning and eugenics would go a long way towards reducing the suffering in the world (by making sure that only people with perfect genes are cloned), others would argue that this is dangerous and could see whole families being excluded from reproducing, due to them not having "acceptable genes".

If cloning does become a reality, the subject of eugenics will need to be thoroughly debated.

At present, there is already a level of eugenics in our everyday lives: couples expecting a child may wish for a daughter rather than a son, with the mother's hair and the father's eyes. If it is discovered that an unborn child has a genetic disorder and is aborted – this is a eugenic decision, as is a couple deciding not to have children to prevent a genetic disease being passed on.

on both cell types. See www.stemcellresearch.org for more information.

Potential uses of cloning

Although currently the risks of cloning outweigh the possible benefits, there are many different potential uses of human cloning technology:

- **Replacing organs and other tissues** – such as new skin for burn victims, brains cells for those with brain damage, spinal rod cells for the paralysed and complete new organs (hearts, liver, kidney and lungs). Pigs are also being genetically modified to make their organs more compatible with humans by removing the gene that causes rejection. People could have their appearance changed (cosmetic surgery) using their own cloned tissue and accident victims and amputees could also benefit from this tissue regeneration.
- **Infertility** – human cloning provides couples and individuals who are unable to have children with another potential option.
- **Replacement of a lost child** – parents who have lost a child through an accident or an illness could clone an identical "replacement" child.
- **Creating "donor" people** – cloned people could be created to provide a source of transplant material.
- **Gene therapy** – cloning technology could be used to prevent, treat and cure genetic disorders by changing the expression of a person's genes. This technology may also provide the cure for cancer by revealing how cells are switched on and off. Gene therapy could be used to treat somatic (body) cells where the change is not passed on to children, or germ (egg and sperm) cells where the changes are passed on.
- **Saving endangered species** – by boosting their numbers through creating clones. However, since clones are almost genetically identical, the genetic diversity of the species would not be increased.
- **Reversal of the ageing process** – once more is understood about the role that our genes play in the ageing process.

However, some of the above uses carry with them some serious ethical implications. See the article on pg 26 to explore these ethical questions further.

Problems with current cloning techniques:

Dolly the sheep was created in 1996 using the cloning methods outlined above. Although Dolly was born looking normal, she is already suffering from several problems associated with the cloning technique, including premature arthritis, which is thought to be a side-effect of the cloning. Other problems with the current cloning techniques, include:

1) **Low success rate:** Dolly the sheep was successfully cloned, It took 276 unsuccessful attempts before it worked. Similar work on mice and other mammals has also produced the same statistics. To date, the success rate (on animals) is 3-4%.
2) **Tumours:** Embryonic stem cells are unstable and difficult to control. They have a tendency to uncontrollably divide leading to tumours/cancer.
3) **Genetic defects:** Although the original DNA from an embryo is removed and replaced with the nucleus from the person to be cloned, some DNA from the original embryo remains in the form of mitochondrial DNA. This can lead to genetic defects that are not fully understood and which are only seen in later life.
4) **Over-growth syndrome:** Clones of animals are larger than average at birth, which can be risky for the mother.
5) **Premature ageing:** The age of a clone is calculated by taking its birth age and then adding the age of the original from which it was cloned. Although Dolly was born in 1996, she originates from the udder of a six-year-old ewe and so her total genetic age is almost 13.
6) **Massive quantities of human eggs required:** If applied to humans, the current method of cloning would use a vast number of human eggs. To provide these eggs, women would have to become "egg factories", and harvesting them is both painful and dangerous. If adult stem cells were used, then human eggs would not be required as cells could be obtained from the patient without harming them.
7) **Reduction in adaptability:** Since, by nature, a clone is a copy of another person, there would be no unique genetic combinations introduced into the human gene pool if human cloning was undertaken on a large scale. Therefore, if a contagious disease struck for which there was no cure, all the clones would be wiped out.
8) **Insertion of the gene:** In gene therapy where a healthy gene can be used to replace a defective gene, viruses are usually used to insert the gene into the person's cells. The virus injects the healthy DNA into the cells and the genetic defect is corrected. However, this is not always successful as the virus cannot always be controlled and has triggered leukaemia in a recent clinical trial in France (refer to page 19).
9) **Lack of knowledge:** Although the Human Genome Project has mapped out where the different genes are, a lot more information is needed on their functions. In some cases, a single gene may have more than one function, and in others several genes can cause a genetic disease.

When does life begin?

Your view on human cloning and the use of stem cells will largely depend on when you think human life begins. If you consider a fertilised human egg to be a human being, as many religions do, then this is the murder of one human being (an embryo) for the sake of another (a patient).

The accepted scientific view is that an embryo only becomes a "human" after 14 days, as only then does it begin to develop human characteristics.

Your decision about when life begins will also affect your view on abortion. In South Africa in late 1996 a law was passed that permits abortion on demand for any woman, up to the 12th week of pregnancy. It also allows for abortion from the 13th to the 20th week if a doctor believes it necessary to ensure the health of the woman, or if "the continued pregnancy would significantly affect the social or economic circumstances of the woman".

Some Chinese cultures believe that humans only become people when they participate in society

Where is cloning allowed?

Around the world, different countries have different rules relating to cloning – some don't allow reproductive cloning, but do allow therapeutic cloning, while other countries allow both types.

In South Africa, there are no laws against cloning of any sort. However, there is also no known cloning research being undertaken.

In China, there are no laws against cloning either. However, with the huge population problem and the policy of only one child per family, there is no interest in reproductive cloning. On the other hand, there is huge interest in therapeutic cloning and, as a result, there is a lot of it on the go in China. Some Chinese cultures believe that humans only become people when they participate in society – so, according to these cultures, embryos and foetuses are not considered to be human beings, thereby eliminating any ethical problems surrounding the creation and destruction of embryos to get the required stem cells.

The Chinese government is funding extensive research and drawing back many Chinese scientists from overseas, to undertake work they would not be allowed to do elsewhere. With easy access and no limits on obtaining the embryonic material they require, it is expected that Chinese scientists will race ahead of the rest of the world in therapeutic cloning technologies.

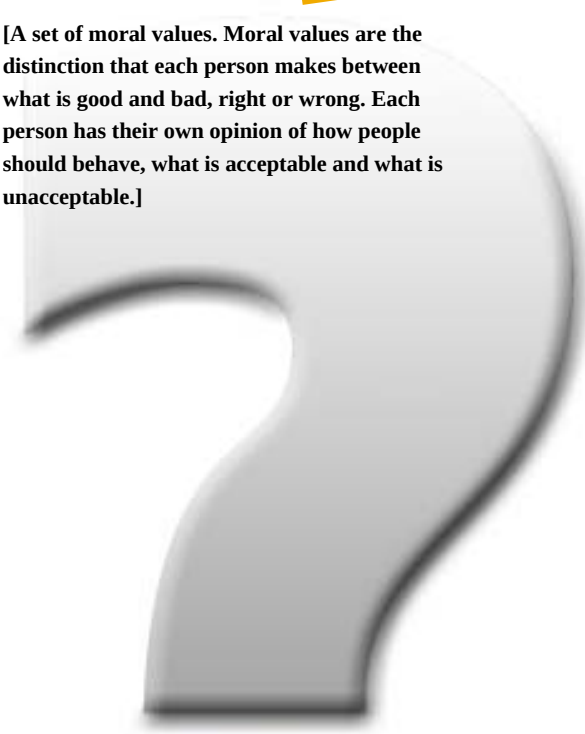
In the UK there are clear rules banning reproductive cloning, but scientists in both the UK and Israel are allowed to generate new embryonic cell lines for therapeutic research. The law in Germany bans the extraction of stem cells from human embryos for research within the country, but in 2002 a new law was passed allowing some human embryonic stem cells to be imported. This means that German scientists are allowed to undertake work on embryonic stem cells if they originate from outside Germany.

In the United States there is no public funding for research on embryonic stem cells. Therefore, although there is no law against therapeutic cloning in the US, there is almost no public research happening due to the lack of money and access to the embryonic material. Simultaneously, an announcement was recently made stating that US public funds (about US$1,4 million, about R11,2 million) will be provided for studies using adult stem cells instead of embryonic stem cells.

These different rules for different countries mean that if a scientist is banned from undertaking cloning in his/her home country, he/she can simply move to a country where it is allowed. To prevent this from happening, the US and about 30 other countries want a global ban on all forms of cloning. However, many countries don't agree and thus no progress is being made on implementing this ban.

The question of [ET

[A set of moral values. Moral values are the distinction that each person makes between what is good and bad, right or wrong. Each person has their own opinion of how people should behave, what is acceptable and what is unacceptable.]



Ethics, or more specifically bioethics, is the caution that should go hand in hand with developing DNA technology. More often than not, as with human cloning, the technology tends to race ahead, with excesses of funding and effort, leaving the ethical debate behind. Only now are people reacting strongly to the ethical implications of cloning research. However, the first human clone has supposedly already been born!

Ethics enables us to draw the line between what is allowed and what is not allowed – and it is based on moral values and the responsibility we have as humans, whatever our beliefs, to protect human life in any form. Ethics is a "grey" area and is very subjective because people believe different things. This is why national and global laws are needed to ensure that there is an agreed point at which everyone draws the line.

You can take many different approaches when deciding what ethical standpoint suits you. There are those who think that "if it can be done, it should be done", while others would say "just because it can be done, it doesn't mean it should be done".

With so many different views and arguments, it is difficult to know what to do. However, it is important that you muddle through all the arguments and take a final stand, as your decision will affect your life in years to come, when cloning technology truly becomes a reality.

Your religion

Your religious beliefs will affect your ethical view of cloning. Many religious groups have already made known their views on human cloning. While most Christian denominations and Islam are totally against all types of cloning, a statement from Orthodox Judaism speaks out against reproductive cloning, but is in favour of therapeutic cloning, rather seeing it as a potential method for saving human lives. Most religious groups believe that God is the giver of life and that life begins at the moment of conception, something that should only take place naturally between a man and a woman.

Your political beliefs

The views of the majority of countries are mainly expressed through their politicians and the laws, rules and regulations they create. Although it is hoped that national laws represent the views of the people, they are often the opinions and decisions of the governments

HICS] and cloning

By Helen Malherbe

or the leaders of the country. With almost no laws on human cloning in China, advances in human cloning technology could position China as a world leader in this regard. Politically, this could be a powerful economic tool to increase wealth, power and control. Some people fear that cloning technology could widen the gap between developing and developed countries even further.

Your socialisation

The way that you have been socialised (ie, the way that you have been brought up and the people you have been with throughout your life) will affect your thoughts on human cloning.

Different countries and cultures have different views and values, and these are usually translated into laws or rules in that specific country. Over time, these laws and rules have to be updated to reflect what is considered acceptable and unacceptable by society.

For example, in the early 1970s, *in vitro* fertilisation (IVF) was a new technology which enabled infertile couples to have children. Although this was considered unacceptable at the time, the technology has gradually become accepted and commonplace (Louise Brown, the world's first "test-tube baby" born in 1978, is now in her 20s!).

Despite the horrors of the Holocaust and the forced sterilisation of people, based on the idea that society is more important than the individual, it is now possible and acceptable to abort an unborn child if it is found to have a genetic disease or defect.

Around the world, surrogate mothers are now bearing other people's children. Also now acceptable in many countries is:

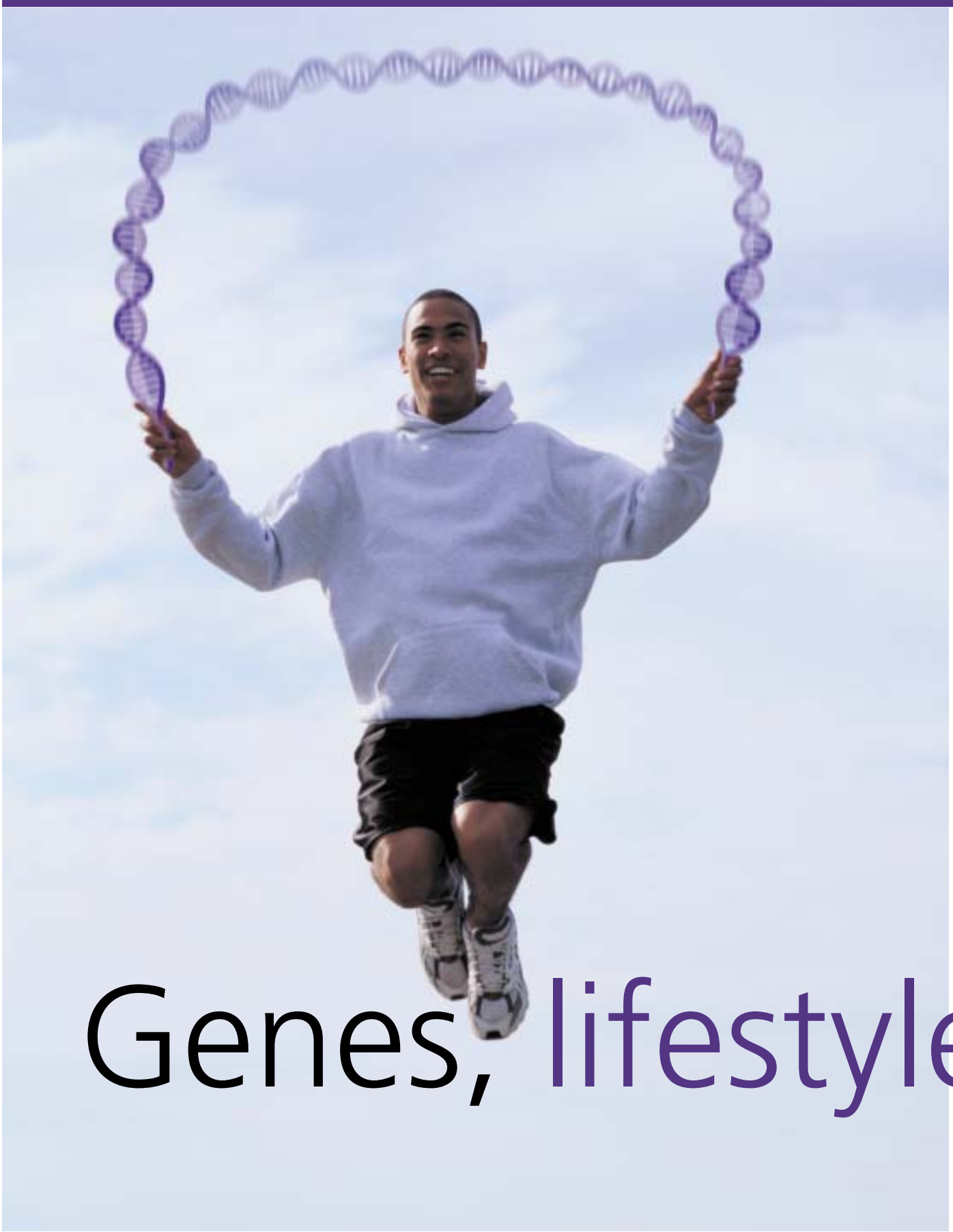
- the use of the contraceptive and morning-after pill; and
- the abortion of unborn babies up to six months old.

How soon do you think it will be before it will be possible to clone ourselves and even download our personalities into them – supposedly making them exactly like us? What do we do when it happens?

QUESTIONS YOU SHOULD ASK YOURSELF ...

- Do you think it is acceptable to clone humans? Would you be cloned if you needed organs that could save your life?
- If you had a clone, would you be a parent or a twin?
- If it takes 276 failures before a "normal" clone is born – then what about all the duds – the ones born with defects and the ones that die before being born?
- Does a clone have a soul?
- Do you think that God would approve of cloning?
- Should cloning be an option for people who are not able to have children?
- Should cloning be used to "replace" a child that has died? Would that not put unfair pressure on the child?
- Should humans be cloned just so that we can harvest organs or other materials from them?
- Who should decide who is cloned? Doctors? Scientists? Presidents?
- What if clones could be made of lunatics such as Hitler?
- Who should be allowed to have access to cloning and related technologies? Who will pay for them?
- Do you think that there should be a complete global ban on both types of cloning, or just on reproductive cloning?
- If there is a global ban on all cloning – how could it be enforced with so many laboratories around the world?
- Do you think that we should be able to "design" babies – eye colour, intelligence, athletic ability, etc?
- If we obtain genetic information about ourselves – who does this information belong to?
- Should people with genetic defects/diseases be allowed to have children?
- Should all pregnant women be offered genetic screening of their unborn babies, with the option to abort if a genetic disease is found?
- If a person has a genetic disease/defect for which there is a cure through gene therapy, should they be forced to have it cured?
- Do you think that we should destroy one class of human beings (embryos) to benefit another (such as people suffering from Alzheimers or Parkinson's disease)?
- If you found out that you were going to have a baby with disabilities, what would you do?
- Do you think that, just because we have the technology to do so, we should allow human beings to be manufactured in massive numbers?
- Should someone with "better" genes be treated differently (eg, paid more) than someone with "bad" genes?

Now that you know more about cloning and the related technologies, you can start forming your own opinion. If you still want to ponder the issue some more, why not ask your science or biology teacher to chair a debate on the subject (splitting your class into a group who are "for" human cloning and a group who are "against").



Genes, lifestyle

If humans were computers, then our DNA would be our "operating system". However, just as loading incompatible software onto a computer, or introducing a computer virus, can cause the operating system to crash, so our actions and the substances we ingest can cause our DNA to stop functioning properly and may even end up killing us.

Most of us have heard of, or have known someone who suffers from, a rare disease such as muscular dystrophy (a severe, usually lethal progressive muscle-wasting disorder) or haemophilia (a bleeding disorder where blood does not clot when one gets cut or bruised). These are both conditions that result from faulty, malfunctioning genes.

While these unavoidable conditions are very sad for those affected by them, it is more frightening to consider that even if we are born with healthy, fully functional genes, this can change during our lifetime, depending on the kind of lifestyle we lead.

Cancer, heart disease, lung disease and diabetes are the four most common types of diseases that result from lifestyle-related (or non-communicable) risk factors. In other words, these are the most common conditions that we suffer from due to living unhealthily. Basically, this means that by living unhealthy lifestyles, we can actually damage our healthy genes and have them turn against us!

Too young to worry about it?

You may be thinking that lifestyle-related diseases are not likely to affect you at your age, and you are hopefully right. But, that doesn't mean that your lifestyle while you are young isn't going to affect your health when you get older. Consider skin cancer. When we are young, having a golden tan often falls high on our priority list, while worrying about the damage we could be doing to our skin does not feature. The problem is that we only have one skin that has to last our lifetime. Each time we get burned, our skin suffers irreversible, long-term damage that could eventually damage the DNA in our skin cells and result in skin cancer.

The same applies to eating habits, exercise habits, smoking and drinking habits, and while no one will stop you from partying with reckless abandon now, the one thing that you can be sure of is that you are going to pay for it later.

For example, the World Health Organisation (WHO) has predicted that if the growth in tobacco use (smoking) goes unchecked, the numbers of deaths related to its use will nearly triple, from four million each year to 10 million each year, in 30 years' time!

Genes and our environment

The good news is that the above lifestyle-related diseases can almost always be avoided by simply eating healthily, getting regular exercise, not smoking and drinking in moderation. Well ... most of the time anyway; our health can also be damaged by living in unhealthy or polluted environments. A recent study published online by the Proceedings of the National Academy of Sciences reported that mice subjected to the air in close proximity to a steel mill had twice as many genetic mutations as mice living in rural areas. This is one of the first demonstrations of how ambient air pollution exposure can result in gene

Each time we get sun burned, our skin suffers irreversible, long-term damage that could eventually damage the DNA in our skin cells and result in skin cancer.

and DISEASE

CONTINUED ON PAGE 30

What is gene testing?

Gene tests involve the examination of the DNA molecule. DNA samples can be obtained from any tissue, including blood. In most cases, a gene test involves scanning a patient's DNA for mutated sequences.

In some cases researchers use short pieces of DNA called probes, whose sequences are the same as the mutated sequences for which they are searching. The probes look for their twin among the three billion base pairs of an individual's genome. If the mutated sequence is present in the patient's DNA, the probe will stick to it, thereby making it possible for the researchers to confirm that the mutation exists.

Another type of DNA testing involves comparing the sequence of DNA bases in a patient's gene, to a normal, or functional, version of the gene in order to diagnose the presence or absence of a disease.

Unfortunately, DNA testing is usually very expensive depending on the size of the mutated sequence that is being tested. The cost of a DNA test can range from hundreds to tens of thousands of rands.

Genetic tests are used for several reasons, including:

- Carrier screening – which tests unaffected individuals who carry one copy of a gene for a disease that needs two copies for the disease to become active. In other words, if two parents carry the diseased gene, then their children will inherit the disease.
- Prenatal diagnostic testing – which tests the amniotic fluid from the uterus of an expectant mother, to see if the child has got a disease. This procedure is known as an amniocentesis and is usually carried out in pregnant women over the age of 35.
- Newborn screening – see "How will the HGP contribute towards the prevention of disease?" on page 17
- Presymptomatic testing for predicting adult-onset disorders such as Huntington's disease. Huntington's disease is a single gene disorder of the central nervous system which usually develops in adult men and women. It is caused by a faulty gene in chromosome four. Unfortunately, it is not yet fully understood how the faulty gene damages the nerve cells in areas of the brain, leading to gradual physical, mental and emotional deterioration. Many people choose not to be tested as there is, as yet, no cure for the disease.
- Presymptomatic testing for estimating the risk of developing adult-onset cancers and Alzheimer's disease.
- Tests to confirm a disease in someone who is already showing symptoms of that disease.
- Forensic or identity testing – if a man wants proof that a child is (or isn't) his offspring, he can ask for DNA identity testing to be done. DNA identity testing is also done when someone has died and their remains make it impossible to identify them. These identity tests can also be used to tie a criminal to a crime scene if no other evidence is available.

CONTINUED FROM PAGE 29

mutation.

In South Africa, we are particularly vulnerable to environmental and pollution-related diseases such as malaria, tuberculosis and cholera. Malaria alone infects between 300 and 500 million people a year and kills between one million and 2,7 million people, mostly children.

As a result, scientists have made it a priority to make the "mozzie" genome and the parasite that it carries, the *Plasmodium falciparum*, some of the first genomes, other than the human genome, to be mapped. It is hoped that this is the first step in finding out things like:

- why the mosquito prefers people to animals; and
- whether it will be possible to develop a vaccine in future.

Scientists are also looking into genetically engineering mozzies that don't bite people or that don't carry the parasite, in the hope that this new species will wipe out and replace the wild ones.

Weak genes

Without sounding like a prophet of doom, there is yet another area where our genes can be negatively affected by both our lifestyle and environment. Allergies are reactions that some people experience due to having "weak genes" that leave their immune systems ill-equipped to break down some of the proteins found in everyday foods. Among the most allergenic foods are: peanuts, soybeans (found in two-thirds of all manufactured foods!), wheat, tree nuts, milk, eggs, shellfish and fish.

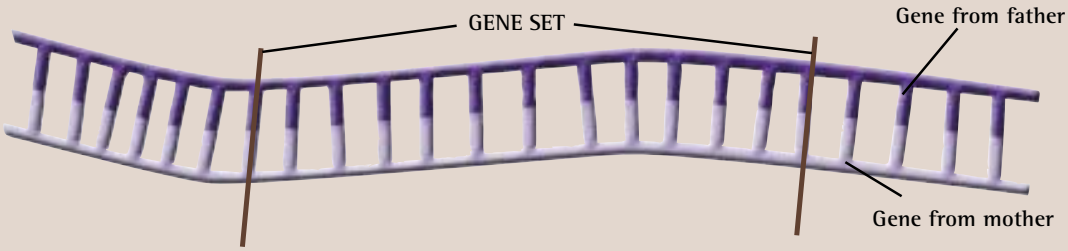
However, instead of trying to find ways to fix the defective gene in the affected humans, scientists are looking at ways of ridding the food of the proteins that are causing the trouble in the first place.

Although research is far from complete and no decisions have been made as to whether it will be commercially viable, researchers like Anthony Kinney at the DuPont Experimental Station in Wilmington, Delaware in the US are experimenting with a technique called RNA interference (RNAi) with soybeans. This technique basically works to silence the genes that code for protein 34, the protein responsible for 65% of all soybean allergies. RNAi serves to confuse a cell into thinking that the RNA that carries the code for protein 34 from the nucleus into the cytoplasm, is a foreign agent. The cell consequently destroys the RNA and effectively "turns off" this gene in the cell.

Why do we all look different?

Slight variations occur in less than 1% of our DNA sequence and produce different variants of a particular gene that is called alleles. These alleles determine how we look, among many other things, but is dependent on which genes are dominant or recessive.

Dominant vs recessive genes



As you already know, a person gets half his DNA from his father and the other half from his mother. This means that he ends up with two sets of genes, one set from his mother and one set from his father (see diagram).

Almost all our genes code for a particular protein, which may be:

- a structural constituent of a given tissue;
- an enzyme which initiates a chemical reaction; or
- a hormone.

Single gene disorders

In some cases a child may inherit an abnormal gene from his mother or father, or from both parents. This abnormal gene may or may not result in a single gene disorder, depending on whether the abnormal gene is dominant or recessive.

For instance, if the father's gene is defective and the mother's gene is normal, but there are no signs of the defective gene causing a problem, then the father's abnormal gene is assumed to be recessive and the person is diagnosed as having a recessive disease.

However, if the father's defective gene does produce disease, then the gene is said to be dominant and the condition is called a dominant hereditary disorder. In some cases a couple that happens to have the same recessive disease may only realise that they carry the disease when their child is born and is discovered to suffer from the disease. In many of these cases, there is a history of the disease in both families and couples such as these should first consider "carrier screening" before having a child.

The incidence of serious single gene disorders is estimated to be about one in 200 births.

Other types of DNA-related disorders

But, single gene disorders are not the only types of diseases that result from malfunctioning DNA. There are also:

- chromosomal disorders, such as Downs Syndrome, where individuals have an extra copy of chromosome 21 (ie, they have 47 chromosomes instead of 46). This unbalanced set of genes results in mild to moderate mental retardation and numerous physical changes.
- multifactorial disorders: some of the most common diseases such as coronary heart disease and cancer are the result of the malfunctioning of numerous genes in our DNA.
- mitochondrial DNA-linked disorders: there are about 20 disorders that have been found to stem from the malfunctioning of DNA in the mitochondria of our cells (mitochondria has its own set of DNA). Due to the fact that mitochondria come only from the egg, these disorders are inherited exclusively from the mother.

Is being fat always our fault?

A recent study done at the Massachusetts General Hospital by Gary Ruvkin and Kaveh Ashrafi, is believed to have narrowed down the pool of genes that may regulate fat storage in humans.

Based on the knowledge that there is more to staying thin than just eating "lots of fruit and vegetables", these scientists are looking to uncover the secret of why some people stay effortlessly thin while eating whatever they want.

What makes the study so unique is that the findings are based on the study of the genome of a microscopic worm called *Caenorhabditis elegans*. The worm was used because about half of the *C. elegans* fat genes have human counterparts.

However, this is just the beginning of the process and the researchers now have to start testing the complementary genes in humans to see if they are "wriggling" in the right direction.

SICKLE CELL ANAEMIA – A GENE WITH MANY FUNCTIONS

Sickle cell anaemia is caused by a defective gene which codes for haemoglobin - the part of the red blood cells that carry oxygen around the body. As a result, the red blood cells are deformed and are sickle-shaped instead of round. The blood is sticky and doesn't pass easily through the veins, preventing oxygen from being delivered around the body. This causes severe pain, anaemia, damage to the organs and can be fatal. Sickle cell is caused by a genetic mutation that first occurred during an epidemic of a deadly form of malaria. It was found that in areas where malaria was a problem, children with one sickle cell gene survived malaria, while those without the gene, died. This shows that while this genetic mutation does cause sickness, it also acts as a form of protection against malaria, thereby showing that it has multiple functions. Sickle cell anaemia is, as yet, incurable and studies are under way to use stem cell transplants in children where the bone marrow (which produces the blood cells) in the patient is destroyed using drugs and replaced with healthy bone marrow from a relative, with normal blood. The disease is most common in people of African and Asian origin (20-30% of West Africans have the disease).

All about sex and ageing

Why do some people last into their hundreds while others check-out in their early sixties? While it's well-documented that lifestyle plays a major role in our length of life, there are still those who eat, drink and smoke their way into their eighties. As a result, researchers have concluded that our genes must also play a part in deciding whether we are going to die young or just keep clocking on the years.

Some research suggests that length of life is directly proportional to fertility. In other words, the fewer children you have, the longer you live and vice versa. Many parents would, no doubt, agree with this theory!

Other research carried out on centenarians (people who live for 100 years or more), has discovered that these people tend to have higher levels of an enzyme called polymerase 1, which reacts swiftly to repair DNA damage when stress is applied.

However, it is hoped that the mapping of the human genome will finally provide us with the recipe to living a long(er) life. But it is important to remember that while our genes may endow us with a high level of protection against the damaging factors that daily life can bring, our lifestyle is always going to play a role in determining how long we will last.

An exciting career choice

GENETICS careers in SA

Throughout the world, advances in genetics research – particularly the soon to be completed Human Genome Project – are forcing many professionals and learning institutions to re-look at the way they do things. South Africa is no exception. Luckily a number of our learning institutions have managed to keep up with the changes that an increased understanding of genetics has brought about in the science and human sciences sectors. However, the impact of genetics on careers is not limited to these sectors only. Genetic and genomic knowledge will also change the shape of the fields of engineering, computer science, mathematics, counselling, sociology, ethics, religion, law, agriculture, education, pharmaceuticals, instrumentation, nuclear medicine, forensics, bioremediation, biofuels and journalism.

Almost everyone will in some way be affected by the applications of information and technologies that emerge from the Human Genome Project (HGP). In fact, the HGP is expected to have such a big impact in the years to come, that the 21st Century has been dubbed the "biology century".

It is expected that genetic data will result in far-reaching changes in the way that medicine and agriculture is practised and that it will provide the foundation for research in most of the biological disciplines.

The benefits of genomic research are already being seen (or are on the verge of being seen) in areas such as:

- forensics and identification science;
- ecology and environmental science;
- toxic waste clean-up (bioremediation);
- the creation of new bioenergy sources and more efficient industrial processes; and
- the understanding of the mysteries of evolution, anthropology and human migration.

New opportunities

Probably one of the biggest concerns that people have when they leave school is whether they are going to be able to find a job. The good news is that if you are planning to go into a career in genetics, your chances of getting a job once you finish your studies, are good.

This is because the more we learn about genetics and how to use it, the more jobs or disciplines are opened up. For instance, when it first became possible to screen people for diseases, scientists didn't realise the impact that having these tests would have on the patients. However, they soon became aware that if they wanted to do these screening tests, the patients would need to be counselled, both before and after, the tests were carried out. This realisation gave rise to the discipline of genetics counselling, which is now an accepted field of study.

Cross-disciplinary

As mentioned, the HGP has not only affected the science and human sciences sectors only, it has also impacted on numerous other fields from law to computer science. This means that if you want to become a lawyer, but are also fascinated by the field of genetics, you needn't have to choose one over the other ... you can simply incorporate the one into the other. For example, if you decide to become a lawyer, you can specialise in the legislation and litigation concerned with genetics and intellectual property issues and the preservation of the privacy of individual genetic information. However, be warned that this kind of specialisation will require more years of study and a lot of commitment on your part.

If you want to find out whether you can incorporate a specialisation in genetics into your current career choice, the list on the opposite page should be of some help.

A current list of careers in genetics (or bioscience)

The list of careers on the opposite page is a not exhaustive, but will give you a good idea of the different career opportunities that are available in different fields (info found on: www.ornl.gov/hgmis):

An exciting career choice

MEDICINE
- Medical genetics, genetic counselling and genetic nursing
- Gene testing and gene therapy
- Organ transplantation, fertility and reproduction
- Public health
- Pharmaceutical industry and suppliers:
  - pharmacogenomics;
  - chemical, vaccine, medicine development and production;
  - database development, operation and use; and
  - communication and work with regulatory agencies.

AGRICULTURE AND WILDLIFE
- Genetic modification of foods and seeds
- Biopesticide and neutriceutical development
- Wildlife management: identification and protection of endangered species
- Authentication of consumables such as wine and caviar

COMPUTATIONAL BIOLOGY (INCLUDING BIOINFORMATICS)
- Database creation, data analysis, modelling and data transfer
- Supercomputing
- Mathematics, statistics and actuarial fields

ENGINEERING DISCIPLINES
- Bioprocessing chamber, vat design and production
- Toxic waste clean-up
- Instrumentation development
- Creation of new energy sources via engineering and life science research
- Biomedical engineering

BUSINESS
- Biosciences industry investing
- Marketing and sales
- Banking

LAW AND JUSTICE
- Education
- Patent specialities
- Specialities in ethical, legal and social issues
- Gene and paternity testing
- DNA forensics – in the laboratory, in the field and in the courtroom

HISTORY AND ANTHROPOLOGY
- Use of genetics to study population and migration patterns
- Study of inheritance over evolutionary time

MILITARY
- Soldier identification
- Pathogen (disease) identification
- Biological and chemical warfare protection
- Radiation exposure assessment

SPACE EXPLORATION
- Research into space effects
- Search for other life forms, evidence of life

BENCH SCIENCE
- Sequencing of many organisms, including humans
- Data analysis and computation
- Functional genomics
- Proteomics
- Human variation in health and disease
- Microbial genetics
- Environmental studies
- Education

BIOSCIENCE COMMUNICATION
- Reporting, writing and editing
- Website development and maintenance
- Public relations
- Marketing
- Special events

NOTE:
Due to limited space, our look at the study of genetics and South African universities will concentrate on what is available in the science and human sciences sectors only.

STU SPEAK

Arvind's story

Arvind Varsani
BSc (Hons), DIS in Medicinal and Pharmaceutical Chemistry, Loughborough University, UK

How did you end up studying genetics? What and who inspired you along the way?

I absolutely loved biology and hence for my GCE 'A' levels, I studied biology, chemistry and maths. I was very keen to study genetics since it was just becoming the hot field, besides I was always a rebel and wanted to do something different to the rest of the Kenyans [Arvind grew up and went to school in Kenya].

I felt my place was in research rather than doing an office job. Unfortunately, my parents thought otherwise and since they were supporting my education I had to reassess the situation.

My parents are very conservative and they wanted me to become a pharmacist or a medic. I couldn't stand the thought of studying medicine for five years, so I managed to convince them that my degree programme in medicinal and pharmaceutical chemistry was a slight variation of pharmacy.

Little did they know that, in actual fact, it would get me jobs mainly in the research sector. While in the UK I did a year internship with Astra Pharmaceuticals (now Astra-Zeneca) in the formulation section, which kicked me into research mode.

I read a lot about viruses during this time and thought they were the coolest things. Back in Kenya, the job prospects were limited, and I struggled to relate to the ethics of the pharmaceutical industry there. Therefore, in a bid to escape all this and pursue my true passion in researching, viruses, I applied for PhD posts all over the world and managed to get a spot at the University of Cape Town to work on the human papillomavirus.

What would you say is boring/ frustrating about your field of study?

As with any field, one tends to get bored doing the same thing over and over again. The most frustrating thing is the time one has to wait to get data for some experiments. Additionally, if there has been an error right at the start, you might only find out about it a couple of months down the line!

What was the title of your PhD?

"Development of candidate vaccines for human papillomavirus." Actually I didn't have much of a choice, I really wanted to do HIV research but my current supervisors, Ed Rybicki and Anna-Lise Williamson offered me a PhD on plant-based vaccines. I am really glad I took up this PhD, I have had an absolute blast doing research for the PhD thesis. In addition to the plant-based vaccines, I have also managed to incorporate a fair amount of structural virus research into my work, which has been absolutely fascinating.

South Africa is considered a third-world country. Would you say that this affects the quality of our genetics research?

I don't see why there should be any prejudice to third-world science. South Africa is well-equipped to handle a lot of the genetic research. South African researchers have made tremendous contributions in the field of science.

What words of warning and encouragement do you have for someone who wants to study genetics?

Empoyment opportunities in the field of genetics are always on the increase. The field of bioinformatics is on the rise too, and this is an awesome field for people with great computational skills and genetic knowledge. Students wanting to make a career out of genetics should marry their other interests in science with genetics.

DENTS - UP!

One can speculate about how one should go about preparing for a career in genetics, but at the end of the day, who is better qualified to tell us about it than those who have already walked this path. *Archimedes* asked a number of PhD and postgraduate students to tell us their stories. Not surprisingly, most of them admit that theirs was a journey of discovery rather than a matter of knowing what they wanted to do from the start. After all, you never really know whether you are going to enjoy something until you try it.

Andy's story

Andrew Shackleton, Bsc (UPE), Bsc (Hons) (UPE)

How did you end up studying genetics? What and who inspired you along the way?

I started off with an interest in veterinary science, but as school biology evolved I realised that I wanted to be involved in zoology. My years as an undergraduate student exposed me to this new world of the "scientific process" and I became hooked. I found genetics classes interesting, but never thought that it would be my latter year field of interest.

When I did my Honours' my subjects involved a lot of conservation techniques and disciplines, and towards the end I became more and more interested in conservation genetics (mostly as a result of reading articles in zoological journals).

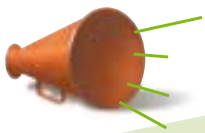
The Zoological Society of Southern Africa placed an advertisement on the Net, looking for candidates to study the population sub-structure and breeding behaviour of bats. This seemed a much more viable option, as I had first thought that I was going to do my Masters degree on Marion Island, looking at the physiological adaptations of springtails and mites! So, I left for Cape Town and I have been working with bats for the past year. I use PCR, microsatellite and mtDNA protocols to answer many intriguing questions about the relatedness of one colony to another. I even trace their migration routes across the country. Lately, I have been looking at mating strategies using *in vitro* DNA amplification to answer questions about cryptic breeders (when breeding behaviour is difficult to observe).

What kind of person do you think is suited to a career in your field of expertise?

A person who has an appreciation of nature beyond aesthetics. In particular, one must be able to think subjectively, and at times impartially – analytical enquiry should be a part of your persona! Biological processes have many facets, but it is only by looking at the picture as a whole that we really begin to make science.

South Africa is considered a third-world country. Would you say that this affects the quality of our genetics research?

In general South African laboratories have some very nifty equipment. Onderstepoort Veterinary School, and even my laboratories have equipment that will get the job done. There are also very good scientists in SA who will assist in



"Fortunately I travel a lot. I get to spend many hours in tranquil, surreal surroundings. Most of the areas I get to visit on field trips are those wilderness sites which are closed to the general public."

making your studies a well-rounded experience.

What words of warning and encouragement do you have for someone who wants to study genetics?

In the words of Einstein: "I stood on the shoulders on giants!". SA varsities are great – you just have to work to make the most of your career. Decide where you want to go – remember it's your future, not your mate's!

What do you love best about what you do?

Fortunately I travel a lot. I get to spend many hours in tranquil, surreal surroundings. Most of the areas I get to visit on field trips are wilderness sites which are closed to the general public. Field trips can take as long as a month – depending on how sample and data collection go. These are very welcome breaks especially in a laboratory-based project such as this one.

Heidi's story

Dr Heidi de Wet
PhD, Department of Chemical Pathology, UCT Medical School: BSc (Hons) in Biochemistry, Potchefstroom University; BSc, majoring in Botany and Biochemistry, Potchefstroom University

How did you end up studying genetics? What and who inspired you along the way?

My subjects in highschool were English, afrikaans, maths, science, biology and music. My maths and science marks were quite poor in matric – I got an E for maths HG and a D for Science HG!

I wanted to pursue a career in zoology or veterinary science, and was allowed to enrol in a zoology/botany-based BSc. After one month of zoology, I realised that I absolutely hated cutting up specimens and spent most of my practicals trying not to faint! So, for my second year I tried something as bloodless as possible – botany. I also did well enough in Chemistry during my first year to pursue it as a second year subject, and took biochemistry (genetics) simply to fill my curriculum up. What a lovely surprise! I loved it! And never looked back. After finishing my Honours course at Potchefstroom I felt like a change and applied for a MSc (which was upgraded to a PhD) at UCT when I saw an advert for a project at their medical school.

What do you love best about what you do?

I'm currently working as a postdoctoral research fellow at Tygerberg Medical School, doing research on bone growth and how bone cells decide to grow – in other words, what genes are up-or down-regulated – in response to cortisone treatment.

Doing research is great because you really have to stay on your toes the whole time – it's a thinking game, trying to tease answers out of a rather unwilling Mother Nature. And, of course, you feel like you are making a difference by contributing something to the understanding of how things work.

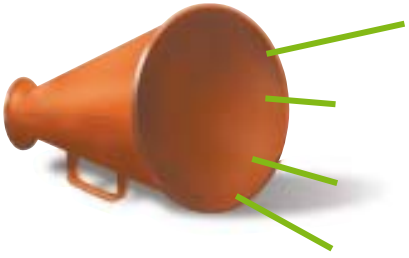
What would you say is frustrating about your field of study?

Being a research scientist involves a lot of donkey work – repeating assays over and over again, because it is, well you know, RE-search! Doing something that no-one has done before takes a lot of time, patience and guesswork.

For every positive result there are usually 50 negatives.

What was the title of your PhD? Why did you choose your specialty?

"The Nucleotide Binding Domains of Multidrug Resistant Proteins". I worked on these membrane transporters that pump drugs out of their targets cells, so cells are resistant to these drugs. It's a common problem in cancers, TB and even malaria. I was working on the ones that cause resistance to chemotherapy in humans – we were expressing these proteins in bacteria, to make production and isolation of large amounts possible.



"Doing research is great because you really have to stay on your toes the whole time – it's a thinking game, trying to tease answers out of a rather unwilling Mother Nature."

South Africa is considered a third-world country. Would you say that this affects the quality of our genetics research?
Yes, because quality of research is often determined by how much funding and resources one has. Most PhD students go and do a "post-doc" research period overseas, and come back with lots of experience and new expertise. South Africa's conservation/population genetics are world class – we have all the animals right here, so we actually have lots of foreign students coming here for their MScs and PhDs.

What words of warning and encouragement would you have for someone who wants to study genetics?
Genetics is a wide term. It can be looking at the mutations in genes that cause metabolic disorders, or expressing human genes in bacteria for easier investigation, or comparing the DNA fingerprints of various animals (to determine how related they are) for conservation biology.

I think it is quite difficult to really know what one likes when one leaves highschool.

Anyone who is interested in biological sciences should try and enrol in a general BSc course that exposes you to basic maths, chemistry, biochemistry, botany and zoology. You never know what you will find you like! And don't be discouraged if your matric marks are less than great – one sometimes just needs to find something that really grabs your attention.

Any last comments?
Listen to Mark Shuttleworth – it's hip to be square! Don't let friends tell you science is boring. A career in science might not always make you rich, but you will be guaranteed to have an interesting, flexible and challenging job for the rest of your life!

Helen's story

Helen Ross-Adams
MSc in Genetics, Stellenbosch University
PhD (in progress) at the University of Aberdeen, Scotland.

How did you end up studying genetics? What and who inspired you along the way?
I always loved biology and nature sciences at school, and was quite active in those sorts of societies.

I went to university thinking I was going to come out an engineer, but found it was really not for me! I switched over to a BSc, which offered a wider variety of subjects, all of which I could get excited about. Genetics was great, and I had a fantastic lecturer whose enthusiasm and love of the subject was infectious.

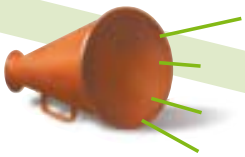
It was so exciting to know what made each of us unique in the world, and how everything about us was carried like a master plan in our genes. I majored in genetics and psychology in my final year, with aspirations of becoming a forensic profiler, just like on TV!

I did my Honours in genetics, which was a lot of hard work, but also lots of fun. It was a natural progression to continue with my Masters. I worked on grapevines, figuring out their genetic fingerprints for the farmers (yes, they have fingerprints too!).

Now I'm in Scotland, and trying to work out what genes cause high blood pressure in people, so they can avoid things like strokes, heart attacks and other nasties.

It was basically through a combination of luck and a love of all things living, that I fell into genetics.

If you'd asked me at school where I'd be eight years on, I wouldn't have had a clue. In fact, I had no future plan and was quite scared at the thought of having to grow up. Now, I'm glad I didn't plan too carefully.



"When I was at school, I didn't know what was on offer in the big wide world career-wise. However, I've now realised that if you enjoy something, there is probably a career out there, tailor-made for you."

What do you love best about what you do?
The feeling of finding something out for the first time is so satisfying and exciting. Every little piece of information you get is like a piece of a larger puzzle.

South Africa is considered a third-world country. Would you say that this affects the quality of our genetics research?
Although research in SA is really a luxury many think we can't afford, the actual work done is top-notch, and the country is crawling with the most amazing minds! I've also realised that the saying "necessity is the mother of invention" is certainly true in SA. So, although we may be strapped for cash, the quality of the research done is comparable to that of international institutes.

What is the title of your PhD? Why did you choose your specialty?
I'm looking for genes that contribute to high blood pressure, and consequently strokes. I'm interested in having my research make a real impact on people's lives.

What words of warning and encouragement do you have for someone who wants to study genetics?

The field is growing so quickly at the moment, now is definitely the best time to get into it. You will learn all sorts of exciting things and hopefully make a bundle of cash in a couple of years time. It's a good idea though, to consider marrying a love of biology with computers, as this area (ie, bioinformatics, is taking off too.

On the down side, be prepared for the long haul. It can take about four years of full-time study to get an Honours degree, and longer if you study further. It's daunting at first, but the time really does fly by.

Any last comments?

When I was at school, I didn't know what was on offer in the big wide world career-wise. However, I've now realised that if you enjoy something, there is probably a career out there, tailor-made for you. Don't get locked into thinking you can only be a doctor, lawyer or engineer; if you put your mind to it and some effort, you can make a career out of doing something that really inspires you.

Mauritz's story

Mauritz Venter
BSc Genetics and Human Physiology, BSc (Hons) Genetics
Currently in the process of a PhD in Plant Biotechnology at the University of Stellenbosch.

Did you study genetics in the science or human sciences sector?

Both. During my BSc I studied the fundamental basics of genetics covering human/medical, plant and animal science. It is only at a postgraduate (MSc and PhD) level that a student specialises in a specific field, usually in human or plant science. There are 'however' many areas of specialisation within the basic science sectors, eg, genetic studies of cancer, animal reproduction, psychiatric disorders, sport science, disease resistance in plants, improvement of wine quality (also known as wine biotechnology) and many more. Currently I am in the plant sciences (plant biotechnology) sector isolating genetic "tools" for the manipulation of grapevines to improve fruit quality.

How did you end up studying genetics? What and who inspired you along the way?

My subjects at school were biology, maths, accounting and science. During the last months of grade 12, I was still not sure what I wanted to do. I eventually decided on a BSc with the option to pursue medicine.

My subjects were genetics, biochemistry and human physiology and during my second year I developed a keen interest in medical genetics.

Plans for medicine did not work out, so instead, I started with an Honours degree in genetics and found that hot-shot terms like "biotechnology" and "molecular biology" represented a mixture of genetics and biochemistry as well as microbiology.

During that time "blue-sky" projects like cloning and the determination of the human genome (to identify all the genes and their locations on all the chromosomes) were going on. I was fascinated, and that was only the beginning for me.

I started my Masters degree at the Institute of Plant Biotechnology. My project supervisor, together with the support of my parents, inspired me to stay in the scientific game and to become a geneticist.

What kind of person do you think is suited to a career in your field of expertise?

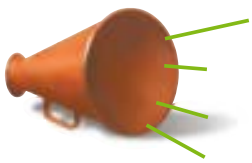
I would say a person should:

1) have patience;
2) be a team player;
3) be able to put science on paper, that is to write regularly and be as concise as possible when presenting his/her results;
4) always plan ahead (not only is the planning of experiments important but also the preparation of back-up strategies if experiments go wrong); and
5) read a lot and be up-to-date with the latest developments and trends in the science sector.

South Africa is considered a third- world country. Would you say that this affects the quality of our genetics research?

Not at all. On the basis of money and human resources, we are behind countries like the United States and Germany, but the quality of genetic (and other molecular biology) research is of the highest international standards.

This can be seen in the publication records of South African scientists. Scientific research can only be published in an international journal when the work is new and it has been reviewed by scientists who are specialists in their field from all over the world. Some



"Unfortunately, in most cases, to have the relative freedom to do independent research in an area of special interest, one has to have a Doctorate or at least a Masters degree, which involves between six to ten years of studying!"

South African scientists have had opportunity to widely publish their research in these journals.

Not only do we have top-notch academic researchers, but the government has decided to invest millions of rands in helping to start genetic (and biotech) companies. This will certainly strengthen South Africa's position as a competitive key player in the international biotechnology arena.

What words of warning and encouragement do you have for someone who wants to study genetics?

Don't worry about specialising in the genetics of plants, humans or animals during the first few years of study. The basic research skills (genetics and molecular biology) can be used for any living organism.

Unfortunately, in most cases, to have the relative freedom to do independent research in an area of special interest, one has to have a Doctorate or at least a Masters degree in genetics (or a related field e.g. biotechnology) and this involves between six to ten years of studying!

As with the information technology (IT) boom, it is envisaged that biotechnology (genetics, biochemistry) will play a much more significant and crucial role in the 21st century. Although the future is unpredictable, if you become part of the genetics revolution, you are bound to have an exciting and challenging career.

Luzuko's story

Dr O Luzuko Matolweni, Phd

How did you end up studying genetics? What and who inspired you along the way?

I developed a love for medicine at a very tender age. I was told that biology, maths and physical sciences were the main subjects I should focus on. However, things changed when I was refused admission to medicine because I failed to meet the required entry level symbol in mathematics. This was the most devastating moment of my life.

I was, however, allowed to register for a BSc degree. My major courses in BSc were botany, zoology and psychology. I went on with my studies for the sake of studying. My heart and soul were in medicine. The good thing is that I was open about it. My parents, teachers and lecturers encouraged me to hang in there.

Soon after having completed an Honours degree in botany, I realised that I was becoming more interested in molecular biology (cell biology and genetics). I did a Masters degree in population genetics which later landed me a Phd. Population genetics is a field in molecular biology that deals with the movement of genes within and among populations. This movement is termed gene flow and, without a doubt, underlies evolution. Currently, I am involved in a research project that seeks to identify genes that lead to heart failure; a huge proportion of diseases are a result of defects in our genetic blueprint (DNA).

What do you love best about what you do?

The research aspect of my career is most stimulating. Reaching out to the world of the unknown and finding new knowledge is very exciting. Research plays a major role in the advancement of knowledge.

What would you say is boring/frustrating about your field of study?

There are no easy routes to answers. However, I believe this is the case with most fields of study and can even be found to be true about life in general.

In genetics the frustration lies in the fact that genetics is not as straight forward as other sciences, largely because of a huge number of influences on gene function and the uncertainties of analysing these factors.

What kind of person is suited to a career in your field of expertise?

This job requires a hardworking and very determined individual. The person should be analytical, knowledgeable, resilient and totally committed to research.

What was the title of your PhD? Why did you choose your specialty?

The title was: "Evolutionary genetics of the Begonia dregei complex (Begoniaceae)'. As I have stated earlier, population genetics is a branch of genetics that deals with the movement of genes within and between populations. It is, therefore, at the population level that genetics reflects historical events and helps us understand the present day diversity of all life forms.

South Africa is considered a third-world country. Would you say that this affects the quality of our genetics research?

It is difficult to provide a direct answer to this question. I believe the quality of the research in this country is very good. We have qualified and very skilled personnel in genetics. However lack of resources and funding may have a profound effect on the rate of research output. Geneticists in this country are unable to keep up with the ever-advancing technology.

What words of warning and encouragement do you have for someone who wants to study genetics?

Love of science is the key if you want to pursue a career in this field. If you have the interest and passion, you will make it. The only word of warning to school leavers out there is that if you come to science with the hope of making lots of money, science is not your field.

Any last comments?

Choose your subjects carefully so that you keep your options open. This will give you something to fall back on in case you do not make it in your choice of study.

What's ON offer AT SA Uni's ?

Archimedes approached a number of the leading universities in the country to find out what they offer in terms of genetics-based courses… This is what we found.

PLEASE NOTE: We could not include all the universities in our survey, but that doesn't mean that they don't also offer genetics-based courses. If you want to find out about genetics-based courses at any other SA university, see "Career Search" on page 48 and contact them directly to find out more.

The University of Pretoria (UP)

The University of Pretoria has a Department of genetics and offers several postgrad degrees in genetics, one of which is human genetics and another bioinformatics. Up to this point, it has not offered any undergraduate courses, however this year they will be offering human genetics and genomics courses at third-year level. This course will cover the basics of what a genome is and will be the start of the study of bioinformatics (the sequencing of information from the human genome and how it is analysed to make sense of it).

Undergraduate training within the genetics programme at UP, includes both basic and applied courses in genetics, thereby giving the students a well-rounded background in genetics. This empowers the student to make informed choices as to their particular field of interest at a postgraduate level.

During the first two years of study students are exposed to a broad range of subjects within the biological sciences, including basic genetics. In the third year the programme focuses at applied genetic topics with subjects such as human genetics, evolutionary and phylogenetics, genomes, population genetics, and plant breeding. All subjects include both a theoretical and a practical component. There is also the opportunity at third-year level to include some elective courses to allow students to broaden their background.

Postgraduate study within this programme includes Honours, Masters and doctorate degrees.

RESEARCH

Research in the Department of Genetics covers a wide range of topics with emphasis on molecular virology, plant biotechnology, molecular genetics, genomics, evolution, molecular ecology, conservation, taxonomy, plant breeding, quantitative genetics and population genetics.

Some of the research currently underway in the department includes:

- cancer genetics;
- cereal genomics; and
- forest molecular genetics and genomics.

MAIN FOCUS AREAS

Main focus areas of study at the UP genetics department are:

- biotechnology;
- plant breeding; and
- human genetics.

Biotechnology:

Biotechnology involves the use of *in vitro* genetic manipulation and recombinant DNA methods to genetically alter plants, animals and microbes.

Biotechnologists aim to correct, modify or enhance specific traits in their target organisms for a wide range of practical purposes, including improved food production, disease treatment,

conservation and bioremediation.

A background in biotechnology will enable you to compete for jobs in a wide range of fields in biosciences. Career opportunities in biotechnology involve work within a laboratory environment.

Biotechnologists could also be involved in teaching and training at various academic institutions or work as pharmaceutical representatives. However, it is worth remembering that the level of training/qualification plays a big role in determining the type of work biotechnologists become involved in.

Human genetics:
Human genetics is an important specialisation or branch within genetics that specifically focuses on aspects pertaining to humans and human evolution. This study programme aims to present students with an understanding of the broad field of genetics, while simultaneously preparing them to specifically focus on human-related aspects of genetics in the future.

The recent advances in decoding the human genome have opened up myriad opportunities that will keep people working in the field of medical and human genetics, intrigued for many years to come.

Plant breeding:
Plant breeding concerns all human activities directed towards the production of plants with an optimised genetic constitution, which meet human needs in a better way. To be able to accomplish this, plant breeders study the fundamental principles that form the basis of the inheritance of traits. Breeders, therefore, need a good understanding of genetics on a molecular, cellular and population level.

With a degree in plant breeding and a background in genetics, you will be able to compete for a position not only in plant breeding, but also in other related fields such as biotechnology, horti- and silviculture, animal breeding and diagnostics. The training will enable you to work in a wide range of environments, for example industry, agriculture, forestry, as well as conservation.

The University of Stellenbosch

The Department of Genetics at Stellenbosch University has eight full-time academic members of staff with research interests that cover disease resistance breeding in wheat, aquaculture, human genetics and molecular plant virology.

UNDERGRADUATE COURSES

Genetics
- introductory genetics
  Part 1: Principles of heredity
  Part 2: Population genetics;
- introductory molecular biology;
- cytogenetics;
- population and quantitative genetics;
- advanced molecular genetics;
- theory of selection;
- plant breeding techniques; and
- quantitative traits and selection methods.

Aquaculture
- introduction to aquaculture;
- aquaculture production and processing; and
- freshwater aquaculture.

Biometry (the study of biological data by means of statistical analysis)
- introductory biometry; and
- linear models and analysis of variance.

POSTGRADUATE COURSES

BSc Hons in genetics
Only students with an average of at least 60% in genetics in the final year, will be admitted to the Honours programme. The programme comprises:
- cytogenetics;
- plant tissue culture;
- basic molecular techniques;
- molecular markers;
- mapping and chromosome maps;
- experimental mapping with Drosophila and genetic data analysis;
- application of molecular techniques in agriculture, medicine, forensic science and gene therapy; and
- gene transfer from unrelated organisms to plants (genetic engineering).

There is a strong emphasis on laboratory skills.

MSc in Genetics
This cause Comprises research of an approved topic as determined by the department. A satisfactory thesis must be presented on completion of the work. Additional study may be required in the form of formal lectures and/or seminars as suggested by the lecturers concerned. An oral examination must be completed.

PhD in genetics
A dissertation containing the results of independent research is required.

STRUCTURE

The genetics department has five well-equipped laboratories plus all the support facilities. In addition it has a plant tissue culture laboratory, a radio-isotope laboratory, a fresh water aquarium and a large teaching laboratory dedicated for Honours training.

Research projects include:

- disease resistance breeding in wheat and maize;
- various aspects of fresh water and marine aquaculture;
- woolly apple aphid resistance;
- human genetic disorders like variegate porphyria;
- molecular genetic analysis of the grapevine chloroplast genome; and
- virus resistance in wine grapes.

CAREER OPPORTUNITIES

The wide spectrum of undergraduate courses and postgraduate research at the department ensures that career opportunities in a number of industries exist. Typically students are employed at research facilities like universities, the Agricultural Research Council, the National Department of Agriculture, the Medical Research Council, and at service-oriented centres like the forensic laboratories of the South African Police Service, providing pathology and genetic diagnostic services. Other industries include local fresh water and marine aquaculture, seed companies, biotechnology and pharmaceutical companies.

The University of Cape Town (UCT)

Although UCT offers genetics as a course in most of the biosciences, UCT is best known for its advanced human genetics focus.

Clinical genetics is a rapidly growing international field which is moving from being something that people only theorised about, to one of deeper investigation at the laboratory level and within families and communities. UCT is well placed having, until recently, been the only accredited training centre for clinical genetics in the country (now WITS' training centre has also been accredited).

Genomic medicine involves an understanding of the human genome and the use of this information to manage disease and predisposition to disease. The Division of Human Genetics has a strong pedigree of research, which is purpose-driven and targeted for use in our clinics. Ultimately, information emerging from the laboratory and clinical aspects of human genetics are combined to provide predictive information and identification of individuals who are at high risk, before they develop disease.

This capability is already being used to predict which individuals, families and specific communities are going to develop breast and colorectal cancer, neurodegenerative diseases (like Huntington's disease and Spinocerebellar ataxia) and muscular dystrophies. Tests can be designed to predict these disorders, even prenatally. This remarkable trend is going to revolutionise the practise of medicine. Soon enough, and with adequate research into our varied South African populations, we will be able to predict who in the community is at highest risk for, eg, other cancers, diabetes, hypertension, cardiovascular disease, asthma, psoriasis, and susceptibility to infectious diseases. UCT is committed to being a leader in crafting and honing its capacity to face future challenges.

A strong niche for training individuals in public health-related modules to do with genetic predisposition to disease, is currently being designed, as is a Masters course in genetic counselling. These niche markets anticipate the demand for "genetic knowledge" in health management.

Furthermore, the development of computer-based tools to complement the search for, and identification of, disease-causing genes is being vigorously pursued as part of the Genomic Medicine endeavour. This field of bioinformatics will also be a niche market that will service our strong research community. This core facility which is currently functional in human genetics is meant to expand in UCT's faculty and become an expert site which will be used for training

South Africans and Africans generally.

STUDY COURSES RELATED TO GENETICS AT UCT

Students emerging with a BSc – with biochemistry, microbiology, physiology, or molecular biology as majors – with at least an upper second class pass, may apply for entry into the Honours programme. This programme is highly innovative and allows the student to choose modules in a variety of disciplines including medical biochemistry, chemical pathology, medical microbiology, human genetics and cell biology, among others.

This is to provide students with exposure to other disciplines. It helps them to avoid them being "vice-gripped" into a discipline which they may have chosen without knowing the full extent of what it was, and allows them to select another discipline to further their studies.

Students are then allowed to select from a range of projects, one from a discipline that will best suit them in order to obtain laboratory training.

Successful Honours students are accepted into a MSc programme in a specific discipline. This is usually two years of bench work with a thesis at the end of that period. The students may have to complete one or more formal courses in areas where they may be considered lacking in necessary detail or qualification.

Research:

The major genetics research projects within this division at UCT include:

a) the genetics of retinal degenerative disorders;
b) the genetics of colorectal and other familial cancers;
c) the genetics of neuromuscular disorders;
d) the genetics of neuropsychiatric disorders; and
e) the genetics of complex chronic disorders, notably hypertension.

The University of the Western Cape (UWC)

In the Department of Biotechnology, genetics – both prokaryotic (the study of the DNA of bacteria) and eukaryotic (the study of the DNA of all other living organisms) – is an integral part of the Applied Biotechnology BSc programme. The Department also offers Honours, Masters and PhD research programmes in biotechnology.

Research projects

The Department has three primary research areas:

- bioinformatics and applied genomics;
- agricultural and food biotechnology; and
- structural biology.

Within these focus areas, individual research staff take part in a range of research activities:

- Professor DA Cowan, leader of the Advanced Research Centre for Applied Microbiology, focuses on metagenomics and gene discovery, particulary with respect to microbial genomes and organisms (bacteria and archaea) from extreme environments.
- Professor C Gerhing leads a team with interests in plant biotechnology, and specifically in the molecular mechanisms of plant stress resistance. His team recently identified a plant hormone which contributes to the control of water stress and salt balance. This could lead towards the generation of salt- and desiccation-tolerant crops.
- Professor DJG Rees and Ms M du Preez are working on research into apple and pear tree genetics. They want to identify genomic markers and develop marker selection systems of plant breeding. Professor Rees also works in the field of apoptosis (the controlled death of an organism's cells as part of its natural growth and development), and in the identification of novel apoptostic compounds in traditional plants. Such compounds are potential medicines.
- Associate Professor S Davison works in the field of viral research, and particularly with honey bee viruses which presently cause a lot of trouble in the bee industry. Professor Davison has also recently initiated a new research programme which involves using new molecular diagnostic systems for forensics.
- Associate Professor P Gouws works closely with the South African food processing industry. He has developed rapid and sensitive methods for the detection of pathogens (agents that can cause disease) in food.
- Ms Z Arieff works with researchers at Tygerberg Hospital in studying human genetic diseases. Thus far, they have identified the gene damage responsible for causing early heart disease in African communities.
- Dr D Pugh is a structural biologist and is working on a series of projects investigating the molecular structure of human and bacterial proteins.

The University of the Witwatersrand (WITS)

Genetics forms a part of most biology courses including zoology, botany, agricultural and microbiology, due to the existence of DNA in all living things. Thus you can specialise in genetics in most biological fields. What secures your chances of following a career in genetics is your registration and successful completion of a BSc at the university.

WITS Department of Human Genetics is particularly advanced in terms of the facilities that it offers, and these include the following laboratories.

Laboratories within the Human Genetics Department

There are four laboratories within the Human Genetics Department, each with their own unique interests and expertise, as well as a clinical division concerned with genetic counselling and clinical genetics.

The Molecular Genetics Laboratory: Research interests include establishing the molecular basis of cystic fibrosis, spinal muscular atrophy, fragile X syndrome, myotonic dystrophy, haemophilia A, the haemoglobinopathies and albinism in southern African populations.

The Population and Evolutionary Genetics Laboratory: This lab uses tools commonly used in molecular biology to study segments of the human genome in living peoples, to reconstruct the prehistory and evolution of modern humans. Using a molecular genetic approach, researchers hope to uncover the demographic and evolutionary processes responsible for producing the complex patterns of variation in subsaharan African and Malagasy populations. This will contribute to efforts to understand genetic variation associated with disease.

The Serogenetics Laboratory: This lab was established in the early 1970s to study the genetic interrelationships between African populations. However, now it carries out biochemical tests used for diagnosing inborn errors of metabolism, and the population work has found a practical application in paternity testing.

The Cytogenetic Laboratory: This lab carries out chromosome analysis on peripheral blood lymphocytes, fibroblasts, amniotic fluid cells, foetal cord blood and chorionic vilii. Fluorescent in situ hybridisation (FISH) studies are carried out for specific cases that show chromosome abnormalities, including translocations, deletions and duplications, as well as unknown chromosome markers.

The Clinical Diagnostic and Genetic Counselling division: This functions as a team that includes medical geneticists, medical officers, genetic counsellors, genetic nurses, a social worker, a psychologist and students in training. They are involved in the genetic counselling of patients and their families. Genetic counselling is a process whereby patients and families are assisted in addressing their concerns related to the development or transmission of a genetic disorder. The main aims of our service include informing patients and their families of the genetics, medical diagnosis, prognosis and recurrence risks of the disorder in the best possible way.

Do you want to find out more?

Are you excited at the prospect of a possible career in the field of genetics, but still have some questions? Below is a list of people who are more than qualified to answer them.

University of Witwatersrand
Michele Ramsay PhD
Department of Human Genetics
Tel: (011) 489-9214
Fax: (011) 489-9226
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Fax: (021) 448-0906
Email: jg@cormack.uct.ac.za
www.uct.ac.za/depts/genetics

University of the Free State
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Faculty of Medicine
Tel: (051) 405-3047
Fax: (051) 444-1161
E-mail: gnmgtp@med.uovs.ac.za
www.uovs.ac.za

University of Western Cape
Prof DA Cowan (HoD)
Department of Biotechnology
Tel: (021) 959-2083
Fax: (021) 959-3505
Email: dcowan@uwc.ac.za

University of Stellenbosch
Dr JT Burger
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www.sun.ac.za/genetics

University of Pretoria
Wilma Fick PhD
Senior lecturer
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Tel: (012) 420-3255
Fax: (012) 362-5327
Email: wilfick@postino.up.ac.za
www.up.ac.za/academic/genetics

Looking for more information? Look online. Here are some web-based resource sites which you will find informative ...

A guide to careers in science
Careers in science and the qualifications you need. Plus plan your career.
ec2.wits.ac.za

The Human Genome Project (HGP)
All about the HGP
www.ornl.gov/hgmis

The Genomic Revolution
An online exhibit by the American Museum of Natural History
www.amnh.org/exhibition/genomics/0_home/index.html

The Genetic Science Learning Center
Explains genetics concepts and how they relate to our lives. Includes on-line activities, labs and experiments
gsic.genetics.utah.edu

Human cloning and genetic engineering – the basic science you need to know
Explains how cloning is done, in theory, using easy-to-understand diagrams
www.arhp.org/patienteducation/onlinebrochures/cloning/index.cfm?id=282

Cloning: right or wrong?
The facts about cloning and what it could mean in future.
cloning.tripod.com

GENERAL SCIENCE SITES
www.fest.org.za

www.scienceinafrica.co.za

www.popsci.com

www.sciam.com

www.newscientist.com

Career Search ...

University contact details

Listed below are the phone numbers and web addresses for universities throughout the country.

Rhodes University: (046) 603-8655	www.ru.ac.za
Stellenbosch University: (021) 808-2493	www.sun.ac.za
University of Natal (PMB): (033) 260-5233	www.nu.ac.za
University of Natal (Dbn): (031) 260-2668	www.nu.ac.za
University of Durban-Westville: 0800 004 991	www.udw.ac.za
University of Port Elizabeth: (041) 504-2511	www.pe.ac.za
University of Cape Town: (021) 650-4399	www.uct.ac.za
University of the Free State: (051) 401-2708	www.uovs.ac.za
Potchefstroom University: (018) 299-2893	www.puk.ac.za
Rand Afrikaans University: (011) 489-2637	www.rau.ac.za
Pretoria University: (012) 420-2980/ 2692/4281/2735	www.up.ac.za
Wits University: (011) 717-1038	www.wits.ac.za
University of Fort Hare: (040) 602-2011	www.ufh.ac.za
University of Transkei: (047) 502-2111	www.utr.ac.za
University of Zululand: (035) 879-1380	www.uzulu.ac.za
University of the Western Cape: (021) 959-2911	www.uwc.ac.za
UNISA: (012) 429-3111	www.unisa.ac.za
Vista University: (011) 938-1701	www.vista.ac.za

Technikon contact details

Listed below are the phone numbers and web addresses for technikons throughout the country.

Border Technikon: Tel: (043) 708-5200	www.bortech.ac.za
Cape Technikon : Tel: (021) 460-3911	www.ctech.ac.za
Eastern Cape Technikon: Tel: (0474) 401-2000	www.tktech.ac.za
Mangosuthu Technikon: Tel: (031) 907-7111	www.mantec.ac.za
ML Sultan Technikon: Tel: (031) 308-5111	www.mlsultan.ac.za
PE Technikon: Tel: (041) 504-3911	www.petech.ac.za
Peninsula Technikon: Tel: (021) 959-6911	www.pentech.ac.za
Technikon Free State: Tel: (051) 507-3911	www.tofs.ac.za
Technikon Natal: Tel: (031) 204-2111	www.ntech.ac.za
Technikon Northern Gauteng: Tel: (012) 799-9000	www.tng.ac.za
Technikon North West: Tel: (012) 703-2241/4	www.tnw.ac.za
Technikon Pretoria: Tel: (012) 318-5911	www.techpta.ac.za
Technikon South Africa: Tel: (011) 471-2000	www.tsa.ac.za
Technikon Witwatersrand: Tel: (011) 406-2911	www.twr.ac.za
Vaal Triangle Technikon: Tel: (016) 950-9000	www.tritek.ac.za

NEED MORE INFO ABOUT TECHNIKONS?

Committee of Technikon Principals (CTP): (012) 326-1066