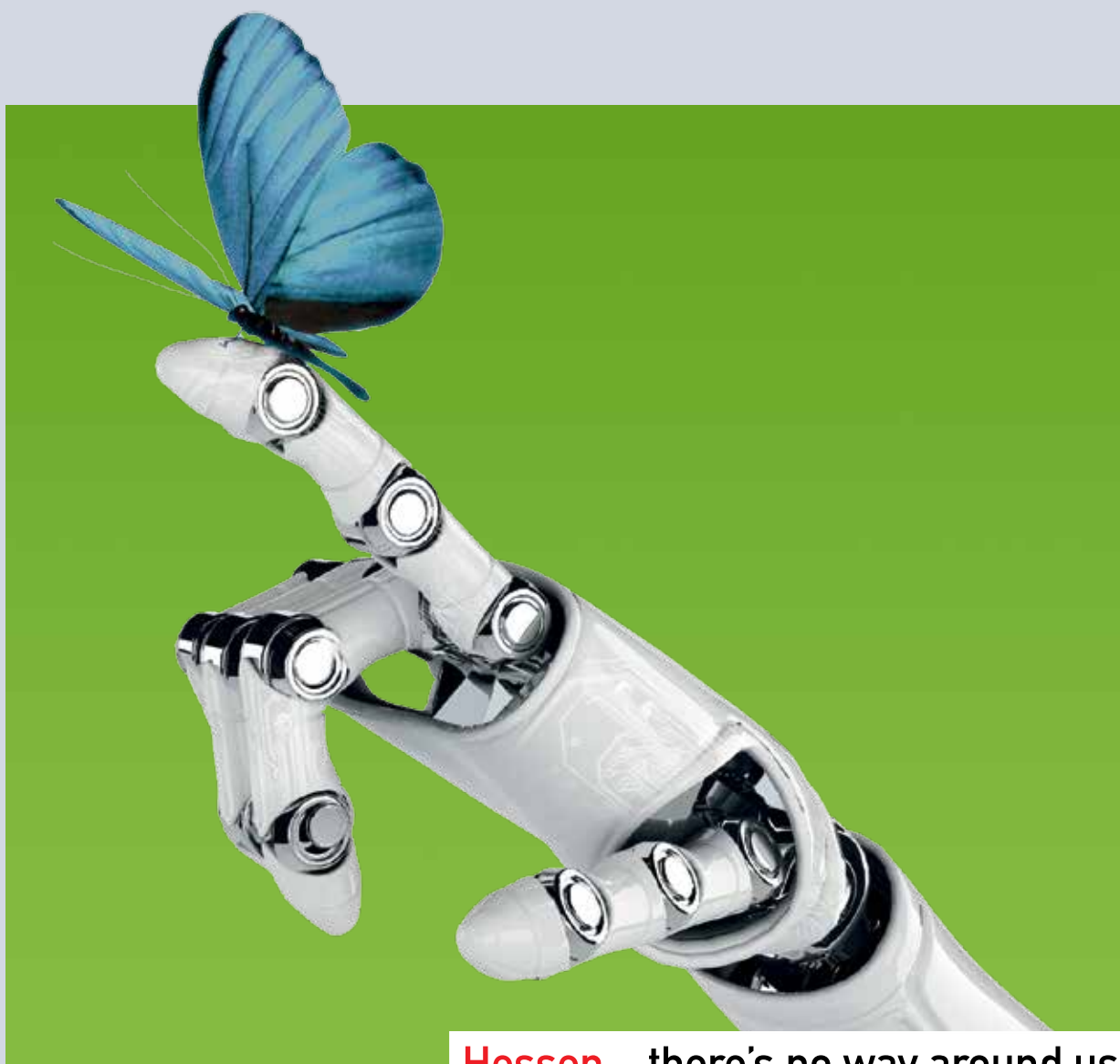




# Competence Atlas Biomimetics in Hessen



**Hessen** – there's no way around us.

# Imprint

## Competence Atlas Biomimetics in Hessen

**Publication Series of the Technologieline Hessen-Nanotech  
of the Ministry of Economics, Energy, Transport  
and Regional Development – State of Hessen**

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# Contents

<b>Preface .....</b>	<b>4</b>
<b>Introduction .....</b>	<b>5</b>
<b>1. Biomimetics .....</b>	<b>6</b>
1.1 Principles.....	6
1.2 Innovation potential of biomimetics.....	8
1.3 Biomimetics landscape in Hessen .....	8
1.4 Application of biomimetics in companies.....	12
<b>2. Competence matrix .....</b>	<b>13</b>
<b>3. Competence profiles biomimetics in Hessen .....</b>	<b>16</b>
<b>4. Network and organisations.....</b>	<b>38</b>
4.1 Regional networks.....	38
4.2 Inter-regional networks .....	40
4.3 International networks .....	41
<b>5. Funding programmes.....</b>	<b>42</b>
5.1 Competition in biomimetics .....	42
5.2 Funding programmes in Hessen .....	42
5.3 Funding programmes in Germany .....	43
5.4 Horizont 2020 - Framework programme of the European Union .....	45
5.5 Foundations .....	47
5.6 Contact partner funding programmes .....	47
<b>6. Training programmes .....</b>	<b>48</b>
6.1 Non-academic education programmes in Hessen .....	48
6.2 Study options .....	50
<b>7. Literature .....</b>	<b>51</b>
<b>Appendix .....</b>	<b>52</b>

## Foreword



Our environment is constantly changing, and nature is likewise constantly adapting itself to new conditions. Four billion years of evolution have come up with many fascinating solutions. Biomimetics sets out to make use of these for the technological challenges of our times.

Biomimetics uses nature as a model for inventions, for the development of new materials and for the efficient use of resources. Since technologies based on biomimetics are – in both senses of the expression – in harmony with nature, they form the basis for sustainable future concepts. To turn this into reality, we will need innovative products, processes and services.

The best-known examples of biomimetics are the Velcro and the Lotus Effect®. But we also have biomimetics to thank for the winglets at aircraft wing tips, which owe their shape to the spread wings of a bird and help to reduce fuel consumption. These biomimetic solutions show the potential offered by nature for resource efficiency and environmental protection.

Mobilising this potential requires an active exchange between science and industry. The Competence Atlas Biomimetics in Hessen makes a contribution here. It was developed as part of the activities initiated by our Technologieline Hessen-Nanotech for the setting up of the Hessian biomimetics network. The Atlas gives an overview of companies and institutions in Hessen which are engaged in various areas of biomimetics. It offers guidance on contacts and funding opportunities, and supports the successful networking of all parties involved. I wish you enjoyable and stimulating reading.

A handwritten signature in black ink, reading "Tarek Al-Wazir".

**Tarek Al-Wazir**

Minister for Economics, Energy, Transport and  
Regional Development – State of Hessen

# Introduction

This Competence Atlas gives an overview of the current biomimetics projects of companies and institutions in Hessen and presents them in clear and concise profiles. A comprehensive competence matrix relates the projects to the topics that had emerged as key issues during the survey of the Bionik-Netzwerk Hessen in 2013. This Competence Atlas includes general information on biomimetics, possible applications, innovation potentials for companies and current funding opportunities, together with an overview of networking initiatives, training and study programmes and a literature list for all persons interested.

**Biomimetics is a source of new technical solutions. More and more companies are beginning to realise its potential and to use it for generating new ideas.**

About 20 companies, universities and institutions are at present listed with competence profiles. The Competence Atlas includes only those which have carried out, or participated in, specific developments in the field of biomimetics. The Competence Atlas does not extend to companies, universities or institutions which, despite their potential for, or interest in, biomimetic developments, have not been involved up to now in their practical implementation.

The list is not final – more key players are expected to join in, not least due to the current biomimetics activities of the Technologieline Hessen-Nanotech and the Bionik-Netzwerk Hessen.

The initiation of the Bionik-Netzwerk Hessen provides an opportunity to increase the number of biomimetics projects in Hessen. The topic attracts many interested parties who attend events and discussions in order to inform themselves about biomimetics.

Technical solutions are of importance primarily for manufacturing companies and for research institutes with an interdisciplinary approach. The Competence Atlas also includes service providers who can offer valuable assistance in the process of biomimetics development.



The Atlas additionally provides brief descriptions of networks and organisations making useful contributions to the development of biomimetics and the coordination of activities. Information on relevant funding programmes and contacts, a list of biomimetics training programmes in Hessen, current study programmes and a general literature list round off the Competence Atlas.

**The competence profiles can also be viewed on the portal [www.kompetenzatlas-hessen.de](http://www.kompetenzatlas-hessen.de) under the technology field "Biomimetics". Companies and institutions can register on their own initiative in the database and, by doing so, receive support from the office of the Bionik-Netzwerk Hessen.**

It is hoped that the Atlas will lead to closer networking of key players and help to initiate new projects, products, processes and services in the area of biomimetics.



# 1 Biomimetics



## 1.1 Principles

Biomimetics (also known as "bionics") is concerned with the use of animals and plants as a source of inspiration for the development of technical products and processes. The Velcro fastener was based on the burrs of burdock plants, and the shape of aircraft wings was copied from birds' wings. There are dirt-repellent paints which were developed out of studies of plant surfaces, and reusable adhesive tapes which were modelled on the foot of the gecko. The many different examples and ideas for biomimetic applications show the potential opened up by this branch of science for the development of innovative products.

However, the transfer process from nature to technology is more than just copying natural forms and structures. For a technical development to be biomimetic in the real sense, the biological model must undergo a process of abstraction. The model is analysed and investigated from the technical angle. Biomimetics comes about when the basic physical, chemical or material-related principles revealed by such investigations are applied to technical products and processes.

The Association of German Engineers defines biomimetics as follows:

**"Biomimetics combines the disciplines of biology and technology for the purpose of solving technical problems by abstracting, transferring and applying the knowledge obtained from biological models."**

(Source: VDI 6220 Bionik – Konzeption und Strategie – Abgrenzung zwischen bionischen und konventionellen Verfahren/Produkten [Part 1: Biomimetics - Conception and strategy - Differences between biomimetic and conventional methods/products]. Berlin: Beuth Verlag, 2012.





## There are two fundamental approaches in biomimetics:

### Bottom-up Principle

A particular characteristic of a biological model gives a scientist or engineer an idea for a new development. However, if the project is to be realised at all, there must first be a notional association between the discovered characteristic and a potential technical application. Examples of this approach are the Lotus Effect® and the Gecko Tape®. Both products are based on knowledge gained in basic biological research. The degree of innovation in such projects is often very high.

### Top-down Principle

Developers carry out a specific search for suitable biological models in nature with the aim of improving a technical artefact. To this end, they precisely define the function of the artefact which they wish to improve and then search the plant and animal worlds for similar functions. An example of this approach is the development of tyres with a better braking effect, based on the model of a cat's paw.

The first step in both cases is a search for analogies – in other words, for similarities between nature and technology. The next step is to carry out a precise analysis of potentially suitable biological systems and to test the possibilities for applying the principles to the technology. Close collaboration between scientists and engineers is essential if this process is to be successful. Here lies one of the great challenges of biomimetics – but at the same time one which opens up unusual opportunities: experts move beyond the limits of their particular disciplines, they come into contact with experts from completely different areas and solve their problems in interdisciplinary teams.

If such collaboration is to succeed, all parties concerned – the technical research and development departments as well as the scientists – must express their knowledge and ideas in a language understood by both sides. It is this which often makes biomimetics such a vivid and fascinating subject even for outsiders.



## 1.2 Innovation potential of biomimetics

This interdisciplinary approach opens up an enormous potential for the creativity process and for future innovations. Project teams can work out completely new and unexpected solutions that would not have been achieved from the purely technical angle.

Biology provides excellent solutions since organisms have had millions of years in which to evolve. In nature, the species which successfully survive are those which are best adapted to their particular habitats. Since the requirements differ greatly and are partly subject to change, they lead to the development of optimised shapes, structures, materials and strategies.

The technical implementation of these principles opens up new opportunities and solutions in many fields of application, such as

- Materials and structures
- Shape and design
- Engineering and devices
- Construction and air-conditioning
- Robotics and locomotion
- Sensors and neural control
- Anthro- and biomedical technology
- Methods and processes
- Evolution and optimisation
- System and organisation

Source: Nachtigall, W.: Bionik: Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler [Biomimetics: Principles and examples for engineers and scientists]. 2nd Edition. Heidelberg: Springer Verlag, 2002

Especially exciting for the technology of the future are the superordinate principles of nature, which can teach us things such as

- Resource and energy efficiency
- Multi-functionality
- Self-organisation, self-healing and self-cleaning works

## 1.3 The biomimetics landscape in Hessen

The areas covered by the biomimetics projects conducted up to now in Hessen are just as variegated as the interdisciplinary and heterogeneous nature of biomimetics itself.

The projects and areas of interest reflect the issues that are particularly relevant to technical and social developments in the region. The following issues have been defined as biomimetic themes and spheres of competence:

### Materials:

- Surfaces/boundaries
- Molecular biomimetics/nanomaterials

### Movement:

- Adaptronics
- Aerodynamics/fluid dynamics (swimming/flying)
- Optimisation
- Automation
- Robotics/mechatronics
- Sensor technology/communication

### Engineering:

- Lightweight construction
- Optimisation (CAO/SKO)
- Architecture/construction/planning
- Design/shape
- Folding

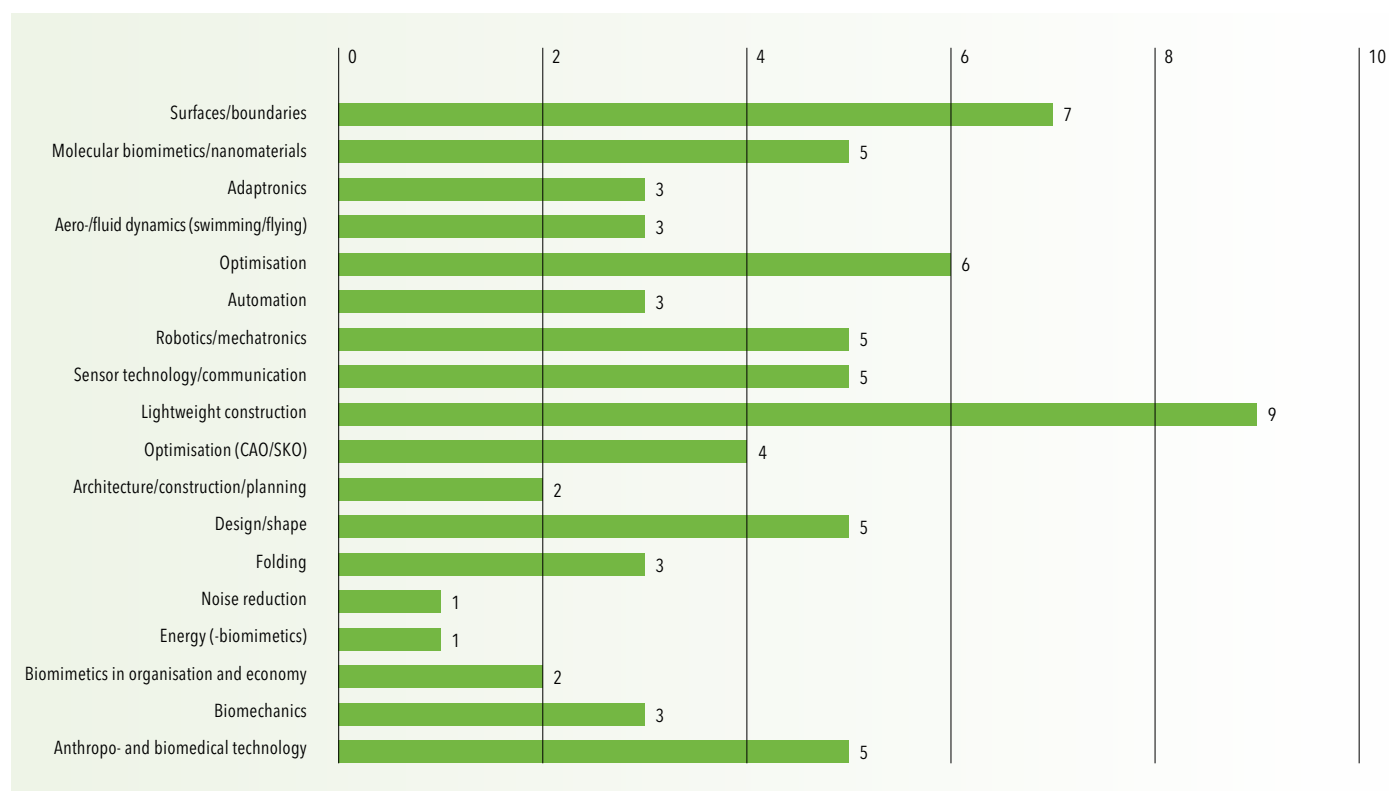
### Others:

- Noise reduction
- Energy (biomimetics)
- Anthro- and biomedical technology
- Biomimetics in organisation and economy
- Biomechanics

In 2013, a survey was conducted to identify key players in the field of biomimetics in Hessen. The underlying data for this were provided by Internet searches and supplemented by contact data from the Bionik-Netzwerk Hessen and the event series "bionics@work". The companies and institutions interested in being included in the Competence Atlas drew up competence profiles presenting the core areas of the biomimetic themes in Hessen.



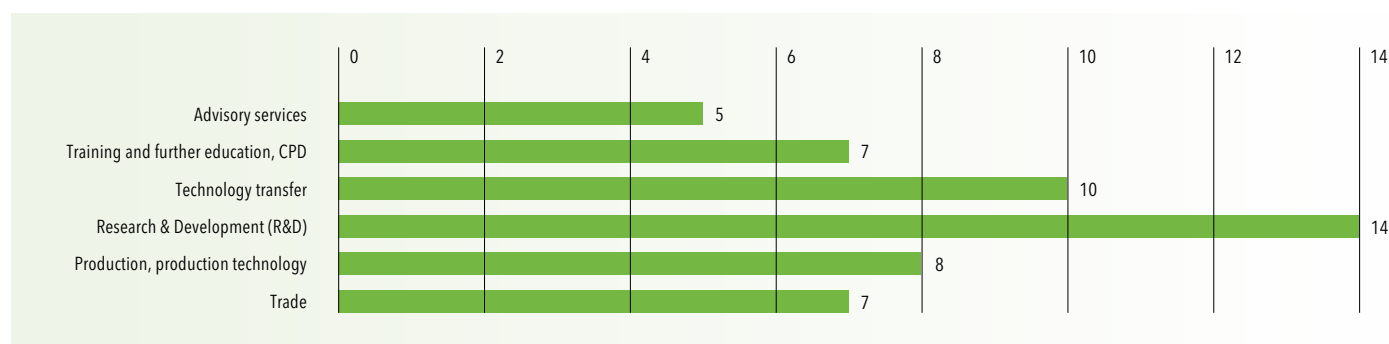
### Number of Hessian companies and institutions listed by particular biomimetic themes (including double entries)



The projects and products listed are invariably associated with several spheres of competence. Hessen concentrates largely on lightweight construction and optimisation, surfaces and boundaries, robotics and

sensor technology, design and shaping as well as anthropo- and bio-medical technology (see Figure above).

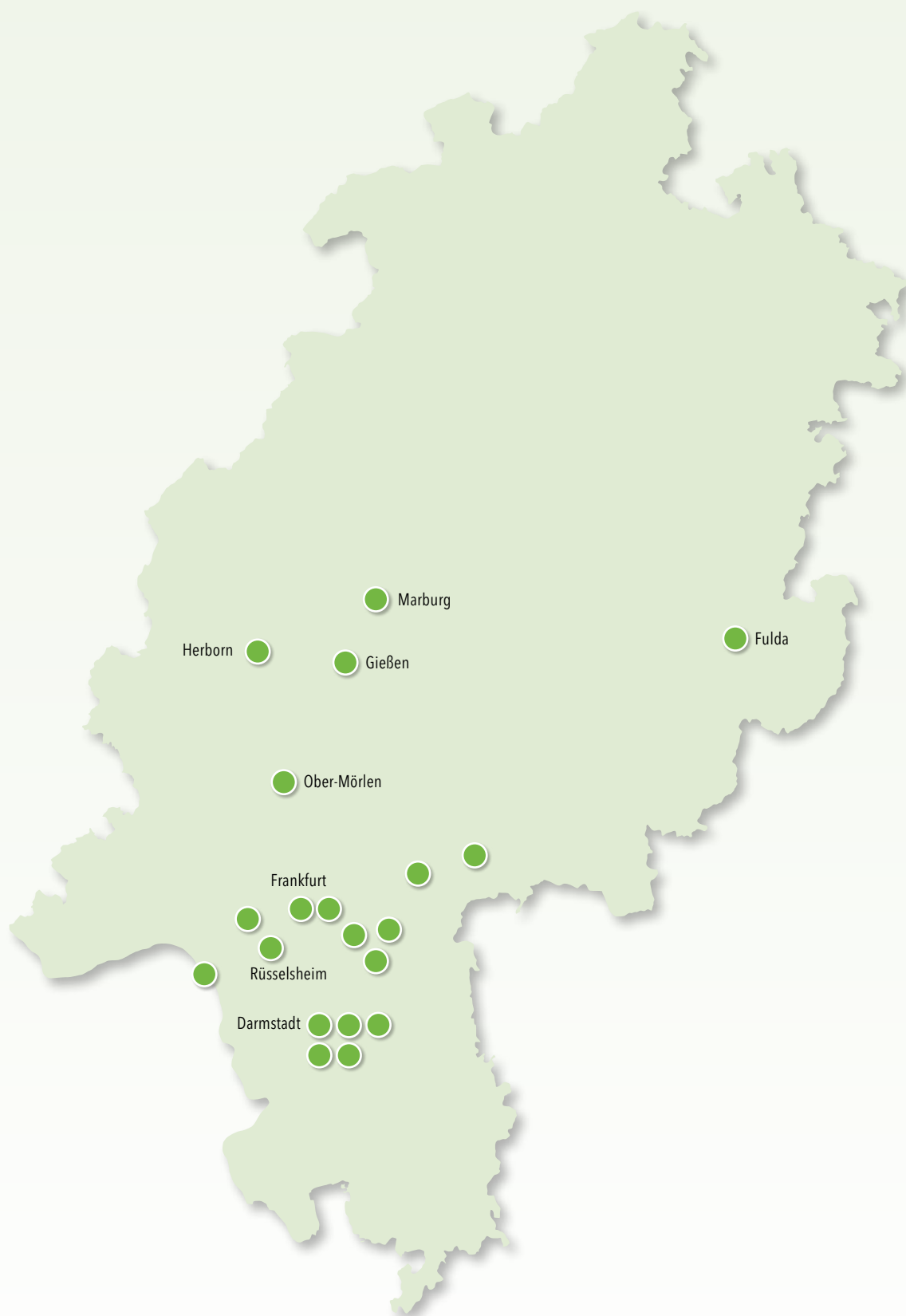
### Number of Hessian companies and institutions listed by business sectors using biomimetics (including double entries)



In Hessen, biomimetics is used mostly in R&D, technology transfer and production technology, to a lesser extent in the sectors trade,

training and further education, and advisory services (see Figure above).

## Regional distribution of biomimetics competences in Hessen





### Hessen's biomimetics projects are of major relevance for the primary challenges of our society:

#### Mobility

Biomimetic lightweight construction can be put to an extensive range of uses in the area of material and resource efficiency. Nature provides solutions that have already been widely introduced in the industrial sector. Bones and trees serve as models for the construction of components with a minimum of material but with high stability. The automotive industry offers particular striking examples of the use of optimised components: Adam Opel AG installs optimised axle journals and engine mounts in its cars. As a result of optimisation, the weight of the engine mount was reduced significantly. Energy efficiency achieved by lightweight construction in the transport industry is especially relevant for Hessen. Mobility plays a key role here, since Hessen is a major hub for aviation and transportation. For this reason there are many companies in the region which offer related services and products. EDAG offers solutions for mobility, for which the engineers and designers also use nature as a source of inspiration. Honda Research Institute Europe explores possible applications of cognitive systems, including the transport sector.

In aircraft construction, biomimetic optimisation was undertaken with the participation of Hessian service providers, such as the engineering firms Ingenieurbüro H. Moldenhauer GmbH or IBDH Ingenieurbüro Dr. Hübner.

#### Automation and robotics

Robots designed along the lines of living organisms can find a variety of applications. Bionic Robotics GmbH offers the lightweight robot BioRob which, thanks to its design and control technology, can safely interact with humans. In the locomotion laboratory of the Technische Universität Darmstadt, the walking robot BioBiped is used to find out how robots can be made to run, walk and stand. Sensitec GmbH developed sensors that are used in biomimetically inspired lightweight robots.

#### Health

Biomimetics is also used for developing new materials and engineering principles for prostheses and biomedical technology. DuPont supplies the plastic for biomimetic hand prostheses. The joint research project LOEWE, with its main focus on PreBionics (Preventive Biomechanics), uses biomechanical findings for optimisation of products, while TransMIT Gesellschaft für Technologietransfer mbH and the University Hospital of Frankfurt am Main are engaged in the development of adhesive materials modelled on mussel proteins. At the Institute of Experimental Biomechanics, a new type of implant was developed for the cervical spine. And, in a completely different area, Evonik Industries AG participated in the development of non-toxic antifouling paints – a contribution to the protection of natural waters.

#### Innovative products

The aim of biomimetics researchers is to develop products and processes that offer advantages over conventional solutions. KARL MAY-ER Textilmaschinenfabrik GmbH has constructed machines with which textiles are manufactured on the pattern of polar bear fur and sharkskin. Velcro fasteners are also produced with these machines. At Rittal GmbH & Co. KG, biomimetics projects were carried out with the aim of developing nature-inspired solutions for shock-absorbing pallets and optimised cable entry systems. The design of innovative products is also the aim of the Institute of Industrial Design at the Darmstadt University of Applied Sciences. Projects carried out here were construction site anchor points which cling fast to the wall like geckos, an emergency airdrop system modelled on airborne seeds, and an ornithopter study.

#### Training and further education

At the Department of Civil and Environmental Engineering, Constructive Design and Building Construction (KGBauko) of the Technische Universität Darmstadt, biomimetics in construction engineering is taught as an interdisciplinary subject, with the future goal of developing smart, active supporting structures. The service provider Bionik-Sigma Innovation GmbH offers events and materials for different target groups to illustrate biomimetics and its potential for the economy.



#### 1.4 Application of biomimetics in companies

There are basically three ways in which biomimetics can be applied in companies:

##### Inspiration in the creative process

In the quest for new ideas for the solution of technical problems, the use of nature as a guide can serve to loosen the thought patterns of specialised disciplines and lead to completely new approaches. Opportunities can come from innovation workshops which use biology as their search box.

##### R&D projects

Biomimetics is used predominantly in research and development projects. Be it student theses or internships, cooperative projects between companies or large collaborative projects involving research institutes, the decisive factor is always the interdisciplinary nature of the project team.

Transfer offices can help companies to find project partners.

The extensive knowledge base for biomimetics comes from biological basic research. In universities, libraries and botanical gardens, biologists explore and systematise the seemingly endless variety of organisms. They examine and catalogue their internal and external structure, shapes, materials, surface texture and many other aspects besides.



##### Application of biomimetic products

The last two decades have seen the development of a whole series of biomimetic products that are still unknown to many companies. Employees concerned with issues touching on biomimetics possess the potential to discover new products, materials, methods and possible applications for their company. In large enterprises this is the job of so-called innovation scouts. However, the subject is so fascinating for many employees that their personal interest drives them to check media reports and attend events on biomimetics.

**Fascination and innovation culture:** Fascination with biomimetics motivates people from all industries and business sectors to analyse technical issues and possible solutions from nature. It thus serves to strengthen a company's innovative culture and to query existing approaches. However, it should not be assumed that biomimetics will deliver the best solution to a problem in all cases. It is a tool that can be used to supplement traditional engineering, but not to replace it.

## 2 Competence matrix

The competence matrix provides a brief overview of the Hessian companies, universities and institutions which are presented in detail in the chapter on "competence profiles".

The company profiles can be browsed at [www.kompetenzatlas-hessen.de](http://www.kompetenzatlas-hessen.de) under the technology field "Biomimetics" and are linked with the following fields of activity and technical competences:

Competence sectors	Competence level 1	Competence level 2
Service	Consultancy Basic/continuing/advanced training in technology transfer	
Research and development (R&D)		
Production, production technology		
Trade		
Biomimetics subdivision	Materials	Surfaces/boundaries Molecular biomimetics/nanomaterials
	Movement	Adaptronics Aerodynamics / fluid dynamics (swimming / flying) optimisation Automation robotics / mechatronics Sensor technology / communication
	Construction	Lightweight construction Optimisation (CAO/SKO) Architecture / building / planning Design / shaping folding
	Others	Noise reduction energy (biomimetics) Organisational and economic biomimetics Biomechanics Anthropology and biomedical engineering

The current projects in Hessen are presented below in a competence matrix. All competences listed for a particular company division are associated with the biomimetic project or product with which the

companies, institutions or universities introduce themselves in the competence profiles. The other company divisions were intentionally omitted from this biomimetics competence matrix.



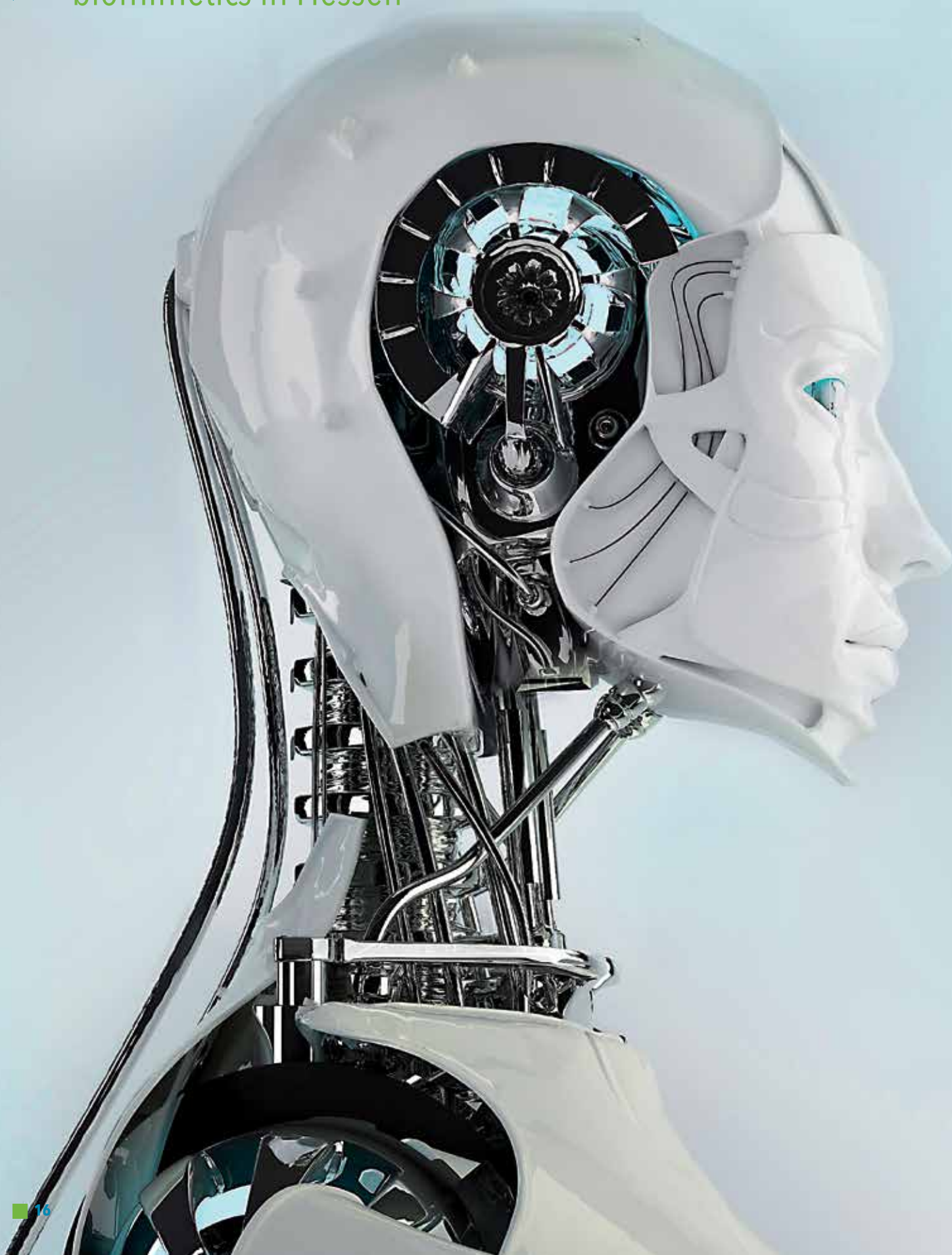
# Competence matrix

## Businesses and institutions in Hessen

Company	Business division						Project/Product
	Service			R&D	Production, production technology	Trade	
	Consultation	Basic/continuing/advanced training	Technology transfer				
Adam Opel AG					○		Engine mount, axle journal
Biomimetic Robotics GmbH				○	○	○	Lightweight robot BioRob
Bionik-Sigma	○	○	○			○	Advisory services and biomimetics events
Dipl.-Ing. H. Moldenhauer GmbH	○		○				Tailored fibre placement (TFP): Fibre placement in the principal stress direction
DuPont de Nemours (Deutschland) GmbH					○	○	Plastics for biomimetic hand prostheses
EDAG Engineering GmbH	○		○	○	○		Competence centre at EDAG for lightweight construction
Evonik Industries AG			○	○	○	○	Antifouling paint
Hochschule Darmstadt / Darmstadt University		○		○			Site anchorage points, emergency airdrop system and ornithopter study
Honda Research Institute Europe GmbH				○			Cognitive/sophisticated systems
IBDH Ingenieurbüro Dr. Hübner	○	○	○	○			Optimisation of multi-variable systems using evolution strategy, aerofoil sections
Institut für Experimentelle Biomechanik			○	○			Implant for cervical spine
KARL MAYER Textilmaschinenfabrik GmbH					○	○	Textiles with surfaces and structure taken from biomimetic model (polar bear fur)
LOEWE-Research Focus Preventive biomechanics – PreBionics		○	○	○			Development of digital human models with in vivo properties and simulation of mechanical interactions
Philipps-Universität Marburg – AG Molekulare Bionik				○			Synthesis of biohybrid compounds
Rittal GmbH & Co. KG					○	○	Shock pallet, cable entry system
Sensitec GmbH			○	○	○	○	Sensors for biomimetics-based lightweight robot
Technische Universität Darmstadt - KGBauKo		○		○			Teaching of "Biomimetics in construction" – exploitable solutions for construction problems
Technische Universität Darmstadt – Locomotion Laboratory of the Institute of Sport Science		○		○			Walking Robot BioBiped
TransMit Gesellschaft für Technologietransfer mbH	○		○	○			Adhesive modelled on mussel proteins
Universitätsklinikum Frankfurt		○	○	○			BioClou wet adhesive

		Areas of applied biomimetics															
Material		Movement						Engineering					Others				
Surfaces/boundaries	Molecular biomimetics/ nanomaterials	Adaptronics	Aero-/fluid dynamics (swimming/flying)	Optimisation	Automation	Robotics/mechatronics	Sensor technology/ communication	Lightweight construction	Optimisation (CAO/SKO)	Architecture/con- struction/planning	Design/shape	Folding	Noise reduction	Energy (biomimetics)	Biomimetics in organi- sation and economics	Biomechanics	Anthropo- and biomedical technology
								○	○								
				○	○	○		○			○						
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### 3 Competence profiles biomimetics in Hessen

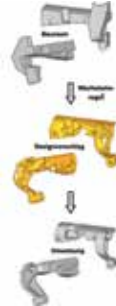


# Adam Opel AG

Rüsselsheim



Wir leben Autos.



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## Axle journal, motor mount

### Description

Simulation-based optimisation is an important tool for developing very light components with high strength. The specific optimisation methods which have proved to be of particular value are those which originated in the area of biomimetics and the basic principles of which were developed at the Karlsruhe Research Centre. The studies carried out there centred round the properties of biological energy carriers (such as trees, claws and bones).

The investigations have shown that biological energy carriers grow into their optimised shapes in accordance with an adaptive growth rule. By simulating the growth rule and applying it to the component to be optimised, this then grows virtually into the optimised shape, as a bone would do, for instance, if it had to take over the function of the component. Since the growth rule leads to a reduction in stress peaks, and ultimately, to a homogeneous stress distribution, it can be used to solve strength problems while using minimal weight.

The classical methods of CAO (Computer Aided Optimisation) and SKO (Soft Kill Option) deduced from the growth rule were introduced in 1992 at Adam Opel AG and modified to the requirements of everyday practice. Later, these programs were supplemented by the TopShape program that can take into account manufacturing constraints for castings. This method now helps to optimise castings such as engine mounts and axle journals, as well as sheet metal parts.

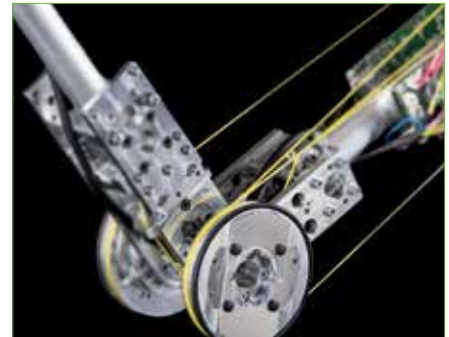
Illustration: CAQ/SKO processing of engine mount (left) and axle journal (right) (source: Adam Opel AG)

### Core competence:

1. Range of services:
  - Vehicle development and production
2. Products and services:
  - Commercial vehicles and motor vehicles
3. Fields of application:
  - Automotive

# Bionic Robotics GmbH

Darmstadt



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Internet [www.bionic-robotics.de](http://www.bionic-robotics.de)

Employees 6  
Established in 2010

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## Core competence:

### 1. Range of services:

Development and optimisation of a lightweight robot, control of elastic systems

### 2. Products and services:

Distribution of the BioRob lightweight robot

### 3. Fields of application:

- Pick and place applications
- Inspection tasks
- Laboratory (stand-alone/part of automation)
- Test systems
- Mobile use

## Lightweight robot BioRob

### Description

The lightweight robot BioRob forms the basis for transferring the functional principles of a biological arm model to the engineering concept of a "biomimetic robot".

BioRob is an elastic and flexible lightweight robot on a human arm as far as dimensions and motion speed are concerned.

Distinctive features of the robot are its lightweight design combined with a remarkable load capacity to own weight ratio. The highly active and particularly passive safety in case of collisions is a special characteristic. This protective measure makes it possible to use the robot in the immediate vicinity of humans without endangering them. Further advantages include the very fast set-up times thanks to its intuitive teach-in-programming (manual guidance or control of the robot for motion capture purposes).

The lightweight robot can work "hand in hand" with employees without additional protective equipment (key word "hybrid fabrication") and relieve them, for example, from performing very repetitive work. Against the background of the demographic change within society, such production concepts become increasingly important particularly for small and medium-sized companies. It is possible to do without expensive safety installations altogether, such as light barriers or guards.

The procurement and operating costs are favourable compared to the conventional robot arm technologies and result in a faster payoff of the investment costs.

Illustration: BioRob lightweight robot (source: Biomimetic Robotics GmbH)



# Bionik-Sigma Innovation GmbH

Darmstadt



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Established in	2008
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## Learning from nature for engineering: Biomimetics events, project support, specialist information and Bionik-Netzwerk Hessen

### Description

Biomimetics means learning from nature for technology. To present the exciting results of biomimetics research in easily understandable terms, Bionik-Sigma offers a number of biomimetics events for various target groups, such as company talks, a creative biomimetics seminar, readings, school workshops, or guided tours on the biomimetics educational trail at the botanical garden of the Technische Universität Darmstadt.

The "biomimetics technology scout" supports companies in planning and implementing biomimetics projects by means of advisory services, research and provision of contacts. Excellent knowledge of the biomimetics landscape, close cooperation with biologists and utilisation of the "biomimetics toolbox" developed by Bionik-Sigma ensure an easy introduction to biomimetics. Biomimetics offers prospects for development of innovative products, optimisation of processes, and inspiration for new ideas.

The office of the network "Bionik-Netzwerk Hessen", initiated by Technologielinie Hessen-Nanotech of the Hessian Ministry of Economics in 2012, is located at Bionik-Sigma Innovation GmbH. General information on biomimetics is available at the office, which also establishes initial contacts and organises various series of talks and seminars. The well-known series of events "Bionik im Betrieb" [bionics@work] of the network addresses companies, scientists and politicians and is designed and organised by this office.

In addition, Bionik-Sigma disseminates information on biomimetics in readily comprehensible terms in specialist articles and publications, such as the award-winning book "Die genialsten Erfindungen der Natur – Bionik für Kinder [The most ingenious inventions of nature – biomimetics for children]", Sigrid Belzer, S. Fischer-Verlag, 2010.

Illustration: Colouring agent solar cells (source: Bionik-Sigma)

### Core competence:

#### 1. Range of services:

Bionik-Sigma is a company divided into Innovation, Education, and Shop.

Bionik-Sigma Innovation organises "biomimetics technology scout" events and related advisory services in order to support companies in their implementation of bionically inspired projects. Bionik-Sigma Education is a leading service provider for educational projects in the biomimetics sector. Bionik-Sigma Shop offers teaching materials for implementation in schools.

#### 2. Products and services:

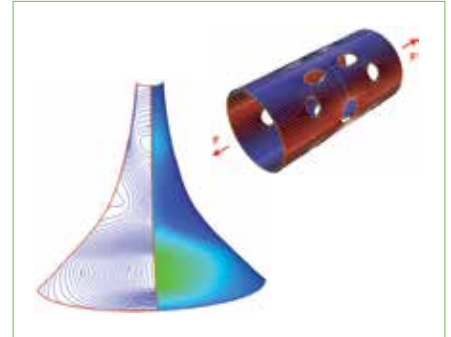
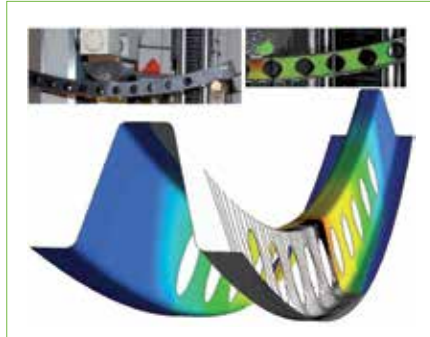
- Events, concepts and advisory services on biomimetics
- Office and coordination of the "Bionik-Netzwerk Hessen"
- Company talks
- Biomimetics technology scout
- Readings, guided tours, school workshops, teacher training courses, and holiday programmes
- Preparation of teaching materials and production of specialist articles
- Consultation in the conception phase of exhibitions
- Trading in dye solar cells, books, experimental materials

#### 3. Areas of application:

- Manufacturing companies from all sectors
- Educational sector

# Dipl.-Ing. H. Moldenhauer GmbH

Rödermark



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Internet	
Established in	1982
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Telephone	
Email	

## Tailored fibre placement (TFP): Fibre placement in the principal stress direction

### Description

Components are optimised in fibre composite structure pertaining to maximum stiffness and high level of stability based on the model of natural fibrous compound structures found in, for example, plants, wood and bones. The short fibres in bones, the so-called bony trabeculae, adjust to the stress direction during their growth. In this direction, the bony trabeculae have the least risk of fracture and the smallest local deformations under stress.

The adaptability of biological structures can be transferred to the construction process. If a bone is regarded as a component, it can be calculated numerically what inner stress will result from an outer stress. The stress can be described in several ways, but only one description is comparable to the orientation of the trabeculae in a bone: the so-called principal stress. Fibres in composite structures must be laid in such a way that they follow the direction of the principal stress. The fibre orientation will then be optimal and custom-made (tailored fibre placement). The necessary prerequisite to calculate an optimal fibre orientation is thus the calculation of a principal stress direction. This calculation is done using the finite element method (FEM) program (for example Abaqus, Ansys, Marc, Nastran, etc.). By integration of this direction, principle stress lines can be calculated with the program CAIOShell (Computer-Aided Internal Optimisation). These stress lines represent the optimal fibre orientation. In general, the optimisation consists of CAIO fibre orientations that are embroidered on a base layer. The CAIO samples contain exact XYZ coordinates for automatic embroidery machines (BMBF BIOTEX project 03X1000L).

#### Illustrations:

Illustration on the left (Logo): Roving along the principal stress directions S1 and S2 in a hull under water pressure.  
(source: Moldenhauer GmbH)

Illustration in the middle: Aircraft frame in a 3-point bending test at the Aircraft Construction Institute of Stuttgart (IFB), test set-up.  
(source: Institut für Flugzeugbau Stuttgart (IFB), Universität Stuttgart) Use of CAIO for the design of optimised fibre orientations in shell structures (source: Moldenhauer GmbH). The black-and-white region shows the extraction of individual fibres from the S2-field. A CAIO design is only complete when it contains S1-fibres that are perpendicular to S2-fibres.

Illustration on the right: 2 CAIO applications: Bicycle seat under the weight of a rider, pipe with openings under longitudinal force.  
(source: Moldenhauer GmbH)

### Core competence:

#### 1. Range of services:

The engineering office Dipl.-Ing. H. Moldenhauer for FEM structure calculations and programming has been in business since 1982. The main focus of this office is on the sector of fibre-reinforced plastics (FRP). Dipl.-Ing. H. Moldenhauer GmbH designs FRP components to optimal force flow for customers.

#### 2. Products and services:

- CAIOShell: Software program for the design of optimised fibre orientations in shell structures
- CAIOLoadpath: Software program for the visualisation of power flows and application of the load path method on 2D and 3D-structures
- CAO: Software program for shape optimisation (according to Prof. C. Mattheck)
- SKO: Software program for topology optimisation (according to Prof. C. Mattheck)

#### 3. Fields of application:

- Automotive
- Aviation and astronautics

# DuPont de Nemours (Deutschland) GmbH

Neu-Isenburg



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Established in	1961
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## Plastics for biomimetic hand prosthesis

### Description

The i-LIMB Hand of the Scottish biomimetics specialist Touch Biomimetics (Edinburgh) is a new type of prosthesis that looks like a human hand and also feels like one. This revolutionary prosthesis has been made possible by the use of the latest materials and construction techniques. For example, the manufacturer uses Zytel® HTN, a particularly robust and light type of high-performance polyamide from DuPont, for 33 components of the artificial hand - including the individual phalanxes and the casing for the controls. Due to the limited available space for the mechanics of the prostheses, Touch Biomimetics required a highly stable and stiff material of which the modulus of elasticity is comparable with a human bone (15 to 16 gigapascal). Additionally, high impact strength and surface quality were necessary. The biomimetic hand is particularly light and robust and receives the same positive feedback from patients and clinical staff alike. All five fingers of the artificial hand are operated individually and equipped with joints. As a result, this gives the wearer access to completely new grip patterns. Thanks to this new dexterity, the user is able to perform up to 90 percent of all essential movements during the day.

(Source: DuPont de Nemours (Germany) GmbH published in materialNews 21.6.2007)

### Further information

[www.plastics.dupont.com/plastics/pdf/europe/design/ed0702e05.pdf](http://www.plastics.dupont.com/plastics/pdf/europe/design/ed0702e05.pdf)  
[www.touchbionics.com/newsevents/latest-news/2006/10/new-details-of-revolutionary-bionic-hand-technology-revealed](http://www.touchbionics.com/newsevents/latest-news/2006/10/new-details-of-revolutionary-bionic-hand-technology-revealed)

Illustration: i-LIMB Hand (source: DuPont/Biomimetic)

### Core competence:

#### 1. Range of services:

DuPont is one of the largest companies in the chemical sector worldwide. Neu-Isenburg is one of the four German locations.

#### 2. Products and services:

- Pet food and protection against disease
- Clothes and textiles
- Chemicals, compounds and solutions
- Composite materials, interplys and laminates
- Construction materials
- Advisory services and process technologies
- Materials for displays and lighting
- Fibres, tissue and non-woven fabrics
- Industrial biotechnology
- Membranes and foils
- Packaging materials and solutions
- Personal protective equipment
- Pharmaceutical products
- Pigments, colouring agents and dyestuff
- Plastics, polymers and resins
- and other

#### 3. Fields of application:

- Consumer goods industry
- Plastics, chemical, agricultural and paper industry
- Coating as well as the adhesive and sealant industry and other

# EDAG Engineering GmbH

Wiesbaden



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## Competence Centre at EDAG for lightweight construction, materials and technologies

The biomimetics are accommodated particularly through the interdisciplinary collaboration of engineering and manufacturing specialists with the design as impulse

### Description

EDAG has been working for many years with applied biomimetics in engineering within the framework of in-house studies or confidential customer projects. A topology-optimised A-pillar node made from thin-walled cast steel can be taken as an example. This highly stable and stress-resilient node was used in the technology carrier of the EDAG "Light Car". The engineering disciplines of lightweight construction, materials and technologies at EDAG work closely together in order to achieve such results. Our designers can also derive biomimetic concepts and implement potential product applications by taking their cue from nature: Steps in this development are analysis of load cases and functions, followed by topological optimisation using Computer-Aided Engineering (CAE), and finally production-oriented design and alignment with knowledge carriers in the field of biology. Particularly the additive manufacturing processes with which we are already familiar as a model and prototype builder offer great potential in biomimetics. The most recent concept car "EDAG Light Cocoon", together with "Bionic Space-Frame" and "GenLight", are good examples of these potentials and can be expected to usher in a paradigm shift on the way to Lightweight Construction 2.0.

Illustration on the left: EDAG's function demonstrator at the IAA 2015: generative production of ultralight multifunctional components as exemplified by the automobile headlight (GenLight). The vision of EDAG is the tool-free production of complex structures with unrivalled design freedom and maximum light construction potential for small series. The idea behind GenLight is to increase the light output of LEDs and improve the efficiency of the system with the aid of a bionic 3D printed cooling structure. (Source: EDAG Engineering GmbH)

Illustration on the right: Demonstrator at the IAA 2015: Together with Laser Zentrum Nord, Concept Laser and BLM, EDAG is presenting an innovative flexible bodywork concept in the form of a bionically optimised Space-Frame. The potential of this lies in the combination of laser-generated nodes with laser-end processed profiles. The basis for this is the "EDAG Light Cocoon - Inspired by Nature. Generatively produced. The ultimate in lightweight construction and sustainability." The "EDAG Light Cocoon" is a visionary lightweight vehicle construction concept with bionically optimised and generatively produced (3D printed) structural components for vehicles. The skeletal, organic vehicle structure is extremely light, material minimised, and fulfils all static and dynamic demands on the components. The outer skin is made of a high-tech textile, one of the lightest of all surface materials. (Source: EDAG Engineering GmbH)

### Core competence:

#### 1. Range of services:

EDAG is the leading and independent developer for the mobility of the future. The expertise lies in the development of complete vehicles, modules and production facilities. EDAG works according to the principle of "production-optimised solution". In other words, the development results are always attuned to the requirements of production.

#### 2. Products and Services:

- Complete development of vehicles and modules
- Complete development of production facilities
- Small batch production (prototypes, tool and bodywork systems)
- Competence Centre "Lightweight construction, materials and technology"
- Competence Centre "Electromobility"
- Competence Centre "Car IT"
- Design studio, model and prototype construction

#### 3. Fields of application:

- Automobile development and production
- Lightweight manufacturing technology
- Electricmobility, Car IT

# Evonik Industries AG

## Service Unit Process Technology & Engineering / Hanau-Wolfgang



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## Antifouling paints

### Description

Evonik Industries AG relies on biomimetics in a number of innovative projects. Service Unit Process Technology & Engineering and the department of Inorganic Materials at Evonik Industries AG have worked on additives in the past as part of a BMBF project with which natural, non-toxic active substances were to be integrated in commercially available marine coatings through microencapsulation and with which, additionally, the coating surface can be structured for particular requirements. An example from nature is the project modelled on dolphin and shark skins, the special surface of which prevents accumulation of biofilms. Another example was a marine sponge which repels fouling with the aid of natural active substances.

The results of the BMBF project were coating formulations with a verifiable antifouling effect. The current state of technology is not yet sufficiently advanced for economic production of these formulations.

### Core competence:

#### 1. Range of services:

Evonik is one of the largest companies in the speciality chemical sector worldwide. Evonik operates an innovative production and research centre for material technology, chemistry and pharmaceuticals within the industrial park of Hanau.

#### 2. Products and Services:

- Inorganic Materials (speciality chemicals)
- Advanced Intermediates (products for the further processing in end applications such as plastics, agricultural products and paper products)
- Coatings & Additives
- Consumer Specialities (raw materials, additives and active ingredients for consumer goods)
- Performance Polymers (high-performance materials)
- Health & Nutrition (health products and nutrition)

#### 3. Fields of application:

- Consumer goods industry
- Plastics, chemical, agricultural and paper industry
- Feed and pharmaceutical industry
- Lacquer, colour and coating, adhesive and sealing industry
- Participations in the areas of energy and real estate

### Further information:

<http://content.media.cebit.de/media/000081/0081125ger.pdf>

Illustration: Test plate on the left side with antifouling effect; test plate on the right side without antifouling effect. (Source: Evonik Industries AG)



# Darmstadt University - Institute for Industrial Design (IFID)

Darmstadt



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## Site anchorage points, emergency airdrop system and ornithopter study

### Description

Students and teaching staff of the Institute for Industrial Design have already elaborated project ideas with a biomimetic background multiple times. Three projects are presented by way of example:

SIGECCO is a system of mobile anchorage points and additional lifting aids that enables the temporary set-up and maintenance of supply structures at a construction site. Cable bundles for alternating current, water, gas and communication, work site distribution board and construction site lighting can be mounted in a very simple and readily manageable way free from residues and without additional aids on walls and ceilings. The reversible adhesion is achieved by nano adhesive plates and by a biomimetically inspired method for fixing, loosening and repositioning the anchorage points.

The EMERGENCY AIR DROP SYSTEM is a newly developed relief air drop system that uses passive flying along the lines of winged seeds. The central construction. The weight of the container within the system causes the wings element, the freight container, is located in the centre of the wing to fold together and an optimal transport situation is created. The wings unfold during the drop of the goods based on the now free space. The system is put immediately into auto-rotation so that a boost is generated and the impact reduced.

MILAN is an ornithopter study (flapping device) which is based on a material feasibility study. An exoskeleton-based construction takes into account the future potential and options of nanotube technology. The complicated sequence of movements of a flap, taking into account the dynamic strains and necessary light construction specifications, could be simulated with the aid of carbon nanotube muscles. This consistent composite based on light construction design, the most modern materials and an effective energy supply will make it possible to create an aircraft in the future that can fulfil the age-old dream of mankind to "fly like a bird".

### Core competence:

#### 1. Range of services:

The IFID is a scientific facility of the Faculty of Design/ study course Industrial Design at Darmstadt University. It fosters the acquisition of scientific and creative knowledge and supports the scientific and creative underpinning and development of teaching and study in the field of industrial design.

#### 2. Products and services:

- Teaching
- Research
- R&D projects
- Development of new methods and models

#### 3. Fields of application:

- Electromobility
- Medical technology



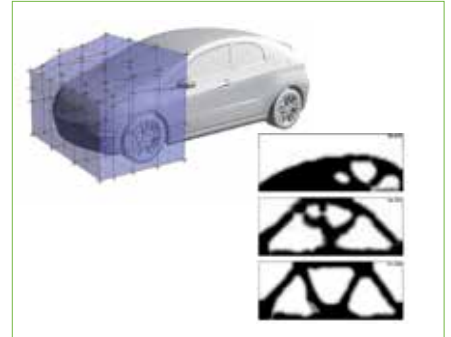
### Further information

[www.ifid-da.de](http://www.ifid-da.de)

Illustration top left: Ornithopter study "Milan"; Illustration top right: Emergency Air Drop System; Illustration bottom left: Attachment point Sigecco (source: Prof. Tom Philipps)

# Honda Research Institute Europe GmbH

## Offenbach



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Gründungsjahr	2003
Contact Email	Prof. Dr. Bernhard Sendhoff <a href="mailto:info@honda-ri.de">info@honda-ri.de</a>

## Cognitive systems & representations, sensory processing & learning, system architecture & embodiment, optimisation & analysis of complex systems

### Description

The biomimetic competences listed above are integrated in various projects designed to investigate and advance intelligent processes and technologies and to apply them to the problems and challenges presented by future mobility solutions and process sequences. The following example "image processing with optical flow for the early recognition of hazards" illustrates how biomimetic processes<sup>1</sup> are put to technical use.

<sup>1</sup>Gibson, J.J. (1950). The Perception of the Visual World.

### Core competence:

#### 1. Range of services:

Innovation through science - "HRI contributes to Honda's dream of a sustainable and joyful society by creating innovations that harmonise technology, nature and people".

#### 2. Products and services:

The exploration of intelligent systems is the focus of the Honda Research Institute Europe. Intelligent systems will influence our future in multiple ways. Sustainable and secure mobility, cognitive robots, intelligent process management and maximum resource efficiency are some of the core topics that are dealt with at the institute. Intelligence is the decisive factor for effective organisation of complexity in products and processes.

#### 3. Fields of application:

- Mobility
- Robotics

### Image processing with optical flow for early recognition of hazards



optical flow field



approaching car mdetection



The pictures clearly illustrate the sequence of image processing: The road users in the foreground are separated from the background by means of the optical flow principle. Movements in the image are calculated and images showing differences in movement are separated. Where necessary, the driver is notified optically.

rider view in dashboard



Illustrations top left: Representation of elements of a traffic scene; online learning of objects in the interaction between people and robots. (source: Honda Research Institute Europe GmbH)

Illustrations top right: Deformation grille around a vehicle model; example of topology optimisation. (source: Honda Research Institute Europe GmbH)

# IBDH Ingenieurbüro Dr. Hübner

Ginsheim-Gustavsburg



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## Core competence:

### 1. Range of Services:

- Engineering office with focus on advisory services for non-sector specific quality and corporate development

### 2. Products of Services:

- Continuous improvement processes (CIP)
- Quality improvements, Kaizen, SixSigma, TQM
- Reliability/availability calculation (MTBF/RAMS)
- Risk analysis (FMEA/FMECA)
- Design of Experiments (DoE)
- Optimisation of multivariable systems and organisational structures
- Quality management

### 3. Fields of application:

- Vehicle construction
- Mechanical engineering
- IT
- Precision mechanics/optics
- Consulting
- Aeronautical engineering
- Offshore oil and gas industry

## Optimisation of multi-variable systems using evolution strategy

### Description

Evolution strategy offers the possibility of setting the parameters of a system in such a way that a specified optimisation goal is fulfilled in the best possible way. The parameters can be dependent on one another – usually a cause of failure for conventional optimisation processes. The evolution strategy was applied successfully for the optimisation of aerofoil profiles.

Evolution strategy is a method modelled on natural evolution. Biological evolution is based essentially on mutation, recombination and selection. The objective of evolution strategy is to design rules of action for achieving, step by step, an ever closer imitation of natural evolution.

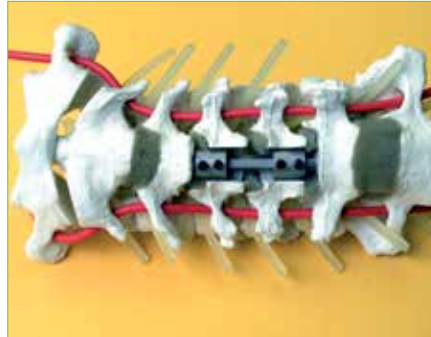
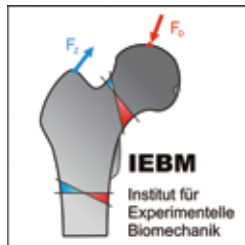
Source: based on Nachtigall, W.: Bionik: Grundlagen und Beispiele für Ingenieure und Naturwissenschaftler [Biomimetics: Principles and examples for engineers and scientists]. 2nd Edition. Heidelberg: Springer Verlag, 2002

### Further information:

[www.consultingregion.de/consulting/content/  
dr-martin-huebner-ibdh-ingenieurbüro-drhübner-qualitätsmanagement](http://www.consultingregion.de/consulting/content/dr-martin-huebner-ibdh-ingenieurbüro-drhübner-qualitätsmanagement)  
[www.xing.com/companies/ibdh-ingenieurbürodr.hübner](http://www.xing.com/companies/ibdh-ingenieurbürodr.hübner)

# Institut für Experimentelle Biomechanik

Institute for Experimental Biomechanics, Ober-Mörlen



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## Implant for axial polysegmented spondylodesis of the cervical spine

### Description

The objective of this project was to develop a new type of endoprosthesis which enables better therapeutic success during long-term use than that of earlier approaches. To this end, existing technical solutions were analysed and available measurement data were evaluated. Comprehensive in-house examinations on biomechanics of the human cervical spine supplemented the examination spectrum. The knowledge gained here led to a new type of endoprosthesis that takes the biological construction principle of the cervical spine better into account than previous endoprostheses. The implantation and anchoring of the implant within the vertebral body results in a better adjustment of the biological structure and technical design under static and dynamic stress. This improved adjustment results in an optimised stabilisation of the cervical spine and particularly in an improved long-term stability.

Registered patent under number: DE 10 2006 022 431 A1 2007.01.18 implant with a connecting piece to bridge a defective vertebral body of the human cervical spine; axial, bicortical, lockable, multi-segmented cervical spine endoprosthesis.

Illustration: Implant for axial polysegmented spondylodesis of the cervical spine (Source: A. Geck)

### Core competence:

#### 1. Range of Services:

Promotion of interdisciplinary research and development in medicine and natural sciences

#### 2. Products of Services:

- Independent evaluation and expert assessment of biomechanical and medical engineering problem-solving approaches
- Development of models and concepts for medical technology, biomechanics and biomimetics
- Working on metrological problems in biomechanics and biomimetics
- Development of endoprostheses and exoprostheses as well as medical equipment and aids

#### 3. Fields of application:

- Medicine
- Medical technology
- Orthopaedics
- Endoprosthetics/exoprosthetics

# KARL MAYER Textilmaschinenfabrik GmbH

Obertshausen



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Fax	+49 (0)6104-4027360
Internet	<a href="http://www.karlmayer.com">www.karlmayer.com</a>
Employees	2,000 worldwide
Established in	1937
Contact	Michael Kieren
Telephone	+49 (0)6104-4020
Fax	+49 (0)6104-40273316
Email	<a href="mailto:michael.kieren@karlmayer.com">michael.kieren@karlmayer.com</a>

## Core competence:

### 1. Range of services:

KARL MAYER is the worldwide leader in the field of warp knitting or double rib machines as well as warp preparation facilities. The family-run group with registered office in Obertshausen near Frankfurt am Main has more than 2,000 employees. The company has branches in the USA, Great Britain, Italy, Hong Kong, Japan and China and in Switzerland. KARL MAYER operates in the business areas of knitting machines, warp preparation and technical textiles

### 2. Products and services:

- Textile machines for the production of
  - Apparel textiles
  - Sport textiles
  - Home textiles
  - Technical or semi-technical textiles

### 3. Fields of application:

- Automotive
- Industry
- Composites
- Sport
- Clothes and fashion

## Textiles with biometrically modelled surfaces and structures

### Description

Based on the observation of how a shark skin functions, new synthetic materials have been developed that reduce the flow resistance when used in swimsuits for competitive swimmers. The suits provide the swimmers with a time advantage of up to 1.5 seconds over a stretch of 100 metres.

High-performance warp knitting machines from KARL MAYER are used to produce special textiles for swimsuits modelled on shark skin.

Other textile machines from KARL MAYER are used to produce Velcro fasteners for baby diapers - an application inspired by the burdock plant - and the production of spacer fabrics with multiple functions. The Institute for Textile and Process Engineering (ITV) in Denkendorf developed from the textile spacers (spacer fabric) a composite with special insulating characteristics modelled on the fur of the polar bear. The innovative material was used by the ITV in the energy-independent building "Polar Bear Pavilion" located on the ITV premises. Additionally, the ITV implemented a project to produce fog collectors as a source of freshwater in the desert. The desert beetle *Onymacris* showed how this is done. Following the example of this survival artist, ITV developed the 3D knitted fabric and nets that convert fog to water. The textiles used in the process were produced on KARL MAYER machines.

### Further information

[www.itv-denkendorf.de/images/ITV/Newsletter/newsletter\\_01\\_13.pdf](http://www.itv-denkendorf.de/images/ITV/Newsletter/newsletter_01_13.pdf)

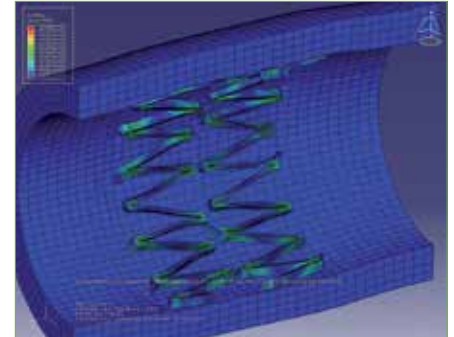
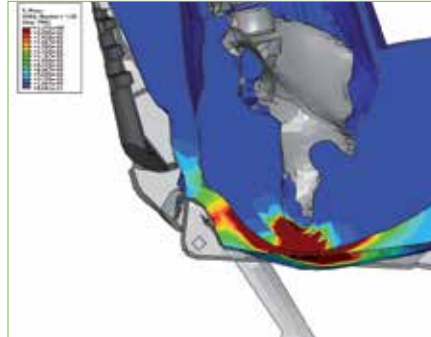
Illustration on the left: Southern side of the Polar Bear Pavilion with roof-mounted solar-thermal collector tracks (© ITV). (Source: KARL MAYER Textilmaschinenfabrik GmbH)

Illustration on the right: Velcros are produced on machines from KARL MAYER Textilmaschinenfabrik GmbH (Source: Bionik-Sigma)



# LOEWE – Research Focus Preventive biomechanics - PreBionics

Institute for Material Sciences (IfM), Faculty of Computer Science and Engineering Sciences, Frankfurt/M



Address	Frankfurt University of Applied Sciences Nibelungenplatz 1, Building 4 60318 Frankfurt/M.
Telephone	+49 (0)69-1533 0
Fax	+49 (0)69-15332400
Internet	<a href="http://www.fh-frankfurt.de">www.fh-frankfurt.de</a> <a href="http://www.praeventive-biomechanik.eu">www.praeventive-biomechanik.eu</a>
Established in	1971
Contact	Prof. Dr.-Ing. habil. Gerhard Silber
Telephone	+49 (0)69-15333035
Fax	+49 (0)69-15333030

## Development of digital human models with in-vivo characteristics and simulation of mechanical interactions

### Description

Within the framework of the "preventive biomechanics" research focus of LOEWE (Hessen's state offensive for the development of scientific and economic excellence), the mechanical interactions between particular regions of the human body and technical supporting constructions such as car seats, vascular prostheses or sport shoes are examined at the Institute for Material Sciences of the Frankfurt University of Applied Sciences. The objective is to minimise the risks of injury from biomechanically optimised products - for example, jogging shoes, bicycle seats, seat cushions, bed systems, and car or aircraft seats - and to increase sitting and wearing comfort.

Analyses of mechanical interactions between the human body or individual body regions and supporting constructions are an important basis for preventive biomechanics in medicine, biology and sport. Examples here are extracorporeal supporting constructions such as bed and seat systems (resting/crashes), health and sport shoes (walking/running) or intracorporeal supporting constructions such as stents or implants (endoprosthetics). Such analyses require universally applicable complex 3D human models, which can be created very efficiently on the basis of the Finite Element Method (FEM). This calculation method is widely used by engineers for optimisation of technical components and enables virtual human models (BOSS-models - Body Optimisation & Simulation System) to be optimised in such a way that various effects can be simulated and measured during interaction with technical supporting constructions.

Text source: changes according to [www.praeventive-biomechanik.eu/cms/teilprojekte/32-mm.html](http://www.praeventive-biomechanik.eu/cms/teilprojekte/32-mm.html) (modified)

A total of 14 sub-projects, using interdisciplinary approaches from engineering sciences, biology and medicine, are being carried out to deal with questions from routine clinical practice concerning harmful interactions between human soft tissue regions and supporting constructions (aids), or implants in bones and cartilage.

Additional research association partners: Goethe-Universität Frankfurt/M. Philipps-Universität Marburg

Associated facilities: Bergische Universität Wuppertal, Johannes-Gutenberg-Universität Mainz and Katholisches Klinikum Mainz

Illustration: Mechanical interactions between soft tissue regions and supporting constructions (studies) (Source: Institut für Materialwissenschaften (ifm), Frankfurt/M.)

Illustration on the left: extracorporeal supporting construction buttocks/seat

Illustration on the right: intracorporeal supporting construction stent/vessel

### Core competence:

#### 1. Range of services:

The University of Applied Sciences of Frankfurt/M is the coordinator of the joint research association.

#### 2. Products and services:

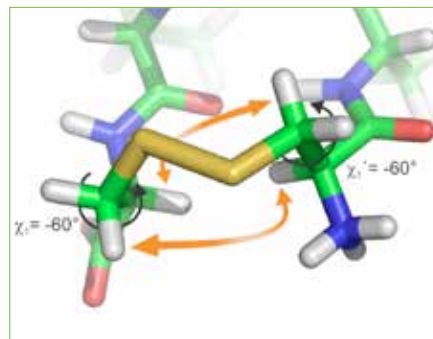
- Application and implementation of R&D projects with industrial partners
- Courses and seminars
- Implementation of experiments on technical materials and in-vivo experiments on subjects with special equipment and imaging processes (MRI)
- Evaluation based on continuum-mechanical methods and theory of materials
- Structure-mechanical analyses with the aid of FEM
- Calculation and simulation of mechanical interactions between humans and technical supporting constructions

#### 3. Fields of application:

- Development of products from the technical and medical market segment based on biomechanical knowledge
- Biomechanical optimisation of technical and medical products based on appropriate optimisation criteria

# Philipps-Universität Marburg – AG Molekulare Bionik

Philipps University of Marburg - Study Group Molecular Bionics, Marburg



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Fax	+49 (0)6421-2822021
Internet	<a href="http://www.uni-marburg.de/fb15/ag-geyer">www.uni-marburg.de/fb15/ag-geyer</a>
Employees	10
Established in	2010
Contact	Prof. Dr. Armin Geyer
Telephone	+49 (0)6421-2822030
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Email	<a href="mailto:armin.geyer@staff.uni-marburg.de">armin.geyer@staff.uni-marburg.de</a>

## Core competence:

### 1. Range of Service:

- Synthesis of peptides and peptidomimetics
- NMR spectroscopy

### 2. Products and services:

- Research and teaching

### 3. Fields of application:

- Biomineralisation
- Auto-antibodies

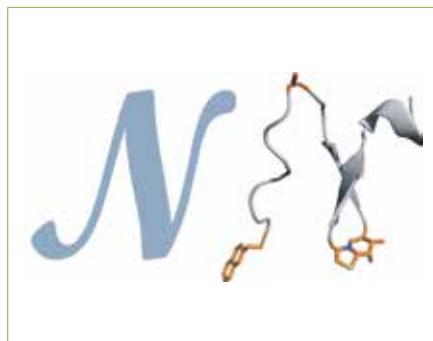
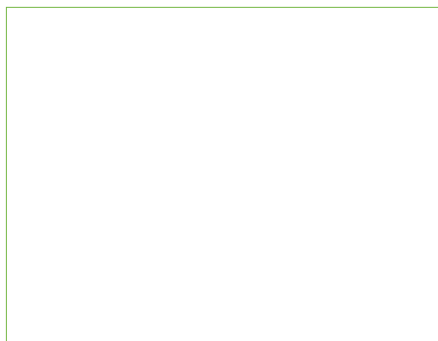
## Synthesis of biohybrid composites - NMR spectroscopy

### Description

The correct sequence of the building blocks of a biopolymer is comparable with the correct sequence of letters in a word. An incorrect letter can change the meaning of a word completely ("cat" becomes "rat") just as an interchanged amino-acid can change the form of a peptide chain. Nature requires only 20 different amino-acids in order to build large protein structures with a high level of precision. This is like an author who writes entire novels using only the 26 letters of the alphabet. A novel is a great deal more than just a long chain of letters, just as a protein is a great deal more than a sequence of different amino-acids.

Biomimetics at the molecular level means the synthesis of sequence-specific polymers with specified dimensions. The constant form of the molecules leads to a function modelled on nature. The molecules interlock like gear wheels. This is called a molecular recognition process. Since all polymer molecules possess the same length (monodisperse) and an identical sequence of monomer building blocks, they all perform the same molecular recognition process which, overall, is much more selective than could ever be achieved with conventional synthetic polymers. Such an epitope can be a recurring charge pattern on a rod-shaped molecule which then brings about the biomineralisation of silicic acid. This follows the model of silicic acid producing organisms which use similar principles for the hierarchical biomineralisation of their skeleton or shell. The precise spatial presentation of a charge pattern is decisive for the success of precipitation processes. Numerous applications for stable-form peptides arise out of medical issues where correct formation of large surface area contacts between proteins at the molecular level is important. Our synthetic epitopes are used where molecular recognition processes have to be clarified. Successful applications of synthetic epitopes are the binding of auto-antibodies of rheumatic arthritis or Alzheimer's dementia.

Additional letters are included in an alphabet as information carrier only if they communicate new functions. Only very few characters make it into our everyday language. The @ or € symbols are prominent examples of such novelties on the computer keyboard. There is little point in integrating a new amino-acid in an epitope unless it can do something extra. Here again we cannot help drawing an analogy between chemistry and language. Building blocks corresponding to the control keys on the keyboard have been unknown up to now in the field of amino acids. The function, which is comparable with a "line break", was realised by the integration of a new amino acid in a synthetic protein. This new amino acid has the form of a hairpin bend and replaces two conventional amino acids, hence the name that is twice as long: Hot=Tap. Hot=Tap restricts the mobility of the protein to a minimum. Just like a hinge, it holds the adjacent amino



acid chains in a predictable form. There is a great need for predictable peptide architectures in medical research. Since these peptides are inherently stable epitopes they can recognise antibodies, like a key that fits only into a specific lock.

The planning of an inherently stable epitope as well as its construction on the peptide synthesiser is only possible when the necessary analytical methods are available to characterise this peptide architecture. The most accurate method of determining the relative spatial arrangement of atoms is crystal structure analysis, which, as a diffraction method, is bound to a crystal in which the individual molecules are crammed together like sardines in a tin. On the other hand, nuclear magnetic resonance (NMR) spectroscopy characterises the molecule in dissolved condition, in which also the molecular recognition processes take place. We watch the molecule (so to speak, the sardine) swimming and are thus able to identify the harmonic interaction of the function of the side chains (so to speak, the fins) in order to determine the function. Although vivid analogies can soon be overstrained, they are useful for developing new areas of application for molecular biomimetics as chemical synthesis of inherently stable biohybrid composites.

Illustration: Amino acids (Source © AG Molekulare Bionik)

Left-hand page, illustration on the left: The keyboard of the natural amino acids is expanded by synthetic building blocks.

Left-hand page, illustration on the right: Long peptide chains can simply be put together on the peptide synthesiser.

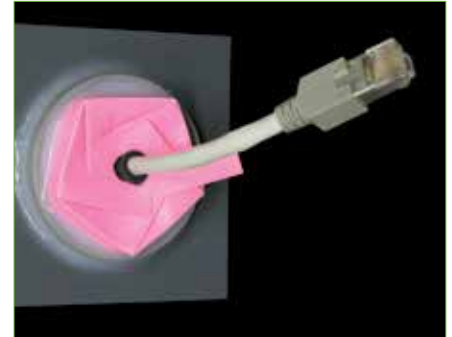
Right-hand page, illustration on the left: The NMR spectroscopy identifies the three-dimensional form of the peptide chain

Right-hand page, illustration on the right: The ligation of both ends of the peptide chain requires a molecular hook and a fitting loop like the lock of a pearl necklace

(Source: Prof. Dr. Armin Geyer)

# Rittal GmbH & Co. KG

Herborn



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Internet	<a href="http://www.rittal.de">www.rittal.de</a>
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Established in	1961
Contact	Uwe Scharf
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Email	<a href="mailto:info@rittal.de">info@rittal.de</a>

## Shock pallet, cable entry system

### Description

We can be proud of the results of a cooperation with the team headed by Prof. Dr. Thomas Speck of the University of Freiburg. These include new approaches for cable entries, that is opening or locking systems through which cables are introduced into a switch cabinet. They should be wide enough to receive the cables easily while at the same time preventing the penetration of moisture, dust and dirt. To this end, there are two examples from nature: the blossoms and trapping leaves of the Venus flytrap, a carnivorous plant from the sundew family. Insects go straight into the trap of this plant. The petals close over their victim like blades fitting into one another and do not let their victim go. This locking system, which is found in much the same way in the night-blooming cactus, provided the idea for the design of an optimally sealing cable entry.

An interesting solution for the safe transport of switch cabinets, in which the highly sensitive electronics are already built in, offers a nature-based, shock-absorbing pallet. The concept is as simple as it is conclusive: To cushion the pallet, artificial "spines" are used which effectively help to absorb impacts. To optimise the structure of the pallet, biomimetic scientists take inspiration from the spines of hedgehogs and porcupines, which protect these animals against injuries from falls. The use of renewable raw material enables the pallet to be recycled. This has not been possible up to now in the case of conventional products.

The biomimetic shock pallet is a joint development of Rittal, the University of Freiburg and ITV Denkendorf.

### Core competence:

#### 1. Range of services:

Rittal is the worldwide leading system provider for switch cabinets, power distribution, air conditioning, IT-infrastructure as well as software and service.

#### 2. Products and services:

"Rittal - The System" combines innovative products, trend-setting engineering solutions and worldwide service for a multitude of requirements.

#### 3. Fields of application:

- Different industries
- Mechanical engineering and plant engineering
- Automobile industry
- Information technology
- and other

Text source: Nanotechnologie in der Natur – Bionik im Betrieb [Nanotechnology in nature – bionics@work]. Publication Series of the Technologieline Hessen-Nanotech of the Ministry of Economics, Transport and Regional Development - State of Hessen, Volume 20, 2011.

### Further information:

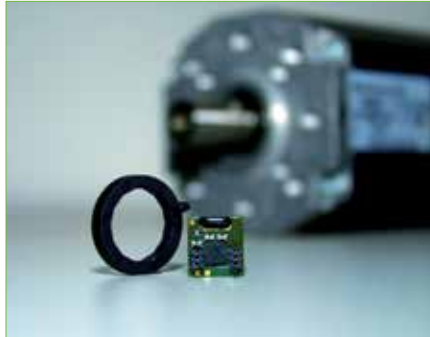
[www.faszination-zukunft.de/bionik/rittal.asp](http://www.faszination-zukunft.de/bionik/rittal.asp)

Illustration on the left: Shock pallet (Source: Rittal GmbH & Co. KG)

Illustration on the right: cable entry (Source: Rittal GmbH & Co. KG)

# Sensitec GmbH

Lahnau



Address	Sensitec GmbH Georg-Ohm-Str. 11 35633 Lahnau
Telephone	+49 (0)6441-97880
Fax	+49 (0)6441-978817
Internet	<a href="http://www.sensitec.com">www.sensitec.com</a>
Employees	140
Established in	1999
Contact	Dr. Rolf Slatter
Telephone	+49 (0)6441-978813
Fax	+49 (0)6441-978817
Email	<a href="mailto:rolf.slatter@sensitec.com">rolf.slatter@sensitec.com</a>

## Sensors for biomimetics-based lightweight robot

### Description

Goniometry is one of the main applications for magnetoresistive (MR) sensors of Sensitec. The contact-free, non-wearing measuring principle, combined with high accuracy and dynamics, makes the MR sensor an ideal choice for the mechanical engineer. The MR sensor offers different possibilities for registering angularities. The MR sensor features a high level of precision, compact dimensions, high reliability and robustness under difficult environmental conditions such as very high or low temperatures, dirt or dust. Based on these characteristics, it is eminently suitable for use in lightweight robots or in so-called walking robots which are frequently modelled on biological examples such as insects or the human musculoskeletal system. The goniometry gives information about the position of, for instance, wheels or robot arms. The measurement takes place either at the shaft end or at the shaft circumference.

### Core competence:

#### 1. Range of services:

Sensitec is a leading manufacturer of sensors based on the magnetoresistive (MR) effect, which are used for the highly precise measurement of path, angle, position, power or magnetic field. Microchips are produced in thin-film technology to automobile quality standard in the wafer factory at the Mainz location, after which they are equipped with electronics at the Lahnau location to form a complete sensor system.

#### 2. Products and services:

- MR sensors and magnetic microsystems for the precise measurement of path, angle, position, power or magnetic field
- Measurement standards
- Chip design and production
- Integrated evaluation circuits, components and system solutions in standardised and customised design

#### 3. Fields of application:

- Industrial automation
- Automotive
- Medical technology
- Drive engineering
- Aviation and astronautics
- and other

Illustration on the left: Typical magnetoresistive encoder kit for robotic applications (Source: Sensitec GmbH)

Illustration on the right: Sensors of Sensitec control the movements of the Mars Rover "Curiosity" (Source: NASA/JPL-Caltech)



# Technische Universität Darmstadt

Department of Civil and Environmental Engineering, Constructive Design and Building Construction, Darmstadt



Address	Technische Universität Darmstadt KGBauKo Franziska-Braun-Straße 3 64287 Darmstadt
Telephone	+49 (0)6151-16-3493
Fax	+49 (0)6151-16-7034
Internet	<a href="http://www.kgbauko.de">www.kgbauko.de</a>
Employees	Up to 15
Established in	1998
Kontaktperson	Professor Architekt Stefan Schäfer
Telephone	+49 (0)6151-163493
Fax	+49 (0)6151-167034
Email	<a href="mailto:info@kgbauko.tu-darmstadt.de">info@kgbauko.tu-darmstadt.de</a>

## Teaching of "Biomimetics in construction" - exploitable solutions for construction problems

### Intelligent buildings adapt to the environment

#### Description

Most buildings are predominantly static and passive, that is they cannot adapt their load-bearing behaviour to the actual situation. However, the long-term objective of the construction biomimetic scientists is to develop intelligent and active supporting structures that can react to environmental influences and stresses during their entire lifespan. Today's bridges are, for example, designed with a permanent maximum load which is accompanied by high material wear and tear. Intelligent bridges, on the other hand, can adjust to the actual situation. They stiffen more strongly when under greater stress, for example when a train travels over them. They relax in phases of minimal stress. When the stress increases, cable-supported bridges could automatically adjust the length of their supporting cables with the aid of computer-controlled presses. The shorter the cable, the higher the stability and efficiency of the bridges. Once the train has gone past the cables will slacken, thus drastically reducing material wear and tear. Conversely, larger and more efficient constructions are conceivable (also bridges with larger span widths).

If biomimetic solutions are consistently used, they hold an enormous potential for different areas:

- Material savings
- Increased performance
- Energy savings
- Optimisation
- Cost savings
- Improved working and living conditions
- Functional improvements

#### Further information:

[www.massivbau.tu-darmstadt.de/kgbauko/forschung\\_6/aktuelleforschungsvorhaben\\_2/bionik/bionikimbauwesen\\_1.de.jsp](http://www.massivbau.tu-darmstadt.de/kgbauko/forschung_6/aktuelleforschungsvorhaben_2/bionik/bionikimbauwesen_1.de.jsp)

"Wie Wollen Wir In Zukunft Bauen?" ["How do we want to build in future?"] Festschrift for the 60th birthday of Prof. Dr.-Ing. Wolfram Jäger, Dresden 2011, lecture by Prof. Dipl.-Ing. Architekt Stefan Schäfer "Bionik – Lösungen für die Fragen des Bauens?" ["Biomimetics solutions for construction issues?"] pp. 31-38, ISBN 978-3-86780-216-1

Illustration: "Optimised framework structures", results of work done by students on a lightweight "Tower" design project (WS 2011/12) (source: KGBauKo)

#### Core competence:

##### 1. Range of services:

Interdisciplinary teaching and research in the field of architecture and civil engineering with subjects such as civil engineering, constructive design, green building design, principles of building construction, basics of planning, designing and constructing, freehand drawing, history of civil engineering and real estate management.

##### 2. Products and services:

- Teaching and research
- Advisory services
- R&D projects
- Development of new methods and models
- Mathematical simulation

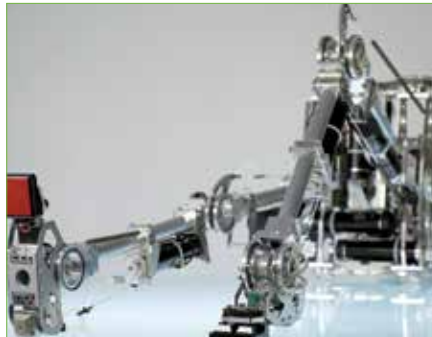
##### 3. Fields of application:

- Architecture/Construction/Planning
- Lightweight construction
- General construction
- Shaping and folding
- Green Building Design
- Energy biomimetics
- Biomimetic optimisation
- Material technologies



# Technische Universität Darmstadt

Locomotion laboratory of the Institute of Sport Science, Darmstadt



Address	Technische Universität Darmstadt Locomotion laboratory of the Institute of Sport Science Magdalenenstraße 27 Building S1/17 111 64289 Darmstadt
Telephone	+49 (0)6151-16 3163
Fax	+49 (0)6151-16 3661
Internet	<a href="http://www.sport.tu-darmstadt.de/sportinstitut">www.sport.tu-darmstadt.de/ sportinstitut</a>
Contact	Prof. Dr. André Seyfarth
Telephone	+49 (0)6151-16 6673
Fax	+49 (0)6151-16 3661
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## Walking Robot BioBiped

### Description

The vision of imitating the skills of humans using humanoid robots has inspired researchers for decades. But transferring human skills to a robot has proved in most cases to be a very difficult challenge. The focus of the working group at the Locomotion laboratory is to investigate human and animal movements for motion capture purposes. Various methods of motion analysis, bio-mechanical modelling and technical test setups are used to analyse the movements comprehensively. The objective of the BioBiped project is to make the humanoid robots run, walk and stand by freely selecting the speed and the type of gait. To achieve this objective, the department of simulation, system optimisation and robotics (SIM) of the Technische Universität Darmstadt and the Locomotion laboratory of the Technische Universität Darmstadt, are collaborating with one another.

### Further information:

[www.biobiped.de](http://www.biobiped.de)

Illustration: BioBiped robots (Source: Institute for sports sciences, Technical University of Darmstadt)

### Core competence:

#### 1. Range of services:

The research group of the sports institute at the Technical University of Darmstadt for Biomechanics. The focus of the work is the analysis and model-based synthesis of biological motion based on mechanical, muscular and neural structures

#### 2. Products and services:

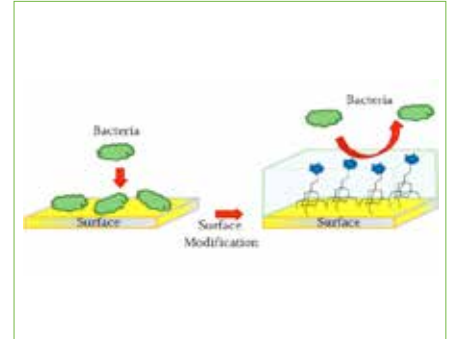
- Teaching
- Research
- R&D projects
- Development of new methods and models
- Development of new software
- BioBiped1

#### 3. Fields of application:

- Medical technology, prosthetics
- Robotics

# TransMIT Gesellschaft für Technologietransfer mbH

Gießen



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Employees	140
Established in	1996
Contact	Prof. Dr. Wolfgang Maison
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Fax	+49 (0)40-428383477
Email	<a href="mailto:maison@transmit.de">maison@transmit.de</a>

## Core competence:

### 1. Range of services:

TransMIT GmbH develops and taps the potential of approximately 6,000 scientists and various research institutes all over Hessen and beyond in the intersecting areas of science and economics

### 2. Products and services:

- Design and synthesis of novel surface binders
- Production of functionalised surfaces for implant medicine
- Antifouling surfaces
- Functionalisation of apatite and titanium surfaces
- Surface analytics (service)
- Support in the development of new functionalised materials
- Assessment of functionalised materials for medical and technical applications

### 3. Fields of application:

- Dental implants
- Teeth (also tooth coatings)
- Joint prostheses
- Biosensors
- Stents
- Cannula for syringes, catheters, infusions
- Ship hulls, marine technology
- Antibacterial coatings for hospital hygiene (door handles and other)

## Adhesive modelled on mussel proteins

### Description

Along the lines of mussel adhesion proteins, composites were initially synthesised at the University of Giessen and then at the University of Hamburg for the purpose of functionalising metallic and bone surfaces. These proteins make it possible to achieve a permanent and stable surface coating. An example in nature that researchers could use was the unique adhesion ability of mussels, familiar from marine biofouling on hulls of ships. The novel composites make it possible to realise permanent surface coatings on medically relevant metals such as iron or titanium, and also directly on bones and teeth. Hence, these are, for example, of great interest for orthopaedic implants such as hip and knee prostheses or dental implants. The coating can prevent infections and biofouling, in other words, the accretion of bacteria and proteins, and can clearly improve the bone growth. Furthermore, the composites that are internationally filed as a patent based on their special characteristics can also be used in a wide range of applications in other fields such as surface modifications for stents, syringes and catheters.

Text source: Charlotte Brückner-Ihl, Justus-Liebig University of Giessen at

[www.zwp-online.info/de/zwpnews/dental-news/branchenmeldungen/muschelproteine-fuer-die-implantatmedizin](http://www.zwp-online.info/de/zwpnews/dental-news/branchenmeldungen/muschelproteine-fuer-die-implantatmedizin)

### Project management

Prof. Dr. Wolfgang Maison, University of Hamburg, Faculty of Chemistry, Pharmaceutical and Medical Chemistry, Bundesstr. 45, 20146 Hamburg, Tel.: +49 (0)40 42838 3497

### Project marketing

TransMIT GmbH, Giessen, Project Area Biomimetic Surface Coating.

### Further information:

[www.transmit.de](http://www.transmit.de)

Illustration on the left: Example: blue mussel (Source: ©fotolia/PRILL Mediendesign)

Illustration on the right: Coating prevents the accretion of bacteria and proteins (Source: Elisa Franzmann, 2010)

# Universitätsklinikum Frankfurt, Goethe-Universität Frankfurt/M.

University Hospital Frankfurt, Goethe University Frankfurt am Main, Frankfurt am Main



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Internet	<a href="http://www.kgu.de/index.php?id=127">www.kgu.de/index.php?id=127</a>
Contact	Prof. Dr. Dr. Robert Sader
Telephone	+49(0)69-63015643
Fax	+49 (0)69-63015644
Email	<a href="mailto:r.sader@em.uni-frankfurt.de">r.sader@em.uni-frankfurt.de</a>

## Core competence:

- 1. Range of services:**  
Interdisciplinary collaboration of various research groups.
- 2. Products and services:**
  - Research
  - R&D projects
  - Development of new methods
- 3. Fields of application:**
  - Adhesive for use in dentistry, especially in implants

## BioClou wet adhesive

Joint project: Hybrid wet adhesive based on mussel proteins for dental implantology

### Description

The chemistry of the adhesive which mussels use to adhere to surfaces is a model for developing an adhesive for implants in the future. The mussel adhesive was first characterised by American scientists. Subsequently the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) in Bremen, synthesised the main components. At present, an adhesion promoting gel is being developed as a medical product which the dentist or oral surgeon can apply after implantation for protecting the peri-implant space (the space surrounding the implant). Application has been filed for a patent in which the Fraunhofer IFAM and Professor R. Sader are parties involved. The product is still being optimised at present, after which the clinical trials will begin. As soon as the initial results are available and the patent process is completed, partners will be sought for manufacturing and distributing the product BioClou.

Text source: Dr. Gisela Peters, Bad Homburg, at:

[www.dzw.de/artikel/vorbild-aus-der-natur-bakteriensicherer-verschluss-durch-muschelklebstoff](http://www.dzw.de/artikel/vorbild-aus-der-natur-bakteriensicherer-verschluss-durch-muschelklebstoff) (modified)

### Joint partners

- Clinic for OMS at the University Hospital of Frankfurt/M., Prof. Dr. Dr. R. Sader  
(Email: [r.sader@em.uni-frankfurt.de](mailto:r.sader@em.uni-frankfurt.de))
- Technical University of Darmstadt, Centre for Engineering Materials, State Materials Testing Institute (MPA), Dr. Ing. Hansgeorg Haupt (Email: [haupt@mpa-ifw.tu-darmstadt.de](mailto:haupt@mpa-ifw.tu-darmstadt.de))
- Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM), Bremen, Dr. Klaus Rischka (Email: [klaus.rischka@ifam.fraunhofer.de](mailto:klaus.rischka@ifam.fraunhofer.de))
- Department of Biomaterials, Faculty of Applied Natural Sciences, University of Bayreuth, Dr. Hendrik Bargel (Email: [hendrik.bargel@uni-bayreuth.de](mailto:hendrik.bargel@uni-bayreuth.de))

### Additional information

[www.ifam.fraunhofer.de/de/Bremen/Klebtechnik\\_Oberflaechen/Klebstoffe\\_und\\_Polymerchemie/Funktionspolymere](http://www.ifam.fraunhofer.de/de/Bremen/Klebtechnik_Oberflaechen/Klebstoffe_und_Polymerchemie/Funktionspolymere)

Illustration on the left: The mussel attaches itself to surfaces by byssus filaments with a protein adhesive. The adhesive can be seen in the form of white adhesion points on a glass surface (Source: Fraunhofer IFAM)

Illustration on the right: From the time of the operation until about two weeks later, there is no effective immunological barrier against the penetration of germs between the epithelial/connective tissue and the implant. (Source: Prof. Robert Sader, Universitätsklinikum Frankfurt)

## 4 Networks and organisations



The focus of the event organised by the Bionik-Netzwerk Hessen is professional exchange and development of new project ideas

There are a number of regional, national and international biomimetics networks and organisations which set out to increase public awareness of biomimetics. They devote themselves to the networking of biomimetics players, support the initiation of biomimetic research and development projects, and are a source of information and contacts. A selection of active networks and organisations with regular events and/or a significant number of network partners can be found below.

### 4.1 Regional networks

#### **Bionik-Netzwerk Hessen**

The Bionik-Netzwerk Hessen was initiated in the year 2012 by the Hessian Ministry of Economics. The objective is to show the companies in the region of Hessen the options and competitive edge provided by biomimetics for the economy. To tap the potential for companies in the areas of research, development, manufacturing and marketing, the department organises events and provides information on biomimetics.

At present the network is a loose association of companies and institutions. The activities offered provide a platform for discussions between companies, their suppliers or service providers, research institutes, associations and networks. Biomimetics is turning out to be a pioneer-

ring topic fostering communication between technical disciplines and between individuals with complementary skills. The basic objectives of the network are exchange of knowledge and development of joint projects. The main interests of the participants are currently directed at lightweight construction, robotics and surfaces, but the network is open to all biomimetic topics.

The Bionik-Netzwerk Hessen has an office at Bionik-Sigma Innovation GmbH. The office supports the implementation of project ideas by providing contacts, information on application and funding options, and assistance with setting up project teams.

#### **Event series "Bionik im Betrieb" ("bionics@work")**

Companies, institutions and interested individuals can obtain information about current biomimetics projects and developments in the successful event series "bionics@work". The office of the Bionik-Netzwerk Hessen designs and organises the events and runs them with the support of well-known partners. A total of 14 events in selected companies or at special locations were organised between August 2011 and October 2015. So far, 76 speakers from science and industry presented projects, products and research work. About 1,000 guests have attended these workshops up to now. Further events are planned.





Network coordinator Sigrid Belzer is the contact person for interested companies and institutions



The event series on " bionics@work " has been organised for interested parties from industry and science since 2011.

An overview of the topics discussed in the series on "bionics@work" and the partners is given in the annex.

#### Contact person:

Sigrid Belzer (network coordinator)

#### Contact:

Bionik-Netzwerk Hessen  
c/o Bionik-Sigma Innovation GmbH  
Holzhofallee 21  
64295 Darmstadt, Germany  
Email: [kontakt@bionik-hessen.de](mailto:kontakt@bionik-hessen.de)  
Telephone: +49 (0)6151-318627  
Internet: [www.bionik-hessen.de](http://www.bionik-hessen.de)

Bionik-Netzwerk  
**HESSEN**

#### Networks in other countries:

##### Baden-Württemberg

Competency network Baden-Württemberg:

[www.kompetenznetz-biomimetik.de](http://www.kompetenznetz-biomimetik.de)

##### Bavaria

Biomimetics in Bayern:

[www.bionicum.de/bionik\\_in\\_bayern](http://www.bionicum.de/bionik_in_bayern)

##### Bremen

Bionik-Innovations-Centrum (B-I-C):

[http://bionik.fbsm.hs-bremen.de/pages\\_DE/BIC\\_start.html](http://bionik.fbsm.hs-bremen.de/pages_DE/BIC_start.html)

##### Saarland

Gesellschaft für Technische Biologie und Bionik:

[www.gtbb.net](http://www.gtbb.net)

##### North Rhine-Westphalia

Bionik-Zentrum Bonn:

[www.bionik.uni-bonn.de/bzbonn-1](http://www.bionik.uni-bonn.de/bzbonn-1)



## 4.2 Supraregional networks

### BIOKON e. V. - The biomimetics competence network

BIOKON is a competence network which operates throughout Germany to bring companies and research institutes together for biomimetic innovations. The application of biological principles to technologies and products within the framework of interdisciplinary partnerships serves to increase the know-how and competitiveness of all partners concerned. Research institutes, universities, companies and individuals are organised in BIOKON. Within the biomimetics competence network, BIOKON brings together biomimetics know-how carriers in the Bionik-Forschungsgemeinschaft, and biomimetics users in the Bionik-Unternehmerforum. In this way science and industry can benefit from a comprehensive transfer of knowledge and technology in a single network. At the same time, BIOKON acts as a communication platform to further political and social awareness of the innovative potential of biomimetics.

Further information:  
[www.biokon.de](http://www.biokon.de)

### Deutsche Gesellschaft für Materialkunde e.V. (DGM)

DGM, the German Materials Society, with head office in Frankfurt am Main, provides a competent forum for all persons professionally concerned with materials, both in the scientific sphere and in industry. With the highly varied potential of its members, its numerous technical committees and its sound infrastructure, DGM provides excellent conditions for the promotion of technical exchanges between science and practical application. Of immediate relevance for biomimetics are the technical committees on "Bio-inspired and interactive materials" and "Biomaterials".

Each technical committee is made up of several working groups with defined objectives. For example, the working group on "Biomimetic biomaterials" in the technical committee of "Biomaterials" pursues the following objectives:

- to address industrial and scientific issues in the field of chemically and biologically functionalised biomaterials for applications in medical technology, biotechnology and tissue engineering
- to develop a scientifically-based understanding of the function-determining properties of materials in direct contact with fluid phase of biological origin and with tissues
- to initiate research and development projects: joint projects between universities, research institutes and industry
- to promote exchanges of experience and the formation of networks between working groups in the fields of biomimetics, medical technology, biotechnology and tissue engineering

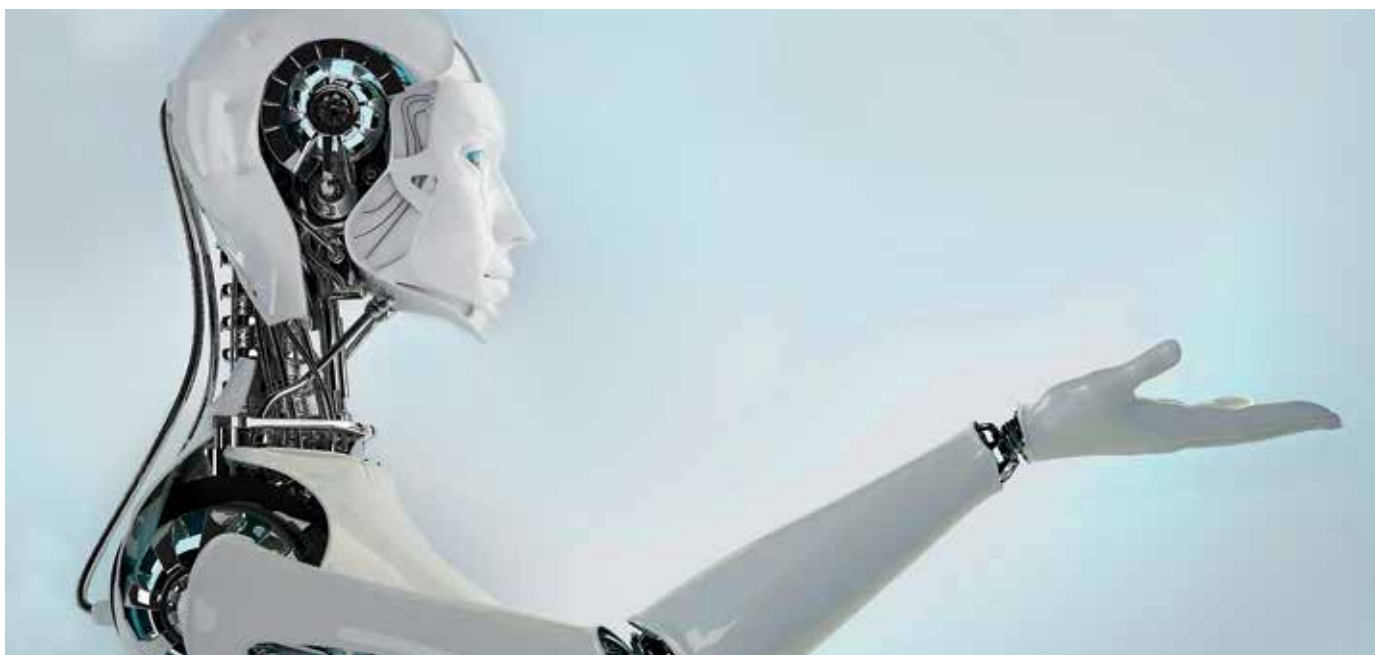
Further information:  
[www.dgm.de](http://www.dgm.de)

### VDI-Gesellschaft, Department of Technologies of Life Sciences

VDI is the largest technical association in Europe. In the Department of Technologies of Life Sciences (VDI-TLS), biomimetics is handled by a technical advisory board which includes renowned experts from the fields of management, industry and science.

The department prepares and updates the VDI guidelines on various biomimetic themes. Guidelines have been published up to now on the following topics: basics and strategy of biomimetics, surfaces, robots, materials and structures, evolutionary algorithms, structural optimisation, sensor technology, architecture and design. In the mean-





time the biomimetic approaches are being standardised at international level jointly with the German Institute for Standardisation (DIN) on the basis of the VDI guidelines.

VDI also organises the international biomimetic award, which is granted once every two years by the Schauenburg foundation to outstanding young scientists. As part of its publicity work it prepares specific presentations of biomimetics at trade fairs and events.

Further information:  
[www.vdi.de](http://www.vdi.de)

### 4.3 International networks

Universities throughout the world are conducting biomimetics research. Networks for practical implementation of the research work are still relatively rare.

European activities in the field of biomimetics are concentrated mainly in Germany, Switzerland, Austria, Sweden and Great Britain. BIO-KON International was established in March 2009 as an umbrella association. The activities in Austria are centred on the Carinthia University of Applied Sciences: [bionikum.austria](http://bionikum.austria). In the Netherlands, the advanced concept team (ESTEC) of ESA is conducting research in biomimetics. The Convergent Science Network of Biomimetic and Biohybrid Systems is promoting biomimetics in Spain. In addition, national subsidiaries of the American network of Biomimicry 3.8 have been established in many countries of Europe in the last few years.

Biomimicry Europe is an overarching association for the furtherance of biomimetics in Europe, especially in France, but also in Belgium, the Netherlands and other European countries.

Further information:  
[www.biokon-international.com](http://www.biokon-international.com)  
[www.bionikum.at](http://www.bionikum.at)  
[www.esa.int/About\\_Us/ESTEC](http://www.esa.int/About_Us/ESTEC)  
[www.csnetwork.eu](http://www.csnetwork.eu)  
[www.biomimicry.eu](http://www.biomimicry.eu)

In the United States, Biomimicry 3.8 specifically promotes the awareness of biomimetic projects by means of consultancy or educational programmes. The Biomimicry 3.8 Institute is an affiliated academic institution.

Further information:  
[www.biomimicry.net](http://www.biomimicry.net), [www.asknature.org](http://www.asknature.org)

Information platforms reflecting the interest in biomimetics can also be found in Asia.

These include the International Center for Material Research (ICMR) and the International Society of Bionic Engineering (ISBE), just to name two examples. The ICMR is an Asian network for materials and the ISBE promotes a network with focus on China.

Further information:  
[www.isbe-online.org](http://www.isbe-online.org), [www.icmr.ucsb.edu](http://www.icmr.ucsb.edu)

## 5 Funding programmes



There are a number of funding options in Hessen and at the national and European level which may be relevant for financing biomimetic projects, or which explicitly have their main focus on biomimetics. There is a wide range of possibilities, extending from thematically open invitations to submit project proposals to large-scale funding programmes for working on specific social challenges.

In addition to large joint R&D projects there are a number of programmes which call in particular on small and medium-sized companies to submit their research proposals.

There are also an international biomimetic award, foundations and training programmes, which are briefly described below.

### 5.1 Biomimetics contest

#### International bionic award - contest for young scientists

<http://www.vdi.eu/engineering/technical-divisions/technologies-of-life-sciences/bionic-award/>

Once every two years, the Schauenburg Foundation presents the International Bionic Award for outstanding research work in the field of biomimetic product development. The prize, which is endowed with 10,000 euros, is awarded by the Foundation jointly with the VDI. The contest is aimed at young scientists from throughout the world. The

international Bionic Award is presented for outstanding work, for example, in the form of a biomimetic product development or a dissertation/postdoctoral thesis which has been completed within the last two years before the date of submission. Individuals as well as teams can participate; the work must be written in English. An international jury of eminent biomimetics experts will decide on the winner(s).

### 5.2 Funding programmes in Hessen

#### Model projects in Hessen: Funds for innovative ideas

[www.innovationsfoerderung-hessen.de/](http://www.innovationsfoerderung-hessen.de/)

Hessen promotes innovative research and development projects which are carried out in cooperations between several partners from science and industry. These include small and medium-sized enterprises (SMEs), universities and other research institutions based in Hessen. The funding is open to all sectors and applications, subject to the condition that the project is characterised by a high level of innovation. The following option is available at present:

- LOEWE-Förderlinie (funding line) 3: SME joint projects: This option is financed out of State funds. Grants are made available for research projects implemented by small and medium-sized companies jointly with universities and research institutions based in Hessen. The Hessen Agentur acts as project sponsor for the Hessian Ministry of Economics.



The first step in obtaining funds is to submit a substantial project outline to the Hessen Agentur before starting the project. This can be done at any time of the year. The team from Hessen model projects is available as contact partner both at project initiation and over the entire duration of the project. All information on the funding of applied research and development projects, contact persons and application documents can be found at:

[www.innovationsfoerderung-hessen.de](http://www.innovationsfoerderung-hessen.de)



### 5.3 Funding programmes in Germany

#### German Research Association (DFG)

[www.dfg.de](http://www.dfg.de)

DFG promotes several special fields of research and core programmes linked to biomimetics:

- SPP 1207 Influencing flow in nature and technology
- SPP 1420 Biomimetic materials research: Functionality by hierarchical structuring of materials
- SPP 1569 Generation of multifunctional inorganic materials by molecular bionics
- SFB 937 Collective behaviour of soft and biological matter

#### High-tech strategy of the Federal Ministry of Education and Research (BMBF)

[www.hightech-strategie.de](http://www.hightech-strategie.de)

The objective of the high-tech strategy is to make Germany a pioneer in the handling of global challenges. Since August 2006 the high-tech strategy has become a national strategy combining a variety of research and innovation activities across all topics and policy areas. The 2006 strategy was developed further with the high-tech strategy of 2020, which focuses on five urgent issues: climate/energy, health/nutrition, mobility, security and communications.



In future-oriented projects, selected missions are placed at the centre of the Federal Government's research and innovation policy. Such projects pursue specific scientific and technological development targets over a period of ten to fifteen years, with innovation strategies and implementation steps being planned on a case-by-case basis. For the solution of larger issues, it is essential to formulate objectives and visions which are socially desired and have the backing of industry, science and politics. To this end the Federal Government – with advice from the Research Union of Industry and Science – has drawn up ten future-oriented projects and identified key technologies.

BioBionik projects can be set up in practically any area.

#### **Ten projects for the future:**

- Carbon-neutral, energy-efficient and climate-adapted cities
- Renewable raw materials as an alternative to oil
- Intelligent restructuring of the energy supply
- Improved disease treatment with individualised medicine
- Better health through specific prevention and tailored nutrition
- Leading a self-determined life even in old age
- Sustainable mobility
- Internet-based services for industry
- Industry 4.0
- Secure identities

#### **Key technologies:**

- Biotechnology
- Service industry
- Vehicle and transportation technologies

- Information and communication technologies
- Aviation technologies
- Maritime technologies
- Microsystems technology
- Nanotechnologies
- Photonics/optical technologies
- Production technologies
- Space technologies
- Material technologies

#### **Central innovation programme for SMEs (ZIM) of the Federal Ministry of Economy and Energy (BMWi)**

[www.zim-bmwi.de](http://www.zim-bmwi.de)

ZIM is a nation-wide funding programme for small and medium-sized enterprises and the applied research institutes working together with them. It is not limited to specific sectors or technologies. However, after the new ZIM guidelines came into effect on 15 April 2015, companies continue to have prospects of support for their innovative efforts. The programme is not confined to particular topics and offers a speedy application and approval procedure for the following funding alternatives:

- ZIM individual projects
- individual R&D projects of companies
- ZIM - joint projects
- Joint R&D projects between/of companies with research institutions
- ZIM cooperation networks
- Cooperation networks as a unity of network management and R&D projects

## 5.4 Horizon 2020 - Framework programme of the European Union

Horizon 2020, the new EU Framework Programme for Research and Innovation, follows on from the 7th EU Research Programme (FRP). Planned to run from 2014 to 2020 and with a budget of around 70 billion euros, Horizon 2020 is probably the largest instrument world-wide for promotion of research and innovation. Horizon 2020 brings together all programmes of the European Commission which are relevant for research and innovation.

[www.horizont2020.de](http://www.horizont2020.de)

The objective of the funding programme is to establish a knowledge and innovation-based society and a competitive economy throughout the EU, while at the same time contributing to sustainable development. To ensure a more effective social impact, the programme focuses on three aspects:

### 1. Scientific excellence:

Promotion of scientific excellence in Europe. Top scientists should be enabled to conduct research at the highest level in the future.

### 2. Leading role of the industry:

The leading role of the industry should be backed up by a powerful innovative capacity. To this end Horizon 2020 promotes key technologies such as nanotechnology, biotechnology, advanced materials and advanced manufacturing technology, provides easier access to risk financing and consistently drives innovations through specific measures in small and medium-sized enterprises.

### 3. Social challenge:

The objective is to bridge the gap between scientific excellence and the market with a view to addressing the major challenges of our age: health, demographic change and welfare, nutrition and food security, bioeconomy; secure, clean and efficient energy; climate protection and transport – to name just a few.

## Horizon 2020 – Structure of the program

Part I Scientific excellence	Part II Leading role of the industry	Part III Social challenges
European Research Council (ERC)	Leading role in basic and industrial technologies <ul style="list-style-type: none"><li>Information and communication technologies</li><li>Nanotechnologies</li><li>Advanced materials</li><li>Biotechnology</li><li>Advanced manufacturing and processing</li><li>Astronautics</li></ul>	Health, demographic change and welfare
Future and emerging technologies (FET)		Challenges of the European bioeconomy
Marie Curie scholarships		Energy
Research infrastructures		Transport
		Climate protection, resource efficiency
	Access to risk financing	Integrative and secure society
	Innovations in SMEs	

It would be possible to submit applications for biomimetics projects in several areas of the funding programme. The framework research programme also includes a funding instrument, the SME instrument, which was developed specially for SMEs and requires no involvement on the part of research institutes.





### Marie Curie programmes of the European Union

[www.ec.europa.eu/research/mariecurieactions](http://www.ec.europa.eu/research/mariecurieactions)

As part of the Marie Curie programmes, researchers can receive financial grants regardless of age, gender or nationality. In addition to generous scholarships, the researchers have the opportunity to gather experience abroad and in the private sector and to enhance their qualifications with other skills or disciplines which could be of advantage for their careers.

Initial training networks for researchers (ITN) are programmes to fund training opportunities for young researchers, which are usually offered by a network of universities, companies and research institutes.

Here are some bionics-related examples from the 7th EU Framework Research Programme topics:

#### ENHANCE:

[www.enhance-itn.eu](http://www.enhance-itn.eu)

Marie Curie Initial Training Network ENHANCE "New Materials: Innovative Concepts for their Fabrication, Integration and Characterisation"

The project includes the entire spectrum of functional materials for micro-electronics, nano-electronics, data storage and photovoltaics, with special emphasis on nanotechnology.

#### BIOMINTEC:

[www.biomintec.de](http://www.biomintec.de)

Marie Curie Initial Training Network BIOMINTEC "Biomineralisation: Understanding of basic mechanisms for the design of novel strategies in nanobiotechnology"

The project focuses on biominerals consisting of calcium carbonate or biosilica glass, since these biominerals have assumed enormous importance in recent years and the interest in them has increased sharply.

#### SHeMat:

[www.shemat.eu](http://www.shemat.eu)

Marie Curie Initial Training Network SHeMat "Training Network for Self-Healing Materials: from Concepts to Market"

Research activities here are concerned with self-healing materials. The objective is to develop self-healing materials from different classes of materials and to bring the most promising material concepts and developments onto the market.



## 5.5 Foundations

### Deutsche Bundesstiftung Umwelt (DBU)

Processes: Environment and health-friendly processes and products

[www.dbu.de/1815.html](http://www.dbu.de/1815.html)

Funding is focused primarily on the development of innovative, health-friendly, climate-friendly, resource-efficient, low-waste and low-emission processes, technologies and products which avoid the shifting of environmental pollution from one area to another. The funding is intended to encourage SMEs to take action and reduce technical and economic implementation risks. Companies can combine their development activities by collaborating with partners on joint projects. Especially in the case of R&D projects showing highly promising results, it is possible to help potential reductions of environmental burdens to be put quickly and efficiently into effect by funding measures which serve to create a network between science and everyday practice.

### Volkswagen foundation

[www.volkswagenstiftung.de/foerderung/herausforderung/experiment.html](http://www.volkswagenstiftung.de/foerderung/herausforderung/experiment.html)

The funding initiative "Experiment!" provides speedy and uncomplicated support for ambitious research projects in the areas of natural science, engineering and life sciences, including behavioural biology and experimental psychology. Sponsorships normally available in Germany are scarcely concerned with the exploration of radically new research ideas which challenge the foundations of mainstream knowledge or aim to establish unconventional hypotheses, methods and technologies or focus on completely new lines of research. This is where "Experiment!" comes in, a new funding initiative with which the Volkswagen Foundation provides support, over a limited period of time and within a defined financial framework, for fundamentally new research projects with an uncertain outcome.

## 5.6 Contact partner Funding programmes

Information about funding programmes and the arrangement of contacts with sponsors can be obtained from regional and topic-specific networks, the state and federal ministries and their project sponsors. Some of these are listed below:

Biomimetics networks of Hessen:

[www.bionik-hessen.de](http://www.bionik-hessen.de)

BIOKON e.V.:

[www.biokon.de](http://www.biokon.de)

Model projects in Hessen:

[www.innovationsfoerderung-hessen.de](http://www.innovationsfoerderung-hessen.de)

Technology Transfer Network (TTN) in Hessen:

[www.ttn-hessen.de](http://www.ttn-hessen.de)

IHK innovation advisory service in Hessen:

[www.ihk-innovationsberatung.de](http://www.ihk-innovationsberatung.de)

Hessen Trade & Invest GmbH:

[www.htai.de](http://www.htai.de)

Enterprise Europe Network Hessen (EEN Hessen):

[www.een-hessen.de](http://www.een-hessen.de)

Funding advice on "Research and innovation" provided by the Federal government:

[www.foerderinfo.bund.de/index.php](http://www.foerderinfo.bund.de/index.php)

Association of German engineers (VDI):

[www.vdi.de](http://www.vdi.de)

Although the list is certainly not complete, it can serve as a guide for those seeking possible sources of funds for research and development projects in the field of biomimetics.

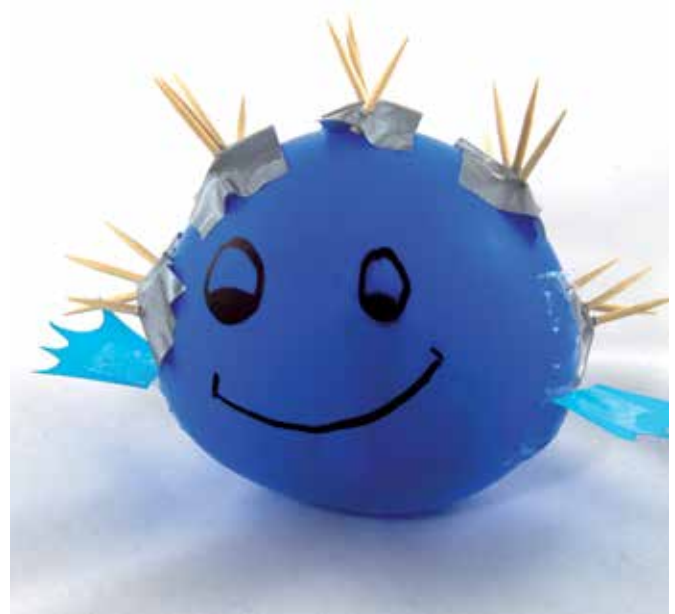
## 6 Training programmes



Motivated and well trained technical staff are vital for a successful and forward-looking company. Employees with innovative ideas can ensure competitive advantages. Biomimetics is especially suitable for introducing people of all ages to the various scientific disciplines – at the same time it fosters interdisciplinary thinking and brings out clearly the importance of creativity for innovation.

Training materials for use in schools are provided by a number of publishers and also by various institutions on their internet sites. Hessen offers many out-of-school learning programmes for children and young people, and also for interested adults, as can be seen from the overview below.

The number of universities and universities of applied sciences teaching biomimetics has increased in the last few years. An overview of the study opportunities will be found at the end of the chapter.



### 6.1 Out-of-school learning programmes in Hessen

#### Bionik Sigma Education

Bionik-Sigma organises workshops, advanced training courses and lectures on biomimetics. Its educational programmes are aimed at schools, educational institutions and companies. Continuing professional development (CPD) events for teachers are particularly well suited for interdisciplinary Minimum Industry Safety Training (MIST) courses. The offer is rounded off by lectures, presentations and publications, also by advisory services for exhibitions and other biomimetics projects.

Further information:

<http://education.bionik-sigma.de>

#### Bioversum Kranichstein

Bioversum Kranichstein organises workshops and project days on specific topics for all age groups, together with lectures and guided tours on various scientific themes.

Further information:

[www.bioversum-kranichstein.de](http://www.bioversum-kranichstein.de)

#### Botanical garden of the Technical University of Darmstadt

The "Green Classroom" – an off-campus classroom at the botanical garden – is intended to appeal especially to children and young people. It is a venue for school events, including workshops on biomimetics. Guided tours are also possible on the biomimetics trail.



The Darmstadt Botanical Garden is a member of the German Botanical Gardens Association, which organises the annual "Botanical Garden Week", an event at which the typical features of teaching, research and everyday work related to the gardens and their collections are presented to the public. The event serves to bring research and expert knowledge closer together and to increase public interest in the practical side of biomimetics. In 2011, the focus of the Botanical Garden Week was on "Biomimetics - Learning from plants for technology" which gave rise to the information panels along the biomimetics trail.

Further information:

[www.verband-botanischer-gaerten.de/bionik\\_in\\_gaerten/ausstellung](http://www.verband-botanischer-gaerten.de/bionik_in_gaerten/ausstellung)

#### **Wiesbaden experimental workshop: biomimetics camps**

The experimental workshop organises courses, school projects and holiday activities for children and young people, for example robotic-bionic camps.

Further information:

[www.experimentierwerkstatt.com](http://www.experimentierwerkstatt.com)

#### **EXPERIMINTA Science Centre FrankfurtRheinMain**

The EXPERIMINTA Science Center is a hands-on museum with many experimental stations which invite visitors to try things out and to be amazed. It organises school workshops, guided tours, special events and regular scientific lectures. In 2013, the focus was on biomimetics.

Further information:

[www.experiminta.de](http://www.experiminta.de)

#### **Senckenberg research institute and natural history museum in Frankfurt am Main.**

The museum's educational programme offers many options, including regular programmes on biomimetics.

Further information:

[www.senckenberg.de](http://www.senckenberg.de)

#### **two4science GmbH**

two4science supports companies and institutions in their commitment to scientific and technical education: As an education service provider, two4science develops individual learning environments for tomorrow's researchers and gives its customers support on practical implementation of their ideas.

Other offers include the organisation of science camps in Hessen during school holidays with a variety of different topics, including biomimetics

Further information:

[www.two4science.de](http://www.two4science.de)



### Environment Centre at Hanau

The education centre of the city of Hanau organises environmental education courses for schools and day-care facilities as well as CPDs for teachers and kindergarten teachers. The Environment Centre offers more than 50 courses and projects, which are also aimed at families, groups of children and senior citizens. In addition to the conventional environmental topics, the interactive mobile exhibition "Nature - the biomimetics lab of ideas" was developed in cooperation with the technical university of Darmstadt. The exhibition is available on loan to schools and companies.

#### Further information:

[www.umweltzentrum-hanau.de](http://www.umweltzentrum-hanau.de)

[www.ideenlabor-natur.de](http://www.ideenlabor-natur.de)

## 6.2 Study options

Many universities run research projects on biomimetic topics. A selection of institutes in Hessen is already included with competence profiles in this Competence Atlas. Courses providing training in biomimetics are offered by the following universities:

#### Bremen University

<http://bionik.fbsm.hs-bremen.de>

#### Bocholt University of Westphalia

[www.w-hs.de/bionik-boh](http://www.w-hs.de/bionik-boh)

#### Technical university of Carinthia

[www.fh-kaernten.at/bauingenieurwesen-architektur/studienueberblick.html](http://www.fh-kaernten.at/bauingenieurwesen-architektur/studienueberblick.html)

#### Hamm-Lippstadt University

[www.hshl.de/materialdesign-bionik-photonik](http://www.hshl.de/materialdesign-bionik-photonik)

#### Rhein-Waal University

[www.hochschule-rhein-waal.de/studium/fachbereiche/technologieundbionik/bionik.html](http://www.hochschule-rhein-waal.de/studium/fachbereiche/technologieundbionik/bionik.html)

The Internet site of the Bionics Competence Network and the Plant Biomechanics Group Freiburg provides a very good overview of the biomimetics study options in Germany in the form of an "education map": [www.bionik-online.de](http://www.bionik-online.de)



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VDI 6222 Blatt1 Bionik – Bionische Roboter [Part 1: Biomimetics - Biomimetic robots]. Berlin: Beuth Verlag, 2013.

VDI 6223 Blatt 1 Bionik – Bionische Materialien, Strukturen und Bauteile [Part 1: Biomimetics - Biomimetic materials, structures and components]. Berlin: Beuth Verlag, 2013.

VDI 6224 Blatt 1 Bionische Optimierung – Evolutionäre Algorithmen in der Anwendung [Part 1: Biomimetic optimisation - Application of evolutionary algorithms]. Berlin: Beuth Verlag, 2012.

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[www.vdi.de/uploads/media/Broschuere\\_TLS\\_Positionspapier\\_Zukunft\\_der\\_Bionik\\_01.pdf](http://www.vdi.de/uploads/media/Broschuere_TLS_Positionspapier_Zukunft_der_Bionik_01.pdf)  
abgerufen am 14.3.2014

# Annex

## Partners of the event series "Bionik im Betrieb" (bionics@work), listed by events

### Overall partners of the event series bionics@work (2011/2012)

Technologielinie Hessen-Nanotech

HA Hessen-Agentur GmbH

Ministry of Economics, Transport and Regional Development - State of Hessen

IHK Darmstadt Rhein Main Neckar

Hessian Ministry of Science and Art

Biokon e.V.

Verband Botanischer Gärten (VBG)

Bionik-Sigma, Sigrid Belzer & Martin Zeuch GbR

European Union

### Kick-off event bionics@work 30.08.2011

Host: IHK Darmstadt Rhein Main Neckar

Partner: Botanical Garden of the Technische Universität Darmstadt

### Workshop on materials, 17.11.2011

Host: Heraeus, Hanau

Partner: DGM, IHK Hanau-Gelnhausen-Schlüchtern





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**Workshop on lightweight construction and structure,  
24.01.2012**

Host: Adam Opel AG, Rüsselsheim

Partner: City of Rüsselsheim



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**Workshop on drives and sensors, Altes Schalthaus  
Darmstadt, 22.3.2012**

Partner: Technische Universität Darmstadt



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**Workshop on surfaces, 08.05.2012**

Host: Rittal, Herborn



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**Closing event on strategies, 19.06.2012**

Host: Dechema e.V. Frankfurt/M.



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**Workshop on form and function - innovation potential of  
biomimetics, 29.11.2012**

Partner: EuroMold, Frankfurt/M.



**Overall partners for the event series bionics@work (2013-2015) as well as for seminars and events (2015)**

Bionik-Netzwerk Hessen

Technologielinie Hessen-Nanotech

Hessen Trade & Invest GmbH

Ministry of Economics, Energy,  
Transport and Regional Development - State of Hessen

European Union

Bionik-Sigma Innovation GmbH



**Workshop on fascinating biomimetics - Innovative projects for vocational training, 15.05.2013**

Host: Science Center Experiminta, Frankfurt/M.

Partner: Hessen-IT, Aldebaran, Festo, IHK Innovationsberatung  
Hessen



**Workshop on noise reduction using nature as an example, 25.09.2013**

Host: Fraunhofer Institute for structural durability and system  
reliability LBF, Darmstadt



**Workshop on technical textiles and composite fibre materials, 13.02.2014**

Host: Karl Mayer Textilmaschinenfabrik GmbH, Obertshausen

Partner: Industrieverband Veredlung – Garne - Gewebe - Technische  
Textilien e.V. (IVGT)



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### **Kreativ-Seminar: Bionik mit Perspektive, 30.01.2015**

Organizer: Bionik-Netzwerk Hessen

Partner: IHK Innovationsberatung Hessen

Venue: IHK Darmstadt

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### **Seminar Bionischer Leichtbau (Biomimetic Lightweight Construction), 20.03.2015**

Organizer: Bionik-Netzwerk Hessen

Venue: Lufthansa Training & Conference Center,  
Seeheim-Jugenheim

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### **Bionics@work, 16.06.2015**

Organizer: Technologielinie Hessen-Nanotech

Venue:: ACHEMA 2015, Messe Frankfurt/M.



VERBAND  
DEUTSCHER  
INDUSTRIE  
DESIGNER



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### **Bionik und 3D-Druck: Von der Idee zum Bauteil, 15.10.2015**

Organizer: Bionik-Netzwerk Hessen

Host: Kegelmann Technik GmbH, Rodgau-Jügesheim

Partner: Verband Deutscher Industrie Designer e.V. (VDID),  
Netzwerk „Design to Business“ der IHK Innovationsberatung Hessen





[www.hessen-nanotech.de](http://www.hessen-nanotech.de)



[www.bionik-sigma.de](http://www.bionik-sigma.de)

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