THE FOETAL CIRCULATION

AND CARDIOVASCULAR SYSTEM, AND THE CHANGES THAT THEY UNDERGO AT BIRTH

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BLACKWELL SCIENTIFIC PUBLICATIONS, LTD., OXFORD
1945

First Printed, *December* 1944
Reprinted . . *June* 1945

TO
SIR JOSEPH BARCROFT
AND
DR. DONALD H. BARRON

THIS BOOK IS PRODUCED
IN COMPLETE CONFORMITY WITH THE
AUTHORIZED ECONOMY STANDARDS

Made and Printed in Great Britain
by Hazell, Watson & Viney, Ltd.
London and
Aylesbury

THE FOETAL CIRCULATION

PREFACE

THIS book contains an account of our own foetal studies, together with a summary of the related findings of other workers. Before going on to discuss it in detail, we wish to make three major acknowledgements : to Lord Nuffield, to Dr. E. C. Amoroso, and to our Publishers respectively.

Lord Nuffield presented to Oxford University, for the use of its Medical School, the beautiful late 18th-century building in which we are privileged to work ; he also provided most of our apparatus, and he has shown a personal interest in our results. We are glad to have this opportunity of expressing our very considerable indebtedness to him.

Dr. Amoroso, of the Royal Veterinary College, has provided or collected, from 1940 onwards, most of the comparative anatomical specimens which we have dissected, and he has himself dissected many others (e.g., those depicted in figs. 48, 121 *b* to *f*, 122, and 128). In addition, he has been responsible for almost all the histological work, and has supervised the production of the photographs and drawings reproduced as figs. 39, 40, 48, 99–100, 102–106, 121 *b* to *f*, 122, and 147. We wish to acknowledge here not only the very great assistance he has so freely given us in the preparation of material for this book, but also the very happy collaboration which we have enjoyed with him during the last four years. We should also like to pay a tribute to his artistry in macro- and micro-dissection. It was, earlier, our hope that his name would appear with ours on the title-page of this book, but a succession of untoward events made this impossible, so we must demonstrate, in this alternative way, our appreciation of his efforts.

Of our Publishers' wholehearted co-operation with us we cannot speak too highly. To Mr. Basil Blackwell and Mr. Henry Schollick in particular we are most grateful, and we realize how fortunate are the authors whose works they undertake to produce.

The foetal studies at the Nuffield Institute were initiated in 1937, when Sir Joseph Barcroft and Dr. D. H. Barron asked if we would co-operate, with our cineradiographic techniques, in the solution of their problem, namely, the determination of the time of functional closure of the ductus arteriosus.[1] We agreed very readily, and two seasons of collaboration gave our combined teams not only the answer to the immediate question, but also the first direct records of the circulation in the intact foetus, delivered by Caesarean section.[2] Thereafter the outbreak of war ended the pleasant partnership that we had enjoyed

[1] At the meeting of the Physiological Society on 13 March 1937, a film made by Barcroft and Barron (" Experimental ' chronic ' lesions in the central nervous system of the sheep's foetus ") was projected immediately before one made by Janker and Franklin (" X-ray cinematographic film of a dog's heart "). This accidental juxtaposition of the two films suggested to Barron the new line of attack.

[2] Priority in the idea of a radiographic recording of the foetal circulation belongs, apparently, to Gargiulo, M. (1936). Unfortunately, his paper in *Riv. di Chir., Como*, **2**, has not been accessible to us, but there is a brief note in *Riforma med.*, 1936, **52**, 971, which reads as follows : " GARGIULO M. *Tentativi di studio della circolazione fetale mediante impiego di raggi Röntgen.* L'O. si propone

with our colleagues from Cambridge, and at the same time reduced our own opportunities for research. In the intervals of other work, however, we have from time to time added to our experimental findings, and we have also made fairly extensive comparative anatomical studies.

In as much as it was the physiological findings which led us on to re-investigate the anatomy, we have given the foetal circulation, rather than the foetal cardiovascular system, pride of place in the title of our book. As our main object, in an Institute for Medical Research, is to discover more about the *human* subject, we should have liked to reproduce as a frontispiece a diagram of the *human* foetal circulation and of its changes at birth. But accurate knowledge of this, based upon radiographic records, is not at present available, so we have preferred to omit a frontispiece altogether when we cannot have the one of our choice. In view of the way in which our foetal researches began, the dedication of the book to Sir Joseph Barcroft and to Dr. D. H. Barron needs no further explanation. We should, however, state that the opinions and interpretations to be found in the text are, unless otherwise indicated or apparent, our own.[1] In other words, if criticism can justly be levelled against anything which we have written, our erstwhile colleagues should not be held jointly responsible, for they have not seen the book during its production.[2]

In general, in the text, we have adhered to the third person singular. But exceptions have been made in respect of Chapter II, which is an account of our own work at the Institute, and of Chapter XIII, our concluding remarks. In Chapter II our major findings about the foetal circulation are introduced by a description of the post-natal circulation, with which the reader is more familiar. In addition, the older terms for certain parts of the foetal cardiovascular system are retained, even though we ourselves have long since discarded them as unsatisfactory. The new terms, with the reasons for their introduction, are given in Chapter III and elsewhere, and a number of them are summarized in the glossary inserted between Chapters III and IV. Until these new terms, or similar ones, are generally used, accounts of the foetal circulation and cardiovascular system will continue to suffer from the erroneous outlook of past centuries. In some Schools the new terms are already in use,

di studiare il circolo fetale con metodo radiologico. Inietta pertanto una sospensione di bario nella vena ombelicale e segue la sua diffusione mediante esami stereografici. La scarsezza delle osservazioni non gli consente pero ancora di pronunciarsi decisamente su questo metodo." We are indebted to Mr. W. J. Bishop, Sub-Librarian of the Royal Society of Medicine, for tracking down this note.

[1] An important exception should be noted at this point. So far as the adult is concerned, we incline to the views of Pitts, Magoun and Ranson (1939) rather than to those of Lumsden (1923, 1924) in respect of the correlation of various types of respiratory pattern with the activities of definite respiratory centres. But Pitts et al. have not yet, it seems, extended their studies to the foetus, and in the absence of such extension we have quoted, though we do not necessarily subscribe to them, views obtaining in the current foetal literature. The passages in which these views are mentioned occur in sections (iv) and (v) of Chapter VI, in section (ii) of Chapter VIII, and in section (ii) of Chapter XI.

[2] As Dr. Barron has more or less simultaneously been producing a review (Barron, 1944) and Sir Joseph Barcroft a book (still in preparation) on subjects which to some extent coincide with those of this present work, we felt that it would be a great advantage if the three accounts gave independent valuations of the available evidence. Though, therefore, we were privileged to see the draft of part of Sir Joseph's book, we deliberately forgot what we had seen ; of Dr. Barron's typescript we saw no part at all.

and the teaching of the subject in these places is in consequence not only more in accord with the facts, but also simpler. We hope that other Schools will be equally ready to adopt the improvements which we have suggested, and thereby to share in the double advantage which we have mentioned.

The actual writing of the book was apportioned as follows. Dr. Barclay and Miss Prichard undertook Chapter II, and Dr. Franklin the remainder. Personal communications from Sir Joseph Barcroft, and from Professors J. Yule Bogue, J. D. Boyd. F. J. Cole, Clifford Formston, J. A. Gunn and Charles Singer, from Dr. W. F. Harper and Dr. G. M. Vevers, and from Mr. M. J. Hirst and others are included by kind permission of these various friends and correspondents. Dr. Douglas McKie, Editor of *Annals of Science*, generously allowed us to quote extensively from Vol. **5** of his journal; Mr. Tom Hopkinson, as Editor, and Mr. Macdonald Hastings, as author, similarly permitted us to reproduce an account of lambing which appeared first in *Picture Post*. Many Librarians went out of their way to help us; we may mention in particular the Staff of the Radcliffe Library, Mr. G. F. Home and Mr. W. J. Bishop of the Royal Society of Medicine, the Librarian of the Royal College of Physicians of Edinburgh, and Dr. Fred Bullock of the Royal College of Veterinary Surgeons. When the text was complete, Professor Yule Bogue was kind enough to read through Chapter IV and to suggest certain improvements in it; we also benefited by his advice in respect of the final arrangement of Chapter VI. Sections (iii) and (iv) of Chapter VII are the gist of our comparative findings about the foetal liver; they owe much to a re-casting which our original account underwent at the hands of Professor A. J. E. Cave, and we take this opportunity of expressing our very great indebtedness to him. We are also under a very deep obligation to Mr. John Stallworthy, F.R.C.S., who read through the part dealing with the human subject (Chapters IX to XII), suggested certain improvements in it, and—in its final form—gave it his imprimatur. Finally, in so far as the text is concerned, we are most grateful to Mrs. J. L. Boldero, who very kindly undertook, as spare-time work, practically the whole of the typing required.

In general, the figures (apart from those already mentioned) were collected and arranged as follows. Dr. Barclay and Miss Prichard dealt with the radiographs, including the five Plates; Dr. Franklin and Miss Prichard with the rest. For figs. 69–79 we wish to thank the Editor of *Picture Post* and Mr. Kurt Hubschman, for figs. 145–146 Drs. C. F. V. Smout and P. Bacsich, and for fig. 155 Dr. J. A. Keen. The majority of the photographs[1] are the work of Mr. M. S. Tuckey, technician at the Nuffield Institute, and his artistry in this line is obvious without further comment. For the actual preparation of the figs. supplied by Dr. Amoroso we are in large measure indebted to Mr. R. L. Williams, F.R.M.S., and Mr. J. Hancock, of the Royal Veterinary College. Finally, in so far as the illustrations are concerned, we wish to thank the Editors and/or Publishers of the *Journal of Anatomy*, the *British Journal of Radiology*, and the *Veterinary Journal* for permission to

[1] Many of them are halves of stereophotographs, which can be viewed by those who care to pay us a visit. We have found stereophotography a most useful means of preserving records of foetal dissections; it often shows up details even better than do the actual specimens.

reproduce various figures which appeared for the first time in those journals.

Our long tale of acknowledgements may be completed by a mention of those who have assisted us, financially and otherwise, in the conduct of our experiments, or who have provided us with specimens. Financial help, for which we were and are most grateful, came on more than one occasion from the Medical Research Council. Personal help has been given by Drs. E. C. Amoroso and J. Badenoch, Professor J. Yule Bogue, Drs. J. L. Boldero, J. G. Emanuel and J. D. Little, Mr. J. C. Scott, F.R.C.S., Drs. J. Trueta and M. Weatherall, Messrs. D. W. H. Barnes, G. F. M. Carnegie, L. T. Cotton, R. W. Emanuel, J. F. Hale, N. C. Hughes Jones, H. M. Lloyd, D. F. Magee, R. T. Turner Warwick, and others ; we wish to express to each of them our very sincere thanks. For the provision of certain foetal and early post-natal specimens we are indebted to Colonel A. E. Hamerton and others of the Zoological Society of London, to Dr. A. H. T. Robb-Smith, and to Professor Charles O'Donoghue ; to them also we offer similar thanks.

The book which, with so much and so varied help, we have been able to produce contains the gist of seven years' radiographic, historical, and anatomical research upon the foetal circulation and cardiovascular system. It is, therefore, too long and too detailed to make much appeal, except through its illustrations, to the dilettante reader. We believe, however, that the more serious student will find himself amply repaid for a few days' careful perusal of our account, in view of the great interest inherent in its subject. We trust, then, that our summary will be of service to medical and veterinary colleagues, to a fair proportion of medical and veterinary students, and to tutor-midwives, and we hope that, in return, they will adopt our simpler and more functional terms for certain parts of the foetal cardiovascular system. Though we cannot at present forecast how much more we shall do in this particular field, we shall be grateful for any helpful comments on what we have written, for extra references, and for suggestions as to possible further lines of research. It is, perhaps, unnecessary to add that all such help will be duly acknowledged in any future publications which we may make.

With this preamble finished, we may pass on to the text proper, beginning with an account of the contributions made by our predecessors during the last eighteen hundred years.

A. E. Barclay.
K. J. Franklin.
M. M. L. Prichard.

Oxford, 1944.

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PART ONE

CHAPTER I

Historical Introduction, containing an Account of Earlier Views, based mainly upon Anatomical Findings, about the Course of the Foetal Blood Flow

THE history of research upon the foetal cardiovascular apparatus, and the development of ideas about the foetal circulation, can be divided into four parts. The first of these deals with the purely anatomical period that preceded Harvey's treatise (1628) on the blood circulation, the second with Harvey's own contribution, the third with the period of anatomy and of physiological hypothesis based mainly upon anatomy, and the fourth with the period of experimental research.

(i) THE PRE-HARVEIAN ANATOMICAL PERIOD

A detailed account, complete except for references to du Bois [1] (1555), du Laurens (1599), Bauhin (1600, 1605, 1620, 1621), and Spigel (1627), is already in print (Franklin, 1941, a, b), so a summary will suffice here.

In the second century A.D. Galen gave the first still extant description of the foramen ovale and its valve, and of the ductus arteriosus.[2] He also wrote briefly, but tellingly, of their post-natal closure.

In a posthumous publication, in 1555, Jacques du Bois mentioned membranous outgrowths (i.e. valves) in various veins, including the trunk of the vena cava as it passes forward from the liver. He thus, probably, anticipated Eustachi (1563), but his statement was so brief that one cannot say more than that.

In 1561 Gabriele Falloppio improved in one respect on Galen's account of the ductus arteriosus ; he also initiated the special use of the word " placenta " (literally, a flat cake or pancake).

In 1563 Bartolomeo Eustachi described and pictured the membrane that later became known as the Eustachian valve. Unfortunately, his figure of this structure was far from typical.

[1] Also referred to in the literature as Dubois and Sylvius. In this account the earlier writers are given their ordinary names rather than the Latinized versions of the same. Hence du Laurens (Dulaurens), Eustachi, Falloppio, Vesal, Aranzi, Botallo, Carcano, Fabrizi, Bauhin, and Spigel rather than Laurentius, Eustachius, Falloppius, Vesalius, Arantius, Botallus, Carcanus, Fabricius, Bauhinus, and Spigelius. But there are variants (e.g. Eustacchi, Gabrielle Falloppia, Fabritii, Fabrizio) of some of the above-listed ordinary names, and the forms used here may not all be the best authenticated ones.

[2] Singer (1925, 20) wrote that Aristotle " perhaps has a reference—certainly the first in history—to the *ductus arteriosus*." According to Professor F. J. Cole (personal communication), D'Arcy Thompson's edition of the *Historia Animalium*, 513a 35 footnote, also gives this view, but in Professor Cole's opinion the identification is very far-fetched, and it is by no means certain that Aristotle knew of the pulmonary artery. According to Professor Singer (personal communication), Ogle, in his edition of Aristotle's *On the Parts of Animals*, held that Aristotle had a reference to the ductus arteriosus ; Arthur Platt, however, did a very careful piece of work on the heart as described by Aristotle (see Singer's *Studies in the History and Method of Science*, **2**, 521) and concluded that Ogle was wrong.