

# Nature Inspired Monitoring and Control

Karl Bayer  
Department of Biotechnology  
University of Natural Resources and  
Applied Life Sciences Vienna / Austria

Muthgasse 18  
A-1190 Wien  
karl.bayer@boku.ac.at,  
www.boku.ac.at

NiSIS 2005  
NiSIS 2005

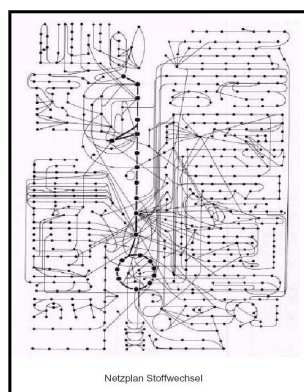
Task Force Proposals: NiMoC

## „What can we learn from living cells“

Microorganisms represent smallest independent viable units

Capability for growth and self-reproduction

Information  
&  
Structure } to perform a set of thousands  
of biochemical reactions  
to sustain environmental  
perturbations



Task Force Proposals: NiMoC

## Evolution derived features of cellular systems

- Biochemical level
- Signal- and control-level
- capability to cope with high complexity of metabolic pathways (*E. coli* contains approx. 3000 enzymes)
- growth rates differ (20 min to several hours)
- high flexibility (approx. 20% of total genes involved in main part metabolism (house-keeping genes))
- coordinated conversion of substrates for growth and synthesis (modularisation, supply of pathways, etc.)

Task Force Proposals: NiMoC

## Living cells perform

### Biochemical reactions

- Catabolic reactions
  - Conversion of substrates into small molecules
  - Generation of free energy
- Anabolic reactions
  - Biosynthesis of complex molecules
    - biocatalytic entities
    - structural elements
    - storage substances

### Information processing

- Regulatory networks
  - Control of chemical reactions
  - Temporal and spatial coordination of reactions
- Signal transduction networks
  - Communication with environment and other cells
  - overcome starvation (exogen and endogen)
- Spatial organisation of individual reactions - compartmentation

Task Force Proposals: NiMoC

Microbial cells represent tailor made models to derive design strategies to perform complex control tasks in other areas of life

Pros:

Controlled cultivation and perturbation under strictly defined environmental and physiological conditions

Recent developments of powerful analytics ( $\mu$ -arrays, 2-D-MS) support advanced monitoring

Bottlenecks: limitations of on-line in-situ monitoring

---

Task Force Proposals: NiMoC

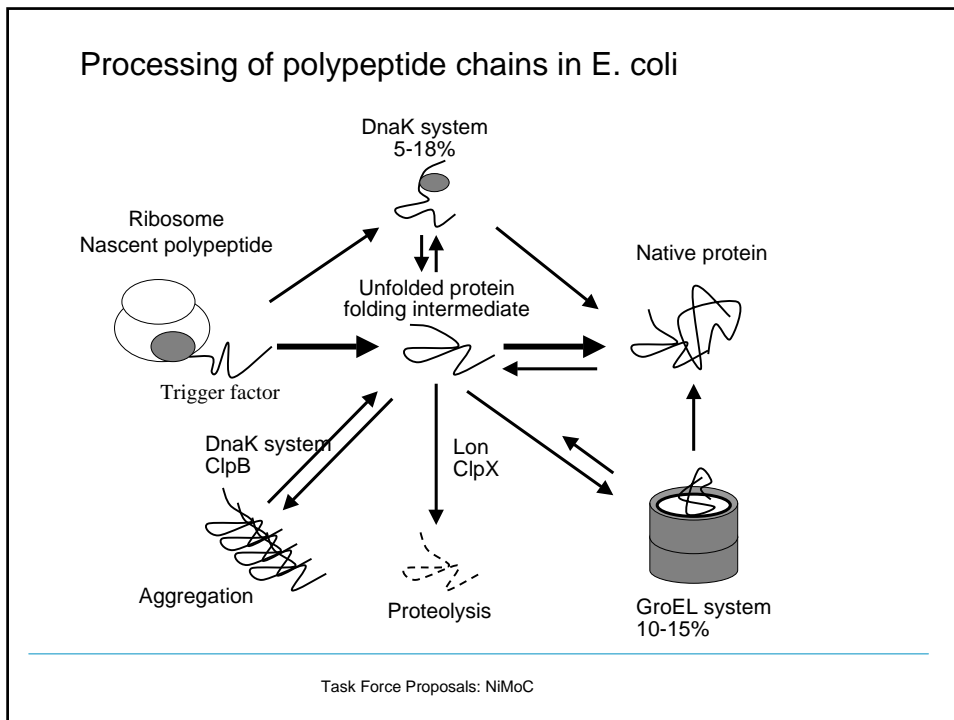
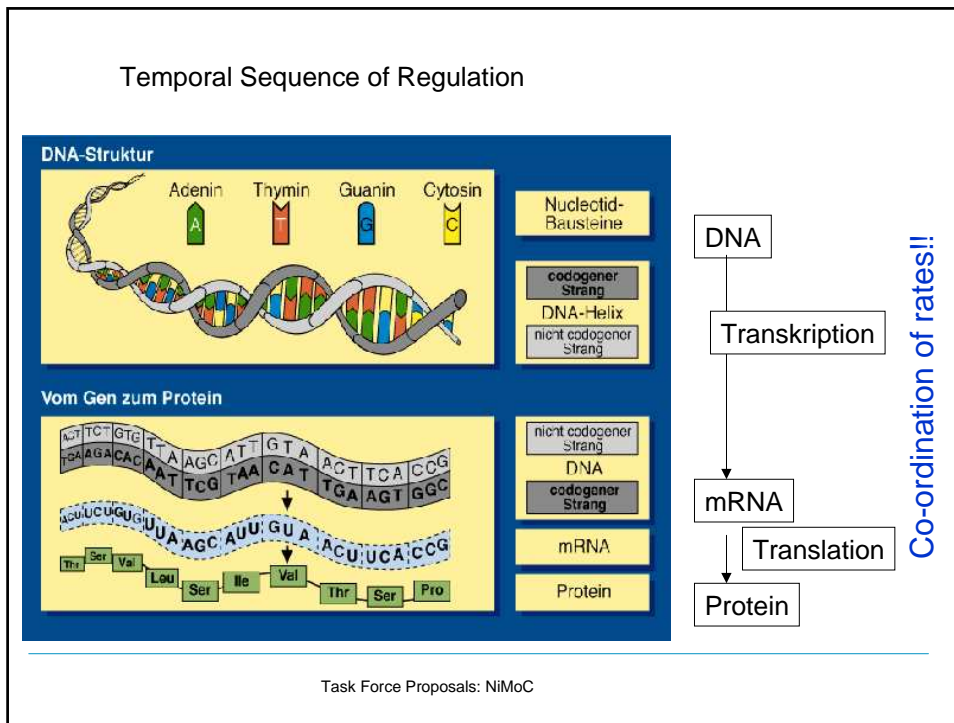
### Examples of sophisticated control regimes

Hierarchical organisation of metabolic regulatory networks

unit	control level	analytes	Purpose
<u>stimulon</u>	global regulatory networks and stress response	signal molecules, ppGpp, cAMP	Genome wide regulation (starvation, etc)
<u>modulon</u>	co-ordination of metabolic subunits	activity of key enzymes	Operons regulated by a global regulator
<u>regulon</u>	Set of operons scattered throughout the genome, subject to regulation by the same regulator		Extend coordinated control to more than one operon
<u>operon</u>	control of single enzymes and enzyme clusters		Unit of transcription (on/off)

---

Task Force Proposals: NiMoC



Key deliverables of task force:

- compilation of different regulatory principles and strategies
- assessment of potential applicability in different technological areas

---

Task Force Proposals: NiMoC

Contribution of life sciences to advanced information systems

- Network architectures
  - Modularisation
  - Hierarchical structure
- } Already established in IT
- Repair
  - Spatial organisation
    - compartmentation
    - domains
    - multi-functionality of protein complexes
    - structure - function relationships
- } Potential for novel features and applications in IT

---

Task Force Proposals: NiMoC

**Proposal of Task Force 'Nature Inspired  
Monitoring and Control'**  
*Submitted by Karl Bayer*

Period: 10/2005 – 10/2007

- Presentation of the Task force during NiSIS 2005 Albufeira
- 1/2005: 1<sup>st</sup> Workshop "Nature Inspired Monitoring and Control" in Vienna
- 2006: 2<sup>nd</sup> Workshop "Nature Inspired Monitoring and Control" in Jena
- 2007 2<sup>nd</sup> Workshop "Nature Inspired Monitoring and Control" in Genova
- Case study of application areas as contribution for the NiSIS Roadmap
- Survey in Information Flow in Biosystems as contribution for the NiSIS Roadmap

Proposed Budget: 17 kEuro (1+4+4+4+1+1)

---

Task Force Proposals: NiMoC

---

Task Force Proposals: NiMoC

### NiSIS Task Force Proposal by Degussa, R. Dudda

- Ni Soft sensors
- **A lot of observers (linear/nonlinear), soft sensors have been developed in the past to control and make our processes more efficient**
- **When changing environmental constraints or the processes itself, the soft sensors or models have to adjusted by the developer or even more worse have to be redesigned or partially rebuilt. This results in very high costs for maintaining soft sensors.**

Task Force Proposals: NiMoC

### NiSIS Task Force Proposal

- Ni Soft sensors
- **Making soft sensors capable to identify their own validity for the state they are applied or even making soft sensors capable to adjust to changing environmental constraints or making them capable to redesign them in some sense, this would help to make the processes more competitive and thereby also the chemical production sites.**
- **Therefore the question which and how nature inspired principles or techniques can we adopt to construct such self aware, self maintaining or even self redesigning soft sensors (Ni soft sensors)**
- **2 workshops to discuss these questions based on a case study on a typical degussa process with a already implemented soft sensor**

Task Force Proposals: NiMoC

## Quorum Sensing TF

- Jon Garibaldi and Reinhard Guthke
- *Quorum Sensing as a Mechanism for Multi-Agent Communication and Interaction*

---

Task Force Proposals: NiMoC

## Quorum Sensing

- Cells (and/or single-celled bacteria)
  - produce a mix of chemicals (proteins)
  - complex non-linear feedback loops
  - affect the function of the cell
- Chemicals diffuse across cell boundaries
- When the concentrations reach certain levels, the production/feedback mechanisms alter
  - gross function of the group of cells changes
  - ‘biochemical decision making’

---

Task Force Proposals: NiMoC

## Novel Paradigm

- The processes of quorum sensing need to be studied and better understood
  - spatially distributed
  - temporally distributed
- ‘Artificial quorum sensing’ is currently a ‘white-spot’ of research interest as
  - a mechanism for multi-agent communication and interaction
  - a novel paradigm for computation

---

Task Force Proposals: NiMoC

## Aims and Objectives

- Aim
  - to initiate a research proposal
    - STReP to FET Open ???
- Objectives
  - identify specific research requirements
  - identify appropriate skills and partners
  - generate a research proposal
  - submit proposal by end of year 1 (31/01/06)

---

Task Force Proposals: NiMoC

## Modality

- **People**
  - Natalio Krasnogor, Biologist, Jon Garibaldi, UoN
  - Reinhart Guthke, Biologists, Jena
  - open call to other members of NiSIS
- **Two workshops**
  - Jena
    - to generate the ideas
  - Nottingham
    - to finalise the proposal
- **Budget**
  - 4 k€ per workshop

---

Task Force Proposals: NiMoC