BIOGRAPHICAL SKETCH

Provide the following information for the Senior/key personnel and other significant contributors.
Follow this format for each person. **DO NOT EXCEED FIVE PAGES.**

NAME: Braun, Dieter

POSITION TITLE: Associate Professor of Biophysics

EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
Technical University Munich	Diploma	04/1997	Physics
Technical University Munich	PhD	04/2000	Physics
Rockefeller University, NY	Postdoctoral	06/2003	Biophysics

A. Personal Statement

My research is centered on integrating the principles of physics and chemistry to unravel the mysteries surrounding the origins of life. Through lab experiments, I aim to understand how life emerged and reconstruct its first evolutionary steps. Although our niche is quite specific (only about 10 groups worldwide focus seriously on this topic), our publications in high-profile, diverse journals such as Nature, PNAS, Nature Physics, Nature Chemistry, Angewandte, JACS, and PRL demonstrate our ability to combine disciplines such as geoscience, chemistry, biology, and physics.

I have a proven ability to design complex experiments from scratch to address specific scientific questions. With this mindset, my membership in the Simons Collaboration on the Origins of Life enhanced my understanding of chemistry, and as a result, our group conducted highly challenging experiments in the field of the origins of life. Before receiving the ERC Starting, Advanced, and Synergy grants, I was awarded the Klung Wilhelmy Prize, the most highly endowed biennial prize for young physicists in Germany.

Although I am seen as an experimentalist, our track record is in combining experimental explorations with full theoretical modeling of the experiments. Our group has gained decade-long experience in engineer-like finite element calculations that combine diffusion and complex kinetic networks with the intricacies of flow dynamics. For instance, recognizing the limitations of existing mass spectrometry software, I programmed a 180 MB, 350-file LabVIEW code suite that automatically fits RNA mass data to simulated isotopologues.

I am very flexible, and we seize new opportunities quickly. For instance, we debugged the debated cGMP polymerization in the dry state of Di Mauro, triggered hydrothermal, microfluidic, and volcanic experiments in collaboration with geoscientist Betty Scheu, and explored sedimentation for short RNA aggregates. Recently, we disproved Dave Deamer's claim of polymerization of 5'-phosphate RNA, which is important for dispelling misconceptions in the field.

Aside from the origin of life, an unexpected combination of optics, physics, and biochemistry is one of my hallmarks. For instance, I developed an imaging lock-in technique based on analog Fourier-space multiplication, which enabled us to image fast kinetics in living cells. Scanning IR lasers enabled light-driven optofluidics in water, and we triggered pH gradients by uncaging to enable all-optical zeta potential measurements. Our studies of thermophoresis led to the founding of NanoTemper, a biotech company with over 210 employees, by my Ph.D. students. We also expect fast evolutionary biotechniques to emerge from this ERC Grant in the future, significantly improving in situ SELEX and leading the way to yet another startup company.

Lastly, I bring together PIs in the field of origin of life in networks. Notably, with the CRC initiative in Munich (now relaunched) and the Origins Excellence initiative (now extended to a second seven-year phase), I established Munich as a hub for origin of life research in Germany and Europe. I foster direct communication through discussion formats, such as the yearly Molecular Origins Munich (MOM) meetings, to balance the sometimes opinionated and hawkish environment in the field. I have organized the MOM meetings since 2016.

Ongoing and recently completed projects that I would like to highlight include:

ERC Synergy Grant
Hannes Mutschler (PI), Role: co-investigator
04/2025 - 04/2031
BubbleLife: From RNA-peptide coevolution to cellular life at heated air bubbles

HFSP
Braun (PI), with Kerstin Göpfrich and Tomoaki Matsuura
05/2023 - 04/2026
Autonomous evolution of synthetic cells under non-equilibrium conditions

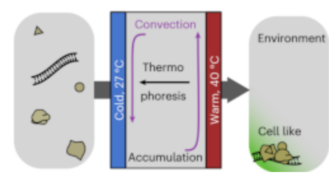
ERC Advanced Grant
Braun (PI)
04/2018 - 03/2023
Mechanisms to emerge and replicate the first sequence information of life
in geothermal microfluidics of early Earth

SFB/TRR 235 Emergence of Life: Exploring Mechanisms with Cross-Disciplinary Experiments
Braun (PI and Spokesperson), with 22 PIs in Munich area and southern Germany
01/2018 - 12/2022
Volcanic matrices to host autonomous DNA replication

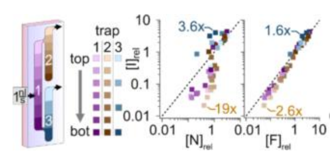
Origins Excellence grant
Andreas Burker (PI), Role: Organizer of Origin of Life section
01/2019 – 12/2025
From the Origin of the Universe to the First Building Blocks of Life

Citations:

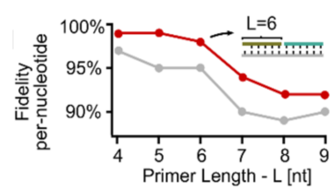
1. *Membraneless protocell confined by a heat flow,* Alexander Floroni, Noël Yeh Martín, Thomas Matreux, Laura I. Weise, Sheref S. Mansy, Hannes Mutschler, Christof B. Mast and Dieter Braun, **Nature Physics** (2025) https://doi.org/10.1038/s41567-025-02935-4



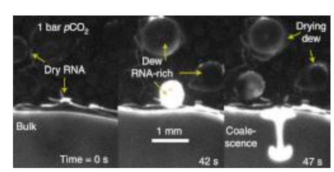
2. *Heat flows purify and boost reactivity of >50 building blocks of life,* Thomas Matreux, Paula Aikkila, Bettina Scheu, Dieter Braun, and Christof B. Mast. **Nature** (2024) doi.org/10.1038/s41586-024-07193-7



3. *High-fidelity RNA copying via 2',3'-cyclic phosphate ligation*, Adriana Serrão, Wunnava Sreekar, Avinash V Dass, Lennard Ufer, Philipp Schwintek, Christof B. Mast and Dieter Braun, **JACS** (2024) doi.org/10.1021/jacs.3c10813



4. *Water cycles in a Hadean CO2 atmosphere drive the evolution of long DNA.* Alan Ianeselli, Miguel Atienza, Patrick Kudella, Ulrich Gerland, Christof Mast & Dieter Braun, **Nature Physics** (2022) doi:10.1038/s41567-022-01516-z



5. *Heated gas bubbles enrich, crystallize, dry, phosphorylate and encapsulate prebiotic molecules.* M. Morasch, J. Liu, C.F. Dirscherl, A. Ianeselli, A. Kühnlein, K. Le Vay, P. Schwintek, S. Islam, M.K. Corpinot, B. Scheu, D.B. Dingwell, P. Schwille, H. Mutschler, M.W. Powner, C.B. Mast & D. Braun **Nature Chemistry** (2019) doi:10.1038/s41557-019-02995

B. Positions, Scientific Appointments, and Honors

Positions and Scientific Appointments

2025	Leading the 'Origin of Life' section in the Origins II Excellence grant (2026-2032)
2025	ERC Synergy Grant 'BubbleLife' with Hannes Mutschler (2025-2031)
2024	Spokesperson of CRC 392 Molecular evolution in prebiotic environments
2023	Fellow of the Max Planck School Matter to Life
2018	Spokesperson of CRC 235 Emergence of Life, ERC Advanced Grant,
2016	Coordinator of Origins of Life part of the Origins Excellence grant (2019-2025)
2015	Initiator of Origins of Life Initiative Munich (OLIM)
2014	PI within the Simons collaboration on the Origins of Life
2012	Prodean of the Physics Faculty
2010	ERC Starting Grant
2008	Startup Company NanoTemper
2007 – Present	Full professor for Systems Biophysics at the LMU Munich (Offers for professorships in Leipzig, Bayreuth and Munich Habilitation)
2005	Parental Leave: half time position for 1.5 years Dual career couple: my wife Veronica Egger is neuroscience professor in Regensburg
2003 – 2007	Emmy Noether research group LMU Munich

Honors

2019	Technology Transfer Price of the German Physical Society
2014	German Founder Prize (Deutscher Gründerpreis) for NanoTemper
2013	Best New Technology Award for NanoTemper
2012	Step Award for NanoTemper
2012	Deutscher Innovation Prize for NanoTemper
2011	Klung-Wilhelmy Weberbank Prize, biannual for physicists <40 years
2003	Emmy Noether research group LMU Munich
2001	Schloessmann Award in Optical Methods in Modern Biology

C. Contributions to Science

1. My main area of expertise is **autonomous Darwinian evolution in millimetre-sized nonequilibria**. These experiments combine the molecular replication of DNA or RNA with non-equilibrium conditions that trigger the selective accumulation of length and strand separation. Initially, we focused on DNA replicated by a protein, such as a polymerase. However, we have made significant progress in establishing replication using RNA without the need for ribozymes. I established the minimal conditions in which the natural and simple activation of 2',3'-cyclic phosphate by RNA is the fuel for Darwinian evolution. My team has shown that alkaline conditions, without the need for special metal ions, are sufficient to polymerize RNA in a dry state in a chiral-selective manner. The resulting oligonucleotides serve as the feedstock for highly precise replication via templated ligation. From our protein-based experiments, we know that templated ligation generates a network of cross-catalytic sequences that co-replicate their respective complementary strands within an autocatalytic network. Given the conditions on early Earth, our approach is close to demonstrating autonomous sequence replication using RNA. The same 2',3'-cyclic phosphate is created when RNA is cleaved, making the system self-sustaining with inherent recombination processes. The pertinent problems are strand separation of ligated RNA, which is relatively easy due to low salt conditions, and recyclization of hydrolysed 2′ or 3′ phosphates back to 2′,3′ cyclic phosphate. We have preliminary results for both processes, which puts us in a unique position to recreate ancient RNA evolution in a laboratory setting and probe the first steps of RNA evolution on early Earth or other planets in our universe.

   a. Rout, S. K., Wunnava, S., Krepl, M., Cassone, G., Šponer, J. E., Mast, C. B., ... & **Braun, D**. (2025). Amino acids catalyse RNA formation under ambient alkaline conditions. Nature Communications, 16(1), 5193.
   b. Calaça Serrão, A., Wunnava, S., Dass, A. V., Ufer, L., Schwintek, P., Mast, C. B., & **Braun, D**. (2024). High-fidelity RNA copying via 2′, 3′-cyclic phosphate ligation. Journal of the American Chemical Society, 146(13), 8887-8894.

c. Ianeselli, A., Atienza, M., Kudella, P. W., Gerland, U., Mast, C. B., & **Braun, D.** (2022). Water cycles in a Hadean CO2 atmosphere drive the evolution of long DNA. Nature Physics, *18*(5), 579-585.
d. Kudella, P. W., Tkachenko, A. V., Salditt, A., Maslov, S., & **Braun, D.** (2021). Structured sequences emerge from a random pool when replicated by templated ligation. Proceedings of the National Academy of Sciences, *118*(8), e2018830118

2. Understanding the **emergence of molecular confinement and the first cells** from the boundary conditions of an early Earth. It is essential that the first molecules be able to trigger Darwinian evolution and provide a high concentration of molecules for frequent interactions. If this is provided by flow forces against diffusion, then we could demonstrate that a strong exponential dependence on length emerges. This would mean that longer RNA and larger molecule assemblies, as well as lipid vesicles, would emerge from an accumulating boundary condition alone. Meanwhile, we have demonstrated this in several settings and achieved Darwinian evolution of nucleic acids with the help of proteins at a heated air-water interface. Consequently, we can sort molecules and co-accumulate long RNA into self-forming vesicles at an air-water interface. It was gratifying to find that complex protein mixtures provided by a cell extract could be confined in this manner, and that we could establish a membrane-free protocell by using only a temperature difference. This demonstrates two things. First, modern biochemistry is compatible with our settings for prebiotic evolution. This demonstrates the long timeline of evolution possible in these settings. Second, we demonstrate how cellular biology can evolve from a setting in which only physical forces bring molecules together and continuously feed them from the outside due to the accumulation mechanism. Therefore, we believe that our microfluidic experiments demonstrate a continuous line of thought from early RNA to modern cells.

   a. Floroni, A., Martín, N.Y., Matreux, T., Weise, L.I., Mansy, S.S., Mutschler, H., Mast, C.B. & **Braun, D.** (2025). Membraneless protocell confined by a heat flow. Nature Physics 1-8.
   b. Schwintek, P., Eren, E., Mast, C. B., & **Braun, D**. (2025). Prebiotic gas flow environment enables isothermal nucleic acid replication. eLife, 13, RP100152.
   c. Matreux, T., Aikkila, P., Scheu, B., **Braun, D**. & Mast, C.B., (2024) Heat flows enrich prebiotic building blocks and enhance their reactivity. Nature, *628*(8006), 110-116.
   d. Morasch, M., Liu, J., Dirscherl, C. F., Ianeselli, A., Kühnlein, A., Le Vay, K., ... & **Braun, D.** (2019). Heated gas bubbles enrich, crystallize, dry, phosphorylate and encapsulate prebiotic molecules. Nature Chemistry, *11*(9), 779-788.

3. My first contribution to science was a series of experiments revealing the underlying microscopic principles of **thermophoresis, or the movement of molecules in a temperature gradient**. In a series of papers, I demonstrated why the local thermodynamic equilibrium approach is correct, despite the field's preconceptions. Recently, however, we found that particles move significantly slower when the temperature gradient exceeds the local equilibrium condition. It was gratifying that the first Ph.D. students successfully commercialized this movement of molecules in a temperature gradient in their company, NanoTemper. I took the liberty of staying on the sidelines, not owning any shares in the company, and helping to promote the difficult early steps. NanoTemper now has over 200 employees and offices around the world. They offer competitive methods for studying protein-molecule interactions, primarily for developing novel drug targets and ensuring the quality of complex RNA vaccines.

   a. Mayer, D. B., Franosch, T., Mast, C., & **Braun, D**. (2023). Thermophoresis beyond local thermodynamic equilibrium. Physical Review Letters, 130(16), 168202.
   b. Reichl, M., Herzog, M., Götz, A., & **Braun, D**. (2014). Why charged molecules move across a temperature gradient: the role of electric fields. Physical review letters, 112(19), 198101.
   c. Mast, C. B., Schink, S., Gerland, U., & **Braun, D**. (2013). Escalation of polymerization in a thermal gradient. Proceedings of the National Academy of Sciences, 110(20), 8030-8035.
   d. Duhr, S., & **Braun, D**. (2006). Why molecules move along a temperature gradient. Proceedings of the National Academy of Sciences, 103(52), 19678-19682.

Complete List of Published Work at
https://www.biosystems.physik.uni-muenchen.de/papers-braun/index.html