

ISTVÁN ZACHAR



ORCID: [0000-0002-3505-0628](https://orcid.org/0000-0002-3505-0628)

Google Scholar: <https://scholar.google.com/citations?user=DLfNQUCAAAAJ>

ResearchGate: https://www.researchgate.net/profile/Istvan_Zachar

Ph.D. in biology, senior researcher at the **Institute of Evolution (IE)**, HUN-REN Centre for Ecological Research (CER), Budapest, Hungary.

CONTACT INFORMATION

Institute address: Institute of Evolution, HUN-REN Centre for Ecological Research, Konkoly-Thege Miklós út 29-33., 1121 Budapest, Hungary

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Institute website: <https://ecolres.hun-ren.hu/en/intezetek/institute-of-evolution/>

Researcher website: <https://ecolres.hun-ren.hu/en/munkatarsak/istvan-zachar/>

PERSONAL INFORMATION

Surname: Zachar

Phonology [IPA]: [ˈiʃtvaːn ˈzɒxɒr]

Nationality: Hungarian

Place and date of birth: Budapest, Hungary, 28th October 1980

Family: father of a daughter (2018) and a son (2020)

STATUS

Highest degree: Ph.D. in biology, Eötvös Loránd University (ELTE), Budapest, Hungary, 2011

Current appointments: Senior researcher at the **Institute of Evolution (IE)**, HUN-REN Centre for Ecological Research (Budapest, Hungary)

Date employed from: 1st October 2017

Affiliations:

- **Institute of Evolution (IE)**, HUN-REN Centre for Ecological Research, Konkoly-Thege Miklós út 29-33., 1121 Budapest, Hungary

- Department of Plant Systematics, Ecology and Theoretical Biology, **Eötvös Loránd University** (ELTE), Budapest, Pázmány Péter sétány 1/C, 1117 Budapest, Hungary

CONTACTS

ResearcherID: [P-5101-2015](#)

MTMT: [10018723](#)

Scopus ID: [35747641700](#)

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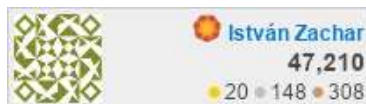
Nature Community: <https://ecoevocommunity.nature.com/users/istvan-zachar>

LinkedIn: <https://hu.linkedin.com/in/istván-zachar-82a14719>

Academia:

GitHub: <https://github.com/IstvanZachar>

StackExchange:



MEMBERSHIPS

MTA Hungarian Scientific Committee on Ecology

PUBLICATION RECORD

peer-reviewed journal articles:	26	citations (total)*:	646
patents:	1	h-index*:	15
book chapters:	2	i10-index*:	18
theses:	2		
software:	1		

(* data from Google Scholar 2026.01.13.)

Peer-reviewed journal articles

- [1] 2025 **Zachar, I.*** Máté, J. & Oszoli, I. The cell nucleus as a barrier against horizontal gene transfer in microbial endosymbioses. To appear in the *Philosophical Transactions of the Royal Society B*.
* Corresponding author; SJR: 1.732, Class: D1; All citations: N/A; independent citations: N/A
- [2] 2025 Számadó, Sz., **Zachar, I.** & Penn, D. G. A general signalling theory: why honest signals are explained by trade-offs rather than costs or handicaps. *Journal of Evolutionary Biology*, doi: <https://doi.org/10.1093/jeb/voaf144>
* SJR: 0.921, Class: Q1; All citations: N/A; independent citations: N/A
- [3] 2024 **Zachar, I.***, Máté, J. & Számadó, Sz. Tautology explains evolution without variation and selection. A comment on: 'An evolutionary process without variation and selection' (2021), by Gabora et al. *Journal of The Royal Society Interface*, 21(218), doi: [10.1098/rsif.2023.0579](https://doi.org/10.1098/rsif.2023.0579)
* Corresponding author; SJR: 1.1, Class: D1; All citations: N/A; independent citations: N/A
- [4] 2024 Oszoli, I. & **Zachar, I.*** Group-selection via aggregative propagule-formation enables cooperative multicellularity in an individual based, spatial model. *PLoS Computational Biology*, 20(5), doi: [10.1371/journal.pcbi.1012107](https://doi.org/10.1371/journal.pcbi.1012107)
* Corresponding author; SJR: 1.65, Class: D1; All citations: N/A; independent citations: N/A

- [5] 2024 Czárán, T., Scheuring, I., **Zachar, I.** & Számadó, Sz. Microbial cooperation and communication: the role of cues in the evolution of bacterial quorum sensing. *BMC Biology* 22(1), doi: [10.1186/s12915-024-01857-6](https://doi.org/10.1186/s12915-024-01857-6)
IF: 7.1; SJR: 2.32, Class: D1; All citations: N/A; independent citations: N/A
- [6] 2023 Boza, G., Barabás, G., Scheuring, I. and **Zachar, I.*** Eco-evolutionary modelling of microbial syntrophy indicates the robustness of cross-feeding over cross-facilitation. *Scientific Reports* 13, doi: [10.1038/s41598-023-27421-w](https://doi.org/10.1038/s41598-023-27421-w)
* Corresponding author; IF: 4.996; SJR: 1.01, Class: D1; All citations: N/A; independent citations: N/A
- [7] 2023 Számadó, Sz., **Zachar, I.***, Czégel, D. & Penn, D. J. Honesty in signalling games is maintained by trade-offs rather than costs. *BMC Biology*, 21(4), doi: [10.1186/s12915-022-01496-9](https://doi.org/10.1186/s12915-022-01496-9)
* Shared first authorship; IF: 8.641; SJR: 3.952, Class: D1; All citations: N/A; independent citations: N/A
- [8] 2022 **Zachar, I.** News & Views: Closing the energetics gap. *Nature Ecology & Evolution*, doi: [10.1038/s41559-022-01839-3](https://doi.org/10.1038/s41559-022-01839-3)
IF: 19.1; SJR: 5.53, Class: D1; All citations: N/A; independent citations: N/A
- [9] 2022 **Zachar, I.** & Boza, G. The evolution of microbial facilitation: sociogenesis, symbiogenesis, and transition in individuality. *Frontiers in Ecology and Evolution*, 10, doi: [10.3389/fevo.2022.798045](https://doi.org/10.3389/fevo.2022.798045)
IF: 3.26; SJR: 1.32, Class: D1; All citations: N/A; independent citations: ...
- [10] 2020 **Zachar, I.*** & Boza, G. Endosymbiosis before eukaryotes: Mitochondrial endosymbiosis establishment in protoeukaryotes. *Cellular and Molecular Life Sciences*, doi: [10.1007/s00018-020-03462-6](https://doi.org/10.1007/s00018-020-03462-6)
* Corresponding author; IF: 7.014; SJR: 3.01, Class: Q1; All citations: 28; independent citations: ...
- [11] 2019 Czégel, D., **Zachar, I.** & Szathmáry, E. Multilevel selection as Bayesian inference, major transitions in individuality as structure learning. *Royal Society Open Science*, 6(8), doi: [10.1098/rsos.190202](https://doi.org/10.1098/rsos.190202)
IF: 2.515; SJR: 1.13, Class: D1; All citations: 14; independent citations: ...
- [12] 2019 Számadó, Sz., Czégel, D. & **Zachar, I.** One problem, too many solutions: How costly is honest signalling of need? *PLoS ONE*, 14(1), doi: [10.1371/journal.pone.0208443](https://doi.org/10.1371/journal.pone.0208443)
IF: 2.766; SJR: 1.164, Class: D1; All citations: N/A; independent citations: N/A
- [13] 2019 Vig-Milkovics, Zs., **Zachar, I.**, Kun, Á., Szilágyi, A., & Szathmáry, E. Moderate sex between protocells can balance between a decrease in assortment load and an increase in parasite spread. *Journal of Theoretical Biology*, 462, 304–310, doi: [10.1016/j.jtbi.2018.11.020](https://doi.org/10.1016/j.jtbi.2018.11.020)
* Corresponding author; IF: 2.049, SJR: 0.746, Q1; All citations: 7; Independent citations: ...
- [14] 2018 **Zachar, I.***, Szilágyi, A., Számadó, Sz. & Szathmáry, E. Farming by the host cell as the origin of mitochondrial endosymbiosis by natural selection. *Proceedings of the National Academy of Sciences*, 115(7), E1504–E1510. doi: [10.1073/pnas.1718707115](https://doi.org/10.1073/pnas.1718707115)
* Corresponding author; IF: 9.661, SJR: 6.092, Class: D1; All citations: 8; Independent citations: 7
- [15] 2018 **Zachar, I.***, Szilágyi, A., Számadó, S. & Szathmáry, E. Reply to Garg and Martin: The mechanism works. *Proceedings of the National Academy of Sciences of the United States of America*, 20, E4545–E4546, doi: [10.1073/pnas.1805021115](https://doi.org/10.1073/pnas.1805021115)
* Corresponding author; IF: N/A, SJR: 6.092, D1; All citations: N/A; Independent citations: N/A

- [16] 2017 Szilágyi, A., **Zachar, I.**, Scheuring, I., Kun, Á., Könnyű, B. & Czárán, T. Ecology and evolution in the RNA World: Dynamics and stability of prebiotic replicator systems. *Life* 7(4):48 doi: [10.3390/life7040048](https://doi.org/10.3390/life7040048)
IF: 3.24, SJR: 1.63, Q1; All citations: 11; Independent citations: 7
- [17] 2017 **Zachar, I.*** & Szathmáry, E. Breath-giving cooperation: Critical review of origin of mitochondria hypotheses. *Biology Direct*, 12(1), doi: [10.1186/s13062-017-0190-5](https://doi.org/10.1186/s13062-017-0190-5)
* Corresponding author; IF: 2.856, Class: D1; All citations: 14; Independent citations: 12
- [18] 2017 Fedor, A., **Zachar, I.**, Szilágyi, A., Öllinger, M., de Vladar, H. P. and Szathmáry, E. Cognitive architecture with evolutionary dynamics solves insight problem. *Frontiers in Psychology*, 8, p. 427, doi: [10.3389/fpsyg.2017.00427](https://doi.org/10.3389/fpsyg.2017.00427)
IF: 2.463, SJR: 1.043, Class: Q1; All citations: 4; Independent citations: 1
- [19] 2016 de Vladar, H. P., Fedor, A., Szilágyi, A., **Zachar, I.** and Szathmáry, E. An attractor network-based model with Darwinian dynamics. Proceedings of the 16th Annual Conference on Genetic and Evolutionary Computation (GECCO '16), ACM, doi: [10.1145/2908961.2931672](https://doi.org/10.1145/2908961.2931672)
IF: N/A, Class: N/A; All citations: 3; Independent citations: 0
- [20] 2016 Szilágyi, A., **Zachar, I.***, Fedor, A., de Vladar, H. P. and Szathmáry, E. Breeding novel solutions in the brain: A model of Darwinian neurodynamics. *F1000Research*, 5, doi: [10.12688/f1000research.9630.1](https://doi.org/10.12688/f1000research.9630.1)
* Shared first authorship; ResearchGate IF: 1.13, SJR: 0.93, Class: Q1; All citations: 7; Independent citations: 0
- [21] 2015 Kun, Á., Szilágyi, A., Könnyű, B., Boza, G., **Zachar, I.** and Szathmáry, E. The dynamics of the RNA world: insights and challenges. *Annals of the New York Academy of Sciences*, **1341**(1), pp. 75–95, doi: [10.1111/nyas.12700](https://doi.org/10.1111/nyas.12700)
IF: 4.383, SJR: 2.11, Class: Q1; All citations: 28; Independent citations: 16
- [22] 2015 Vasas, V., Fernando, C., Szilágyi, A., **Zachar, I.**, Santos, M. and Szathmáry, E. Primordial evolvability: impasses and challenges. *Journal of Theoretical Biology*, 381, pp. 29–38., doi: [10.1016/j.jtbi.2015.06.047](https://doi.org/10.1016/j.jtbi.2015.06.047)
IF: 2.239, SJR: 0.75, Class: Q1; All citations: 15; Independent citations: 11
- [23] 2013 Szilágyi, A., **Zachar, I.** & Szathmáry, E. Gause's principle and the effect of resource partitioning on the dynamical coexistence of replicating templates. *PLoS Computational Biology*, **9**(8), e1003193, doi: [10.1371/journal.pcbi.1003193](https://doi.org/10.1371/journal.pcbi.1003193)
IF: 4.867, SJR: 3.1, Class: D1; All citations: 7; Independent citations: 4
- [24] 2011 **Zachar, I.***, Fedor, A. & Szathmáry, E. Two different template replicators coexisting in the same protocell: Stochastic simulation of an extended chemoton model. *PLoS ONE*, **6**(7), e21380, doi: [10.1371/journal.pone.0021380](https://doi.org/10.1371/journal.pone.0021380)
* Corresponding author; IF: 4.092, SJR: 1.16, Class: D1; All citations: 11; Independent citations: 8
- [25] 2011 **Zachar, I.** The feasibility of segmentation of protolanguage. *Interaction Studies* **12**(1), 1–35, doi: [10.1075/is.12.1.01zac](https://doi.org/10.1075/is.12.1.01zac)
IF: 1.105, SJR: 0.25, Class: Q2; All citations: 1; Independent citations: 1
- [26] 2010 **Zachar, I.** & Szathmáry, E. A New Replicator: A theoretical framework for analyzing replication. *BMC Biology* **8**(21), pp. 21, doi: [10.1186/1741-7007-8-21](https://doi.org/10.1186/1741-7007-8-21)
IF: 5.203, SJR: 3.84, Class: D1; All citations: 33; Independent citations: 20

Manuscripts to be published

- [1] **Zachar, I.*** & Számadó, Sz. Resolution of the duality of cultural inheritance. Under review at *Royal Society Open Science*, preprint available at <https://doi.org/10.1101/2024.10.09.617348>.
- [2] Krishnan, N., **Zachar, I.**, Kun, Á., Gokhale, C. S. & Garay, J. Host-initiated microbial association leads to stable ectosymbiosis in an ecological model. Under review at *PLoS Computational Biology*, preprint available at <https://doi.org/10.1101/2024.09.08.611858v2>.
- [3] Krishnan, N., **Zachar, I.**, Kun, Á., Broom, M. & Garay, J. The significance of growth inhibition in establishing ectosymbiotic integration. *In preparation*.
- [4] Garay, J., Varga, T., Broom, M. & **Zachar, I.** Effect of random mating of gametes and random mating genotypes on selection in Mendelian population. *In preparation*.

Book chapters

- [1] 2013 **Zachar, I.**, Kun, Á., Fernando, C. & Szathmáry, E. Replicators: From molecules to organisms, in: Kernbach, S. (ed.), *Handbook of Collective Robotics: Fundamentals and challenges*. Pan Stanford Publishing, Singapore, pp. 473–501.
All citations: 2; Independent citations: 0
- [2] 2007 Szathmáry, E., Szatmáry, Z., Ittész, P., Orbán, G., **Zachar, I.**, Huszár, F., Fedor, A, Varga, M. & Számadó, S. *In silico* evolutionary developmental neurobiology and the origin of natural language, in: Lyon, C., Nehaniv, C. & Cangelosi, A. (eds), *Emergence of communication and language*, chapter 8, Springer Verlag, London, pp. 151–187, doi: [10.1007/978-1-84628-779-4_8](https://doi.org/10.1007/978-1-84628-779-4_8).
All citations: 10; Independent citations: 4

Patents

- [1] 2017 Szathmáry, E., Szilágyi, A., **Zachar, I.**, Fedor, A. & de Vladar, H. P. *Electronic devices, artificial evolutionary neural networks, methods and computer programs for implementing evolutionary search and optimisation*. Pub. No. WO/2017/148536, International Application No. PCT/EP2016/054694, Publication Date: 08.09.2017, International Filing Date: 04.03.2016, url: [WO2017148536](https://pubs.uspto.gov/patent/publicationDetails.do?seqNo=1&pubNo=WO2017148536).

Theses

- [1] 2011 **Zachar, I.** *Replicator Formalism: A general account of replication*. Ph.D. thesis, Eötvös Loránd University (ELTE), Biology Doctoral School, Budapest. pp. 147. doi: [10.13140/RG.2.1.3981.5209](https://doi.org/10.13140/RG.2.1.3981.5209).
- [2] 2004 **Zachar, I.** *Identifying Tertiary Myliobatoids* [in Hungarian]. M.Sc. thesis, Eötvös Loránd University (ELTE), Department of Palaeontology, Budapest. pp. 49. doi: [10.13140/10.13140/RG.2.1.2687.7520](https://doi.org/10.13140/10.13140/RG.2.1.2687.7520).

Software

- [1] **Phylogenetics**, a software package to do phylogenetics with the Wolfram Language (Wolfram Research); freely available at my [GitHub profile](#).

FUNDING

- 2026.01.01–2029.12.31:** PI of “*Origin of the cell nucleus*” NKFIH ADVANCED_25 #152615 (120M HUF).
- 2025–2027:** Consortial member of the “*Direction, agency and function in the evolution of symbiotic integration*” project funded by the John Templeton Foundation under grant ID 63451, PI: Tom Williams (Bristol University, UK).
- 2023.09.01–2024.08.31:** ÚNKP Bolyai+ Research Scholarship no. ÚNKP-23-5-ELTE-117 (PI: István Zachar, 12 mo, 1 200 K HUF).
- 2022.09.01–2025.08.31:** Bolyai János Research Scholarship no. BO/00570/22/8 (PI: István Zachar, 36 mo, 9 000 K HUF).
- 2022.09.01–2023.08.31:** ÚNKP Bolyai+ Research Scholarship no. ÚNKP-22-5-ELTE-1138 (PI: István Zachar, 12 mo, 1 200 K HUF).
- 2019.07.01–2024.06.30:** Participant in NKFI KKP #129848 *Evolution and learning* (PI: Eörs Szathmáry, 5 years, total funding 283 002 K HUF (~775 000 EUR)).
- 2019.12.01–2022.11.30:** Participant in NKFI K #132250 *Signalling games: honesty and reputation* (PI: Szabolcs Számadó, 3 years, total funding 24 463 K HUF (~67 000 EUR)).
- 2017.10.01–2021.09.30:** Participant in NKFI K #124438: „*Competitive-cooperative dynamics on several levels of evolutionary and ecological organization*” (PI: Tamás Czárán, 5 years, total funding: 32 332 K HUF (~100 000 €)).
- 2014.09.01–2017.09.30:** Project leader in NKFI PD #112788: “*The origin of mitochondria*” (PI: István Zachar, 3 years, total funding: 16 458 K HUF (~52 000 €)).
- 2007.12.01–2011.06.30:** Participant in NKFI K #76785: “*The Social and Mental Dynamics of Cooperation*” (PI: Eörs Szathmáry, 5 years, total funding: 7 500 K HUF (~23 700 €)).
- 2010:** Nemzeti Kulturális Alap grant NKA-2533/0008: „*Interactive investigation of ecological systems*” educational software development (Gergely Boza, Balázs Könnyű, Vera Vasas, István Zachar).

ORGANIZED EVENTS

- 2025.04.22–25:** International conference: “[Honest Signalling and communication: from Microbes to Humans](#)”, Lorentz Center Leiden, The Netherlands, organized by Sarah Zala (University of Veterinary Medicine, Vienna), Szabolcs Számadó (HUN-REN Centre for Social Sciences), **István Zachar** (HUN-REN Centre for Ecological Research), Károly Takács (Linköping University) and Bianca Beersma (VU University Amsterdam).
- 2023.09.14–15:** International conference on [Honest Signalling: from Microbes to Humans](#), Centre of Social Sciences, Budapest. Organizers: Szabolcs Számadó (University of Technology and Economics, Budapest), Sarah Zala (University of Veterinary Medicine, Vienna), **István Zachar** (Institute of Evolution, Budapest), Károly Takács (Linköping University).

CONFERENCES, WORKSHOPS, INVITED TALKS

- 2025.05.19–20:** Zachar I.: “Finding order – Dynamical models of microbial cooperation may explain endosymbiosis and eukaryogenesis”, invited talk at the “Origins of Eukaryotic Excitability” workshop at Heidelberg, DE (organizers: Gáspár Jékely, Kirsty Wan).

- 2024.06.07–08:** Zachar I.: *A Darwinian model of cultural replication: A resolution of the duality of cultural inheritance*, invited talk at the EUPhilBiol 2024 Conference (Budapest), organizer: Eörs Szathmáry, HAS.
- 2024.05.20–23:** Zachar I.: *From replicators to major evolutionary transitions*, invited talk at the Volkswagen Workshop @ ISTA (Vienna), organizers: Andela Saric (ISTA, Vienna), Buzz Baum (Cambridge, UK).
- 2023.11.27:** Zachar, I.: *Ecological and evolutionary challenges towards eukaryotic complexity*, invited talk at the "Evolution of genomic and cellular complexity" symposium, Utrecht University, organizers: Paulien Hogeweg, Berend Snel, Sam von der Dunk.
- 2023.09.14–15:** **Zachar, I.:** *The cost of the past: How trade-offs rather than handicaps maintain honest signalling?* Talk at the [Honest Signalling: from Microbes to Humans](#) conference, Centre of Social Sciences, Budapest.
- 2022.08.14–19:** Poster at **ISME18**, Lausanne, Switzerland Boza, G., Barabás, Gy., Scheuring, I. & **Zachar, I.** *An eco-evolutionary modelling of microbial syntrophy: Cross-feeding is more robust than cross-catalysis.*
- 2020.02.04:** Invited talk at the **Institute of Parasitology, Biology Centre of the Czech Academy of Sciences**, České Budějovice, CZ. Title: *Evolutionary and ecological issues at the origin of mitochondria.*
- 2020.02.11–13:** Presentation at the **Darwin Days**, Tihany, Hungary, organized by Institute of Evolution, MTA Centre for Ecological Research. Title: *Evolutionary and ecological issues at the origin of mitochondria.*
- 2018.04.15–18:** Invited speaker at the **US Janelia: New Opportunities to Study Origins of the Eukaryotic Cell** conference (Ashburn, Virginia, USA). Title: *The origin of mitochondria from an eco-evolutionary point of view* ([link](#)).
- 2018.05.10:** **Zachar, I.:** *A mitokondrium és az eukarióta sejtek eredete* (in Hungarian, [link](#), [video](#)). Presentation at the **Budapest Science Meetup**, MTA, Budapest.
- 2017.11.16:** István Zachar: *The ecological model of the origin of the eukaryotic cell*. Presentation at the conference **Integrative Ecology** of the MTA ÖK Centre for Ecological Research, part of the *Festival of Hungarian Science 2017*.
- 2016.07.20–24:** 16th Annual Conference on Genetic and Evolutionary Computation (GECCO '16): de Vladar, H. P., Fedor, A., Szilágyi, A., **Zachar, I.** and Szathmáry, E. *An attractor network-based model with Darwinian dynamics*. Proceedings of the 16th Annual Conference on Genetic and Evolutionary Computation, ACM, doi: [10.1145/2908961.2931672](#).
- 2013.05.07–12:** Presentation at the Systems Chemistry Workshop at Badacsony, Lake Balaton, Hungary. **Zachar, I.:** *Generalized replicator theory*.
- 2012.06:** Poster presentation at the Spring School on Early Life (Lyon). Szilágyi, A., **Zachar, I.** & Szathmáry, E. *Coexistence of template replicators in the chemoton*.
- 2011.10:** Poster presentation at the COST-ESF Conference: Systems Chemistry III, Heraklion (Crete). **Zachar, I.** *The emergence of division of labour in template replication*.
- 2011.10:** Poster presentation at the COST-ESF Conference: Systems Chemistry III, Heraklion (Crete). **Zachar, I.**, Fedor, A. & Szathmáry, E. *Two different template replicators coexisting in the same protocell*.

- 2010.09:** Presentation at “The Evolution of Cooperation and Trading” (TECT). Szathmáry, E., Fernando, C. & **Zachar, I.** *Emergence of language and evolutionary dynamics in the brain during ontogeny.*
- 2009.10.18–23:** Poster presentation at the COST-ESF Conference: Systems Chemistry II: Evolution And Systems, Balatonfüred (Hungary). **Zachar, I.** *Replicator Formalism.*
- 2009.08.29–09.04:** Poster presentation at the International Summer School on Embodied Language Games and Construction Grammar (organized by the Evolutionary Linguistics Association), in Cortona (Italy). Fedor, A. & **Zachar, I.** *Evolution of grammar based on modular replication.*
- 2008.08.30–09.06:** Poster and oral presentation at the TECT-INCORE: *Tools of the trade in cooperation research* summer school (Obernai, France). **Zachar, I.,** Szathmáry, E. & Steels, L. *An evolutionary approach on lexicon alignment.*
- 2008.03.11–15:** Poster presentation at the 7th Evolang (Evolution of Language Conference), Barcelona, Spain. **Zachar, I.,** Szathmáry, E. & Steels, L. *An evolutionary approach on lexicon alignment.*
- 2008.02.04–08:** Poster presentation at the Third European PhD Complexity School (Evolution in biological systems: from molecules to life and language), Turin, Italy (Organized by ISI Foundation). **Zachar, I.,** Szathmáry, E. & Steels, L. *An evolutionary approach on the origin of lexicon and grammar.*
- 2007.12.07:** Short presentation at ECAgents Evaluation Meeting, Berlin, Germany. **Zachar, I.** *A replicative model of the origin of lexical and grammatical elements.*
- 2007.07.14–19:** Participation at the "International School on Complexity - Course on Statistical Physics of Social Dynamics: Opinions, Semiotic Dynamics, and Language" held in Erice, Sicily. Also participating the "International Summer Atelier: Modeling Language Evolution with Computational Construction Grammar" parallel to the summer school. Organized by Vittorio Loreto ("Sapienza" Università di Roma) and Luc Steels (Sony CSL, Paris).
- 2007.06:** Participation at the "Masterclass on Language Evolution: Computer models for empirical data" held in Noordwijk, Netherlands. Organized by Paul Vogt (Tilburg University) and Bart de Boer (University of Groningen).
- 2006.04.12–15:** Participation at the 6th EVOLANG (Evolution of Language) International Conference, Rome, Italy. Organized by Angelo Cangelosi (University of Plymouth) and others.
- 2006:** Poster presentation at ECAgents Review Meeting, Roma, Italy. **Zachar, I.,** Szathmáry, Z., Ittész, P., Varga, M., Fedor, A., Számadó, Sz. & Szathmáry E. *Measuring the heritability of neural connections in ENGA generated communicating agents.*
- 2003.08:** Poster and oral presentation at the VI. Shallow Tethys conference, Budapest. **Zachar, I.** *Identifying Tertiary Myliobatoids from Hungary.*
- 2003.07:** Poster presentation at the I. EAVP (European Association of Vertebrate Paleontology) conference, Basel. **Zachar, I.** *Identifying Tertiary Myliobatoids from Hungary.*

SCHOLARSHIPS

- 2022.09.01–2023.08.31:** **ÚNKP Bolyai+ Research Scholarship** of the New National Excellence Program of the Ministry for Culture and Innovation, no. ÚNKP-22-5-ELTE-1138.
- 2022.09.01–2025.08.31:** **János Bolyai Research Scholarship** of the Hungarian Academy of Sciences, no. BO/00570/22/8, title: “*Evolutionary and ecological constraints of the origin of eukaryotes*”.

2016.10.1–2017.06.30: Postdoctoral research fellow at the **Institute of Advanced Studies, Kőszeg** ([iASK](#)), Center for Cooperation and Conflict in Evolutionary Systems. Research project: “*Computational modelling of insight problem solution with evolutionary algorithms*”, project leader: Eörs Szathmáry.

2012–2015: Postdoctoral scholarship at the **Parmenides Foundation, Munich** (Germany): FP7 ERC advanced grant project EVEEVO (*Evolution of Evolvable Systems*; PI: Eörs Szathmáry; 2012-2017; no. #294332)

2007.09–2007.11: Young Researcher scholarship at **ELTE University**, Budapest (Hungary).

2007.02–2007.06: Junior Fellow scholarship at **Collegium Budapest, Institute for Advanced Study**, Budapest (Hungary). Research project: *Finding and Analyzing the Replicator of an Artificial Cultural Evolution Simulated in ENGA - Finding the Unit of Memetic Evolution in silico*.

RESEARCH EXPERIENCE

2021–...: Senior researcher at the Institute of Evolution, HUN-REN Centre for Ecological Research, Budapest.

2017–2021: Senior researcher in the [GINOP Evolutionary Systems Research Group](#) (GINOP 2.3.2-15-2016-00057) at the Centre for Ecological Research, Tihany, Hungary.

2017.11.01–2022.06.30: Senior research assistant in the MTA-ELTE Theoretical Biology and Evolutionary Ecology Research Group (ELTE, Budapest, Hungary).

2017–...: Research fellow at the [Parmenides Foundation, Centre for the Conceptual Foundation of Science](#), Pullach (Munich), Germany.

2016.10.1–2017.06.30: Postdoctoral research fellow at the [iASK Institute of Advanced Studies, Kőszeg](#), Center for Cooperation and Conflict in Evolutionary Systems: “*Computational modelling of insight problem solution with evolutionary algorithms*”, project leader: Eörs Szathmáry.

2014.09.01–2017.09.30: Postdoctoral research assistant at **Eötvös Loránd University** (ELTE), Department of Plant Systematics, Ecology and Theoretical Biology. NKFIH #112788: “The origin of mitochondria”, project leader: Dr. István Zachar.

2013–2015: Postdoctoral position in the **EU FET-open project INSIGHT** (*Insight: Darwinian Neurodynamics*; PI: Eörs Szathmáry @ Parmenides Foundation; 2013-2016; agreement no. 308943; total funding 2 219 079 €).

2012–2015: Postdoctoral position in the **FP7 ERC advanced grant project EVEEVO** (*Evolution of Evolvable Systems*; PI: Eörs Szathmáry @ Parmenides Foundation; 2012-2017; project #294332; total funding 2 616 700 €).

2012.10.01–2015.09.30: postdoctoral research fellow at the [Parmenides Foundation, Centre for the Conceptual Foundation of Science](#), Pullach, Germany.

2012.01.01–2012.07.01: Postdoctoral research fellow at the [Queen Mary University of London](#) (UK), project leaders: Drs. Chrisantha Fernando and Alex Mesoudi. Research on human insight learning, modelling cognitive processes using machine learning, conducting experiments on human subjects.

2009–2011: Postdoctoral position in the **FP7 EU project e-Flux Evolutionary microfluidix** project (PI: Eörs Szathmáry; 2009-2011; project #225167; total funding: 2 300 000 €).

2007.12.01–2011.06.30: Research assistant at the **Theoretical Biology and Ecology Research Group** of the Hungarian Academy of Science (HAS), under the project OTKA #76785 “*The Social and*

Mental Dynamics of Cooperation", PI: Eörs Szathmáry @ Eötvös Loránd University Budapest. Research on the origin of compositional language, replicator theory and origin of compartmentalized template replication.

2008.10: Visiting student at the **Artificial Intelligence Lab** at Vrije Universiteit Brussels. Working jointly with Dr. Joachim de Beule on an analytical model of lexicon alignment and origin of compositionality.

2007.09.01–2007.10.01: Visiting student at **SONY CSL Lab**, Paris, at prof. Luc Steels. Working on an evolutionary (replication-selectional) model of lexicon alignment and grammar origin.

2007.02.01–2007.07.01: Junior fellow scholarship at **Collegium Budapest**, research title: "*Finding and Analyzing the Replicator of an Artificial Cultural Evolution Simulated in ENGA - Finding the Unit of Memetic Evolution in silico*".

2004–2011: **Ph.D. thesis work** at Eötvös Loránd University, Department of Plant Systematics, Ecology and Theoretical Biology: "*Replicator formalism. A general account of replication*". Supervisor: prof. Eörs Szathmáry.

2004–2008: Worked in the European FET project **ECAgents** (*Embodied and Communicating Agents*; PI: Eörs Szathmáry; 2004-2008; ID FP6 - IST-2003-1940; total funding 2 616 700 €) at Collegium Budapest. experimenting with newly developed evolutionary neural-network-modelling software framework called ENGA (Evolutionary Neurogenetic Algorithm). Testing core and client-part of the software, running biologically relevant simulations.

2002–2004: **Master thesis work** at Eötvös Loránd University, Department of Plant Taxonomy and Ecology: "*Modelling neutral and adaptive evolutionary processes, in case of Weismannian and Lamarckian heredity*". Supervisor: prof. Eörs Szathmáry.

1999–2003: **Thesis work** at Eötvös Loránd University, Department of Palaeontology: "*Identifying Tertiary Myliobatoids (Rajiformes, Batomorphi, Elasmobranchii) from Hungary*". Supervisor: prof. László Kordos (head of the Geological Institute of Hungary).

INDUSTRIAL EXPERIENCE

2018–2023: Consultant developer at the biotech firm [RIBBON Biolabs GmbH](#). The company specializes in fast, high-throughput, mass-scale synthetization of biosequences (DNA). I developed algorithms and interface to simulate and ease the combinatorial build-up of synthesis, and designed methods and *in silico* experiments to benchmark and monitor simulations.

SUPERVISION, MENTORING

Ongoing supervision of multiple BSc, MSc, PhD students at Eötvös Loránd University, Budapest.

2022–2023: Mentoring in the ELTE Talantum Programme for highschoolers

2022–...: István Oszoli Ph.D., ELTE.

2024–...: Máté Halász Ph.D., ELTE.

2022–2024: Jakab Máté M.Sc., ELTE.

2020–2022: István Oszoli M.Sc., ELTE: "*Modelling the origin of aggregative multicellularity*".

2020–2021: Jakab Máté B.Sc., University of Veterinary Medicine Budapest: Modelling catalytic syntrophy in bacterial communities.

2019–2020: István Oszoli B.Sc., ELTE: "*Origin of multicellularity*".

2018–2019: Judit Tolnai M.Sc., ELTE: „*Modelling the parasitic origin theory of mitochondria*”.

EDUCATION

2004–2007: Ph.D. in Theoretical Biology and Ecology at ELTE Eötvös Loránd University (Budapest), Biology Ph.D. School (6 semesters) (2011 12. 8., no.: P-3562/2011).

1999–2004: M.Sc. in Biology at ELTE Eötvös Loránd University (Budapest) (10 semesters). Additional studies in Palaeontology (2004 6. 30., no.: PTE 006950).

1995–1999: ELTE Trefort Ágoston High School, Budapest.

REVIEW SERVICES

Regular reviewing of MSc, BSc, PhD theses at ELTE Eötvös Loránd University.

Regular refereeing in the following journals:

- *Frontiers in Ecology and Evolution*
- *Nature Ecology & Evolution*
- *Journal of Theoretical Biology*
- *BioEssays*
- *BioSystems*
- *Briefings in Bioinformatics*
- *Alife*

DISSEMINATION, COMMUNICATION AND MEDIA COVERAGE

2025.02: Kornél Farkas & István Zachar (in Hungarian): „*Mesterséges endoszimbiózisok és mikróbák – Eukarióták eredete (4. rész)*”. *Természet Világa*, 156(2).

2025.01: István Zachar (in Hungarian): „*Egy új birodalom felemelkedése: az Archeák – Eukarióták eredete (3. rész)*”. *Természet Világa*, 156(1).

2024.09.27: Presentation at the Researcher’s Night: István Zachar: “*The most dramatic jump in the history of Life on Earth*” ([link](#)).

2023.10: István Zachar (in Hungarian): „*A mitokondrium kora – Eukarióták eredete (2. rész)*”, *Természet Világa*, 154(10).

2023.09: István Zachar (in Hungarian): „*Az eukarióták eredete – Felemelkedés (1. rész)*”, *Természet Világa*, 154(9).

2023.09.29: Presentation at the Researcher’s Night: István Zachar: “*The most dramatic jump in the history of Life on Earth*”.

2023.04.06: István Zachar: “[A unique leap of Life on Earth: The emergence of Eukaryotes](#)”, Dissemination piece in *Qubit* online scientific magazine.

2023.02.05: Report on research by [Origo](#) news portal.

2023.01.23: “[The peacock’s tail and other flashy ornaments don’t have to come at a cost](#)” Commentary in *PNAS*.

2023.01.19: [When can syntrophic microbial cooperation win over selfish cheaters?](#) Blog post in *Nature Community*.

2022.10.02: “[Two billion years old mystery of Life on Earth](#)” Report on research by *24.hu* news portal.

2022.09.30: Presentation at the Researchers' Night: István Zachar: "*The most dramatic jump in the history of Life on Earth*".

2018.03.27: Radio interview with InfoRadio Sigma of the Hungarian Academy of Sciences ([link](#), [link](#)).

2018.03.29: Appearing on the homepage of the Hungarian Academy of Sciences ([link](#)).

2018.03.09: Report on our [PNAS paper](#) (by Hungarian Academy of Sciences): "*Sejtjeink kétmilliárd éves ősei lehettek a földi élet legsikeresebb farmerei*" ([link](#)).

2018: "*Mitochondria and the origin of eukaryotic cells*" presentation at the Budapest Science Meetup conference ([link](#)).

TEACHING EXPERIENCE, COURSES

Regular lectures and seminars at ELTE University, Budapest:

- *Origin and early evolution of eukaryotes* (ELTE ID: xeukarsb18em)
- *Frontiers of evolutionary research* (ELTE ID: xevofrb22ea)
- *Programming and modelling in C for biologists*
- *Combinatorics, Probability Theory and Statistics*, for senior biology students
- *Introduction to Programming*, for biologists
- *Introduction to Biology*, for freshmen

LANGUAGE KNOWLEDGE

Fluent in English and Hungarian. Latin intermediate level.

MODELLING SKILLS

Skilled in systems biology, systems chemistry, and general computational biology methods. Amongst others, proficient in:

- differential equations, time evolution, numerical integration, fixpoint analysis, bifurcation exploration;
- stochastic modelling, Gillespie algorithm;
- reaction-diffusion systems, spatially explicit models, cellular automata;
- evolutionary models, adaptive dynamics;
- process algebra;
- individual based ecological models, infection models;
- *ape*, *castor*, etc. phylogenetic tools in R, Mathematica, etc.

COMPUTER SKILLS

Programming and scripting languages:

- proficient in: C, R, *Wolfram Language*
- competent in: Bash, Windows shell, Python, Pascal, Delphi, Matlab, BlenX stochastic simulation language, HTML, etc.

Other software: MS Office suite, OpenOffice, Corel Graphics Suite, Adobe Photoshop, Autodesk 3D Studio Max, EndNote, JabRef, etc.

OTHER ACHIEVEMENTS

2011: Full scale skeletal and cranial reconstructions of extinct dinosaurs *Hungarosaurus tormai* (Nodosauridae), *Mochlodon vörösi* (Rhabdodontidae), a *Mosasauroidea* species and cranial reconstruction of *Ajkaceratops kozmai* (Bagaceratopsidae), also with full scale head reconstructions for the ["Lost Worlds"](#) permanent exhibition of the Hungarian Natural History Museum.

2000–2022: Palaeontological field work at the excavations of the [Hungarian Dinosaur Expedition](#).

RESEARCH INTEREST

I am interested in all major evolutionary transitions and the unifying Darwinian principles behind the various inheritance systems involved. According to Universal Darwinism, the same principles apply to e.g. the origin of the first cells and to the origin of animal societies. The stunning analogy between biological and cultural evolution fascinates me, and I have been working on understanding the extent of unifying Darwinian principles behind them and other fields. I have been studying how information is maintained in Darwinian systems, especially during evolutionary transitions, for example, in endosymbiosis, multicellularity, honest animal communication and cultural evolution. I have been modelling the ecological and evolutionary dynamics of evolutionary units at various levels since 20+ years, including the origin of Life, the origin of the eukaryotic cell and the origin of human culture and language.

I am a long time avid *Mathematica* programmer (flagship product of Wolfram Research Inc.), and a significant contributor to the [Mathematica.StackExchange](#) Q&A site. Since I enjoy programming, I design and implement my own models in C, R, *Mathematica*, etc. I am especially interested in language evolution, from both the biological and the literary aspects (from Hurford and Bickerton to Eco and Tolkien). I am designing an evolutionary phonotactics platform to model phonological evolution in real or simulated languages and to generate artificial languages. I am an expert in the mythology and languages of Arda. For more than 20 years I was involved in palaeontology at a semi-professional level participating in excavations at the Iharkút and Villány locations in Hungary digging for Mesozoic dinosaurs and other vertebrates (organized by the [Hungarian Dinosaur Expedition](#)). I have built skeletal reconstructions of these dinosaurs for the Hungarian Natural History Museum.

2026 January, Budapest



István Zachar