Crossover research
Well constructed systems biology

This project explores the need for integrated projects that crossover ethical-political and epistemic quality measures in order to demonstrate viable systems biology approaches in the context of social needs. Project members are based at NTNU and Oxford University, selected based on previous history of collaboration.

1. Relevance

This project addresses the main concern of the call, namely to develop arenas for learning processes between ELSA research and researchers in technology and natural sciences, in this case biology, medicine and computer science. By engaging in the development of the increasingly important field of systems biology applied to cancer research, the project addresses the call for projects on emerging biotechnologies. The Appendix describing the background of the call says:"A focus of this call is to make more manifest what types of skills are necessary in order to carry out interdisciplinary, interactive projects." The proposed project addresses this by integrating researchers and by combining perspectives from the social sciences, natural sciences and technology in a project that aims at demonstrating and improving the viability of systems biology. The participants of the integrated project are motivated by the goal to search for epistemic and acceptable ethical-political conditions for realization of a systems biology project in a context of meeting urgent societal needs. This constructive goal enables reflection on the interactions between the partners in the integrated project and on its consequences, mapping how mutual learning processes are stimulated or how they fail. By combining resources from people who for many years have worked in integrated projects where STS and applied ethics approaches is merged with biotechnology and systems biology, the project group has developed the necessary skills for pursuing this kind of research. Our shared goal provides a uniting framework for the participants' motivation for time-consuming interdisciplinary work.

2. Aspects relating to the research project

2.1. Background: Gastrin systems biology: the case of this integrated project

Systems biology studies how millions of molecules inside cells are organized into vast protein-gene networks and is proving to allow building, simulating and validating new hypotheses from a systems perspective, taking into account the dynamical interactions of biological parts and processes and the emergence of new functionalities. Systems biology holds promise for defining the molecular networks that directly respond to genetic and environmental perturbations associated with disease and for causally linking such networks with pathophysiological disease states[1] and can make important contributions to understanding key clinical aspects of cancer and in research and development of biomarkers for diagnosis, targets for new drugs as well as new treatment strategies.[2]

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[1] Schadt EE Molecular networks as sensors and drivers of common human diseases. *Nature.* 461:218-23, 2009

[2] Aebersold R, et al Report on EU-USA workshop: how systems biology can advance cancer research. *Mol Oncol.* 3(1):9-17, 2009

The hormone gastrin is the central regulator of stomach acid secretion and growth and differentiation of gastrointestinal mucosa and has been linked to development of neuroendocrine tumors of the gastrointestinal tract and, in conjunction with additional factors such as inflammation, to development of gastric adenocarcinoma[3]. In Norway there are approximately 450 new cases of these tumors annually, and the prognosis is grave with a survival rate of 20 and 10%, respectively. A systems biology workflow to study gastrointestinal tumor biology has been established. The workflow is based on molecular biology in its special concern for the information transfer and on physiology for its particular dealing with adaptive states of the cell and organism. The computational biology systems we are developing allow not only for retrieving vast amount of data and knowledge from scientific literature and databases, but also make knowledge and data available through Semantic Web technologies allowing hypothesis generation through complex queries and computational reasoning using Semantic Web technology[4] implemented at NTNU in the BioGateway knowledgebase (www.semantic-systems-biology.org). Using high throughput gene expression screening followed by data analysis and modeling, more than 2000 new gastrin-responsive genes have been identified and mathematical modeling has provided a large set of hypotheses detailing how gastrin activates transcription factors, repressors and effector genes in a pattern that is similar to a general growth factor regulatory networks. These hypotheses depicting new molecular networks that convey the interplay between forward signaling and negative feedback in gastrin responses are now being refined and tested in high throughput experimental cell culture system transfected cell arrays (TCA)[5] and will soon be followed up by experimental animal and patient studies in order to assess their relevance for tumor diagnosis, prognosis and treatment. The involvement in the project of researchers in Gastroenterology and Clinical Cancer at St. Olavs Hospital ensures that we can extend our observations to biological material obtained from patients with different degrees of hypergastrinaemia for various periods of time as well as from patients with gastrointestinal cancers.

Background for integration: Three idioms

Systems biology represents a potentially powerful scientific field with radical societal transformative potentials. These powers need to be studied in terms of how actions are mediated through the field's experimental systems. Experimental systems are one powerful way to pursue intuitions, proposals and ideas within what Hacking called a self-vindicating laboratory setting. In Rheinberger's words, an experimental system is the smallest working unit designed to give unknown answers to questions that the experimenters are not yet able clearly to ask. However, creating experimental systems may imply irreversible social and political changes which is particularly evident in large experimental systems.[6]

In the humanities and social sciences, the notion of experimental systems have come to play a crucial role as a theoretical concept opening a doorway for alternative epistemological

[3] Watson SA, Grabowska AM, El-Zaatari M, Takhar A. 2006 Gastrin - active participant or bystander in gastric carcinogenesis?, *Nat Rev Cancer (12):936-46*

[4] Antezana E, Blondé W, Egaña M, Rutherford A, Stevens R, De Baets B, Mironov V, Kuiper M., BioGateway: 2009 a semantic systems biology tool for the life sciences. *BMC Bioinformatics*. Oct 1;10 Suppl 10:S11

[5] Fjellbo CS, Misund K, Günther CC, Langaas M, Steigedal TS, Thommesen L, Lægreid A, Bruland T. 2008 Functional studies on transfected cell microarray analysed by linear regression modelling. *Nucleic Acid Research*, 35: e97,

[6] Hacking, I. 1992 The Self-Vindication of the Laboratory Sciences. In Pickering, A. 1992 (ed.) *Science as Practice and Culture*. - Rheinberger, H-J. 1997 *Toward a History of Epistemic Things* .

accounts of the particular powers of experimental sciences. With reference to Pickering[7] and Jasanoff, we may speak of three successive "idioms" for thinking about science, technology and society. First, "the representational idiom" that casts science as an activity that seeks to "produce knowledge that maps, mirrors, or corresponds to how the world really is". This idiom simultaneously cast ideals for sharp separation between ethical-political activities and the epistemic activities of science, in Taylor's[8] words, these activities are "epistemologically modeled". During the 1990s these ideal relationships where often identified and discussed in terms of the "social contract" between science and society, ideals that where in need of being reconsidered.[9] Second, what Pickering called the "performative idiom", represents the first attempt to articulate an alternative. In this idiom scientific truths were expressed in terms of what we have to deal with, rather than what we may represent. The activities of the experimental sciences were depicted as an ordering activity, i.e. the epistemic activity was described as the one of creating orders or "stability"[10]. These stable or reliable orders they crossed over the natural and the social, and are often referred to as "socio-technical" orders.

Third, the contemporary challenge, for instance expressed in the present ELSA call, is to develop ideals for such a process within what Jasanoff has called the "co-production idiom". The normative questions need to be framed differently – as a questions of how the totality is to be shaped in terms of "well-constructed collectives".[11] The methodologies of studying and assessing normative questions also need to be re-considered. Much attention has recently been given to the need for ELSA researchers to take on a responsible role as co-constructors in a more participatory way than they have been used to.[12] These responses call for various forms of engagement of scientists and citizens in order to build reflexive capacities within and outside scientific enterprise, sometimes summarized under the heading of a call for "anticipatory governance". Reflexive capacity is measured in terms of the capability to both recognize the diversity of possible pathways of technology developments and one's own role in bringing about a particular pathway.

2.2. Approaches, hypotheses and choice of method

The originality of the approach.

This project seeks to integrate what we would identify as applied ethics approaches with the above mentioned STS approaches. Latour borrowed the crossover notion from genetics having chromosomal crossover in mind. Crossover terms in Latour's analogy are descriptive

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[7] Jasanoff, S. 2004 The Idiom of Co-Production. In Jasanoff, S. (ed.) *States of Knowledge*: Pickering, A. 1995 *The Mangle of Practice* (p5-7).

[8] Taylor, C. 1984 Philosophy and Its History. In Rorty,R et.al. (eds.) *Philosophy in History*.

[9] Winner, L. 1993 A New Social Contract for Science. *Technology Review* (96) 65. - Lubchenco, J. 1997 Entering the Century of the Environment: A New Social Contract for Science. *Science* (279) 491-497. - Guston, D. H. and Keniston, K. 1994 Updating the Social Contract for Science. *Technology Review* (97) 60-69. - Gibbons, M. 1999 Science's New Social Contract With Society. *Nature* (402) 81-84.

[10] Fujimura, J. H. 1996. *Crafting Science*. Galison, P. 1987. *How Experiments End.* Pickering, A. 1995 *The Mangle of Practice*. Rheinberger, H-J. 1997. *Toward a History of Epistemic Things.* Knorr-Cetina, K. 1999 *Epistemic Cultures*

[11] Latour, B. 2004 *The Politics of Nature*.

[12] Rip, A.; Schot, J.W.; Misa, T.J. 1995 *Managing Technology in Society. The Approach of Constructive Technology Assessment* - Guston, D, og Sarewitz, D. 2001 Real-time technology assessment. *Science and Public Policy* (33) 5-16, 2001 - Fisher, E. et.al 2006 Midstream Modulation of Technology: Governance From Within. *Bulletin of Science, Technology & Society* (26) 485-496, 2006.

terms making it possible to capture the exchange, mixing and mutual blending of the social and the natural. The crossover terms were to play a role in understanding *how* things become. The "thing" under consideration is here what has been theorized as a dynamic "actor-network", paying specific attention to how actions are mediated. In engaging in the production of this "thing" however, we need to overcome the methodological restrictions of sticking to "how" questions. We need an approach that takes into account the nature of embedded normative realities, through explicit normative analyses and development of analytical terms that enable "crossing-over" the issues we recognize as respectively epistemic and ethical-political.

We suggest the notion of "ethos" to fill such a role as a normative crossover term. Ethos is presented as a short cut reference to traces of human evaluation embedded in an actor-network. Human agents cannot escape evaluating their own actions, although the evaluation may be weak or strong, that is, even crucial decisions we live by may be more or less well explicit deliberated or more or less well argued.[13] The notion of ethos of a technological system draws attention to immanent evaluative traces of human action and may provide useful guidelines for the work of instigating morally accountable developmental processes.

The analyst who claims to account for the process where an actor-network is created, along with its ethos, needs to be challenged with respect to how well this network articulates the ethos. Such a work of articulation needs to be understood as having two interconnected components, one of revealing (which appeals to a recognition of how things really are) and one of conveying (which carries an invitation to see things differently). The ethos, as the assumption goes, articulates the conditions under which the constructed actor-network appears as a desirable and justified actor-network. If one seeks to articulate such an ethos, given the complexity of issues, one will have to engage interdisciplinary activity in the question of clarifying what the ethos should be.

Three work packages, and choice of methodologies

The project will be organized in three interrelated work packages. First, the experimental system of the systems biology research group will be studied as they will constitute a dynamic "model system" for this proposed project. Second, this model system will provide an experimental platform for improvements of the quality of systems biology both in terms of epistemic and ethical-political measures. Third, this research activity will itself be subjected to reflexive scrutiny. The aim is to critically evaluate the limitations and possibilities of integrated projects for the improvement of the quality of scientific work in the making.

The discussions emerging from this collaborative task, both in the daily wet-lab and computational biology work as well as in research group meetings, are framed by substantial philosophical analysis aiming to formulate and answer essential questions for systems biology. We seek interactions in various arenas like a) academic structured workshops, b) monthly research group meetings and c) individual discussions between participants at a more informal basis. The achievements and contributions from the project will be conveyed in journals co-authored by the collaborators from the various disciplines of the proposed endeavor. We regard this strategy to be of high importance and relevance for the true integration of our planned interactive research.

[13] Taylor, C. 1995 *Philosophical Arguments.*

Wp1: **What are the characteristics of the architecture of systems biology?**
Wp 1 takes place the first year of the program. The aim is to articulate transitions in scientific practices along with the norms that are embedded in these novel forms of practices.

Based on earlier collaboration with members of the research group we have identified three interrelated *developmental axes* of systems biology that focus our analysis in wp1.

1. Computational Biology The combination of *in vivo* and *in silico* experiments radically changes the nature of the experiment in biology[14]. Decisive transitions of biology follow from a a) shift in the meaning and role of model systems from animal/plant models to mathematical and computational models and b) need for organizing, analyzing and manipulating loads of information, requiring collaboration between laboratory units following the need to overcome three related problems: i) data overload in individual experimental runs as well as ii) data and iii) knowledge deficient capacity of individual laboratories. Computational Biology including mathematical modeling and knowledge management plays a crucial role in the process of reshaping and holding together the experimental system of systems biology.

2. Long term and short term goals The challenges of systems biology, broadly understood, follow from the visions of understanding biology as integrated systems rather than isolated parts. We identify this vision as long term goals that, in the NTNU research group, has through the last decade run under different headings like, “post-genomics”, “functional genomics” or “physiological genomics”. These long term goals are sources of controversy as they imply extensive work of building novel unverified methodological platforms. The long term goals therefore have to be step-wise supported by more specific do-able short term goals (such as in our case, the contribution to better understanding of cancer) when approaching peers, and funding agencies. The architecture of experimental systems biology then will be shaped in the tension between choices and strategies of short and long term goals.

3. Modern research conditions. The visions of systems biology are mediated by short time goals of what the field may do for medicine, agriculture, fish farming and the different associated industries. As such, systems biology also engages patient groups, industry, environmental NGOs, national and inter-national legislation, ethical committees and politicians. The research performed in laboratory units often has practical or innovative goals that directly aim at affecting our lives (such as finding diagnostic markers and searching for genetic therapies or facilitating plant and animal breeding). A wide spectrum of interests and values are therefore put into play in ways that induce different games of strengthening or weakening of different aspects of the research process. The dynamics of (“mode2” or “post-academic”)[15] fields like systems biology have become increasingly more difficult to follow.

The study of the actual dynamics of the development of systems biology is situated in the study of the work of constructing the particular workable unit of systems biology at NTNU.

Method
This project assumes the actor-network to embed normative evaluation of worth and seeks to trace and articulate this in paying attention to the three developmental axis. The post doc will

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[14] Kitano H 2002 Computational systems biology. *Nature*. 420:206-10
[15] Gibbons. M et.al. 1992 *The new production of knowledge* - Ziman, J.2000 *Real Science*

be stationed in the laboratory at the Medical Faculty/St.Olavs university hospital during the first year working close to the wet-lab and computational biology researchers in mapping the characteristic and important normative features of the architecture of systems biology. The output of these analyses will be presented and discussed at least once a month in meetings within the systems biology research group and evaluated in the consortium in three seminars during the first year. Drafts for two papers co-authored by members of the group will serve as a basis for further discussions to take place in wp2.

Wp2: How can the architecture of systems biology be modified in the making?
Wp 2 takes place the second year of the program. The aim is to a) take the analysis of wp1 as a point of departure for substantial discussions of conditions for well constructed architectures of systems biology and b) be sensible to, and document the interaction process, in preparing the work of wp3.

There are a number of topics discussed in the humanities and social sciences that should either inform systems biology or be corrected.[16] Wp2 aims at mobilizing discussions relating to the outcome of wp1. These discussions may sometimes have epistemic, sometimes ethical or political nature. The task is to translate the humanist analysis into considerations that matter for working scientists and vice versa. There is, for instance, a possibility that one science entering the trading zone of systems biology dominating the other, and how such questions may be broached relating to the perceived and actual dominance of certain modes of enquiry over others.[17] And one may raise ethical conserns of personalized medicine, or questions concerning if or how a possibly non-reductivist systems biology account of life affect or understading of human freedom - or questions of social and global justice. The challenge at hand in wp2 is to translate these forms of questions into questions of concerns of experimentation and the building of experimental systems of systems biology.

Method
The discussion takes place, in addition to regular monthly group meetings and three yearly seminars, as well as a joint workshop involving the integrated research group at Oxford coordinated by Annamaria Carusi. Having a specific focus for each seminar helps to reduce the complexity and communication across disciplines. One of the key challenges is to create working conditions where collaborating researchers reach into and share some responsibility for each other's disparate fields in order to create "interactional expertise" of trading zones and the ""pidgin" or "creole" language that may appear in such zones.[18]

Trading zones appear when activities of disparate groups are oriented towards overlapping goals where something is at stake for participants. This not only implies seeking mutual understanding but also efforts to direct their own scientific activities so that the researchers from the other fields are able to reach their aims and even take responsibility for and develop engagement in the scientific achievements in the other disciplines. When researchers mutually strive to translate their own research so that it is accessible to others, and likewise

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[16] O'Malley and Duprey 2005. Fundamental issues in systems biology. *BioEssays* (27) 1270–76. Boogerd, F (ed.) 2007 *Systems Biology: Philosophical Foundations*. Carusi, A. et.al. Tribal Warfare or Uneasy Truce in Biology. http://ora.ouls.ox.ac.uk/objects/uuid%3A938f44c7-e0c4-4b8f-a4c3-d2fac38f9044
[17] Duprey.2001. Human nature and the limits of science. . – Duprey 1996. Against scientific imperialism. In PSA 1994: Proceedings of the 1994 Biennial Meeting of the Philosophy of Science Ass., Forbes et.al (ed).
[18] Galison, P. (1997). *Image & logic*: - Collins, H. M., & Evans, R. (2002). The third wave of science studies. *Social Studies of Science*, 32(2), 235-296.

attempt to understand the research activities, goals and underlying assumptions and frameworks of other fields, a potential for mutual learning processes may arise. Experiences that create such trading zones will be documented and subjected to discussion within the consortium.

As the proposed project focuses on understanding how integrated projects can be of scientific and socio-ethical value, it will be of great importance to explore the impact of the interactions and discussions on the activity within the integrated project. To achieve that we will engage in reflection on the interdisciplinary work processes on a regular basis in order to determine to what extent it has impact on the underlying value systems of the involved researchers, and how it has altered the way the research is conducted.

Some of the meetings and one of the seminars of wp2 will take the form of intensive engagement events around the topics. These events will include, for example a further forum on scientific method in biology, building on that run by Carusi et al[19], addressing questions of scientific imperialism; or a tour of animal facilities where animal testing is carried out, with invited speakers to explain the current state of animal testing in Norwegian, European and other regions, with an in-depth discussion; and other opportunities for debate.

One or two articles aiming at epistemic and or ethical-political analysis of systems biology will be written, a work that will serves as a basis for furter discussion in wp3

Wp3: What are the potentials and limitations of modulation through integrated projects? *The aim is to extract and disseminate learning outcome of the work of wp1 and wp2.*

This workpackage takes place during the third year. It is a workpackage when we test to which degree the experiment of the humanities and science groups working together in the first two workpackages has indeed made a difference to our working practice, to the broad domain of systems biology, and to the more timely inclusion of ethical considerations. We draw out the lessons of earlier interactions and discuss these lessons within the entire group in monthly meetings, three seminars and one workshop. Our discussions will be structured by three themes:

a) Humanities/science research practices: to what extent have we succeeded in working together in a truly engaged way? To what extent have we succeded in providing substantial analysis that can make a difference? What has changed in our own work practices, what resistances to change are there, and why are there these resistances? In the normative sense, what is the justification of these modifications and resistances?

b) Crossover epistemic and ethical-political issues: to what extent did topics cross over and make a difference to the broad domain of systems biology? What type of problems did this create. Were we able to find descriptive and evaluative normative crossover terms?

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[19] Carusi, A., Rodriguez, B., Wakefield, J., et al. (2009) *Forum for Scientific Method in Biology: Transcript.* Oxford e-Research Centre, University of Oxford.

c) Ethics coming too late: To what extent can we avoid ethics coming too late? If powerful technologies comes at the cost of moral confusion, how can we find creative ways for continuous societal and ethical exploration and evaluation to live alongside this inevitability?

Method:
1) Diary study and regular monthly group meetings: For this work package we will invite project members to maintain a diary of their experience of wp1 and 2, which will be shared during meetings. This will enable us to capture the detail of shifts and changes in our interactions.
2) Three seminars over the year will focus on specific topics that arise.
3) One workshop will bring together the strands from 1) and 2).

One article focusing on learing outcome of integrated project will be written.

2.3. The project plan, project management, organization and cooperation

The project group consists of scholars from the humanities and the natural sciences sharing a concern for the question of what role the humanities can and should play in scientific and technological innovation processes. The members are highly experienced in cross disciplinary interaction and have strong incentives for seeking collaboration. This project challenges the quality of humanistic work to be evaluated not only in terms of internal standards, but also in terms of its ability to make a difference to the course of events. It also provides an opportunity to turn the question into a research topic in its own right while at work trying to cross over disciplinary boarders.

We apply for a three year post.doc. We foresee however challenges in recruiting qualified persons for such an interdisciplinary work task, and are prepared to consider the position redesigned as a ph.d. recruitment position.

The project is organized as project management group although will also be responsible for coordinating the project and the practical aspects of the workshop organisation.Rune Nydal has applied for a sabbatical, planning to visit CRS-ASU, where David Gustion is the principal investigator. If granted he will partly work on the project and Bjørn Myskja will be the responsible project leader and together with Astrid Lægreid kooordinate the activity.

Since our approach is interdisciplinary (see attached CVs for the project management groups fields of expertise) the consortium will interact and work together under all the subprojects.

Project Coordinator will be ***Rune Nydal*** , Associate professor at the Programme for Applied Ethics, Department of Philosophy, NTNU. He is a co-editor of the journal Etikk i praksis, and is a member of Regional committee for FUGE mid-norway. He has undertaken an empirical study of the emergence of the field of functional genomics in Norway, which now seeks empirical extension in systems biology. Been part of the project management group of NanoEthos and NanoTrust.
Project Management Group; the project management group will be chaired by the project coordinator and involve professor Astrid Lægreid and associate professor Bjørn Myskja. The

project management group will also be responsible for coordinating the project and the practical aspects of the workshop organisation.

Astrid Lægreid is Professor of functional genomics at the Dept. of Cancer research and molecular medicine with a research focus on gastrointestinal molecular cell biology, genome wide gene expression analysis, systems biology modeling and knowledge management related to retrieval and management of biological information from literature and databases as well as ethical and science history aspects of functional genomics and systems biology. Her scientific leadership experience includes 15 years as group leader, principal investigator and initiator and leader of national functional genomics core facility as well as the position as Pro-Rector Research at NTNU, 2005-2009.

Bjørn Myskja is Vice Dean for research at the Faculty of Arts and Associate Professor at the Department of Philosophy, NTNU. His main research areas include theoretical and applied ethics, in particular the ethics and politics of technology. He has coordinated the ethics part of an integrated EU-project on genetic modification of plants and is currently project leader of the RCN funded projects Nanotrust and Nanoethos, and active researcher on the RCN funded project In genes we trust?. Myskja was one of the co-authors on the report *Nanoteknologier og nye materialer: Helse, miljø, etikk og samfunn.*

Liv Thommesen is a professor of molecular medicine at Dept of biomedical sciences, Faculty of Technology, Sør-Trøndelag University College/ Dept. Cancer research and molecular medicine, NTNU. Her expertise is in molecular cell biology spanning intracellular signaling, knock in (expression plasmids) / knock out (siRNA) experiments, cellular read-outs system (reportergene assays, proliferation, migration, apotosis, subcellular localization), transfected cell arrays (TCA), gene expression microarrays.

Arne K Sandvik, professor gastrophysiology, Dept. Cancer research and molecular medicine, Faculty of Medicine, NTNU/St.Olavs Hospital. His expertise is in gastrointestinal physiology; clinical gastroenterology; neuroendocrine physiology, animal studies; microarray technologies; transcriptomics. Sandvik is the leader of the NTNU-branch of the National Platform for MicroArray Technology and High-Throughput Genomics (http://www.microarray.no/).

Martin Kuiper, professor systems biology, Department of Biology, Faculty of Natural Sciences and Technology, NTNU, has an expertise in molecular biology, genetics, omics technologies, data mining and modeling, functional assessment of clustered data, network based analysis, application ontologies, semantic integration of protein-centric data, data querying and visualization and leads a research group focusing on data analysis and mining and the development of semantically integrated data in BioGateway (www.semantic-systems-biology.org), semantic enrichment, relation ontologies, component and network/pathway information (including parameters for mathematical modeling), user assistance in querying the knowledge base

Annamaria Carusi, senior research associate at the e-Research Centre, University of Oxford, studies social, ethical and epistemological aspects of computational methods and techniques used in science. Recent publications include work on the role of visualizations in computational biology, analyses of trust in virtual environments, and the ethical implications of digital social research.

2.4. Budget

Personal costs include one three year post-doc position. Other costs includes travel costs and three yearly seminars of which two is extended to a workshop including international partners. The faculty of Humanities, NTNU will offer Annamaria Caruci a three year professor II position, starting January 2011. Her poristion is linked to the two integrated ELSA project at the Faculty of Humanities (Crossover is one of them).

3. Perspectives and compliance with strategic documents

3.1. Compliance with strategic documents

The project complies with NTNU's strategies of advancing interdisciplinary capasities as well as NTNU's Strategic research area Medical Technology.

3.2. Relevance to society

The project seeks means of improving research processes in developing fields of high interest to society and to document the learning outcomes relevant for improved understanding of the many-faceted interplays between science, technology and society.

3.3/3.4. Environmental perspectives and ethical aspects

We foresee no environmental impact. Ethical implications as well as how to install real time assessment of systems biology are researched in this project

3.5. Gender equality and gender perspectives

Systems biology as well as the humanistic and social sciences that are engaged by systems biology is generally male dominated in Norway. A gender balance is enforced in this project in terms of project members and will be taken into account in seminars and workshops arranged in the project.

4. Communication with users and utilization of results

4.1 /4.2Communication and dissemination

Principal users are ELSA scholars, policy makers and systems biologists communicated through standard academic channels like journals and national and international conference presentations.

The results of the project will be submitted for publication in leading international peer-reviewed journals and presented at national and international conferences. In addition the project will be presented in local and national media, in order to foster integration of societal concerns in the technology development. Several of the scientific publication will be co-authored by participants from each of the integrated disciplines in order to achieve the planned amalgamation and mutual responsibility for the outputs of the proposed project.

We foresee the following publications
Wp1: 2 papers on the nature of architecture of systems biology (one for each topic). The papers will be published in philosophy and science studies journals.
Wp2: 1-2 papers on possible modifications of the architecture of systems biology. The papers will be published in applied ethics and science studies journals.
Wp3: 1 papers on lessons learned focusing subjects such as the role of substantial discussions, of crossover ramifications, implications and effects and on consequences of ethics coming to late. The paper will be published in a science studies journal.