

From the McArthur to the Millennium Health Microscope (MHM): future developments in microscope miniaturisation for international health

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The ambition to produce a functional miniature microscope suitable for tropical disease diagnostics in developing countries has exercised the ingenuity of many talented designers over the last 75 years. In the early 1930's the late Dr John McArthur produced the first prototype of his pioneering folded optic design and this portable gem measured a mere 102 x 63 x 51 mm, yet was able to deliver everything which would be expected from a conventional bench microscope of similar optical specification (see Figure 1).



Fig.1. Microscope innovations:
(a) McArthur (b) Readiview (c) Trekker (d) Millennium Health Microscope

To achieve this high degree of miniaturisation McArthur employed a folded optical prismatic system: light entered from above the microscope via a mirror and then passed through a small condenser to the specimen, a revolutionary concept at that time. The objectives were arranged below the specimen and the image was reflected by two prisms to the eyepiece. A comprehensive range of interchangeable objectives was offered including 4:1 and a 100:1 oil immersion.

McArthur's vision, predicated on the widespread use of his ultra-portable microscopes for the diagnosis of tropical diseases in peripheral health centres [see Box 1]. Further to his metal models a later one, produced in moulded plastic by the Open University (OU), took the design even further forward suggesting that future low-cost microscopes would inevitably utilise plastic fabrication technology. During his life, McArthur received many awards, including the Duke of Edinburgh's Prize for innovative design in the 1980s for the OU model, but was perhaps never given full recognition for his pioneering work on microscope design, nor for his studies of malaria and mosquitoes in East Asia.

Despite good intentions, McArthur's vision of revolutionising the way microscopy is used in tropical diseases was sadly never realised. Even with the cheaper OU model the manufacturing costs of the instrument was still out of reach of the comparatively meagre financial budgets of Ministries of Health and without an appropriate technology transfer/implementation model between north-south country partnerships, all initiatives ultimately stalled. Although an eminently practical solution in microscope technology, the McArthur microscope was largely unaffordable for this health market. Sadly the production of the McArthur microscope ceased following his death

in 1996 and the international health scene lost a longstanding advocate and strong voice for practical field microscopy.

Inspired by McArthur's work a small group of Cambridge designers including Keith Dunning and Richard Dickinson (former Head of Design for Sinclair, UK) launched a new folded-optic microscope in 1990, subsequently licensed to Meade Instruments USA and marketed as the *Readiview* (see Figure 1B). Like the McArthur, the *Readiview* is extremely compact and measures 105 mm in diameter x 25 mm in height, yet offers full functionality with magnifications of 80x and 160x. Three dimensional optical folding enables the microscope top to form a generously sized stage and the articulated lighting arm provides bright field, dark ground and reflected illumination dependent on position. Unlike the McArthur the

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Readiview is capable of viewing opaque specimens in addition to conventional microscope slides and has become popular amongst amateur and professional biologists alike. In 2004 a companion microscope, the *Trekker*, was launched for those requiring a low power (35x) version for fieldwork in forensics, botany, zoology, entomology and paleontology (see Figure 1C). Together with its low cost, ergonomics and supreme ease of use the *Trekker* has also become popular as an introduction to microscopy for younger people. Full technical descriptions of the *Readiview/Trekker* concept can be found at www.looksmall.com.

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With the better affordability of the *Readiview*, at approximately 100 USD (a tenth of the price of a suitable conventional compound) it was perhaps time to revisit McArthur's original vision as there still is a pressing need for microscopic diagnosis of tropical diseases. In reality with the continual attrition of facilities within rural health clinics in Africa, the demand is ever growing for lower cost, more sustainable equipment. Having visited many rural clinics in Africa, the availability of compound microscopes, especially amongst field-based roving health teams, is a major logistic bottleneck. Whilst improved technology and low-cost instruments provide some of the necessary ingredients for a working recipe, other factors are also needed such as better technology transfer/implementation models which would overcome the many socio-economic obstacles. Undoubtedly, an affordable, durable and effective microscope creates a way forward for infrastructure improvement - but after innovation first comes validation.

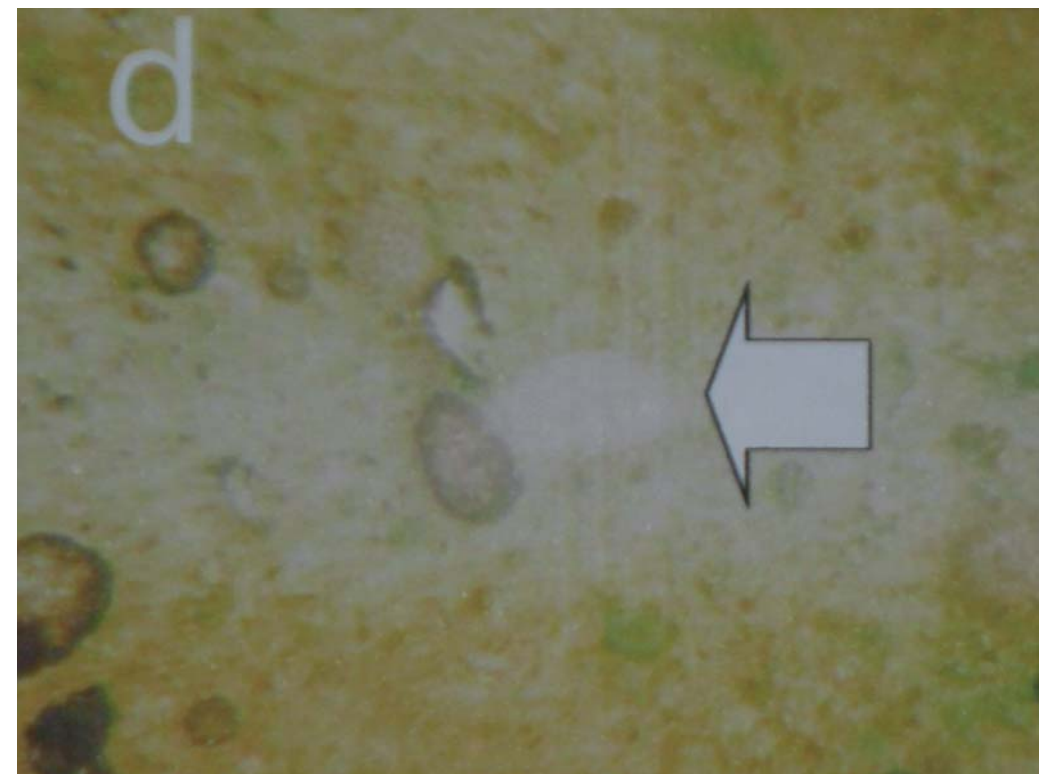
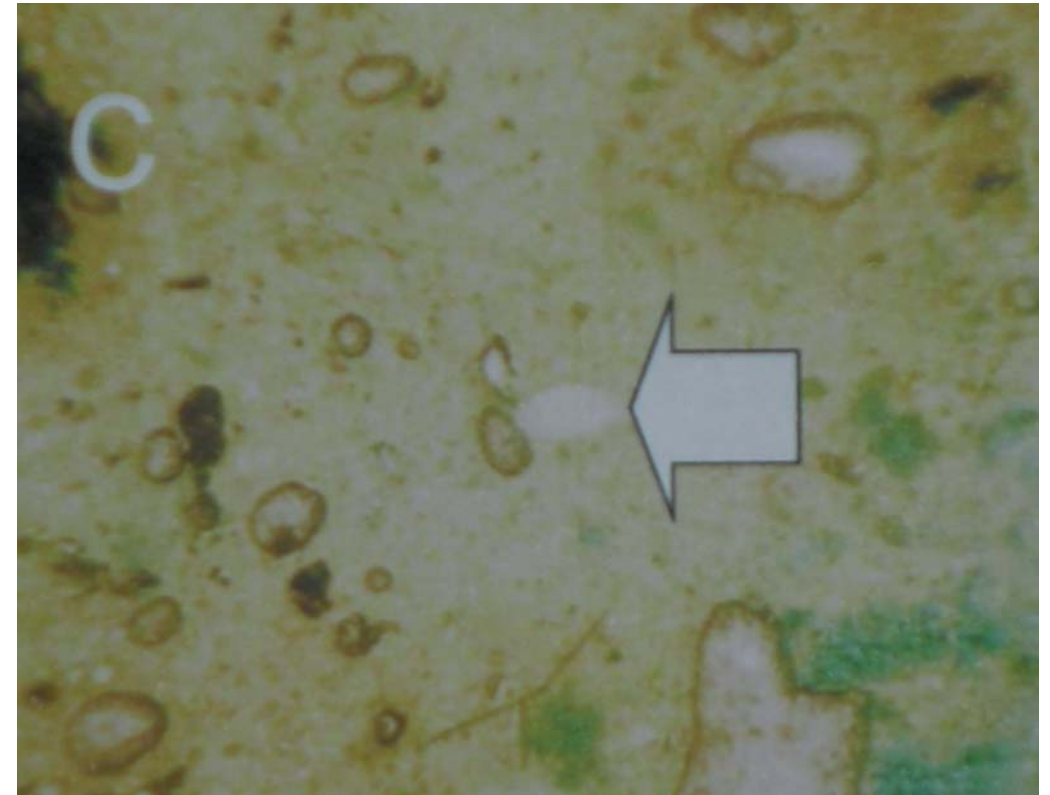
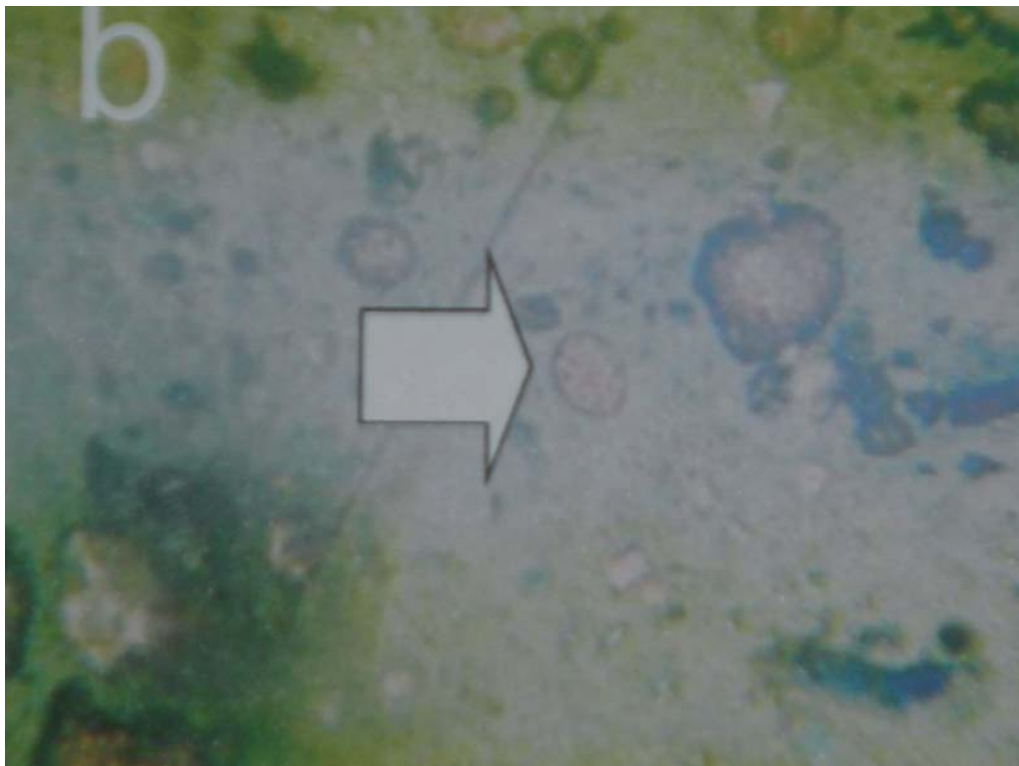
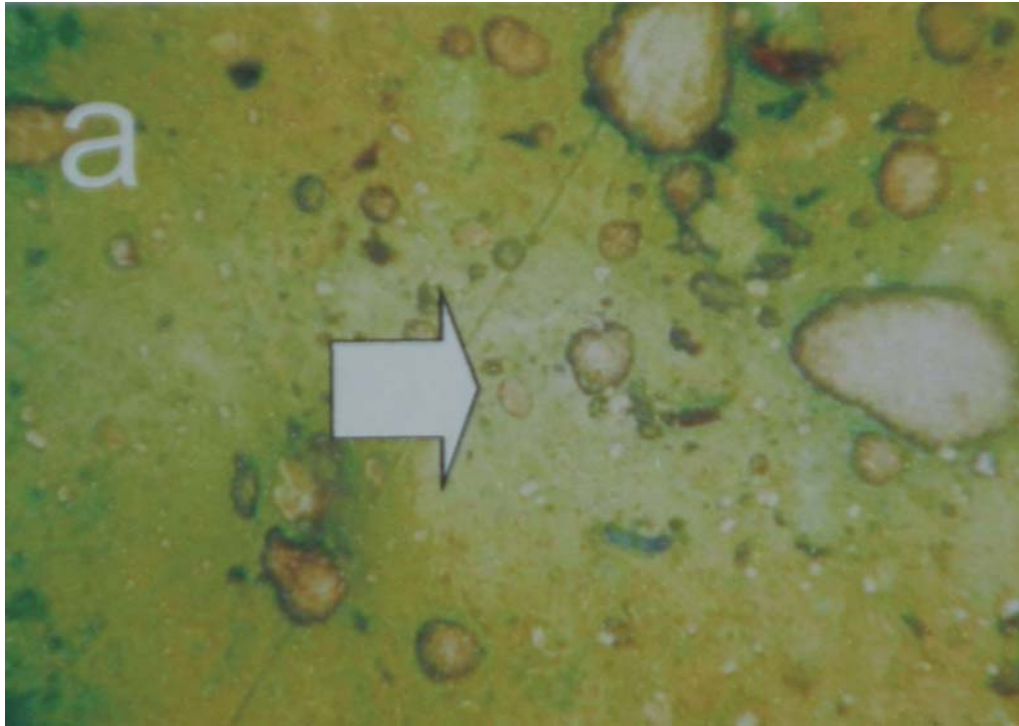
Field tests of the efficacy of the *Readiview* for visualisation of helminth eggs (see Figure 2) have been very good and quite satisfactory for routine diagnosis (see *American Journal of Tropical Medicine and Hygiene* 73, 949-955). This in itself is very important as control of helminthiasis in school-age children relies upon diagnosis in a subset of children within a selection of schools; if the disease is shown to be a problem at each site then all children, and sometimes the surrounding adult community, is offered medications *en masse*. Although the existing model is satisfactory for visualisation of borne helminths e.g. microfilariae of lymphatic filariasis, for protists, however, the optical

magnification range of the *Readiview* needs further improvement to place it on a par with the higher powered McArthur.

In the process this technological improvement would then allow visualisation of blood borne protists and with this in mind, the *Millennium Health Microscope* (MHM) was conceived. Being a significant upgrade to the *Readiview* instrument its low-cost design could nevertheless be fabricated inexpensively in the Far East. This low cost of production, together with the proven manufacturing techniques already developed for *Readiview* and *Trekker* production, could be the production breakthrough.

Subject to the availability of seed grant funding to finance R&D, tooling and clinical trials the MHM could be available within the next two years at no more than 75 USD. The MHM will offer a range of interchangeable objectives (10:1, 40:1 and 100:1 oil immersion) integrated lighting, an indexing stage and interchangeable RMS eyepieces. It is hoped that the availability of this instrument will encourage health organisations to purchase and donate the MHM to developing countries in a cost:donation model, perhaps alongside the major pharmaceutical suppliers, who might be inspired to distribute these inexpensive microscopes as part of a corporate care culture in deserving countries. Proposals for funding the MHM are presently being written and we would greatly appreciate any advice from readers of *infocus Magazine* to help in realisation of John McArthur's enduring vision.

Fig.2. Helminth eggs in a faecal smear. Hookworm egg (arrowed) at: (a) 80x and (b) 160x, is approximately 60 microns in length. Schistosome egg (arrowed) at: (a) 80x and (b) 160x, is approximately 150 microns in length. All images of a Kato-Katz thick faecal smear were taken with a Readiview using a T-mount adaptor for a manual Olympus OM1 with ASA 200 film.



Box 1: A short primer on diagnosis of tropical diseases

Contrasting with infectious diseases in First World countries from either viral and/or bacterial agents, diseases in the tropics are largely resultant from a totally different group of agents, the protists (single celled animals) and helminths (worms). While there are many viral and bacterial diseases which sometimes overlap between regions and populations of the world e.g. HIV, the disease burden of infectious and parasitic diseases in the tropics is really alarming. More importantly, they continue to be a scourge of socio-economic development, keeping many populations entrenched in grinding poverty through prolonged illness.

For protists, the greatest culprit is malaria being present within 140 countries, placing some 3.2 billion people at risk (see www.who.int/topics/malaria/en/), while for helminths, 650 million people are at risk of schistosomiasis (see www.who.int/topics/schistosomiasis/en/). Collectively both diseases reap greatest havoc in continental Africa where in addition to these, several others are also worthy of mention: protists – trypanosomiasis, leishmaniasis and babesiosis; helminths – lymphatic filariasis, onchocerciasis and soil-transmitted helminthiasis.

Rather surprisingly, perhaps, is that nearly all of these diseases are routinely diagnosed by microscopic examinations of either blood, stool or urine specimens. Prior to inspection these samples would have undergone a simple preparative and staining procedure. For example, finger-prick blood is taken and smeared onto a glass slide, dehydrated and then stained with Giemsa which is sufficient to visualize *Plasmodium* spp. under oil emersion, or stool is size filtered through a specific mesh, smeared and stained with malachite green to visualize *Schistosoma* and other helminth eggs at 100x magnification. Visualization of eggs, often produced in copious amounts from the adult worm is critical to precise disease identification (more information available at www.rms.org.uk/infocus).

For a fuller description of tropical diseases and their methods of diagnosis reference should be made to Monica Cheesbrough's excellent text entitled *District Laboratory Practice in Tropical Countries* (ISBN: 0521676304).

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Keith Dunning's background is in the aviation industry. A former pilot who served on the Flight Safety Committee of British Airways, he developed an interest in light microscopy which is used for the study of aircraft components following fatigue failure and for the examination of the minute debris found in aircraft engines and systems which often determines the prior cause of a major failure. A strong advocate for making microscopy much more accessible, he has worked on the design and production of the *Readiview* and *Trekker* concepts and is one of the founding trustees of the *Millennium Health Microscope Foundation* (see page 24). He is a Fellow of the RMS.



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Dr Russell Stothard's main interests are in tropical parasitic disease research with particular emphasis in schistosomiasis and trypanosomiasis, having published over 60 scientific papers. Having a first B.Sc degree in Microbiology & Zoology, practical microscopy has been a continuing theme throughout M.Sc. and Ph.D. training. As a senior researcher within the WHO Collaborating Centre for Schistosomiasis and Snail Hosts of the Natural History Museum, Russell travels extensively throughout Africa to collect samples and provide advice on all aspects of disease control. As Honorary Secretary of the Royal Society of Tropical Medicine and Hygiene, he is keen to ensure that research is translated into practical health solutions on the ground. He is a founding trustee of the *Millennium Health Microscope Foundation*.

THE MILLENNIUM HEALTH MICROSCOPE FOUNDATION (MHMF)

Aiming to save the lives of many in the rural tropics with affordable diagnostic microscopy

The *Millennium Health Microscope* Foundation is a not-for-profit charity with clearly defined principal aims set within a strategy of innovation, validation and implementation. It aims to develop the *Millennium Health Microscope* (MHM), a robust and low-cost microscope of appropriate specification for diagnosis of tropical diseases, to work with selected Ministries of Health in at least 4 developing world countries to ascertain the best implementation strategy for the MHM and to develop a suitable economic model for cost-effective mass production and use of the MHM within the developing world health sector.

The non-profit Foundation is constituted with an experienced Board of Trustees, several of whom are pre-eminent in the field of tropical medicine with impressive records of work in peripheral health centres and field infection surveillance in developing countries. Other trustees bring expertise in microscopy, in the governance of non-profit organisations, fund raising activities and specific expertise in industrial design, optics and low-cost microscope manufacture.



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