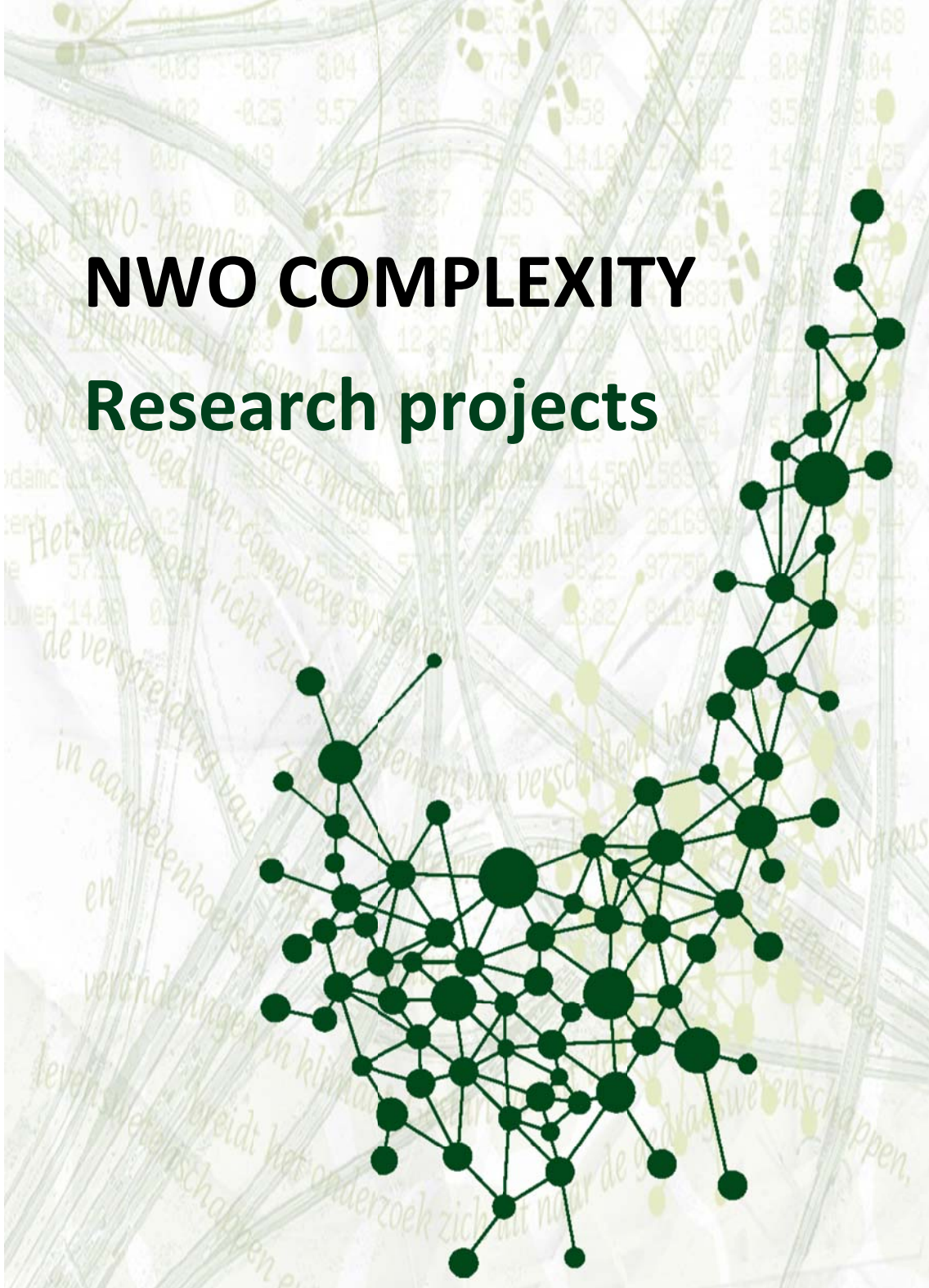


# NWO COMPLEXITY

## Research projects




# ***Complexity Facts & Figures***

- ❖ Complexity focuses on multidisciplinary research at the area of complex systems driven by the real societal problems. The main focus is on the macroscopic dynamic behavior of systems emerging from the dynamic interaction of the microscopic elements.
- ❖ Complexity involves a synthesis of knowledge from different scientific disciplines, such as mathematics, computer science, economy, social sciences, life sciences, chemistry.
- ❖ In the first Complexity round 14 research projects are granted. The projects start in 2011 and will last until 2015.
- ❖ Budget of 6 M Euro for the first round projects is a joint investment of several NWO departments: EW, CW, ALW, MaGW, ICT-regie and NWO theme bonus.
- ❖ The programme committee is guiding Complexity educational and communication activities. The committee members are:

Prof. dr. Rob de Boer, UU	Prof. dr. Jaap Kaandorp, UvA
Dr. Jurjen Bos, Equens	Prof. dr. Peter de Ruiter, WUR
Prof. dr. Jason Frank, CWI	Prof. dr. Kees Stam, VUMC
Prof. dr. Koen Frenken, TU/e	Prof. dr. Maarten van Steen, VU
Prof. dr. Cars Hommes, UvA	Prof. dr. Peter Vervest, EUR
- ❖ An advisory board is guiding the high level programmatic issues. This board involves representatives from academia and industry:

Dr. Lorike Hagedoorn, TNO	Dr. Tjark Tjin-A-Tsoi, NFI
Prof. Roland Kupers, Oxford/Shell	Prof. dr. Job Swank, DNB
Prof. dr. Peter Nijkamp, VU	Prof. dr. Peter Vervest, EUR
Prof. dr. E.W. Meijer, TU/e	
- ❖ The NWO office is coordinating and supporting the activities of the programme committee and the advisory board.
- ❖ Industrial partners and financial contributors are Equens, CHESS, DNB and NS.
- ❖ Programme managers: dr.ir. Natasa Golo and dr. Lex Zandee.

<b><i>PROJECT NAME</i></b>	<b><i>PROJECT LEADER</i></b>
Host-pathogen co-evolution from an immunological epidemiological perspective	Prof. dr. R.J. de Boer (UU)
Identification of synaptic gene networks in complex brain disorders using a Bayesian framework	Dr. L.N. Cornelisse (VU MC)
PREdictability of KURoshio current path transitionS	Prof. dr. ir. H.A. Dijkstra (UU)
Critical Transitions and Early-warning Signals in Spatial Ecosystems	Prof. dr. A. Doelman (CWI)
Coupling of self-assembly and metabolism in protocells	Prof. dr. J.H. van Esch (TUD)
The emergence of self-regulating systems under variable environments	Prof. dr. K. Frenken (TU/e)
Complexity in Public Transport: Passenger Behavior and System Optimization	Prof. dr. L.G. Kroon (EUR)
Food for thought and thought for food, the local-global entanglement of the slow food movement	Dr. A. Lagendijk (RU)
The neuronal network organization of the biological clock	Prof. dr. J.H. Meijer (LUMC)
Stability and rewiring in adaptive neuronal networks	Dr. A. van Ooyen (VU)
Correlating fluctuations across the scales	Prof. dr. M.A. Peletier (TUD)
Complexity and stability in food webs: the role of nutritional quality and infectious disease agents	Prof. dr. P.C. de Ruiter (WUR)
Complex Dynamic Arrest: A novel Phase Transition in Space-Time	Prof. dr. P. Schall (UvA)
Understanding financial instability through complex systems	Prof. dr. C.H. Hommes (UvA)

A portrait of Prof. dr. Rob de Boer, a man with curly brown hair and glasses, wearing a yellow jacket over a dark shirt. He is looking slightly to the right of the camera.

Project leader Prof. dr. Rob de Boer  
(Theoretical Biology &  
Bioinformatics, Utrecht  
University)

Researchers: Dr. Michiel van Boven, National  
Institute for Public Health and  
the Environment (RIVM)

Mr. Chris van Dorp

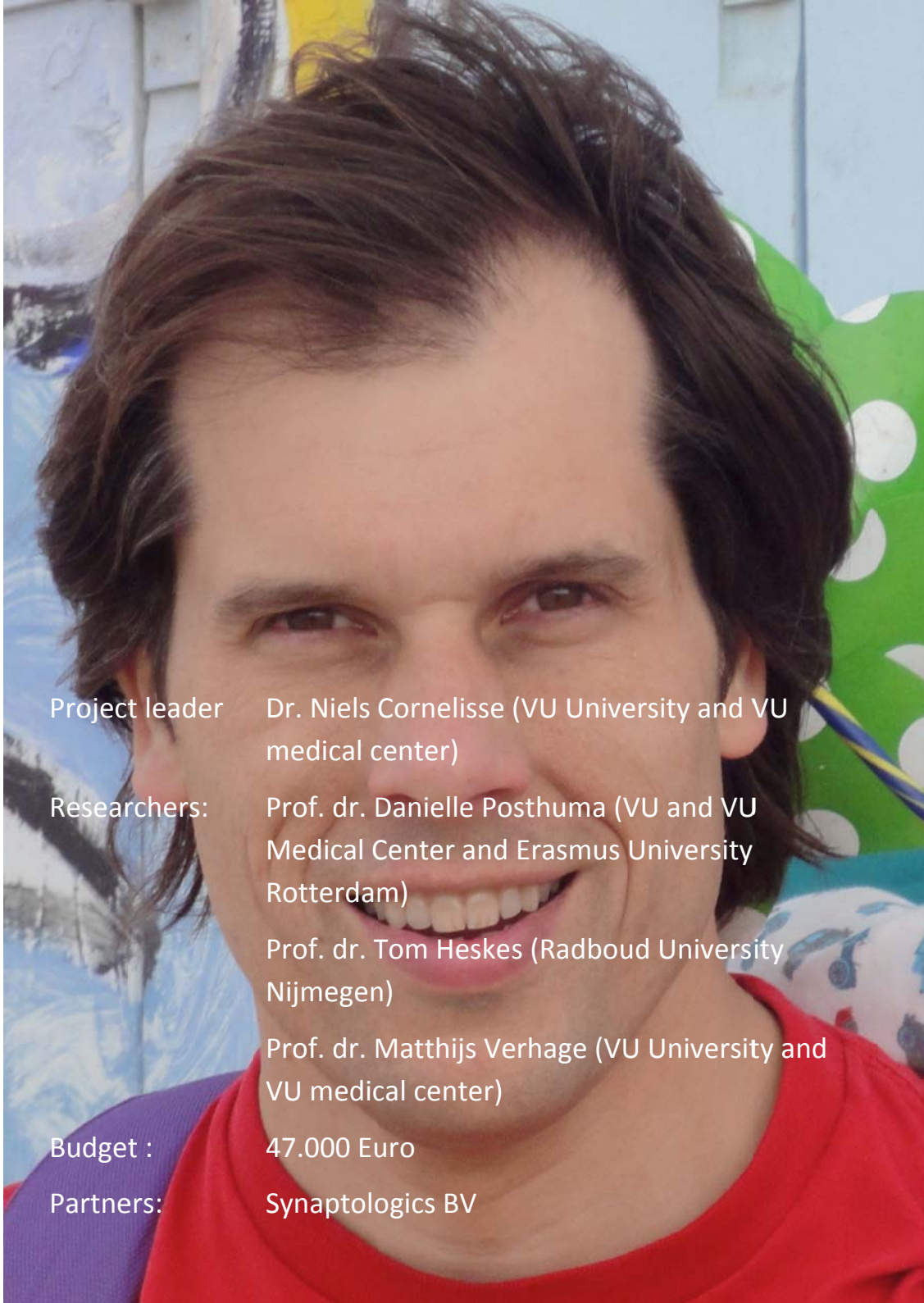
Budget : 442.390 Euro

Partners: Dr. Jacco Wallinga (National  
Institute for Public Health and  
the Environment (RIVM))

Dr. Can Kesmir (Theoretical  
Biology & Bioinformatics,  
Utrecht University)

# ***Host-pathogen co-evolution from an immuno-epidemiological perspective***

The evolution of host-pathogen interactions is an active research area in the complexity field. Questions in this field have mainly been addressed from an epidemiological point of view, assuming that pathogens evolve in a homogeneous population of hosts. However, a hallmark of the immune system is that hosts differ genetically, and mount different immune responses even to the same pathogen. Therefore, pathogens evolve in highly heterogeneous host populations, and in each newly infected host a pathogen has to cope with immune responses that differ from the responses that it has learned to cope with in previous hosts. We argue that this will have important implications for host-pathogen coevolution, in particular the balance between virulence (i.e., pathogen-induced damage to the host) and transmission. We hope to shed new light on questions as to why some pathogens induce acute infections that are cleared in several days (e.g. influenza A), while others lead to long-lasting chronic infections (e.g. HIV). We take an interdisciplinary approach linking immunological and epidemiological modeling of host-pathogen co-evolution, using an agent-based approach. These models track the immune response of each host, the evolution of the pathogen quasi-species within that host, and the evolutionary dynamics on the population level. Focusing on data from HIV and influenza A infections, we will build models that are simple but nevertheless operate in a realistic parameter regime both at the immunological and epidemiological level. Our new approach to study host-pathogen evolution is expected to produce results that differ markedly from earlier epidemiological studies.



Project leader     Dr. Niels Cornelisse (VU University and VU medical center)

Researchers:     Prof. dr. Danielle Posthuma (VU and VU Medical Center and Erasmus University Rotterdam)

Prof. dr. Tom Heskes (Radboud University Nijmegen)

Prof. dr. Matthijs Verhage (VU University and VU medical center)

Budget :            47.000 Euro

Partners:           Synaptologics BV

# ***Identification of synaptic gene networks in complex brain disorders using a Bayesian framework***

Brain disorders are one of the most pressing health problems in today's western society. Despite the fact that most brain disorders are highly heritable it has been difficult to identify gene defects causing the disease. Most likely the expected complexity of these diseases, involving interactions between very many genes, hampered the identification of disease genes so far. In this project we want to improve standard methods for identification of disease genes using Bayesian statistics. Bayesian approaches have been very successful applied to other complex problems like weather forecasting, stock market analysis and traffic prediction. Here we will use a similar approach to map the gene networks in synapses, small dynamic units in the brain of about  $1 \mu\text{m}^3$  in size, which are critical for information processing. Synaptic dysfunction is currently implicated in a wide range of neurological and psychiatric disorders, including neurodegenerative diseases, depression, and mental retardation. If we have a good view on how gene networks in synapses are organized we will use again Bayesian statistics to investigate how genes in this network differ between patients and healthy persons, pointing to potential disease genes. On the long run, this must pave the way for new rational therapeutic strategies, exploiting the predictive power of a probabilistic network description.



Project leader: Prof. dr. ir. Henk Dijkstra  
(Utrecht University)

Researchers: Dr. ir. Fred Wubs (RUG)

Budget : 450.000 Euro

Partners: E. Simonnet (INLN, Fr)

T. Sapsis (MIT, USA)

S. Pierini (U Naples, It)

# ***PREdictability of KURoshio current path transitionS***

The Kuroshio Current near the Japanese coast in the North Pacific Ocean undergoes decadal time scale transitions between different paths. The aim of this project is to assess the predictability of these path transitions and to determine the effects of the large-scale (equivalent) barotropic instabilities, meso-scale eddies and wind-stress variations on this predictability. In the project we will use a combination of direct numerical simulation, stochastic parameterization of the effects of meso-scale eddies, techniques from the theory of random dynamical systems and data-assimilation methods to analyse the flows in one- and two-layer shallow water models of the Kuroshio Current. Ensemble methods will be used to investigate the predictability of the Kuroshio path transitions, including a study of the impact of specific observations, in deterministic and stochastic models.



Project leader:

Prof. dr. Arjen Doelman  
(Leiden University)

Prof. dr. Max Rietkerk  
(Utrecht University)

Dr. Jens Rademacher (CWI)

Researchers:

Koen Siteur (Utrecht  
University)

Eric Siero (Leiden  
University)

Budget :

460.026 Euro

# ***Critical Transitions and Early-warning Signals in Spatial Ecosystems***

Understanding and predicting critical transitions is one of the central challenges within the field of 'Complexity'. These sudden shifts are exhibited by many complex systems and typically occur as the system passes through a critical threshold. Especially relevant is the question whether the shift can be predicted before this threshold is reached. This is a subtle issue, as even close to such threshold, the complex system in general does not exhibit obvious indications of the approaching transition. This research project concerns the understanding and prediction of sudden shifts in spatially extended systems, specifically the catastrophic transition of desertification in (semi-)arid ecosystems. A crucial property of such systems is their ability to respond to changes in the environment by adapting the spatial structure; in the case of desertification: the nature of the vegetation pattern. Based on recent advances in field studies, ecological modeling and mathematical methods, a novel approach will be followed by which it is possible to unravel the response of spatial ecosystems to changes in the environment. The aim is to isolate mechanisms by which patterned states may destabilize and initiate a critical transition in response to a (slowly) varying environment, to identify characteristic indicators for these mechanisms, and to analyze the predictive power of these early-warning signals.



Project leader: Prof. dr. Jan van Esch (TU Delft)

Researchers: Ir. Ralph. Bosmans (TU Eindhoven)  
Prof. dr. Luc Brunsveld (TU Eindhoven)

Dr. Ger Koper (TU Delft)

Dr. Rienk Eelkema (TU Delft)

Prof. Dr. Signe Kjelstrup (TU Delft)

Budget : 498.000 Euro

Partners: TU Delft, TU Eindhoven

# ***Coupling of self-assembly and metabolism in protocells***

It is the aim of this project to develop a self-organizing system relevant to the prebiotic emergence of protocells that shows how feedback loops triggered by molecular assembly can lead to macroscopic self-organization and compartmentalization of metabolic pathways. To this extent we propose to develop a prototype system in which the autocatalytic formation of lipid bilayer membranes is exploited to trigger the catalytic activity of membrane-bound enzyme, thereby connecting chemical reaction networks and self-assembly events.

Key objectives are: - to develop a molecular system where membrane formation leads to activation of an enzymatic pathway, which in turn has either a positive or a negative influence on the initial membrane formation. - to develop a molecular system where membrane formation leads to activation of an enzymatic pathway, which in turn can catalyze a second self-assembly process, leading to compartmentalization or addressing of a second enzymatic pathway or feedback loop. - to develop a general model for the interplay of these processes, which can answer the following questions: What are the minimal components or boundary conditions for the emergence of self-organization? How robust are these self-organizing systems, i.e. are they self-correcting, are they likely to emerge, or even inevitable? The approaches described here provide a rational way towards increasingly complex and connected autopoietic vesicular systems and chemical reaction networks, which eventually might lead to self-organization in artificial protocells. Moreover, this research will enable the extension of current gene-based protocells in static confinements towards dynamic compartmentalization, thereby encoding autopoietic protocells with genetic information.



Project leader: Prof. dr. Koen Frenken (School of Innovation Sciences, Eindhoven University of Technology)

Researchers: Prof. dr. Pauline Hogeweg (Theoretical Biology, Utrecht University)

Prof. dr. Sander Tans (AMOLF)

Budget : 500.000 Euro

# ***The emergence of self-regulating systems under variable environments***

Complex systems are systems that contain many interacting components. The components function interdependently. This means that a change in one component can have positive or negative effects in other components. That is why it is so hard to improve the overall functioning of a complex system.

This principle underlying complex systems is a general principle that applies to different real-world systems. Our project looks at two of such systems. The first system is living organisms. The functioning of an organism depends to a large extent of the particular set of genes that regulate the behavior of an organism. Here, the genes are the components and the living organism is the system. The interdependencies between the components in the system stem from the fact that genes function interdependently. Through a mutation in a genes, a gene alters the functioning of the gene in the system and – through the interdependencies – also the functioning of other genes. Natural selection will favor those sets of genes that function collectively in a coherent way, in the sense that genes mutually reinforce each other's functioning.

The second type of systems we want to look at, are technological artifacts (like cars, planes, etc). Artifacts contain many different technological components that interact in very specific ways. Just as for organisms, the interdependencies between the components in the artifact imply that a change in one component (through technological innovation) may improve the functioning of this part of the technology, but typically creates malfunctioning in other parts of the technology.

The project aims to build computer simulation models of complex organisms and complex artifacts as to understand the precise mechanisms underlying their evolution. One particular interest of the project is to understand the advantages of flexible systems that can regulate their functioning depending on the state of their environment. In biology, such flexible systems would be organisms that can survive in different selection environments. In the case of technology, such systems would be technologies that can be used for different purposes. We will also test our simulation models using empirical data. In the case of organisms, we will do this using experiments where we can let populations of organisms evolve under lab conditions. In the case of technologies, we will make use of historical data on aircraft designs that have been invented over the past 100 years.



Project leader: Prof. dr. Leo Kroon (Erasmus University Rotterdam)

Researchers: Prof. dr. mr. Peter Vervest (Erasmus University Rotterdam)

Dr. Ting Li (Erasmus University Rotterdam)

Dr. Gabor Maroti (Erasmus University Rotterdam)

Evelien van der Hurk MSc (Erasmus University Rotterdam)

PhD. student N.N.

Budget : 450.000 Euro

# ***Complexity in Public Transport: passenger behaviour and system optimization***

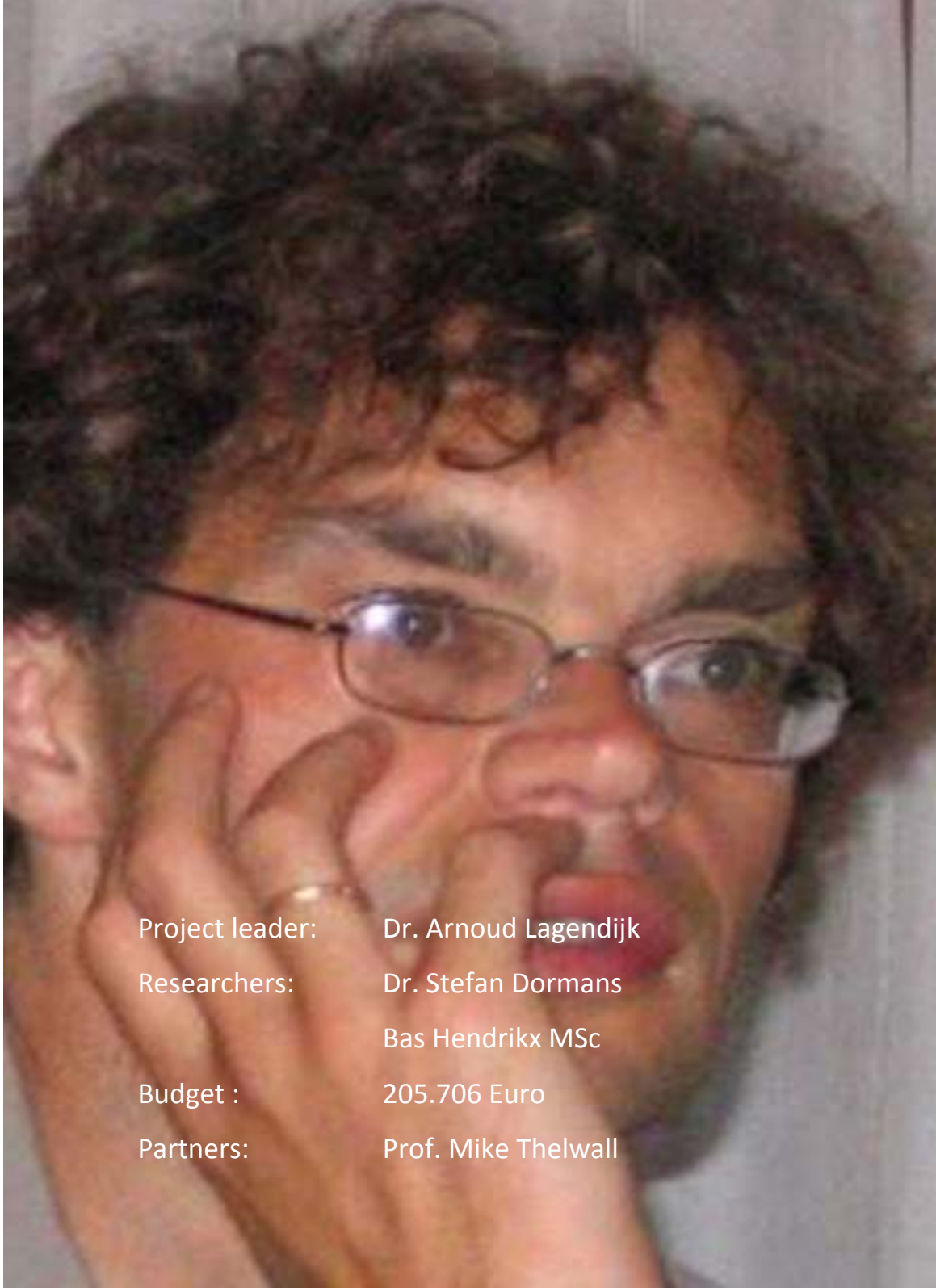
This research project studies the complexity of passenger behaviour in public transport, especially the passengers' sensitivity to strategic modifications and to real-time disturbances of the public transport system. It also examines how the resulting understanding can be used to achieve win-win results for the passengers and for the Public Transport Operators (PTOs). This research project will be enabled by the availability of data from smart cards and cell phones, which provides opportunities to understand passenger behaviour in public transport in far more precision than was previously possible.

For the planning stage, this project aims to understand the sensitivity of passengers to strategic modifications in frequencies, capacities, and tariffs of the public transport system. This understanding may be used to seduce passengers to travel outside the peak hours or along less busy routes. As a consequence, for the PTOs a more efficient allocation of rolling stock will be enabled. For disturbed real-time operations, this project aims to understand the reactions of the passengers to disruptions, and also how these reactions can be influenced by providing adequate, possibly more individualized, travel information. This will allow the PTOs to improve their services during disruptions.

This research project is carried out in three steps:

1. First, a detailed insight into passenger behaviour in public transport is obtained by analyzing and combining real-life datasets, such as smart card data and cell phone data.
2. Second, simulation models are applied to combine individual passenger behaviour into forecasted aggregated passenger flows.
3. Third, mathematical optimization models are developed for revenue management and disruption management, where passenger behaviour is incorporated effectively.

This multi-disciplinary research project is carried out by the Rotterdam School of Management of Erasmus University (RSM/EUR) together with NS and RET. It builds upon previous joint research of RSM/EUR and NS on revenue management and on mathematical system optimization.



Project leader: Dr. Arnoud Lagendijk  
Researchers: Dr. Stefan Dormans  
Bas Hendrikx MSc  
Budget : 205.706 Euro  
Partners: Prof. Mike Thelwall

# ***Food for thought and thought for food: the local-global entanglement of the Slow Food movement***

Since its establishment in Italy in 1989, The 'Slow Food'-movement has evolved into a significant global social movement promoting sustainable, local and high quality food production and consumption. Across the globe, local chapters of the movement, so-called *convivia*, have proliferated promoting a wide diversity of 'slow food' ideas and practices. Over the years, this 'grassroots' organisation has acquired a stable global presence and identity, without having strong central coordinating mechanisms. This project focuses on the development and diffusion of the Slow Food Movement and aims to understand its global identity.

One of the main drivers behind the success of the movement is its diversity. Starting out as a campaign against Fast Food, the movement now encapsulates a wide range of food-related topics. In some places the focus is on small-scale, local food production, while other places focus primarily on organic farming. Many of the *convivia* revolve around the cooking and eating of pure and untreated food, while the movement as a whole also engages with wider debates on biodiversity, alternative economies and food safety.

To explore the complex network of the movement as well as in its constituent parts, this project uses a threefold network-approach. Firstly, we investigate websites of *convivia* and the way these articulate certain ideas and practices and how they link to other related websites. Secondly, we map the most important discourses and events (like international conferences, important publications, etc.). Finally, we study the movement's grassroots in selected local sites. Using a combination of GIS, network and web analysis, discursive analysis, and ethnography, we trace the various groups, networks, and factors that impact upon the development of the Slow Food movement. In addition, the project engages with the movement exploring the scope for further developing grassroots identities within a global setting. Eventually, the project aims to develop its network approach in such a way that it can be used to analyse more complex global phenomena.



Project leader: Prof. Johanna Meijer (Leiden University)  
Prof. C.C.A.M. Gielen (Radboud University  
Nijmegen)

Researchers: Dr. J. Rohling (Leiden University)  
Dr. M. Zeitler(Radboud University  
Nijmegen)

Budget : 415.270 Euro

# ***The neuronal network organization of the biological clock***

Twenty-four hour rhythms are an essential property of many living organisms, and arise from an internal circadian clock. In mammals, this clock resides in the suprachiasmatic nucleus (SCN), a tiny structure of 20,000 neurons at the base of the brain. This nucleus generates intrinsic circadian rhythms which are transmitted to other parts of the central nervous system. As a consequence, many behavioral, biochemical and physiological events show daily fluctuations. While circadian rhythms parallel the rotation of the earth, seasonal rhythms follow the earth revolution around the sun. Both classes of rhythms have developed as an adaptation to the considerable changes in the environment, and interestingly, both are controlled by the SCN.

Although it is clear that the SCN clock is comprised of many individual oscillatory neurons, it is not clear how these neurons communicate and synchronize to one another, or how they respond to environmental light input. With state-of-the-art methods we will study how interacting neuronal populations within the clock adapt to the environmental light cycle and to changes in day length. The experimental findings will be incorporated in a multi-oscillator computational model of the circadian clock. Using this combined approach we will elucidate how system level properties of the circadian system emerge from a multitude of coupled circadian oscillators. We aim to show not only *that* new properties emerge at multiple levels of organization, but also *how* they emerge from interactions between oscillating units.



Project leader: Dr. Arjen van Ooyen (VU University Amsterdam)

Researchers: Dr. Jeroen Geurts (VU Medical Center)  
Dr. Markus Butz (VU University Amsterdam)

Budget : 443.648 Euro

# ***Stability and rewiring in adaptive neuronal networks***

Structurally, networks consist of nodes connected by links, with the pattern of links defined as the topology of the network. Functionally, nodes interact dynamically with each other. The topology of the network thereby strongly influences the dynamics, and often needs to be precisely tuned for the network to function properly. A central question is how a network reaches and stays in this tuned state. In most networks, new links may be formed and others broken as a function of the dynamics on the network. This gives rise to complex reciprocal interactions, with topology influencing dynamics and dynamics affecting topology. Our hypothesis is that this reciprocity plays a central role in the self-organization and stability of networks. We will study this general hypothesis in neuronal networks, in which nodes are neurons and links synaptic connections between neurons. For proper network function, synaptic connectivity should be precisely tuned. However, synaptic connections also continuously change. An intriguing question therefore is how specific function and connectivity emerges in developing neuronal networks and how it is maintained in the face of ongoing plasticity. Many processes involved in the formation of synaptic connections are dependent on the neuron's level of activity. A reciprocal interaction therefore exists between network activity and connectivity. In novel neuronal network models that, unlike existing models, have a dynamical structure, we study how this reciprocity determines the self-organization and stability of neuronal networks. These findings will be applied to shed light onto the poorly understood network degeneration in multiple sclerosis brains.



Project leader: Prof. dr. Mark Peletier (Department of Mathematics & Institute for Complex Molecular Systems, Technical University of Eindhoven)

Researchers: Prof. dr. Marc Geers (Department of Mechanical Engineering, TU/e)

Dr. Sc. Nat. Markus Hütter (Department of Mechanical Engineering, TU/e)

Dr. Adrian Muntean (Department of Mathematics & Institute for Complex Molecular Systems, TU/e)

Dr. Ron Peerlings (Department of Mechanical Engineering, TU/e)

Budget : 446.390 Euro

Partners: Prof. Oettinger (ETH)

Mielke (Berlin)

Groma (Budapest)

Zaiser (Edinburgh)

# ***Correlating fluctuations across the scales***

This project focuses on a scientific challenge that is pivotal for many complex systems: the emergence of large-scale features and slow dynamics from microscopic complex behaviour.

Classical averaging techniques tend to fail for systems with complex spatiotemporal behaviour, because they disregard essential information present in the fluctuations of the system. Large-scale emergent features arise from correlations in the fine-scale fluctuations in space and time, and a successful coarse-graining method must capture this microscopic order and propagate it up the scales.

We will develop new concepts and methods to address this challenge, and apply them to the specific example of dislocation networks that are at the origin of plastic deformation in metals. We will do this by leveraging recent developments in coarse-graining, in the form of generalized gradient flows and the framework of the General Equation for the Non-Equilibrium Reversible-Irreversible Coupling. While the former is rigorous and mathematical in nature, the latter is rooted in physics and based on non-equilibrium statistical mechanics.

Using these two frameworks we will approach the central issue both from a rigorous and from a physics-based perspective, allowing us to benefit from the advantages of each as well as from their mutual interaction. It is to be expected that this strategy will clarify the link between both methodologies, lead to a more profound understanding of existing and emerging Ansatzes, and establish for the first time a truly coarse-grained metal plasticity model devoid of phenomenological assumptions.



Project leader: Prof. dr. Peter de Ruiter (Wageningen University)

Prof. dr. Hans Heesterbeek (Utrecht University)

Researchers: Cassandra van Altena,  
Sanja Selakovic

Budget : 468.026 Euro

Partners: Prof. Dr. Han Olff  
Prof. Dr. Andy Dobson  
Prof. Dr. Wim van der Putten  
Prof. Dr. Wayne Getz

# ***Complexity and stability in food webs: the role of nutritional quality and infectious disease agents***

Food webs bring structure to the ecosystems of our planet by disentangling the complex networks of feeding relations between species ('who eats whom'). Understanding how stability emerges from complexity in such trophic networks, how robust these networks are, and what the consequences are for biodiversity and energy flow in ecosystems, touches on the most central problems in ecology.

Until now food web theory is based on predator-prey interactions defined as 'material' flows from resources to consumers. This proposal challenges this approach in two ways. The first is that feeding is more than the one-dimensional variable 'energy' that a consumer gains by eating a resource, but also regards the nutritional composition (quality) of the food in relation to the consumer's requirements. The second is that feeding can be the carrier of infectious diseases caused by parasites and pathogens. Both aspects influence the dynamics of the populations in fundamental ways and thereby food web complexity, patterns of interaction strengths, and ultimately, stability.

The project will bring together for the first time the disciplines food web ecology, ecological stoichiometry, epidemiology, and mathematical biology. In our new approach, trophic interactions are treated as the 'carrier' for the parallel transfer and spread of nutrients and infectious agents through networks. We start our approach firmly on empirical ground—using detailed data from 250 belowground food webs from the Netherlands and from three carnivore-herbivore ecosystems in Africa—and then go beyond these specific systems aiming to bridge important gaps between current ecological theory and real food webs.



Project leader: Dr. Peter Schall (University of Amsterdam)

Researchers: Daniel Miedema (PhD)

Prof. dr. Bernard Nienhuis (University of Amsterdam)

Budget : 407.000 Euro


Partners: Prof. dr. Gijsje Koenderink (AMOLF)

Prof. Giulio Biroli (Saclay)

Prof. Frans Spaepen (Harvard)

# ***Complex Dynamic Arrest: A novel Phase Transition in Space-Time***

Dynamic arrest is a central phenomenon in complex systems across biology, geology, material science, transport, traffic, etc. It is an essential observation that with increasing density or interaction of the system's constituent units, their motion slows down dramatically, and the system finally comes to a stand still. While for many systems in nature, the dynamic arrest is beneficial as it gives rise to stability and memory (as e.g. in genetics), in other cases such as traffic and transport, this effect is rather detrimental. A unified understanding of this important phenomenon, however, seems far out reach. In particular, it has not been established if this dynamic transition is analogous to equilibrium phase transitions with their accompanying singularities in thermodynamic quantities. Recently, two different approaches have been developed, which aim to use the tools of equilibrium phase transition to complex, dynamic and non-equilibrium phenomena. One of them is based on the use of multi-point correlation functions and the other on the idea that apparent dynamic transitions indicate the proximity of a real phase transition in a larger parameter space. We will combine these two approaches, and apply these concepts to a range of systems from biology, via materials science to traffic and transport to investigate a universal description of complex dynamic arrest. Using an efficient combination of experiments, simulations, and databases, we address a broad range of systems, and we will explore the definition of dynamic critical exponents and dynamic universality classes, in analogy to equilibrium phase transitions. The broad range of systems will put us in a particularly strong position to test recent revolutionary ideas to understand dynamic arrest as a phase transition in four-dimensional space-time. Our results will elucidate universal aspects of complex dynamics in an interdisciplinary context.

A portrait of Prof. dr. Cars Hommes, a man with grey hair and a mustache, wearing a light blue striped shirt. The background is a blurred industrial or laboratory setting.

Project leader: Prof. dr. Cars Hommes (University of Amsterdam)

Researchers: Dr. Cees Diks  
Dr. Marco van der Leij  
Daan in't Veld MSc

Budget : 434.401 Euro

Partners: DNB

- Dr. Wilko Bolt
- Dr. Maria Demertzis
- Prof. dr. Job Swank
- Dr. Maarten van Oordt
- Dr. Chen Zhou
- Dr. Iman van Lelyveld

# ***Understanding financial instability through complex systems***

The macroeconomic models used by central banks for monetary policy and economic forecasting do not perform well in extreme circumstances, as has become evident during the global financial-economic crisis in recent years. The president of the European Central Bank Jean Claude Trichet stated on November 18, 2010: “In the face of the crisis, we felt abandoned by conventional tools”, and went on to call for the development of complex systems based approaches to improve our understanding of the economy. Traditional models are centered around the benchmark representative rational agent model with a unique stable equilibrium. In contrast, the present research project focuses on the interactions of many heterogeneous, boundedly rational agents with limited knowledge and abilities, and the resulting global dynamic behaviour of the economy.

By considering the macro-economy and global financial markets as a *complex* system, new means arise to describe sudden changes in the dynamic behavior, such as market crashes and economic decline. Economic and financial crises may then be understood as the outcomes of critical transitions from a “good” equilibrium to a “bad” equilibrium, triggered by small external shocks, amplified by positive feedback and nonlinear effects, finally leading to big changes in the economy. Such sudden regime shifts are absent in the conventional models, but typical of complex systems, and have important implications for economic policy and crisis management.

An ambitious goal of the project is to build a “realistic” agent-based model of the financial-economic crisis and, for example, study how financial networks affect the stability, fragility and resilience of financial markets and the macro economy, and how financial institutions (e.g. market regulations) contribute to economic (in)stability. Another challenge is to use time series methods to build early warning systems of financial crises and combine these methods with behavioral agent-based models for a better understanding of economic crises. An improved understanding of the current and earlier crises may contribute to a new pro-active, instead of reactive, economic and monetary policy to maintain economic stability and help prevent future crises.



