An Introduction to Synthetic Biology

PART 3

By Patrick Redmond

This is the third part of a conference given by Patrick Redmond. We published the other parts on the dangers of microchips and the genetic modification of foods in previous issues of the Michael Journal.

Patrick Redmond graduated with a Doctorate in History from the University of London, England in 1972. He taught at the University of the West Indies in Trinidad, then at Adhadu Bello University in Kano, Nigeria before joining IBM. He worked for IBM for 31 years before retiring. During his career at IBM he held a variety of jobs. These included; from 1992 until 2007 working at the IBM Toronto lab in technical, then in sales support. He has written two books and numerous articles. Here is the third half of the presentation he gave in Toronto on April 13, 2008.

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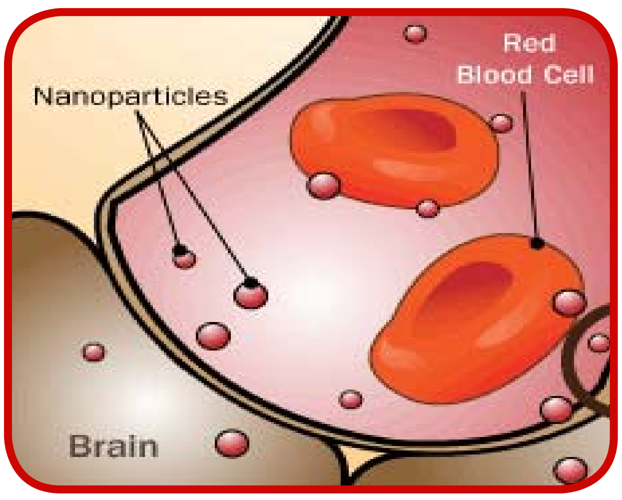
Much of what I am going to say is based on an excellent analysis from ETC group, an action group that deals with erosion, technology and concentration. It's called Extreme Genetic Engineering. They are an international civil society organization based in Canada and are funded by CIDA (Canadian International Development Agency) and other groups.

The next subject of my talk on new technologies is synthetic biology. This type of biology involves a pretty tight control over people, food and other entities. Build life from scratch, that's what synthetic biology wants to do. It involves using gene synthesizers to write the sequences of DNA code one letter at a time, creating new letters and rearranging all into new genetic networks and bundling it into an artificial body and letting it go forth and multiply. There are four technologies that are part of it: nanotechnology, biotechnology, information technology and cognitive science.

How big is this market?

As just one component of the market, nanotechnology is massive. Global demand for nano-scale materials, tools and devices was an estimated $7.6 billion in 2003, with $1 trillion pretensions by 2011.



Nanotechnology used in the medical field

The nanoscale moves matter out of the realm of conventional chemistry and physics into "quantum mechanics." At the molecular level there exists a "material unity" so that all matter – life and non-life – is indistinguishable and can be seamlessly integrated. The goal of NBIC (National Center for Biotechnology Information) is to "improve human performance," both physically and cognitively (e.g., on the battlefield, wheat field, and on the job).

ETC Group refers to converging technologies as BANG (an acronym derived from bits, atoms, neurons and genes) which are the basic units of transformative technologies.

At the core of synthetic biology is a belief that all the parts of life can be made synthetically (that is, by chemistry) engineered and assembled to produce working organisms.

Using computer metaphors, DNA code is the software that instructs life, while the cell membrane and all the biological machinery inside the cell is the hardware that needs to be put together to make a living organism.

Companies are forming all over the world that build artificial life, one chemical at a time and ship it as small sections of DNA to labs for further development. These short strands are known as oligos. Genetic engineers use them as hooks to copy natural DNA. The usual length of DNA strands produced is 3000 base pairs, which totals one rung of the DNA ladder.

Synthetic biologists predict that within 2 years a million base pair bacterial genome will be constructed. In 18-24 months a yeast genome of 12 million base pairs could be synthesized. Soon after that, it will become a plant chromosome.

Drew Endy of MIT (Massachusetts Institute of Technology) states: "There is no technical barrier to synthesizing plants and animals, it will happen as soon as anyone pays for it."

Rob Carlson of the University of Washington states that within 10 years a single person could sequence or synthesize the entire DNA that describes all the people on the planet in 8 hours, and then do his own within seconds. This is really interesting; they are working on creating medicines with your DNA that would be for you alone. No-one else would or could use it, so that would eliminate many problems with the black market of medications.

Today, building the entire genome of a human being with around 3 billion base pairs would cost $2.5 billion, so this means if you're wealthy enough you could do it. In 10 years they will be synthesized from scratch. Now they produce DNA, so they need to arrange it. Francis Crick, co-discoverer of the DNA double-helix writes; "DNA makes RNA, RNA makes proteins, and proteins make us." The building blocks for proteins are amino acids. Codons (chemical bases) determine which amino acids will be produced within the cell, which is added to the protein under construction.

There are 64 codons but only 24 amino acids. Synthetic biologists work below the level of the gene, at the codon level, to rearrange codons to build new sets of biological instructions. For example, one codon might work better in plants; other codons might work better in bacteria.

Some biologists remove codons, others combine them and make standard parts. Still others design new amino acids from combinations not found in nature. Their job would be easy if units of DNA, or genes, were linked to specific traits. But they are not. They interact in subtle and complex networks, each producing proteins that promote or suppress the behavior of other genes.

Geneticists are now mapping the interactions between genes to understand what is necessary to produce a desired protein. This is known as the genetic pathway.

Biologists are rebuilding and altering these pathways as discreet sections of the genome, then putting them together as a synthetic chromosome.

In doing this, they can increase the production of a protein or stimulate the production of an entirely different substance, such as plastic or a drug.

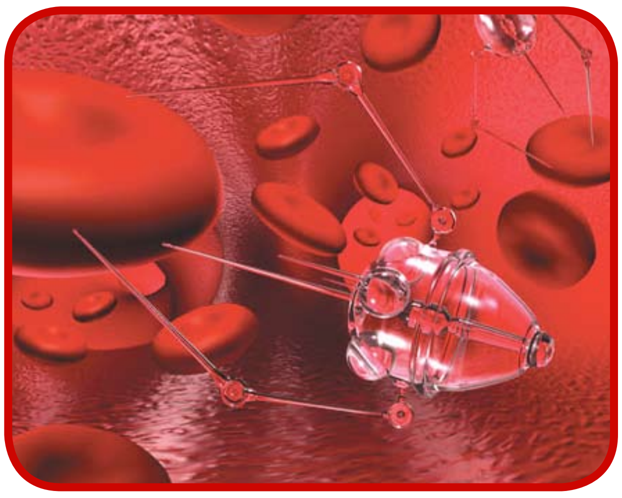
There are five areas of research in synthetic biology:

1. Making minimal microbes – post-modern genomics

Craig Venter is a leader in this. He has been promoting the minimizing of the genome of organisms. For example, they took the 517 genes (made up of 580,000 DNA base pairs) of the bacterium Mycoplasma genitalium (a bug that causes urinary tract infections) and reduced them to 386.

They are doing this with other organisms. The goal is to use minimal microbes as platforms to build new synthetic organisms whose genetic pathways are programmed to perform useful commercial tasks – such as generating alternate fuels, such as ethanol or hydrogen.

The key is to find a microbe that will cheaply and efficiently break down cellulose to sugars and then ferment these sugars into ethanol – without costing energy. One of the problems with ethanol today is that it takes more energy to create it than to use it, so it is not efficient.



Nanobots are being designed to detect disease

Dartmouth and University of Stellenbosch teams have engineered yeast that can survive on cellulose alone, breaking down the plant's cell walls and fermenting the derived sugars into ethanol.

Perdue researchers have developed modified yeast than can produce 40% more ethanol from biomass than naturally occurring yeast and is working with gas companies to convert straw into fuel. A few years ago, the United States donated a few acres of land to help with the research on this project.

This research is supported by corporate agriculture energy people, for example Vinod Khosla, the co-founder of SUN computer and Sergey Brin (who funded Google), Bill Gates, Paul Allen (Microsoft) and Richard Branson (Virgin Airlines).

Cellulosic ethanol has been declared a Clean Development Mechanism (CDM) under the Kyoto protocol. Kyoto taxes countries that produce carbon and gives that to the third-world. So the artificial products that they create are considered "clean" products to offset the dairy products being used in the West. We can expect large plantations in the third-world to produce these goods. There are in total 55 projects that are under way, and 32 of them are in India.

The effect on the south will be reduced food production and new monocultures. It will have negative effects on soil, water, biodiversity, land tenure and livelihoods.

Venter's colleague, Hamilton Smith, when asked if they were playing God answered, "we don't play." These guys are pretty proud – they can create life; they are like God.

2. Assembly line DNA – life-forms to order

Drew Endy of MIT is following a different path. He dismisses genetic code that has evolved in nature as messy. You have to understand what this means. God developed genetic code, and he says that it is messy! He invents new biological systems.

He and his colleagues have invented several hundred discrete DNA modules that behave a little like electronic components. They include sequences that that turn genes on or off, transmit signals, and change colors. These modules are called bio-bricks, like Lego. Each is a strand of DNA designed to reliably perform one function. They combine these into longer circuits and drop them into E coli, yeast or another microbial host to see if they function.

Endy talks about building circuits into human body cells that count how many times they divide to prevent run-away growth, then hooking to a suicide mechanism before tumors form. They are saying that they can cure cancer that way.

Emanuel Nazareth of the University of Toronto imagines using bio-blocks to build programmable cells that scour the body crunching through cholesterol.

3. Building artificial cells from the bottom up – ersatz evolution

This group aims to create artificial life forms without using DNA at all. Los Alamos National Laboratory is funding Steen Rasmussen to do this. They are trying to design life by creating its essential ingredients and mixing them together in a test tube. They want to create a proto-cell with three elements: a metabolism that harvests and generates energy, an information-storing module (like DNA) and a membrane to hold it together.

They are part of the PACE (A Practical Approach to Concurrent Engineering) consortium, a project involving 14 European and US universities and funded by the European Commission.

At Oak Ridge National Laboratory, the US Department of Energy lab that played a major role in the production of enriched uranium for the Manhattan Project, have hit upon a nano-technique for injecting DNA into millions of cells at once. Millions of carbon nano-fibres are grown sticking out of a silicon chip with strands of synthetic DNA attached to the nanofibres. Living cells are then thrown against and pierced by the fibres, injecting the DNA into the cells in the process: Once injected, the synthetic DNA expresses new proteins and new traits.

Oak Ridge has entered into collaboration with the Institute of Paper Science and Technology in a project aimed to use this technique for genetic manipulation of loblolly pine, the primary source of pulpwood for the paper industry in the USA.

4. Pathway engineering – bug sweatshops

A team at Berkeley is engineering the genetic pathways of cells to produce valuable drugs and industrial chemicals.

They have synthesized a dozen genes to make the pathways behind a class of compounds known as isoprenoids – high value compounds important in drugs and industrial chemicals.

The Gates Foundation is supporting their work on a powerful anti-malarial compound known as artemisinin. It will become an unlimited and cheap drug.

They are also re-engineering the pathways that produce natural rubber. These pathways will then be incorporated into bacteria, or sunflowers or desert plants to boost rubber production. So in theory, your maple tree could start producing rubber.

Chris Voigt at UCSF (University of California in San Francisco) is re-engineering a strain of salmonella to produce the precursor to spider silk.

DuPont has added genetic networks to the cellular machinery of E coli which, when mixed with corn syrup, produce a key component in Sorona, a spandex like fibre. DuPont and Tate & Lyle are building a $100 million dollar factory in Tennessee to produce this. They expect it to cause as much fuss as the introduction of nylon in the 1930s.

5. Expanding Earth's Genetic System – alien genetics

Steven Benner of the Westheimer Institute for Science is creating new biological modules that can be chemically synthesized so that they reproduce and pass on their genetic inheritance in the same way that DNA does.

He has created new nucleotide bases, adding to the four natural DNA bases. He states: "In five years or so, the artificial genetic systems that we have developed will be supporting an artificial life-form that can reproduce, evolve, learn and respond to environmental change."

Eric Kool of Stanford has created a new molecule and states "one day his xDNA could be the genetic materials for a new form of life, maybe here or on another planet."

Implications of Synthetic Biology

1. Building better bio-weapons

Ekhard Wimmer of SUNY (State University of New York) ordered some oligos and pasted them together into a functional version of polio virus. They injected mice to confirm that it worked, that the mice then had polio.

Serguei Popov, who genetically engineered bio-weapons for the Soviet Union's secret bio-warfare program said that 25 years ago they produced one virus a month. Now it is much faster. A reporter from the Guardian bought a fragment of DNA of variola major. They estimated they could crank out a synthetic version of it in less than two weeks for the cost of a car. We are talking of smallpox, a highly infectious disease.

Chemical Warfare

Biologists working in pathway engineering can construct genetic networks that code for particular proteins which, inserted into microbial hosts, such as E coli or yeast, can function as bio-factories producing snake, insect and spider venoms, plant toxins and bacterial toxins such as anthrax, botulism, cholera, staphylococcal food poisoning and tetanus.

When they talk about a pandemic, this is what they are talking about. Because they know that they can create these diseases and they can spread them very quickly around the world. A CIA study said in 2003 that the same science that may cure some of our worst diseases could be used to create the world's most frightening weapons.

Nano-capsules and microcapsules make an ideal vehicle for delivering chemical and biological weapons because they can carry substances intended to harm humans as easily as they can carry substances intended to kill weeds and pests. By virtue of their small size, DNA nano-capsules may be able to enter the body undetected by the immune system and then become activated by the cells' own mechanisms to produce toxic compounds.

When programmed for external triggers such as ultrasound or magnetic frequencies, activation can be controlled remotely.

2. Creating better animals

DNA Nano-vaccines: the USDA is completing trials on a system for mass vaccination of fish using ultrasound. Nano-capsules containing short strands of DNA are added to a fishpond where they are absorbed into the cells of the fish. Ultrasound is then used to rupture the capsules, releasing the DNA and eliciting an immune response from the fish. This technology has so far been tested on rainbow trout by Clear Springs Foods (Idaho, US) – a major aquaculture company that produces about one-third of all US farmed trout.

According to science reporter W. Wayt Gibbs, synthetic biology involves "designing and building living systems that behave in predictable ways, that use interchangeable parts, and in some cases that operate with an expanded genetic code, which allows them to do things that no natural organism can." One of the goals, writes Gibbs, is to "stretch the boundaries of life and machines until the two overlap to yield truly programmable organisms."

New animal types can be created. One goal is to functionalize biochips for breeding purposes. With the mapping of the human genome behind them, geneticists are now rapidly sequencing the genomes of cattle, sheep, poultry, pig and other livestock hoping to identify gene sequences that relate to commercially valuable traits such as disease resistance and leanness of meat. By including probes for these traits on biochips, breeders will be able to speedily identify champion breeders and screen out genetic diseases.

3. Producing artificial food

Instead of harvesting grain and cattle for carbohydrates and protein, nano-machines (nanobots) could assemble the desired steak or flour from carbon, hydrogen, and oxygen atoms present in the air as water and carbon dioxide.

Nanobots present in foods could circulate through the blood system, cleaning out fat deposits and killing pathogens." – Dr. Marvin J. Rudolph, Director, DuPont Food Industry Solutions, in Food Technology, January 2004.

Some are being tested on astronauts. Tissue engineers at Touro College (New York City) and at the Medical University of South Carolina (USA) are experimenting with growing meat by "marinating" fish myoblast (muscle) cells in liquid nutrients to encourage the cells to divide and multiply on their own. The first goal is to keep astronauts in space from going hungry.

In 1999, Kraft Foods, the $34 billion Altria (formerly known as Phillip-Morris) subsidiary, established the industry's first nanotechnology food laboratory. The next year, Kraft launched the NanoteK consortium, enveloping fifteen universities and public research labs from around the globe. None of the scientists involved in the consortium are food scientists by training; rather, they're a mix of molecular chemists, material scientists, engineers and physicists.

Mars, Inc., one of the world's largest private food corporations, was issued US patent 5,741,505 in 1998 on "edible products having inorganic coatings." The coatings create a barrier to prevent oxygen or moisture from reaching the product under the coating, thereby increasing shelf life. They use this to keep products looking good for longer periods of time.

Kraft is also working on sensors that will be able to detect an individual's nutritional deficiencies and then respond with smart foods that release molecules of the needed nutrients.

In addition to aiding nutrient delivery, nano-particles may be used in foods to alter other properties. For example, margarine, ice cream, butter and mayonnaise all belong to a class of foods known as colloids, where small particles are dispersed in some other medium – liquid, gas or solid. Unilever, Nestle and others are conducting research and already hold patents on new ways to make colloids using nano-particles that will extend shelf-life, prolong flavor sensation in the mouth, alter texture and improve stability.

Kraft's NanoteK consortium scientists are developing nano-capsules whose walls burst at different microwave frequencies so the consumer can 'switch on' new tastes or colors. So if you want your hot dog to taste like a steak, you would just change the frequency on the microwave.

4. Creating new drugs

Drugs themselves are set to shrink. Nano-sized structures have the advantage of being able to sneak past the immune system and across barriers (e.g., the blood brain barrier or the stomach wall) the body uses to keep out unwanted substances.

Kris Pister, who owns a company called Dust, says that in 2020 there will be no unanticipated illness. "Chronic sensor implants will monitor all of the major circulator systems in the human body, and provide you with early warning of impending flu, or save your life by catching cancer early enough that it can be completely removed surgically."

5. Intellectual monopoly

We saw this above.

6. Loss of genetic resources and biodiversity

In a few years it will be easier to synthesize a virus than to request it from a culture collection or find it in nature.

With a shift from biological samples to digital DNA samples, the legal concept of national sovereignty over genetic resources will end. Scientists will no longer need to sign legally binding Material Transfer Agreements.

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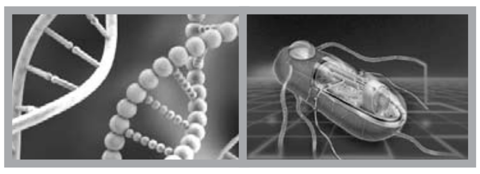

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DNA databases could become as user-friendly as Google. In fact, Google has signaled interest in storing all of the world's genomic data in their Google-farms.

7. Implications for trade

In our molecular future, the farm will be a wide area bio-factory that can be monitored and managed from a laptop and food will be crafted from designer substances delivering nutrients efficiently to the body.

Nano-biotechnology will increase agriculture's potential to harvest feed-stocks for industrial processes.

Meanwhile tropical agricultural commodities such as rubber, cocoa, coffee and cotton – and the small-scale farmers who grow them – will find themselves quaint and irrelevant in a new nano-economy of "flexible matter."

8. Robots could replace people.

The US Department of Agriculture (USDA), in what they originally dubbed "Little Brother Technology," identifies agricultural sensor development as one of their most important research priorities. The USDA is working to promote and develop a total "Smart Field System" that automatically detects, locates, reports and applies water, fertilizers and pesticides – going beyond sensing to automatic application.

Industry is already experimenting with wireless sensor networks for agriculture. Computer chip maker Intel, whose chips have nano-scale features, has installed larger wireless sensor nodes (called 'motes') throughout a vineyard in Oregon, USA. The sensors measure temperature once every minute and are the first step towards fully automating the vineyard. The next steps are to apply water, fertilizers and pesticides as needed.

Every plant will have its own sensors so it can tell the computer what it needs. These dust sensors now cost about $40.

They are being used in many other applications.

• Wildlife Habitats: At Great Duck Island off the coast of Maine (USA) a network of 150 wireless sensor motes have been monitoring the microclimates in and around nesting burrows used by seabirds. The aim is to develop a habitat monitoring kit that allows researchers to monitor sensitive wildlife and habitats in non-intrusive and non-disruptive ways.

• Bridges: In San Francisco (USA) a network of sensor motes has been installed to measure the vibration and structural stresses on the Golden Gate Bridge as a form of proactive maintenance.

• Redwood trees: In Sonoma County, California (USA), researchers have strapped 120 motes to redwood trees in order to wirelessly and remotely monitor the microclimate around the trees from Berkeley, over 70 kilometers away.

• Supermarkets: Honeywell is testing the use of motes to monitor grocery stores in Minnesota (USA).

9. Changes in mineral availability

Research from the University of Texas-El Paso confirms that plants can also soak up nano-particles that could be industrially harvested. In one particle farming experiment, alfalfa plants were grown on an artificially gold-rich soil on university grounds.

10. Synbiosafety

In genetic engineering, we learned that living organisms evolve and mutate, that we don't know a lot about how living organisms work, that they can escape and interact with their environment, and that they may not work the same as their known counterparts.

Robots working in a factory

Characteristics – such as electrical conductivity, reactivity, strength, color and especially important, toxicity – can all change in ways that are not easily predicted. The life expectancy of Ph.D. chemists working in US labs is already about ten years less than their non-lab counterparts.

11. Automate much of war

DARPA (Defense Advanced Research Projects Agency) works on new military projects. In one of them, the objective was to deploy smart dust networks over enemy terrain to feedback real time news about troop movements, chemical weapons and other battlefield conditions without having to risk soldiers' lives.

This evolving to general use involving ubiquitous wireless sensors embedded in everything from the clothes we wear to the landscapes we move through could fundamentally alter the way we relate to everyday goods, services, the environment and the State. The aim is to develop what researches call 'ambient intelligence' – smart environments that use sensors and artificial intelligence to predict the needs of individuals and respond accordingly: offices that adjust light and heating levels throughout the day or clothes that alter their colors or warmth depending on the external environment.

12. Control over people

For example, the US government's "SensorNet" project attempts to cast a net of sensors across the entire United States, that will act as an early warning system for chemical, biological, radiological, nuclear and explosive threats. The SensorNet will integrate nano, micro and conventional sensors into a single nationwide network that will feed back to an existing US network of 30,000 mobile phone masts, forming the skeleton of an unparalleled national surveillance network. This includes Canada, since we are going into the North American Union.

Michael Mehta, a sociologist at the University of Saskatchewan (Canada), believes that the environment equipped with multiple sensors could destroy the notion of privacy altogether – creating a phenomenon that he calls "nano-panopticism" (i.e., all seeing) in which citizens feel constantly under surveillance.

So what do we as people of faith, conclude?

1. While there is much potential good in what is being done, there is a strong confidence that holds that science does not need God. Many scientists believe they are their own gods.

2. Scientists will bring disaster to our world by meddling and degenerating God's creation.

The Pope has talked about it happening and made the following ominous statement:

"Man is capable of producing another man in the laboratory who, therefore, is no longer a gift of God or of nature. He can be fabricated and, just as he can be fabricated, he can be destroyed. Therefore, if this is man's power, then he is becoming a more dangerous threat than weapons of mass destruction." – said (then) prefect of the Vatican Congregation for the Doctrine of the Faith, Cardinal Joseph Ratzinger (Pope Benedict XVI) on Oct. 27, 2004.

Patrick Redmond

"A family who prays together, stays together"

"The Most Holy Virgin in these last times in which we live has given a new efficacy to the recitation of the Rosary to such an extent that there is no problem, no matter how difficult it is, whether temporal or above all spiritual, in the personal life of each one of us, of our families... that cannot be solved by the Rosary. There is no problem, I tell you, no matter how difficult it is, that we cannot resolve by the prayer of the Holy Rosary."

Sister Lucia dos Santos

The Rosary is a universal prayer that has a three-fold purpose: mystical contemplation, intimate reflection and pious intention.

At Fatima, Our Lady instructed Lucia, Francisco, and Jacinta to recite the Rosary often for the conversion of sinners. The Rosary links us closely to the lives of Jesus, Mary and Joseph. When we recite the Rosary, we are invited to meditate on the mysteries: Joyful, Luminous, Sorrowful, and Glorious.

Fr. Patrick Peyton was a well-known priest who promoted the family Rosary. He used to say: "A family who prays together, stays together." The reality of the Rosary's power is something that has been manifested many times throughout history. Fr. Peyton himself was cured of advanced tuberculosis while he was in the seminary. He decided thereafter to dedicate his life to the promotion of this great devotion to Mary, and presently his cause for sainthood is in Rome.

In 1571, the recitation of the Rosary stopped the advancement of the Turks at Lepanto, and two years after that, Pope Gregory XIII established the Feast day of the Holy Rosary. In Hiroshima, Japan, in the year 1945, the atomic bomb went off 1 kilometer from a house where eight German Jesuit missionaries faithfully prayed the Rosary every day. The house remained untouched, and the missionaries received no adverse effects from the powerful rays of radiation. They stated that: "we believe that we survived because we were living the message of Fatima. We lived and prayed the Rosary daily in that home."

We all need to know the reasons WHY we should pray the Rosary. We will not feel it necessary to pray it unless we understand WHY we should do so. St. Louis de Montfort's book, The Secret of the Rosary will help us to understand completely; he tells us: "The holy Rosary is a gift come down from Heaven; a great present that God gives to His most faithful servants. God is the Author of the prayers of which it is composed and of the mysteries it contains."

In a sermon on the Holy Rosary, Clement Losoun said: "After St. Dominic had gone to heaven devotion to the Rosary waned until it was very nearly dead, when a terrible pestilence broke out in several parts of the country. The wretched people sought the advice of a saintly hermit who lived in the desert with great austerity. They besought him to intercede to Almighty God for them. So the hermit called upon the Mother of God for them. So the hermit called upon the Mother of God, imploring her, as Advocate of Sinners, to come to their aid.

"Our Lady then appeared and said: 'These people have stopped singing my praises. This is why they have been visited with such a scourge. If only they will go back to the ancient devotion of the Most Holy Rosary, they will enjoy my protection.' So the people did what Mary asked and made themselves Rosaries, which they started saying with all their heart and soul."

Here is Pope John Paul II's Message for the World Youth Day in 2003: "Dear young people, do not be ashamed to recite the Rosary alone, while you walk along the streets to school, to the university or to work, or as you commute by public transport. Adopt the habit of reciting it among yourselves, in your groups, movements and associations. Do not hesitate to suggest that it be recited at home by your parents and brothers and sisters, because it rekindles and strengthens the bonds between family members. This prayer will help you to be strong in your faith, constant in charity, joyful and persevering in hope."

To learn how to say the Rosary, order our brochure or go to www.mostholyrosary.com.