







#### **Reimagining Resistance** Towards a new paradigm of human-bacterial relations Part of the Reimagining Resistance Series

Published by: The Reimagining Resistance Group Email contact: microbiana2015@gmail.com

Web site: www.microbiana.org

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#### **Supported by ReAct**

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**Design:** El Gato

May, 2016.



Towards a new paradigm of human-bacterial relations

A Resource Book

## **Acknowledgment**









This Resource Book, titled 'Reimagining Resistance: Towards a new paradigm of human-bacterial relations' has been jointly written, compiled and edited by Mary Murray and Satya Sivaraman. Sections 6.2, 6.3, 6.4 and Box 9 were co-authored with Arturo Quizhpe and Kléver Calle, while Section 4 titled 'Reimagining Resistance and Art' and section 5 titled 'Arts for Social Change' have been co-authored by Mary Murray and Janet DeBoos.

We would like to thank the many scientists, microbiologists, clinicians and artists whose work and views we have derived inspiration from or referenced as part of the report.

This Resource Book is for educational purposes only and will be used to encourage further debate, dialogue and research on a variety of themes. The content of this publication will be translated into Spanish also and along with the English version made freely available to a wide audience through the internet.

The Resource Book would not have been possible without the substantial contribution of ReAct. Their support is greatly appreciated.

## **Foreword**

Since its origins, the University of Azuay has kept as a fundamental premise the search for academic excellence. Academic excellence has in turn to be closely linked to a high quality university education according to social needs. Within this context, and being responsible for research and community outreach as prioritized university activities, it is my honor to introduce to the international academic community this very valuable book "Reimagining Resistance: Towards a new paradigm of human-bacterial relations". This book is the result of a joint effort of a well-known group of scientists and artists, who contributed, with their particular point of view, to producing a reference document that will surely promote analysis and reflection attitudes in the reader, broadening research horizons.

Antibiotic resistance, a public health problem caused by multiple factors, is becoming a serious threat for humankind. For this reason it is of great importance to create collective awareness about this latent risk. "Reimagining resistance" uses innovative resources and analogies that focus on facilitating the understanding of this phenomenon through a pleasant reading, while showing the relationships between technical aspects and aspects of the social, cultural, historical and political environment. The reader will quickly arrive at the state of the art in these matters.

Without doubt, the reading of this work will allow the unspecialized person to understand fairly well the microbial world, the relationship of microbes and the human body, and the relationships of humans and bacteria. Additionally, the reader will easily comprehend the role of medicine in developing and promoting strategies for attitude-change and comprehensive approaches to face current and future problems while building effective control alternatives.

Jacinto Guillén García DEAN OF RESEARCH UNIVERSITY OF AZUAY

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# Introduction

It is not surprising at all that the closest analogy often used to explain the phenomenon of rapidly spreading antibiotic resistance (ABR) is that of global warming<sup>(1)</sup>.

The release of gases that contribute to global warming happens through many natural processes but the burning of vast amounts of non-renewable resources of energy as part of human consumption results in release of gases in quantities that threatens to make such warming irreversible.

Similarly ABR is a phenomenon that is found normally in many species of bacteria as part of the natural evolutionary process. However, the use, abuse or misuse of human-produced antibiotics in large quantities, accelerates the emergence and spread of ABR by artificially selecting bacteria that are either

already resistant or have acquired such resistance from others in course of time.

In other words, like global warming ABR is also a complex phenomenon that arises from the interaction of routine natural processes with a variety of human interventions in the ecosystem. And in both cases it is clear that no simple, standalone technical intervention can really mitigate the problem.

The response called for in the case of global warming includes a wide range of measures, from drastically cutting down emission of harmful gases to changing individual lifestyles. This in turn involves changes in everything from global economic policy to transformation of energy-consumption behavior in thousands of local contexts, involving a very large proportion of the world's population.

1. www.bbc.co.uk/news/health-21178718

While ABR is yet to be seen as a threat on the same scale as global warming there is no doubt that any response to it too would have to take into account a vast number of factors and players. With the quest for new antibiotics to fix the problem proving to be elusive in recent decades, attention needs to turn to the need for a more integrated and indeed ecological approach to the problem.

The 'Reimagining Resistance' perspective argues that the crisis of ABR signifies the need for a paradigm shift in how we understand the microbial world, its relation to the human body and the role of medicine in the human-microbe equation. The challenge of ABR provides us an opportunity to ask new questions and often very basic and simple ones, that delve into not just the science but also the history, culture, politics and language of medicine itself.

Some of the questions that need to be asked now for example are as to what exactly is the prevailing notion of 'health' in modern societies? The World Health Organization defines it as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'<sup>(2)</sup>. In practice however much of the focus of modernday healthcare is on just treating the symptoms of disease, with increasing dependence on different new technologies to achieve this. There is little reference to the inter-connections of human health with society and nature or on ensuring the mental and social well-being of people.

Yet another question that new research in microbiology is throwing up is about the long term evolutionary role of microbes on our planet? While the role of bacteria in evolution of life in general is well understood recent new research is showing how the several thousand bacterial species and sub-species in the human body play a critical role in the human body and its various functions.

Indeed, from our new emerging knowledge of the human microbiome the question can be raised, what exactly does it mean to be a 'human being' today in biological terms? Given the fact that microbial species

WHO definition - World Health Organization; who.int/about/definition/en/print.html



Peter Cameron, Canberra Disctrict 9, detail.



Peter Cameron, Canberra District 8, detail.

in the human body represent a genetic pool that is an astounding 360 times more than our own genes, there is little doubt that our microbiome is an essential 'organ' and not a mere invasive 'parasite' that we need to 'get rid off'.

As Dr Martin Blaser, Director of the Human Microbiome Program at New York University has pointed out in his recent book Missing Microbes<sup>(3)</sup>, damaging these species has severe health consequences. His research team has produced further evidence that widespread use of antibiotics may be contributing to the rise of obesity, asthma, diabetes, acid reflux and even certain forms of cancer.

At another level, though today it may appear 'there is no alter-

native' to antibiotics to tackle harmful bacteria, we also need to enquire into the role of human action in turning harmless bacteria into pathogenic ones. There is considerable evidence (4) to believe that the process of urbanization, poor living conditions, changing diet and lifestyles and the concurrent lowering of natural human immune systems have driven at least some of the large-scale epidemics in human history.

There are other questions too that need to be raised in the context of how we visualise or describe the microbial world, disease and treatment. Are we using the appropriate language required to understand what is really happening or are we blindly following the often loaded terminology we have inherited from the history and politics of modern science?

For example, though the ecological dimension of bacterial resistance is better understood today than ever before, even now the most popular metaphor used for dealing with bacteria and the infectious diseases they cause is that of war. Just as human beings cannot go to 'war' with global

Blaser, M.J. (2014). Missing microbes: how the overuse of antibiotics is fueling our modern plagues. p12-13. Henry Holt, NY.NY.

<sup>4.</sup> http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2626828/pdf/8903148.pdf







Peter Cameron, Guthega, 13, 2005.

warming it is perhaps futile to constantly talk about 'fighting', 'defeating' or 'eliminating' the vast and diverse world of bacteria and new ways of 'seeing' the issue need to be acknowledged or allowed to emerge.

Can artists, sensitive to the ecological processes that govern all life forms, help us frame our questions in a better manner or gather new perspectives where our stale words fail us? Can they help us imagine and reimagine this invisible world and our intimate connection with it? Can sociological or cultural studies of how human beings live and operate in different contexts provide us clues to why microbes behave the way they do and to serve what purpose? In the same vein, can we also consider the collectives of living organisms called 'human beings', despite differences in scale, as being analogous in some ways to microbial colonies and gain some more insight into the world of the latter<sup>(5)</sup>?

And going well beyond the discussion about bacteria in the context of human or animal health is it possible to understand the microbial world as full of intelligent organisms that play the role of preserver of all life forms on Planet Earth? Even more fundamentally we need to ask whether it is productive at all to constantly frame questions about the microbial world in an anthropocentric manner, without considering the breathtaking diversity and even aesthetic beauty of the microbial world? Given

 <sup>&#</sup>x27;Self-engineering capabilities of bacteria'; Eshel Ben-Jacob and Herbert Levine J. R. Soc. Interface (2006) 3, 197–214 doi:10.1098/rsif.2005.0089. Published online 1 November 2005

the fact that microbes are the oldest living organisms on Earth and every other form of life – including ours – has evolved from them, is it possible we can actually learn something from them and reverse the ecological catastrophe our planet is headed towards?

This resource book is part of the 'Reimagining Resistance' initiative, ongoing since 2006, to capture the ecological, cultural, social and other dimensions of the issue of ABR. The attempt is to point to the different ways in which ABR and its implications for human societies can be understood, through reference to work already underway in various disciplines and pointing to the linkages between them.

The book does not claim to provide answers to the tough and complex questions emerging through this process of dialogue and enquiry. Instead it seeks to frame the right questions and take them to as wide an audience as possible in the hope that we, like bacteria themselves, can collectively find the right answers needed.

It does however argue for a new pattern of thinking that includes developing a fascination for and knowledge of the wider microbial world, including its ecology and role in human and environmental health, while gaining a deeper and more nuanced knowledge of bacteria that are harmful to humans and ani-

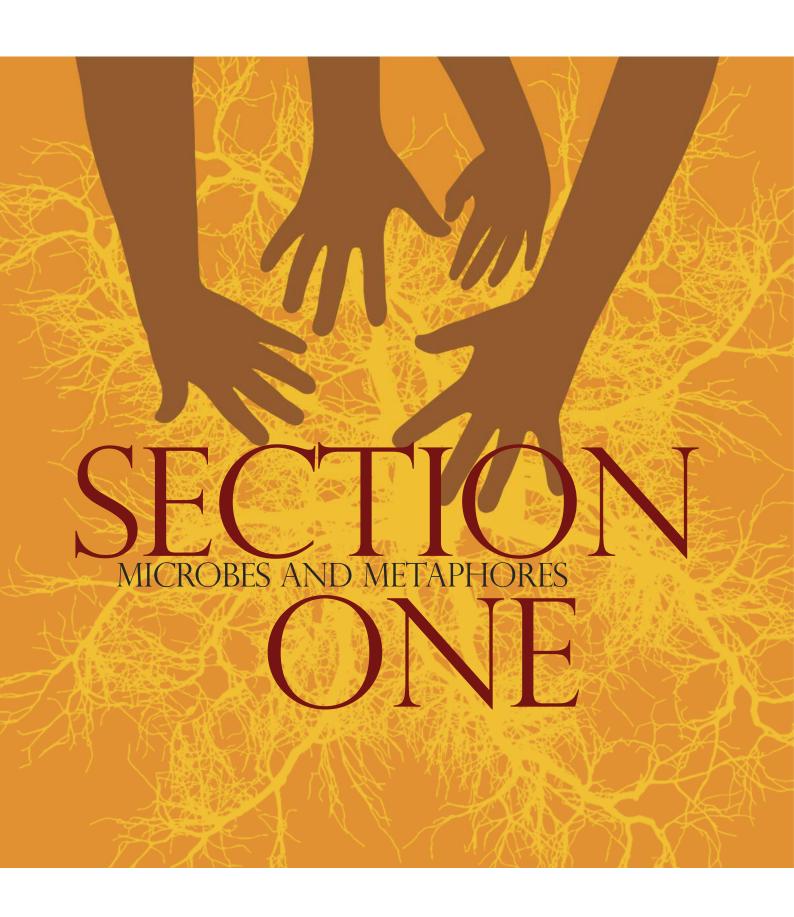


Peter Cameron, Canberra District 12, detail.

mals, processes of human and animal immunity and the circumstances in which this harm is triggered. We argue that a true understanding of ABR or antibiotics and the need to restrain and target their use to specific situations cannot really be internalised without this knowledge and way of thinking.



Peter Cameron, Guthega, 12, 2005.



## **1.1** The War Metaphor

Ever since the advent of the germ theory of disease in the nineteenth century with Louis Pasteur and Robert Koch much of microbiology and medical research of infectious diseases has revolved around the search for 'pathogenic' microbes (both bacteria and virus). Once discovered, in the context of both human and animal diseases, the attempt has been to then find an 'antimicrobial' therapy to eradicate these 'disease-causing agents'.

It is a world of simple warfare there are microbes that cause harm and there are anti-microbials to destroy them. There is no doubt that this approach has 'worked' up to a point with a steady stream of antibiotics being produced from the early part of the twentieth century till the eighties helping overcome a variety of infectious diseases from sepsis to tuberculosis. One outcome of this success though has also been to deeply embed the war metaphor of 'good antibiotics' shooting down 'bad

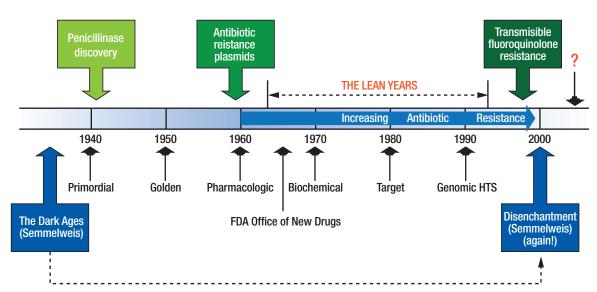
pathogens', that has somewhat precluded thinking along other, more nuanced lines.

Of course, it must be pointed out that the first antibiotic agents themselves were a product that emerged from the ecological insights of pioneering researchers such as Rene Dubos and Selman Waksman into the processes in soil bacteria that results in the natural production of antibiotics. Dubos<sup>(6)</sup>, a key figure in the history of antibiotics, even went on to become one of the biggest champions of the environmental movement in the US in its early stages. Yet little of his ecological approach actually rubbed off on many fellow researchers or public perception of microbes as being 'enemies'.

In the early days of the antibiotic era it was noticed that antibiotic use produced a number of side-effects on the human body due to the killing of benign bacterial species, generally known as commensal flora, in the body along with the 'pathogen'. This indicated quite clearly that there was an 'equilibrium' of microbial communities that affor-

Dubos is the originator of the slogan, 'Think Global, Act Local', a favourite chant of the environmental movement worldwide.

#### **Events in the Age of Antibiotics**



History of antibiotic discovery and concomitant development of antibiotic resistance. The dark ages, the preantibiotic era; primordial, the advent of chemotherapy, via the sulfonamides; golden, the halcyon years when most of the antibiotics used today were discovered; the lean years, the low point of new antibiotic discovery and development; pharmacologic, attemps were made to understand and improve the use of antibiotics by dosing, administration, etc; biochemical, knowledge of the biochemical actions and antibiotics and resistance mechanisms led to chemical modification studies to avoid resistance; target, mode-of-action and genetic studies led to efforts to design new compounds; genomic/HTS, genome sequencing methodology was used to predict essential targets for incorporation into high-throughput screening assays; disenchantment, with the failure of the enormous investment in genome-based methods, many companies discontinued their discovery programs. Other milestones in the history include the creation of the FDA Office of New Drugs after the thalidomide disaster led to stricter requirements for drug safety, including the use of antibiotics. This slowed the registration of novel compounds. Before antibiotics were discovered, Semmelweis advocated hand washing as a way of avoiding infection; this practice is now stongly recommended as a method to prevent transmission.

ded protection to the body and which was disturbed by the antibiotic. Indeed, a standard medical procedure to counter the side-effects of antibiotics on patients for many decades now has been to stimulate the human gut to restore its commensal flora using probiotics of various kinds.

However it has been the emergence and spread of ABR, blunting the efficacy of antibiotics considerably over the last few decades, that is prompting

researchers to take a relook at the entire human host-microbe equation. The treatment failure, morbidity and often death caused by ABR has given rise to an urgent need to examine how the use of antibiotics has increased the evolutionary pressure to select for bacteria that have either natural or acquired resistance to the drug, thus making the disease more difficult to tackle. The ongoing impact of antibiotic resistance has indeed confirmed the importance of understanding its evolutionary, genetic, and ecological origins.

# **1.2** What exactly is Antibiotic Resistance?<sup>(7)</sup>

Each antibiotic (or antibacterial agent) is injurious only to a certain segment of the microbial world, so for a given antibacterial there are some species of bacteria that are susceptible and others that are not. Bacterial species not susceptible to a particular drug are' naturally resistant'. Species that were once sensitive but eventually became resistant to it are said to have "acquired resistance". It is important to note that "acquired resistance" affects a subset of strains in the entire species; that is why the prevalence of "acquired resistance" in a species

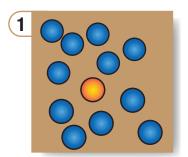
is different according to location.

Antibiotic resistance, the acquired ability of a pathogen to withstand an antibiotic that kills off its sensitive counterparts, originally arises from random mutations in existing genes or from intact genes that already serve a similar purpose. Exposure to antibiotics and other antimicrobial products, whether in the human body, in animals, or the environment, applies selective pressure that encourages resistance to emerge, favoring both "naturally resistant" strains and strains which have "acquired resistance" (see figure 2 next page).

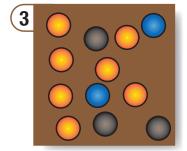
Bacteria also transfer genes horizontally, passing genetic information directly to other microbes, thus spreading resistance determinants to harmless environmental or commensal microorganisms and to pathogens, thus creating a reservoir of resistance.

Resistance is also spread by the replication of microbes that carry resistance genes, a process that produces genetically identical (or clonal) progeny.

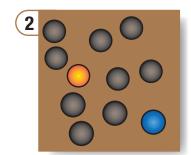
This section is adapted from: 'Antibiotic Resistance: An Ecological Perspective on an Old Problem', American Academy of Microbiology, convened October 12-14, 2008.



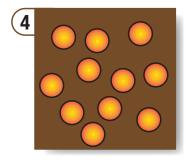
A colony of bacteria including a resistant variety...



The resistant bacteria multiply and take over from the normal bacteria



... get exposed to antibiotics. Most of the normal bacteria die



Eventually the entire bacterial ecosystem has become resistant.

The specific meaning of "antibiotic resistance" depends entirely on context. The definition used in this document refers to the ability of a bacterial microorganism to survive concentrations of antibiotics that kill sensitive cells of the same strain. It is important to note that for every antibiotic, there are sensitive strains, which are killed or inhibited by the drug, and naturally resistant strains. When a sensitive strain gains the ability to withstand an antibiotic, it is "antibiotic resistant." In other words, antibiotic resistance simply means that a pathogen is less susceptible than its counterparts and may not respond to the antibiotic administered, because it may possess a resistance gene that is resistant. Like all other living things, the

Normal bacteria

Resistant bacteria

Dead bacteria

evolution of microorganisms is Darwinian: in the face of change, the fittest survive. Antibiotics represent an evolutionary challenge that microorganisms must surmount or perish.

Resistance is commonly considered simplistically—either an organism is resistant or it's not. In reality, resistance exists as a gradient that reflects phenotypic and genotypic variations in natural microbial populations. Among "wild type" strains, for example, the minimum inhibitory concentration of a given antibiotic can vary by four or five-fold. Moreover, the genes in clinical isolates can be identical to those in "naïve," unexposed populations. Different mechanisms of resistance confer different levels of resistance. Low levels of resistance are often overlooked but can play an important role in the expansion of resistance. The currently accepted definitions of antibiotic resistance do not take such diversity into account.

Resistance is often portrayed as an undesirable consequence of antibiotic abuse or misuse. This view is simplistic and inaccurate. The rate of antibiotic resistance emergence is related to all uses of these drugs, not just misuse, and the total amount of antibiotics used and the environment also play roles. An underlying driving factor behind resistance may actually be a lack of adequate hygiene and sanitation, which enables rapid proliferation and spread of pathogens.

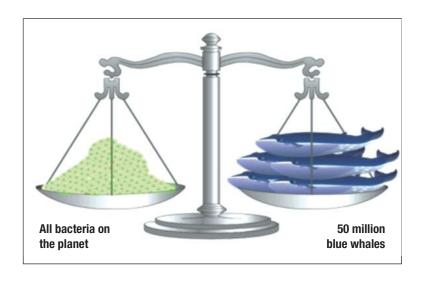
Rapid diagnostic methods and surveillance are also some of the most valuable tools in preventing the spread of resistance. Access to more rapid diagnostic tests that could determine the causative agent and antibiotic susceptibility of infections more quickly would inform better decision-making with respect to antibiotic use, help slow the selection of resistant strains in clinical settings, and enable better disease surveillance. A rigorous surveillance network to track the evolution and spread of resistance is also needed and would probably result in significant savings in healthcare.

## **1.3**The Ecological Metaphor

The ecological perspective in particular has gained traction in more recent years with new research in microbiology showing the sheer vastness, diversity and significance of the microbial species that are found in the human body. This together with the fact, that a lot of recent research shows bacteria act, not as individual living organisms much of the time, but as communities, even communicating among themselves to decide their course of action, has further pointed to the need for an ecological perspective in dealing with them.

There are many other pointers to the ecological nature of the ABR issue:

At a fundamental level is the simple fact that microbes are both the oldest and most numerous of all living organisms on Planet Earth. One estimate puts the combined weight of all the microorganisms as being 80 percent of all the biomass



on Earth<sup>(8)</sup>. In a sense all the 'visible' species are floating in a sea of 'invisible' microorganisms, with the latter having played a key role in the evolution of the former.

Microbial activity is essential for the survival of life on the planet and the numbers of beneficial bacteria vastly outnumber those that are pathogenic or potentially so. From nutrients and waste recycling to regulating atmospheric gases and maintaining complex human metabolic processes microbes are indispensable. A study in 1997<sup>(9)</sup> estimated the contribution of ecological systems, mostly involving microbial activity, to the global to be US\$33trillion, almost twice the global gross domestic product for that year.

A healthy adult human harbours some 100 trillion bacteria in his/her gut alone. That is ten times the number of 'human' cells. While human egg and sperm provide about 22,000 different genes to the body, the microbiome (as the collective communities of bacteria in the body are known) is reckoned to contribute an additional 8 million genes i.e. 360 times more than what humans have on their own<sup>(10)</sup>.

Interview with Prof. Michael Gillings, Macquarie University, Australia. http://www.microbiana.org/content/microorganisms-are-good-guys

<sup>9.</sup> The value of the world's ecosystem services and natural capital Robert Costanza, Ralph d'Arge, Rudolf de Groot, Stephen Farberk, Monica Grasso†, Bruce Hannon, Karin Limbur, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Suttonkk & Marjan van den Belt; NATURE I VOL 387 I 15 MAY 1997.

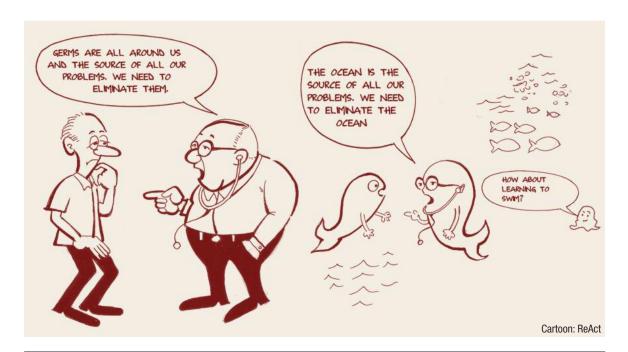
 <sup>&#</sup>x27;NIH Human Microbiome Project defines normal bacterial makeup of the body', June 2012. http://www.nih.gov/news/health/jun2012/nhgri-13.htm

The accepted view among microbiologists of the microbiome is that it is an organ of the human body. It weighs as much as many organs, about a kilogram or more, similar to the human brain<sup>(11)</sup>.

Another clear indicator of the ecological dimension of ABR is that both antibiotics and bacterial resistance occur naturally in the pristine environment and are obviously part of a much older evolutionary process. There is a constant dynamic exchange of genetic material happening between different species of bacteria naturally, a process that has been speeded up by the advent of manufactured antibiotics.

Significantly, while antibiotics have been defined conventio-

nally as 'a substance produced by a microorganism (as a bacterium or a fungus) and in dilute solution having the capacity to inhibit the growth of or kill another microorganism (such as a disease germ)'(12), according to some researchers this is based on sparse knowledge of the ecology and biology of naturally occurring low-molecular-weight organic compounds. According



- $11. Interview\ with\ Prof.\ Stanley\ Falkow,\ Stanford\ University,\ USA.\ http://www.microbiana.org/category/content/research.$
- 12. Webster's Third International Dictionary (1981)

to Julian Davies for example the modulation of cellular transcription patterns represents the 'normal' function of the vast majority of low-molecular-weight natural products, including antibiotics. "Perhaps it is best said that "an antibiotic is a therapeutic agent produced by a pharmaceutical company", this definition being useful only in the context of a property of small molecules outside of their normal environment", he says<sup>[13]</sup>.

Today, thanks to its production on an industrial scale, the planet is encountering antibiotics in far greater quantity as well as concentration than found in nature. This is triggering off a chain of evolutionary and microbiological phenomena that are yet to be fully understood.

Human activity, including urbanisation, use of new chemicals like biocides and the attempts to sterilize our living spaces using commercial disinfectants, is creating new ecological niches for resistant bacteria to flourish. Sites of heavy antibiotic use or pollution such as urban waste water systems, hospitals or sites of pharmaceutical pro-

duction are particularly good breeding grounds for resistant bacteria and/or circulation of resistant genes.

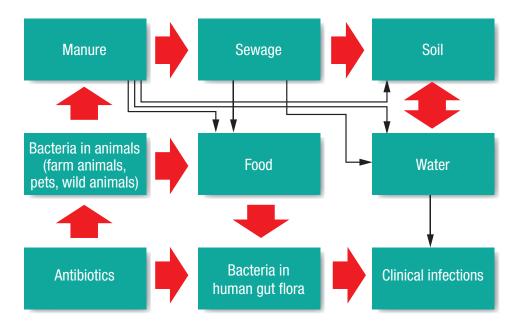
In the United States, the Centers for Disease Control and Prevention estimated roughly 1.7 million hospital-associated infections (HAI), from all types of microorganisms, including bacteria, combined, cause or contribute to 99,000 deaths each year<sup>(14)</sup>. HAIs are the 6th leading cause of death in the US, ahead of diabetes, influenza/pneumonia, and Alzheimer's. A large proportion of antibiotics are used for non-therapeutic purposes in animal farming or agriculture(15). This also results in contamination of the food chain with consequences for the development of bacterial resistance in both the human body as well as the environment.

Antibiotics deal with bacteria which are the oldest and most numerous living organisms on earth with the greatest diversity of species among any class of living organisms. The scientific hurdle that has hit innovation of antibiotics in recent decades is due to the fact that because of

<sup>13.</sup> Julian Davies, 'Are antibiotics naturally antibiotics?', J Ind Microbiol Biotechnol (2006) 33: 496–499 DOI 10.1007/s102-95-006-0112-5

<sup>14.</sup> http://www.nytimes.com/2010/02/27/-business/27germ.html?em=&adxnnl=1& adxnnlx=1267412412-yP2bfl/3pu4+g-34XVmluJA&\_r=0

<sup>15.</sup> http://www.tufts.edu/med/apua/news/-newsletter 33 3555326098.pdf



their vast numbers and the speed of their mutations bacteria seem to already possess or have an endless ability to evolve resistance mechanisms to deal with any new way of killing or disarming them<sup>(16)</sup>. Without understanding the processes and function of elements in bacterial ecology more deeply, conceiving new treatments for infection may be short-lived.

It is also becoming clear that treatment of infections with antibiotics is only half the story when it comes to dealing with disease. The other half is the role played by the body's own immune system. The delicate balance between immunity and infection needs to be taken into consideration before every use of antibiotics. Other medical approaches that tackle the ability of the host to protect itself need to be explored rather than being fixated on 'eliminating' the 'pathogen'.

Essentially the point is that the processes involved in infection,

http://academy.asm.org/index.php/general-microbiology/420-antibioticresistance-an-ecological-perspective-o n-an-old-problem

resistance or even recovery of the human body are part of very dynamic and non-linear systems similar to those involved in any ecological process. Unfortunately modern medicine often treats the body as a mechanical device to be 'repaired' or 'engineered' and with parts that can be 'replaced'.

# **Box 1**Pathogen versus Commensal

In medical literature pathogens (from the Greek phrase 'the birth of pain') are normally distinguished from commensals (Middle English, 'sharing a meal') – not by the fact that they cause disease as is popularly misunderstood- but due to the fact they have greater ability to cross anatomic borders and breach host defences. In other words pathogens are able to penetrate, survive and replicate in parts of the human body where other microbes cannot (17).

When it comes to disease though, the terms pathogen or

commensal are not entirely helpful as both are capable of causing illness among humans or animals. Many disease causing agents in the body, such as the bacteria that cause tuberculosis or pneumonia or meningitis, live asymptomatically in the human body for very long periods of time without causing any harm. Stanley Falkow, a veteran microbiologist at Stanford University calls them 'commensal pathogens' to emphasise the fact the neat separation between 'commensals' and 'pathogens' does not work all the time(18).

In fact there is growing evidence to show that that the routine elimination of a number of 'pathogenic' bacteria and the decline of infectious diseases has led to a rise in immune disorders in Western countries, such as multiple sclerosis, Crohn's Disease, and asthma. The elimination of Helicobacter pylori for example is now linked to a rise in esophageal cancer and asthma<sup>(19)</sup>.

What all this is pointing to is the fact there seems to be a dynamic equilibrium inside the body between the different mi-

<sup>17.</sup> Stanley Falkow, 'Bacterial Pathogenicity:
An Historical and Experimental Perspective', Microbial Evolution and Co-Adaptation: A Tribute to the Life and Scientific Legacies of Joshua Lederberg: Workshop Summary, Institute of Medicine, 2009, p.126.

<sup>18.</sup> ibid 19. ibid

crobial species and the human immune system. The microbiome or elements of it help keep the immune system toned up to protect the body. Harming the microbiome in any way results in a loss of this balance and the immune system turning against the body as in the case of the various immune disorders.

## **Box 2**The 'One Health' approach

One Health<sup>(20)</sup> is an important global movement gaining popularity, that recognizes that the health of humans, animals and ecosystems are interconnected. It brings together human, veterinary and wildlife health communities to take a more coordinated approach to disease and epidemics in general. The aim of what has now become the One Health Global Movement is to improve health and well-being through the prevention of risks and the mitigation of effects of crises that originate at the interface between humans, animals and their various environments.

While the origins of many human diseases in animal, bird or wildlife populations is well known, surprisingly there is little sharing of information between health professionals working in these sectors. There is also very little knowledge of how fluctuating environmental conditions, such as caused by global warming, affects the etiology of various diseases. The One Health Movement is promoting collaboration across sectors that have a direct or indirect impact on health, is stimulating thinking and working across 'silos', and optimizing resources and efforts while respecting the autonomy of the various sectors.

Though starting off with the modest goal of helping create common databases and platforms for exchange of expertise the One Health concept has the potential to radically alter the practice of healthcare

<sup>20.</sup> http://www.onehealthglobal.net/what-isone-health/

by helping diagnosis and treatment take a more ecologically grounded approach. In the context of ABR there is a need to work with the movement to emphasise the importance of ecological and indeed microbial 'health', and to understand the environmental and interspecies drivers of resistance development and transfer.

#### 1.4

## 'Bacteria are Us': An interview with Stanley Falkow

Stanley Falkow, PhD,82, is a microbiologist and a professor of microbiology and immunology at Stanford University School of Medicine. He is sometimes referred to as the father of molecular microbial pathogenesis, which is the study of how infectious microbes and host cells interact to cause disease at the molecular level. He formulated molecular Koch's postulates, which have guided the study of the microbial determinants of infectious diseases since the late 1980s.

In this interview here with Mary Murray and Satya Sivaraman of ReAct conducted in November 2010, Dr Falkow talks about a host of issues from the changing view of microbial life in modern microbiology to the implications of such change for tackling antibiotic resistance.

**ReAct:** We are interested in new research which is changing the understanding of antibiotics, antibiotic resistance and microbial life and which is throwing up possibilities of new approaches, which will not create resistance.

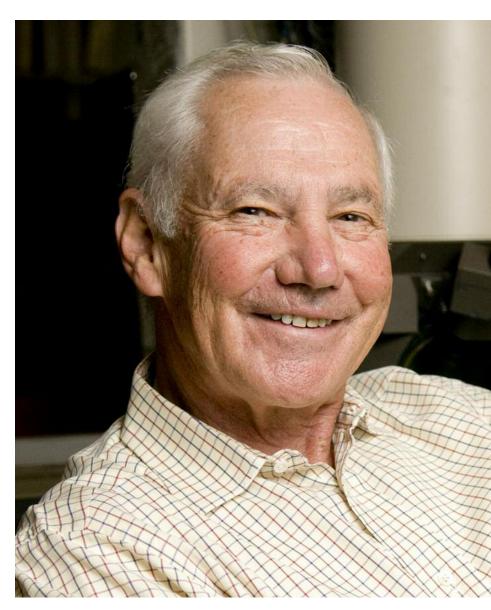
Stanley Falkow (SF): First the understanding was that we have bacteria on us. Then it became that we have a community (of bacteria) that is part of us and outnumbers us vastly. And now it has become almost as if it is an organ that is part of the human, which interacts with the signals coming from the human and vice versa. So I have actually been using the Gaia hypothesis<sup>(21)</sup>, it is almost like that now. It is just not that these organisms are contaminants and so on and foreign things. They are really part of what a human is.

<sup>21.</sup> The Gaia hypothesis, also known as Gaia theory or Gaia principle, proposes that all organisms and their inorganic surroundings on Earth are closely integrated to form a single and self-regulating complex system, maintaining the conditions for life on the planet.

At least in the field of microbiology that is part of the changing way people are thinking. The other thing is, there is an incredible appreciation now for what happens if we disrupt that natural part and the biggest disrupter that has been studied so far are antibiotics. The kind of work being done here (at Stanford), for example by David Relman and other people, which has just begun, it is clear that this is a biological cataclysm, particularly if it occurs early in life.

ReAct: New research is looking at ways of not creating resistance and/or managing or responding to the natural process in a much less aggressive way so we come out better. Do you think that is going to come more from some combination of probiotics, vaccines and some other completely novel approaches?

**SF:** I think that's the only answer. For example, it is quite clear that the growth-enhancing effects of antibiotics...here people say it is all nonsense. It is not nonsense. There is a great body of literature that clearly shows that if you feed these ani-



Stanley Falkow. Photo by L.A. Cicero. Source: http://news.stanford.edu/news/2008/september24/med-lasker-092408.html

mals antibiotics...they have a more efficient conversion of their food into weight, into meat. It is very clear. And there are some disease prevention properties but not very much because most things become resistant. Nonetheless, there is this aspect. And, that likely has to do with its impact on the flora.

And, it seems to me that if one were to look at the difference between conventional food animals raised with or without antibiotics and found out a serious basis for what that distinction was, using the modern tools of molecular genetics and genomics and so on, I think you would come up with a way to substitute, perhaps in a probiotic way, or with chemicals that do not have any bacterial impact, ways to duplicate that. That would obviate the need to use antibiotics.

By the same token, it is very clear – and even the pediatricians have begun to understand –that giving little children antibiotics can have a bad effect. It can have implications which go far beyond their childhood into later life in terms of auto-immune diseases and so on. But it means that there has to be ways of treating or preventing infection early. And I think what is being done now in understanding neo-natal immunology is going to lead to new classes of vaccines where we will be able to prevent disease and not have disruptive impact on the flora.

**ReAct:** That is very interesting. So would you say that the way we are using our technology is really assisting our more slowly evolving immune system compared to the microbes fast-evolving system.

SF: Well, the microbes, they can replicate a good deal just in one day in the intestine in terms of gene changes. I don't think we've understood just how close that relationship is. What we consider immunity is in part dependent on microbes. Our immune system does not finish evolving. It continues to evolve because we have a microbial flora. And so the entire immune system, the innate immune system, is designed to react to microbial products. Even the

maturation of the intestinal tract is dependent on meeting, as it were, the right organisms. There is a difference between...for example women who have children by Caesarean section versus natural childbirth. If you look at their microbiota, it is quite different and for a very long time.

**ReAct:** Evolution in microbial life has a role as a great selector, the natural selector, and driving force for the whole evolution of the species? What is their role in the survival of species?

**SF:** Very simple. The bacterium wants to be bacterium. It is one thing that the organisms understand. The driving force is replication. So anything that permits them to replicate is good, anything that stops them is bad. If there is competition, anything that lets them win this race is good, anything that makes them lose this race is bad. Then there are things, which I think the ecologists called cheaters, who learnt how to cheat the system to get ahead. Those are all in a sense things that are part of it. It becomes a matter of genes, genetics and survival. **ReAct:** What role do they play in the development of human species...

SF: It is again very hard to answer that because it is goes back much further. It was already a natural consequence of being a human or really being eukaryotic. The earliest free-living organisms that we call eukaryote, they were complicated and already had a bacteria endo-symbiont, that we call the mitochondria. The relationship between microbes and multicellular organisms go back a long time. It took a very, very long time for multicellular organisms actually to evolve and to work. In part they may have evolved because their bacterial competitors were always coming and killing them. By the same token, the first time something that was equivalent to amoeba ate a bacterium that was in its food, that day the bacteria knew it had to become, in a sense, a pathogen. They had to resist their own demise. So it has been virtually a predatorprey relationship. Which went then into mutualism, which went into in some cases symbiosis and others endosymbiosis. And so that is a very ancient and honourable profession. So by the time humans came into the picture it was already clear that you had microbial flora, and microbes that inhabited living things that were part of those living things.

**ReAct:** The antibiotics in the modern period are 60–70 years old. But historically for 2000 years people have been using antibiotic-like substances in traditional medicine. In fact, of which fecal matter was very essential part... Do we go back to that?

**SF:** Absolutely true. Let me tell you something, which has never been published. I have started

talking about this recently. People talked of doing fecal transplants to cure people of Clostridium difficile infections and they work. That shows the importance of the microbiota and so on. But, on the other hand, in the 1950s, when I began working in a hospital, in 1957, there were virtually no antibiotics and when people came for surgery basically they were given neomycin and other things to get their gut sterilized. And these people were sent home and were quite ill with all kinds of problems from having their flora decimated. These old time doctors would tell the patients, "Bring a fecal sample when you come for admission" and then they would have me put them in gelatin capsules. I would clean them off, sterilize the outside and put them in the fridge. And then when we send them home, after their surgery, maybe a week later, we ask them to take the bottle, and tell them—"take two of these everyday and eat a lot of lettuce'. And it helped; it wasn't a cure but it helped.

Since the last ice age there is probably nothing that has impacted microbial life more than antimicrobials used on a global basis. It just had an enormous impact, the scale of it - and the fact is there was selection; the reservoirs. The main threat in relation to antibiotics and perhaps in animal feeds as well, is not that organisms are going to enter into humans and kill them. It is hard to convey to people the idea that there is a reservoir of resistance genes that are fully and freely available and they would be disseminated and then experimented with [in the larger ecosystem]. That is a hard concept to get through. When Don Kennedy in the 1970s, was a Commissioner of the FDA he



22. Martin J. Blaser, MD is the Frederick H. King Professor of Internal Medicine, Chairman, Department of Medicine, and Professor of Microbiology at New York University School of Medicine. He is an established researcher in microbiology and infectious diseases. Blaser's work has focused on Helicobacter pylori, Campylobacter, Bacillus anthracis, and more recently on the human microbiome.

wrote in his register that he wanted to eliminate antibiotics in animal feeds from the United States. That led to such an outburst, not necessarily from the doctors but this was from people in agriculture and pharmaceutical industries and the Congress just stopped it. There was no way! And now, if you argue about identifying the reservoir of resistance genes they will think you are crazy.

**ReAct:** Thinking about the true nature of the human-microbe relationship, what kind of metaphor do you think of ...'war and free market'...

SF: It is not a war. No, not war. Never. The thing I have been thinking about more, is as Gaia or as an organ. I think it is part, an extension of the human. You can't deal with this as something separate because it is part of the human. If you talk to Martin Blaser<sup>(22)</sup>, he will say in part that we have disrupted the normal microbiota by human practices and the protective aspects have gone. Martin argues that there is a correlation between the disappearance of H. Pylori and the appearance of esophageal cancer and asthma and other things. But it is more like a marker for things and I pose this question often in my lectures, "If you go back 200 years, or even 100 years, and you begin to think what was the flora of the humans worldwide, something like 80-90 per cent of humans carried Helicobacter and the vast majority of them were asymptomatic. Having said that, one per cent still developed cancer. One percent of humanity is quite a lot of people... But most people were asymptomatic. Was H. Pylori a pathogen or part of the normal flora?

Mycobacterium tuberculosis infects an enormous number of people worldwide, 90 some per cent of them are asymptomatic their whole life. If there were a vaccine, which was that effective, we would be happy! So is mycobacterium tuberculosis, part of the normal human flora or not? Twenty per cent of humanity carries and excretes the typhoid bacillus and all of us have carried at one time meningococcus and pneumococcus. The issue is that we have, for better or worse, interfered

with what was the normal biology of the humanmicrobe interaction.

**ReAct:** Given that now when the situation is how it is ... do you think we have to learn a bit more to live with infections?

SF: No, we have to understand more our relationship with microbes. We have to come with what has always been the best idea, that is, prevent infections to the extent possible. The first living creature that you come across when you are born is a micro-organism. And you carry the progeny of that microbe in many cases with you till the day you die and that organism would under normal circumstances participate in consuming you. You are really with them the whole way. That is the reality of life, right now there are people...they are going to die. And one of the major causes of death is going to be infection of some kind because of an immune system breakdown. So, you cannot have an infection-free society; may be, some day but not certainly in the near future.

But you can prevent a vast amount of illness and the vaccines that have worked have shown that. Even that, the fear is now that with immunization Haemophilus - Type B influenza has disappeared in the technologically advanced parts of the world as a cause of meningitis. It is not just that it can prevent disease, organisms can't live in the humans that are immunized. The pneumococcal vaccine does the same thing. So we are generating a whole bunch of new little humans who don't have the same kind of pneumococcal populations that the rest of the world have had for most of

history. And there are of course some people concerned is this going to be good, bad, indifferent and there are already papers coming out saying that it may not be the best thing in the world. But that's what going to be, because it prevents disease not only in the young but it also prevents disease in the old. It has a herd immune effect. So older people are protected against this.

#### 1.4.1 Book Review

## Missing Microbes: How the Overuse of Antibiotics Is Fueling Our Modern Plagues

Martin J. Blaser (Author); Henry Holt & Company (Publisher); 273 pages; 2014

In recent years the world has rightly focused on the threat to antibiotics from bacterial resistance. However, recent new research is pointing to something equally worrying – the harmful long-term effects of antibiotics themselves on the human body.

In a new book released in early 2014, Dr Martin Blaser, Director of the Human Microbiome Program at NYU, discusses damning new evidence that widespread use of antibiotics may be contributing to the rise of obesity, asthma, diabetes, acid reflux and even certain forms of cancer.

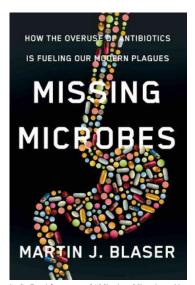
The reason why these 'wonder drugs', that have saved countless lives over the last seven decades,

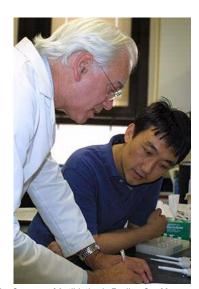
are turning out to be harmful in their own way lies in their indiscriminate elimination of both harmful and beneficial microbes in the human body. While the human microbiome has evolved over hundreds of thousands of years, with both bacAmong other things, bacteria help the human body extract energy from food and have the ability to make essential vitamins. They also help the body fight off disease. Even more significantly they can also affect the brain, because a lot of serotonin

discovered. Missing Microbes is an important text that is warning us that indiscriminate use of antibiotics is wiping out the diversity of the microbiome, with potentially serious consequences for our long-term health.

Dr Blaser's studies show that antibiotic use during early childhood poses the greatest risk to long-term health, and in many countries children are administered antibiotics repeatedly for a variety of ailments which probably don't require them. At the same time, increasing numbers of C-section deliveries deprive babies of important contact with their mothers' microbiomes.

Dr Blaser offers the example of Helicobacter Pylori, a little comma-shaped organism, which plays a critical role in controlling the release of digestive acids in the stomach. The use of antibiotics since then has wiped out H. Pylori in the populations of many developed countries, reducing ulcer and also incidence of stomach cancer but increasing the chances of acid reflux or heartburn and oesophagal cancers.





Left: Book's cover of "Missing Microbes: How the Overuse of Antibiotics Is Fueling Our Modern Plagues. Right: Martin Blaser (left) working in his lab. Photo by Carl Glenn.

terial and human cells in peaceful symbiosis the use and abuse of antibiotics in modern times are threatening the extinction of many microbial species essential to our well-being. is made in the gut by neuroendocrine cells that are in conversation with the microbiota. There are hundreds of bacterial species whose real function in helping the human body is yet to be "Our research shows that people who have H. pylori are less likely to have childhood-onset asthma and hay fever. If one species can have that effect, it's fascinating to think about what all the other species we harbor are doing" says Dr Blaser. It is estimated that an average person probably has at least several thousand species in his/her body but the true number is not known and current investigations have only scratched the surface of the microbiome.

While Dr Blaser's research findings are still a pioneering effort and will need more follow-up, the evidence he has already marshalled about the health impacts of antibiotics is substantial.

Results from a series of experiments in Dr. Blaser's lab, on infant mice fed a variety of antibiotic regimens, lend strong support to the theory that exposure to antibiotics early in life has long-term effects on metabolism, and may contribute significantly to childhood and adult obesity. Just as antibiotics are used as 'growth enhancers' in the animal farming industry to fatten up pigs and cows, their use in human populations results in similar effects.

A recent review of 15 studies involving 163,796 births also found that, compared with babies delivered vaginally, those born by Cesarean section were 26 percent more likely to be overweight<sup>(23)</sup> and 22 percent more likely to be obese as adults.

Other increasingly common conditions such as asthma, inflammatory bowel disease and celiac disease, are also linked to the damage done to the human microbiome by antibiotics.

One way of avoiding the adverse effects of antibiotics according to Dr Blaser is to develop better diagnostics and narrow spectrum antibiotics to knock out the pathogenic bacteria without disrupting the health-promoting ones. In the meanwhile it is best to do away as much as possible with the needless use of antibiotics, whether in human health or the food industry and save the pill for the really ill.

<sup>23.</sup> Mode of Delivery and Offspring Body Mass Index, Overweight and Obesity in Adult Life: A Systematic Review and Meta-Analysis; Karthik Darmasseelane, Matthew J. Hyde , Shalini Santhakumaran, Chris Gale, Neena Modi; Published: February 26, 2014; DOI: 10.1371/journal.pone.0087896

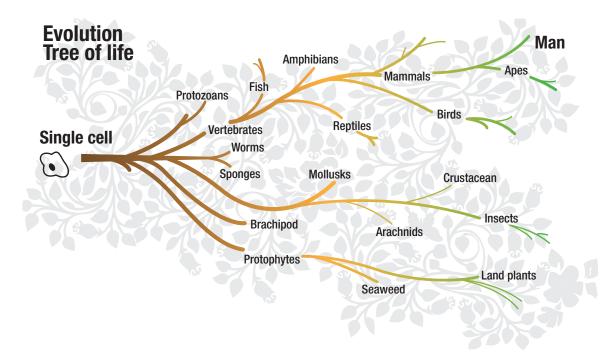
### 1.4.2 Antibiotic Resistance as if Evolution mattered

If one could imagine a football match between the human species and bacteria there is no doubt at all who the ultimate winner would be. The bacteria would win not just because of their greater numbers but because they are by definition living organisms who know how to score goals, no matter how good the goalkeeper.

What gives bacteria this power to both resist and overcome the best of human made defences? It

is the power of evolution as billions upon billions of bacteria rapidly mutate and the process of natural selection throws up a winning football team every second. There is simply no other collection of living organisms on Earth with both the scale and speed to achieve anything even closely similar.

It is with this evolutionary roulette wheel in their possession that bacteria have historically developed resistance through repeated encounters with antibiotics found in nature itself. In the past seven decades, since the advent of manmade antibiotics, resistant bacteria are being artificially selected through human use of antibiotics. In other words,



the story of antibiotic resistance is essentially the story of evolutionary processes.

And yet, over a century and a half after Charles Darwin came up with the theory of evolution, its understanding is not always reflected very well in daily medical practice.

In practice, many physicians operate as if 'yes, human beings have arrived where they are through evolution but for all practical purposes they have either stopped evolving or the consequences of such evolution are negligible'. The typical physician, by training, habit and perhaps to a fair extent even by necessity therefore deals with the immediate symptoms of his patient, treating them as if they were stand alone machines of sorts to be restored back to an imaginary 'pristine' condition a machine that has already evolved to its maximum evolutionary potential.

Flowing from this perspective, physicians seem to have adopted a 'standard model' of the human body defined by a set of parameters measured in pu-

rely quantitative terms and derived from studies in Western contexts - any deviation from which invites immediate 'treatment'. The other ecological contexts in which people live, their social or economic situations, their cultural practices are rarely taken into account and diverse individuals across the globe are lumped together as part of a larger statistical mass. Furthermore, the idea that human beings in different contexts may still be undergoing natural or artificial selection of some kind, is never taken into account.

As if this were not bad enough there is also the reduction of the idea of treatment mainly to the use of medicines with a 'pill for every ill'. All medicine is both cure and poison at the same time and the needless intake of drugs has become a major cause of disease in our times. As has been revealed by the scandals in recent years. involving several painkillers or diabetes and cholesterol medications, there is growing evidence that the medicine itself is often a threat larger than the disease it is supposed to cure. Yet another example of doctors forgetting the principles of evolution lies in the way they look upon every natural response of the human body to internal or external provocations as an 'ailment' in itself. For example, pain, nausea, cough, fever, vomiting, diarrhea, fatigue, and anxiety – all normal responses of the body – are also among the most common medical 'problems'. Much of medical practice focuses on relieving such 'suffering' by prescribing medications that block these responses. From an evolutionary point of view however these responses are not problems on their own but the body's attempt to remedy a deeper underlying problem.

In serious cases, interventions are required of course. For example, blocking fever can prevent seizures, and stopping vomiting can prevent dehydration. However, in many of these cases blocking these natural defenses of the human body may not just be needless but also risky. The excessive suppression of cough for example can cause death and every year thousands of people die due

to paracetamol poisoning as they misuse the drug to 'cure' every pain or fever<sup>(24)</sup>. The needless use of antibiotics in the context of coughs and colds is a good example of how both doctors and patients together try to wish away the fact that the human body, through a long history of evolution, has acquired self-healing abilities and often does not need external assistance to look after itself.

Yet another aspect of the evolutionary process that is usually overlooked in routine medical practice has to do with the fact that human beings, by bringing about drastic changes to their environment, are fast-forwarding the evolutionary process in unimaginable ways. Over the last ten thousand years of settled agriculture and the rise of 'civilization' - human beings have 'selected' many things with conscious intent- their habitats, mix of food they eat, choice of shelters, clothing, transportation through the domestication of animals and invention of the wheel.

In modern times the invention of the internal combustion engine and the automobile; transformation of 'personal' climate through air conditioning and heating; the widespread use of synthetic materials; and use of new medicines such as antibiotics would rank among the most significant factors affecting the pace of evolution of not just human beings but also their diseases. Surprisinaly, barring a few. most of all these new factors shaping human health are not taken into account by medical professionals while dealing with their patients. How many physicians have the time or inclination to advise patients about the environmental factors, such as pollution or contamination of food with pesticides or for that matter antibiotics?

An area where an understanding of evolution is critical in medicine, for example, is infection control. It is found that nosocomial strains of several bacterial species tend to become increasingly virulent with the duration of circulation in hospital

settings. When these organisms are exposed to antibiotics, they are likely to become resistant to treatment. Adding to the problem is the fact that the hands, clothes and other objects worn by hospital staff are often carriers of infection and the design of neonatal nurseries and ICUs of hospitals in particular are conducive for breeding "superbugs." Some have suggested that the only way of exterminating these bugs maybe through cutting off their evolutionary pathway occasionally by moving nurseries or ICUs at intervals to a completely different sterile room with fresh supplies and no transfer of infants or patients from the previous setting. Though this involves considerable expense the cost may well be worth it in terms of lowering resistant infection rates<sup>(25)</sup>.

Similarly, from an evolutionary perspective the current medical practice of managing the evolution of resistance by rapidly eliminating pathogens before they can mutate with large do-

<sup>24.</sup> http://qjmed.oxfordjournals.org/content/95/9/609.long

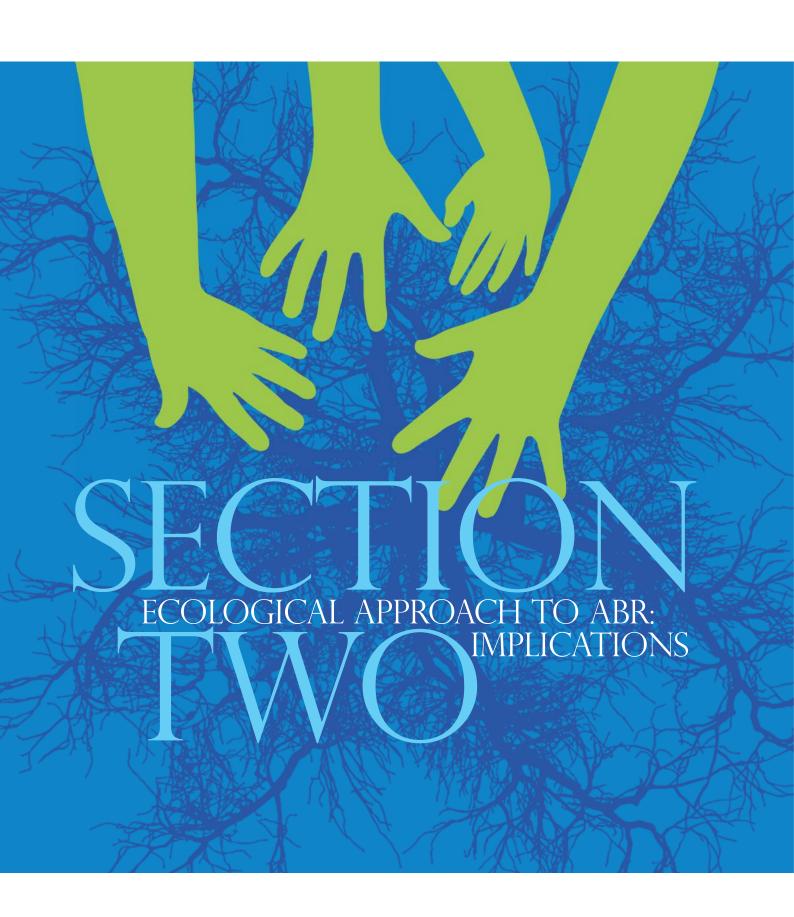
<sup>25.</sup> Randolph M Nesse, West J Med. May 2001; 174(5): 358–360.

ses of antibiotics administered for long periods is now open to major question. While this might prevent de novo resistance, it maximizes the evolutionary advantage of any resistant pathogens that are present. Because most resistance genes are not new mutations but preexisting and horizontally transferred ones, high dosing with antibiotics to rapidly 'cure' pathogen infections efficiently may promote the very resistance that it is trying to prevent. The resistant bacteria rapidly fill the space vacated by susceptible strains. An evolutionary approach requires understanding the ecology of how multiple co-existing strains of bacteria compete for resources and hold each other in some kind of check. It also requires understanding the role of the immune system in controlling this dynamic before numbers of particular strains overwhelm it. This requires an understanding of each pathogen, its social milieu and the context. The quiding principle of evolutionary models is to impose no more

selection (through dosing and duration of antibiotic treatment) than is absolutely necessary to control infections<sup>(26)</sup>.

To sum it up, whether it be antibiotic resistance or any other problem an evolutionary approach is essential to get a grip on what is happening and what needs to be done. Instead of seeing disease as a defect in a previously perfect machine, the evolutionary perspective allows us to see the body as a product of natural selection, full of tradeoffs and vulnerabilities that all too often lead to disease.

Physicians therefore should not reduce themselves to mechanics or 'medical engineers' repairing a static machine. Instead they should be healers or even 'farmers' of the human body who understand the evolutionary and ecological tradeoffs that give rise to disease and influence those forces positively to manage infection, compensate for what the body cannot repair, and relieve suffering when possible.



The ecological approach to ABR has several implications for health authorities, clinical practitioners, pharmaceutical researchers, health activists, pharmacists and consumers. A few of these are:

### **2.1** New scientific insights

#### 2.1.1 Human Microbiome Project

Microscopic study of the healthy human body has demonstrated that microbial cells outnumber human cells by about ten to one. Until recently though, this abundant community of human-associated microbes remained largely unstudied, leaving their influence upon human development, physiology, immunity, and nutrition almost entirely unknown. The NIH Common Fund Human Microbiome Project (HMP)<sup>(27)</sup> was established in the United States with the mission of generating research resources enabling comprehensive characterization of the human microbiota and analysis of their role in human health and disease.

Traditionally, microorganisms have been studied as cultures in the laboratory. However the vast majority of human-associated microbial species have never been successfully isolated in the laboratory, presumably because their growth is dependent upon specific conditions or substances which have not been duplicated in the laboratory. Advances in DNA sequencing technologies have created a new field of research, called metagenomics, allowing comprehensive examination of microbial communities without the need for cultivation.

Instead of examining the genomes of individual bacterial strains that have been grown in the laboratory and then trying to reassemble



<sup>27.</sup> For further information please see http://hmpdacc.org/

communities without the need to culture the microbes. In the HMP, this approach is complementing genetic analyses of available reference strains, providing unprecedented information about the complexity of human-associated microbial communities. Other advanced 'omics technologies like transcriptomics, proteomics and metabolomics, which measure the biological properties of whole microbial communities, are being used to provide insights into how the microbiome and human host interact to support

the community of microbes, the

metagenomic approach allows

analysis of genetic material harvested directly from microbial

The NIH Human Microbiome Project is one of several international efforts designed to take advantage of large scale, high throughput multi 'omics analyses to study the microbiome in human health. As a community resource program, the HMP is a partner in an international collaboration to generate rich, comprehensive, and publicly available datasets of the microbiome. This informa-

health or to trigger disease.

tion will be available worldwide for use by investigators and others in efforts to understand and improve human health. In 2012, a series of papers from the project were published in the journal Nature<sup>(28)</sup>, and Science and Science Translational Medicine<sup>(29,30)</sup>, joined forces to publish a series of articles reviewing what is known about the gut microbiota.

#### 2.1.2 Hospital Microbiome Project<sup>(31)</sup>

Responding to the need to understand the sources of infection in healthcare settings since January 2013 a multidisciplinary team of researchers have initiated the Hospital Microbiome Project (HosMP)(32), which could have a revolutionary impact on patient care in hospitals across the globe. The aim of the HosMP is to sample the building, patients, and staff at a newly constructed University of Chicago Medical Center Hospital in Chicago, Illinois, USA, to create a 'roadmap' of microbial transmission routes and

<sup>28.</sup> The Human Microbiome Project Consortium. Structure, function and diversity of the healthy human microbiome. Nature, Vol. 486, 14 June, 2012, p 207-214.doi:10.1038/nature11234; David Relman. Learning about who we are. Nature, Vol. 486, 14 June, 2012, p194-195.

Mueller, K. et al. The Gut Microbiota. SCIENCE, Vol. 336, 8 June 2012, p. 1245; www.sciencemag.org; Elizabeth K. Costello et al. The Application of Ecological Theory Toward an Understanding of the Human Microbiome, Science 336, 1255 (2012);DOI: 10.1126/science.122-4203

Lemon, K., et al.Microbiota-Targeted Therapies: An Ecological Perspective. Science Translational Medicine, Vol. 4, Issue 137, 6 June, 2012. Downloaded from http://stm.sciencemag.org/ on March 11, 2015;

<sup>31.</sup> http://commonfund.nih.gov/hmp/over-view

<sup>32.</sup>http://www.standardsingenomics.org/ind ex.php/sigen/article/view/sigs.4187859 /946

succession within the hospital infrastructure and to provide researchers with the most detailed exploration of microbial colonization of a new hospital ever undertaken.

An important study<sup>(33)</sup> in 2011 of the microbiome in built environments found that the phylogenetic diversity of airborne bacterial communities was lower indoors than outdoors, and mechanically ventilated rooms contained less diverse microbial communities than did windowventilated rooms. Bacterial communities in indoor environments contained many taxa that are absent or rare outdoors, including taxa closely related to potential human pathogens.

The relative abundance of bacteria closely related to human pathogens was higher indoors than outdoors, and higher in rooms with lower airflow rates and lower relative humidity. The observed relationship between building design and airborne bacterial diversity suggests that we can manage the community of microbial species that potentially colonize the human microbiome during our time indoors.

#### Box 3

Fecal transplants to tackle ABR

Fecal transplantation is being tried as a treatment for C. difficile infection because, conceptually, it makes sense. Physicians are beginning to recognize that one of the reasons why C. difficile infection may occur and recur is because antibiotics perturb patients' intestinal microflora, now called the microbiome. When the microbiome is altered unfavorably, patients are in a state of dysbiosis, and the community of living organisms in the intestine will no longer be able to protect the host against C. difficile infection, which grows to occupy their vacated space. By reintroducing a healthy diversity of bacteria, fecal transplantation can re-establish colonization resistance to prevent C. difficile from gaining a foothold and becoming a dominant organism in the environment of the gut.

**Source:** http://www.ncbi.nlm.ni-h. gov/pmc/articles/PMC3365524/

<sup>33.</sup> http://www.nature.com/ismej/journal/v6/n8/full/ismej2011211a.html#bib63

# 2.1.3 Targeting the Host instead of the Pathogen

According to Prof. Stanley Cohen of Stanford University, who - along with Herbert Boyer - invented recombinant DNA technology<sup>(34)</sup>, the public health crisis of antimicrobial drug resistance in bacteria and viruses has resulted largely from the practice of treating infectious diseases with therapeutics designed to attack pathogens, resulting in the spread of mutant microbes that are insensitive to drug therapy. According to him, to be successful, many pathogens require the cooperation of host cells, which furnish the invader with genes and gene products necessary for pathogen propagation and transmission. Interfering with host functions that are recruited by pathogens provides an alternative to drugs that target pathogens. 'Host-oriented therapeutics' as Cohen calls it, is still at an early stage of development, but holds great promise by providing new targets for medication, other than the microbes themselves.

# 2.1.4 New antibiotics from nature

The pervasiveness of antibiotic resistance in the environment suggests that antibiotics—that is, molecules with antibiotic activity—are equally abundant in nature, produced by bacteria (and also by plants) to serve a variety of purposes according to Prof. Julian Davies, University of British Columbia, Canada<sup>(35)</sup>. Thus, to find novel antibiotics, his laboratory is pursuing a strategy of identifying organisms that produce bioactive compounds, then analyzing these compounds for their antibiotic properties.

# **Box 4**The Sibling Lethal Factor

In 2000, a group of researchers led by Israeli biophysicist Eshel Ben-Jacob discovered a fascinating phenomenon of competition between two sibling bacteria colonies of P. dendritiformis when inoculated side by side.

<sup>34.</sup> http://www.genomenewsnetwork.org/ resources/timeline/1973\_Boyer.php

<sup>35. &#</sup>x27;Antibiotic Resistance and the Future of Antibiotics', Microbial Evolution and Co-Adaptation: A Tribute to the Life and Scientific Legacies of Joshua Lederberg: Workshop Summary, Institute of Medicine, 2009.

Recent detailed studies of the phenomenon revealed that the two colonies not only inhibited each other from growing into the territory between them but induced the death of those cells close to the border. By employing molecular biology methods combined with the new genome sequencing information and bioinformatics, they discovered a new toxin (sibling lethal factor), which acts selectively only on the same bacterial strain. The findings suggest a new strategy for fighting bacteria by self-toxins they produce.

### 2.1.5 Nature as a source of antibiotic resistance

The antibiotic resistance naturally created in the environment needs to be monitored carefully. Prof. Jo Handelsman, Yale University describing a process by which she and coworkers are searching the soil metagenome—DNA derived from soil, mainly of bacterial and archaeal origins, digested and ligated into a vector used to transform Escherichia coli—for both antibiotic and antibiotic resistance activities<sup>(36)</sup>. One compound they have discovered is a single enzyme possessing two antibiotic resistance domains: one that disables penicillin-like compounds; the other, cephalosporin-like compounds. Although never before seen, such an enzyme may someday find its way into the human microbiome (or microbial community), Handelsman said, and if so, its potential to confer broad-spectrum antibiotic resistance might pose a serious threat to public health.

### 2.1.6 Targeting inter-bacterial communication

Bacterial communities have been found to operate a system of stimulus and response -or communication- correlated to their population density, a phenomenon called quorum sensing. Such quorum

- SECTION 2 \_\_ 43 \_-

<sup>36. &#</sup>x27;Expanding the Microbial Universe: Metagenomics and Microbial Community Dynamics', Microbial Evolution and Co-Adaptation: A Tribute to the Life and Scientific Legacies of Joshua Lederberg: Workshop Summary, Institute of Medicine, 2009, p. 180.

sensing allows bacteria to coordinate their collective response, for example by forming biofilms, that are resistant to both antibiotics as well as hostimmune response. Researchers believe that drugs that target quorum-sensing behavior could be the next generation of antibiotics, especially for antibiotic-resistant infections. Drugs that disrupt the quorum-sensing system and prevent the bacterial community from expressing genes that are harmful to the host could help buy time for the immune system to respond to the bacteria.

### **Box 5**Antibiotic Pollution

In the 60 years since their introduction, millions of metric tons of antibiotics have been produced and employed for a wide variety of purposes. Improvements in production have provided increasingly less expensive compounds that encourage nonprescription and off-label uses. The main cost component of the oldest and most frequently used antibiotics is now probably mainly in the packaging. The planet is saturated with these toxic agents, which has of course contributed significantly to the selection of resistant strains. The development of generations of antibiotic-resistant microbes and their distribution in microbial populations throughout the biosphere are the results of many years of unremitting selection pressure from human applications of antibiotics, via underuse, overuse, and misuse. This is not a natural process, but a manmade situation superimposed on nature; there is perhaps no better example of the Darwinian notions of selection and survival.

**Source:** Julian Davies and Dorothy Davies, Microbiol. Mol. Biol. Rev. 2010, 74(3):417. DOI: 10.1128/MM-BR.00016-10

# **2.2**Socio-economic determinants of health

Apart from the purely natural environmental factors there is also sufficient evidence to show that antibiotic use is often driven by various social, economic and cultural factors in human societies, thus being an essential part of the ecology in which both microbes and ABR flourish. It is now also being recognised that socio-economic determinants such as access to nutrition, safe drinking water and sanitation play a key role in spread of infectious diseases and better prevention initiatives are required to reduce the use of antibiotics and through that the incidence of ABR.

### **Box 6**Anxiety drives antibiotic use

Parent pressure makes a difference. For pediatric care, a recent study showed that doctors prescribe antibiotics 65 percent of the time if they perceive parents expect them; and 12 percent

### of the time if they feel parents do not expect them.

**Source:** http://www.cdc.gov/gets-mart/campaign-materials/press\_kit/Cold-Flu\_Season-508.pdf

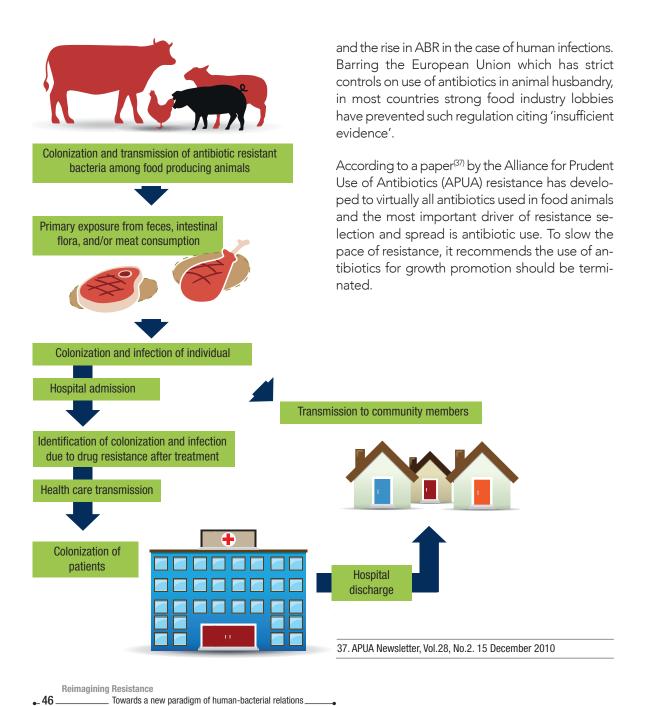
# 2.2.1 Role of nutrition and traditional remedies

It is quite well known that infectious diseases thrive in the context of malnutrition. In India alone every year over 2.5 million children under the age of 5 die of malnutrition-linked diseases. mostly pneumonia and diarrhea. Rampant anemia among mothers and poor breastfeeding practices often prevents infants from getting the crucial boost of immunity they need to ward off infections. The absence of safe drinking water and sanitation also exacerbates the situation.

While access to life-saving antibiotics is obviously critical in many of these cases it is not always possible to deliver these when needed or ensure their appropriate use. Therefore it is essential to find ways of both improving nutritional status of women and children in local and resource poor settings while also exploring the wide range of traditional medicine that have beneficial effects in tackling infection. Herbal remedies in particular should be considered as part of diet and not as 'medicine' and evaluation of their efficacy should be done keeping issues of access, cultural norms and costs in perspective.

# **2.3** Antibiotics in animal and food production

In a new report, released in September 2013, on the threat of ABR in the United States the US CDC says, 'antibiotics should be used in food-producing animals only under veterinary oversight and only to manage and treat infectious diseases, not to promote growth.' About 80 percent of all antibiotics distributed in the U.S. were for food animals, and there is growing evidence of the link between such use



# 2.3.1 Biocides and Antibiotic Resistance

A new study<sup>(38)</sup> published by the American Society of Microbiology's journal mBio has linked glyphosate and two other widely-used herbicides–2,4-D and dicamba–to the spread of antibiotic resistance.

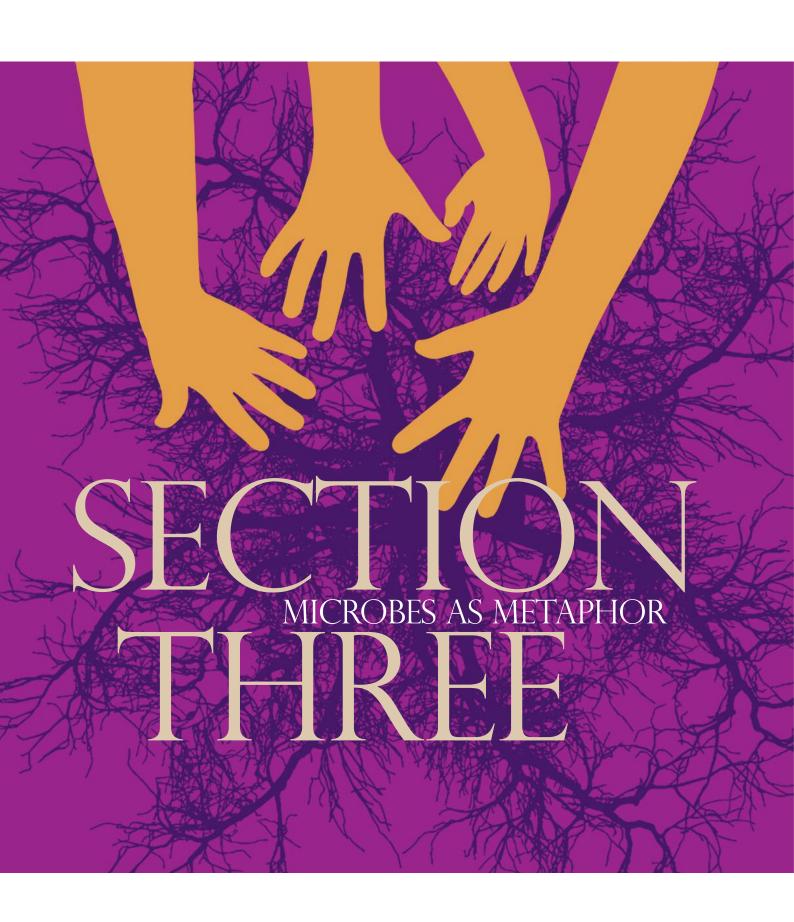
The study found that exposure to these herbicides changed the way bacteria responded to a number of antibiotics, including ampicillin, ciprofloxacin, and tetracycline—drugs widely used to treat a range of infections.

Biocides, such as herbicides, are routinely tested for toxicity but not for sublethal effects on microbes. The new study, led by Jack Heinemann, professor of genetics at the University of Canterbury in New Zealand, focuses precisely on the sub-lethal effect of these biocides on bacteria and the result they found was that it increases their resistance to antibiotics.

The study says that because these herbicides are not "supertoxic" to bacteria like E. coli and Salmonella they are not killed outright at levels typically used to kill weeds. Instead, the bacteria stay alive while activating proteins known as efflux pumps in order to rid themselves of toxins. And this defense mechanism can make the bacteria develop resistance to the threat from which it is defending itself, making them stronger.

According to the study the combination of high use of both herbicides and antibiotics in proximity to farm animals and important insects, such as honeybees, might also compromise their therapeutic effects and drive greater use of antibiotics. The authors of the study conclude that there is a need to address the crisis of antibiotic resistance by broadening our view of environmental contributors to the evolution of resistance.

<sup>38.</sup> Kurenbach B, Marjoshi D, Amábile-Cuevas CF, Ferguson GC, Godsoe W, Gibson P, Heinemann JA. 2015. Sublethal exposure to commercial formulations of the herbicides dicamba, 2,4-dichlorophenoxyacetic acid, and glyphosate cause changes in antibiotic susceptibility in Escherichia coli and Salmonella enterica serovar Typhimurium. mBio 6(2):e00009-15. doi:10.1128/mBio.00009-15.



#### 3.1

#### Representing Microbes

The popular perception of microbes is marked by sheer ignorance on one hand and paranoia on the other. One reason for this is the fact that the study of microbes emerged, a couple of centuries ago, largely in the context of how they were responsible for various human infections.

This, potentiated by cultural memory of past epidemics and 'contagions' and the 'war metaphor' mindset in modern medicine, has resulted in a public view of all microbes as being necessarily 'pathogenic' and 'dangerous'. Adults and children mostly see microbes as monsters. When asked to draw or make puppets or posters of microbes, the images are mostly negative. This is also a reflection of the dominant cultural paradigm that equates invisible microbes, their large numbers and link with some diseases with dirtiness and danger.

Going beyond the narrow 'medical' view and exploring the explosion in information on microbial ecology and bacteriology in the last decade or so yields fascinating insights into the very processes of life on Earth. The new information also reveals the great intrinsic beauty, aesthetic and wisdom of microbial eco-systems.

Another particularly fascinating aspect of the new emerging knowledge in microbiology and microbial ecology is that it could help sharpen our understanding of human societies and behaviour. In a sense today there is a need to understand the microbe as a metaphor for the human condition. In the context of the larger universe we live in human beings are also like microbial colonies. Like microbes human beings too are basically trying to survive, find nutrition, security and reproduce. Instead of focusing on just the disease-causing nature of certain microbial species can we look beyond and begin to learn something from these invisible organisms?

### **Box 7**Bacteria's Social-IQ<sup>(39)</sup>

In a recent research article, published in BMC Genomics, an international team from Israel, USA, Netherlands, Russia and

Source: Eshel Ben-Jacob. Reproduced with his kind permission.

39. Adapted from: http://tamar.tau.ac.il/ ~eshel/html/intelligence\_of\_Bacteria.ht ml#nogo

India (led by Prof. Ben-Jacob from Tel Aviv university and a Fellow of the Center for Theoretical Biological Physics at UCSD, and his research student Ms. Alexandra Sirota-Madi) first presented the sequenced genome of the social and pattern-forming bacteria – the Paenibacillus vortex that created the colonies shown in the picture.

While studying the genome, the team developed Social-IQ scores for bacteria and performed comparative analysis of 500 bacteria whose genome was sequenced. The score is based on the number of genes which afford bacteria abilities to communicate and process environmental information (twocomponent and transcriptionfactor genes), to make decisions and to synthesize offensive (toxic) and defensive (neutralizing) agents as needed during chemical warfare with other microorganisms. Notably, they found that the Paenibacillus vortex (with two other Paenibacillus bacteria strains) has the highest Social-IQ score among all 500 sequenced bacteria, over 3 standard deviations higher than average, indicating a capacity for exceptionally brilliant social skills. Humans with IQ of three standard deviations above average include scientists like Albert Einstein, Stephen Hawking and Richard Dawkins.

### **3.2** Fear of Contagion

The first recorded plague pandemic, began in 541 AD and was followed by frequent outbreaks over the next two hundred years that eventually killed over 100 million people and affected much of the Mediterranean basin –virtually all of the 'known' world at that time<sup>(41)</sup>.

The second pandemic, often called the "Black Death", originated in China in 1334 and spread along the trade routes



Engraving of the plague doctor by Paulus Fürst (1656). Person wearing a hat, a mask suggestive of a bird beak, goggles or glasses, and a long gown. The clothing identifies the person as a "plague doctor" and is intended as protection. Descriptions indicate that the gown was made from heavy fabric or leather and was usually waxed. The beak contained pungent substances like herbs or perfumes, thought at the time to purify the air and helpful in relieving the stench. The person also carries a pointer or rod to keep patients at a distance. (Library of Medicine)<sup>(40)</sup>.

<sup>40.</sup> http://www.cdc.gov/plague/history/

<sup>41.</sup> http://www.cdc.gov/plague/history/; Khan, IA. Plague: the dreadful visitation occupying the human mind for centuries. Trans R Soc Trop Med Hyg. 2004 May;98(5):270-7.

to Constantinople and then, by 1347, to Europe where it killed 20 million people in 5 years. Estimates of the proportion of the European population this represented vary from 25% to 60%<sup>(42)</sup>. It came upon a Europe that had suffered 30 years or so of pestilence and famine due to change in climatic conditions already causing reduced soil fertility and a decrease in population<sup>(43)</sup>.

It was difficult to study the cause of the disease as it was highly infectious and death usually came within four days of the first signs of the illness. It is believed that priests and monks unwittingly spread the infection as they went from home to home to perform last rites. It is estimated that 90% of priests and 75% of physicians died during the epidemic because of their willingness to serve during the worst of the plague<sup>(44)</sup>.

The disease itself caused horrifying and painful symptoms. Cause and effect of the disease was unknown. In the absence of the germ theory and the knowledge of the flea as vector from rats, the ancient ideas of

contagion and its causes were triggered. Fear was palpable. Lightning-fast convictions of cause spread, including that the Jews had poisoned the rivers. Thus the ancient practice of purification and expulsion of the scapegoat resulted in murder and expulsion of Jews. These ancient notions of cause and effect have roots deep in human experience of epidemic, pestilence and natural disaster and are associated with ritual purification and killing or expulsion.

The visual arts of the day were concerned directly with the consequences of the Black Death. Death and the process of dying became major themes through the following century and a half, contributing images well-known today such as the Grim Reaper. Artists showed that death did not discriminate between rich and poor, high or low class, believers or pagans.

The plague also paved the way to extreme behavior. 'Staring down their mortality, many people gave into lewdness and revelry, while others turned to religion and extreme piety' (45).

<sup>42.</sup> Ibid

<sup>43.</sup> http://www.cdc.gov/plague/history/

<sup>44.</sup> http://healthdecide.orcahealth.com/201 2/08/21/ring-around-a-rosie/#.Um43-JiPgOs

Mark Damen ( 2013) Man and Disease, Course notes, USU 1320: History and Civilizationhttp://www.usu.edu/markdamen/1320Hist&Civ/chapters/06PLAGUE. htm

Despite the vast devastation caused by this pandemic, however, massive labor shortages due to high mortality rates sped up the development of many economic, social, and technical modernizations. It has even been considered a factor in the emergence of the Renaissance in the late 14th century<sup>(46)</sup>. The foundations of feudal society in Europe began to crumble. Amongst the many consequences was the beginning of more hygienic conditions in cities.

'The Black Death itself was over, but the worst of it still lay ahead, the memories of its rampage and the crippling, nauseating fear it might return one day, as in fact it did sporadically over the next few centuries' (47).

While better scientific understanding led to identification of the microorganisms responsible for particular infections and how they are spread, and better hygiene and infection control began to reduce the incidence of infection, the collective memory mediated in images, stories and other cultural expressions have strengthened the cultural roots of fear of conta-

gion. This may be one factor triggered in the desire for 'safety' or 'protection' of having a sterile daily environment free from the fear of any threat from microbes by killing them all. Commercial images for disinfecting products seem to engage elements of this fear with a promise of protection.

There was real fear in ancient times and a trigger to act on that fear - wrong as we now see it. Today, however, we should question whether the war metaphor and the messages that are being used to communicate the problem of antibiotic resistance and its implications for a return to the pre-antibiotic era, are triggering this kind of fear and/or a more generalized anxiety. What is the difference?

Ginette Paris (48) identifies anxiety (and depression) as characterized by a poverty of images. Anxiety is fear without image. The danger is not identifiable – where as true fear is always of something precise and triggers action – fight or flight. But anxiety does not allow one to name what is feared. Not knowing what one is afraid of re-

http://www.cdc.gov/plague/history/; Benedictow, Ole J. 2004. The Black Death 1346-1353: The Complete History. Woodbridge: Boydell Press.

<sup>47.</sup> http://www.usu.edu/markdamen/1320 Hist&Civ/chapters/06PLAGUE.htm

<sup>48.</sup> Ginette Paris. Wisdom of the Psyche: Depth psychology after neuroscience. Routledge; NY. 2007 p. 198.

presses action. Anxiety is a vicious circle. Inhibition of action produces anxiety and anxiety paralyses action.

People were not anxious in the middle ages, but they were terribly afraid of many things. When they did not know the cause of the plague, the doctors and people themselves created a cause – and gave it a precise image (negative conjunction of the planets, putrid emanations from the centre of the earth, sin, Jews 'poisoning' the rivers...).

Atrophy of the capacity to imagine is the breeding ground for self-inflicted misery. When old mythologies are corrupt and dysfunctional, one solution is to replace the ideas they symbolized by demonstrating their falseness, using the rationality of science. But for the psyche, the weakening of imagination is a trauma because what is lost in the imaginal realm can only be replaced by images, not by abstract concepts. Joy is a better teacher than pain – always<sup>(49)</sup>.

So might we say so about infection, microbes and uncons-

ciousness about our immune system – we are living without images, trying to turn the concepts of science into something to live by. But without the capacity to imagine, and a conscious process to restore or create substantive images to live by, a generalized anxiety about the threat of invisible microbes, symptoms, death robs us of our capacity to act and adapt to be an integral part of an ever changing, dying, evolving, inventive ecosystem.

#### Box 8

The Metaphor of Soil

The comparison of the human body to soil (top soil) is due to Rene Dubos, the French-American scientist, who pioneered the discovery of modern antibiotics, by isolating antibacterial substances from soil microorganisms.

Dr. Dubos's research rose from the idea that soil, being what he called a "self-purifying environment," maintains its natural balance (of nutrition) through

49. Ginette Paris. ibid,p. 197.

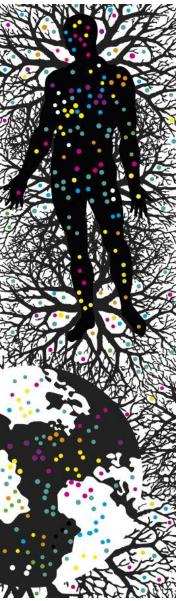
Reimagining Resistance

\_\_\_ Towards a new paradigm of human-bacterial relations \_\_\_\_\_

the decomposition of organic matter aided by the powers of resident microorganisms. Some of these soil bacteria, he reasoned, might be useful against disease-causing microbes (like those causing pneumonia) by helping break down the polysaccharide capsule that protected them.

At a later stage in his career Dubos, declared in a paper published in the American Journal of Medical Sciences in 1964, that the digestive tract was an ecosystem and advocated an ecological approach to the study of the human body. Dubos, whose initial training was in agronomy before he took to microbiology, also described the human body- just like soilas being a repository of numerous species of bacteria, that co-existed with each other and the body in a largely symbiotic or benign balance.

He highlighted the fact that 'infection' is a normal state of the human body and the key issue was determining what were the conditions that turned infection into disease. Dubos emphasised the need for studying bac-



Source: React Global

teria in context—shifting the focus away from their cultivation in sterile laboratories to the dynamics of their actual relations in nature and their interactions with their environment.

Dubos approach was a precursor to current interest in microbiology on studying the human microbiome and the role of microbial flora in shaping human health.

# **3.3**Sumak Kawsay: A New Contract with Nature

Sumak Kawsay corresponds to the worldview of the ancient Quechua way of life. From the original Quechua when translated into Spanish it means 'buen vivir', whose closest English translation could be 'living well'.

According to its proponents it exists in a similar form among the Aymara as 'Suma Qamana', and among the Guaraní as 'Tekopora' or 'Teko Kavi'. In its original Quechua meaning, Sumak indicates 'excellent, fullness, su-



Photo: Arturo Quizhpe

- Acosta A y Martínez E, comp., El buen vivir: Una vía para el desarrollo, Abya Yala, Quito, 2009.
- 51. Luis Macas, Abogado Kichua ecuatoriano. Foro Público: "El Buen Vivir de los Pueblos Indígenas Andinos. Coordinadora Andina de las Organizaciones Indígenas (CAOI). Lima, 01, 2010. Expresidente de la Confedereación de Nacionalidades Indígenas de Ecuador (CONAIE)
- Moberg, Carol L. René Dubós, Friend of the Good Earth, Microbiologist, Medical Scientist, Environmentalist. ASM Press. Washington DC, 2005
- "Termina la vida y empieza la supervivencia" CARTA DEL JEFE INDIO SEATTLE AL SEÑOR FRANKLIN, PRESIDENTE DE LOS EE.UU.

blime, superior, beautiful'; while Kawsay, means "life", and dignified life in its fullness<sup>(50)</sup>.

The ancestral notion of "sumak kawsay" is considered as an element of the Pachamama or Mother Earth by the indigenous people. Sumak Kawsay seeks balance with nature in the satisfaction of needs, based on the principle of "take only what is necessary", as opposed to mere emphasis on endless economic growth.

Life is the essence of all vital beings. It is diverse, harmonious

and unique. It is characterized by an active process of intense exchange, flow, and interplay between the various forms of life, ecosystems, human beings and nature. This is a state of fullness of the entire human and natural community expressed in harmony and balance both externally and internally<sup>(51)</sup>.

"Sentient beings are inextricably linked with the environment" (52). The alterations of these interconnections between living beings, the breakdown of the web of life, only produces disease, devastation and death, because there is an intimate connection between human health and the health of the entire planet.

"Humanity did not make the fabric of life, it's just a strand ... and what it does to the web or tissue of life it does unto itself too" said Chief Seattle<sup>(53)</sup>.

From the vision of the native peoples, "Kawsay Sumak", signifies to live in community and in brotherhood, based on reciprocity, solidarity and complementarity, in the relations between human beings, in the relations between humans with the other forms of life and nature<sup>(54)</sup>.

The essential elements of the culture of life are "to complement each other and not to compete, to live in harmony between people and with nature; to share and not take advantage; to fulfill our roles and functions without destroying man nor nature". These elements are from the vision of the ancestral peoples, expressed in harmony with nature and life, in the recovery of " our peoples' experiences, harmony, and mutual respect"; feeling a part of nature, for there is nothing separate; returning to our path, the path of balance, a path that would allow for the balance between the people, the harmony between man and nature; recovering the health of Mother Earth, respecting its own capacity for self regulation of the life and the planet<sup>(55)</sup>.

For Donato Camey, a Mayan Kaqchikel doctor, nature is the teacher of teachers. It recognizes that life is based on balance and harmony with all the living forms that we see and do not

see, which still requires us to respect the sacred space of each living being, because each one has a mission and important role in the continuity of life.

This global vision suggests that the future of the human being and of its surroundings - nature - are inseparable. Respect for the environment and for human beings themselves is the same. The human being is part of, must have an awareness of and is responsible for nature. In the words of the same authors, the human being "recognizes his/her need for nature and the universe in order to live". Remember that the human being belongs to the Earth, and not the contrary. These words seem very pertinent in a period in which there are multiple threats to the environment, whose preservation is essential to ensure food security and the development of all<sup>(56)</sup>.

According to Pablo Dávalos, Sumak Kawsay, is the strongest and most radical critique of the paradigm of economic growth driven by free markets, and an opportunity to counter the teleological notion of 'develop-

<sup>54.</sup> David Choquehuanca Céspedes, Ministro de Relaciones Exteriores del Estado Plurinacional de Bolivia. Ponencia en el Encuentro Latinoamericano. "Pachamama, Pueblos, Liberación y Sumak Kausay. Quito, 27, Enero 2010

<sup>55.</sup> David Choquehuanca Céspedes, Ministro de Relaciones Exteriores del Estado Plurinacional de Bolivia. Ponencia en el Encuentro Latinoamericano. "Pachamama, Pueblos, Liberación y Sumak Kausay. Quito, 27, Enero 2010

<sup>56.</sup> Cochoy A, María F, Yac Noj, Pedro C et al, Raxalaj Mayab' k'aslemalil. Cosmovisión Maya, plenitud de la vida, Programa de las Naciones Unidas para el Desarrollo, Ciudad de Guatemala.

ment'. It offers as an alternative a different form of relationship between human beings, in which selfish individuality should be subject to the principle of social responsibility and

tes. There is no separation between society and nature. A society can become highly productive and technological, integrating nature to its own internal dynamics<sup>(57)</sup>.

The concept of the Sumak Kawsay allows precisely this: a new vision of nature, without ignoring technological advances or productivity gains, but rather projecting them to the inside of a new contract with nature, where the society is not separate from this, or seen as something external, or as a threat, or as the radical other, but as part of its own dynamics, as the foundation and condition for the possibility of its existence in the future.



Photo: Javier Andrade Córdova



Photo: Pato Chávez

#### 57. Dávalos, Pablo (5 ago 2008) Alainet (ed.) Reflexiones sobre el sumak kawsay (el buen vivir) y las teorías del desarrollo. Consultado el 10 de noviembre del 2012.

58. Monsalvo and Quizhpe, 2004

ethical commitment, and a relationship with nature in which this is recognized as a fundamental part of human society. Nature becomes part of the life of society, is nested in such a way that it is present in every action that the society genera-

#### Box 9

"Alegremia": A new measure of health

The vision of the communities of northern Argentina led<sup>(58)</sup> to the creation of the concept of 'alegremia' as an indicator of the level of health from a holistic perspective, not a quantitative or measurable indicator where

figures have only a relative value. According to the concept, alegremia or level of 'joy in the blood' has no maximum values but is an expression of our personal, family, social and community health – AND – its measurement is with the 6 'A's: Air, shelter, water, food, art and love (each of which in Spanish begins with the letter 'A').

Alegremia is a concept of health that, although always present in our minds, was not defined in detail. It represents satisfaction, "being good to yourself and others", a state of optimism and permanent joy. It is the feeling of collective solidarity. The term ALEGREMIA has been coined permanently and disseminated in the Second People's World Health Assembly held in 2005. This has enabled it to penetrate all corners of the planet.

Alegremia cannot be defined with accuracy nor quantified



Photo: Silvina Alessio



with empirical indicators. It is a concept opposed to positivism, being humanistic and basically qualitative.

Alegremia is love and tenderness, is enduring and persistent, is respect for diversity, is balance with nature, is biological, psychological and social welfare. It proposes Joy as a process of construction, a wager, and it is not the theoretical happiness that is nearest to religious patterns<sup>(59)</sup>.

The six components of Alegremia, represent "the basics, what is essential, what cannot be disrespectful to anyone". Magically all begin with the letter "A": Aire, Agua, Alimento, Abrigo, Amor, Arte (meaning air, water, food, shelter, love, art respectively).

**Air** that we breathe, which has to be pure, free from contamination.

Clean water, as an essential human right.

**Food** for our health, without poison for plants and animals.

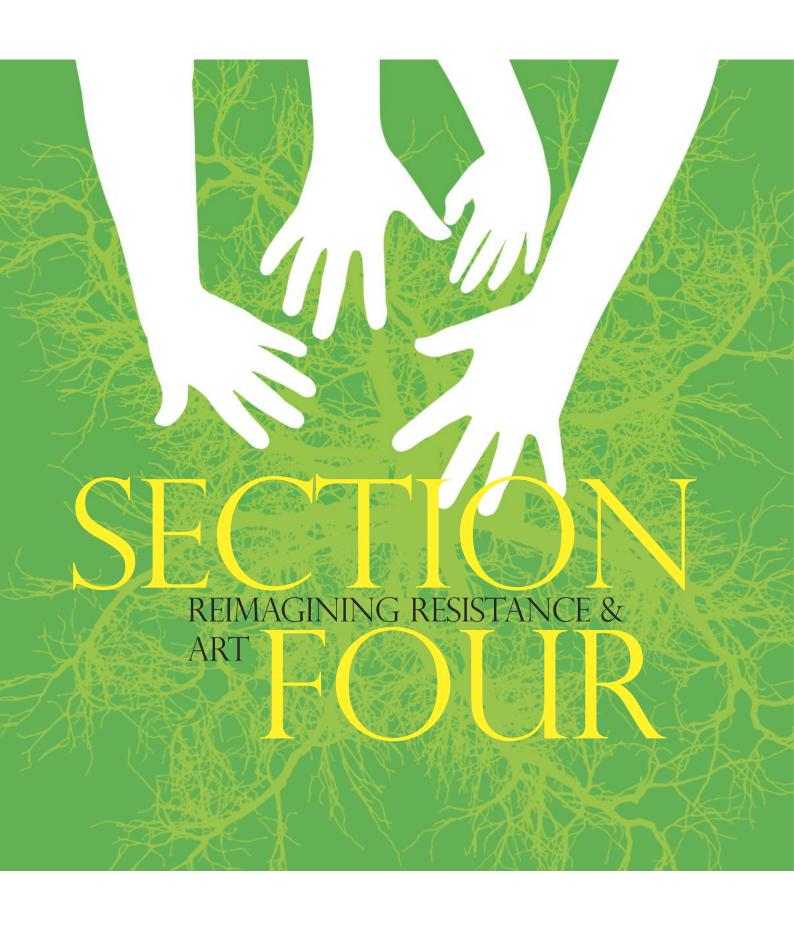
**Shelter,** dignified, that entertains us, where we can live as a family.

**Love** is necessary to live...as a couple, in the family, between neighbors

**Art**, which gives us room for creativity, feeds our spirit.

59. Hermida, Hernán. LA ALEGREMIA EN EL DESARROLLO DEL ARTE, LA ENSE-ÑANZA DE LA SALUD Y LAS CIENCIAS, Cuenca, Ecuador, 5/6/06, Discurso Inaugural del IXº Seminario Internacional Niños, Salud y Ciencia.





# **4.1**Why Art and the Microbial World in Reimagining Resistance?

The ecosystem is rich and diverse in the life processes of creation and decay. We as human beings are intimately connected to it - not least through the bacterial world. We are subject to it, respond and contribute to its life processes with our particular attributes.

One innate human characteristic is to be continually engaged in making sense of this world and transcending it. Art-making is one of the powerful ways in which we do this. Art critiques and finds new ways of understanding and describing reality. It can perhaps help us capture processes that are not adequately described by current terminology and go beyond what the 'trained' mind can visualise or imagine. It can help us break open the war metaphor and find a deeper and over time a shared understanding of our complex relationship with the microbial world. Art helps us internalize a subject and react to it. Our reactions may be positive or negative or we may be left in a state of wondering or imagining. In this way artists help us see, feel and think differently.

Art as an object. In this perspective, the finished piece of artwork is an object of our admiration and prompts us to reflect. Objects may deal with issues and problems that cause us stress, anxiety and outright fear. Reflecting on beautiful, disturbing and/or intriguing objects can evoke strong emotion. Thus, it is possible to find be-



Michelle Day, BloodVine, 2007. Materials: Thread, wire, organza, disperse dye, human hair, animal teeth and modelling clay. Photo by Stuart Hay.



auty in things where the primary emotion may be abhorrent – such as eloquently beautiful photos of war or here in this image of unnatural growth, Michelle Day begins to come to terms with the death of her mother from ovarian cancer.

The object is also a 'thing' in its own right (in Heidegger's definition where it is not so much an object of our admiration but assumes a life of it's own<sup>(60)</sup>). It persists and insinuates itself into our consciousness through its essential nature.

Artists do and have always made seductive, important and interesting visions of the big themes of life. Their works may evoke remembered images, feelings and open our minds. They may perhaps help us face our chronic fear of the unfamiliar to live more curiously with the unknown. 'From time to time, we encounter works of art that seem to latch on to something we have felt but never recognized clearly before"(61). Art works (objects and things) frame questions for us to examine after the event, we could say.

Art as a process. In this perspective art means an active engagement with the world. Products always result but are not the main focus - rather the ongoing engagement with the theme and the material is what is important. Thus art practice is active and unfixed. It invites us to deeper knowledge of our own selves and the world we are part of – to an embodied knowledge.

Nicolas Bourriard, in his seminal 2002 work 'Relational Aesthetics', sees art practice as 'a set of artistic practices which take as their theoretical and practical point of departure the whole of human relations and their social context, rather than an independent and private space" (62).

For the artist, art practice means occupying the space where we can imagine. This is how understanding happens. It often involves a lot of repetitive work but is important if we want to move beyond the first level of engagement with a theme. For example, while a beautiful artwork may result in us being in a state of wonder, wonderment tends to be a passive state. Full

<sup>60.</sup>See also Thing Theory: Bill Brown. Critical Inquiry, Vol. 28, No. 1, Things (Autumn, 2001), pp. 1-22 Published by: The University of Chicago Press Stable URL: http://www.jstor.org/stable/1344258 Accessed: 08-08-2014 16:30 UTC.

<sup>61.</sup> Alain de Botton and John Armstrong, (2013). Art as Therapy. Phaidon Press.

<sup>62.</sup> Bourriard, N (2002). Relational Aesthetics. Les Presses du réel, 2002, p113.

understanding is not achieved after one event. The process of understanding is a repetitive process of imagining and examining, re-imagining and re-examining, in practiced and repetitive ways which raises the possibility of a different way of looking. Repetitive engagement with the wider world is the strength of relational practice.

So artists can produce works that are both 'objects' (i.e. on which we can reflect creating a state of wonder and questioning) or are 'things', which through their own agency can alter our perception. From time to time iconic works of art that speak almost universally emerge from artists' own deep art practice embodied exploration in small repetitive steps. When the artwork invites us into its space, the audience engages in a similar revisitation and questioning inspired by the work. This process is what changes a paradigm both within the artist and within society. In society, when enough results exist that do not confirm the existing paradigm, a creative process of alternative questioning is unleashed requiring courage to observe and engage

afresh. Art-as-object/thing and art-as-process are both important in initiating and/or deepening engagement in exploring and questioning current paradigms.

"We can look at disease this way. We can attack with antibiotics up front, or we can take the time to integrate it into our understanding of self. Skilled artists do this. They look and they 'wonder' about things, often for a long time without finding an answer. Drawing on internalised skills allows them to express this 'wonderment' in a way that talks to other people and which (in the case of pottery) creates a continuous thread between the solitary act of making and the act of use." Janet DeBoos(63).

Art also makes things glamorous. Most of the time we are enticed to see as glamorous the things that advertising and new media promote. Art can make other things glamorous – water towers, blades of grass by a river, or bacteria. Artists rescue everyday experiences that we unfairly neglect under the pressure of everyday life and commerce, says Alain de Botton (64).

<sup>63.</sup> Janet Deboos, Chapter 5, 'Microbes and Metaphors:Re-imaging bacteria, infection and the body', ReAct 2010

<sup>64.</sup> http://www.abc.net.au/radionational/pro grams/booksandartsdaily/art-astherapy3a-alain-de-botton/5345780

Good artists can reveal the sheer beauty and mystique of microbial life on our planet, and challenge the human species to develop more humility about its position and role on Planet Earth.

#### Collective processes of art-making

Community arts processes actively stimulate community dialogues and cultural expression of new understanding on the themes explored. Community arts and arts for social change are processes where people collectively make art, facilitated by the knowledge of artists. They are a form of cultural expression embodying the exploration of knowledge and development of understanding by the community on themes important to them. They can lead to powerfully internalized understanding of complex issues and contribute to long term paradigm change<sup>(65)</sup>. Thus they can be transformative processes.

### Art practice is healthy: health is the art of care and joy in nature

Let us revisit the concept of health from the perspective of Sumak Kawsay, cosmovision of the Andean indigenous people<sup>(65)</sup>, and of alegremia<sup>(67)</sup>. Art, is one of the 6A's of alegremia, one of the 6 essentials of life, 'not one of which is disrespectful to anyone' (see Box 9). Art feeds our creativity and our spirit. Art is integral to the concept of joy and balance with nature. This is a radical unquantifiable measure of health.

Susan Semple, a research scientist at the University of South Australia has entered into a deep process of learning from Australian indigenous people to understand illness and health, including the art of caring for plants. She explains:

Some of the indigenous individuals I work with talk much more about the interplay between the components in their medicines

Judith Marcuse – personal communication, Workshop Faculty of Arts, University of Cuenca, 2013. See also section 5.
 Section 3.3
 Box 9.

and the microbes in the environment, more about the need for a balance between all things rather than the need to "kill" or "eliminate" the causes of disease. Some of the strongest medicines are those that "protect" a person rather than treating an illness after the fact. Western medicines are often seen as too strong or "raw"(68). For indigenous people, there is a need to use all the components of the plant medicine together, not just single chemical entities, in order to get the balance of effects without harm.

Caring for the plants used as traditional medicine and the whole environment in which they are a part is also of great importance to the health of indigenous people. Some studies are starting to recognise the role that natural resource management by Indigenous people on their traditional lands can play in the improvement of their health outcomes (for example see Burgess et al 2005<sup>(69)</sup>).

Many in the frame of Western medicine are beginning to discover the connection between art, health and healing. The Foundation for Art and Healing, established in 2010, explores the psychological and clinical connections between these states. Understanding is growing of the intricate relationship between many types of health disorders and a person's way of experiencing emotions, stress, attitudes and beliefs.

A growing body of research demonstrates that a variety of creative engagements (the arts) can positively impact emotions, attitudes and beliefs, contributing to greater health and wellness for the individual. Additionally, the arts have long been recognized for their power to bridge differences — connecting individuals of different backgrounds and experiences through the shared experience of art, music, literature and dance, thus healing communities as well as individuals(70). A review of literature on the relationship between engagement with the creative arts and health outcomes shows that engagement in music, visual arts therapy, movement-based creative expression or expressive writing can decrease anxiety, stress and mood disturbances. In patients

<sup>68.</sup> the words of Mr David Claudie Kaanju traditional owner from Cape York Peninsula

<sup>69.</sup> Burgess, C., F. Johnston, et al. (2005).

"Healthy country: healthy people? Exploring the health benefits of Indigenous natural resource management." Australian and New Zealand Journal of Public Health29: 117-122

<sup>70.</sup> http://www.artandhealing.org/why-it-matters/

with certain chronic conditions such as HIV and cancer, there was an increase in immune-system functioning<sup>(71)</sup>.

#### 4.2

#### Artists' views of the microbial world, human concerns, new possibilities

With these insights into how art and culture enrich and change our lives, we can look into the ways artists, interested in the themes of the microbial world and the ecological nature of human relationship with this world, confront us, inspire us and alter our emotion and perceptions. It is as if they remind us of half-conscious knowledge about these themes, urge us to have hope and to reach for another world that we desire deep down but find hard to act on.

#### Two scientists' views of the beauty of the microbial world

MICHAEL GILLINGS, Professor of Evolutionary Microbiology, Macquarie University, Australia, is enthusiastic about the beauty of microorganisms. He says we can see beautiful microbes all the time, but we just don't know it. They are invisibly around us being beautiful. Take for example lichens, he says, which we see everywhere. Lichens are examples of cooperation between a fungus and a photosynthetic green algae or cyanobacterium - two microorganisms cooperating to produce one organism.

Anytime you walk on any rock you are actually walking on a living sur-

face of microorganisms. Here at Macquarie University in Sydney we are on Hawkesbury sandstone. Unless you physically break a piece of Connection between art, healing and pusandstone off, you don't actually see rock. What you see is a coating blic health: A review of current literature. of lichens and microorganisms. Even the surface of soil is held together American Journal of Public Health, v.100, no. 2. Pages 254 - 263 by microbial mats.

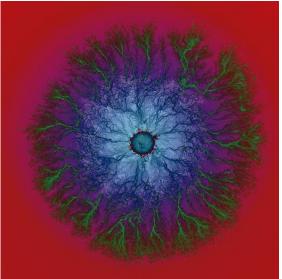
<sup>71.</sup> Stuckey, H.L. and Nobel, J. (2010) The

He recognizes that most people do not like slime – but he sees a certain beauty in green tendrils of cyanobacteria in streams. He remarks also, "If you just get a microscope or, if you are lucky, a scanning electron microscope, you can see fantastic scenes beautiful, giant, blue amoeba and amazing diatoms. One of the best examples are diatoms. Diatoms are single celled marine plants, essentially, that have highly complex silicon jewel-like structures. In Victorian times people collected diatoms like microscopic flowers and arranged them on microscope slides. They would visit each other to compare the beauty. They look like stained glass windows in baroque cathedrals. There are millions of beautiful and tiny cell structures in microscopic images. It is a sad commentary on modern humans that our use for diatoms is mainly as diatomaceous earth filters in swimming pools and as kitty litter. So, every time you empty the cat litter you should imagine that there are thousands and millions of microscopic jewels in there, tiny cell structures of dead diatoms as beautiful as any stained glass window" (72).

The natural beauty of the microbial patterns formed under various conditions can be made visible as ESHEL BEN **JACOB**, Professor of Complex Systems, Tel Aviv University, Israel, and colleagues have done, by colouring the images of the bacterial colonies they have grown in their work to understand the dynamics of decision-making in bacterial colonies. This includes: the patterns that bacterial colonies form under different environmental conditions; and, the intricate processes that they follow to achieve their objectives of survival, security, reproduction and even resistance. Here are extracts from his work with accompanying images. These he calls bacterial art – he wants us to appreciate the beauty and complexity of this world as the colonies go about making crucial decisions to adapt to conditions they encounter and share the information with the whole colony.

Under unpredictable hostile environmental conditions, when the odds are against survival, the bacteria turn to a wide range of strategies for adaptable collec-

<sup>72.</sup> Interview conducted with Michael Gillings by Mary Murray and Satya Sivaraman. (2009) Microbes and Metaphors Chapter 2.



'Bloody Mary'. Source: Eshel Ben-Jacob. Reproduced with his kind permission.

Source: Eshel Ben-Jacob. Reproduced with his kind permission.

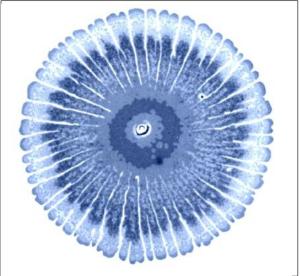
tive responses. These cooperative modes of behavior are manifested through remarkable different patterns formed during colonial self-organization. The aesthetic beauty of these geometrical patterns is striking evidence of an ongoing cooperation that enables the bacteria to achieve a proper balance of individuality and sociality as they battle for survival, while utilizing pattern-formation mechanisms that we have only recently begun to understand<sup>[73]</sup>.

In multi-colonial communities (e.g., sub-gingival plaque), bacterial social intelligence is usually used for cooperation between colonies of different species. For example, each colony develops its own expertise in performing specific tasks for the benefit of the entire community, and they all coordinate the work done. Some bacteria undertake the task of keeping valuable information which is costly to maintain and may be hazardous for the bacteria to store<sup>(74)</sup>.

73. http://star.tau.ac.il/~eshel/gallery.html; 74. lbid



'The end'. Source: Eshel Ben-Jacob. Reproduced with his kind permission.



'H'. Source: Eshel Ben-Jacob. Reproduced with his kind permission.

They can single out defectors by collective alteration of their own identity into a new gene expression state. By doing so, the cooperators can generate a new "dialect" which is hard for the defectors to imitate<sup>(75)</sup>.

Bacteria modify colonial organization in the presence of antibiotics. We might even discover that the last five decades of evolution in bacterial social intelligence is largely a result of their encounter with our socially irrational massive use of antibiotic materials in agriculture and human intake<sup>(76)</sup>.

There is phenomenal potential of the microbial world as both subject and object of art. But artists would argue that only colouring the images of bacteria to show their beauty and activity is not truly art...

75. Ibid 76. Ibid

## Cultural images from the time of the plague

The fear of contagion following epidemic and pestilence is common to all human genera-



The Black Death in Florence (Marcello, 1348).

tions and one powerful underlying cultural factor in human fear of infection. It is perhaps a

collective invisible force driving the desire to take antibiotics to prevent infection getting a hold. Iconic images from the time of the Black Plague, such as the Grim Reaper (Section 3.2) and street scenes from Florence (opposite), persist. They represent ingrained collective memory of the lived experience. Overcoming this fear and the predominant perception of being in a war with bacteria, with antibiotics our only weapons, is a collective and individual challenge.

## Three artists who disturb our sense of disgust of bodily functions with beauty

Art also helps us remember what really matters...the people we call good artists are, in part, the ones who appear to have made the right choices about what to communicate and what to leave out. ... We might say that good artwork pins down the core of significance, while its bad counterpart, although undeniably reminding us of something, lets

an essence slip away. It is an empty souvenir<sup>(77)</sup>.

Art can confront us with what we associate with disgust – but at the same time created with a beauty that puts us into a paradoxical state between the two and thus opens our minds. 'Art is important as a container for our secrets, for ideas and emotions that are hard to share over the dinner table'<sup>(78)</sup>.

MARCEL WANDERS is a designer who used new technologies of 3-D image capture to get a picture of the shape of a sneeze. This image was then turned into a real object used as a model for his 'Snotty Vase'. The vase is used for flowers, and in this context the shape of a sneeze, and all the mucous attendant on that is subsumed in a thing of beauty.

MAREK CECULA is a ceramic artist who also embraces the idea of infection. In his 'Scatology' series, he makes exquisite porcelain surgical and hospital objects that confront the unmentionable with the beautiful. This work was exhibited at the height of the AIDS epidemic



Marcel Wanders Airborne Snotty Vases. Source: www.marcelwanders.com



Image: Scatology Marek Cecula, USA/Poland – Scatology/Hygiene series Reproduced with kind permission of the artist

when there was an extremely high level of anxiety about body waste. His suggestion was that fear is not the answer- maybe getting to know (and therefore

- 77. http://www.brainpickings.org/index.php /2013/10/25/art-as-therapy-alain-debotton-john-armstrong/
- 78. http://www.abc.net.au/radionational/programs/booksandartsdaily/art-as-the rapy3a-alain-de-botton/5345780



Anna Dumitriu Bed flora - Transmission Electron Microscope Image.



see the beauty in) the 'enemy' was the way to go.

British artist **ANNA DUMITRIU** wants to open our minds to the presence and importance of the 'normal' bacteria in our lives – the ones that live in our digestive system – called 'normal flora', and even the ones that live on our favourite chair and in our beds. Her mantra is "Not how clean is your house – but how sublime is your ecosystem".

She set out to find a way to chat with people about normal flora. She began to crochet the pattern made by the microbial flora she had cultured from her bed. She crocheted this pattern while chatting to people in the local hospital foyer- waiting area, and others joined in.



Anna Dumitriu Chair and bed flora detail. Source: Anna Dumitriu with kind permission to publish

I also cultured bugs growing on an ordinary chair and carved and needle pointed the image back on to it, the crocheted bed flora piece was exhibited in London and is shown opposite placed over the chair and the 'growing' spilling over onto the floor.

Anna's work includes performance – talking with an audience at the science Museum in London for example about the process of exploring normal flora while she extends her crochet work<sup>(79)</sup>.

#### Paradigm change

The following examples are given to illustrate art works and art processes that uncover, explore or stimulate whole new patterns of thinking - that are shaping and offering new paradigms and that may unsettle or entrance viewers. As antibiotic resistance, like climate change and other major complex issues of our times, presents us with a challenge to think where self stops and 'other' begins -'other' as humans and as the whole ecosystem or other species within it  exposure to visual and other images that arrest our usual patterns of thinking become more and more important.

THEO JANSEN from the Netherlands is an artist who has worked for several decades developing autonomous wind driven creatures made from basic building materials - not proteins but plastic conduit tubing and plastic PET bottles. In doing this he is creating a 'New Nature' and is thus able to imagine and understand the problems and difficulties of (first) Nature. He hopes to eventually release herds of these beasts to roam the beaches of the Netherlands coast-feeding on wind, thinking about and reacting to danger, maybe even replicating? His work is both performance and 'thing'. The 'things' enable us to imagine the 'other' but see ourselves<sup>(80)</sup>.

Bioart is a newly emerging art form aiming to dissolve the frontier between art and science. It is considered by some as a new artistic category generating questions within art and science about the human form and life in general<sup>(81)</sup>.

 $<sup>79.\</sup> http://www.annadumitriu.co.uk/$ 

<sup>80.</sup> See http://www.strandbeest.com

Laura Moscatel, Presentation to Symposium on Art and Microbes, University of Cuenca, 2013.





If the plant accepts my protein and reproduces, the laws of physics allow it. We are going back into the moment of time of evolution before we all became what we are. This creates a temporal tension.

82. http://www.ekac.org/nat.hist.enig.html; Eduardo Kac, 2009. Lecture at Ars Electronica http://90.146.8.18/webcasts/files /FE\_2009\_09\_04\_symp2\_kac\_E.mp4 **EDUARDO KAC**, a 'transgenic artist' using the tools of biotechnology and genetics, has created a number of cutting-edge interactive networked installations. His work called 'The natural history of the enigma' re-

flects on the contiguity of life between different species. He created a new form of life, called a plantimal. He took a sample of his own blood and extracted chromosome No. 2 which identifies what is 'not him'. Independent of consciousness, the gene recognises what is not self – a foreign body - and organizes the body's rejection. He integrated this element that recognises 'other' into 'other' - in this case the leaf of a petunia plant. In the plantimal his gene was expressed only in the red veins on the 'face of the flower'. He used the redness of his blood and the redness in the plant's veins as markers of shared heritage in the wider spectrum of life<sup>(82)</sup>.

To do this, he cut a leaf of a petunia plant and exposed it to bacteria carrying this new gene and an antibacterial resistance gene. He allowed the bacteria to deliver the genes into the leaf cells. The cells were grown in an antibiotic medium to prevent growth of any other cells. A new self, partially human and partially plant emerged. The images here of his work are stills from his website (Reference 77).

SYMBIOTICA, THE CENTRE FOR EXCELLENCE IN BIOLO-GICAL ARTS, is an artistic laboratory that fuses the disciplines of art and life sciences to encourage better understanding of cultural ideas around scientific knowledge and to critique ethical and cultural issues relating to the manipulation of life, identity and the relationship between human beings and other living beings and environments. It is located in the medical school of the University of Western Australia.

Led by **ORON KATTS** and **IO-NAT ZURR** it is exploring the construction and growth of complex organisms and the development of half-life.

Many of the ideas that Symbiotica has been working with were exhibited in 2013 at the Powerhouse Museum in Sydney in a show called Semipermeable[+], curated by Oron Katts. It brought together 14 artists from different disciplines to present, articulate and re-visit the notion of the membrane – from protocells, infection and DNA through skins and garments, to borders and state control.

'Maintaining integrity and protection, the membrane acts as an interface to the world. The strongest visual (and auditory) cues deal with where one thing ends and another begins, from the perception of self to societies and nations. Semipermeable[+] looks at the membrane as a site, metaphor and platform for a series of artistic interventions and projects' (83).

**TAGNY DUFF** created a series of sculptures called Living Viral Tattos from human and pig skin.

'When we humans walk in a city, run through the halls of a busy airport, roll through a bus terminal or a train station, we are travelling not only through streets, hallways and tunnels, but through microbes. The series of sculptures, Living Viral Tattos, are made of human and pig skin and a biological synthetic virus called Lentivirum, a derivative of HIV strain 1, so that transfection and contagion would occur at the cellular level. The virus, cells and tissue are inert now and the biomaterial reveals areas of bluish brownish stains<sup>(84)</sup>.

<sup>83.</sup> Introduction to the exhibition, Powerhouse Museum, 2013. http://www.news.uwa.edu.au/201306065729/arts-and-culture/art-skins-cells-infection-and-dna-exhibits-sydney. See also - http://www.symbiotica.uwa.edu.au/activities/exhibitions/seminermeahle-

<sup>84.</sup> http://www.symbiotica.uwa.edu.au/activities/exhibitions/semipermeable-

**DONNA FRANKLIN** uses mycology as an artistic tool. Inher work Fibre Reactive she has grown in the laboratory a unique biological garment from the Australian orange bracket fungus. By its very existence this

'cultured' experience of nature. The work aims to rupture the meaning of the 'garment' and its role in commodity culture, and draw attention to our own mortality<sup>(85)</sup>. It also ruptures the divide between human and microorganism, in the process making the beauty of the organism so evident.



### Artists directly engaged with the Reimagining Resistance process

PANYA CHIYAKUM— Ratchaburi Thailand. Panya has long been acknowledged as one of Thailand's most accomplished wildlife artists, painting the ecosystem of the forest and teaching children to see, paint and develop a sensitivity for the forest and the life therein.

I am really attracted to the enigma of microbes. If we could understand the mysteries of bacterial ecology and behaviour of bacteria, might it not be possible to live a complementary life with all species?

85. Caption to the exhibition installation; see also http://www.symbiotica.uwa.edu.au/activities/exhibitions/semipermeable-

dress aims to raise debate around the contentious manipulation of living entities as commodities. Through intervention we have constructed a



TRACES OF LIVING



Panya Chaiyakum and Niracha Mongkolchai. Flowing from his participation in the Microbes and Metaphors dialogue, he began exploring the microbial theme. He created a series of ceramic microbes, followed by a project with pharmacists learning from nature how to paint and express their concepts of the relationship between medicines use and the broader environment. See Section 6.5.



Peter Cameron - "Lichen" Detail from Canberra District 8.

PETER CAMERON is an Australian landscape artist who explores land through imagination and deep feeling for the processes of life and death within the very structure of the landscape and its sentience 'carrying within itself a host of complexly conscious communities moving in a web of seasonal dialogues.' Imagination is important to him, even though

he sees it as less valued in current life. '...It will harvest whatever seed it sows. It grows through the attention and belief it's given. A good working relationship develops between what is experienced outside the body and what is sensed within. Subtle flows and rhythms become more apparent. Cataclysmic events will always shock. These are all natural ingredients for the creation of stories we tell ourselves, individually and as a culture (86).

His reflections about microbes following engagement in the reimagining resistance processes raise interesting philosophical questions.

'Microbes might be a god or a kind of god – 'the generation of diversity' god. An individual image goes to make up a whole system – a thinking organism. The connections between the microbes, these forming and reforming structures, can easily be understood as a potent lifeforce exhibiting various drives, hence consciousness. A fungi makes decisions. We should think about them on their terms – otherwise it is colonization.'

86. http://www.petercameron.com/booklet /The-Rise-and-Fall-of-Land.pdf

#### Conclusion

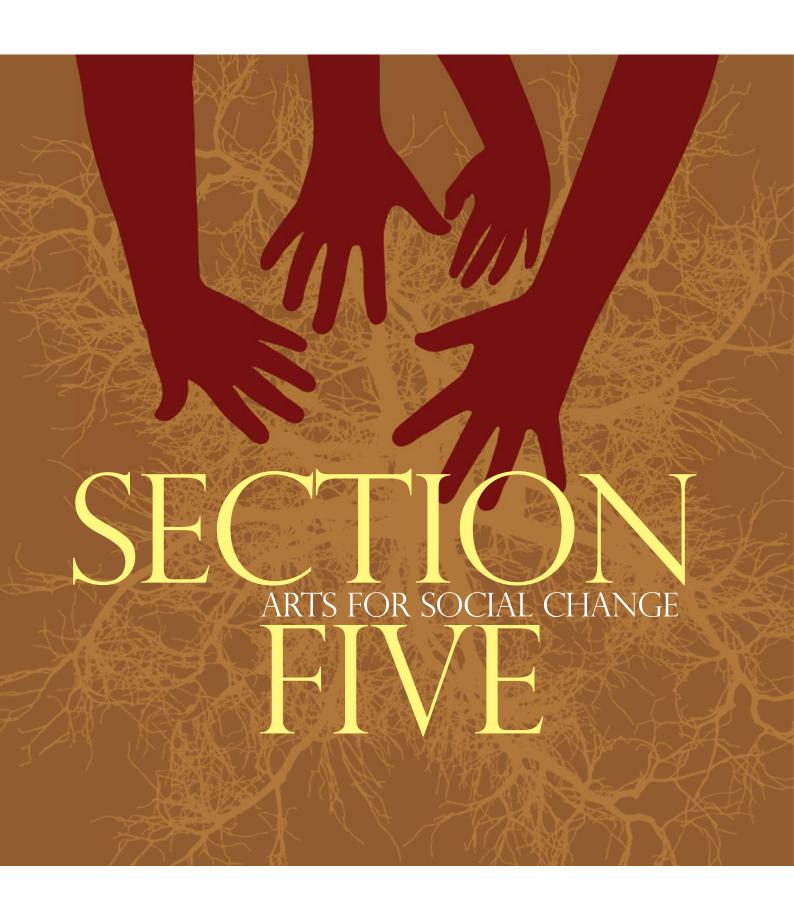
Our ability to understand the microbial world is influenced and limited by our technology. Just imagine if Leevenhook and Robert Hooke had not come up with the idea of animalcules and the microscope when they did. What if the breakthrough to see the invisible world with the aid of technology had been made now when we might see traces of the collective phenomenon – such as is being done in metagenomics now. We would have a very different prevailing paradigm of the microbial world.

As the work to understand and characterize the microbiome matures, images will hopefully emerge of the complex patterns formed by diverse colonies of microbes living together in an interacting balance. We need images to visualize the critical role they play in the networks of different living ecosystems and the ultimate hope they offer for the guaranteed existence of life on Planet Earth.

The artists whose work is portrayed above are engaged in an ongoing process of examining and understanding complex issues for which there are no easy answers in modern life. These artists are producing objects of art, which play with us and vice versa. They all point to a major change in thinking required of us as individuals and as society – a change that requires transcending deeply rooted individual and collective fears, and responses to those fears. We need images to live by, as Ginette Paris proposed (see Section 3.2).

The reimagining resistance and microbes and metaphors dialogue will continue to survey and engage artists interested in the theme of human-microbe relations, our disruption of the microbial world, our harnessing of the microbial world, our embracing of the microbial world as it is for our health and that of the ecosystem.

Artists, scientists and ourselves as communities must root the processes and images of this paradigm change in the human language of image and feeling. These are after all, the fastest and most infective human traits of consciousness and communication compared to the slow plodding processes of thought, planning and rationality.



What is the relationship of the arts to social change? Many see it as a useful instrument to drive change towards a certain goal. However, the Reimagining Resistance perspective questions this instrumental perspective. Certainly, good artists can help create more powerful communication messages. While this is useful, RR is interested in a more fundamental question. Are arts processes in the wider community generative of change processes themselves, including their direction and goals? Are they perhaps working at a fundamental level somehow?

The RR vision is long-term. Its trajectory has been created by those interested in participative processes that open imagining to a different consciousness with which to live the human-bacterial relationship. This section sets out the ideas and processes used in the growing field of arts for social change as a framework to introduce a number of community arts projects that have emerged within the Reimagining Resistance process. These are described individually in more detail in the following sections.

Yael Harlap surveyed and analysed the arts for social change field in 2006 for the International Centre of Arts for Social Change in Vancouver, founded by Judith Marcuse<sup>(87)</sup>. 46 artists and/or organisations participated in the study from around the world, but mostly from North America. When asked 'What does social change mean in your work?', the responses showed the tremendous variation in aesthetics, practices and products. However, common themes emerged (Box 10) which Yael formulated as a loose set of principles underlying why artists engage in this work. There was also a strong and important assertion by a number of groups that they do not have social change as a goal or meaning in their work – but social change often results.

Of seven themes, three were common to all areas of work and show the deep interest of artists and communities in many levels of social relationships including acceptance and critical thinking as Harlap illustrates:

Harlap, Y, (2006). Toward training: the meanings and practices of social change work in the arts. http://www.icasc.ca/toward training 2006

#### **Box 10**

#### Seven themes in arts for social change

Working toward equity and justice

Raising consciousness and awareness

Fostering individual empowerment and participation

Bringing people together and building relationships among individuals and groups;

Creating dialogue

Giving voice and telling stories

Creating new visions and opening new imaginations for what the world could be

Working toward equity and justice. For the artists and organizations this covers a wide range of areas: 'working towards inclusivity, tolerance, and equal access to material and intellectual resources; challenging injustice; uprooting racism; shifting the meaning of diversity; and more <sup>(88)</sup>.

Raising consciousness and awareness ... 'includes fostering critical perspectives and critical thinking; making connections from the local to the global; being subversive; challenging assumptions, prejudices, or stereotypes; asking questions; and changing people's attitudes "(89).

Fostering individual empowerment and participation. Although the concept of social change implies changes in communities or societies, many of the artists and organizations in the study saw this process of change as evolving through a process of individual empowerment and participation in neighborhoods and communities "By being agents of change in your own life you affect the community as a whole; change starts at an individual level and that changes the structures that you are part of. I think this kind of work is really good at that. Not about making structural changes, but about exploring and identifying ways [...] to change on the individual level".Headlines Theatre<sup>(90)</sup>.

Although not exclusive to the domain of community-engaged arts, the arts have a particular role in creating dialogue and bringing people together and in building relationships among individuals and groups, and do them particularly well. Harlap says' Creating dialogue includes creating safe spaces for conversations, opening dialogue between people and groups who

88. Ibid, p 193. 89. Ibid, P 194. 90. Ibid P. 194. would not usually have the opportunity to engage with each other, and talking openly about previously taboo topics'<sup>(91)</sup>. Thus the arts are good at the processes of social cohesion and holding relationships together across difference.

Giving voice and telling stories is unique to the domain and means 'representing untold stories in a community, bearing witness by bringing hidden stories to light, valuing youth voice, and supporting the community in finding a common voice'<sup>(92)</sup>. "It goes back to our mission, representing the untold and undertold histories and stories of people, from a woman-centred perspective using movement from the African diaspora. We represent on stage what is often forgotten or dismissed or diminished."Urban Bush Women<sup>(93)</sup>.

Exclusive to the domain, says Harlap, is the theme of creating new visions and opening new imaginations for what the world could be...lt includes 'expressions of creativity, hope, freedom and expression...practicing new ways of being in the world, people being able to assign their own affiliations, fostering creativity and fun, engaging in positive expression, giving people new perspectives, and more. This theme fits very well with RR work. Four groups captured the essence of this theme:

"In our work those visions then become—we have permanent installations, public art works— they're reminders of these visions of equality, justice and hope, and hopefully it gives people direction for their social action" (94). Myths and Mirrors Community Arts.

"Really creating a paradigm shift, a different way of looking at issues and coming to deal with issues from a community perspective. [...] It really is about a paradigm shift, not doing things the way they've been done if it's not working anymore" (55). The Center for Art and Public Life.

"Dance allows people to go into that liminal space where they can be who they are and not who they are at the same time, so they can practice new identities" (96). Ludus Dance.

91. Ibid, P 195

92. Ibid, P. 196.

93. Ibid, P. 196.

94. Ibid. P. 196.

94. Ibid, P. 196. 95. Ibid, P. 196

96. Ibid. P. 196-197.

'transient utopias and far-reaching ripples': "we can change things a lot within our own environment, in ways we know and ways we don't know [...]. It creates inspirations for the way the world could be and society could be "(97). Jumblies Theatre.

These examples seem to indicate that rather than being instruments of particular change, the processes of community arts generate in themselves processes of change and create visions for new possible worlds. In terms of process or product, the seven themes can be thought of as either a meaning of or a strategy for creating social change. Giving voice and telling stories may be the outcome of social change work, or in another setting, it may be a process en route to another endpoint such as equity and justice. At the heart of debates around process and product—quality of community engagement and quality of artistic work—is this question of integrity between representation through the arts and everyday processes and practices<sup>(98)</sup>. Not only is the artistic work a new vision for what the world could be, but the community-engaged process can embody, or strive to embody, new ways of working together.

This is an important insight for RR processes. Beyond the particulars of needed change in relation to antibiotic resistance, the RR processes aim to create new ground for collectively envisioning new relationships between human and bacterial worlds and thus for collectively re-examining, re-imagining and re-realizing what antibiotics are and their effects in a cooperatively shared and renewing ecosystem. This sense of 'walking the talk' may be one special strength of community-engaged arts done well.

### What impact have organisations and artists working in this field had?

Harlap coined the term 'instrumentation strategy' in assessing the success of arts organization according to the explicit goals of each,

97. Ibid, P. 197. 98. Ibid, P. 197. By this she meant to assess value and impact in relation to how the meanings of social change for each group animate and motivate the artistic and community engagement practices.

A number of organisations however, while finding this 'thought-provoking', were clear that this did not capture the essence of their work. New methods are needed, including critical response and inclusivity, that more truly reflect what the domain of social change and the arts is about. Process and product are often closely intertwined and inseparable in this work, and the meaning of social change is often also its means<sup>(99)</sup>.

Some examples from Harlap's review will help in clarifying the crucial importance of interwoven process and product in the methods that have evolved so far in the Reimagining Resistance project (art, photography, and performance ethnography). They also highlight the holistic nature of this kind of work and how the scope of themes engage communities in different

ways relevant to them. Overtime, a climate of change is generated. They also show that evaluation methods need to reflect the nature of the work itself – an important issue for RR.

Raising consciousness was the central focus and meaning of social change for two organisations: namely The Beehive Design Collective and Porte Parole.

The Beehive Design Collective is a collection of loosely affiliated visual artists - worker bees - who collaborate primarily to develop visual tools for communicating the way the world works and explaining complex human, economic, and environmental consequences of globalization, with a focus on North-South relations in the Americas and Latin American solidarity. Its main process of social change is focused on its vision of making connections between local and global circumstances and conditions. It uses storytelling and art, gives voice and creates dialogue and new visions for how the world might be(100). Visual storytelling is the artistic method and community

99. Ibid, P. 226 100. Ibid, P. 199.

engagement is a strong process. "we see ... a desperate need for more visual tools to explain the way the world works." It spreads information by first making these visual tools that then "take on a life of their own, mutate, cross-pollinate, and other people adopt them and become storytellers". Success, for the Beehive Collective, includes seeing the visual images used in community organizing both in the North and the South:

Our most ambitious graphic to date. 9 years in the making! This double-sided folding poster illustrates stories of resistance, resilience and solidarity from Mexico to Colombia. A map drawn in old colonial style depicts the modern invasion of megaprojects planned for the region... and opens to reveal the view from below, where communities are organizing locally and across borders to defend land and traditions, protect cultural and ecological diversity, and build alternative economies.



Beehive Collective.

Whatever the work is about, if the people who are the most directly affected by that story or that work feel compelled to embrace the work and are using it themselves, that's when we feel satisfied with what we've done...knowing that lots of people in Colombia are using the Colombian poster for their own work, that's how we know it was successful...



Beehive Collective.

This is evidence for the Beehive Collective that the collaborative, decentralized process of creating the work is successful— that the people whose stories are invested in the artistic work embrace the work. It is also evidence that others acknowledge that the visual tools can be used for raising consciousness, as they adopt the posters themselves for that purpose<sup>(101)</sup>.

Porte Parole is a small theatre company that creates and produces documentary theatre based on material drawn verbatim from interviews or archival documents such as court trial transcripts or media archives. The core of social change for them is raising consciousness through story-telling and creating dialogue through modeling a new approach to communication. The artistic and community engagement practices involve collecting individual stories and iuxtaposing them in ways that tell a new more encompassing story that does justice to the complexity of the situation being represented. Annabel Soutar, the artistic director and co-founder says:

The aim is to show the beautiful and wild differences of opinion that exist about the same story. Getting at a unified vision of reality seems impossible. I love how one story can exist through many different voices, many different angles. [It] reminds us whenever we're consuming news, [to] question the authority speaking to us, ask how the way they're telling the story speaks in their own human voice and therefore [is] prejudice[d] in some way... So whenever you root human stories in a specific context, you can change people's attitudes and that makes the world an easier place to live(102)

She sees outcomes as too intangible and complete understanding of the nature of social change too difficult to be able to identify clear impacts. "I think it happens in very small increments, and it's very hard to pinpoint and to measure, and that we shouldn't give up on it despite how [difficult it is] to measure it in a scientific way." Her main criteria of success is aesthetic – satisfaction with the quality of the piece. She sees evidence of an increased flow

101. Ibid, P. 202. 102. Ibid, P. 207-208. of information about the issue or community when she is contacted by people touched by the work<sup>(103)</sup>.

Chickenshed Theatre<sup>(104)</sup> and the Liz Lerman Dance Exchange<sup>(105)</sup> are organisations that reject the concept of social change in different ways – though they embrace social changes that emerge through their work.

The power of Chickenshed's organizational culture is what creates social change. It models an inclusive world by working inclusively, propagating Chickenshed methods by teaching, training and mentoring new theatre companies that want to work inclusively. The artistic practice is theatre performance. "Performance drives Chickenshed, allows us to develop our methodology....the theatre that spearheads everything is really good, and we say the inclusion makes the work artistically more excellent... there isn't that much theatre that has both quality and inclusion "(106). Chickenshed assumes explicitly that social change happens through individual change "by providing people with an opportunity here where they can succeed, and trying to record that success so they can take it to other places in the community or other communities Most artistic products start off with a process of critical thinking and exploring identity: an individual questioning themselves and their own perspective".

Chickenshed Theatre is a theatre company based in London, engaging in performance and education in inclusive theatre. It has fostered the creation of other theatres in London and beyond that use its methods in inclusive theatre. Social change for the organization means creating new visions and opening new imaginations for what the world could be. "In simple terms we're looking for an inclusive society, with all its organizations, activities, communities, being open to anyone who's part of those communities...If we engage in social change, that's the end we want to look for: an inclusive society", says Paul Morall. But, he qualifies, "We're a theatre company; we didn't set out to make [social change] a feature of our work, we just wanted to involve everyone in the performing arts. The way we've done it, people use Chickenshed as a model for what the world should be like. It wasn't something we set out to do".

Chickenshed also models inclusivity in its approach to assessing impact. "You know something's been successful if people carry on coming, and when people are attending, are they fully engaged in all the activities? [...]"(107). Initially, Chickenshed approached leaders of Council in different boroughs to engage new communities in developing inclusive theatre; now it is approached by communities

103. lbid, P. 212.

104. lbid, P 213

105. Ibid, P. 115-116.

106. Ibid, P 213

107. lbid, P 215

wanting to set up theatre companies in the Chickenshed model. There have also been examples of inclusive policies adopted from borough to borough in direct response to Chickenshed's work.

Liz Lerman Dance Exchange's work is an encounter with four guiding questions: Who gets to dance? Where is the dance happening? What is it about? Why does it matter? By addressing these questions, the Dance Exchange seeks to re-integrate the many functions of dance—aesthetic, healing, spiritual, social—into one practice<sup>(108)</sup>. It rejects the idea of social change as a motivating force. John Borstel, Humanities Director, says:

**Liz Lerman Dance Exchange** has been engaging communities in dance locally, nationally and sometimes internationally, for 30 years. Its main activities are performance, community engagement or residencies, and educational programming, which ranges from dance classes for children to institutes for professional dancers who are interested in doing community engagement work. The Dance Exchange seeks to combine all three mutually reinforcing areas in any situation..

"Art for social change implies to me something about why you're motivated to make the art, and in our case, while we see the social implications of art and the social impacts of art as very integral to what we're doing, we tend to see the art as the central thing and the mo-

tivation primarily about the art and human experience needed through the art...

...we might go into a community like a nursing home, and there might be somebody there who hasn't walked or spoken, and by the time the workshop is over, the person who hasn't been walking is walking again. We might go into a community where police and youth are engaging only in an adversarial way and by the time our workshop is over they're having a conversation; they're making a plan for how they can continue talking. If we have a goal to make the person walk, or to have people communicate, we would never succeed, but because we make art the goal, those things happen. We're never going in directively saying 'we want to increase communication,' but by virtue of what we do ... participation and organization and social action often do extend from our work....We en-

108. lbid, P. 115-116.

Reimagining Resistance

gage people a lot in developing their skills in working together, and being together in spite of differences of ideology"(109).

The company has developed a set of tools that supports its methodology of collaborative inquiry through dance:

"In a residency, we'll spend the morning teaching tools, explain them, give small assignments to experience [using the tools], and in the afternoon [participants will] be challenged to apply those tools to a given task. 'Here are some tools, now you and three other people need to cre-



Left up: photo by Jaclyn Borowski. Right up: Liz Lerman. Photo by John D. & Catherine T. MacArthur Foundation. Left down: photo by George Hagegeorge. Right down: photo by Jaclyn Borowski. Source: http://danceexchange.org/

109. lbid, P. 219.

ate a dance work or an approach to a community that involves those tools.' [They're] not just deploying [the tools] but [they] need to do collaborative negotiation...." Thus community participants contribute to creating work "in a process we strongly influence and direct," and they provide feedback to each other and the company through Liz Lerman's critical response process<sup>(110)</sup>.

The Dance Exchange can be brought into a community or a set of relationships because their presence is seen as a catalyst for new ways for people to see each other. For example, the company is supporting the Wesleyan University in building relationships between arts and sciences. It describes its impacts as creating networks, developing relationships, and building social capital.

"Our work has been seen ... to exemplify the idea of social capital, generally the idea that social networks benefit everyone by serving as a resource for human need ...I think a word we're more likely to use than 'agents of social change' is 'artists as citizens'—fully engaged, invested in the life of the community, understand[ing] that actions will have an impact whether for good or ill, and with the right orientation and tools, it can be an impact for good."

#### Conclusion

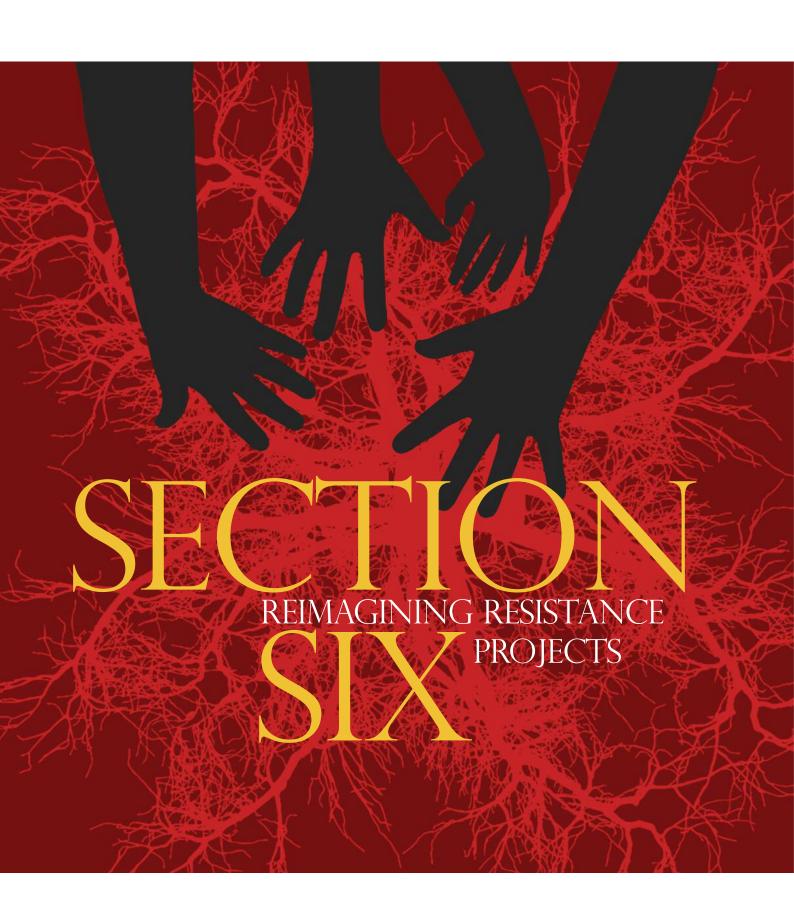
A strong message from the examples above is the importance on focusing on the quality of the process and it's interweaving with the products being created - they are inseparable. The quality and authenticity of one is reflected in the other. The issue of ABR is a challenge to communicate. It is complex, depends on many interacting and changing factors, and cannot be explained in simple cause and effect terms. Although antibiotic use is one major factor, a new way of seeing and feeling is needed to come to terms

110. lbid, P. 221.

with the implications of restraining antibiotic use. Individual attitudes and practice affect collective health. It has been easy to represent bacteria as monsters, as a threat to humans. But in doing so, the reality of our dependence on their proper functioning for life and health is hidden. Our existential intimacy with the microbial world is hidden. Our interconnectedness through the microbial world is hidden.

To be ecological, to be transdisciplinary – is to participate consciously in the reality of human-bacterial life. This goes beyond understanding only. Arts processes, such as those described, ask participants to question their own views.

In uncovering and promoting a new paradigm in human-bacterial relations, Reimagining Resistance intends to raise consciousness. Raising awareness [say of antibiotic resistance and the overuse of antibiotics] and raising consciousness [of the importance of the microbial world to life and health in balance with its disease causing effects] are not the same thing. The importance of community arts and arts for social change is the internalization of the process, an internal dialogue that is amplified in a community dialogue, that becomes individually and collectively embodied. The most important element for Reimagining Resistance is the desire to create new visions and opening new imaginations for what the world [of human-microbial relations] could be. The following section describes initiatives attempting to do just that.



The Reimagining Resistance process has resulted in a number of interesting projects that have mobilized different kinds of communities into collective processes in attempting to bring a new imagination to the bacterial-human relationship and the ecosystem at large. The next two sections look at the results of the Microbes and Metaphors process that produced the Microbes and Metaphors report; and at the particular meaning and processes involved in edu-communication, a term coined by the ReAct Latin America group which has been extremely active in creating and experimenting with these types of processes. The sections following these look into creative participative processes that have been sparked off by or come together under the Reimagining Resistance process. These have sought variously to raise awareness, create dialogue, mobilise people to imagine another way of relationship with the microbial world, and to look together with different images at the deep causes of antibiotic resistance, and at society and the environment in a highly-consuming global pharmaceutical world. The projects are: FotoResistencia 'Making Microbes and Balancing Bodies'; When Thai pharmacists turn into artists; Who Killed Antibiotics; and the 'Gardening for Health' kit that links nutrition to health and medicine.

## **6.1** Microbes and Metaphors Report

Microbes and Metaphors became the working title for ReAct's work of engaging a broad range of scientists, clinicians, artists, communicators and social activists. The work focused on identifying, understanding and bringing to light new research in microbiology, microbial ecology, antibiotic resistance and related fields that were pointing to the emergence of a new paradigm involving microbes, medicine and human society. Work was also undertaken to explore with artists and social activists the deep processes behind changing patterns of thinking, to stimulate exchange of ideas across disciplines and identify a body of work in different media that might illustrate the path of changed perceptions.

It was in an attempt to initiate an open and multi-disciplinary discussion around these issues that ReAct organized 'Microbes and Metaphors: Re-imaging bacteria, infection

and the body', a gathering of microbiologists, artists and social activists at Wee Jasper, Australia from 5 to 9 December 2008. During 2011, the review and editing of contributions from this workshop resulted in publication of the 'Microbes and Metaphors' report, a hard copy limited edition, and subsequently publication as an edocument<sup>(111)</sup>.

## **6.2** Edu-Communication

The history of transformation of scientific paradigms is also the history of people's involvement and knowledge. The conventional view is that creativity, knowledge and ability is the prerogative of an elite group of trained people. Intelligence, wisdom and creativity are however not the privilege of just 'experts' and instead reside in people everywhere. To reimagine resistance, therefore, we must also look outside the classical institutions of knowledge and include the arena of traditional and cultural practices.

While not easy, this is a process of both uncovering new paradigms as well as creating them in a way that is grounded.

While awareness of ABR has increased in general terms, the population does not talk enough about it, are not sensitized to it, and do not exchange information. The task of communicating the significance of ABR to the public remains a problem of explaining the science, creating a new narrative about human-bacteria relations while dealing with deep-rooted cultural prejudice about or ignorance of the microbial world.

How can people participate in a really active way in the process of reimagining resistance and not merely be passive recipients of information or expert advice? Participation should start at the very beginning from conceptualization of a health program or initiative. What do the people think themselves, what are their own tools in the community for communicating, monitoring, evaluating and reflecting?

How to organize? People's own ways of organizing are central,

See www.microbiana.com and http: //www.reactnetworking.org/call-forparadigm-shift-in-understanding-themicrobial-world/



Photo: Kléver Calle

from mothers groups to community meetings and so on. The role of health educators or promoters is to facilitate knowledge and skills building.

Edu-communication is understood not as an event, but a complex process where people take for themselves the important decisions of their lives. The challenge is to participate with people, not only discuss with people.

How does 'edu-communication' get people involved? Educommunication is a two-way interactive process, in this case, between health professionals and the community. It is a horizontal relationship. It is not a vertical relationship through a leader of the masses, or a oneway transfer of information. To address ABR, behavior change needs to be seen as changing the basis of the determinants of behavior. The process of participation, of self-organizing, of relating the issue to what people think and know, is fundamental in developing skills and communication social change.

The global determinants of ABR, which include the in-

fluence of multinational industries, particularly the pharmaceutical industry, and played out through many channels of society, including TV and the internet, influences the use of antibiotics with drastic results. Therefore, the re-imagining resistance process seeks an educommunication method which is interactive, with clear goals and which involves people.

# **6.3** FotoResistencia: The art of 'seeing' the invisible

FotoResistencia began as a practical initiative taking an 'edu-communication' approach and responding to the limitations of the biomedical approach to ABR and the health system itself.

The biomedical approach to antibiotic resistance presents the misuse of antibiotics as the main cause of bacterial resistance and microbes as the cause of infectious diseases. It does not go far beyond into the causes of the 'causes' nor does it look at the relationships between the components involved in this public health problem nor the social, cultural and ecological dimensions of contem-

there is little that can get them to contain antimicrobial resistance or solve the problem of infectious diseases.

There is a need to collectively re-imagine the role of community health professionals and the health system itself, learning to look at the problem in the socio-cultural context in which it occurs, looking at their relationships with economic inequities, cultural phenomena, medicalization of life, with the ecological crisis and the crisis of production and consumption systems.

Recognising the reductionism of the biomedical approach, we propose to re-imagine the problem from a holistic approach, both to identify its causes and also to invent solutions. To invent solutions properly involves identifying the causes properly. To do this, it is essential to recognise that everything is linked: biology, culture, spirituality, economics, politics, etc. Health is the result of the harmonious relations of all, and disease, an expression of disharmony. Bacterial resistance to antibiotics is a serious consequence of disharmony. The mission of health



Photo: Vicente Tello

porary life. Health professionals working at the community level have been trained in the biomedical view and act accordingly. Under these conditions, professionals taking the holistic approach is to identify the root causes and relationships, and help to restore harmony.

Within the health system, the holistic strategy is the strategy of Comprehensive Primary Health Care, which understands collective health as a reflection of social, cultural and environmental conditions in which community life unfolds. The work of

health workers and the health system aims primarily to promote the conditions of collective health. To fulfill this mission, health professionals require a meta-clinical training in the skills of socio-cultural research, communication, education, management and advocacy.

FotoResistencia arises in this context as a tool based on documentary photography, to build a holistic perspective of bacterial resistance, reinstate the humanistic spirit and community health. In short, FR aims to help restore eco-social harmony.

Why photography? Mainly for three reasons:

- The representation of antibiotic resistance through photo documentary images helps to go beyond the biomedical approach to the underlying problems.
- 2) The power of photographic images on the social imagination;
- 3) The links that documentary photography germinates between photographers, photographed subjects and audiences.

Professionals received training and mentoring during the Foto-Resistencia project and work is on-going to disseminate the images with their stories and to discuss bacterial resistance with communities using the photo-documentary as the central input. From the work carried out in 2011 and 2012, we would like to share two preliminary findings



Photo: Juana Ochoa.

that support the usefulness of documentary photography to re-imagine resistance:

- 1) The photograph drives health workers to restore relations with the community. Juan Campoverde, MoH doctor in a small rural town, says, "Photography is not only an opportunity to investigate or edu-communicate, but to return to friends and patients the love they give us."
- 2) The camera is a means to rediscover and resignify reality. William Guzman, MoH community physician, explains, "When I'm behind a camera, I focus on what I did not see before or was not looking carefully at." Simultaneously and consistently, the photographs are an input to reinterpret reality by the health team and the community together: "To see the photos, look at the details that are not seen in a routine medical visit or see things that we would rather not see", reflects Juana Ochoa, community dentist belong to the Social Security system.

There remain many pending tasks. Perhaps the main task is to stimulate discussion among those represented, those representing, and those scrutinizing representations along their political, ethical and cultural axes. of representation. But Abstract photography has been shown to be a suitable mechanism to investigate reality and bring it nearer, and make edu-communication, through this art form, a way to recreate relationships. The great challenge of FotoResistencia is the resistance of the health system and a health culture that, despite the rhetoric, are still highly biomedical.

"Are we going to take pictures of bacteria?", asked some health workers at the first workshop of FotoResistencia. Though we dreamed of diving, camera in hand, into the microcosm of bacteria rising up in resistance, the purpose was not that. It was to reimagine resistance from a holistic perspective as the first major step to restore health and harmony and build on the worldview of Sumak Kawsay for bacteria and human beings.

## **6.4**Caravan for Life and Bacteria

On 14 November 2012, in Cuenca, a city nestled in the Andes, hundreds of children, young people and university teachers festively roamed the streets, in what was surely the first Caravan for Life and Bacteria in the world. The Caravan was the culmination of Art & Microbes, a pilot cooperative project between science, the arts and the community on the microbial world and its resistance to antibiotics, driven by ReAct Latin America and the Faculties of Medical Sciences and Arts of the University of Cuenca.

Officially, Art & Microbes began about one month before the Caravan, with a presentation of the rationale and the direction of the project to teachers and students of the Faculty of Arts, who were reluctantly engaged through 'a proposal from [the Faculty of] Medicine'. Several working sessions with students and teachers of both Faculties were organized to analyse issues concerning the mi-



Photo: Kléver Calle Photo: Kléver Calle

crobial world and antibiotic resistance. Communication material and artistic expressions alluding to the theme began brewing: fanzines, performances, costumes, banners, etc.

It was suggested that the sessions be conducted alternately in the Medical Sciences and the Arts faculties in order to balance the power relationship. This central tension in the relationship focused on the difference in expectations with respect to the roles of each faculty: the people of Medical Sciences wanted "help" to channel more efficiently their 'scientific' message

and the arts people wanted to take part in the construction of the message. In the end, the tension was resolved in favour of Medical Sciences. Our observation is that the Medical Sciences group already had an ongoing discourse for dealing with ABR, while the Arts group was only newly getting into the topic. The arts sector agreed to use the medical discourse because of the pressure to deliver something on the designated day for the caravan.

The caravan messages were predominantly of a medical nature, such as 'Don't self-medi-

cate with antibiotics because the bacteria become stronger and more dangerous'. All messages had a more artistic wrap as a result of the collaboration, the medical group seeing this as making an efficient message.

However, in the live Caravan through the city streets there were clear contradictions between what the 'messages' of the posters said, and what was expressed in body language in the dance, the rhythms, the food, the joy. These images did not involve fear of bacteria, nor blame those who use antibiotics inappropriately.

In early 2013, the process was re-injected with new drive. 'Reimaginando la Resistencia' was born from discussions between ReAct Latin America and researchers from the University of British Columbia and Concordia University in Canada. As with Art & Microbes, it was agreed with the University of Cuenca to initiate cycles of dialog, design and implementation of projects between teachers and students from the faculties of Medical Sciences and the Arts to re-imagine the world of bacteria and their resistance to antibiotics.

In May 2013, two workshops were held with representatives of three sponsoring institutions and the International Center for Arts for Social Change (Canada). These helped focus objectives and set basic tenets. Thus a key issue was resolved, namely, the conditions under which this interand trans-disciplinary collaboration should operate: each speaking from his/her field but without barriers to enter into the field of another.

Four groups were formed for interdisciplinary work to create their own project. The most exciting project experience, in our view, was entitled 'Feel me! Here I am! With compliments, Your Bacteria.'

The original idea, conceived by Sofia Narvaez (microbiologist and infectious diseases teacher) and Geovanny Sagbay (interior designer, musician and lecturer in the Faculty of Arts), was to perform a dance work telling the story of bacteria meeting with antibiotics and the consequences. 'We were wondering how to reveal the feeling of bacteria towards people, through a scene with dance and music, without falling into stereotyped clichés and



Photo: Silvina Alessio



Photo: Kléver Calle

marketing,' recalls Sofia. Later, from the Faculty of Arts, Cristina Bustos (dance teacher), Raul Rodriguez (student of music) and students of the dance troupe joined the project.

Students of arts and medicine (fifth year, studying infectious diseases, under Sofia) were then recruited. Their first task was to investigate everything they could about the microbial world. Then, mixed

groups began to work. The result combines video images with dance. As Sofia says 'Each of the students took on the role of bacteria which are looking for survival in a hostile environment, through bodily expression'. When antibiotics use leads to massive and indiscriminate death, 'resistant bacteria joined

to contain Antibiotic Resistance in October 2013, before an audience from approximately 20 countries to an immensely positive reception.

The most important achievements were the changes in perceptions about bacteria among the participants. For example, change in DNA for its evolution', but in reality it is its survival, it is what they need to do to survive'. 'I've gotten the idea that these bacteria live together as any human being lives with another human being, or as any living being, since no living being lives alone but has their communities'.



Photoframe of Esteban Espinoza's video.

the picture in order to help their friends and start all over again, as at the beginning of the work, a microbial flora united and a little stronger'.

The work was presented at the II International Seminar Recovering the health of ecosystems

Karla Martinez, one of the medical students, said: 'I see that it is a living being that defends itself against an attack, it does not want to disappear. This is antibiotic resistance as of now. It is not an evilness of bacteria toward us... [Before] I would only say: 'Well, now, it is a

## **Box 11**Making Microbes and Balancing Bodies

Making Microbes and Balancing Bodies, a new project under Reimagining Resistance brings together several approaches that have proven effective previously. This project, carried out in conjunction with the third Australian Ceramics Triennale in Canberra in mid 2015, was derived directly and jointly from the work of Microbes and Metaphors and Awakening the Dragon. Awakening the Dragon is a community involvement project in Singapore in 2013 that sought to bring attention to the imminent demolition of one of the last two remaining dragon kilns in that country<sup>(112)</sup>. A series of community workshops that involved over 3,000 Singaporeans in working on the 'last firing' of the kiln, was so successful it resulted in a 'stay of execution' for the kiln for two years, pending a second Awaken the Dragon festival in 2014, and reconsideration by the Singaporean government of the nature of the site redevelopment to reflect the wide community involvement in ceramics.

Making Microbes and Balancing Bodies has begun work (using art school student volunteers) with the first of a number of schools and community groups in and around Canberra running 'Making Microbes' workshops in which clay representations of body flora are made. Three groups ranging from 5 to 11 years listened to a story about microbes and the human body. The youngest group heard a story about how microbes first come into and onto a baby's body during and after birth. The next group heard a story about the microbe communities in the human digestive tract. The oldest group heard a story about a scientist who decided to investigate the communities of microbes in the human mouth. Each child worked in a group and used their imagination to make a microbe that was part of a community of different microbes. They were asked to think how their microbes communicated with different kinds of communities of microbes. Each child was then identified with a number, and photographed holding their clay 'microbe'. They then placed their microbe on to a large drawing on the floor of either a newborn baby and mother still joined by placenta (youngest group), or a drawing of the gastrointestinal tract from mouth to anus (middle group), or a drawing of the oral cavity from mouth to throat. The works after firing will then be re-assembled onto the drawings (to be mounted in mdf board) for exhibition (along with prints of the portrait photographs). The human body metaphor is direct and apparent, and the need for understanding this for body health is the ongoing outcome.

The excitement generated by these workshops amongst the

<sup>112. (</sup>see https://www.facebook.com/Awakenthedragonkiln and http://www.bbc. com/news/business-21271699)



Calamity by Pongsak Nata.

children was remarked on by all teachers in the school. Ideas and questions about microbes were followed up in science, maths and language classes. Volunteers from the local community potters group were also excited by their participation and have proposed their facilities be used and that the microbe theme would be a good one for school holiday workshops that they usually run.

Next steps are to do further workshops with parents of the first group of children, and to extend workshops to other schools and community groups.

## **6.5** Thai pharmacists turn into artists

In November 2011 when a group of around 20 Thai pharmacists joined a two week workshop to learn how to paint at the Khao Yai National Park, 200 kms north of Bangkok, the experience transformed their view of the world.

Organised by the Drugs System Monitoring and Development Program (DMD) of the Chulalongkorn University it was a novel experiment in getting health professionals to discover the artists inside their own selves to express the concepts they have developed of medicines in life and the environment – with antibiotics and resistance in the back of their minds.

The net result was a series of impressive paintings depicting the complex relations between human beings, medicine, microbes and nature. Since then the paintings have been exhibited all around Thailand and adorned special calendars and postcards used to promote ra-

tional use of medicine. Here we interview Panya Chaiyakam the artist who helped train the pharmacists to become artists about the process involved and the highlights of the experience.

"After I was introduced to Khun Niyada Kiatying-Angsulee of the DMD we started working on this project. She wanted me to get artists to work on the theme of microbes. The artists I went to however did not want to take up a theme that they did not understand. So I went back to Khun Niyada and told her to bring together pharmacists whom I would teach how to draw and paint on the theme of microbes and antibiotics. That is how we started the pharmacists painting project. I planned my work in such a way that it had to succeed!

We got together at a quiet place in Khao Yai National Park and started step by step with the project. The first step was to make the pharmacists gathered to understand that all drawings were primarily made up of microbe-like dots. Many dots together made a line.

The second step was to tell them that in Nature there are several kinds of lines, vertical, horizontal and so on. It was important to see these lines while drawing a picture, a branch here and a tree-trunk there. After the first day they all learnt how to draw. On the second day they

graduated from using just the pencil to drawing pen, water-colors and brush. Amazingly on the second day all of them could paint.

Then I prepared all the materials they needed to produce the paintings they wanted to do.



Nature of Life by Yupadee Sirisinsuk.

The easel, the paints, brushes and so on. Then we asked the participants to make a mindmap of what they wanted to show in the painting. They were then divided into four small groups.

After the mind-map exercise the third step was to ask each participant to do their own concept design. At this stage each individual was alone with their own work. All of them had to submit their designs to me for scrutiny. As an artist I could then judge the design for quality of tone, lines and composition. I told them to go about their work slowly and not be afraid of making mistakes. To not draw is the biggest mistake according to me. Next day the participants had to put in details of their sketch in colour. Then I taught them how to use the colour and they started to paint.

Achan Niyada said to me 'I am a scientist, I don't know how to paint. What should I paint?". Suddenly the shadow of a nearby tree fell across her easel making a shape on it. She said, 'Oh! I know now what I want to

draw and paint!'. I said, "You are great. This is a good way to know what you don't know!".

I observed that the pharmacists were able to do what the artist cannot do. The concept, design and the ideas in the composition, while inspired by nature, were influenced deeply by their love for their profession. They had never realized that they were also capable of producing works of art also while being pharmacists. The workshop helped them discover this side of their talents.

I have taught many groups of people before to paint but the pharmacists were special. The colours, the primary pigments have their own values which are not measurable in grams or kilograms. They are not judged by weight but by sense of colour. Other groups never understand the concept of value in colour but the pharmacists grasped this easily because they have spent a lot of time mixing chemicals, medicine in liquid or powder form as part of their professional work. They were able to transfer this experience into the task of painting.

The importance of art in reimagining resistance is not about theory but about a way of looking at life. Life is not just about material things. It is a combination of many things. Who knows what is the energy that we spend in our life and where it comes from? Who knows who is doing this for us? It is like a flashlight from the sky. People look at the stars and see the stars. They love the stars, the moon and the sun. People get inspiration from nature and they do art. And art is for others.

Like cave art, it is not only for the artist himself but for others. They have to use art to express themselves to others. Maybe it is through a religious gesture, through dance, to describe the miracle of life. It is ten thousand years since these cave paintings were done and this shows art has always been part of us. The expression of each style of art from around the world says something to me, speaks its language to me.

I believe that art is the only media to join with the world. It is very easy for people to understand this form of communication. We should use it as a tool to take our message to the target. This makes it easy".

## **6.6** Who Killed Antibiotics?

This project, completed to the concept stage with a trailer animation, aims to create an edutainment animation series based on the adventures of the world famous detective duo of Herlock Shlomes and Dr Whatsup. Titled 'Who Killed Antibiotics?' the series will be a fictional murder mystery that tries to understand why the effectiveness of antibiotics – arguably the cornerstone of all modern medicine – is declining at such a rapid pace.

To dramatise the issues involved, our story is set ten years ahead in the future and also assumes that all classes of antibiotics are finally dead and presumably 'murdered' by culprits ranging from industry and health ministries to doctors and patients alike. The 'murder we-

apons' used, among other blunt and sharp instruments, have been decades of indiscriminate use of antibiotics including their abuse in areas such as animal factory farming.

The task of Shlomes, Whatsup and others in the series is to find out whodunit! They do all this with the help of the latter's precocious 10 year old daughter are the characters of Sprayalot, mother of Doalot who is under the control of Dr Control Freak who wants to kill all the bacteria in the world and take over the planet.

As our detectives go around the globe solving the mystery of why antibiotics are 'dying' one by one they will explore topics ranging from antibiotic resis-



Doalot who has the amazing ability to communicate with animals, insects and microbes. To add an element of fun while giving some more depth to the issues we are dealing with also

tance and public health to microbiology and microbial ecology. Their findings and insights will be presented in simple, easy to understand terms and topped with lots of fun and humor.

We chose the animation format, as we believe this has the broadest range of appeal to our target audience of families and communities. It is planned that the series will be supported by this website and other media such as books, comics, information packs and a blog, which we hope will provide a significant forum and resource to help tackle this growing problem.

Apart from the animation series itself, consisting of seven minute episodes meant for broadcast on television, there will also be an interactive website (www.whokilledantibiotics.org), a set of comic books, DVDs and even popular merchandise such as soft toys and T-Shirts. All this diverse edutainment material can be used by teachers, health workers and policy makers, each in their own settings, to educate their target audiences and bring about social action and behavior change.

For further information see: http://digitalmixes.co.uk/whokilledantibiotics/animation.php

## **6.7** Dancing with the Bacteria

For centuries food, in all its amazing varieties across the globe, has been considered the best medicine. The link between imbalances in nutrition, through either over-nutrition, under-nutrition or malnutrition, is clearly acknowledged by both medical professionals as well as the general public.

While access to food continues to be a problem in many parts of the world today, this is compounded by the fact that a very large amount of food available is contaminated in one form or the other by chemical residues from pesticides, preservatives and antibiotics. Monoculture of certain crops and the pressure from commercial



factors have also led to a shrinking of the diversity of cuisine and reduced consumer choices drastically.

The crisis of non-availability of good quality and safe food is particularly acute in urban areas where people are at the mercy of whatever the market has to offer. Unlike in rural areas, very few have the opportunity or time to produce their own food.

In response to this crisis, there has been a sharp increase in the production of organic food worldwide – free of chemicals, in particular pesticides. The numbers of people taking to kitchen or terrace gardening in cities and towns is also growing rapidly. At the same time, new research on the Human Microbiome in microbiology is revealing the large role of friendly bacteria in the metabolism of the human body and their impact on overall human health.

The proposed project, will explore the link between food, medicine, microbes and human health through a set of activities, that can address a wide range of problems, from food safety and security to the overuse of harmful medicines and rising expense of healthcare.

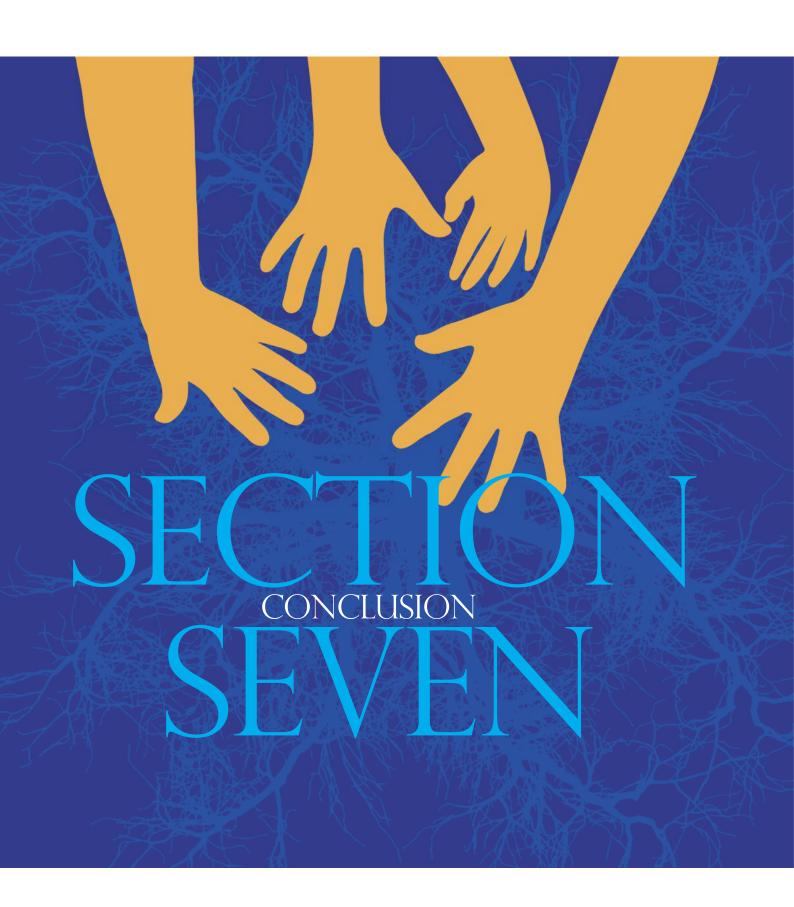
The first activity involves learning and practicing kitchen gardening to ensure availability of safe,

chemical-free food at home. Gardening and recycling of organic waste also offers a variety of other benefits, through exercise, lowering stress levels, saving costs and the general therapeutic effects of contact with soil.

The second activity is understanding the link between food and medicine, through knowledge of the medical properties of regular ingredients of food and the right way to cook and consume them. While traditional cuisines around the world have evolved taking into consideration local cultural and geographical conditions – globalisation has brought food from around the world to our tables and with that – a host of opportunities and challenges.

The third activity is related to the demystification of medicine and medical systems – on which the excessive dependence of modern-day citizens can only be described as very 'unhealthy', apart from 'expensive' and non-negotiable. The basic knowledge that all human beings should have includes an understanding of the human anatomy, how diseases develop, rational use of medicine and the routine procedures of modern medicine.

The project was launched in late March, 2015 at a workshop in Chiang Mai, Thailand with participation from organic farmers, pharmacists, nutritionists and environmental activists.



Taking an ecological approach to antibiotic resistance and infectious diseases is a more complex path to understand than the idea that pharmaceutical research will somehow, almost magically save the power of existing antibiotic pills or find new ones for us. Given the fact that this 'magic', in terms of effective, resistance-proof antibiotics, has proven elusive for nearly four decades now even those formerly skeptical of the ecological perspective are waking up to its importance.

What this ecological approach to ABR means in practice is simply paying more attention to all the factors that drive the phenomenon – appropriate nutrition, healthy lifestyles, safe environments, removing irrational fear of bacteria, understanding the role of the human microbiome. All these may seem more difficult than just popping a colored pill in our mouths but today if we are to deal with ABR and other similar health challenges there is no choice but to conceive of health, not as a static 'outcome', but a dynamic process in which we will have to be on the ball all the time.

Communicating this concept is not easy but luckily new tools are emerging. Engagement with the arts, especially through community arts processes in the context of social change, can help open a door to understanding new ways to explaining the complex problem of antibiotic resistance to wider audiences. Beyond communicating, it seeks to engage people to internalize, to

embody knowledge of the microbial world and its intimate and fundamental importance in the working of human life and the ecosystem we live in

In this resource book we have argued that in the long run, true motivation to wean ourselves from the non-essential use of antibiotics will entail a collective and individual understanding of what we risk by disrupting the larger, natural harmony of this world to serve narrow, short-term human benefits. It will also require a greater understanding and care for our bodies, what we eat, the air we breathe, how we live and their link with the environment around us.

We are right now still in the process of garnering much new knowledge, establishing trans-disciplinary networks, and understanding the basics of how to live in an ecological way. The scientific and artistic initiatives involved are relatively new and evolving but the enthusiasm and level of participation and mobilization indicates that we are on a good track to open up new frontiers of questions, exploration and knowledge.

Indeed, we are perhaps at the cusp of an individual and collective transformation that will enable human societies to come to terms with the innumerable other living organisms, particularly microbes, that not only share the planet with us but are also its main source of life.





The phenomenon of antibiotic resistance (ABR) has been recognized in recent years as a growing threat to the advance of modern medicine globally. Resistance to most antibiotics is increasing and has already reached crisis point for some gram-negative infections. The search for technical solutions to the problem have yielded few results and no significant new antibiotics are emerging from the R and D pipelines.

On the positive side, there is a new paradigm emerging on the role of microbes in human health that has potential to show the way forward in dealing with ABR in an innovative manner. Recent work in microbiology, immunology, microbial ecology and biophysics points to the need for an ecological approach to ABR and the rejection of the war metaphor in medicine or the treatment of the human body as a standalone machine.

Similarly, in the social sciences, there is new research explaining the cultural/anthropological basis of health-seeking behavior that have implications for controlling ABR. The role of art in bringing about critical awareness of complex themes such as the human-microbe-medicine equation are being explored. New communication techniques for dissemination of relevant information on health and ABR are emerging while the role of socio-economic determinants of health is finding renewed emphasis.

The booklet 'Reimagining Resistance: Towards a new paradigm of human-bacterial relations' is a resource book that describes the new research and the novel options emerging in recent times that have great potential to deal with ABR. Part of the Reimagining Resistance initiative, ongoing since 2006, it calls for a truly multi-disciplinary approach to ABR that combines the latest insights from both the natural and social sciences.





