

The *Dictyostelium discoideum* model system

Guest Editors

Ricardo Escalante¹ and Elena Cardenal-Muñoz²

¹*Instituto de Investigaciones Biomédicas “Alberto Sols” (CSIC-UAM), Madrid, Spain*

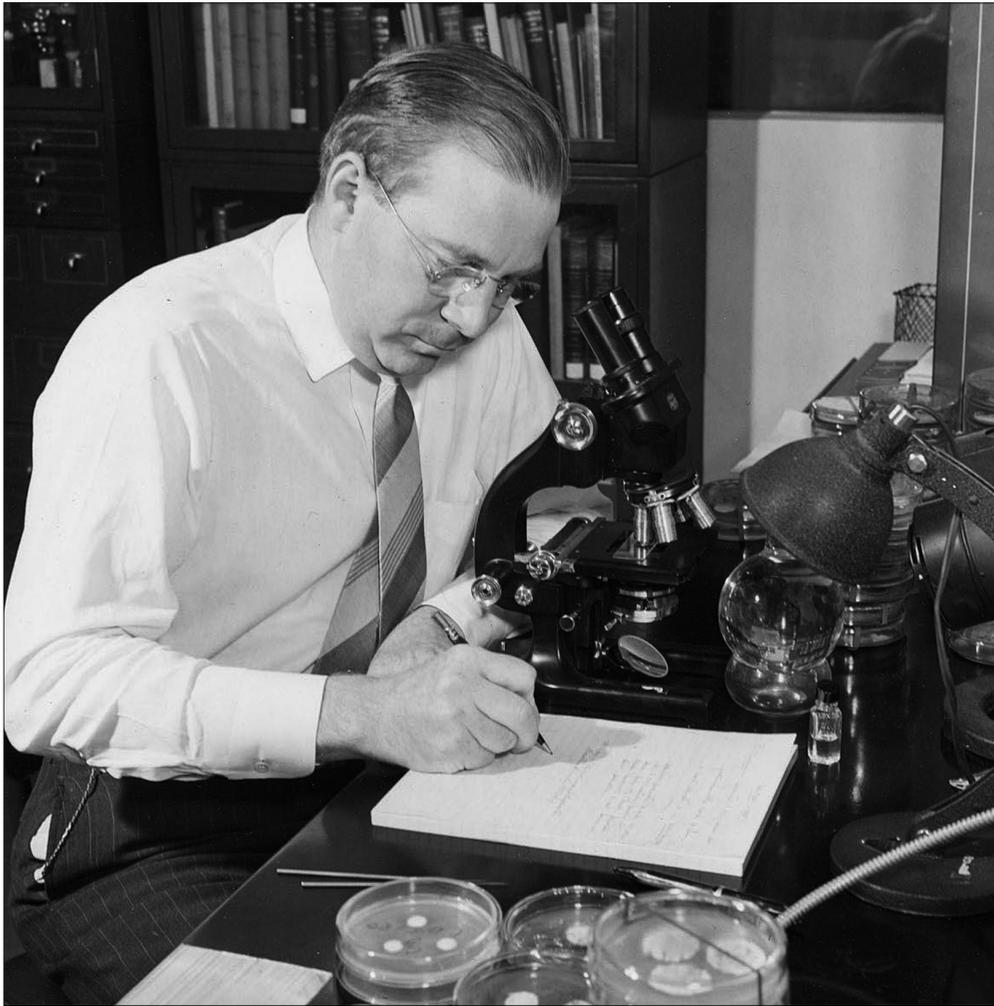
rescalante@iib.uam.es -  <https://orcid.org/0000-0001-8547-531X>

²*Département de Biochimie, Faculté des Sciences, Université de Genève, Sciences II, Genève, Switzerland*

elena.cardenal@unige.ch -  <https://orcid.org/0000-0003-4757-9323>

THE INTERNATIONAL JOURNAL OF
DEVELOPMENTAL
BIOLOGY

Volume 63 Nos. 8/9/10 Special Issue 2019



Kenneth Bryan Raper (1908-1987)

Kenneth B Raper

This Special Issue of *The International Journal of Developmental Biology* is dedicated to Kenneth Bryan Raper (1908-1987), who discovered *Dictyostelium discoideum* and described the remarkable features of this organism, setting up the basis for its use as a model system. Photo reproduced with permission from the University Archives and Records Management of the University of Wisconsin-Madison, USA.

Preface

Dictyostelium discoideum: the organism and the model

When we set out to organize this Special Issue, we faced the difficult task of gathering together a large variety of topics with the unique commonality of having been studied in a single model organism, *Dictyostelium discoideum*. This apparent setback turned into a wonderful opportunity to learn about an organism as a whole, which provides a more complete understanding of life processes, their natural meaning and their changes during evolution. From studies dedicated almost exclusively to cell motility, differentiation and patterning, the versatility of *D. discoideum* has allowed in recent years the expansion of our knowledge to other areas, including cell biology and many others related to human diseases. The present collection of papers can be considered as a journey throughout the mechanisms of life, where *D. discoideum* acts as a very special tourist guide.

Social amoebas are remarkable microorganisms that live in the soil feeding on bacteria. More than 150 species dispersed world-wide have been discovered to date. One of these species, *Dictyostelium discoideum* (hereafter referred to as Dictyostelium) was discovered in 1933 by Kenneth Raper in the Craggy Mountains of Western North Carolina (Raper, 1935). When food becomes scarce, the Dictyostelium cells aggregate to form a simple multicellular organism of few millimeters in size. The duality of this amoeba as a single and multicellular organism is a remarkable characteristic that has attracted the interest of evolutionary biologists trying to reveal the paradigm of multicellular evolution.

The seminal works by McCutcheon (McCutcheon, 1946) in leucocytes and Bonner in Dictyostelium (Bonner, 1947) were essential to determine that these cells actually move towards chemical gradients. Since then, Dictyostelium has become a leading model to uncover the molecular mechanisms of chemotaxis. Knowing how cells recognize and signal each other before and after their aggregation is fundamental to understand how a multicellular organism organizes. How do initially equivalent cells differentiate and form developmental patterns? How do the cells communicate and interact with their environment, including interactions with other organisms such as bacteria? Dictyostelium, despite its apparent simplicity, is a valid model to answer all these questions.

As mentioned, switching from uni- to multicellularity is a remarkable characteristic of Dictyostelium. However, the striking similarity of single amoebas to animal cells, especially to those of the immune system, in comparison with the cells of plants or fungi, has contributed to the flourishing of Dictyostelium as a cell biology model. There are many examples of homologous proteins in Dictyostelium and animals that have been lost in the fungi or plant lineages, despite the fact that Dictyostelium is closer in evolution to the latter. In contrast to plant and fungi, Dictyostelium and metazoan cells lack a cell wall, an absence that allows them to move by chemotaxis and feed by phagocytosis and macropinocytosis, key processes which make these amoebae more similar to animal cells. But the similarities between Dictyostelium and animal cells extend to genes and proteins that regulate other well-conserved processes such as cell division and growth, autophagy, innate immunity, mitochondrial metabolism, etc.

The gene-hunting strategy followed by an exceptional generation of open-minded scientists, including William Loomis and many others (Loomis, 1998; Sugang *et al.*, 2011) was fundamental in the search for genes affecting Dictyostelium's development. Loomis' path has been followed by genome analyses leading to the discovery of disease-related genes (Eichinger *et al.*, 2005). It is fascinating to think that an amoeba could help us understand the pathological mechanisms of human diseases. But yes indeed, a growing number of disease-associated processes are now being modeled in Dictyostelium, including infection by pathogenic microbes (Steinert, 2011), disorders that affect the lysosomal, autophagy and cellular trafficking processes (Maniak, 2011; Mesquita *et al.*, 2017), and mitochondrial diseases (Francione *et al.*, 2011) to mention just a few examples.

Another interesting aspect arises from the simplicity of Dictyostelium's handling in the laboratory. Its fast growth at room temperature and atmospheric CO₂ levels, as well as under diverse conditions (on agar or in liquid, in static or shaking, with or without light, etc.) makes Dictyostelium ideal for teaching at any educational level, as simple and reproducible experiments can be performed with very modest settings.

There is no doubt that the potential of Dictyostelium as a model system is still far from being reached. Whether all perspectives will be fulfilled or not depends on many different factors, including the fierce competition with other systems for funding. In this regard, the support of a centralized NIH-funded resource, dictyBase and dicty stock center, that gathers, organizes and annotates all available information about Dictyostelium and stores valuable strains and plasmids is critical for the future development of this model.

This collection of reviews, written by leading scientists in their fields, is an updated overview of the research that is now being conducted with Dictyostelium. We hope that it will also serve the non-specialist readers to understand the peculiarities and commonalities of this organism with other, perhaps more popular, models. The research areas covered by Dictyostelium nowadays exceed the limits of this Special Issue. We would like to apologize for the many topics and authors that could not be well represented in this collection and acknowledge the great job of reviewers and the editors of the *Int. J. Dev. Biol.*

Ricardo Escalante and Elena Cardenal-Muñoz
Madrid (Spain) and Geneva (Switzerland) 2019

References

- BONNER JT (1947). Evidence for the formation of cell aggregates by chemotaxis in the development of the slime mold Dictyostelium discoideum. *J Exp Zool* 106: 1–26.
- EICHINGER I, PACHEBAT JA, GLÖCKNER G, RAJANDREAM MA, SUCGANG R, BERRIMAN M, SONG J, OLSEN R, SZAFRANSKI K, XU Q, *et al.*, (2005). The genome of the social amoeba Dictyostelium discoideum. *Nature* 435: 43–57.
- FRANCIONE LM, ANNESLEY SJ, CARILLA-LATORRE S, ESCALANTE R, FISHER PR (2011). The Dictyostelium model for mitochondrial disease. *Semin Cell Dev Biol* 22: 120–130.
- LOOMIS WF (1998). The Dictyostelium genome sequencing project. *Protist* 149: 209–212.
- MANIAK M (2011). Dictyostelium as a model for human lysosomal and trafficking diseases. *Semin Cell Dev Biol* 22: 114–119.
- MCCUTCHEON M (1946). Chemotaxis in Leukocytes. *Physiol Rev* 26: 319–336.
- MESQUITA A, CARDENAL-MUÑOZ E, DOMINGUEZ E, MUÑOZ-BRACERAS S, NUÑEZ-CORCUERA B, PHILLIPS BA, TÁBARA LC, XIONG Q, CORIA R, EICHINGER I, GOLSTEIN P, KING JS, SOLDATI T, VINCENT O, ESCALANTE R (2017). Autophagy in Dictyostelium: Mechanisms, regulation and disease in a simple biomedical model. *Autophagy* 13: 24–40.
- RAPER KB (1935). DICTYOSTELIUM DISCOIDEUM, A NEW SPECIES OF SLIME MOLD FROM DECAYING FOREST LEAVES. *J Agric Res* 50: 135–147.
- STEINERT M (2011). Pathogen-host interactions in Dictyostelium, Legionella, Mycobacterium and other pathogens. *Semin Cell Dev Biol* 22: 70–76.
- SUCGANG R, KUO A, TIAN X, SALERNO W, PARIKH A, FEASLEY CL, DALIN E, TU H, HUANG E, BARRY K, *et al.*, (2011). Comparative genomics of the social amoebae Dictyostelium discoideum and Dictyostelium purpurium. *Genome Biol* 12(2): R20. (doi: 10.1186/gb-2011-12-2-r20).

Further Related Reading, published previously in the *Int. J. Dev. Biol.*

Evidence for an evolutionary relationship between Vmp1 and bacterial DedA proteins

Luis-Carlos Tábara, Olivier Vincent and Ricardo Escalante
Int. J. Dev. Biol. (2019) 63: 67-71
<https://doi.org/10.1387/ijdb.180312re>

Dictyostelium discoideum Sir2D modulates cell-type specific gene expression and is involved in autophagy

Rakhee Lohia, Punita Jain, Mukul Jain, Pradeep Kumar Burma, Anju Shrivastava and Shweta Saran
Int. J. Dev. Biol. (2017) 61: 95-104
<https://doi.org/10.1387/ijdb.160038ss>

The Dictyostelium prestalk inducer DIF-1 directs phosphorylation of a bZIP transcription factor

Yoko Yamada, Yuzuru Kubohara, Haruhisa Kikuchi, Yoshiteru Oshima, Hong-Yu Wang, Susan Ross and Jeffrey G. Williams
Int. J. Dev. Biol. (2013) 57: 375-381
<https://doi.org/10.1387/ijdb.130046jw>

An orthologue of the Myelin-gene Regulatory Transcription Factor regulates Dictyostelium prestalk differentiation

Hiroshi Senoo, Hong-Yu Wang, Tsuyoshi Araki, Jeffrey G. Williams and Masashi Fukuzawa
Int. J. Dev. Biol. (2012) 56: 325-334
<https://doi.org/10.1387/ijdb.120030jw>

Bimodal distribution of motility and cell fate in Dictyostelium discoideum

Pavana Goury-Sistla, Vidyanand Nanjundiah and Gopal Pande
Int. J. Dev. Biol. (2012) 56: 263-272
<https://doi.org/10.1387/ijdb.113384ps>

ASET/MYND chromatin re-modelling protein regulates Dictyostelium prespore patterning

Beatriz Nuñez-Corcuera, Joanna Birch and Jeffrey G. Williams
Int. J. Dev. Biol. (2011) 55: 205-208
<https://doi.org/10.1387/ijdb.113309bn>

Synergy between two transcription factors directs gene expression in Dictyostelium tip-organiser cells

Hong Yu Wang and Jeffrey G. Williams
Int. J. Dev. Biol. (2010) 54: 1301-1307
<https://doi.org/10.1387/ijdb.103141hw>

