Electronic Journal of Biotechnology ISSN: 0717-3458
Vol.7 No.2, Issue of August 15, 2004

Received February 24, 2004 / Accepted March 15, 2004
REVIEW ARTICLE

# Art, biotechnology and the culture of peace

**Edgar DaSilva**
Former Director
Division of Life Sciences,
c/o INSULA
UNESCO House
Paris 75015, France
E-mail: e.dasilva@wanadoo.fr

**Keywords:** biotech art, cultural heritage, fermentation, peace.

**Biotechnology, in its voyage from ancient times into the expanding frontier areas of today's world of scientific research, has revealed itself as the gene of diplomacy and international cooperation in the relationships between nations (DaSilva, 2002). Economic and biotechnological considerations, strong elements in themselves, drive policy implementation that draws upon the support and sustenance of the public's logic and understanding of science obtained through the avenues of art and culture. More and more scientists are teaming up with artists to harness the world of microbes and biotechnology in the pursuit of one's natural well-being, of the conservation of environmental heritage, and of human comradeship and welfare. Art and culture in revealing the human face of biotechnology help engender solidarity amongst different cultures. Furthermore, they nurture individual solidarity and collective commitment in especially young children --- tomorrow's architects in the quest of the culture of a sustainable peace.**

Biotechnology, through the passage of time and its applications in agriculture, industry and medicine, has moved beyond the frontiers of biobased materials and revolutionized medicine into the domains of the arts, philosophy and theology. A vector that binds the haves and the haves-not of society in the frameworks of market-driven economies and worldwide poverty, biotechnology has contributed to the emerging trade profiles of the newly industrialized countries in the southern hemisphere (RIS, 2003). Some four decades ago attention was drawn to the catalytic role of microbes in diplomacy and to use of their 'technological carte blanche' for improving the quality of life and human well-being worldwide (Foster, 1964).

In current times, the human face of biotechnology and its societal dimensions and implications is being revealed and transformed through the arts, cine fiction, literature, and TV. More and more scientists are teaming up with artists to harness the world of microbes and biotechnology in the pursuit of one's natural well-being, of the conservation of environmental heritage, of human comradeship and welfare, and of mental and spiritual tranquillity ----the foundation stones of a veritable quest of a culture of peace[1] pioneered in UNESCO and the UN system by Federico Mayor in his capacity as then Director-General of UNESCO.

"*If we wish to create a lasting peace we must begin with the children"*

Mahatma Gandhi

Economic and biotechnological considerations, strong elements in themselves in motoring policy implementation need, nevertheless, the support and sustenance of the public's logic and understanding of science that nurture individual and collective peace especially in young children ---tomorrow's architects of a much desired sustainable peace through the avenues of art and culture[2]. The concept of culture that impacts on economic development and prosperity embraces traditional beliefs and customary practices, the so-called high arts such as literature, painting, dance and opera; and all the elements of popular culture, including soap operas, M-TV videos, dime store novels, (comic strips) and blockbuster movies'. All these elements of culture influence "how markets develop, how they are perceived, and how people choose to express themselves as participants in the market process" (Lavoie and Chamlee-Wright, 2002). Culture matters in economic development since the latter is the guarantor of cultural heritage and of cultural advantages in the market-oriented economies of today's world. Cultural entrepreneurialship can make a significant impact since it drives national kinship and regional strategies in engendering a work ethic that helps combat, minimise, and eradicate the scourges of disease, hunger, lack of shelter, loss of inspirational and spiritual motivation, poverty and unemployment. Cultural heritage and legacy are the twin motors of technological advancement and economic development that have their roots in ancestral agricultural practices and food fermentations.

*Corresponding author


**Figure 1.** Illustration of the concept used in a technical compartmentation of different processes used by living machines in an integrated biosystem for the production of (bioenergy, fish, landscape plants) resulting from wastewater treatment and pond water to recharge ground water reserves. "Thus it is also a zero-water discharge technology" (Personal communication -3/7 January, 2004 with E.L. Foo, Chairman, International Organization of Biotechnology and Bioengineering (IOBB), and Co-ordinator of IOBB-Integrated Biosystems Network, Department of Biotechnology, Royal Institute of Technology, Stockholm, Sweden, who provided the picture).

For examples of small and large scale operations (see IBSNET proceedings 1998, 2000). See also "Selected Publications/ Proceedings" in http://www.ias.unu.edu/proceedings/icibs/ibs/ibsnet/.

## BIOTECHNOLOGY - ANCESTRAL ART AND CULTURE

The practice of biotechnology in the cradle of agriculture ---The Fertile Crescent in 10,000 BC and its contributions to the evolution and spread of culture and languages beyond the then Middle Eastern arc of then peace, plenitude and prosperity ----and today's cradle of distrust, dissension and destruction, has been the focus of scientific analysis and technical review. Archaeological, genetic and botanical evidence of seed remains and of agricultural practices and tools reveal intuitive application of domestic skills in the development of cultural practices and rudimentary microbial fermentations in Mesopotamia *circa* 6000 BC. Moreover, the origins and evolution of cultural and linguistic diversity have been traced in the dissemination of seeds, their sowing in different geographical areas, and to the development of agricultural traditional-based agricultural knowledge and practices (Cavali-Sforza, 1991; Price and Gebauer, 1995; Bar-Yosef, 1998; Diamond and Bellwood, 2003). Thus there exists a strong worldwide linkage between agricultural diversity and cultural diversity.

### Fermentation technology and art

Folkloristic manufacture of some 38 domestic-based traditional alcoholic foods and beverages by indigenous people in Asia, Africa and Latin America involved a two-step common pathway using a starch-rich substrate for production of fermentable sugars for use by yeasts and lactic acid bacteria, and the preparation of a starter culture with a desired microflora (Ishida,2002).

"*Your food shall be your medicine and your medicine shall be your food*"

Hippocrates (460-377 B.C.)

Discovery and study of the brewing reliefs of the Old Kingdom (2650 – 2134 BC) in the tomb of the royal acquaintances and manicurists Niankhkhnum and Khnumhotep of King Nyuserre Ini (2453 – 2422 BC) matched the detailed beer-making processes practised and described by the alchemist Zosimus in the 3rd century AD.

In Korea, onggi pottery (Sayers and Rinzler, 1987) from the period of the Yi dynasty (1392 –1910) is still in current use


**Figure 2. Biotechnology cover art illustrating interaction of art with: Agrofoods: Food adjuncts, Nutraceuticals and Functional Foods.** Source: Agro FOOD industry hi- tech – published by Tekno Scienze. Reproduced with permission of Tekno Scienze.

in the traditional preparation of fermented cabbage--- *kimchi,* (Young-Ja, 2000).

In 1624 D. Stolcius von Stolcenberg in Frankfurt used the alchemical approach in fermentation art to pictorially describe in *Viridarium chymicum* the phases of putrefaction and fermentation.

In summary, current folkloristic fermentation methods are more closely associated with the ancient Egyptian beer brewing process captured in the murals and reliefs in the tombs of the pharaohs as well as those in documented ancient papyrus records and writings. And, the successful replication today in Japan of the ancient beer brewing process reaffirms the long-held universal admission that the practice of microbiology in that country is indeed the practice of art and science (Ishida, 2002). The cultural nuances of the brewing art- science relationship of fermentation technology ---art in ancient times and science in the modern era (Table 1) have been captured through the elegance and the eloquence of the painters' brush. (Hodgson and Bormann, 1988).

## Fermented foods and culture

"*Beer is a living proof that God loves us and wants us to be happy*"

Benjamin Franklin

The worldwide cultural heritage of biotechnology is found predominantly in food and nutrition. The food intake of millions of people since time immemorial has been influenced by customary beliefs and cuisine skills indisputably associated with the dietary cultures of the Chinese, the Indian and the Persian-Arabic civilizations in the Southern hemisphere. The application of traditional knowledge, emerging from repetitive domestic practices, is

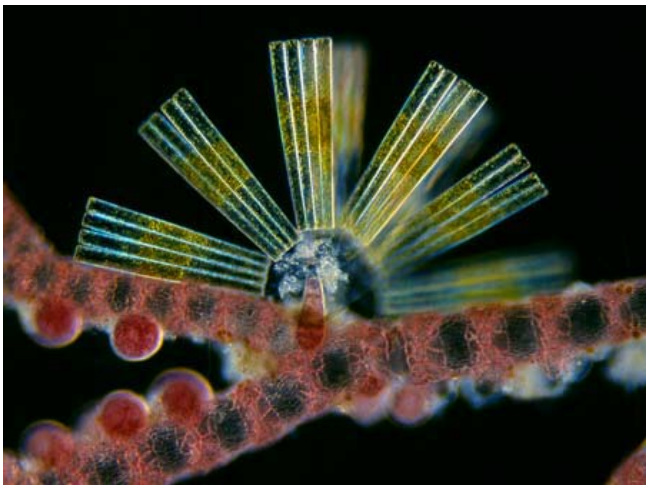


**Figure 3. Diatoms also live attached to a substrate.** These sessile diatoms can often be found as brown scum growing on red algae or other larger organisms. Reproduced with permission for educational purposes and not for commercial gain or profit. Image copyright: artist Wim van Egmond. It may not be reproduced without permission.

now associated with the use of a variety of rural fermentation processes in the preservation of food and food harvests. In addition, the incorporation of seasonings and spices has added to the flavours of fermented fish, meat and vegetable foods. Endowed with medicinal properties in some cases, and providing for easy digestibility, increased micronutrient content and enhanced food textures and tastes fermented foods like flags have become part of the national fabric and identity (Table 2). *Arak* (Lebanon, Middle East); *Champagne* (France); *Hama* (Syria) *Ikigage* (Rwanda); *Jben* (Morocco); *Kaschiri* (Brazil); *Cachiri* (Colombia); *Kimchi* (Korea), *Masata* (Mozambique), *Munkoyo* (Zambia), *Patagras* (Cuba); *Sake* (Japan), *Sauerkraut* (Germany), Surstromming (Sweden); and *Tairu* (Malaysi

**Table 1. Biotechnology and culture expressed through the painters' brush.**

| Artist | Origin | Title of work | Remarks |
|---|---|---|---|
| Hans Holbein -The Younger (1497-1543) | German | The Cheese Burgher | Reawakening of artists to fermentation and its products |
| Johannes Vermeer (1632-1675) | Dutch | Dough Kneaders | |
| Albrecht Dürer (1471-1528) | German | Great Piece of Turf, Die BioReaktore | Depicts frustrations of fermentation artists and lifelessness of life |
| Aubrey Beardsley (1872-1898) | British | The Frontispiece for A Gentleman's Guide to Conversational Art in Slurry Management | Illustrates concept of aseptic flow and operation |
| Katsushika Hokusai (17601-1849) | Japanese | Mt. Fuji Seen Behind a Cistern | Description of the hydrodynamic process |
| Vincent Van Gogh (1853-1890) | Dutch | The Artist's Room in Arles | Expresses need for automation in fermentation |
| Edvard Munch (1863-1944) | Norwegian | Headspace | Deals with foam control |
| Wassily Kandinsky (1866-1944) | Russian | Medium Composition IV (Algal Culture) | Organisms require different nutrients to thrive under artificial conditions; Uncannily "combines concept of agitation with the undiscovered structure of the helical genetic material" |
| Paul Klee (1879-1940) | Swiss | Red Ballon Inflated by $CO_2$ | Introduces air filtration and baffling; impeller shows production of ribosomal RNA in the nucleolus that was demonstrated 50 years later |
| Lyonel Feininger (1871-1956) | American | Many Valves | Anticipates CAD use in baffler design |
| Alberto Giacometti (1471-1956) | Swiss | Kultur Vessel | Gives outline of a wiry reactor that teems with the intricate life of it contents |
| Henry Moore[a] (1898-1986) | British | Relaxed Cell Mass | Duality of cell as fermentor and fermentor as cell |

| | | | |
|---|---|---|---|
| Piet Mondran (1872-1944) | Dutch | Arrangement | Develops black box and modular concepts of fermentation design |
| Henri Rousseau (1844-1910) | French | Eden Regained | Living rather than the technological aspects of fermentation emphasized |
| Marc Chagall (1887-1985) | French (Russian born) | The Brewmaster | "Fermentor and technologist become one" |
| Amedeo Modigliani (1884 -1920) | Italian | Impella | Significant contribution to vessel architecture |
| Salvador Dali (1904 -1989) | Spanish | Autumn Autolysis | Transition from growth to stationary phases resulting from nutrient depletion in growth medium |
| Juan Miro (1893-1983) | Spanish | Steel Life | "Anticipates, respectively, sterilizable biosensing and plant cell culture" |
| Jackson Pollock (1912-1956) | American | Rheology I4 | Produces a joyous carnival of mycelium and hydro-dynamics |

[a]Received a commission for the monumental Reclining Figure 1957-58 in Roman travertine marble (LH 416) for the UNESCO headquarters in Paris.

are all well known examples of the mix of human and microbial skills that constitute the cultural art and component in the production of fermented foods.

*"Bread has always held a central position on the historical scene. It is a never-ending source of inspiration, and a highly symbolic object that gives rise to great curiosity and provides a fruitful theme for creative minds"*

Lionel Piolãne[3]

## ZERO-EMISSION BIOTECHNOLOGY AND ENVIRONMENTAL ART

Cultural heritage and environmental-societal relationships are enriched by the palette and patterns of colours of the artist Mother Nature that have been locked into her sculptural art and scenic landscapes and that have been preserved in the corridorsof time for future generations. Environmental art with its calming, inspiring, soothing and uplifting therapeutics has also been used to make potent ecological activist and pictorial statements on issues of relevance to development, the environment, and poverty, etc

"*Since the turn of the Millennium, world concern over environmental issues such as pollution and global warming, species depletion, new genetic technologies, AIDS, BSE and foot-and -mouth epidemics has increased. Artists, in turn, are responding by answering collective cultural needs and developing active and practical roles in environmental and social issues*"

Clive Adam[4]

Environmental or ecoart[5] is about art, humanity and nature as exemplified in the biosphere reserves and multiple ecosystems. (Table 3) It is about aesthetics, biology, culture, chemistry, education, ethics, history, microbiology, physics, society and the environment and their interconnections with one another in the repertoire of Nature's heritage bequeathed to humankind.

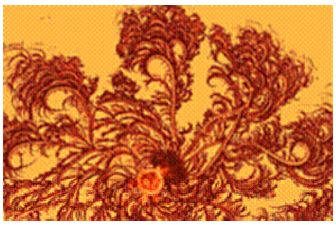
The increasing pace of technology in the early 1950s ushered in the era of a grey galloping industrial technology that utilized the brute forces of heat and temperature of a petroleum-based economy to feed the culture of consumerism, and by consequence the culture of waste. Smog and acid rain containing the atmospheric toxins of noxious gases soon made known their presence. The 3Bs of societal status –big, better, and bountiful--the credo of the age of consumerism brought in its wake damage to the environment, realization of the finite availability of fossil-based fuels and the inescapable truth of the rising costs of

the war against infectious diseases and malnutrition that were in metastasis mode emptying the bank of human health resources worldwide. The energy, economic and environmental security of the mid-1970s bear the scars of the use of oil as a weapon that paralysed and transformed the transportation sector, and that ironically gave birth to the concepts of the 3RS –reduce, reuse and recycle --that have become the foundation stone of zero-emission biotechnology in the framework of a carbohydrate-based economy that is rich in aesthetic, artistic, clean, green potential.

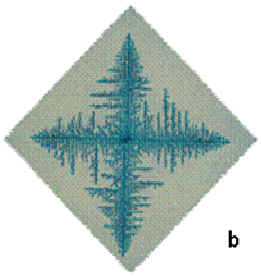
In this context and through the lens of hindsight, the series of the 10 Global Impacts of Applied Microbiology Conferences (GIAMS) organised in cooperation with UNESCO benefited from the wisdom of John Roger Porter (USA), Carl-Goran Heden (Sweden), Jacques Senez (France), Jan Wilhem Maurits la Riviere (Holland), and Hisaharu Taguchi (Japan) ---the undisputed scientific captains of international co-operation in the applications of microbiology for human welfare.

The GIAMS, as is now evident through evaluation and assessment of outputs, ushered in new grounds for research by students from the developing countries; and nudged the development of curricula by policy-makers in the emerging fields of environmental microbiology and geomicrobiology. Moreover, the series of these conferences attracted decision- and policy-makers to the human face of microbiology that was undergoing a transformation that was being influenced by the widespread application of innovative developments in environmental, food, industrial and medical microbiology. Blueprints and concepts for bioresource utilization, conservation of microbial germplasm, recycling of wastewaters, etc. aimed at sustainable development had already started to emerge into the agenda of international cooperation way ahead of the applications of the biotech revolution that was then being prophesised on the basis of new breakthrough fundamental research results with genetic engineering techniques.

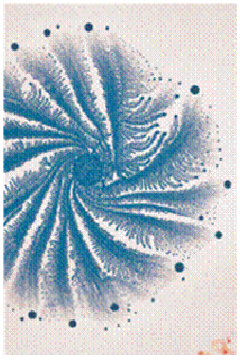
In the last decade of a 30-year-old period of unrivalled international collaboration with the international scientific community emerging pilots and widely respected scientists such as Kei Arima (Japan) and Rita Colwell (USA), and Indra Vasil (India/USA) would bring new vision in devising novel collaborative partnerships with UNESCO to deliver the applications of industrial and marine microbiology, and of plant biotechnology, that would significantly contribute to a reduction in the worldwide divide between the generators and users of biotech knowledge (Electronic Journal of Biotechnology, 2001).



a



b



c

**Figure 4a.Branching chiral organization of Paenibacillus dendritiformis[a].**

**Figure 4b. A colony of bacteria self-organize into a snow-flake-like shape.**

**Figure 4c. In extremely hard agar, Paenibacillus vortex bacteria congregate into tight, rotating vortices that cut through the growth medium like a circular saw.** The cooperative behavior allows the colony to grow outward; the saw's "teeth" are the dark dots at the end of each branch".

[a]Reproduced with the permission of Professor Eshel Ben-Jacob, School of Physics and Astronomy, Tel Aviv University, Israel. All materials are solely for educational purposes and not for commercial gain or profit. For further use contact: eshel@albert.tau.ac.il. Also see Bacterial Art Gallery in http://star.tau.ac.il/~eshel/.

**Table 2: Fermented foods consumed worldwide in different communities (adapted from (Kavanagh, 1994; Steinkraus, 1995).**

| Natural Inoculum | Product | Substrate | Use | Socio-cultural Feature |
|---|---|---|---|---|
| **Africa** | | | | |
| *Saccharomyces cerevisiae* | African beers from sorghum, maize or sorghum-maize mixes | Sorghum and maize | Alcoholic beverage | Sorghum beer -utshwala (Zulu) and utywala (Xhosa) popular with Bantu tribes working in gold and diamond mines |
| Lactic acid bacteria | *Talla* (tella) | Sorghum-maize-wheat, mix | Home-processed beer | Served in Ethiopian country-side wedding ceremonies |
| Fungal mix of *Aspergillus*, *Penicillium* and *Rhizopus s*pecies | Kenkey | Maize | Staple food | Popular with the working class Ghanaian coastal people –*Gas, Fantis* and *Ewes*; eaten for its nourishing value |
| Lactic acid bacteria | *Bussa* | Sorghum-millet-mix | | Popular with the Luo, Abuluhya and Maragoli people in Kenya |
| *Rhizopus oryza, A.flavus* and *Penicillium citrinum mix* | *Pito* | Sorhgum mash | Alcoholic/food beverage | Source of income for Guinean and Nigerian women who learn the art of domestic brewing during adolescence whilst preparing weekly supplies of this supposedly 'energy-providing' and medicinal drink |
| *L. mesenteroides* with lactic acid bacteria, etc. | Gari | Cassava roots | Staple food | Consumed as *eba* by Nigerian low-income groups |
| Lactic acid bacteria –yeast mix | Ogi | Maize | Staple food | Nigerian breakfast porridge prepared by low-income group housewives now being considered for rural markets |
| **Arab States** | | | | |
| Lactic acid bacteria | *Bouza* (Egypt) | Wheat | Wheat-based beverage | *Bouza* – once an ancient divine offering at funeral services, today consumed by lower-income groups |
| Lactic acid bacteria | Liban argeal (Iraq) | Milk | Milk food | Fermented milk |
| Lactic acid bacteria | *Merissa* (Sudan) | Sorghum-millet-cereal mix | Alcoholic/food beverage | Similar in production and use with *Bouza, Bussa,* and *Talla* |
| **Asia** | | | | |
| *Mucor purpureus* | Ang-kak | Rice | Colorant | Use dates back to Chinese *Yuan* dynasty |
| Aerobic bacteria | Bagoong | Fish (paste) | Seasoning | *Prahoc* (Cambodia); *Bagoon* (Philipiines); *Ngapi* (Mynamar) |
| *Leuconostoc mesenteroides, Saccharomyces* sp. | Dosai | Black gram and rice | Breakfast food | Indian pancakes widely popular with all income groups |
| *L. mesenteroides* | Idli | Mix of rice and black gram (3:1) | Rice cake | Staple part of vegetarian cuisine and diet |
| Aerobic bacteria | Mam | Fish or shrimp paste | Liquid seasoning | *Patis* (Philippines), *Nam pla deak* (Thailand) *Nuoc mam* (Vietnam) |
| *Aspergillus oryzae, Saccharomyces rouxii* | Miso | Rice and soybean | Seasoning | Traditional rural industry in Japan |
| *Bacillus natto* | Natto | Soybeans | Cake | Food supplied in military campaigns; supposed to have originated in Buddhist temples |

| | | | | |
|---|---|---|---|---|
| *Neurospora* species | Oncom | Peanut press cake | Meat substitute | Part of daily diet of the West Javanese |
| *L.mesenteroides* | Puto | Rice | snack | Essentially a Filipino food |
| **Europe** | | | | |
| '*Beer*' Yeasts | Beer | Barley and other starch substrates | Second worldwide staple beverage after tea | Beer-making reportedly associated with the Natufian culture; the oldest known recipe for making beer is written on a 4000 year old tablet in a hymn to the Sumerian goddess of beer *Ninkasi*; Jiu (aka *Kiu*) is an ancient Chinese beer over 4000 years old; The Sumerians are assumed to be the first civilized culture to brew beer |
| *Lactobacillus bulgaricus* | Bulgaricus butter milk | Low-fat milk | Food | National product; and the basis of Metchnikov's conclusion recontribution to prolongation of life |
| Lactobacilli-yeast mix | Kefir | Fresh milk | Food beverage | Use originating in the Caucasian mountains linked to the longevity of life amongst the peoples of Armenia, Azerbaijan, and Georgia |
| Yeasts | Kvass | Fermented rye or barley, or soaked and fermented dark rye bread | Low-alcoholic beverage | A national Russian drink; Ukrainian kvass made from beetroot is credited with beneficial medicinal properties |
| Lactobacilli | Sauerkraut | Cabbage | Food | "Sauerkohl", prepared in German homes as - a winter diet food now widely accepted and marketed un Europe an North America, was known in ancient China to have fed, seemingly, the armies of Genghis Khan |
| **Latin America and the Caribbean** | | | | |
| Lactobacilli-yeast mix | Chicha | Maize, sweet potatoes or ripe plantains | Alcoholic beverage | Characteristic of the Andes region (Bolivia, Colombia, Ecuador, Peru). This drink nowadays consumed at agricultural, family, social and religious events, was considered by "the Incas to be the vehicle that linked man to his gods through the fecundity of the earth" |
| *Leuconostoc* species | Pulque | Maguey cactus (*aka* agave or century plants) | Alcoholic beverage | National drink of Mexico inherited from the Aztecs who used it as an offering to the goddess Mayahuel |
| Lactobacilli | Queso Chaqueno | Milk | Food | Current cheese process has originated from the process used by the Jesuits in 16$^{th}$ century in Moxos Pampas of Bolivia |


**Figure 5. Stamp issued to commemorate the 1966 IAMS Conference in the then Soviet Union.** Source: http://www.stamprussia.com/3306b.jpg.

In UNESCO itself, the names of Michel Batisse (France), Anton Burgers (Holland), Maheshwar Dayal (India), Adriano Buzzati-Traverso (Italy), John Fobes (USA), James Harrison (Canada), and Federico Mayor (Spain) have become synonymous either with visionary science programming or the institutionalization of technological networking foresight in applied micobiology and the novel biotechnologies. Evidence of the fruit of such enterprising leadership and programming vision is resident in the number of extrabudgetary projects that were developed for Africa, the Arab States, Asia, Europe and Latin America within the framework of cooperation between UNESCO and several UN agencies and donor Member States such as Japan and the USA.

Long-term eco-aesthetic project activities illustrate the utility of the *four-in-one* technology that integrates the principles of biosolar power, conservation of the environment, sanitary engineering and village economy to yield a gaseous biofuel –methane derived from solid biomass residues and grey- and blackwater biowastes. These developments result from the well-known integrated biosystems such as the Maya Farms (Philippines) and the Xinbu village model (China). Such systems that utilize the 3Rs – reduce, reuse and recycle are at the basis of greenclean technology processes in developing novel "ecological gardens" or "eco-courtyards" (Figure 1) that bears witness to the transition from the "creative waste" culture, resulting from the galloping growth of the corporate food industries, to the culture of commonsense in the use of non-renewable and renewable resources concerning the production of the 5Fs: Food, Feed, Fibre, Fuel, and Farmaceuticals.

## MICROBES AND CULTURAL HERITAGE

The Convention for the Protection of the World Cultural and Natural Heritage adopted by the UNESCO General Conference in 1972 provides a legal mechanism that helps to ensure the safeguarding of tangible heritage inclusive of cultural monuments, cultural and natural sites, and cultural landscapes for future generations. This cultural and tangible heritage however is at times open to deterioration, decay and discolouration resulting from metabolic processes of microbial entities and other biodeteriogens. The entire domain of the intangible component of cultural heritage comprised of the treasurehouses of the arts, the crafts, and the customs such as languages, songs, rituals, and agricultural, ecological and rural technical crafts, and ancestrally transmitted from generation to generation through several centuries is seemingly not covered by the Convention.

The time-honored classics "The Microbe Hunters and Three Centuries of Microbiology" reveal the role of microbiology in the internationalization of science and of research education. Developments in modern-day biotechnology have given rise to new frontiers in agriculture, medicine, ethics, biosafety, industry, intellectual property, legal obligations and cultural heritage (Brady, 1997; Brodwin, 2000; Ciferri and Tiano, 2000; DaSilva, 2003). Works of art ranging from buildings to books, wall paintings to textiles, and from sculptures to glass etchings are globally subject to defacement and degradation by microbial action. Environmental pollution takes it toll notwithstanding geographic location or gross domestic product country-status.

Use of miniaturized biosensors and molecular biology helps detect microbial activity associated with destruction of cultural assets -paintings and works of art, historical buildings and monuments in stone and marble (Pinăr et al. 2001). The appreciation of cultural heritage and cultural property gains in time through use of information technology and biotech probes to monitor biodeterioration in safeguarding ancient cave paintings, stone mural graphics and subterranean mosaics. Innovative biotech-based approaches are now being designed to safeguard and conserve the archaeological, artistic and cultural heritage of Europe (Table 4).

The conservation of the planet's cultural and physical heritage ironically is to be found in the dual physiological role of microbial influence. Biodeterioration and bioconservation involve methods that identify microbial entities that cause bio-structural damage and deterioration; and, that use microorganisms to reduce, prevent, bioremediate, conserve and restore cultural property and heritage. Often these efforts are accompanied by studies on the molecular aspects of ageing of paints used several hundred years ago. Bacterial intervention has been used recently in Italy to restore a medieval fresco that was glue-hidden some fifty years ago (Arie, 2003). *Pseudomonas stutzeri* has been used successfully in the biorestoration of the fresco "Conversion and Battle of St. Elfisio" by the artist Spinello Aretino in the Camposanto cemetery begun in 1278 by Giovanni Simone in Pisa. The bioremediating potency of the bacterium is now being envisaged

**Table 3. Examples of the range of environmental art**

| | | |
|---|---|---|
| **Research Project** | | |
| 2002<br><br>Greenmuseum Online Exhibition with annual updates | From the Mojave Desert. Moisture – project members Claude Willey, Deena Capparelli, Bernard Perroud, Adam Belt, Mark Tsang, SE Barnett and Kahty Chenoweth | "An experimental research project undertaken by a Los Angeles-based artist collective to monitor and develop location-sensitive structures for the collection, retention, and use/re-use of water in the Mojave Desert"; millions have lived without love. No one has lived without water. Turkish businessman[a] |
| **Workshop** | | |
| 2003, September<br><br>University of Art and Design Helsinki, Helsinki, Finland | Fermentation workshop/seminar organize by the Environmental Unit, Department of Art, (Uiah, 2003) | Use of Fermentation as a metaphor describes contemporary issues such as "the fusion of the mass media and the encounter of different languages and cultures" |
| **Solar Energy Art** | | |
| 1989 -2003<br><br>Ancient monuments, architectural installations and public buildings in Germany ,Italy, Northern Ireland, UK,USA | Solar Spectrum Environmental Art called Secrets of the Sun – Millennial Meditations (Clarke, 2001) that "uses the emotional impact of art to address the full range of nature from its most elemental expression as pure light to its most complex expression as global ecology" was created by Peter Erskine (1989-1992)[b] | "all human life and our useful inventions are totally dependent on the delicate balance of Nature - our life support system. In addition to it's aesthetic value, I want to use the emotional impact of my art to wake people up about our global ecological crisis" |
| **Waste Management** | | |
| 1999, April- July<br><br>Ontario Art Gallery, Ontario,<br><br>Canada<br><br>(www.absolutearts.com/artsnews/1999/07/09/25575.html | Waste Management—featuring art work by Tom Freidman, Germanie Koh,Michael Landy, Danile Olson, Sandra Recchio, Joseph Scanlan, David Shrigley and Kelly Wood | Through sculpture, drawings, etc. Waste management deals with the attitudes and values of the disposable and recyclable materials encountered in contemporary culture. A sort of a transition from Homo consumens to Homo conservans and Homo recyclans |
| 2003, December – 2004, February<br><br>Govett-Brewster Art Gallery, New Plymouth,<br><br>New Zealand | Bloom: Mutation, Toxicity and the Sublime featuring: Hany Armanious, Christine Borland, David Hatcher, Tamami Hitsuda, Eduardo Kac, Denise Kum, Jun Nguyen-Hatsushiba, Susan Norrie, Motohiko Odani, Saskia Olde Wolbers, Patricia Piccinini, Magnus Wallin | Explores environmental damage resulting from heavy metal dumping and use of Agent Orange; genetic engineering and its representation in literature in film and literature |

| | | |
|---|---|---|
| | and Boyd Webb | |
| **ZeroCircles Art Project** | | |
| 1998 -1999<br><br>Interspecies Inc[c] | ZeroCircles by Daniel Dancer[d] | Project activity "is a strategic blend of art, spirit and environmental politics". The "zeros signify an end to commercial extraction on public lands" and as circles "zero pollution, zero waste, zero population growth, zero cut on public land" and "humankind's oldest symbol of wholeness and empowerment" |

[a] See http://moisture.greenmuseum.org/about.html for details on project phases.

[b] See http://www.erskinesolarart.net/peter.html for further information on international exhibitions and permanent installations.

[c] A research program that provides creative opportunities to interact directly with wild animals, and habitat through music, art and ceremony (http://www.interspecies.com/).

[d] Shards and Circles, Trafford Press, Manchester, 1990, 258 p. and ZeroCircles in Interspecies Newsletter, Fall 1998 by Daniel Dancer.

for use in the biorestoration of damaged fresco work in 1330 by Taddeo Gaddi, Francesco Traini and Bonamico Buffalmacco.

## BIOTECHNOLOGY AND ART

The pursuit of science has been a significant factor in the evolution of art. Salvador Dali, Alexis Rockman, Mark Francis, Susan Rankaitis and the sculptor Tom Otterness were inspired by the discovery of the DNA molecule that is now an icon in the arts and the sciences (Gamwell, 2002a, Gamwell, 2002b). Leonardo da Vinci (1452 - 1519) is widely acknowledged for his mastery of science and art in his documentations of the human body. Indeed medical illustration and instruction derives from dissection and deduction as exemplified in the accurate and visionary classical "*De Humani Corporis Fabrica*"of Andreas Vesalius in 1543 (Dalke, 2003).

Harmony with nature provides an insight into natural microbial and biotechnical architecture –the cultural face of biotechnology (Ben Jacob, 2003) and into the structural ethics of creation of novel forms, and by consequence to the need for technical communication and peace with different cultures and peoples through the medium of environmental art and peace (Uiah, 2003). Current biotech controversies concerning biotech-derived food and feed products indicate that information and understanding will have no role in the fate of biotechnology which will be "based on the ideological beliefs and the cultural values adopted by individual human beings who, in turn, will shape societal beliefs and values" (Kershen, 1999).

### Biotechnology and cover art

The arts and its components – the audiovisual word, digital art, music, paintings, sculptural art and works of prose and verse constitute a powerful medium for an appreciation of the culture of fermentation (Hodgson and Bormann, 1988). They contribute to the evolution of the human face of biotechnology and its significance for peace. Through the world of colors, drawings and paintings that emphasizes the cultured face rather than the delinquent side of humanity, biotechnology emerges to motivate and to inspire, and to appreciate the interphasing of culture in science and vice-versa through the looking glass of art (Figure 2).

Several leading and prestigious scientific periodicals have employed this modality to attract and educate the young, and to alert and instruct policy-makers in the biotech issues of the day that will impact on the sustainability of future environmental, economic and socio-cultural development for human welfare. An apt example, a novel potential teaching aid is the cover commentaries of Potter (2003)[6], amongst others, that reinforce the work of time-honored exponents of the arts ---- Jacques-Louis David, Henri Matisse, Pablo Picasso, Vincent van Gogh, etc., with the scourge of new and re-emerging diseases. Some of these emerging diseases result from the practices of domestication of animals and subsequent cohabitation with them as pets thus requiring periodic surveillance and epidemiological monitoring. Similar biotech art work is portrayed on the covers of the periodical dealing with beer with brewing techniques[7].

### Bioart

Notwithstanding that the intertwining of the world of culture with that of laboratory cell culture has its critics


**Figure 6. Stampsissued in the Musée de la Poste de Paris commemorating the inventors of the fundamental biotechnological processes of Appertisation and Pasteurisation.** Stamps in the Musée de la Poste de Paris commemorating Nicolas Appert (1749 - 1841) postage stamp designed and engraved by Henry Cheffer, 1955 (all rights reserved) and copyrighted Musée de la Poste de Paris; Louis Pasteur (1822 - 1895) postage stamp designed and engraved by Jacques Gauthier, 1973 (all rights reserved) and copyrighted Musée de la Poste de Paris; In: Geniuses with Postage Stamps.

(Nadis, 2000), interest in the expression of biotechnology in the form of art is on the increase. Art galleries and exhibitions of paintings and electronic bio-art are eloquent witnesses of the "odyssey in art in science" (Palevitz, 2002) as the biotechnologies and "bioscience moves into the galleries as bioart" (Cohen, 2002). "Microorganisms in Art" was a prominent event of a joint meeting off the Australian and New Zealand Societies for Microbiology that focused on blending the art of microbial research with the art and culture of New Zealand (MicroNZ, 2003).

"*A monkey is a machine that preserves genes up tree, a fish is a machine that preserves genes in water; there is even a small worm that preserves genes in German beer mats. DNA works in mysterious ways*"

Richard Dawkins[8]

Bio-art[9] captured naturally through the implement of time in rock and stone is proof of the artistic genius of Mother Nature's creations and filigree handiwork in once living invisible microbial forms.Witness to the test of time, fossil biotechnology like genetic and microbial art involves the merging of the frontiers between art and science. The paleontological unveiling of the structural mysteries and symmetries of microbial and planktonic life provides an insight into what early microscopic life and its milieu in the Proterozoic-Phanerozoic transitionary (Seilacher, 1997). One such natural legacy bequeathed for future artistic and scientific research is the world of diatoms the priceless "jewels of the sea" that embody in their morphology myriad concepts of geometrical designs and kaleidoscopic forms that can only serve to excite and stimulate artistic minds in deciphering the cytoarchitectural handiwork of Mother Nature (Figure 3).

Biosci-art, indeed, varies in scope and range (Table 5). Also known as bio-art, it excites, intrigues, questions, teaches and unifies opinions and viewpoints as humanity moves forward through the motor of biotechnology. The forms of expression of biological art are many ranging from bank notes and stamps to works of art such as electronic games, music, paintings, sculpture and tapestries. For example, the visual Art and Exhibitions initiative of the Philadelphia International Airport (2003) is designed to humanize through sculptural works the airport environment and its "terminals in enhancing and enriching the cultural experience of the public travelling via Philadelphia". For example at Terminal F, concourse 1, jewelry made exclusively from dried plant material, "an art for that was introduced to this region at the 1996 Philadelphia Flower Show" has been an exhibit.

"*'Genesis' is transgenic artwork that explores the intricate relationship between biology, belief systems, information technology, dialogical interaction, ethics and the Internet*"

Eduardo Kac[10]

Bioart reinforces science, helps in the social interpretation of the pros and cons of *genesciernce* through the "theater of transgenics"; and, is of value in engendering public awareness and in functioning as a teaching and research in academic course work (Neave, 2002; O'Reilly, 2003). Moreover, bioart provides an aesthetic appreciation of scientific research and an environment that is pertinent to the conduction of high-level mental activity (Kemp, 2003).

The expanding world of bioart and of DNA aesthetics (Cohen, 2002; Kemp, 2003) has seemingly arisen from the work of pioneers in genesthetics (Davis, 2003), synthetics,

**Table 4. Innovative strategies for conservation of cultural heritage in Europe.**

| Acronym | Project Activity/ Strategy |
|---|---|
| ASSET | Assessment of suitable products for conservation treatments of sea-salts decay - focus on identification and selection of suitable productsto isolate sea-salts trapped in the pores of European historic buildings that may be exposed to sea-salts (sea flooding, rising damp and marine spray); and to and prevent further penetration as a means to safeguard the historic buildings |
| BACPOLES | Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and shipwrecks -aims to better understand bacterial degradation of wooden foundation poles and archaeological sites in soil or water in anaerobic or microaerophilic conditions. The project will initially rely on a study with wood-attacking bacteria using advanced molecular DNA biology techniques for the prediction, diagnosis, and curing environmental damage through possible use of specific bacterial phages under strict controlled conditions. Techniques developed could be of significance in the conservation of historic buildings |
| BIOBRUSH | Bioremediation for Building Restoration of the Urban Stone Heritage in European States - focus on identification of appropriate non-pathogenic microbes capable of destroying mineral salty crusts, and of other bacteria that in reverse action produce “bio-calcite” consolidating stone materials |
| BIODAM | Inhibition of biofilm damage on mineral materials - Study of incorporated protective chemicals such as biocides, cell wall conditioners, etc. into biofilm communities damaging rocks in European heritage buildings. A major issue is the targeted cracking of resistant biofilm organisms and extracellular deposited polymeric substances |
| BIOREINFORCE | Bioremediated calcite precipitation for monumental reinforcement - Optimal use of scientific methodologies developed for the conservation of monumental and historic buildings to reduce the inevitable risk of stone damage as a means to due to decreasing the costs of maintenance.<br><br>The application of aqueous soluble natural product with consolidating properties helps strengthen the weathered stones, minimizes loss of stone material, safeguards against colour changes, crust formation, glossy appearance, and contributes to the safety of the working conditions of technical staff |
| CATS | Cyanobacterial attack of rocks: Control and preventive strategies to avoid damage caused by cyanobacteria and associated microorganisms in Roman hypogean monuments - Control and preventive strategies focus on the conservation and restoration of the Roman hypogea that is part of the Cultural Heritage of Europe. Elimination and eradication of the metabolic activity of cyanobacterial biofilms, that leads to the biotransformation and biodecay of substrata and to severe damage essentially of calcareous substrata, helps to preserve important sites of archaeological and touristic significance as well as to improve the quality of life and the sustainable management of the artistic patrimony of Europe and more particularly the Mediterranean region |
| COALITION | Concerted action in using molecular microbiology as an innovative conservation strategy for indoor and outdoor cultural assets - Provision of updated information and novel micro-analytical molecular biology techniques to scientists, conservators, restorers and other end-users to protect against microbial destruction of monument stones, statues, mortars, bricks, and the biodeterioration and decay of mural paintings, tapestries, woods, glass, paper, etc., and to arrest and overcome in the loss of European cultural assets and |

| | |
|---|---|
| | heritage |
| PAPYLUM | Chemiluminescence as a novel tool in paper conservation - Development of a new prototype instrument with non-destructive sampling and data evaluation data properties to predict paper lifetime and rate of degradation of paper -based library materials to make more adequate existing conservation treatments; and. to plan future conservation strategies for orientation of thousands of European libraries and archives in the use of the best practices in this field |
| VIDRIO | Prevent weathering due to condensation particle deposition and microorganism growth on ancient stained glass windows with protective glazing - Identification and improvement of the best practice to preserve, in their original context, ancient stained glass windows exposed to environmental variables and mass tourism. Scientific research will be done for the Sainte Chapelle of Paris and St. Urbain's Church in Troyes (France) and the Cathedral of Cologne (Germany). Sainte Chapelle and the Cathedral of Cologne are in UNESCO's World List of Cultural Heritage. The VIDRIO project will provide a global, multidisciplinary framework, for the first time, to study from a physical (microclimatic conditions), chemical (glass surface deposition and corrosion) and biological (microbial contamination and population growth) aspects of the deterioration process of stained glass and the efficiency of protective glazing without neglecting the aesthetic and artistic aspects |

Source: Basztura, 2003.

and in the deciphering of the artistry of microorganisms that during colony development (Figure 4a, b, c) and under different environmental conditions produce a wealth and variety of scenic patterns that structurally mimic the natural structural beauty of snowflakes, etc. (Ben-Jacob, 2003). Perhaps, in the coming years, UNESCO's list of Digital Art Awards could be meritoriously enriched through the giving of consideration to the range of bio-art that has now come to be, in some cases an integral component of academic endeavor, and in other cases a key component of the artistic expression in facilitating the advancement and understanding of science.

Biosci-art can also be found on stamps and banknotes. In fact virtually every country has issued stamps that capture for posterity the range and wealth of plant and animal biodiversity as a tool for young scientists attracted by the modern fields of conservation biology and biotechnology. The pioneering work of microbiologists in preventive medicine worldwide in Belgium, France, Ghana, Hungary, India, Japan Peru, Portugal, Spain and Uruguay has been honoured philatelically (Doty, 1975). Microbiology meetings have been commemorated on stamps (Figure 5). Nicolas Appert and Louis Pasteur, pioneers in microbiology (Figure 6), and the fundamental discoveries of eight Nobel Prize geneticists (Figure 7), amongst many others, now constitute the artistic, cultural and scientific heritage of humanity. Biotechnology on stamps is science and culture across frontiers *via* land, sea and airmail providing a momentary inducement to participate in the enquiry of the biosciences; and artistic appreciation of international science and culture. Stamps also serve to educate and to make the public aware of the culture of fear and terror provoked by disease and its impact on human resources. The microbiologist Robert Koch has been honoured on stamps for his investigations and discoveries on stamps in Belgium, Germany, Romania, Sweden, etc. Savona-Ventura, 1997 has described the important role played by postage stamps in tracing and recording Maltese medical history. More recently, the United States Postal Service issued a stamp to focus national attention on the Acquired Immune Deficiency Syndrome In like manner, the UN and UNPA released in October, 2002 a set of stamps on AIDS Awareness to mobilize funds to combat and control the epidemic. The UN Global Fund for AIDS, Tuberculosis and Malaria will benefit from the sale of the UN commemorative stamp.

Like stamps, banknotes are more than just a medium of exchange of money. Currency notes promote a sense of solidarity in national and international participation vis-à-vis technological achievements. Apart from conveying messages of a nation's history, political and social advancements, banknotes are records of artistic, cultural and scientific contributions of human endeavor in the cause of bettering the quality of life of humankind. The labors of Oswaldo Cruz, Paul Ehrlich and Louis Pasteur are examples that have been recognized on national banknotes as integral components of the techno-cultural heritage of their respective countries (Figure 8).

## Making the invisible visible and conservation of microbial heritage


**Figure 7. The Nobel Stamps of 1989.** The stamps of eight geneticists and Nobel Laureates (Physiology or Medicine) were engraved by *Martin Mörck* after originals by *Göran Österlund*. And printed by recess/offset at the PFA. The FDC illustration is by Göran Österlund and the postmark is by Jan Magnusson; copyrighted 1989, Sweden Postal Stamps. The discoveries presented are using fruit flies Thomas H. Morgan showed how the genes are linked in the chromosomes (1933); James. D. Watson and F.H.C. Crick solved the riddle of the molecular structure of DNA with the aid of M.H.F. Wilkins diffractogram. The DNA molecule contains the genetic material storing hereditary information (1962); Werner Arber, Daniel Nathans and Hamilton D. Smith (1978) discovered the enzymes with which it is possible to cut a DNA molecule in predetermined places. If DNA molecules are cut from different animal species, the ends can be joined together to form hybrid DNA molecules; Barbara McClintock (1983) discovered how genes sometimes change places on the chromosomes, the so called "jumping genes".

Culture collections of microorganisms are storehouses of microbial germplasm and to a very great extent mimic natural conditions in which microbes exist and engage in their routine well-honed metabolic symphonies and orchestras of enzymatic action. Notwithstanding the unravelling of the natural genomic blueprints of microorganisms of economic, medical, environmental and industrial significance the challenge in the immediate future is to attract young researchers to the cause of research in taxonomy, biosafety, and biosecurity. Utilisation of biosci-art which captures the time-development of bacterial growth (Salleh, 2000) and colony enlargement (Raichman et al. 2003) could provide an incentive in attracting potential curators and researchers to further investigate the artistry of novel microbial species as in Box 1.

Bioluminescent bacteria have been used by a team of artists and researchers at the Montana State University to illustrate through living and glowing–in-the–dark bacteria the richness of shapes and clusters formed by microbes in biofilms (Table 5).Similarly the use of bioluminescent dinoflagellates (*Pyrocystis fusiformis*) and fungi (*Amillaria mollea, Mycena chlorophos*,) in innovative introductory courses could help attract young students to curate the specialized study of fungi and protozoa. Furthermore, the palette of natural and colourful pigments of microbes in bacterial art and paintings as employed by Sir Alexander Fleming has the possibilities of functioning as an attractive teaching tool in general microbiology and environmental microbiology (Adams and Hendry, 2002). And, the changing hues and patterns of Winogradsky's column are witness to the natural creativity of art by the different and varying populations of photosynthetic bacteria and other pigmented species that coexist in the revelation of the artistic side of the microbial world.

Students and researchers in culture collections have much to gain from the painstaking and meticulous work by the artist Wim van Wegmond using 3D photomicrographic and stereoscopic microscopy that provide valuable insights into the world of the miniscule living and invisble forms. The beauty of *Noctiluca scintillans* and *Volvox aureus* are online display in the Institute for the Promotion of less than One millimeter and the Micropolitan Museum of Microscopic Art.

## Biotechnology in Literature, Cinema and TV

Much has been written about microbes and genetic engineering. Hilaire Belloc commemorated the microbe and its features in a well-known poem in 1897. In prose the themes and artistic works are many ---*i.e.* the warnings of the advent of fictional chimeric forms and the dangers of genetic engineering, etc., by:

- Michael. Crichton (The Andromeda Strain, 1971) – foretells the advent of a deadly virus).
- Michael Crichton (Jurassic Park, 1991) - remote tropical island on which dinosaurs have been cloned by extraction of DNA from the stomachs of Mesozoic insects preserved in amber).
- W.Gibson (Necromancer, 1984) - biotechnological manipulation of people in the service of dubious corporate interests.
- J.B.S. Haldane (Daedalus,1923) – human development outside the womb or through ectogenesis.
- Aldous Huxley (Brave New World, 1932) – human production line.
- Ira Levin (The Boys from Brazil, 1978) – aims at cloning multiple clones.
- Stan Lee (X-Men, 2000) created in comic book format in 1963 in which gifted humans -'The Mutants' help the marginalized and persecuted in society. In: the movie Professor Charles Xavier's students—Storm, Cyclops, Phoenix, Rogue, and Wolverine are all "mutants" whose scrambled DNA gives them superpowers to combat the bad-guy mutant Magneto.

**Table 5. Some examples on the scope and range of bioart.**

| Year | Art Exhibit/ Description | Remarks |
|---|---|---|
| **Bio-Art Exhibitions, Festivals, etc.** | | |
| 1986<br><br>Exhibition, Westpac Gallery of Victoria Arts, Centre,<br><br>Melbourne, Australia | The Brew ('Upstream') and The Wash ('Downstream') by Jan Senbergs | Commissioned by the Commonwealth Serum Laboratories in celebration of its 70th Anniversary which with his other works and photographs by Mark Johnson capture "the vivid celebration of the arts, science and industrial-scale biotechnology" |
| 1991<br><br>National Museum of Natural History, Smithsonian Institution, USA | Seeds of Change: A Quincentennial Commemoration. The Seeds of Change exhibit is named for five "seeds" --corn, potatoes, sugar, diseases and horses that through their key roles in initiating changes 500 years ago shaped the course of human history in the Americas; and altered the lives of people around the world | Commissioned by the Smithsonian Institution to capture the biological and cultural impacts - of the encounter between the Old and the New worlds. Panel versions of "Seeds of Change", are co-sponsored by the American Library Association and the Smithsonian Travelling Exhibition Service (SITES) |
| 1999<br><br>Roche Molecular Biochemicals Exhibition[a] | The Art of Biochemistry (where science meets art) by Manfred Kage | Commissioned by Roche Molecular Biochemicals with impressive pictorials of bio-chemical and enzymatic products used in industrial applications |
| 2000, April<br><br>Exit Gallery, Montana State University-Bozeman,<br><br>Montana, USA | Bioglyphs by artists Robert Royhl and Sara Mast with researchers Betsey Pitts, Phil Stewart and graphic artist Peg Dirclox | "A collaboration created by the MSU-Bozeman School of Art, the Center for Biofilm Engineering and billions of bioluminescent bacteria" |
| 2001<br><br>The Saatchi Gallery Eyestorm Collection[b],<br><br>London, UK | Several paintings in the 1990s: Negative; Elements; Growth Series; Pulse 2; Symbiosis; Bifurcation by Mark Francis | Paintings modeled on the scientific images of microbiology - using microbes and magnified cells |
| April<br><br>Henry Art Gallery, Seattle, Washington,<br><br>USA | Gen Terra by Critical Art Ensemble (CAE)[c], Gene(sis) | Premiere of "Participatory Transgenic DNA Performance" -Exhibition of Contemporary Art that explores human genomics through an arts-based public dialogue |
| June<br><br>New York Museum, New York, USA | GenTerra | Audience participation in lab practices using genetic materials and DNA recombinant technology to grow transgenic bacteria |
| September | Radioactive Biohazard: Reinterpreting Biotechnology as Art by geneticist and | Interpretative aid to obtaining a better understanding of science through art |

| | | |
|---|---|---|
| Warren Robbins Gallery, University of Michigan, Michigan, USA | artist Hunter O'Reilly[d] and MARJ Inman of Electric Eye Neon | using fluorescent micrographs of actual cells and microbes |
| October- December<br><br>Coroccan Gallery of Art, Washington D.C., USA | Molecular Invasion, by CAE with Beatriz Da Costa and Claire Pentecost | Collective participation and will attempts to reverse genetically modified crops |
| October/November,<br><br>Gallery Oldham<br><br>Manchester, UK[e] | Clean Rooms: Art Meets Biotechnology Exhibition by the Arts Catalyst- (Silvers Alter - Gina Czarnecki; Gen Terra - CAE; Uncontrolled Hermit - Neil White and From Farm to Pharm - Brandon Ballengée) | Societal and ethical issues of biotechnology dealt with through art works, computer graphics and performances that explore perceptions of clean room environments, containment, evolution and transgenics |
| 002<br><br>June, Exhibition<br><br>Best Western Hotel<br><br>Greifswald, Germany | Biotechnicum by Myrtle Clark Bremer | Images of marine microorganisms at International Conference 'Natural Products from Marine Microorganisms' organized by the Institute of Marine Biotechnology with support from the European Society for Marine Biotechnology |
| 2003<br><br>February (online)<br><br>Rudolfov, Czech Republic[f]<br><br><br>July –Townshend International School, Hluboka nad Vltavaou, Czech Republic | Dialogue of Science with Art by Civic Initiative Group<br><br><br><br><br>Science and Art, Bridge of Minds-Dialogue of Cultures | Initiative created to bridge the communication gap between artists and scientists. Goals were: 1) discovery of artistic inspirations in the organic and inorganic worlds; 2) to discover the joy of creativity and knowledge in the science=art equation |
| March - May<br><br>Art Biotech Exposure, Nantes, France | Genesis - biotech art from Eduardo Kac[g] (Brazil/USA); Symbiotica[h] /Tissue Culture and Art (Australia); George Gessert[i] (USA); Marta deMenezes[j] (Portugal); Joe Davis[k](USA); Marion Laval-Jeantet and Benoit Mangin[l] (France), etc. | A collection of works that capture the aesthetics of natural systems in creative art that mimics godlike power and facilitates acceptance of les studios biotechnologiques |
| April - August 2003<br><br>TwoTen Gallery,<br><br>Welcome Building, London. UK | Four Plus: Writing DNA - celebrating the 50th anniversary of the discovery of the structure of DNA by ten artists: Kevin Clarke, Jessica Curry and Dan Pinchbeck, Richard Dedomenici, Gair Dunlop, Ruth Maclennan, Penny McCarthy, Gonzalo Páramo Pino and Graeme J. Walker | Commissioned by the Wellcome Trust an exhibition that with a focus on James Watson, Francis Crick, Rosalind Franklin and Maurice Wilkins shows new perspectives in the discovery of DNA; and that captures the social history and passion of science |
| June – August<br><br>Natural History Museum,<br><br>London, UK | Work by Critical Art Ensemble CAE with Beatriz DaCosta | CAE presentation gives public an opportunity to decide upon the pros and cons of transgenics and to even create their own GMOs |

| | | |
|---|---|---|
| June – September,<br><br>Schirn, Kunsthalle Frankfurt,Germany | Free Range Grain by CAE with Beatriz DaCosta and Shyh-shiun Shyu[m] | Designed as a "live performative, conceptual art project for a European audience to examine" (if the EU can maintain it's borders' in a relationship of "(gene-contaminated)" commodity and borders in a global economy" |
| 2003, December – 2004 (February)<br><br>Govett-Brewster Art Gallery<br><br>New Plymouth,<br><br>New Zealand | Gene Pool by Len Lye | Works from the Len Lye Foundation Collection with considerations of nearly "the direct transposition of the chemistries of generic information" |
| *Games* | | |
| 2003, May<br><br>Presentedby Creative Time with Hamaca and released by Natalie Bookchin | Metapet - a world (with socioethical implications) in which an uncooperative worker is replaced with a genetically - engineered human | The world's first transgenic virtual pet game in which biotech resulting from biotech innovation in which genetic engineering and the culture of corporate creativity give rise to novel pets[n, o] |
| *Paintings* | | |
| 1992<br><br>Amoeba Art Incorporated Enon, Ohio, USA | The Last Supper, Mona Lisa, David, Summer's Day at the Park, Much Ado About nothing, etc. - by artist /microbiologist Vincent Lessar and Armin Forte | Total integration of art and science is achieved in aesthetic unicellular microscopic slide paintings that result from use of extensive scientific research and skilled microscopic techniques[p] |
| 1998<br><br>6th Annual Digital Salon, School of Digital Arts, November, New York, USA | Transmission Helix; Manhattan Microbes, Helicopter Microbes, and Airplane Microbes - created in 1997 and 1998 by Ale Heilner, New York-based artist and educator | "This series of 'microbe images' seeks to invert traditional understanding of internal and external environments[q] |
| 2002, February<br><br>Natuurmuseum Rotterdam<br><br>Rotterdam, The Netherlands | Group Portrait of[r]<br><br>Microorganisms by Wim van Egmond | Emphasizes the role of Microorganisms and the variety of life in Nature's museum of biodiversity |
| 2003, April<br><br>New York Academy of Sciences Exhibition | Secret Agents: The Microbe Paintings by Suzanne Joelson | Exhibition of 11 paintings that makes art through the microscope of aesthetic colours out of invisible microbes often feared[s] |
| April – August<br><br>TwoTen Gallery | Four Plus: Writing DNA | Exhibition celebrating the 50th anniversary of the discovery of the structure of DNA |
| October<br><br>Art Gallery, Genome News Network | Dabbling in DNA[t] - describes some 25 paintings by Luis Soriano –aka as Negro da Ponte (Argentine/France) | Paintings done between 1974 - 1976 captured the abstract aesthetics of the DNA molecule |
| November | Petal Power in Monkey flowers[u] - describes observations by H.W. | Focuses on colour relationships between the birds and the bees |

| | | |
|---|---|---|
| Art Gallery. Genome News Network | Bradshaw Jr. and D.W. Schemske | |
| ***Sculptural Works*** | | |
| 1991<br><br>Smithsonian Institution, USA | Spaghetti Meets Tomato by Roark Gourley in Seeds of Change: A Quincentennial Commemoration | Commissioned by the Smithsonian Institution, the 3-dimensional wall sculpture captures the food and cultural perspectives of an historic meeting of two worlds |
| 2003<br><br>Philadelphia International Airport | a) The Balance of Nature by Steven Donegan is based on microorganisms that have been “enlarged and reinterpreted in copper” (Terminal B).<br><br>b) Animal Instincts captures the reality of nature in porcelain by Linda Cordell (Terminal E) - Philadelphia International Airport (2003) | Seemingly, such exhibitions provide and quiet and soothing environments conducive to reducing stress-related conditions |
| August 2003 - April 2004<br><br>Creative Time presents Peace as part of the Art on the Plaza series at The Ritz-Carlton New York, Battery Park, USA | *Peace by Zhang Huan in which* a large bronze bell (inscribed with the names of the artist's ancestors from his native Chinese village) hangs next to a gilded life cast of the artist's rigid perpendicular naked body carrying naturalistic details such as creases in the skin and strands of hair | *Peace* explores ancestral history and ethnic assimilation whilst embodying the relation of experience to environment, identity to culture, and body to spirit through performance, photography, and sculpture |
| 2003, November - February, 2004<br><br>Singapore Expo, Hall 1 | Bodyworlds by Gunther von Hagen | Uses plastination - a process that solidifies body tissues and preserves form and colour |
| **Miscellanea - Humour, Language, Opinions, Views, etc.** | | |
| 1979, November 10-11<br><br>The International Herald Tribune (IHT) | World’s Oil Supply May be Eaten Away by Art Buchwald | Humoristic article following Supreme Court agreement to decide whether one “can patent a new life form created by man in laboratory” |
| 1996, November 28<br><br>The International Herald Tribune (IHT) | Ok., I’ll Talk Turkey by Art Buchwald | Relates the origin of a food tradition on “le Jour de Merci Donnant” for French readers |
| 1997, May 29<br><br>The International Herald Tribune (IHT) | Literature and Lepidoptera by Steve Coates | “Butterfly specialists sing the praises of the Nabokov blues” |
| 2000, July 23<br><br>Denver Post (DP), Miami Herald (MH), and The International Herald Tribune (IHT) | Genetics is a funny business (DP); and as Cracking the Code ( in MH and IHT) by Dave Barry | Humoristic article with focus on significance of DNA |
| 2003, November 15-16<br><br>The International Herald Tribune (IHT) | It’s Flu Season Again, So Get Your Snail Shot | Humoristic strategy and precautions to avoid catching a cold or flu |

| | | |
|---|---|---|
| 2003, July 10<br><br>The International Herald Tribune (IHT) | The Incredible Shrinking Y by Maureen Dowd | Female dominance in the future? |
| 1997, April 6<br><br>The International Herald Tribune (IHT); The New York Times (NYT) | Consider The Clone: Duplication of Effort (IHT); Clone, Clone, Clone, Clone (NYT) by William Safire | Instructive article in Language Section on the origin of "clone" as a noun, verb and adjective and its significance in linguistics and political metaphors |
| 2000, October 15<br><br>ON LINE OPINION-<br><br>Australia's e-journal of social and political debate<br><br>http://www.onlineopinion.com.au/ | The Wonderful World of Genetic Whimsies by Wendy | Observations on the whimsical sides of genes and biotechnology |
| 2001, April 16<br><br>The International Herald Tribune (IHT) | The Disease with the Changing First | Article in Language Section on nomenclature of Foot and Mouth Disease. Also known to describe a gaffe or dentapedalogy, *i.e.* The science of opening one's mouth and putting one's foot into it? |

[a] See Biochemica Newsletter, 1999, no. 3. Available from Internet: http://www.roche-applied-science.com/PROD_INF/BIOCHEMI/no3_99/PG42.PDF.

[b] See http://www.eyestorm.com/saatchi/biograph-yfrancis-.asp; http://www.contemporaryfinearts.de/lay/turk/bio_turk.html and http://www.eyestorm.com/artist/Mark_Francis.aspx.

[c] Biotech art displays and performances (*i.e.*Gene(sis), Yougenics, GenTerra, Cult of the New Eve,Contestational Biotechnology, Society for Reproductive Anachronisms, The Flesh Machine, Free Range Grain, have been held at the Beursschouwl, Brussels, Belgium; the Kiasma Museum of Contemporary Art, Helsinki, Finland; The Public Nethase Museum Quartier, Vienna, Austria; The Kapellica Museum, Ljubljana, Slovenia; The Kunsthall Frankfurt, Germany; Rutgers State University, New Jersey, USA; The Museum of Contemporray Art, Toulouse, France; the Korean Web Art Festival, Seoul, Republic of Korea, etc. See http://critical.art.net for displays in 2003 and 2004.

[d] Explores implications of biotechnology for humanity and confronts headline issues such as anthrax, human cloning, DNA forensics, etc.; See also Living Drawings in http://www.artbyhunter.com/.

[e]See http://www.nhm.ac.uk/cleanrooms/crhome.htm.

[f] Dialogue between Science and Art was officially established in May 2002 by Dr. Michal Giboda. See http://giboda.aoedesign.de/profile.html.

[g] Green fluorescent bunny (GFB) created with Louis Bec, Louis-Marie Houdebine and Patrick Prunet, Jouy-en-Josas Center, France, 2000.http://www.ekac.org/; See also http://www.ekac.org/genexhis.html for details of an exhibition history of Genesis.

[h] Tissue culture used as a tool of artistic forms that blur the boundaries between what is born/manufactured, animate/inanimate in tissue sculptures of Pig Wings, Disembodied Cuisine, Artificial Wombs (see also Biofeel: Art and Biology Exhibition, Perth, Australia (August, 2002). See http://www.symbiotica.uwa.edu.au/ for displays in 2003 and 2004. q

[I] The art world is more friendly to the Darwinist view that every aspect of culture is an expression of nature. This view, by the way, is also shared by Buddhists, Taoists, and many Native Americans, among others from On Exhibiting Hybrids in Art + Technology Supplement of CIRCA (http://www.recirca.com/) 90, p. 08-09.

[j] See http://artplusscience.free.fr/05menezes.htm for painting of genes and chromosomes in human cells, real time brain functioning, and creation of live butterflies with modified wing patterns (NucleArt).

[k] Eminence grise of the bioart movement' developed DNAgraphy for use in artistic messages and poetic images. See Conformations of the MICROVENUS http://www.uwm.edu/~horeilly/bioart/joedavis/papersbyjoedavis/conformatmicrovenusjoedavis.pdf

[l] See Art orienté objet,édition de 2003, 183 p. (**Bookstorming**http://www.bookstorming.com/), 24, rue de Penthièvre ,75008 Paris, France.

[m] Moved from Germany to Next Five Minutes Tactical Festival, Amsterdam, Holland, then to the Esc Gallery Graz, Austria (December, 2003); and then to the Massachusetts Museum of Contemporary Art, Massachusetts, Boston, USA – personal communication with Steve Kurtz of CAE.

[n] http://metapet.net/index.html andhttp://www.hamaca.org/.

[o] Glowing red zebra fish developed in 2001 at the National University of Singapore by Professor Gong Zhiyuan will from 2004 be on sale in the USA as the first genetically modified pet New Scientist.com news service 24 November, 2003. See http://www.newscientist.com/news/.

[p] Seehttp://www.rit.edu/~scu9387/corporation/.

[q] See http://www.wordcircuits.com/gallery/sandsoot/heilner.html.

[r] See February 2002 edition of Micscape Magazine for text of "Group Portrait of Microorganisms –Making an Art work for the Natuurmuseum Rotterdam" by Wim van Egmond (http://www.microscopy-uk.org.uk/mag/indexmag.html?http://www.microscopy-uk.org.uk/mag/artfeb02/artwork.html).

[s] See http://www.nyas.org/about/newsDetails.asp?newsID=26&year=2003.

[t] See http://www.genomenewsnetwork.org/articles/10_03/soriano.shtml, article by Birgit Reinert.

[u] See http://www.genomenewsnetwork.org/articles/11_03/monkeyflower.shtml, article by Birgit Reinert.

- Stan Lee (Spider-Man, 2002) created in comic book format in 1963 in which a lonely orphaned teenager Peter Parker's life is transformed after being bitten by a spider that has been exposed to radiation and which infects him with by 'a spider sense' that alerts him to impending danger. In the movie version Spiderman's powers originate from a genetically-engineered spider's bite.

- Leo Szilard. (The Day of the Dolphins, 1960) – dolphins invent new technology -- (biotechnology?).

- G. R. Taylor. (The Biological Time Bank) - released in 1969 as Genetic Engineering on BBC Third Program).

- Alvin Toffler (Future Shock, 1970) - in which "cloning would make it possible to fill the world with twins of themselves".

- H.G. Wells (The Island of Dr. Moreau, 1886) who a hundred year later Marlon Brando portrayed in film the brilliant geneticist Dr. Moreau.

The arts have through the pen (The Secret, Brave New World, Genometry, The Boys of Brazil) and the palette of artificial and natural luminescent phenomena as in the green fluorescent bunny and the bioluminescent bacteria have helped to provide an insight into the mysteries of life through interpretations and speculative enquiry. Cancer, the scourge of the rich and the impoverished, induces a culture of fear and terror unexpectedly. Cancer, nevertheless brings forth ironically a sense of solidarity betwixt the potent and the poor in combating the virtually incurable disease. Moreover there is some sort of unspoken human communion that binds the afflicted from all strata of society (von Engelhardt, 2003). Cinema (GATTACA, etc.) and TV (Bionic Man and Woman) releases of today focus on topical issues. On the other hand scientists are breaking new ground through engagement in genetic culture and DNA-art, thus emphasizing the indisputable relevance of art to science and vice-versa (Durant, 1992; Madoff, 2002; Center for Genetics and Society, 2003; Miodownik, 2003; Monaghan, 2004).


**Figure 8. 50 Cruzados ND (1986) (Oswaldo. Cruz, microscope).** Source: http://www.banknotes.com/br.htm.

## Medicine and art

Medical art is generally believed to have first been recorded in the cuneiform tablets of ancient Mesopotamia. Subsequent evolution is to be found in well-known papyri such as the Brugsch, Georg Ebers, Edwin Smith and Kahun papyri that document the evolution of medicine and its concepts from the ancient Egyptian practices and philosophies which through the course of time were enriched by subsequent or contemporary developments in Ayurvedic (Vedic Period) Chinese (Nei Jing), Galenic, Hippocratic, and Islamic medicine. The birth of the shared history emerging from the impact of the meeting between the Old and the New worlds is accompanied by the introduction of alien ailments, cultural habits and languages that would radically change the cultural. demographic, disease and linguistic profiles of the New World (Ubelaker, 1999).

**Table 6. Artists and scientists contributing to making of DNA, genetic and microbe music[a].**

| Year | Artist- Scientist Team | Remarks |
|---|---|---|
| 1983 | David Deamer –Cell, biologist/musician, University of California, Santa Cruz, USA | Researches musical messages in our genes, (Music: The Arts, OMNI Magazine, April 5) |
| | With composer Riley McLaughlin | Produces music cassettes DNA Suite and DNA Music dealing with the translation of specific DNA sequences into music |
| 1984 | Kenshi Hayashi and Nobuo Munakata- biochemists, National Cancer Research Institute, Tokyo, Japan | Conversion of DNA sequences to music makes recognition of specific DNA patterns easier, (Basically Musical, Nature, Vol. 310:96, 12 July); Compositions of gene music by N. Munakata available at Gene Music and Sangen Studio (http://www.toshima.ne.jp/~edogiku/) |
| 1986 | Susumo Ohno and Midori Ohno (biologists), City of Hope Cancer Center, California, USA | Examines relationship between patterns of genetic sequence data and musical structure ("The All Pervasive Principle of Repetitious Recurrence Governs Not Only Coding Sequence Construction But Also Human Endeavor In Musical Composition", Immunogenetics, 1986, vol. 24, p. 71-78) |
| 1988 | Composer Susan Alexjander and David W. Deamer   | Start collaboration on science/art project that measures vibrational frequencies of the DNA bases –adenine. cytosine, thymine and guanine) followed by sound programming and translation into music released as *SEQUENCIA* in cassette version 1990, and a CD in 1994. ("Listen to your DNA", 26 November, 1998, BBC Online network) the musical sound of DNA is played) |
| 1989 | John Dunn (pioneer artist with DNA music and programmer- Algorithmic Arts) and Kent (Kim) Bridges (botanist), University of Hawaii, Hawaii, USA | Embark upon project that uses sound to "visualize data" of DNA and results in release of CD "Inflections". First public presentation of this music was at the University of Hawaii in a concert "Inflections: Musical Interpretations of DNA Data", in January, 1991, with music composed by J. Dunn and by K. Bridges, and visuals by artist Sonia Sheridan (Dunn, J., personal communication, 2003) |
| 1992-1995 | John Dunn (Algorithmic Arts) | DNA music samples (Human sex hormone; Starfish, Slime mould, Sea Urchin, etc.) based on DNA data from the NIH GenBank (1992); and, of (HIV DNA, Frog Mitochondria and Alpha/Beta Folding) created in 1995 with Algorithmic Arts software can be accessed from http://algoart.com/music.htm |
| 1994-2002 | Linda Long (biochemist and musician), Exeter University, UK | Develops technique at Bath University to translate protein structures into music; issues CDs Music of the Plants derived from protein fro medicinal plants and herbs (*i.e.*Phytolacca americana; Datura stramonium) and Music of the Body derived from protein hormones in the human body; Launches Molecular Music™ in 2001 and makes available online virtual exhibit on http://www.molecularmusic.com/ in 2002 |
| 1995 | Peter Gena (artist) and Charles Strom | Demonstrate translation of DNA sequences into music |

| | | |
|---|---|---|
| | (medical geneticist) Nichols Institute/Quest Diagnostics, San Juan, California, USA | (Musical Synthesis of DNA Sequences in:<br><br>1. 6th International Symposium on Electronic Art (ISEA), Montreal, Canada, p. 83-85;<br><br>2. X1 Colloquio di Informatica Musicale, University di Bologna, p. 203-204) |
| 1996 | John Dunn (Algorithmic Arts) and Dr. Mary Anne Clark (biologist), Texas Wesleyan University, Texas, USA | Collaboration results in 1998 Life Music CD with 9 tracks: 1. Beta-globin; 2.Calmodulin; 3. Gamma Lens Crystallin; 4. Alcohol Dehydrogenase; 5.Lysozyme C (Clark); 6.Lysozyme C (Dunn); 7.Triose Phosphate Isomerase; 8.Spidroin; 9.Collagen.<br><br>http://algoart.com/music.htm and http://www.whozoo.org/mac/Music/CD.htm; excellent website of Dr. Clark for review of Genetic Music http://www.whozoo.org/mac/Music/Sources.htm |
| 1996 | Ross King (biologist) University of Wales, Aberystwyth, UK and Colin Angus (musician) | Develop a computer program ProteinMusic (PM) that converts DNA sequences into music with the futuristic possibility that “users could feed in their own DNA sequences and develop their own anthems”. The PM software was used to produce the “track 'S2 Translation' that was generated from the DNA sequence and the amino acid characteristics of the S2 (membrane) protein” in the CD Axis Mutatis. (Protein music, Computer applications in the Biosciences, vol.12, p. 251-252) |
| 1999 | David Lane (entrepreneur and musician) | As a student at the University of Arizona developed the transformation of genetic information (DNA, RNA, Protein) into digital sound; and founded AudioGenetics. “DNA is music. There’s a musical component somehow to life. I know it’s there” |
| 1999 | Erik Jensen Diablo Valley College (DVC) and Ronald J. Rusay (Chemist), DVC and University of California, Berkeley, USA | Music by Ronald Rusay generated from protein strings (Musical Representations of the Fibonacci String and Proteins Using Mathematica, Abstract No. 55 in International Mathematica Symposium, Hagenburg, Austria.<br><br>Musical Representations of the Fibonacci String and Proteins Using Mathematica, The Mathematica Journal, 2001, vol. 8, no. 2.<br><br>Music from: DNA/Proteins/Math which uses Bio2MIDI written by John Dunn (Algorithmic Arts) with Bio2MIDI documentation support from:Dr. Mary Anne Clark, Texas Wesleyan University: http://department.txwes.edu/bio/mclark/index.htm |
| 2000 | Joe Davis (biologist/artist) and Katie Egan , Department of Biology,<br><br>MIT, Massachusetts, USA | Present “sound and video library” of wild protist cultures collected in their “microbial farm” in ARS ELECTRONIC 2000, Linz Austria.<br><br>1. http://www.aec.at/festival2000/texte/artistic_molecules_2_e.htm<br><br>2. Artistic Molecules, Microbes and the “Listening |

| | | |
|---|---|---|
| | | Microscope" http://www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_j_ars_elec.htm "Experimenting with spectrum analysis, I found that slightly different acoustic signatures corresponded to slightly different species of microorganisms. The signatures of a given species however tend to be uniquely distinct to that species. So as it turns out, the two plants of the same species must indeed 'sing the same song', unless perhaps the Ecuadorian brujo knows of some exceptional organism unlike those we have observed to date" -Joe Davis: Listening to Living Cells,<br><br>http://users.skynet.be/P-ART/PARADISE/JOURNAL/JOURNL52/journ52.htm |
| | Jacques (microbiologist) and Fran (computer expert) Soddell, La Trobe University, Australia | Jacques and Fran Soddell have monitored the growth of the fungus Mucor M41 in music in a mp3 file. Growth as it takes place in real time is pictorially seen onscreen with the music it generates as the fungal species grows |
| 2001 | Aurora Sanchez Sousa(microbiologist) Hospital Ramon y Cajal, Madrid, Spain and has collaborated with Richard Krull (musician) France | Produce their CD Genoma Music released in 2001 and using the DNA sequences of various genes of Candida albicans and translating the genetic keys A (adenine), C(Cytosine), G(Guanine), T(Thymine) into musical keys, such as La, Do, Sol, Re. *"Musical and genetic sequences unite to express the essence of life: sensations and feelings" - A. Sanchez Sousa* |
| 2001-2002 | David Lindsay (writer and musician), USA | Interest in genetic music results from attempt to copyright his own DNA. See: DNA Copyright Lecture delivered at Science, Industry and Business Library, The New York Public Library, April 5, 2001. A Striking Resemblance:DNA Dissociation as a Rhythmic Event, http://www.lazslo.com/dnaarticle.html |
| 2003 | Sirsak Teparkum (geneticist) National center for Genetic Engineering and Biotechnology, Thailand | Creates with computer specialist and music composer CD Genomic Music comprised of songs created using the genetic sequences for jasmine rice, an orchid, a cat, a dog, a shrimp, human hemoglobin, a human neurotransmitter, *E. coli*, and the hepatitis virus B; and which was exhibited BioThailand 2003; and which provided the musical accompaniment for a play commemorating the 50$^{th}$ anniversary of the discovery of DNA "Science for some people is difficult and hard to understand; often they avoid it as much as possible," he said. "Therefore, I just hope that my genomic music could be used as a tool to reach out between the two distinctive fields of science and music to make things look (and sound) easier." --S. Teparkum (Discovery News, 6 August, - DNA Codes Inspire 'Genomic Music') |

[a]Adapted from: GeneticMusic: An Annotated Source List MA Clark, Texas Wesleyan University (http://www.whozoo.org/mac/Music/); Transcriptions- The Music of Protein Sequences (http://www.whozoo.org/mac/Music/Sources.htm); and The Labs are Alive with Sound of DNA (Jeffline Forum, June-July 2002 (http://jeffline.tju.edu/Education/forum/02/06/articles/sound.html).

الطب علم يتعرف منه أحوال بدن الانسان
من جهة ما يصح ويزول عن الصحة
ليحفظ الصحة حاصلة و يسترد ها زائلة

*"Medicine is a science from which one learns the states of the human body with respect to what is healthy and what is not, in order to preserve good health when it exists and restore it when it is lacking"*

Ibn Sina (known in the West as Avicenna), on the opening to the Qanun fi al-tibb (The Canon on Medicine)[11]

The documentation of the artistry of the medical skills and surgical implements in use in those ancient times bear eloquent and undeniable witness to the evolution of modern medical art that is now enshrined in museums and embedded in the archives of prestigious libraries

worldwide. Two examples are the National Library of Medicine[12] with its repertoire of exhibitions on the history of medicine and the Wellcome Trust Medical Photographic Library[13] with a focus on "medicine past and present, social history east to west, a thousand years of human culture" and the examples of modern medical art concerning clinical medicine and the impact of the modern pharmaceutical industry best are respectively The Art of Medicine and Pharmakon; and that featured in Medicine in Art [14].

Furthermore periodicals such as the Journal of theAmerican Medical Association (JAMA), Lancet and Nature Medicine, and the Electronic Journal of Biotechnology occasionally carry medical and biotechnical artwork on their covers as a means of transmitting learning and understanding to readers schooled in medicine and the arts. Classical sketches and computer imaging reveal the combination of art and science in furthering the healthcare for the welfare of humankind. Killick-Kendrick, 1988 shared his collection of humorous verses following an outbreak of an "epidemic of clerihews with men of science as the subject". The effects of drugs ranging from instant death to resurrection and from inducement of love and romance in a much desired recipient have been captured in a review of the "strange pharmacopoeia of opera and stage" (Max, 1988). The effect of art and music in healthcare environments is well-known. Aesthetic and graphic medical art and soothing music with their educational and palliative effects uplift sagging morale in clinical and hospital environments by engendering good-feel perceptions that reduce anxiety, pain and stress.

## Music and microbes

Computer science has recently been used to capture from living cells the music patterns and soundscapes that result

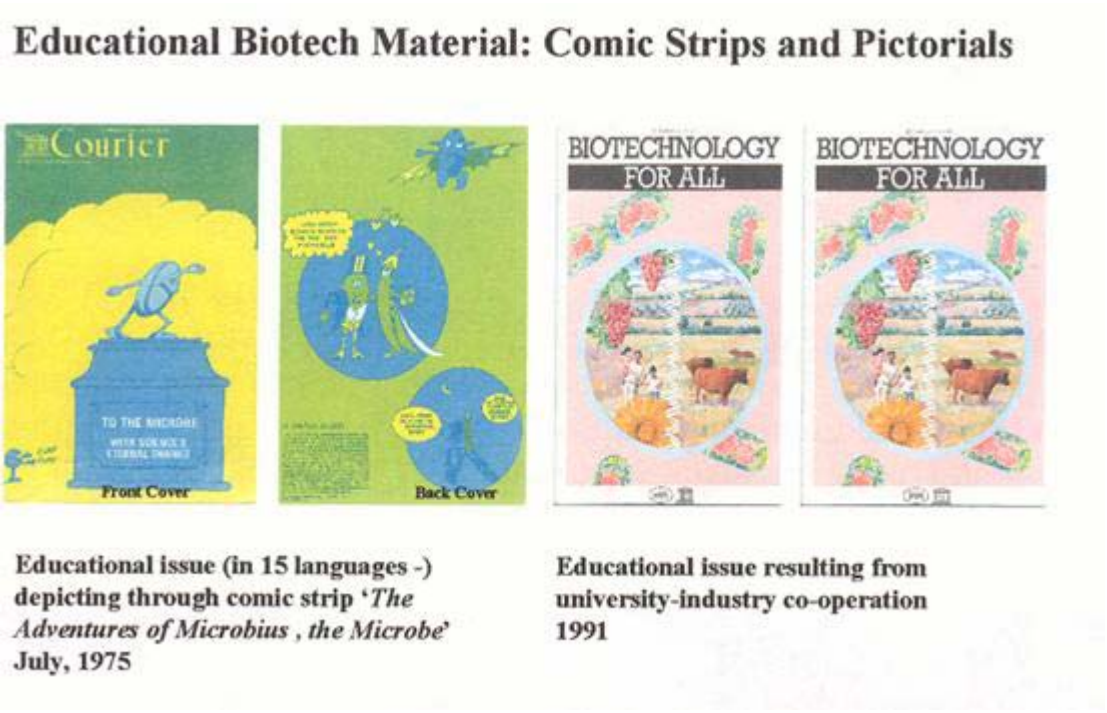



**Figure 9. Biotech educational material with articles in The UNESCO Courier[a] authored by eminent scientists; and pictorials in Biotechnology for All designed by university academic staff in the UK for the young and older student generations.**

[a]Consequent to discussions between S. Koeffler, Olga Rodel, A.C.J Burgers and E.J. DaSilva (UNESCO) and Jean-Marie Cement (France) and Safoura Assia (Iran) scientists at France's Molecular Genetics Centre at Gif-sur-Yvette in the outskirts of Paris.

from the merging of scientific fact and knowledge with artistic expression and thought. In reviewing scientist-composers and composers who have ventured into science there is justification that music and science together constitute key elements of creativity and scientific thinking (Root-Bernstein, 2001; Parsons, 2003).

"*Imagine the mRNA to be like a long piece of magnetic recording tape, and the ribosome to be like a tape recorder. As the tape passes through the playing head of the recorder, it is "read" and converted into music, or other sounds...When a "tape" of mRNA passes through the "playing head" of a ribosome, the "notes" produced are amino acids and the pieces of music they make up areproteins*"

Douglas Hofstadter[15]

This rapid developing field opens up new vistas of science education and research through the teaming up of artists and scientists (Table 6) and bears witness to the changing way of doing and teaching science. John Dunn and Mary Anne Clark have captured protein music in an audio CD Life Music as a means to facilitate interest and teaching in the complexities of cell, micro, and molecular biology. An update of the physiological relevance to DNA music reinforces the physio-musical conversion of codons into computer-generated music with annotations of recent music (Gena and Strom, 2001).

"*No molecule in the history of science has reached the iconic status of the double helix of DNA. Its image has been imprinted on all aspects of society, from science, art, music, cinema, architecture and advertising*"

Martin Kemp (2003)

**Figure 10. *Lachenalia* bulbs developed at the ARC/Vegetable and Ornamental Plant Institute.** (ARC/VOPI). Reproduced with the permission of the ARC-VOPI/UNESCO BETCEN. See also http://www.arc.agric.za/.

DNA-, gamma crystalline and protein-based music are examples in the learning of protein structure and biochemistry. The music of the plant proteins of medicinal plants and herbs (Table 6), has been tapped in a CD Music of the Plants (Long, 1999) to provide calming, relaxing and strength-giving ambiences in health clinics, spas, and dental and hospital environments. One may even dance to genomic music derived from encoding DNA sequences into MIDI sequencers and other music files (MP3s) to play genetic "tunes" (Knickerbocker, 2001). Artisitic molecules, singing plants and a "listening microscope" --- audioscope to listen to different acoustic signatures of different microbes have been part of Ars Electronica 2000 (Davis, 2000).

Unique microbe music recording real time actual growth and expressed in musical sound results from a combination of computing and microbiological skills. Using earlier algorithmic constructs and specific computer language (Prusinkiewicz and Lindenmayer, 1990), Jacques and Fran Soddell of La Trobe University have monitored the growth of the fungus *Mucor* M41 in music in a mp3 file (Salleh, 2000). Growth is recorded pictorially online and onscreen with the music it makes as growth occurs. Other mp3 formats are slime mould music and the synthesized musical interpretation of the spider silk protein –spidrion (Pulse of the Planet, 2001).

The interaction of the arts, music and biotechnology is borne out in the names of rock groups and album titles and songs that reveal a seeming awareness of microbes and genetics and their expression of the issues and the moods of the late 1960s and the late 1990s (Table 7). In current times, perhaps the debates on the pros and the cons of gene modification issues in the agrofood sector may have contributed to a seeming awareness of genetics that can be gauged from the discography database labels of electronic music - Genetic Music, Genetic Razor, Genetic Records, Genetic Recordings, Genetic Stress, Genetic Rhythm Records, etc.

## Education and art

In recent times several initiatives have been made towards the development of a culture of appreciation of biotechnology and the appreciation of biotechnical applications in improving the quality of life and conserving environmental heritage.

"*The use of music has become important as a way to enhance and influence more natural acquisition of information*"

Caine and Caine, (1994)

The mix of imagination, new scientific technologies --- biotechnology, information technology and nanotechnology, and easily accepted modes of sustaining child and student interest over a long period of time constitute on one hand a challenge and, on the other hand, the difference in evolving patterns of science education. The challenge spurs school and college teachers to adapt and to transform their traditional teaching methods into modern updated techniques that give more meaning and

substance to their crucial role as educators and then as agents of development of the policy decision-makers and the intellectual fabric of tomorrow. That being said, the difference in patterns of science education is reflected in the technological gap that characterises the four components of the planet's economic and technological categorization of nations ---namely the industrialized societies, the new technologically-advancing developing countries, the late developing countries and the least developed countries. New tools of science education involve computer self-teaching programs and CD materials, TV screenings and even the medium of the cinema. Useful as these are, they are, nevertheless, not easily accessible to poverty-stricken communities in the worldwide rural and urban sectors of the planet's pool of tomorrow's presidents, prime ministers, philosophers and philanthropists, and policy-makers as is evident in today's time-honoured and conflicting fora of Davos; Porto Alegre; and of Bombay starting 2004.

One attractive medium that combines the parameters of cultural heritage, and teleology – a quality that has been at the basis of many a scientific discovery, and its offshoot fiction that becomes fact as seen with Jules Verne, H. G. Wells, Arthur Conan Doyle, etc., is that of the comic strip. This teaching tool in primary schools (Rota and Izquierdo, 2003) draws upon the power of the pictorial-instructing and visual-retaining word to encourage youngsters to have a better appreciation of the potential, the pitfalls and the practise of ethics in biotechnology (Harms, 2002). Early initiatives specifically designed for young school children as well as for older people now seem well-justified (Figure 9).

Another teaching tool is the medium of music that is closely intertwined with human cultural endeavour inspiring and touching the biological emotions of humanity (Gray et al. 2001; Hotz, 2002). Music embraces the rich and the poor in a unifying bond of human consciousness; and yet, as a powerful tool transcends the intricacies of language and vocabulary in the domain of communication technology. And, whilst much of the neurobiological and physiological impulses associated with music have been deciphered, there remains still the unexplained the role of music in influencing human emotions and driving romance (Anon, 2000).

Research, student response and personal initiatives have shown that music helps instruct, improve and strengthen academic learning (Caine and Caine, 1994); and that is also a useful medium in the instruction of medical students to study infectious diseases (Landers, 2001). Food safety and lyrics by the food toxicologist Carl Winter (Table 6) are based on popular tunes and composed of rewritten lyrics to transmit the messages of food safety and biosafety educational programmes such as "We are the Microbes and Eat it". Other educational songs using attractive, popular, and easily recognizable tunes are:Mantenga Bien la Comida (La Bamba – Ritchie Valens); Clonin' DNA (Surfin' *USA* – Beach Boys); and Beware La Vaca Loca (Livin' La Vida Loca - Ricky Martin). Gospel lyrics by Stephen Baird are: The Family of Man (1989); Walk Down In The Water (1999); Charlie Darwin (2000); The Ballad of Gregor Mendel (2000); and We're 99.9% The Same (2001).

## THE DARK SIDE OF BIOTECHNOLOGY - CULTURE AND PEACE

Peace is more than the absence of war and violence. The obverse face of the coin of all-embracing peace has its origins in the roots of education, culture and tolerance whereas the reverse face symbolizes the resulting absence of civil disorder, societal abuse, and violence. There is much truth in "*mens sano in corpore sano*" that provides the basis for building the foundations of peace.

"*In the absence of scientific evidence that GM foods are harmful, it's a tragedy that they 've been denied to desperately hungry* people around the world"

David Appell[16]

Poverty, hunger, social intolerance, and lack of education contribute to the societal unraveling of the fabric of peace woven through decades through the threads of tolerance, social literacy, Trade wars such as the banana-export wars and the denial of biotech-derived foods to hungry and malnourished populations disadvantaged by their poverty-stricken status; ecological and natural disasters, and emergent diseases do not help. Communal mistrust, ethnic unrest, unemployment, poverty, social injustice, etc. constitute a dissuasion for the culture of peace that seeks advantageous one-upmanship amongst peoples in the international arena, and by consequence that feeds the trade and weapons market for high-tech bio- and chemical weapons.

**Table 7. Intermix of the arts, music and biotechnology.**

| Year | Title | Artist | Origin | Remarks |
|---|---|---|---|---|
| 1968 | Microbes Lyrics | George Harrison | UK | Instrumental piece in album Wonderwall music with Indian musicians. No clue to choice of lyrics title |
| | A Very Cellular | Mike Heron of | UK | In album –The Hangman's Beautiful Daughter. |

| | | | | |
|---|---|---|---|---|
| | Song | The Incredible String Band | | The song tells a tale of amoebae |
| 1970s | Can'bl Sel | Allan Bryant | UK | Album of 7 tracks on the intermix of phonetics with organic chemistry |
| 1970s | | Fatal Microbes | UK | Punk rock group of the 1970s. No clue to group name |
| | | The Germs | USA | Short-lived rock punk band of the 1970s. No clue to band name |
| 1979 | Chain of Command | Andy Partridge of XTC | UK | Draws attention to the associative role of microbes |
| 1989-2001 | Ain't Gonna Be No Judgment Day | Stephen Baird | USA | All materials copy-righted by 2002 Scientific Gospel Productions (http://www.scientificgospel.com/) |
| 1993 | Goodbye Humanosaurus | Andy Partridge of XTC | UK | Predicts extinction of humans through their own use of "CFC's and germ-war microbes" |
| 1997 | DNA Music | | USA | Student develops a school learning project in which music is created from DNA sequences (Miner, C. and Della Villa, P. DNA Music, The Science Teacher, May 1977, vol. 6, p. 19-212) |
| 1998 | Music for Microbes | Andreas Koepnick | Germany | Musicians use "virtual-reality glasses" with videotape "to observe single- celled microbes as a living score… - performance project with the chamber ensemble new music Berlin". Earlier works are: Microlives and virtual reality; slides; and The World Generator |
| 2000 | First of the Microbe Hunters | Stereolab | UK | Comprised of 7 tracks with no clue for choice of album title |
| 2001 | Microbes | Frieband | Holland | One of the many names used by Frans de Waard. Music composed of 12 tracks with no clue for choice of album title |
| | Microbes and Peter Rabbit | Mark Belletini (Church Minister, Columbus, Ohio) | USA | Liturgical Materials comprised of opening words, readings, sermon and laudate dealing with lichens, symbiosis, etc. and the praise of life and its interconnections |
| | Food Safety Music (some titles: We are the Microbes; Beat it) | Carl. Winter (see remarks) | USA | Songs about microbes based on popular tunes: We are the Champions by Queen and Beat It by Michael Jackson. Other lyrics deal with genetic modification, mad cow-disease; and still others have slide sets. Contact address: Carl Winter, Food Safe Program, Food Science and Technology Dept, University of California, One Shields Av, Davis, CA 95616-8598, USA. See also reviews in archives of USA Today, Harper's Magazine, Chicago Tribune, UC Davis Dateline) |

| | | | | |
|---|---|---|---|---|
| 2002-2003 | Decomposers | Musically Aligned | USA | Provision of standards-based educational music |
| 2003 | The Inter-planetary, Collaborative Music Project (ICoMP) | The Extremophiles (see remarks) | USA | The musicians for the project on microbes in extreme environments (hence the name The Extremophiles): Commander Frank Schubert, Engineer /National Geographic correspondent Sam Burbank, NASA planetary scientist Kelly Snook, exobiologist Penny Boston, NASA space psychologist Ephimia Morphew, biologist/ engineer Steve Daniel. Space artist Michael Carroll creates album art for Soundtrack for a Mars Movie with 20 songs |

"*Friend and lovers may do you more harm than a designated enemy. A handshake may be as dangerous as a gun*"

Suzanne Joelson[17]

Disregard and disrespect for peoples and principles of ethics weaken the basic national and global cornerstones --- education, conservation of young and promising male and female lives, tolerance, etc., that drive a sense of racial equality, respect for gender, social diversity, and the security of an impartial justice so necessary for the cultural pursuit of peace given that most of the cultural heritage of the southern hemisphere is in collections and on display in museums elsewhere. 'Complex issues such as climate change, food and water security, poverty, HIV/AIDS and other contagious diseases, biological diversity……..demand innovative and interdisciplinary approaches from both the natural and the social and human sciences also taking into account the role and importance of local and traditional knowledge[18]. Efforts in 'building a global culture of science' (Varmus, 2003) and by consequence of peace, must concentrate on eradicating bioterrorism that betrays a lack of cultural responsibility to one's faith and to one's peoples. The inviolability and the invincibility of the bright side of biotechnology must remain intact and prevail through well-thought out containment process and control protocol in combating the dark side of biotechnology that is being expressed through bioinsecurity, bioterrorism and biowarfare.Thus, artists, creators of novel art, intellectuals, scientists and researchers in bioart have an important role in helping secure worldwide a durable culture of peace.

## THE DEVELOPING COUNTRIES AND BIOTECH ART

Many developing countries constitute the cusp of the southern arc of the newly industrialised countries that are in the Far East, Central and Southeast Asia, sub-Saharan Africa, and in South and Central America (Table 8).

Argentina, Brazil, Chile, China, Egypt, India, Jordan Kenya, Malaysia, Singapore, South Africa and Thailand, etc., have made impressive advances using biotechnology for economic development *vis-à-vis* availability and consumption of natural resources, and population growth. Biosci-art in these countries is more conservative in expression given their rich cultural traditions and heritage (Figure 10 and Figure 11). In addition, an awareness of transgenic art and bio-art exists through artistic expressions which though modest are nevertheless in progress in these countries.

**Figure 11. The leaves are dried and then hand painted by Indian craftsmen. Reproduced with permission from Handicraft Greetings.** These paintings are used as souvenirs. Enquiries for information on their preparation should be addressed contact Ajay Jindal at 232/20A., Chandigarh, India 180020 or at info@handicraftgreetings.com.

The conservation of cultural heritage in the developing countries benefits from the - Use of aesthetic green

technologies that contribute to their economic advancement.

Diversification of biotech markets that generate income from small and-medium scale enterprises such as the banana industry in the Caribbean region; floriculture that earns foreign-exchange for rural communities and that embellishes the cultural tastes of the industrialized world; ornamental plants that enrich the aesthetic component of landscape management; and fermented foods and medicinal plants that draw upon domestic cultural practices in the conservation of human resources and that contribute to the development of rural-based self-based employment. Forward planning with an eye on sustaining meritorious endogenous development through investment in short-term intensive training at specialized microbial and plant biotechnology centres can help make a priceless contribution (Electronic Journal of Biotechnology, 2001; Vasil, 2002).

## CONCLUDING REMARKS

Since times immemorial an interaction between art and biotechnology has existed. Irrespective of whether the bread or the beer fermentation came first in the days of early Natufian culture, there is widespread agreement that fermented foods have been a medium of communication that binds the nutritive habits of different cultures and societies.

Moreover, current day market products of fermented foods result from the routine application of domestic skills enriched by feminine instinct and intuition in using 'starter culture' microbial machinery to provide sustenance and strength to millions of middle- and low-income families lacking access to much needed dietary micro- nutrients.

Biotechnology, in its voyage from ancient times into the expanding frontier areas of today's world of scientific research, has revealed itself as the gene of diplomacy and international cooperation in the relationships between nations.

In recent times there has been some sort of an explosion concerning the interaction between science, art, culture and peace. There is a growing interest in bioart that seems to appeal to the aesthetic soul of humankind. Max Delbrück's colour-coded toothpick message to Nobel-Laureate George Beadle was inspirational in 'expressing human language in the form of DNA "when" in 1958 no synthetic, or artificially constructed nucleic acids were available' (Davis, 2000).

In close interaction with information technology (IT) and nanotechnology (NT), biotechnology (BT) is undisputedly part of the corporate world. In never-ending evolution this interaction, arising from the convergence of the streams of knowledge of microbiology, engineering, chemistry, genetics and medicine, advances socio-economic development, and contributes to the culture and defense of peace. The devising of biosafety measures against emerging diseases and the development of a state of communal preparedness and individual readiness help combat confusion and uncertainty arising from the threat of sudden bioterrorism and biowarfare. Moreover, they are important elements in developing a culture of peace that derives from the arts and the sciences. Anticrop warfare has been identified as a destabilizing mechanism in seeding national disquiet, economic erosion and unsustainable development. And, biodeterioration and pollution are weapons of damage to national cultural heritage. Moreover, the intermix of the arts and biotechnology is now being appreciated as an important element of cultural heritage; and as a biological expression of culture and peace through the lenses of art, genetics, fermentation technology, literature, and religion. Such interaction can only help dispel the misunderstanding of biotech processes and the mistrust of gene-derived products that contribute to negative expressions of international cultural differences, trade wars and to the seeding of disquiet and disharmony that undermine the environment of peace.

Thus there is a need to:

(i) Appreciate the role of molecular art in the life sciences in socio-economic development.

(ii) Continue investing in the biotechnologies that will power bio-based cultural and economic progress, worldwide, beyond the 2010s.

(iii) Build upon the remarkable advances made by the newly-industrialized countries such as China and India in using the art of gene-based technologies in improving the quality of life. (iv) Acknowledge the role of the life sciences in aesthetic and ethical technological progress.

Developments in biotechnology are evocative of John Milton's poetic works - "Paradise Lost and Paradise Regained". Research and technological acceleration in moving from a hydrocarbon-based economy to a carbohydrate-based treasury have given rise to a new category of biobased utility products, therapeutics and cloning processes that reveal the realities – pitfalls and the promises of a "Paradise Now"; and the realities of a "Paradise Future".

The use of art as a vehicle to appreciate science and to enrich the diversity of culture cannot be denied or dismissed as mere rhetoric as is so often the case. 'Creation draws on the roots of cultural tradition, but flourishes in contact with other cultures. For this reason heritage in all its forms must be preserved, enhanced and handed on to future generations as a record of human experience and aspirations, so as to foster creativity in all its diversity (Figure 11) and to inspire genuine dialogue among cultures[19]. Art as a language of communications appeals to the inborn sense of appreciation of Nature's works and

**Table 8. Bioart in some biotech cities in the Developing World.**

| Biotech City | Features |
|---|---|
| Bangkok | 2003 - Year of Biotechnology; CDs of soundtrack of DNA code set to music made available In Bio-Thailand 2003, Pattaya |
| Bangalore | 2003 - Sculpture of Double Helix unveiled at BangaloreBio2003[a] as pivotal feature on Mahatma Gandhi Road celebrating 50-year anniversary of DNA discovery |
| Beijing | 2000 - Exhibition on Human Genome Project organized by the China Association for Science and Technology and governmental bodies to promote an awareness between genes and diseases |
| Bloemfontein | Widely known as "The City of Roses" or the "Spring of Flowers". Also houses the National Museum of Rock Art |
| Cape Town | 2003 - Cape Town Flower Show with a focus on the intermix of nature, art, culture and learning in floral art interpretations of environmental themes; traditional food plants and their cultural uses; economic empowerment and landscape architecture (Figure 10) |
| Cairo | Bread and beer fermentation processes are the oldest examples of bioart seen in the tombs of the pharaohs (see Fermentation and Art) |
| Mexico | 2000 – Insectario in watercolors and drawings "depicts the fascination and terror that some insects generate in us…." And captures the artistry and architectural structure of insects and their symbolical, mythical, and cultural meanings |
| Sao Paulo | 1999 - Invenção: Thinking the next millennium? Conference[b] that examines "the consequence of the convergence of art, science and technology on our sense of self and human identity, on consciousness, community and the city as well as on learning and leisure" |
| Shanghai | 2003 - Chinese lady artists will create the first Art Car in China with the theme "DNA in Art and Technology" in collaboration with Germany as partner country - DNA exhibition with sessions on molecule construction, genetic displays, etc. to promote an appreciation and understanding of DNA |
| Singapore | Biopolis for biomedicine, bioinformatics and biotechpreneurship; Pioneering course on Cyberart at the National University of Singapore encourages students to explore inter alia the intermix of art and biotechnology |

[a]Widely considered to be the 'Science capital of India' as well as the country's 'Biotech City' that showcases an annual prestigious conference event.

[b]A summary of the salient and thought-provoking presentations (with abstracts) with indication of the range and scope of bio- or biosci-art since prior to the onset of the millennium can be found at http://www.itaucultural.org.br/invencao/invencao.htm.

by consequence of non-violence. Art binds culture, science and humanity together to overcome societal impotence and paralysed governance. The four-in-one formula helps to nudge decision-makers into novel initiatives to eradicate poverty, environmental desecration, ethnic unintentional bias, and health insecurity of the young and the aged.

Art can enlighten science (Rothwell, 2004). One complements and draws upon each other for promoting public understanding and investment in science in subjects ranging from the bioconservation of the environment and space biology to underwater biotechnology and biodefense technology. Either alone or in combination, the use of

artistic and scientific expressions brings a new dimension towards the teaching of the biosciences and in the conduction of bioresearch that unravels natural aesthetics in the morphological, metabolic, and physiological expressions and of technological applications of the 'weird and wonderful world' of biotechnology[20].

"*Artistic talent is a gift from God and whoever discovers it in himself has a certain obligation: to know that he cannot waste this talent, but must develop it*"

Pope John Paul [21]

**Box 1. Some newly discovered bacterial species.**

| Species | Comment |
|---|---|
| *Deinococcus radiodurans* | Occurs in the Atacama Desert, Chile |
| *Dehalococcoides ethenogenes* | half-micron-long bacterium that breaks down toxic industrial chemicals e.g trichlorethylene |
| *Nanoarchaeum equitans* | Smallest bacterium discovered in Regensburg, Germany |
| *Polaromonas naphthalenivorans* | Of value in decontamination of coal |
| *Serpulina pilosicoli* | Also known as "little serpent of the hairy colon", causes severe diarrhea in pigs |
| *Thiomargarita namibiensis* | Largest prokaryote discovered off the coast of Namibia |
| *Wolbachia pipientis* | Bacterial symbiont associated with parthenogenesis and a change in host selection behavior in wasps |

## DEDICATION

As a follow-up of the dedication to his dream team of international scientists (DaSilva, 2003), the author dedicates this article to all those who collaborated with him through different governmental, non-governmental, and intergovernmental organizations.

A special tribute is paid to all those scientists from well over 100 countries, and especially to succeeding generations of MIRCEN and BETCEN Directors who have given freely of their time away from office and home in giving meaning and substance to the successful implementation of UNESCO's applied microbiology and biotechnological programmes. This includes also past editors -- Fred Skinner (UK), Jacques Nyns (Belgium), Jacques Senez (France) that helped the author launch the MIRCEN Journal; and especially the current editor Colin Ratledge (UK) who helped expand and sustain the journal now as the "World Journal of Microbiology and Biotechnology" into a bimonthly issue in hard copy and online format.

The selfless commitment and dedication of all past and current members of the Journal's editorial board for their contribution to the sustenance of the high-quality of the Journal is placed on record through this contribution.

In similar manner the author acknowledges the sterling efforts of Fernando Acevedo (Chile), and of Graciela Muñoz (Chile), Editor of the Electronic Journal of Biotechnology for providing an online forum through the feature section "Biotechnology Issues for Developing Countries" that through the past decade has grown in contribution on a geographical basis as well as in biotechnological content and scope.

That being said, there is another dream team of scientific managers whose visionary approach and support in a 30-year period of international co-operation that needs to be placed on record. This dream team is as follows in alphabetical order:

1. Kei Arima (Japan/IUMS)

2. Amadou BA (Senegal)/UNECO/UNDP/ICSU –African Biosciences Network

3. Adnan Badran (Jordan/ Arab Biosciences Network; UNESCO)

4. Wim Barreveld (Netherlands/FAO)

5. Michel Batisse (France/UNESCO)

6. Mark Cantley (UK)/EEC/EU)

7. Reuben Olembo (Kenya/UNEP))

8. Mynt Maung (Mynamar/UNIDO)

9. Federico Mayor (Spain/UNESCO)

10. Vic Skerman (Australia/WFCC-WDC)

11. Walter Shearer (USA/UNU)

## REFERENCES


ADAMS, Martin and HENDRY, Pattie. The Lost Art of Bacteriology. *The Microbiologist*, December 2002, p. 14-15.Also available from Internet: http://www.sfam.org.uk/pdf/features/paintbugs.pdf.

ANON. The Biology of Music. *The Economist*, 12-18 February, 2000, p. 83 -85. Also available from Internet: http://cogweb.ucla.edu/Abstracts/Music_00.html.

ARIE, Sophie. Bacterium restores glue-hidden fresco. *The Guardian*, 27 June, 2003. Also available from Internet: http://www.guardian.co.uk/arts/news/story/0,11711,986008,00.html)

BAR-YOSEF, Ofer. The Natufian Culture in the Levant, Threshold to the Origins of Agriculture. *Evolutionary Anthropology*, 1998, vol. 6, p. 159-177.

BASZTURA, Joanna (ed.). Compilation of FP5 Projects. The City of Tomorrow and Cultural Heritage. Edition February 2003. Also available from Internet: http://www.cordis.lu/eesd/ka4/home.html.

BEN JACOB, Eshel. Bacterial self-organization: co-enhancement of complexification and adaptability in a dynamic environment. *Philosophical Transactions of the Royal Society of London Series A.,* 2003, vol. 361, p. 1283-1312. Also available from Internet: http://star.tau.ac.il/~eshel/papers/nobel.pdf.

BRADY, Nyle C. Quo Vadis International Agricultural Research. In: Bonte-Friedman, C. and Sheridan, K. eds. *The Globalization of Science. The Place of Agricultural Research*, New Expanded edition. The Hague: International Service for Natural Agricultural Research (ISNAR), 1997, p. 15-25. Also available from Internet: http://www.isnar.cgiar.org/publications/pdf/vision/brady.pdf.

BRODWIN, Paul. *Biotechnology and Culture: Bodies, Anxieties, Ethics*. Bloomington, Indiana University Press, 2000. 248 p. ISBN 0253214289.

CAINE, Renata. N. and CAINE, Geoffrey (eds.). *Making Connections: Teaching and the Human Brain*, Menlo Park, CA: Addison-Wesley, 1994. p. 224. ISBN 0201490889.

CAVALI-SFORZA, Luigi L. Genes, Peoples and Languages, *Scientific American*, 1991, p. 72-78.

CENTER FOR GENETICS AND SOCIETY. *Analysis: Art and Popular Culture,* 11 August, 2003. http://www.genetics-and-society.org/analysis/popular.html.

CIFERRI, Orio and TIANO, Piero (eds.). *Of Microbes and Art: The Role of Microbial Communities in the Degradation and Protection Cultural Heritage*. Kluwer Academic/Plenum Publishers, Dordecht, Netherlands, 2000, 286 p. ISBN 0306463776.

CLARKE, John R. Seeing Rainbows Among the Ruins: Peter Erskine's "New Light on Rome". *Sculpture Magazine*, September 2001, vol. 20, no. 7. Also available from Internet: www.sculpture.org/documents/scmag01/sept01/erskine/ersk.htm.

COHEN, Hal. Bioscience Moves into Galleries as Bioart. *The Scientist*, 2002, vol. 16, no. 22, p. 57.

DALKE, Kate. 1) Scientific Artists capture the World; 2) Medical Illustration starts with Dissection, 3) Pastel Proteins, Special Issue Art & Science, *Genome News Network,* 2003, October 3. Available at: http://www.genomenewsnetwork.org/articles/10_03/capture_world.shtml.

DASILVA, Edgar J. International Biotechnology: Diplomacy, Policy and Statesmanship, Editorial. *Electronic Journal of Biotechnology* [online], 15 April 2002, vol. 5, no. 1. http://www.ejbiotechnology.info/content/vol5/issue1/editorial.html. ISSN 0717 3458.

DASILVA, Edgar J. Quo Vadis Biotechnology? *Current Trends and Future Issues*, 2003. Available from Internet: http://www.iva.se/biotechnology/.

DAVIS, Joe. Project Statement Ars Electronica 2000. Available from Internet: http://www.aec.at/festival2000/texte/artistic_molecules_2_e.htm.

DAVIS, Joe. Genesthetics. *Joe Davis Bioart archive*, 2003: http://www.clondiag.com/art/joe.davis/index.php.

DIAMOND, Jared and BELLWOOD, Peter. Farmers and Their Languages: The First Expansions. *Science, April 2003,* vol. 300, no. 5619, p. 597-603.

DOTY, Robert B. Microbiology on Stamps. *ASM News*, 1975, vol. 41, p. 679-684.

DUNN, John and CLARK, Mary A. Life Music: The Sonification of Proteins. *Leonardo Online: Articles*. 1997. Available from Internet: http://mitpress2.mit.edu/e-journals/Leonardo/isast/articles/lifemusic.html.

DURANT, John. Introduction. In: *Biotechnology in Public-A Review of recent Research*.The Science Museum, London, UK for the European Federation of Biotechnology. 1992, p. 9-17.

*Electronic Journal of Biotechnology* [online]. UNESCO Microbial Resources Network (MIRCENS) Activities - Review of Activities (1 January 1990 - 31 August, 2001), 2001. Available from Internet: http://www.ejbiotechnology.info/content/mircen/index.html .

FOSTER, Jackson W. Microbes in Diplomacy. *The Graduate Journal* , 1964, vol. 6, p. 322-332.

GAMWELL, Lynn. *Exploring the Invisible: Art, Science and the Spiritual*. Princeton University Press. 2002a. 344 p. ISBN 0691089728.

GAMWELL, Lynn. Science in Culture. *Nature*, 2002b, vol. 422, no. 817, p. 817.

GENA, Peter and STROM, Charles. A physiological Approach to DNA music, 2001. Portable Document Format. Available from Internet: http://www.artic.edu/%7Epgena/docs/gena-strom-DNA.pdf.

GRAY, Patricia M.; KRAUSE, Berme; ATEMA, Jelle; PAYNE, Roger; KRUMHANSL, Carol and BAPTISTA, Luis. The Music of Nature and the Nature of Music. *Science*, 2001, vol. 291, no. 5501, p. 52-54.

HARMS, Ute. Biotechnology Education in schools, *Electronic Journal of Biotechnology*, [online]. 15 December 2002, vol. 5, no. 3. Available from Internet: http://www.ejbiotechnology.info/content/vol5/issue3/teaching/01/index.html

HODGSON, John and BORMANN, Ernst. F-art: The Expression of Biological Culture. *TIBTECH*, 1988, vol. 6, VII – X, p. 64-65.

HOTZ, Robert L. Music leaves its mark on the brain. *The Los Angeles Times*, December 13, 2002. Also available from Internet: http://www.latimes.com/chi-021214brain,0,7563471.story.

ISHIDA, Hideto. Insight into Ancient Egyptian Beer Brewing Using Current Folkloristic Methods. *MBAA TQ*, 2002, vol. 39, no. 2, p. 81-88. Also available from Internet: http://www.mbaa.com/pdfs/TQfeature/2003Egyptian_Beer.pdf.

KAVANAGH, Thomas W. Archaeological Parameters for the Beginnings of Beer. *Brewing Techniques*, September/October 1994, vol. 2, no. 5. Also available from Internet: http://www.brewingtechniques.com/library/backissues/issue2.5/kavanagh.html.

KEMP, Martin. The *Mona Lisa* of modern Science. *Nature,* 2003, vol. 421, no. 6921, p. 416-420.

KERSHEN, Drew L. Biotechnology: An Essay on the Academy, Cultural Attitudes, and Public Policy. *AgBioForum*, 1999, vol. 2, no. 2, p. 137-146. Also available from Internet: http://www.agbioforum.org/v2n2/v2n2a12-kershen.htm.

KILLICK-KENDRICK, R. Parasitological Clerihews. *Fortnightly Supplement, Trends in Biotechnology*, June 1988, vol. 2, p. 1-4.

KNICKERBOCKER, Brad. It's "genomic music" but can you dance to it? *The Christian Science Monitor*, June 6, 2001,p.189.

LANDERS, Susan J. Teacher scores singing songs of sickness. *American Medical News,* July 2, 2001. Also available from Internet: http://www.ama-assn.org/amednews/2001/07/02/hlsb0702.htm.

LAVOIE, Don and CHAMLEE-WRIGHT, Emily. Culture and the Wealth of Nations. Cato Policy Report 2002, vol. 24, p. 12-15. Also available from Internet: http://www.cato.org/pubs/policy_report/v24n1/nations-wealth.pdf.

LONG, Helen, L. *Molecular Music*. 1999. GB Patent No. 2350469, c/o Molecular Music, POB 55, Crediton, Devon EX 17 4WF, UK.

MADOFF, Steve H. The wonders of Genetics Breed a New Art. *The New York Times*, *Arts and Leisure Section*, May 26, 2002. Also available from Internet: http://www.ekac.org/nytimes.html.

MAX, B. This and That: thanatomimetics, bradychronotoxins, osmocides and ototoxins. *Fortnightly Supplement, Trends in Biotechnology*, November 1988, vol. 2, p. 8-12.

*MicroNZ*. [online]. 2003. Available from Internet:http://asmconferences.org/micronz/.

MIODOWNIK, M.. Genetic Art. *Materials Today*, June 2003, vol. 6, p.13. Also available from Internet: http://www.materialstoday.com/pdfs_6_6/column.pdf.

MONAGHAN, Peter. The Humanities' New Muse: Genomics. *The Chronicle of Higher Education*, 2004, vol. 50, no. 24, p. A12.

NADIS, Steve. Science for art's sake. *Nature*, 2000, vol. 407, no. 6805, p. 668-670.

NEAVE, Ruth. Is Science Art? Page maintained Jarron, M.H., 2002, April 2. Available from Internet: http://www.dundee.ac.uk/museum/science.htm.

O'REILLY, Hunter. Biology Through Art Course (for students of University of Wisconsin-Milwaukee), 2003. Available from Internet: http://www.uwm.edu/~horeilly/bioart/.

PALEVITZ, Barry A. An Odyssey in Science and Art. *The Scientist*, 2002, vol. 16, no. 22, p. 18.

PARSONS, Lawrence. Brain Basis of Musical Performance, Cognition, Perception, and Improvisation. Subtle Technologies 03, May 22-25, 2003. University of Toronto, Toronto, Canada. Available from Internet: http://www.subtletechnologies.com/2003/parsons.html.

Philadelphia International Airport. Art and Exhibitions. 2003. Available from Internet: http://www.phl.org/art.html.

PINĂR, Guadalupe; RAMOS, Cayo; RÖLLEKE, Sabine; SCHABEREITER-GURTNER, Claudia; VYBIRAL, Dietmar; LUNITZ, Werner and DENNER, Ewald W.B.M. Detection of Indigenous *Halobacillus* Populations in Damaged Ancient Wall Paintings and Building Materials: Molecular Monitoring and cultivation. *Applied and Environmental Microbiology*, 2001, vol. 67, no. 10, p. 4891-4895.

POTTER, Polyxeni. About the Cover. *Emerging Infectious Diseases*, 2003, vol. 9, no. 10, p. 1506.

PRICE, T. Douglas and GEBAUER, Anne B. Eds. Last Hunters - First Farmers: new Perspectives on the Prehistoric Transition to Agriculture. School American Research Advanced Series, School of American Research Press, Santa Fe, NM. 1995. 354 p.

PRUSINKIEWICZ, Przemyslaw and LINDENMAYER, Aristid. The Algorithmic Beauty of Plants. Springer-Verlag, 1990, 230 p. ASIN 0387972978.

Pulse of the Planet, 2001. Available from Internet: http://www.pulseplanet.com/.

RAICHMAN, Nadav; GABAY, Tamir; KATSIR, Yael; SHAPIRA, Yoash and BEN-JACOB, Eshel. Engineered Self-Organization in Natural and Man-made Systems. In: *Proceedings of Tenth International Symposium on Continuum Models and Discrete Systems (CMDS 10)-NATO Advanced Research Workshop.* 30 June - 4th July, 2003, Shoresh, Israel). BERGMAN, D.J. and INAN, E., eds. Kluwer Press (in press) - Personal Communication with Professor E. Ben Jacob.

Research and Information System for the Non-Aligned and Other Developing Countries. (RIS). *World Trade and Development Report 2003.* Cancun and Beyond. Academic Foundation, New Delhi, India, 2003, 130 p.

ROOT-BERNSTEIN, Robert. S. Music, Creativity and Scientific Thinking. *Leonardo,* 2001, vol. 34, no. 1, p. 63-68. Also available from Internet: http://hipercubo.uniandes.edu.co/redes03/pdf/leonardo/music_scientific.pdf.

ROTA, Gladis and IZQUIERDO, Juan. "Comics" as a tool for teaching biotechnology in primary schools. *Electronic Journal of Biotechnology* [online]. 15 August 2003, vol. 6, no. 2. Available from Internet: http://www.ejbiotechnology.info/content/vol6/issue2/issues/2/index.html

ROTHWELL, Nancy. Can Art Enlighten Science? February 2004. http://www.arts.telegraph.co.uk/connected/main.jhtml?xml=/connected/2004/02/13/ecfvos13.xml.

SALLEH, Anna. Couple make music with fungus. *Australian Broadcasting Science Online*, November 10, 2000, Available from Internet: http://www.abc.net.au/science/news/stories/s210368.htm.

SAVONA-VENTURA, Charles. Maltese Medical history as seen through Postage Stamps. 1997. Available from Internet: http://www.geocities.com/hotsprings/2615/medhist/stamps.html.

SAYERS, Robert and RINZLER, Ralph. The Korean Onggi Potter. *Smithsonian Folklife Studies*, Smithsonian Institution Press, Washington DC, USA. 1987. 288 p. SF5.

SEILACHER, Adolph. Fossil Art. *The Royal Tyrell Museum of Palaeontology*, Drunheller, Canada, 1997, 64 p.

STEINKRAUS, Keith. H. Handbook of Indigenous Fermented Foods; 2nd Edition, Revised and Expanded; publ. Marcel Dekker Inc., New York.-Basel-Hong Kong, 1995, p. 776. ISBN 0-8247-93512-8.

UBELAKER, Douglas.H. The Impact of Disease: Two Worlds Meet. *Perspectives in Health*, 1999, vol. 4, no. 1, p. 14-17. also available from Internet: http://www.paho.org/English/DPI/Number7_article3.htm.

University of Art and Design Helsinki (UIAH). Workshop and Seminar in Environmental Art – Fermentation. (1st – 12th September, 2003, Helsinki, Finland. Available from Internet: http://www2.uiah.fi/conferences/fermentation/english.htm.

VARMUS, Harold. Building a global culture of science. *The Lancet*, 2003, vol. 360, sup. no. 1, p.1-4.

VASIL, I. K. Turning Point Article – The Wanderings of a Botanist, *In Vitro Cellular and Dervelopemntal Biology–Plant*, 2002, vol. 38, p. 383-395.

VON ENGELHARDT, D. Cancer as a Dialogue between Biology and Culture. *The Aventis Magazine*, 2003/1, p. 12-17. Also available from Internet: http://www.aventis.com/main/home_static.asp.

YOUNG-JA, Lee. Onggi Folk Museum. *Koreana*, 2000, vol. 14, no. 3, p. 24.

---

[1] As defined by the United Nations, the Culture of peace is a set of values, attitudes, modes of behaviour and ways of life that reject violence and prevent conflicts by tackling their root causes to solve problems through dialogue and negotiation among individuals, groups and nations (UN Resolutions A/RES/52/13: Culture of peace; A/RES/53/243: Declaration and Programme of Action on a Culture of Peace).

[2] "Culture should be regarded as the set of distinctive spiritual, material, intellectual and emotional features of society or a social group, and that it encompasses, in addition to art and literature, lifestyles, ways of living together, value systems, traditions and beliefs" (paragraph 5 in the Preamble of the UNESCO Universal Declaration on Cultural Diversity).

[3]Lionel Poilâne (1945-2002) "the best known baker in Paris and the man who, perhaps more that any, other made French traditional breadmaking honorable and artistic again; and the only bread in France known by its bakers' name". See: Lionel Poilâne by Bruce Jackson, Buffalo Report, November 4, 2002.

[4] Director of the Centre for Contemporary Art and the Natural World, Poltimore, UK*(http://www.greenmuseum.org/), 2002.*

[5] Term used freely and interchangeably with ecological art, land art, earth art, "ecoventions", etc., the term is used as umbrella-term to cover all aspects of art and sculpture in nature. See also: http://www.greenmuseum.org/ (definition of environmental art); http://www.ecoartspace.org/; (curriculum); and http://faculty.ssu.edu/~acn/ (art and nature conferences).

[6] a) PaintingCat Fight (1786-1788) by Francesco José de Goya y Lucientes in issue dealing with synoptic articles on Toxoplasmosis.

b) Painting Beware of Luxury(circa 1665) by Jan Steenin vol. 9. 1035 indicating that microbes in their transmission of animal diseases to humans are just "singing what they hear".

c) Past Covers of the Emerging Infectious Diseases journal can be found at http://www.cdc.gov/ncidod/eid/cover_images/covers.htm.

[7] See http://www.brewingtechniques.com/library/backissues.html .

[8] The Selfish Gene, ed Richard Dawkins, Oxford University Press, UK, (1st Edition,1976) - Paperback edition 1990, 352 p.

[9] The term bioart (or bio-art), popularly in usage by the community of molecular biologists is also used to embrace genetic art and it synonym transgenic art. Generally-speaking artistic creations depicting the intermingling of the biosciences or biotechnologies with art are described as biosci-art another form of bioart. In this contribution, bioart is used as an umbrella term to cover all forms of animate and inanimate art that range from the artistry of microorganisms through eco, electronic, genetic art to classical paintings, musical expressions and sculpture, and inclusive of cine and literary work. It excludes environmental art[1] and medical art.

[10]Travis, J. (2000). Genes on Display – DNA becomes part of the artist's palette, Science News Online, Vol.158, No. 25, December. See also Table 5.

[11]The Canon of Medicine (Kitab al-Qanun fi al-tibb) by Ibn Sina (d. 1037/428 H). A rare complete copy made in Iran probably at the beginning of the 15th century. NLM MS A53, fol. 368b, the illuminated opening of the 4th book. In: Islamic Culture and the Medical Arts.

[12]Exhibitions in the History of Medicine, National Library of Medicine, http://www.nlm.nih.gov/exhibition/exhibition.html.

[13] The Wellcome Trust Medical Photographic Library is the world's leading source of images on the history of medicine, modern biomedical science and clinical medicine,http://medphoto.wellcome.ac.uk.

[14] See exhibitions at http://www.wellcome.ac.uk/ for The Art of Medicine and Pharmakon; and http://www.lemieuxgalleries.com/artist_medicine.html for Medicine in Art/Art in Medicine.

[15]Hofstadter, D. (1979). Godel, Escher, Bach: On Eternal Golden Braid, publ. Basic Book Inc., NY, USA.

[16]Future Food, p. 61-66, In: The Pleasures and Politics of Food, The Wilson Quarterly, vol. 27.

[17]New York Academy of Sciences, April 30, 2003, press release.

[18]Strategic objective 5: Improving security by better management of the environment and social change, In: Mainstreaming the Culture of Peace, ed. UNESCO-BSP (2002), p. 26, publ. UNESCO-BSP, France.

[19] Cultural Diversity and Creativity (Article 7; and Main Line of Action 15) in The UNESCO Universal Declaration on Cultural Diversity, adopted unanimously by the 185 Member States represented at the 31st session of the General Conference in 2001 in the wake of the events of 11 September 2001; official text at http://unesdoc.unesco.org/images/0012/001271/127160m.pdf.

[20]Visions of Science is a photographic awards scheme organised by Novartis Pharmaceuticals in association with The Daily Telegraph to encourage ongoing discussion about science through an attention-grabbing image that gives new insight into the world of science and the workings of nature,

http://www.visions-of-science.co.uk/f-intro.htm.

1. The World As you Never Seen It Before (Highfield, R. - filed: 20 September, 2001).

2. Photographs Capture The Sheer Beauty of Science (Derbyshire, D. - filed: 17 September, 2002).

3. Exposed: The Weird and the Wonderful (Derbyshire, D. - filed: 24 September, 2004).

4. Can Art Enlighten Science (Rothwell, N. - filed 13 September, 2004).

[21]http://www.cnn.com/2004/WORLD/europe/01/26/pope.breakdancers.ap/index.html.