Boolean Networks in Systems Life Sciences

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Self-Introduction

Postdoc in the Algorithmic Cheminformatics Group
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Head of the group: Prof. Daniel Merkle

Graph Transformation for Chemistry

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This Course

Format:
Lectures + exercise sessions.

Evaluation:
Oral exam: 15+15 minutes (introduce a topic + questions).
Compulsory exercise sheet (at least 50% correct).

Materials:
jurikolcak.eu/teaching

Unofficial:

L. Paulevé and S. Sené. Boolean networks and their dynamics: The impact of updates.
In *Systems Biology Modelling and Analysis*, chapter 6, pages 173–250. John Wiley & Sons, Ltd, 2022

C. Baier and J.-P. Katoen. *Principles of Model Checking*.
The MIT Press, Cambridge, MA, USA, May 2008

Boolean Networks

Abstract (high-level) model of interacting entities.

All variables in the model are Boolean, valued 0 or 1.

Variables connected with directed edges (interactions or influences).

Interaction interplay defined by means of Boolean (logical) functions.

Main application area: Gene regulation networks.

Systems Life Sciences

Complex systems in **life sciences**.

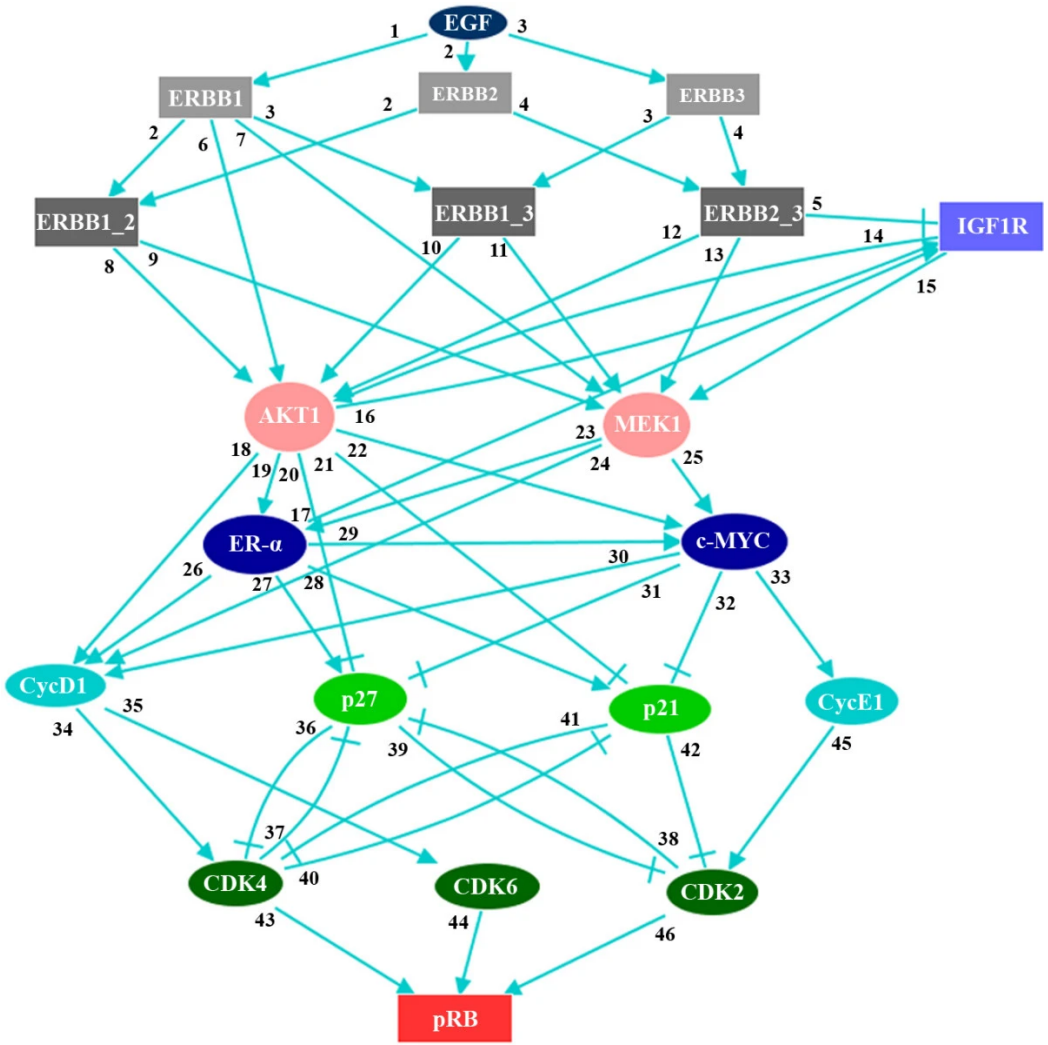
Mathematical and computational study of systems as a whole, with focus on complex interactions between the components and the arising emergent properties/behaviours, which are not observable by study of the components individually.

Holistic approach: "A system is more than the sum of its parts."

The dynamics (behaviour) of the systems and dynamical properties are of interest.

Hypothesis driven.

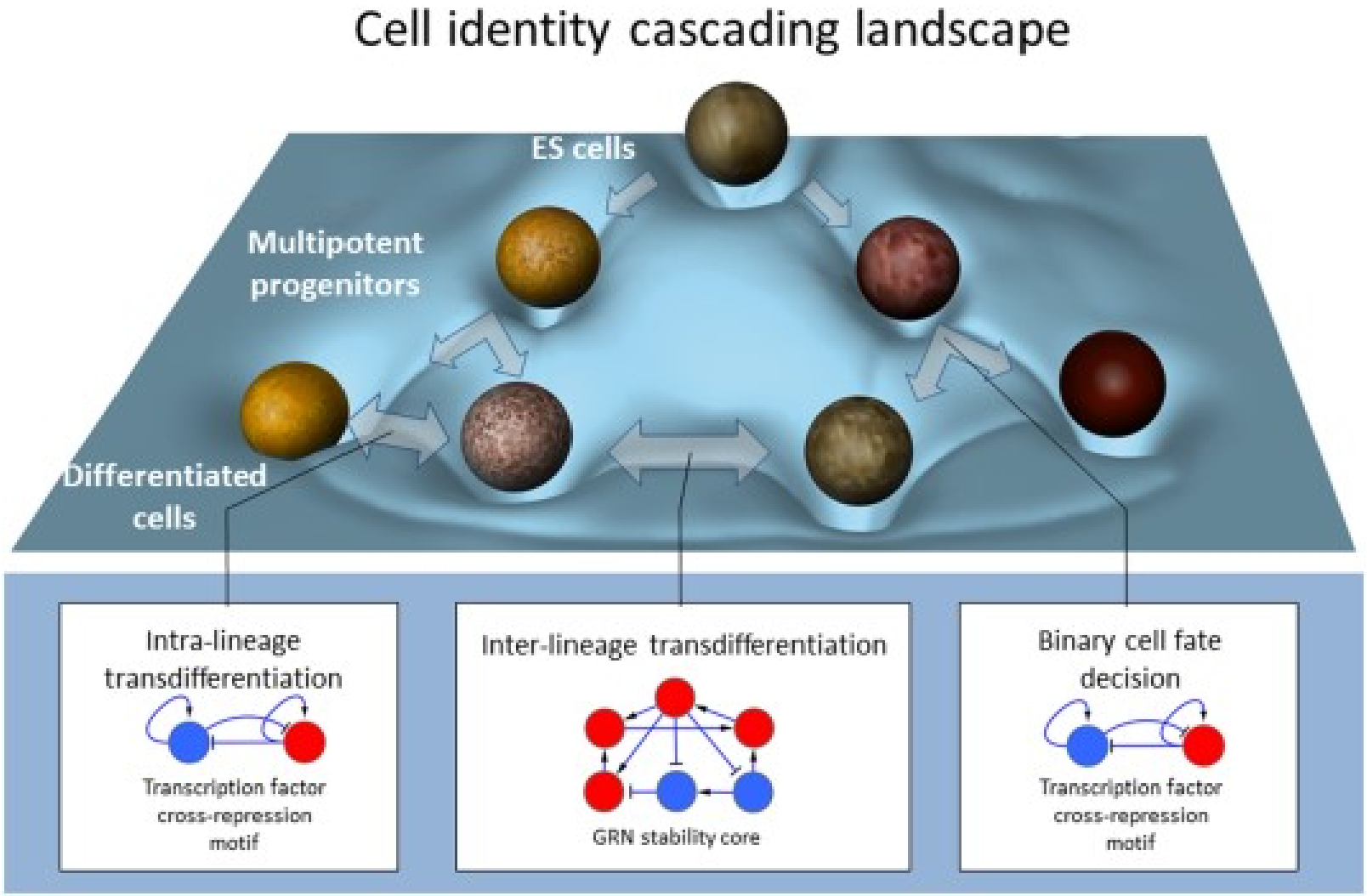
Drug Target Detection



Ö. Sahin, H. Fröhlich, C. Löbke, U. Korf, S. Burmester, M. Majety, J. Mattern, I. Schupp, C. Chaouiya, D. Thieffry, A. Poustka, S. Wiemann, T. Beissbarth, and D. Arlt. Modeling erbb receptor-regulated g1/s transition to find novel targets for de novo trastuzumab resistance.

BMC Systems Biology, 3(1):1, Jan 2009

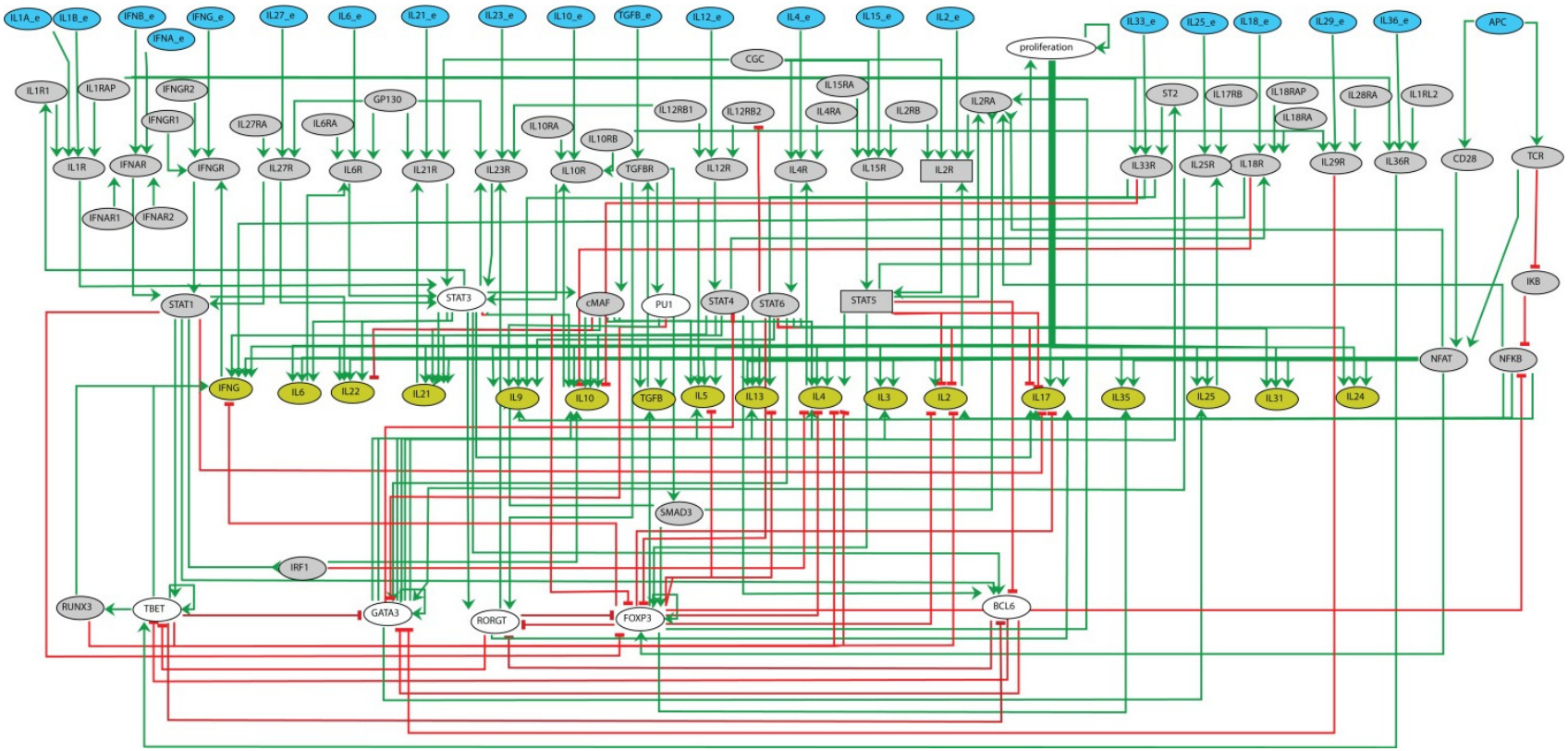
Cell Differentiation



I. Crespo and A. del Sol. A general strategy for cellular reprogramming: The importance of transcription factor cross-repression.

Stem Cells, 31(10):2127–2135, Oct 2013

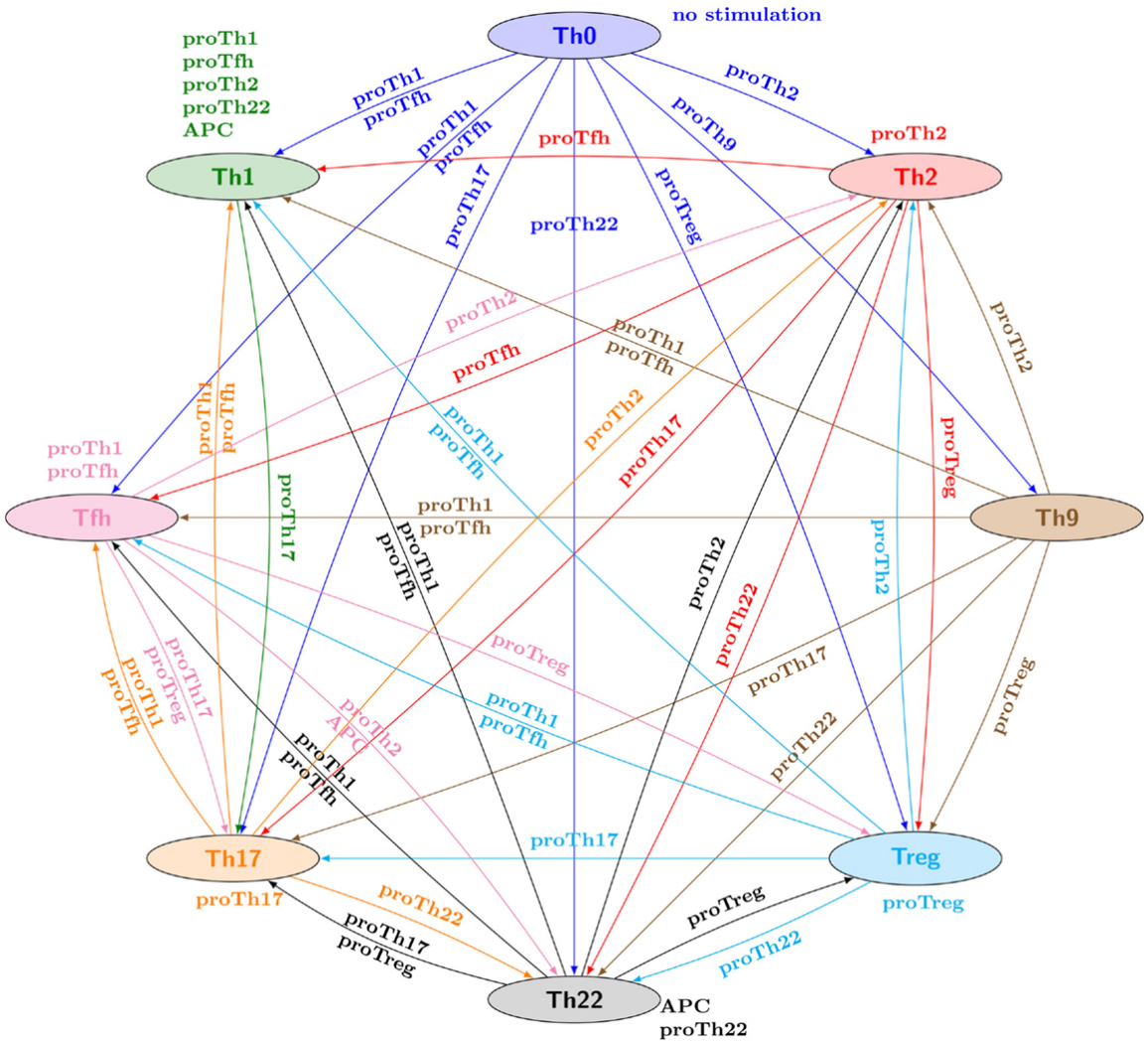
Cell Differentiation – T-helper Cell Example



W. Abou-Jaoudé, P. T. Monteiro, A. Naldi, M. Grandclaudon, V. Soumelis, C. Chaouiya, and D. Thieffry.
Model checking to assess t-helper cell plasticity.

Frontiers in Bioengineering and Biotechnology, 2, 2015

Cell Reprogramming



W. Abou-Jaoudé, P. T. Monteiro, A. Naldi, M. Grandclaudon, V. Soumelis, C. Chaouiya, and D. Thieffry.
Model checking to assess t-helper cell plasticity.

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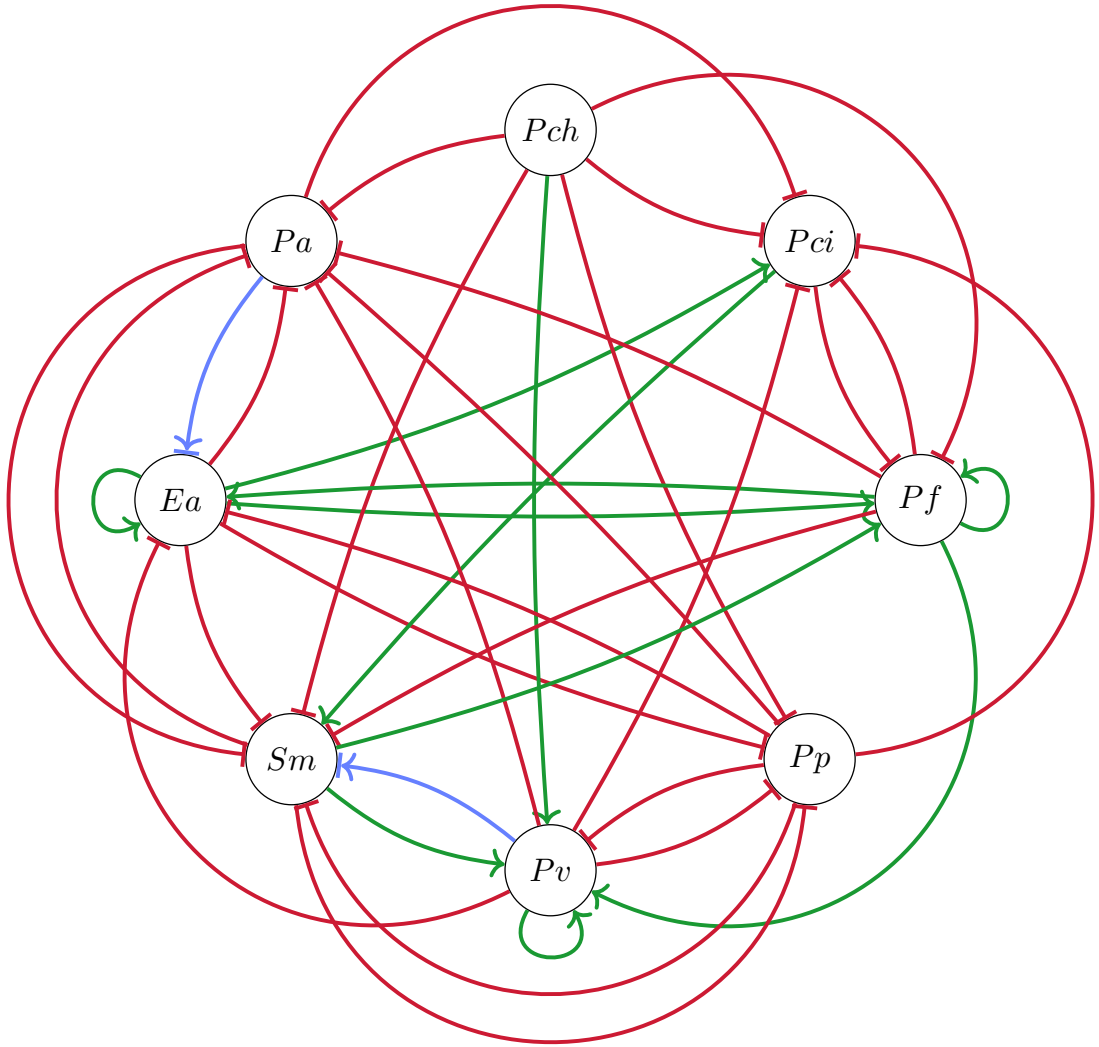
Microbial Communities



Work in progress...

Outline

24/10/25 Dynamical Models in Life Sciences – an Overview;

31/10/25 Boolean Algebra and Propositional Logic;

07/11/25 Boolean Networks (Syntax+(Classical) Semantics);

14/11/25 Transition Systems;

21/11/25 Interaction (Influence) Graphs;

28/11/25 Most Permissive Semantics;

05/12/25 Model Verification (Temporal Properties);

12/12/25 Model Checking;

19/12/25 Network Inference;

09/01/26 Complexity;

16/01/26 No Lecture;

23/01/26 Ongoing Work: Microbial Interaction Inference;

30/01/26 Review (on demand);

06/02/26 Review (on demand);