It is precisely her apparent lack of acquaintance with the irritating inconsistencies of the real products of the early hand-press which makes one wish that the author had stuck to deploying her other incontestable bibliographical arguments concerning the replicative and hence preserving power of print. It is the printing press's ability to produce quickly (once the initial type-setting is complete) multiple copies (not all necessarily or even usually exactly alike, but sufficiently so) to the limits of technical or economic capability which marks it off as a radically different and more efficient mass communications medium from scribal reproduction. Eisenstein's book must put paid to anyone's doubts on this score.

Aspiring Ph.D.s will plunder her pages for research topics, so they need to be warned that Eisenstein's complete dependence on modern literature has produced some considerable distortion in her otherwise comprehensive account of the revolutionary changes effected by the invention of printing from movable types. Fifteen years is none too long a time in which to absorb the suffocating amount of commentary and exegesis which has gathered around the large historical themes with which this book is concerned. It is to be doubted whether quite so much of the resulting synthesis needed to be presented to the reader. These lavishly produced volumes were published at £35 a set, a sufficiently horrid price which has risen, in the interim, to an absurd and indefensible £50. A severely condensed version in paperback, setting out the author's main hypotheses, minus much of the supporting material from secondary literature but retaining the valuable bibliographical index, would be a signal service on the part of the publisher not only to students but also to the author herself.

Eric J. Freeman
Wellcome Institute

ROBERT G. FRANK jr., *Harvey and the Oxford physiologists. A study of scientific ideas*, Berkeley, Los Angeles, and London, University of California Press, 1980, 8vo, pp. xviii, 368, illus., £16.50.

Harvey's discovery of the circulation of the blood (1628) is customarily looked upon as an isolated event in medical history. It is treated as an erratic block which stands out as the Copernican turning-point when the old order was put down and an entirely new dispensation was embarked upon. In reality, the situation was fluid. The truth of the new view and the observational and experimental detail on which the conclusions and finally the discovery were based remained as much alive as the Harveian spirit. However, Harvey, the lifelong thinker vexed by the problem of the purpose of circulation, could hardly have failed to see that he would leave a large legacy of unanswered questions – a programme for research. This notably concerned respiration – the constant need for air, the real necessity of its entry into lungs and heart in view of the non-existence of "vital" or any other "spirit" supposedly generated and "cooled" by it; his explanation of the colour difference between arterial and venous blood in terms of the Aristotelian unity (*henotes*) of all blood as products of a "straining" or optical artefact may have contributed to dissatisfaction just as much as his playing-down of the lymphatics and the role of the thoracic duct.

In 1642, when he had reached his sixty-fourth year, Harvey arrived at Oxford with the king after the Battle of Edgehill, and during his next four years' service he intensely continued research in co-operation with such men as Highmore, Charleton, Willis, Ralph Bathurst, Scarburgh, Greaves, and Merrett – the earlier circle out of which later the brilliant "Scientific Community in Commonwealth and Restoration Oxford" grew. It included a dozen "major" scientists, among them immortals such as Hooke, Lower, Mayow, Willis, and Wren; some forty-six "minor' scientists of whom Hodges, Locke, Merrett, Oldenburg, Scarburgh, and Sharrock are outstanding examples; and about fifty "virtuosi", themselves without scientific merit, but eager participants and followers. A total of 240 medical, scientific, and technical books palpably indicates the productivity of the "community"; its real achievement in laying the groundwork to the modern physiology of respiration was the result of controversies and discussions of secular significance. It is to these individuals that the highly perceptive, clear, and exhaustive work under notice is dedicated – it easily finds its place among the classics in medical and scientific history.

Only a few of the numerous and highly involved controversies can be touched upon here. Though unanimous in upholding and defending blood circulation (where still needed), there was a marked shifting away from Harvey's vitalism towards mechanistic atomism and one of its consequences, namely generation from preformed structures instead of Harveian epigenesis from a homogeneous medium. Highmore, in spite of his close personal relationship with Harvey, was an atomist and preformationist – with the help of the microscope, he believed that he had found evidence against the Harveian primacy of the blood and that he had seen outlines of the heart preceding it. To Boyle, atomism was paramount. although he (unlike coarse mechanists of the Cartesian and Gassendi persuasion) endowed the atoms with differences in quality and hence – a fervent believer – made peace with his god. Indeed it was particles – to wit the "nitro-aerial" brand – which played a decisive role in elucidating the problems of respiration left unsolved by Harvey. Air became a medium in which such particles of vital necessity were suspended, which also explains Boyle's interest in the physical rather than the chemical properties of air. He could show that it was not the narrowing of the air space by accumulating vaporous exhalations which extinguished a candle (and, following that, the life of an animal in the chamber of his exsuction pump), but the consumption of something particulate in the air which altered its "elasticity". However, this was a physical approach to be greatly improved upon by the chemical considerations on air by Robert Hooke – the hero of the story, outstanding by his prophetic genius, his versatility, and creative technical skill. Here Bathurst, one of the early Harveian collaborators at Oxford, preceded with his chemical appreciation of the *pabulum nitrosum* as added to and providing vital energy in the blood, and its reception in the lung rather than its production of "vital spirit" in the heart. This would seem to have facilitated the notion of respiration as gas exchange between blood and air in the lung. Bathurst also recognized aerial nitre as a salt – volatile by contrast with mineral nitre, a fixed salt. It was a "spiritus nitrosus" rather than a substantive constituent – "nitre" – of blood (as believed by Ent who may have inspired him in the first place). Bathurst, incidentally, did away with the elusive cooling function of the air – obviously out of place in "cold" fishes to which air is still indispensable, and in the athlete heating up with his high intake of air. Hooke decidedly stated that saline particles are suspended in air – a menstruum of all sulphurous bodies dissolved by dint of a substance inherent in air like that which is "fixt in Salt-Peter". It is these latter – nitrous-saline – particles which cause combustion.

All this was based on earlier chemical studies of "niter" by Boyle. He had explored "niter" – potassium nitrate – in the light of corpuscular philosophy – atomism – and at the same time connected it with Bathurst's concept of an aerial *pabulum nitrosum*, aerial niter, as the vital principle of venerable Paracelsian tradition. Nitrates – sodium and potassium – are rich in oxygen and powerful oxidizing agents; they were used as such in the laboratory where they provided energy and "heat", just as they did as essential ingredients in gunpowder and fertilizers. Bacon had said that "niter was the life of Vegetables". The issue was obscured by mechanical (versus chemical) theories of respiration. Thus Walter Needham denied in 1667 any entry or influence of air in respiration, the latter merely achieving a thorough mixture and amalgamation (comminution), rendering the blood fit for circulation by virtue of the continuous motion of the lungs. This in its turn provoked the crucial experiment of Hooke and Lower; exercising his superb technical ingenuity, Hooke had preserved life through continual insufflation of a stationary (collapsed) lung. Obviously, then, bare motion of the lungs contributed nothing to life; it was the permanent provision of fresh air which kept the animal alive. The question remained – did fresh air add something to the blood or did it remove something from it? Experimenting on Needham's suggestion, Hooke and King might have seemed to support the former alternative – used-up air was effete. At all events, as Boyle saw it, it provided a further point in rejecting the mechanical and favouring the chemical-particulate view.

The peripateia and indeed much of the climax came with Lower's *De corde* of 1669 – the secular fruit of his collaboration with Hooke. Its basic consideration was the difference between arterial and venous blood which Harvey, the Aristotelian, had played down: perhaps the closed circle which he had established detracted in his view from its importance, nay this neglect may have been the *felix culpa* that promoted his discovery of the very closeness of the blood-course. Nor could the lung claim the same attention which he concentrated on heart and blood. Now the light-focus was reversed: it fell brilliantly on the floridity of arterial by contrast with the darkness of venous blood; it moved away from the heart, traditionaly regarded as the source of animal heat, towards the lung and the air it breathed. Circulating arterial becomes venous blood and the latter can be re-converted into the former by exposure to air. It is this arterialization through air received in the lung (and not in the heart) that is also responsible for animal heat. Arterial blood from a choking animal assumes the properties of venous blood – even after death it can be re-arterialized when drawn through the insufflated lung. Though moving the focus of attention seen as a whole, Lower's work thus completed the dismantling of Galen's system in the Harveian spirit; he finished what Harvey had started – he strengthened the latter's view of the heart as a muscular pump; with Harvey, Lower excluded Cartesian ebullition; and, again with Harvey, made blood the nidus of heat. He found the latter to be irrelevant for arterialization, which he (unlike Harvey) attributed to air actually entering the blood.

But what is the magic substance of vital significance in the air? Here the work of John Mayow (1668–74) brings back from Bathurst's time and newly from Lower the fine nitrous particles with which the air abounds – joining blood-sulphur, they are responsible for "fermentation" and subsequent incalescence of blood. It was the same combination which, in Willis's view, fed the "flamy" soul of brutes (1672). To Mayow, flame was the nitro-aerial spirit set into motion which had also to lend the driving force in meteorological phenomena as the transmitter of impulses of light. What Mayow really achieved was the transference of the nitro-aerial particles from physico-chemical theory into physiology. Boyle was only interested in elasticity-changes of the air, to which the replacement of one "air" by another ("vitiated air") may not have made any difference. Mayow "brought forward several experiments in which a decrease in volume and hence a loss in elasticity was demonstrable" (p. 265): a bladder forming the base of a bell-jar would be sucked into it, because the air inside the jar depleted in volume and elasticity could no longer resist the elasticity of the air outside. He also quantified the loss by measuring the rise of water caused by a flame or a breathing animal inside the jar – he found the reduction in volume by the breathing of animals to be about one-fourteenth. Since the animal survived the flame in the jar considerably, Boyle, Hooke, and others were not ready to identify respiration with combustion. Against this, to Mayow it simply indicated a differential need for nitro-aerial particles greater in the flame (one-thirtieth) than in the animal – which is not far from the figures valid today and, of course, basically correct. Whereas Boyle was not so sure, Hooke remained influenced by Mayow's nitro-aerial particles – "nitrousness of air" had to explain fire, motions, fermentation, hot springs, the slaking of quick-lime, the volatile salt in blood. Mayow further devised an experiment to show that it was through fermentation (with "exaltation") that a fluid like blood could separate the nitro-aerial particles and hence the elasticity from the air – leaving a non-respirable rest. He had still to prove that the blood removes something from the air in the lungs in order to turn arterial and that this is not due to something being extracted from the blood. For Lower had merely established that the colour-change of arterial blood takes place in the lungs and requires fresh air. Mayow did so, showing that only arterial blood would expand, rise, and give off a visible exhalation in a vacuum. His particles then helped him to solve Harvey's problem as to how the foetus "breathed" – simply by visualizing a transport of nitro-aerial particles from the mother to the embryo by the umbilical vessels. It was thus a synthesis "peculiarly his own" of "many of the diverse threads of thought that had run through the work of the Oxford community since the 1640s" (p. 272) that had led Mayow from anatomy and physiology to a chemical view – in this combustion and respiration through absorption of nitro-aerial particles found their common head in fermentation. Of the Oxonians, Mayow felt largely indebted to Boyle and Lower (as also, to a lesser degree, to Hooke and Millington), but his admiration for Willis (as expressed in his first *tractatus* of 1668) had markedly given place to criticism in the *tractatus quinque* of 1674. By that time Willis had declared against fermentation as source of heat and favoured a "flame" as the vector of vitality in the blood, an old-fashioned belief.

The nitro-aerial particles, however, soon lost much of their appeal – Boyle showed himself sceptical about their exclusive rights; nitre, he said, finally may be one of many kinds of saline particles in the air. Hooke seemed to be old-fashioned when, at the end of 1682, he recalled the experiments of keeping dogs alive by blowing into their lungs, not through maintaining circulation, but by supplying nitrous particles. By that time the protagonists had died and this should have been the reason for the decline of interest. On the whole, however, the secular progress which had been the work of the post-Harveian Oxford group and their successors in other places, as collected and epitomized by Oldenburg for the Royal Society, could not fail in providing explanation in place of description and thus helping to complete Harvey. Heat innate to Galen had now become firing energy generated in connexion with respiration of air that was no longer "cooling", but changed the colour of blood, arterializing it.

It was concerted teamwork extended over some forty years of political upheaval – perhaps it was *utilitas ex adversis capienda* that brought Harvey to Oxford after the revolutionary mob had sacked his house with his collections and manuscripts. With Boyle and Locke, Lower concentrated on arterial blood-colour, which had not worried Harvey. Nor could Harvey, the Aristotelian vitalist, have spared much sympathy with atomism and corpuscular concepts (including preformationism) which became the order of the day through the chemical approach of Boyle, Highmore, Petty, Willis, and Bathurst. The air pump, however, turned Boyle's interests to the physical rather than the chemical properties of air, by contrast with Hooke's interest in the latter. Lower joined Hooke in rejecting and disproving Needham's mechanical theory of respiration by building up the technique of insufflation and transfusion. Hooke again connected aerial nitre with combustion, Willis with blood-fermentation, combustion, and heat-generation to reach the final synthesis of all these views in Mayow.

How these grand results were achieved through mutual influence and inspiration, following as it were logically one from the other in teamwork, is exposed in the book under notice with a felicitous clarity, historical *acribeia*, and completeness – all based on first-hand, mostly manuscript sources – that has no equal in the extant literature of the subject. (A forerunner which should be studied in conjunction with the book is the author's brilliant contribution to J. J. Bylebyl's *William Harvey and his age* on 'The image of Harvey in Commonwealth and Restoration England' (Baltimore and London, 1979, pp. 103–143) with its eloquent diagram of the ramification of Harvey's known scientific association and probable scientific relationship in Cambridge and Oxford (p. 108).) The present book is elegantly produced and well illustrated. The Paracelsian tradition of nitre and its connexion with air and vital combustion has been accorded its due in the pre-history of the nitro-aerial particles. The reviewer believes that a complementary study of Helmont (1579–1644) in depth would be even more rewarding; he is mentioned briefly in this book as one of the literary sources adduced by Bathurst supporting acid as the gastric digestive agent (p. 108). More significantly, Bathurst referred to a Helmontian experiment in connexion with the separation of dross from the blood in the lung (p. 109). Marginally, Helmont also occurs in the discussion of Boyle's chemistry (p. 141), and Locke and Willis on fermentation (pp. 166, 187). His collected works appeared in 1648 containing under *Blas humanum* a most progressive reform of the traditional views on pulse including the role of air for life. He emphatically rejected its supposed cooling action with the same arguments as those used later by Bathurst. It was also Helmont who developed gas-exchange as the true function of respiration: used-up venous blood – its residue – is converted into a "volatile salt" which is "blown away" by the air breathed in. That it can be so converted is due to a *magnale* – a celestial "conjugal associate" – a "ferment" – of air filling its pores and spaces; it is thus not the whole substance, but this content of air which is breathed and maintains life. In this Helmont is basically assisted by his discovery of *Gas* as object-specific exhalations different from such common,– non-specific – *volatilia* as air and water-vapour (see W. Pagel, *William Harvey's biological ideas*, Basle and New York, 1967, pp. 79, 194). From the account of Bathurst in the present book, Helmont's view of respiration should well have been significant. Helmont's concern with the colour-change and "thinning-out" – the salty-sulphurous nature – of arterial blood by virtue of pulse and air and the absence of any heat-focus and ebullition in the heart, are also topical. Already in 1647, Hermann Conring had ridiculed Kepler's idea of a fiery light-focus in the heart and reduced the Galenic heart-fire to "something mobile *like* fire" (*mobile igni simile*, in: *De calido innato signe animali*, Helmstadt, 1647, cap. XII, p. 120, XV, p. 149, ignem vitalem non lucere, p. 154: Kepleriana indigna sunt, quae confutes, rhetori inania declamanti). A major point of interest on the Helmontian side is the emphasis laid in the present book on Boyle's preoccupation with the physical rather than the chemical properties of air – the "spring of the air", its "elater" or elasticity leading to his famous "law". *Gas* – Helmont's "spirit so far unknown and called by a new name" (*Complexionum atque mistion elemental figment.*, 14) was neglected, if considered at all, or played down as one of various forms of "factitious air", for example by Boyle and by Glisson in his late work *On the stomach and gut* (1677). It remained to another century to rediscover it and give Helmont his due. It cannot be denied, however, that he was critical against Paracelsus' making even life as a whole dependent upon saltpetre which so much intrigued the Oxford group ("salem e nobis fluidum et intus presentem merum salpetri cagastrum vocat. Adeoque nedum carnes et cruorem sed et totum corpus cum vita esse salpetra et cagastrica persuadere conatur", in: *Tria prima Chymicorum*, 31). Helmont's *Gas* and *gases* thus shared oblivion and resurgence with the nitro-aerial particles and other concepts of Harvey's immediate successors waiting for iatro-mechanics and phlogiston to wane.

Finally, here we have a book which has added a new page and dimension to the history of physiology and indeed to the history of medicine, however little the momentous discoveries of the period influenced the medical practice of their day. Without them there would be no modern medicine and without the work under notice no way to understand its development in depth.

Walter Pagel

JOHN D. SPILLANE, *The doctrine of the nerves. Chapters in the history of neurology*, Oxford University Press, 1981, 4to, pp. xii, 467, illus., £25.00.

Dr. Spillane is a distinguished neurologist who has contributed importantly during the last few decades to the progress of clinical neurology. In his retirement he now turns to its history, aware of his possible shortcomings as a historian, but with com-

https://doi.org/10.1017/S0025727300034931 Published online by Cambridge University Press