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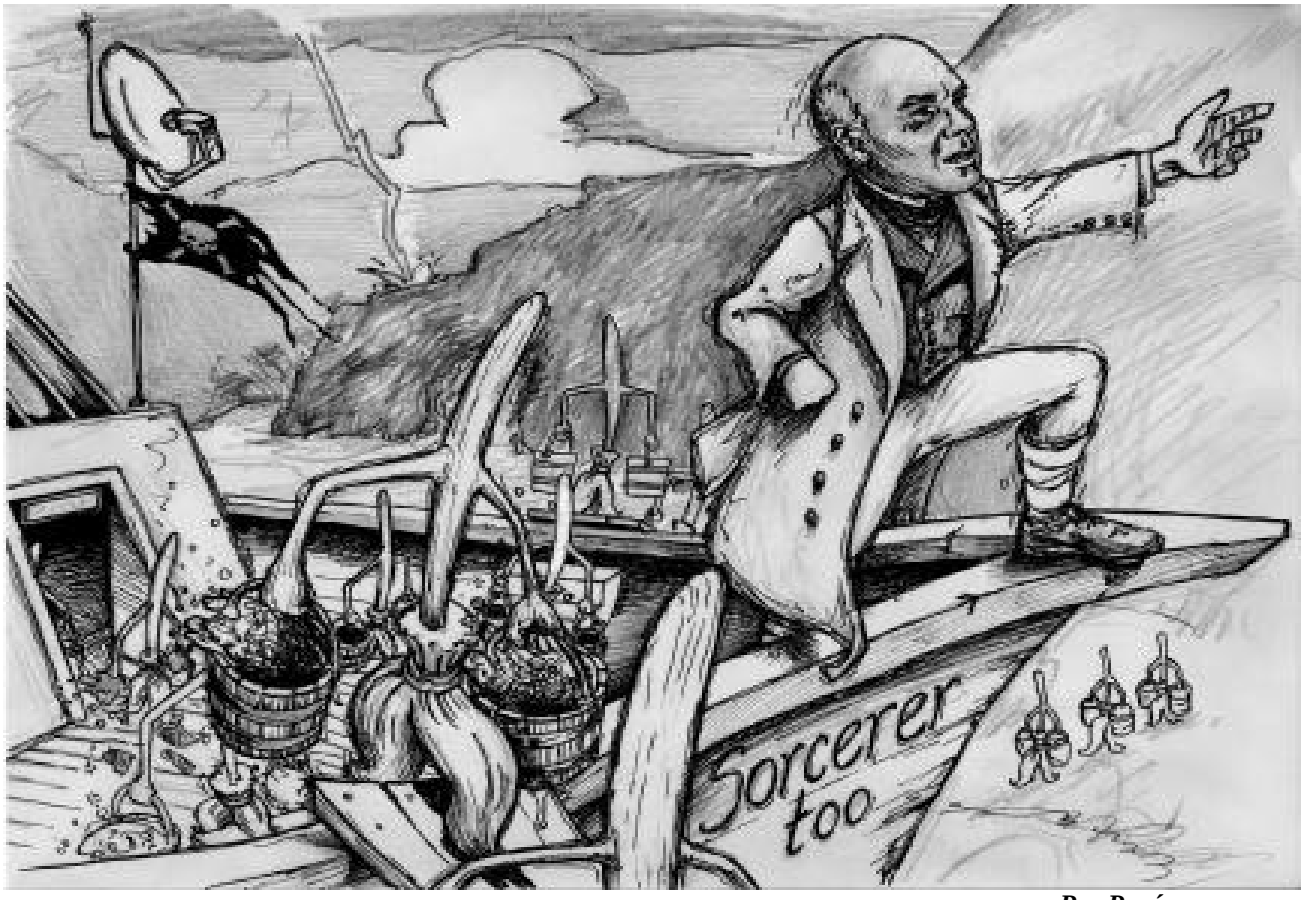
# Playing God in the Galapagos

## *J. Craig Venter, Master and Commander of Genomics, on Global Expedition to Collect Microbial Diversity for Engineering Life*

J. Craig Venter, the genomics mogul and scientific wizard who recently created a unique living organism from scratch in a matter of days, is searching for pay-dirt in the biodiversity-rich Galapagos Islands. From his 95-ft. yacht, Sorcerer II, Venter is hop-scotching around the globe collecting microbial diversity from gene-rich seas and shores every 200 miles.[1] Venter's ship has already sampled in the Sargasso Sea (North Atlantic), Mexico, Costa Rica, Panama, Ecuador (Galapagos), Chile and is now en route to French Polynesia (Tahiti, Bora Bora, etc.). In the Sorcerer's wake, governments are left with troubling questions about public domain diversity and private patenting, unresolved ethical and ecological concerns about the human-made creation of novel life forms, and huge gaps in the global community's capacity to address new technologies.

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# *J. Craig Venter – the Sorcerer's Apprentice – in Search of Another Origin of the Species in the Galapagos*

***Issue:*** A global maritime microbe-hunting expedition launched by J. Craig Venter of human genome mapping fame threatens to turn a nation's biomaterials from public domain goods into patentable, private commodities. Although the Institute for Biological Energy Alternatives (IBEA) – one of Venter's three non-profit institutes and the one leading the initiative – has promised not to patent the raw microbes it collects and sequences, patents could be claimed on modified microbes or on new life forms engineered from the collected microbes. Venter's yacht, the Sorcerer II, is now steaming toward the South Pacific after collecting land and marine microbes from Maine to Mexico, Panama, Chile, and – most recently – on Ecuador's famous Galapagos Islands. Venter's ocean odyssey poses ethical and ecological issues about emerging technologies that can create human-made species.

***Implications:*** The maverick US biologist's expedition has already discovered more new genes than scientists knew to exist including nearly 800 photoreceptor genes that convert sunlight to energy. Venter's team is also collecting microbes that survive and thrive in harsh environments (extremophiles) such as in volcanoes or hot sulfur vents on the ocean floor. Extemophiles are becoming a prized target for pharmaceutical, agricultural and chemical research. But, more importantly, the voyage of the Sorcerer II symbolizes the convergence of two major technological trends. Venter has shown that it is possible to map a microbe and then use it as a template for building a new life form that might be put to industrial work. As Venter and biotechnologists build new life from stripped-down microbes, nanotechnologists are busy building biological machines – or hybrid machines employing both organic and inorganic matter – from the bottom-up. The two trends converge on the shifting shores of *nanobiotechnology* – the current darling of US venture capitalists. The implications are breathtaking: not just new species and new biodiversity – but life forms that are human-directed and self-replicating. Nanobiotechnology is moving science from genetically-modified organisms to atomically-modified organisms.

***Policies:*** As fascinating as the IBEA initiative is, it challenges national sovereignty and raises more doubts about the already problematic access and benefit-sharing work of the Convention on Biological Diversity (CBD).[2] More significantly, Venter's work poses ethical and environmental concerns about the use of biodiversity to build new life forms from scratch. Intellectual property claims on human-made life also pose concerns about *ordre public*.

***Fora:*** The immediate situation facing the Ecuadorian government could be addressed through national debate and efforts to retain sovereignty over the samples already sent to the USA, as provided in the export license granted to Venter by the Galapagos National Park. The United Nations must create a new mechanism that will make it possible for the international community to monitor the development of new technologies whose introduction could affect (positively and/or negatively) human health, the environment, or society's well-being. ETC Group believes this could best be achieved by the creation of an International Convention for the Evaluation of New Technologies (ICENT) at the UN. At present there is no intergovernmental body that has the capacity to monitor and evaluate trends in science and technology and their far-reaching societal impacts. Civil society agendas must urgently incorporate debate and action on the orientation of science and the impact of new technologies.

Civil society organizations in Ecuador were stunned to learn that Venter's itinerant research team, with funding from the US government, has already completed "extensive sampling" in the Galapagos, according to an announcement made by Venter at a press conference on March 4 in Washington, DC.[3] In what Ecuadorian civil society organizations consider a breach of national law, and an attack on the country's sovereignty, biodiversity samples collected by Venter have already been shipped to the United States for sequencing.[4]

Although Venter's US-based, non-profit research institute, the Institute for Biological Energy Alternatives (IBEA), had been negotiating a Memorandum of Understanding (MOU) with the government of Ecuador to establish terms of access to the Galapagos Islands, the MOU was never signed. (Venter claims that he does have signed MOUs with the governments of Mexico and Chile to collect samples in their territories.) IBEA was granted an "export license" signed by the director of the Galapagos National Park and an employee of the Ecuadorian Service for Plant and Animal Health (SESA) which permits the transport of samples back to IBEA's headquarters in Rockville, Maryland (USA) where gene sequencing will take place. The permit stipulates that the samples remain the property of the Galapagos National Park while in the custody of Craig Venter. Civil society organizations in Ecuador charge that Venter's expedition is biopiracy because the permit was not authorized by the appropriate government authority, because there was no public consultation, and because nothing prevents Ecuadorian resources from being privatized through monopoly patents at some later point. They also believe that Venter's research raises profound social and ethical questions.

Will microbes collected in the Galapagos form the genetic template for Venter's new, artificial life forms? Who will own and control the products of microbial diversity engineered by Venter? In recent years the fields of biotechnology and nanotechnology have merged to form a new discipline known as *nanobiotechnology.* Since 1999, venture capitalists have devoted over $450 million to nanobiotechnology. Combined with the US government's commitment of around $800 million to nanotech last year, researchers have unprecedented potential to merge the living and non-living realms. Venter's functionalized life forms could play a prominent role in nano-bio products and processes.

***J. Craig Venter—The Sorcerer's Apprentice:***
Controversy is nothing new for Dr. Venter. The maverick scientist ignited worldwide protest in 1991 when he filed for patents on thousands of genes from the human brain while working at the US government's National Institutes of Health (NIH). As former head of Celera Genomics, the company he founded in 1998, Venter gained notoriety by sequencing the human genome in just three years (using his own DNA), in a direct challenge to the publicly-funded Human Genome Project.

***Ecuadorian Groups Charge Marine Biopiracy:***
"Venter's institute has flagrantly violated our Constitution and several national laws, including the Andean Pact Decision 391 on access to genetic resources," said Elizabeth Bravo of Acción Ecológica, an environmental advocacy organization based in Quito.

"When negotiations on access to genetic resources take place behind closed doors, in the absence of public debate or information, and in the context of opening the doors for monopoly patents – we call it biopiracy," said Bravo. "The issue is not simply about IBEA's failure to negotiate legal access and benefit sharing, we are profoundly troubled by the potential of Venter's institute to allow for privatization of all microbial organisms of commercial interest found in one of the richest and most unique ecosystems of the planet." Although Venter promises that intellectual property on raw microbes and their gene sequences will not be sought, there is nothing to prevent monopoly patent claims on commercially useful results derived from collected diversity.

"The Institute's research is funded by the US government, so it clearly raises the issue of national sovereignty over biodiversity – a fundamental principle of the United Nations Convention on Biological Diversity, which the US government has failed to sign. Finally, we are deeply concerned by the serious ethical questions that Venter's research raises related to the creation of new life forms in the laboratory," said Bravo.

Civil society organizations in Ecuador, including Acción Ecológica, are demanding that samples collected by Venter's institute not be used and be repatriated to Ecuador. They also demand that the government of Ecuador make all documents public before signing any biodiversity agreements related to the Galapagos or other Ecuadorian territory.

***Genomes-to-Life?*** Literally following in the footsteps of Charles Darwin's famous 19th century expeditions, Venter seeks to revolutionize 21st century evolutionary biology – this time with "environmental genomics." Since 2002, Venter's Institute for Biological Energy Alternatives has been awarded $12 million from the "Genomes to Life" program of the US government's Department of Energy (DOE) to create new life forms in the laboratory that could be engineered to produce energy or clean up greenhouse gases. Exotic microbes – such as those found in the Galapagos – are the raw materials for creating new energy sources and new life forms. Because of its extraordinarily rich endemic biodiversity – diversity found nowhere else on Earth – the Galapagos is a must-visit port of call.

A recent article in *The Scientist* notes that, in addition to the worthy goal of developing clean energy, these are money-making microbes that could offer huge financial rewards:

"A few dozen life scientists are racing to fine-tune these microbes physiologically, chemically, and genetically to produce hydrogen in a cost-effective manner with next-to-zero pollutants. The reward is enormous. Not only could it prevent further global warming, slash energy pollution, and strengthen the economy, but the winner of this race would own the intellectual property rights to the technology that could be at the foundation of a multitrillion dollar industry. In other words, the gold rush is on."[5]

According to Venter, even nutrient poor waters in the North Atlantic have yielded extremely high levels of gene diversity. At the press conference on March 4 Venter announced that his collecting expedition in the Sargasso Sea in 2003 yielded off-the-charts mega-diversity.[6] Seawater collected in the Sargasso contained a minimum of 1,800 previously unknown species. Venter's institute also identified 1,214,207 genes – bits of DNA that perform a specific function – about 10 times the total number of genes discovered to date from all other sources. (Venter estimates that there are 10 to 20 billion genes on Earth.) The team also found nearly 800 new photoreceptor genes, which allow organisms to harness energy from sunlight.

*In Vivo, In Vitro, In Venter?*
**From Survival of the Fittest to Survival of the Fastest**

Even as the Sorcerer II was bucketing up microbes from the Galapagos Islands, British media reported the discovery of HMS Beagle, Charles Darwin's sunken and long-lost sailing vessel that took him around the world and to the Galapagos in 1835. It was his sojourn on the remote islands that inspired his groundbreaking work, *On the Origin of Species*, published first in 1859. His theory of evolution, sometimes summarized as "the survival of the fittest" has dominated genetics and biology ever since.

Estimated to retain 96% of their original species diversity due to their remoteness, the 127 islands that make up the Galapagos archipelago have been thought to hold an incredible range of plants, vertebrates and invertebrates numbering in the thousands. At his March 4th news conference, J. Craig Venter drew on the parallels between the work of HMS Beagle and of Sorcerer II noting that Darwin learned by observation while he worked by sequencing – from the survival of the fittest to the survival of the fastest? Yet, Venter's team is truly breaking new ground. Until three decades ago, life could only be made *in vivo*; then it became possible to fertilize an egg *in vitro* – in a test-tube. Could building life from scratch be known as *in Venter*?

***How are microbes captured, preserved and exported to the USA from the Sorcerer II?***

**Filters** - On the yacht, samples are pumped through a series of filters that grow progressively finer (3 micron, .8 micron, and .1 micron). The filters trap organisms of various sizes so that the filters become the "containers" of the microbes.

**Freezer** - Filters containing samples are put into a bag, labeled, and then frozen in a zero degree Celsius freezer on board the boat. Throughout the voyage these bags of microbes are put on dry ice and shipped back to labs in the United States.

**Microscope** - A Nikon microscope projects onto a 42-inch flat-screen TV mounted on the wall in the boat cabin. Researchers look at organisms on slides to do a rough count.

*Source: www.sorcerer2expedition.org*

***Intrepid In-Venter?*** In November 2003 the US government's Secretary of Energy, Spencer Abraham announced that scientists at IBEA had already assembled more than 5,000 building blocks of DNA to create a small artificial virus, a so-called phage that infects bacteria. "This advance brings us closer to our goal of creating entire microbes that are 100 to 1,000-times larger than the artificial virus created so far," said Secretary Abraham.[7]

*"Microbes are kind of the master chemists of our planet."* – Dr. Edward DeLong, senior scientist, Monterey Bay Aquarium Research Institute in California.[8]

**Another *Origin of the Species*?** What Venter's IBEA has done with US Department of Energy funds so far is no less than revolutionary science. Rather than incorporate a specific gene of interest into an existing organism – something genetic engineers have been doing for three decades – Venter has created a made-to-order organism from scratch. What are the implications?

The first and greatest impact of Venter's made-to-order life forms may come in the field of nanobiotechnology. While "Gray Goo" has grabbed the headlines in the nanoworld press (where self-replicating nano-scale robots escape control until they wreak havoc on the global ecosystem), the more likely future scenario is that the merger of living and non-living matter will result in hybrid organisms and products that end up behaving in unpredictable and uncontrollable ways. In a "Green Goo" scenario, a designer microbe turns out to have designs of its own. Industry hasn't been able to control and contain genetically modified organisms. What happens when a newly-made organism – the product of nanobio – breaks out on its own?

There are also concerns that a human-made organism will provide the groundwork for a new generation of biological weapons. Ironically, Venter abandoned an earlier quest to construct the world's first simple artificial life form in 1999 because he believed that the risk of creating a template for new biological weaponry was too great.[9] This time Venter has a plan for minimizing the risks: "We may not disclose all the details that would teach somebody else how to do this."[10]

Some scientists, including Venter himself, see his work as advanced genomics and genetic engineering, and separate from the field of nanobiotechnology. Carlo Montemagno, co-director of the Institute for Cell Mimetic Space Exploration and Chair of the Department of Bioengineering at UCLA, has already successfully created complex working nanomachines with biological engines. He doesn't consider Venter's recent creation of new life forms genuine nanobiotechnology – yet. What would turn Venter's bioengineering project into nano-bio, according to Montemagno, is the presence of a component

involving non-biological "precision assembled matter."[11] Michael Heller, Professor of Bioengineering and Electrical and Computer Engineering agrees.[12] Though recognizing that all biology operates on the nano-scale, he considers nanobiotechnology the combination of synthetic devices with biology, such as the insertion of a sensor inside a cell.

In the end, it doesn't matter how laudable the goal or what you call it; the creation of human-made machines – whether biological or non-biological or some combination – will have profound implications for the environment and our definition of life itself.

**Conclusion: Controversy in His Wake**

***Concerning new life forms***: Venter's research on the creation of new life forms takes us into uncharted waters. Although IBEA insists on making a distinction between Venter's microbial collecting expedition and his contract to build novel microbial life forms for the U.S. Department of Energy, it defies reason to suggest that the unique microbes and genes picked up by Sorcerer II will not be viewed as interesting for the DOE project especially when the expedition is discovering so many new photosensitive genes relevant to energy alternatives. The extraordinary appeal of solving the world's energy problems by harnessing new, engineered life forms, tends to eclipse the very real concerns about potential negative consequences, including Green Goo or what Britain's Astronomer Royal, Martin Rees refers to as the risk of "bioerror or bioterror."[13] Society is utterly unprepared to address these issues. Revolutionary science demands close scrutiny and requires public assessment. The United Nations – through the creation of an International Convention for the Evaluation of New Technologies (ICENT) – must create the capacity to examine the social, economic and ethical impacts of new technologies. At present there is no intergovernmental body that has the capacity to monitor and evaluate trends in science and technology and their far-reaching societal impacts. But also in light of the failure of the United Nations CBD to provide for protection against the privatization of collective resources and knowledge, societies need to urgently engage in debates about the orientation and implications of new technologies, and strategies to recuperate the social control of science for the common good, as well as strategies to prevent the privatization of collective resources.

***Concerning Ecuador's bioresources***: Who will ultimately control – and profit from – the microbial diversity collections that are shipped from Venter's ocean expedition to his sequencing laboratory in Rockville, Maryland (USA)? Contrary to the emphatic statements made by Venter and his institute, concerns about intellectual property are *not* resolved. In a letter to the ETC Group, IBEA's lawyer, Reid Adler, writes, "no patents or other intellectual property rights will be sought by IBEA on these genomic DNA sequence data."[14] But Adler also asserts: "After these data are published, researchers in a given country may wish to study microbes that have particular scientific interest or have potential commercial value." In other words – and this is a critical distinction – there is nothing to prevent Venter or any other researcher from claiming monopoly patents on commercially useful results derived from microbes or sequence data. Adler also writes that all the data collected will be placed in the public domain for everyone to use. Yet, the export license issued to Venter makes it clear that the samples remain the property of Ecuador and the permit says nothing about the sequenced data being placed on the Internet. In the absence of this permission, Venter's institute has no legal right to make decisions about what happens to Ecuador's property, or under what conditions its biodiversity is made available.

**Extreme Science: The Study of Extremophile Life**

*Extremophiles*—literally, lovers of outer limits—belong to a special class of microorganisms that survive in conditions so harsh that sustainable life would seem unlikely. Extreme heat, extreme cold, the absence of oxygen and sunlight, the presence of toxic metals such as arsenic and zinc—it turns out that none of these environmental conditions precludes life. Adventurous researchers, outer-limit lovers in their own right, have begun looking at these ultra-hardy organisms for answers to some of the toughest scientific questions, such as how to produce clean energy and how to clean up toxic waste.

- *Deinococcus radiodurans*, uncovered in the Atacama Desert in Chile, is thought to be the toughest microbe on earth because of its ability to live where there is very little water and very few nutrients and because of its ability to repair its own DNA after being exposed to drought and high doses of radiation.[15]
- Five previously-unknown organisms have been found to live, in the Iron Mountain Mine in Northern California, hundreds of feet underground at 50 degrees Celsius in water poisoned with arsenic. Studying these organisms could help devise ways to clean up toxic sites.[16]
- *Methanogenium frigidum*, found in Ace Lake in Antarctica, thrives in extremely cold water with no oxygen and no sunlight and it produces methane gas, a potential alternative energy source.
- Still other microbes of interest brave the wasteland that is the intestinal tracts of humans.

Researchers aren't studying extremophiles out of pure academic interest or as a science-nerd's microscopic version of the "Survivor" reality show. They're looking for potential products and processes that have yet to be produced through conventional means. US Secretary of Energy Spencer Abraham, while announcing one of his grantees' successful creation of an artificial virus (Craig Venter's Institute for Biological Energy Alternatives), suggested that, "it is easier to imagine, in the not-too-distant future, a colony of specially designed microbes living within the emission-control system of a coal-fired plant, consuming its pollution and its carbon dioxide."[17] Abraham added, "we can make specialized microscopic bugs that eat carbon dioxide, others that can get trees to grow in barren soil and hostile climates, and create hydrogen for tomorrow's fuel cell vehicles."[18]

### *Dr. J. Craig Venter*
### Venter Timeline

**1991** – National Institutes of Health researcher Dr. J. Craig Venter ignites worldwide protest when his research laboratory, part of the Human Genome Project, files for US patents on thousands of gene sequences from the human brain.

**July 1992** – Backed by $70 million in venture capital, Venter leaves NIH to become President and CEO of the non-profit, Institute for Genomic Research (TIGR). The non-profit institute will provide all rights to any products it develops to a new company, Human Genome Sciences Inc., of which Venter is part-owner.

**1995** - TIGR decodes the first complete genetic material of a free-living organism (*Haemophilus influenzae*).

**May 1998** - Venter announces that he is forming a private company, Celera Genomics, that within three years would sequence the complete genetic code of human life - seven years before the projected finish of the US government's Human Genome Project.

**January 1999** -- Venter announces that Celera Genomics is on the threshold of constructing the world's first simple artificial life form, based on 300+ genes borrowed from a simple microbe. But Venter says that Celera will halt further work because artificial organisms could be misused and become a template for biological weapons.

**October 1999** - Celera Corporation files preliminary patents on sequences of human DNA making up some 6,500 whole or partial genes.

**June 2000** – Celera and the publicly-funded Human Genome Project jointly release first drafts of the human genome.

**January 2002** – Venter forced to resign from Celera Genomics, the company he founded.

**April 2002** – Venter announces that the DNA used by his former company, Celera Genomics, to decode the human genome was largely his own.

**August 2002** – Venter announces plans to build the largest genome sequencing center, to vastly decrease the time and cost required to determine the DNA code of people, animals and microbes. "Our goal is to get to where we can do a whole

genome analysis in minutes or hours, in contrast to months or years," Dr. Venter said.
Venter becomes president of three not-for-profit organizations, The Center for the Advancement of Genomics, the Institute for Biological Energy Alternatives, and the J. Craig Venter Science Foundation. According to Venter, these organizations are dedicated to exploring social and ethical issues in genomics, as well as seeking alternative solutions to energy through microbial sources.

**November 2002** – Craig Venter and Nobel Laureate Hamilton Smith announce that they are recipients of US$3 million grant from the US Energy Department to create a new, "minimalist" life form in the laboratory – a single-celled, partially human-made organism.

**April 2003** – the US Dept. of Energy awards an additional $9 million over three years to Venter's Institute for Biological Energy Alternatives, for energy-related genomics work.

**September 2003** – Dog genome unveiled; the poodle whose genome was sequenced belongs to Venter.

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[1] Detailed information about the expedition and a map of the Sorcerer II's route is illustrated on a new web site: www.sorcerer2expedition.org
[2] See ETC Group, "From Global Enclosure to Self Enclosure: Ten Years After – A Critique of the CBD and the 'Bonn Guidelines' on Access and Benefit Sharing," *ETC Communique*, Issue # 83, January/February, 2004, Available on the Internet: www.etcgroup.org
[3] On March 4, 2004 Venter's Institute for Biological Energy Alternatives announced the results of microbial diversity collected in the Sargasso Sea and also described sampling in Mexico, Costa Rica, Panama, and the Galapagos, among others. See www.sorcerer2expedition.org
[4] See Acción Ecológica, Boletin De Prensa, Mientras Unos Juegan A Crear Vida, En Galapagos Se La Roban, Quito, 9 de marzo del 2004. www.accionecologica.org
[5] Sam Jaffe, "Biologically Derived Hydrogen – Future Fuel?" *The Scientist*, Vol. 17, Issue 8, 28, April 21, 2003.
[6] Details are described in an article appearing in *Science Online*, "Environmental Genome Shotgun Sequencing of the Sargasso Sea," J. Craig Venter, et al., March 4, 2004. Available on the Internet: www.sciencemag.org/
[7] Anonymous, Department of Energy News Release, "Researchers Funded by the DOE 'Genomes to Life' Program Achieve Important Advance in Developing Biological Strategies to Produce Hydrogen, Sequester Carbon Dioxide and Clean up the Environment, November 13, 2003. Available on the Internet:
http://www.doegenomestolife.org/news/111303press.shtml
[8] Andrew Pollack, "A New Kind of Genomics, with an eye on Ecosystems, *New York Times*, October 21, 2003.
[9] P. Cohen, "A terrifying power," *New Scientist*, January 30,1999, p. 10.
[10] Justin Gillis, "Scientists Planning to Make New Form of Life," *The Washington Post*, November 21, 2002, p. A1
[11] Personal communication with Carlo Montemagno, New York City, Friday, February 27, 2004.
[12] Personal communication with Michael Heller, New York City, Friday, February 27, 2004.
[13] Martin Rees, *Our Final Hour*, New York: Basic Books, 2003, p. 41. Rees is a professor at Cambridge University and England's Astronomer Royal.
[14] Letter from Reid Adler, General Counsel of IBEA, to Pat Mooney, Executive Director, ETC Group, 3 March 2004.
[15] Kate Ruder, "Radiation-Resistant Microbe Found in Chilean Desert," November 14, 2003. Available on the Internet:
http://www.genomenewsnetwork.org/articles/11_03/desert.shtml
[16] Kate Ruder, "Iron Mountain's Champion Extremophiles," *Genome News Network*, February 6, 2004. Available on the Internet:
http://www.genomenewsnetwork.org/articles/2004/02/06/iron_mtn.php?print=1
[17] Anonymous, Department of Energy News Release, "Researchers Funded by the DOE 'Genomes to Life' Program Achieve Important Advance in Developing Biological Strategies to Produce Hydrogen, Sequester Carbon Dioxide and Clean up the Environment, November 13, 2003. Available on the Internet: http://www.doegenomestolife.org/news/111303press.shtml
[18] Remarks by Secretary of Energy Spencer Abraham, Forrestal Auditorium, November 13, 2003. Available on the Internet:
http://doegenomestolife.org/news/111303abraham.shtml

**The Action Group on Erosion, Technology and Concentration, formerly RAFI, is an international civil society organization headquartered in Canada. The ETC group is dedicated to the advancement of cultural and ecological diversity and human rights. www.etcgroup.org. The ETC group is also a member of the Community Biodiversity Development and Conservation Programme (CBDC). The CBDC is a collaborative experimental initiative involving civil society organizations and public research institutions in 14 countries. The CBDC is dedicated to the exploration of community-directed programmes to strengthen the conservation and enhancement of agricultural biodiversity. The CBDC website is www.cbdcprogram.org. The views expressed in this *Communiqué* are not necessarily those of our CBDC partners.**