Journal of Mathematical Biology (2018) 77:1623–1627
https://doi.org/10.1007/s00285-018-1259-1

Mathematical Biology

Karl-Peter Hadeler: His legacy in mathematical biology

Odo Diekmann[1] · Klaus Dietz[2] · Thomas Hillen[3] · Horst Thieme[4]

Received: 11 June 2018 / Published online: 2 July 2018

Abstract
Karl-Peter Hadeler is a first-generation pioneer in mathematical biology. His work inspired the contributions to this special issue. In this preface we give a brief biographical sketch of K.P. Hadelers scientific life and highlight his impact to the field.

Mathematics Subject Classification 01A70 · 92B05

K. P. Hadeler—a life long passion for science.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00285-018-1259-1) contains supplementary material, which is available to authorized users.

✉ Thomas Hillen
thillen@ualberta.ca

1 Utrecht University, Utrecht, The Netherlands

2 University of Tüebingen, Tüebingen, Germany

3 University of Alberta, Edmonton, AB, Canada

4 Arizona State University, Tempe Arizona, USA

With great affection, we present this special issue of the *Journal of Mathematical Biology*, in memory of a pioneer in mathematical biology: Professor Dr. rer. nat. K. P. Hadeler. The authors of this special issue are part of the second or third generation of mathematical biologists. The subjects, methods, conferences, and journals of our community are based on the visionary work of first generation pioneers in mathematical biology, such as K. P. Hadeler.

K. P. Hadeler, often called Karl or KP, was born in 1936 in Hamburg where he entered the university of Hamburg in 1956 for a double *Staatsexamen* degree in mathematics and biology. He obtained his Ph.D. (1965) and Habilitation (1967) also in Hamburg, under the supervision of Lothar Collatz. During that time he spent 1 year at the University of Moscow, and his first two papers (Hadeler 1964a, b) were written in Russian. His first 30 papers were in the area of linear algebra, numerical analysis and operator theory. Only later, in the 1970s did he start to work on biological problems (Thieme 2017).

Karl's first faculty position was at the University of Erlangen in 1970, which was followed one year later by a Chair in Biomathematics at the University of Tübingen. At that time he started the mathematical modelling of biological systems in earnest and he published papers on lateral inhibition (Hadeler 1974b), population genetics (Hadeler 1973), reaction–diffusion equations (Hadeler and Rothe 1975), delay differential equation models (Hadeler 1976), and he wrote his textbook "Mathematik für Biologen" (Hadeler 1974a). He co-founded the *Journal of Mathematical Biology* in 1974 with H. J. Bremermann and F. A. Dodge, and made it thrive in continued cooperation with S. Levin (2006). In 1975 he started the long lasting series of Oberwolfach meetings on "Mathematische Modelle in der Biologie", with W. Jäger and H. Werner. As a side note we mention that Karl participated in a total of 51 Oberwolfach workshops, which means that he spent almost one year of his life in Oberwolfach! In the period 1994–1996 Karl served as president of the European Society of Mathematical and Theoretical Biology (ESMTB), following James D. Murray, who was the first president, 1991–1993. It is fair to say that mathematical biology in Germany had its birth in the early 1970s, and that Karl was a major contributor to this development (Hillen et al. 2006; Levin 2006).

Karl retired from the University of Tübingen in 2005 and he became Research Professor at Arizona State University from 2005 to 2011. Karl enjoyed the change of scenery tremendously and he developed new material while teaching graduate students in Arizona. This material was developed into a textbook "Topics in Mathematical Biology" (Hadeler 2017), which he dedicated to his loving wife Helgard. Unfortunately, Karl was not able to witness the publication of his last book as he peacefully passed away at home on February 03, 2017.

Karl has made substantial contributions and listing all of them would make this preface excessively long. A full publication list is included in the supplemental materials. Here we like to present some highlights of Karl's work:

- Since 1973 he has published 7 papers related to population genetics. He showed in Hadeler and Liberman (1975) that the fundamental law of population genetics does not hold if fertility is a property of a mating type.

- Another major contribution relates to pair formation models, where he showed the existence and uniqueness of positive solutions (Hadeler 2012, 2017).
- A major interest were reaction–diffusion equations, travelling waves and invasion phenomena and applications of those. His paper Hadeler and Rothe (1975) has been widely cited, as it systemized the phase plane analysis method of heteroclinic orbits, that arise as travelling waves in reaction–diffusion equations. Among his 25 contributions to this field we like to highlight the travelling wave analysis of reaction–diffusion models with quiescent compartment, where an exact minimum wave speed was computed (Hadeler and Lewis 2002). Quite recently, in Hadeler (2016), he showed that slower speeds than the Fisher speed are possible, if a free-boundary condition is used on the wave front, similar to Stefan problems in physics, which is a very interesting observation.
- In eleven papers he considered oscillations and he was able to show a Bendixson-Dulac result for homogeneous systems (Hadeler 1992a), a quite substantial finding.
- Hyperbolic models for species movement and invasion have been a center of attention of 14 of his publications. Hyperbolic models are used in cases where it is important that species have a finite velocity. Those models generalize reaction diffusion equations, and Karl generalized many results to the hyperbolic case such as invasion speeds, travelling waves, invariance principles, pattern formation, parasitic infections, epidemic spread, and population models (Hadeler 1988, 1994, 1999).
- Karl considered delay differential equations as an additional useful tool in biological modelling. He contributed 9 papers to delay equation modelling, where we highlight reference (Hadeler and Bocharov 2003) with the stimulating title: *Where to put delays in population models?*.
- The majority of Karl's contributions are in the areas of disease dynamics and epidemiology with some 45 papers. Karl developed new models for vector borne diseases (Hadeler 1985), host-parasite models (Hadeler and Dietz 1983), and HIV infections (Hadeler 1992b). A major contribution is the systematic analysis of vaccination strategies (Hadeler and Müller 1995, 2007).
- His last major research area involved quiescent phases, sedentary phases and resting phases in population models. In a series of 9 papers he analysed epidemics with quiescence, predator prey models with quiescence, diffusion with quiescence, etc. He was able to show that quiescence stabilizes a population model, it reduces instabilities and it also shrinks periodic orbits. A good overview of this body of work is given in his textbook (Hadeler 2017).
- Besides of these major areas of Karl's work, he contributed to many different fields. His curiosity was difficult to tame, and he published several articles on the chemostat, on granular matter, the Schrödinger equation, proteasomal cleavage, cardiovacular disease, and cellular automata (Hadeler and Müller 2017).

All of his publications have one aspect in common. While the models are inspired by biological processes, the results are mathematically rigorous and no analytical shortcuts are taken. His work inspired a new generation of young scientists. He supervised about 27 Ph.D. students and several of them hold faculty positions around the world. His students have experienced that the beauty and power of mathematical reasoning can be used to gain insight into the basic mechanisms of biology. All his students and collaborators are extremely grateful for his wisdom, inspiration, guidance and support. We are part of his legacy and thus his work continues and the contributions to this special issue carry his vision forward. As practiced by Karl himself, many young scientists are included as authors. The contributions demonstrate current topics and new directions. They show the path into the future for the next generation of mathematical biologists.

References

Hadeler KP (1964a) An estimate for the spectrum of normal operators (Russian). Dokl Akad Nauk SSSR 157: 284 –287 (trans. (1964) Sov Math Dokl 5:944–947)

Hadeler KP (1964b) On the spectrum of normal operators and of their perturbations (Russian). Dokl Akad Nauk SSSR 158: 1042–1043 (trans. (1965) Sov Math Dokl 5:1371–1372)

Hadeler KP (1973) Selektionsmodelle in der Populationsgenetik. In: Brosowski B, Martensen E (eds) Methoden und verfahren der mathematischen physik, vol 9. Bibliographisches Institut, Mannheim, pp 137–160

Hadeler KP (1974a) Mathematik für Biologen (trans. (1982) Matemáticas para Biólogos (Spanish). Editorial Reverté, Barcelona). Springer, Berlin

Hadeler KP (1974b) On the theory of lateral inhibition. Kybernetik 14:161–165

Hadeler KP (1976) On the stability of the stationary state of a population growth equation with time-lag. J Math Biol 3:197–201

Hadeler KP (1985) Vector models for infectious diseases. In: Sleeman BD, Jarvis RJ (eds) Ordinary and partial differential equations. Proceedings of the Eighth Confernce, Dundee, Scotland, 25.–29. 6. 1984, Lecture Notes in Mathematics 1151. Springer, Berlin, pp 204–216

Hadeler KP (1988) Hyperbolic travelling fronts. Proc Edinb Math Soc 31:89–97

Hadeler KP (1992a) Periodic solutions of homogeneous equations. J Differ Equ 95:183–202

Hadeler KP (1992b) Structured population models for HIV infection Pair formation and non-constant infectivity. In: Jewell NP, Dietz K, Farewell VT (eds) AIDS epidemiology: methodological issues. statistical methodology for study of the AIDS epidemic. Mathematical sciences research institute, Berkeley, California, 30.9.–4. 10.1991. Birkhäuser, Basel, pp 146–154

Hadeler KP (1994) Travelling fronts for correlated random walks. Can Appl Math Q 2:27–43

Hadeler KP (1999) Reaction transport systems in biological modelling. In: Capasso V, Diekmann O (eds) Mathematics inspired by biology. Lectures given at the 1st Session of the Centro Internazionale Matematico Estivo (C.I.M.E.), Martina Franca, Italy, 13.–20. 6.1997. Lecture notes in mathematics 1714. Springer, Berlin, pp 95–150

Hadeler KP (2012) Pair formation. J Math Biol 64:613–645

Hadeler KP (2016) Stefan problem, traveling fronts, and epidemic spread. Discrete Contin Dyn B 21:417–436

Hadeler KP (2017) Topics in mathematical biology. Springer, Heidelberg

Hadeler KP, Bocharov G (2003) Where to put delays in population models, in particular in the neutral case. Can Appl Math Q 11:159–173

Hadeler KP, Dietz K (1983) Nonlinear hyperbolic partial differential equations for the dynamics of parasite populations. Comput Math Appl 9:415–430

Hadeler KP, Lewis MA (2002) Spatial dynamics of the diffusive logistic equation with a sedentary compartment. Can Appl Math Q 10:473–499

Hadeler KP, Liberman U (1975) Selection models with fertility differences. J Math Biol 2:19–32

Hadeler KP, Müller J (1995) The effects of vaccination on sexually transmitted disease in heterosexual populations. In: Arino O, Axelrod DE, Kimmel M, Langlais M (eds) Mathematical population dynamics: analysis of heterogeneity, theory of epidemics, vol 1. Wuerz, Winnipeg, pp 252–278

Hadeler KP, Müller J (2007) Optimal harvesting and optimal vaccination. Math Biosci 206:249–272

Hadeler KP, Müller J (2017) Cellular automata: analysis and applications. Springer, Heidelberg

Hadeler KP, Rothe F (1975) Travelling fronts in nonlinear diffusion equations. J Math Biol 2:251–263

Hillen T, Lutscher F, Müller J (2006) Preface. Dedicated to K.P. Hadeler's 70 birthday. J Math Biol 53(4):491–495

Levin S (2006) On Karl Hadeler becoming 70. J Math Biol 53:496–498

Thieme HR (2017) From homogeneous eigenvalue problems to two-sex population dynamics. J Math Biol 75:783–804