

Results and Problems
in Cell Differentiation
Volume 14

Structure and Function of Eukaryotic Chromosomes

Edited by W. Hennig



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Structure and Function of Eukaryotic Chromosomes

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With 99 Figures

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Results and Problems in Cell Differentiation

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Structure and Function of Eukaryotic Chromosomes

This book is dedicated to
Professor WOLFGANG BEERMANN
in honor of his 65th birthday

Preface

In 1985 I discussed with John Sommerville the state of chromosome research. We both felt that it would be worthwhile organizing a workshop for colleagues active in chromosome research, since the exciting new developments in this field obtained with the new molecular techniques often appeared to be insufficiently integrated into classical knowledge.

When Peter Hausen and I considered that the 65th birthday of Professor Wolfgang Beermann ought to be celebrated with some kind of scientific activity, emphasizing the importance and widespread influence of his scientific work, I remembered our earlier discussion. We felt that the birthday of W. Beermann would be an excellent opportunity to assemble scientists from all over the world and to try and achieve some kind of integration of classic and modern aspects of chromosome research. The opening and closing words spoken by Mel Green and Joe Gall are enclosed, since they emphasize one of the chapters written in chromosome research.

This volume is a document of a symposium organized in 1986 in Tübingen. However, it is not the documentation of a symposium in the usual sense. I have asked the invited speakers of this symposium to prepare a manuscript which meets the original intention and tries to integrate the classic knowledge from cytology and genetics with molecular data. Although some topics of chromosome research have occasionally been treated in other publications, a comprehensive assembly of the present knowledge has not yet been available. I hope that this volume alters the situation by providing an up-to-date account of various fields of chromosome research.

In various contributions it will become evident that often fundamentally new ideas are still necessary to arrive at a real understanding of the phenomena. This is particularly true for all questions on chromosome structure. Understanding gene regulation is closely connected to understanding chromosome structure. This shows that we are still far away from even understanding gene function. This book may help to induce new approaches stimulated by the recognition of the unsatisfactory state of our insight.

For several reasons it has not been possible to achieve a complete coverage of all the divergent aspects of chromosome structure and function. In particular, the important contributions of yeast chromosomes, which have not been appreciated by the classic cytologists as suitable material for research, are not represented. I hope that this volume will nevertheless prove valuable for all those fascinated by chromosomes, by questions on gene function and by cellular differentiation processes.

I am extremely grateful to all contributors for their dedication and co-operation. I feel very excited to read the various chapters on a research line which has been the focus of my own scientific career and which began in the 1960's in W. Beermann's Department in the extremely fascinating and stimulating environment of internationally leading colleagues. Only today can I fully appreciate the primary importance and value of such a scientific environment for post-graduate education.

Nijmegen, April 1987

WOLFGANG HENNIG

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Introduction

M. M. GREEN¹

"There is no science without fancy and no art without facts"

V. Nabokov

I am enormously pleased and honored to introduce this book, partly based on a Symposium which was convened in part to belatedly celebrate the 65th birthday of our colleague and friend Wolfgang Beermann, to wish him well and many more birthdays, in part to recognize and to bring up-to-date his genuinely significant research contributions to the subject of "Eukaryote Chromosome Structure and Function", and in part to wish him Godspeed, as he contemplates emeritus status.

I have for some time pondered the question: Am I qualified to make this introduction? For reasons which I shall spell out promptly, I conclude I am qualified. Because I am neither a cytologist nor a developmental biologist nor biochemist, just a "fly pusher" of the traditional *Drosophila* school, I can be completely objective in evaluating Beermann's research contributions. Furthermore, having been Beermann's friend for almost 25 years, having published with him and worked in *Abteilung* Beermann, I can provide some personal insights into the research environment which he cultivated. And, finally, since I am Beermann's senior by almost 5 years and have enjoyed the emeritus status for almost 4 years, I believe I can provide him with worthwhile advice as he embarks on his new career.

In the synopsis which follows I shall try and provide for you a personal view of Wolfgang Beermann's research accomplishments to date, the research environment he generated, the impact he and his students and associates have had in the realm of eukaryote chromosome structure and function and the lessons we can learn. I will close with some friendly advice!

The eminent bacteriologist and Nobel laureate Paul Ehrlich attributed scientific discovery to four elements: *Geld* (money), *Geduld* (patience), *Geschick* (skill or talent), and *Glück* (luck). If I may be so bold, I would add two more elements: *Gehirn* (brains) and *Gedanke* (idea). *Glück*, if translated as chance not luck, has a role in research only, as Pasteur emphasized, if one is prepared for the chance event.

How does Beermann's research fit into the remaining elements? *Geld*, it seems to me has played only a trivial role. His research employed a compound microscope, slides and coverglasses, stains, a few dissecting tools, and a place to raise *Chironomus*. All in all, by current standards these are an inexpensive array. Even his reprint costs were not excessive because the sum total of his publications spanning more than 3 decades is 45! (This seeming dearth of publications inparts an

¹ University of California, Davis, California 95616, USA.

important lesson on scientific research. Quality, not quantity, bespeaks Beermann's published work. When he had something to say, he published. He was immune from the "publish or perish" syndrome which generates too many premature and/or redundant publications and overburdens the libraries of the world!)

Geduld has been a necessary element in carrying out the painstaking, precise polytene chromosome cytology which Beermann produced; and the laboratory breeding of *Chironomus* species with their few annual generations manifestly demanded patience.

The remaining three elements, viz. *Geschick*, *Gehirn*, and *Gedanke*, taken together, I believe are necessary elements in the dictum of the renowned biologist and Nobel laureate, Szent-Györgi's on the nature of scientific research viz. "research is to see what everyone else has seen and to think what no one else has thought." Here, I shall briefly cite three Beermann publications which explicitly and elegantly fulfill Szent-Györgi's dictum.

First, *Chromomerenkonstanz und spezifische Modifikationen der Chromosomenstruktur in der Entwicklung und Organdifferenzierung von Chironomus tentans* (Chromomere constancy and specific modifications of chromosome structure in the development and organ differentiation of *C. tentans*), published in 1952, is a benchmark paper in the annals of research on chromosome structure and developmental biology. Here, Beermann sees in the polytene chromosomes what others have seen – Balbiani rings by Balbiani, puffs first seen in *D. melanogaster* and so named by Bridges – demonstrates the differential occurrence of puffs in different organs of *C. tentans* and thinks what no one else has thought before, viz. that the puffs must represent the visual manifestation of gene action! Their differential occurrence in different organs is the consequence of differential gene action. Subsequent biochemical research confirmed the correctness of this deduction.

In a second paper *Geschlechtsbestimmung und Evolution der genetischen Y-Chromosomen bei Chironomus* (Sex determination and the evolution of the genetic Y chromosomes of *Chironomus*) Beermann demonstrates that with patience and keen powers of observation, it is possible to carry out cytogenetic experiments with *Chironomus*. Here he establishes that in *Chironomus*, lacking heteromorphic sex chromosomes, males are the heterogametic sex and maleness is determined by a cytogenetically delimited "dominant" sex differentiator linked to one chromosome.

Finally, Beermann's striking powers of observation and deduction are manifest in a paper entitled *Ein Balbiani-Ring als Locus einer Speicheldrüsenmutation* (A Balbiani ring as the locus of a salivary gland mutation). Here he observes that in the salivary glands of *C. tentans*, four specific cells lack secretory granules not found in the equivalent four cells of *C. pallidivittatus*. By making crosses between the two species he demonstrates the granules to be inherited as a unitary, recessive Mendelian character, and linked to one particular chromosome. A puff specific to the four cells of *C. pallidivittatus* and absent in the same cells of *C. tentans* associates the secretory granules with the puff and affirms the conclusion that gene expression and puff formation are inexorably linked!

As I implied at the outset, an individual's research contributions are made in two ways: in part by personal research efforts and in part through the influence

a researcher exerts on his students and associates, the role model one exemplifies. In his relationship with students and associates, Beermann followed, I do believe, a long-standing, but slowly disappearing German tradition which is illustrated in the following excerpt taken from the biography of the distinguished German biochemist and Nobel laureate, Otto Warburg, written by his equally distinguished Nobel laureate student, Hans Krebs. Krebs described Warburg's graduate education as follows: "In 1901, Warburg began his studies of chemistry at the University of Freiburg. As was customary in central Europe, he later moved to another university, Berlin, where he completed his studies with a doctoral thesis under Emil Fischer in 1906 ... Fischer himself, though a head of a large institute with many teaching commitments, spent most of his working time at the bench, side by side with his research students. He set an example by his style of working, his high standards of reliability and personal integrity on which Warburg modeled himself throughout his life."

In the foregoing, by substituting the name Beermann for Fischer, an accurate and apt description of Beermann's research style and role model is achieved. He worked and continues to work at the bench with the patience and the enjoyment of a researcher whose reliability and integrity are impeccable! His influence on his students and associates has generated an array of original and significant research projects which gained for *Abteilung* Beermann a rightly deserved international reputation. The scope of these investigations goes beyond the cytology of *Chironomus*, thereby attesting to the great breadth of Beermann's interests and knowledge in the areas of cytology, genetics, and development. I will cite here only a few studies to emphasize the scope of the research, e.g., the cytogenetics and differentiation of the Y chromosome in *Drosophila hydei* carried out by Hess and Meyer and by Hennig; chromosome diminution in *Cyclops* studied by Sigrid Beermann; the biochemistry of *Chironomus* larval salivary gland secretion initiated by Grossbach. Consistent with a long-standing German research tradition, all these studies – some of them doctoral dissertations – bear the imprint of Beermann's guidance, advice, and attention to detail. None of the publications derived from dissertations bears his name! (There is yet another important lesson in scientific research to be learned from the foregoing. Only at the bench can a researcher see the unusual, the unexpected. For it is upon those "cherished exceptions" that much scientific progress depends. How much is the current breed of researchers missing in discoveries and excitement by sitting behind a desk instead of at the bench or by indulging in what Otto Warburg disparagingly called "academic tourism?")

It is fitting and appropriate that a number of the chapters of this present book will bring up-to-date research themes pioneered by Beermann and his students and associates. Accordingly, Edström discusses the Balbiani ring system, Taylor considers the replication of eukaryote chromosomes, Schweizer examines the nature of polytene chromosome banding, Korge describes the current status of salivary gland secretions, Judd considers the organization of the white eye color locus in *D. melanogaster*, and Nöthiger reviews the problem of sex determination in eukaryotes.

To round out the theme of this book, Callan discusses the behavior of chromosomes during meiosis, Scheer considers the contributions of the Miller spread-