Women in Biotechnology

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Editors

Women in Biotechnology

Creating Interfaces

Springer

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ISBN 978-1-4020-8610-6 e-ISBN 978-1-4020-8611-3

Library of Congress Control Number: 2008930761

Cover image: *Esercizi di equilibrio (Exercises in equilibrium)* (1999, biro e pastello su carta) remains with the artist Paola Gandolfi

Printed on acid-free paper

9 8 7 6 5 4 3 2 1

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Foreword

Johannes Klumpers

Biotechnologies, such as genetic engineering, cloning and biodiversity, raise many legal and ethical concerns, so it is important that people understand these issues and feel able to express their opinions. This is why the European Commission has been, for a number of years, supporting actions to improve communication among scientists in these diverse areas.

The project ‘Women in Biotechnology’ (WONBIT), financed under the 6th Framework programme of the European Commission, is an excellent example of what can be done to target opinion-formers such as scientists, economists and lawyers in bottom-up activities, and to encourage a debate on gender issues triggered by developments in the life sciences.

WONBIT gave rise to a successful international conference highlighting the importance of adopting good practices and ethical considerations in parallel with the rapid pace of progress in biotechnology – from a woman’s point of view. In particular, the conference addressed women in decision-making positions in biotechnology with specific reference to scientific excellence, social competencies and management qualities as well as issues relating to environment, society and the younger generation.

But it did not stop there: a key part of the conference was dedicated to stimulating public debate among non-specialists, which has led to a number of recommendations to policy-makers on better communication in biotechnology, on taking better account of the gender aspects of research, and on involving more women in the decision-making process that surrounds developments in biotechnology.

I am sure that this publication on the outcome of the WONBIT conference will contribute to enhancing the significance of women’s role and presence in biotechnology, as well as changing outdated attitudes that view biotechnology as a simple production tool to a view that recognises its use and development to be both environmentally sustainable and socially acceptable.

Head of Unit ‘Scientific Culture and Gender’, European Commission, DG Research

Foreword

Annamaria Simonazzi

Biotechnology is a ‘hot topic’. Many of the great problems facing humanity – from how to cope with lethal infections or diseases to economic development issues – are susceptible to biological intervention. Biological technology opens up great opportunities and raises formidable challenges. Simple genetic engineering is now routine: with the filing of the first patent application for an artificial living organism, the idea that someone might own the rights to it raises legal and ethical concerns.

Despite countless conferences held throughout the world, an authoritative woman’s perspective on these issues is still lacking. The international conference on ‘Women in Biotechnology’, jointly organized in Rome, Italy (June 2007) by the Fondazione Brodolini and the Women and Science Association (Associazione Donne e Scienza), Italy and under the auspices of the European Commission, was intended to remedy this shortcoming.

The conference’s multidisciplinary approach made it possible to profit from interaction among different specializations and bodies of expertise in addressing a range of relevant issues: What is women’s role in directing and shaping the main lines of research in universities and laboratories? To what extent are women participating in the economic development and industrial exploitation of research results? What have women to say concerning the application of these results to such a wide range of problems? Finally, how do biotechnologies affect, for better or worse, women’s lives and opportunities?

The interaction among women active in various fields – from the frontier of scientific research to investigation of the consequences on human bodies, economies and societies – produced lively debate. The papers collected in this book evidence the richness of this debate. Rather than putting forward a single solution, they develop a shared methodology for the analysis of problems, seeking to furnish a framework to guide the decisions of policy makers and institutions. The promotion of women’s role in society has been the focus of the social policy research activities of the Fondazione Brodolini and I am sure that the construction of this shared methodology will greatly contribute to the increased visibility and influence of women in the policy debate on biotechnologies.

Head of the Scientific Board of the Fondazione Brodolini Rome, Italy

Acknowledgements

We thank the European Commission, Research Directorate-General for their financing of the WONBIT project, under Contract No. 036675 (SAS6). We want to thank Johannes Klumpers and particularly Ekaterina Charvalos, Project Officer in charge of the project, for assisting us at each stage in preparation both of the Conference and the book. We are deeply thankful also to the Brodolini Foundation, an organization that has been active for many years in promoting women's endeavors in social sciences and that has promoted and coordinated the Wonbit project; especially we thank Annamaria Simonazzi, Diego Teloni and Barbara Leda Kenny who have been throughout very helpful, friendly and collaborative.

Last, but not least, we are grateful to the friends of the Women and Science Association (Associazione Donne e Scienza), Italy – of which both editors are members – for discussions over the years on post-academic science and biotechnologies, making it possible to lay the groundwork for this project.

Thanks also to Stefano Bolelli Gallevi, who has efficiently assisted us in preparing the book for the publisher.

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Abbreviations

ABI	AgroBioInstitute
ACU	Assisted Conception Units
ADA	Anti-Drug Antibodies
ADHD	Attention Deficit Hyperactivity Disorder
AHRA	Assisted Human Reproduction Act
ANT	Altered Nuclear Transfer
ARPANET	Advanced Research Projects Agency Network
ART	Assisted Reproductive Technologies
ATP	Adenosine Triphosphate
AWID	Association for Women's Rights in Development
BAS	Bulgarian Academy of Sciences
BBB	Blood Brain Barrier
BBSRC	Biotechnology and Biological Sciences Research Council
BSE	Bovine Spongiform Encephalopathy
Bt	Bacillus thuringiensis
CAT	Chloramphenicol Acetyltransferase
CAUT	Canadian Association of University Teachers
CDWRI	Cotton & Durum Wheat Research Institute
Cesagen	Centre for the Economic and Social Aspects of Genomics
CEU	Central European University
CF	Cystic Fibrosis
CGD	Chronic Granulomatous Disease
cGMP	Current Good Manufacturing Practice
CMS	Cytoplasmic Male Sterility
CNR	Cell Nuclear Replacement
CNS	Central Nervous System
CNT	Carbon Nanotube
CNT	Cell Nuclear Transfer
CORE	Comment on Reproductive Ethics
CPCB	Central Pollution Control Board
CRC	Canadian Research Chairs

DAI	Dobrudja Agricultural Institute
DC	Direct Current
DC	Discrete Choice
DH	Department of Health
DNA	Deoxyribonucleic Acid
EB	Eurobarometer
EGP	Environmental Genome Project Protection Agency
EJ	Environmental Justice
EJM	Environmental Justice Movement
ELAD	Extracorporeal Liver-Assist Device
ELSA	Ethical Legal Social Aspects
ELSI	Ethical, Legal and Social implications
ENWISE	ENlarge Women In Science to East
EPA	Environmental Protection Agency, USA
EPWS	European Platform of Women Scientists
ES	Embryonic Stem
ESF	European Social Forum
ESRC	Economic and Social Research Council
ET	Embryo Transfer
ETC Group	Action Group on Erosion, Technology and Concentration
FAO	Food and Agriculture Organization
FAQ	Frequently Asked Questions
FDA	Food and Drug Administration
FGRI	Fruit Growing Research Institute
GE	Genetically Engineered
GFP	Green Fluorescent Protein
GI	Gastrointestinal
GKT	London School of Medicine at Guy's, King's College and St Thomas' Hospitals
GM	Genetically Modified
GMO	Genetically Modified Organism
GMP	Good Manufacturing Practice
GSCE	General Support Center Europe
GUS	β-glucoronidase
hES	Human Embryonic Stem Cell
HESCCO	Human Embryonic Stem Cell Coordinators
HFCS	High Fructose Corn Syrup
HFE act	Human Fertilisation Embryology Act
HFEA	Human Fertilisation Embryology Authority
HGDP	Human Genome Diversity Project
HGP	Human Genome Project
HOOO	Hands Off Our Ovaries

HRT	Hormonal Replacement Therapy
HT	Herbicide Tolerance
HTA	Human Tissue Act
ICPD	International Conference on Population and Development
ICSI	Intracytoplasmic Sperm Injection
IDRC	Institute of Development Research Canada
IFIs	International Financial Institutions
IGen	IGeneration
INN	International Nonproprietary Names
IPCB	Indigenous People's Council on Biocolonialism
IPGR	Institute for Plant Genetic Resources, Bulgaria
IRB	Institutional Review Board
ISO	International Organization for Standardization
IVF	In Vitro Fertilisation
Karnobat AI	Agricultural Institute of Karnobat
Kyustendil AI	Agricultural Institute of Kyustendil
LGBTQ	Lesbian, Gay, Bisexual, Transgender, and Queer Persons
LMOs	Living Modified Organisms
MAGIC	Myoblast Autologous Grafting in Ischemic Cardiomyopathy
mESC	Mouse Embryonic Stem Cells
MHRA	Medicines and Healthcare Products Regulatory Agency
MIUR	Ministry of University and Research (Ministero dell'Istruzione, dell'Università e della Ricerca)
MON 810	Genetically Modified Corn Line by Monsanto
MP	Members of Parliament
MRC	Medical Research Council
MRI	Maize Research Institute
ms infinity	Math and Science Infinity
MS	Mass Spectrometry
MT	Metric Ton, A Measurement of Mass Equal to One Thousand Kilograms
MWNT	Multi-Walled Carbon Nanotube
NBS	National Blood Service
NCAS	National Center for Agricultural Sciences
NCT	National Center for Toxicogenomics
NESCI	North East England Stem Cell Institute
NGO	Non-governmental Organization
NGS	National Geographic Society
NHGRI	National Human Genome Research Institute
NHMRC	National Health and Medical Research Council
NIEHS	National Institute of Environmental Health Sciences

NIH	National Institutes of Health
NMR	Nuclear Magnetic Resonance
NNI	National Nanotechnology Initiative
NPs	Nanoparticles
NPT	Neomicin Phosphotransferase
NRT	New Reproductive Technology
NSERC	Natural Sciences and Engineering Research Council of Canada
OECD	Organisation for Economic Cooperation and Development
OSHA	Occupational, Safety and Health Administration
OTC	Ornithine Transcarbamylase
PEG	Polyethylene Glycol
PGD	Preimplantation Genetic Diagnosis
PUS	Public Understanding of Science
QD	Quantum Dots
R&D	Research and Development
RCTs	Random-Controlled Trials
RNA	Ribonucleic Acid
ROS	Reactive Oxygen Species
S&T	Science and Technology
SCID	Severe Combined Immunodeficiency
SCNT	Somatic Cell Nuclear Transfer
SCWIST	Society for Canadian Women in Science and Technology
Septemvri RCES	Regional Center for Extension Services in Septemvri
Shoumen AI	Agricultural Institute of Shoumen
SNP	Single Nucleoti Polymorphism
STS	Science and Technology Studies
SWNT	Single-Walled Carbon Nanotube
UFA	University Faculty Award
UKSCB	UK Stem Cell Bank
UNESCO	United Nations Educational, Scientific and Cultural Organization
US PTO	United States Patent & Trademark Office
V. vinifera	Vitis vinifera
VCRI	Vegetable Crops Research Institute
VEI	Viticulture & Enology Institute
WHO	World Health Organization
WISEST	Women in Scholarship, Engineering, Science and Technology
WSF	World Social Forum
X-EDS	Energy-Dispersive X-ray Spectroscopy

Introduction

Francesca Molfino and Flavia Zucco(✉)

1 Post-academic Science

In the area of natural and physical science, biology, as a life science, seeks to account both for the conservation of individuals and the invariance of certain laws of the discipline, and for their transformations. It seeks to construct laws and at the same time account for processes that often seem to be incompatible with their absolute, generalised nature. On the inclusion of man in contemporary science we see a form that we might define as 'phagotization of the human dimension in its biological sense, and a rootedness of our humanness in the material bases common to all living things (e.g. DNA, physical-metabolic functions, cognitive neural connections, knowledge of the outside world dependent on belonging to the species)' (Gagliasso 2001). The aim is to account for the entire human person (psychic characteristics, forms of societal and economic organisation) through the *apparatus of the laws* of biological evolution, recently integrated with the laws of molecular genetics and population genetics.

However, once the human species found a place as an object of the natural sciences, it should have brought with it the relevant set of humanities but, since they were deemed insufficient for the production of 'scientific' truths, and thus unreliable, no intermediate space was created for exchange between the various ways of thinking about humankind. The rift between the various forms of knowledge that had begun to open in the last few centuries grew wider and deeper. This separateness was imposed in part because it was believed that science could draw upon the 'absolute truth' (credibility turned to faith), thereby substituting the certainties belonging to religion, philosophy and psychology.

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A great impact on the view of science from the inside has come from theories in the history of science and philosophy of science. The critical work of influential thinkers about science (Popper, Lakatos, Kuhn, Latour) has weakened the positivistic picture of it and done away with the idea of 'Pure Science' as representation of the 'Eternal Truth'.

This representation of science was mainly due to Robert Merton (1973), the first and best-known science sociologist, who depicted it as communitarian, universal, original, sceptical and neutral. Many critics of Merton's model contest that science had never strictly corresponded to that description. However what is sure is that nowadays it is not even remotely applicable to contemporary science. According to John Ziman (1996, 1998), contemporary science belongs to scientists and their institutions and it is exclusive to the highly developed countries, bound to main research financed trends, assertive and commissioned.

Science is no longer a relatively uncontested practice within society (Levitt 1999). The change is sometimes revealed in the idea that the modern contract between science and society has broken down and needs updating (Nowotny et al. 2002; Ziman 2000).

The internal and external causes of change in the practice of science should be distinguished. The internal causes have to do with the increasing theoretical, technological and practical complexity of science as a practice. The external causes have to do with the financial, institutional and societal conditions of science.

Science and technology appeared as knowledge and applications that solved problems, found solutions, and extended the scope of human skills and actions. And yet it is precisely because of the apparently limitless growth of technological applications and the difficulty of forecasting the consequences that the latter are no longer determined by precise needs but take the form of highly complex negotiations between those who devise them, control them (the scientific community) and the various social parts concerned. This complex negotiation will determine the winning theories and technology, as well as the theories to be discarded, although not necessarily less true than the 'winners'. Not only are the ends of technologies complicated and compromised by chance as well as social influences, but the origins of the technologies are also thus conditioned. Kevin Kelly (1998) suggests that in contemporary science it is *the pursuit of novelty* that prevails, rather than of knowledge, that *the production of tools* has taken the place of that of theories. The difference there used to be between science and technology has disappeared: what matters is not to increase knowledge but to produce new opportunities.

In addition, scientific practice has become vastly more complex. The financial, social and institutional conditions of doing science have changed. For instance, many scientists are public employees (with all the related implications); there is much more investment from corporate business, much more science policy steering on the political level and much more attention from the media and the public. Thus the societal climate with which science is confronted is more pressing and influential, both at the institutional level and in respect of relations with the public.

Paradoxically, the growth and expansion of science have led to criticism of the very assumptions it rests on, above all through the endless proliferation of diverse methodologies and results.

As Ulrich Beck (1992) remarks: ‘The access to reality and truth once ascribed to science gives way to decisions, rules and conventions that could have had different outcomes’. Science ‘becomes *increasingly necessary*, but at the same *decreasingly adequate* for socially binding definition of the truth’. This loss of function ‘derives from the triumph of differentiation in claims of scientific validity’. The differentiation of science ‘rises the uncontrollable tide of particular results, conditional, uncertain and unrelated. This *hypercomplexity* of hypothetical learning can no longer be mastered with methodical rules of verification’.

The hypertrophic development of technologies leads towards a paradoxical outcome: the initial purpose of applying technology to create an environment suited to human beings is turning into a serious threat to the environment itself. The practice of science together with specific scientific results and activities has become far more controversial. A great many meta-studies have brought the achievements of science into perspective and made society much more aware of the drawbacks and side effects of scientific and technological progress.

These changes contribute to a situation in which science is more interconnected with a democratic society. Because science meets with criticism from outside, it is bound to be more self-critical and to deliver more value for the money, support and other facilitating conditions that flow from society to the practice of science. The challenge is to accommodate the demand for moral justification, public accountability and transparency without jeopardizing scientific freedom, creativity and progress. For it is undeniable that the processes of communication between science and society and evaluation of prospects and results are faced with many pitfalls and obstacles. At the very time that the threats and risks appear increasingly serious and evident, scientific applications are growing ever less accessible to attempts to determine proofs, attributions of responsibility and indemnifications (Beck 1992).

Various political movements have taken a critical stance on the consequences of biotechnologies, but in the course of time the need has arisen – given the impossibility of taking a plausible position with scientific necessities and the positive results of many technologies – for the scientists themselves to take the initiative in rediscovering their self-reflecting function. Change in the negative consequences of biotechnologies can only come about by starting out within technological knowledge, since they can neither be rejected outright nor passively endured.

2 The Encounter Between Feminism and Science: Some Brief Notes on Fox Keller, Harding and Haraway

Women began to take a stance on science over thirty years ago, producing a vast number of publications over the years (for detailed examination of the literature see the exhaustive bibliography in Rosser 2000); here we will simply offer some thoughts and pointers on certain contributions that seem to us representative of the feminist approach to science.

The attitude taken by feminists to science is coherent with the position women have adopted towards culture, taking the form of both rejection and critical endeavour to change it. Feminism has had a hermeneutic action, leading to a completely new re-interpretation of the tradition; it becomes a form of deconstructionist philosophy, calling into question the subject, the assumptions at the epistemological, ethical and political levels: scientific knowledge does not form in a vacuum, and does not simply and solely extend the theoretical context of previous researches.

Over and above the various critical points of view, the great merit of the feminist positions lies in having addressed an array of assumptions in our culture of which we had been unaware – for example, the recognition of science and culture as based on the male view of the difference between sexes as domination and subordination.

In the early 1960s various feminist scholars dedicated biographies to women scientists to demonstrate that they had made original contributions, and that these contributions could to some extent be seen as exemplary of femininity (Barbara McClintock[1]), while certain other studies have shown that female research could be cancelled by male-managed science (consider the well-known episode of scientist Rosalind Franklin recounted by Sayre 1975).

The first step towards science was thus a matter of accrediting women as rightful members of the scientific community, revealing just how many fundamental – and often unacknowledged – contributions they had made to science. Studies have since continued from these examples on the hurdles, barriers and gender stereotypes that scientific organisations and academies put in the way of women scientists. Behind this remains the idea of science as a field of learning that is in itself objective, devoid of values, open to men and women, and that the inequality of access, results and career can be mainly a matter of cultural prejudice and policy.

Subsequently, at the end of the 1980s, some feminist historians, science philosophers (Harding 1986; Haraway 1989) and scientists (Hubbard 1990; Fausto-Sterling 1992; Birke 1986) called into question the alleged lack of values in science; for example, the generalised validity of certain experimental results concerning heart diseases, where women had for thirty years been excluded in 82% of studies (Rosser 2000).

Feminist criticism went on from the ‘woman question’ issue in science to the question as to whether science may in some way be influenced by the values of women.

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[1] Barbara McClintock dealt with the genetic development of maize, and was awarded the Nobel Prize. Fox Keller (1983) argues that Barbara McClintock conceived a model differing from the standard models of her time, less hierarchic, more diversified, with a system of genetic transmission in a field centred on a guide-molecule. Fox Keller does not hold that McClintock took a different approach to genetics because she is a woman, but that being a woman she has a sensibility or finds a certain affinity with certain models in scientific research, departing from the dominant models of the time, thanks to which she won the Nobel Prize for the discoveries related to them. This is a particularly subtle and complex argument, holding that there can be a way of addressing issues, a perspective, a sensibility vis-à-vis certain models, certain metaphors, an ability to devise a type of plausible explanations that can be correlated with gender differences.

Evelyn Fox Keller (1985) sees promise in crossing the traditional disciplinary confines, which, risky as it may be, could open up fresh opportunities. It offered all the participants – male and female – different, new tools for interpretation, deconstruction and reconstruction of that tangle of influences between cultural norms, technical-scientific development and their metaphorical expression. Without this disciplinary crossover, Fox Keller doubted that a greater number of women would be able to modify this type of science since, while one aspect of the cultural revolution of the last two decades is the striking increase in the number of women scientists, above all in the life sciences, nevertheless the presence of women does not in itself guarantee real change.

In *The century of the gene* Fox Keller (2000) analyses the 'Genome Project' from an anti-reductionist standpoint. The idea was passed down by biologists from the decades following the discovery that the molecular foundations of genetic information would disclose 'the secret of life'; that it was only necessary to decode the message in the sequence of nucleotides to understand 'the programme' that makes an organism what it is.

Things were soon found to be rather more complex: a gene can be involved in the synthesis of many proteins (tens at times, or even hundreds), while a protein can have to do with various genes, and a certain fragment of DNA can be reorganised and transcribed in all sorts of ways. But this is not the end of the story, for genes do not determine the destiny of an organism: in fact, their activity depends crucially on the environment, and the priority of the gene as the fundamental concept to account for biological function and structure is now part of the last century, and increasing importance is being attributed to epigenetic control of the genome.

Genetic reductionism has proved an immensely useful strategy for scientific research, and often still is, and it is true that the molecular biologists are not so green as to use the gene concept without due consistency: they know that there is no longer any univocal definition, but use partial definitions that work in operation and offer the possibility to identify (and patent) DNA sequences associated with certain proteins, to formulate hypotheses and explain experimental observations.

However, Fox Keller holds that this line on genes has reached the limits of its efficacy, and has not only generated confusion (especially among non-specialist readers and users) (see Chapter 7), but has also limited the imagination of biology researchers.

Fox Keller points out that the greatest significance of feminist criticism of science is political, but also, as a scientist, criticizes that science, with its reductionism, presented itself as the source of absolute certainties. For this reason, in the last few years she has moved away from investigation into the relations between women and science to concentrate on a more sustained critical scrutiny of biology.

In a recent article Fox Keller (2005), ever attentive to the metaphors of science, notes that in biology there has been a movement away from reductionism to 'systems biology', or in other words 'treating biological entities as complex living systems rather than an amalgam of individual molecules'; thus 'new methods are required perhaps to be borrowed from other disciplines'. 'The new paradigm grows out of rapid advances in instrumentation for the biosciences, the vast improvements in computing speeds and modelling capabilities, the growing interest from physical and information scientists in biological problems, and the recognition that new approaches are needed for biology to achieve its full promise of improving human well-being'. Nevertheless Fox Keller does not for now see any common 'appropriate theoretical framework' shared by engineers, computer scientists, physicists and mathematicians. Biology has become a driving science for technological investments and attracts physicists and, above all, mathematicians, but the meaning of certain terms in the other disciplines needs to be changed, for example: essential and fundamental. No longer 'is the essence of a process to be sought in abstract or simple laws, but in the messy specificity of particular adaptations that have come into existence by the haphazard processes of evolution'. 'Biology throws a serious monkey wrench into all our traditional assumptions about what ought to count as deep or fundamental, about what counts as explanation, or even about what we will count as progress' (Keller 2005).

On the future of biology Fox Keller wonders, for example, whether the importance has been evaluated 'of the temporal dynamics of our systems', if 'we paid enough attention to the time keeping of our regulatory systems'. A fundamental focus to address the various issues raised by scientific complexity has become, for Fox Keller, reformulation 'of the linguistic habits that have underlined our existing theoretical traditions'.[2]

As we have mentioned, feminists have a different point of view on science; a radical tendency has developed to reject science as a means for man to dominate

[2] 'What I am suggesting is that, prior to the need to construct an appropriate theoretical framework may well be the need to construct a more appropriate linguistic framework, one that takes us beyond the paradigm of building the whole out of the parts, and begins to accommodate the historical co-construction of parts and wholes that is so central a theme of evolutionary biology. Indeed, one of the greatest benefits of the remarkable technical developments we have seen in recent years is that it has begun to be possible to explore the dynamic interactions that not only bind parts into wholes, but equally, that reveal the ways in which those interactions constitute the parts themselves. The beginnings of a new lexicon is already evident as geneticists seek to forge new ways to think about biological function, looking for the clues to that function not in particular genes, nor in the structure of DNA and its protein products, but rather in the communication networks of which the DNA and the proteins are part'.

'Communication has become the new buzz word in biology, and it captures the discovery by traditionally reductionist life scientists of the powers of sociality. This is a definite good, but communication is just one term. The more we learn about how the parts work not only in interaction and versatile systems of gene regulation, about the signals mediating all the different levels of organization, and about the variety of epigenetic mechanisms of inheritance at play and the evolutionary feedback between the different mechanisms, the more compelling the need for an entire new lexicon, one that has the capacity for representing the dynamic interactivity of living systems, and for describing the kinds of inherently relational entities that can emerge from those dynamics. To repeat, time is crucial here: it is the medium in which interactions occur.

For too long we have tried to build a biology out of nouns, a science constructed around entities. Perhaps it is time for a biology built out of verbs, a science constructed around processes. Perhaps even genes can be revived for the twenty-first century by reconceptualizing them as verbs. I envision, in short, a conceptual framework that rests on a dynamic and relational epistemology' (Keller 2005).

nature – as exploitation of the earth's resources and learning functioning reciprocally with the industrial and capitalist revolution (Merchant 1979). More recently this approach has been emphatically espoused by women working and living in the third world, underlining the interconnections between biology and social, political and economic plans, and actively seeking to do something about the exploitation of the countries of the South, whose resources are sapped and learning misappropriated (Shiva 2001). Insofar as it is mainly produced and managed by male western culture, science invades and destroys the indigenous cultures of countries like India and Africa in the name of a learning that is supposed to be thoroughly universal and objective but is, rather, partial, situated and local.

Sandra Harding (1986, 1998a) argued that, just as in the past the development of science was inextricably interwoven with the expansion of Europe, so one might hypothesise a different, female science deriving from the women's movements in which, starting from real, everyday life the gap between the dominant conceptual schemes and bodily experience might be closed. However, according to Harding (1998b) it is not a matter of exposing the 'hard' conception of science, proposing, as in the case of many critiques, a version somehow 'weakened' or softened. While Harding sees the illusions of realism and universality, the dreams of neutrality, intrinsic to the image of science, as memories of an epistemological innocence, she is equally opposed to any conclusions that smack of relativism. Harding thus advances her proposal of *strong objectivity*, a fuller objectivity for more extensive and comprehensive scientific learning, able to take up and absorb the challenge of what had hitherto been seen as a threat, and held defensively at a distance from its limits: the world that produces it, the subjects, bodies, values, cultures, society, relationships and differences.

Women and postcolonial movements have given birth to the demand for 'equal respect and equal material resources, equal recognition and distributive justice'. Harding calls for a new form of subjectivity, 'leadership by the idea of the Other', based on the communication that has now reached every component of the global economy.

A new objectivity can make use of the prospect deriving from the experience and voices of those who are on the dominated, subjected side of the dominant science. Thus the power disadvantage becomes epistemic advantage; the subjected, marginalised individual would be recognised as a vantage point inaccessible to those in the dominant position.

Harding keeps as the central core of her thought the feminist starting point of consciousness raising, of the nomination and re-signification of female experience.

This new epistemology is open to a strong self-reflexivity which Harding holds necessary to construct a strong scientific objectivity that does not presume to overcome its partiality by denying it.

The feminist theoreticians Harding (1986) and Fox Keller look to a science that could offer better and richer explanations, that allows us to live better in the world, and give critical, reflective relations with both our and other people's domination practices. So the problem of women in science may seem more ethical than political or epistemological. Donna Haraway plunges into technological discourse, criticising the pursuit of purity and non-contamination characteristic of certain ecofeminist positions as too close to colonialist, racist argumentation.[3]

Haraway introduced the figure of the 'Cyborg'[4] at the end of the 1970s as an image of a new femininity, taking a distance from the feminism that considered the body and its procreative function as the basis of the 'difference', in that it provided the structure of femininity with characteristics associated with care and naturalness. This should not mean adopting the cyborg model, but rather represent a stimulus to imagine and propose new ways of perceiving the body consequent to the technological invasion.

For feminist philosophy altering the living body–machine duality produces changes in the programme of categories of thought. Modifying perception of that which is living, biotechnology tends to transform human relations and culture, above all when manipulations of the genetic code or artificial reproduction are at issue. On the other hand, Haraway continues with the feminist critique of science, seeing it as learning bound up with the social structure in that it represents forms of life and of practices shared by a community, and is based on and makes use of set narrative patterns. Thus she interprets science as domination over nature, identified with the maternal female figure – as male learning asserting itself in breaking away from nature, in neutrality and objectivity.[5]

Scientific thought, human sciences and culture are also based on certain other dualities such as: mind/body, objectivity/subjectivity, public/private, man/animal, natural/artificial, etc.

While criticising the scientific assumptions advanced as vehicles of absolute truths, Haraway refuses to fall back on a relativist position. What she proposes

[3] As Judith Wajcman points out in her book *Technofeminism* (2004), Haraway's optimism is 'a refreshing antidote to the technophobia that characterizes much radical feminist and ecological thought. Indeed, in stressing the liberatory potential of science and technology, she is rephrasing an old modernist theme linking science with progress. While critical of many aspects of the way this happens, such as extending private property to include life forms (patenting), she warns against a purist rejection of the 'unnatural', hybrid entities produced by biotechnology. Sharing her 'frank pleasure' at the introduction into tomatoes of a gene from flounders, which live in cold seas, which enables tomatoes to produce a protein that slows freezing, she revels in the very difficulty of predicting what technology's effects will be'. 'Haraway's ground-breaking work has transformed feminist scholarship on technoscience' (Wajcman 2004).

[4] The term 'cyborg' or bionic organism indicates a being, also human, of humanoid form consisting of a set of artificial and biological organs. The term comes from contraction of cybernetic organism (an organism that is a self-regulating integration of artificial and natural systems). It was popularised by Manfred E. Clynes (who was the chief research scientist in the Dynamic Simulation Laboratory at Rockland State Hospital in New York) and Nathan S. Kline in 1960, conceiving of a human being enhanced to survive in inhospitable extraterrestrial environments. They held that close relations between human and machine were the key to cross the new frontiers of space exploration in the near future.

[5] The occurrence of certain forms of rhetoric peculiar to scientific texts is addressed, albeit somewhat differently, in an interesting chapter (*Literature*) of the book *Science in Action* (Latour 1987).

is to consider science as 'situated knowledge',[6] whose contingency and partiality are to be recognised, while stressing that contingency and partiality do not necessarily mean falsity.

Haraway proposes a strong female subject incarnating the new forms of learning – a hybrid bodily image of an organism at once human and mechanical. Given that in reality membership of a social group has become changeable, without limits and irrelevant to individual biographies, the 'cyborg' metaphor reformulates a theory of the subject uniting particular-body with universal-machine, and marks a breakaway from belonging to a class, sex or ethnicity. Thus it is possible to represent the individual in her most personal aspect: the body, which, however, through union with technology, becomes a universal subject, and bodiliness compenetrated by the technological factor becomes second nature. Transforming himself with these technological elements shared by the community, the human being leaves all metaphysical leanings behind, abolishing those dualities on which culture had been based up to our own times.

If technology has given humankind a means to evolve from the very beginning of its existence on earth, then the human being is not 'given', as it were, but evolved over the millennia; shifting technology within the human being is thus a consequent operation, by no means perverse. Technological interventions occur at such an elaborate and highly developed level that they become co-production with the evolutionary potential of the species. With the advent of technologies women can transcend the biological body as the basis of gender difference and redefine themselves 'outside the historical category of woman, other, object'.

With a background in biology, but also with parallel study of philosophy and literature, Haraway declares that it was impossible for her to be a biologist 'without a kind of impossible consciousness of the radical historicity of these objects of knowledge'. Since we are going through a phase of radical reconfiguration of species categories, which are essential tools in biology, Haraway's interest is now to explore the ways we create and participate in categories and find the limits and connections of species categories as 'ongoing kin-kind work that has very important kinds of instrumentalization these days'.

Instead of falling back on science fiction, Haraway transforms and transposes into philosophical considerations and examples designed to provoke the

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[6] Although it is now a well-known concept, we will quote the definition given in the Wikipedia:

Situated knowledge is knowledge specific to a particular situation. Imagine two very similar breeds of mushroom, which grow on either side of a mountain, one nutritious, one poisonous. Relying on knowledge from one side of an ecological boundary, after crossing to the other, may lead to starving rather than eating perfectly healthy food near at hand, or to poisoning oneself by mistake.

Some methods of generating knowledge, such as trial and error, or learning from experience, tend to create highly situational knowledge. One of the main benefits of the scientific method is that the theories it generates are much less situational than knowledge gained by other methods. Situational knowledge is often embedded in language, culture, or traditions. Retrieved September 22, 2007, from http://en.wikipedia.org/wiki/Knowledge#Situated_knowledge.

consequences of contemporary biology, manipulations and experiments on the cells.

In her latest manifesto on 'companion species', with her characteristic paradoxical style Haraway deals with the relations between species (Haraway 2003), with how the borderlines between what is human or animal have become contingent, so open to change as to be continually crossed. We're part of a crowd, with other species and environments; nature, the other living species, are not something separate from the person, but are to be seen rather as part of us.

Of the metaphors applied to evoke the person, the 'cyborg' seems to have proved the most lasting and widespread over the past years.

This is possibly because describing the human as a highly sophisticated *biochemical and informational* machine which will be capable of *re-engineering* mind and body has transposed perception of the manipulation of life in images of exceptional bodies, reduction of human beings to chemical materiality, to a re-programmable information system. The plethora and diffusion of science-fiction images in films, novels, videogames and comics suggests there is not only a problem of public ignorance of science, but also of how science knowledge can be received and processed by the public (Selinger and Crease 2006). In the 1970s in biology, too, cell activity was described solely with the same metaphor of a machine that combines a mechanical model with a more recent model of machines inherited from cybernetics: a mechanism without intentionality under the control of a program.[7]

The movement going under the name of 'cyberfeminism' has taken up Haraway's themes, but shows greater interest in processing gender images through science

[7] 'Nowadays each entity active in the cell is described as a machine: ribosomes are assembly lines, ATP synthases are motors, polymerases are copy machines, proteases and proteosomes are bulldozers, membranes are electric fences, and so on'.

'Subsequently, in the nanotechnologies, other metaphors have marked a possible change in these images; phenomena are described according to a dynamic model of nature in which the biomaterial components are 'multifunctional composite structures'. 'Whereas engineered materials are usually processed for a single property, biomaterials are multifunctional composite structures. The interest of material scientists, especially chemists working on high performance composites, is to learn something about the art of associating heterogeneous structures from nature itself. In their effort to design composite structures at the molecular level, they either turned their attention to such familiar materials as wood, bone, or mucus, or to mollusk shells, insect cuticles, spider-silk, etc. These composite structures – associating hard and soft, combining inorganic and organic components, and capable of high performance – appeared to be ideal models for human technology for various reasons. They are models of functional diversity, being adapted for a variety of tasks including growth, repair, and recycling'.

'Consequently, the focus is less on the ultimate components of matter than on the relations between them. Interfaces and surfaces are crucial because they determine the properties of the components of composite materials and how they work together. Nanochemistry distinguishes itself from the culture of purity and high vacuum chambers by advancing an impure process of composition and hybridization that mimics natural materials'.

'The top of their 'art' consists in making heterogeneous components converge in the right location and assemble into larger aggregates without any external intervention spontaneously' (Bensaude-Vincent 2004).

fiction and looks mainly to artistic forms of expression, working on possible imaginary models of the female figure and body.[8] Other feminists have criticised Haraway, seeing the ambiguously androgynous 'cyborg' body images as hybrid. Utopian machine-human beings dreaming up physical omnipotence and stressing the stereotypes on women, 'militarism' and 'patriarchal capitalism' (Balsamo 2000), instead of freeing femininity from the status of 'other' than male. Moreover, attributing technologies with a transforming, liberating power could also be put down to the fact that Haraway is a white woman of Anglo-Saxon culture; other women in different positions and with different cultures may not be motivated to take up this approach, and might indeed feel discriminated in turn if the position were to become hegemonic. For example, African-American women maintain that race is the primary oppression and view the scientific enterprise as a function of White Eurocentric interests.

Not surprisingly, scientific research, biotechnologies, and reproductive technologies reflect the varying complex aspects of the interrelationship between developed and developing countries in general and between the particular cultures of colonized and colonizing countries. General themes include the underdevelopment of the Southern continents by Europe and the other Northern continents (Harding 1993); ignoring, obscuring, or misappropriating earlier scientific achievements and history of countries in Southern continents; fascination with so-called 'indigenous science' (Harding 1998b); the idea that the culture, science, and technology of the colonizer or former colonizing country remain superior to those of the colony or postcolonial country; and the insistence that developing countries must restructure their local economies to become scientifically and technologically literate so they can join and compete in a global economy (Mohanty 1997). In Northern, formerly colonizing, countries the concurrent restructuring effects of multinational corporations and other forces of globalization are evidenced in downsizing, privatization, and widening economic gaps between the poor and the very wealthy. The particular forms and ways that these general themes take shape and play out vary, depending on the history, culture, geography, and length of colonization for both the colonized and colonizing countries (Rosser 2000).

In parallel with development in other fields of learning, the last ten years have seen increase and diversification in the positions and critiques of the feminists. In the case of science we once again find contrasting positions, albeit with differences within

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[8] In the WONBIT conference some artists evoked with videos relations between human and machine (Eleonora Oreggia), laboratory and home (Catherine Fargher), contemporary biomedical engineering and representations of corporeality (Trish Adams), skin/time time system and sex/gender system (Nicole Pruckermayr) and between various popular cultural settings and biotechnology (Ruby Sircar).

Thanks to the low cost of digital production and distribution, young artists are able to show on the Internet their creations of new female images. Cyber-feminism, too, seems to repeat or imitate the stages and strategies of the movements of the 1960s–1970s. There exist women-only lists, self-help groups, women networks and inevitably discussion and adoption of positions regarding the new technologies and the various points of view of the other women. See: www.cyberfeminism.net.