The Cell in Medical Science

edited by Felix Beck
and John B. Lloyd

vol 1

The Cell in Medical Science

Volume 1: The Cell and its Organelles

edited by

F. BECK, *Department of Anatomy, University of Leicester*

and

J. B. LLOYD, *Research Unit in Biochemistry, Keele University*

1974

Academic Press
London New York

A Subsidiary of Harcourt Brace Jovanovich, Publishers

ACADEMIC PRESS INC. (LONDON) LTD.
24/28 Oval Road,
London NW1

United States Edition published by
ACADEMIC PRESS INC.
111 Fifth Avenue
New York. New York 10003

Library of Congress Catalog Card Number: 78-172366
ISBN: 0 12 084201 7

PRINTED IN GREAT BRITAIN BY
WILLMER BROTHERS LIMITED, BIRKENHEAD

Preface

The increasing importance of cell biology in Medical Science is becoming clear to clinicians and laboratory scientists alike. It is the meeting ground of many traditional disciplines and forms a central theme for many others. Its impact on subiects as diverse as immunology and neurobiology is already very great and one cannot but appreciate the potential that the application of its techniques and discipline must have for the future.

Many excellent introductory books of cell biology are available but beyond these one has in general to pass either to reviews or to original articles in order to probe more deeply. The present volumes are designed for readers who already have an elementary knowledge of cell biology; they present various aspects of the subject in depth and try to indicate some of the directions in which contemporary cell biology is moving and the methods it uses. No attempt is made to provide a comprehensive cover of cell biology, but the topics are chosen so as to produce a coherent work rather than a series of unconnected essays. We are greatly indebted to our contributors for their willingness to work within a number of constraints and for their patience with a multitude of editorial requests made to help us achieve our aims.

Volume 1 of this book is concerned with the generalized cell unit, and its chapters deal with the biophysical and biochemical basis of the structure and function of the chief subcellular organelles. Volume 2 contains a series of chapters on the relationship of the cell to developmental processes both within the cell itself and in the organism as a whole. There follow chapters on specific cellular specializations, particularly within the neuromuscular system. Here morphological adaptation for specific functional purposes is described in detail. This theme is again followed in Volume 3 where connective tissues, various endocrines, absorptive and secretory cells are dealt with. Volume 4 begins with three chapters on metabolic control mechanisms, and these are followed by chapters on the relationship between the cell and its environment in various pathological states; immunological processes, inflammation, wound healing and carcinogenesis are treated within this framework.

We believe this book will be of value to senior undergraduate students and to research workers looking for summaries on a variety of related topics concerned with cell structure and function. The contributors have been asked to provide only brief bibliographies which enable the reader to develop his own interest; the chapters do not attempt to include an extensive review of the literature.

Like many before us, we are indebted to Academic Press for the patience, forbearance and unfailing courtesy of numerous members of their staff.

F. BECK
University of Leicester
J. B. LLOYD
University of Keele

February 1974

Contents of Volume 1

The Cell and its Organelles

The Cell and its Organelles

1. The Cell as a Unit

E. N. WILLMER
Emeritus Professor of Histology, University of Cambridge, England

I. Introduction

Once upon a time cells in the body used to be compared with the bricks in a building and, just as there may be different types of bricks for different purposes, so each cell was regarded as something rather rigid and determinate: for example, there were muscle cells, liver cells, nerve cells and so on. This view, however, is now as dead as the Dodo. A more apt, though still inadequate, analogy is sometimes drawn between the cells in the body and the individuals in a human community. This comparison is at least more vital.

Cells were first described as essentially micro-anatomical units and their size was such that, at the time, investigation of their physiology and biochemistry was well-nigh impossible. However, subsequent progress in micro-techniques has so emphasized the diversity, adaptability, individuality, versatility and plasticity of cells that the concept of the cell as a rigid morphological unit is now quite untenable and the present concept is very different from that prevalent in the days of Schleiden and Schwann (1838–9). Even to describe cells as physiological units is sometimes fallacious in view of the fact that the functional unit is often a combination of cells. Cardiac muscle is an obvious example, and the partnership between nerve and neuroglia (Chapter 19) is another less obvious though equally important one.

II. Evolutionary Aspects

It may be helpful first to review the concept of the cell in relation to evolution and differentiation, as this may emphasize the dynamic and adaptive qualities of cells. The cells of the metazoa can, with considerable justification and in spite of essays to the contrary, be compared in many respects with the protozoa, and it is now recognized that with only a few relatively minor exceptions the free-living protozoa (and indeed probably the bacteria too) have developed all the essential metabolic pathways and enzyme systems that are known to be necessary to sustain the life of metazoan cells. In other words, they possess in their genomes all the necessary DNA sequences for the construction of the normal metabolic enzymes and proteins for cellular activity, though not necessarily those required for all the special products like keratin, collagen, or the various proteins of the blood. With this in mind, the problems of human cytology are seen to be largely those that arise as a consequence of grouping, or possibly subdividing, the original protozoan units into colonial units, and of the subsequent evolution of these colonial forms: i.e. to develop organs and tissues which have adapted them to life among their competitors and in special environments. Human cytology can be no more studied without reference to the ancestral past than human behaviour can be considered as independent of human history and pre-history.

Within certain defined limits the protozoon is an adaptable form. It may or may not possess polarity, i.e. an anterior and a posterior end, but each individual is normally adapted to living in an environment which, compared with itself, is large and uniform and which therefore affects all parts of the cell surface more or less equally. Many different environments have been successfully colonized by the protozoa and this has led to a great diversity in form and function among them; each type is suited to the particular niche that it occupies, whether that niche be the ocean, the fresh-water pond, the soil or the cytoplasm of an human erythrocyte. Protozoa are essentially cells whose responses are dependent upon the interplay between their own inherited characters and their immediate environment. Occasionally they are able to change from one form into another. For example, *Naegleria gruberi* (Fig. 1) can be either amoeboid or flagellate, and it changes form according to the salt concentration of the environment. In some protozoa, a similar change of form follows a cell division, as in the production of flagellate gametes, but *Naegleria* is peculiar in that the change of form (which is comparable with some processes of differentiation in higher animals) can occur directly, without involving mitosis (Willmer, 1956). Changes in the ionic content of the surrounding fluid cause almost immediate changes of form, even inducing or eliminating polarity. *Naegleria* is certainly an exceptional organism, but nevertheless it has its lessons for the human cytologist, in showing how quickly and extensively protoplasmic units can respond to their immediate environment, to say nothing of the more subtle and unseen biochemical adaptations that may also be occurring.

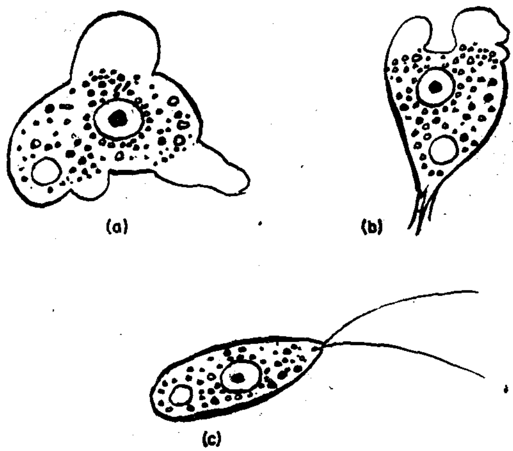

Fig. 1. *Naegleria gruberi* (a) Unpolarized amoeboid form. (b) Intermediate, polarized, amoeboid form. (c) Free-swimming flagellate form.

A. COLONIES AND THE DEVELOPMENT OF MICROENVIRONMENTS

When, however, protozoan cells (?) first united into colonies, or multinucleate protozoa became multicellular organisms (and it matters not for the present discussion how these colonies or organisms originated) then the cells of each colony or organism immediately created new and different environments for themselves and for all the other constituent cells. The uniform external environment of the protozoa was for ever lost, so far as the individual cells were concerned. For successful colony formation therefore, the cells had to be able to adapt themselves to these new microenvironments, without at the same time producing conditions inimical to the other cells of the colony. Moreover, the stability of the colony as a whole had to be preserved. The availability of oxygen, the elimination of toxic products and all such-like requirements had to be met. Similarly, if the colony took the form of a hollow blastula-like organism (Fig. 2), as is certainly suggested by the widespread occurrence of this form in the embryogenesis of invertebrates, all the cells had to work together to maintain its coherence, shape, size and probably also its buoyancy. Furthermore,

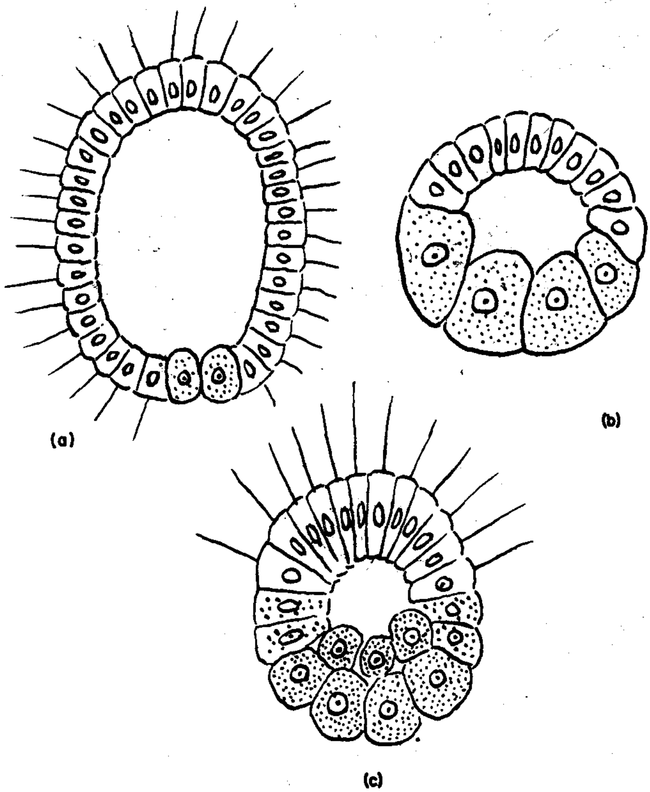

Fig. 2. Various forms of blastula. (a) and (b) Blastulae with sharp division between two types of cells. (c) Blastula with a gradation of cells.

if in the interest of stability and coherence the cells formed "tight junctions" between themselves then the contained fluid could well differ materially from the fluid of the surroundings. In that case the cells inevitably become polarized, with one surface facing the outside world and the opposite surface facing the fluid of the "blastocoel" cavity. In such an organism, toxic substances have to be excreted and hydrostatic and ionic equilibria have to be preserved. It is possible that all this could be done by a uniform population of cells, but a comparative study of the many different organisms of this kind, as they occur in the form of the blastulae of invertebrates, suggests that the conditions may be best satisfied by the combination of cells of two or more classes. In calcareous sponges, for example, the blastulae are composed partly of flagellated cells and partly of more phagocytic cells without flagella. In nemertine worms, the cells of the animal pole of the blastula differ from those of the vegetal pole. It has been shown that when the blastula is bisected equatorially the cells of the "animal" half reunite and form a hollow sphere, while those of the "vegetal" half cohere to form a solid mass or "morula". Obviously the two groups of cells have different means of coherence or deal with their surrounding fluids quite differently, and it seems probable that in the normal blastula they combine together to maintain the equilibrium of the embryo, because the normal embryo neither shrinks nor swells unduly, nor does it suffer from the accumulation of toxic products. In many embryos there is no sharp division between the "animal" and "vegetal" cells, but a more or less gradual transition from one to the other, i.e. an axial gradient, as shown in Figure 2c.

Again, if the early gastrula of the frog is divided latitudinally into three segments, an animal pole region, an equatorial region, and a vegetal pole region, the equatorial part alone can survive and reform into a viable embryo. It presumably contains an adequate mixture of the "animal" and "vegetal" cells. It may be noted that this survival does not depend on the presence of the dorsal lip, since this was contained in the vegetal third (Paterson, 1957).

B. CONTROL OF THE CELLULAR ENVIRONMENT

Symbiotic Pairs

These observations thus point to the very early evolution of a kind of symbiosis between cells of different sorts. A symbiosis by which equilibrium can, presumably, be more effectively conserved than it could be by one type of cell only, whose activities if left unbalanced and unchecked could easily lead to the fatal deterioration of the immediate cellular environment. If such a symbiosis exists, even in relatively primitive and simple organisms like the embryos of invertebrates and amphibia, it is likely that similar associations continue to exist between the cells of higher organisms, and that they have developed into even more elaborate patterns among the adult tissues of higher vertebrates.

Thus it may be often misleading, even wrong, to consider cells as separate and independent units. Probably they more often exist as members of partnerships. It is certainly notable that practically every