

## Dr. Benjamin M. Friedrich

Date of birth: 22.07.1979

Marital status: married, three children

Nationality: German

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### Education

2016	Habilitation in Theoretical Physics at TU Dresden: pending - Title of thesis: 'Nonlinear dynamics and fluctuations in biological systems' - Notification at Faculty board: passed without conditions on 20.01.2016
02/09	PhD in Theoretical Physics (supervisor Frank Jülicher) - Title of PhD thesis: 'Chemotaxis of sperm cells' - Thesis submission: 20.10.08, PhD defense: 17.02.09 ( <i>summa cum laude</i> )
10/99 – 03/04	Diploma course Mathematics at Universität Leipzig ( <i>Final grade 1.0</i> ) - Title of Diploma thesis: 'Periods and Algebraic deRham Cohomology'
10/01 – 07/02	Master's course at University of Cambridge, UK - Degree: Certificate of Advanced Study in Mathematics ( <i>distinction</i> )
08/91 – 07/98	Abitur (A-levels) in Rostock ( <i>Final grade 1.0</i> )

### Professional experience

since 04/16	Research Group Leader 'Biological Algorithms Group' in the Biological Systems Path of the Center for Advancing Electronics Dresden, TU Dresden
10/11 – 03/2016	Independent Research Fellow at the Max Planck Institute for the Physics of Complex Systems, Dresden Mechanical and chemical regulation in complex biological systems
09/09 – 08/11	Post-doc with Samuel Safran at the Weizmann Institute of Science, Rehovot, Israel Statistical physics of the cytoskelib
08/05 – 08/09	PhD student and post-doc with Frank Jülicher at the Max Planck Institute for the Physics of Complex Systems, Dresden
09/07	Guest stay in the lab of U. Benjamin Kaupp at the Institut für Zelluläre Signalverarbeitung, Forschungszentrum Jülich Data analysis for sperm chemotaxis experiments
01/05 – 07/05	Guest scientist with Angela Stevens at the Max Planck Institute for Mathematics in the Sciences, Leipzig Work in mathematical biology (elasticity of prokaryotic flagella)

09/04 – 10/04	Visiting Associate with the Boston Consulting Group GmbH
04/04 – 08/04	Teaching assistant in Mathematics at Universität Leipzig, Germany
10/99 – 03/04	Diploma course Mathematics at Universität Leipzig ( <i>Final grade 1.0</i> )
10/01 – 07/02	Study at University of Cambridge, UK Master's degree: Certificate of Advanced Study in Mathematics ( <i>distinction</i> )

### Awards & Scholarships

2009	Otto-Hahn medal of the Max-Planck Society
1998	Bronze medal prize at the International Mathematics Olympiad, Taiwan
2010-2011	Koshland fellowship (Weizmann Institute of Science)
2009-2011	Postdoctoral fellowship from German Academic Exchange Service (DAAD)
2005-2008	PhD-scholarship German National Academic Foundation (Studienstiftung)
2001-2002	Scholarship from German Academic Exchange Service (DAAD)
1999-2004	Scholarship German National Academic Foundation (Studienstiftung)

### Acquired third-party funding

2016-2018	<b>"The mechanosensitive flagellum"</b> French 'Agence National de la Recherche': - <i>selected for funding (success rate 7%)</i> - <i>declined by me in favor of cfaed offer</i>	(400k€) declined by me
2015-2018	<b>FR 3429/1-1</b> <b>"Synching noisy flagella"</b> Theory of synchronization in collections of beating flagella, accounting for active flagellar fluctuations DFG priority program "Microswimmers" (SPP 1726)	174k€
2009-2011	<b>Statistical physics of active force generators in the cytoskeleton of biological cells</b> DAAD post-doctoral scholarship	54k€
2010-2011	<b>Theory of cellular mechano-sensing</b> "Dean of Faculty" Koshland fellowship of the Weizmann Institute of Science	18k€

**Publications in peer-reviewed journals**

1. **B.M. Friedrich**: A mesoscopic model for helical bacterial flagella, *J. Math. Biol.* **53**, p. 162-178, 2006
2. **B.M. Friedrich**, Frank Jülicher: Chemotaxis of sperm cells, *Proc. Natl. Acad. Sci. U.S.A.* **104**(33), p. 13256-13261, 2007 (highlighted in Nature Physics)
3. **B.M. Friedrich**: Search along persistent random walks, *Phys. Biol.* **5**, p. 026007(6), 2008
4. B.M. Friedrich, Frank Jülicher: The stochastic dance of circling sperm cells: Sperm chemotaxis in the plane, *New J. Phys.* **10**, p. 123025(19), 2008
5. **B.M. Friedrich**, Frank Jülicher: Steering chiral swimmers along noisy helical paths, *Phys. Rev. Lett.* **103**, 068102, 2009
6. **B.M. Friedrich**, I.H. Riedel-Kruse, J. Howard, F. Jülicher: High-precision tracking of sperm swimming fine structure provides strong test of resistive force theory, *J. exp. Biol.* **213**, p. 1226-1234, 2010
7. **B.M. Friedrich**, S. A. Safran: Nematic order by elastic interactions and cellular rigidity sensing, *Europ. Phys. Lett.* **93**, p. 28007(6), 2011
8. **B.M. Friedrich**, A. Buxboim, D. Discher, S. A. Safran: Striated acto-myosin fibers can re-organize and register in response to elastic interactions with the matrix, *Biophys. J.* **100**, 2011
9. E. Fischer-Friedrich, **B. M. Friedrich**, N. S. Gov: FtsZ rings and helices: Physical mechanisms for the dynamic alignment of biopolymers in rod-shaped bacteria, *Physical Biology* **9**, 1, 2012
10. L. Armon, S. R. Caplan, M. Eisenbach, **B. M. Friedrich**: Testing human sperm chemotaxis: How to detect biased motion in population assays, *PLoS ONE* **7**(3), 2012
11. **B. M. Friedrich**, S. A. Safran: How cells feel their substrate: Spontaneous symmetry breaking of active surface stresses, *Soft Matter* **8**(11), 2012
12. L. Alvarez, L. Dai, **B.M. Friedrich**, I. Gregor, R. Pascal, N. Kotzur and U. B. Kaupp: The rate of change in  $Ca^{2+}$  concentration controls sperm chemotaxis, *J. Cell Biol.* **196**(5), 2012
13. **B. M. Friedrich**, E. Fischer-Friedrich, N. S. Gov, S. A. Safran: Sarcomeric pattern formation by actin cluster coalescence, *PLoS Comp. Biol.* **8**(6), 2012
14. **B. M. Friedrich**, F. Jülicher: Flagellar synchronization independent of hydrodynamic interactions, *Phys. Rev. Lett.* **9**, p. 138102, 2012 (selected as "Editor's suggestion")
15. K. Polotzek, **B. M. Friedrich**: A three-sphere-swimmer for flagellar synchronization, *New J. Phys.* **15**, p. 045005, 2013
16. V. Geyer, F. Jülicher, J. Howard, **B.M. Friedrich**: Cell body rocking is a dominant mechanism for flagellar synchronization in a swimming alga, *Proc. Natl. Acad. Sci. U.S.A.* **110**, p. 18058, 2013
17. L. Alvarez, **B.M. Friedrich**, G. Gompper, U.B. Kaupp: The computational sperm cell, *Trends in Cell Biology*, **24**, p. 198, 2014
18. R. Ma, G.S. Klindt, I.-H. Riedel-Kruse, F. Jülicher, **B.M. Friedrich**: Active phase and amplitude fluctuations of flagellar beating, *Phys. Rev. Lett.* **113**, p. 048101, 2014
19. S. Werner, J.C. Rink, I.-H. Riedel-Kruse, **B.M. Friedrich**: Shape mode analysis exposes movement patterns in biology, *PLoS One*, 0113083, 2014
20. S. Werner, T. Stückemann, M. Beiran Amigo, J.C. Rink, F. Jülicher, **B.M. Friedrich**: Scaling and regeneration of self-organized patterns, *Phys. Rev. Lett.* **114**, p. 138101, 2015 (selected as "Editor's suggestion")

21. J.F. Jikeli\*, L. Alvarez\*, **B.M. Friedrich\***, L.G. Wilson\*, R. Pascal, R. Colin, M. Pichlo, A. Rennhack, C. Brenker, U.B. Kaupp: Sperm navigation along helical paths in 3D chemoattractant landscapes, *Nature Communications* **6**, 7985, 2015 (\* = equal contribution)
22. G.S. Klindt, **B.M. Friedrich**: Flagellar swimmers oscillate between pusher- and puller-type swimming. *Phys. Rev. E* **92**, 063019, 2015
23. V.F. Geyer, P.Sartori, **B.M. Friedrich**, F. Jülicher, J. Howard: The static and dynamic components of the flagellar beat of *Chlamydomonas* can be controlled independently, *Current Biology Report*, **26**, 1098, 2016
24. **B.M. Friedrich**: Hydrodynamic synchronization of flagellar oscillators. *European Physics Journal*, Special Topics Issue on “Microswimmers”, *Editorial recommendation for acceptance*

### Other publications

- S1. **B.M. Friedrich**: Wege zum Sierpinski-Gitter, *Junge Wissenschaft* **48**, p. 29-31, 1997
- S2. **B. M. Friedrich**: The Dynkin diagrams of rational double points (Essay), 2002.  
arXiv:math/0506107
- S3. **B. M. Friedrich**: Periods and algebraic deRham cohomology (Diploma thesis), 2004.  
arXiv:math/0506113
- S4. **B.M. Friedrich**: Chemotaxis of Sperm cells (PhD thesis), TU Dresden, 2008
- S5. **B.M. Friedrich**, U.B. Kaupp: Wie Spermien zum Ei finden: Eine schwimmende Nervenzelle, *Physik in unserer Zeit*, **42**, p. 196-200, 2011
- S6. **B.M. Friedrich**, V.F. Geyer: Grünalgen wackeln sich in den Takt, *Physik in unserer Zeit*, **45**(3), p. 113, 2014
- S7. **B.M. Friedrich**, I.H. Riedel-Kruse: Flagellar beating: row with the flow. *eLife*, e03804, 2014
- S8. Johannes Baumgart, **B.M. Friedrich**: Fluid dynamics: Swimming across scales, *Nature Physics*, 2014
- S9. **B.M. Friedrich**: Hydrodynamic synchronization in flagellar oscillators. In “Microswimmers – From Single Particle Motion to Collective Behavior”. Eds. G. Gompper et al., FZ Jülich, Jülich, 2015 (book chapter)
- S10. L. Soler, R. Körbitz, **B.M. Friedrich**, A. Richter, S. Sánchez: Thermotaxis of catalytic microjet swimmers, *sub judice*
- S11. Gary S. Klindt, C. Ruloff, C. Wagner, **B.M. Friedrich**: A force-velocity relationship of the flagellar beat, preprint

Publication list with abstracts: <http://publicationslist.org/benjamin.friedrich>

**Invited talks**

1. "Chemotaxis of sperm cells" at *Collective dynamics and pattern formation in active matter systems workshop*, Berlin, 2009
2. "What sperm head wiggling can tell us about flagellar hydrodynamics" at *Symposium JDPG*, Dresden, 2011
3. "Steering along circular and helical paths is robust and efficient" at *1st International CAESAR conference*, Bonn, 2011
4. "Rigidity sensing and cellular forces" at *Minisymposium on Biological Machines*, Rehovot, Israel, 2012
5. "Flagellar synchronization independent of hydrodynamic interactions" at *Active Particles and Microswimmers*, Ringberg, 2013
6. "How Chlamydomonas rocks to synchronize its flagella", *Symposium Micro- and Nanomachines*, Hannover, 2014
7. "Sperm navigation along helical paths in 3D chemoattractant landscapes" at *MOTIMO workshop*, Toulouse, 2015
8. "Principles of flagellar synchronization" at 'Microswimmers' summer school, FZ Jülich, 2015
9. "The navigation principle of marine sperm chemotaxis" at 'The Omnipresent Cilium – Structure, Signalling, and Motion', Bonn, 2015
10. Speaker invitation at *EMBO conference: 'The Molecular & Cellular Basis of Regeneration and Tissue Repair'*, Paestum, Italy, 2016
11. Speaker invitation at summer school: '*Living and Active Matter*', Corsica, 2016, declined
12. Speaker invitation at *BioSoft Frontiers conference*, Tel Aviv, 2016

Seminar talks and contributed talks are not included.

**Reviewer for scientific journals and grant agencies:**

Physical Review Letters (20x), Nature Physics, eLife, PLoS Computational Biology, Wellcome Trust, Israel Science Foundation, Journal of Experimental Biology, Biophysical Journal, New Journal of Physics, Europhysics Letters, European Physical Journal, PLoS ONE, Physical Review E (18x), Biomicrofluidics, Biology Open, Biomechanics and Modeling in Mechanobiology, Systems Biology in Reproductive Medicine, Journal of Marine Systems

Joint reviews with senior researchers: Science, Proc. Natl. Acad. Sci. U.S.A.

**Organization of international workshop: Principles of biological and robotic navigation**

Co-organizers: Samuel Sanchez (Barcelona), U. Benjamin Kaupp (Bonn)

29.-31.08.2016, Max Planck Institute for the Physics of Complex Systems, Dresden

## Teaching experience and supervision of students

Summer term 2016	<b>Nonlinear dynamics and stochastic processes</b> at TU Dresden - stability, bifurcation theory, pattern formation, Langevin equations (2h/week, Masters level)
Summer term 2015	<b>Continuums mechanics for Biological Physics</b> at TU Dresden - fluid dynamics, elasticity theory, applications in biological physics (2h/week lecture, 2h/week tutorial, Masters level)
Winter term 2014/15	<b>Kinematics of noisy motion</b> at TU Dresden (3x 2h lecture series)
Summer term 2014	<b>Continuums mechanics for Biological Physics</b> at TU Dresden (2h/week lecture, Masters level)
Summer term 2007	<b>Tutor „Physikpraktikum“</b> at TU Dresden
Winter term 2006/07	<b>Tutor „Theoretische Mechanik“</b> at TU Dresden
Summer term 2004	<b>Tutor „Algebra I (Gruppen, Ringe, Körper)“</b> at Universität Leipzig
<b>Supervision of Post-Docs</b>	<ul style="list-style-type: none"> <li>- Dr. Justus Kromer: Dynamic decision making in sperm navigation</li> <li>- Dr. Jens Karschau: Self-organization of resilient transport networks</li> </ul>
<b>Supervision of PhD students</b>	<ul style="list-style-type: none"> <li>- Steffen Werner, Physics of Regeneration in the Flatworm <i>Planaria</i> (submitted 12/2015)</li> <li>- since 2013: Gary Klindt, Synchronization of noisy flagellar oscillators</li> <li>- since 2013: André Scholich, Functional architecture of liver tissue</li> </ul>
<b>Supervised Bachelor &amp; Master theses</b>	<ul style="list-style-type: none"> <li>- 2014: Simon Syga, Nematic order in complex tissues (grade 1.0)</li> <li>- 2007: Philipp Lätzel, Sperm chemotactic signaling (grade 1.3)</li> </ul>
<b>Summer students</b>	<ul style="list-style-type: none"> <li>- Manuel Beiran (2013), Principles of scalable pattern formation, contribution to Phys. Rev. Lett.</li> <li>- Katja Polotzek (2012), Flagellar synchronization, published in New Journal of Physics</li> <li>- Jing Yang (2007), Hydrodynamics of <i>Chlamydomonas</i> swimming</li> </ul>