From the McArthur to the Millennium Health Microscope (MHM): Future Developments in Microscope Miniaturization 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 Fig. 1A**).

To achieve this high degree of miniaturization 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 was predicated on the widespread use of his ultra-portable microscopes for the diagnosis of tropical diseases in peripheral health centers [**see Box 1**]. Following his machined metal model a later version, produced in molded plastic by the Open University (OU), took the design even further forward with the realization that future low-cost microscopes would inevitably utilize 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.

Fig. 1. *Microscope innovations: (a) the McArthur.*

Despite good intentions, McArthur's vision of revolutionizing the way microscopy could be used in tropical diseases was sadly never realized. Even with the cheaper OU model, the cost of the instrument was still out of reach of the comparatively meager 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 its targeted 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 a 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 Fig. 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 *Readiview* is capable of viewing opaque specimens in addition to conventional microscope slides and became increasingly popular amongst amateur and professional biologists alike during the 1990s. 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 Fig. 1C**). Together with its low cost, good ergonomics and supreme ease of use the *Trekker* has become evermore popular as an introduction to microscopy for younger people. More detailed technical descriptions of the *Readiview/Trekker* concept may be found at *www.looksmall.com*.

With the better affordability of the *Readiview*, at approximately 80 USD and at least a tenth of the price of a suitable conventional compound, it was perhaps time to revisit McArthur's original vi-

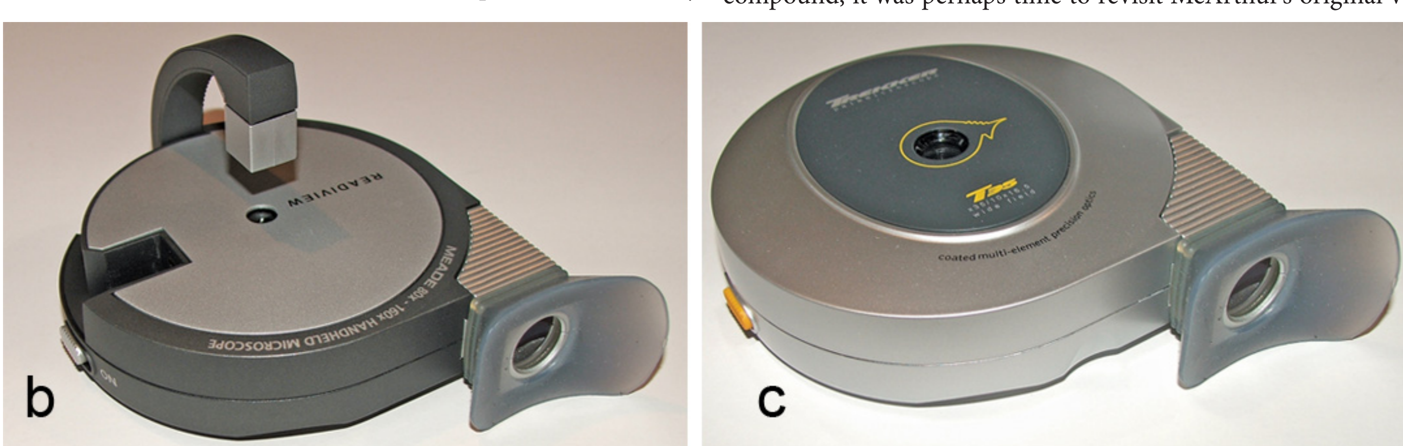

Fig. 1. *Microscope innovations: (b) Readiview and (c) Trekker.*

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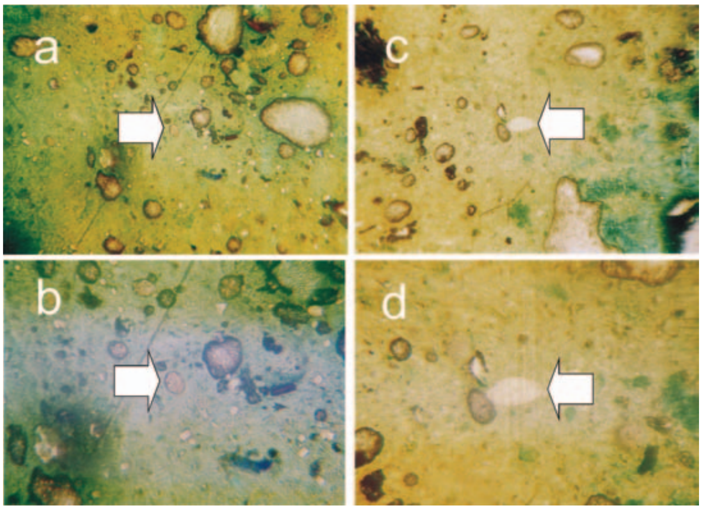

Fig. 2. *Helminth eggs in a faecal smear. Hookworm egg (arrowed) at: (a) 80x and (b) 160x, is approximately 60 microns in length. Schistosome egg (arrowed) at: (c) 80x and (d) 160x, is approximately 150 microns in length. All images of a Kato-Katz thick faecal smear were taken with a Readiview using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

sion as there remains a pressing need for microscopic diagnosis of tropical diseases. In reality with the continual attrition of facilities within rural health clinics in Africa, this demand is ever growing for more sustainable, lower cost equipment. Having visited many rural clinics in Africa, the availability of compound microscopes amongst field-based roving health teams is still a major logistic bottleneck. Whilst improved technology and low-cost instrumentation provide some of the necessary ingredients for a working recipe, to bake the true cake of success other factors need attention, such as the development of a better technology transfer/implementation model which employs '*on-the-ground*' validation and implementation studies. Undoubtedly, an affordable, durable and effective microscope creates an initial way forward for infrastructure improvement, but this needs combining with an appropriate technology transfer/implementation model to create a sustainable demand for the utilization within the tropical health sector, overcoming many socio-economic barriers.

Field tests of the efficacy of the *Readiview* for visualization of helminth eggs (**see Fig. 2**) have been very good and quite satisfactory for routine diagnosis purposes (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 of disease within a sub-set of children from 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 *Readiview* is satisfactory for visualization of blood-borne helminths *e.g.* microfilariae of lymphatic filariasis, for protists, the optical magnification range of the *Readiview,* however, needs further improvement to place it equally on par with the higher powered McArthur. In so doing, this technological improvement would allow visualization of other blood-borne protists and with this in mind, the *Millennium Health Microscope* (MHM) was conceived. Being a significant upgrade to the *Readiview*, the low-cost design of the NHM could nevertheless be fabricated inexpensively in the Far East with many of the *Readview's* components. This low cost of production with the proven manufacturing techniques already developed for *Readiview* and *Trekker* could be the production breakthrough. Hand-in-hand with this innovation and with further validations in the field, e.g. a detailed pilot implementation study within the tropical health sector advocating proof-of principle and overall cost-effectiveness, real progress towards McArthur's vision could be made.

Subject to the availability of seed grant funding to finance R&D, tooling and clinical trials, the MHM could be available within the next 2-3 years at no more than 75 USD per unit in its standard form with 10:1 and 40:1 objectives. 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 organizations to purchase and donate the MHM to developing countries in a cost:donation model, alongside major pharmaceutical suppliers, who might be inspired to distribute these inexpensive microscopes as part of a corporate care culture in deserving countries for monitoring and surveillance of tropical diseases. Proposals for funding the MHM are presently being written and we would be greatly appreciative for any advice from readers of Microcopy Today at the above e-mail addresses. ■

Box 1: A short primer on diagnosis of tropical diseases

In contrast with infectious diseases resultant from either viral and(or) bacterial agents in First World countries, infectious 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 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 http://www.who.int/topics/malaria/en/), while for helminths, 650 million people are at risk of schistosomiasis (see http://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.

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 schistosome 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, forms the foundation of parasitological diagnosis (see http://www.who.int/bookorders/anglais/detart1.jsp?sesslan=1&codlan=1&codcol=15&codcch=417). For a fuller description of tropical diseases, and their methods of laboratory diagnosis, reference should be made to Monica Cheesbrough's excellent text entitled *District Laboratory Practice in Tropical Countries* (ISBN: 0521676304).