Genetics

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Preface

Writing a general book on a popular and rapidly expanding subject like genetics belongs to the same category of human folly as trying to cross the Atlantic in a rowboat. In both kinds of enterprise one runs a considerable risk of drowning. In this voyage I did my best to ignore the waves of rather good texts with broadly similar aims that started to appear as soon as my book had passed the point of no return, but I could not help worrying about the tides of new data that constantly threatened to overwhelm my system of navigation. I have tried hard to get my view of genetics accurately positioned in the present and pointing in the right direction for the future, but some of the most exciting and important aspects of contemporary genetics, such as the control of eukaryotic gene activity and its connection with chromatin structure, cannot be definitively charted at the present time. A book such as this has to be based on a blend of established fact and debatable clues. I hope that the reader will find the distinction between the two sufficiently clear.

My aim has been to provide a picture of the current state of genetics for the student or other scientifically interested reader with no previous knowledge of the subject. I have assumed some familiarity with, or at least access to, elementary biochemistry. The original concept was of a general book for the student who did not want to be distracted by a lot of references to original sources. However, I have always felt rather cheated by general books that make interesting statements without giving chapter and verse. It seemed a reasonable compromise to provide sufficient references to lead the persistent enquirer to the original sources, but to place these unobtrusively, without titles, at the back of the book. I am not sure now that this was the best plan, but there it is. Often the reference given is only one of several that might have been cited, and has been selected because of its comparatively recent date and potential value as a guide to earlier papers. The sources listed at the ends of chapters under Further Reading are of a somewhat different character; they are mostly books and reviews that will provide the reader with a great deal of additional background information.

Some readers of the book in typescript have commented that the approach is 'ahistorical', which is broadly true. Here and there I have been unable to resist a historical allusion, but I have certainly not treated the history of genetics systematically, nor given credit to all the pioneers who would have featured prominently in a historically-orientated work. This is my excuse for not providing an index of authors, even though I have tried to make the general subject index as comprehensive as possible. The rather full subject index

is, in turn, my excuse for not including a glossary of technical terms. I believe that nearly all terms a reader will wish to have explained will be listed in the index and defined on the page of first reference.

I feel that I should say something about the Problems at the end of most of the chapters. By the standards of some other books there are not a great many of them, but I have tried to make them interesting. In most cases they are based on real data and require the student to think a little beyond the material presented in the preceding chapter(s). One or two reviewers have remarked that the problems are very demanding and, having just reworked most of them in search of errors, I must admit that some (though not all) are rather difficult. However, the reader can take comfort from the fact that behind every difficult problem there is an easier one, namely looking up the answer and showing that it works. Any student who can show that an answer *does not* work should be given extra credit.

Finally, I must thank all those without whose help this book could hardly have been possible. Dr John Gillman, of John Wright & Sons, must take the credit, if credit is the right word, for having persuaded me to undertake the project. He has been a constant source of encouragement. Mrs Jane Sugarman has been a most helpful and understanding sub-editor, and a model of equanimity in trying circumstances. Among a number of reviewers who saw the draft in typescript Dr Frank Stahl provided a particularly thorough and critical appraisal. I am indebted to him for a large number of suggestions on specific points, most of which I adopted. Several of my Edinburgh colleagues were kind enough to read individual chapters. Professor Douglas Falconer, in particular, helped to make the chapter on quantitative genetics less defective than it might otherwise have been. Mr Graham Thomas was generous of his time in reading the entire book in galley proof, and he picked up a number of errors that had escaped my own scrutiny. Mr E. D. Roberts, formerly artist in the Edinburgh Department of Genetics, undertook, after his official retirement, the onerous task of producing the drawings for figures. Unfortunately he was not able to finish quite all of them, and most of the remainder were drawn by me. I am afraid that the reader will have no difficulty in distinguishing his work from mine. Most of the photographs were solicited gifts. The donors are acknowledged in the legends, and I thank them all for their generosity.

J. R. S. F.

Contents

1 Cells, DNA and Chromosomes

1.1 Introduction

Living organisms are characteristically made up of cells. Most bacteria and a number of fungal and algal species consist of single free cells. All large organisms are multicellular, but even these originate from single cells—spores or fertilized eggs.

The essential property of the cell is its capacity for self-replication, that is to say its ability to propagate more cells like itself. In the case of unicellular organisms, the products of cell division, the daughter cells, are most commonly just like the mother cell which gave rise to them. In multicellular forms we see diversification of cell type as development proceeds, so that the mature organism contains many different kinds of cell each with a specialized function. Notwithstanding this differentiation, at least those cells which are destined to give rise to the next generation retain the potential for recapitulating the whole course of development characteristic of the species. Thus both in unicellular and multicellular organisms there must exist a system of information, a sort of master plan or blueprint, contained within a single cell and capable of being copied and transmitted faithfully through cell division to daughter cells. In this chapter we will be concentrating upon those structures and molecules which are particularly relevant to this self-copying, or self-replicating, property of cells.

1.2 Prokaryotic and eukaryotic modes of organization

The living world is divided into two main classes of organisms—the prokaryotes and the eukaryotes. The former class consists of the bacteria and the blue-green algae (Cyanophyta), and the latter includes all the rest.

The typical prokaryotic cell is enclosed by a protective cell wall, the composition of which varies greatly from one group to another but is always different from anything found in eukaryotes. Inside the cell wall the **protoplasm** is bounded by a double-layered selectively permeable **cell membrane** which, in striking contrast to the situation in eukaryotes, is the only membrane in the cell. The prokaryotic cell membrane is a complex structure performing many different functions. The enzyme complexes responsible for cell respiration and also (in photosynthetic bacteria) the pigments and enzymes involved in photosynthesis are associated with the cell membrane. In the much larger cells of eukaryotes all these functions are carried out by complex internal membranous structures (**organelles**).

The most conspicuous internal feature of the prokaryotic cell, easily seen in thin sections with the electron microscope, is a compact mass of intricately folded and coiled deoxyribonucleic acid (DNA). If a bacterial cell is made to burst by exposure to low osmotic pressure after removal of its cell wall with the enzyme lysozyme, the DNA is sometimes released in the form of a completely unfolded