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REVIEWS

Fluid Behaviour in Biological Systems. By L. LEYTON. Clarendon Press, Oxford, 1975. 235 pp. £12.00.

This book arose out of courses of lectures on physics for biologists and on environmental physics which the author gives to first year biology undergraduates at Oxford. Such courses, and therefore such books, are being recognized with increasing frequency on both sides of the Atlantic to be an important part of the scientific training of biologists (and, to a disappointingly lesser extent, of medical students). It is not appropriate to present a dry parade of mathematical methods or of physical principles, on the assumption that the application will become clear in the students' later courses; this happens in physics, but in biology the use of quantitative methods and of mathematics is still not extensive, and few biology courses incorporate such material. Thus it is constantly necessary to demonstrate why physics or mathematics is important in biology, and how it is applied. This can be done only through numerous actual biological examples, so that at the end of the course the student has some idea of how to construct a suitable physical or mathematical model of a biological phenomenon, as well as a little experience in using it to make predictions. It seems to me that a book (or course) on physics or mathematics for biologists cannot succeed unless it adheres to these principles.

According to the author's preface, one of the main aims of this book is to provide for biologists a reasonably comprehensive account of the principles of fluid mechanics and their biological application. His approach corresponds exactly to that advocated above, and for that reason alone I would recommend the book to anyone who is contemplating teaching a course on physics or mathematics for biologists. There are chapters on flow in tubes, on porous media, over plane surfaces and over immersed bodies, with frequent applications to the movement of sap in trees, to animal respiration, to water movement in soil and wood, to the nature of air flow over leaves and crop fields, and to animal locomotion in air and water, to which a separate chapter is devoted. Then there are chapters on heat and mass transfer (diffusive and convective), with application to the overall balance of heat, respiratory gases, and water for both plants and animals. There is a chapter on "The environment above the ground", in which the effects of radiation, evaporation and air movement on crops and forests are analysed together. There is a brief chapter on non-Newtonian fluids, with particular reference to blood and its circulation and to the intracellular movement of cytoplasm. The final chapter discusses water movement from the thermodynamic point of view, introducing the water potential (which has the units of pressure) and the various factors (gravity, pressure, capillarity, osmosis) which influence it, and concluding with a brief introduction to irreversible thermodynamics. Again the main application is to water transport in the soil–plant–atmosphere system.

As can be seen from the above outline, the author's personal research interests are in the fields of botany and forestry, and where possible he chooses his examples from them. He succeeds in conveying the fascination of the subject, and the useful advances which have been made by very simple applications of physics. His discussions of the water balance of plants, and of water movement within them, are especially stimulating. When it comes to other areas of biology, on the other hand, this book is rather disappointing, largely because of the considerable omissions. For example, only two pages are devoted to the circulation of the blood, one of the most familiar fluid flow problems in biology: the pressure wave is mentioned once, but not defined or analysed; McDonald's book *Blood Flow in Arteries* (Edward Arnold, 1974, 2nd edition) is not even referred to; the medical importance of haemodynamics is not mentioned. Respiratory mechanics is given only 1½ pages, and airway resistance is treated very superficially by an analysis which has long been out of date. No other physiological fluid system is mentioned at all. Discussion of biological phenomena is often broken off just when it becomes interesting. For example, the counter-current heat exchange system employed by cetaceans and wading birds (among others) to maintain the temperature of their blood is mentioned, but no explanation is given: a simple explanation is available, as shown by Schmidt-Nielsen in his little book *How Animals Work* (Edward Arnold, 1973). The same is true for the discussion of diffusion through walls containing a number of pores: an analysis is given, but is cut short before the interesting effects of wind speed on vapour diffusion are examined.

It may be that these deficiencies are unimportant, since the biology undergraduate will not be aware of them. However, my other criticism of this book is important: that is that several of the basic fluid mechanical principles are explained in a way which is at best confusing and at worst wrong. The author rightly stresses the importance of boundary layers, but the analysis of the thickness (δ) of a boundary layer on a flat plate fails to distinguish between the essentially dimensional arguments which lead to $\delta = k(\nu x/U)^{\frac{1}{2}}$, and the details of the calculation, with a particular velocity profile, which predicts the value of k (about 5). The details are worked out for a linear velocity profile, with little indication of the expected error apart from the statement that "within the boundary layer, the shape of the velocity profile is parabolic". Other errors arise in the discussion of laminar and turbulent flow. A proper definition of the two is not given, so that once or twice the author falls into the trap of confusing laminar flow in a pipe with Poiseuille flow. Thus in his discussion of airway resistance he suggests that the drop in total head down the lung is the sum of a term proportional to the square of the flow rate (for those tubes in which the flow is turbulent) and one proportional to the first power (for those in which it is laminar), ignoring the fact that no airway (except the trachea) is more than about four diameters long, so that nowhere can the flow be fully developed, and nowhere will either power be correct. He also supposes that the critical instantaneous Reynolds number in arteries is similar to or lower than that for steady flow in long straight tubes, whereas it is nowadays thought to be somewhat higher (depending on the heart rate); the significance (if any) of turbulence in arteries is still a very controversial subject. In the discussion of turbulent heat and mass transfer, the author makes much play with the viscous sublayer, which he calls the laminar sublayer and implies to be a region in which the velocity fluctuations are negligible; this is likely to be misleading. Another error occurs in the chapter on animal locomotion, where the lift force on a wing is both drawn and stated to be perpendicular to the wing, not to the relative airstream. The formulae quoted are correct, but a student reading this chapter is unlikely to be able to apply them correctly.

I think that a correct explanation of fluid mechanical results is important (albeit lengthy when mathematics is to be avoided), but a misleading explanation is worse than an empirical statement of the results, with which on several other occasions the author is satisfied. In these cases the implication is that biology students should not worry about the mechanisms, but should merely know where to find the formulae. That may be dangerous.

The above criticisms are not intended to be damning. I have tried to expose the weaknesses so that the teacher does not lean too heavily on the text, but I still think this is a good book, and to be recommended for teaching purposes since the approach to the subject and the use of botanical examples are excellent. Other bonuses are a first-class treatment of dimensions and units (S.I. everywhere), a very high standard of printing and proof-reading, and a suitably sceptical attitude to the literature (which of course includes books, and book reviews).

T. J. Pedley

Shorter Notices

Developments in Mechanics. Volume 8. Proceedings of the 14th Midwestern Mechanics Conference. Edited by C. W. Bert, M. L. Rasmussen, D. M. Eagle and M. C. Jischke. University of Oklahoma Press, 1975. 626 pp. $25.00.

This heavy volume contains 26 submitted papers on solid mechanics, 9 on fluid mechanics, and 3 general lectures, of which one, "New horizons in regional and small scale meterology", by D. K. Lilly, may be of direct interest to fluid dynamicists. A notable feature of the volume is that page numbers have been omitted in the list of contents, an editorial oversight that makes the location of any particular paper just a little time-consuming. Production is by photo-offset, the result being legible and clear, though hardly beautiful. The volume will no doubt be welcomed by those who attended the Conference, but it is difficult to believe that it will be of great interest to many others.

Advances in Applied Mechanics. Volume 15. Edited by Chia-Shun Yih. Academic Press, 1975. 266 pp. $16.50 or £7.90.

This well-established annual contains this year three long articles (or 'mini-monographs'), all of considerable current interest: "River dynamics", by Vito A. Vanoni, an account largely of bed forms and sediment transport in rivers; "Matching problems involving flow through small holes", by E. O. Tuck, an imaginative treatment of a wide range of problems to which 'inner and outer' methods may be applied; and "Structure of turbulence in boundary layers", by W. W. Willmarth, a courageous attempt to rationalize and systematize work on intermittency, bursts, coherent structures, etc., topics on which generally much is currently written and little understood. All in all, a genuinely welcome addition to the series.

La Météorologie. Société Météorologique de France. Four numbers per year. New sixth series began June 1975.

The SMF has relaunched this periodical in an expanded and very diversified format. In the first two issues, of 140 and 204 pages respectively, there are articles ranging all the way from "Concepts nouveaux sur la mécanique de la turbulence", by J. Blanchet (with many pages of equations), to "La guerre météorologique: mythe ou réalité de demain?" by D. Dettwiller. There is also official reporting of the activities of the SMF, in the manner of the Bulletin of the AMS. There are sections both for professional review and research articles, and for articles and news items of interest to a wider public, rather as in "Weather" or "Weatherwise". There are also plenty of magnificent pictures.

Annual Review of Fluid Mechanics. Volume 8. Edited by M. VAN DYKE, W. G. VINCENTI and J. V. WEHAUSEN. Annual Reviews Inc., 1976. 418 pp. $15.00.

Drawing this year on authors working in five different countries, the latest volume in this series contains the following articles.

Hydraulics' latest golden age, H. Rouse.
Useful Non-Newtonian models, R. Bird.
Optical effects in flow, A. Peterlin.
The stability of time-periodic flows, S. H. Davis.
Aerodynamics of buildings, J. E. Cermak.
Mixing and dispersion in estuaries, H. H. Fischer.
Homogeneous turbulent mixing with chemical reaction, C. Hill.
Instability in non-Newtonian flow, J. R. A. Pearson.
Computation of turbulent flows, W. C. Reynolds.
Hot-wire anemometry, G. Comte-Bellot.
Multiphase fluid flow through porous media, R. A. Wooding & H. J. Morel-Seytoux.
Currents in submarine canyons: an air–sea–land interaction, D. L. Inman, E. Nordstrom & E. Flick.
Boundary-layer stability and transition, E. Reshotko.
Turbulent flows involving chemical reactions, A. Libby & F. A. Williams.
A blunt body in a supersonic stream, V. V. Rusanov.

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Corrigenda

'Stokes flow past a particle of arbitrary shape: a numerical method of solution',

by G. K. Youngren and A. Acrivos, *J. Fluid Mech.* vol. 69, 1975, p. 377.

Equations (2.14*a*) and (2.14*b*) need correction. The factor $1+R'^2$ in equations (2.14*a*) (in two places) and (2.14*b*) (in two places) should be raised to the power $\frac{1}{2}$. In (2.14*a*) the last term within square brackets should be preceded by a minus sign. It should have been said that

$$r_{xy}^2 = (x_1-y_1)^2+\{R(x_1)-R(y_1)\}^2.$$

Also, the discussion in appendix A regarding the existence of a unique solution to (2.9) is incorrect because, as can easily be verified (Ladyzhenskaya 1963, p. 59), (A 1) has the single eigensolution $\phi_i(\mathbf{y}) = n_i(\mathbf{y})$. Therefore, with U_i given, the surface-stress force f_i can be determined from (2.9) only up to an additive term λn_i, with λ being a constant scalar, which is the surface-stress force that results when $U_i = U_i^{(e)}$, the latter being the single eigensolution of

$$U_i^{(e)}(\mathbf{x})+\frac{3}{4\pi}\iint_{S_p}\frac{(x_i-y_i)(x_j-y_j)(x_k-y_k)\,n_i(\mathbf{y})\,U_k^{(e)}(\mathbf{y})}{r_{xy}^5}\,dS_y = 0.$$

It is a simple matter to show, however, that for particles of a given shape, the addition of a term λn_i to f_i will have no effect on the velocity and pressure fields, as given by (2.6) and (2.7), and hence λ can be set equal to zero without loss of generality.

'Structural development of gas–liquid mixture flows',

by R. A. Herringe and M. R. Davis, *J. Fluid Mech.* vol. 73, 1976, p. 97.

Equations (15) and (20) of this paper should read

$$n_d = \tfrac{1}{4}\pi D^2 n = \rho_5(D)\,dD\,N_d \tag{15}$$

and

$$\rho_6(D) = \frac{N\pi D^3}{6q_g}\rho(D) = \frac{2N_d}{3q_g}D\rho_5(D). \tag{20}$$

'Interaction of free and forced convection in horizontal tubes in the transition regime', *J. Fluid Mech.* vol. 57, 1973, p. 269.

The authorship of this paper should be changed from H. R. Nagendra as the sole author to H. R. Nagendra and M. A. El-Hawary as co-authors. Dr El-Hawary had originally set up the experiment, developed the measuring technique, and obtained and analysed part of the results presented in the paper. Dr Nagendra was appointed to continue the experimental programme after Dr El-Hawary had left the University of British Columbia in Canada, where this work was initiated and completed. At the time the paper was submitted for publication by Dr Nagendra, the full name and address of Dr El-Hawary were unknown to him. Dr El-Hawary is presently an assistant professor at the Faculty of Engineering, Ain-Shams University, Abbasia, Cairo, Egypt.