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ACADEMIA MEXICANA DE CIENCIAS
MEXICAN ACADEMY OF SCIENCES

FOR THE RESPONSIBLE USE OF GENETICALLY MODIFIED ORGANISMS

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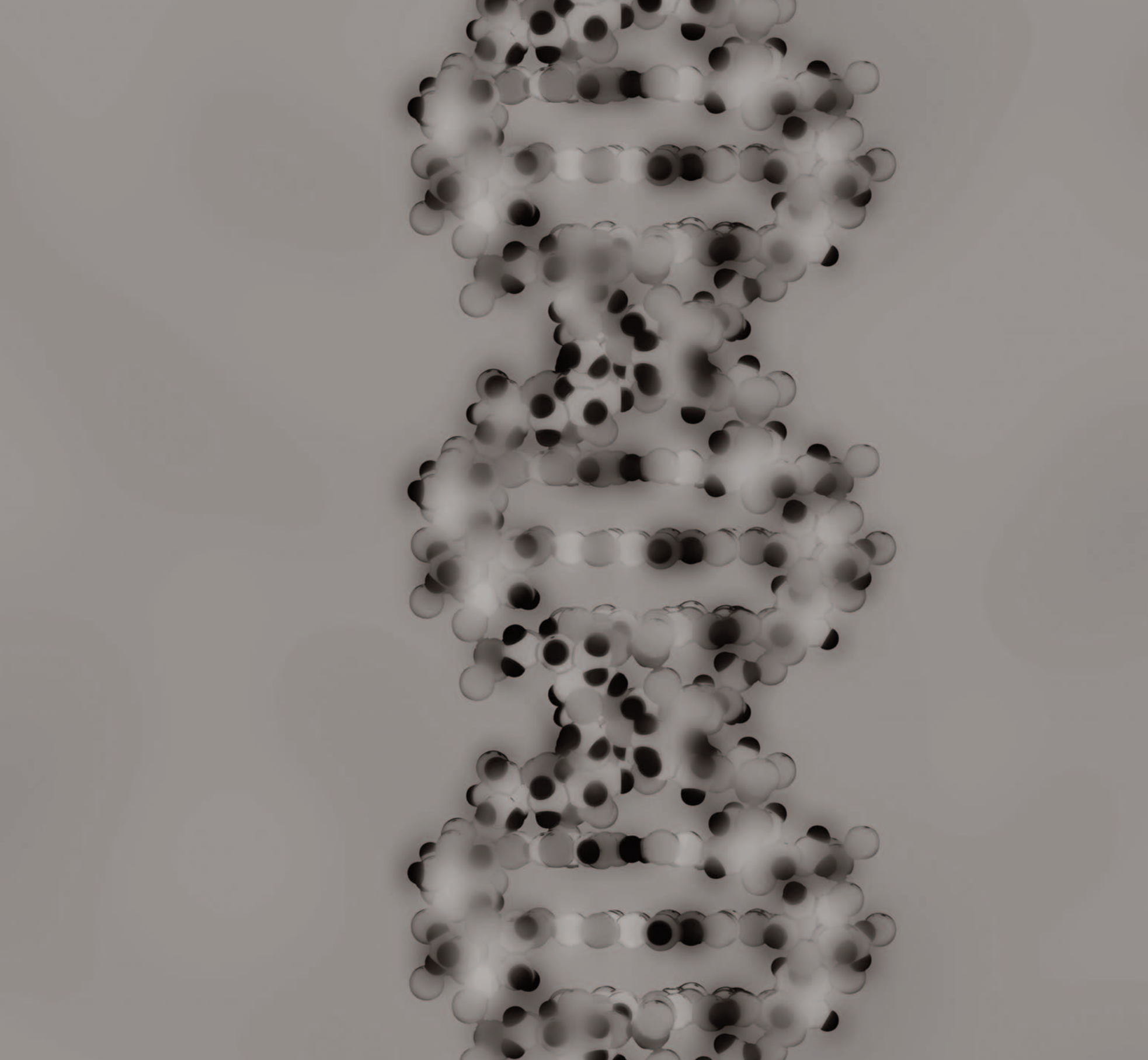
BIOTECHNOLOGY COMMITTEE

CHAIR
FRANCISCO GONZALO BOLÍVAR-ZAPATA

MEXICAN ACADEMY OF SCIENCES



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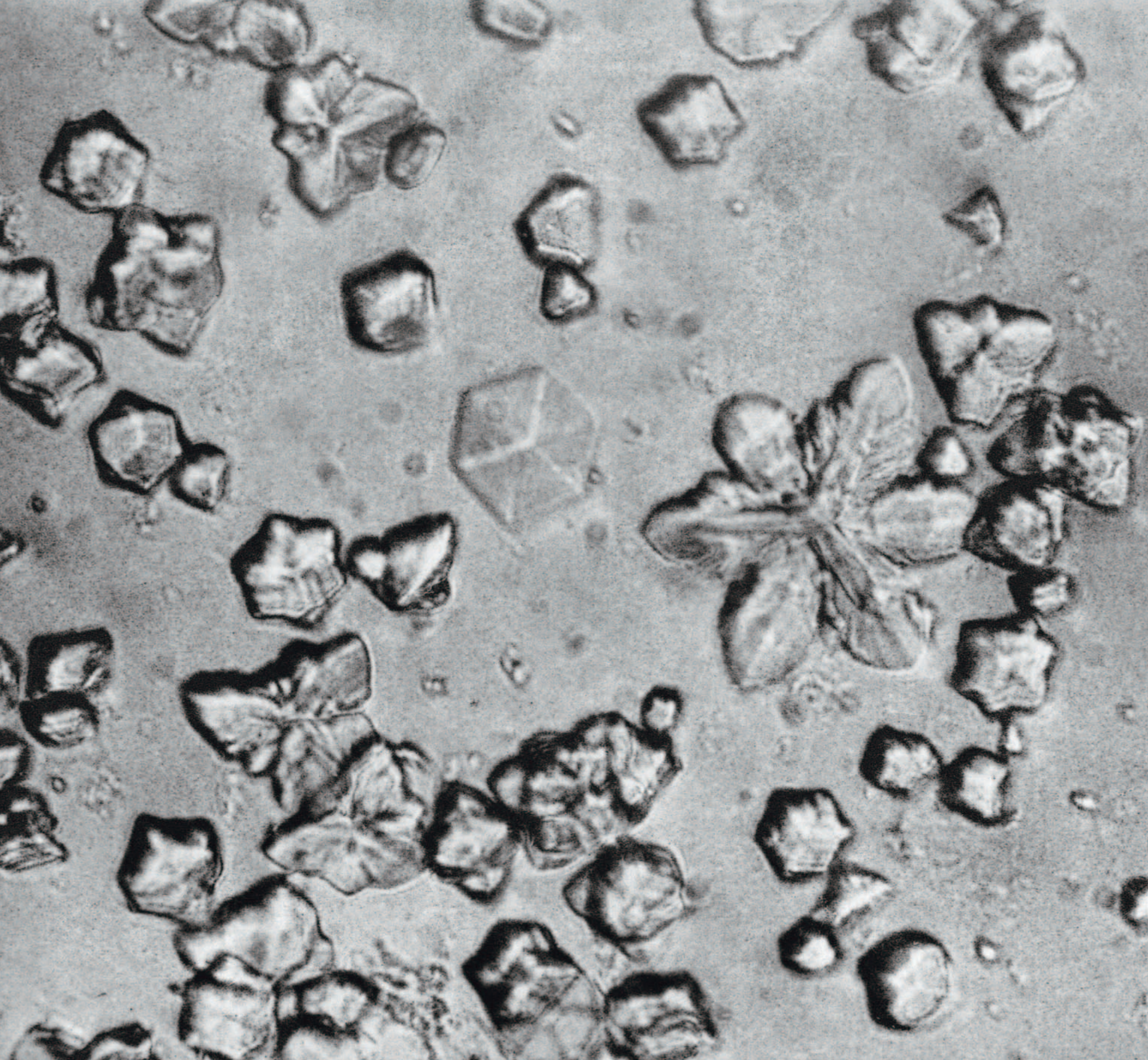

FOREWORD

Science is an intrinsically human activity rooted in its spirit of inquiry as well as a fundamental part of the culture of nations. Science seeks to produce knowledge about the universe and nature, including the human race in order to know and understand ourselves better. We have witnessed an extraordinary advance in scientific knowledge in recent decades, which has permanently deepened our understanding of the universe, nature and human society. This scientific knowledge also forms the basis of the technology used to cope with society and the world's needs and problems. Competitive, responsible, sustainable technology is required to satisfy many of the needs and extraordinary problems facing mankind and our home, planet earth.

Biotechnology is a multidisciplinary activity based on the knowledge of more traditional disciplines, such as microbiology, genetics, biochemistry, molecular biology, biochemical engineering and other more recent ones such as genomics and bioinformatics. On the basis of the knowledge of living cells and the way they function, through these disciplines, biotechnology has helped meet demands in the solution of key problems in various sectors such as health, agriculture, livestock and fishing, industry and the environment.

Through modern genetic engineering and genomic techniques, it is possible to isolate or synthesize genes of any origin. Genes are segments of molecules of deoxyribonucleic acid (DNA), the genetic material of all living beings. These genes can be used to construct transgenic or genetically modified organisms (GMO) in order to develop better biological systems and environmentally-friendly biological technology for the production of medicine and food and the protection of our habitat.

This book, written by the Biotechnology Committee of the Academia Mexicana de Ciencia (AMC), comprising 21 academic experts in various fields, including seven Mexican National Science Award winners,

explains the reasons why GMO have been developed as one of the most important tools in modern biotechnology, to contribute to the solution of various problems and demands.

The document also presents a key set of scientific evidence through which this group of experts maintains that since transgenic organisms are created through similar processes to those that occur in nature, they are organisms with similar levels of risk to those that exist in the biota.

The text also presents and analyzes the legal framework that exists in Mexico, which governs the responsible use of GMO. This legal framework comprises the Cartagena Protocol for Biosafety and the Biosecurity Law of GMO.

The AMC Biotechnology Committee would like to point out that GMO and their products, currently used as food or medicine, have been subject to a large number of analyses and evaluations proving that they do not harm either human health or the environment. The World Health Organization and the government agencies responsible for the approval and use of GMO have pointed out that the transgenic organisms used today have not caused any damage, which is why they continue to be used in over 50 countries.

The AMC has supported the work of its Biotechnology Committee in order to make the scientific information underlying its considerations available to society in general, as well as legislators and professionals in the Secretariats of Health, Agriculture and the Environment, among others, in order for the decisions made regarding the use of GMO to be based on scientific evidence. For this reason, this book, as well as other related texts, is available on the AMC website in an electronic version. The AMC thanks the Consejo Nacional de Ciencia y Tecnología (CONACYT, Mexico) for its support in publishing this book.

Biotechnology and GMO used responsibly constitute an opportunity and a powerful tool for giving added value to the products in Mexican biodiversity, which is one of our greatest assets, and for helping to solve the extraordinary global and national problems we face in this century.

Arturo Menchaca Rocha
President
Academia Mexicana de Ciencias

Francisco Gonzalo Bolívar-Zapata
Chair
Biotechnology Committee, AMC

February 2012

BIOTECHNOLOGY COMMITTEE OF THE ACADEMIA MEXICANA DE CIENCIAS

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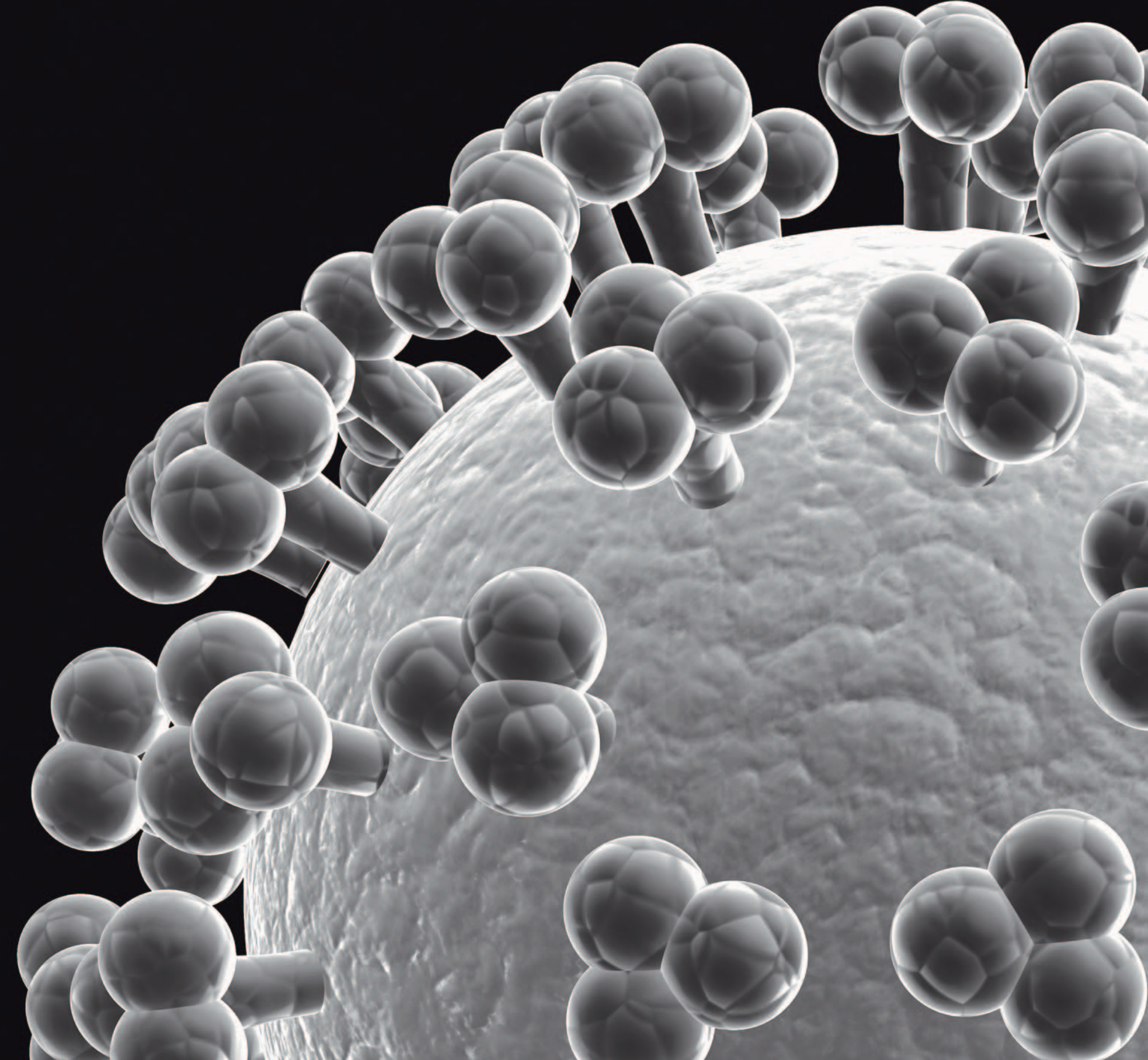


I. INTRODUCTION

For over 30 years, human beings have used genetically modified (GMO) or transgenic organisms and the products obtained from them to help solve various problems in key sectors for the well-being of mankind, such as health, food production and the recovery of polluted ecosystems.

Thanks to GMO, pharmacies have over a hundred new biological medicines such as insulin for the treatment of diabetes and interferon, a protein that forms part of the immune system as well as new vaccines for disease prevention and treatment of various clinical problems.

Several varieties of transgenic plants are eaten as food while others have significantly reduced the amount of chemical pesticides used to eliminate plagues, many of which are carcinogenic and recalcitrant. Nowadays, transgenic plants are grown on over 134 million hectares in 27 countries while transgenic organisms and their products are consumed in over 50 countries by over 300 million inhabitants.

Although there is no proof to date of damage to human health caused by the use and consumption of live organisms or their products that have been subject to genetic modification using these new tools, this technology, like any other, may pose risks. Through its various offices, The United Nations Organization (UN) has therefore implemented several agreements, documents and legal frameworks to ensure the responsible management of GMO. Mexico signed one of those documents, the Cartagena Protocol for Biosafety, which establishes a framework for the transborder management of GMO. On the basis of this commitment, the Senate drew up a biosecurity bill for GMO management in 2000 which became law in 2005 when it was passed by the two Chambers of Congress. These two mandates constitute the legal framework existing in Mexico for GMO management.

This publication was produced by the Biotechnology Committee of the Academia Mexicana de Ciencias (AMC) for various purposes.

Figure I.1 Cultivation of transgenic soybeans.
This characteristic makes plants pest-resistant without using chemical pesticides.

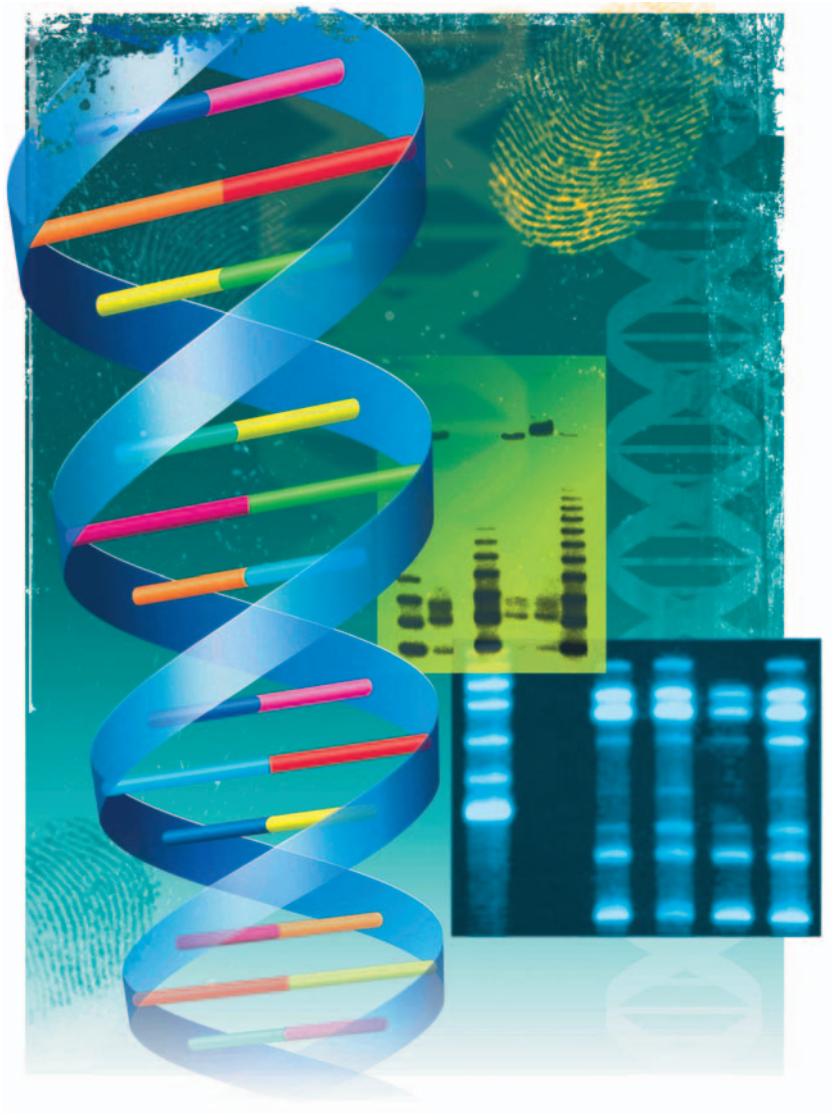


Figure I.2. DNA is the molecule containing the genetic information of all living beings. Genetic Engineering techniques enable one to synthesize and isolate genes of any origin, while these genes make it possible to construct transgenic organisms.

The first is to explain what modern biotechnology is, what the structure of deoxyribonucleic acid (DNA) is, where genes are located, how proteins are produced from genes and how the emergence of genetic engineering techniques to manipulate the DNA of living cells has made it possible to genetically modify various living organisms, giving rise to GMO or transgenic organisms.

The second is to describe the impact GMO have already had on various sectors in contributing to the solution of various problems in modern society, related to health, food, industry and environmental pollution.

The publication also seeks to present a vast set of published evidence that scientifically sustains the idea that GMO are created by similar processes to those that occur daily in nature and are therefore organisms with similar levels of risk to those existing in the biota. The scientific evidence published in journals and books supporting the various arguments and specific considerations presented and indicated in each particular section in the various chapters of the book, are listed at the end of each section.

Lastly, the AMC Biotechnology Committee issues a series of recommendations for the responsible use of GMO in addition to the legal framework, which in Mexico is governed by the Cartagena Protocol on Biosafety (CPBS), the Biosecurity Law of Genetically Modified Organisms (BLGMO) and the regulations of this law.

This publication includes four appendices: bibliographical references, the glossary, a list of key events related to the development of biotechnology and the "20 Questions on Genetically Modified Foods" drawn up by the World Health Organization (WHO). In this last publication, the WHO states that foods of transgenic origin used to date have not caused any damage to human health or the environment.

Regardless of sharing the WHO's views, the AMC Biotechnology Committee assumes that any technology entails potential risks. It therefore repeats its recommendation that if solid, overwhelming scientific evidence is produced, independently supported by various research groups, on possible damage to human health or the environment due to the consumption of a transgenic product, the authorities must not authorize the production or consumption of this particular transgenic product. This has been the case of modified plants, whose development was halted due to the suspicion of the possible risks that modifications might cause human health. This happened with the Starlink corn in the United States and modified peas in Australia. In both products, the new transgenic proteins were designed to protect crops from insects. However, there was a risk that they might cause allergies in sensitive consumers, as a result of which their consumption was not authorized and the Starlink variety was taken

Figure I.3 Maize grains in which genetic material has naturally been transposed and rearranged, which has given rise to different colors.

off the market. A similar thing has happened with certain drugs whose use has proved harmful to human health. The government agencies responsible for the use of these drugs have pulled these medicines off the pharmacy market. In the case of products of transgenic origin used today in fifty countries, only the cases mentioned have been recalled by the appropriate agencies. Finally, 25 Nobel Prize awardees have signed a Declaration in favor of Agricultural Biotechnology.

As established in the Cartagena Protocol, the Mexican Law for the Biosafety of Genetically Modified Organisms (BLGMO) and its Regulations, it is crucial to continue carrying out evaluations of the possible current and potential risks of GMO and their products on a case-by-case basis to guarantee the responsible use of these organisms, for the benefit of human health, biodiversity and the environment.

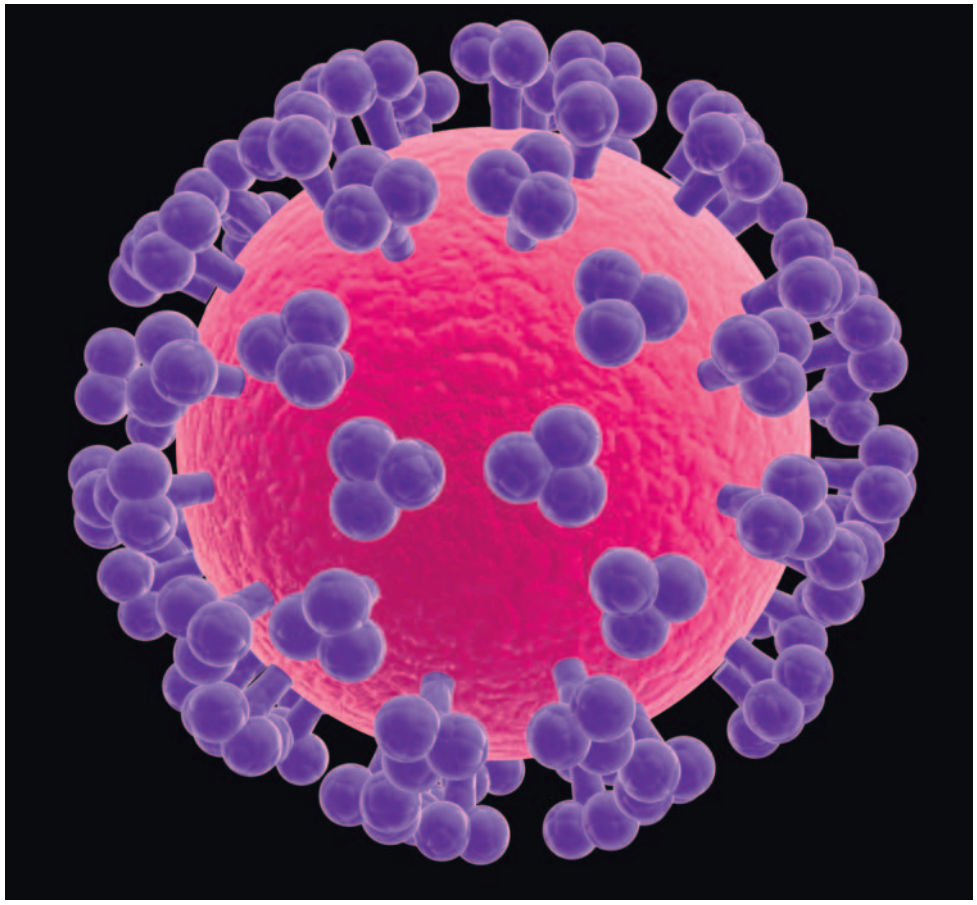
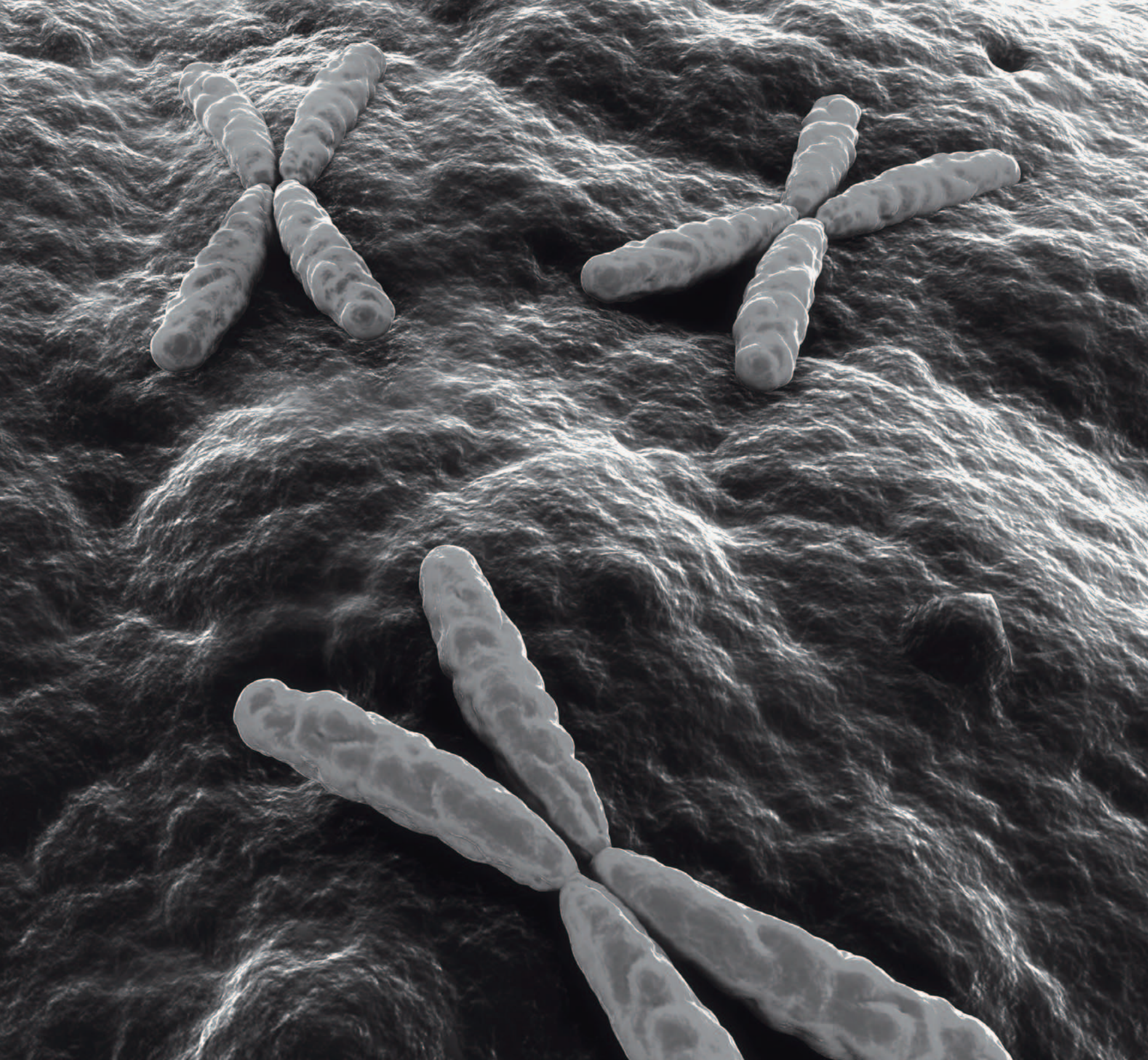


Figure I.4 AIDS-causing virus. Some viruses are vectors responsible for transferring genetic material between different organisms.



II. BIOTECHNOLOGY, GENES, PROTEINS AND TRANSGENIC ORGANISMS. ORIGINS AND JUSTIFICATION OF THE CONSTRUCTION AND USE OF GENETICALLY MODIFIED ORGANISMS

Humans have used other living creatures to satisfy our need for food, health and housing and in this process, we have damaged and abused the planet and its biodiversity. Moreover, many natural resources are exhausted, agricultural productivity is insufficient and explosive world population growth annually increases the need for food and medicine. Hence, the current and future importance of the development of biotechnology in conjunction with other technologies, as part of a responsible response to these problems.

Biotechnology is a multidiscipline based on the knowledge created in various disciplines that permits the integral study, modification and use of the planet's living creatures —microorganisms, plants and animals— (figure II.1). On the basis of this, biotechnology seeks to make responsible, sustainable use of biodiversity, through the development of effective, clean, competitive technology to facilitate the solution of major problems in health, agricultural and industrial production and repair environmental damage.

Appendix 3 contains a chronological list of the most important examples of the use of living beings through biotechnological processes to satisfy our needs for food and health. This appendix also includes certain key scientific events linked to living cells and biotechnology (*Watson* et al. *1998 and 1996, Glick and Pasternak 1998, Bolívar* et al. *2002, 2003 and 2007, Kreuzer and Massey 2005, Hayden 2011, BIO 2011).*

• In 1953, James Watson and Francis Crick discovered the double helix structure of DNA, the biological molecule in which all genetic information of all living beings is stored. DNA is a double helix formed by two anti-parallel, complementary polymers (figure II.2). Each of these two polymers or helices is also comprised of the union of millions of monomers that are like the beads

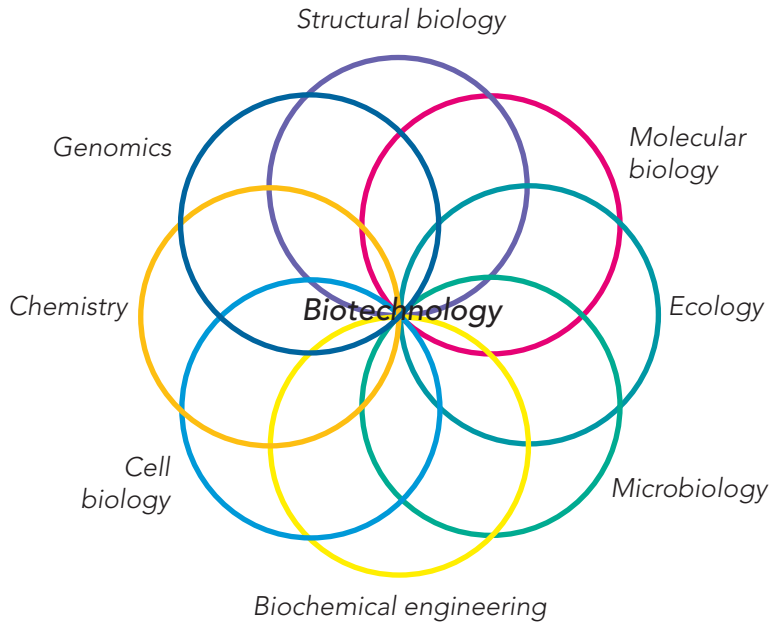


Figure II.1. Biotechnology is a multidisciplinary activity, since it is based on various disciplines.

(monomers) in a necklace (polymer). There are only four types of monomers or genetic letters in the DNA of all living beings, called nucleotides. These are located at 3.4 A° from the next monomer in the polymer forming part of each of the two helices (an A° is the ten millionth part of a meter). Moreover, in every type of DNA, a nucleotide with an Adenine base (A) always has, in the nucleotide of the thread or complementary helix, one with a Thymine base (T) and every nucleotide with a Guanine base (G) has a nucleotide with a Cytosine base (C) in the complementary thread. These are the universal rules for all DNA in all living beings. The main difference between all DNA is the sequence of these four types of nucleotides with their A, T, G and C bases in every letter of every DNA molecule, in which there are various million nucleotides, just as there are only 26 letters in the alphabet for making all words and the different sequence of these letters in the words is what creates a different meaning for each of them. The double helix structure allows them to be duplicated (replicated) which in turn enables the replicated genetic material to be transferred to the daughter cells.

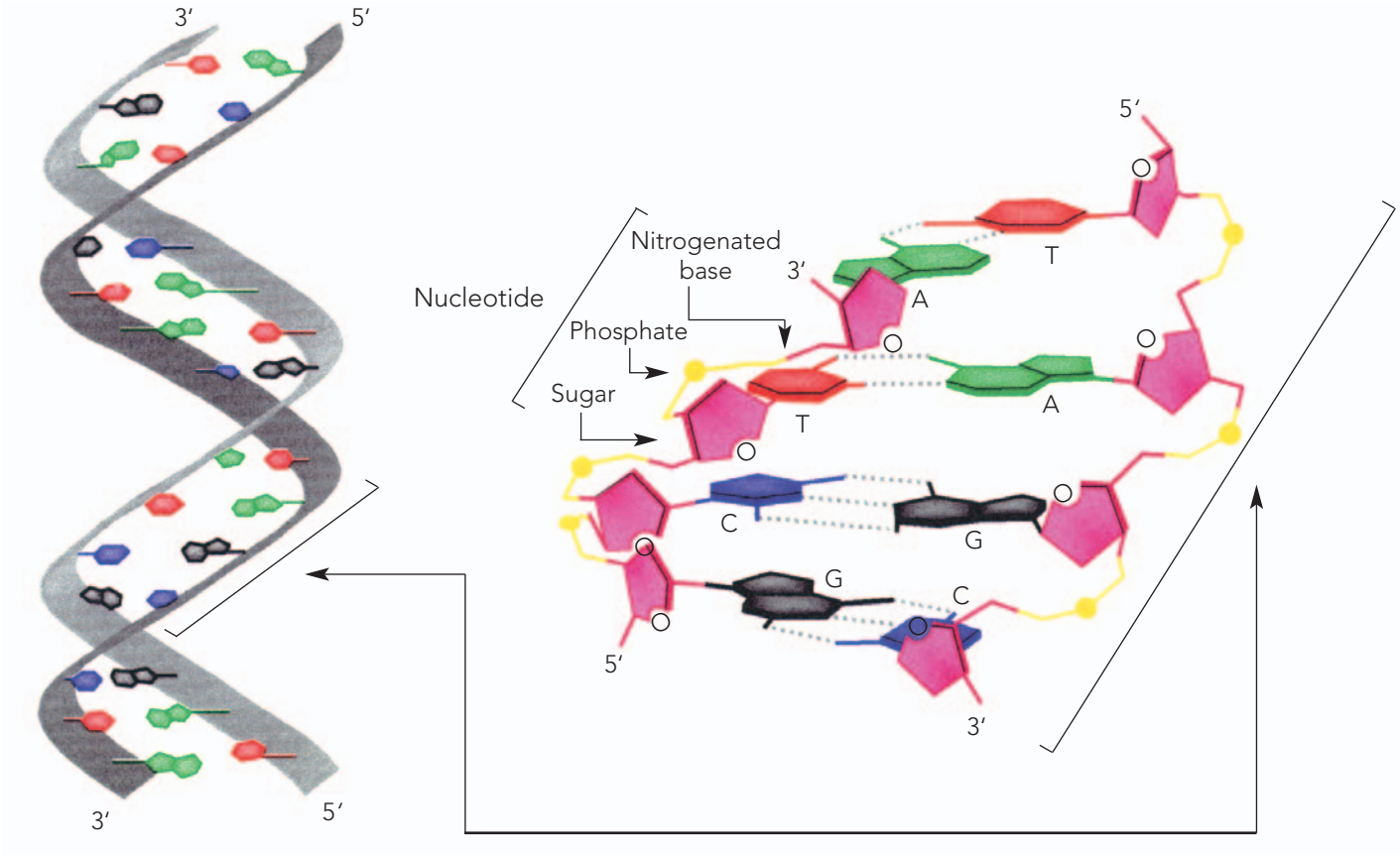


Figure II.2. DNA structure comprising two complementary helices. Each of these two helices or threads comprises four types of nucleotides (A,G,C,T). Each nucleotide comprises deoxyribose sugar (in purple), a phosphate group (in yellow) and a puric (G [in black] or A [in green]) or pyrimidic base (C [in blue] or T [in red]). Its double helix structure is the same in all living beings, enabling it to be replicated.

DNA forms part of the chromosomes, structures located in the cell nucleus, while genes are segments of the DNA molecules that form part of the chromosomes (figures II.3 and II.4). Most of them encode a specific protein from that gene while the rest of the genes encode ribonucleic acid molecules (RNA) which do not translate, in other words, their information does not turn into proteins (figures II.5, II.6 and II.7).

The cell copies or transcribes the information from the genes in RNA molecules. As one can see from figure II.5, the process of DNA transcription is undertaken by the RNA polymerase enzyme, which separates the two

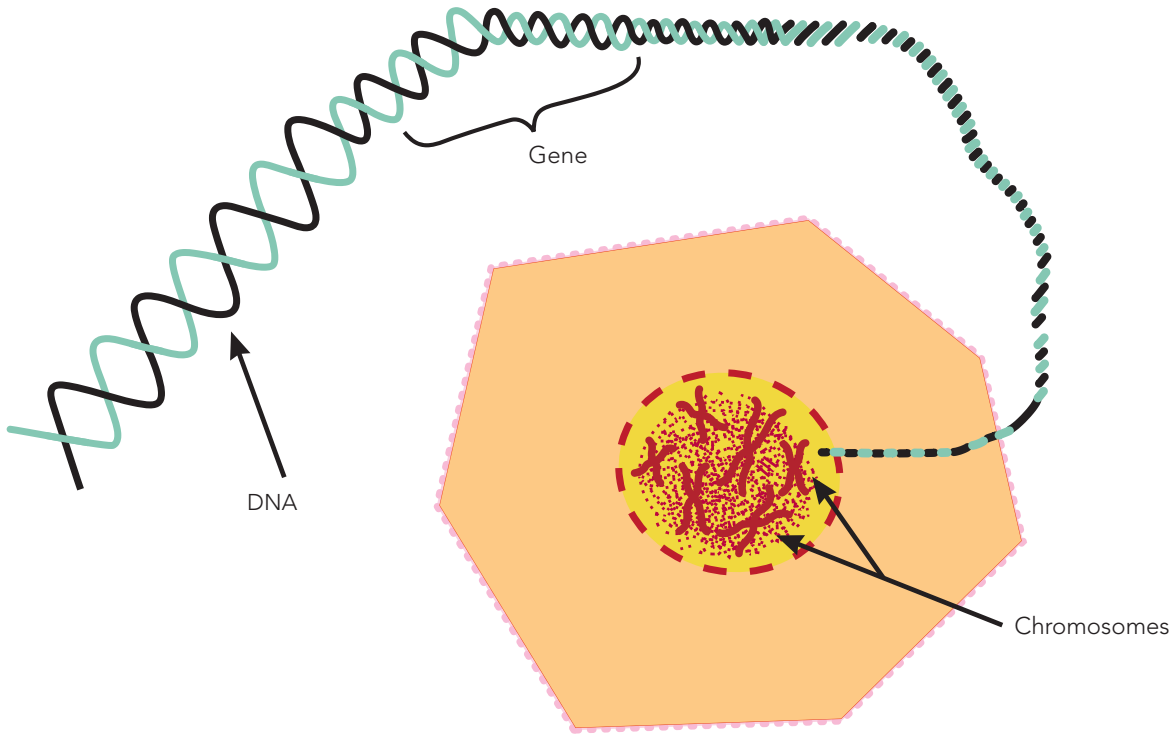


Figure II.3. Composition and organization of genes in chromosomes. Chromosomes are cell structures located in the cell nucleus, comprising proteins and DNA, while genes are specific segments of the genetic ribbon called DNA. Genes are segments of the DNA molecules in the chromosomes. Every type of living organism has a specific, different number of chromosomes in relation to other living beings.

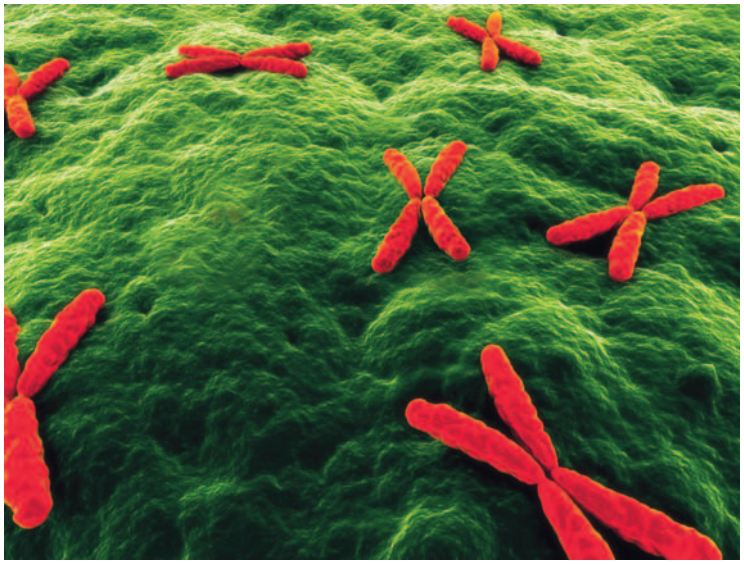


Figure II.4 Chromosomes in the replication process.

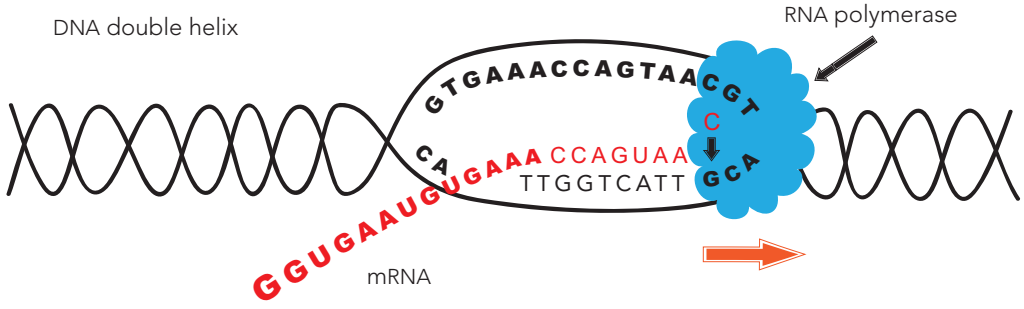


Figure II.5 The process of DNA transcription permits RNA synthesis from the nucleotide sequences of the genes.

DNA threads. Using one of them as a mold, it synthesizes the molecules of the messenger RNA (mRNA) shown as a red ribbon in the figure. This is how specific regions of DNA that include genes are copied. RNA molecules are linear polymers with hundreds of four different nucleotides: A,G,C and U. The main difference from DNA is that Uracil (U) is used instead of Thymine (T) which is used during DNA synthesis. The molecules of the

Aminoacids

Alanine	Ala	A	Leucine	Leu	L
Arginine	Arg	R	Lysine	Lys	K
Asparagine	Asn	N	Methionine	Met	M
Aspartic acid	Asp	C	Proline	Pro	P
Cysteine	Cys	D	Serine	Ser	S
Phenylalanine	Phe	F	Tyrosine	Tyr	Y
Glicine	Gly	G	Threonine	Thr	T
Glutamic acid	Gln	Q	Tryptophan	Trp	W
Glutamine	Glu	E	Valine	Val	V
Histidine	His	H	End of translation	stop	
Isoleucine	Ile	I			

Nucleotides

Guanine	G
Adenine	A
Thymine	T
Cytosine	C

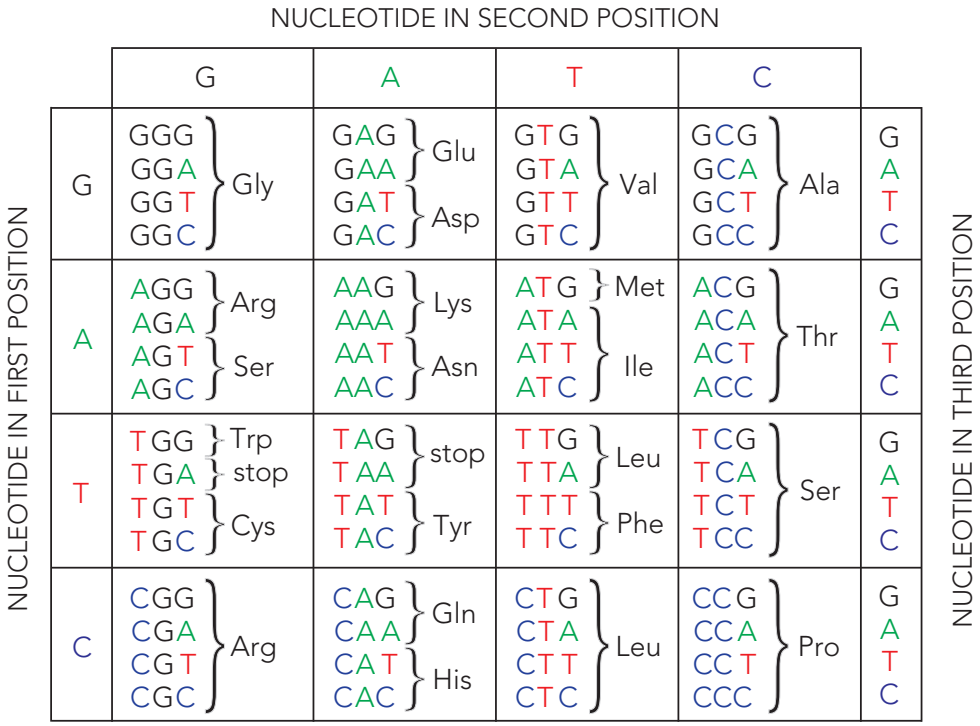


Figure II.6 The genetic code is universal.

messenger RNA that carry the gene information are intermediaries in protein synthesis. Their information is used in the ribosomes to translate into proteins (Figure II.7).

All living beings use the same genetic code to convert and translate the information encoded in nucleic acids (DNA and RNA) in the amino acid sequences that constitute proteins (figure II.6). The genetic code is universal, in other words, it is the same in all living beings and used in the same way in all cells. This code enables the cell to translate the genetic information stored in the genes into proteins by interpreting the genetic information present in the messenger RNA into blocks of three nucleotides (triplets or codons). Proteins are polymers or long biological necklaces with hundreds of amino acids in which each amino acid (or bead in the necklace) is a monomer (figure II.7). The cell has 20 different amino acids to synthetize the over one hundred thousand proteins in the human body. One can draw an analogy between the letters of the alphabet, which would be amino acids and words, which would be proteins. The order of the letters is responsible for the meaning of the words, just as the order of amino acids in protein is responsible for their meaning or biological function.

Each of the 20 different amino acids is encoded by a triplet or codon of the three nucleotides at the level of the messenger RNA. The messenger RNA is therefore, as shown in figure II.5, a molecule with information formed by a sequence of nucleotides. This information is translated or converted into proteins when these nucleotides are read in triplets by the ribosomes as shown in figure II. 7.

In a four-letter genetic code (A,G,C,T) organized in triplets, there are 64 different codons and figure II.6 shows these 64 combinations. There are amino acids encoded by six different triplets such as leucine (Leu) and amino acids such as tryptophan (Trp) which is only encoded by one triplet (TGG). There is a GTA codon that encodes for methionine, the amino acid with which most proteins begin. There are also three codons, GTA, TAA and TGA, triplets that can be read in the ribosomes that are responsible for finalizing the translation process. In other words, protein molecule synthesis ends in this type of triplet and the protein is released from the ribosomes (figure II.7).

As noted earlier, proteins are polymers with 20 different amino acids and the molecular biological tools used by living cells to perform most of their functions. Examples of proteins include insulin, collagen and tripsin, biological molecules that perform important key functions in our bodies.

As one can see from figure II.7, protein synthesis occurs at the ribosomes. The messenger RNA, shown as a yellow ribbon in the figure, is the intermediary in protein

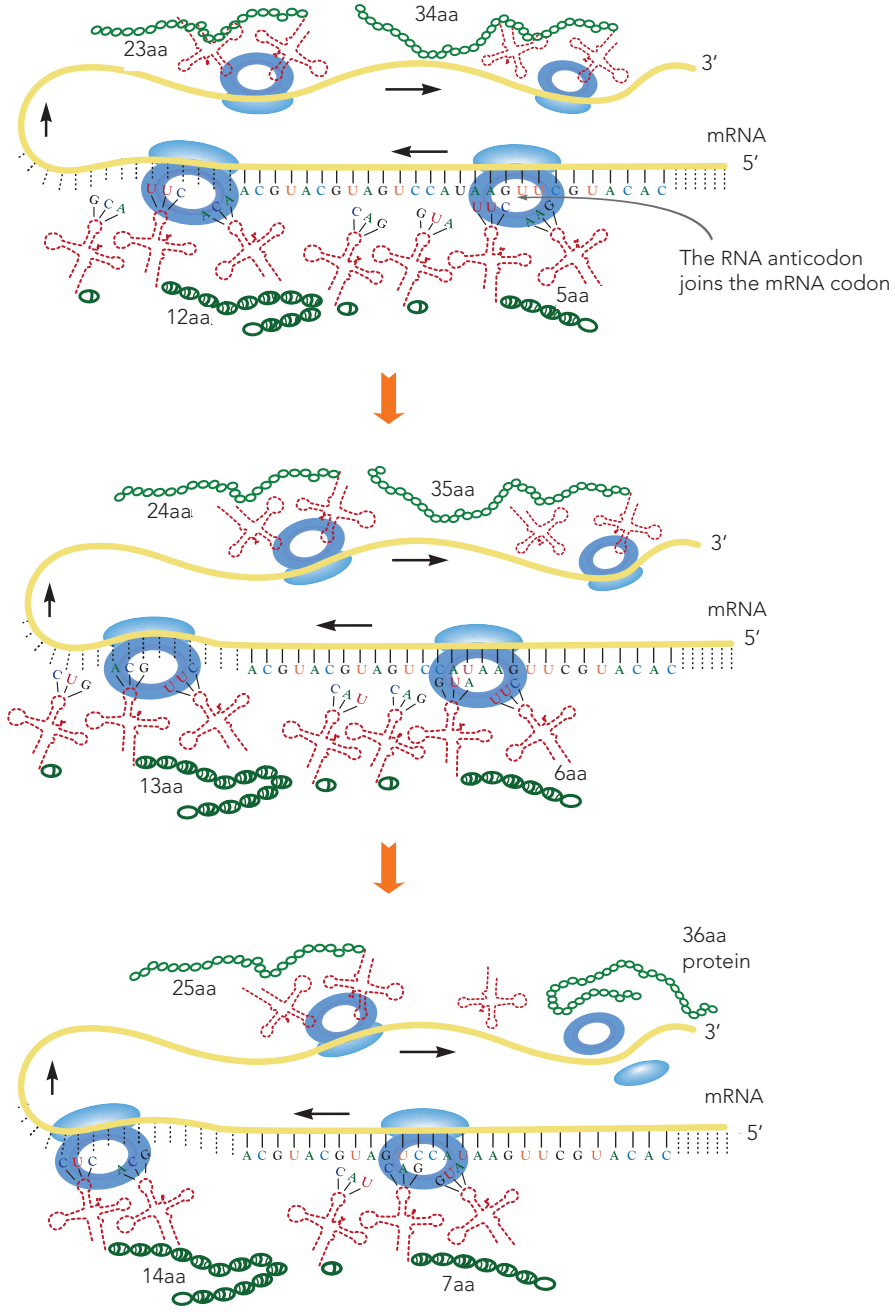


Figure II.7. Protein synthesis: the messenger RNA and its translation into ribosomes permit the synthesis of the biological polymers that are proteins.

synthesis (proteins shown as necklaces with green beads). Since it is a copy of the DNA, the messenger RNA takes information from the genes to the ribosomes, where it is translated into proteins. The amino acid or protein chains are synthesized when the ribosomes (blue structures) move like a reading head over the messenger RNA molecules. A single messenger RNA is normally used to synthesize various molecules of the same protein, when it is simultaneously read by various ribosomes, such as the four shown in the figure and synthesizes four chains of the same protein in this example.

While the messenger RNA is read by the ribosomes, the messenger codons are associated with the complementary anticodons of the transfer RNA molecules (red structures) that are "loaded" with the respective amino acids according to the genetic code (see figure II.6). Immediately afterwards, a transfer phenomenon occurs with the new amino acid that arrives and is incorporated into the nascent protein chain, comprising various amino acids previously linked to each other. The first (top) section of figure II.7 shows the four ribosomes in which protein synthesis has already begun. Four small proteins have been formed with 5, 12, 23 and 34 amino acid (aa) residues each, looking like green beads on the necklaces. The second section of the figure shows how the amino acid necklaces have increased their number in the protein molecules. In all of them, the size of the necklace has grown by an extra amino acid (6, 13, 24 and 35aa). Lastly, in the third section of the figure, the chain's growth has permitted the incorporation of an extra amino acid into all the nascent protein chains (7, 14, 25, 36aa). This is how the polymers or biological necklaces are elongated or grown, leading to the synthesis of complete proteins (in this example, 36 amino acids). Proteins with the complete number of amino acids are released from the ribosome when the messenger reading is completed, as shown in the last section of the figure. The ribosome that participated in reading of the messenger RNA is also released.

Human beings are organisms comprised of various trillions of cells (pluricellular) and we have approximately 21,000 genes in our 23 pairs of chromosomes in the nucleus of each of our cells. In addition in the cytoplasm of our cells we have organelles like the mitochondria. Each human mitochondria has a unique chromosome that carries 37 genes (involved in the synthesis of ATP) that are also part of our genome (see Chapter III). We have approximately one hundred thousand different proteins encoded by these genes to perform most of our biological functions. Bacteria, organisms comprising a single cell (unicellular) have a single chromosome with approximately 4,000 genes that encode for 4,000 proteins with which these organisms live and function

(*Avery* et al. *1944, Watson and Crick 1953, Watson et al. 1988 and 1996, Glick and Pasternak 1998, Venter* et al. *2001, Iborra* et al. *2004, Kreuzer and Massey 2005, Bolívar 2007, Hayden 2011).*

• In 1973, due to the emergence of genetic engineering techniques, also called recombinant DNA techniques (rDNA), biotechnology achieved a new dimension. As a result of these technologies, it is possible to isolate specific genes of an organism, multiply their number and insert them (transfer them) to another one cell, thereby generating transgenic organisms or genetically modified organisms (GMO).

Figure II.8 shows a general scheme for the construction of transgenic plants and animals. The first step (A) is to isolate or chemically synthesize the gene of whatever origin —transgene— (except from the receptor cell) that will be used to construct the GMO. The DNA molecule carrying this transgene is shown in red. Through various procedures, such as electroporation, transformation or biobalistic, the fragment of heterologous DNA or transgene of any origin is inserted (B) into the receptor cell by crossing the cell membrane (C) and then the membrane of the cell nucleus. Through this process, the transgene inside the nucleus of the receptor cell (D) can be recognized by the cell machinery so that it can be incorporated

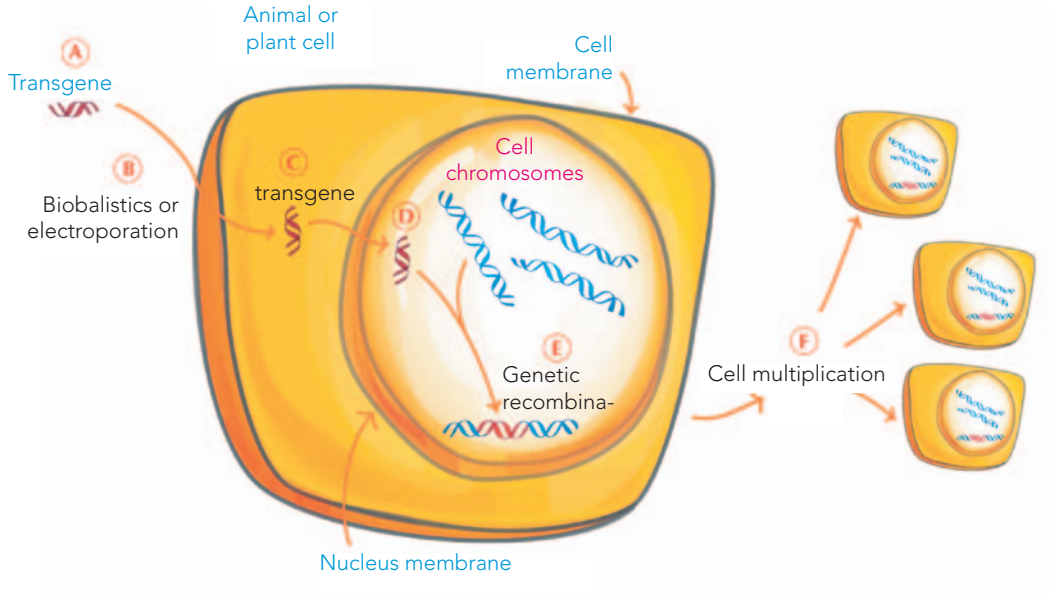


Figure II.8 General scheme for the construction of animal and transgenic plant cells.

as part of its genetic material. This process (E) occurs through genetic recombination between the transgene and the DNA of a chromosome in the receptor cell.

The transgene is therefore incorporated as a new segment of the chromosomal DNA, indistinguishable from the genetic material in the cell. Subsequently, through the process of cell multiplication (F) which gives rise to daughter cells that are identical to the original

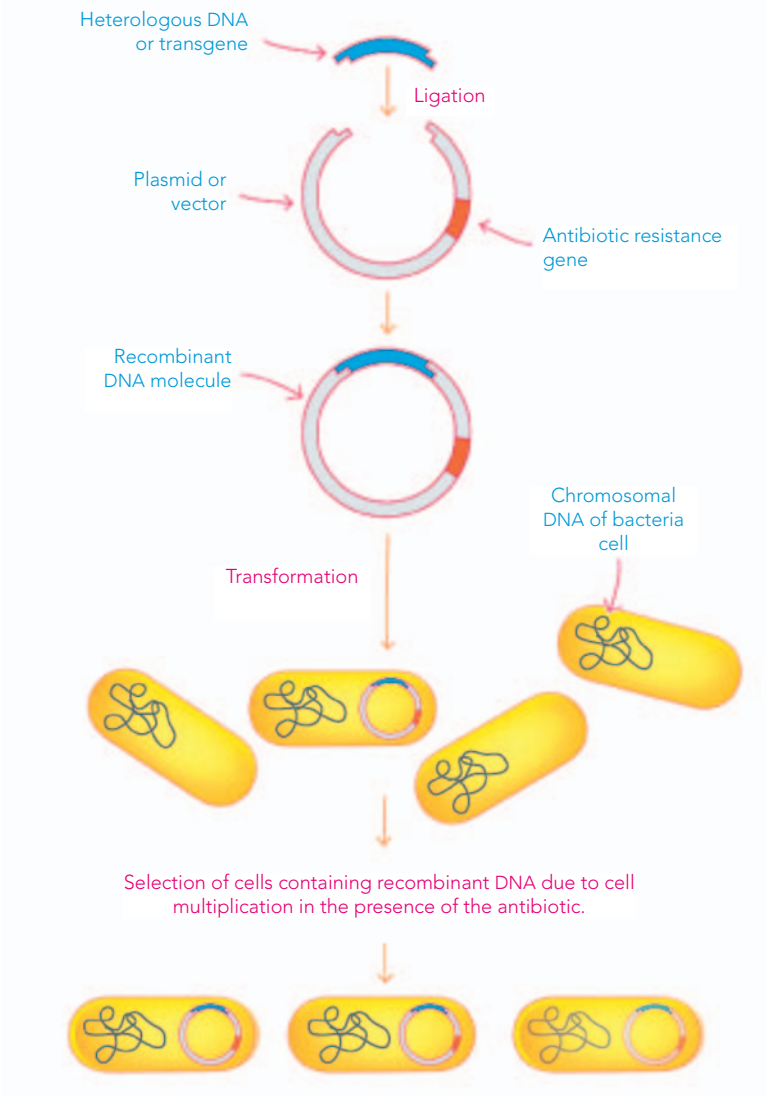


Figure II.9. General scheme used to construct transgenic bacteria.

receptor cell, the transgene's presence is stabilized and transmitted through the offspring of the original cell. A complete organism can be produced through the daughter cells.

Figure II.9 shows the procedure most commonly used to create transgenic bacteria. In this case, a vector or plasmid, a small DNA molecule, is used to joint or incorporate a fragment of DNA of any origin (transgene or heterologous DNA), thereby forming a recombinant DNA molecule that carries the transgene within it. The plasmid also contains a gene that confers resistance to an antibiotic. This recombinant DNA molecule, which carries the DNA of the plasmid and the DNA of the transgene, can subsequently be incorporated into the receptor cell through the process of transformation. Subsequently, the cells carrying this molecule are selected and grow in the presence of the antibiotic, thanks to the resistance gene present in the plasmid. This gives rise to a set or colony of daughter cells in which they all carry the transgene as part of the recombinant molecule (Kornberg 1960, Smith and Wilcox 1970, *Jackson* et al. *1972, Cohen* et al. *1973, Sánchez* et al. *1975, Heyneker* et al. *1976, Bolívar* et al. *1977 and 2007, Korana 1979, Goeddel* et al. *1979, Itakura and Riggs 1980, Herrera-Estrella* et al. *1983, Mullis and Falona 1987, Watson* et al. *1988 and 1996, Tagahian and Nickoloff 1995, Glick and Pasternak 1998, Lengeler* et al. *1999, Yao* et al. *2002, , Kreuzer and Massey 2005, Prudhomme* et al. *2006, Barrera 2007, Herrera-Estrella and Martínez 2007).*

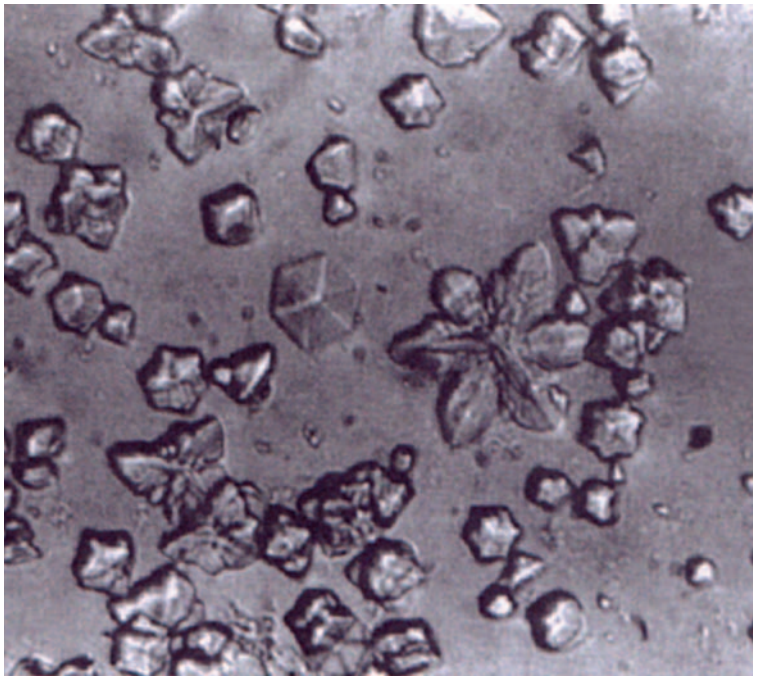
• Transgenic organisms are designed and constructed to generate a new capacity to the receptor organism, which lies in the transferred genetic material or transgene (figure II.10). The aim of sustainable modern biotechnology is to perform genetic modifications in various organisms of the biodiversity that make it possible to construct GMO that will contribute to solving problems in various sectors, with the certainty that these organisms will be living organisms created through processes that occur on an everyday basis in nature. As a result, GMO have a lower risk and impact on the environment, biodiversity and human and animal health than technologies based on chemically synthesized products that are recalcitrant, unrelated to the environment and some of which cause damage to health (*Itakura* et al. *1977, Goeddel* et al. *1979, Watson* et al. *1988 and 1996, Glick and Pasternak 1998, Lengeler* et al. *1999, Yao* et al. *2002, Estruch* et al. *1999, Nuccio* et al. *2000, Yao* et al. *2000, Brink* et al. *2000, Larrick and Thomas 2001, Daar* et al. *2002, López-Munguía* et al. *2002, Herrera-Estrella* et al. *2002, Arias and Muñoz 2002, Barrera 2002, Noyola* et al. *2002, Gracia 2002, Bosch 2002, Bolívar* et al. *2002 and 2007, Purohit 2003, Sinagawa-García* et al. *2004, Kreuzer and Massey 2005,*

Figure II.10. Transgenic organisms
and their products are used in the production
of food, medicine and clothing.

Ollivier and Magot 2005, Barrera 2007, Herrera- Estrella and Martínez 2007, López-Munguía 2007, Ramírez and Uribe 2007, Arias 2007, Osuna and Paredes 2007, Gracia 2007, Ayala-Rodríguez et al. *2009, James 2009, Gilbert 2010, BIO 2011).*

• The first objective that led to the modification of cells to obtain transgenic organisms was the production of proteins identical to human ones to deal with health problems, which have been commercialized for over 30 years. In pharmacies in Mexico and the rest of the world, there are medicines of transgenic origin, also called recombinant proteins or biomolecules, such as insulin, the growth hormone, interferons, blood anticoagulants (plasminogen) and humanized antibodies, among other products, used to treat and prevent disease, including genetic and infectious ones caused by pathogenic organisms such as viruses and bacteria (figures II.11 and II.12). These new biological products are produced commercially with transgenic organisms and no damage

Figure II.11. Health products on sale in Mexican pharmacies, based on recombinant proteins of transgenic origin from the Mexican company Probiomed.



Figures II.12. Human insulin crystals produced by transgenic microorganisms at the Institute of Biotechnology, Universidad Nacional Autónoma de México (UNAM).

Figure II.13. Process for producing biotechnological medicines.

Figure II.14. Transgenic organisms and their products are used in the production of several types of food such as beer, cheese, delactased milk and juice.

to human health has been reported to date due to these medicines, nor has environmental damage been reported due to the industrial handling of microorganisms of recombinant origin (figure II.13). Without GMO, it would be impossible to meet the needs of the population suffering from diabetes, anemia and cancer, among many other diseases, since the supply would be limited, not only by the low concentration of these proteins in human blood and tissues but by the ethical complexity derived from a market based on raw material of this nature. Moreover, the transgenic organisms that produce these proteins that are identical to human ones cannot currently be replaced by any other technology. Since 1981, the use of these proteins identical to human ones of transgenic origin such as biomedication has significantly contributed to maintaining and improving human health and dealing with life-threatening diseases such as diabetes and cancer (*Itakura* et al. *1977, Goeddel* et al. *1979, Pennica* et al. *1983, Watson* et al. *1988 and 1996, Copsey and Delnatte 1990, Winter and Milstein 1991, Glick and Pasternak 1998, Brink* et al. *2000, Arias and Muñoz 2002, Daar* et al. *2002, Kreuzer and Massey 2005, Barrera 2007, Ramírez and Uribe 2007, Bolívar* et al. *2007, BIO 2011).*

• The use of proteins with enzymatic activities of transgenic origin has also had a significant impact on food production. An example is the use of recombinant quimokine in cheese production (in the USA, it is used in the production of approximately 70% of all cheese). Other enzymes of transgenic origin, such as amylase, are used in starch hydrolysis. The most important examples include pectinase, used for clarifying juice; glucose-oxydase and catalases for dehydrating egg; lipase for maturing cheeses and transforming oils; glucose-isomerases for the production of fructose syrup, glucanase, employed in beer production and lactase for degrading the lactose in milk (figure II.14). Likewise, recombinant proteases are used to make biodegradable detergents. Although in most of these cases, purified proteins of transgenic origin are used, there are applications, such as the beer industry, in which the entire microorganism is used with a new enzymatic activity derived from its modification (*Glick and Pasternak 1998, Brink* et al. 2000, Padilla and López-Munguía 2002, López-Munguía 2002, Kapuscinski et al. *2003, Kreuzer and Massey 2005, Por qué Biotecnología 2006, López- Munguía 2007, Barrera 2007, Bolívar* et al. *2007, BIO 2011).*

• Transgenic plants have been commercialized since 1996. Fifteen years later, the plants used commercially today have not caused harmful effects on human health or biodiversity beyond those caused by agriculture in general. Approval of any transgenic plant as

food requires a protocol of analysis to demonstrate its innocuousness. As established in the Cartagena Protocol and in the Mexican Law for Biosafety of Genetically Modified Organisms (BLGMO) -as well as other regulations in various countries of the world- risk evaluation must consider the characteristics of the GMO, particularly the new gene and protein for which it is encoded, the analysis of all the products of metabolism and therefore the composition of the plant as well as the unintentional effects of modification. Among other tests, innocuousness must be proved through animal testing of both proteins of transgenic origin and the food as a whole (of which proteins constitute a minimal amount). There are certain recent publications indicating the possible negative and toxic effects on animals due to the consumption of certain transgenic crops. These publications are not conclusive, however, nor have they been independently reproduced by other groups. Consequently, neither the WHO nor the various government agencies responsible for the worldwide approval and management of GMO in various countries such as the Food and Drug Admnistration (FDA) in the USA consider that the results published on the studies of toxicity in certain animals warrant taking some of the transgenic plants currently consumed off the market. If some of them were repeatedly, conclusively and independently shown by various research groups to have toxic effects, these transgenic products would have to be taken off the market.

It is important to point out that the use of transgenic crops has made it possible to reduce the use of chemical pesticides, many of which are recalcitrant products, which has translated into a lower impact on the environment. Moreover, some chemical pesticides also have carcinogenic effects. Maize, rice and soybeans are consumed in many countries while an increasing number of hectares are used to grow transgenic plants. A total of 1.7 million hectares were brought under cultivation in 1996. By 2007, 114.3 million hectares had been registered and by 2009, there were over 134, planted with different varieties of GMO in 27 countries. At present, nine different transgenic plant species are cultivated: rice, maize, soybean, canola, squash, papaya, alfalfa, beetroot and cotton (figure II.15), (*Potrykus 1989, Struck*et al. *1997, Glick and Pasternak 1998, Nuccio* et al *11999, Yao* et al. *2000, Herrera-Estrella* et al. *2002, Noyola* et al. *2002, Herrera-Estrella* et al. *2003, Purohit 2003, Chen* et al. *2003 and 2004, Rascón-Cruz* et al. *2004, APBN 2004, Zhu* et al. *2004, Hammond* et al *2004, Zhuo* et al. *2004, Green* et al. *2004, Kreuzer and Massey 2005, Rhee* et al. *2005, Trigo and Capp 2006, WHO 2006, Valdez-Ortiz et al. 2007, Poulsen* et al. *2007a and 2007b, Malley* et al. *2007, Domingo 2007, Bolívar* et al. *2007, Herrera-Estrella and Martínez 2007, Sakamoto* et al. *2007 and 2008,*

Figure II.15. Various plants cultivated as transgenic varieties: alfalfa, maize, soybean, canola and squash.

Schroder et al. *2007*, *Seralini* et al. *2007 and 2009*, *MacKenzie* et al. *2007*, *McNaughton* et al. *2008*, *He* et al. *2008 and 2009*, *Healy* et al. *2008*, *Delaney* et al. *2008*, *James 2008 and 2009*, *CIBIOGEM 2008*, *Magaña-Gómez* et al. *2008*, *Appenzeller* et al. *2009a and 2009b*, *Mathesius* et al. *2009*, *Ayala-Rodríguez et al.* 2009, Domon et al. 2009, Herouet-Guicheney et al. 2009, Tutel'ian et al. *2009*, *Juberg* et al. *2009*, *De Vendomois* et al. *2009*, *BIO 2011*, *Domingo and Bordonaba 2011).*

• It has been estimated that by the year 2050, the world population will have risen from its current figure of 7 billion to 9 billion, meaning that mankind will face increasingly serious problems: loss of agricultural productivity; soil deterioration; water shortage; exhaustion of energy sources; global warming; pollution; new pests and diseases; reduction of green areas and loss of biodiversity among others (figure II.16). Biotechnology is a powerful tool enabling society to propose new scenarios to help deal with these calamities. Organisms with new properties, such as new varieties of transgenic plants capable of growing with smaller amounts of water will enable the countries developing biotechnology to deal with several of these and other local and world problems. Implementing suitable regulations will help to orient the development of GMO towards those that will solve the problems of each country, with a lower environmental impact and the proper, sustainable use of its natural resources. Blocking biotechnology, particularly in Mexico, which is a megadiverse country, would deprive this country of an opportunity provided by science and biological technology to help correct the course. Importantly, 25 Nobel Prize awardees have signed a declaration in support of Agricultural Biotechnology (*Bourlag 1953 and 2007*, *Estruch*et al. *1997*, *The Biotech Revolution 1998*, *Glick and Pasternak 1998*, *Nuccio* et al. *1999*, *Yao* et al. *2000*, *Larrick and Thomas 2001*, *Potrykus 2001*, *Herrera-Estrella* et al. *2002*, *López-Munguía* et al. *2002*, *Noyola* et al. *2002*, *Barrera 2002*, *Bolívar* et al. *2002 and 2007*, *Rascón-Cruz* et al. *2004*, *Green* et al. *2004*, *Kreuzer and Massey 2005*, *Ollivier and Magot 2005*, *James 2009*, *Tang* et al *2009*, *Gilbert 2010*, *BIO 2011*, *AgBioWorld, 2011*).

a

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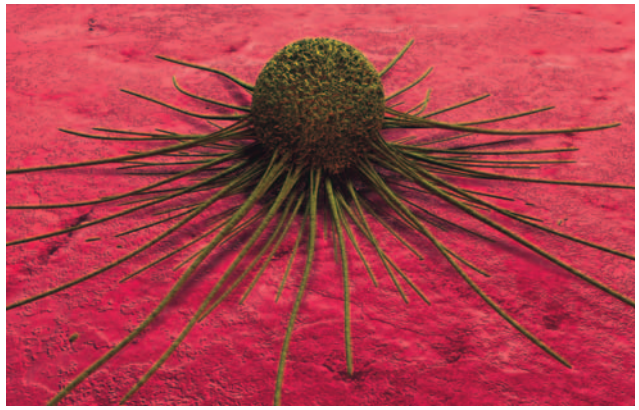
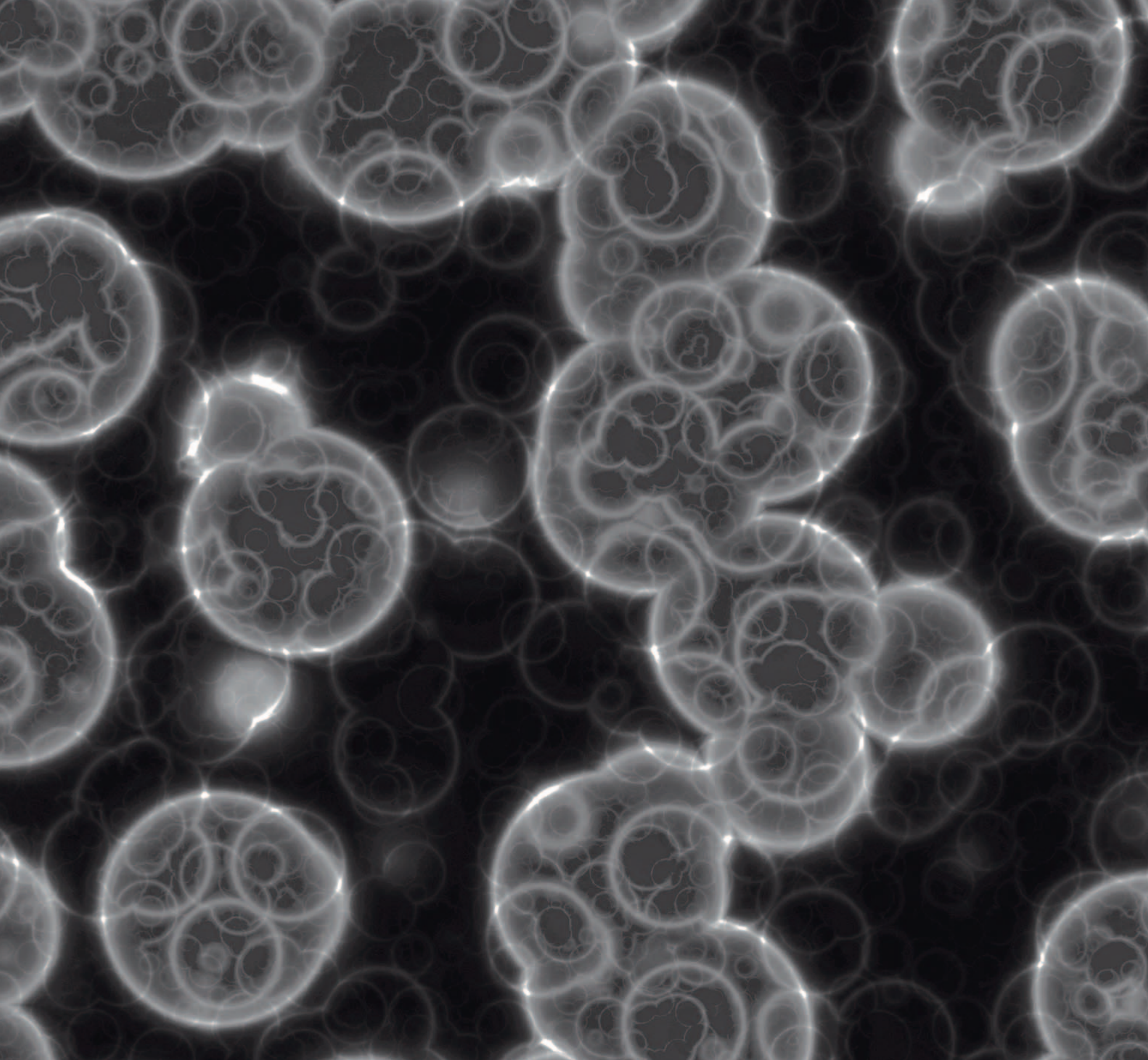


e

Figure II.16. Important problems:
a) and b) pests in potato and tomato crops, c) worms in maize kernels, d) ecosystem pollution and e) cancer cell.



III. SCIENTIFIC EVIDENCE SUPPORTING THE LOW RISK OF TRANSGENIC ORGANISMS AND THEIR PRODUCTS, SINCE THEY ARE ORGANISMS PRODUCED THROUGH HORIZONTAL DNA TRANSFER WHICH OCCURS ON A DAILY BASIS IN NATURE

There is solid scientific evidence supporting the harmlessness and lack of damage to human health and biodiversity of the transgenic organisms used nowadays, and the reasons for considering them a natural technological alternative with low risk and impact for the environment.

The information and considerations given below provide key elements on the low risk of using GMO since they are organisms created through horizontal DNA transfer and the reorganization of genomes, which occur in nature independently of transgenic organisms. This is due to the fact that the DNA of all living beings and viruses has the same general structure, which naturally permits the recombination of genetic materials of various origins inside cells. This information, which is scientifically supported, is necessary for the evaluation of the transgenic organisms people wish to use.

• Charles Darwin's theory of evolution states that all living beings are descended from a single, common biological ancestor (figure III.1). This proposal has been strengthened and consolidated by a great deal of scientific evidence over the years. This includes evidence produced by the determination of nucleotide sequences (sequencing) of genomes of different organisms, including humans, which has made it possible to show that all living beings share genetic material, including many genes. Indeed, the genome of the human race is 98% identical to that of the chimpanzee, 90% identical to that of the mouse, 40% identical to that of the fly, 30% identical to some plants and 20% identical to yeast (figure III.2). Part of our DNA includes genes of bacterial origin, including those located in the mitochondria, which are organelles of our cells.

There is so much evidence supporting the theory of evolution that for many researchers, including Richard Dawkins, evolution is already a fact rather than a theory, which has happened and happens in the same way the earth revolves around the sun and plants fix the

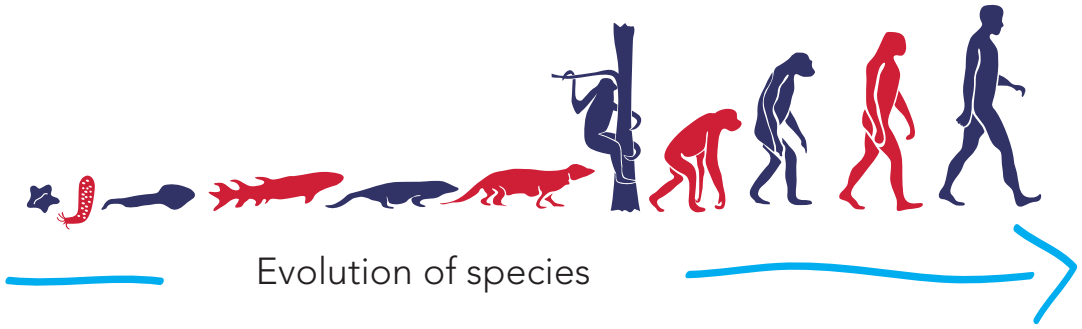


Figure III.1. The accumulated evidence strongly indicates that all living beings derive from a common biological precursor.

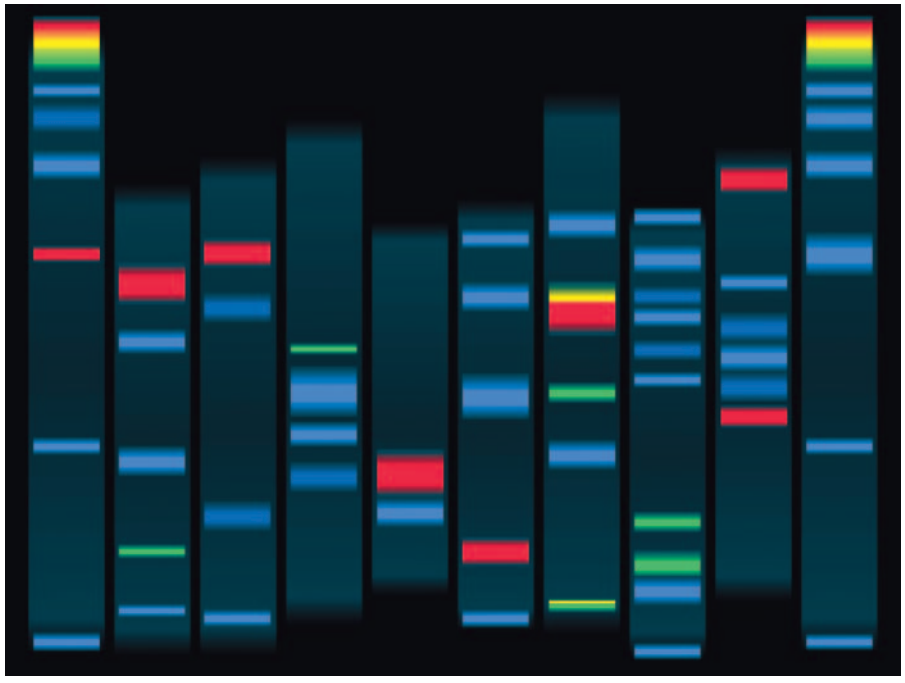


Figure III.2. Technique used to determine the sequence of nucleotides comprising the DNA in the genomes of living beings.

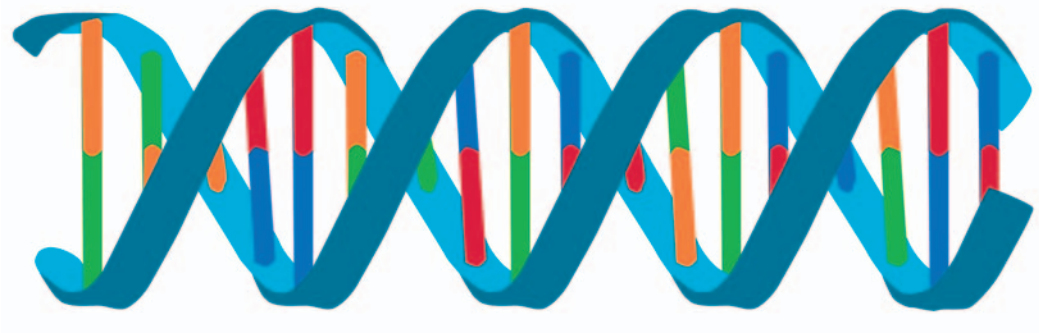


Figure III.3. Two-dimensional structure of DNA. Genetic material has the same general structure in all living beings as well as in viruses.

energy of the sun's rays. In keeping with the theory of natural selection and other evidence of the association between organisms, evolution can now be understood as a process of adaptive evolution, which produces better and more capable organisms (*Darwin and Wallace 1859, Darwin 1859, Wallin 1927, Johanson and Edey 1981, Watson* et al. *1988 and 1996, Brown 1999, Andersson* et al. *2001, Venter* et al. *2001, Young and Deis 2004, Herrel* et al. *2004, Kreuzer and Massey 2005, Margulis and Sagan 2005, Carroll 2006, Bolívar 2007, Touchon* et al. *2009, Bolívar* et al. *2007, Dawkins 2009, Coyne 2009, Hayden 2011*).

• With the exception of the RNA viruses, the genetic material comprising DNA has the same general structure in both viruses and all living beings, whether they are bacteria (prokaryote organisms that do not have a nucleus) or plants and animals (eukaryote organisms), which have a nucleus in their cells where the DNA resides in the chromosomes (figures III.3 and III.4).

The universal structure of DNA makes it possible to naturally transfer, incorporate, stabilize and recombine genes from an organism with genetic material from others. Living cells recognize genetic material of another origin that may be acquired by different means - viral infection or horizontal transfer- and in many cases incorporate, replicate and use them as their own and as part of their genome after a genetic recombination process that reorganizes the genome (*Avery* et al. *1944, Watson and Crick 1953, Nass 1969, Watson* et al. *1988 and 1996, Brown 1999, Venter* et al. *2001, Margulis and Sagan 2005, Kreuzer and Massey 2005, Bolívar* et al. *2007, Touchon* et al. *2009, Schanable* et al. *2009, Murat* et al. *2010, Jiang* et al. *2011*).

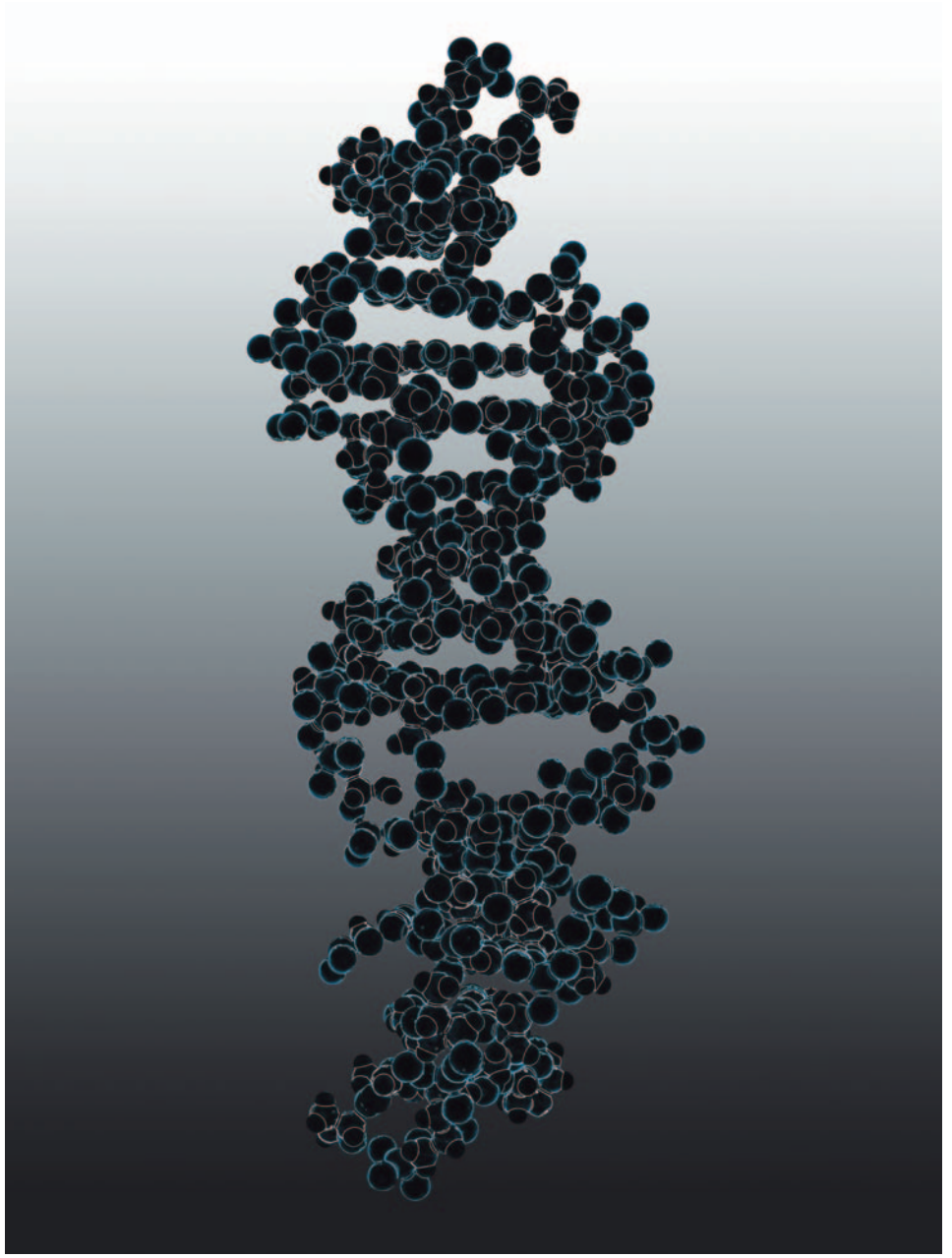


Figure III.4. Three-dimensional structure of DNA.

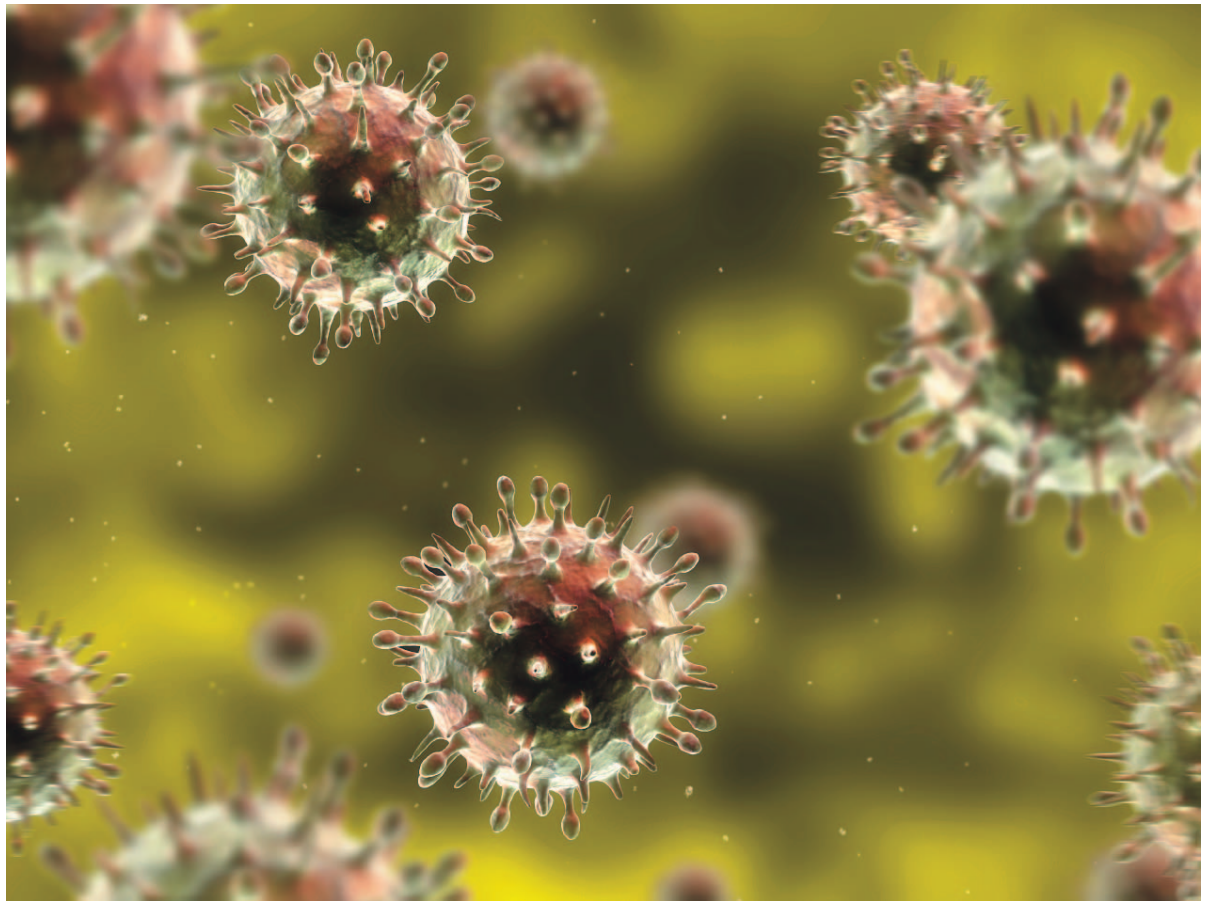


Figure III.5. Influenza virus.

• Horizontal transfer of genetic material is a natural phenomenon or process that takes place on a daily basis in nature in all species of living beings, with viruses being largely responsible for this phenomenon.

When a virus (figure III.5) infects a cell, its own (viral) genetic material is incorporated into the cell, which is how viral DNA or RNA are horizontally transferred to the infected cell (figure III.6). When this viral genetic material is injected into the cell, there are various alternatives for what will happen to the genetic material from the virus, depending on the type of virus involved. Viral genetic material usually takes over the machinery of the infected cell, using it to make several copies of the virus genome. The viral genetic material is also utilized for synthetizing the proteins that form part of the viral particles generated, in other words, the new viruses. The cell is subsequently destroyed and numerous copies of the recently formed viruses are expelled. An example of this type of virus is the A(H1N1) influenza virus which has RNA as genetic material and has also proved capable of infecting at least three animal hosts: humans, pigs, and birds (avian influenza). This natural phenomenon of zoonosis appears to occur far more frequently than we would imagine or can detect, given the capacity of viruses to infect different organisms. Moreover, different animals can also be simultaneously infected by several viruses from different organisms. This type of phenomenon increases the frequency of new arrangements and recombinations of the general material of viruses, as happens with the influenza virus.

Another type of viruses that infect bacteria, called transductants, are capable of generating both new viruses and particles called pseudo viral particles, which include the DNA of infected bacteria, rather than the genetic material of the virus. Thus, these particles, which are functional, since they can infect other bacteria, allow horizontally transfer of genetic bacterial DNA through these viral pseudoparticles to other bacteria.

Other types of virus that exist in both bacteria and animal and plant cells are those capable of incorporating their genomes as part of the genetic material of infected cells. In the case of bacteria, this type of virus is known as lisogenic and can incorporate its viral DNA into different sites or *loci* of the bacterial chromosome. In the case of eukaryote organisms such as plants and animals, there are viruses called retroviruses such as the HIV-AIDS, whose genomes consist of RNA. These type of viruses are capable after infecting the receptor cell, of transcribing (copying) its genome from RNA to DNA, through a process of reverse transcription and subsequently incorporating a copy of its DNA genome into different sites in the chromosomes of the infected eukaryote cells through the process of genetic recombination (figure III.7). In both cases, in both bacteria

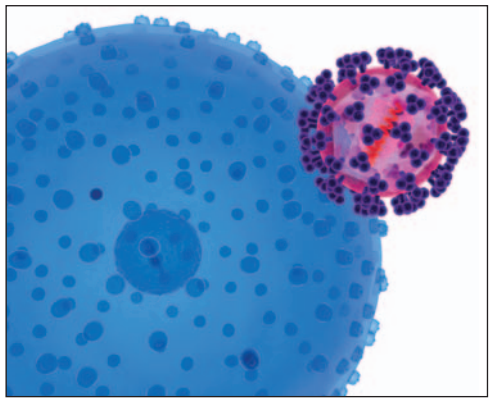


Figure III.6. Diagram of retrovirus infecting a cell.

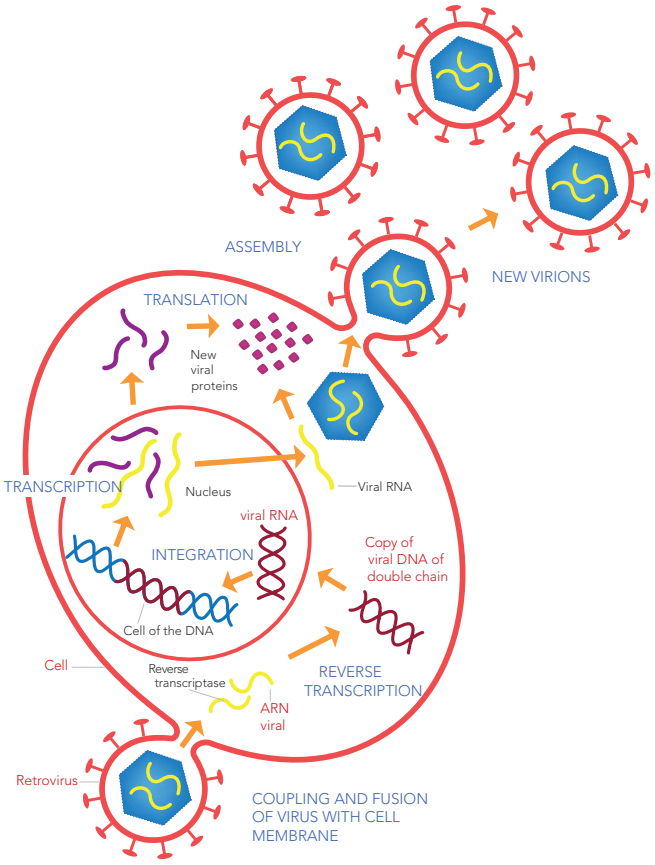


Figure III.7. Scheme of viral infection of a eukaryote cell by a retrovirus, through which the viral RNA is copied as DNA that is then recombined and incorporated into the DNA of the chromosome of the infected cell.

(prokaryotes) and animal and plant cells (eukaryotes) these viruses (lisogenic and retroviral) have the capacity to reorganize and modify the genome of infected cells. Lastly, recent evidence suggests that other types of virus different from retroviruses such as bornaviruses and ebolaviruses may also be capable of modifying the animal genome.

Thus, through natural processes, living beings increase, modify and reorganize their genomes in cells infected by viruses. There is mounting evidence that indicates that this phenomenon of horizontal transfer by viral infection has played a key role, together with other mechanisms as we shall see later on, in the evolution of species and the structuring and reorganization of genomes. The reason for this is that as mentioned earlier DNA, which reaches the cell through viral infection, has the same structure in both living organisms and the lisogenic viruses in bacteria and the organism produced by the reverse transcription of the genetic matter of retroviruses that have RNA as a genome. Thus, cells can recombine and reorganize their own DNA with genomes of viral origin and with DNA of any other origin.

The natural phenomenon or process of horizontal transfer of genetic material occurs permanently in the microbial kingdom, where bacteria receive and incorporate genetic material that includes plasmids, due to the "transformation phenomenon". This mechanism enables heterologous genetic material to be transported through cell membranes and stabilize.

Normally, in order to stabilize, DNA from another origin is incorporated as part of the genome of the receptor cell through the process of genetic recombination. This genetic material may come from any of the various organisms inhabiting the soil, including those that die. Indeed, it is a well-known fact that when the *S. pneumoniae* bacteria, which causes pneumonia, is subjected to antibiotic treatment, it suffers stress, which in turn increases its capacity for transformation by DNA (figure III.8). Through this phenomenon, it will probably increase its ability to acquire genes from other organisms, such as those related to resistance to antibiotics, produced by other microorganisms. This information clearly indicates that there are organisms with mechanisms that enable their capacity to be transformed by DNA to increase their capabilities. This suggests that transformation through linear DNA may be a natural phenomenon that is not only passive but active. Another example of an important bacterium is *Escherichia coli*. Different strains or variants of this bacteria are natural commensals and inhabit the intestines of various mammals including humans. However, there are pathogenic strains of *E. coli* that may create major problems, causing intestinal diarrhea and severe damage to

Figure III.8. Pathogenic bacterial cultures in Petri dishes capable of increasing their capacity to be transformed by linear DNA.

other organs such as the kidneys. It has been conclusively proved that horizontal DNA transfer in this and other pathogenic bacteria is the process responsible for creating several pathogenic varieties. A new pathogenic strain of this bacterium, originally classified as the *E. coli* EH104:H4 strain for humans was recently described in Europe. It infected many individuals during a very short period, several of whom died. This variety simultaneously causes intestinal diarrhea with blood and the "Hemolytic-uremic" syndrome responsible for bleeding in the kidneys. This new variety is probably the result of the incorporation into an existing pathogenic bacterium of DNA of another pathogenic bacterium, which thereby modified and increased its ability to cause damage. In the case of *Escherichia coli* strains (figure III.9), which are philogenetically very close,

the horizontal incorporation of DNA may occur through transformation with genetic material released into the environment or through a conjugation process that also occurs in bacteria. Preliminary data on the genome sequence of the new variant suggest that its genome consists mainly of the DNA of the EAEC 55989 strain of *E. coli* (Entero-Aggregative *E. coli*) in addition to genetic material from another type of *E. coli* called EHEC (Entero Hemorrhagic *Escherichia coli)*, which produces a "Shiga" type toxin, causing intestinal diarrhea and in some cases, infection of the kidneys, leading to hemorrhaging in these organs. Alternatively, the new strain could already have been present as a variant of EHEC, which at least acquired the gene that encodes for this Shiga toxin.

It has also been found that the horizontal transfer of genetic material from microorganisms to plants occurs naturally, as in the case of *Agrobacterium tumefaciens* and tobacco. Bacteria (figures III.9 and III.10) are organisms used as a model in laboratories since they can easily be transformed by linear or circular DNA of the same origin or others. They are also used as important organisms for their study because of the problems they can cause, particularly in the area of human, animal and plant health.

Transformation by DNA increases and reorganizes the genome of living receptors cells, expanding their capacities and functions (*Lwoff 1953, Sánchez* et al. *1973, Jackson* et al. *1973, Cohen* et al. *1973, Herrera-Estrella* et al. *1983, Michel and Dubon 1986, Colleaux* et al. *1986, Watson* et al. *1988 and 1996, Mazodier* et al. *1991, Mazodier and Davis 1991, Ptashne 1992, Joset and Guespin 1993, Arber 1993, Tagahian and Nickoloff 1995, Matic* et al. *1995, Campbell 1996, Voytas 1996, Kaper* et al. *1997, Aravind* et al. *1998, Doolittle 1998, Lengeler* et al. *1999, Brown 1999, Denamur* et al. *2000, Hacker and Koper 2000, Madigan* et al. *2000, Emini 2002, Schubert* et al. *2002 and 2009, Herrera-Estrella* et al. *2002, Brussow* et al. *2004, Chen and Dubnau 2004, Kreuzer and Massey 2005, Margulis and Sagan 2005, Prudhomme* et al. *2006, Barrera 2007, Bolívar* et al. *2007, Bolívar 2007, Herrera-Estrella and Martínez 2007, Treangen* et al. *2008, Touchon et al. 2009, Arias* et al. *2009, Dawkins 2009, Garten* et al. *2009, Belyi* et al. *2010, Horie* et al. *2010, Murat* et al. *2010, Enserink 2011, Kupferschmidt 2011).*

• There is evidence that the genome of higher organisms evolved naturally and increased part of its genetic material through viral infections and probably genetic material derived from microorganisms that infected our ancestors, which explains how the genomes of receptor cells were reorganized.

In this respect, the information supporting the incorporation of genetic material at early stages of the

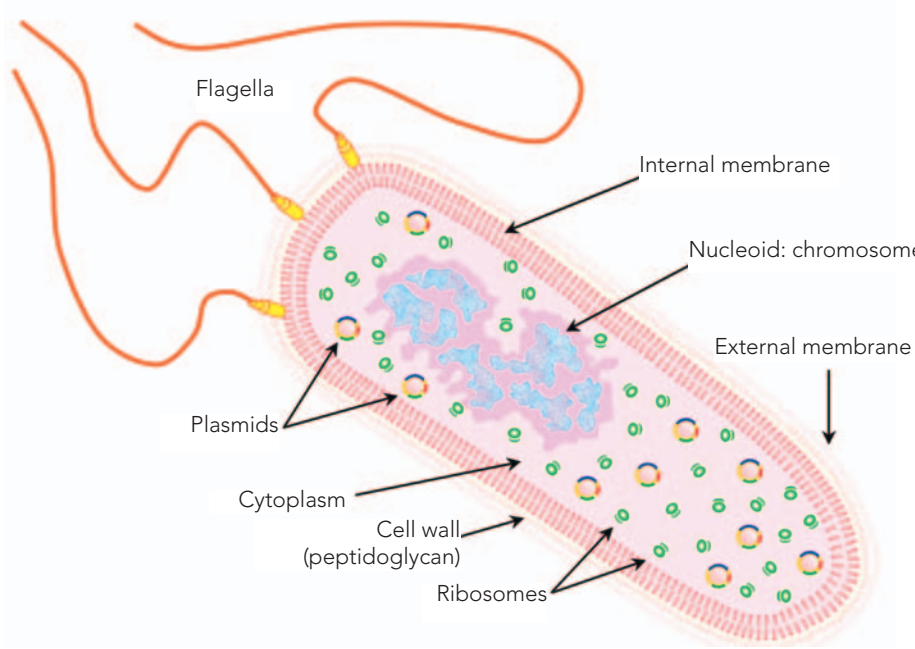


Figure III.9. Diagram of bacterial cell such as *Escherichia coli* and its components.

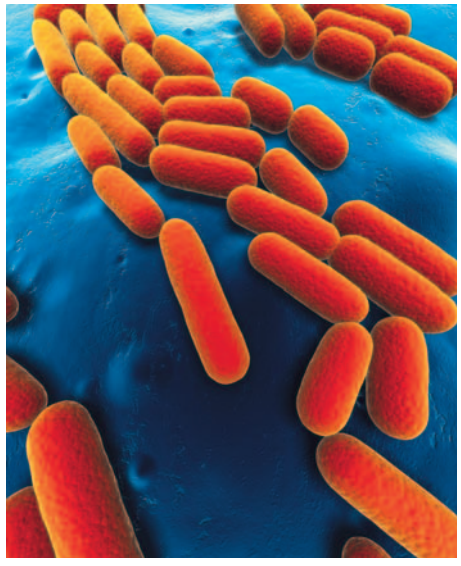


Figure III.10. Bacteria, unicellular organisms seen under the microscope.

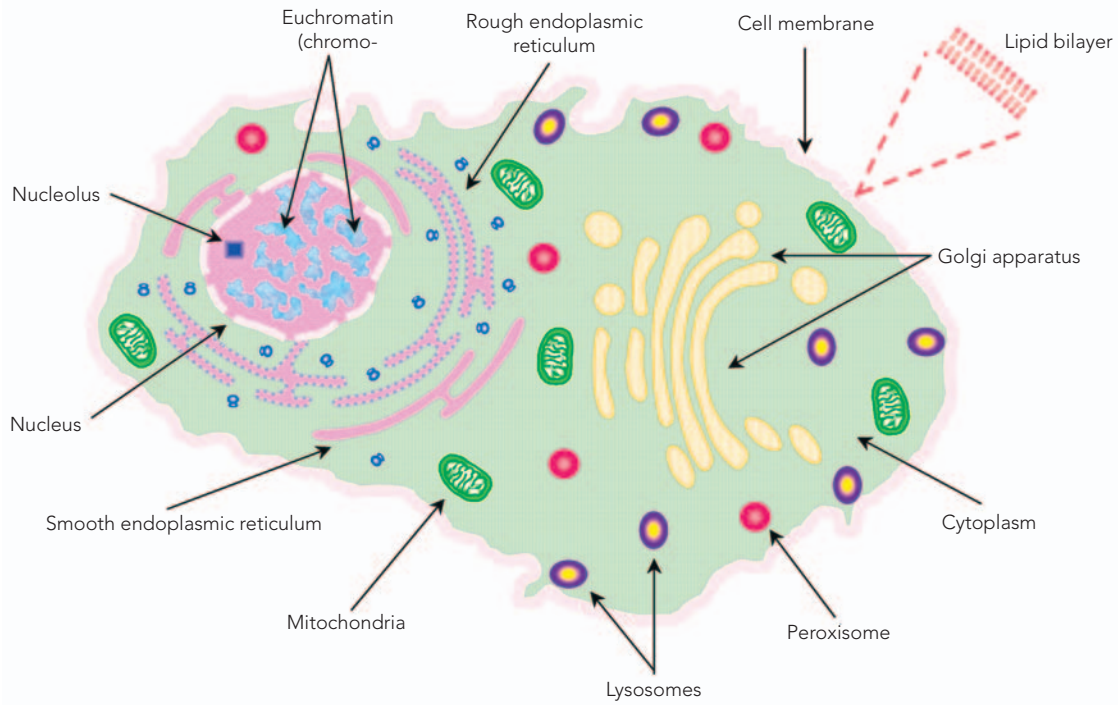


Figure III.11. Diagram of an animal cell and its components, including mitochondria.

evolution of animal and plant cells through infection by precursors of the current cellular organelles is quite clear. These are similar to bacteria, as seems to be the case of the mitochondria (a cellular organelle in animals and plants responsible for the synthesis of biological energy such as ATP) and the chloroplast (responsible for the synthesis of chlorophyll and photosynthesis in plants) (figures III.11, III.12, III.13 and III.14). These organelles have genetic material, a unique chromosome which, as in the case of the chromosomes of bacteria, is circular, in addition to having their own ribosomes in which their proteins, that are very similar to those of bacteria, are synthesized. The human mitochondrial chromosome contains 37 genes coding for the proteins involved in ATP synthesis and RNAs involved in protein synthesis. Therefore, the human genome is composed not only of the 21,000 genes located in 23 pairs of chromosomes in the nuclei of our cells, but also includes 37 genes located in our mitochondrial chromosome. In the case of the maize genome, the mitochondrial chromosome contains approximately 90

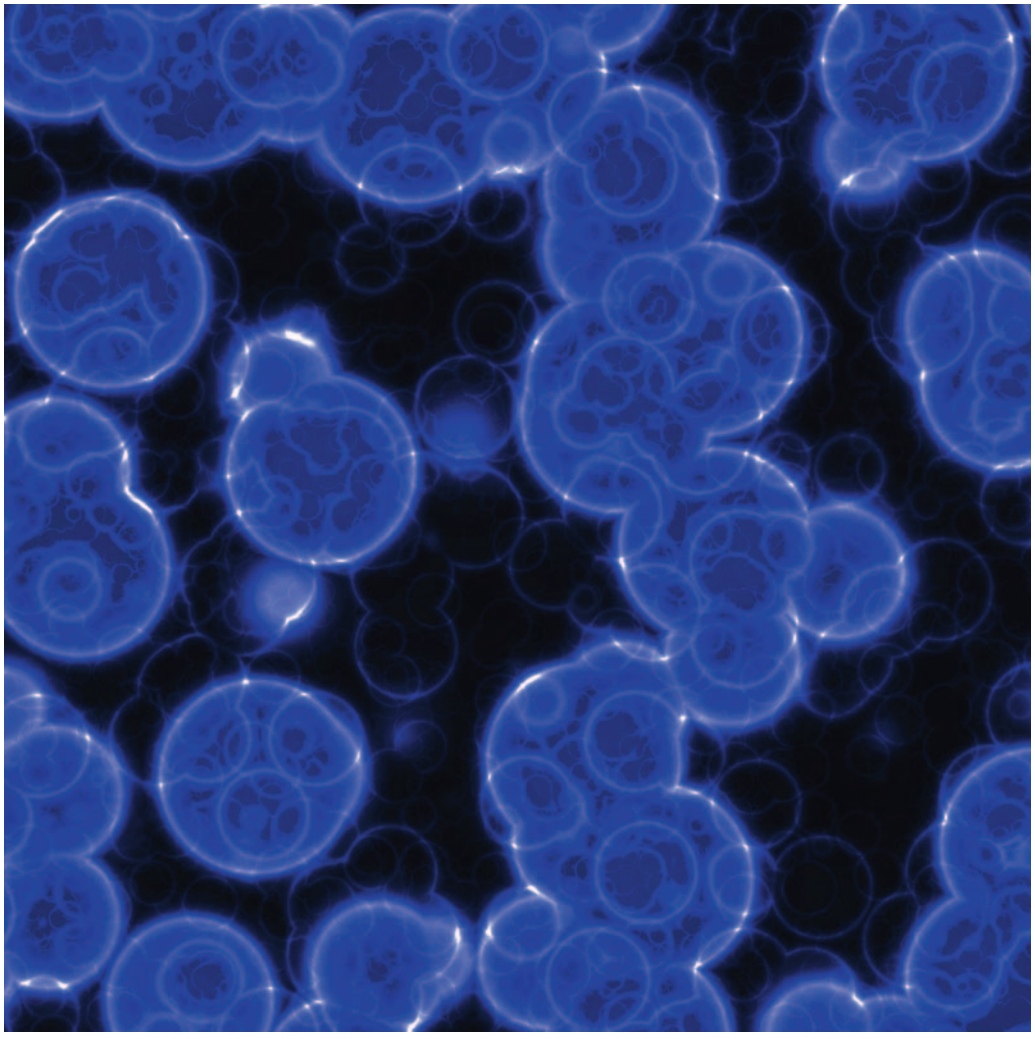


Figure III.12. Cells of animal origin seen under a microscope.

genes and the chloroplast chromosome carries 104 genes. Therefore, the genome of this plant that contains about 32,000 genes located in the chromosomes of the nuclei of these plant cells includes 200 additional genes located in these two organelles.

The precursors of these organelles may have been naturally incorporated into the precursors of higher cells, first through infection and then through a permanent association, creating an endosymbiosis that provides benefits for both original organisms (adaptive evolution). In fact, in 1927, Ivan Wallin proposed that the endosymbiosis in which bacteria take part could be one of the natural processes supporting the origin and evolution of species. There are many studies showing that bacteria and mitochondria are very similar organisms that share many characteristics (*Darwin 1859*, *Hogg 1861*, *Wallin 1927*, *Nass 1969*, *Smith 1979*, *Yang* et al. *1985*, *Watson* et al. *1988 and 1996*, *Gupta and Golding 1996*, *Osusky* et al. *1997*, *Doolittle 1998*, *Andersson* et al. *1998*, *Brown 1999*, *Lengeler* et al. *1999*, *Venter* et al. *2001*, *Borden-*

Figure III.13. *Arabidopsis thaliana* plant used as a plant model.

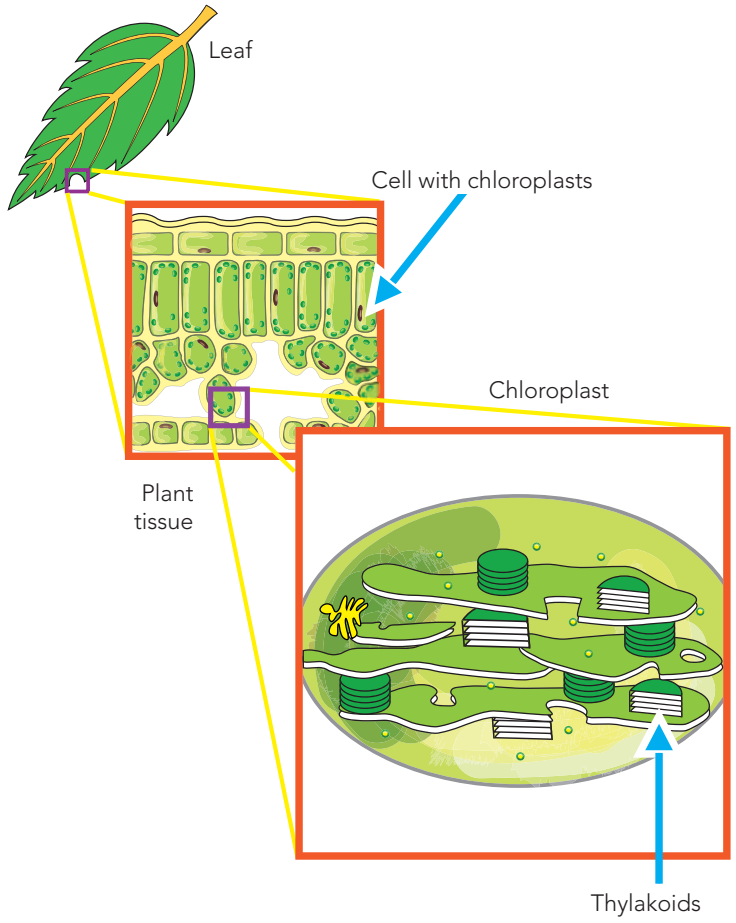


Figure III.14. Diagram of a plant cell and its components, including chloroplasts.

stein 2003, Herrel et al. *2004, Iborra et al. 2004, Clifton* et al. *2004, Maier* et al. *2005, Kreuzer and Massey 2005, Margulis and Sagan 2005, Carroll 2006, Coyne 2009, Schnable* et al. *2009, Dawkins 2009, Horie* et al. *2010, Murat* et al. *2010, Belyi* et al. *2010, Hayden 2011*).

• In the case of plants (figure III.13), it is important to note that plant chromosomes have a large number of genes from photosynthetic bacteria, which gave rise to chloroplasts during evolution (figure III.14). These organisms have lived and live in close contact in the earth's

soil and facilitate the process of horizontal DNA transfer. This is forcefully verified through the determination of the sequence (nucleotide sequencing) of the genomes of the plants *Arabidopsis thaliana*, rice and maize.

The incorporation of genetic material of different origins, including the case of the obvious incorporation of mitochondria into the precursor cells of animal and plant cells, would seem to indicate that in addition to the changes in their own genes due to mutations, the living cell naturally acquires new skills and advantages through the incorporation of other genetic materials of different origins originally acquired through endosymbiosis as well as horizontal DNA transfer. One can infer from this that the process of horizontal DNA transfer is one of the natural mechanisms involved in the evolution of species, since it enables the cell to acquire new abilities to contend with different needs (*Wallin 1927*, *Watson* et al. *1988 and 1996, Brown 1999, Goff* et al. *2000, Andersson* et al. *2001, Venter* et al. *2001, The Arabidopsis Genome Initiative 2002, Herrel* et al. *2004, Clifton* et al. *2004, Maier* et al. *2005, Kreuzer and Massey 2005*, *Margulis and Sagan 2005, Carroll 2006, Bolívar 2007*, *Herrera-Estrella and Martínez 2007, Bolívar* et al. *2007*, *Coyne 2009, Dawkins 2009, Vielle-Calzada* et al. *2009, Schnable* et al. *2009, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Jiang* et al. *2011*).

• In our genome and in the DNA of all living organisms, there are transposons, which are a sort of repeated genetic material, part of which is probably of bacterial and viral origin, accounting for at least 30% of the human genome. In maize, transposons constitute 85% of its genome.

Transposons are DNA sequences that can translocate or re-locate their position in the genome. In other words, they can "jump" from one genetic place (locus) to another and even between chromosomes. They have therefore played and continue to play a key role in the reorganization and probably in the evolution of the genome. In maize, the different colored grains in a cob are the result of this type of phenomenon which occurs in a single individual (figures III.15 and III.16).

Another type of material repeated in our genome and that of all higher organisms, including plants, is known as retroviral. Retroviruses, as mentioned earlier, are a sort of virus with RNA genomes. This type of repeated material, which constitutes 8% of the total in our genome, was probably stabilized in the human genome and that of our biological precursors by viral infection mechanisms and the subsequent incorporation into our chromosomes of the viral genomes of retroviruses such as HIV-AIDS. This type of horizontal transfer has influenced and continues to naturally and regularly influence the dynamics and reorganization of the genome in the living cell (McClintock 1957 and 1987, Maeda and

Smithies 1986, Watson et al. *1988 and 1996, Federoff 1989, Berg and Howe 1989, Purugganhanaud and Wesler 1992, Griffiths* et al. *1993, McDonald 1995, Voytas 1996, Brown 1999, Goff* et al. *2000, Venter* et al. *2001, Andersson* et al. *2001, The Arabidopsis Genome Initiative 2002, Herrera-Estrella* et al. 2002, *Kreuzer and Massey 2005, El-Sayed* et al. *2005, Herrera-Estrella and Martínez 2007, Bolívar* et al. *2007, Vielle-Calzada* et al. *2009, Schnable* et al. *2009, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Belyi* et al. *2010, Horie* et al. *2010, Jiang* et al. *2011*).

• Within this same context of the reorganization of the genome as a natural, everyday phenomenon, there is

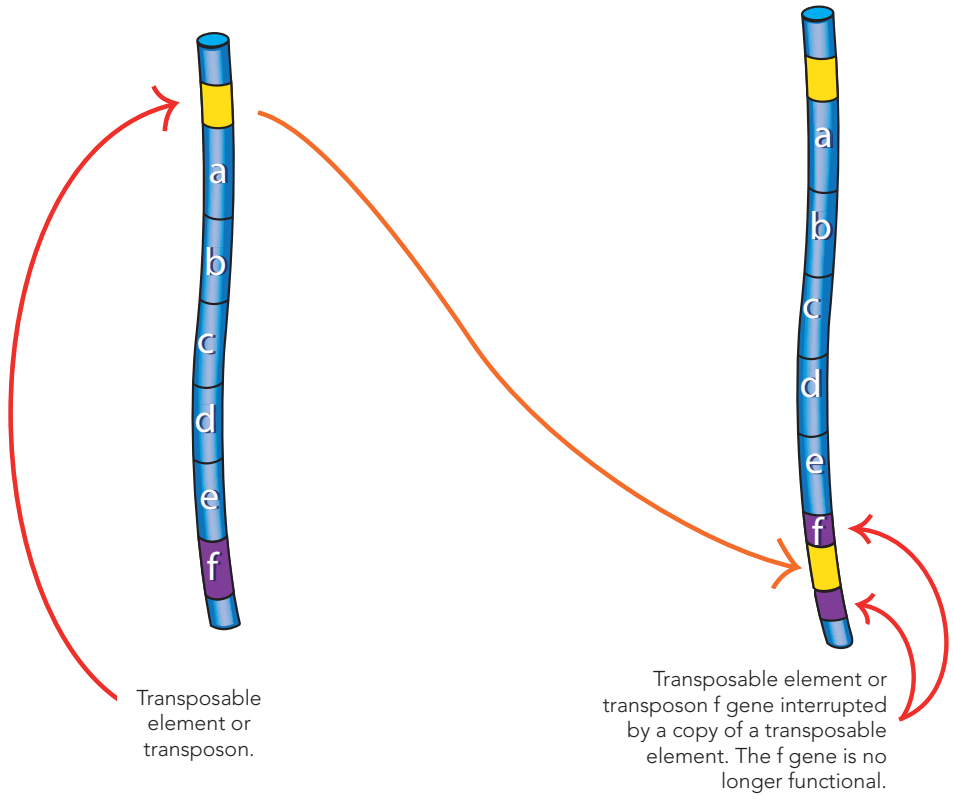


Figure III.15. Reorganization of genetic material through the phenomenon of transposition in which a DNA fragment (the transposon or transposable element) is relocated in the genome, occupying another genetic locus. In doing so, it can interrupt or deactivate a gene, as shown in the figure.

Figure III.16. Corn cob showing different colored kernels, resulting from the relocation of the transposons in the DNA of these kernels.

evidence that in genetically and physiologically close organisms, such as trypanosomes (important parasites of higher organisms), there has been an enormous reorganization of genes and chromosomes. In these organisms, chromosomes reorganize and change number and size as well as the position of genes. The number of chromosomes is modified, but most of the important genes remain in different positions. In bacteria, the recombination and reorganization of the genome is the most important phenomenon, above mutation in the evolution of certain bacteria such as *Escherichia coli*, which inhabits our intestine together with many other different bacteria.

Determining the sequences of the nucleotides of yeast and *Arabidopsis* genomes showed that during their evolution there was apparently a complete duplication of their genomes, followed by the loss, modification and duplication of genes, as well as the presence of fragments of the chloroplast genome in the nucleus. Evidence of the rearrangement of genetic material by various mechanisms has also been recently reported in other plants.

This evidence clearly indicates that the genomes of eukaryotes, specially plants, are extremely dynamic and continuously modified. This and examples in many other organisms indicate the genome's capacity for reorganization in the living cell, without affecting its functional capacity as a living being (Hozim and Tonewaga 1976, Watson et al. *1988 and 1996, Lewin 1994, Wolfe and Shields 1997, Lengeler* et al. *1999, Brown 1999, The Arabidopsis Genome Initiative 2002, Herrera-Estrella* et al. *2002, Kellis* et al. *2004, Kreuzer and Massey 2005*, *Margulis and Sagan 2005, El-Sayed* et al. *2005, Ivens* et al. *2005, Herrera-Estrella and Martínez 2007, Touchon* et al. *2009, Vielle-Calzada* et al. *2009, Schnable* et al. *2009, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Jiang* et al. *2011*).

• As pointed out earlier, when a living organism is modified to give rise to a genetically modified or transgenic organism, regardless of the methods used (transformation, biobalistics or electroporation [figures III.17, III.18 and III.19], which do not in themselves affect the genome of the receptor cell), specific genetic material is introduced into a cell through the process of horizontal DNA transfer. Subsequently, through the mechanism of genetic recombination, the transgene is incorporated as a segment of the receptor cell's genetic material into one of its chromosomes (figures II.8, II.9 and III.7). If during this event, which is a *de facto* reorganization of the genome, a codified function of the chromosome vital to the cell was affected, this particular transgenic organism would not survive. The same type of event could happen in the case of the genome's natural

reorganization when it is infected by a retrovirus —the HIV causing AIDS for example (figure III.7) or affected by a transposon (figures III.15 y III.16) that changed position in the chromosome. This is due to the fact that these phenomena can cause the insertion of their genetic material into an essential *locus*, meaning that the receptor cell in which the arrangement occurred would not survive.

In short, this type of event might occur not only as a result of the use of isolated genes incorporated through genetic engineering (transgenes). It can also occur naturally, since it is a process that could be

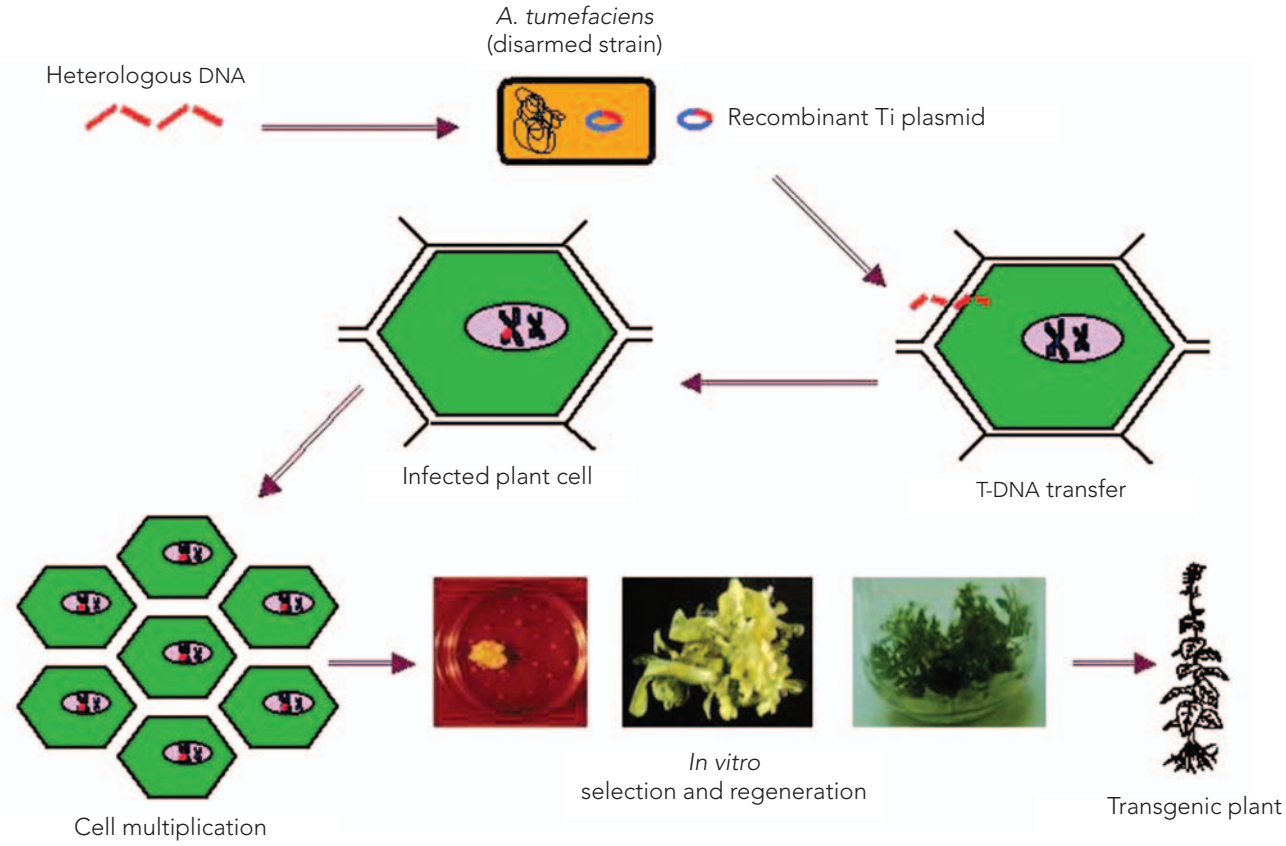


Figure III.17. Plant modification through genetic engineering. Different techniques are used to transfer heterologous DNA (transgene) to plant cell nuclei, which then multiply, giving rise to a transgenic plant.

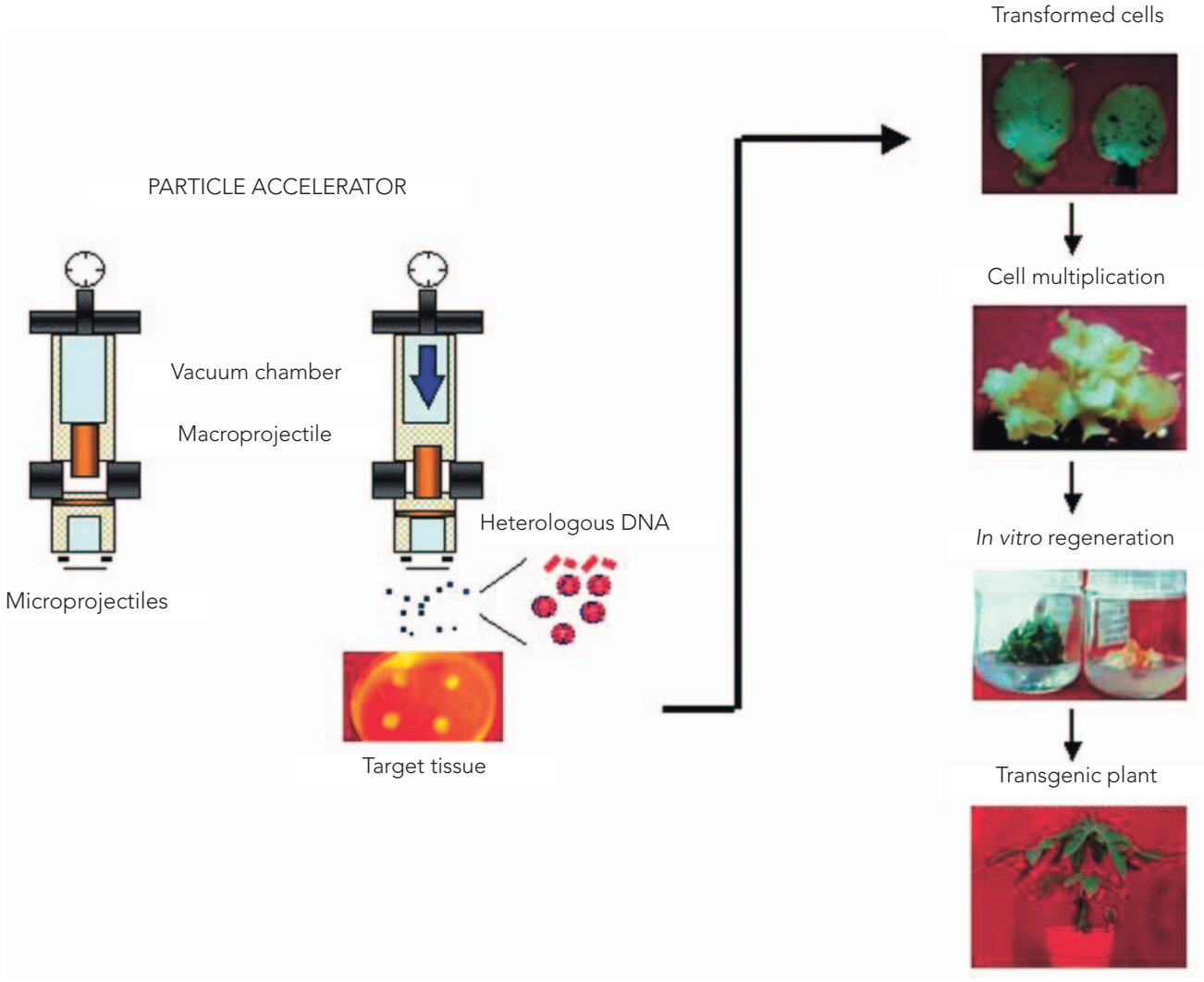


Figure III.18. The biobalistic technique makes it possible to incorporate heterologous genes or transgenes into plants.
Genetic material is introduced, with the help of small metal bullets, into the cell nucleus using the same type of horizontal transfer process.
Once in the cell nucleus, through the mechanism of genetic recombination, the transgene is incorporated into the cell genome.
A transgenic plant is produced on the basis of this transformed cell.

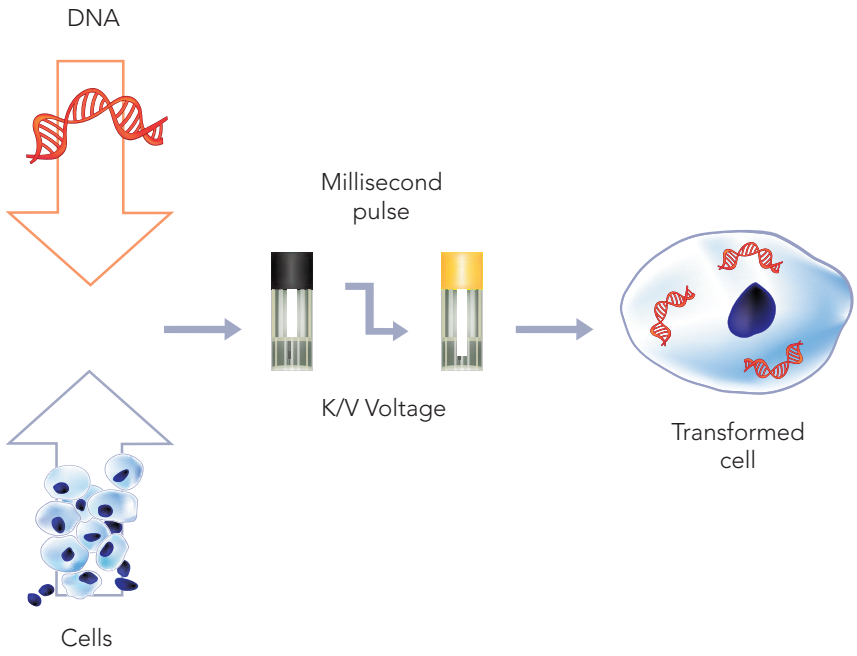


Figure III.19. Flow diagram of electroporation or electrotransformation method used to incorporate genetic material including trangenes into animal cells. In this method, the cell membrane is permeabilized by an electric pulse, which makes it possible to incorporate the heterologous DNA into the cell and subsequently in its nucleus, thereby producing a cell genetically transformed by the transgene.

caused by a viral inflection or DNA transpositions, such as those that often occur in maize (figure III.16). This phenomenon could cause the death of the receptor individual in which the re-arrangement occurred, but not an ecological catastrophe. The incorporation and reorganization of genetic material in a genome is therefore a natural process that occurs on an everyday basis in nature, regardless of transgenic organisms. This is because, regardless of its origin, since DNA has the same general structure, it is naturally transferred and recombined with the genetic material of the receptor cell.

One can infer from this that the process of modifying living organisms to produce GMO or transgenic organisms is equivalent to the natural process that occurs when a transposon is translocated or a fragment of viral genetic material is integrated into the genome of a living cell (figures II.8, II.9, III.7, III.15 and III.16). All these processes result in the reorganization of the

genome of the receptor cell, regardless of whether the process is begun by a viral DNA, a transposon, a DNA incorporated by horizontal transfer or a transgene. The cell does not distinguish them because they are DNA sequences that have the same general structure (figures III.3 and III.7) and this phenomenon occurs naturally and on a daily basis (*Jackson* et al. *1972, Cohen* et al. *1973, Sánchez* et al. *1975, Heyneker* et al. *1976, Korana 1979, Itakura and Riggs 1980, Herrera-Estrella* et al. *1983 and 2003, Mullis and Fallona 1987, Watson* et al. *1988 and 1996, Purugganhanaud and Wessler 1992, Taghagian and Nickoloff 1995, McDonald 1995, Glick and Pasternak 1998, Brown 1999, Andersson* et al. *2001, Yao* et al. *2002, Kreuzer and Massey 2005, Margulis and Sagan 2005, Xing and Lee 2006, Barrera 2007, Herrera-Estrella and Martínez 2007, Bolívar 2007, Bolívar* et al. *2007, Schubert* et al. *2008, Touchon* et al. *2009, Vielle-Calzada* et al. *2009, Schnable* et al. *2009, Belyi* et al. *2010, Horie* et al. *2010, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Jiang* et al. *2011*).

• The genetic modification of organisms to generate GMO not only involves changes in the genome of the receptor cell but also in the transcriptome (at least for the presence of the messenger RNA [mRNA] of the transgene) in the proteome (at least due to the synthesis and function of the protein encoded by the transgene) and in the metabolome (because of the metabolic resources involved in the synthesis of the new product encoded by the transgene).

Some groups that question GMO have pointed out that transgenosis involves changes that unpredictably and negatively modify the genome, proteome, transcriptome and metabolome of transgenic organisms. They also argue that GMO and the methods used to build them could encourage epigenetic changes (due to chemical changes in DNA) in the receptor cells and that these changes may be inherited and create problems in subsequent generations. Some of these groups have also pointed out that the DNA fragments used to construct transgenic organisms may transfer their own DNA modification patterns (methylation of certain residues of cytosine nucleotides) in receptor cells.

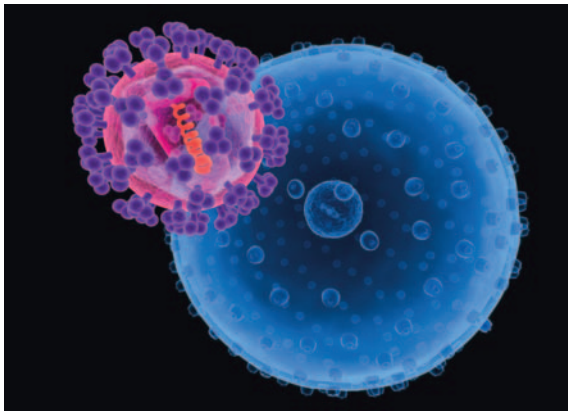
To date, there has been no scientific evidence of damage to human health caused by GMO and their products currently used, or specifically due to the difference in the methylation patterns at the level of the modification of cytosine residues of the transgenic organisms used. In all the processes of genome reorganization, including those mediated by horizontal DNA transfer, there may be different patterns of DNA methylation in a cell while new patterns in the re-arranged cell may also be created. Once again, however, this is not an exclusive phenomenon of transgenes and may occur

due to retroviral infections and other processes that may cause the natural reorganization of the genome. In addition, it is possible to eliminate the chemical groups (methyl groups located in certain cytosine residues) that normally modify the DNA in nature by using small DNA (oligonucleotides), produced *in vitro* in the laboratory by amplification through polymerase chain reaction (PCR) techniques and also through chemical synthesis. DNA is not chemically modified by methyl groups in either of these two processes. This is how one answers the doubts over incorporating genetic material in which some of its groups of cytosine have been modified, as occurs when DNA extracted from living organisms and viruses containing some nucleotides of methylated cytosine, is utilized.

All GMO used nowadays, not only transgenic organisms but also those derived through other traditional methodologies, have undergone significant changes and the reorganization of their genomes, transcriptomes and metabolomes, with no evidence of catastrophe or ecological damage. Viral infection and the transposition of genetic material also naturally create rearrangements in the transcriptomes, proteomes and metabolomes of the cells affected (figure III.20). In fact, there seem to be a great variety of non-transgenic crops that have appeared due to the natural rearrangements and modifications of their genomes and others caused by humans through traditional improvement techniques. An example of this situation continues until the present, as in the case of broccoli and cauliflower. One of these vegetables could well be regarded as a genetic aberration of the other, since this change occurred as a result of human action. Nowadays, many of the modified organisms used as food, not only transgenic ones, are being studied in detail. Most of the varieties of these crops have not harmed human health or biodiversity, although some of them display significant differences in their genomes, transcriptomes and proteomes (Itakura and Riggs 1980, Mullis and Falonna 1987, Watson et al. *1988 and 1996, Joset and Guespin 1993, Matzke and Matzke 1996, Lengeler* et al. *1999, Brown 1999, Kreuzer and Massey 2005, Margulis and Sagan 2005, Filipecki and Malepszy 2006, Bolívar* et al. *2007, Batista* et al. *2008, Fratamico 2008, Traavik* et al. *2009, Davis* et al. *2010, Doerrer* et al. *2010, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Jiang* et al. *2011*).

• Given all this evidence to support a genome's plasticity and capacity for reorganization and horizontal DNA transfer as a natural phenomenon (figures III.6 and III.20), it is difficult to understand the concern that a gene from a bacteria (*Bacillus thuringensis*) living in the soil that encodes the Bt protein, which is toxic for certain insects but not for animals, and has been incorporated by

DNA structure is the same
in all living creatures and viruses.



Scheme of a retrovirus infecting a cell.
In this natural process, viral genetic material
is horizontally transfered into the cell.

Transgenic maize cultivar.

Corn cobs with kernels in which DNA transposition has taken
place and their genomes have been naturally rearranged.

Figure III.20. Processes that occur naturally, as in the case of the maize cob or the infection of a cell by a retrovirus, in which the genome of the cells of living organisms, whether plants or animals, is rearranged. They also include the case of transgenic maize, whose construction is achieved through horizontal transfer processes (as in the case of viral infection) and the rearrangement of genetic material (as in the case of transposons in maize). This is possible because the DNA structure is the same in all living beings and in viruses. These considerations underpin the low risk of GMO constructed using similar techniques to the processes that occur daily in nature.

genetic engineering techniques (horizontal DNA transfer) into a plant, could cause an ecological catastrophe. This is based, as mentioned earlier, on the fact that living beings have evolved and will continue to do so by acquiring genetic material through horizontal transfer, changing and re-arranging their genes and chromosomes and modifying their genomes, proteomes and metabolomes without causing an ecological catastrophe. The scenarios that cause concern due to the presence of a transgene in an organism could occur daily due to natural horizontal transfer and the reorganization of the genome when plants or animals are infected by viruses, bacteria or other organisms.

Concern that GMO will be responsible for negatively transforming and degrading existing species used in agriculture and additional ones that comprise the biosphere are minimized because there is increasing evidence of the genome's plasticity and the fact that phenomena of changes and reorganization in the genome, transcriptome and proteome, occur naturally in the biosphere, quite apart from transgenics. Many of these processes of changes and reorganizations of genomes (transcriptomes, proteomes and metabolomes) are caused through horizontal DNA transfer, a natural phenomenon. One can infer from this that since the transgenic organisms are created by horizontal transfer, a process which already exists in nature, the GMO are organisms with similar levels of risk to those that exist in nature (*Watson* et al. *1988 and 1996, McDonald* et al. *1995, Lengeler* et al. *1999, Brown 1999, Andersson* et al. *2001, Venter* et al. *2001, Herrera-Estrella and Martínez 2003 and 2007, Ibarra* et al. *2003, Kreuzer and Massey 2005*, *Margulis and Sagan 2005, Batista* et al. *2008, Schubert* et al. *2008, Touchon* et al. *2009, Doerrer* et al. *2010, Belyi* et al. *2010, Horie* et al. *2010, Murat* et al. *2010, Swanson-Wagner* et al. *2010, Krom and Ramakrishna 2010, Jiang* et al. *2011*).

• Over hundreds of years, mankind has genetically modified the species used for its food and until recently, without knowing about the structure of genetic material, through the use of mutagens, which are known to produce several changes and rearrengements in the genomes of organisms (figure III.21). These original techniques of mutagenesis and the organisms created, however, have not been questioned as much as transgenic organisms despite the fact that nowadays we know that the methods previously used produce enormous changes in the genome, transcriptome and proteome of these organisms. This lack of questioning is probably due to the lack of damage caused by these organisms whose genomes have, however, been extensively modified, unlike those of transgenic organisms, in which only a single gene has been incorporated.

It should be noted that the combination of various species did not occur initially as a result of experiments with recombinant DNA but through the generation of plant varieties. The first records of genetic plant manipulation date from 1919, when the first plantations with hybrid seeds developed on the basis of selecting and crossing two different maize plants were reported. This methodology permitted a 600% increase in the agricultural production of this cereal over a period of approximately 55 years.

Likewise, genetic modifications for the improvement of agricultural crops carried out over the past 70 years using traditional mutagenesis techniques that incorporated different mutations and deletions have produced over 2,200 plant varieties and although they have barely been studied, no adverse effects have been reported to date. Plant manipulation began empirically approximately 10,000 years ago, when the human race began domesticating plants. This activity made it possible to obtain the plants we now know as maize, wheat, rice, sorghum and potato among many others, which did not exist as such in nature and served as the basis for the establishment of the world's great cultures (*Bourlag 1953 and 2007, Glick and Pasternak*

Figure III.21. New maize varieties.

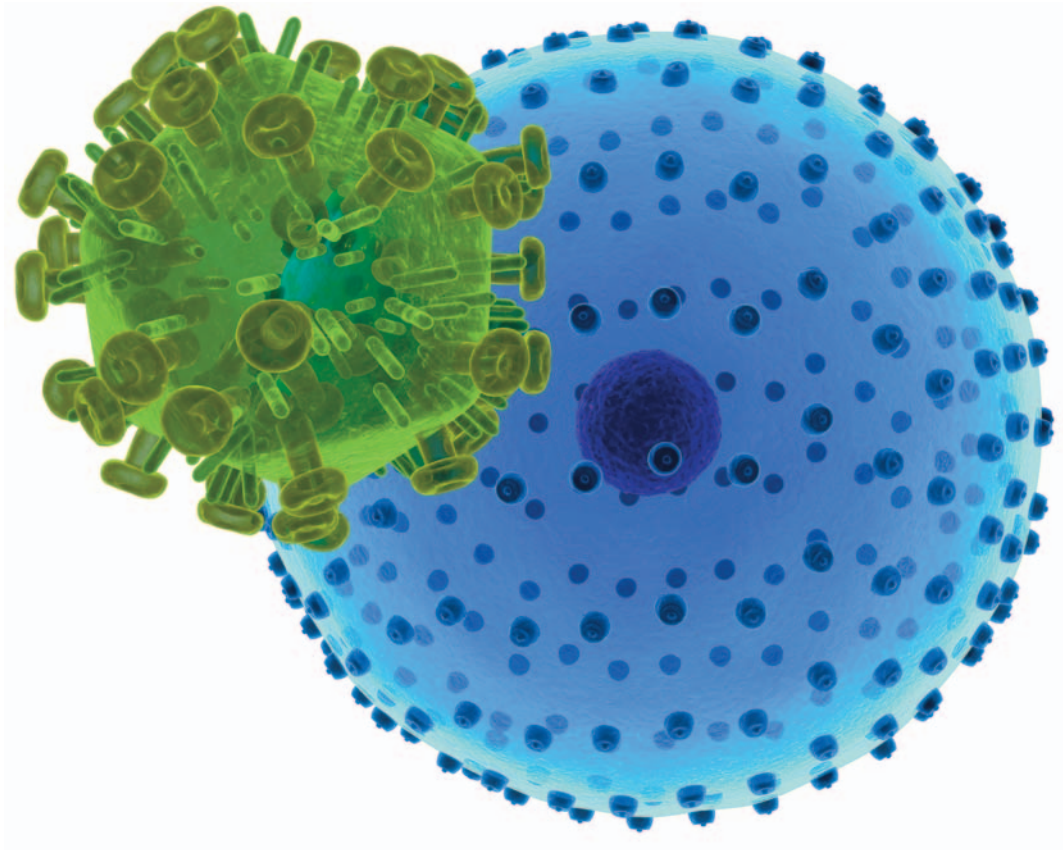


Figure III.22. Scheme of virus infecting a cell in which the phenomenon of horizontal transfer of genetic material occurs.

1998, Herrera-Estrella et al. *2002, Kreuzer and Massey 2005, Margulis and Sagan 2005, INIA 2006, Bolívar* et al. *2007, Batista* et al. *2008, James 2009, Doerrer* et al. *2010, Davis* et al. *2010, ISAAA 2010, BIO 2011).*

• As a result, all GMO used nowadays, not only transgenic organisms but also those obtained through other traditional methodologies, can be said to have undergone many, sometimes significant changes, in their genomes, transcriptomes and proteomes. Using this capacity to modify living organisms obviously cannot be ruled out by the argument that not all the potential risks of modifying the genomes, transcriptomes and proteomes of living organisms are known, since this would mean giving up the design and development of the best biological systems optimized for problem solving, while traditional methods seek similar objectives yet with random, less accurate strategies.

Since many of the genetic re-arrangements occurred naturally (figures III.6, III.7, III.16, III.20 and III.22) and many were caused by humans, we have today new and better species and varieties of living organisms with genetic modifications for solving many of our problems (Bourlag 1953 and 2007, *Watson* et al. *1998, Potrykus 2001, Herrera-Estrella* et al. *2002, Herrel* et al. *2004, Kreuzer and Massey 2005, Margulis and Sagan 2005, Bolívar* et al. *2007, Batista* et al. *2008, Fratamico 2008, James 2009, Dawkins 2009, Belyi* et al. *2010, Horie* et al. *2010, Doerrer* et al. *2010, Davis* et al. *2010, Bio 2011).*

• Lastly, it is important to note that to date, there is no solid scientifically supported and independently proved evidence by various groups of the damage to human health or to the environment or biodiversity due to the use of transgenic organisms or their products present in the market nowadays, although the absence of evidence of damage obviously does not imply a definite absence of risk (figure III.23). In its document, "20 questions on genetically modified foods," (Appendix 4), however, the World Health Organization notes that no human health problems have been caused by the consumption of these products. In many cases, the final products of transgenic origin that reach the consumer, such as soybean oil or corn starch, are chemically identical to conventional products. Their effect on human health is therefore indistinguishable, regardless of their origin.

There are many studies analyzing the toxicity of various transgenic plants when used as fodder for various animals. From all these studies, one can infer that no damage is caused by consuming the GMO used today. There are only two reported cases (Starlink maize in the US and a variety of peas in Australia) in which these products have been recalled because of their possibly allergenic effects. However, certain studies

Figure III.23. Genetically modified maize is used as food in many countries.

Figure III.24. Techniques for evaluating the characteristics of new plant varieties and the risks of transgenic organisms and their products.

published recently note that there may be some negative effects of possible toxicity due to the consumption of certain transgenic cultivars by certain animals. The authors of some of these reports conclude and recommend that further research be conducted to confirm their findings. It is crucial to insist on the importance of having other independent groups repeat these studies (figure III.24). If a significant negative effect is overwhelmingly proved, the use of these particular cultivars as food must be suspended. However, it should be pointed out that in none of the cases reported as having possibly negative effects on animal health have the government agencies responsible for the authorization and release of GMO taken the decision to recall them, since other factors, such as the presence of chemical pesticides or herbicides polluting the GMO, might be responsible for the detected possibly negative effects (*Potrykus 1989, Noteborne* et al. *1995, Hammond* et al. *1996, Struck* et al. *1997, Brake and Vlachos 1998, Pusztai* et al. *1999, Hashimoto* et al. *1999, Nuccio* et al. *1999, Yao* et al. *2000, Wang* et al. *2000, Momma* et al. *2000, Teshima* et al. *2000 and 2002, Spencer* et al. *2000, CDC 2001, Kosieradzka* et al. *2001, Noyola* et al. *2002, Herrera-Estrella* et al. *2002 and 2003, Reuter* et al. *2002, Thomas and Fuchs 2002, Hammond 2002, Arias and Muñoz 2002, Bernstein* et al. *2003, Purohit 2003, Bakshi 2003, Ibarra* et al. *2003, Chen* et al. *2003 and 2004, Hammond* et al. *2004, Rascón-Cruz* et al. *2004, Sinagawa-García* et al. *2004, APBN 2004, Zhu* et al. *2004, Zhuo* et al. *2004, Brake and Evenson 2004, Green* et al. *2004, Kreuzer and Massey 2005, Margulis and Sagan 2005, Rhee 2005, Metcalfe 2005, WHO 2006, Trigo and Capp 2006, Bolívar* et al. *2007, Domingo 2007, Valdez-Ortiz* et al. *2007, Poulsen* et al. *2007a and 2007b, Malley* et al. *2007, Constable* et al. *2007, Ramírez and Uribe 2007, Herrera- Estrella and Martínez 2007, Sakamoto* et al. *2007 and 2008, Schroder* et al. *2007, Seralini* et al. *2007 and 2009, MacKenzie* et al. *2007, McNaughton* et al. *2008, He* et al. *2008 and 2009, Healy* et al. *2008, Delaney* et al. *2008, James 2008 and 2009, CIBIOGEM 2008, Magaña-Gómez* et al. *2008, Appenzeller* et al. *2009a and 2009b, Mathesius* et al. *2009, Domon* et al. *2009, Herouet-Guicheney* et al. *2009, Ayala-Rodríguez* et al. *2009, Tutel'ian* et al. *2009, Juberg* et al. *2009, De Vendomois* et al. *2009, BIO 2011, Domingo and Bordonaba 2011).*

• In short, after everything described in this publication, it is essential to note that the events involved in the modification, due to the horizontal transfer of genetic material, and the reorganization of genomes, including those that have taken place in GMO, are phenomena that are permanently present in the biosphere. They are natural events that form part of the characteristics of living systems which, on the one hand, have been partly

responsible for the evolution of species and on the other, for the generation of new live organisms (whether naturally or anthropogenically) with the reorganization of their genomes (transcriptomes, proteomes and metabolomes) that make them more suitable for dealing with many of the problems and requirements of human society and the biosphere itself. Thus, organisms in the biota undergo genetic modifications, increases and re-arrangements that occur on a daily basis, which is why GMO are organisms with low risk levels, as happens in nature.

All human activities have an impact on nature and the environment. It is therefore essential to create both awareness and the frameworks for minimizing the negative effects on the planet by using better cultivars and doing so more efficiently (figure III.25). The premise that as human beings, we are not entitled to modify living systems to solve urgent problems, because this poses a serious risk due to the modification of their genomes, is simply untenable. Accepting this premise would mean giving up a tool that has been developed to replicate in a designed, directed way, with a lower risk coupled with respect for biodiversity, what happens permanently and naturally in the biosphere. This would rule out the possibility of designing better genetically modified organisms to meet the requirements of the human race and defend and restore polluted, destroyed ecosystems. It is both unacceptable and immoral to stand idly by in the face of the alternative of continuing to use technology that destroys and pollutes the environment such as chemical pesticides and weed-killers, many of which cause severe damage to health, biodiversity and the environment. Nor can one continue to destroy forests and woods for crop cultivation to satisfy the need for food.

There is no such thing as risk-free technology. Biotechnology is a technology with a low risk which also, thanks to the concern over possible risks involved in its use, now has mechanisms for evaluating and handling possible biological risks. It is essential to continue making responsible use of this technology through a case-by-case analysis and evaluation, based on the scientific evidence of transgenic organisms and their products. One should not forget that in Mexico, the Biosecurity Law of Genetically Modified Organisms, as we shall see in the following section, describes the principles and policies of biosecurity as well as prohibiting the use of this technology for other unsuitable and in some cases illegal purposes, such as the development of biological weapons, for example. Any technology can be used irresponsibly, which is immoral, illegal and unacceptable and improper use must be punished. This should not, however, limit the responsible progress of science and technology for the benefit of society and the world.

Figure III.25. Biotechnology must be used to help preserve biodiversity and recover polluted ecosystems.

IV. RESPONSIBLE USE AND APPLICATION OF GENETICALLY MODIFIED ORGANISMS

IV.1. General considerations regarding the responsible use of scientific knowledge and biotechnology

Science is a human activity intrinsically rooted in a spirit of enquiry that seeks to produce scientific knowledge on the universe and nature, including human beings and society.

Supporting the originality of new scientific knowledge must take place through peer evaluation and its publication in arbitrated peer reviewed journals and books. It is crucial to support the veracity of knowledge, since the lack of sustenance and lies destroy the credibility of scientific work.

Scientific knowledge has been used for the development and innovation of relevant, competitive technology, to solve problems and create satisfiers for society.

– The use of scientific knowledge and technology must occur: i) in a responsible way that respects health and preserves the environment; ii) fairly, while trying to reduce social differences and inequities; iii) with respect for cultural wealth; iv) in keeping with an appropriate legal framework and v) after a detailed analysis of the benefits and risks posed by the use or non-use of a par ticular technology for solving a problem.

– In particular, and in the case of biotechnology, as pointed out earlier, there has been no solid scientific evidence to date of a negative impact or damage caused by the use of GMO and their products currently available on the market. However, as with any type of technology, some transgenic products may have potential risks, making it essential to evaluate their use, and in particular, the release of GMO into the environment, on a case-by-case basis, using solid scientific evidence. It is important to note that the knowledge used for this evaluation must be properly supported. There are countless examples of publications being withdrawn

from journals since they contain false or unsupported evidence. Knowledge and published evidence must be independently obtained by several research groups in order to sustain knowledge and published evidence. It is also essential for experiments to be carried out under suitable conditions with proper controls (figure IV.1). Scientific knowledge in this area of biotechnology must also be used to create the bases for developing suitable, statistically validated technologies for the evaluation of biological technologies and their products, including those that use and evaluate GMO.

IV.2. International agreements and regulation in Mexico on the use of GMO

The use of GMO and their release into the environment has raised questions and created a global awareness of the importance of analyzing responsibly and exhaustively the release of GMO into the environment, bearing in mind different factors and possible risks. This has permitted, through discussions and reviews by experts, the creation of international agreements and national legislations for the responsible handling of GMO.

International context

• One of the international agreements is the Convention on Biological Diversity (CBD), signed by Mexico and more than a hundred countries, which came into effect in 1993. This Convention includes the commitment to establish an agreement on biotechnology security and biosecurity. As a result, in 2000, the CBD's Cartagena Protocol on Biosafety (CPBS) was passed in 2000. It was subsequently ratified by Mexico and came into effect in this country in September of 2003.

Through the Cartagena Protocol, signatory countries pledged to establish the necessary regulations and measures to evaluate the transborder movements of transgenic organisms that could have adverse effects on the conservation and sustainable use of biological diversity or human health (CBD 1993, CPBS 2000).

• The most important international organizations that engage in analysis and participate in the discussion and establishment of cooperation mechanisms related to biosecurity include:

The Organization for Economic Cooperation and Development (OECD) that has an area devoted to biotechnology. Its contributions about GMO include the Edinburgh Conference, which concluded with the

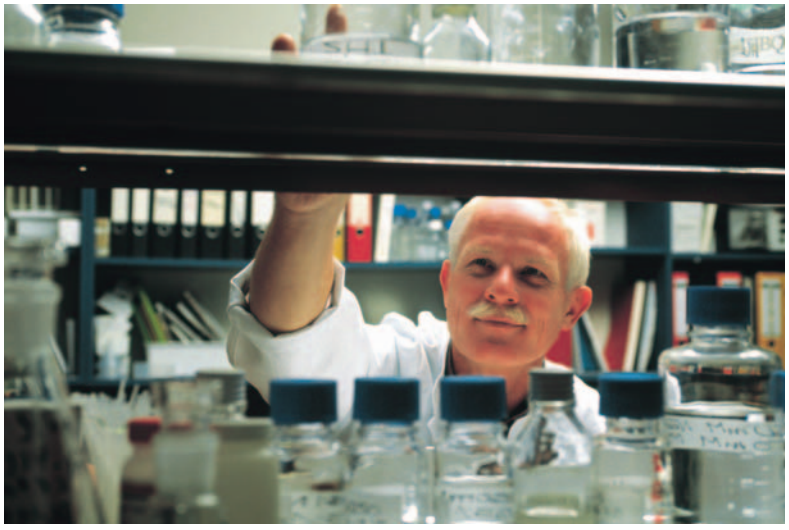


Figure IV.1. Evaluation of transgenic organisms and their products.

establishment of a consultation and discussion panel on GMO. Participants (400 representatives from 40 countries, including NGO) identified key aspects such as the need for a more open, transparent and inclusive debate in the definition of policies in the area as well as the recognition of the use of transgenic organisms and their harmlessness for human health, among other aspects.

Likewise, regarding biotechnology, the OECD works on the organization of meetings, studies and the publication of documents including the version revised in 2006 of "OECD Guidance for the Designation of a Unique Identifier for Transgenic Plants" http://www2.oecd.org/biotech/, which has established the guidelines for assigning codes to GMO. A database has also been compiled in keeping with the Cartagena Protocol, containing a list of the GMO used: http://bch.biodiv.org/about/default.shtml. This database enables the authorities of member countries to share information on the products of the new biotechnology.

The WHO agrees over the evaluation of the risk of releasing GMO and considers that the various genetically modified organisms (GMO) include genes inserted in different ways. This means that every GM food and its harmlessness must be individually evaluated on a case by case basis and that it is impossible to make general statements about the safety of all GM foods. It also notes that the GM foods currently available on the international market have passed the risk evaluations and not caused damage, meaning that they are unlikely to pose a risk to human health. Moreover, no effects on human health have been shown as a result of the consumption of these foods by the population in the countries where they were approved. The continuous use of risk assessment based on the principles of Codex Alimentarius, and where appropriate, post-commercialization monitoring, must form the basis for assessing the harmlessness of GM foods.

The United Nations Food and Agriculture Organization (FAO) and the WHO have supported GM food testing protocols (*FAO 2000*, *Dix* et al. *2004*, *WHO 2006*, *OECD 2006*, *Codex Alimentarius 2006*, *Constable* et al. *2007, Fratamico 2008, Codex Alimentarius 2009, James 2009).*

• It is important to note that to date, 27 countries have transgenic crop fields and that there is an annual increase in the area under cultivation. In 2009, 134 million hectares were reported to be under cultivation with transgenic crops, which included maize, rice, soybean, potato, beet, squash, alfalfa, canola and cotton. There is an important international debate on the assessment, release and safety aspects of GMO (figures IV.1, IV.2 and IV.3).

In the United States of America (USA), the country with the largest production and use of transgenic products, there has been a major debate on the benefits and possible risks of these products since their inception 30 years ago. In this respect the National Academy of Sciences (NAS) and the National Research Council (NRC) of this country have drawn up a set of key documents related to transgenic organisms, including the following: a) safety of food of transgenic origin; b) transgenic plants' effect on the environment; c) animal biotechnology and d) monitoring GM cultivars, in order to use a scientific basis to guide decision-making regarding the use of GMO.

In the European Union, legal frameworks have been developed for the use and release of GMO. In Europe, the use of new cultivars, including transgenic potatoes, was recently authorized. The use of rice and new varieties of transgenic maize was also approved in China.

The intellectual property of most cultivars is owned by transnational companies such as Monsanto, Dupont, Dow Agrochemicals, Syngenta and Bayer, which supply grain to smallholders in various countries (NRC 1989,

Figure IV.2. Transgenic maize.

Figure IV.3. Transgenic rice cultivar.

2002a, 2002b and 2004, Royal Society of London 2000, Thomas and Fuchs 2002, Gil and Martínez 2003, Flannery et al. *2004, AEBC 2004, APBN 2004, Dix* et al. *2004, OECD 2004 and 2006, WHO 2006, Jaffe 2006, Trigo and Capp 2006, CIBIOGEM 2008, James 2008 and 2009, Kanter 2009, Tang* et al. *2009, ISAAA 2010, BIO 2011).*

Mexican national context

• In Mexico, the Congress (figure IV.4), with the support of the AMC Biotechnology Committee and in keeping with the international commitments acquired, particularly the Cartagena Protocol on Biosafety, after a process of consultation, discussion and revision lasting three years, issued the Biosafety Law on Genetically Modified Organisms (BLGMO) in 2005.

This law is designed to guarantee the protection of human health, the environment, biological diversity, and animal, plant and human health in activities involving GMO. Key features included in the Law are given below:

i) The definition of biosafety principles and policy, such as case by case and step by step assessment based on scientific knowledge;

ii) The determination of the capacities of the various government departments involved in the evaluation of GMO;

iii) The establishment of the bases for the functioning of the Inter-Secretarial Commission on the Biosafety of Genetically Modified Organisms (CIBIOGEM);

iv) The definition of the bases of the procedures for the case by case evaluation and monitoring of the possible risks of using GMO;

v) The establishment of regimes for handling GMO (permits, announcements and authorizations);

vi) Bases for the establishment of the National Information System on Biosecurity and the National Register of GMO Biosafety;

viii) The definition of the bases for establishing guidelines regarding biosafety;

ix) Establishing control measures and sanctions;

x) Defining measures for public participation, access to information and social participation through CIBIOGEM's Mixed Advisory Board;

xi) Defining instruments to encourage scientific and technological research in the area of biosafety and biotechnology.

This Law, published in the Mexican Official Gazette (Diario Oficial de la Federación) in 2005 (BLGMO, 2005), already has a regulation published in 2008 to implement it (RLBOGM, 2008).

Figure IV.4. Chamber of Deputies in Mexico.

• Mexico purchases transgenic seeds as cattle fodder (figure IV.5). There are research centers and universities engaged in the development of suitable cultivars for conditions in Mexico. There are also companies in the area of health that produce recombinant human proteins for treating various diseases and clinical problems.

Since 1988, the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) has assessed the experimental release of GMO. Within the framework of the BLGMO, efforts have begun to assess the possible uses and release of GMO by CIBIOGEM. Over 60 permits have been granted for the experimental planting of transgenic cultivars. In Mexico, transgenic cultivars are registered in the name of transnational companies: Monsanto and subsidiaries, Bayer and subsidiaries and Dow Agrochemicals. In March 2011, SAGARPA granted Monsanto the first permit to grow transgenic maize at the pilot level in the state of Tamaulipas, the phase prior to commercializing grain.

However, it should be noted that regardless of the existing legal framework for the responsible use of GMO, Mexico lacks a comprehensive state agriculture policy concerning these and other key issues (such as intellectual property, benefits for small peasents) to guarantee fairer use of knowledge and technology for the benefit of society and the Mexican biota (*BLGMO 2005*, *Bolívar* et al. *2007*, *RLBOGM 2008*, *CIBIOGEM 2008*, *James 2009*, *ISAAA 2010*, *www.sagarpa.gob.mx 2011*, *BIO 2011*).

IV.3. Recommendations and considerations for the use and responsible application of transgenic organisms

A list of additional recommendations for the legal framework on the responsible use of GMO is given below.

• There is an international consensus on the need to assess possible risks and follow up, on a case-by-case basis, using solid scientific knowledge, on the GMO that are to be used and released into the environment. It is also necessary to monitor the presence of GMO in different niches in the short, medium and long terms. This analysis must consider the comparison of the benefits and possible risks derived from the use of a particular GMO, as well as the risks of not using them if current production and degradation schemes continue to be used *(NRC 1989, 2002a, 2002b and 2004, Beck 1999, FAO 2000, Hails 2000, Royal Society of London 2000, Dale 2002, Thomas and Fuchs 2002, Herrera-Estrella 2002, Ortiz and Ezcurra 2003, Kapuscinski et al. 2003, Flannery* et al. *2004, AEBC 2004, APBN 2004, Dix* et al.*2004, Bradford* et al. *2005, Kreuzer and Massey 2005*, *Bertoni and Marsan 2005, WHO 2006, Jaffe 2006, Singh* et al. *2006, OECD 2006, Trigo and Capp 2006, Bolívar* et al. *2007*, *CIBIOGEM 2008*,

James 2008 and 2009, Villalobos 2008, Tang et al. *2009, Kanter 2009, Traavik* et al. *2009, ISAAA 2010, BIO 2011).*

• There is also a consensus over the importance of conducting interdisciplinary research on transgenics through the use of the "omic" sciences (genomics, proteomics, metabolomics) as well as ecology and bioinformatics, among others. This is important, since there are scientists who consider that transgenes may elicit responses that are not obvious in the genome, transcriptome and proteome, in the receptor organism. Others think that this is not the case, since, as noted in Chapter III of this document, the horizontal transfer of genetic material and the reorganization of the genome, transcriptome and proteome are phenomena that occur permanently due to viral infections or the transposition of DNA in nature, regardless of transgenics.

As noted earlier, transgenic organisms are produced by horizontal DNA transfer processes and the reorganization of the genome, phenomena that occur in nature. Organisms in the biota undergo genetic modifications on a daily basis. GMO are therefore organisms with similar risk levels to those that occur in nature and in some cases, with fewer modifications than the cultivars used traditionally (*Watson* et al. *1988 and 1996*, *Dix* et al. *2004*, *Kreuzer and Massey 2005*, *Margulis and Sagan 2005*, *Bolívar* et al. *2007*, *Batista* et al. *2008, CIBIOGEM 2008, Fratamico 2008, Traavik* et al. *2009, Doerrer* et al. *2010, Davis* et al. *2010, Krom and Ramakrishna 2010, Mallory-Smith and Sánchez 2011, BIO 2011).*

• It has been pointed out, on the basis of solid scientific evidence, that GMO and above all, the transgenic cultivars used nowadays as food, have not damaged human health. It is important to note, however, that exhaustive tests must continue to be carried out to prove the harmlessness of the transgenic foods consumed and of the new products being launched on the market (figures IV.1 and IV.6). There are several publications in which attempts have been made to analyze the possible toxicity of transgenic plants and no damage to the various animals used in these studies has been reported to date. These studies sustain the lack of damage caused by the use of GMO and their products as foods. However, there are also certain publications that would seem to indicate possible effects on certain animals due to the consumption of some transgenic cultivars. In this respect, it is essential to ensure that the scientific knowledge published is well founded and that the possible evidence of negative effects due to the use of transgenic organisms does not necessarily imply damage. It is also crucial for any evidence published indicating possible effects caused by the use of transgenic foods and their products to be independently obtained by other re-

Figure IV.5. Transgenic maize imported into Mexico for cattle fodder.

search groups to corroborate results. There are numerous cases of published evidence in international journals that are withdrawn because they are false or incomplete or because they lack the proper controls and conditions. There are also, unfortunately, published articles whose results cannot be independently reproduced.

Emphasis has been placed on the fact that neither the WHO nor the governmental agencies of the various countries responsible for the analysis and evaluation of the use of transgenic organisms have changed their position on harmlessness or the lack of damage caused by the use of the transgenic foods and medicines currently available on the market. It has been said that, in the case of the Starlink corn, the government agency responsible in the USA, the FDA, decided to withdraw it from the market since it might cause allergies in a certain type of consumer. If there were overwhelming evidence that were independently confirmed on damage to health due to the consumption of a certain transgenic, this particular transgenic would have to be recalled, as in the case of Starlink and as happens when a drug that

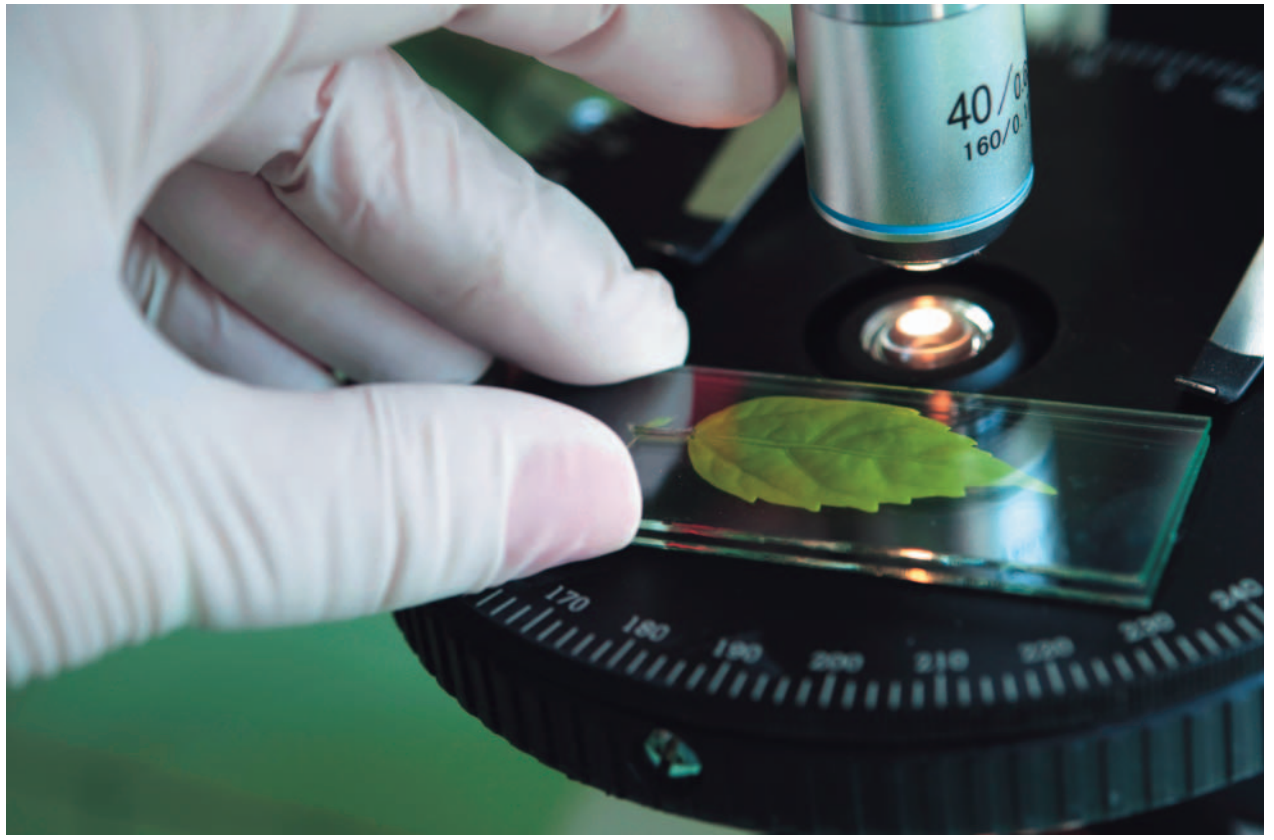


Figure IV.6. The analysis and characterization of transgenic cultivars is stipulated in the BLGMO to evaluate the possible risk of these foods.

proves to cause damage to health is withdrawn (*Potrykus 1989, NRC 1989, 2002a, 2002b and 2004, Noteborne* et al. *1995, Hammond* et al. *1996 and 2004, Estruch* et al. *1997, Brake and Vlachos 1998, Pusztai* et al. *1999, Hashimoto* et al. *1999, Nuccio* et al. *1999, FAO 2000, Yao* et al. *2000, Wang et al. 2000, Momma et al. 2000, Teshima* et al. *2000 and 2002, Spencer* et al. *2000, Reuter* et al. *2002, Thomas and Fuchs 2002, Hammond 2002, Arias and Muñoz 2002, Herrera-Estrella* et al. *2002 and 2003, Noyola* et al. *2002, Pryme and Lembcke 2003, Bakshi 2003, Ibarra* et al. *2003, Chen* et al. *2003 and 2004, Purohit 2003, APBN 2004, Dix* et al. *2004, OECD 2004 and 2006, Zhu* et al. *2004, Zhuo* et al. *2004, Brake and Evenson 2004, Green* et al. *2004, Kreuzer and Massey 2005, Rhee* et al. *2005, Metcalfe 2005, Trigo and Capp 2006, WHO 2006, Miller* et al. *2006, Bolívar* et al. *2007, Poulsen* et al. *2007a and 2007b, Malley* et al. *2007, Domingo 2007, Constable* et al. *2007, Ramírez and Uribe 2007, Herrera- Estrella and Martínez 2007, Sakamoto* et al. *2007 and 2008, Schroder* et al. *2007, Seralini* et al. *2007 and 2009, MacKenzie* et al. *2007, McNaughton* et al. *2008, He* et al. *2008 and 2009, Healy* et al. *2008, Delaney* et al. *2008, James 2008 and 2009, CIBIOGEM 2008, Fratamico 2008, Magaña-Gómez* et al. *2008, Tang* et al. *2009, Codex Alimentarius 2009, Appenzeller* et al. *2009a and 2009b, Mathesius* et al. *2009, Domon* et al. *2009, Herouet-Guicheney* et al. *2009, Tutel'ian* et al. *2009, Juberg* et al. *2009, De Vendomois* et al. *2009, ISAAA 2010, Krom and Ramakrishna 2010, BIO 2011, Domingo and Bordonaba 2011).*

- It is important to conduct social, economic and bioethical studies on the use of this technology (in other words, the impact of patents in poor countries together with ethical, social and economic aspects). There is information suggesting that there were economic profits of over $50 billion USD during the period from 1996-2008 due to the use of transgenic organisms in agriculture and that 50% of these corresponded to a reduction in production costs and above all, to a lower use of chemical pesticides. In particular, it led to a 34 million kilograms reduction in the use of pesticides, accounting for nearly 10% of the total amount of chemical pesticides used today. The use of 134 million ha planted with transgenic crops accounts for 9% of the total of the 1.5 billion ha cultivated worldwide. Transgenic products have now been used by over 300 million persons in 57 countries.

At the same time, it is essential to have a state agricultural policy in Mexico and in other countries that will consider these issues and the responsible use of transgenic organisms in a comprehensive fashion in order to guarantee the fairer use of this technology for the benefit of Mexican society, especially peasants, and its biota.

It is important to stress that in Mexico there are groups that have developed transgenic organisms that are already used in this country, together with new varieties of plants that could be used for the benefit of this country. It is therefore essential to provide interdisciplinary training for human resources and to strengthen the infrastructure of both research and the organizations able to provide an integral assessment of GMO and their use (figure IV.7). Establishing the means for disseminating the information generated in this area is also crucial (*Watson* et al. *1998 and 1996*, *Goedell* et al. *1979, Moses and Cape 1991, FAO 2000, Hails 2000, Bosch 2002, Thomas and Fuchs 2002, Purohit 2003, Gil and Martínez 2003, Rascón-Cruz* et al. *2004, Sinagawa-García* et al. *2004, Flannery* et al. *2004, Kreuzer and Massey 2005*, *Why Silence is not an Option 2006, OECD 2006, WHO 2006, Constable* et al. *2007, Valdez-Ortiz* et al. *2007,Herrera-Estrella y Martínez 2007, Ramírez and Uribe 2007, CIBIOGEM 2008, James 2008 y 2009, Ayala-Rodríguez* et al. *2009, ISAAA 2010, BIO 2011*).

• For the scientific community, organisms and products of transgenic origin constitute a tool that cannot be ignored in the development of agriculture. Strict control must be maintained, on the evaluation of possible risks to human health and biodiversity that could be caused by the new generations of transgenics. There are over 134 million ha under cultivation with GMO in 27 countries worldwide. There are, however, differences of opinion in Mexico over the advisability of immediately releasing varieties of transgenic cultivars of which this country is the center of origin, such as maize. Thus, while some ecologists hope that no other modified maize will touch Mexican farm land; other scientists believe that permits should be granted to cultivate it in certain regions. This should only take place after the level of possible risk and the necessary controls for minimizing and monitoring the flow of genes have been evaluated in field studies. Indeed, the consequences of an eventual genic flow due to pollen are also a polemic issue. However, a study on the flow of genes that confers resistance on herbicides has recently been reported. This report notes that it has been proved that this type of gene transfer ocurrs between cultivars that have not been genetically modified and certain grasses and other plant species related to these cultivars. This shows that the genic flow occurs independently of the transgenes and that DNA transfer takes place in nature between cultivars and related species. This has enabled cultivars and other organisms in the biota to acquire new capacities naturally on an everyday basis. This minimizes the concern that transgenics will cause and be the organisms responsible for creating grasses with various genes that are resistant to antibiotics, also called

Figure IV.7. Training human resources is crucial to promoting the development of science and biotechnology.

"supergrasses" since this natural phenomenon of transferring herbicide resistance genes between cultivars and other plant organisms related to them occurs regardless of transgenes. In other words, the genic flow is independent of the origin of the gene and biosafety must refer to the eventual damage that could be caused by a gene, regardless of its origin (*Watson* et al. *1988 and 1996*, *NRC 1989*, *2002a*, *2002b and 2004*, *Dale 2002*, *Thomas and Fuchs 2002*, *Kling 2003*, *Schieman 2003*, *Kreuzer and Massey 2005*, *INIA 2006*, *Singh* et al. *2006*, *Bolívar* et al. *2007*, *Valdez-Ortiz* et al. *2007*, *Herrera-Estrella and Martínez 2007*, *CIBIOGEM 2008*, *James 2008 and 2009*, *Ayala-Rodríguez* et al. *2009*, *Traavik* et al. *2009*, *Krom and Ramakrishna 2010*, *Murat* et al. *2010*, *ISAAA 2010*, *Bio 2011*, *Mallory-Smith and Sánchez 2011).*

• Another concern among sectors in Mexico that have expressed negative views on transgenic plants is that certain transgenic varieties currently commercialized by multinational firms are unsuitable for Mexican national agriculture, since pests in the United States are different from those in Mexico. Support for academic groups in this country's public institutions is therefore essential, so that they can develop the varieties required by Mexico. Many countries are already developing new second generation crops that attempt to boost the quality of food, as in the case of golden rice. This strain produces larger amounts of Vitamin A precursors and third generation varieties of maize that require smaller amounts of water to grow [figures II.15 and IV.8] *(Watson et al. 1988 and 1996*, *Ye* et al. *2000*, *Potrykus 2001*, *Ibarra* et al. *2003*, *Zhang* et al. 2004, Flannery et al. *2004*, *Rascón-Cruz* et al. *2004*, *Sinagawa-García* et al. *2004*, *Kreuzer and Massey 2005*, *Bolívar* et al. *2007*, *Herrera-Estrella and Martínez 2007*, *Byun* et al. *2008*, *James 2009*, *Ayala-Rodríguez* et al. *2009*, *Tang* et al. *2009*, *ISAAA 2010*, *Gilbert 2010*, *BIO 2011).*

• It is essential to organize the participation of academic, industrial and government sectors to create multidisciplinary groups that will provide advice using scientifically supported information. In particular, in Mexico CIOBIOGEM and the state secretariats involved in the evaluation of biological risk in agreement with the BLGMO must define strategies and methodologies for the risk assessment of transgenic organisms in order to achieve the following: i) the approval of their use and release into the environment based on solid scientific evidence; ii) the verification of the GMO used and iii) the follow-up and diagnosis of the presence of GMO in different ecological niches (*NRC 1989*, *2002a*, *2002b and 2004*, *Beck 1999*, *FAO 2000*, *Thomas and Fuchs 2002*, *ICSU 2003*, *Schieman 2003*, *Kapuscinski* et al. *2003*,

Figure IV.8. Transgenic golden rice cultivar.

BLGMO 2005, Kreuzer and Massey 2005, Why Silence is not an Option 2006, OECD 2006, Jaffe 2006, Bolívar et al. *2007, CIBIOGEM 2008, James 2009, ISAAA 2010, Bio 2011).*

• It is important to analyze the advisability of using or modifying successful strategies from different countries for national and regional regulation, according to the capacities, characteristics and needs of each country. Fifteen European Union member countries include the following aspects in risk assessment: i) the way the gene introduced changes the plant modified; ii) evidence of toxicity and allergenicity and iii) an assessment of the effects on beneficial organisms in the environment and the consequences of gene transfer (e.g. through pollinization). Several countries (including European Union countries such as Spain) are already discussing the conditions for the co-existence of first and second generation GMO crops -such as transgenic corn that requires a smaller amount of water- to grow than traditional crops. Conversely, countries such as Mexico, for example, are still discussing whether or not to carry out experimental tests, with moratoria being suggested for the latter (*NRC 1989, 2002a, 2002b and 2004, Royal Society of London 2000, Dale 2002, Thomas and Fuchs 2002, Schieman 2003, ICSU 2003, Purohit 2003, AEBC 2004, APBN 2004, Kreuzer and Massey 2005, Ponti 2005, OECD 2006, Trigo and Capp 2006, Domingo 2007, CIBIOGEM 2008, INRA 2009, James 2009, ISAAA 2010, BIO 2011).*

• Legislators and those responsible for administrative areas must have up-to-date, scientifically supported information on the issue and the assessment of technical and scientific personnel. It is essential for the government entities responsible for the definition of policies for releasing transgenics, to have sufficient elements to issue the corresponding guidelines that will define the administrative procedures for the use of GMO in keeping with national legislation and international agreements. It is crucial to have sufficient human and material resources to be able to implement the national or regional regulations and in Mexico the BLGMO and its regulation (*FAO 2000,Thomas and Fuchs 2002, BLGMO 2005, Kreuzer and Massey 2005, OECD 2006, WHO 2006, Dix* et al. *2006, Singh* et al. *2006, CIBIOGEM 2008, James 2009, ISAAA 2010, BIO 2011).*

IV.4. Illegal and questionable uses of certain GMO

• In Mexico, the BLGMO explicitly states that no GMO can be used as a biological weapon. It is possible to create GMO that could have a negative impact on human, animal and plant health, which would be illegal. These GMO cannot and should not be constructed. Examples

include bacteria that normally live in the human intestine, into which toxin-producing genes could be incorporated that affect health, such as botulism and cholera. An example in the area of plants could be the use of terminator genes that would prevent the germination of the following generations of seeds, since these genes could be horizontally transferred to other plants and cause damage.

• There is a consensus in the Mexican scientific community on the fact that edible plants, specifically corn, should not be genetically modified to enable them to produce substances of industrial interest, such as plastics, even if they were biodegradable. In particular, the use of food cultivars for the production of pharmaceutical compounds (vaccines, protein hormones, antibodies) should be analyzed in detail, since the possible consumption of these plants, which could produce medicines, could also have unpredictable secondary effects related to the dose of medicine consumed in the transgenic cultivar.

In principle, plants such as tobacco and cotton could be used to produce certain types of medicine and compounds currently manufactured by the chemical industry to reduce pollution, since these plants are inedible.

V. FINAL CONSIDERATIONS

The issue of modern biotechnology applied to agriculture has many elements of discussion and controversy. However, with regard to the production of new biomedication in the health sector, applications are advancing steadily, dealing with many clinical problems and providing powerful, new environmentally friendly tools for reducing and solving many of these problems.

A well-informed society is required that will be able to analyze each of the technological alternatives for dealing with the various problems and demands, together with firm support from the scientific community in order to be able to evaluate and exploit them.

Biodiversity is one of the Mexico's and world's greatest riches. It must be used responsibly and sustainably to incorporate greater added value into products of biological origin. Biotechnology has helped in this respect and may continue to help in many respects. This requires solid scientific information that has been comprehensively and responsibly analyzed, without automatically ruling out transgenic organisms and their products in order to conduct an objective analysis of the advantages and risks of both using and not using GMO.

This publication presents a set of scientifically supported evidence that supports the reasons for regarding GMO as organisms with similar levels of risk to those that exist in the biota, since they are created through the horizontal transfer of genetic material and the reorganization of genomes, phenomena which occurs on an everyday basis in nature and which has been partially responsible for the evolution of species.

The text includes recommendations for the responsible use of GMO which in Mexico is governed by the Cartagena Protocol on Biosafety, the Biosecurity law of Genetically Modified Organisms and their regulations.

The use of any technology has potential risks. In this respect, it is important to note that in the case of

certain drugs whose use has proved to damage health, the government agencies responsible usually withdraw these medicines from the market (i.e. drug stores). In the case of products of transgenic origin, particularly transgenic food, there are two examples (Starlink maize in USA and a variety of peas in Australia) in which possibly allergenic effects were found due to their consumption. Starlink maize was recalled by the FDA in the USA and the peas were not commercialized. However, as regards to the transgenic crops used today, there is solid scientific evidence of the lack of damage to human health, based on many publications showing the lack of damage due to animals' consumption of various transgenic cultivars.

Nevertheless, there are various recent publications reporting possibly negative effects in certain animals due to the consumption of certain GMO. It is important to note the importance of having these experiments independently repeated by several groups in order to validate results, since there may be other factors responsible for this damage, such as the presence of chemical pesticides or herbicides in the transgenic cultivars used, which might account for the negative effects detected by certain groups. However, if damage by a particular GMO is convincingly proved, then its use must be prohibited.

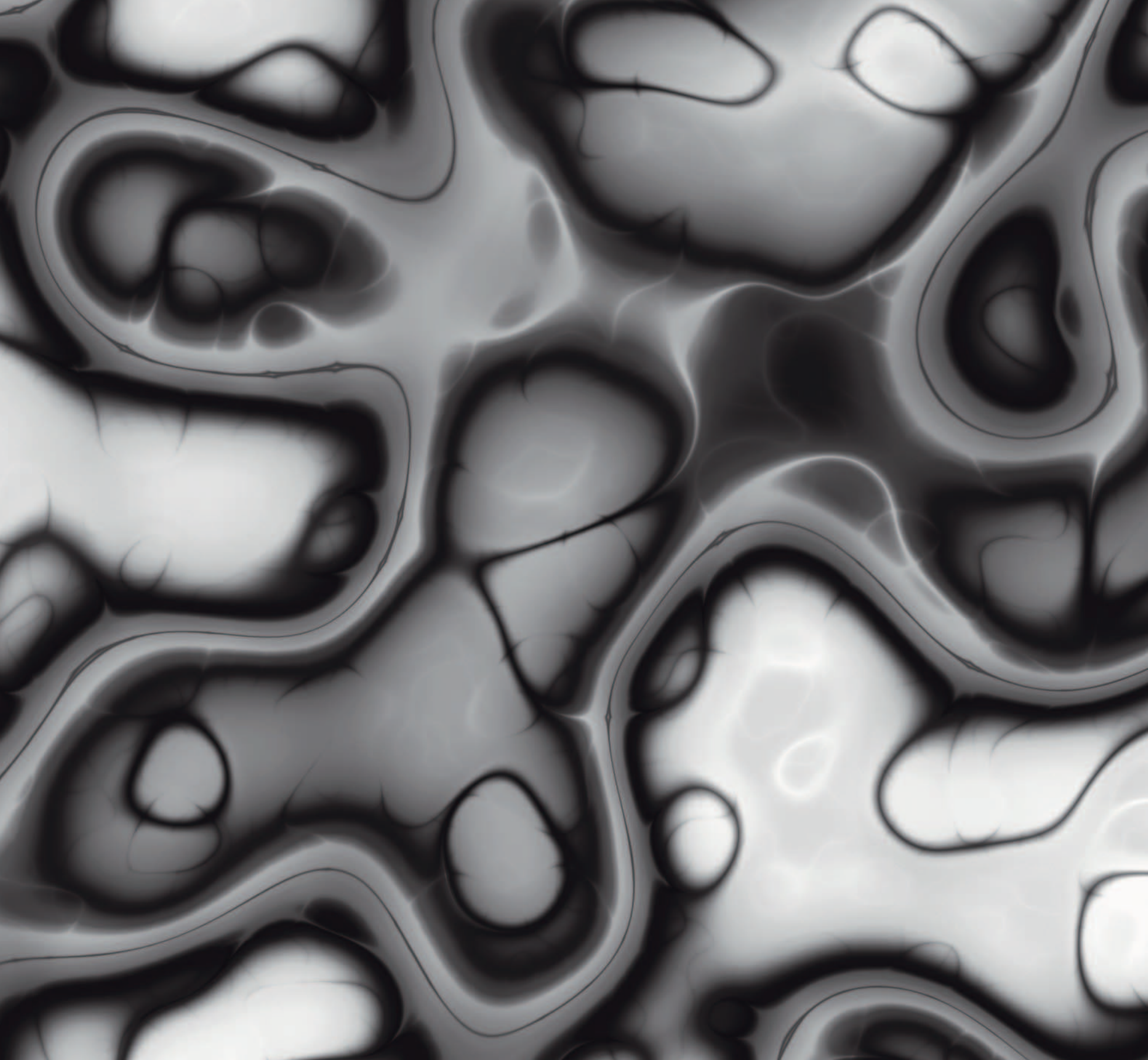
To date, the data published in the literature have not led to the elimination or recall of the transgenic cultivars that allegedly cause this damage by the government agencies in the various countries responsible for authorizing the use and release of these GMO. Consequently, the transgenic organisms and their products currently authorized and available on the market continue to be used and consumed in over 50 countries by nearly 300 million persons.

There is a significant amount of solid scientific evidence independently produced by several groups which supports the low risk involved in using transgenics or their commercial products since they are organisms created by horizontal DNA transfer and genome reorganization which occurs on a daily basis in nature.

Biotechnology is not inherently good or bad. It has the potential to decrease or increase the impact of agricultural activity on the environment. The challenge is to develop, provide and administer biotechnology with responsibility for the benefit of human beings and the environment.

Figure V.1. The environment and biodiversity
of our planet are crucial to human life.

Figure V.2. In these maize cobs, the genetic material in the cells
of the grains responsible for colors has been naturally rearranged.



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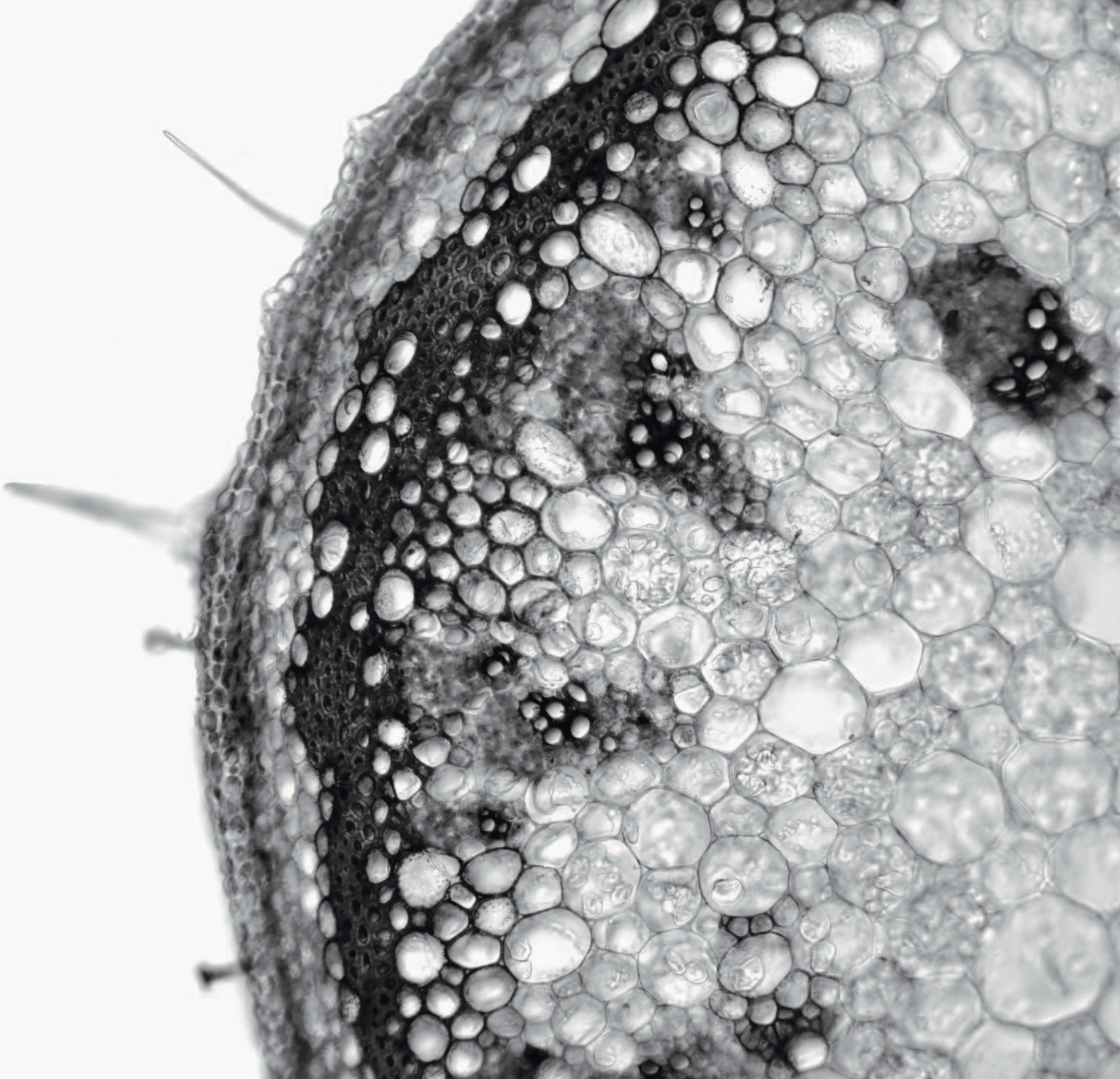


APPENDIX 2: GLOSSARY

Adenine. One of the four nitrogenated organic bases forming the nucleotides comprising DNA and RNA [see Figures II.2, II.5, II.6] (see DNA, RNA, bases).

Agrobacterium. Bacterium that may be pathogenic for certain plants, which is able to incorporate parts of its DNA into the cells of the plants it infects (see DNA, bacterium, plant).

Agroecological biotechnology. Emerging area of biotechnology at the interface of ecological, environmental, agricultural and evolutionary disciplines (see biotechnology, GMO, biological resources).

AIDS. Disease known as the Acquired Immunodeficiency Syndrome caused by the HIV virus (see retrovirus, genome reorganization).

Alanine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see proteins, amino acid, protein synthesis, codon, genetic code, polymer, mRNA, transfer RNA).

Allergenicity. Possible effect of producing allergic episodes in user (see immunogenic).

Amino acid. Protein monomer. Building blocks (monomers) of proteins (polymer).There are 20 different amino acids in the proteins of living beings [see Figures II.6, II.7] (see protein, transcription, translation, ribosome, monomer, polymer).

Amplification. Methodology enabling DNA fragments to be copied and therefore multiplied, through PCR techniques or molecular cloning in organisms (see PCR, oligonucleotide, genetic engineering).

Amylase. Protein with enzymatic capacities used to make syrups. Also produced by genetic engineering (see protein, enzyme, genetic engineering, genetically modified foods).

Animal. Member of one of the five kingdoms into which living organisms are divided (Animal Kingdom). Animals cells are heterotrophic and developed through the fertilization of an egg by a sperm. The fertilized egg or zygote is developed and differentiated at the cellular level and forms different tissues (see DNA, cell, heterotroph, zygote, gamete, organism).

Animal or plant health. Measures that must be adopted and implemented to preserve, deal with and limit the risks of disease or chemical or biological pollution that affects animals and plants. In the context of this book, risks include those that may occur due to the presence of GMO and their products (see biological risk, biosafety, transgenic, risk).

Antibiotics. Substances produced generally by organisms used to inhibit the growth of pathogenic microorganisms to humans and animals (see pathogenic organism).

Antibody. Protein produced by the immunological system of mammals in order to be joined to a specific antigen, which may be an invading agent (virus, bacterium, fungus) or small molecules not present in the organism (see immunogen, antigen, vaccine).

Anticodon. The sequence of three nucleotides present in the transfer RNA molecules (tRNA) through which they are joined to codons (comprising three nucleotides) determined by the sequence of messenger RNA. Protein synthesis is carried out by reading sequentially and associating transfer RNA molecules through their anticodons with the complementary codons or triplets of messenger RNA [see Figures II.5, II.6, II.7] (see mRNA, codon, genetic code, transfer DNA, ribosome, protein, amino acid, protein synthesis).

Antigen. Foreign substance in an organism that induces the production of antibodies and of the overall immune system of higher animals (see immunogen, antibody).

***Arabidopsis thaliana*.** Plant with small genome used as a model for the study of higher plants [see Figure III.13] (see cell, plant).

Arginine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, monomer, codon, genetic code, polymer, RNA messenger, transfer RNA).

Asparagine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, codon, genetic code, monomer, polymer, RNA messenger, transfer RNA).

Aspartic acid. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see proteins, amino acid, protein synthesis, codon, genetic code, polymer, monomer, messenger RNA, transfer RNA).

ATP. AdenonsineTriPhosphate, the molecule universally used by all living beings to store biological energy. In animals and plants it is mainly synthesized in mitochondria (see metabolism, metabolite, cell, mitochondria).

Autotrophs. Organisms capable of producing their own food (see bacteria, transgenic plant).

***Bacillus thuringensis* (Bt).** Bacterial microorganism living in the countryside that produces proteins that may have insecticidal functions. Genes from this organism have been isolated that produce these proteins for the construction of insect-resistant transgenic plants (see bacteria, transgenic plant, recombinant DNA).

Bacteria. Members of one of the five kingdoms of living organisms (Monera Kingdom). Single-cell autotrophic microorganism responsible for many essential biological functions such as biological nitrogen fixation and compound biodegradation. Also called prokaryotes since they do not have a nucleus where the DNA is located as is the case of eukaryotes (such as animals and plants) [see Figures III.9] (see microorganism, prokaryote, eukaryote, organism).

Bacteria *S. pneumoniae*. Pathogenic bacteria causing infection in the respiratory apparatus of humans and other animals [see Figures III.8] (see bacteria, pathogenic organism).

Bacteriphage. A virus that infects bacteria [see Figures III.9] (see bacteria, virus).

Bases, nucleotide components. Nucleotides are monomers comprising DNA and RNA nucleic acids polymers.

They consist of a nitrogenated base (purine or pyrimidine), a sugar (deoxyribose or ribose) and a phosphate group. There are 5 bases in the nucleic acids; two purines, Adenine (A) and Guanine (G) and three pyrimidines: Cytosine (C), Thymine (T) and Uracil (U). Adenine, Guanine and Cytosine are present in DNA and RNA. Thymine is only present in DNA and Uracil is only present in RNA [see Figures II.2, II.5, II.6, II.7] (see DNA, RNA, monomer, nucleotide, transcription, replication, DNA structure, protein synthesis).

Base pairs. The term represents complementary nucleotides. In DNA, adenine (A) is bonded to Thymine (T) and Guanine (G) to Cytosine (C) [see Figures II.2, III.4] (see DNA, nucleotide, base).

Biobalistics. Method used to construct transgenic plants that use gold microprojectiles covered with the DNA to be incorporated into a cell [see Figures II.8, III.18] (see genetic engineering, transgenic, transgenic plant, GMO, transgene, horizontal DNA transfer).

Biocatalysis. Biological process in which one or more enzymes take part, outside the cell context, to catalytically speed up the processes. The processes may involve the synthesis, modification or degradation of biological and organic compounds, including food (see protein, amino acid, genetically modified foods, enzyme).

Biochemical engineering. Discipline that uses knowledge of engineering and biochemistry for the industrial production of goods and services based on living beings and their parts (see biotechnology, biodiversity, fermentation, technology).

Biochemistry. Discipline studying chemical processes at the level of living organisms (see cell, biotechnology).

Biodegradable or biodegradation. Degrades (breakdown of compounds) through naturally occurring processes through living organisms (see recalcitrant, bioinsecticide, transgenic plants).

Biodiversity. Set of all the living organisms on the planet (see biota, ecosystem, genetic resources).

Bioethics. The branch of ethics dedicated to providing the principles for proper human behavior in regard to life, both human and non-human (animal and plant) and the environment in which acceptable living conditions may take place. In the broadest sense, bioethics is not restricted to the medical sphere but includes all the ethnical problems concerned with life in general, meaning that it includes issues related to the environment and the proper treatment of animals. It also considers various aspects related to life such as biological information and its patentability; the individual's biological privacy and the considerations underpinning the immorality of cloning human beings, among other issues (see organism, privacy, cloning, bioinformatics).

Bioinformatics. Discipline that comparatively studies existing information on the sequences of informational biological molecules based on software development for the analysis of genomics sequences (see protein, DNA, gene, RNA, genomics, sequence bank).

Bioinsecticide. Product of biological origin used to combat insect plagues. Bioinsecticides are biodegradable products. Genes with bioinsecticide capacities from bacteria in plants are incorporated, creating transgenic plants that produce their own insecticides against specific plagues (see pesticide, biodegradable, recombinant DNA, gene, transgenic plant.)

Biological diversity. See biodiversity.

Biological function. The role played by a biological molecule—such as proteins or nucleic acids—to enable the cell

to carry out its metabolism (see protein, protein synthesis, metabolism, cell, enzyme).

Biological macromolecule. Polymers such as proteins and nucleic acids comprising millions of atoms linked into long chains (see DNA, polymer, protein, monomer, amino acid, nucleotide).

Biological molecule. Set of covalently joined atoms (strong chemical bonds). Normally synthesized by a living organism (see cell, protein, polymer, monomer, DNA, RNA).

Biological resources. Genetic resources, organisms or parts of them, populations or any other biotic component of ecosystems with a real value, utility or potential for human beings (see biodiversity, biota, biotechnology).

Biological risk. Risk to human, animal, plant or environmental health that may be posed by certain types of modern products and biotechnological processes including transgenic organisms, their consumption as food and their release into the environment (see biosafety, transgenic, biotechnology security, GMO, risk).

Biological synthesis. Cellular process whereby cells produce biological molecules. Some of these, such as proteins, antibiotics and vitamins have commercial value (see cell, metabolism,proteins).

Biological system. Refers to living organisms which include microorganisms, plants and animals (see cell, plant, animal, microorganism, biodiversity, biotechnology).

Biological technology. Set of methods based mainly on the knowledge of living organisms which, since they are properly scaled, permit the industrial production of biological molecules of commercial interest. Alternatively, biological technology can also be a set of methods used to solve a problem, such as, for example, the pollution of a specific ecological habitat [see Figure II.10] (see biotechnology, fermentation, technology, biochemical engineering, genetic engineering).

Biological weapon. Possibility of using a genetically modified live organism or one existing in nature to cause damage or death in other organisms (see biosecurity, biological risk, transgenic).

Biology. The science of living creatures (see biodiversity, biota, cell).

Biomass. In fermentative processes, it is the cell mass produced during the process. In biodiversity, it is the amount of live cell matter present in the world (see fermentation, bacteria, biodiversity, biotechnology, biochemical engineering, technology).

Biomedicine. Substance produced by processes based on molecular biotechnology that have a therapeutic, preventive or rehabilitative effect, presented in a pharmaceutical form and identified as such by its pharmacological activity and physical, chemical and biological properties. These substances include insulin, interferon and the human growth hormone [see Figure II.11] (see drug, biospharmaceutical, medicine, insulin, interferon, technology, recombinant DNA, GMO).

Biopesticide. Product of biological origin used to combat insect pests. In the context of genetically modified organisms, it refers to the capacity acquired by a transgenic plant to kill pests by incorporating a gene of another origin that will confer pest resistance [see Figure II.15] (see pest, transgenic, insect, transgenic plant, transgene, recalcitrant, technology).

Biopharmaceuticals. Drug produced by molecular biotechnology (see drugs, medication, biomedicine, recombinant DNA, technology).

Biopolymer. Chains, necklaces or polymers made from monomers or biological beads. Proteins and nucleic acids are polimers [see Figures II.2, II.5, II.7] (see monomer, polymer, nucleic acids, protein, DNA, RNA, amino acid).

Bioprospecting. Activity designed to identify useful biological products on the basis of biodiversity. May include organic compounds, genes, proteins or complete organisms (microorganisms, plants or animals) (see biodiversity, biotechnology, biological resource).

Bioremediation. Use of techniques implying the use of organisms (whether live or their products) to restore a contaminated habitat (see biopesticides, technology, recalcitrant, biota, biotechnology)

Biosecurity or Biosafety In the context of modern biotechnology. It is the legal framework, procedures, norms and entities that guarantee proper use with the least possible risk for human, animal and plant health and the environment of certain types of products and processes in modern biotechnology, including transgenic organisms (see biological risk, transgenic, biotechnology security, monitoring).

Biosphere. Set of living beings on planet Earth (see biota, biodiversity, biology).

Biota. Set of animals, plants and microbes on planet earth (see plant, animal, genetic rsources, biosphere, biology).

Biotechnology. Any technological application that uses biological resources, living organisms and their parts or products for the creation or modification of products or processes for specific uses [see Figure II.5] (see modern biotechnology, recombinant DNA, technology, GMO).

Biotechnology security. In the Convention on Biological Diversity, an agreement was reached on "biotechnology security." To this end, the Cartagena Protocol was established whereby signatory countries pledged to establish the necessary regulations and measures to evaluate the transborder movements of transgenics that could have adverse effects on human health and biological diversity (see biodiversity, biological risk, biosecurity risk, transgenic).

Bornavirus. Virus with RNA as genetic material different from retroviruses. The presence of its genetic material has been detected in animal cells (see virus, health, pathogenic organisms, horizontal DNA transfer).

Botulism. Sickness that causes a toxin of the *Clostridium botulinum* bacterium which can cause the death of men and animals (see bacteria, pathogenic organism).

Cancer. Generic term used to name a set of diseases that may occur in practically any type of cell tissue, characterized by the uncontrolled tumoral growth of cells in this tissue (see cell, metabolism, genetic illness, carcinogenic, pesticides).

Carbohydrate. Molecules with different sugars and their polymers include glucose, fructose, saccharose, cellulose and starch (see metabolism, catabolism, glucose, polymer).

Carcinogenic cancer-producing substance or agent. Pesticides are substances used to kill pests, many of which are carcinogenic and recalcitrant (see cancer, pesticide, recalcitrant).

Case by case. This refers to the Mexican Biosecurity Law of Genetically Modified Organisms (GMO). This law states

that GMO must be evaluated individually for each transgenic. The evaluation of one transgenic cannot be generalized to others (see biosecurity, biological risk, risk assessment, transgenic, step by step evaluation).

Catabolism. Cell capacity whereby it is possible to create sources of biological energy and cell precursors on the basis of certain types of nutrients like sugars (see metabolism, carbohydrate, glucose, carbohydrate, cell, ATP).

Catalytic. Process in which a component (catalyst) accelerates the transformation of chemical compounds into others. Since the catalyst does not alter the end of the reaction, it can be used repeatedly (see enzyme, protein, biocatalysis, process).

Cell. Basic unit of living systems. Bacteria are single-cell organisms, whereas humans have trillions of different cells in their organism [see Figures II.3, III.11] (see organism, metabolism, catabolism, DNA, protein).

Cell differentiation. Process whereby a cell called a zygote produces several million or trillion cells and then tissues and organs with different functions according to the organism (see cell, zygote, gamete, chromosome pairs).

Cell engineering. Set of methodologies that permit the manipulation of genetic information as well as the metabolic pathways of a living organism to redirect the cellular machinery in order to produce or increase the synthesis of specific biological molecules of commercial interest such as the biomedicines insulin and the human growth hormone (see cell, metabolic pathway, biological macromolecule, biomedicine, metabolism, biotechnology, genetic engineering, technology, organism).

Cell metabolite. Molecule that is synthesized or degraded by the cell in order to carry out its various functions. Several metabolites are also monomers of biological polymers such as amino acids, which are monomers of proteins and nucleotides, monomers of DNA (see metabolism, metabolic pathway, catabolism, protein, amino acid, cell, nucleotide, amino acid, DNA, organism).

Center of origin. The place or country where a certain species originated. Mexico is the center of origin of maize (see biodiversity, biota, biological resources).

Chemical synthesis. Process of fabrication through chemical reactions making it possible to produce complex molecules including oligonucleotides and proteins (see oligonucleotide, protein, nucleotide, DNA, primer, probe).

Chloroplast. Intracellular organelle of plants in which photosynthesis occurs. Contains chlorophyll. It has its own genetic material and its structure maintains elements that exist in bacteria, which is why they were originally thought to be prokaryotes of this type [see Figure III.14] (see organelle, mitochondria, cell, endosymbiosis, symbiogenesis, evolution).

Cholera. Gastrointestinal diseases that may be fatal, caused by the *Vibrio cholerae* bacterium (see bacterium, pathogenic organism).

Chromosome. Cell structure located in the cell nucleus in the case of eukaryote organisms, comprising a single DNA molecule and associated proteins. Its size and number vary according to the species. It may have half a million to several hundred million nucleotides. This DNA molecule contains genes as specific segments. Humans have 23 chromosome pairs and prokaryotes such as *the E. coli* bacteria have a single chromosome [see Figures II.3, III.9, III.11, III.14] (see DNA, proteins, cell, chromosome pairs, gamete, eukaryote, prokaryote, bacteria, gene, nucleotide).

Chromosome pairs. Higher eukaryotes such as humans have duplicated genetic information, in other words, we are diploids. Half our information comes from the father and the other half from the mother. When the sperm and ovule fuse, a zygote is formed, on the basis of which the individual develops. The gametes, sperm and ovule, are haploids, in other words, they only have 23 chromosomes in the case of humans. When they fuse, they create a zygote with 23 chromosome pairs, each one of which is derived from the two gametes (see chromosome, DNA, gene, gamete, zygote, cell differentiation, cell).

Chymosin. Enzyme originally obtained from calves' stomachs to make cheese. First protein of transgenic origin accepted in the food industry (see protein, genetically modified foods, harmlessness, recombinant product, technology).

Clone. Set of genetically identical cells, viruses or molecules originating from a single parent [see Figures II.8, II.9] (see DNA molecular cloning, colony, cell).

Codon. Sequence of three nucleotides present in the DNA or RNA which encodes for an amino acid during translation, also known as a coding triplet or triplet [see Figures II.6, II.7] (see amino acid, DNA, genetic code, mRNA, translation, protein synthesis, transfer RNA, ribosome).

Coexistence of crops. Possibility of simultaneous existence of transgenic crops with traditional cultivars (see biosecurity, biological risk, transgenic, biota, biodiversity).

Colinearity between gene and proteic product. The order of nucleotides in the gene, specifically the order of each three nucleotides, is responsible for the order of amino acids in the coded protein for which they encode the set of nucleotides comprising a particular gene. The final structure of proteins depends on the order, at the primary level, in other words, of the sequence of amino acids comprising it. If this order is altered, the protein function may also be altered. The order of the mutations or changes that occur in a gene is reflected strictly in the order of the changes in the amino acids in the protein obtained from this gene, in other words, there is colinearity between the gene and its proteic product [see Figures II.5, II.6, II.7] (see gene, DNA, amino acid, protein, protein synthesis, genetic code, mRNA).

Collagen. Protein comprising several tissues, particular those of animal skin (see protein, cell, animal).

Colony. Structure created by growth through duplication or multiplication of microbial cells. All the cells in a colony (in the order of one billion) are identical to each other and to the cell that produced them (see cell, bacteria, clone, recombinant DNA).

Comparative genomics. Set of methods used to analyze and compare the genomes of different organisms (see bioinformatics, biodiversity, genome, sequence bank).

Competent cells. Cells that can incorporate genetic material of another origin (see transformation, DNA, genetic material, cell, metabolism).

Complementary DNA (cDNA). The DNA obtained enzimatically by copying a specific messenger RNA by reverse transcriptase [see Figure II.2, III.7] (see reverse transcription, DNA, mRNA, PCR).

Conformation. Three-dimensional arrangement that adopts a molecule (or any object) by virtue of the different angles of rotation its chemical links may acquire (see DNA structure, protein).

Cultivars. Crops or sown fields (see plant, transgenic plant, seed, biodiversity).

Cystein. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, codon, genetic code, polymer, monomer, mRNA, transfer RNA).

Cytosine. One of the four nitrogenated organic bases forming the nucleotides comprising DNA and RNA [see Figures II.2, II.5, II.6] (see DNA, RNA, nucleotide, polymer, monomer, bases).

Deletion. Phenomenon through which a fragment or at least a nucleotide is lost in DNA sequences. This change produces a mutation (see DNA, nucleotide, genotype, mutation, gene).

Deoxyribose Sugar. Forms part of the deoxyribonucleotides in DNA [see Figures II.2] (see DNA, glucose, nucleotide, base).

Deoxyribonucleic acid (DNA). This is the biological molecule containing the genetic information of all living organisms. It forms part of the chromosomes, which in turn are structures located in the nucleus of the cells of animals and higher plants. Human cells contain 23 chromosome pairs. Each human chromosome comprises a single DNA molecule approximately two to six centimeters long (depending on the size of the chromosome), which is associated with many protein molecules, particularly those called histones, whose function is to provide structure for the chromosome. In each of the trillions of cells in our organism, there are 23 chromosome pairs (with the exception of gamete cells: spermatozoids and ovules in which there are only 23 chromosomes) and each set of 23 chromosomes comes from each of our parents. If the 23 DNA molecules of all our 23 chromosomes were lined up, they would measure approximately one meter.

Genes are specific regions or segments of each of these DNA molecules [see Figure II.3]. We have approximately 21,000 genes in our 23 chromosomes and as a result of the Human Genome Project, we know the position of each and every one of these genes in the 23 chromosomes. Each of these genes, as a specific fragment of DNA, is the genetic information that encodes for a protein. If we have 21,000 different genes, this means that human beings can synthesize at least 21,000 different proteins, each from a specific gene.

Proteins, in turn, are biological polymers (necklaces) comprising 20 different monomers or beads called amino acids. In order to be able to understand the mechanisms enabling living cells to synthesize proteins on the basis of the genes located in the DNA, it is necessary to explain the structure of the DNA molecule. In 1953, Watson and Crick deciphered the molecular structure of DNA. DNA is a double helix comprising two antiparallel, complementary polymers [see Figures II.2, III.4]. Each of these two polymers or helices is in turn comprised of the union of millions of monomers that are like the beads (monomers) of a necklace (polymer). There are only four types of monomers or genetic letters in the DNA of all living beings, called nucleotides. These are located at 3.4 A° from the next monomer in the polymer forming each of the two helices. Moreover, in every type of DNA, a nucleotide with an Adenine base (A) always has, in the nucleotide of the thread or complementary helix, one with a Thymine base (T) and every nucleotide with a Guanine base (G) has a nucleotide with a Cytosine base (C) in the complementary thread. These are the universal rules for all DNA in all living beings. The main difference between all DNAs is the sequence of these four types of nucleotides with their A, T, G and C bases in every letter of every DNA molecule, in which there are several million nucleotides, just as there are only 26 letters in the alphabet for making all words and the different sequence of these letters in the words is what creates a different meaning for each of them. Thus we can say, from what we know of DNA, that the discovery of its chemical structure has become one of the unifying features of mod-

ern biology. Not only is the general structure of DNA the same in all living beings but the organization and regulation of genes, which as mentioned, are fragments or specific segments of this double helix, are also in general, the same in all organisms. This characteristic is what permitted the birth of genetic engineering, a methodology that enables "*in vitro* editing (in a test tube) at the molecular level" of this material [see Figures II.8, II.9]. Using videocassette tapes as an analogy, the genetic material of all living beings can be said to have the same "format," which is why it can be "molecularly edited" in a test tube. The general structure of DNA is exactly the same in all living beings, from bacteria to human beings (see DNA structure, replication, nucleotide, protein, gene, mRNA, transcription, chromosomes, cell, base pairs, molecule, DNA sequencing).

Diabetes. Illness in which blood sugar levels are not properly controlled, due in some case of the low production of insulin secreted by the pancreas cells [see Figures II.12] (see insulin, biodrug, genetic illness, biomedicine, genome, protein, cell).

Diagnosis or detection. Process of identifying substances through the use of specific detectors: antibodies or probes (specific fragments) of DNA to detect proteins or specific genes (see PCR, oligonucleotide, monitoring, DNA, technology).

Diploids. In adult organisms, cells in most eukaryotes contain two copies of each chromosome, which is why they are known as diploids. Each of these copies comes from one of the sex cells (gametes) –one female, one male- that fused to create the zygote (see chromosome pairs, cell, DNA, chromosome, zygote, gamete, haploid).

DNA. See deoxyribonucleic acid.

DNA molecular cloning. Set of methods permitting the incorporation and eventual amplification through repeated replication of a specific fragment (molecule) of DNA in an organism and its eventual transfer into its offspring. This technique makes it possible to obtain a population or clone of organisms in which they all have a copy of the original DNA molecule. It constitutes one of the central procedures of genetic engineering [see Figures II.8, II.9, III.17, III.18, III.19] (see genetic engineering, genetically modified organism, clone, recombinant DNA, transgene, GMO).

DNA or genomes sequencing. Methodologies that make it possible to determine the position (sequence) of nucleotides, one after the other, in the polymer in the DNA molecule thread. As an analogy, we can use the sequence of letters in words, where the letters are the nucleotides and the words the DNA. There are various techniques for determining the sequence of the millions of nucleotides in the DNA molecules. The information produced is stored in banks of sequences that enable them to be analyzed and compared [see Figures II.2, III.2, III.4] (see DNA, nucleotide, comparative genomics, bioinformatics, nucleotide sequencing, sequence bank).

DNA Polymerase. Protein with enzyme activity that takes part in the DNA replication process. This mechanism enables each of the DNA threads to be copied and two double helixes to be created from the double helix. In this process, deoxyribonucleotides are added one at a time (see DNA, replication, DNA structure, enzyme, protein, amino acid).

DNA transformation. See transformation.

Double helix. DNA is a molecule comprising two complementary, antiparallel helices. Each helix or thread is also a polymer with many nucleotides [see Figures II.2, III.3] (see DNA, replication, DNA structure, nucleotide).

Drug. Substance with biological activity identified by its physical, chemical and biological properties which meets

the conditions to be used as the active principle of a medicine [see Figures II.11, II.12] (see biodrug, medicine, biomedicine, insulin, interferon, human growth hormone, technology).

Ebolavirus. Virus whose genetic material comprises RNA different from retroviruses. The presence of its genetic material has been detected in animal cells (see virus, bornavirus, cell, RNA, retrovirus).

Ecology. Science that studies the relationship between living beings and their environment (see biodiversity, biology, biota, biotechnology.

Ecosystem. Community of living beings whose vital processes are linked to each other and develop on the basis of the physical and chemical factors in a single environment (see biodiversity, biota, biodiversity).

Encodes. This refers to the capacity of genes to store information that can be used by living cells to synthesize proteins. A gene stores information (encodes) to synthesize a protein [see Figures II.2, II.3, II.4, II.5, II.6, II.7] (see gene, DNA, protein, transcription, amino acid, RNA, mRNA).

Endosymbiosis. Relationship in which one of the members of a species lives very close or even within one of the members of the endosymbiotic relationship. Together they comprise the symbiont. A key role has been attributed to this type of process in the evolution of species [see Figures III.11, III.14] (see mitochondria, organelle, plant, symbiogenesis, evolution, theory of evolution).

Enzymatic hydrolisis. Process whereby enzymes break the covalent unions (strong unions) of other proteins, carbohydrates, nucleic acids and other molecules (see enzyme, protein, catalytic, chymosin, tripsin, lipase, lactase, catabolism, cell).

Enzyme. Protein with catalytic activity capable of accelerating a biochemical reaction to achieve the synthesis or modification of biological compounds. The molecules used by an enzyme to generate products are called substrates [see Figures II.6, II.7] (see protein, catalytic, substrate).

Epigenetic. Study of the mechanisms that produce effects on the phenotype by using chemical modifications (such as the methylation of cytosine residues in DNA) to alter genetic expression without altering the nucleotidic sequences or genotype of an organism (see DNA, nucleotide, gene, cytosine, phenotype, methylation, genetic expression).

***Escherichia coli* (*E. coli*).** Bacterium that has been widely studied and used in many laboratories and industry for the production of recombinant molecules and other products of commercial interest such as human insulin and human interferon. The nucleotide sequence of its only chromosome, in which there are only 4,225, has been determined. It is one of the bacteria that inhabits human and animals guts [see Figures II.12, III.9] (see bacterium, DNA, gene, nucleotide, insulin, interferon, recombinant product).

Eukaryote. Living organism which, unlike the prokaryote, has a nucleus in its cells where its DNA is found in various chromosomes. These organisms may comprise a single cell, like yeast or several cells like plants and animals including humans [see Figures III.11, III.14] (see plant, animal, yeast, cell, organism, prokaryote, nucleus, DNA).

Evolution. Biological process whereby cells and organisms acquire new functions through genetic changes (mutations) and the acquisition of genetic material through horizontal transfer, genome reorganization or endosymbiosis. As a result of these new functions, organisms can be better equipped to perform their biological function and prevail in an environment in which they compete with many other organisms. Darwin's theory of evolution states that all ex-

isting organisms have a common precursor and that through evolution, the diversity of the planet, including the human race, has been developed [see Figures III.1 III.2, III.3] (see theory of evolution, horizontal transfer, mutation, genome reorganization, endosymbiosis, mitochondria).

Exon. Parts of the genes that encode for parts of a protein whose information are stored in that segment of that gene. Genes are formed by exons (which encode for parts of the protein) and introns, regions that do not encode for protein [see Figures II.3, II.7] (see gene, intron, protein, transcription, mRNA, RNA processing, bases).

Fatty acid. Natural molecules comprising natural fats and oils.

Fermentation. Term used to explain the process whereby microbial cells can be multiplied in a suitable synthetic or semi-synthetic culture medium and produce substances, many of which have commercial value, such as beer, bread, antibiotics and more recently recombinant proteins such as human insulin (see biomass, cell, bacteria, antibiotic, insulin, recombinant product, biological technology, biochemical engineering, technology).

Functional genomics. Study of the function of the genes in the genome of an organism and the organization and control of the various genetic networks that establish the physiology of this organism (see bioinformatics, genomics, genome, DNA, gene, protein, sequence bank).

Fungus. Member of one of the five kingdoms (Fungi Kingdom) in which living organisms are classified. Group of eukaryotic saprophytic organisms responsible for many of the processes involving the biodegradation of compounds and molecules from other organisms (see bioinsecticide, pesticide, recalcitrant, biodegradable, biota, biodiversity).

Gamete. Haploid cells (containing a single copy of each gene) of nearly all animals and many plants capable of fusing and forming a zygote or egg producing a descendant. In higher animals, the male gamete is the sperm and the ovule is the female gamete (see cell, replication, DNA, zygote).

Gene. DNA segment containing information to synthesize a protein or RNA molecule. In addition to the encoding sequences called exons, many genes also contain non-encoding sequences such as introns and regulating regions. Genes are sequences of four types of nucleotides comprising DNA. The order or sequence of nucleotides in threes (triplets or codons) is responsible for the order of the amino acids in proteins. This order of nucleotides is "transcribed" into a messenger RNA molecule and "translated" into a protein in the cell ribosomes [see Figures II.2, II.3, II.5] (see colinearity, protein product, mRNA, nucleotide, DNA, transcription, exon, intron, protein, cell, DNA structure, chromosome).

Gene expression. Sensors and mechanisms whereby cells decide to express (or take) a gene to synthesize the messenger RNA and on the basis of this, to synthesize the particular protein encoded by this gene. The mechanisms regulating the expression of an organism's genetic information enable it to adapt quickly to changes in the environment. In principle, genes only function (or are expressed) when the organism requires and therefore provide the protein product for which they encode and only in the cells that so require [see Figures II.3, II.5] (see DNA, gene, promoter, operator, epigenetics, DNA structure, mRNA, proteome).

General DNA structure. Three-dimensional conformation of the DNA molecule, which is the same in all living beings. DNA comprising two polymers (two helices), where each in turn comprises four types of nucleotides, which are the monomers comprising these two helices. By being linked in space and because of the characteristics of these struc-

tures, they are shaped three-dimensionally and form a double helix [see Figures II.2, II.3, III.4] (see DNA, polymer, conformation, nucleotide, replication, double helix).

Genetic code. The genetic code is universal, in other words, it is used in the same way by all living beings. This code enables cells in any organism to "translate" the genetic information stored in the genes located in DNA into proteins. Proteins are polymers in which each amino acid is a monomer. There are 20 different aminoacids comprising nearly one hundred thousand proteins in the human body. An analogy can be drawn between the letters of the alphabet, which would be the amino acids and words, which would be the proteins. The order of the letters is responsible for the meaning of words, just as the order of amino acids in protein is responsible for their meaning or biological function. Each of the 20 amino acids in turn is encoded by a triplet or codon of three nucleotides in the messenger RNA (or the gene that gave rise to it).

In a code with four genetic letters (A,G,C and T) organized into triplets, there may be 64 different triplets. In our genetic code, there are therefore amino acids encoded by up to six different triplets such as leucine (leu) and there are amino acids such as tryptophan (trp) that are only encoded by a single triplet (in this case TGG). There are also three codons, GTA, TAA and TGA, triplets that can be read in the ribosomes responsible for finalizing the translation process. In other words, at this point, when reaching one of these stop codons the protein molecule synthesis concludes and the molecule is released from the ribosomes so that it can be used by the cell according to its biological function [see Figures II.2, II.3, II.4, II.5, II.6, II.7] (see amino acid, DNA, leucine, gene, ribosome, transcription, translation, mRNA, transfer RNA, triplet or codon, ribosome, protein synthesis).

Genetic control. Elements and mechanisms that participate in the regulation of gene expression [see Figure II.5] (see genetic expression, promoter, DNA, transcription, gene).

Genetic diagnosis. Methodology that permits the detection of specific DNA sequences among millions, through the use of probes or detectors of specific nucleic acids (see PCR, oligonucleotide, DNA, gene).

Genetic engineering. Sets of molecular methods and tools to manipulate the genetic material (DNA and RNA) of living organisms *in vitro* (in test tubes in the laboratory). Genetic engineering is synonymous with recombinant DNA methodology. This methodology has been used to create transgenics. The term "biogenetics" is inaccurate and should not be used [see Figures II.8, II.9, III.17, III.18, III.19] (see molecular DNA cloning, recombinant DNA molecule, ligase enzyme reaction, recombinant DNA, molecular tools, plasmid, technology, biobalistics, transgenic, GMO).

Genetic desease. Result of alterations, normally through mutation, of one or more genes, which results in the dysfunction of the products of these genes (see insulin, diabetes, biodrug, biomedicine, cell, cancer, gene, genome, protein).

Genetic *locus*. Specific region of the DNA of a chromosome in which a gene is located [see Figure II.3] (see DNA, gene, DNA structure, genome, *locus*).

Genetic map. Order or position in which genes are located in chromosomes in relation to the other genes. An analogy can be drawn with geographical maps, in which countries (genes) are located in continents (chromosomes) (see gene, chromosome, genome).

Genetic material. All material of plant, animal, microbial or viral origin, comprising nucleic acids and containing genes [see Figures II.2, II.3. III.4, III.7, III.9, III.11, III.14] (see DNA, RNA, gene, cell, biodiversity, genome).

Genetic recombination. Mechanism whereby living cells naturally rearrange fragments of genetic material. This may happen as a result of the translocation of existing genetic material, such as transposons, to another place in the genome. It may also happen due to infection from a virus or as a result of the incorporation of genetic material existing in the soil due to the death of living organisms. This phenomenon permits or is responsible for the reorganization of the genome of living organisms [see Figures II.8, II.9, III.7, III.15] (see genome reorganization, viral infection, genes, DNA integration, recombinant DNA molecule, ligase enzyme reaction, heterologous, transformation, influenza, genome, reorganization).

Genetic resources. Genetic material with a real or potential value that exists in the organisms comprising the earth's biodiversity (see biodiversity, DNA, biota, technology, biotechnology).

Genetically modified foods or transgenic foods. Foods that are, contain or come from genetically modified organisms (GMO). The WHO has pointed out that no damage to human health has been caused to date by the consumption of this type of foods [see Figures II.14, II.15] (see transgenic, harmlessness, chymosin, lipase, technology, scientifically based evidence, biological risk, DNA, amylase, pectinase).

Genetically modified organism (GMO). Organism that has been altered by modifying its genetic material, usually through the incorporation of genetic material of another origin through an horizontal DNA transfer mechanism. Synonym of transgenic [see Figures II.8, II.9, II.10, II.11, II.14, II.15, III.17, III.18, III.19] (see genetic engineering, transgenic, recombinant DNA molecule, technology, molecular DNA cloning).

Genetics. Discipline that began in 1860 with the experiments of Gregor Mendel to study the way genes in living cells operate and are organized and how characteristics are transmitted from father to son (see gene, vertical DNA transmission, gamete, zygote, cell).

Genic or genetic flow. Process whereby a set of genes is transferred from one population to another. In plants, pollen is the main vehicle for the mobility of genes to other plants (see biological risk, biosecurity, plant, seed, case by case).

Genome. Set of all the DNA genetic material with a living organism in each of its cells. In the case of bacteria, it is the genetic material present in its only chromosome. In the case of human beings, it is the genetic material present in our 23 chromosome pairs with over 21,000 genes in all the cells in the human body, with the exception of gametes (sperm and ovule) which only have one copy of each of the 23 chromosomes. In addition, humans have 37 mitochondrial genes as part of their genome [see Figures II.3, III.7, III.9, III.11, III.14] (see DNA, chromosome, gene, gamete, haploid, chromosome pairs, virus, proteome).

Genome duplication. Event presumed to have occurred in various precursors of current organisms such as yeast and the *Arabidopsis thaliana* plant. This event has made it possible to duplicate the original amount of genetic material and then, through a change in the mutation of certain genes, to create new functions [see Figure III.13] (see DNA, plant, gene, protein).

Genome reorganization. Process that makes genome segments change or alter their position. This phenomenon means that a DNA fragment of infectious origin (viral or bacterial) is incorporated into a cell and gives rise, through genetic recombination, to the integration, translocation or relocation of DNA fragments. Cells naturally reorganize their genome. Transposons, DNA sequences that move and relocate their positions in the genome, are responsible for

this phenomenon of reorganization without the need for a DNA from a virus or a bacteria [see Figures II.8, II.9, III.7, III.15] (see genetic recombination, transposon, genetic engineering, gene, DNA, genome, evolution, transposition, genetic recombination, AIDS, horizontal gene transfer).

Genomic medicine. Modern genomic science and molecular biology techniques used in medicine for the detection and treatment of genetic and infectious diseases including cancer and neurodegenerative diseases [see Figures II.11, II.12] (see cancer, diagnosis, drug, biomedicine, medicine, technology).

Genomic science. See genomic.

Genomics. Analysis of the set of all genes and their regulating regions (promoters, terminators, operators and spacers) in a living organism. The analysis includes the determination of the sequence of nucleotides comprising the genome in the organism. There are thousands of organisms in which the nucleotide sequence of all its DNA molecules resident in the chromosomes have been determined. The *Escherichia coli* bacterium has just over a million nucleotide pairs in its genome and just over 4,000 genes. The human race has 3,500 million nucleotide pairs in the 23 chromosome pairs in our genome which includes approximately 21,000 genes [see Figures II.2, III.2, III.7, III.9, III.11, III.14] (see genome, *E. coli,* molecule, DNA, gene, chromosome, chromosome pairs, proteome).

Genotype. Used to name the genetic components of a particular individual or variety. It refers, in the last analysis, to its genome sequence. The expression of the genotype is the phenotype (see phenotype, gene, genome, DNA).

Glucose. Sugar, a molecule of six atoms of carbon that forms part of the carbohydrates present in food, used by living beings to produce biological energy and cell precursors and thereby grow and reproduce (see carbohydrate, cell, ATP, metabolite, catabolism, metabolism, molecule, organism).

Glutamic acid. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see protein, amino acid, protein synthesis, codon, monomer, gene, genetic code, polymer, mRNA, transfer RNA).

Glutamine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, monomer, gene, codon, genetic code, polymer, mRNA, transfer RNA).

Glycine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, codon, monomer, gene, genetic code, polymer, mRNA, transfer RNA).

Guanine. One of the four nitrogenated organic bases forming the nucleotides comprising DNA and RNA [see Figures II.2, II.5, II.6] (see DNA, RNA, bases, nucleotide).

Haploid. Gametes of higher organisms (spermatozoid and ovule) only have one copy of each chromosome, which is why they are haploids. When they fuse they produce a zygote that has two pairs of each chromosome. The zygote is a diploid cell for this reason and contains two copies of each chromosome. Bacteria are haploids since they only have one copy of each gene and a single chromosome (see chromosome, DNA, haploid, zygote, genome, gene).

Harmlessness. Absence of damage to health, the environment and biodiversity. In the context of this book, due to the use of GMO or their products (see biological risk, biosecurity, genetically modified foods, scientifically based evidence, recombinant products, chymosin).

Heterologous. Refers to genetic material that has a differ-

ent origin from that of the receptor cell. It is also used to refer to passenger DNA incorporated through genetic engineering techniques through a vector in a cell [see Figures II.8, II.9] (see DNA, genetic engineering, plasmid, transgene, GMO, molecular tools).

Heterologous DNA. DNA from a different species to that of the receptor organism [see Figures II.8, II.9] (see genetic engineering, plasmid, passenger, transgene).

Heterotroph. Organism that does not produce its own food, like humans (see bacteria, plant, animal, cell, metabolism).

Histidine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, codon, monomer, gene, genetic code, polymer, mRNA, transfer RNA).

HIV. Human Immunodeficiency Retrovirus causing AIDS [see Figures III.6, III.7] (see virus, AIDS, retrovirus, genome reorganization).

Horizontal DNA transfer. Mechanism whereby a cell can receive genetic material from other organisms (such as a virus or a bacteria) or by incorporating existing genetic material into the environment through the phenomenon of transformation. This process allows a cell to incorporate and use genetic material from another source. Through this phenomenon, the genome may reorganize, which is why the cell acquires new functions encoded by the new genetic material [see Figures II.8, II.9, III.7, III.11, III.14, III.17, III.18, III.19] (see genome reorganization, transformation, DNA, virus, evolution, heterologous, transgene).

Human genome project. An international effort dedicated to determine the nucleotide sequence of the human genome [see Figures II.2, II.3, III.2, III.4] (see DNA, genome, sequencing, cell, sequence bank)

Human growth hormone. Protein produced in the pituitary gland that regulates the growth of different tissues. It is currently produced by genetic engineering techniques and used in the clinical treatment of dwarfism [see Figures II.11, II.12] (see insulin, biomedicine, recombinant product, technology, cell).

Hybrid seeds. Product of a new variety produced by crossing and selecting two different species of a plant such as maize or wheat (see plant, genetic flux, technology).

Hybridization. Applied to nucleic acids, it refers to their capacity to find or associate with the opposite or complementary DNA thread (see replication, DNA, cDNA, nucleic acids, RNA, nucleotide).

Immunogen. Foreign substance in an organism capable of triggering an immune response in higher animals (see allergenicity, cell, vaccine, pathogen, antibody).

***In vitro*.** Refers to experimental conditions in which there are no cells or living organisms. They are the conditions that occur in a test tube or in the laboratory (see recombinant DNA, cell).

***In vitro* recombination.** Technique that permits the isolation of genetic material (genes) from one origin and enables it to be combined with DNA of a different origin in a test tube (*in vitro*) in the laboratory. Synonym of genetic engineering. These techniques are used to construct transgenic organisms [see Figures II.8, II.9] (see genetic engineering, transgenic, genetic recombination, molecular DNA cloning).

***In vivo*.** Refers to experimental conditions that use living cells or organisms (see cell, metabolism, organism).

Infection. Mechanism used by pathogenic organisms (viruses, bacteria, funguses) to take over the machinery of

the infected organism. In some cases, it may cause the death of the infected organism [see Figures III.6, III.7, III.8] (see bacteria, virus, pathogenic organism cell).

Influenza. Refers to the virus that causes flu. There are different varieties of these viruses. The AH1N1 influenza recently emerged, created a worldwide pandemic. This type of virus can infect different animals, which is why the genome of the AH1N1 comprises RNA of human, avian and porcine origin, resulting from genetic recombination [see Figures III.5, III.6, III.7] (see RNA, virus, zoonosis, genetic recombination, cell, genome reorganization, pathogen).

Informational biological molecule. Molecule containing biological information. There are two types of informational biological molecules: proteins and the two nucleic acids, DNA and RNA (see DNA, RNA, nucleic acids, protein, amino acid, molecule, nucleotide).

Innovation. Introduce improvements or novelty into a product or technology (see biological technology, genetic engineering, biochemical engineering, biotechnology, technology).

Insulin. Protein with 51 amino acids that regulate the level of blood sugar. It was the first human protein produced in bacteria through genetic engineering techniques. There are individuals who, due to a mutation of the insulin gene, are unable to produce functional insulin, which is why they suffer from a genetic disease called *Diabetes mellitus* [see Figures II.9, II.11, II.12] (see protein, genetic disease, diabetes, mutation, drugs, biomedicine, *E. coli*, recombinant product, amino acid, DNA).

Integration of exogenous DNA. Process whereby heterologous DNA is incorporated into the genome of the receptor strain through covalent unions, meaning that it remains as a constitutive segment of the new rearranged genome [see Figures II.8, II.9, III.7] (see DNA, transformation, infection, virus, genetic recombination, genome reorganization, heterologous DNA, transgene, GMO).

Interferon. Human protein that forms part of the humoral immune system of vertebrates. There are a variety of proteins with various sequences included among interferons. They are produced as biomedicine by genetic engineering [see Figures II.11, II.12] (see amino acid, protein, drug, *E. coli*, biomedicine, insulin, GMO).

Intron. DNA fragments found in many of the genes of eukaryotes that do not normally encode for the protein that encodes this gene. Genes are composed of exons that encode for protein and introns that do not. When genes of eukaryotic cells are transcribed into mRNA, introns permit differentiated processing for the messengers carrying them. Thus, on the basis of an original transcription, several small transcripts are produced that lead to different combinations of introns and exons. That is why it is possible to produce more than one protein on the basis of a gene [see Figures II.2, II.3, II.5] (see gene, exon, DNA, DNA structure, transcription, RNA processing).

Isolate genes. Ability to separate a specific DNA segment containing one or more genes from the whole genome. Genes can also be chemically synthesized (see DNA, gene, genome, oligonucleotide).

Isoleucine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, DNA, gene, protein synthesis, monomer, codon, genetic code, polymer, mRNA, transfer RNA).

Lactase. Enzyme used in hydrolysis, or breaking down lactose, a component of milk. It is also produced through genetic engineering techniques [see Figure II.14] (see protein, enzyme, lactose, technology, genetic engineering, GMO).

Lactose. Carbohydrate present in milk (see glucose, carbohydrate, lactase, catabolism, molecule).

Leucine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, gene, protein synthesis, DNA, RNA, monomer, codon, genetic code, polymer, mRNA, transfer RNA).

Ligase enzyme reaction. The use of this enzyme to ligate or unite covalently (strong bond) two different DNA molecules [see Figures II.8, II.9] (see DNA, enzyme, recombinant DNA, molecule).

Lipase. Enzyme used in oil production from vegetables. Also produced by genetic engineering [see Figure II.14] (see protein, genetically modified foods, technology, genetic engineering).

Lisine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, codon, monomer, gene, genetic code, polymer, mRNA, transfer RNA).

Locus. The site on the chromosome where a specific gene is located [see Figures II.2, II.3] (see chromosome, DNA, gene).

Medicine. Any substance that has a therapeutic, preventive or rehabilitative effect, presented in a pharmaceutical form and identified as such by its pharmacological activity and physical, chemical and biological properties (see drug, biomedicine, insulin, technology, interferon, GMO).

Megadiverse. Possessing enormous diversity (see biodiversity, biota, biological resource).

Messenger RNA (mRNA). The first step in protein synthesis is the synthesis or formation of an RNA molecule called a messenger RNA (mRNA), which uses one of the DNA threads or chains as a mold. Messenger RNA is a molecule that is chemically very similar to DNA; it forms linear chains in the cell without ramifications. As a result, the genetic information contained in DNA, in other words, the order of the DNA deoxyribonucleotides is transferred to a complementary sequence of ribonucleotides during mRNA synthesis. Transcription is an enzymatic process mediated by the polymerase RNA enzyme and governed by two rules: it always occurs, like DNA replication in a 5′⌀3′ direction and normally, only one of the DNA chains is transcribed or copied in a mRNA molecule. The genetic information contained in each mRNA molecule is subsequently translated into protein molecules in an enzymatic process carried out in the cellular organelles known as ribosomes. Three main different types of RNA take part in this biosynthetic mechanism: ribosomal RNA (rRNA) which, together with various proteins, forms ribosomes; mRNA, which transports the genetic information contained in DNA and lastly the transfer RNA (tRNA) which serve as adaptors for the linear arrangement of specific amino acid of the protein to be synthesized according to the mRNA sequence. Protein synthesis, the translation of the RNA message, is also carried out in a 5′⌀3′ direction through the polymerization of amino acids in ribosomes to synthesize proteins by reading the messenger RNA by triplets according to the genetic code. This process is similar to what happens when a cassette tape is played. The information for each song contained in a segment of the tape is translated into a melody when this section of the cassette tape runs past the tape recorder heads. In the case of living cells, the tape corresponds to the mRNA carrying the information and the ribosomes correspond to the tape recorder heads that read the tape and transform (translate) the information into proteins, which, in the analogy, would be the biological melodies or songs [see Figures II.2, II.3, II.4, II.5, II.6, II.7, III.7, III.11] (see DNA, transcription, translation, ribosome, protein, anticodon, codon, transfer RNA, genetic code, amino acid, protein synthesis).

Metabolic pathway. Set of enzymatic reactions in a cell to perform the synthesis or degradation of cell metabolites (see cell, metabolism, cell metabolite, molecule, metabolome, glucose, catabolism).

Metabolic pathway engineering. Set of methodologies that permit the directed modification of the means of biosynthesis and degradation of biological compounds in living organisms (see metabolism, cell, cell engineering, genetic engineering, catabolism, gene).

Metabolism. Set of all the enzymatic processes in the cell enabling it to transform nutrients into energy, new biological molecules and new cells (see cell, metabolic pathway, ATP, catabolism, organism).

Metabolite. Cell compounds of low molecular weight, synthesized by enzymes with specific functions in the cell (see cell, metabolism, enzyme, metabolomics, ATP).

Metabolome. Set of metabolic pathways and their metabolite products in a living organism (see cell, genome, proteome, cell, metabolite, organism).

Metabolomics. Systemic, overall analysis of cell metabolites —not proteins—in a cell. The analysis includes the identification, quantification, characterization, location, synthesis, degradation and relation with other, different metabolites in a living cell as a result of its numerous metabolic pathways that permit the synthesis of all metabolites (see metabolism, metabolic pathway, metabolite, protein, cell, metabolome, genome, proteome, metabolite).

Methionine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, codon, genetic code, polymer, monomer, gene, mRNA, transfer RNA).

Methylation. Addition of the chemical group called methyl ($-CH_3$) to proteins and nucleic acids. In the case of DNA and RNA, methylation occurs in some of the residues of the cytosine nucleotides (see methylation pattern, DNA, nucleotide, cytosine, epigenetic).

Methylation pattern. Positions held and in some cases preserved by the modifications of certain methyl groups ($-CH_3$) in the residue of the cytosine nucleotide (see methylation, nucleotide, DNA, epigenetics, cytosine).

Microbe. Synonym of microorganism. Organism with one or a few cells invisible to the human eye like bacteria [see Figure III.9] (see bacteria, yeast, prokaryote, cell).

Microbiology. Discipline that studies microorganisms —those that cannot normally be seen by the naked eye since they are so small—usually consisting of one or a few cells (see virus, bacteria, yeast, microbe).

Microinjection. Introduction of DNA into a cell through the use of extremely thin syringes (see DNA, cell, GMO, transgene, biobalistic).

Microorganism. See microbe.

Mitochondria. Intracellular organelles with their own genes in which ATP synthesis is carried out. They are thought to have originally been bacteria that were incorporated by endosymbiosis to create new, more adapted and capable forms of life. They exist in humans and in all the animals and plants in the world [see Figures III.11, III.14] (see organelle, endosymbiosis, DNA, chloroplast, cell, symbiogenesis, evolution, ATP, metabolism, catabolism, metabolite).

Mobilization. Transfer or translocation of genetic material from one place of the genome to another. This may occur within the same cell or between different cells and may en-

courage the genetic reorganization of the genome [see Figures III.7, III.15, III.17, III.18, IIII.19] (see transposon, vector, genome reorganization, evolution, transformation).

Modern biotechnology. Multidisciplinary activity based on state-of-the-art knowledge created in various disciplines (including molecular biology, biochemical engineering, immunology, genomics, ecology) which permits the integral study and manipulation of biological systems (microbes, plants, animals and insects). Modern biotechnology seeks to make intelligent, respectful use of biodiversity through the development of clean, competitive, efficient biological technology to facilitate the solution of major problems in sectors such as health, agriculture and fishing, industry and the environment [see Figure I.1] (see biological technology, biotechnology, technology, biological system, biodiversity, GMO, genetic engineering).

Molecular biology. Discipline studying living organisms at the molecular level. This branch of biology emerged following the identification of nature at the molecular level of DNA in 1953 [see Figures II.1, II.2] (see DNA, DNA structure, recombinant DNA, biotechnology).

Molecular medicine. Application of molecular biology techniques in medicine for the treatment of hereditary and infectious diseases (see molecular biology, genomic medicine, biomedicine, drug, diagnosis, technology).

Molecule. A group of atoms held together by strong chemical (covalent) bonds. A molecule may consist of atoms of the same kind like oxygen in the O_2 molecule, or two different atoms like in the CO_2 molecule. Molecules are the components (substances) of inorganic and organic matter including living organisms. Most of the molecules in living cells are composed of carbon, nitrogen, hydrogen, oxygen and phosphorus atoms. DNA, RNA and proteins are molecules (biological molecules) composed of millions of these atoms arranged with different order and structure that allow their biological functions [see Figures II.2, II.5, II.7] (see DNA, gene, protein, cell).

Molecular tools. Set of biological molecules a living cell usually requires to carry out its functions to handle its own nucleic acids. These molecules are used *in vitro* in the laboratories to manipulate the genetic material of cells. These tools include plasmids and enzymes that modify and polymerize nucleic acids [see Figures II.8, II.9, III.17, III.18, III.19] (see plasmid, nucleic acids, genetic engineering, molecular DNA cloning).

Monitoring. Refers to the capacity to supervise, detect or diagnose the presence of transgenics in various niches over time (see crop, transgenic, diagnosis, biosecurity, biological risk, evaluation).

Monomer. Constituent unit of a polymer. Proteins are polymers in which the amino acids are monomers [see Figures II.2, II.5, II.7] (see amino acid, nucleotide, DNA, polymer, protein).

Moratorium. Actions to halt the use of a technology or product for different periods of time (see biological risk, biosecurity, monitoring, diagnosis).

Mutagenesis. Process whereby changes are caused in the genetic material of an organism. The process may be spontaneous or induced (see DNA, mutation, mutagenic, DNA, nucleotide, gene).

Mutagenic. Chemical changes, energy, technologies and genetic material used to cause changes in the genome sequence of an organism (see mutagenesis, DNA, nucleotide, mutation).

Mutant. Organism with a modification in the nucleotide sequence of its genome in relation to the original organism (see DNA, gene, mutation, evolution, nucleotide).

Mutation. The genetic information contained in the DNA may undergo changes or modifications known as mutations. Mutations are a cause of hereditary variation and therefore mainly responsible for evolution. It is a well-known fact that organisms experience mutations in their DNA due to environmental factors such as solar radiation, interaction with chemical products and viral infections. DNA may undergo various types of changes which may alter a single nucleotide to complete chromosomes. Alterations in the sequence of the nucleotides of a gene can cause a change in the interpretation phase of the gene in the mRNA and therefore create a protein with an altered amino acid sequence, which is no longer able to perform its original function (see gene, DNA, nucleotide, mutagen, evolution, protein, amino acid, nucleotide, mutant).

Nucleic acids. Informational biological molecules containing genetic information, of which there are two types: DNA and RNA (see DNA, RNA, protein).

Nucleotide. Building blocks of nucleic acids. Monomers of DNA and RNA nucleic acids comprising a base, a sugar and a phosphate molecules. There are five nitrogenated biological bases in the nucleic acids of living creatures. Three of them: Guanine (G), Cytosine (C) and Adenine (A) are present in DNA and RNA. DNA also contains Thymine (T) while RNA has Uracil (U) instead of Thymine (see DNA, RNA, mRNA, transcription, transduction, ribosome, monomer, polymer, nucleic acids, molecule).

Nucleotide sequencing. See DNA sequencing.

Oligonucleotide. DNA molecule with a low number (~5 to 200) of nucleotides. Oligonucleotides are used as probes or trackers in diagnosis systems and as primers in polymerization and the amplification of DNA using PCR techniques. They can be chemically synthesized (see PCR, replication, diagnosis, amplification, DNA, nucleotide, polymer).

Omic sciences. Set of genomic, proteomic, transcriptomic and metabolomic sciences (see genomic, proteomic, metabolomic, transcriptomic).

Operator. Refers to a regulatory region present in many genes used to link regulatory molecules, normally proteins (repressors, activators) to modulate genetic expression (see genetic expression, genome, DNA, gene).

Organelle. Cell structure specializing in a specific function, such as the nucleus, mitochondria, chloroplasts, ribosomes [see Figures III.11, III.14] (see cell, endosymbiosis, mitochondria, evolution).

Organism or living organism. In the context of this book, organisms are living beings of the five kingdoms (Animal, Plantae, Fungi, Monera (Prokaryotes), and Protista) that comprise the biota of the world. They are composed of cells highly organized, capable of aquire materials and energy from the environment to allow their growth and reproduction. They are also capable of respond to environmental factors and to evolve [see Figures II.10, II.16, III.12, III.13, III.25] (see biota, cell, bacteria, plant, animal, fungi, biology, transgenic plant).

Passenger. Refers to genetic material that may be incorporated into a vector in order to be transferred and incorporated into a cell [see Figures II.8, II.9, III.17, III.18] (see genetic engineering, molecular DNA cloning, plasmid, heterologous DNA, molecular tools, transgene, recombinant DNA).

Pathogen. See pathogenic organism.

Pathogenic organism. Organism capable of causing infections in another through a process of infection [see Figures III.6, III.7, III.8] (see botulism, bacteria, *S. pneumonia*, influenza, cholera, infection).

PCR (*Polymerase Chain Reaction*), Chain reaction of polymerase. Methodology that permits in the test tube the specific amplification—copying millions of times—of DNA fragments. This is achieved through various DNA synthesis cycles using the DNA polymerase enzyme (see oligonucleotide, replication, diagnosis, DNA, nucleotide, primer).

Pectinase. Enzyme used to make juice. Also produced through genetic engineering (see protein, genetic engineering, technology, genetically modified foods).

Pesticide. Substance used to kill insects that cause plagues. Many of these pesticides are of chemical origin and cause health problems. In some cases, they even cause cancer and many of them are recalcitrant. Moreover, most chemical pesticides are not specific to an insect or plague. Consequently, when they are used, they not only kill the plague but also indiscriminately kill many other organisms that are not the target [see Figures II.15, II.16] (see cell, cancer, bioinsecticide, technology, recalcitrant, carcinogenic, biosecurity).

Phenotype. Refers to the observable manifestation of a certain genotype. Each genotype has a phenotype. For example, dark skin coloring (phenotype) corresponds to the presence of a gene that produces melanine in large amounts (genotype) (see gene, genotype, mutation, DNA, cell, genome).

Phenylanine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, codon, monomer, gene, genetic code, polymer, mRNA, transfer RNA, gene, DNA).

Photosynthesis. Process whereby plants and certain bacteria are capable of synthesizing biological compounds and biomass using sunlight as an energy source [see Figure III.14] (see plant, chloroplast, organelle, mitochondria, endosymbiosis, evolution, cell).

Plant. Member of one of the five kingdoms into which living organisms are divided (Plantae Kingdom). Plants are multicellular eukaryote organisms usually with roots in the earth [see Figures II.15, III.13, III.14] (see DNA, cell, animal, zygote, gamete, organism).

Plasmid. Circular DNA molecular that constitutes additional genetic material to the bacterial chromosome and is capable of autonomously replicating. Used as a tool for molecularly cloning DNA [see Figure II.9] (see genetic engineering, molecular tools, molecular DNA cloning, transgene, heterologous DNA).

Plasminogenic. Precursor protein which, when activated by proteases, becomes plasmin, which is involved in the start of the process of dissolving blood clots. It is produced through genetic engineering techniques [see Figures II.11, II.12] (see drug, protein, biomedicine).

Point mutation. Change of a single nucleotide in a gene (see mutation, DNA, gene, nucleotide).

Polymer. Molecule formed by various monomers. By analogy, monomers would be the beads on a necklace, which would be the polymer [see Figures II.2, II.5, II.7] (see protein, amino acid, nucleotide, DNA, RNA, monomer).

Polymerase chain reaction. See PCR.

Polypeptide. Amino acid chain. Synonym of protein [see Figure II.7] (see protein, amino acid, polymer, monomer).

Primer. DNA molecule with simple helix (oligonucleotide) with a low molecular weight, used as the first element for beginning complementary DNA synthesis in replication processes (see oligonucleotide, diagnosis, PCR, DNA polymerase).

Probe. Specific fragment of DNA or RNA which, because of its association with the complementary sequence, is used in diagnostic methods (see diagnosis, oligonucleotide, primers, DNA, RNA, replication, DNA polymerase).

Prokaryote. Live, single-cell organism, like bacteria, which has a single chromosome and does not have a nuclear membrane [see Figure III.9] (see cell, bacteria, eukaryote, microbe).

Proline. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, codon, genetic code, monomer, gene, polymer, mRNA, transfer RNA).

Promoter. Small DNA sequence that permits the start of the transcription of the gene into mRNA that controls it, normally located in the front part of the gene. The promoter is recognized by the RNA polymerase enzyme to begin the process of gene transcription [see Figure II.5] (see gene, DNA, genetic regulation, transcription, mRNA, DNA structure).

Protease. Enzyme that degrades or hydrolyzes proteins (see protein, amino acid, recombinant product, metabolite, enzyme).

Proteic or proteinic. Related to proteins (see protein, amino acid, polymer, DNA, RNA).

Protein. Proteins are informational macromolecules but unlike DNA, the molecule containing the genetic information to synthesize proteins. Proteins are the tools used by cells to perform most of their functions. In other words, proteins contain the cell's functional information. Examples of these proteins include the following: Insulin, a protein that regulates blood sugar levels; hemoglobin, another protein that transports oxygen from the lungs to all the cells in the organism in red globules; tripsin, a protein that works in our digestive apparatus to digest other proteins from other organisms, which form part of our diet. In addition to these three proteins there are many others -approximately one hundred thousand- in our human organism. As a result of these proteins and the specific functional information in each of them, the organism and its various organs, tissues and cells perform their tasks. Proteins are biological polymers (like necklaces) comprising 20 different monomers (the beads on the necklace) called amino acids, the building blocks of the proteins. For this reason, there is not one amino acid for each of the nucleotides comprising the genes. The obvious consequence is that each of the amino acids in a protein must be "encoded" by groups of nucleotides. When the "genetic code" was deciphered, it was found that each amino acid is encoded by a group of three nucleotides called "triplet" or "codon." It was also found that in some cases, more than one triplet encodes for the same amino acid and that certain triplets encode termination or initiation signals for protein synthesis. This genetic code is universal, since it is the same for all living beings. Proteins can be chemically modified after their synthesis, which is why their activity can be modulated [see Figures II.2, II.3, II.5, II.6, II.7, III.11, III.14] (see genetic code, codon, anti-codon, transfer RNA, messenger RNA, ribosomal RNA, ribosome, protein synthesis, DNA, amino acid, polymer, macromolecule, biology, gene, polymer, molecule, monomer).

Protein sequencing. Position (sequence) of amino acids, one immediately after the other, in the protein polymer. By way of an analogy, we have the sequence of beads on a necklace, where each bead is an amino acid and the necklace is the protein [see Figures II.5, II.6, II.7] (see amino acid, protein, polymer, monomer).

Protein structure. Three-dimensional conformation that has a given protein in certain physiological conditions in the cell (see protein, cell, amino acid, RNA, mRNA conformation).

Protein synthesis. Cellular process whereby proteins in ribosomes are synthesized. The cell uses the nucleotide sequence present in the mRNA, which is interpreted in nucleotides in threes by the transfer RNA, giving rise to protein synthesis [see Figures II.5, II.6, II.7, III.11] (see DNA, RNA, mRNA, transfer RNA, genetic code, codon, protein, anticodon, nucleotide, transcription, translation).

Proteome. Set of all the proteins contained in a living organism [see Figure II.7] (see protein, cell, genome, DNA).

Proteomic. Analysis of proteic components (of proteins) comprising living cells. This analysis not only includes the identification and quantification of the proteins in a cell but also the synthesis, degradation, location, modification, interaction, activity and functions of these informational biological macromolecules (see protein, cell, biological macromolecule, genomic, DNA).

Provirus. DNA of a retrovirus when it has been incorporated into the genome of the infected cell [see Figure III.7] (see retrovirus, virus, genome, DNA).

Pseudoviral. Particle comprising the viral proteins that contains non-viral genetic material of the cell infected by the original virus (see virus, DNA, genome).

Recalcitrant. Compounds normally produced by man that are not degradable or biologically recyclable (see pesticide, risk, cancer, bioremediation).

Recombinant. See recombinant product.

Recombinant DNA. See genetic engineering.

Recombinant DNA molecule. Molecule comprising DNA of cellular and heterologous origin. These molecules can be produced in the laboratory by using genetic engineering techniques that make it possible to isolate and join DNA fragments of different origins—using the ligase enzyme reaction—; this is how the recombinant DNA molecule is created. These recombinant molecules can be introduced in one or more cells. If one of the two molecules is a vector such as a plasmid or a virus, this permits the replication of the recombinant DNA and the stabilization of this molecule inside the cell into which it was incorporated [see Figures II.8, II.9, III.17, III.18, III.19] (see plasmid, vector, genetic engineering, DNA molecular cloning, transgenic, genetic recombination, transgene, GMO, ligase enzyme reaction, technology).

Recombinant product. Product obtained through the use of recombinant DNA techniques, also called genetic engineering [see Figures II.8, II.9, II.11] (see drug, transgenic, genetically modified foods, insulin, lactase, chymosin, interferon, GMO).

Recombinant protein. Protein obtained through genetic engineering techniques or recombinant DNA techniques [see Figures II.8, II.9, II.11] (see genetic engineering, GMO, protein, technology, DNA).

Regulating gene. DNA sequence carrying the information for a protein that participates in gene expression regulation (see gene, structural gene, DNA, mRNA, transcription, protein).

Release into the environment. Refers to the process whereby transgenics can be placed in or released into the environment. It refers to vegetable crops and also to the use of micro-organisms for the bioremediation of polluted habitats or the environment (land, earth, water) (see step-by-step evaluation, biosecurity, biological risk, transgenic, biodiversity).

Remediation. Set of techniques making it possible to remedy or clean a polluted system or habitat (see fungus,

recalcitrant, biodegradable, bioremediation, technology, biopesticide).

Replication. Enzymatic cell process whereby DNA molecules are duplicated and created two identical double helices on the basis of a single double helix. The process requires the separation of the two helices from the original molecule (see DNA, DNA polymerase, PCR, double helix, nucleotide, polymer).

Resistance. In molecular biology, it is a system that permits the selection of an organism and generally uses genes that encode for the proteins that confer resistance to an antibiotic (see antibiotic, gene, protein, plasmid, recombinant DNA).

Retrovirus. Virus with an RNA genome (like the human immunodeficiency virus (HIV) that causes AIDS) and infects eukaryotic cells. It is replicated inside the cell by synthesizing a complementary DNA copy on the basis of its RNA (reverse transcription). This complementary DNA is latter inserted into the chromosomal DNA of the guest cell and gives rise to viral messenger RNAs as well as the genomic RNA that are incorporated into the new viruses [see Figures III.6, III.7] (see genome reorganization, DNA, reverse transcription, cDNA, RNA, virus).

Reverse transcription. Process of copying DNA from RNA. Occurs in cells infected with retroviruses that have RNA as genetic material. When this genetic material is introduced into the cell, DNA copies are produced from the virus RNA. In the case of retroviruses, this DNA material copied from RNA can be incorporatd into the genome of the infected cell [see Figure III.7] (see retrovirus, DNA, mRNA, genome reorganization, cDNA, AIDS).

rHGH (*Recombinant Human Growth Hormone*). See human growth hormone.

Ribonucleic acid (RNA). Ribonucleotide polymer resembling DNA except that instead of thymines it has uracils in its nucleotides and instead of 2-deoxyribose it has D-ribose. It is formed or synthesized by the transcription or copy of specific DNA regions. There are three main types of RNA involved in protein synthesis: a) Messenger RNA (mRNA), involved in the transmission of genetic information on the basis of DNA; b) Transfer RNA (tRNA) involved in information coupling and c) ribosomal RNA (rRNA) involved in the structuring and function of ribosomes, organelles in which proteins are synthesized [see Figures II.2, II.3, II.5, II.6, II.7] (see DNA, mRNA, transfer RNA, molecule, nucleotide, ribosome, protein synthesis, protein).

Ribose. Sugar molecule forming part of the ribonucleotides in RNA [see Figure II.5] (see nucleotide, RNA, molecule).

Ribosomal RNA. Type of RNA that forms part of the ribosomes and is involved in protein synthesis by reading the mRNA which are synthesized or transcribed on the basis of genes [see Figures II.5, II.6, II.7] (see mRNA, transfer RNA, genetic code, amino acid, transcription, translation, protein, anticodon, RNA, odon, protein synthesis).

Ribosome. Organelle in which proteins are synthesized, according to the instructions present in the messenger RNA. It is an aggregate of proteins and RNA [see Figures II.7, III.9, III.11] (see organelle, transcription, translation, mRNA, transfer RNA, ribosomal RNA, codon, anticodon, protein, amino acid, translation, protein synthesis, RNA).

Risk. Likelihood that danger or damage will occur. This probability of occurrence depends on various factors: the possibility of exposure and the possibility that the danger or damage will occur after exposure has occurred. Within the context of GMO, it is the possibility that the presence or use of transgenic organisms or their products might cause damage to human or animal health or the world's

biodiversity. To date, there is no scientific evidence indicating damage to human health or biodiversity due to the use of GMO or their products. All technology has the implicit possibility of causing damage if it is used irresponsibly or illegally. However, to date, GMO have not caused any scientifically proven damage. Many countries already have the legislation and are developing standards for the responsible handling of GMO that minimizes the possible risks of their use (see biological risk, biosecurity, biotechnology security, transgenic, GMO).

Risk assessment. Strategies and protocols using procedures based on solid scientific knowledge to assess the evidence of possible risks due to the use of GMO (see biological risk, risk, biosecurity, scientific knowledge, case by case, step by step evaluation).

RNA. See ribonucleic acid.

RNA polymerase. Protein with enzymatic activity involved in RNA synthesis (transcription), which uses one of the two DNA chains as a mold [see Figures II.5, III.7] (see RNA, DNA, transcription, protein, enzyme).

RNA processing. Cell processes that reduce the size of RNA transcripts. These processed RNA molecules are usually the functional molecules in the cell (see DNA, gene, RNA, transcription, intron, exon).

Scientific knowledge. Knowledge produced through scientific research. This knowledge has permitted the detailed understanding of the functioning of the universe, nature and life itself as well as various scientific problems. The publication of scientific knowledge in journals must guarantee the conditions for it to be repeated and validated by other independent groups. Knowledge generated by scientists must be published in journals or arbitrated books in order to be validated. Scientific knowledge is responsible for supporting and developing technologies that have permitted technological progress (see scientifically supported evidence, scientific research, technology, risk evaluation, risk).

Scientific research. Human activity based on the scientific method designed to explain the organization and functioning of natural systems and phenomena, including biological systems. This activity produces new knowledge on the different systems of study normally published in specialized, arbitrated journals (see scientific knowledge, technology, risk).

Scientifically based evidence. Set of data scientifically supported through the publication of these data in international, arbitrated journals. Data published in journals must be able to be repeated by independent groups in order to be validated, particularly in the case of risk and harmlessness issues. Much of this evidence can subsequently be incorporated into books and other documents drafted by Academies of Sciences and other organizations such as the WHO and FAO with internationally acknowledged members in order to guide and support governments' decisions (see biosecurity, biological risk, risk, evaluation, harmlessness, scientific knowledge, technology).

Sequence bank. Data base containing the identified DNA, RNA and protein sequences (see bioinformatics, DNA, RNA, proteins).

Serine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, proteins, protein synthesis, codon, genetic code, polymer, monomer, gene, mRNA, transfer RNA).

Single-cell organism. Organism comprising a cell (see bacteria, cell, organism).

Step by step evaluation. Refers to the evaluation provided for in the Mexican Biosecurity Law of GMO, which indicates that in processes involving the possible release of a GMO, the evaluation must be carried out at different levels or stages: 1) greenhouse; 2) small sown fields with experimental release and 3) larger sown fields (see release into the environment, biological risk, biosecurity, case by case, risk assessment, risk, scientifically based evidence).

Structural gene. Specific fragment of genetic material containing the information for a protein. Gene regulation is achieved through specific DNA sequences in the regions prior to genes, known as 5′regions [see Figure II.2] (see gene, exon, intron, promoter, operator, regulating gene, RNA processing).

Substantive or substantial equivalence. Concept proposed by the OECD to indicate that a product of transgenic origin has similar nutritional characteristics to its conventional counterpart (see biosecurity, biological risk, transgenic, harmlessness, genetically modified foods).

Substrate. Substance or molecule with which an enzyme specifically interacts and is then transformed into a product (see protein, molecule, metabolite, enzyme).

Support. Sustain and defend with scientific reasons (see scientific evidence, risk, scientifically based evidence).

Symbiogenesis. Term that refers to the creation of new life forms, organs or organelles achieved through the permanent association of previously established life forms. A key role has been attributed to this type of process in the evolution of species [see Figures III.11, III.14] (see endosymbiosis, chloroplast, mitochondria, organelle, cell, evolution).

Terminator genes. Genes that can prevent the germination of the seeds of a crop that has them as part of its genome (see biological risk, biosecurity, transgenic plant, risk).

Theory of evolution of species. Proposed by Darwin, this theory states that all the living beings in the world are derived from a common organism [see Figures III.1, III.3] (see evolution, endosymbiosis, genome reorganization, organelle, mitochondria, symbiogenesis, organism).

Technology. The use of scientific knowledge, allows the development of processes—tools, machines, techniques—that can be used to solve society problems and deal with human demands such as food, medicine, lodging and preserving biodiversity and the environment (see biotechnology, biological technology, biological resource, biochemical engineering, biomass, biomedicine, biopesticide, biopharmaceuticals, bioremediation, chymosin, diagnosis, vaccination, drug, fermentation, genetic engineering, transgene, genetic resources, genetically modified foods, GMO hybrid seeds, innovation, lactase, lipase, medicine, molecular medicine, pectinase, pesticides, recombinant DNA product, remediation, scientific knowledge, scientific based evidence).

Therapeutic protein. Proteins used in disease treatment. Nowadays, many of them are produced through genetic engineering techniques [see Figures II.11, II.12] see drug, biomedicine, technology, insulin, protein).

Threonine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see proteins, amino acid, protein synthesis, codon, genetic code, polymer, mRNA, transfer RNA, gene, monomer).

Thymine. One of the four nitrogenated bases consisting of the nucleotides comprising DNA. There are millions of nucleotides in chromosomal DNA [see Figures II.2, II.5, II.7] (see DNA, replication, bases, nucleotide).

Toxicity. Refers to the possible effect of poisoning in the user (see biological risk, risk).

Transcription. Cell process whereby messenger RNA, ribosomal RNA and transfer RNA are synthesized from DNA using RNA polymerase [see Figures II.3, II.5, II.6, II.7] (see DNA, RNA, mRNA, ribosome, protein, RNA polymerase).

Transcriptome. Set of all the RNA transcripts that can be synthesized from the DNA sequences of a cell [see Figures II.5, II.7] (see transcription, RNA, gene, DNA, genome, proteome).

Transcriptomic. Analysis of set of RNA transcripts that can be produced in a cell. This set varies according to the different metabolic conditions: it determines which genes are being expressed and giving rise to the set of mRNA, rRNA, tRNA and many other small RNA produced on the basis of the transcription of a cell genome. The analysis includes the quantification, characterization, location, modification, degradation and other functions associated with RNAs. Gene transcription of the genome genes into RNA occurs as a result of the RNA polymerase, an enzyme that is part of the machinery for transcribing (copying) DNA onto RNA (see transcriptome, genome, RNA, gene, mRNA, RNA polymerase, transcription).

Transfer RNA. Type of RNA that links the various amino acids in the process of protein synthesis. Proteins are synthesized in the ribosomes using the messenger RNA, whose sequence of nucleotides is read in threes according to the genetic code. Nucleotides are read in threes—in the form of triplets—by transfer RNAs using their anticodon sequences, thereby permitting the incorporation of amino acids by associating anticodons with the triplets or codons of the messenger at the ribosomes [see Figures II.5, II.6, II.7] (see messenger RNA, ribosomal RNA, mRNA, RNA, codon, anticodon, genetic code, amino acid, triplets, protein synthesis).

Transformation. Phenomenon enabling genetic material to be inserted into a cell. If it is incorporated into the genome of the receptor cell, the DNA can be stabilized and transferred to daughter cells. In bacteria, genetic material can also be stabilized through genetic engineering techniques by linking it to a vector or plasmid [see Figures II.8, II.9, III.17, III.18, III.19] (see genome reorganization, horizontal DNA transfer, transgenosis heterologous, plasmid, genetic engineering, transgene).

Transgene. Genetic material of a different origin, incorporated into an organism by genetic engineering techniques. The organism resulting from this process is called trangenic or genetically modified [see Figures II.8, II.9, III.17, III.18, III.19] (see genetic engineering, DNA, transgenic, ligase enzyme reaction, horizontal DNA transfer, heterologous DNA).

Transgenic. GMO Synonym. Biological organism into which one or more genes (transgenes) have been incorporated from an organism of another species, through genetic engineering and other horizontal DNA transfer techniques (biobalistics or electroporation). These new transgenes are usually stabilized through genetic recombination with genetic material from receptor cells. Through the multiplication of these transformed cells, transgenes may be transmitted to their offspring [see Figures II.8, II.9, III.17, III.18, III.19] (see genetic engineering, biological risk, biosecurity, molecular DNA cloning, biobalistics, transgenic plant, horizontal DNA transfer, GMO, recombinant DNA molecule, ligase enzyme reaction, technology, transgen).

Transgenic foods. See genetically modified foods [see Figures II.14, II.15]

Transgenic organism. See transgenic, GMO.

Transgenic plant. Plant into which genetic material of another origin (the transgen) has been incorporated. Normally for the purpose of creating resistance to an insect or providing new metabolic properties for the new organism

[see Figures II.8, II.15] (see transgenic, bioinsecticide, genetic engineering, biobalistics, pesticides, transgen).

Transgenosis. Process whereby genetic material (transgene) is incorporated from one given organism into another. Transgenics are created when the donor and receptor are different [see Figures II.8, II.9] (see transgenic, genetic engineering, transformation, horizontal DNA transfer, genome reorganization).

Translation. Enzymatic process whereby the cell recognizes and reads the mRNA codon sequence and through this process, creates a protein chain, in keeping with the genetic code, reading the nucleotides comprising the mRNA in threes [see Figures II.2, II.3, II.5, II.6 II.7] (see colinearity between gene and proteic product, nucleotide, cell, protein, ribosome, transcription, protein synthesis).

Transposase. Enzyme responsible for the movement or relocation of a transposon to another place in the genome of a cell [see Figures III.15, III.16] (see transposon, genome reorganization, genome, protein).

Transposition. Mechanism whereby a DNA fragment (the transposon) is relocated in the genome of the cell in which it occurs. Through this mechanism, the genome is reorganized as a result of the change of position of the transposon. In some cases, the transposon can inactivate a gene by interrupting it due to its translocation. In corn cobs with colored grains, these changes in coloring are the result of the relocation of the transposons in these grains. This is a natural process that occurs on a daily basis [see Figures III.15, III.16] (see transposon, genome reorganization, evolution, genetic modification, DNA, retrovirus).

Transposon. DNA element capable of relocating (moving) from one part of the genome to another within a single cell through the actions of transposases [see Figures III.15, III.16] (see transposase, genome reorganization, transposition).

Tripanosomes. Parasitic animals on other animals (see pathogenic organism).

Triplet. See codon.

Trypsin. Protein with enzymatic capacities (enzyme) higher animals use to degrade other proteins that form part of food in the stomach (see protein, enzyme).

Tryptophan. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, monomer, gene, codon, genetic code, polymer, mRNA, transfer RNA).

Tyrosine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see protein, amino acid, protein synthesis, monomer, gene, codon, genetic code, polymer, mRNA, transfer RNA).

Uracil. One of the four nitrogenated organic bases consisting of the nucleotides comprising DNA. There are millions of nucleotides in an RNA molecule [see Figures II.5, II.6, II.7] (see RNA, transcription, translation, nucleotide, bases).

Vaccination. Set of biological molecules which, when inserted into a mammal, may produce specific antibodies and possibly create immunity against this particular set of biological molecules (see immunogen, antibody, technology).

Valine. One of the 20 amino acids comprising proteins [see Figures II.6, II.7] (see amino acid, protein, protein synthesis, monomer, gene,codon, genetic code, polymer, mRNA, transfer RNA).

Vector. Type of DNA such as plasmids or viruses that can replicate their genetic material within certain guest cells and is capable of transferring DNA fragments between different organisms [see Figure II.9] (see genetic engineering, molecular tools, ligase enzyme reaction, transgenic, plasmid, virus).

Verification and Follow-Up Processes. Refers to the protocols to detect the presence of GMO in various organisms and scenarios, and the procedures for ensuring the follow-up of these detection processes (see biosecurity, biological risk, risk, monitoring, transgenic, GMO).

Vertical DNA transmission. Inheritance of genes and genetic material from parents to children (see gametes, cell, chromosomes, zygote).

Virulence. Measure of pathogenic nature (or pathogenicity) of a microorganism. It is determined by the set of molecules and mechanisms used by viruses and pathogenic organisms such as some bacteria to infect an organism (see virus, bacteria, pathogenic organism).

Virus. Microscopic particle formed and organized by the association of proteins comprising a nucleic acid molecule (DNA or RNA). Viruses are cell parasites that can only be multiplied when they infect susceptible guest cells [see Figures III.5, III.6, III.7] (see DNA, RNA, AIDS, nucleic acids, cell, retrovirus).

Wild strain. Natural variety of a particular organism. Its counterpart is a mutant strain with particular changes in its genome (see mutant, genome, DNA).

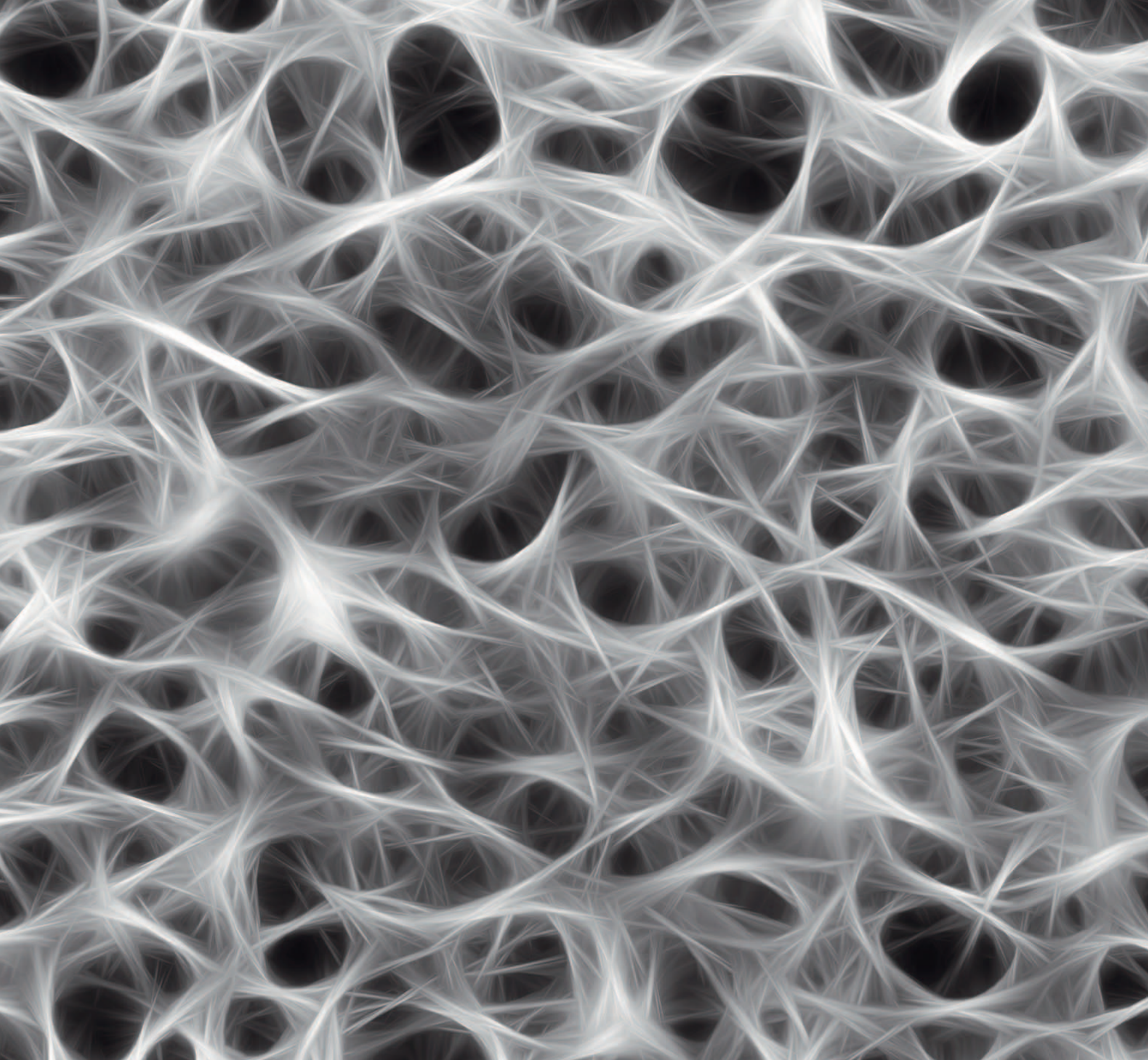
X Chromosome. Type of chromosome present in two copies in the cells of female organisms and in a single copy in male organisms (see gamete, zygote, chromosome, cell).

Y Chromosome. Type of chromosome present in a single copy only in the cells of male organisms (see gamete, zygote, chromosome, cell).

Yeast. Single-cell eukaryote organism used for alcohol production and other compounds, including recombinant products. It has 16 chromosome pairs in its nucleus and the entire nucleotide sequence of its genome, which contains 6,241 genes, has been determined (see eukaryote, genome, cell, metabolism).

Zoonosis. Infections that occur in animals and are transmitted to the human race. One example of these naturally occurring infections is the influenza virus (see virus, influenza).

Zygote. Egg fertilized by the fusion of two haploid sex cells. In the case of humans, it involves a spermatozoid and an ovule. After the fusion of the gametes, the zygote is already a diploid cell, since it contains two copies of each gene, one from the father and the other from the mother (see gamete, haploid, diploid, cell, chromosome).



APPENDIX 3: LIST OF RELEVANT FACTS AND EVENTS RELATED TO BIOTECHNOLOGY AND THE USE OF LIVING BEINGS AND THEIR PRODUCTS TO MEET OUR FOOD AND HEALTH NEEDS

This appendix also includes certain key scientific events linked to living cells and biotechnology.

500 B.C. The first antibiotic based on soybean mold poultices was used to treat burns in China.

100 The first insecticide was produced in China from chrysanthemum powder.

1761 E. Jensen develops the first smallpox virus.

1859 C. Darwin creates and publishes his theory of evolution.

1870 The first genetic crossings are developed in cotton to create better quality strains.

The first maize hybrid was produced in a laboratory.

1871 Deoxyribonucleic acid (DNA) in sperm trout is described.

1880 G. Mendel discovers that there are discrete genetic elements (subsequently called genes) containing the specific characteristics of living organisms, which are handed down to their offspring.

1885 L. Pasteur develops the rabies vaccine.

1911 T. Morgan and his collaborators draw up the first genetic maps with the positions of the genes in the fruit fly's chromosomes.

1922 A. Fleming discovers penicillin.

1933 The first improved maize hybrid is commercialized.

1942 Penicillin obtained from mushroom fungus is commercially produced

1944 O. Avery, C. McLeod and M. McCarthy demonstrate that DNA is the substance in which genetic information is stored.

1951 The first cattle are artificially inseminated.

1953 J. Watson and F. Crick describe the structure of the DNA double helix.

1957 B. McClinton postulates the existence of transposons to explain the rearrangement of genetic material that occurs in the different colored grains in maize cobs.

1958 M. Messelson and F. Stahl proved that DNA replication occurs through the separation of the two DNA helices and the copying again, of its two helices to form two identical double helices on the basis of the original double helix.

DNA is synthesized in a test tube for the first time.

1960 A. Kornberg isolates the DNA polymerase used in gene amplification techniques.

1961 S. Brenner and his collaborators discover the messenger RNA and prove that it has the information and capacity needed to direct the incorporation of amino acids into protein synthesis.

M. Niremberger and collaborators establish the universal genetic code on the basis of F. Crick's proposals.

F. Jacob and collaborators isolate the first element regulating gene expression.

1967 The DNA ligase enzyme was isolated, making it possible to link DNA fragments of different origins in the test tube.

1970 H. Smith and collaborators isolate the first nuclease restriction enzyme that cuts DNA molecules in specific places.

1973 S. Cohen and H. Boyer develop the first transgenic organism through the insertion of a fragment of frog DNA in a bacterial plasmid, subsequently inserted into the *Escherichia coli* bacteria.

1977 R. Maxam and W. Gilbert and F. Sanger and collaborators simultaneously develop methods to determine the sequence of DNA nucleotides.

Introns and exons are discovered in the genes of higher organisms.

K. Itakura and collaborators create the first transgenic organism that will permit the synthesis of human hormones in bacteria.

1978 The complete genomic sequence of a virus, the ∅ X 174, is reported.

1979 The first genetic engineering company is created: Genentech, Inc., in the United States of America.

D. Goeddel and collaborators report the production of human insulin by transgenic organisms.

Recombinant human growth hormone is produced in transgenic organisms.

1980 The Supreme Court of Justice of the United States of America approves the patenting of live organisms.

1981 The genome sequence of human mitochondria is reported.

The first transgenic animal is produced by inserting human genes into a mouse.

1982 P. Valenzuela and collaborators develop the first product of transgenic origin used as a vaccine in humans to immunize against the hepatitis virus.

Insulin is commercially produced as the first medicine of transgenic origin.

1983 M. Montagu and collaborators design and construct the first transgenic plants.

1985 Genetic markers for identifying diseases in humans are discovered.

1987 K. Mullis and collaborators develop the DNA polymerase chain reaction system (PCR), making it possible to amplify specific fragments of DNA millions of times.

1988 On the initiative of J. Watson, the United States National Health Institutes set up the Office for the Investigation of the Human Genome.

Human interferon of recombinant origin is produced as the first biological medicine of transgenic origin for cancer treatment.

The first pest-resistant transgenic maize plant (Bt maize) is produced.

1990 Three groups simultaneously develop the capillary electrophoresis method that made it possible to optimize the automation of DNA sequencing methods.

1992 The Food and Drug Administration (FDA) in the United States approves the use of the transgenic growth hormone to increase the production of cows' milk.

1993 The first recombinant medicine for multiple sclerosis treatment is approved.

One hundred and fifty countries sign the United Nations Convention on Biological Diversity.

1994 The first gene related to breast cancer is discovered.

1995 The nucleotide sequence of the first genome of a living organism, the *H. influenzae* bacteria is reported.

Recombinant antibodies of transgenic origin are incorporated for cancer treatment.

1996 The nucleotide sequence of the first genome of an eukaryote, *S. cerevisiae*, is discovered.

The first cultivar of transgenic origin is commercialized.

The recombinant human plasminogen activator used to dissolve blood clots caused by myocardial infarctions is placed on the market.

1997 Dolly, the first farm animal cloned from an adult cell, is created.

1998 The nucleotide sequence of the first genome of an animal, the *C. elegans* worm, is obtained.

Use of the first recombinant medicine for treating breast cancer is approved in the United States of America.

1999 The complete nucleotide sequence of a human chromosome is reported for the first time (Number 22).

2000 The nucleotide sequence of the genome of a plant, *Arabidopsis thaliana*, is reported for the first time.

Field testing for the first virus-resistant recombinant potato is approved in Kenya.

The Cartagena Protocol for Biosafety, included in the United Nations Convention on Biological Diversity, is approved.

2001 The research groups of C. Venter and F. Collins simultaneously report the draft of the nucleotide sequence of the human genome.

2002 The nucleotide sequences of mouse and rice genomes are reported.

The first transgenic rootworm-resistant maize plant is approved in the United States of America.

2003 The nucleotide sequence of the human genome is completed.

The Cartagena Protocol for Biosafety comes into effect.

2004 The United Nations Food and Agricultural Organization (FAO) notes that transgenic cultivars for food production are an important tool in meeting world food needs.

2005 The Mexican Law of Biosafety of Genetically Modified Organisms is passed in Mexico.

2006 The recombinant vaccine against the papilloma virus is approved in the United States of America.

The United Nations World Health Organization publishes the document "20 Questions on Genetically Modified Foods," (Appendix 4) showing that foods of transgenic origin have not harmed health.

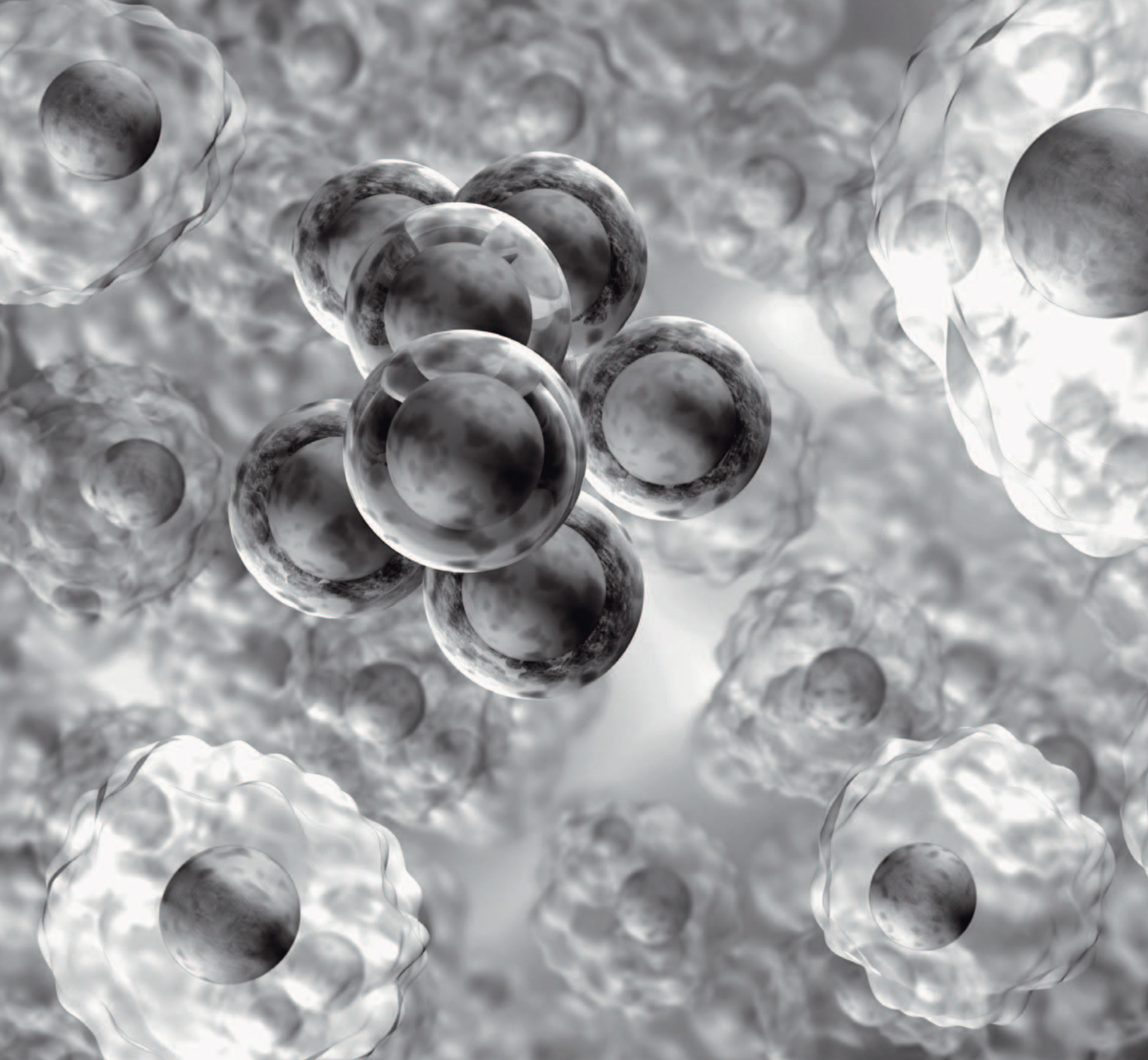
2007 The recombinant virus against the H5N1 flu virus is approved in the United States of America.

2009 Use of the first transgenic animal for the production of the human antithrombin protein is approved in the United States of America.

The maize genome sequence is reported.

The European Union approves the use of the transgenic potato and other strains of transgenic maize, after a long debate on biosafety.

2011 Twenty-seven countries have planted nine different cultivars of transgenic organisms, which have been consumed in 50 countries by over 300 million inhabitants.



APPENDIX 4: ELECTRONIC DOCUMENT PUBLISHED BY THE WORLD HEALTH ORGANIZATION (WHO)

20 QUESTIONS ON GENETICALLY MODIFIED (GM) FOODS

These questions and answers have been prepared by WHO in response to questions and concerns by a number of WHO Member State Governments with regard to the nature and safety of genetically modified food.

Q1. **What are genetically modified (GM) organisms and GM foods?**

Genetically modified organisms (GMOs) can be defined as organisms in which the genetic material (DNA) has been altered in a way that does not occur naturally. The technology is often called “modern biotechnology” or “gene technology”, sometimes also “recombinant DNA technology” or “genetic engineering”. It allows selected individual genes to be transferred from one organism into another, also between non-related species.

Such methods are used to create GM plants – which are then used to grow GM food crops.

Q2. **Why are GM foods produced?**

GM foods are developed – and marketed – because there is some perceived advantage either to the producer or consumer of these foods. This is meant to translate into a product with a lower price, greater benefit (in terms of durability or nutritional value) or both. Initially GM seed developers wanted their products to be accepted by producers so have concentrated on innovations that farmers (and the food industry more generally) would appreciate.

The initial objective for developing plants based on GM organisms was to improve crop protection. The GM crops currently on the market are mainly aimed at an increased level of crop protection through the introduction of resistance against plant diseases caused by insects or viruses or through increased tolerance towards herbicides.

Insect resistance is achieved by incorporating into the food plant the gene for toxin production from the bacterium *Bacillus thuringiensis* (BT). This toxin is currently used as a conventional insecticide in agriculture and is safe for human consumption. GM crops that permanently produce this toxin have been shown to require lower quantities of insecticides in specific situations, e.g. where pest pressure is high.

Virus resistance is achieved through the introduction of a gene from certain viruses which cause disease in plants. Virus resistance makes plants less susceptible to diseases caused by such viruses, resulting in higher crop yields.

Herbicide tolerance is achieved through the introduction of a gene from a bacterium conveying resistance to some herbicides. In situations where weed pressure is high, the use of such crops has resulted in a reduction in the quantity of the herbicides used.

Q3. **Are GM foods assessed differently from traditional foods?**

Generally consumers consider that traditional foods (that have often been eaten for thousands of years) are safe. When new foods are developed by natural methods, some of the existing characteristics of foods can be altered, either in a positive or a negative way National food authorities may be called upon to examine traditional foods, but this is not always the case. Indeed, new plants developed through traditional breeding techniques may not be evaluated rigorously using risk assessment techniques.

With GM foods most national authorities consider that specific assessments are necessary. Specific systems have been set up for the rigorous evaluation of GM organisms and GM foods relative to both human health and the environment. Similar evaluations are generally not performed for traditional foods. Hence there is a significant difference in the evaluation process prior to marketing for these two groups of food.

One of the objectives of the WHO Food Safety Programme is to assist national authorities in the identification of foods that should be subject to risk assessment, including GM foods, and to recommend the correct assessments.

Q4. **How are the potential risks to human health determined?**

The safety assessment of GM foods generally investigates: (a) direct health effects (toxicity), (b) tendencies to provoke allergic reaction (allergenicity); (c) specific components thought to have nutritional or toxic properties; (d) the stability of the inserted gene; (e) nutritional effects associated with genetic modification; and (f) any unintended effects which could result from the gene insertion.

Q5. **What are the main issues of concern for human health?**

While theoretical discussions have covered a broad range of aspects, the three main issues debated are tendencies to provoke allergic reaction (allergenicity), gene transfer and outcrossing.

Allergenicity. As a matter of principle, the transfer of genes from commonly allergenic foods is discouraged unless it can be demonstrated that the protein product of the transferred gene is not allergenic. While traditionally developed foods are not generally

tested for allergenicity, protocols for tests for GM foods have been evaluated by the Food and Agriculture Organization of the United Nations (FAO) and WHO. No allergic effects have been found relative to GM foods currently on the market.

Gene transfer. Gene transfer from GM foods to cells of the body or to bacteria in the gastrointestinal tract would cause concern if the transferred genetic material adversely affects human health. This would be particularly relevant if antibiotic resistance genes, used in creating GMOs, were to be transferred. Although the probability of transfer is low, the use of technology without antibiotic resistance genes has been encouraged by a recent FAO/WHO expert panel.

Outcrossing. The movement of genes from GM plants into conventional crops or related species in the wild (referred to as "outcrossing"), as well as the mixing of crops derived from conventional seeds with those grown using GM crops, may have an indirect effect on food safety and food security. This risk is real, as was shown when traces of a maize type which was only approved for feed use appeared in maize products for human consumption in the United States of America. Several countries have adopted strategies to reduce mixing, including a clear separation of the fields within which GM crops and conventional crops are grown.

Feasibility and methods for post-marketing monitoring of GM food products, for the continued surveillance of the safety of GM food products, are under discussion.

Q6. **How is a risk assessment for the environment performed?**

Environmental risk assessments cover both the GMO concerned and the potential receiving environment. The assessment process includes evaluation of the characteristics of the GMO and its effect and stability in the environment, combined with ecological characteristics of the environment in which the introduction will take place. The assessment also includes unintended effects which could result from the insertion of the new gene.

Q7. **What are the issues of concern for the environment?**

Issues of concern include: the capability of the GMO to escape and potentially introduce the engineered genes into wild populations; the persistence of the gene after the GMO has been harvested; the susceptibility of non-target organisms (e.g. insects which are not pests) to the gene product; the stability of the gene; the reduction in the spectrum of other plants including loss of biodiversity; and increased use of chemicals in agriculture. The environmental safety aspects of GM crops vary considerably according to local conditions.

Current investigations focus on: the potentially detrimental effect on beneficial insects or a faster induction of resistant insects; the potential generation of new plant pathogens; the potential detrimental consequences for plant biodiversity and wildlife,

and a decreased use of the important practice of crop rotation in certain local situations; and the movement of herbicide resistance genes to other plants.

Q8. **Are GM foods safe?**

Different GM organisms include different genes inserted in different ways. This means that individual GM foods and their safety should be assessed on a case-by-case basis and that it is not possible to make general statements on the safety of all GM foods.

GM foods currently available on the international market have passed risk assessments and are not likely to present risks for human health. In addition, no effects on human health have been shown as a result of the consumption of such foods by the general population in the countries where they have been approved. Continuous use of risk assessments based on the Codex principles and, where appropriate, including post market monitoring, should form the basis for evaluating the safety of GM foods.

Q9. **How are GM foods regulated nationally?**

The way governments have regulated GM foods varies. In some countries GM foods are not yet regulated. Countries which have legislation in place focus primarily on assessment of risks for consumer health. Countries which have provisions for GM foods usually also regulate GMOs in general, taking into account health and environmental risks, as well as control- and trade-related issues (such as potential testing and labelling regimes). In view of the dynamics of the debate on GM foods, legislation is likely to continue to evolve.

Q10. **What kind of GM foods are on the market internationally?**

All GM crops available on the international market today have been designed using one of three basic traits: resistance to insect damage; resistance to viral infections; and tolerance towards certain herbicides. All the genes used to modify crops are derived from microorganisms.

Crop	*Trait*	*Areas/countries with approval*
Maize	Insect resistance	Argentina, Canada, South Africa, United States, EU
	Herbicide tolerance	Argentina, Canada, United States, EU
Soybean	Herbicide tolerance	Argentina, Canada, South Africa, United States, EU (for processing only)
Oilseed rape	Herbicide tolerance	Canada, United States

Chicory	Herbicide tolerance	EU (for breeding purposes only)
Squash	Virus resistance	Canada, United States
Potato	Insect resistance/herbicide tolerance	Canada, United States

Q11. **What happens when GM foods are traded internationally?**

No specific international regulatory systems are currently in place. However, several international organizations are involved in developing protocols for GMOs.

The Codex Alimentarius Commission (Codex) is the joint FAO/WHO body responsible for compiling the standards, codes of practice, guidelines and recommendations that constitute the Codex Alimentarius: the international food code. Codex is developing principles for the human health risk analysis of GM foods. The premise of these principles dictates a premarket assessment, performed on a case-by-case basis and including an evaluation of both direct effects (from the inserted gene) and unintended effects (that may arise as a consequence of insertion of the new gene). The principles are at an advanced stage of development and are expected to be adopted in July 2003. Codex principles do not have a binding effect on national legislation, but are referred to specifically in the Sanitary and Phytosanitary Agreement of the World Trade Organization (SPS Agreement), and can be used as a reference in case of trade disputes.

The Cartagena Protocol on Biosafety (CPB), an environmental treaty legally binding for its Parties, regulates transboundary movements of living modified organisms (LMOs). GM foods are within the scope of the Protocol only if they contain LMOs that are capable of transferring or replicating genetic material. The cornerstone of the CPB is a requirement that exporters seek consent from importers before the first shipment of LMOs intended for release into the environment. The Protocol will enter into force 90 days after the 50th country has ratified it, which may be in early 2003 in view of the accelerated depositions registered since June 2002.

Q12. **Have GM products on the international market passed a risk assessment?**

The GM products that are currently on the international market have all passed risk assessments conducted by national authorities. These different assessments in general follow the same basic principles, including an assessment of environmental and human health risk. These assessments are thorough, they have not indicated any risk to human health .

Q13. **Why has there been concern about GM foods among some politicians, public interest groups and consumers, especially in Europe?**

Since the first introduction on the market in the mid-1990s of a major GM food (herbicide-resistant soybeans), there has been increasing concern about such food among politicians, activists and consumers, especially in Europe. Several factors are involved.
In the late 1980s – early 1990s, the results of decades of molecular research reached the public domain. Until that time, consumers were generally not very aware of the potential of this research. In the case of food, consumers started to wonder about safety because they perceive that modern biotechnology is leading to the creation of new species.

Consumers frequently ask, "what is in it for me?". Where medicines are concerned, many consumers more readily accept biotechnology as beneficial for their health (e.g. medicines with improved treatment potential). In the case of the first GM foods introduced onto the European market, the products were of no apparent direct benefit to consumers (not cheaper, no increased shelf-life, no better taste). The potential for GM seeds to result in bigger yields per cultivated area should lead to lower prices. However, public attention has focused on the risk side of the risk-benefit equation.

Consumer confidence in the safety of food supplies in Europe has decreased significantly as a result of a number of food scares that took place in the second half of the 1990s that are unrelated to GM foods. This has also had an impact on discussions about the acceptability of GM foods. Consumers have questioned the validity of risk assessments, both with regard to consumer health and environmental risks, focusing in particular on long-term effects. Other topics for debate by consumer organizations have included allergenicity and antimicrobial resistance. Consumer concerns have triggered a discussion on the desirability of labelling GM foods, allowing an informed choice. At the same time, it has proved difficult to detect traces of GMOs in foods: this means that very low concentrations often cannot be detected.

Q14. **How has this concern affected the marketing of GM foods in the European Union?**

The public concerns about GM food and GMOs in general have had a significant impact on the marketing of GM products in the European Union (EU). In fact, they have resulted in the so-called moratorium on approval of GM products to be placed on the market. Marketing of GM food and GMOs in general are the subject of extensive legislation. Community legislation has been in place since the early 1990s.

The procedure for approval of the release of GMOs into the environment is rather complex and basically requires agreement between the Member States and the European Commission. Between 1991 and 1998, the marketing of 18 GMOs was authorized in the EU by a Commission decision.

As of October 1998, no further authorizations have been granted and there are currently 12 applications pending. Some Member States have invoked a safeguard clause to temporarily ban the placing on the market in their country of GM maize and oilseed rape products. There are currently nine ongoing cases. Eight of these have been examined by the Scientific Committee on Plants, which in all cases deemed that the information submitted by Member States did not justify their bans.

During the 1990s, the regulatory framework was further extended and refined in response to the legitimate concerns of citizens, consumer organizations and economic operators (described under *Question 13*). A revised directive will come into force in October 2002. It will update and strengthen the existing rules concerning the process of risk assessment, risk management and decision-making with regard to the release of GMOs into the environment. The new directive also foresees mandatory monitoring of long-term effects associated with the interaction between GMOs and the environment.

Labelling in the EU is mandatory for products derived from modern biotechnology or products containing GM organisms. Legislation also addresses the problem of accidental contamination of conventional food by GM material. It introduces a 1% minimum threshold for DNA or protein resulting from genetic modification, below which labelling is not required.

In 2001, the European Commission adopted two new legislative proposals on GMOs concerning traceability, reinforcing current labelling rules and streamlining the authorization procedure for GMOs in food and feed and for their deliberate release into the environment.

The European Commission is of the opinion that these new proposals, building on existing legislation, aim to address the concerns of Member States and to build consumer confidence in the authorization of GM products. The Commission expects that adoption of these proposals will pave the way for resuming the authorization of new GM products in the EU.

Q15. **What is the state of public debate on GM foods in other regions of the world?**

The release of GMOs into the environment and the marketing of GM foods have resulted in a public debate in many parts of the world. This debate is likely to continue, probably in the broader context of other uses of biotechnology (e.g. in human medicine) and their consequences for human societies. Even though the issues under debate are usually very similar (costs and benefits, safety issues), the outcome of the debate differs from country to country. On issues such as labelling and traceability of GM foods as a way to address consumer concerns, there is no consensus to date. This has become apparent during discussions within the Codex Alimentarius Commission over the past few years. Despite the lack of consensus on these topics, significant progress has been made on the harmonization of views concerning risk assessment. The Codex

Alimentarius Commission is about to adopt principles on premarket risk assessment, and the provisions of the Cartegena Protocol on Biosafety also reveal a growing understanding at the international level.

Q16. **Are people's reactions related to the different attitudes to food in various regions of the world?**

Depending on the region of the world, people often have different attitudes to food. In addition to nutritional value, food often has societal and historical connotations, and in some instances may have religious importance. Technological modification of food and food production can evoke a negative response among consumers, especially in the absence of good communication on risk assessment efforts and cost/benefit evaluations.

Q17. **Are there implications for the rights of farmers to own their crops?**

Yes, intellectual property rights are likely to be an element in the debate on GM foods, with an impact on the rights of farmers. Intellectual property rights (IPRs), especially patenting obligations of the TRIPS Agreement (an agreement under the World Trade Organization concerning trade-related aspects of intellectual property rights) have been discussed in the light of their consequences on the further availability of a diversity of crops. In the context of the related subject of the use of gene technology in medicine, WHO has reviewed the conflict between IPRs and an equal access to genetic resources and the sharing of benefits. The review has considered potential problems of monopolization and doubts about new patent regulations in the field of genetic sequences in human medicine. Such considerations are likely to also affect the debate on GM foods.

Q18. **Why are certain groups concerned about the growing influence of the chemical industry on agriculture?**

Certain groups are concerned about what they consider to be an undesirable level of control of seed markets by a few chemical companies. Sustainable agriculture and biodiversity benefit most from the use of a rich variety of crops, both in terms of good crop protection practices as well as from the perspective of society at large and the values attached to food. These groups fear that as a result of the interest of the chemical industry in seed markets, the range of varieties used by farmers may be reduced mainly to GM crops. This would impact on the food basket of a society as well as in the long run on crop protection (for example, with the development of resistance against insect pests and tolerance of certain herbicides). The exclusive use of herbicide-tolerant GM crops would also make the farmer dependent on these chemicals. These groups fear a dominant position of the chemical industry in agricultural development, a trend which they do not consider to be sustainable.

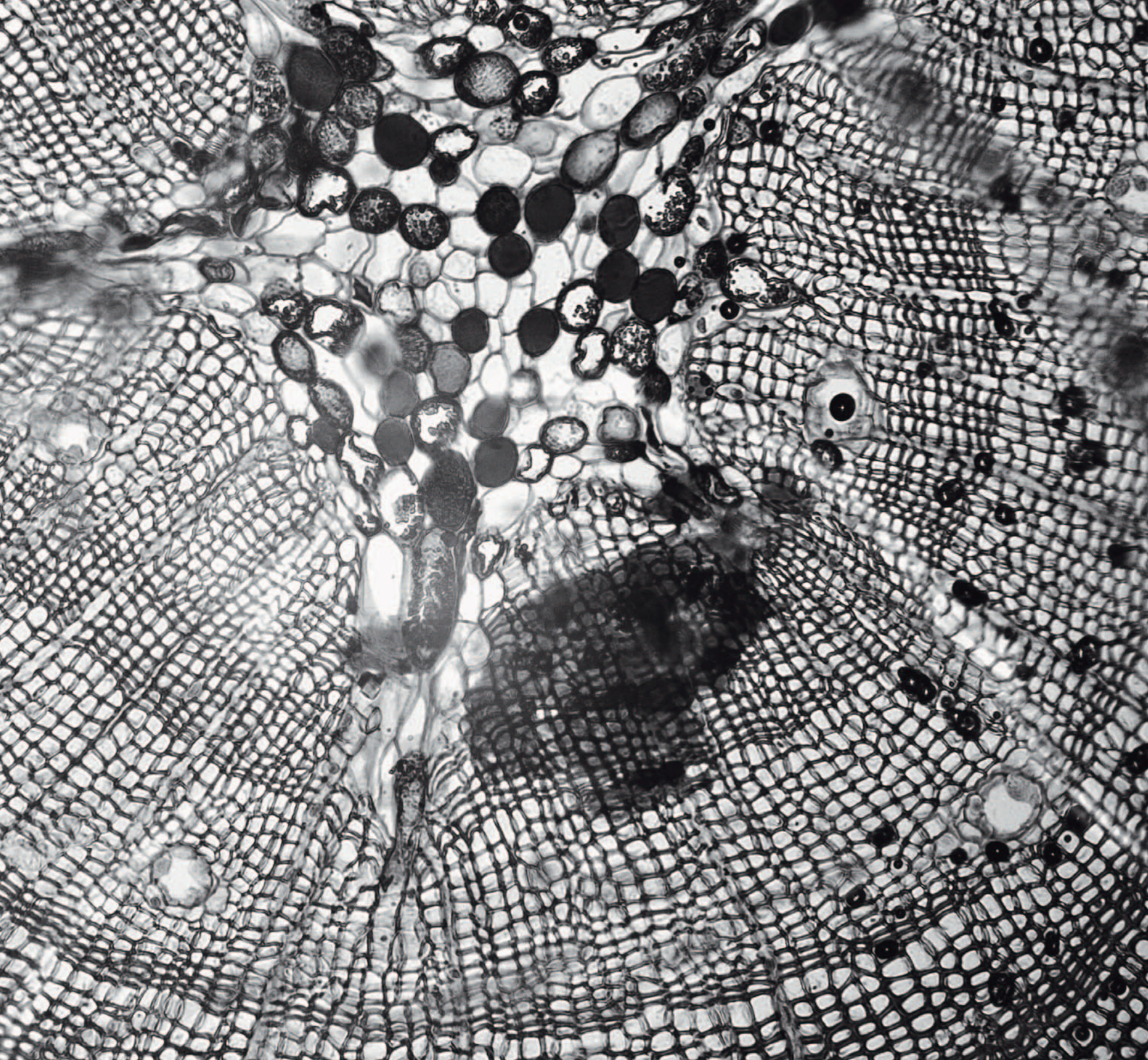
Q19. **What further developments can be expected in the area of GMOs?**

Future GM organisms are likely to include plants with improved disease or drought resistance, crops with increased nutrient levels, fish species with enhanced growth characteristics and plants or animals producing pharmaceutically important proteins such as vaccines.

Q20. **What is WHO doing to improve the evaluation of GM foods?**

WHO will take an active role in relation to GM foods, primarily for two reasons: (1) on the grounds that public health could benefit enormously from the potential of biotechnology, for example, from an increase in the nutrient content of foods, decreased allergenicity and more efficient food production; and (2) based on the need to examine the potential negative effects on human health of the consumption of food produced through genetic modification, also at the global level. It is clear that modern technologies must be thoroughly evaluated if they are to constitute a true improvement in the way food is produced. Such evaluations must be holistic and all-inclusive, and cannot stop at the previously separated, non-coherent systems of evaluation focusing solely on human health or environmental effects in isolation.

Work is therefore under way in WHO to present a broader view of the evaluation of GM foods in order to enable the consideration of other important factors. This more holistic evaluation of GM organisms and GM products will consider not only safety but also food security, social and ethical aspects, access and capacity building. International work in this new direction presupposes the involvement of other key international organizations in this area. As a first step, the WHO Executive Board will discuss the content of a WHO report covering this subject in January 2003. The report is being developed in collaboration with other key organizations, notably FAO and the United Nations Environment Programme (UNEP). It is hoped that this report could form the basis for a future initiative towards a more systematic, coordinated, multi-organizational and international evaluation of certain GM foods.



AUTHORS' BIOS

Carlos Federico Arias-Ortiz

Researcher level C at the Institute of Biotechnology at the National University of Mexico (UNAM). He obtained a BA at the Chemistry School and a PhD in Basic Biomedical Research at UNAM. He subsequently pursued post-doctoral studies at the California Institute of Technology (CalTech), in the United States. His area of research is molecular virology, particularly the study of epidemiology and the molecular biology of viruses that cause child gastroenteritis, including rotavirus and astrovirus. He recently began a line of research dedicated to the study of genetic variability and the molecular evolution of the influenza virus in order to understand the molecular determinants associated with its virulence and drug resistance and the development of diagnostic methods for viral pathogens associated with gastrointestinal and respiratory diseases. He has published over 100 articles in international journals, including the Journal of Virology, Virology, Nucleic Acids Research, Journal of Molecular Biology, Proceedings of the National Academy of Sciences, EMBO Reports and Trends in Microbiology. His papers have been cited on more than 2,000 occasions in world literature. He has trained 38 students, 13 at the BA level, 16 at the MA level and nine at the doctoral level. He has delivered over 250 papers at national and international congresses. He has been a reviewer for papers submitted to various international journals and guest editor at the Annual Review of Genetics. He was guest editor of a special issue of Virus Research on RNA interference in animal viruses and is currently an editorial board member of Archives of Medical Research and the Journal of Virology and Virology, the two most important specialized journals in the area. He was guest professor at the National Health Institute of Japan, the California Institute of Technology and the National Center for Scientific Research (CNRS) in France. He has received the Weizmann Award and the Research Prize in the area of Natural Sciences, both prizes awarded by the Mexican Academy of Sciences, and the Carlos J. Finlay Prize awarded by UNESCO. He was appointed International Researcher at the Howard Hughes Medical Center for 15 years and awarded the TWAS 2008 Prize in Biology. He is currently director of the Institute of Biotechnology at UNAM and belongs to level III of the Mexican National System of Researchers (SNI).

Elena Arriaga Arellano

Holds an MA in Dental Medical and Health Sciences and specializes in Bioethics at UNAM. She completed a MA in Administration at the Technological Institute of Mexico (ITAM); undertook a diploma course in Technology Administration and qualified as a Biochemical Engineer at the Autonmous Metropolitan University, *campus* Iztapalapa (UAM-I). She is a faculty member at the UNAM Institute of Biotechnology (IBT) and at the Mexican National Academy of Bioethics. Elena Arriaga served as manager of the Secretariat of Technology Transfer at IBT for 10 years. She was subsequently invited to coordinate the Secretariat of Management, Liaison and Technological Development at the UNAM Scientific Research Office. Among the activities she undertook at these offices were the coordination of the identification, dissemination and management of applications for research funds, helping researchers negotiate collaboration and technology transfer agreements in Mexico and abroad and designing strategies for intellectual property protection with patents. She has taken part in the development of projects and studies on biotechnology patents, access to genetic resources, analysis of the legal framework related to biotechnology, diagnosis and market research for biotechnology in Mexico, recommendations for the development of biotechnology in Mexico and aspects related to the biosecurity and bioethics of genetically modified organisms (GMO). She took part in the study on the opportunities and threats posed by the expansion of patents to the protection of biotechnologies in Mexico, sponsored by the United Nations (UN). She supported the technical coordination of studies on priorities in international technical cooperation, sponsored by the United Nations Development Program (UNDP) and the Secretariat of Foreign Affairs and advised professors at the UNAM Chemistry School in the SIMBIOSIS project on the construction of biotechnology indicators in certain South American countries, supported by the Organization of American States (OAS). She has participated in the publication of articles and books on the issues mentioned earlier and has delivered papers on her research at national and international congresses and meetings. On the basis of the studies undertaken by the Biotechnology Committee, she compiled the following documents: The National Biotechnology and Genomics Program and its executive summary, which formed part of the National Science and Technology Program 2001-2006. After being revised by an *ad hoc* committee organized by the Scientific and Technological Advisory Forum, the programs were published by the National Council of Science and Technology (CONACYT, Mexico). Since 2010, she has participated in a working group on the drafting of the Official Standard on the report of the release of genetically modified organisms, coordinated by the Ministery of Environment and Natural Resources (SEMARNAT, Mexico). Elena Arriaga is currently undertaking a research project on "Towards a Proposal for the Integral Evaluation of System Risk: the case of transgenic plants."

Hugo Alberto Barrera-Saldaña

After pursuing a degree in biochemistry at the University of Nuevo León (UANL, Mexico), he obtained a doctorate in Biomedical Sciences with a specialty in Molecular Biology (School of Graduates in Biomedical Sciences of the University of Texas, Houston, 1982; Dr. Grady F. Saunders' Laboratory) and undertook a post-doctorate at Prof. Pierre

Chambon's laboratory in LGMR-CNRS at the Louis Pasteur University of Strasbourg, France (1984). He is also a specialist in converting technology to capital (IC² Institute UT-Austin and at the Technological Institute for Graduate Studies at Monterrey—ITESM, Mexico—, 1999). He is currently Regulation Secretary at the Research Division, Head of the Genomics and Bioinformatics Laboratory and director of the Medical Biotechnology Unit at the UANL School of Medicine. He is a pioneer in Latin America in the molecular diagnosis of several diseases in clinical gene therapy protocols (prostate cancer) and in internationally respected research on the regulation, evolution, disfunction and biotechnological use of growth hormone genes. In 1988, together with researchers from Genentech, Inc, and the universities of Texas and Washington, he set a world record for the longest length of manually sequenced human genes, regarded as evidence of the feasibility of the human genome project. He has contributed to the creation of two graduate degrees (Molecular Biology and Genetic Engineering at UANL and Genomic Biotechnology at IPN), a bachelor's degree program (Genomic Biotechnology at UANL) and various subjects. Dr. Barrera has founded and directed various research centers such as the Engineering and Genetic Expression Laboratories Unit, the molecular diagnosis and medical biotechnology service units at UANL and the National Polytechnic Institute (IPN) Center for Genomic Biotechnology in Reynosa, Tamaulipas, Mexico. He has helped modernize human genetics research units in Mexico, Colombia, Venezuela and Peru. He has been awarded the largest number (18) of UANL research prizes (three in 1994 and two in 2003 and 2004) and over 20 national prizes, such as the National Food Prize, the Dr. Jorge Rosenkranz Research Prize (in 1989 and 2005), the Glaxo-SmithKline Foundation (2005) as well as several awards given by the National Chamber of the Pharmaceutical Industry (CANIFARMA) and CARPERMOR, Mexico, among others. He was selected in 1998 as distinguished alumnus of the School of Graduates in Biomedical Sciences at the University of Texas in Houston. He was profiled in the July 2003 issue of *Nature Medicine* journal and in the February 2006 issue of *Contenido* journal. He is a member of many scientific societies both in Mexico and abroad and has authored over 115 indexed publications, with over 2,500 citations, a book, and two biotechnology patents and has been responsible for several technological transfers to the productive sector. He was president of the National Scientific Committee of BioMonterrey 2006, CONACYT and SNI evaluation committees, technical secretary during the Week of Health Culture and Quality of Life at the Universal Forum on Cultures and a member of CIBIOGEM Advisory Board and the first coordinator of the CONACYT New Trends in Medicine Network. He was declared distinguished citizen in his native city (Miguel Alemán, Tamaulipas) and awarded the Medal for Academic and Scientific Merit on the fiftieth anniversary of its founding.

Francisco Gonzalo Bolívar-Zapata
(Committee chair)

Was born in Mexico City in March 1948. He obtained a doctorate in Chemistry (biochemistry) at the National University of Mexico (UNAM), where he is *Emeritus* professor and researcher. In 1982, he was appointed the first director of the recently-created Center for Research on Genetic Engineering and Biotechnology at UNAM. In September 1991, UNAM

turned the center into the Institute of Biotechnology and Bolívar was appointed its first director, a post he held until 1997. That year he was appointed UNAM scientific research coordinator, a post he held for three years. During the period from 1996 to 2000, he also served as vice-president and president of the Mexican Academy of Sciences (AMC). He has produced groundbreaking research and technological development at the global level in the area of molecular biology and biotechnology, particularly in the isolation, characterization and manipulation of genes in microorganisms. Bolívar-Zapata was a member of a group of researchers which, through genetic engineering techniques, achieved the production of human proteins in bacteria for the first time in San Francisco, California in 1977. He has also produced groundbreaking work in the area of the engineering of metabolic pathways in microorganisms to achieve genetic modification and in bacterial physiology for the design and optimization of microorganisms that produce metabolites and proteins for the benefit of society and for commercial purposes. He has over 200 publications in journals and books, cited over 13,000 times in the world literature, including 800 citations in 330 textbook and specialized books. As a professor and tutor, he has taught a range of programs and supervised over 60 theses, mostly at the graduate level. Many of his former students are now research professors and technicians at UNAM and other national and international institutions, including industry. He has participated in over 200 congresses and workshops and delivered over 150 teaching and dissemination seminars and conferences. He has written and edited popular and opinion books, including five volumes of his scientific and popular work as a member of El Colegio Nacional, Mexico.

As president of the AMC and at the invitation of the President of Mexico, he participated with CONACYT and the President's Advisory Board of Science (CCC) in drawing up and building consensus on the Bill for the Promotion of Scientific and Technological Research, unanimously approved by the Mexican Congress in 1999. As coordinator of the AMC Biotechnology Committee, from 2000 onwards, he organized efforts to help Congress draft the GMO Biosecurity Act passed by Congress in February 2005. As president of the AMC, coordinator of Scientific Research, director, UNAM researcher and a member of the AMC, he has intervened with Congress and the President's office on behalf of the promotion of science, technology, public universities and biotechnology. He has received various distinctions and 12 prizes for his work, including: the National Chemistry Prize awarded by the Federal Government in 1980; the Natural Science Research Prize, awarded by the AMC in 1982; the Manuel Noriega Science and Technology prize, awarded by the Organization of American States in 1988; the National University Prize, in 1990; the Prince of Asturias Prize for Scientific and Technical Research, awarded by the Prince of Asturias Foundation in Spain, in 1991; the National Science and Arts prize in the field of Physical, Mathematical and Natural Sciences, awarded by the Mexican government in 1992; the TWAS Prize in the area of Biology awarded by the Third World Academy of Sciences in Italy in 1997; and the Luis Elizondo Prize, awarded by the Instituto Tecnológico y de Estudios Superiores de Monterrey, Mexico, in 1998. The University of Lieges, Belgium and the Universidad Autónoma Metropolitana, Mexico, have awarded him honorary doctorates and he has received distinctions and awards from the autonomous Mexican uni-

versities of Coahuila, Nuevo León and Morelos and the Benemérita in Puebla. He was recently awarded the José María Morelos y Pavón Outstanding Citizens of Morelos 2009 Prize, for his contribution to the development of the state of Morelos, Mexico. He has been a member of the National System of Researchers (level III) and the Advisory Board of Sciences to the President's Office since 1992 and of El Colegio Nacional since 1994. He was a member of the Board of Directors of the Universidad Autónoma Metropolitana from 1997 to 2005. He is currently a member of the UNAM, CONACYT and UAEM (University of the State of Morelos, Mexico) boards of directors.

Mayra de la Torre-Martínez

A biochemical engineer and graduate of the National Polytechnic Institute (IPN, Mexico), Dr. de la Torre-Martínez obtained a Doctorate in Microbiology from the same Institute and was a visiting postdoctoral scholar at the Swiss Federal Institute of Technology in Zurich, Switzerland. From 1977 to 2005 she was a researcher in the Center for Research and Advanced Studies of the IPN. Since 2005 she has been a permanent researcher at the Center for Research on Food and Development in Hermosillo, Sonora, Mexico. Her achievements comprise the development of several processing technologies for the creation of biotechnological products currently on the market, principally for small- and medium-sized companies (referred to in Mexico as PYMES). These include yeast for a variety of purposes, products developed for the biocontrol of plagues and phytodiseases, and products for the food industry. She led a research team which designed and built a pilot plant of multiple fermentations purpose , which was devoted to research, development and innovation in collaboration with companies, as well as the creation of products developed for field tests, the development of markets and the acquirement of records. She is currently still collaborating with small—and medium—sized companies in both research, development and innovation and the design of industrial plants. She was also a member of the Scientific Advisory Board of the Inter-Secretariat Commission for Biosafety of GMO (CIBIOGEM, Mexico) and has collaborated in the creation of norms for the handling of genetically modified organisms in accordance with the Mexican Biosafety Law of GMO. She developed and is responsible for the BIONNA Digital Platform for Innovation in Biotechnology in the Americas, a project financed by the Organization of American States. At present her basic scientific research is centered on a new system of "quorum sensing of the *Bacillus thuringiensis*". She has supervised more than 47 theses, mostly at the postgraduate level. For her work she has received several distinctions, and she became the first woman to be awarded the National Prize of Science and Arts, as well as the youngest laureate in the entire history of the prize. She has also received the TWAS prize for Engineering Science and the Life Sciences Prize from the Interscience Organization. She has been a member of the Mexican National System of Researchers (SNI) since 1985, as a level III national researcher. She is currently vice-president of the Latin America and Caribbean region of the Organization of Women Scientists for the Developing World, and assistant manager of the Committee on the Area of Agro-Food of the CYTED (Science and Technology for Development) and the president of the Interscience Association. She is a member of the Advisory Board for Science to the President of Mexico.

Jorge Espinosa-Fernández

Jorge Espinosa-Fernández was born in Mexico City in 1956. He graduated in Law from the National University of Mexico in 1979. In 1981 he obtained a Master's Degree in Public Administration (in the area of Public Finance and Public Policies Analysis) from the University of New York. In 1978 he set up his first legal practice. He has worked in various Mexican offices: He was the coordinator of Legal-Administrative Studies of the General Management of Organization and Programming of the Department of Fishing, during 1981 and 1982. In 1983 he was head of Administrative and Legal Services at the Institute for Security and Social Services of State Workers. From 1984 to 1985 he was Director of Regional Planning of the Head Office of Organization and Budget, of the under-secretariat of Planning of the Health Department. From June 1985 to March 1987 he was Director General of Decentralization and Administrative Modernization of the Health Department. He was Director General of Legal Affairs of the Health Department from 1987 to 1988. In 1989 he served as director of Legislation and Norms of the Legal Office of the Department of the Federal District. He has also been a legal consultant to several offices, academies, industries and companies devoted to science and technology, biotechnology, intellectual property, pharmaceutical regulation, health systems and international controversies. He has also been a professor of Management Theory at the Law School at UNAM, a member of the Commission for Legal Studies of Federal Public Administration of the Presidency of Mexico, a representative of the Health Department in government organizations in various public-sector entities, coordinator of the Sub-Committee on Legal Reform in Health and Social Security, a legal consultant to the Secretariat of Social Development (Ecological Law), a legal consultant of the Secretariat of Energy, a legal consultant of the National Council of Science and Technology and of the Advisory Board of Science of the Presidency of the Mexican Republic, with a focus on legislation and protection, a professor at the Bachelor's, Master's and graduate level at the National University of Mexico (UNAM), the Universidad Iberoamericana, the Universidad Anáhuac del Sur and La Salle, as well as the author of several publications on legal-administrative matters.

Enrique Galindo-Fentanes

Enrique Galindo-Fentanes was born in Mexico in 1957. He grew up and studied in Puebla, where he graduated in Chemical Engineering in 1979. He obtained his Master's degree in Basic Biomedical Research and his doctorate in Biotechnology at the National University of Mexico (UNAM) in 1983 and 1989, respectively. He carried out a postdoctoral stay at the University of Birmingham, England and was a visiting scholar at the Zurich Polytechnic (ETH), in Switzerland. He is currently a tenured C level researcher and subject teacher at the Biotechnology Institute at UNAM. He is the author of 126 articles of original research (102 of which were published in international peer-reviewed journals). He has been invited to submit articles to various forums, as well as chapters in several books and in the Encyclopedia of Life Support Systems. He has published 64 works of revision and/or popular science. He is the coeditor of *Advances in Bioprocess Engineering* and *Advances in Bioprocess Engineering II* (Kluwer Academic, 1994 and 1998), and the editor of *Frontiers in Biotechnology and Bioengineering*

(Mexican Society of Biotechnology AC, 1996). He is also the author of six approved patents. He has participated in the development of three biotechnological processes that have been transferred to their users. He has supervised 26 Bachelor's degree theses, 20 Master's theses and five doctoral dissertations. His career has received the Mexican National Prize on Science and Food Engineering (1987, 1995 and 2002), the 1990 Prize awarded by the Mexican Institute of Chemical Engineers, the National Prize for Science-Puebla in 1987, the 1989 National University Distinction for Young Academics, the 1994 Academy of Scientific Research Prize, the 2004 Sven Brohult Prize—the highest distinction awarded by the International Foundation for Science—and the 2010 AgroBio Prize for a career in Agricultural Biotechnology. Since 1984 he has been a member of the Mexican National System of Researchers (SNI), level III since 1999. He is a regular member of the Academia Mexicana de Ciencias, the Engineering Academy of Mexico and the Academy of Science of Morelos, Mexico, of which he was president in 2007-2008. He was vice-president and president of the Mexican Biotechnology and Bioengineering Society (1996-2000). He has served on the CONACYT committee in the area of biotechnology and agricultural science, the engineering and technology committee of the Scientific and Technological Advisory Board, and the National System of Researchers' Review Board (SNI) in the area of biotechnology and agricultural sciences. In 2009 and 2010 he was the coordinator of the editorial committee of the Academy of Sciences of Morelos. He is currently the head of the Department of Cellular Engineering and Biocatylisis of the Biotechnology Institute in the UNAM, in Cuernavaca, Morelos, and belongs to the *ad hoc* biotechnology committee of the Academia Mexicana de Ciencias (AMC). His academic interests are centered on bioprocess. His group has studied the production of viscosifying agents of foods (bacterial polysaccharides), biomass produced by mushrooms and the development of biosensors for the food industry. He has developed technologies for the production and application of agents for the biological control of mango anthracnose, which have enabled the production of high quality fruit.

Amanda Gálvez-Mariscal

Amanda Gálvez-Mariscal obtained a doctorate in Biotechnology from the National University of Mexico (UNAM). She studied for a Master's Degree in Food Science and Technology at the Massachusetts Institute of Technology (MIT) and a Bachelor's Degree in Chemistry, Pharmaceuticals and Biology Food Technology at La Salle University, Mexico. She has been a tenured professor at the UNAM Chemistry School in the Department of Food and Biotechnology for 27 years. She lectures on food chemistry, molecular biology and food biosecurity. Her work was recognized by the National Food Science and Technology Award in 1990 and 2002. She is a member of the National System of Researchers (SNI) and became the coordinator of the University Food Program (PUAL) of UNAM in August 2006. Dr. Gálvez was also a member of the Mexican delegation for the Cartagena Biosecurity Protocol from 1995 to 2006. She has served as an adviser to the National Commission for the Use and Knowledge of Biodiversity (CONABIO, Mexico), the Department for the Environment and Natural Resources (SEMARNAT, Mexico) and the Foreign Affairs Secretariat (SRE, Mexico) on the topic of biosecurity. In that

area, she has carried out work monitoring and detecting GMOs for the Department of Health with her work team from the PUAL and the UNAM Chemistry School. Since 2009, the PUAL has been the national point of contact for CONACYT and the Foreign Affairs Secretariat, Mexico, in the aforementioned areas.

Adolfo Gracía-Gasca

Adolfo Gracía-Gasca obtained a degree in Biology from the National University of Mexico (UNAM) Science School, followed by a Master's Degree and Doctorate in Science (Biology) from the same School. He is a permanent C and Pride D researcher at the Institute of Sea Sciences and Limnology at UNAM, as well as a postgraduate and graduate professor at UNAM. His lines of research are: the fishing ecology of decapod crustaceans, sustainable marine resource use and the ecology of benthic communities. He is the author of more than 70 publications on ecology and marine biology, as well as fishing resource management. He has supervised 20 Bachelor's theses, 13 Master's theses and five doctoral dissertations. He is a level II researcher in the Mexican National System of Researchers (SNI) and a regular member of the Mexican Academy of Sciences and several national and international scientific societies. He has taken part in numerous collegiate bodies at UNAM and national committees. He was a scientific advisor to the National Chamber of the Fishing and Aquaculture Industry (1993-1999), and director of the Institute of Sea Sciences and Limnology at UNAM for two periods. Since 2008 he has been the coordinator of the Academic Council on Biological, Chemical and Health Sciences, also at UNAM.

Luis Herrera-Estrella

Luis Herrera-Estrella was born in Mexico City in 1956. He graduated as a biochemical engineer from the National School of Biological Sciences of the National Polytechnic Institute (IPN, Mexico), and then continued his Master's Degree studies at the IPN Center for Research and Advanced Studies (CINVESTAV), and his doctoral studies in the Genetics Department of the State University of Ghent, in Belgium. In 1984 Dr. Luis Herrera was awarded the title of doctor of sciences, the highest distinction offered by the University of Ghent. That same year, he received the Minuro and Ethel Tsutsui Award, a biannual prize presented by the Academy of Science of New York to the best doctoral dissertation in the international sphere. This was for his research which led to the creation of the first plants to be modified by genetic engineering and the methods which are currently employed to produce them on a routine basis. This contribution is considered a milestone in the development of molecular biology and plant biotechnology. His later discoveries became watersheds in the study of the mechanisms that regulate gene expression in plants and in demonstrating the fundamental role of the transit peptide in the processes of inserting proteins into chloroplast. In 1986, after having worked for two years as a researcher affiliated to the State University of Ghent he returned to Mexico to found and organize the Genetic Engineering Department at the Irapuato Campus of CINVESTAV. A number of years later, a study by UNESCO recognized this project as one of the five most important centers of research on molecular biology in developing countries and in 1987, UNESCO awarded Dr. Herrera the Javed Husain prize as the most outstanding young researcher in natural sciences. He

later devoted part of his basic research program to the study of problems concerning Latin American agriculture. He studies the molecular mechanisms of the action of toxins produced by pathogenic plant bacteria and has successfully developed transgenic plants resistant to the toxin produced by one of the pathogens which caused the greatest losses in bean cultivation. Using the experience in molecular biology and genetic engineering acquired in earlier years, his work group developed the methodology for the genetic transformation of the tomatillo, papaya, Creole corn and asparagus, plant species of great importance in Latin America. His contributions in basic research to the development of agriculture in tropical zones earned him the recognition of the Third World Academy of Science, which awarded him the TWAS prize for Biology in 1994. He later carried out pioneering work on the mechanisms of tolerance to toxic concentrations of aluminum in acid soils and the molecular mechanisms that allow plants to adapt the architecture of their roots to respond to adverse environmental factors such as drought and the low availability of nutrients in the soil. His research work has been expressed in more than 100 publications in international journals, including five articles in *Nature*, four in Science, seven in EMBO *Journal*, three in PNAS, two in *Plant Cell* and one in *Cell*. Dr. Herrera has directed 12 Bachelor's theses and has graduated eight Master's degree students and 29 doctors in science. The impact of his scientific work is reflected in the over 4,500 citations that his publications have received. In the sphere of technological development, Dr Herrera has also made major contributions that have been recognized by five international patents and two more currently being processed. The applications generated by his basic research made him the recipient, along with the engineers González Camarena and Celeda Salmón, of the Gold Medal of the World Organization of Intellectual Property, as one of the three most outstanding inventors in Mexico. He has received four prizes in Mexico: the Academia Mexicana de Ciencias Award, the Lázaro Cárdenas Medal from the National Polytechnic Institute (IPN), the National Prize in Science and Arts, and the Luis Elizondo Prize from the Technological Institute of Monterrey. His participation on the international scientific stage has earned him important distinctions such as the presidency of the International Society of Plant Molecular Biology, membership of the select group of International Scholars of the Howard Hughes Medical Institute for 20 years, and his appointment as Foreign Member of the United States National Academy of Sciences. His research programs remain concerned with scientific innovations, and he recently headed the creation of the National Laboratory of Genomics for Biodiversity with the support of CONACYT, the Secretariat of Agriculture, Livestock and Fishing Resources (SAGARPA), the Secretariat of Public Education (SEP) and the Government of the State of Guanajuato, Mexico.

Alfonso Larqué-Saavedra

Alfonso Larqué-Saavedra graduated in Biology from the National University of Mexico (UNAM), then obtained his Master's Degree in Science at the College of Graduates and his doctorate at the University of London. He was a visiting scholar and researcher at the universities of Lancaster (1978), Cambridge (1978), Stanford (1984), Essex (1984) and Texas, in Austin (1992-1993). His research work has focused principally on: 1) the hormonal control of water for plants,

2) bioproductivity and 3) the added value of natural resources. His research has been published in journals in his specialty such as *Nature, Global Biology and Bioenergy, Physiologia Plantarum , J. Exp. Botany, Planta* and *Molecular Biotechnology*, amongst others. He is a pioneer in studies of the effect on aspirin on plants and directs the following courses: Water in plants, Plant hormones, Scientific bases of productivity and plant physiology. Dr. Larqué is the author of 103 published scientific articles and written, compiled or edited 21 books, 30 popular scientific articles, 32 chapters in books, three patents, two brand registrations and four technological developments transferred to the social sector. He has trained 143 students at the Bachelor's, Master's and doctorate level. He has been a judge for the National University (UNAM) Prize and the Mexico Science and Technology Prize, and a member of the Review Commission of Mexican Academic Staff at the Ecology Institute (INECOL), El Colegio de la Frontera Sur (ECOSUR), of the External Evaluation Committee of El Colegio de Michoacán (COLMICH) and of the Center for Research on Food and Development (CIAD). He has belonged to the Review Commission of the National System of Researchers (SNI) and been a judge of the AgroBIO Mexico Prize 2005 for research and investigative journalism into agricultural biotechnology. He has also been a member of the Board of Directors of the El Colegio de Michoacán (COLMICH), El Colegio de la Frontera Sur (ECOSUR), the Biological Research Center of the Northeast (CIBNOR), the Center for Technical Research and Assistance in Technology and Design of the State of Jalisco (CIATEJ), and of the Ecology Institute (INECOL). He has also been part of the Review Commission of Academic Staff of the Center for Atmospheric Science, the Institute of Biology and the UNAM Science School. Dr Larqué has received several distinctions including the National Prize for Sciences and Arts 2000, awarded by the Government of Mexico; the National Prize for Research on Food 1987, awarded by the Secretariat of Fisheries-SARH-CONACYT-Conasupo and the State of Mexico Prize awarded by the Government of the State of Mexico. In 1988, he received the National Prize for Food Science and Technology from CONACYT and Coca-Cola, in 1998; the CENTEOTL Prize, awarded by the Produce Foundation for his contributions to the development of the Mexican countryside in 2007, and the Third World Academy of Science (TWAS) Prize for Agriculture in 2010. He is a member of the National System of Researchers (level III). Dr Larqué is a tenured research professor at the Center for Scientific Research of Yucatán, advisor to the Technological Research, Innovation and Development System of Yucatán (SIIDETEY), and director of the Scientific and Technological Park of Yucatán.

Agustin López-Munguía-Canales

Dr López-Munguía is a chemical engineer and a graduate of the National University of Mexico Chemistry School (UNAM). He obtained a Master's Degree in Biochemical Engineering from the University of Birmingham, England and a Doctorate in Biotechnology from the National Institute of Applied Sciences in Toulouse, France. He has published over 100 research articles in national and international arbitrated journals and has several patents, technological developments and technology transfers to industry in the area of biocatalysis. He is the editor and author of *Food biotechnology*, published by Limusa (1993), and of the follow-

ing books: *Alimentos: del tianguis al supermercado*, from the CONACULTA Journey to the Center of Science collection (1995), *Biotecnología*, from the CONACULTA Third Millennium collection (2000), *Alimentos transgénicos*, also part of the CONACULTA Third Millennium collection (2000), *Proteinas*, selected for the 2005-2006 Classroom Libraries competition, as part of the Nation of Readers program —supported by the Secretariat of Public Education—and *Alimentos*, part of the Paper Traces series, published by Santillana this year. He is also the author of various popular science articles, in particular for the magazine *¿Cómo ves?* He is a tenured professor of Biotechnology at the UNAM Chemistry School. He has directed more than 60 theses at the Bachelor's, Master's and doctorate level. He has reached level III in the Mexican National System of Researchers (SNI). Among the awards he has received are the Prize of the Mexican Academy of Sciences in the area of Technology in 1990, the National University Award 2000 in the area of Technological Innovation and the National Sciences and Arts Prize in the area of Technology in 2003, awarded by the Mexican government.

Adalberto Noyola-Robles

Adalberto Noyola-Robles was born in San Luis Potosí, Mexico, in 1956. He studied environmental engineering at the Autonomous Metropolitan University *campus* Azcapotzalco (1976-1980) in Mexico City. He obtained a Master's Degree and Doctorate in Engineering (wastewater treatment) from the National Institute of Applied Science (INSA) of Toulouse, France (1981-1985). After having worked for two years at the Iztapalapa *campus* of the Autonomous Metropolitan University, he joined the UNAM Engineering Institute as a researcher in 1987. He is a tenured C, Pride level D researcher, a member of the Mexican National System of Researchers (SNI) (1986), and has been a level III researcher since 2003. He is currently the director of the UNAM Engineering Institute (2008-2012). He is a collaborating professor at the Federal University of Paraná, Brazil, and has taught short courses in several Latin American countries. His line of research is wastewater and sludge treatment by biological means, in particular by anaerobic methods. He has participated in several degree thesis juries at the Bachelor's and graduate level, in Mexico and abroad. His academic work has earned the following awards: the 1991 National University Distinction for Mexican Young Academics, the 1993 CIBA Prize for Technological Innovation in Ecology and the León Biálik University Prize in 1992 and 1998. He has been awarded recognitions by engineering associations in Colombia and Venezuela. He has taken part in the organization of national and international events and congresses, both as president and as coordinator of the scientific committees. He is a reviewer of several scientific journals and acts as a project judge for CONACYT (Mexico), CONICYT (Uruguay), CNP (Brazil) and several universities. He is a member of the Mexican Federation of Sanitary Engineering and Environmental Science (FEMISCA), the Mexican Biotechnology and Bioengineering Society, the Environmental Engineers College of Mexico, the National Engineering Academy and the International Water Association (IWA), in which he participates as a member of the Operative Committee of the Specialist Group on Anaerobic Digestion. He has had an active academic career, having been vice-president and president of the Mexican Biotechnology and Bioengineering Society (1994-1996), president

of the Mexican Federation of Sanitary Engineering Sanitary and Environmental Science (FEMISCA) (1997-1998), and president of the Inter-American Association of Sanitary and Environmental Engineering (AIDIS) for the 2006-2008 biennial, a continental association with over 10,000 members in 24 countries.

Octavio Paredes-López

Octavio Paredes-López studied Biochemical Engineering and obtained a Master's Degree in Food Science at the National School of Biological Science of the National Polytechnic Institute (IPN, Mexico). He obtained a Master's Degree in Biochemical Engineering at the Czech Academy of Sciences. He subsequently completed a Doctorate in Plant Science from the University of Manitoba in Winnipeg, Canada. He has carried out research and postdoctoral stays in the United States, England, France, Germany, Switzerland, the Czech Republic and Brazil. He has reached level III of the Mexican National System of Researchers and was named a National Researcher of Excellence. He is the author of 330 scientific and technical articles, 50 chapters in books and reviews, three books published internationally and dozens of newspaper articles, and has supervised 35 Bachelor's theses, 46 Master's theses and 34 doctoral dissertations. He has received the following Mexican and international prizes and distinctions: 1) The National Bank of Mexico (BANAMEX), Agricultural and Fishing Branch, 2) the 1983 Lázaro Cárdenas Medal as a distinguished IPN researcher, 3) the Nestlé Prize for Research and Development on Human Food, 4) The National Prize for Food Science and Technology on five separate occasions, 5) the 1986 National Prize for Merit in Food Science and Technology, 6) the 1991 Andrés Manuel del Río National Prize for Chemistry, awarded by the Mexican Chemistry Society, 7) the 1991 National Prize for Science, awarded by the President of Mexico, 8) an honorary doctorate from the Autonomous University of Querétaro in 1992, 9) guest professor at the University of Manitoba, Canada and of the University of Texas A&M, United States, 10) Lázaro Cárdenas Prize for Distinguished IPN Graduates 1993, 11) Miguel Hidalgo y Costilla Prize, Congress of the State of Guanajuato 1993, 12) CONACYT Heritage Chair I, 1994, 13) Distinguished Citizen of Irapuato 1995 14) Favorite Son of the Municipality of Mocorito, Sinaloa, 1994, 15) Luis Elizondo Scientific and Technological Award of the Board of the Instituto Tecnológico y de Estudios Superiores de Monterrey, 1994, 16) lifelong member of El Colegio de Sinaloa, 1997, 17) Third World Academy of Sciences-Third World Network of Scientific Organizations Award 1998, Trieste, Italy 18) founder of the International Academy of Food Science and Technology within the group of 30 world scientists selected by the International Union of Food Science and Technology, Sydney, Australia, 1999, 19) general editor and associate editor of six international science journals, 20) honorary doctorate in 1999 from the University Council of the University of Sinaloa, 21) Vasco de Quiroga Award, the highest distinction conferred by the Municipality of Irapuato, 2000, 22) Vice President (2002-2004) and President (2004-2006) of the Mexican Academy of Sciences, 23) chosen as one of the 300 most influential leaders of Mexico (*Revista Líderes Mexicanos*, 2005 and 2006), 24) honorary doctorate, University of Manitoba, Canada, 2005, 25) Doctorate in Science, University of Manitoba, Canada, 2005, 26) National Ocho Columnas de Oro Prize, area of Science and Technology, from the University

of Guadalajara and *Ocho Columnas* newspaper, Jalisco, 2006, 27) special award for scientific merit from the World Cultural Council, Mexico 2006, 28) member of the UNAM Board of Directors, UNAM 2006, 29) appointed Exemplary Sinaloa Resident by the Council for Exemplary Sinaloa Residents in the World, Sinaloa 2007 and 30) member of the Advisory Board of the St. Catharine´s College Society-Branch for Mexico, University of Cambridge 2007, 31) scientific advisor for the Diploma Course and Master's Program in Science Teaching (Sinaloa Program for Pre-School to High School Teachers) 2007, 32) member of the Advisory Board of the International Center for the Advancement of Health, Regional Innovation and Science (ICAHRIS/CIASIRS), Canada 2008, 33) designated national emeritus researcher by the National System of Researchers, 2008. He was founder and director of the Irapuato Unit of the IPN Center for Research and Advanced Studies (CINVESTAV), where he has been a professor since 1981.

Tonatiuh Ramírez-Reivich

Tonatiuh Ramírez-Reivich graduated as a Chemical Engineer from the National University of Mexico (UNAM) and obtained a Doctorate in Chemical Engineering and Biochemistry from the University of Drexel, USA. Since 1990 he has been a researcher at the Biotechnology Institute at UNAM, and is also a level III Mexican national researcher. He has received several distinctions, including the 1998 Research Prize from the Academia Mexicana de Ciencias; the 2010 National University Prize; the 2000 National University Prize for Young Academics, Mexico; the Sigma Xi Prize for the best postgraduate work at the University of Drexel, USA; the Carlos Casas Campillo Prize, awarded by the Mexican Society of Biotechnology and Bioengineering; on two occasions the Prize for Academic Merit to the best international student of the University of Drexel, USA. He is member of the Editorial Committee of the *Biotechnology and Bioengineering* journal; Associate Editor of the *Biochemical Engineering* Journal, and has received several prizes awarded by organizations such as House of Science Annual Prize from the Autonomous University of the State of Morelos, Mexico, and the National Engineering Academy. He has been a pioneer in Mexico in the bioengineering of the cultivation of superior eukaryotes and in the application of computational methods for the control of bioprocesses, including, in addition to the cultivation of animal cells, fermentations with recombined microorganisms, mixed and axenic cultures, descending scaling and the production of viral pseudo particles with application in vaccinations and nanomaterials. He has published 75 scientific articles, edited two internationally published books and over 30 popular science articles and book chapters and his work has been cited approximately 800 times in scientific literature. His work has been transferred from the academic to the industrial sphere through his extensive consultancy work and his participation in companies and institutions, both national and international. This work has borne many fruits such as the development of new products and biotechnological processes in the area of food, pharmaceuticals and the environment.

Sergio Revah-Moiseev

He is a tenured C level research professor at the Autonomous Metropolitan University (UAM) *campus* Cuajimalpa, Mexico, and since June 2009 has been the director of the Natural

Sciences and Engineering Division, where he founded the Processes and Technology Department, which he directed for four years. Until September 2005 he belonged to the Area of Chemical Engineering at UAM *campus* Iztapalapa. He began his academic career at the UAM in 1976 as an assistant professor. He continued his postgraduate training in the United States and France and began to consolidate his research team from 1987 onwards. He initially worked on projects studying the biotechnological processes in food and later studied their applications for the environment. In the field of pollution control through biotechnological processes, Dr. Revah's laboratory is recognized worldwide and has trained many professionals at graduate and postgraduate level. His work has been cited over 1,200 times. He has participated in the scientific committees of the principal congresses in his field and has reviewed articles for the leading journals. He has gained the support, in addition to that of the UAM, of institutions such as the National Council for Science and Technology (CONACYT, Mexico), private Mexican companies and international agreements. Twice a year he organizes one of the most important congresses in his field, the most recent being the Duke-UAM Conference on Biofiltration, held in Washington DC in October 2010. In terms of creating links, he has carried out projects with companies with a technological base, and in one of these he remains a partner and technological assessor. He has obtained various distinctions such as becoming a level III member of the Mexican National System of Researchers (SNI), the Ciba-Geigy Prize in Environmental Technology, the Manuel Noriega Morales Prize for Science and Technology, from the Organization of American States and recently the 2010 National Prize for Science and Arts in the technology field, Mexico.

Jorge Soberón-Mainero

Jorge Soberón-Mainero was born in Mexico City in 1953. He graduated as a biologist from the Science School at the National University of Mexico (UNAM) in 1977. He obtained a Master's Degree from the same school in 1979 and his Doctorate in Science from Imperial College at the University of London in 1982. He is currently a professor and senior scientist at the Biodiversity Research Center of the University of Kansas, USA. Dr. Soberón has published over a hundred papers in international journals, popular science literature, books and chapters, articles in proceedings and technical reports. He has taught courses on population ecology, mathematics, conservation ecology and politics and biodiversity diplomacy at the Bachelor and Master's Degree level, both at UNAM and foreign universities (Mérida, Venezuela, Imperial College, University of London, University of Kansas). He is also the Head of the "Andrés Marcelo Sada" Department of Sustainable Development at the Technological Institute of Monterrey and has supervised twelve theses at the Bachelor's, Master's and doctoral level. He has been invited to deliver the keynote address at over 50 international conferences. From 1992 to 2005, Dr. Jorge Soberón was the Executive Secretary of the National Commission for the Knowledge and Use of Biodiversity (CONABIO, Mexico). He has been or is a member of the managing or scientific councils of the Global Environment Fund (STAP of the GEF), Washington DC; the International Center for Insect Physiology and Ecology (ICIPE), in Nairobi, Kenya; the Global Biodiversity Information Facility (GBIF); Copenhagen, Denmark; the World Conservation Monitoring Center, Cambridge, England; NatureServe, Washington DC; Pronatura, Mexico; the All Species Foundation, San

Francisco, California; the Center for Applied Biodiversity Science (CABS), Washington DC; the Encyclopedia of Life, Washington DC; the Smithsonian Museum, and the JRS Biodiversity Foundation. He is also a member of the External Evaluating Committee of the Ecology Institute. As a delegate or head of a delegation representing Mexico at Conferences of the Parties, he has attended working group meetings or scientific committees for agreements on Biological Diversity (CDB), the Convention on International Trade in Endangered Species (CITES), and the trilateral meetings on wildlife in NAFTA countries.

Xavier Soberón-Mainero

Xavier Soberón-Mainero was born in Mexico City. He graduated in Chemistry from the Universidad Iberoamericana and obtained his doctorate in Biomedical Research from the National University of Mexico (UNAM). Since 1981 he has been a researcher at the Biotechnology Institute (IBt) at UNAM, where he participated in setting up and consolidating genetic engineering and biotechnology. He has been a visiting scholar at the City of Hope Medical Center, in the area of Los Angeles, California; the University of California, San Francisco and the University of California, San Diego. His research has focused on the chemical DNA synthesis and its application in the study of proteins, as well as the development of biopharmaceuticals and vaccinations and biocatalysis. He has published over 50 original research articles in peer-reviewed journals, in addition to several other works of analysis and popular science, including a book published by the Fondo de Cultura Económica, Mexico. He also owns three patents covering the applications of synthetic DNA in the developments of new biocatalysers and metabolic engineering. He has coordinated the installation, development and operation of the Departments of Synthesis and Sequencing of Macromolecules and of Computing of the Biotechnology Institute at UNAM. He has been a professor of Master's Degree and doctoral programs in Biomedical and Biochemical Sciences at UNAM and supervised approximately twenty theses at the Bachelor's and Master's degree level. He also lectures on the Genomic Science degree course at UNAM, which he helped to found. He was director of the IBt for two four-year periods, between 1997 and 2005. He was president of the Morelos Academy of Sciences from 2004 to 2006. He has received several Mexican prizes and distinctions, including the 1999 National Prize for Chemistry and recognition as level III national researcher. He has undertaken numerous assessment activities, such as his participation in the Biotechnology Committee of the Mexican Academy of Sciences and in CONACYT, Mexico, uninterruptedly since 1998. He acted as director of the National System of Researchers (SNI) in 2008 and 2009, and is currently the Director General of the National Institute of Genomic Medicine of the Mexican Health Department.

Irineo Torres-Pacheco

Irineo Torres-Pacheco graduated as an agricultural engineer specializing in phytoimprovement at the Agrobiology School of the Michoacán University of San Nicolás de Hidalgo, Mexico. He carried out postgraduate studies at the Irapuato Campus, Mexico, of the Research and Advanced Studies Center, obtaining a Master's Degree in Plant Biology and a doctorate in Plant Biotechnology. His research work studies production with a multidisciplinary biosystems focus. He has published 59 articles in 19 international journals, including

Phytopathology, *Journal of General Virology, Plant Pathology, Sensors, Journal of Botany, Hort Science, Journal of Applied Entomology, African Journal of Biotechnology*, *Computers and Electronics in Agriculture, Revista Mexicana de Fitopatología, Chapingo Serie Hortícola, Agrociencia, Fitotecnia y Agricultura Técnica en México* and his work has been cited in over 400 related articles worldwide. He has supervised 32 student theses, including 17 Bachelor's Degree and seven Master's Degree theses and three doctoral dissertations. He has delivered over 90 presentations and conferences in national and international congresses. He was a Permanent Researcher and founding Leader of the Laboratories Unit of the National Biotechnology Office of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, Mexico) in the Bajío Experimental Field. He headed the project that generated the technology for handling decay in chili cultivation. He was a member of the First Advisory Board of the Intersecretarial Biosecurity and Genetically Modified Organisms Commission. He was the National Head of Plant and Biotechnology Research at the INIFAP. He was also director of the Regional Research Center at INIFAP. He now reviews the articles published in the *Revista Mexicana de Fitopatología y Fitotecnia*, a national indexed journal. He is the editor of the Editorial Sign Post of Kerala, India and Intech in Vienna, Austria. He collaborates as a guest professor at the Cuautitlán Higher Studies School (FES) and Iztacala FES of the National University of Mexico. He is a category VII research professor and coordinator of the Academic Body of Biosystems Engineering in the Engineering School at the Autonomous University of Querétaro, Mexico, and is a level III member of the Mexican National System of Researchers (SNI).

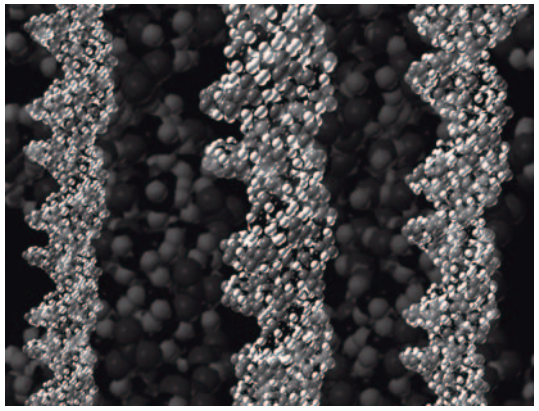
Jaime Uribe-De la Mora

Jaime Uribe graduated in Chemical Engineering from the Universidad Iberoamericana and obtained a postgraduate degree in Economics, Mexico. He began his professional career in the Loreto y Peña Pobre Paper factory, and then worked at Kimberly Clark and subsequently in the plastic industry at Manufacturera Aztlán, Mercadotecnia Industrial and finally Platifin, where he held the post of director general. Along with four other partners he founded Fine Chemical Products in 1970, where he occupied the post of head of production and in 1975 became the director general of the company and of Proquifin, of which he is also the founder. These companies in Mexico produced pharmochemicals (the principal active components of medicines), both by chemical synthesis and extractive processes. Amongst the products made were sulfametazine, sulfathiazole, dipyrones, vitamin B12, cyanocobalamin, hydroxocobalamin, cloramfenicol and its salts. Through extractive processes the company created chorionic gonadotropin from the urine of pregnant women and heparine from the intestinal mucus of pigs, which was collected from all over the country. In 1988 he began work to develop proteins using rDNA technology. He is a pioneer of industrial biotechnology and the only maker of proteins and vaccinations in Mexico. In 1994 he acquired Probiomed and in 1998 began the commercialization of products with an rDNA base, made in Mexico at every stage from the gene and cloning to the medicine. The company managed to achieve the highest national integration percentage in the pharmaceutical industry and the highest manufacturing added value of the entire industry at national level, as a result of which he was awarded the 1999 National Prize for

Technology, the same year in which it was created. He has always strived for the integration of productive chains, seeking links and collaboration in the academic-scientific sector both in Mexico and abroad. In 2008 he was president of the National Association of Medicine Producers (ANAFAM) and in 2009 president of the National Chamber of the Pharmaceutical Industry (CANIFARMA, Mexico). He is currently the president and director general of Probiomed, president of the Pro-Life Foundation and vice-president of the Association of Mexican Biotechnology Companies (EMBIOMEX).

Gustavo Viniegra-González

Gustavo Viniegra-González was born in Mexico City in 1940. He graduated as a medical surgeon from the National University of Mexico (UNAM) in 1965 and in 1967 was named Master of Science (Biochemistry) by the Research and Advanced Studies Center of the National Polytechnic Institute (IPN, Mexico). He obtained a doctorate in biophysics from the University of California, San Francisco in 1971 and was a post doctorate student at the University of Pennsylvania in 1972. That same year he entered as a permanent A researcher to create the Biotechnology Department of the Institute of Biomedical Research of the UNAM. He was promoted to permanent B researcher in 1976. Since 1977 he has been a tenured C level professor at the Iztapalapa *Campus* of the Autonomous Metropolitan University (UAM, Mexico), where he contributed to the founding of the Biotechnology Department. The principal distinctions he has been awarded are as follows: in 1982 he became a partner of the Mexican Biotechnology and Bioengineering Society; in January 2002 he was named national emeritus researcher; in 2002 he was chosen as a representative of the Area of Engineering and Technology at the Scientific and Technological Consultative Forum and was admitted to the French Order of Academic Palms; from 2006 to 2009 he was the coordinator of Academic Liaison at UAM Iztapalapa; in 2010 he was a visiting researcher at the Federal University of Rio de Janeiro. He organized and supervised the group which recorded the first biotechnological invention to be licensed commercially by a Mexican university (the Biofermel process). His specialized work has received more than 743 citations (not including self-citations) published in international scientific journals with an impact factor of h=21. Dr Gustavo Viniegra's lines of research are mushroom physiology and genetics, the development of specialized strains for the fermentation of solid substrates and the genetic transformations of *Aspergillus niger* to increase enzyme production.



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