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J. J. LISTER AND THE ESTABLISHMENT OF HISTOLOGY

by

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AMONG THE 1200 microscopes in the Wellcome Institute for the History of Medicine, one stands out for its special importance in the history of microscopy and medicine. This is number 234/1949, which was made in 1826 by James Smith¹ to the design of Joseph Jackson Lister (1786–1869), father of the famous Lord Lister. The instrument was presented to the Museum by the Misses Lister, and its provenance is assured.

J. J. Lister was a wine merchant who devoted his leisure hours to the improvement of the microscope. Before his work bore fruit, the poor performance of the instrument at high magnifications had two unfortunate results. Sometimes it was distrusted and not used for serious research even in those areas such as histology where it was obviously desirable, and sometimes it was used and its spurious results were accepted as correct. In the first category is Marie-François-Xavier Bichat (1771–1802), who was instrumental in establishing what we now call histology as the basis of pathological processes, in place of gross anatomical changes which previously had been the basis of pathology.² However, he distrusted the microscope and never used it, preferring simple dissection and chemical tests. As an example of the second category there is Henri Milne-Edwards (1800–1885) whose 1823 paper on the structure of tissues³ described them all, regardless of origin, as being made up of globules about 1/300mm in diameter. Although he himself modified these conclusions shortly afterwards,⁴ this classic paper reports results which we now know to be due entirely to inadequate lenses on his microscope.

Three main inadequacies are present in uncorrected lenses. These are chromatic and spherical aberrations, and coma. The first causes colour fringes round details of

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¹ Some account of this well-known instrument-maker is given in G. L'E. Turner, 'Hugh Powell, James Smith, and Andrew Ross: makers of microscopes', in J. North (editor), *Mid-nineteenth-century scientists*, Oxford, Pergamon Press, 1969, see pp. 104–138.

² Xav. Bichat, *Anatomie générale, appliquée à la physiologie et à la médecine*, 4 vols., Paris, Brosson Gabon, 1801, see vol. 4, p. 439.

³ H. Milne-Edwards, 'Mémoire sur la structure élémentaire des principaux tissus organiques des animaux', *Archs. gén. Méd.*, 1823, 3: 165–184.

⁴ J. V. Pickstone, 'Globules and coagula: concepts of tissue formation in the early nineteenth century', *J. Hist. Med.*, 1973, 23: 336–356.

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the image, and had been overcome for the telescope by 1760, but the smaller lenses of the microscope had proved much more difficult to correct. François Beeldsnijder (1755–1808) used a flint-glass negative lens sandwiched between two crown-glass positive lenses, about 1791,⁵ to produce an objective of 21mm focal length capable of resolving 1/100mm without colour fringes. Other prominent workers of the time also managed to make, in the trial-and-error manner then usual, more or less satisfactory objectives corrected for chromatic aberration. This did not solve the more serious problem of spherical aberration: this arises from the fact that a lens brings axial rays to a different focus from marginal ones, and causes poor image quality especially as it is associated with coma, where what should be a small circle in the image occurs as a smear of light resembling a comet. The diagram illustrates the optical basis of such defects. Even as late as 1824, Fresnel showed that the newest achromatic lenses were no better than the older kinds at magnifications over x200,⁶ a serious assessment for those interested in histological detail.

It is to J. J. Lister that we owe our escape from this situation. He discovered that an achromatic lens has two aplanatic foci, that is, that in one position each side of such a lens there is a focus where spherical errors are minimal. He also found that if a second lens is arranged at the aplanatic focus of the first, higher magnifications are obtained still without spherical or chromatic defects, coma also being effectively removed. In this way a train of compound lenses could be made to achieve high magnification with good definition. His results were summarized before the Royal Society in 1830,⁷ but before that time he was using such objectives for original work.

It was obvious to him that the stand (the mechanical parts of the microscope) would have to be made more rigid if the better performance of his improved lenses was to be usable: high magnifications magnify vibration as well as the specimen. The microscope referred to is shown in plate I, and it is obvious that much effort was expended in securing rigidity: not only is the stand inherently stable, but the nosepiece fine adjustment works smoothly and slowly as required for high-power use. The instrument is still usable today, but however good the stand the real interest lies in the objective, and this has been investigated in some detail.

In the study of the history of the microscope much attention has been given to the stand, but relatively little to the optical components,⁸ and scarcely any to specimen preparation. Naturally, these two latter aspects of microscopy are at least as important as knowledge of the mechanical parts: for the present account some detailed work

⁵ P. H. Van Cittert, *Descriptive catalogue of the collection of microscopes in charge of the Utrecht University Museum*, Groningen, Noordhof, 1934.

⁶ A. J. Fresnel, 'Rapport sur le microscope achromatique de M. Selligue', *Annls. Sci. nat.*, 1824, 3: 345.

⁷ J. J. Lister, 'On some properties in achromatic object-glasses applicable to the improvement of the microscope', *Phil. Trans. R. Soc. Lond.*, 1830, 130: 187–200.

⁸ In addition to the work published by Van Cittert (op. cit., note 5 above), the optical performance of the microscope has been little discussed. The following, however, are useful:

S. Bradbury, 'The quality of the image produced by the compound microscope: 1700–1840', *Proc. R. Mic. Soc.*, 1966, 2: 151–173.

G.L'E. Turner, 'The microscope as a technical frontier in science', *ibid.*, 1966, 2: 175–199.

A useful account of various aspects of microscopic optics has been gathered together in E. Frison, *L'évolution de la partie optique du microscope au cours du dix-neuvième siècle*, Leiden, Rijksmuseum voor de Geschiedenis der Natuurwetenschappen, 1954.

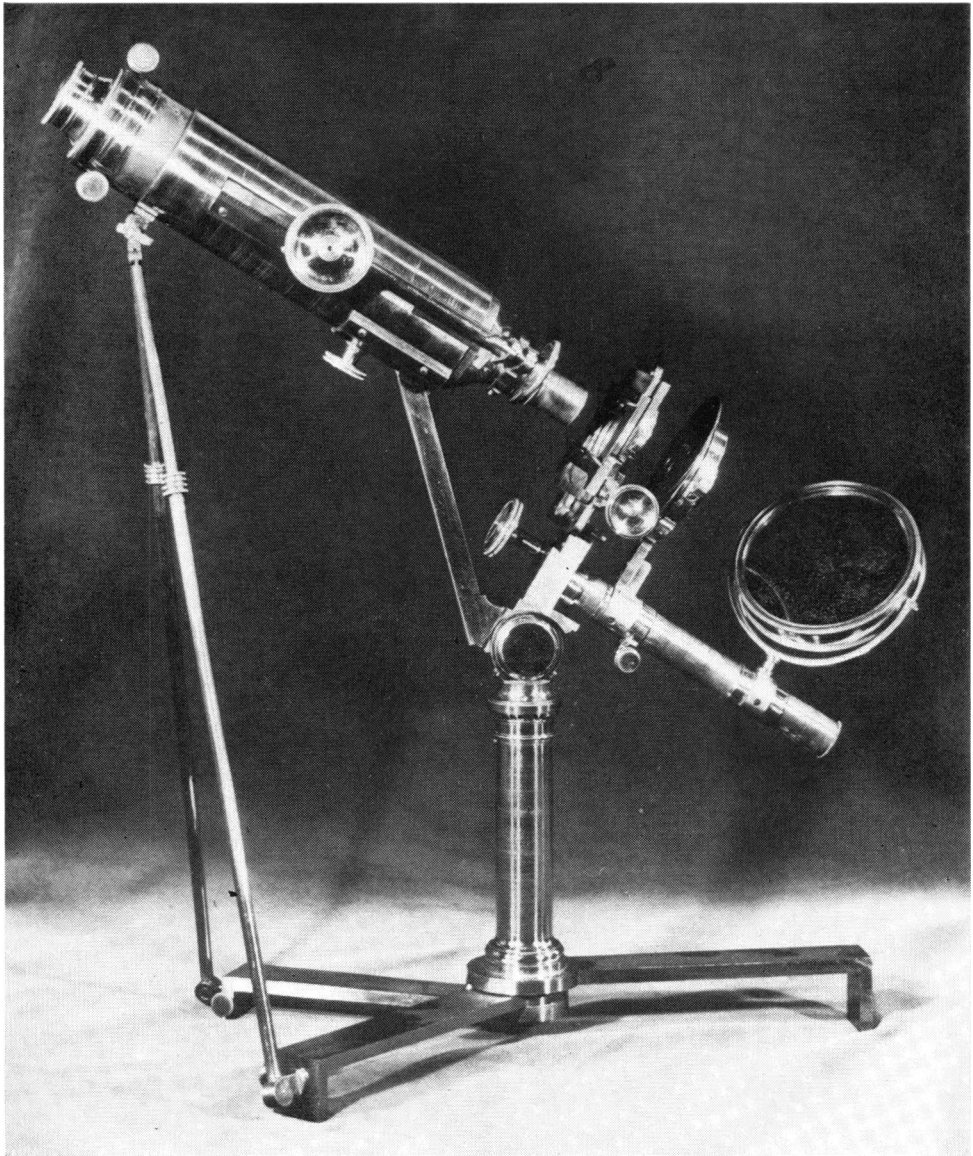


Plate I: J J Lister's microscope, made by Smith in 1826.

The general design of the stand, 234/1949 in the Wellcome collection, is seen in this plate. The body tube measures 278mm in length when fully closed, and can be extended by two pulls held by the two pinch screws. The eyepiece is of the normal Huygenian type. Coarse focusing is by the rack and pinion seen at the side of the body tube, and fine focusing by the micrometer screw fixed to the nose-piece. Movements are fitted to the stage, and a diaphragm-circle is fitted below, above the large-diameter mirror. The telescopic struts secure increased rigidity for high-power observations, and the whole folds into a mahogany case. The instrument is still usable, with smooth operation of all fittings attesting to the fine workmanship and good quality of the brasswork.

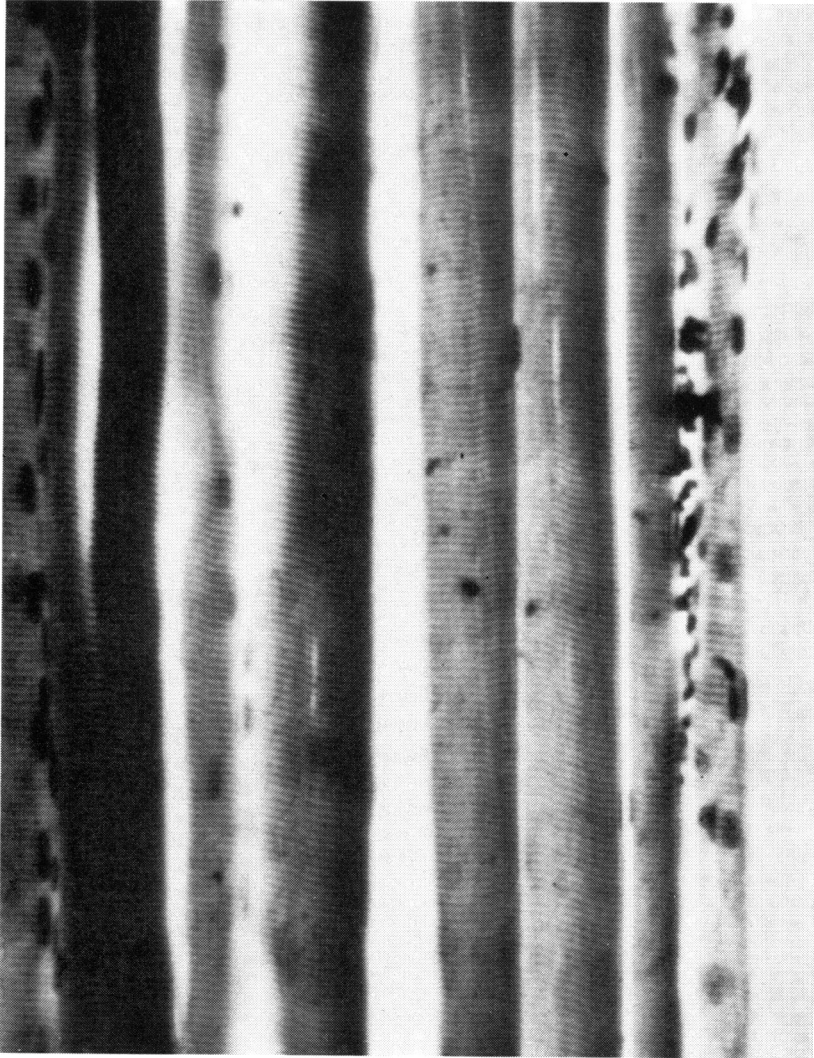


Plate II: photomicrograph of striped muscle, made with the instrument.

A good-quality longitudinally sectioned striated muscle preparation was photographed with the microscope, and is printed here at a magnification of x450. The quality is good in spite of the magnification being higher than theory would dictate. It should be stressed that this is not what Hodgkin and Lister would have seen when writing their 1827 paper, for their specimens would have been unstained and would have offered much less contrast. Nonetheless, even with this low power objective, the striations would have shown, and it would have been obvious that a fibrous and not a globular structure was present.

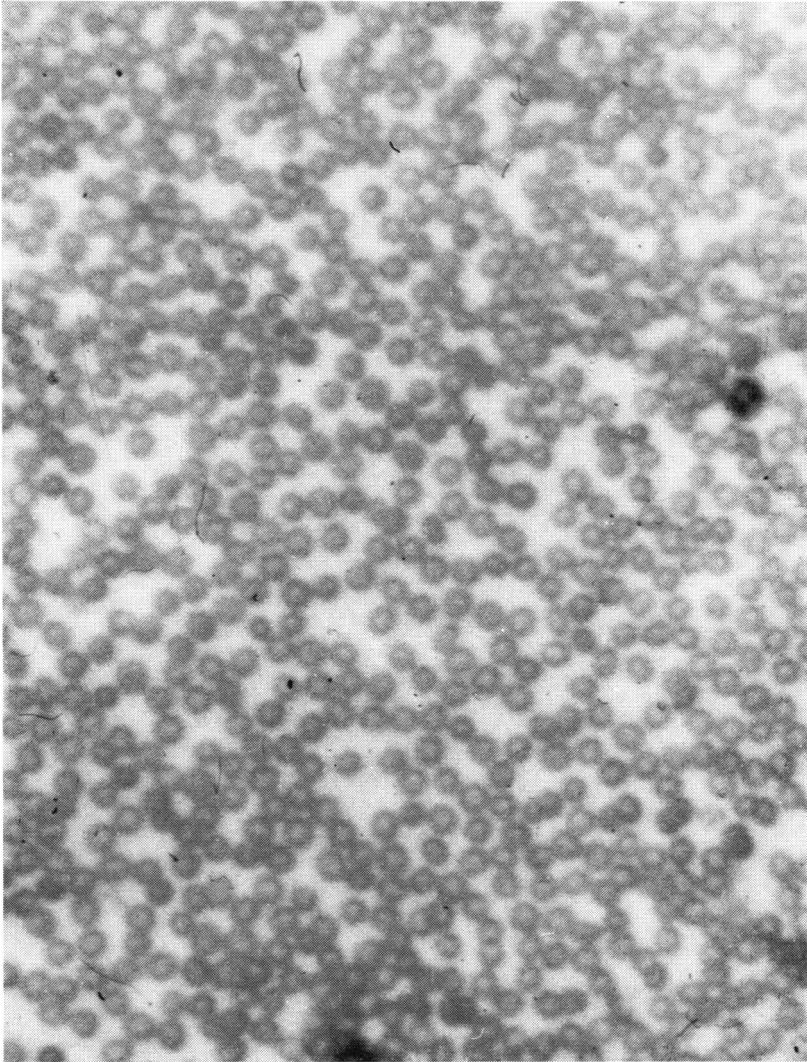


Plate III: photomicrograph of blood film, made with the instrument. Again, this modern, human blood film is stained, and exhibits greater contrast than any smear Hodgkin and Lister would have investigated. Nonetheless, at its printed magnification of x450 good detail of the red cells is seen, showing that their statement that no central nucleus was present was based on good observation.

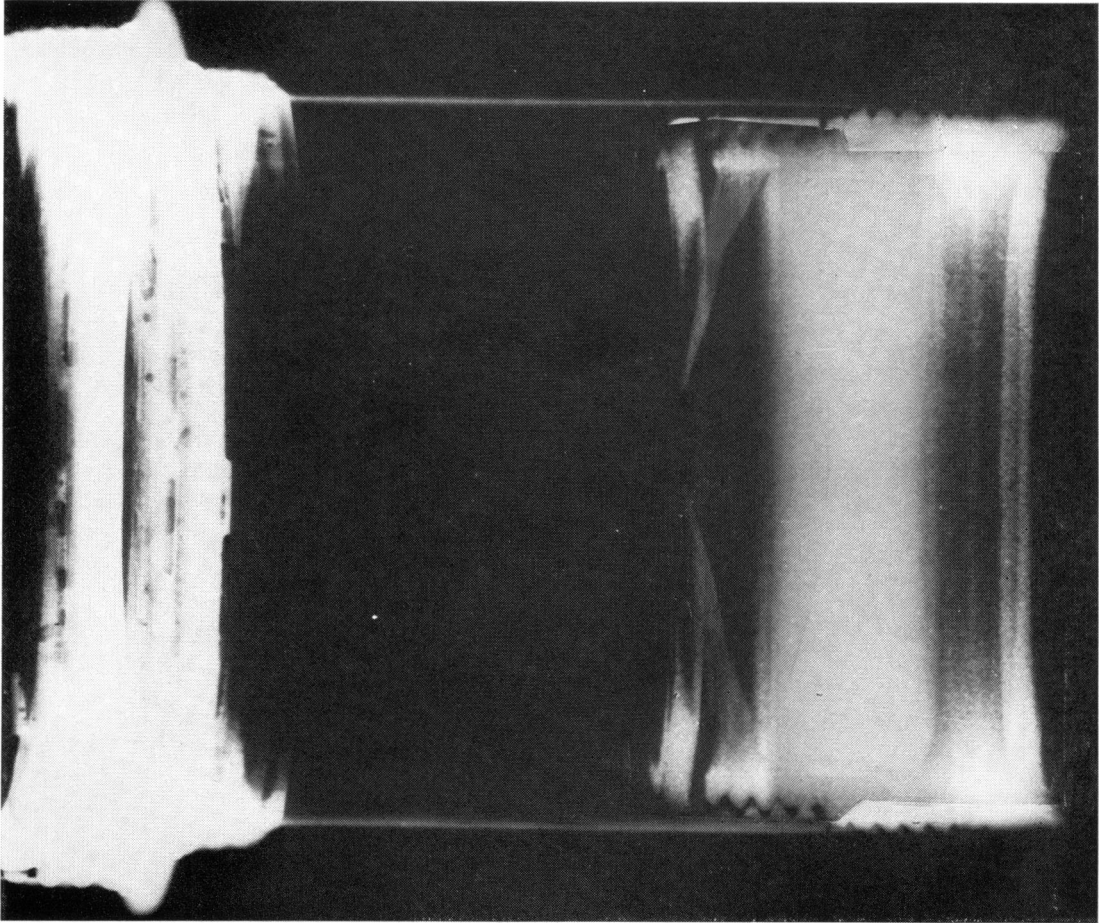


Plate IV : composite radiograph of the objective.

The tube carrying the interchangeable diaphragm was removed to allow greater clarity in the pictures. One radiograph was made by contact, showing the lenses. A further radiograph was made by a high-definition microfocussing machine, giving a much enlarged image of the metal parts. The two were printed separately and a composite print made to show both glass and metal clearly. The overall length of the objective is 27mm, and width is 18mm. The cell carrying the lenses is 10.5mm long, and is screwed into the barrel to tighten the loose lenses. The front component is greenish in hue, and the faces of the outer crown-glass components which touch the flint-glass component have a greater curvature than the outermost faces. The whole objective is well made, and stands comparison with others made fifty years later.

The author is much indebted to Mr. D. J. Thomson for making the radiographs.

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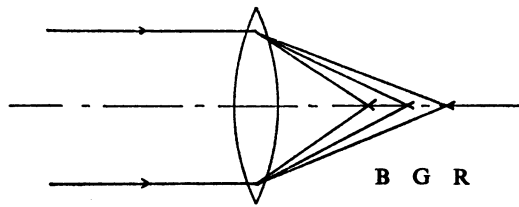


Figure 1. A simple lens brings rays of white light to foci of different colours, blue being refracted most and red least. This defect causes imprecise images, with colour fringes round the edges of the objects.

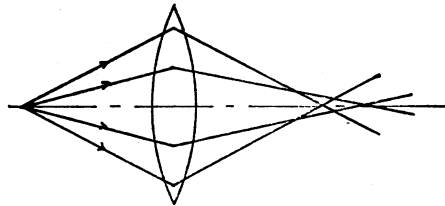


Figure 2. A simple lens brings rays, even of one colour only, to different foci: rays passing nearer the middle of the lens are focused farther away. This causes generally poor definition. An associated defect is coma: instead of a spot of light appearing circular, it focuses as a comet-like smear.

These aberrations together degrade the quality of the image severely, and the more powerful the lens the worse the defects become. To overcome the poor quality, early lens-makers put a small aperture behind the objective, thus cutting out most of the marginal rays. This does reduce the defects, but only at the expense of reducing the amount of light transmitted, and of reducing the possible resolving power (which we now know depends on a lens gathering as wide an angle of light as possible). Thus such workers as the globulists were actually seeing diffraction effects, and not the real structure.

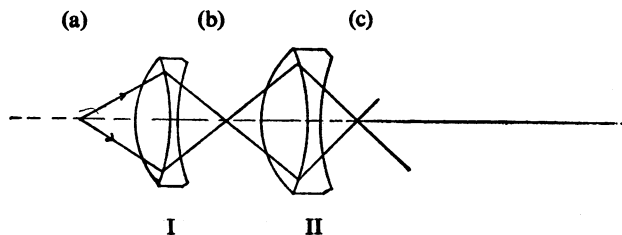


Figure 3. Here we see a compound lens, made up of two doublets. Each doublet consists of a positive lens of crown glass cemented to a negative lens of flint glass: this arrangement corrects chromatic (but not spherical) aberration. However, if an object as placed at (a), the so-called aplanatic focus of lens I, an image formed at (b), the second aplanatic focus of lens I, will be free from spherical aberration and coma. If lens II is also arranged to have its front aplanatic focus at (b), it will in turn form an image at (c) which is still free from errors, and more highly magnified. This was J. J. Lister's important discovery, which opened the way to the profitable use of high magnifications with the microscope.

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on other microscopes in the Wellcome Institute and elsewhere has established comparative parameters for the performance of objectives.⁹ The instrument has been used with tissues prepared by the crude methods of the 1820s—generally, unfixed fresh material simply teased and/or squashed to be thin enough to see through, and viewed either uncovered or with a mica slip.¹⁰ Plate II shows a photomicrograph made with the instrument, of a modern good-quality stained preparation of striated muscle, and plate III shows a similarly-made picture of a modern blood film. Both are remarkably good in quality for the magnifications employed.

Plate IV shows a composite X-ray picture of the objective, and it is at once apparent that this cannot be an aplanatic objective according to the Lister specification, as there is only one group of lenses present; these are arranged in exactly the same way as those of Beeldsnijder referred to above. The components are not cemented, but are in air contact. Visually, the front component is greenish in colour, and the X-ray shows that the central flint lens is very dense. The group is carried in a barrel screwed to the front of the objective tube, and immediately behind the rear component is the diaphragm, of diameter 8mm. It is most interesting to note that this diaphragm is not fixed, but is carried in the end of a demountable tube, allowing insertion of a variety of diameters. This has been done, in 1mm steps from the maximum of 10mm: the stop found *in situ* was the widest which could be used without degrading the image quality. The screw thread seems to be peculiar to the instrument.

The focal length of the objective was measured, and is 19mm (=3/4"). An Abbe apertometer was used to measure the numerical aperture, which is 0.16. More important, an Abbe test plate was used to assess chromatic and spherical aberrations, and the almost complete absence of such defects is most striking: the objective is as good as any modern 2/3rds achromatic objective. It will be obvious, however, that in spite of this quality, Lister would not have needed to design an especially rigid stand to accommodate such a low-power lens. We must assume that a higher power objective, made on the aplanatic principle, was originally included with the instrument, but is now lost. The fine mahogany case certainly has space for two other objectives.

However, for the medical historian, the use to which this instrument was soon put is of great interest. A young man, Dr. Thomas Hodgkin (1798–1866), the physician of Guy's Hospital whose name was to be perpetuated in "Hodgkin's disease", collaborated with Lister in a famous paper.¹¹ This described for the first time the true microscopic structure of a range of tissues. The difference in the results described by Milne-Edwards in 1823 and by Hodgkin and Lister in 1827 is enormous, and in common with Hughes¹² we must assert ". . . With this paper animal histology may be said properly to begin."

From Lister's work, and this microscope, two important consequences flowed. First was the eventual production of good microscopes in commercial quantities, in England and abroad, so that by 1840 a range of instruments suitable for serious

⁹ B. Bracegirdle, 'The optical performance of seventeenth and eighteenth century microscopes', *Hist. Med.* [in press].

¹⁰ B. Bracegirdle—unpublished work.

¹¹ T. Hodgkin and J. J. Lister, 'Notice of some microscopic observations of the blood and animal tissues', *Phil. Mag.*, 1827, ns2: 130–138.

¹² A. Hughes, 'A history of cytology', London, Abelard-Schuman, 1959, see p. 8.

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work was easily available. The second was that the instrument was applied, especially in Germany, to establishing the nature of normal and pathological tissues. This revolutionized medicine by the 1850s. J. J. Lister's microscope was the fuse which brought about an explosion of work on the nature of tissues, and paved the way for the later elucidation of the role of bacteria as agents of disease.

SUMMARY

This paper is the first of a series describing objects from the Museum of the Wellcome Institute for the History of Medicine. The microscope of J. J. Lister which marked a breakthrough in optical performance is examined in the context of the contribution made to the establishment of histology as an important medical discipline.